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

ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-8J: Dam Rating Curves, Fort Loudoun

(402 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 090304 001	Calculations (nuclear)	L58 091230 022

Calc Title: Initial Dam Rating Curves, Fort Loudoun

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	GEN	CEB	CDQ000020080009	0	1	Entire calc ☒ Selected pages ☐
NEW								

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

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

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

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

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
wbbondurant	901.755.7166	CEB	See Page 6	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Bryant Bondurant *Bryant Bondurant*	12/22/09	Andrew Murr *Andrew Murr*	12/23/2009
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
L. Yu Lin *L. Lin*	12/23/09	K.E. Spates *K.E. Spates*	12/28/09

STATEMENT OF PROBLEM/ABSTRACT

NK 12/23/09

Dam rating curves (headwater rating curves) for 20 dams are required as inputs to TVA's SOCH and TRBROUTE models, which perform flood-routing calculations for the Tennessee River and tributaries. The dam rating curves provide total dam discharge as a function of headwater elevation. This calculation presents dam rating curves for Fort Loudoun Dam.

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

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

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

☐ LOAD INTO EDMS AND DESTROY
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NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 090304 001	Calculations (nuclear)	N/A

Calc Title: Dam Rating Curves, Fort Loudoun

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC						Entire calc ☐ Selected pages ☐
NEW	CN	NUC	GEN	CEB	CDQ000020080009	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
000	N/A	N/A

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

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

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
attinsley	865-220-4418	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Andrew Tinsley	2/10/09	Chris Triplett	2/10/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
DAVID AUT for Dr. L. Lin / Scott Zinkham		Ken Spates	3/3/09

STATEMENT OF PROBLEM/ABSTRACT

Dam rating curves (headwater rating curves) for 20 dams are required as inputs to TVA's SOCH and TRBROUTE models, which perform flood-routing calculations for the Tennessee River and tributaries. The dam rating curves provide total dam discharge as a function of headwater elevation. This calculation presents dam rating curves for Fort Loudoun Dam.

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NPG CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	GEN	CEB	CDQ000020080009	1

ALTERNATE CALCULATION IDENTIFICATION

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

CATEGORIES NA

KEY NOUNS (A-add, D-delete)

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

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

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	EN	WBN	CEB	54018	
A	P	EN	SQN	CEB	22404	
A	S	CN	GEN	CEB	CDQ000020080036	

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 CDQ000020080009

Title Initial Dam Rating Curves, Fort Loudoun Dam

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue of Calculation, Total Pages – 158 Total Pages Appendix A – 37 Pages including Attachments
1	This calculation was revised to address the following: • PER 203951-The verification of the previous revision of this calculation was completed by personnel who had not completed the required NEDP-7 Job Performance Record (JPR). A verification JPR is now in place for all personnel engaged in verification tasks. Checking includes only changes made in this revision as the checking of the calculation was not impacted by PER 203951. The verification is inclusive of work completed prior to this revision. • PER 203872- replace NEDP-2 forms on Pages 2 through 6 with the forms from the NEDP-2 Revision in effect at the time of calculations issuance. • PER 173047- Formulas were inserted in the Excel Spreadsheet where there were previously zeros. • PER 177492 – Model data was used to determine the spillway coefficients. • Calculation was revised to address the modification made to raise the elevation of the Marina Saddle dam and the South Embankment. Reference 41 provides the new elevation of the Marina Saddle dam and South Embankment following the addition of sand-filled HESCO baskets. • Replaced Unverified Assumption 3.2.1 with Assumption 3.1.8 based on Ref. 37 and Appendix B • Replaced Unverified Assumption 3.2.2 with Assumption 3.1.9 • Replaced Unverified Assumption 3.2.3 with Assumption 3.1.10 • Replaced Unverified Assumption 3.2.4 with Assumption 3.1.11 • Rating curve Cases 1, 1A, 2, 2A, 3, 4 and 9 were updated. Rating curve Cases 5, 6, 7, and 8 are no longer to be used. • Added References 37, 38, 39, 40, 41 • Added Appendix B to evaluate the margin of forces on tainter gates • Revised Assumption 3.1.5 Significant changes in Revision 1 are noted with a right margin revision bar. Administrative changes and typos are excluded. Pages Added: 1a, 6, B1, B2, B3 Pages Revised: 1-5, 7, 9, 11-13, 17, 18, 19, 21-55, Att.13-1, Att.13-2, Att. 14-1, Att.14-2, Att.14-3, Att.14-4, Att.15 Total pages of calculation hard copy for Revision 1= 161

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Calculation Identifier: CDQ000020080009 | Revision: 1

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Calculation Identifier: CDQ000020080009 | Revision: 1

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2	Hydraulic Design Chart 711 (Ref. 6)	1 Page
3	Polynomial fit to HDC 711 suggested design curve for submergence factor (Ref. 6)	1 Page
4	Flow over tainter gates (Ref. 7)	4 Pages
5	Seismic Failure Plan and Elevation (Ref. 2)	1 Page
6	Overall Turbine Discharge (Refs. 29 and 36)	3 Pages
7	Unit 1 Turbine Discharge (Ref. 30)	3 Pages
8	Unit 2 Turbine Discharge (Ref. 31)	3 Pages
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11	Spillway and Lock Overflow Parameters (Refs. 1, 9, 20, 24, 25, 26,27,28,34)	11 Pages
12	North Embankment, Service Bay, and Powerhouse Overflow Parameters (Refs. 1, 10, 11, 21, 22, 23, 24, 28)	11 Pages
13	Marina Saddle Dam Overflow Parameters (Refs. 13, 14)	5 Pages
14	South Embankment Overflow Parameters (Refs. 1, 12, 15-20, 28, 36)	14 Pages
15-1	Tailwater Rating Curve (Ref. 37)	1 Pages
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A1	Location and numbering of spillway gates (Ref. A1)	1 Page
A2	Gate arrangements and gate openings (Ref. A1)	1 Page
A3	Measured gate openings (Ref. A2)	1 Page
A4	Definition sketch for spillway discharge	1 Page
A5	Submergence factors for Orifice Flow through Radial Gates (Refs. A6 and A10)	1 Page
A6	Excerpt from Reference A3 (Ref. A3)	5 Pages
A7	Excerpt from Reference A4 (Ref. A4)	6 Pages
A8	Pages 490 and 491 from Reference A7 (model scale ratios) (Ref. A7)	1 Page
A9	Geometry for flow under an open tainter gate	5 Pages
A10	Gates, general arrangement, TVA drawing no: 54W200, R6 (Ref. A8)	1 Page
A11	Spillway crest details, TVA drawing no: 51N205, R4 (Ref. A9)	1 Page
A12	Point at which nappe touches bottoms of gates (Ref. A4)	1 Page
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A16	Orifice discharge coefficient plot (Ref. A4)	1 Page
A17	Orifice discharge coefficients on Hydraulic Design Criteria plot (Ref. A5)	1 Page
A18-A23	See listing of electronic attachments on page 6	N/A

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

NPG CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080009 Revision: 1

Method of verification used:

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

Verifier: L. Yu Lin Date 12/23/09

L. Lin

Comments:

This calculation entitled, "Dam Rating Curve, Fort Loudoun," was verified by independent design review. The process involved a critical review of the calculation to ensure that it is correct and complete, uses appropriate methodologies, and achieves its intended purpose. The inputs were reviewed and determined to be appropriate inputs for this calculation. The results of the calculation were reviewed and were found to be reasonable and consistent with the inputs provided. Backup files and documents were consulted as necessary to verify data and analysis details found in the calculation.

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

The methodology used to justify the operability of the gates is based solely on the conclusions of the "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates." Appendix B uses the same assumptions, methodology, and approach developed in the Watts Bar radial gate analysis to determine the forces on the radial gates in a closed position with the forces on the gates in the maximum open position. This appendix does not assert that a structural analysis has been performed beyond that found in the Watts Bar radial gate calculation.

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

NPG COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document CDQ000020080009	Rev. 1	Plant: GEN	

Subject:
Initial Dam Rating Curves, Fort Loudoun Dam

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

There is no electronic input or output files associated with this calculation.

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

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

Attachment 16: 16 - Fort Loudoun DRC_Rev1.xls
Spreadsheet for dam rating curve calculations
Attachment 17: Fort Loudoun Area Topo.pdf
A high-resolution PDF file of the topo map portion in Figure 2.
Attachment 18: Complete PDF copy of Reference 2
Attachment 19: Complete PDF copy of Reference 3 (also referenced as A1)
Attachment 20: Complete PDF copy of Reference 7
Attachment 21: Complete PDF copy of Reference 36
Attachments 22 through 48: Large resolution PDF files of References 1 and 9-34

Attachment A18: Watts Bar Model Data for Dam Ratings.xls
Spreadsheet for model data calculations
Attachment A19: Complete PDF copy of Reference A3
Attachment A20: Complete PDF copy of Reference A4
Attachment A21: Large resolution PDF file of Reference A8
Attachment A22: Large resolution PDF file of Reference A9
Attachment A23: Combined Submergence Factors for Watts Bar and Fort Lo.xls
Spreadsheet for model data calculations

☐ Microfiche/eFiche

1. Purpose

Dam rating curves (headwater rating curves) for twenty dams geographically located on the Tennessee River and its tributaries above the existing Bellefonte Nuclear facility are required as inputs to TVA's SOCH and TRBROUTE models, which perform flood-routing calculations. The dam rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents dam rating curves for Fort Loudoun Dam.

TVA developed methods of analysis, procedures, and computer programs for determining design basis flood levels for nuclear plant sites in the 1970's. Determination of maximum flood levels included consideration of the most severe flood conditions that may be reasonably predicted to occur at a site as a result of both severe hydrometerological conditions and seismic activity. This process was followed to meet Nuclear Regulatory Guide 1.59. At that time, there were no computer programs available that would handle unsteady flow and dam failure analysis. As a result of this early work and method development TVA developed a runoff and stream course modeling process for the TVA reservoir system. This process provided a basis for currently licensed plants (Sequoyah Nuclear Plant, Watts Bar Nuclear Plant, and Browns Ferry Nuclear Plant). The Bellefonte Nuclear Plant (BLN) Units 1 & 2 Final Safety Analysis Report (FSAR) was also based on this process.

BLN Unit 3 & 4 Combined Operating License Application (COLA) was submitted using data and analysis that was determined for the original BLN FSAR (Unit 1 and Unit 2) and was documented in a 1998 reassessment. In 1998, the analysis process and documentation was brought under the nuclear quality assurance process for the first time. A quality assurance audit conducted by NRC staff in early 2007 raised several questions related to the documentation of past work regarding design basis flood level determinations. This calculation supports a portion of the effort to improve this design basis documentation.

Preparation of all calculations supporting nuclear development and licensing are subject to TVA Standard Department Procedure NEDP-2. This standard dictates the process in which calculations are prepared, checked, verified, stored, and cross referenced in a goal to provide the highest quality nuclear design input and output possible.

As required by NRC Regulatory Guide 1.59, the most severe seismically induced floods reasonably possible should be considered for each site in addition to the floods produced by the severe hydrometeorological conditions. Also, the consideration of seismically induced floods should include the same range of seismic events as is postulated for the design of the nuclear plant. The seismic design basis for the plant requires consideration of an Operating Basis Earthquake (OBE) or 0.5 Safe Shutdown Earthquake (SSE) and a full SSE.

Figure 1 is a plan and elevation view of Fort Loudoun Dam (a portion of Reference 1). For headwaters in the normal operating range, discharge is passed through the turbines or over the spillway. The spillway consists of fourteen spillway bays, each with a radial, or tainter gate, to control discharge. If, as during a probable maximum flood (PMF) event, headwater rises above the normal operating range, discharge may pass also over the nonoverflow section, the navigation lock, the tops of the open spillway gates, the tops of the spillway piers, and the north and south embankments. In addition, as indicated in Figure 2, discharge may also pass over the Marina Saddle Dam that closes a low point in the reservoir rim. The purpose of this calculation does not evaluate the design loading conditions of the dam. Rating curves are provided for several cases as listed in Table 1.

Table 1: Rating Curve Cases

Case	Ft. Loudoun	Tellico
1	Pre Failure with Turbines	Pre Failure
1a	Pre Failure without Turbines	Pre Failure
2	Spillway Gates Closed with Turbines	Pre Failure
2a	Spillway Gates Closed without Turbines	Pre Failure
3	South Embankment Failure with Spillway Gates Open	Pre Failure
4	South Embankment Failure with Spillway Gates Closed	Pre Failure
~~5~~	~~South Embankment Failure with Spillway Gates Open~~	~~Embankment Failure~~
~~6~~	~~South Embankment Failure with Spillway Gates Closed~~	~~Embankment Failure~~
~~7~~	~~Pre Failure – Spillway Gates Open~~	~~Embankment Failure~~
~~8~~	~~Pre Failure – Spillway Gates Closed~~	~~Embankment Failure~~
9	Seismic Failure	Pre Failure

Note: *See Section 4.26 for further explanation of the seismic failure Case 9 for Fort Loudoun and Tellico*

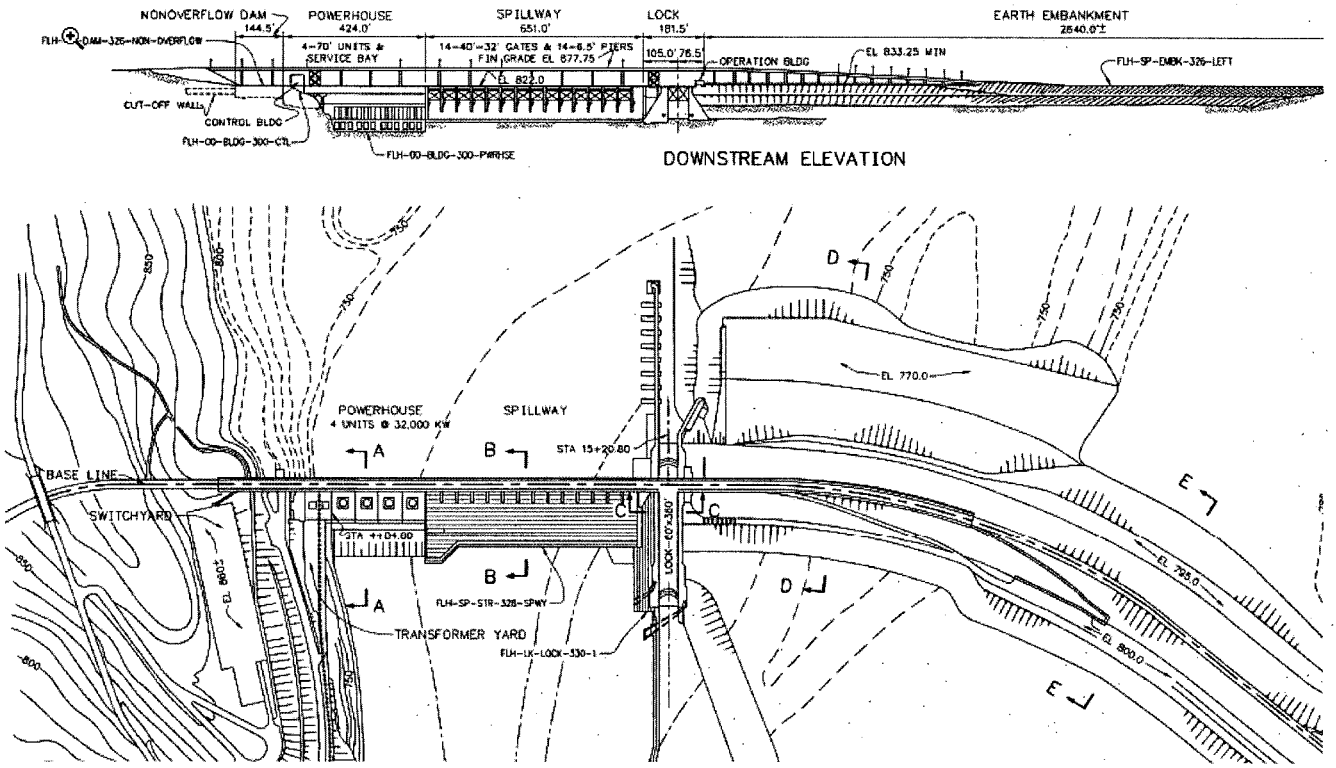

Figure 1 – Fort Loudoun Dam, General Plan and Elevation (Ref. 1).

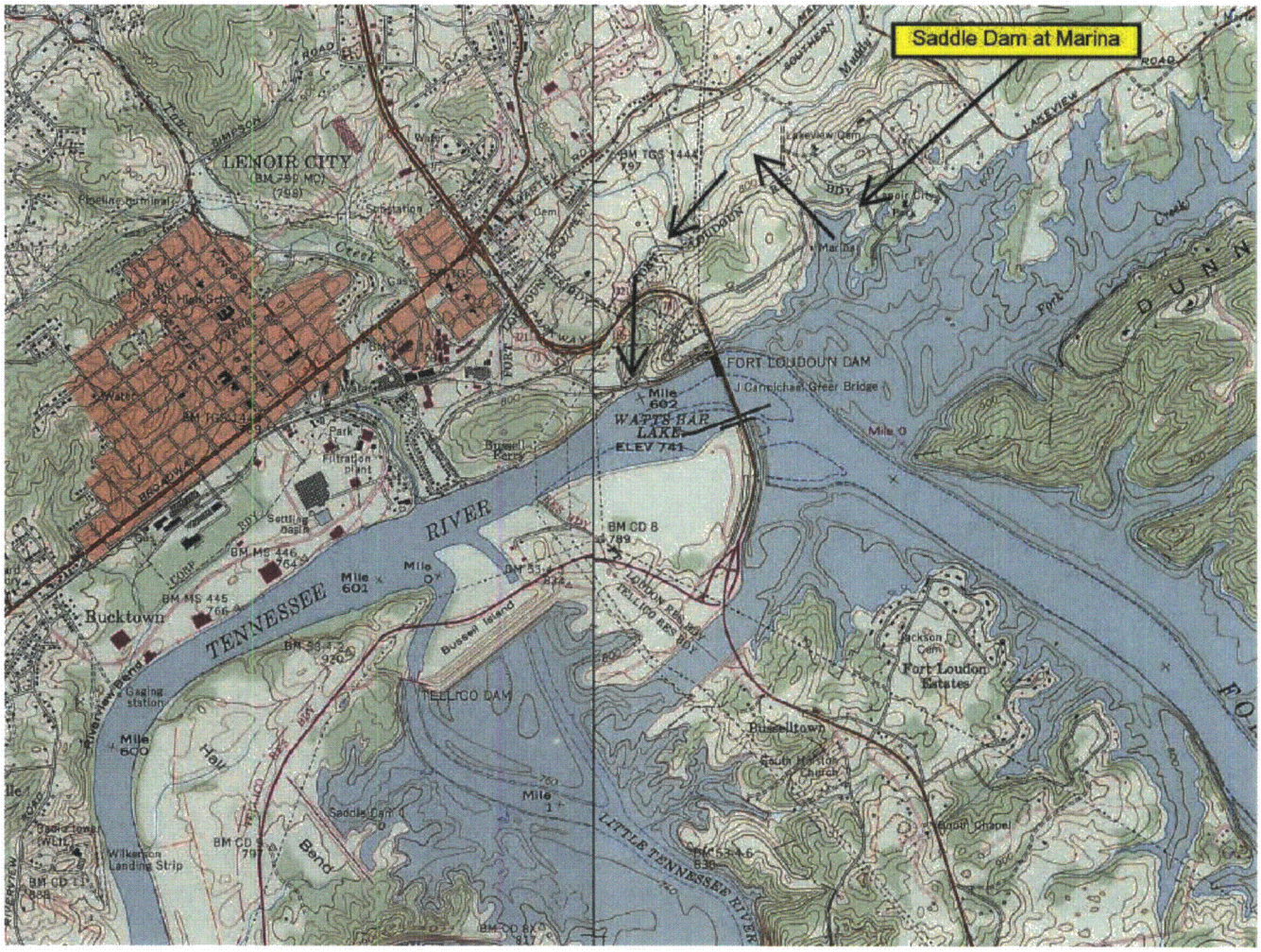

Figure 2 – Topographical Map Showing Marina Saddle Dam

2. References

1. TVA drawing no: 10W200, R11 (Attachments 1, 11-4, 12-4, 14-11, and 22)
2. TVA Calculation. "Ft. Loudoun – Concrete Stability Analysis for SSE and ½ SSE + ½ PMF." RIMS 880525E0010. Accession Number B66880520302. Revision 1 (Attachments 5 and 18).
3. "Fort Loudoun Dam Spillway Discharge Tables", River Operations, Tennessee Valley Authority, 2004. RIMS Acc. No. L58 081212 809 (Attachment 19).
4. "Hydraulic Design Criteria," USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988.
5. Handbook of Hydraulics, E. F. Brater and H. W. King, Sixth Ed., McGraw Hill, 1976.
6. Hydraulic Design Chart 711 (HDC 711) from Reference 3 (Attachment 2).
7. "Rating Curves for Flow over Drum Gates," Joseph N. Bradley, Paper No. 2677, Transactions of the American Society of Civil Engineers, vol. 119, pp. 403-433, 1954 (Attachment 20).
8. Reference Deleted
9. TVA drawing no: 21/2.2 (Attachments 11-6 and 23)
10. TVA drawing no: 22W200, R10 (Attachments 12-6 and 24)
11. TVA drawing no: 22W214, R9 (Attachments 12-8 and 25)
12. TVA drawing no: 23W200, R11 (Attachments 14-14 and 26)
13. TVA drawing no: 23W220-1, R2 (Attachments 13-4 and 27)
14. TVA drawing no: 23W220-2, R2 (Attachments 13-5 and 28)
15. TVA drawing no: 23W230-1, R3 (Attachments 14-5 and 29)
16. TVA drawing no: 23W230-2, R2 (Attachments 14-6 and 30)
17. TVA drawing no: 23W230-3, R2 (Attachments 14-7 and 31)
18. TVA drawing no: 23W230-4, R2 (Attachments 14-8 and 32)
19. TVA drawing no: 23W230-5, R3 (Attachments 14-9 and 33)
20. TVA drawing no: 23W230-7, R1 (Attachments 14-10 and 34)
21. TVA drawing no: 41N508, R4 (Attachments 12-5 and 35)
22. TVA drawing no: 41N615, R1 (Attachments 12-7 and 36)
23. TVA drawing no: 46N402, R6 (Attachments 12-9 and 37)
24. TVA drawing no: 51N200, R2 (Attachments 11-7, 12-10, and 38)
25. TVA drawing no: 61W220-1, R0 (Attachments 11-5 and 39)
26. TVA drawing no: 61W804-1, R1 (Attachments 11-10 and 40)
27. TVA drawing no: 66N201, R7 (Attachments 11-9 and 41)
28. TVA drawing no.: 80H3401, R3 (Attachments 11-8, 12-11, 14-12, and 42)
29. TVA drawing no.: 41N600, R5 (Attachments 6-2 and 43)
30. TVA drawing no.: 47B901, R0 (Attachments 7-3 and 44)
31. TVA drawing no.: 47B904, R0 (Attachments 8-3 and 45)
32. TVA drawing no.: 47B908, R0 (Attachments 9-3 and 46)
33. TVA drawing no.: 47B912, R1 (Attachments 10-3 and 47)
34. TVA drawing no.: 64W204. R0 (Attachment 11-11and 48)
35. Open Channel Flow, Sec. 2.7, F. M. Henderson, Macmillan, New York, 1966.
36. TVA Water Control Project Blue Book. Fort Loudoun Dam. July 1998. (Attachment 6, 14-13, and 21)
37. "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analyses," Tennessee Valley Authority, May 29, 2009 (EDMS No. L58 090529 800)
38. "SOCH Model Calibration, Ft. Loudoun - Tellico," CDQ000020080036 (EDMS L58 090814 003)
39. "Dam Lock Gate Technical Evaluation for the PMF," Tennessee Valley Authority, 2009, (EDMS No. L58 090908 001).
40. "SOCH Model Calibration, Watts Bar," CDQ000020080037 (EDMS L58 090814 002)
41. "Bellefonte Units 3 and 4 Hydrology Project Request for Information (RFI) Response Information Continuation Sheet," RFI Number BWSC_75578_2009_054 (EDMS L58 091216 801)

3. Assumptions & Methodology

The initial dam rating curves developed in these calculations will be used in simulations of probable maximum flood events. Consequently, the rating curves have been calculated well above the normal operating range and several feet above the top of the dam.

3.1 Assumptions

3.1.1 Assumption: Power generation will continue until valid reason to shut off turbines is demonstrated.
Technical Justification: Turbine flow will contribute to flow through the dam in the event of a PMF occurrence. The head differential will be less than optimal since the tailwaters will almost certainly be elevated during such an event. Reference 29 (Attachment 6-2) shows that turbine flows can logically be included for headwater ranges between 790' and 815' and tailwater ranges below 797'. The turbine flow will be based on the equation developed in Attachments 6 thru 10 and a gross head of 15' (See Attachment 6) will be considered the minimum amount of head to operate the turbines. The flow through all four turbines will not exceed 32,200 cfs (see Attachment 6) under any circumstances.

3.1.2 Assumption: The North Embankment will fail at the same headwater elevation of the nonoverflow section and will fail to the overflow elevation of the core wall.
Technical Justification: Since the North Embankment and the nonoverflow section of the dam are located next to each other, they will be assumed to fail at the same elevation of 826.5' (Reference 21, Attachment 12-5). This assumption is valid since the embankment will not be overtopped until that elevation. The failure length and depth will be consistent with the length of the core wall that extends beneath the North Embankment as outlined in Attachment 12 of this calculation. Since the length of this failed section is relatively minimal when compared to the rest of the dam, failure will be assumed at any elevation greater than the overtopping height of 826.5' and no separate failure case will be computed. The assumption has minimal effects on the final rating curves produced by this calculation.

3.1.3 Assumption: For calculating overflow discharge at the Marina Saddle Dam, the reservoir water elevation may be assumed to equal the headwater elevation at Fort Loudoun Dam.
Technical Justification: The Marina Saddle Dam is located less than one mile from Fort Loudoun Dam (see Figure 2). The calculation of overflow at the Marina Saddle Dam, both before and after failure, is approximate in nature and will not be made more uncertain by neglecting differences between the water level at the Marina Saddle Dam and the Fort Loudoun headwater during a PMF.

3.1.4 Assumption: The total discharge used to determine tailwater from the rating curve includes discharge from the Marina Saddle Dam.
Technical Justification: Discharge from the Marina Saddle Dam will enter the tailwater about one half mile downstream from the Fort Loudoun Dam (see Figure 2) and will have an effect on the tailwater levels.

3.1.5 Assumption: The PMF headwaters at Ft. Loudoun and Tellico will be the same until the elevation reaches 830.0. For PMF headwaters above 830.0, it is assumed that the PMF headwater at Tellico linearly increases from 830.0 to 834.0 as the PMF headwater at Ft. Loudoun increases from 830.0 to 837.0.
Technical Justification: Development of initial rating curves requires an assumption about the relationship between headwater elevations at Ft. Loudoun and Tellico. The assumed relationship was based on preliminary SOCH analysis. Since this assumption affects only the initial curves and has no effect on rating curves determined from future iterative analyses, this assumption is acceptable.

3.1.6 Assumption: The South embankment and Marina Saddle Dam will fail to the approximate original ground elevation.
Technical Justification: Original ground elevation represents the most probable extent to which the Marina Saddle Dam and South embankment would fail. They may erode less than this but would not be expected to erode further. While no documentation regarding the failure elevation of these sections exists, this is a similar approach taken on other dams in the Bellefonte FSAR. Since the original ground elevation is not clearly stated on the drawings, estimates of the original ground elevation are utilized. Slight variances from the original ground elevation have minimal effect on the final curves.

3.1.7 Assumption: Elevations of the top of the Marina Saddle Dam and South Embankment have been raised to elevation 837.(Ref. 41).
Technical Justification: TVA has made physical modifications to both the Marina Saddle Dam and South Embankment.

3.1.8 Assumption: All spillway gates will remain operable and will be set to the maximum openings specified in the spillway discharge tables.
Technical Justification: For technical justification, see Reference 37, "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Anaylses", and Appendix B. The radial gates will remain operable in the maximum opened position based on the findings of the "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates" (Reference B1). Appendix B uses the same assumptions, methodology, and approach as the Watts Bar radial gate analysis to compare forces on the gates in a closed position with forces on the gates in the maximum open position to provide technical justification for the gates to remain operable in the maximum open position during a PMF.

3.1.9 Assumption: The upper gate of the navigation lock will not fail when overflowed.
Technical Justification: For technical justification, see Reference 39, "Dam Lock Gate Technical Evaluation for the PMF".

3.1.10 Assumption: The tailwater rating curve included as Attachment 15 is used in the initial dam rating curve calculations.
Technical Justification: The final tailwater curve was verified in the unsteady SOCH Model Calibration, Ft. Loudoun - Tellico (Reference 38).

3.1.11 Assumption: Steady-state tailwater rating is sufficient for computing submergence effects on the initial dam rating curves.
Technical Justification: The final tailwater curve is validated in the unsteady SOCH PMF calculation (Reference 38) by ensuring consistency with the headwater-tailwater relationship across the modeled dam configuration. This calculation provides the initial dam rating curve for the SOCH PMF calculation.

3.2 Unverified Assumptions (UVA)

None

3.3 Methodology -- Discharge Equations

Discharges past the dam are computed as either "free" discharge or "orifice" discharge. Free discharge refers to free surface overflow and is computed using a weir-type equation as follows (Reference 4 shows weir flow equations for overflow discharges):

$$Q_f = C_f L H_c^{1.5} \quad (1)$$

in which Q_f = free discharge (cfs), C_f = free discharge coefficient (($ft^{0.5}/s$ -- may vary with HW), L = length of overflowing section (ft), H_c = head on crest (ft) = HW - Z_c, HW = headwater elevation (ft), and Z_c = top, or crest, elevation of overflowing section (ft).

This equation is modified to account for tailwater submergence as follows:

$$Q_{fs} = Q_f S_f \quad (2)$$

in which Q_{fs} = "corrected" free discharge (cfs) and S_f = tailwater submergence factor (dimensionless -- varies between 0 and 1). S_f varies with d/H_c where d = TW - Z_c (ft) and TW = tailwater elevation (ft).

Flows over the nonoverflow section, the navigation lock, the tops of the open spillway gates, the tops of the spillway piers, the nonoverflow dam, the powerhouse, the south embankment, the north embankment, and the Marina Saddle Dam are treated as

free discharge. Flow over the spillway crest is treated as free discharge for headwater elevations below $H_c = H_{Lmin}$, the head at which the overflowing nappe first touches the bottoms of the open gates (see Attachments A4 and A12). H_{Lmin} varies with gate opening, V, defined as the vertical distance between the bottom of the gate and the spillway crest.

For headwater elevations above $H_c = H_{Lmin}$ flow through the spillway gates is treated as orifice discharge. Orifice discharge refers to flow passing through a contracted opening and is computed using an orifice-type equation as follows (e.g., Reference 4, Hydraulic Design Chart 311-1):

$$Q_g = C_g G_n L \sqrt{2g(H_c - H_{mp})} \qquad (3)$$

in which Q_g = orifice discharge (cfs), C_g = orifice discharge coefficient (varies with gate opening and H_c), G_n = effective gate opening = minimum distance between the gate lip and the crest (ft), g = acceleration of gravity, and H_{mp} = vertical distance between the mid-point of G_n and the crest.

This equation is modified to account for tailwater submergence as follows:

$$Q_{gs} = S_g Q_g \qquad (4)$$

in which Q_{gs} = "corrected" orifice discharge (cfs) and S_g = tailwater submergence factor (dimensionless -- varies with d/H_c and gate opening, G_n).

3.4 Methodology -- Spillway Discharge Calculations

The discharge coefficient, C_f, for free discharge over a spillway crest varies with head, H_c (References 4 and 5 both provide this kind of data). For the Watts Bar spillway crest, the relationships H_{Lmin} (V), $C_f(H_c)$, and $S_f(d/H_c)$ are available from model test data (Appendix A). This data is used for Fort Loudoun calculations since the spillway crest and gates are of identical design and construction. The relationship between orifice discharge coefficient, C_g, and head, H_c, for various gate openings, V (up to V = 23.83 feet), is also available from the model test data. The crest length, L, and crest elevation, Z_c, are shown on TVA drawings (e.g., Reference 1). The parameters G_n and H_{mp} are determined from geometry (Appendix A). Model data for Nickajack and Tellico Dams are used to estimate S_g (d/H_c, G_n) for Fort Loudoun Dam (Appendix A, References A6 and A10).

The physical model used to measure spillway discharge included several bays and the piers between them. Consequently, pier contraction effects are implicitly included in the discharge coefficients derived from the model test data.

Under the assumption that all spillway gates are fully open, the two end bays (first and last) are the only spillway bays subject to end contraction effects. These effects, which may reduce discharge through these two bays by a few percent, are neglected in this calculation. Neglecting this minor effect has negligible impact on the overall rating curve.

3.5 Methodology -- Discharge Coefficients and Submergence Factors for Overflow Sections

Values of the discharge coefficient, C_f, and the submergence factor, S_f, for flows over the nonoverflow section, the navigation lock, the tops of the open spillway gates, the tops of the spillway piers, the north embankment, the south embankment, the Marina Saddle Dam, the failed Marina Saddle Dam, and the failed south embankment are estimated using Hydraulic Design Chart 711 (Reference 6) which is included as Attachment 2. Length, L, and crest elevation, Z_c, in each case is determined from TVA drawings (all relevant drawings are listed as References).

The upper plot of HDC 711 (Reference 6) shows that C_f is about 2.65 for very broad crests ($H_1/B < 0.4$ where $H_1 = H_c$ and B = streamwise length of the crest) and gradually increases to 3.3, the maximum value for a "broad-crested" weir, as H_1/B increases to about 1.2. As H_1/B increases above 1.2, C_f continues to increase as the weir transitions from broad-crested to sharp-crested at about $H_1/B = 2.0$. Since the estimation of discharge over the top of various sections of a dam and its embankments is an approximation, small variations in C_f with H_c are not modeled and the effects of end contractions are neglected. A single representative value for C_f within the range of its variation is used for all headwater elevations included in the rating. Neglecting minor variations in C_f values and end contractions has negligible impact on the dam rating curve.

The lower plot of HDC 711 shows several curves of C_s/C_f (equivalent to S_f) versus H_2/H_1 (equivalent to d/H_c). As illustrated in Attachment 3, the curve labeled "suggested for design (broad crests)" is well-represented by the following polynomial:

$$S_f = 1.0 + 0.023\sigma - 5.0259\sigma^2 + 18.266\sigma^3 - 44.658\sigma^4 \quad \text{for} \quad 0 \le \sigma \le 0.37 \quad \text{broad crest} \qquad (5)$$

in which $\sigma = d/H_c - 0.6$. According to this relationship, submergence affects discharge over a broad-crested weir for $d/H_c > 0.6$.

In cases of very high headwater, σ will have a value higher than 0.37. To account for this, Equation 5 was visually extrapolated. The extrapolated points are shown as the blue points on Attachment 3. To use these points, it is necessary to linearly interpolate between the points listed in Table 2 below.

Table 2: S_f for $\sigma > 0.37$

σ	S_f
0.37	0.409
0.38	0.35
0.39	0.25
0.395	0.15
0.40	0.00

4. Design Input

Sect.	Input Parameter	Source	Symbol	Value
4.1	**Acceleration of gravity**	Common knowledge	g	32.2 ft/sec^2
4.2	**Spillway crest parameters**			
4.2.1	Crest length	14, 40-foot wide bays, Ref. 1	L	560 feet
4.2.2	Crest elevation	Ref. 1	Z_c	783 feet
4.2.3	Free discharge coefficient	Polynomial fit to model data given in Att. A13 and discussed in Appendix A	$C_f(H_c)$	Equation A5
4.2.4	Submergence factor for free discharge	Curve fit to model data given in Att. A14 and discussed in Appendix A	$S_f(d/H_c)$	Equation A6
4.3	**Spillway gate parameters**			
4.3.1	Vertical opening	Field measurements given in Att. A3 and discussed in Appendix A	V	29.87 feet
4.3.2	Effective gate opening	Computed in Appendix A	G_n	30.31 feet
4.3.3	Mid-point elevation of opening relative to crest	Computed in Appendix A	H_{mp}	14.83 feet
4.3.4	Headwater elevation at which nappe touches gates	H_{Lmin} estimated in Appendix A	$H_{Lmin} + Z_c$	820.94 feet
4.3.5	Orifice discharge coefficient	Extrapolated curve given in Att. A15 and Table A3 and discussed in Appendix A	$C_g(H_c)$	Interpolate between points in Table A3
4.3.6	Submergence factors for orifice discharge	Family of curves developed in Ref. A6, given in Att. A5, and discussed in Appendix A	$S_g(d/H_c, H_c/G_n)$	Interpolate between points in Table A1
4.4	**Spillway gate overflow (Gates Fully Open)**			
4.4.1	Overflow discharge coeff.	Justification in Attachment 4	C_f	3.3
4.4.2	Overflow elevation	Computed in Appendix A	Z_c	829.92 feet
4.4.3	Overflow length	14, 40' Wide Bays	L	560 feet
4.5	**Spillway Gate Overflow (Gates Closed)**			
4.5.1	Free discharge coeff.	Attachment 4	C_f	3.6
4.5.2	Overflow elevation	Reference A8	Z_c	815 feet
4.5.3	Overflow length	14, 40' Wide Bays	L	560 feet
4.5.4	Orifice Height	Reference A8	G_s	3.5 feet
4.5.5	Transition Elevation from Free to Orifice Discharge	Paragraph 4.22		820 feet
4.5.6	Gated Discharge Coefficient	Paragraph 4.22	C_g	0.7
4.6	**Spillway Deck and Spillway Piers Overflow (Gates Raised)**			
4.6.1	Discharge coefficient	Justification in Attachment 11	C_f	2.7
4.6.2	Overflow elevation	Justification in Attachment 11	Z_c	822 feet
4.6.3	Overflow length	Justification in Attachment 11	L	137 feet
4.7	**Spillway Deck and Spillway Piers Overflow (Gates Closed)**			
4.7.1	Discharge Coefficient	Justification in Attachment 11	C_f	2.7
4.7.2	Overflow elevation	Justification in Attachment 11	Z_c	822 feet
4.7.3	Overflow length	Justification in Attachment 11	L	697 feet
4.8	**Spillway Seismic Failure**			
4.8.1	Discharge Coefficient	Paragraph 4.26	C_f	2.65
4.8.2	Overflow elevation	Paragraph 4.26	Z_c	750 feet
4.8.3	Overflow length	Paragraph 4.26	L	651 feet

Sect.	Input Parameter	Source	Symbol	Value
4.9	**Lock Gate Overflow**			
4.9.1	Discharge Coefficient	Justification in Attachment 11	C_f	3.3
4.9.2	Overflow elevation	Determined in Attachment 11	Z_c	818.7 feet
4.9.3	Overflow length	Determined in Attachment 11	L	60.1 feet
4.10	**Lock Wall Overflow**			
4.10.1	Discharge coefficient	Justification in Attachment 11	C_f	2.75
4.10.2	Overflow elevation	Determined in Attachment 11	Z_c	822 feet
4.10.3	Overflow length	Determined in Attachment 11	L	74.5 feet
4.11	**Nonoverflow Dam Overflow**			
4.11.1	Discharge coefficient	Justification in Attachment 12	C_f	3.3
4.11.2	Overflow elevation	Determined in Attachment 12	Z_c	826.5 feet
4.11.3	Overflow length	Determined in Attachment 12	L	107.5 feet
4.12	**Powerhouse Overflow**			
4.12.1	Discharge coefficient	Justification in Attachment 12	C_f	2.7
4.12.2	Overflow elevation	Determined in Attachment 12	Z_c	822 feet
4.12.3	Overflow length	Determined in Attachment 12	L	354.5 feet
4.13	**North Bank Overflow – 2 Sections**			
4.13.1	Discharge coefficient	Justification in Attachment 12	C_f	3.3
4.13.2	Overflow elevation	Determined in Attachment 12	Z_c	818, 822 feet
4.13.3	Overflow length	Determined in Attachment 12	L	35, 20 feet
4.14	**Marina Saddle Dam, 2 Sections**			
4.14.1	Discharge coefficient	Justification in Attachment 13	C_f	2.65, 2.65
4.14.2	Overflow elevation	Justification in Attachment 13	Z_c	837, 837 feet
4.14.3	Overflow length	Justification in Attachment 13	L	540, 30 feet
4.15	**Marina Saddle Dam Failure**			
4.15.1	Discharge coefficient	Justification in Attachment 13	C_f	2.65
4.15.2	Overflow elevation	Justification in Attachment 13	Z_c	815 feet
4.15.3	Overflow length	Justification in Attachment 13	L	570 feet
4.16	**Intact South Embankment – 2 Sections**			
4.16.1	Discharge coefficient	Attachment 14	C_f	2.65, 2.65
4.16.2	Overflow elevation	Attachment 14	Z_c	837, 837 feet
4.16.3	Overflow length	Attachment 14	L	2208, 50.9 feet
4.17	**South Embankment Failure – 2 Sections**			
4.17.1	Discharge Coefficient	Paragraph 4.24, Attachment 14	C_f	2.65
4.17.2	Overflow elevation	Paragraph 4.24, Attachment 14	Z_c	754, 770 feet
4.17.3	Overflow length	Paragraph 4.24, Attachment 14	L	1130, 1130 feet
4.18	**Seismic South Embankment Failure – 2 Sections**			
4.18.1	Discharge Coefficient	Paragraph 4.26	C_f	2.65
4.18.2	Overflow elevation	Paragraph 4.26	Z_c	750, 785 feet
4.18.3	Overflow length	Paragraph 4.26	L	1625, 625 feet
4.19	**Turbine Discharge**			
4.19.1	Maximum HW Elevation	Paragraph 4.27		822 feet
4.19.2	Maximum TW Elevation	Paragraph 4.27		800 feet
4.19.3	Minimum Gross Head	Paragraph 4.27	$H_{g,\,min}$	15 feet
4.19.4	Discharge, Case 1 & 2	Paragraph 4.27, Also Attachment 6	Q_T	Equation 6
4.19.5	Discharge, Other Cases	Paragraph 4.27	Q_T	0 cfs
4.19.6	Maximum Discharge	Paragraph 4.27, Also Attachment 6	$Q_{T,\,max}$	32,200 cfs
4.20	**Tailwater Rating Curve**	Paragraph 4.28	TW(Q)	Equation 7
4.21	**Upper limit on headwater elevation for rating**	Paragraph 4.29	HW_{max}	837 feet

4.22 Spillway Gate Overflow (Gates Closed)

Reference A8 (Attachment A10) shows the relationship between the closed spillway gates and the top of the spillway deck. Cases 2, 2a, 4, 6, and 8 are all analyses with the gates closed. In these analyses, it is anticipated that there will be flow between the top of the closed gates and the bottom of the spillway deck. The behavior of this flow is unknown as the configuration of the deck as well as other equipment (i.e. hoists) will get in the way of the flow. In order to estimate this flow, it will be treated as a free flow from an elevation of 815' to 820'. The free discharge coefficient is calculated in Attachment 4 and the flow is calculated using Equation 1. Equation 1 can be modified to account for submergence by using Equation 2 and the overflow S_f developed by Equation 5. Above an elevation of 820', the flow will be assumed to be a gated or orifice flow. The opening is actually 3.5' tall so an estimate of 5' for the point at which the nappe touches the bottom of the spillway deck should be adequate. C_o will be assumed at 0.7 and the flow will be calculated as outlined by Equation 3. The opening between the top of the gate and the bottom of the spillway deck can be scaled from Reference A8 and will be used as 3.5'. Several of the cases will produce high enough tailwaters to affect the gated discharge. In this case, there is no model data to give a relation for S_g. Since Equation 3 is based upon the shape of the orifice and the driving head (H_c-H_{mp}), the driving head can be adjusted to account for submergence. When d/Hc exceeds 0.6, the driving head will be the smaller of H_c-H_{mp} or HW-TW (all variables defined previously). This method will produce adequate results for the headwater rating curves.

4.23 North Embankment Failure

Since the north embankment of the dam will be overtopped for a relatively small length, it will be assumed to erode away and fail at an elevation of 826.5' as outlined in Assumption 3.1.2. This assumption is valid since the embankment will not be overtopped until that elevation. The failure length and depth will be consistent with the length and elevation of the core wall that extends beneath the north embankment as outlined in Attachment 12 of this calculation. Since the length of this failure is relatively minimal when compared to the rest of the dam, failure will be assumed at any elevation greater than the overtopping height of 826.5' and no separate failure case will be computed. In other words, the embankment will be considered failed to the elevations in Attachment 12 as soon as the headwater elevation reaches 826.5'. There will be no flow over this embankment at headwater elevations less than that. This assumed failure path has minimal effect on the final rating curves produced by this calculation.

4.24 South Embankment Failure (Non Seismic)

Reference 12 (Attachment 14-14) shows the approximate elevation of original ground elevation along the length of the south embankment. Several of the failure cases for Fort Loudoun Dam include the failure of this embankment. Since there is no failure analysis of this embankment, it will be assumed to fail to its original elevation. The original ground occurred as a natural slope and will therefore be divided into two equal sections for purposes of analysis.

For the purpose of the initial dam rating curve calculation, the following parameter values are used for the failed section 1 of the south embankment: overflow elevation, Z_c = 754 feet; overflow length, L = 1130 feet; and C_f = 2.65. The following parameter values are used for the failed section 2 of the south embankment: overflow elevation, Z_c = 770 feet; overflow length, L = 1130 feet; and C_f = 2.65. Development of these parameters is outlined in detail in Attachment 14. It is not possible to accurately determine these values without conducting a physical model study. Given, that the embankment failure scenario is an estimate and that the goal of this calculation is to analyze the effects of a sudden large discharge of uncertain magnitude into the Fort Loudoun tailwater, the indicated parameter values are adequate. The value for C_f is appropriate for a crest that is very broad compared to the depth of water flowing over it (Ref. 6, Att. 2).

4.25 Marina Saddle Dam Failure

Soon after overtopping, the Marina Saddle Dam is assumed to fail. Critical flow through a cross-section near the saddle dam location will control the discharge through the gap but exactly which cross-section will act as the control is not obvious from the topography shown in Figure 2. Discharge could be computed simply by using the broad-crested weir overflow equation (Equation 1) with C_f = 2.65 (wide crest compared to depth; see Ref. 6), L =570 feet (length of the failed saddle dam [4.15.3]), and Z_c = 815 feet. The failure of this dam will discharge water directly into Muddy Creek. Muddy Creek runs at an elevation varying from 750' at the point where the water would be discharged into it to an elevation of 740' where it enters the

Tennessee River after Fort Loudoun Dam. With the large elevation difference between the failed saddle dam and Muddy Creek, it is assumed that the flow through the saddle dam will control the flow. The topography and postulated flow path shown in Figure 2 confirms this assumption.

The failure of the Marina Saddle Dam is not expected to provide any relief to the overtopping of Fort Loudoun Dam and any effects on such will therefore be ignored.

4.26 Seismic Failure

As required in the TVA nuclear plant design basis, the impact of the following combined seismic and flooding cases must be considered in the plant design:

Condition 1 - Plant flood level due to postulated upstream dam failures due to an Operating Basis Earthquake (OBE) during a 0.5 PMF.
Condition 2 - Plant flood levels due to postulated upstream dam failures due to a Safe Shutdown Earthquake (SSE) during a 25-year flood.

A review of the current PMF design basis for the TVA nuclear plants indicates that the critical OBE seismic case is coincident failure of the Fontana, Hiwassee, Apalachia and Blue Ridge Dams due to an OBE during a 0.5 PMF. The critical SSE seismic case is coincident failure of the Norris, Cherokee and Douglas dams due to a SSE during a 25-year flood.

Fort Loudon Dam Seismic Failure Configuration

The Fort Loudoun Dam will be assumed to seismically fail as outlined in Reference 2 (Attachment 5). Note that Attachment 5 is from the Watts Bar FSAR. This figure came from the calculation listed in Reference 2 and is included only due to the poor quality of the reproduction of the calculation. There are two main parts to the failure – the south embankment and the spillway.

A large portion of the south embankment will fail as outlined in Attachment 5. For the purposes of the initial dam rating curve calculations, the south embankment will be broken into two separate pieces in order to accurately model the overflow elevations. The first section will have an overflow elevation of 750 feet and a length of 1625 feet. The second section will have an overflow elevation of 785 feet and a length of 625 feet. Both sections will have an overflow discharge coefficient (C_f) of 2.65.

The failed portion of the spillway can be seen in Attachment 5. For the purpose of the initial dam rating curve calculation, the following parameter values are used for the failed spillway: overflow elevation, Z_c = 750 feet; overflow length, L = 651 feet; and C_f = 2.65.

It is not possible to accurately determine C_f values without conducting a physical model study. Given, that the seismic failure scenario is an estimate and that the goal of this calculation is to analyze the effects of a sudden large discharge of uncertain magnitude into the Fort Loudoun tailwater, the indicated parameter values are adequate. The values for C_f are appropriate for a crest that is very broad compared to the depth of water flowing over it (Ref. 6, Att. 2).

Tellico Dam Seismic Failure Configuration

Lack of seismic dam stability calculations for Tellico necessitates an assumption of total failure of the Tellico Dam in the PMF analysis under OBE or SSE conditions.

Dam Rating Curve Conditions

The seismic dam rating curve provided in this calculation in Section 6.9 (Case 9) assumes the above described Fort Loudon Seismic failure configuration coincident with a Tellico Dam ***intact*** configuration. An intact Tellico Dam configuration is used because Fort Loudon Dam tailwater characteristics have not been determined for a seismically failed Tellico condition. Since an intact Tellico Dam will reduce the Fort Loudon Dam tailwater and will result in an increased PMF flow (and water level) downstream, Case 9 (intact Tellico) is considered a conservative representation of the Fort Loudon Dam in modeling for the Condition 1 and Condition 2 analysis combinations.

Tellico Dam will be assumed to be completely failed in the SOCH PMF-seismic analysis cases. Following this analysis and to support removing the tailwater curve unverified assumption in Section 3, the Fort Loudon tailwater and the dam rating will either (1) be revised to reflect the more accurate tailwater characteristics which can then be used in a revised PMF-seismic analysis or (2) a technical justification provided for retaining the tailwater curve provided in Attachment 15.

4.27 Turbine Discharge

Fort Loudoun Dam has four turbines (see Attachment 1). The turbines will be operated during a PMF until the tailwater or headwater reaches a level at which electrical components will get wet or excessive vibration occurs. The occurrence of excessive vibration is not predictable so turbine discharge is added to the total dam discharge until the limiting tailwater or headwater elevations are reached.

Electrical components may get wet if the tailwater rises above the level of the switchyard or if the tailwater or headwater rises to a level where water may enter the powerhouse. Once water enters the powerhouse, generation will be suspended and the units will not be restarted until a thorough inspection of the electrical equipment is done. Attachment 1 indicates that the switch yard would be under water for tailwater elevations above 860 feet, which is beyond the expected tailwater elevations of this calculation. Section A-A on Attachment 1 verifies that water cannot enter the powerhouse for tailwater elevations below 800 feet. For headwater elevations above 822 feet, water will flow over the intake deck as illustrated in Section A-A.

Turbine discharges are included in the rating curves for cases 1a and 2a, but not for the other cases. Case 1a and 2a are the only logical cases in which to include the turbine flows since all the other cases produce headwaters or tailwaters that are too high to safely continue operation of the turbines.

Gross head versus generator output is plotted in References 30 through 33 (also included in Attachments 7 thru 10). Since there are no plots of gross head versus turbine discharge, it is necessary to extrapolate the data from the before mentioned references. Turbine discharge is plotted as an independent variable. These lines were extrapolated to their point of intersection with the "full gate discharge" line to produce a rough curve for discharge vs. gross head for each of the turbines. The extrapolation and supporting calculations can be found in Attachments 7 thru 10. After a curve was developed for each turbine, they were added together to form a composite curve (Attachment 6). This composite curve was plotted along with the normal operating range data provided in the Fort Loudoun Blue Book (Reference 36, Attachment 6-3). A polynomial curve was fit to all the data shown in Attachment 6-1 and this curve is used to model the turbine discharge. The equation developed by this fit is:

$$Q_T = -21.7981h_g^2 + 2301.2018h_g - 23779.5655 \qquad (6)$$

Where h_g is the gross head defined as the headwater elevation minus the tailwater elevation.

The extrapolation of these curves also gives an estimate of the minimum required gross head at which the turbines would be operable. The gross head at which turbine output goes to zero ranges from 12-15' depending on the turbine. A value of 15' will be utilized for this number as it represents the first point at which one of the turbines would reach zero power output. Therefore, if there is a difference between the headwater and tailwater elevation of less than 15 feet, it is assumed that there will be no turbine discharge. The normal operating range data provided in Attachment 6-3 is used to estimate the maximum discharge possible through the turbines and is taken as 32,200 cfs.

4.28 Tailwater rating curve

Tailwater interactions with Tellico are a necessity in this analysis since both dams discharge into the Tennessee River within one mile of each other. Therefore, the flows from both dams as well as the discharge from the Marina Saddle Dam are used in order to calculate the tailwater elevations.

The tailwater rating curve used in this calculation is shown in Attachment 16. This curve was discerned from preliminary SOCH Model runs performed for the Watts Bar Reservoir (Ft. Loudoun Tailwater). The tailwater rating in Attachment 15 has been extended to a discharge of 2,000,000 cfs by extrapolation based on engineering judgment for discharges greater than 1,200,000 cfs. The polynomial indicated in Attachment 15 and repeated below is used for the initial dam rating curve calculations.

$$TW = 745.07 + 0.1276Q - 0.9492x10^{-4}Q^2 + 4.350x10^{-8}Q^3 - 0.7392x10^{-11}Q^4 \quad (7)$$

in which Q = total discharge past the dam (including Tellico Discharge and Marina Saddle Dam Discharge) in cfs divided by 1000 ("1000 cfs").

4.29 Upper Limit on Headwater Elevation Included in Rating Curves

The initial dam rating curves need to include all headwater elevations that may occur during a PMF event. Because the Marina Saddle Dam and South Embankment are not postulated to fail after overtopping, the headwater at Fort Loudoun Dam is not expected to rise past 837 feet, which is the top of the south embankment and Marina Saddle Dam. If during the SOCH modeling it is determined that the elevation needs to be higher, then the curve will be revised.

5. Special Requirements/Limiting Conditions

N/A

6. Calculations

The calculations consist of computing spillway and overflow discharges (from Equations 1 through 4) for a list of headwater elevations ranging from the minimum for which discharge exceeds zero up to 837 feet [4.20]. Headwaters only a few feet above the embankments are included because the embankments are expected to fail soon after being overtopped. The The initial dam rating curve for each case is a plot of headwater elevation versus total dam discharge. All tailwater elevations were computed by an iteration process due to the effects of the tailwater interaction between Fort Loudoun and Tellico as well as the submergence. An example of the iteration process can be found in Attachment 15-2.

Rating curve Cases 1, 1A, 2, 2A, 3, 4 and 9 were updated. Rating curve Cases 5, 6, 7, and 8 are no longer valid because the embankments were raised, but these rating curves were not modified to reflect the raised embankment elevations.

6.1 Case 1 and 1a, Pre-Failure Condition

For the pre-failure condition, discharges are computed for headwaters ranging from 773 feet, the spillway crest elevation, to 837 feet, the limit of the headwater elevation [4.21]. Discharge passes through the spillway section and the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000.

Figure 3 shows the spreadsheet calculations for the pre-failure initial dam rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The next two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW elevation. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit provided in Attachment 15. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway, it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 3 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next five columns (under the header "Spillway"), H_c, $C_f|C_g$, d/H_c, S_g, and $Q_f|Q_g$. Free discharge occurs for headwater elevations below 820.9 feet [4.3.4] and orifice discharge occurs for headwaters above 820.9 feet. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.2.3] computed from Equation A5 and below the line the listed discharge coefficient is C_g [4.3.5] computed by interpolation between the points in Table A3. S_g is computed to account for submergence effects by interpolating between points in Table A1 when d/H_c exceeds 0.6. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 3 for orifice discharge. The orifice discharge is modified by Equation 4 to account for the submergence effects when d/H_c is greater than 0.6.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next 24 columns are overflow discharges in cfs for the lock walls, lock gates, spillway deck, spillway gates, north embankment, powerhouse, nonoverflow dam, south embankment, and the saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.6.1], [4.4.1], [4.13.1], [4.12.1], [4.11.1], [4.16.1], [4.14.1]), elevation Z_c ([4.10.2], [4.9.2], [4.6.2], [4.4.2], [4.13.2], [4.12.2], [4.11.2], [4.16.2], [4.14.2]), and length L ([4.10.3], [4.9.3], [4.6.3], [4.4.3], [4.13.3], [4.12.3], [4.11.3], [4.16.3], [4.14.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that the lock walls, lock gates, spillway deck, the north embankment, and the powerhouse overflows had to be modified using Equation 2 in order to account for submergence. S_f is calculated using Equation 5 and interpolation in Table 2.

The final column is the turbine discharge. This discharge is calculated as outlined in Section 4.27.

Case 1a is presented in Figure 4. This calculation is identical to Case 1 except for the subtraction of the turbine discharge. This case will be used for falling headwaters where the turbines have already been shut down and can not be turned back on yet.

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Figure 3: Pre-Failure Conditions

g = 32.2 ft/s²

Spillway Parameters
L = 560 feet
Z_c = 783 feet
G_n = 30.314 feet
H_{mp} = 14.828 feet
H_{Lmin} = 37.94 feet

Overflow Discharge, Q_f in cfs

HW feet	Q Ft Loudoun Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	Main Dam TRM 602.3 TW feet	Spillway H_c feet	$C_f \mid C_s$	d/H_c	$S_f \mid S_s$	Spillway $Q_f \mid Q_s$ cfs		Lock Walls d/H_c	Lock Walls Sf	Lock Walls Q	Lock Gates d/H_c	Lock Gates Sf	Lock Gates Q	Spillway Deck d/H_c	Spillway Deck Sf	Spillway Deck Q	Spillway Gates d/H_c	Spillway Gates Sf	Spillway Gates Q	North Bank Section 1 d/H_c	North Bank Section 1 Sf	North Bank Section 1 Q	North Bank Section 2 d/H_c	North Bank Section 2 Sf	North Bank Section 2 Q	Non Overflow d/H_c	Non Overflow Sf	Non Overflow Q	Power House d/H_c	Power House Sf	Power House Q	South Bank Sec. 1 Q	South Bank Sec. 2 Q	Saddle Dam Sec. 1 Q	Saddle Dam Sec. 2 Q	Turbine Discharge Q
										C_f =			2.75			3.30			2.70			3.30			3.30			3.30			3.30			2.70	2.65	2.65	2.65	2.65	-
										Z_c =			822			818.7			822			829.92			818			822			826.5			822	837	837	837	837	-
										L =			74.5			60.1			137.0			560.0			35.0			20.0			107.5			354.5	2208.0	50.9	540	30	-
773	20.55	0.00	20.55	747.65					0				0			0			0			0			0			0			0			0	0	0	0	0	20546
775	22.44	1.06	23.50	748.02					0				0			0			0			0			0			0			0			0	0	0	0	0	22443
777	24.14	3.01	27.15	748.46					0				0			0			0			0			0			0			0			0	0	0	0	0	24137
779	25.67	5.58	31.25	748.97					0				0			0			0			0			0			0			0			0	0	0	0	0	25671
781	27.07	8.70	35.77	749.51					0				0			0			0			0			0			0			0			0	0	0	0	0	27066
783	28.33	12.32	40.65	750.10	0	3.090		1.000	0				0			0			0			0			0			0			0			0	0	0	0	0	28333
785	34.09	16.42	50.51	751.28	2	3.191		1.000	5055				0			0			0			0			0			0			0			0	0	0	0	0	29033
787	43.97	20.99	64.96	752.97	4	3.277		1.000	14682				0			0			0			0			0			0			0			0	0	0	0	0	29287
789	56.82	26.01	82.83	755.01	6	3.350		1.000	27571				0			0			0			0			0			0			0			0	0	0	0	0	29252
791	72.23	31.46	103.68	757.33	8	3.412		1.000	43235				0			0			0			0			0			0			0			0	0	0	0	0	28992
793	89.91	37.31	127.22	759.86	10	3.465		1.000	61368				0			0			0			0			0			0			0			0	0	0	0	0	28547
795	109.70	43.54	153.24	762.55	12	3.512		1.000	81756				0			0			0			0			0			0			0			0	0	0	0	0	27943
797	131.45	50.13	181.58	765.36	14	3.554		1.000	104243				0			0			0			0			0			0			0			0	0	0	0	0	27206
799	155.07	57.05	212.12	768.27	16	3.591		1.000	128718				0			0			0			0			0			0			0			0	0	0	0	0	26356
801	180.52	64.25	244.77	771.23	18	3.627		1.000	155111				0			0			0			0			0			0			0			0	0	0	0	0	25411
803	207.77	71.72	279.49	774.22	20	3.661		1.000	183379				0			0			0			0			0			0			0			0	0	0	0	0	24391
805	236.82	79.40	316.22	777.23	22	3.695		1.000	213506				0			0			0			0			0			0			0			0	0	0	0	0	23315
807	267.70	87.23	354.92	780.23	24	3.728		1.000	245492				0			0			0			0			0			0			0			0	0	0	0	0	22204
809	300.43	95.13	395.56	783.20	26	3.763	0.008	1.000	279350				0			0			0			0			0			0			0			0	0	0	0	0	21079
811	335.05	103.04	438.09	786.14	28	3.798	0.112	1.000	315090				0			0			0			0			0			0			0			0	0	0	0	0	19959
813	371.58	110.94	482.51	789.03	30	3.833	0.201	1.000	352717				0			0			0			0			0			0			0			0	0	0	0	0	18861
815	410.02	118.80	528.82	791.86	32	3.869	0.277	1.000	392217				0			0			0			0			0			0			0			0	0	0	0	0	17801
815.796	425.84	121.92	547.76	792.97	32.796	3.883	0.304	1.000	408452				0			0			0			0			0			0			0			0	0	0	0	0	17393
816	430.08	120.88	550.96	793.15	33	3.887	0.308	1.000	412658				0			0			0			0			0			0			0			0	0	0	0	0	17418
817	450.77	120.38	571.15	794.30	34	3.905	0.332	1.000	433549				0			0			0			0			0			0			0			0	0	0	0	0	17222
818	471.53	125.41	596.95	795.73	35	3.923	0.364	1.000	454878				0			0			0			0			0			0			0			0	0	0	0	0	16656
819	492.46	135.20	627.65	797.37	36	3.940	0.399	1.000	476631				0	1.000		33			0			0			0			0			0			0	0	0	0	0	15792
820	513.69	150.12	663.80	799.23	37	3.958	0.439	0.999	498787				0	1.000		294			0			0			0			0			0			0	0	0	0	0	14606
821	515.17	169.55	684.72	800.28	38	0.793	0.455	0.989	514478				0	1.000		692			0			0			0			0			0			0	0	0	0	0	0
822	513.62	192.73	706.34	801.33	39	0.775	0.470	0.988	512427				0	1.000		1189			0			0			0			0			0			0	0	0	0	0	0
823	512.79	218.74	731.52	802.53	40	0.756	0.488	0.985	509486			1.000	205	1.000		1768	1.000		370			0			0			0			0	1.000		957	0	0	0	0	0
824	512.16	247.01	759.17	803.81	41	0.738	0.508	0.982	505405			1.000	579	1.000		2420	1.000		1046			0			0			0			0	1.000		2707	0	0	0	0	0
825	511.18	277.21	788.39	805.13	42	0.720	0.527	0.978	500082			1.000	1065	1.000		3136	1.000		1922			0			0			0			0	1.000		4973	0	0	0	0	0
826	520.83	308.64	829.47	806.93	43	0.719	0.556	0.971	504661			1.000	1639	1.000		3912	1.000		2959			0			0			0			0	1.000		7657	0	0	0	0	0
827	534.11	341.15	875.26	808.87	44	0.717	0.588	0.963	508256			1.000	2291	1.000		4742	1.000		4136			0		1.000	3119	1.000		738	1.000		125	1.000		10701	0	0	0	0	0
828	543.85	375.82	919.67	810.69	45	0.716	0.615	0.953	510440			1.000	3011	1.000		5625	1.000		5436			0		1.000	3652	1.000		970	1.000		652	1.000		14067	0	0	0	0	0
829	552.48	412.64	965.12	812.50	46	0.714	0.641	0.940	510713			1.000	3794	1.000		6556	1.000		6851			0		1.000	4214	1.000		1222	1.000		1402	1.000		17727	0	0	0	0	0
830	558.17	451.56	1009.73	814.23	47	0.713	0.665	0.921	507310			1.000	4636	1.000		7534	1.000		8370	1.000		42		1.000	4801	1.000		1493	1.000		2323	1.000		21658	0	0	0	0	0
831	568.86	474.20	1043.06	815.51	48	0.711	0.677	0.908	506286			1.000	5532	1.000		8556	1.000		9987	1.000		2074		1.000	5414	1.000		1782	1.000		3386	1.000		25843	0	0	0	0	0
832	581.48	497.58	1079.05	816.87	49	0.711	0.691	0.892	505157			1.000	6479	1.000		9620	1.000		11697	1.000		5544		1.000	6050	1.000		2087	1.000		4576	1.000		30268	0	0	0	0	0
833	594.01	521.74	1115.76	818.24	50	0.711	0.705	0.875	502413			1.000	7474	1.000		10725	1.000		13495	1.000		9989	0.02	1.000	6710	1.000		2408	1.000		5879	1.000		34920	0	0	0	0	0
834	605.35	546.93	1152.28	819.59	51	0.711	0.717	0.853	497153			1.000	8516	0.06	1.000	11869	1.000		15376	1.000		15230	0.10	1.000	7392	1.000		2744	1.000		7286	1.000		39788	0	0	0	0	0
835	616.35	572.16	1188.51	820.92	52	0.711	0.729	0.830	490356			1.000	9603	0.14	1.000	13052	1.000		17338	1.000		21159	0.17	1.000	8096	1.000		3094	1.000		8791	1.000		44864	0	0	0	0	0
836	627.10	596.79	1223.88	822.22	53	0.711	0.740	0.806	482207		0.02	1.000	10732	0.20	1.000	14271	0.02	1.000	19377	1.000		27705	0.23	1.000	8820	0.02	1.000	3457	1.000		10387	0.02	1.000	50139	0	0	0	0	0
837	638.13	621.10	1259.23	823.51	54	0.711	0.750	0.781	473321		0.10	1.000	11902	0.26	1.000	15526	0.10	1.000	21489	1.000		34814	0.29	1.000	9566	0.10	1.000	3834	1.000		12070	0.10	1.000	55605	0	0	0	0	0

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Figure 4: Pre-Failure Conditions - No Turbine Flow

g = 32.2 ft/s²

Spillway Parameters
L = 560 feet
Z_c = 783 feet
G_h = 30.314 feet
H_{mp} = 14.828 feet
$H_{L,min}$ = 37.94 feet

Overflow Discharge, Q_i in cfs

HW feet	Q Ft Loudoun Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	Main Dam TRM 602.3 TW feet	Spillway H_c (feet)	Spillway $C_f \mid C_g$	Spillway d/H_c	Spillway $S_f \mid S_g$	Spillway $Q_f \mid Q_g$ (cfs)	Lock Walls d/H_c	Lock Walls Sf	Lock Walls Q	Lock Gates d/H_c	Lock Gates Sf	Lock Gates Q	Spillway Deck d/H_c	Spillway Deck Sf	Spillway Deck Q	Spillway Gates d/H_c	Spillway Gates Sf	Spillway Gates Q	North Bank Section 1 d/H_c	North Bank Section 1 Sf	North Bank Section 1 Q	North Bank Section 2 d/H_c	North Bank Section 2 Sf	North Bank Section 2 Q	Non Overflow d/H_c	Non Overflow Sf	Non Overflow Q	Power House d/H_c	Power House Sf	Power House Q	South Bank Sec. 1 Q	South Bank Sec. 2 Q	Saddle Dam Sec. 1 Q	Saddle Dam Sec. 2 Q
												C_f = 2.75			C_f = 3.30			C_f = 2.70			C_f = 3.30			C_f = 3.30			C_f = 3.30			C_f = 2.70			C_f = 2.65	C_f = 2.65	C_f = 2.65	C_f = 2.65
												Z_c = 822			Z_c = 818.7			Z_c = 822			Z_c = 829.9			Z_c = 818			Z_c = 822			Z_c = 826.5			Z_c = 822	Z_c = 837	Z_c = 837	Z_c = 837	Z_c = 837
												L = 74.5			L = 60.1			L = 137.0			L = 560.0			L = 35.0			L = 20.0			L = 107.5			L = 354.5	L = 2208.0	L = 50.9	L = 540	L = 30
773	0.00	0.00	0.00	745.07					0			0			0			0			0			0			0			0			0	0	0	0	0
775	0.00	1.06	1.06	745.20					0			0			0			0			0			0			0			0			0	0	0	0	0
777	0.00	3.01	3.01	745.45					0			0			0			0			0			0			0			0			0	0	0	0	0
779	0.00	5.58	5.58	745.78					0			0			0			0			0			0			0			0			0	0	0	0	0
781	0.00	8.70	8.70	746.17					0			0			0			0			0			0			0			0			0	0	0	0	0
783	0.00	12.32	12.32	746.63	0	3.090		1.000	0			0			0			0			0			0			0			0			0	0	0	0	0
785	5.05	16.42	21.48	747.77	2	3.191		1.000	5055			0			0			0			0			0			0			0			0	0	0	0	0
787	14.68	20.99	35.67	749.50	4	3.277		1.000	14682			0			0			0			0			0			0			0			0	0	0	0	0
789	27.57	26.01	53.58	751.64	6	3.350		1.000	27571			0			0			0			0			0			0			0			0	0	0	0	0
791	43.24	31.46	74.69	754.09	8	3.412		1.000	43235			0			0			0			0			0			0			0			0	0	0	0	0
793	61.37	37.31	98.68	756.78	10	3.465		1.000	61368			0			0			0			0			0			0			0			0	0	0	0	0
795	81.76	43.54	125.30	759.65	12	3.512		1.000	81756			0			0			0			0			0			0			0			0	0	0	0	0
797	104.24	50.13	154.38	762.66	14	3.554		1.000	104243			0			0			0			0			0			0			0			0	0	0	0	0
799	128.72	57.05	185.77	765.77	16	3.591		1.000	128718			0			0			0			0			0			0			0			0	0	0	0	0
801	155.11	64.25	219.36	768.94	18	3.627		1.000	155111			0			0			0			0			0			0			0			0	0	0	0	0
803	183.38	71.72	255.09	772.13	20	3.661		1.000	183379			0			0			0			0			0			0			0			0	0	0	0	0
805	213.51	79.41	292.92	775.34	22	3.695		1.000	213506			0			0			0			0			0			0			0			0	0	0	0	0
807	245.49	87.28	332.77	778.53	24	3.728		1.000	245492			0			0			0			0			0			0			0			0	0	0	0	0
809	279.35	95.25	374.60	781.69	26	3.763		1.000	279350			0			0			0			0			0			0			0			0	0	0	0	0
811	315.09	103.25	418.34	784.80	28	3.798	0.064	1.000	315090			0			0			0			0			0			0			0			0	0	0	0	0
813	352.72	111.23	463.94	787.84	30	3.833	0.161	1.000	352717			0			0			0			0			0			0			0			0	0	0	0	0
815	392.22	119.17	511.38	790.81	32	3.869	0.244	1.000	392217			0			0			0			0			0			0			0			0	0	0	0	0
815.80	408.45	122.32	530.77	791.97	32.796	3.883	0.274	1.000	408452			0			0			0			0			0			0			0			0	0	0	0	0
816	412.66	121.49	534.15	792.17	33	3.887	0.278	1.000	412658			0			0			0			0			0			0			0			0	0	0	0	0
817	433.55	120.99	554.54	793.36	34	3.905	0.305	1.000	433549			0			0			0			0			0			0			0			0	0	0	0	0
818	454.88	126.09	580.97	794.85	35	3.923	0.339	1.000	454878			0			0			0			0			0			0			0			0	0	0	0	0
819	476.66	136.09	612.75	796.58	36	3.940	0.377	1.000	476631			0		1.000	33			0			0			0			0			0			0	0	0	0	0
820	499.08	150.96	650.04	798.53	37	3.958	0.420	1.000	498787			0		1.000	294			0			0			0			0			0			0	0	0	0	0
821	515.17	169.55	684.72	800.28	38	0.793	0.455	0.989	514478			0		1.000	692			0			0			0			0			0			0	0	0	0	0
822	513.62	192.73	706.34	801.33	39	0.775	0.470	0.988	512427			0		1.000	1189			0			0			0			0			0			0	0	0	0	0
823	512.79	218.74	731.52	802.53	40	0.756	0.488	0.985	509486		1.000	205		1.000	1768		1.000	370			0			0			0			0		1.000	957	0	0	0	0
824	512.16	247.01	759.17	803.81	41	0.738	0.508	0.982	505405		1.000	579		1.000	2420		1.000	1046			0			0			0			0		1.000	2707	0	0	0	0
825	511.18	277.21	788.39	805.13	42	0.720	0.527	0.978	500082		1.000	1065		1.000	3136		1.000	1922			0			0			0			0		1.000	4973	0	0	0	0
826	520.83	308.64	829.47	806.93	43	0.719	0.556	0.971	504661		1.000	1639		1.000	3912		1.000	2959			0			0			0			0		1.000	7657	0	0	0	0
827	534.11	341.15	875.26	808.87	44	0.717	0.588	0.963	508256		1.000	2291		1.000	4742		1.000	4136			0		1.000	3119		1.000	738		1.000	125	1.000	10701	0	0	0	0
828	543.85	375.82	919.67	810.69	45	0.716	0.615	0.953	510440		1.000	3011		1.000	5625		1.000	5436			0		1.000	3652			970		1.000	652	1.000	14067	0	0	0	0
829	552.48	412.64	965.12	812.50	46	0.714	0.641	0.940	510713		1.000	3794		1.000	6556		1.000	6851			0		1.000	4214		1.000	1222		1.000	1402	1.000	17727	0	0	0	0
830	558.17	451.56	1009.73	814.23	47	0.713	0.665	0.921	507310		1.000	4636		1.000	7534		1.000	8370	1.000	42			1.000	4801		1.000	1493		1.000	2323	1.000	21658	0	0	0	0
831	568.86	474.20	1043.06	815.51	48	0.711	0.677	0.908	506286		1.000	5532		1.000	8556		1.000	9987	1.000	2074			1.000	5414		1.000	1782		1.000	3386	1.000	25843	0	0	0	0
832	581.48	497.58	1079.05	816.87	49	0.711	0.691	0.892	505157		1.000	6479		1.000	9620		1.000	11697	1.000	5544			1.000	6050		1.000	2087		1.000	4576	1.000	30268	0	0	0	0
833	594.01	521.74	1115.76	818.24	50	0.711	0.705	0.875	502413		1.000	7474		1.000	10725		1.000	13495	1.000	9989	0.02	1.000	6710		1.000	2408		1.000	5879	1.000	34920	0	0	0	0
834	605.35	546.93	1152.28	819.59	51	0.711	0.717	0.853	497153		1.000	8516	0.06	1.000	11869		1.000	15376	1.000	15230	0.10	1.000	7392		1.000	2744		1.000	7286	1.000	39788	0	0	0	0
835	616.35	572.16	1188.51	820.92	52	0.711	0.729	0.830	490356		1.000	9603	0.14	1.000	13052		1.000	17338	1.000	21159	0.17	1.000	8096		1.000	3094		1.000	8791	1.000	44864	0	0	0	0
836	627.10	596.79	1223.88	822.22	53	0.711	0.740	0.806	482207	0.02	1.000	10732	0.20	1.000	14271	0.02	1.000	19377	1.000	27705	0.23	1.000	8820	0.02	1.000	3457		1.000	10387	0.02	1.000	50139	0	0	0	0
837	638.13	621.10	1259.23	823.51	54	0.711	0.750	0.781	473321	0.10	1.000	11902	0.26	1.000	15526	0.10	1.000	21489	1.000	34814	0.29	1.000	9566	0.10	1.000	3834		1.000	12070	0.10	1.000	55605	0	0	0	0

6.2 Cases 2 and 2a – Spillway Gates Closed

For the spillway gates closed condition, discharges are computed for headwaters ranging from 773 feet, an arbitrary starting point for turbine discharge, to 837 feet, the limit of the headwater elevation [4.21]. This case is similar to case 1 except for there is no discharge through the spillway until the gates themselves are overtopped. Discharge passes through the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000.

Figure 5 shows the spreadsheet calculations for the spillway gates closed initial dam rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The next two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW rating curve. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit [4.20]. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway (mainly at Tellico in this calculation), it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 5 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next four columns (under the header "Spillway"), H_c, $C_f|C_g$, d/H_c, and $Q_f|Q_g$ as outlined in section 4.22. Free discharge occurs for headwater elevations below 820 feet [4.5.5] and orifice discharge occurs for headwaters above 820 feet. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.5.1] computed in Attachment 4 and below the line the listed discharge coefficient is C_g [4.5.6] as discussed in Section 4.22. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 3 for orifice discharge.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next eleven columns are overflow discharges in cfs for the lock walls, lock gates, spillway deck, north embankment, powerhouse, nonoverflow dam, south embankment, and the saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.7.1], [4.13.1], [4.12.1], [4.11.1], [4.16.1], [4.14.1]), elevation Z_c ([4.10.2], [4.9.2], [4.7.2], [4.13.2], [4.12.2], [4.11.2], [4.16.1], [4.14.2]), and length L ([4.10.3], [4.9.3], [4.7.3], [4.13.3], [4.12.3], [4.11.3], [4.16.1], [4.14.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1.

The final column is the turbine discharge. This discharge is calculated as outlined in Section 4.27.

Case 2a is presented in Figure 6. This calculation is identical to Case 2 except for the subtraction of the turbine discharge. This case will be used for falling headwaters where the turbines have already been shut down and can not be turned back on yet.

Figure 5: Spillway Gates closed with Turbine Flow

g = 32.2 ft/s²

Spillway Parameters
L = 560 feet
Z_c = 815 feet
G_n = 3.500 feet
C_f = 3.600 feet
C_g = 0.7 feet

Overflow Discharge, Q_f in cfs

HW feet	Q Ft Loudoun Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	Main Dam TRM 602.3 TW feet	Spillway feet H_c	$C_f \mid C_g$	d/H_c	Spillway cfs $Q_f \mid Q_g$	Lock Walls d/H_c	Sf	Q	Lock Gates d/H_c	Sf	Q	Spillway Deck d/H_c	Sf	Q	North Bank Section 1 d/H_c	Sf	Q	North Bank Section 2 d/H_c	Sf	Q	Non Overflow d/H_c	Sf	Q	Power House d/H_c	Sf	Q	South Bank Sec. 1 Q	South Bank Sec. 2 Q	Saddle Dam Sec. 1 Q	Saddle Dam Sec. 2 Q	Turbine Discharge Q
									C_f =		2.75			3.30			2.70			3.30		3.30			3.30			2.70	2.65	2.65	2.65	2.65	-
									Z_c =		822			818.7			822			818		822			826.5			822	837	837	837	837	-
									L =		74.5			60.1			697.0			35.0		20.0			107.5			354.5	2208.0	50.9	540	30	-
773	20.55	0.00	20.55	747.65				0			0			0			0			0			0			0			0	0	0	0	0	20546
775	22.44	1.06	23.50	748.02				0			0			0			0			0			0			0			0	0	0	0	0	22443
777	24.14	3.01	27.15	748.46				0			0			0			0			0			0			0			0	0	0	0	0	24136
779	25.67	5.58	31.25	748.97				0			0			0			0			0			0			0			0	0	0	0	0	25671
781	27.07	8.70	35.77	749.51				0			0			0			0			0			0			0			0	0	0	0	0	27066
783	28.33	12.32	40.65	750.10				0			0			0			0			0			0			0			0	0	0	0	0	28333
785	29.48	16.42	45.90	750.73				0			0			0			0			0			0			0			0	0	0	0	0	29481
787	30.52	20.99	51.51	751.40				0			0			0			0			0			0			0			0	0	0	0	0	30520
789	31.46	26.01	57.46	752.10				0			0			0			0			0			0			0			0	0	0	0	0	31456
791	32.20	31.46	63.66	752.82				0			0			0			0			0			0			0			0	0	0	0	0	32200
793	32.20	37.31	69.51	753.50				0			0			0			0			0			0			0			0	0	0	0	0	32200
795	32.20	43.54	75.74	754.21				0			0			0			0			0			0			0			0	0	0	0	0	32200
797	32.20	50.13	82.33	754.96				0			0			0			0			0			0			0			0	0	0	0	0	32200
799	32.20	57.05	89.25	755.73				0			0			0			0			0			0			0			0	0	0	0	0	32200
801	32.20	64.25	96.45	756.53				0			0			0			0			0			0			0			0	0	0	0	0	32200
803	32.20	71.72	103.92	757.35				0			0			0			0			0			0			0			0	0	0	0	0	32200
805	32.20	79.41	111.61	758.19				0			0			0			0			0			0			0			0	0	0	0	0	32200
807	32.20	87.31	119.51	759.04				0			0			0			0			0			0			0			0	0	0	0	0	32200
809	32.20	95.40	127.60	759.89				0			0			0			0			0			0			0			0	0	0	0	0	32200
811	32.20	103.66	135.86	760.76				0			0			0			0			0			0			0			0	0	0	0	0	32200
813	32.20	112.09	144.29	761.63				0			0			0			0			0			0			0			0	0	0	0	0	32200
815	32.20	120.70	152.90	762.51	0	3.600		0			0			0			0			0			0			0			0	0	0	0	0	32200
815.80	33.63	124.19	157.82	763.01	0.796	3.600		1432			0			0			0			0			0			0			0	0	0	0	0	32200
816	34.22	124.05	158.26	763.05	1	3.600		2016			0			0			0			0			0			0			0	0	0	0	0	32200
817	37.90	123.98	161.88	763.42	2	3.600		5702			0			0			0			0			0			0			0	0	0	0	0	32200
818	42.68	129.73	172.41	764.46	3	3.600		10475			0			0			0			0			0			0			0	0	0	0	0	32200
819	48.36	140.79	189.15	766.09	4	3.600		16128			0	1.000		33			0			0			0			0			0	0	0	0	0	32200
820	55.03	157.31	212.34	768.29	5	3.600		22540			0	1.000		294			0			0			0			0			0	0	0	0	0	32200
821	55.59	177.43	233.02	770.18	6	0.700		22698			0	1.000		692			0			0			0			0			0	0	0	0	0	32200
822	58.62	201.33	259.95	772.56	7	0.700		25228			0	1.000		1189			0			0			0			0			0	0	0	0	0	32200
823	32.34	228.25	260.58	772.61	8	0.700		27526	1.000		205	1.000		1768	1.000		1882			0			0			0	1.000		957	0	0	0	0	0
824	40.68	257.91	298.59	775.81	9	0.700		29646	1.000		579	1.000		2420	1.000		5323			0			0			0	1.000		2707	0	0	0	0	0
825	50.58	290.19	340.77	779.15	10	0.700		31625	1.000		1065	1.000		3136	1.000		9779			0			0			0	1.000		4973	0	0	0	0	0
826	61.75	324.95	386.70	782.57	11	0.700		33486	1.000		1639	1.000		3912	1.000		15055			0			0			0	1.000		7657	0	0	0	0	0
827	78.01	361.86	439.87	786.26	12	0.700		35250	1.000		2291	1.000		4742	1.000		21040	1.000		3119	1.000		738	1.000		125	1.000		10701	0	0	0	0	0
828	92.56	401.00	493.56	789.72	13	0.700		36929	1.000		3011	1.000		5625	1.000		27658	1.000		3652	1.000		970	1.000		652	1.000		14067	0	0	0	0	0
829	108.30	441.94	550.24	793.11	14	0.700		38536	1.000		3794	1.000		6556	1.000		34853	1.000		4214	1.000		1222	1.000		1402	1.000		17727	0	0	0	0	0
830	125.11	484.85	609.96	796.43	15	0.700		40078	1.000		4636	1.000		7534	1.000		42583	1.000		4801	1.000		1493	1.000		2323	1.000		21658	0	0	0	0	0
831	142.89	510.16	653.05	798.69	16	0.700		41563	1.000		5532	1.000		8556	1.000		50811	1.000		5414	1.000		1782	1.000		3386	1.000		25843	0	0	0	0	0
832	161.59	535.98	697.57	800.91	17	0.700		42996	1.000		6479	1.000		9620	1.000		59511	1.000		6050	1.000		2087	1.000		4576	1.000		30268	0	0	0	0	0
833	181.16	562.45	743.61	803.09	18	0.700		44384	1.000		7474	1.000		10725	1.000		68657	1.000		6710	1.000		2408	1.000		5879	1.000		34920	0	0	0	0	0
834	201.55	589.38	790.93	805.24	19	0.700		45729	1.000		8516	1.000		11869	1.000		78229	1.000		7392	1.000		2744	1.000		7286	1.000		39788	0	0	0	0	0
835	222.74	616.47	839.21	807.35	20	0.700		47036	1.000		9603	1.000		13052	1.000		88209	1.000		8096	1.000		3094	1.000		8791	1.000		44864	0	0	0	0	0
836	244.69	643.96	888.65	809.42	21	0.700		48307	1.000		10732	1.000		14271	1.000		98580	1.000		8820	1.000		3457	1.000		10387	1.000		50139	0	0	0	0	0
837	267.38	671.05	938.43	811.44	22	0.700		49546	1.000		11902	1.000		15526	1.000		109329	1.000		9566	1.000		3834	1.000		12070	1.000		55605	0	0	0	0	0

Figure 6: Spillway Gates Closed - No Turbine Flow

g = 32.2 ft/s²

Spillway Parameters
L = 560 feet
Z_c = 815 feet
G_n = 3.500 feet
C_T = 3.600 feet
C_g = 0.7 feet

Overflow Discharge, Q_t in cfs

HW feet	Q Ft Loudoun Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	Main Dam TRM 602.3 TW feet	Spillway feet H_c	$C_t \mid C_g$	d/H_c	cfs $Q_t \mid Q_s$	Lock Walls d/H_c	Sf	Q	Lock Gates d/H_c	Sf	Q	Spillway Deck d/H_c	Sf	Q	North Bank Section 1 d/H_c	Sf	Q	North Bank Section 2 d/H_c	Sf	Q	Non Overflow d/H_c	Sf	Q	Power House d/H_c	Sf	Q	South Bank Sec. 1 Q	South Bank Sec. 2 Q	Saddle Dam Sec. 1 Q	Saddle Dam Sec. 2 Q
									C_t =		2.75			3.30			2.70			3.30			3.30			3.30			2.70	2.65	2.65	2.65	2.65
									Z_c =		822			818.7			822			818			822			826.5			822	837	837	837	837
									L =		74.5			60.1			697.0			35.0			20.0			107.5			354.5	2208.0	50.9	540	30
773	0.00	0.00	0.00	745.07				0			0			0			0			0			0			0			0	0	0	0	0
775	0.00	1.06	1.06	745.20				0			0			0			0			0			0			0			0	0	0	0	0
777	0.00	3.01	3.01	745.45				0			0			0			0			0			0			0			0	0	0	0	0
779	0.00	5.58	5.58	745.78				0			0			0			0			0			0			0			0	0	0	0	0
781	0.00	8.70	8.70	746.17				0			0			0			0			0			0			0			0	0	0	0	0
783	0.00	12.32	12.32	746.63				0			0			0			0			0			0			0			0	0	0	0	0
785	0.00	16.42	16.42	747.14				0			0			0			0			0			0			0			0	0	0	0	0
787	0.00	20.99	20.99	747.71				0			0			0			0			0			0			0			0	0	0	0	0
789	0.00	26.01	26.01	748.33				0			0			0			0			0			0			0			0	0	0	0	0
791	0.00	31.46	31.46	748.99				0			0			0			0			0			0			0			0	0	0	0	0
793	0.00	37.31	37.31	749.70				0			0			0			0			0			0			0			0	0	0	0	0
795	0.00	43.54	43.54	750.45				0			0			0			0			0			0			0			0	0	0	0	0
797	0.00	50.13	50.13	751.23				0			0			0			0			0			0			0			0	0	0	0	0
799	0.00	57.05	57.05	752.05				0			0			0			0			0			0			0			0	0	0	0	0
801	0.00	64.25	64.25	752.89				0			0			0			0			0			0			0			0	0	0	0	0
803	0.00	71.72	71.72	753.75				0			0			0			0			0			0			0			0	0	0	0	0
805	0.00	79.41	79.41	754.63				0			0			0			0			0			0			0			0	0	0	0	0
807	0.00	87.31	87.31	755.52				0			0			0			0			0			0			0			0	0	0	0	0
809	0.00	95.40	95.40	756.42				0			0			0			0			0			0			0			0	0	0	0	0
811	0.00	103.66	103.66	757.32				0			0			0			0			0			0			0			0	0	0	0	0
813	0.00	112.09	112.09	758.24				0			0			0			0			0			0			0			0	0	0	0	0
815	0.00	120.70	120.70	759.16	0	3.600		0			0			0			0			0			0			0			0	0	0	0	0
815.80	1.43	124.19	125.62	759.69	0.796	3.600		1432			0			0			0			0			0			0			0	0	0	0	0
816	2.02	124.05	126.06	759.73	1	3.600		2016			0			0			0			0			0			0			0	0	0	0	0
817	5.70	123.98	129.68	760.11	2	3.600		5702			0			0			0			0			0			0			0	0	0	0	0
818	10.48	129.73	140.21	761.21	3	3.600		10475			0			0			0			0			0			0			0	0	0	0	0
819	16.16	140.79	156.95	762.92	4	3.600		16128			0	1.000		33			0			0			0			0			0	0	0	0	0
820	22.83	157.31	180.14	765.22	5	3.600		22540			0	1.000		294			0			0			0			0			0	0	0	0	0
821	23.39	177.43	200.82	767.21	6	0.700		22698			0	1.000		692			0			0			0			0			0	0	0	0	0
822	26.42	201.33	227.75	769.70	7	0.700		25228			0	1.000		1189			0			0			0			0			0	0	0	0	0
823	32.34	228.25	260.58	772.61	8	0.700		27526	1.000		205	1.000		1768	1.000		1882			0			0			0	1.000		957	0	0	0	0
824	40.68	257.91	298.59	775.81	9	0.700		29646	1.000		579	1.000		2420	1.000		5323			0			0			0	1.000		2707	0	0	0	0
825	50.58	290.19	340.77	779.15	10	0.700		31625	1.000		1065	1.000		3136	1.000		9779			0			0			0	1.000		4973	0	0	0	0
826	61.75	324.95	386.70	782.57	11	0.700		33486	1.000		1639	1.000		3912	1.000		15055			0			0			0	1.000		7657	0	0	0	0
827	78.01	361.86	439.87	786.26	12	0.700		35250	1.000		2291	1.000		4742	1.000		21040	1.000		3119	1.000		738	1.000		125	1.000		10701	0	0	0	0
828	92.56	401.00	493.56	789.72	13	0.700		36929	1.000		3011	1.000		5625	1.000		27658	1.000		3652	1.000		970	1.000		652	1.000		14067	0	0	0	0
829	108.30	441.94	550.24	793.11	14	0.700		38536	1.000		3794	1.000		6556	1.000		34853	1.000		4214	1.000		1222	1.000		1402	1.000		17727	0	0	0	0
830	125.11	484.85	609.96	796.43	15	0.700		40078	1.000		4636	1.000		7534	1.000		42583	1.000		4801	1.000		1493	1.000		2323	1.000		21658	0	0	0	0
831	142.89	510.16	653.05	798.69	16	0.700		41563	1.000		5532	1.000		8556	1.000		50811	1.000		5414	1.000		1782	1.000		3386	1.000		25843	0	0	0	0
832	161.59	535.98	697.57	800.91	17	0.700		42996	1.000		6479	1.000		9620	1.000		59511	1.000		6050	1.000		2087	1.000		4576	1.000		30268	0	0	0	0
833	181.16	562.45	743.61	803.09	18	0.700		44384	1.000		7474	1.000		10725	1.000		68657	1.000		6710	1.000		2408	1.000		5879	1.000		34920	0	0	0	0
834	201.55	589.38	790.93	805.24	19	0.700		45729	1.000		8516	1.000		11869	1.000		78229	1.000		7392	1.000		2744	1.000		7286	1.000		39788	0	0	0	0
835	222.74	616.47	839.21	807.35	20	0.700		47036	1.000		9603	1.000		13052	1.000		88209	1.000		8096	1.000		3094	1.000		8791	1.000		44864	0	0	0	0
836	244.69	643.96	888.65	809.42	21	0.700		48307	1.000		10732	1.000		14271	1.000		98580	1.000		8820	1.000		3457	1.000		10387	1.000		50139	0	0	0	0
837	267.38	671.05	938.43	811.44	22	0.700		49546	1.000		11902	1.000		15526	1.000		109329	1.000		9566	1.000		3834	1.000		12070	1.000		55605	0	0	0	0

6.3 Case 3 - South Embankment Failure, Fort Loudoun Spillway Gates Open – Tellico Intact

For the South Embankment Failure condition, discharges are computed for headwaters ranging from 773 feet to 837 feet, the limit of the headwater elevation [4.21]. Discharge passes through the spillway section and the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000.

Figure 7 shows the spreadsheet calculations for the pre-failure initial dam rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The next two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW elevation. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit provided in Attachment 15. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway, it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 7 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next five columns (under the header "Spillway"), H_c, $C_f|C_g$, d/H_c, $S_f|S_g$, and $Q_f|Q_g$. Free discharge occurs for headwater elevations below 820.9 feet [4.3.4] and orifice discharge occurs for headwaters above 820.9 feet. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.2.3] computed from Equation A5 and below the line the listed discharge coefficient is C_g [4.3.5] computed by interpolation between the points in Table A3. S_f is computed to account for submergence effects using Equation A6 when d/H_c exceeds 0.6. S_g is calculated by interpolating between values in Table A1. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 3 for orifice discharge. The free and orifice discharges are modified by Equations 2 and 4, respectively, to account for the submergence effects when d/H_c is greater than 0.6.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next 33 columns are overflow discharges in cfs for the lock walls, lock gates, spillway deck, spillway gates, north embankment, nonoverflow, powerhouse, south embankment, and saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.6.1], [4.4.1], [4.13.1], [4.11.1], [4.12.1], [4.17.1], [4.15.1]), elevation Z_c ([4.10.2], [4.9.2], [4.6.2], [4.4.2], [4.13.2], [4.11.2], [4.12.2], [4.17.2], [4.15.2]), and length L ([4.10.3], [4.9.3], [4.6.3], [4.4.3], [4.13.3], [4.11.3], [4.12.3], [4.17.3], [4.15.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that all overflows had to be modified using Equation 2 in order to account for submergence. S_f is calculated using Equation 5 and interpolation in Table 2.

TVA

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Subject: Initial Dam Rating Curves, Fort Loudoun	Prepd: WBB		
	Checked: ACM		

Figure 7: South Embankment Failure with Spillway Gates Open

g = 32.2 ft/s²

Spillway Parameters
L = 560 feet
Z_c = 783 feet
G_h = 30.314 feet
H_{mp} = 14.828 feet
H_{Lmin} = 37.94 feet

Overflow Discharge, Q_t in cfs

HW feet	Q Ft Loudoun Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	Main Dam TRM 602.3 TW feet	Spillway H_c feet	$C_f \mid C_s$	d/H_c	$S_f \mid S_g$	$Q_f \mid Q_g$ cfs	Lock Walls d/H_c	Sf	Q	Lock Gates d/H_c	Sf	Q	Spillway Deck d/H_c	Sf	Q	Spillway Gates d/H_c	Sf	Q	North Bank Section 1 d/H_c	Sf	Q	North Bank Section 2 d/H_c	Sf	Q	Non Overflow d/H_c	Sf	Q	Power House d/H_c	Sf	Q	South Bank Sec. 1 d/H_c	Sf	Q	South Bank Sec. 2 d/H_c	Sf	Q	Saddle Dam d/H_c	Sf	Q	Turbine Discharge Q
									C_f =			2.75			3.30			2.70			3.30			3.30			3.30			3.30			2.70			2.65			2.65			2.65			-
									Z_c =			822			818.7			822			829.92			818			822			826.5			822			754			770			815			-
									L =			74.5			60.1			137.0			560.0			35.0			20.0			107.5			354.5			1130.0			1130.0			570			-
773	226.55	0.00	228.55	769.59					0			0			0			0			0			0			0			0			0	0.82	0.851	210989		1.000	15560			0	0
775	254.90	1.06	255.96	772.21					0			0			0			0			0			0			0			0			0	0.87	0.768	221420	0.44	1.000	33480			0	0
777	281.97	2.97	284.94	774.68					0			0			0			0			0			0			0			0			0	0.90	0.689	227456	0.67	0.983	54511			0	0
779	307.82	5.19	313.01	776.97					0			0			0			0			0			0			0			0			0	0.92	0.627	234549	0.77	0.906	73275			0	0
781	333.55	7.52	341.07	779.17					0			0			0			0			0			0			0			0			0	0.93	0.578	242844	0.83	0.830	90703			0	0
783	359.51	9.98	369.48	781.31	0	3.090		1.000	0			0			0			0			0			0			0			0			0	0.94	0.540	252656	0.87	0.761	106853			0	0
785	386.65	12.47	399.12	783.46	2	3.191		1.000	5055			0			0			0			0			0			0			0			0	0.95	0.505	260791	0.90	0.694	120808			0	0
787	415.04	14.97	430.01	785.59	4	3.277		1.000	14682			0			0			0			0			0			0			0			0	0.96	0.472	267668	0.92	0.632	132691			0	0
789	444.66	17.46	462.12	787.72	6	3.350		1.000	27571			0			0			0			0			0			0			0			0	0.96	0.442	274059	0.93	0.577	143029			0	0
791	475.62	19.93	495.54	789.84	8	3.412		1.000	43235			0			0			0			0			0			0			0			0	0.97	0.416	280195	0.94	0.528	152186			0	0
793	507.88	22.38	530.26	791.94	10	3.465		1.000	61368			0			0			0			0			0			0			0			0	0.97	0.392	285638	0.95	0.487	160877			0	0
795	541.72	24.76	566.48	794.04	12	3.512		1.000	81756			0			0			0			0			0			0			0			0	0.98	0.370	290988	0.96	0.451	168974			0	0
797	577.29	27.03	604.32	796.13	14	3.554		1.000	104243			0			0			0			0			0			0			0			0	0.98	0.351	296566	0.97	0.420	176486			0	0
799	613.31	29.66	642.96	798.17	16	3.591		1.000	128718			0			0			0			0			0			0			0			0	0.98	0.329	297346	0.97	0.400	187241			0	0
801	650.96	32.30	683.26	800.21	18	3.627		1.000	155111			0			0			0			0			0			0			0			0	0.98	0.309	297874	0.97	0.383	197974			0	0
803	690.46	34.90	725.36	802.24	20	3.661		1.000	183379			0			0			0			0			0			0			0			0	0.98	0.290	298218	0.98	0.368	208860			0	0
805	731.84	37.45	769.28	804.27	22	3.695		1.000	213506			0			0			0			0			0			0			0			0	0.99	0.274	298419	0.98	0.355	219913			0	0
807	774.70	40.10	814.79	806.29	24	3.728		1.000	245492			0			0			0			0			0			0			0			0	0.99	0.261	301542	0.98	0.338	227662			0	0
809	819.09	42.82	861.91	808.31	26	3.763	0.973	0.413	279350			0			0			0			0			0			0			0			0	0.99	0.251	306543	0.98	0.320	233198			0	0
811	865.19	45.52	910.71	810.32	28	3.798	0.976	0.394	315090			0			0			0			0			0			0			0			0	0.99	0.242	311490	0.98	0.304	238614			0	0
813	912.88	48.18	961.06	812.34	30	3.833	0.978	0.376	352717			0			0			0			0			0			0			0			0	0.99	0.233	316311	0.98	0.289	243855			0	0
815	962.00	50.81	1012.81	814.35	32	3.869	0.980	0.360	392217			0			0			0			0			0			0			0			0	0.99	0.225	320924	0.99	0.275	248857			0	0
815.796	981.98	51.81	1033.79	815.16	32.796	3.883	0.980	0.353	408452			0			0			0			0			0			0			0			0	0.99	0.221	322151	0.99	0.270	250308	0.20	1.000	1073	0
816	1007.43	30.86	1038.29	815.33	33	3.887	0.980	0.361	412658			0			0			0			0			0			0			0			0	0.99	0.228	333274	0.99	0.278	259988	0.33	1.000	1511	0
817	1035.23	29.67	1064.90	816.34	34	3.905	0.980	0.354	433549			0			0			0			0			0			0			0			0	0.99	0.224	335271	0.99	0.272	262212	0.67	0.983	4200	0
818	1057.83	34.18	1092.00	817.35	35	3.923	0.982	0.344	454878			0			0			0			0			0			0			0			0	0.99	0.218	334173	0.99	0.263	261741	0.78	0.896	7033	0
819	1075.70	43.83	1119.53	818.38	36	3.940	0.983	0.331	476631			0		1.000	33			0			0	0.38	1.000	0			0			0			0	0.99	0.211	330353	0.99	0.252	258878	0.84	0.812	9808	0
820	1089.86	57.57	1147.42	819.41	37	3.958	0.984	0.318	496787			0	0.55	1.000	294			0			0	0.71	0.962	0			0			0			0	0.99	0.202	324336	0.99	0.240	254066	0.88	0.733	12374	0
821	1076.21	83.99	1160.20	819.88	38	0.793	0.971	0.309	160921			0	0.51	1.000	692			0			0	0.63	0.997	0			0			0			0	0.98	0.305	501685	0.98	0.361	393814	0.81	0.860	19096	0
822	1083.61	104.01	1187.62	820.89	39	0.775	0.972	0.295	152978			0	0.66	0.985	1171			0			0	0.72	0.951	0			0			0			0	0.98	0.301	504900	0.98	0.358	401689	0.84	0.818	22871	0
823	1089.63	125.69	1215.33	821.91	40	0.756	0.973	0.281	145299		1.000	205	0.75	0.933	1650		1.000	370			0	0.78	0.900	0		1.000	0			0		1.000	957	0.98	0.295	505864	0.98	0.354	408749	0.86	0.777	26541	0
824	1094.16	149.10	1243.25	822.93	41	0.738	0.974	0.269	138261	0.46	1.000	579	0.80	0.882	2133	0.46	1.000	1046			0	0.82	0.850	0	0.46	1.000	2707			0	0.46	1.000	2707	0.98	0.288	505079	0.98	0.349	414276	0.88	0.737	30074	0
825	1096.99	174.17	1271.15	823.94	42	0.720	0.975	0.260	132795	0.65	0.992	1056	0.83	0.833	2614	0.65	0.992	1906			0	0.85	0.805	0	0.65	0.992	0			0	0.65	0.992	4931	0.99	0.282	505149	0.98	0.340	414992	0.89	0.702	33544	0
826	1097.62	201.66	1299.28	824.97	43	0.719	0.976	0.250	130060	0.74	0.936	1535	0.86	0.786	3076	0.74	0.936	2771			0	0.87	0.760	0	0.74	0.936	0			0	0.74	0.936	7171	0.99	0.275	502710	0.98	0.329	413470	0.91	0.668	36823	0
827	1099.26	228.23	1327.48	825.99	44	0.717	0.977	0.241	127231	0.80	0.880	2016	0.88	0.742	3520	0.80	0.880	3640			0	0.89	0.719	2241	0.80	0.880	649		1.000	125	0.80	0.880	9418	0.99	0.267	499353	0.98	0.319	411105	0.92	0.636	39957	0
828	1099.88	255.74	1355.62	827.02	45	0.716	0.978	0.233	124560	0.84	0.827	2490	0.89	0.702	3949	0.84	0.827	4495			0	0.90	0.681	2488	0.84	0.827	802	0.34	1.000	652	0.84	0.827	11632	0.99	0.261	496574	0.98	0.309	409217	0.92	0.608	43025	0
829	1099.67	284.08	1383.75	828.04	46	0.714	0.979	0.224	121442	0.86	0.777	2948	0.91	0.665	4363	0.86	0.777	5323			0	0.91	0.647	2726	0.86	0.777	950	0.62	0.999	1401	0.86	0.777	13773	0.99	0.254	493608	0.98	0.300	407134	0.93	0.581	46001	0
830	1098.61	313.24	1411.84	829.07	47	0.713	0.980	0.214	117856	0.88	0.731	3389	0.92	0.632	4762	0.88	0.731	6119		1.000	42	0.92	0.616	2955	0.88	0.731	1092	0.73	0.943	2191	0.88	0.731	15832	0.99	0.247	490541	0.98	0.291	404930	0.94	0.557	48897	0
831	1126.24	312.67	1438.91	830.05	48	0.711	0.980	0.208	116080	0.89	0.700	3874	0.92	0.612	5237	0.89	0.700	6995	0.12	1.000	2074	0.93	0.597	3233	0.89	0.700	1248	0.79	0.890	3015	0.89	0.700	18099	0.99	0.247	499957	0.98	0.290	413809	0.94	0.544	52621	0
832	1159.45	306.36	1465.81	831.04	49	0.711	0.980	0.203	114698	0.90	0.675	4373	0.93	0.596	5731	0.90	0.675	7895	0.54	1.000	5544	0.93	0.582	3523	0.90	0.675	1409	0.83	0.844	3863	0.90	0.675	20428	0.99	0.248	511167	0.98	0.290	424295	0.94	0.534	56524	0
833	1186.23	306.69	1492.92	832.03	50	0.711	0.981	0.196	112722	0.91	0.650	4857	0.93	0.579	6206	0.91	0.650	8769	0.69	0.974	9733	0.94	0.566	3800	0.91	0.650	1565	0.85	0.801	4708	0.91	0.650	22691	0.99	0.247	519088	0.98	0.288	431861	0.95	0.522	60229	0
834	1213.44	306.55	1519.98	833.02	51	0.711	0.981	0.190	110667	0.92	0.628	5345	0.94	0.563	6685	0.92	0.628	9650	0.76	0.920	14010	0.94	0.552	4081	0.92	0.628	1722	0.87	0.762	5555	0.92	0.628	24971	0.99	0.246	527183	0.98	0.287	439585	0.95	0.511	63985	0
835	1245.32	301.56	1546.88	834.01	52	0.711	0.981	0.185	109525	0.92	0.609	5848	0.94	0.551	7185	0.92	0.609	10559	0.81	0.871	18438	0.94	0.540	4374	0.92	0.609	1884	0.88	0.730	6415	0.92	0.609	27323	0.99	0.246	536995	0.98	0.286	448854	0.95	0.503	67922	0
836	1283.67	289.89	1573.56	834.99	53	0.711	0.981	0.183	109535	0.93	0.594	6377	0.94	0.541	7714	0.93	0.594	11513	0.83	0.830	22985	0.94	0.531	4684	0.93	0.594	2054	0.89	0.703	7300	0.93	0.594	29791	0.99	0.247	549262	0.98	0.287	460334	0.95	0.496	72120	0
837	1331.54	268.38	1599.92	835.96	54	0.711	0.981	0.182	110049	0.93	0.584	6947	0.94	0.534	8292	0.93	0.584	12543	0.85	0.796	27705	0.95	0.525	5024	0.93	0.584	2238	0.90	0.682	8235	0.93	0.584	32457	0.99	0.250	565713	0.98	0.290	475589	0.95	0.492	76749	0

6.4 Case 4 - South Embankment Failure, Fort Loudoun Spillway Gates Closed – Tellico Intact

For the South Embankment Failure with spillway gates closed condition, discharges are computed for headwaters ranging from 773 feet to 837 feet, the limit of the headwater elevation [4.21]. This case is similar to case 3 except for there is no discharge through the spillway until the gates themselves are overtopped. Discharge passes through the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000.

Figure 8 shows the spreadsheet calculations for the spillway gates closed initial dam rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The next two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW rating curve. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit [4.20]. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway (mainly at Tellico in this calculation), it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 8 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next five columns (under the header "Spillway"), H_c, $C_f|C_g$, d/H_c, S_f, and $Q_f|Q_g$ as outlined in section 4.22. Free discharge occurs for headwater elevations below 820 feet [4.5.5] and orifice discharge occurs for headwaters above 820 feet. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.5.1] computed from Equation A5 and below the line the listed discharge coefficient is C_g [4.5.6]. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 3 for orifice discharge. Free discharge is modified by Equation 2 using the S_f calculated from Equation 5. Orifice discharge is modified as outlined in Section 4.22.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next 33 columns are overflow discharges in cfs for the lock walls, lock gates, spillway deck, north embankment, powerhouse, nonoverflow dam, south embankment, and the saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.7.1], [4.13.1], [4.12.1], [4.11.1], [4.17.1], [4.15.1]), elevation Z_c ([4.10.2], [4.9.2], [4.7.2], [4.13.2], [4.12.2], [4.11.2], [4.17.2], [4.15.2]), and length L ([4.10.3], [4.9.3], [4.7.3], [4.13.3], [4.12.3], [4.11.3], [4.17.3], [4.15.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that all overflows had to be modified using Equation 2 in order to account for submergence. S_f is calculated using Equation 5 and interpolation in Table 2.

TVA

Calculation No. CDQ000020080009	Rev: 1	Plant: GEN	Page: 31
Subject: Initial Dam Rating Curves, Fort Loudoun	Prepd: WBB		
	Checked: ACM		

Figure 8: South Embankment Failure with Spillway Gates Open

g = 32.2 ft/s²

Spillway Parameters
L = 560 feet
Z_c = 815 feet
G_n = 3.500 feet
C_f = 3.600 feet
C_g = 0.7 feet

HW feet	Q Ft Loudoun Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	Main Dam TRM 602.3 TW feet	Spillway H_c (feet)	Spillway C_f | C_g	Spillway d/H_c	Spillway S_r	Spillway Q_f | Q_g (cfs)
773	226.55	0.00	226.55	769.59					0
775	254.90	1.06	255.96	772.21					0
777	281.97	2.97	284.94	774.68					0
779	307.82	5.19	313.01	776.97					0
781	333.55	7.52	341.07	779.17					0
783	359.51	9.98	369.48	781.31					0
785	385.99	12.55	398.54	783.41					0
787	413.19	15.25	428.44	785.49					0
789	441.27	18.08	459.35	787.54					0
791	470.35	21.04	491.39	789.58					0
793	500.55	24.12	524.68	791.61					0
795	531.97	27.32	559.30	793.63					0
797	564.71	30.64	595.35	795.64					0
799	598.84	34.06	632.90	797.65					0
801	634.34	37.61	671.95	799.64					0
803	671.38	41.26	712.64	801.63					0
805	709.98	45.00	754.98	803.62					0
807	750.15	48.83	798.97	805.60					0
809	791.87	52.73	844.60	807.58					0
811	835.07	56.73	891.80	809.55					0
813	879.67	60.80	940.47	811.52					0
815	925.52	64.96	990.48	813.49	0	3.600			0
815.796	944.42	66.53	1010.95	814.28	0.796	3.600		1.000	1432
816	972.18	41.62	1013.80	814.39	1	3.600		1.000	2016
817	998.95	40.93	1039.88	815.39	2	3.600	0.194	1.000	5702
818	1021.01	45.93	1066.94	816.41	3	3.600	0.471	1.000	10475
819	1038.81	56.05	1094.86	817.46	4	3.600	0.615	0.999	16116
820	1052.93	70.42	1123.34	818.52	5	3.600	0.704	0.963	21710
821	1062.47	88.50	1150.98	819.54	6	0.700	0.757	-	13287
822	1071.28	108.36	1179.64	820.60	7	0.700	0.800	-	13034
823	1078.35	129.89	1208.24	821.65	8	0.700	0.831	-	12808
824	1083.37	153.29	1236.66	822.68	9	0.700	0.854	-	12626
825	1087.05	178.18	1265.23	823.73	10	0.700	0.873	-	12424
826	1089.51	204.40	1293.91	824.77	11	0.700	0.888	-	12208
827	1089.99	232.85	1322.85	825.82	12	0.700	0.902	-	11941
828	1090.64	260.77	1351.40	826.86	13	0.700	0.913	-	11740
829	1090.14	289.58	1379.72	827.89	14	0.700	0.921	-	11576
830	1089.17	318.85	1408.01	828.93	15	0.700	0.928	-	11411
831	1115.92	319.32	1435.24	829.92	16	0.700	0.933	-	11442
832	1148.04	314.25	1462.29	830.91	17	0.700	0.936	-	11501
833	1177.98	311.43	1489.41	831.90	18	0.700	0.939	-	11536
834	1204.44	312.19	1516.63	832.90	19	0.700	0.942	-	11544
835	1235.22	308.44	1543.66	833.89	20	0.700	0.945	-	11581
836	1271.84	298.62	1570.46	834.88	21	0.700	0.947	-	11657
837	1316.91	280.03	1596.94	835.85	22	0.700	0.948	-	11788

Overflow Discharge, Q_f in cfs

HW feet	Lock Walls d/H_c	Lock Walls Sf	Lock Walls Q	Lock Gates d/H_c	Lock Gates Sf	Lock Gates Q	Spillway Deck d/H_c	Spillway Deck Sf	Spillway Deck Q	Spillway Gates d/H_c	Spillway Gates Sf	Spillway Gates Q
C_f =			2.75			3.30			2.70			3.30
Z_c =			822			818.7			822			829.92
L =			74.5			60.1			137.0			560.0
773			0			0			0			0
775			0			0			0			0
777			0			0			0			0
779			0			0			0			0
781			0			0			0			0
783			0			0			0			0
785			0			0			0			0
787			0			0			0			0
789			0			0			0			0
791			0			0			0			0
793			0			0			0			0
795			0			0			0			0
797			0			0			0			0
799			0			0			0			0
801			0			0			0			0
803			0			0			0			0
805			0			0			0			0
807			0			0			0			0
809			0			0			0			0
811			0			0			0			0
813			0			0			0			0
815			0			0			0			0
815.796			0			0			0			0
816			0			0			0			0
817			0			0			0			0
818			0			0			0			0
819			0		1.000	33			0			0
820			0		1.000	294			0			0
821			0	0.37	1.000	692			0			0
822			0	0.58	1.000	1189			0			0
823		1.000	205	0.69	0.974	1723		1.000	370			0
824	0.34	1.000	579	0.75	0.928	2245	0.34	1.000	1046			0
825	0.58	1.000	1085	0.80	0.881	2762	0.58	1.000	1922			0
826	0.69	0.970	1590	0.83	0.834	3263	0.69	0.970	2871			0
827	0.76	0.916	2099	0.86	0.787	3731	0.76	0.916	3789			0
828	0.81	0.865	2604	0.88	0.744	4186	0.81	0.865	4701			0
829	0.84	0.817	3099	0.89	0.706	4632	0.84	0.817	5596			0
830	0.87	0.771	3575	0.90	0.671	5058	0.87	0.771	6455		1.000	42
831	0.88	0.739	4087	0.91	0.649	5551	0.88	0.739	7379	0.00	1.000	2074
832	0.89	0.711	4608	0.92	0.630	6060	0.89	0.711	8320	0.48	1.000	5544
833	0.90	0.685	5123	0.92	0.612	6560	0.90	0.685	9250	0.64	0.993	9917
834	0.91	0.661	5629	0.93	0.594	7050	0.91	0.661	10162	0.73	0.945	14392
835	0.91	0.640	6147	0.93	0.579	7558	0.91	0.640	11099	0.78	0.899	19014
836	0.92	0.623	6688	0.94	0.567	8094	0.92	0.623	12076	0.82	0.858	23767
837	0.92	0.610	7266	0.94	0.559	8673	0.92	0.610	13118	0.84	0.824	28671

HW feet	North Bank Section 1 d/H_c	North Bank Section 1 Sf	North Bank Section 1 Q	North Bank Section 2 d/H_c	North Bank Section 2 Sf	North Bank Section 2 Q	Non Overflow d/H_c	Non Overflow Sf	Non Overflow Q	Power House d/H_c	Power House Sf	Power House Q
C_f =			3.30			3.30			3.30			2.70
Z_c =			818			822			826.5			822
L =			35.0			20.0			107.5			354.5
773			0			0			0			0
775			0			0			0			0
777			0			0			0			0
779			0			0			0			0
781			0			0			0			0
783			0			0			0			0
785			0			0			0			0
787			0			0			0			0
789			0			0			0			0
791			0			0			0			0
793			0			0			0			0
795			0			0			0			0
797			0			0			0			0
799			0			0			0			0
801			0			0			0			0
803			0			0			0			0
805			0			0			0			0
807			0			0			0			0
809			0			0			0			0
811			0			0			0			0
813			0			0			0			0
815			0			0			0			0
815.796			0			0			0			0
816			0			0			0			0
817			0			0			0			0
818			0			0			0			0
819		1.000	0			0			0			0
820	0.26	1.000	0			0			0			0
821	0.51	1.000	0			0			0			0
822	0.65	0.991	0			0			0			0
823	0.73	0.946	0		1.000	0			0		1.000	957
824	0.78	0.900	0	0.34	1.000	0			0	0.34	1.000	2707
825	0.82	0.854	0	0.58	1.000	0			0	0.58	1.000	4973
826	0.85	0.809	0	0.69	0.970	0			0	0.69	0.970	7429
827	0.87	0.764	2381	0.76	0.916	676		1.000	125	0.76	0.916	9804
828	0.89	0.723	2641	0.81	0.865	839	0.24	1.000	652	0.81	0.865	12165
829	0.90	0.687	2897	0.84	0.817	998	0.56	1.000	1402	0.84	0.817	14479
830	0.91	0.654	3142	0.87	0.771	1152	0.69	0.970	2253	0.87	0.771	16704
831	0.92	0.633	3429	0.88	0.739	1317	0.76	0.921	3117	0.88	0.739	19094
832	0.92	0.616	3726	0.89	0.711	1484	0.80	0.876	4009	0.89	0.711	21528
833	0.93	0.599	4018	0.90	0.685	1650	0.83	0.835	4908	0.90	0.685	23934
834	0.93	0.582	4304	0.91	0.661	1813	0.85	0.796	5801	0.91	0.661	26296
835	0.93	0.568	4601	0.91	0.640	1980	0.87	0.762	6702	0.91	0.640	28719
836	0.94	0.557	4915	0.92	0.623	2155	0.88	0.734	7624	0.92	0.623	31247
837	0.94	0.549	5254	0.92	0.610	2341	0.89	0.711	8587	0.92	0.610	33944

HW feet	South Bank Sec. 1 d/H_c	South Bank Sec. 1 Sf	South Bank Sec. 1 Q	South Bank Sec. 2 d/H_c	South Bank Sec. 2 Sf	South Bank Sec. 2 Q	Saddle Dam d/H_c	Saddle Dam Sf	Saddle Dam Q	Turbine Discharge Q
C_f =			2.65			2.65			2.65	-
Z_c =			754			770			815	-
L =			1130.0			1130.0			570	-
773	0.82	0.851	210989		1.000	15560			0	0
775	0.87	0.768	221420	0.44	1.000	33480			0	0
777	0.90	0.689	227456	0.67	0.983	54511			0	0
779	0.92	0.627	234549	0.77	0.906	73275			0	0
781	0.93	0.578	242844	0.83	0.830	90703			0	0
783	0.94	0.540	252656	0.87	0.761	106853			0	0
785	0.95	0.510	263846	0.89	0.702	122142			0	0
787	0.95	0.487	276205	0.91	0.653	136983			0	0
789	0.96	0.467	289580	0.92	0.612	151686			0	0
791	0.96	0.451	303878	0.93	0.578	168472			0	0
793	0.96	0.437	319047	0.94	0.550	181504			0	0
795	0.97	0.426	335067	0.95	0.526	196907			0	0
797	0.97	0.417	351929	0.95	0.506	212777			0	0
799	0.97	0.409	369640	0.95	0.490	229195			0	0
801	0.97	0.402	387864	0.96	0.477	246477			0	0
803	0.97	0.396	406985	0.96	0.466	264392			0	0
805	0.97	0.392	426996	0.96	0.456	282982			0	0
807	0.97	0.388	447882	0.96	0.449	302268			0	0
809	0.97	0.384	469612	0.96	0.442	322256			0	0
811	0.97	0.382	492141	0.96	0.436	342934			0	0
813	0.97	0.380	515403	0.97	0.431	364267			0	0
815	0.98	0.378	539313	0.97	0.427	386203			0	0
815.796	0.98	0.377	547752	0.97	0.425	394161		1.000	1073	0
816	0.97	0.385	562833	0.97	0.434	405621		1.000	1511	0
817	0.97	0.383	573223	0.97	0.431	415754	0.19	1.000	4272	0
818	0.98	0.378	579834	0.97	0.425	422852	0.47	1.000	7849	0
819	0.98	0.372	583179	0.97	0.416	427403	0.62	0.999	12075	0
820	0.98	0.364	584616	0.97	0.406	430041	0.70	0.963	16266	0
821	0.98	0.360	591514	0.97	0.400	436489	0.76	0.923	20491	0
822	0.98	0.354	593686	0.97	0.391	438801	0.80	0.878	24575	0
823	0.98	0.345	591821	0.97	0.382	441914	0.83	0.835	28551	0
824	0.98	0.334	585463	0.98	0.376	446265	0.85	0.795	32434	0
825	0.98	0.322	577689	0.98	0.369	450101	0.87	0.756	36114	0
826	0.98	0.311	568965	0.98	0.361	453604	0.89	0.718	39581	0
827	0.98	0.298	556897	0.98	0.354	455838	0.90	0.680	42714	0
828	0.98	0.288	549326	0.98	0.345	455920	0.91	0.648	45862	0
829	0.99	0.280	544332	0.98	0.333	452123	0.92	0.619	49010	0
830	0.99	0.272	539183	0.98	0.322	448150	0.93	0.593	52042	0
831	0.99	0.270	546955	0.98	0.319	455640	0.93	0.578	55837	0
832	0.99	0.270	556634	0.98	0.318	464832	0.94	0.565	59791	0
833	0.99	0.269	564764	0.98	0.316	472649	0.94	0.552	63671	0
834	0.99	0.267	571121	0.98	0.312	478885	0.94	0.539	67446	0
835	0.99	0.265	579493	0.98	0.310	486923	0.94	0.528	71401	0
836	0.99	0.266	590589	0.98	0.310	497410	0.95	0.520	75615	0
837	0.99	0.267	605616	0.98	0.311	511439	0.95	0.515	80213	0

6.5 Case 5 - South Embankment Failure, Fort Loudoun Spillway Gates Open – Tellico Embankment Failure

For the South Embankment Failure condition, discharges are computed for headwaters ranging from 750 feet to 837 feet, the limit of the headwater elevation [4.21]. Discharge passes through the spillway section and the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000. Note that this case is coupled with an embankment failure from Tellico which produces elevated tailwaters.

Figure 9 shows the spreadsheet calculations for the pre-failure initial dam rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The first two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW elevation. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit provided in Attachment 15. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway, it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 9 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next five columns (under the "Headwater Spillway"), H_c, $C_f|C_g$, d/H_c, S_f, and $Q_f|Q_g$. Free discharge occurs for headwater elevations below 820.9 feet [4.3.4] and orifice discharge occurs for headwaters above 820.9 feet. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.2.3] computed from Equation A5 and below the line the listed discharge coefficient is C_g [4.3.5] computed by interpolation between the points in Table A3. S_f is computed to account for submergence effects using Equation A6 when d/H_c exceeds 0.6. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 3 for orifice discharge. The free and orifice discharges are modified by Equations 2 and 4 , respectively, to account for the submergence effects when d/H_c is greater than 0.6.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next 33 columns are overflow discharges in cfs for the lock walls, lock gates, spillway deck, spillway gates, north embankment, nonoverflow, powerhouse, south embankment, and saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.6.1], [4.4.1], [4.13.1], [4.11.1], [4.12.1], [4.17.1], [4.15.1]), elevation Z_c ([4.10.2], [4.9.2], [4.6.2], [4.4.2], [4.13.2], [4.11.2], [4.12.2], [4.17.2], [4.15.2]), and length L ([4.10.3], [4.9.3], [4.6.3], [4.4.3], [4.13.3], [4.11.3], [4.12.3], [4.17.3], [4.15.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that all overflows had to be modified using Equation 2 in order to account for submergence. S_f is calculated using Equation 5 and interpolation in Table 2.

Case No Longer Valid

TVA

Calculation No. CDQ000020080009	Rev: 1	Plant: GEN	Page: 33
Subject: Initial Dam Rating Curves, Fort Loudoun	Prepd: WBB		
	Checked: ACM		

Figure 9: South Embankment Failure with Spillway Gates Open Combined with Tellico Embankment Failure

$g = 32.2$ ft/s^2

Spillway Parameters
$L = 560$ feet
$Z_c = 783$ feet
$G_n = 30.314$ feet
$H_{mp} = 14.828$ feet

HW feet	Q Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	TW feet	Spillway H_c feet	C_f | C_g	d/H_c	S_f | S_g	Q_f | Q_g cfs
750	0.00	45.64	45.64	749.3					0
755	2.99	74.21	77.20	753.4					0
760	27.32	99.01	126.32	759.5					0
765	43.80	127.77	171.58	764.7					0
770	59.53	160.08	219.61	769.7					0
773	76.59	173.71	250.29	772.8					0
775	88.24	183.55	271.78	774.8					0
777	98.85	195.17	294.02	776.8					0
779	110.43	206.45	316.88	778.8					0
781	122.37	218.39	340.75	780.8					0
783	133.98	231.51	365.49	782.8	0				0
785	148.77	242.71	391.48	784.8	2	3.191	0.897	0.752	3803
787	164.48	254.08	418.56	786.8	4	3.277	0.948	0.566	8308
789	180.98	266.09	447.07	788.8	6	3.350	0.966	0.468	12900
791	197.28	279.12	476.40	790.8	8	3.412	0.974	0.407	17590
793	213.63	294.19	507.82	792.8	10	3.465	0.979	0.366	22450
795	230.26	310.13	540.39	794.8	12	3.512	0.982	0.336	27454
797	247.89	326.98	574.87	796.8	14	3.554	0.985	0.313	32619
799	265.85	345.28	611.13	798.8	16	3.591	0.986	0.295	38011
801	285.03	363.90	648.93	800.8	18	3.627	0.987	0.282	43689
803	304.69	383.43	688.12	802.8	20	3.661	0.988	0.271	49623
805	326.83	404.00	730.83	804.8	22	3.695	0.989	0.261	55824
807	348.55	425.59	774.14	806.8	24	3.728	0.990	0.254	62316
809	371.88	448.17	820.05	808.7	26	3.763	0.990	0.247	69113
811	396.89	471.67	868.56	810.7	28	3.798	0.991	0.242	76229
813	421.48	496.00	917.48	812.7	30	3.833	0.991	0.237	83664
815	447.76	521.03	968.80	814.7	32	3.869	0.991	0.233	91412
816	471.01	523.94	994.95	815.7	33	3.887	0.991	0.234	96519
817	486.00	534.62	1020.61	816.7	34	3.905	0.991	0.232	100619
818	499.69	547.92	1047.62	817.7	35	3.923	0.991	0.230	104435
819	510.87	563.58	1074.45	818.7	36	3.940	0.992	0.227	107963
820	519.70	580.99	1100.69	819.7	37	3.958	0.992	0.223	111245
821	497.77	629.37	1127.14	820.7	38	0.794	0.992	0.127	66060
822	499.78	654.85	1154.63	821.7	39	0.775	0.992	0.118	61132
823	500.92	680.84	1181.76	822.7	40	0.757	0.992	0.109	56221
824	498.83	710.04	1208.87	823.7	41	0.738	0.993	0.100	51212
825	495.28	740.38	1235.67	824.7	42	0.720	0.993	0.093	47325
826	491.30	770.98	1262.28	825.7	43	0.719	0.993	0.086	44563
827	488.79	802.30	1291.09	826.7	44	0.717	0.994	0.079	41826
828	482.30	836.55	1318.85	827.7	45	0.716	0.994	0.073	39155
829	475.75	870.43	1346.18	828.7	46	0.714	0.994	0.068	36858
830	467.34	905.01	1372.35	829.7	47	0.713	0.994	0.063	34801
831	456.99	942.72	1399.71	830.8	48	0.711	0.995	0.058	32452
832	444.92	981.72	1426.64	831.8	49	0.711	0.995	0.053	30154
833	432.49	1021.11	1453.61	832.8	50	0.711	0.996	0.049	27928
834	419.18	1060.93	1480.12	833.8	51	0.711	0.996	0.044	25810
835	407.33	1100.41	1507.74	834.8	52	0.711	0.996	0.040	23908
836	394.01	1141.13	1535.14	835.8	53	0.711	0.996	0.037	22190
837	378.21	1182.59	1560.79	836.8	54	0.711	0.997	0.034	20514

Overflow Discharge, Q_f in cfs

HW feet	Lock Walls d/H_c	Lock Walls S_f	Lock Walls Q_f	Lock Gates d/H_c	Lock Gates S_f	Lock Gates Q_f	Spillway Deck d/H_c	Spillway Deck S_f	Spillway Deck Q_f	Spillway Gates d/H_c	Spillway Gates S_f	Spillway Gates Q_f
C_f =			2.75			3.3			2.7			3.30
Z_c =			822			818.7			822			829.92
L =			74.5			60.1			137.0			560.0
750			0			0			0			0
755			0			0			0			0
760			0			0			0			0
765			0			0			0			0
770			0			0			0			0
773			0			0			0			0
775			0			0			0			0
777			0			0			0			0
779			0			0			0			0
781			0			0			0			0
783			0			0			0			0
785			0			0			0			0
787			0			0			0			0
789			0			0			0			0
791			0			0			0			0
793			0			0			0			0
795			0			0			0			0
797			0			0			0			0
799			0			0			0			0
801			0			0			0			0
803			0			0			0			0
805			0			0			0			0
807			0			0			0			0
809			0			0			0			0
811			0			0			0			0
813			0			0			0			0
815			0			0			[illegible]			0
816			0			0			[illegible]			0
817			0			0			[illegible]			0
818			0			0			[illegible]			0
819			0			33			[illegible]			0
820			0	0.77	0.912	268			0			0
821			0	0.86	0.776	[illegible]			[illegible]			0
822			0	0.90	0.672	799			[illegible]			0
823	0.69	0.973	205	0.93	0.597	1055	[illegible]	0.973	[illegible]			0
824	0.85	0.809	469	0.94	0.539	1305	[illegible]	0.809	846			0
825	0.90	0.686	730	0.95	0.495	1551	0.90	[illegible]	1319			0
826	0.93	0.598	980	0.96	0.459	1796	0.93	[illegible]	1770			0
827	0.94	0.535	1225	0.97	0.430	2041	0.94	0.535	2211			0
828	0.95	0.487	1467	0.97	[illegible]	[illegible]	0.95	0.487	2649			0
829	0.96	0.451	1710	0.97	0.386	[illegible]	0.96	0.451	3088			0
830	0.97	0.421	1952	0.98	0.367	2767	0.97	0.421	3524		1.000	42
831	0.97	0.395	2183	0.98	[illegible]	3003	0.97	0.395	3941	0.77	0.911	1889
832	0.98	0.371	[illegible]	0.98	[illegible]	[illegible]	0.98	0.371	4342	0.89	0.723	4006
833	0.98	0.352	[illegible]	0.98	[illegible]	[illegible]	0.98	0.352	4752	0.93	0.597	5965
834	0.98	0.327	[illegible]	[illegible]	0.289	3425	0.98	0.327	5023	0.95	0.514	7628
835	0.98	0.305	[illegible]	0.99	[illegible]	3567	0.98	0.305	5281	0.96	0.457	9669
836	0.99	[illegible]	3066	0.99	0.260	3708	0.99	0.286	5536	0.97	0.415	11504
837	[illegible]	[illegible]	[illegible]	[illegible]	0.245	3797	0.99	0.269	5773	0.97	0.380	13241

HW feet	North Bank Section 1 d/H_c	North Bank Section 1 S_f	North Bank Section 1 Q_f	North Bank Section 2 d/H_c	North Bank Section 2 S_f	North Bank Section 2 Q_f	Non Overflow d/H_c	Non Overflow S_f	Non Overflow Q_f	Power House d/H_c	Power House S_f	Power House Q_f
C_f =			3.30			3.30			3.3			2.7
Z_c =			818			822			826.5			822
L =			35.0			20.0			107.5			354.5
750			0			[illegible]			0			0
755			0			[illegible]			0			0
760			0			0			0			0
765			0			0			0			0
770			0			0			0			0
773			0			[illegible]			0			0
775			[illegible]			0			0			0
777			[illegible]			0			0			0
779			0			0			0			0
781			0			0			0			0
783			[illegible]			0			0			0
785			[illegible]			0			0			0
787			0			0			0			0
789			0			0			0			0
791			0			0			0			0
793			0			0			0			0
795			0			0			0			0
797			0			0			0			0
799			0			0			0			0
801			0			0			0			0
803			0			0			0			0
805			0			0			0			0
807			0			0			0			0
809			0			0			0			0
811			0			0			0			0
813			0			0			0			0
815			0			0			0			0
816			0			0			0			0
817			0			0			0			0
818			0			0			0			0
819			0			0			0			0
820			0			0			0			0
821			0			0			0			0
822			0			0			0			0
823			0			0			0	0.69	0.973	931
824			0			0			0	0.85	0.809	2190
825			0			0			0	0.90	0.686	3412
826			0			0			0	0.93	0.598	4580
827	0.97	0.417	1300	0.94	0.535	395	0.43	1.000	125	0.94	0.535	5722
828	0.97	0.395	1442	0.95	0.487	473	0.82	0.857	559	0.95	0.487	6855
829	0.98	0.376	1583	0.96	0.451	551	0.89	0.706	990	0.96	0.451	7990
830	0.98	0.359	1725	0.97	0.421	629	0.93	0.602	1398	0.97	0.421	9119
831	0.98	0.341	1845	0.97	0.395	703	0.94	0.528	1787	0.97	0.395	10197
832	0.98	0.319	1927	0.98	0.371	775	0.96	0.473	2164	0.98	0.371	11237
833	0.99	0.299	2009	0.98	0.352	848	0.97	0.432	2538	0.98	0.352	12297
834	0.99	0.282	2088	0.98	0.327	896	0.97	0.399	2906	0.98	0.327	12997
835	0.99	0.268	2172	0.98	0.305	942	0.98	0.372	3266	0.98	0.305	13666
836	0.99	0.256	2254	0.99	0.286	988	0.98	0.350	3636	0.99	0.286	14325
837	0.99	0.237	2271	0.99	0.269	1030	0.98	0.320	3857	0.99	0.269	14939

HW feet	South Bank Section 1 d/H_c	South Bank Section 1 S_f	South Bank Section 1 Q_f	South Bank Section 2 d/H_c	South Bank Section 2 S_f	South Bank Section 2 Q_f	Saddle Dam d/H_c	Saddle Dam S_f	Saddle Dam Q_f
C_f =			2.65			2.65			2.65
Z_c =			754			770			815
L =			1130.0			1130			570
750			0			0			0
755		1.000	2995			0			0
760	0.92	0.621	27316			0			0
765	0.97	0.401	43803			0			0
770	0.98	0.311	59531			0			0
773	0.99	0.271	67091	0.92	0.610	9494			0
775	0.99	0.251	72455	0.96	0.471	15785			0
777	0.99	0.231	76258	0.97	0.407	22589			0
779	0.99	0.216	80702	0.98	0.368	29729			0
781	0.99	0.203	85424	0.98	0.338	36946			0
783	0.99	0.193	90466	0.98	0.310	43511			0
785	0.99	0.184	94867	0.99	0.288	50102			0
787	0.99	0.175	99256	0.99	0.271	56918			0
789	0.99	0.168	103991	0.99	0.258	64089			0
791	0.99	0.161	108743	0.99	0.246	70945			0
793	0.99	0.157	114635	0.99	0.232	76545			0
795	0.99	0.153	120605	0.99	0.220	82199			0
797	0.99	0.150	127047	0.99	0.210	88225			0
799	1.00	0.147	133182	0.99	0.202	94659			0
801	1.00	0.145	139804	0.99	0.196	101537			0
803	1.00	0.143	146521	0.99	0.191	108545			0
805	1.00	0.142	154614	0.99	0.188	116392			0
807	1.00	0.140	162194	0.99	0.184	124043			0
809	1.00	0.140	170556	0.99	0.181	132214			0
811	1.00	0.139	179733	0.99	0.179	140930			0
813	1.00	0.139	188380	0.99	0.177	149432			0
815	1.00	0.139	197861	0.99	0.175	158492			0
816	1.00	0.142	207257	0.99	0.177	165727			1511
817	1.00	0.141	211774	0.99	0.176	170188	0.85	0.800	3417
818	1.00	0.141	215604	0.99	0.175	174271	0.90	0.686	5384
819	1.00	0.139	218006	0.99	0.173	177544	0.92	0.606	7327
820	1.00	0.136	218947	0.99	0.170	179982	0.94	0.548	9254
821	1.00	0.141	230894	0.99	0.173	188830	0.95	0.516	11447
822	1.00	0.139	232611	0.99	0.171	191752	0.96	0.482	13485
823	1.00	0.136	232822	0.99	0.168	193805	0.96	0.454	15524
824	1.00	0.132	230745	0.99	0.164	194524	0.97	0.430	17534
825	1.00	0.127	227089	0.99	0.159	194318	0.97	0.409	19536
826	1.00	0.122	222584	0.99	0.154	193612	0.97	0.389	21416
827	1.00	0.117	217984	1.00	0.149	192620	0.98	0.372	23335
828	1.00	0.112	213290	1.00	0.143	188829	0.98	0.357	25294
829	1.00	0.107	208502	1.00	0.136	184930	0.98	0.341	27015
830	1.00	0.102	202839	1.00	0.130	180227	0.98	0.323	28315
831	1.00	0.097	195498	1.00	0.122	174005	0.98	0.305	29485
832	1.00	0.091	187243	1.00	0.114	166937	0.99	0.289	30579
833	1.00	0.085	178857	1.00	0.107	159722	0.99	0.274	31658
834	1.00	0.079	170344	1.00	0.099	152360	0.99	0.262	32723
835	1.00	0.074	162512	1.00	0.093	145579	0.99	0.251	33843
836	1.00	0.070	154563	1.00	0.086	138666	0.99	0.231	33572
837	1.00	0.064	145682	1.00	0.080	130889	0.99	0.212	33016

Case No Longer Valid

6.6 Case 6 - South Embankment Failure, Fort Loudoun Spillway Gates Closed – Tellico Embankment Failure

For the South Embankment Failure with spillway gates closed condition, discharges are computed for headwaters ranging from 750 feet to 837 feet, the limit of the headwater elevation [4.21]. This case is similar to case 5 except for there is no discharge through the spillway until the gates themselves are overtopped. Discharge passes through the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000. Note that this case is coupled with an embankment failure from Tellico which produces elevated tailwaters.

Figure 10 shows the spreadsheet calculations for the spillway gates closed initial dam rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW and Total Discharge. The next two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW rating curve. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit [4.20]. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway (mainly at Tellico in this calculation), it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 10 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next five columns (under the header "Spillway"), H_c, $C_f|C_g$, d/H_c, S_f, and $Q_f|Q_g$ as outlined in section 4.22. Free discharge occurs for headwater elevations below 820 feet [4.5.5] and orifice discharge occurs for headwaters above 820 feet. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.5.1] computed from Equation A5 and below the line the listed discharge coefficient is C_g [4.5.6]. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 3 for orifice discharge. Free discharge is modified by Equation 2 using the S_f calculated from Equation 5. Orifice discharge is modified as outlined in Section 4.22.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next 30 columns are overflow discharges in cfs for the lock walls, lock gates, spillway deck, north embankment, powerhouse, nonoverflow dam, south embankment, and the saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.7.1], [4.13.1], [4.12.1], [4.11.1], [4.17.1], [4.15.1]), elevation Z_c ([4.10.2], [4.9.2], [4.7.2], [4.13.2], [4.12.2], [4.11.2], [4.17.2], [4.15.2]), and length L ([4.10.3], [4.9.3], [4.7.3], [4.13.3], [4.12.3], [4.11.3], [4.17.3], [4.15.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that all overflows have to be modified using Equation 2 in order to account for submergence. S_f is calculated using Equation 5 and interpolation in Table 2.

Case No Longer Valid

TVA

Calculation No. CDQ000020080009	Rev: 1	Plant: GEN	Page: 35
Subject: Initial Dam Rating Curves, Fort Loudoun	Prepd: WBB		
	Checked: ACM		

Figure 10: South Embankment Failure with Spillway Gates Closed Combined with Tellico Embankment Failure

g = 32.2 ft/s²

Spillway Parameters: L = 560 feet; Z_c = 783 feet; G_h = 30.314 feet; H_{mp} = 14.828 feet

Spillway Gate Overflow Parameters: L = 560 feet; Z_c = 815 feet; G_h = 3.500 feet; C_g = 0.7

Overflow Discharge, Q_i in cfs

HW feet	Q Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	TW feet	Spillway feet H_c	$C_f \mid C_g$	d/H_c	S_f	cfs $Q_s \mid Q_g$	Lock Walls d/Hc	Lock Walls Sf	Lock Walls Q	Lock Gates d/Hc	Lock Gates Sf	Lock Gates Q	Spillway Deck d/Hc	Spillway Deck Sf	Spillway Deck Q	North Bank Section 1 d/Hc	North Bank Section 1 Sf	North Bank Section 1 Q	North Bank Section 2 d/Hc	North Bank Section 2 Sf	North Bank Section 2 Q	Non Overflow d/Hc	Non Overflow Sf	Non Overflow Q	Power House d/Hc	Power House Sf	Power House Q	South Bank Sec. 1 d/Hc	South Bank Sec. 1 Sf	South Bank Sec. 1 Q	South Bank Sec. 2 d/Hc	South Bank Sec. 2 Sf	South Bank Sec. 2 Q	Saddle Dam d/Hc	Saddle Dam Sf	Saddle Dam Q
										C_f =		2.75			3.30			2.7			3.30			3.30			3.30			2.70			2.65			2.65			2.65
										Z_c =		822			818.7			822			818			822			826.5			822			754			770			815
										L =		74.5			60.1			697.0			35.0			20.0						354.5			1130.0			1130			570
750	0.00	45.64	45.64	749.3					0			0			0			0			0			0						0			0			0			0
755	2.99	74.21	77.20	753.4					0			0			0			0			0			0			0			0		1.000	2995			0			0
760	27.32	99.01	126.32	759.5					0			0			0			0			0			0			0			0	0.92	0.621	27316			0			0
765	43.80	127.77	171.58	764.7					0			0			0			0			0			0						0	0.97	0.401	43803			0			0
770	59.53	160.08	219.61	769.7					0			0			0			0			0			0						0	0.98	0.311	59531			0			0
773	82.65	173.71	256.36	772.8					0			0			0			0			0			0						0	0.99	0.271	67091		1.000	15560			0
775	88.24	183.55	271.78	774.8					0			0			0			0			0			0						0	0.99	0.251	72455	0.96	0.471	15785			0
777	98.85	195.17	294.02	776.8					0			0			0			0			0			0						0	0.99	0.231	76258	0.97	0.407	22589			0
779	110.43	206.45	316.88	778.8					0			0			0			0			0			0						0	0.99	0.216	80702	0.98	0.368	29729			0
781	122.37	218.39	340.75	780.8					0			0			0			0			0			0						0	0.99	0.203	85424	0.98	0.338	36946			0
783	133.98	231.51	365.49	782.8					0			0			0			0			0			0						0	0.99	0.193	90466	0.98	0.310	43511			0
785	146.32	245.22	391.53	784.8					0			0			0			0			0			0						0	0.99	0.185	95868	0.99	0.290	50450			0
787	158.98	259.54	418.52	786.8					0			0			0			0			0			0						0	0.99	0.178	101320	0.99	0.275	57659			0
789	172.44	274.55	446.99	788.8					0			0			0			0			0			0						0	0.99	0.173	107180	0.99	0.263	65264			0
791	186.26	290.30	476.56	790.8					0			0			0			0			0			0						0	0.99	0.168	113114	0.99	0.254	73141			0
793	199.78	307.60	507.38	792.8					0			0			0			0			0			0						0	0.99	0.164	119497	0.99	0.243	80279			0
795	213.73	326.48	540.21	794.8					0			0			0			0			0			0						0	0.99	0.161	126741	0.99	0.232	86990			0
797	227.94	346.35	574.29	796.8					0			0			0			0			0			0						0	0.99	0.159	134116	0.99	0.223	93826			0
799	243.13	367.27	610.40	798.8					0			0			0			0			0			0						0	0.99	0.157	142020	0.99	0.216	101109			0
801	259.35	389.29	648.64	800.8					0			0			0			0			0			0						0	0.99	0.156	150479	0.99	0.211	108873			0
803	275.90	412.45	688.35	802.7					0			0			0			0			0			0						0	0.99	0.155	159098	0.99	0.206	116802			0
805	293.55	436.77	730.32	804.7					0			0			0			0			0			0						0	0.99	0.154	168300	0.99	0.202	125250			0
807	311.55	462.27	773.82	806.7					0			0			0			0			0			0						0	0.99	0.154	177672	0.99	0.199	133879			0
809	330.72	488.91	819.62	808.7					0			0			0			0			0			0						0	0.99	0.154	187656	0.99	0.196	143060			0
811	350.25	516.64	866.89	810.7					0			0			0			0			0			0						0	0.99	0.154	197820	0.99	0.194	152435			0
813	371.01	545.36	916.37	812.7					0			0			0			0			0			0						0	0.99	0.154	208621	0.99	0.192	162392			0
815	393.03	574.95	967.99	814.7	0				0			0			0			0			0			0						0	0.99	0.154	220079	0.99	0.191	172955			0
816	413.81	579.48	993.29	815.7	1	3.6	0.669	0.983	1981			0			0			0			0			0						0	0.99	0.157	229185	0.99	0.194	181162	0.67	0.983	1484
817	429.11	590.85	1019.96	816.7	2	3.6	0.832	0.834	4753			0			0			0			0			0						0	0.99	0.157	234591	0.99	0.193	186200	0.83	0.834	3561
818	441.84	604.80	1046.65	817.7	3	3.6	0.887	0.721	7548			0			0			0			0			0						0	0.99	0.156	238602	0.99	0.191	190038	0.89	0.721	5656
819	451.83	621.11	1072.94	818.7	4	3.6	0.916	0.637	10279			0			[illegible]	33		0			0			0						0	0.99	0.154	241183	0.99	0.188	192636	0.92	0.637	7701
820	461.05	639.18	1100.24	819.7	5	3.6	0.933	0.576	12978			0	[illegible]	[illegible]	[illegible]	275		0			0			0						0	0.99	0.152	243274	0.99	0.184	194804	0.93	0.576	9722
821	462.85	664.32	1127.17	820.7	6	0.7	0.944	-	6373			0	[illegible]	[illegible]	[illegible]	550		0			0			0						0	0.99	0.150	246336	0.99	0.181	197811	0.94	0.531	11781
822	466.45	687.74	1154.19	821.7	7	0.7	0.953	-	6344			0		0.688	818			0			0			0						0	1.00	0.146	245945	0.99	0.178	199525	0.95	0.494	13815
823	470.59	709.86	1180.45	822.7	8	0.7	0.959	-	6296	0.67	0.981	[illegible]	[illegible]	[illegible]	1077		1.000	1882			0			0	0.67	0.981	939	1.00	0.142	244016	0.99	0.173	200345	0.96	0.463	15834
824	473.21	734.86	1208.07	823.7	9	0.7	0.964	-	6228	0.84	0.8[illegible]	47[illegible]	[illegible]	0.550	1330	0.84	0.820	4367			0			0	0.84	0.820	2221	1.00	0.137	240516	0.99	0.169	200245	0.96	0.437	17831
825	473.15	761.79	1234.94	824.7	10	0.7	0.969	-	6140	0.90	0.6[illegible]	[illegible]	[illegible]	0.503	1576	0.90	0.696	6810			0			0	0.90	0.696	3464	1.00	0.131	235416	0.99	0.163	199204	0.97	0.414	19798
826	472.67	789.65	1262.32	825.7	11	0.7	0.973	-	6051	0.[illegible]	0.607	995	[illegible]	0.466	1821	0.92	0.607	9142			0			0	0.92	0.607	4650	1.00	0.126	230207	0.99	0.158	198094	0.97	0.394	21711
827	472.45	818.22	1290.67	826.7	12	0.7	0.976	-	5950	[illegible]	[illegible]	[illegible]	0.96	0.435	2065	0.94	0.541	11391	0.97	0.421	1314	0.94	0.541	399	0.42	1.000	125	0.94	0.541	5794	1.00	0.120	224125	0.99	0.152	196463	0.98	0.376	23582
828	469.00	849.10	1318.10	827.7	13	0.7	0.978	-	5847	0.95	[illegible]	1481	0.97	0.410	2309	0.95	0.492	13605	0.97	0.398	1455	0.95	0.492	477	0.81	0.863	562	0.95	0.492	6928	1.00	0.114	217927	1.00	0.146	192934	0.98	0.360	25487
829	465.12	880.68	1345.80	828.7	14	0.7	0.980	-	[illegible]	0.96	0.45[illegible]	[illegible]	0.97	0.388	2546	0.96	0.454	15831	0.98	0.378	1595	0.96	0.454	555	0.89	0.712	998	0.96	0.454	8052	1.00	0.109	212392	1.00	0.139	188380	0.98	0.345	27298
830	458.91	913.20	1372.11	829.7	15	0.7	0.982	-	[illegible]	0.9[illegible]	0.42[illegible]	1964	0.98	0.369	2782	0.97	0.424	18039	0.98	0.361	1735	0.97	0.424	533	0.92	0.606	1407	0.97	0.424	9175	1.00	0.104	205972	1.00	0.132	183011	0.98	0.325	28549
831	450.75	949.76	1400.51	830.7	16	0.7	0.984	-	5527	0.9[illegible]	[illegible]	2197	0.98	0.353	3019	0.97	0.397	20182	0.98	0.344	1861	0.97	0.397	708	0.94	0.531	1799	0.97	0.397	10265	1.00	0.098	198651	1.00	0.124	176812	0.98	0.307	29727
832	438.80	987.86	1426.66	831.8	17	0.7	0.986	-	5383	0.98	0.373	2417	0.98	0.330	3172	0.98	0.373	22198	0.98	0.321	1940	0.98	0.373	779	0.96	0.476	2176	0.98	0.373	11290	1.00	0.092	189623	1.00	0.116	169059	0.99	0.291	30766
833	428.23	1026.27	1454.50	832.8	18	0.7	0.987	-	5246	0.98	0.354	2644	0.98	0.309	3311	0.98	0.354	24288	0.98	0.301	2022	0.98	0.354	852	0.97	0.434	2552	0.98	0.354	12353	1.00	0.086	181253	1.00	0.108	161861	0.99	0.276	31850
834	414.60	1065.43	1480.03	833.8	19	0.7	0.989	-	5093	0.98	0.328	2796	0.99	0.290	3441	0.98	0.328	25685	0.99	0.284	2097	0.98	0.328	901	0.97	0.400	2917	0.98	0.328	13064	1.00	0.080	171951	1.00	0.100	153798	0.99	0.263	32855
835	403.77	1104.38	1508.14	834.8	20	0.7	0.990	-	[illegible]	0.98	0.306	2940	0.99	0.275	3583	0.98	0.306	27005	0.99	0.269	2181	0.98	0.306	947	0.98	0.373	3278	0.98	0.306	13735	1.00	0.075	164129	1.00	0.094	147027	0.99	0.251	33978
836	389.57	1144.62	1534.19	835.8	21	0.7	0.991	-	[illegible]	0.99	0.286	3074	0.99	0.260	3716	0.99	0.286	28236	0.99	0.256	2259	0.99	0.286	990	0.98	0.351	3642	0.99	0.286	14361	1.00	0.070	155377	1.00	0.087	139396	0.99	0.232	33710
837	374.56	1185.64	1560.20	836.8	22	0.7	0.992	-	4658	0.99	0.269	3206	0.99	0.246	3814	0.99	0.269	29446	0.99	0.238	2281	0.99	0.269	1033	0.98	0.320	3868	0.99	0.269	14976	1.00	0.065	146500	1.00	0.080	131624	0.99	0.213	33157

Case No Longer Valid

6.7 Case 7 – Pre Failure - Fort Loudoun Spillway Gates Open – Tellico Embankment Failure

For this Pre-Failure Case, discharges are computed for headwaters ranging from 783 feet to 837 feet, the limit of the headwater elevation [4.21]. Discharge passes through the spillway section and the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000. Note that this case is coupled with an embankment failure from Tellico which produces elevated tailwaters.

Figure 11 shows the spreadsheet calculations for the pre-failure initial dam rating curve (spreadsheet included in Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The first two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW elevation. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit provided in Attachment 15. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway, it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 11 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next five columns (under the heading "Spillway"), H_c, $C_f|C_g$, d/H_c, S_f, and $Q_f|Q_g$. Free discharge occurs for headwater elevations below 820.9 feet [4.3.4] and orifice discharge occurs for headwaters above 820.9 feet. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.2.3] computed from Equation A5 and below the line the listed discharge coefficient is C_g [4.3.5] computed by interpolation between the points in Table A3. S_f is computed to account for submergence effects using Equation A6 when d/H_c exceeds 0.6. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 3 for orifice discharge. The free and orifice discharges are modified by Equations 2 and 4, respectively, to account for the submergence effects when d/H_c is greater than 0.6.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next 36 columns are overflow discharges in cfs for the lock walls, lock gates, spillway deck, spillway gates, north embankment, nonoverflow, powerhouse, south embankment, and saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.6.1], [4.4.1], [4.13.1], [4.11.1], [4.12.1], [4.16.1], [4.14.1]), elevation Z_c ([4.10.2], [4.9.2], [4.6.2], [4.4.2], [4.13.2], [4.11.2], [4.12.2], [4.16.2], [4.14.2]), and length L ([4.10.3], [4.9.3], [4.6.3], [4.4.3], [4.13.3], [4.11.3], [4.12.3], [4.16.3], [4.14.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that all overflows had to be modified using Equation 2 in order to account for submergence. S_f is calculated using Equation 5 and interpolation in Table 2.

Case No Longer Valid

Figure 11: Pre Failure with Spillway Gates Open - Combined with Tellico Embankment Failure

g = 32.2 ft/s²

Spillway Parameters
L = 560 feet
Z_c = 783 feet
G_h = 30.314 feet
H_{cp} = 14.828 feet

Overflow Discharge, Q_i in cfs

HW feet	Q Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	TW feet	Spillway feet H_c	$C_f \mid C_d$	d/H_c	$S_f \mid S_d$	cfs $Q_i \mid Q_d$
						C_f =			2.75
						Z_c =			822
						L =			74.5
783	0.00	362.75	362.75	782.6	0				0
785	4.65	383.99	388.64	784.6	2	3.191	0.791	0.919	4645
787	11.02	404.69	415.71	786.6	4	3.277	0.897	0.750	11018
789	17.56	426.45	444.01	788.6	6	3.350	0.933	0.637	17555
791	24.17	449.47	473.63	790.6	8	3.412	0.950	0.559	24166
793	30.86	473.83	504.68	792.6	10	3.465	0.960	0.503	30857
795	37.69	499.56	537.25	794.6	12	3.512	0.967	0.461	37691
797	45.05	526.28	571.33	796.6	14	3.554	0.971	0.432	45047
799	52.68	554.47	607.15	798.6	16	3.591	0.974	0.409	52679
801	60.62	584.18	644.80	800.6	18	3.627	0.976	0.391	60620
803	68.90	615.47	684.37	802.6	20	3.661	0.978	0.376	68904
805	77.57	648.35	725.92	804.5	22	3.695	0.979	0.363	77566
807	86.64	682.82	769.46	806.5	24	3.728	0.981	0.353	86638
809	96.15	718.82	814.97	808.5	26	3.763	0.981	0.344	96147
811	106.11	756.25	862.36	810.5	28	3.798	0.982	0.337	106110
813	116.53	794.97	911.50	812.5	30	3.833	0.983	0.330	116529
815	127.39	834.76	962.15	814.5	32	3.869	0.983	0.325	127394
816	133.02	852.54	987.55	815.4	33	3.887	0.983	0.327	133015
817	140.98	872.62	1013.60	816.4	34	3.905	0.983	0.325	140982
818	146.46	893.54	1040.01	817.4	35	3.923	0.984	0.322	146465
819	151.50	915.11	1066.61	818.4	36	3.940	0.984	0.318	151464
820	156.33	937.05	1093.38	819.4	37	3.958	0.985	0.313	156036
821	118.80	1000.73	1119.52	820.4	38	0.794	0.984	0.227	118148
822	115.88	1030.61	1146.49	821.4	39	0.775	0.985	0.221	114863
823	114.46	1059.10	1173.55	822.4	40	0.757	0.985	0.216	111548
824	113.14	1087.65	1200.79	823.4	41	0.738	0.986	0.208	107258
825	110.08	1118.04	1228.12	824.4	42	0.720	0.987	0.198	101166
826	107.44	1148.04	1255.49	825.5	43	0.719	0.987	0.184	95585
827	104.33	1180.89	1285.22	826.5	44	0.717	0.988	0.165	87099
828	99.47	1213.41	1312.87	827.5	45	0.716	0.989	0.147	78617
829	95.68	1244.85	1340.53	828.5	46	0.714	0.989	0.131	71311
830	93.18	1274.95	1368.13	829.5	47	0.713	0.990	0.119	65338
831	91.82	1304.02	1395.85	830.6	48	0.711	0.991	0.105	58718
832	91.47	1332.13	1423.60	831.6	49	0.711	0.992	0.093	52567
833	92.17	1359.05	1451.22	832.6	50	0.711	0.992	0.083	47725
834	98.28	1380.39	1478.67	833.6	51	0.711	0.993	0.075	43664
835	111.23	1394.93	1506.16	834.7	52	0.711	0.994	0.067	39606
836	123.64	1409.96	1533.60	835.7	53	0.711	0.994	0.060	35915
837	131.86	1426.68	1558.54	836.7	54	0.711	0.995	0.053	32408

HW feet	Lock Walls d/H_c	Sf	Q	Lock Gates d/H_c	Sf	Q	Spillway Deck d/H_c	Sf	Q	Spillway Gates d/H_c	Sf	Q
			2.75			3.30			2.70			3.30
			822			818.7			822			829.92
			74.5			60.1			137.0			560.0
783			0			0			0			0
785			0			0			0			0
787			0			0			0			0
789			0			0			0			0
791			0			0			0			0
793			0			0			0			0
795			0			0			0			0
797			0			0			0			0
799			0			0			0			0
801			0			0			0			0
803			0			0			0			0
805			0			0			0			0
807			0			0			0			0
809			0			0			0			0
811			0			0			0			0
813			0			0			0			0
815			0			0			0			0
816			0			0			0			0
817			0			0			0			0
818			0			0			0			0
819			0			1.000 33			0			0
820			0	0.56	1.000	294			0			0
821			0	0.74	0.938	649			0			0
822			0	0.82	0.853	1014			0			0
823	0.41	1.000	205	0.86	0.778	1376	0.41	[illegible]	370			0
824	0.71	0.959	556	0.89	0.712	1725	0.71	[illegible]	1004			0
825	0.81	0.862	918	0.91	0.654	2051	[illegible]	[illegible]	1658			0
826	0.86	0.775	1270	0.93	0.604	2362	[illegible]	[illegible]	[illegible]			0
827	0.89	0.701	1606	0.94	[illegible]	2665	0.89	0.701	2900			0
828	0.92	0.640	1926	0.95	[illegible]	[illegible]			3478			0
829	0.93	0.587	2228	0.95	0.494	3242	0.93	[illegible]	4022			0
830	0.94	0.543	2517	0.96	0.467	[illegible]	0.94	0.543	4544		1.000	42
831	0.95	0.502	2776	0.96	0.440	3783	0.95	0.502	5013	0.59	1.000	2074
832	0.96	0.465	3011	0.97	0.414	3981	0.96	0.465	5437	0.80	0.876	4856
833	0.97	0.433	3240	0.97	0.390	4183	0.97	0.433	5850	0.88	0.749	7484
834	0.97	0.409	3479	[illegible]	[illegible]	4397	0.97	0.409	6281	0.91	0.649	9892
835	0.97	0.383	3679	0.98	[illegible]	4601	0.97	0.383	6643	0.93	0.570	12063
836	0.98	0.361	3879	[illegible]	0.3[illegible]	4673	0.98	0.361	7002	0.95	0.508	14062
837	0.98	0.338	4023	0.98	0.3[illegible]	4721	0.98	0.338	7263	0.96	0.458	15953

HW feet	North Bank Section 1 d/H_c	Sf	Q	North Bank Section 2 d/H_c	Sf	Q	Non Overflow d/H_c	Sf	Q	Power House d/H_c	Sf	Q
			3.30			3.30			3.30			2.70
			818			822			826.5			822
			35.0			0			107.5			354.5
783			0			0			0			0
785			0			0			0			0
787			0			0			0			0
789			0			0			0			0
791			0			0			0			0
793			0			0			0			0
795			0			0			0			0
797			0			0			0			0
799			0			0			0			0
801			0			0			0			0
803			0			0			0			0
805			0			0			0			0
807			0			0			0			0
809			0			0			0			0
811			0			0			0			0
813			0			0			0			0
815			0			0			0			0
816			0			0			0			0
817			0			0			0			0
818			0			0			0			0
819			0			0			0			0
820			0			0			0			0
821			0			0			0			0
822			0			0			0			0
823			0			0			0	0.41	1.000	957
824			0			0			0	0.71	0.959	2597
825			0			0			0	0.81	0.862	4289
826			0			0			0	0.86	0.775	5934
827	0.94	0.542	1690	0.89	0.701	738		1.000	125	0.89	0.701	7504
828	0.95	0.510	1862	0.92	0.640	970	0.66	0.987	652	0.92	0.640	9000
829	0.96	0.481	2025	0.93	0.587	1222	0.80	0.873	1225	0.93	0.587	10407
830	0.96	0.455	2185	0.94	0.543	1493	0.87	0.771	1792	0.94	0.543	11757
831	0.97	0.430	2327	0.95	0.502	1782	0.90	0.682	2308	0.95	0.502	12971
832	0.97	0.406	2454	0.96	0.465	2087	0.93	0.605	2769	0.96	0.465	14069
833	0.97	0.383	2568	0.97	0.433	2408	0.94	0.544	3195	0.97	0.433	15138
834	0.98	0.364	2694	0.97	0.409	2744	0.95	0.496	3613	0.97	0.409	16254
835	0.98	0.346	2800	0.97	0.383	3094	0.96	0.455	4001	0.97	0.383	17189
836	0.98	0.321	2827	0.98	0.361	3457	0.97	0.421	4371	0.98	0.361	18119
837	0.99	0.298	2855	0.98	0.338	1296	0.97	0.390	4713	0.98	0.338	18795

HW feet	South Bank Sec. 1 d/H_c	Sf	Q	South Bank Sec. 2 d/H_c	Sf	Q	Saddle Dam Sec. 1 d/H_c	Sf	Q	Saddle Dam Sec. 2 d/H_c	Sf	Q
			3.33			2.65			3.30			3.20
			833.3			836.6			833.6			830
			2208.0			50.9			540			30
783			0			0			0			0
785			0			0			0			0
787			0			0			0			0
789			0			0			0			0
791			0			0			0			0
793			0			0			0			0
795			0			0			0			0
797			0			0			0			0
799			0			0			0			0
801			0			0			0			0
803			0			0			0			0
805			0			0			0			0
807			0			0			0			0
809			0			0			0			0
811			0			0			0			0
813			0			0			0			0
815			0			0			0			0
816			0			0			0			0
817			0			0			0			0
818			0			0			0			0
819			0			0			0			0
820			0			0			0			0
821			0			0			0			0
822			0			0			0			0
823	0.41	1.000	957			0			0			0
824	0.71	0.959	2597			0			0			0
825	0.81	0.862	4289			0			0			0
826	0.86	0.775	5934			0			0			0
827	0.89	0.701	7504			0			0			0
828	0.92	0.640	9000			0			0			0
829	0.93	0.587	10407			0			0			0
830	0.94	0.543	11757			0			0			0
831	0.95	0.502	12971			0			0	0.56	1.000	96
832	0.96	0.465	14069			0			0	0.79	0.885	240
833	0.97	0.433	15138			0			0	0.87	0.757	378
834	0.97	0.409	16254	0.49	1.000	4306			451	0.91	0.655	503
835	0.80	0.873	14229			0	0.76	0.919	2712	0.93	0.574	616
836	0.89	0.723	23592			0	0.87	0.757	5018	0.95	0.511	720
837	0.92	0.610	31908		1.000	34	0.92	0.633	7071	0.96	0.460	819

Case No Longer Valid

6.8 Case 8 – Pre Failure - Fort Loudoun Spillway Gates Closed – Tellico Embankment Failure

For the South Embankment Failure with spillway gates closed condition, discharges are computed for headwaters ranging from 750 feet to 837 feet, the limit of the headwater elevation [4.21]. This case is similar to case 7 except for there is no discharge through the spillway until the gates themselves are overtopped. Discharge passes through the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000. Note that this case is coupled with an embankment failure from Tellico which produces elevated tailwaters.

Figure 12 shows the spreadsheet calculations for the spillway gates closed initial dam rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW and Total Discharge. The next two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW rating curve. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit [4.20]. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway, it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 12 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next five columns (under the header "Spillway"), H_c, $C_f|C_g$, d/H_c, S_f, and $Q_f|Q_g$ as outlined in section 4.22. Free discharge occurs for headwater elevations below 820 feet [4.5.5] and orifice discharge occurs for headwaters above 820 feet. The transition point is indicated by a horizontal line. Above the line, the listed discharge coefficient is C_f [4.5.1] computed from Equation A5 and below the line the listed discharge coefficient is C_g [4.5.6]. Column $Q_f|Q_g$ is the spillway discharge computed from Equation 1 for free discharge and from Equation 3 for orifice discharge. Free discharge is modified by Equation 2 using the S_f calculated from Equation 5. Orifice discharge is modified as outlined in Section 4.22.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next 33 columns are overflow discharges in cfs for the lock walls, lock gates, spillway deck, north embankment, powerhouse, nonoverflow dam, south embankment, and the saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.7.1], [4.13.1], [4.12.1], [4.11.1], [4.16.1], [4.14.1]), elevation Z_c ([4.10.2], [4.9.2], [4.7.2], [4.13.2], [4.12.2], [4.11.2], [4.16.2], [4.14.2]), and length L ([4.10.3], [4.9.3], [4.7.3], [4.13.3], [4.12.3], [4.11.3], [4.16.3], [4.14.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that all overflows have to be modified using Equation 2 in order to account for submergence. S_f is calculated using Equation 5 and interpolation in Table 2.

Case No Longer Valid

TVA

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Subject: Initial Dam Rating Curves, Fort Loudoun	Prepd: WBB		
	Checked: ACM		

Figure 12: Pre Failure with Spillway Gates Closed - Combined with Tellico Embankment Failure

g = 32.2 ft/s²

Spillway Parameters
L = 560 feet
Z_c = 783 feet
G_h = 30.314 feet
H_{rep} = 14.828 feet

Spillway Gate Overflow Parameters
L = 560 feet
Z_c = 815 feet
G_h = 3.500 feet
C_f = 3.5
C_g = 0.7

Overflow Discharge, Q_f in cfs

HW feet	Q Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	TW feet	Spillway feet H_c	C_f | C_g	d/H_c	S_f	cfs Q_s | Q_g
779	0.00	314.31	314.31	778.6					0
781	0.00	338.04	338.04	780.6					0
783	0.00	362.75	362.75	782.6					0
785	0.00	388.51	388.51	784.6					0
787	0.00	415.41	415.41	786.6					0
789	0.00	443.53	443.53	788.6					0
791	0.00	472.96	472.96	790.6					0
793	0.00	503.80	503.80	792.5					0
795	0.00	536.15	536.15	794.5					0
797	0.00	570.12	570.12	796.5					0
799	0.00	605.81	605.81	798.5					0
801	0.00	643.31	643.31	800.5					0
803	0.00	682.69	682.69	802.5					0
805	0.00	724.02	724.02	804.5					0
807	0.00	767.30	767.30	806.4					0
809	0.00	812.53	812.53	808.4					0
811	0.00	859.61	859.61	810.4					0
813	0.00	908.40	908.40	812.4					0
815	0.00	958.70	958.70	814.3	0				0
816	1.96	981.61	983.57	815.3	1	3.6	0.293	1.000	1960
817	5.51	1004.02	1009.53	816.3	2	3.6	0.6405	0.994	5509
818	9.38	1026.58	1035.96	817.3	3	3.6	0.7593	0.921	9382
819	13.37	1049.33	1062.70	818.3	4	3.6	0.8208	0.851	13338
820	17.51	1072.17	1089.68	819.3	5	3.6	0.8588	0.786	17216
821	9.92	1106.58	1116.50	820.3	6	0.7	0.8823	-	9251
822	10.20	1133.65	1143.84	821.3	7	0.7	0.9016	-	9139
823	13.50	1157.75	1171.25	822.3	8	0.7	0.9161	-	9019
824	19.20	1179.50	1198.70	823.3	9	0.7	0.9276	-	8890
825	24.94	1201.22	1226.16	824.4	10	0.7	0.9372	-	8725
826	30.60	1223.13	1253.73	825.4	11	0.7	0.9452	-	8550
827	38.32	1245.27	1283.59	826.4	12	0.7	0.9519	-	8363
828	43.99	1267.37	1311.36	827.5	13	0.7	0.9578	-	8158
829	49.35	1289.74	1339.10	828.5	14	0.7	0.9628	-	7947
830	54.49	1312.17	1366.67	829.5	15	0.7	0.967	-	7746
831	59.16	1335.16	1394.33	830.5	16	0.7	0.971	-	7500
832	63.38	1358.60	1421.98	831.6	17	0.7	0.9747	-	7220
833	67.25	1382.25	1449.50	832.6	18	0.7	0.978	-	6929
834	76.12	1400.65	1476.77	833.6	19	0.7	0.9806	-	6688
835	92.00	1412.05	1504.05	834.7	20	0.7	0.983	-	6429
836	106.98	1424.17	1531.15	835.7	21	0.7	0.9851	-	6160
837	120.10	1438.28	1558.38	836.7	22	0.7	0.987	-	[illegible]

HW feet	Lock Walls d/H_c	Lock Walls Sf	Lock Walls Q	Lock Gates d/H_c	Lock Gates Sf	Lock Gates Q	Spillway Deck d/H_c	Spillway Deck Sf	Spillway Deck Q	North Bank Section 1 d/H_c	North Bank Section 1 Sf	North Bank Section 1 Q	North Bank Section 2 d/H_c	North Bank Section 2 Sf	North Bank Section 2 Q	Non Overflow d/H_c	Non Overflow Sf	Non Overflow Q	Power House d/H_c	Power House Sf	Power House Q	South Bank Sec. 1 d/H_c	South Bank Sec. 1 Sf	South Bank Sec. 1 Q	South Bank Sec. 2 d/H_c	South Bank Sec. 2 Sf	South Bank Sec. 2 Q	Saddle Dam Sec. 1 d/H_c	Saddle Dam Sec. 1 Sf	Saddle Dam Sec. 1 Q	Saddle Dam Sec. 2 d/H_c	Saddle Dam Sec. 2 Sf	Saddle Dam Sec. 2 Q
C_f =			2.75			3.30			2.7			3.30			3.30			[illegible]			2.70			3.33			2.65			3.30			3.20
Z_c =			822			818.7			822			818			822			826.5			822			833.3			836.6			833.6			830
L =			74.5			60.1			697.0			35.0			20.0			107.5			354.5			2208.0			50.9			540			30
779			0			0			0			0			0			0			0			0			0			0			0
781			0			0			0			0			0			0			0			0			0			0			0
783			0			0			0			0			0			0			0			0			0			0			0
785			0			0			0			0			0			0			0			0			0			0			0
787			0			0			0			0			0			0			0			0			0			0			0
789			0			0			0			0			0			0			0			0			0			0			0
791			0			0			0			0			0			0			0			0			0			0			0
793			0			0			0			0			0			0			0			0			0			0			0
795			0			0			0			0			0			0			0			0			0			0			0
797			0			0			0			0			0			0			0			0			0			0			0
799			0			0			0			0			0			0			0			0			0			0			0
801			0			0			0			0			0			0			0			0			0			0			0
803			0			0			0			0			0			0			0			0			0			0			0
805			0			0			0			0			0			0			0			0			0			0			0
807			0			0			0			0			0			0			0			0			0			0			0
809			0			0			0			0			0			0			0			0			0			0			0
811			0			0			0			0			0			0			0			0			0			0			0
813			0			0			0			0			0			0			0			0			0			0			0
815			0			0			0			0			0			0			0			0			0			0			0
816			0			0			0			0			0			0			0			0			0			0			0
817			0			0			0			0			0			0			0			0			0			0			0
818			0			0			0			0			0			0			0			0			0			0			0
819			0		1.000	[illegible]			0			0			0			0			0			0			0			0			0
820			0	0.46	1.000	294			0			0			0			0			0			0			0			0			0
821			0	0.69	[illegible]	[illegible]			0			0			0			0			0			0			0			0			0
822			0	0.79	[illegible]	[illegible]			0			0			0			0			0			0			0			0			0
823	0.33	1.000	205	0.84	[illegible]	1439	0.33	1.000	1882			0			0			0	0.33	1.000	957			0			0			0			0
824	0.67	0.980	579	0.88	0.746	[illegible]	0.67	0.980	5218			0			0			0	0.67	0.980	2707			0			0			0			0
825	0.79	0.889	947	0.90	0.685	[illegible]	0.79	0.889	8696			0			0			0	0.79	0.889	4423			0			0			0			0
826	0.85	0.804	1318	0.92	0.632	24[illegible]	0.85	0.804	12104			0			0			0	0.85	0.804	6156			0			0			0			0
827	0.88	0.728	16[illegible]	[illegible]	0.585	2776	0.88	0.728	15308	0.94	0.564	1760	0.88	0.728	537		1.000	125	0.88	0.728	7786			0			0			0			0
828	0.91	0.661	[illegible]	[illegible]	0.544	3060	0.91	0.661	18270	0.95	0.527	1924	0.91	0.661	641	0.63	0.996	652	0.91	0.661	9292			0			0			0			0
829	0.93	0.603	[illegible]	0.95	0.508	3330	0.93	0.603	21029	0.95	0.494	2080	0.93	0.603	738	0.79	0.888	1245	0.93	0.603	10696			0			0			0			0
830	0.94	0.556	[illegible]	0.96	0.477	3595	0.94	0.556	23657	0.96	0.465	2233	0.94	0.556	830	0.86	0.786	1826	0.94	0.556	12032			0			0			0			0
831	0.95	[illegible]	283[illegible]	[illegible]	0.448	3833	0.95	0.512	26028	0.96	0.438	2371	0.95	0.512	913	0.90	0.695	2353	0.95	0.512	13238			0			0	0.54	1.000	96
832	0.96	0.473	[illegible]	0.97	0.421	4048	0.96	0.473	28170	0.97	0.412	2496	0.96	0.473	988	0.92	0.617	2822	0.96	0.473	14328			0			0	0.79	0.896	243
833	0.96	[illegible]	32[illegible]	0.97	0.395	4240	0.96	0.439	30170	0.97	0.388	2602	0.96	0.439	1058	0.94	0.552	3244	0.96	0.439	15344			0			0	0.87	0.766	382
834	[illegible]	0.413	[illegible]	0.98	0.374	4443	0.97	0.413	32281	0.98	0.368	2721	0.97	0.413	1132	0.95	0.502	3656	0.97	0.413	16418	0.47	1.000	4306			0			451	0.91	0.663	509
835	0.[illegible]	0.3[illegible]	[illegible]14	0.98	0.355	4639	0.97	0.387	34116	0.98	0.350	2836	0.97	0.387	1196	0.96	0.460	4041	0.97	0.387	17352	0.80	0.879	14325			0	0.76	0.924	2727	0.93	0.580	623
836	[illegible]	[illegible]364	3905	0.98	0.331	4723	0.98	0.364	35874	0.98	0.324	2857	0.98	0.364	1258	0.97	0.424	4404	0.98	0.364	18246	0.88	0.729	23776			0	0.87	0.763	5055	0.95	0.515	727
837	[illegible]	[illegible]	4063	0.98	0.307	4764	0.98	0.341	37317	0.98	0.301	2880	0.98	0.341	1309	0.97	0.393	4747	0.98	0.341	18980	0.92	0.615	32158		1.000	34	0.92	0.638	7126	0.96	0.464	825

Case No Longer Valid

6.9 Case 9 – Fort Loudoun Seismic Failure

For the seismic failure case, discharges are computed for headwaters ranging from 750 feet to 837 feet, the limit of the headwater elevation [4.21]. Discharge passes through the spillway section and the various overflow sections as headwater rises above the crest elevations in each case. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam plus discharge in cfs past the west saddle dam divided by 1000.

Figure 13 shows the spreadsheet calculations for the seismic failure initial dam rating curve (spreadsheet included as Attachment 16). The final result, the rating curve, is defined by the first two columns, HW vs. Total Discharge. The next two columns are a synopsis of the flows from Tellico Dam. Since Tellico and Fort Loudoun discharge into the same tailwater within close vicinity to each other, it is necessary to include the flows from Tellico to calculate the TW elevation. The fifth column (TW) gives the tailwater associated with the "Total Flow" from the tailwater rating curve polynomial fit provided in Attachment 15. This is computed to check for tailwater submergence effects on the discharge. Since the tailwater elevations reach levels that reduce flow through the spillway, it is necessary to iterate through different tailwater elevations until the total computed discharge fits the tailwater rating curve [4.20]. Figure 13 shows the final results but does not show the iteration steps. The results are readily checked by computing the individual discharges, adding them up to compute total discharge, and then making sure the listed tailwater and total discharge agree with the tailwater rating curve.

Spillway discharge in cfs is computed in the next four columns (under the header "Spillway"). Since the spillway has failed from seismic loading, it will fail as shown in Attachment 5 and outlined in Section 4.26. It is treated as a standard weir overflow and is computed using Equation 1 and the parameters listed in Section 4.8. The flows are modified by Equation 2 to account for submergence effects. S_f is calculated using Equation 5 and interpolation in Table 2.

The column following the spillway discharge column shows "C_f=", "Z_c=", and "L=" in three rows to indicate the meaning of the values included in those rows in the "Overflow Discharge" columns.

The next 27 columns are overflow discharges in cfs for the lock walls, lock gates, north embankment, nonoverflow, powerhouse, south embankment, and saddle dam. The overflow discharge coefficient C_f ([4.10.1], [4.9.1], [4.13.1], [4.11.1], [4.12.1], [4.18.1], [4.14.1]), elevation Z_c ([4.10.2], [4.9.2], [4.13.2], [4.11.2], [4.12.2], [4.18.2], [4.14.2]), and length L ([4.10.3], [4.9.3], [4.13.3], [4.11.3], [4.12.3], [4.18.3], [4.14.3]) in each case are indicated in the three rows above the computed discharges. All overflow discharges are computed using Equation 1. Note that all overflows had to be modified using Equation 2 in order to account for submergence. S_f is calculated using Equation 5 and interpolation in Table 2.

TVA

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	Checked: ACM		

Figure 13: Post Seismic Configuration

g = 32.2 ft/s²

Overflow Discharge, Q_f in cfs

HW feet	Q Ft Loudoun Total Discharge 1000 cfs	Tellico Flow 1000 cfs	Total Flow 1000 cfs	Main Dam TRM 602.3 TW feet		Spillway H_c	Spillway d/H_c	Spillway Sf	Spillway Q	Lock Walls d/H_c	Lock Walls Sf	Lock Walls Q	Lock Gates d/H_c	Lock Gates Sf	Lock Gates Q	Spillway Deck d/H_c	Spillway Deck Sf	Spillway Deck Q	North Bank Section 1 d/H_c	North Bank Section 1 Sf	North Bank Section 1 Q	North Bank Section 2 d/H_c	North Bank Section 2 Sf	North Bank Section 2 Q	Non Overflow d/H_c	Non Overflow Sf	Non Overflow Q	Power House d/H_c	Power House Sf	Power House Q	South Bank Sec. 1 d/H_c	South Bank Sec. 1 Sf	South Bank Sec. 1 Q	South Bank Sec. 2 d/H_c	South Bank Sec. 2 Sf	South Bank Sec. 2 Q	Saddle Dam Sec. 1 Q	Saddle Dam Sec. 2 Q
					C_f =				2.65			2.75			3.30			2.70			3.30			3.30			3.30			2.70			2.65			2.65	2.65	2.65
					Z_c =				750			822			818.7			822			818			822			826.5			822			750			785	837	837
					L =				651			74.5			60.1			137.0			35.0			20.0			107.5			354.5			1625.0			625.0	540	30
750	0.00	0.00	0.00	745.07		0			0			0			0			0			0			0			0			0			0			0	0	0
755	67.00	0.00	67.00	753.21		5	0.641	0.994	19164			0			0			0			0			0			0			0	0.64	0.994	47836			0	0	0
760	120.76	0.00	120.76	759.17		10	0.917	0.633	34541			0			0			0			0			0			0			0	0.92	0.633	86220			0	0	0
765	170.84	0.00	170.84	764.31		15	0.954	0.488	48864			0			0			0			0			0			0			0	0.95	0.488	121974			0	0	0
770	224.15	0.00	224.15	769.37		20	0.969	0.416	64114			0			0			0			0			0			0			0	0.97	0.416	160039			0	0	0
773	258.12	0.00	258.12	772.40		23	0.974	0.386	73544			0			0			0			0			0			0			0	0.97	0.389	184573			0	0	0
775	280.81	0.96	281.77	774.41		25	0.977	0.370	79825			0			0			0			0			0			0			0	0.98	0.373	200985			0	0	0
777	303.92	2.34	306.26	776.43		27	0.979	0.356	86259			0			0			0			0			0			0			0	0.98	0.360	217663			0	0	0
779	327.65	3.91	331.56	778.44		29	0.981	0.341	91981			0			0			0			0			0			0			0	0.98	0.350	235672			0	0	0
781	352.06	5.64	357.71	780.44		31	0.982	0.325	96809			0			0			0			0			0			0			0	0.98	0.343	255253			0	0	0
783	377.32	7.53	384.85	782.44		33	0.983	0.311	101841			0			0			0			0			0			0			0	0.98	0.337	275482			0	0	0
785	403.50	9.55	413.06	784.43		35	0.984	0.300	107112			0			0			0			0			0			0			0	0.98	0.332	296391			0	0	0
787	430.97	11.64	442.61	786.44		37	0.985	0.285	110681			0			0			0			0			0			0			0	0.98	0.326	315827	0.72	0.953	4463	0	0
789	459.63	13.81	473.45	788.45		39	0.986	0.271	113983			0			0			0			0			0			0			0	0.99	0.320	335341	0.86	0.778	10308	0	0
791	489.47	16.10	505.56	790.46		41	0.987	0.260	117736			0			0			0			0			0			0			0	0.99	0.315	355724	0.91	0.658	16005	0	0
793	520.55	18.49	539.04	792.46		43	0.987	0.251	121937			0			0			0			0			0			0			0	0.99	0.310	376976	0.93	0.577	21641	0	0
795	552.99	20.98	573.97	794.46		45	0.988	0.243	126559			0			0			0			0			0			0			0	0.99	0.307	399069	0.95	0.522	27361	0	0
797	586.85	23.58	610.42	796.46		47	0.988	0.237	131598			0			0			0			0			0			0			0	0.99	0.304	421997	0.95	0.483	33254	0	0
799	622.21	26.27	648.48	798.45		49	0.989	0.232	137065			0			0			0			0			0			0			0	0.99	0.302	445769	0.96	0.454	39377	0	0
801	659.14	29.05	688.19	800.45		51	0.989	0.228	142972			0			0			0			0			0			0			0	0.99	0.300	470398	0.97	0.432	45767	0	0
803	697.67	31.93	729.60	802.44		53	0.989	0.224	149331			0			0			0			0			0			0			0	0.99	0.298	495892	0.97	0.415	52449	0	0
805	737.84	34.90	772.74	804.43		55	0.990	0.222	156147			0			0			0			0			0			0			0	0.99	0.297	522254	0.97	0.401	59440	0	0
807	779.64	37.95	817.58	806.42		57	0.990	0.220	163416			0			0			0			0			0			0			0	0.99	0.297	549474	0.97	0.391	66747	0	0
809	823.02	41.07	864.10	808.40		59	0.990	0.219	171121			0			0			0			0			0			0			0	0.99	0.296	577529	0.98	0.382	74374	0	0
811	867.92	44.28	912.21	810.38		61	0.990	0.218	179231			0			0			0			0			0			0			0	0.99	0.296	606377	0.98	0.375	82315	0	0
813	914.21	47.57	961.78	812.37		63	0.990	0.218	187697			0			0			0			0			0			0			0	0.99	0.295	635957	0.98	0.369	90561	0	0
815	961.74	50.93	1012.67	814.35		65	0.990	0.217	196457			0			0			0			0			0			0			0	0.99	0.295	666193	0.98	0.364	99092	0	0
815.796	980.96	52.29	1033.25	815.14		65.796	0.990	0.217	200009			0			0			0			0			0			0			0	0.99	0.295	678390	0.98	0.362	102561	0	0
816	1006.07	31.31	1037.38	815.29		66	0.989	0.226	209235			0			0			0			0			0			0			0	0.99	0.299	691083	0.98	0.370	105750	0	0
817	1032.88	30.50	1063.37	816.28		67	0.989	0.227	214728			0			0			0			0			0			0			0	0.99	0.300	707673	0.98	0.368	110476	0	0
818	1054.51	35.40	1089.91	817.28		68	0.989	0.225	218032			0			0			0			0			0			0			0	0.99	0.299	721832	0.98	0.365	114643	0	0
819	1071.49	45.43	1116.93	818.28		69	0.990	0.222	219368			0		1.000	33			0	0.28		0			0			0			0	0.99	0.297	733804	0.98	0.360	118290	0	0
820	1084.80	59.55	1144.35	819.30		70	0.990	0.217	219065			0	0.46	1.000	294			0	0.65		0			0			0			0	0.99	0.295	743956	0.98	0.354	121487	0	0
821	1095.73	76.34	1172.07	820.32		71	0.990	0.211	217718			0	0.70	0.963	666			0	0.77		0			0			0			0	0.99	0.292	752959	0.98	0.348	124388	0	0
822	1105.06	94.93	1199.99	821.34		72	0.991	0.205	215696			0	0.80	0.876	1042			0	0.84		0			0			0			0	0.99	0.289	761228	0.98	0.341	127091	0	0
823	1113.15	115.01	1228.16	822.37		73	0.991	0.198	212543	0.37	1.000	205	0.85	0.794	1404	0.37	1.000	370	0.87		0	0.37		0			0	0.37	1.000	957	0.99	0.286	768225	0.98	0.334	129450	0	0
824	1119.67	136.86	1256.53	823.41		74	0.992	0.190	208308	0.70	0.963	558	0.89	0.717	1736	0.70	0.963	1007	0.90		0	0.70		0			0	0.70	0.963	2607	0.99	0.282	773993	0.98	0.326	131464	0	0
825	1123.86	161.21	1285.07	824.45		75	0.993	0.181	203144	0.82	0.857	912	0.91	0.648	2032	0.82	0.857	1647	0.92		0	0.82		0			0	0.82	0.857	4262	0.99	0.278	778693	0.99	0.318	133169	0	0
826	1128.60	184.97	1313.57	825.49		76	0.993	0.173	198282	0.87	0.759	1243	0.93	0.589	2302	0.87	0.759	2245	0.94		0	0.87		0			0	0.87	0.759	5809	0.99	0.275	783770	0.99	0.310	134945	0	0
827	1133.21	208.96	1342.17	826.53		77	0.994	0.165	192611	0.91	0.670	1535	0.94	0.536	2540	0.91	0.670	2771	0.95	0.517	1611	0.91	0.670	494	0.05	1.000	125	0.91	0.670	7171	0.99	0.271	787909	0.99	0.303	136440	0	0
828	1136.81	233.89	1370.70	827.57		78	0.994	0.158	187248	0.93	0.596	1794	0.95	0.490	2759	0.93	0.596	3239	0.96	0.475	1736	0.93	0.596	578	0.71	0.959	625	0.93	0.596	8382	0.99	0.267	792434	0.99	0.296	138012	0	0
829	1139.62	259.59	1399.22	828.61		79	0.995	0.150	181659	0.94	0.533	2023	0.96	0.451	2957	0.94	0.533	3652	0.96	0.439	1850	0.94	0.533	652	0.84	0.817	1145	0.94	0.533	9450	1.00	0.263	796739	0.99	0.289	139498	0	0
830	1140.59	286.76	1427.35	829.63		80	0.995	0.138	170357	0.95	0.487	2259	0.97	0.422	3180	0.95	0.487	4079	0.97	0.412	1979	0.95	0.487	728	0.89	0.701	1627	0.95	0.487	10554	1.00	0.261	804033	0.99	0.284	141798	0	0
831	1173.58	280.79	1454.37	830.62		81	0.995	0.141	177350	0.96	0.470	2600	0.97	0.414	3540	0.96	0.470	4695	0.97	0.405	2193	0.96	0.470	838	0.92	0.639	2162	0.96	0.470	12148	1.00	0.262	821181	0.99	0.284	146871	0	0
832	1198.27	283.36	1481.63	831.62		82	0.995	0.140	179482	0.96	0.451	2920	0.97	0.402	3871	0.96	0.451	5273	0.97	0.395	2388	0.96	0.451	941	0.93	0.586	2680	0.96	0.451	13644	1.00	0.261	835814	0.99	0.283	151256	0	0
833	1226.69	282.04	1508.73	832.61		83	0.995	0.141	183617	0.96	0.436	3262	0.97	0.394	4226	0.96	0.436	5890	0.97	0.387	2598	0.96	0.436	1051	0.94	0.548	3219	0.96	0.436	15240	1.00	0.262	851599	0.99	0.283	155988	0	0
834	1260.17	275.46	1535.63	833.60		84	0.995	0.143	190487	0.97	0.427	3633	0.97	0.389	4614	0.97	0.427	6560	0.97	0.383	2828	0.97	0.427	1171	0.95	0.521	3795	0.97	0.427	16975	1.00	0.262	868928	0.99	0.284	161181	0	0
835	1300.91	261.37	1562.28	834.58		85	0.995	0.149	201308	0.97	0.421	4047	0.97	0.387	5048	0.97	0.421	7307	0.98	0.381	3084	0.97	0.421	1304	0.95	0.504	4429	0.97	0.421	18908	1.00	0.263	888444	0.99	0.285	167026	0	0
836	1351.77	236.53	1588.30	835.54		86	0.995	0.155	213695	0.97	0.425	4562	0.97	0.392	5593	0.97	0.425	8237	0.97	0.386	3407	0.97	0.425	1470	0.95	0.500	5197	0.97	0.425	21314	0.99	0.266	913734	0.99	0.289	174560	0	0
837	1421.63	191.78	1613.41	836.46		87	0.994	0.166	232403	0.96	0.439	5228	0.97	0.406	6304	0.96	0.439	9439	0.97	0.400	3829	0.96	0.439	1684	0.95	0.511	6173	0.96	0.439	24425	0.99	0.271	947560	0.99	0.297	184589	0	0

7. Results/Conclusions

For convenience, the headwater rating results, separate from the calculation details provided above, are tabulated as headwater elevation (HW) in feet vs. total discharge (Q_{Tel}) in cfs in Figure 14. Figure 15 shows all the headwater rating curves on a single graph. Figures 16 – 24 show the headwater rating curves for each individual case with their respective tailwaters. Graphs which consider the interaction between Tellico Dam and Fort Loudoun Dam for all cases are included as Figures 25 and 26.

The initial dam rating curves developed in this calculation provide Tellico total dam discharge vs. headwater elevation for use in TVA's SOCH and TRBROUTE models for simulation conditions satisfying the assumptions in [3.1]. In particular, the Fort Loudoun Dam spillway gates must all be fully raised and the interaction between Tellico Dam and Fort Loudoun Dam must be accounted for.

Rating curve Cases 1, 1A, 2, 2A, 3, 4 and 9 were updated. Rating curve Cases 5, 6, 7, and 8 are no longer valid because the embankments were raised, but these rating curves were not modified to reflect the raised embankment elevations.

The Case 1 (pre-failure) curve is used for rising headwaters until the earthen embankment and saddle dam are judged to fail. The Case 1A (pre-failure) curve is used for falling headwaters. Both Case 1 and 1A consider Fort Loudoun spillway gates to be fully open. Tellico is assumed in its pre-failure condition.

The Case 2 (pre-failure) curve is used for rising headwaters until the earthen embankment and saddle dam are judged to fail. The Case 2A (pre-failure) curve is used for falling headwaters. Both Case 2 and 2A consider Fort Loudoun spillway gates to be closed. Tellico is assumed in its pre-failure condition.

The Case 3 (embankment failure – gates open) curve is used for rising and falling headwaters after the south embankment has failed. Case 3 considers the Fort Loudoun spillway gates to be fully open. Tellico is assumed in its pre-failure condition.

The Case 4 (embankment failure – gates closed) curve is used for rising and falling after the south embankment has failed. Case 4 considers the Fort Loudoun spillway gates to be closed. Tellico is assumed in its pre-failure condition.

~~The Case 5 (embankment failure – gates open) curve is used for rising and falling headwaters after the south embankment has failed. Case 5 considers the Fort Loudoun spillway gates to be fully open. Tellico is assumed to follow its embankment failure condition.~~

~~The Case 6 (embankment failure – gates closed) curve is used for rising and falling headwaters after the south embankment has failed. Case 6 considers the Fort Loudoun spillway gates to be closed. Tellico is assumed to follow its embankment failure condition.~~

~~The Case 7 (pre-failure – gates open) curve is used for rising and falling headwaters prior to any failures at Fort Loudoun. Case 7 considers the Fort Loudoun spillway gates to be open. Tellico is assumed to follow its embankment failure condition.~~

~~The Case 8 (pre-failure – gates closed) curve is used for rising and falling headwaters prior to any failures at Fort Loudoun. Case 8 considers the Fort Loudoun spillway gates to be closed. Tellico is assumed to follow its embankment failure condition.~~

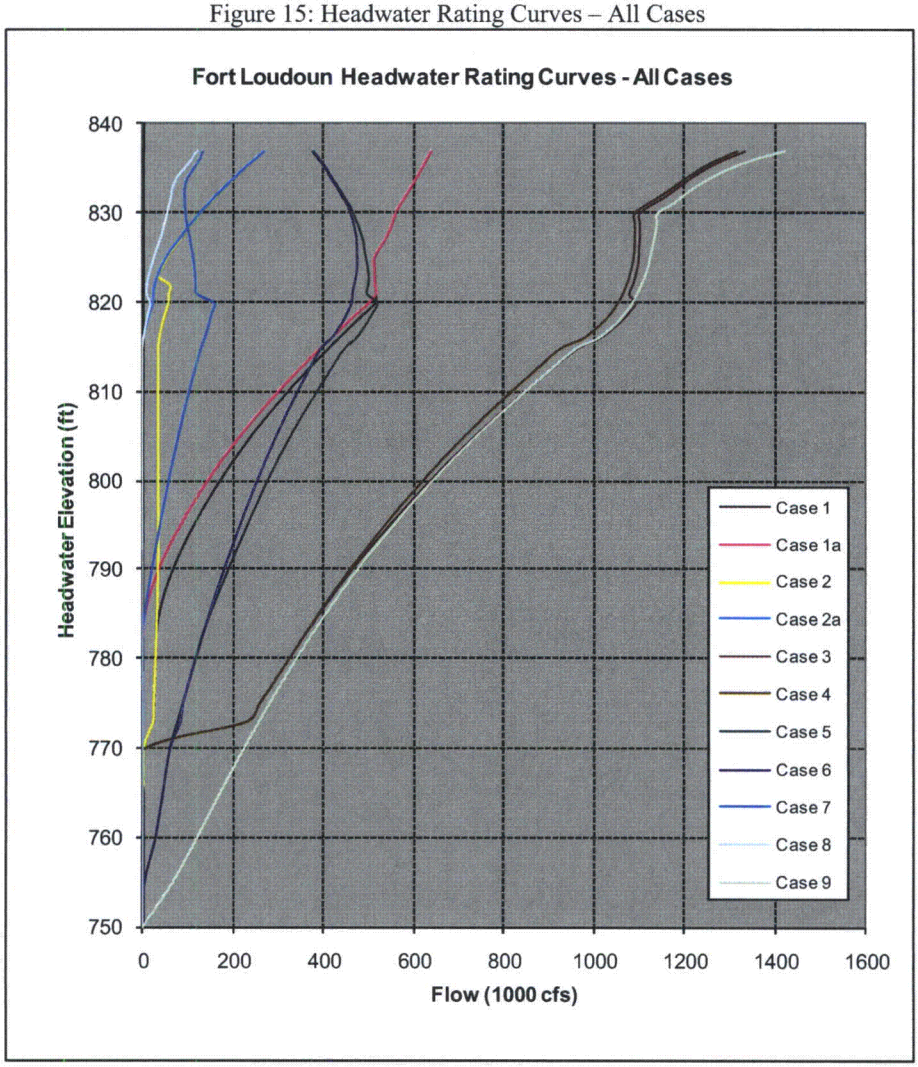
The Case 9 (seismic failure) curve is used for rising and falling headwaters until the earthen embankment and saddle dams are judged to fail, sometime after the headwater rises above its overflow elevation of 837 feet. Case 9 considers the Tellico Dam is in its pre-failure configuration.

The final two curves combine the Tellico and Fort Loudoun Dam Rating Curves.

Summary of All Cases - Total Flow											
HW Elevation (ft)	Total Flow (1000 cfs)										
	Case 1	Case 1a	Case 2	Case 2a	Case 3	Case 4	~~Case 5~~	~~Case 6~~	~~Case 7~~	~~Case 8~~	Case 9
750	0.00	0.00	0.00	0.00	0.00	0.00	~~45.64~~	~~45.64~~	~~0.00~~	~~0.00~~	0.00
755	0.00	0.00	0.00	0.00	0.00	0.00	~~77.20~~	~~77.20~~	~~0.00~~	~~0.00~~	67.00
760	0.00	0.00	0.00	0.00	0.00	0.00	~~126.32~~	~~126.32~~	~~0.00~~	~~0.00~~	120.76
765	0.00	0.00	0.00	0.00	0.00	0.00	~~171.58~~	~~171.58~~	~~0.00~~	~~0.00~~	170.84
770	0.00	0.00	0.00	0.00	0.00	0.00	~~219.61~~	~~219.61~~	~~0.00~~	~~0.00~~	224.15
773	20.55	0.00	20.55	0.00	226.55	226.55	~~250.29~~	~~256.36~~	~~0.00~~	~~0.00~~	258.12
775	23.50	1.06	23.50	1.06	255.96	255.96	~~271.78~~	~~271.78~~	~~0.00~~	~~0.00~~	281.77
777	27.15	3.01	27.15	3.01	284.94	284.94	~~294.02~~	~~294.02~~	~~0.00~~	~~0.00~~	306.26
779	31.25	5.58	31.25	5.58	313.01	313.01	~~316.88~~	~~316.88~~	~~0.00~~	~~314.31~~	331.56
781	35.77	8.70	35.77	8.70	341.07	341.07	~~340.75~~	~~340.75~~	~~0.00~~	~~338.04~~	357.71
783	40.65	12.32	40.65	12.32	369.48	369.48	~~365.49~~	~~365.49~~	~~362.75~~	~~362.75~~	384.85
785	50.51	21.48	45.90	16.42	399.12	398.54	~~391.48~~	~~391.53~~	~~388.64~~	~~388.51~~	413.06
787	64.96	35.67	51.51	20.99	430.01	428.44	~~418.56~~	~~418.52~~	~~415.71~~	~~415.41~~	442.61
789	82.83	53.58	57.46	26.01	462.12	459.35	~~447.07~~	~~446.99~~	~~444.01~~	~~443.53~~	473.45
791	103.68	74.69	63.66	31.46	495.54	491.39	~~476.40~~	~~476.56~~	~~473.63~~	~~472.96~~	505.56
793	127.22	98.68	69.51	37.31	530.26	524.68	~~507.82~~	~~507.38~~	~~504.68~~	~~503.80~~	539.04
795	153.24	125.30	75.74	43.54	566.48	559.30	~~540.39~~	~~540.21~~	~~537.25~~	~~536.15~~	573.97
797	181.58	154.38	82.33	50.13	604.32	595.35	~~574.87~~	~~574.29~~	~~571.33~~	~~570.12~~	610.42
799	212.12	185.77	89.25	57.05	642.96	632.90	~~611.13~~	~~610.40~~	~~607.15~~	~~605.81~~	648.48
801	244.77	219.36	96.45	64.25	683.26	671.95	~~648.93~~	~~648.64~~	~~644.80~~	~~643.31~~	688.19
803	279.49	255.09	103.92	71.72	725.36	712.64	~~688.12~~	~~688.35~~	~~684.37~~	~~682.69~~	729.60
805	316.22	292.92	111.61	79.41	769.28	754.98	~~730.83~~	~~730.32~~	~~725.92~~	~~724.02~~	772.74
807	354.92	332.77	119.51	87.31	814.79	798.97	~~774.14~~	~~773.82~~	~~769.46~~	~~767.30~~	817.58
809	395.56	374.60	127.60	95.40	861.91	844.60	~~820.05~~	~~819.62~~	~~814.97~~	~~812.53~~	864.10
811	438.09	418.34	135.86	103.66	910.71	891.80	~~868.56~~	~~866.89~~	~~862.36~~	~~859.61~~	912.21
813	482.51	463.94	144.29	112.09	961.06	940.47	~~917.48~~	~~916.37~~	~~911.50~~	~~908.40~~	961.78
815	528.82	511.38	152.90	120.70	1012.81	990.48	~~968.80~~	~~967.99~~	~~962.15~~	~~958.70~~	1012.67
816	547.76	530.77	157.82	125.62	1033.79	1010.95	~~994.95~~	~~993.29~~	~~987.55~~	~~983.57~~	1033.25
817	550.96	534.15	158.26	126.06	1038.29	1013.80	~~1020.61~~	~~1019.96~~	~~1013.60~~	~~1009.53~~	1037.38
818	571.15	554.54	161.88	129.68	1064.90	1039.88	~~1047.62~~	~~1046.65~~	~~1040.01~~	~~1035.96~~	1063.37
819	596.95	580.97	172.41	140.21	1092.00	1066.94	~~1074.45~~	~~1072.94~~	~~1066.61~~	~~1062.70~~	1089.91
820	627.65	612.75	189.15	156.95	1119.53	1094.86	~~1100.69~~	~~1100.24~~	~~1093.38~~	~~1089.68~~	1116.93
821	663.80	650.04	212.34	180.14	1147.42	1123.34	~~1127.14~~	~~1127.17~~	~~1119.52~~	~~1116.50~~	1144.35
822	684.72	684.72	233.02	200.82	1160.20	1150.98	~~1154.63~~	~~1154.19~~	~~1146.49~~	~~1143.84~~	1172.07
823	706.34	706.34	259.95	227.75	1187.62	1179.64	~~1181.76~~	~~1180.45~~	~~1173.55~~	~~1171.25~~	1199.99
824	731.52	731.52	260.58	260.58	1215.33	1208.24	~~1208.87~~	~~1208.07~~	~~1200.79~~	~~1198.70~~	1228.16
825	759.17	759.17	298.59	298.59	1243.25	1236.66	~~1235.67~~	~~1234.94~~	~~1228.12~~	~~1226.16~~	1256.53
826	788.39	788.39	340.77	340.77	1271.15	1265.23	~~1262.28~~	~~1262.32~~	~~1255.49~~	~~1253.73~~	1285.07
827	829.47	829.47	386.70	386.70	1299.28	1293.91	~~1291.09~~	~~1290.67~~	~~1285.22~~	~~1283.59~~	1313.57
828	875.26	875.26	439.87	439.87	1327.48	1322.85	~~1318.85~~	~~1318.10~~	~~1312.87~~	~~1311.36~~	1342.17
829	919.67	919.67	493.56	493.56	1355.62	1351.40	~~1346.18~~	~~1345.80~~	~~1340.53~~	~~1339.10~~	1370.70
830	965.12	965.12	550.24	550.24	1383.75	1379.72	~~1372.35~~	~~1372.11~~	~~1368.13~~	~~1366.67~~	1399.22
831	1009.73	1009.73	609.96	609.96	1411.84	1408.01	~~1399.71~~	~~1400.51~~	~~1395.85~~	~~1394.33~~	1427.35
832	1043.06	1043.06	653.05	653.05	1438.91	1435.24	~~1426.64~~	~~1426.66~~	~~1423.60~~	~~1421.98~~	1454.37
833	1079.05	1079.05	697.57	697.57	1465.81	1462.29	~~1453.61~~	~~1454.50~~	~~1451.22~~	~~1449.50~~	1481.63
834	1115.76	1115.76	743.61	743.61	1492.92	1489.41	~~1480.12~~	~~1480.03~~	~~1478.67~~	~~1476.77~~	1508.73
835	1152.28	1152.28	790.93	790.93	1519.98	1516.63	~~1507.74~~	~~1508.14~~	~~1506.16~~	~~1504.05~~	1535.63
836	1188.51	1188.51	839.21	839.21	1546.88	1543.66	~~1535.14~~	~~1534.19~~	~~1533.60~~	~~1531.15~~	1562.28
837	1223.88	1223.88	888.65	888.65	1573.56	1570.46	~~1560.79~~	~~1560.20~~	~~1558.54~~	~~1558.38~~	1588.30

Cases 5, 6, 7, and 8 are no longer valid because embankments were raised.

Figure 15: Headwater Rating Curves – All Cases



Cases 5, 6, 7, and 8 are no longer valid because embankments were raised.

Figure 16: Cases 1 and 1a Headwater Rating Curve

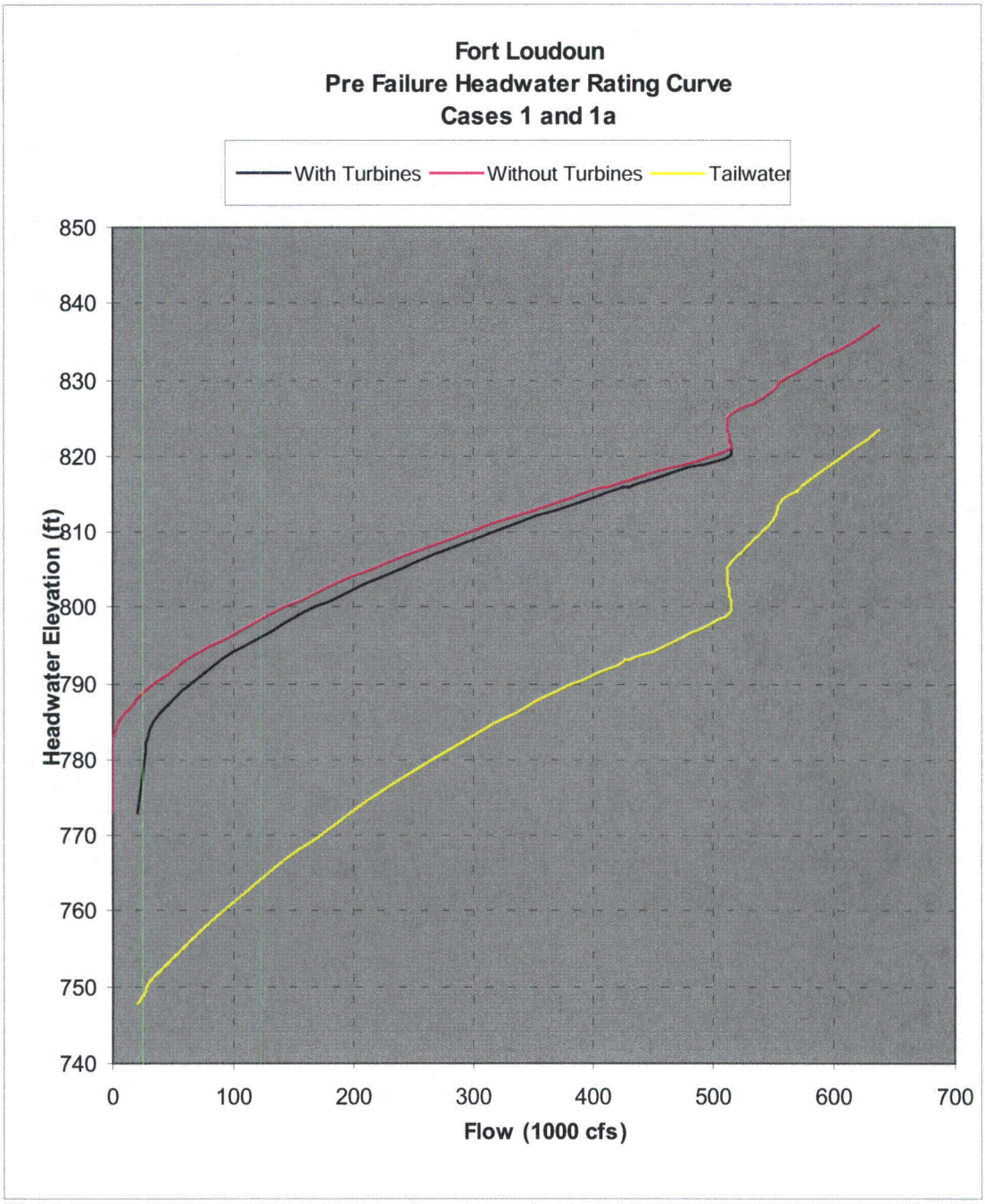


Figure 17: Cases 2 and 2a Headwater Rating Curve

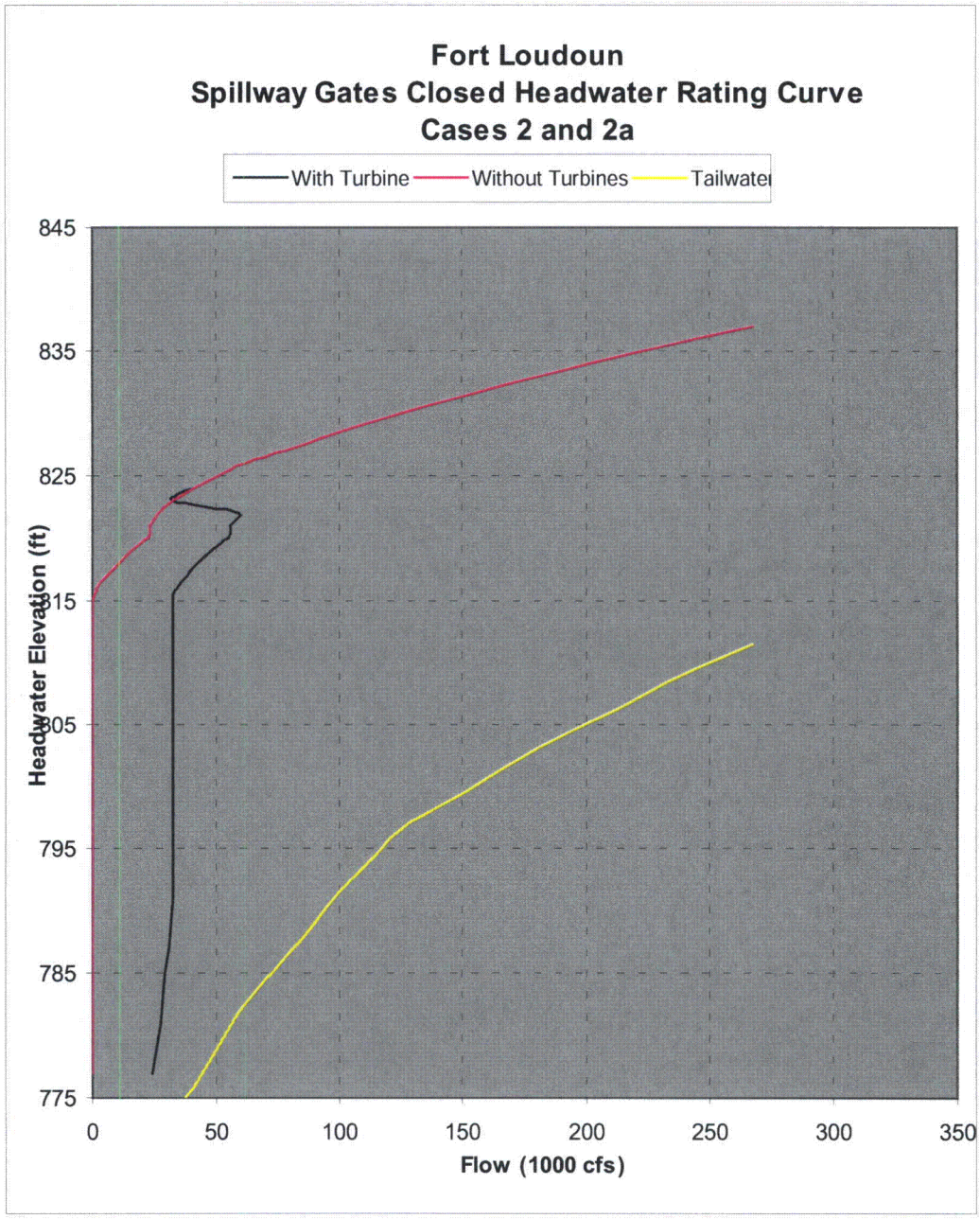


Figure 18: Case 3 Headwater Rating Curve

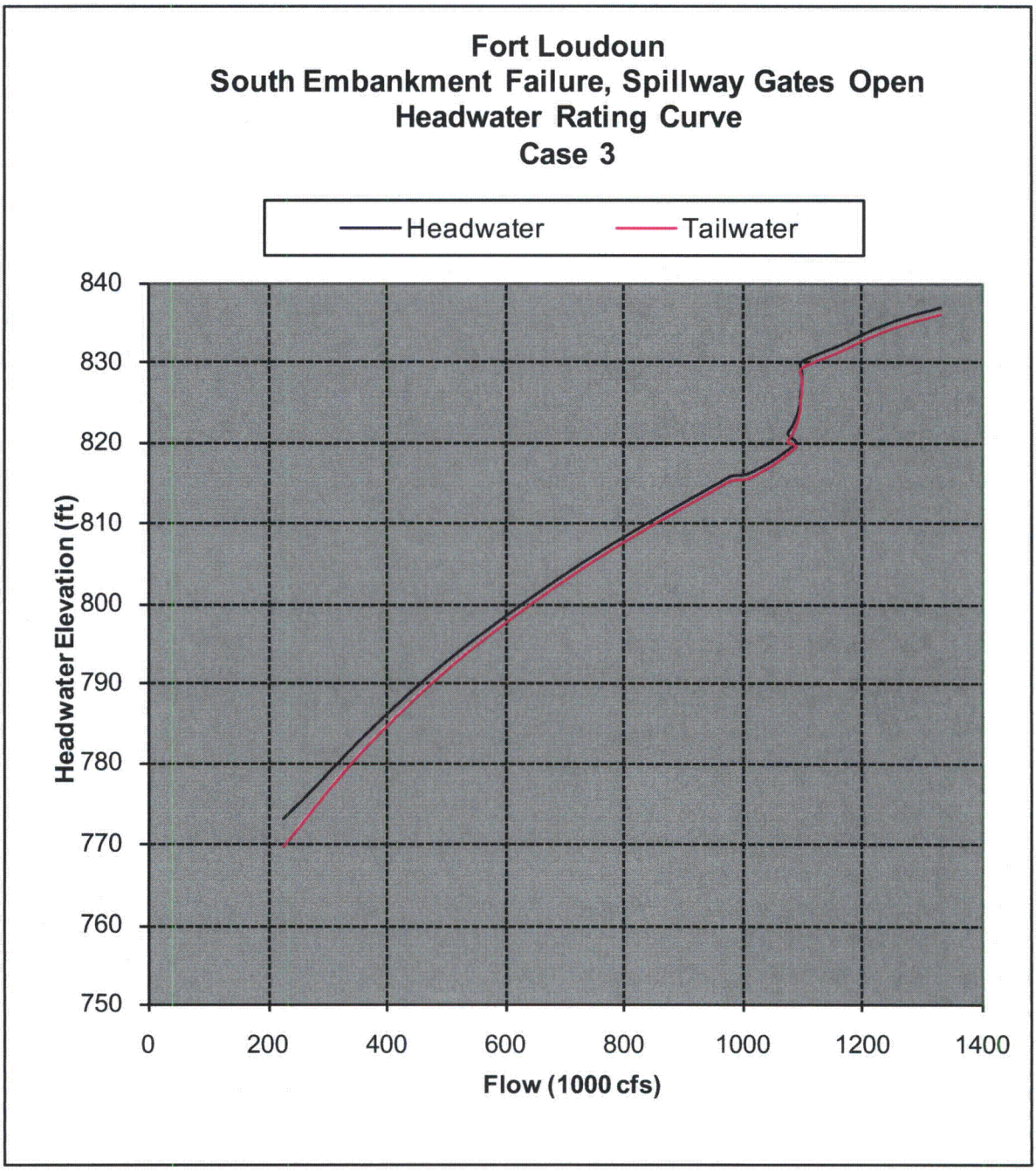


Figure 19: Case 4 Headwater Rating Curve

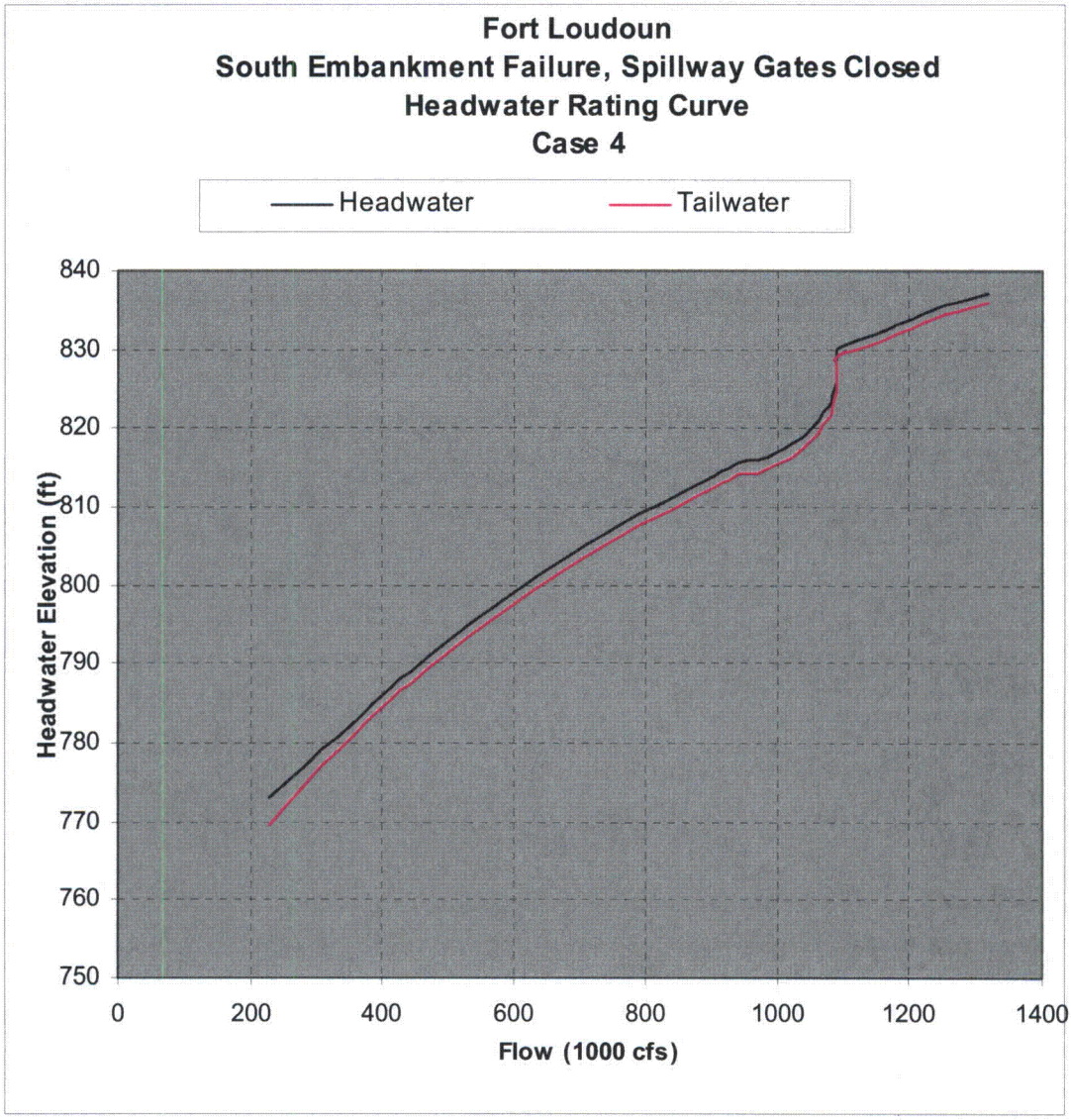
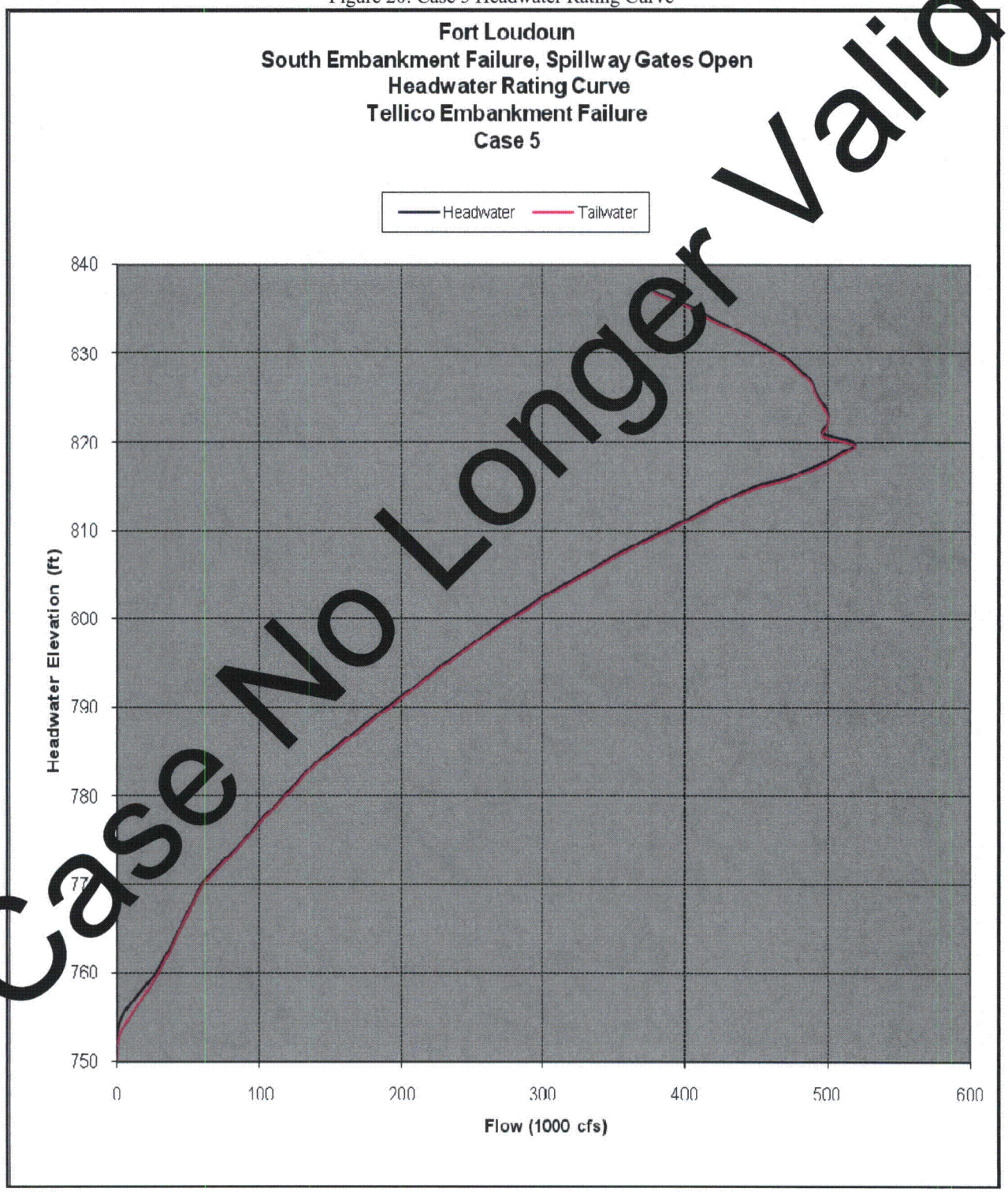
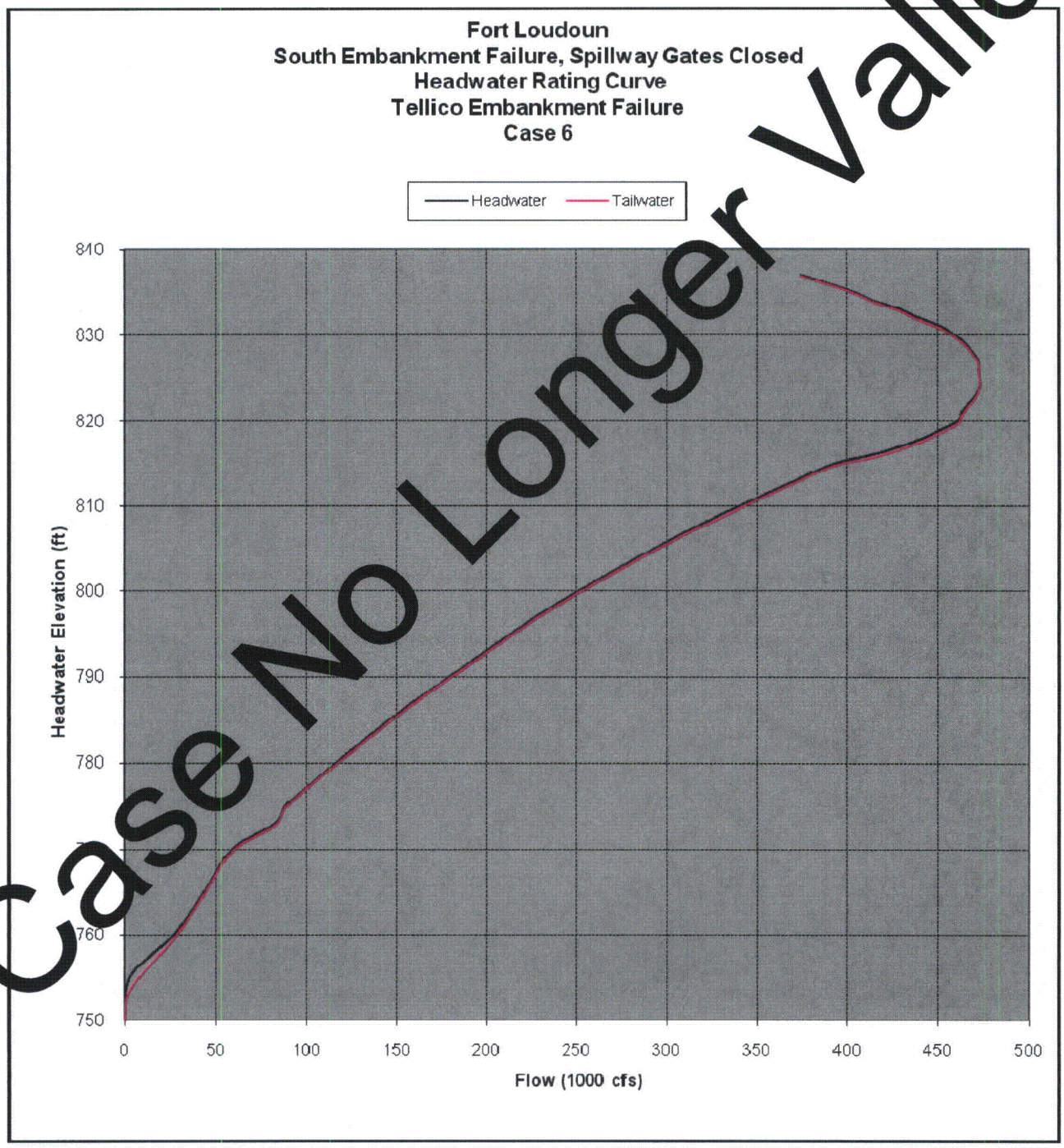


Figure 20: Case 5 Headwater Rating Curve



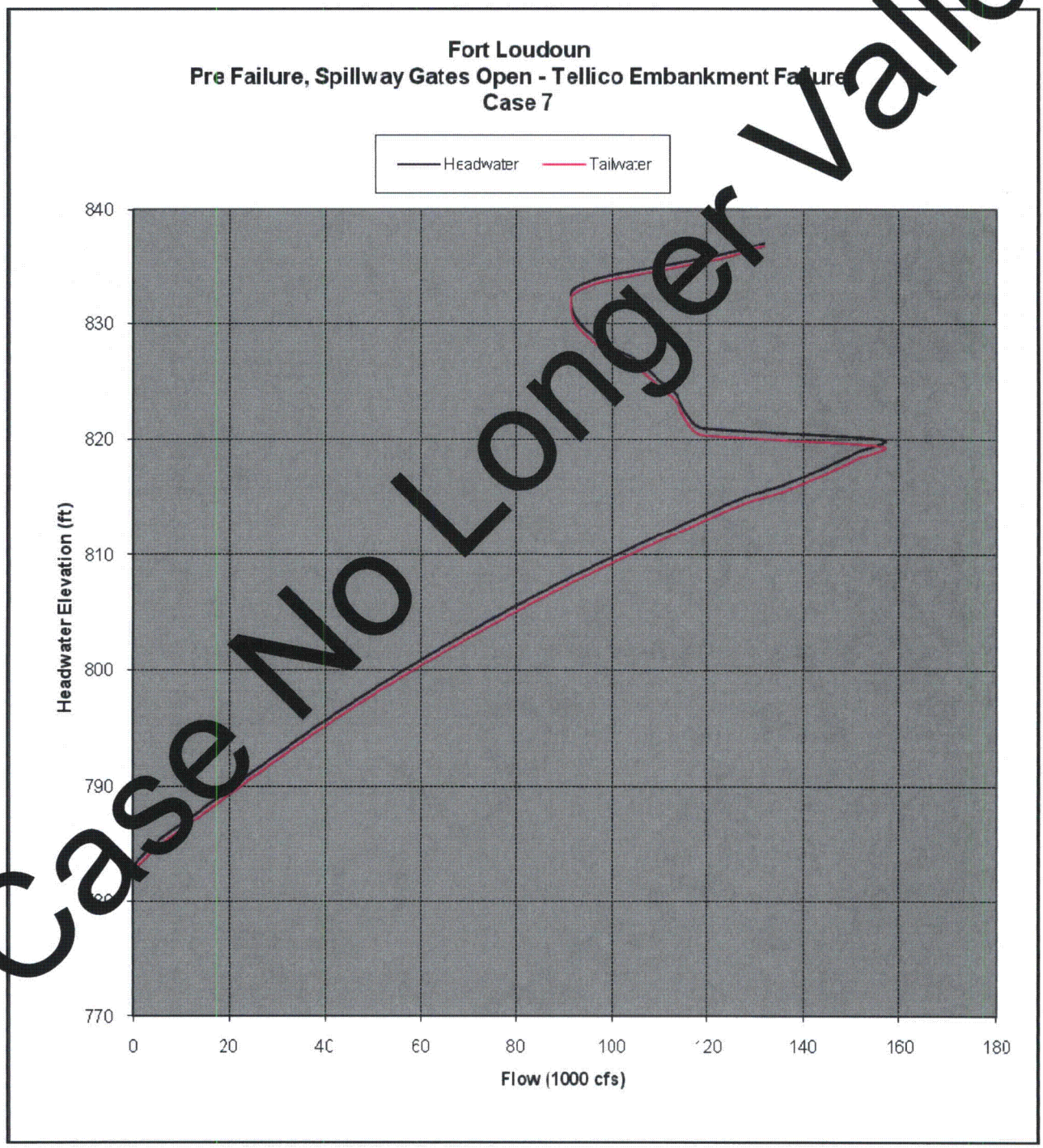
Case No Longer Valid

Figure 21: Case 6 Headwater Rating Curve



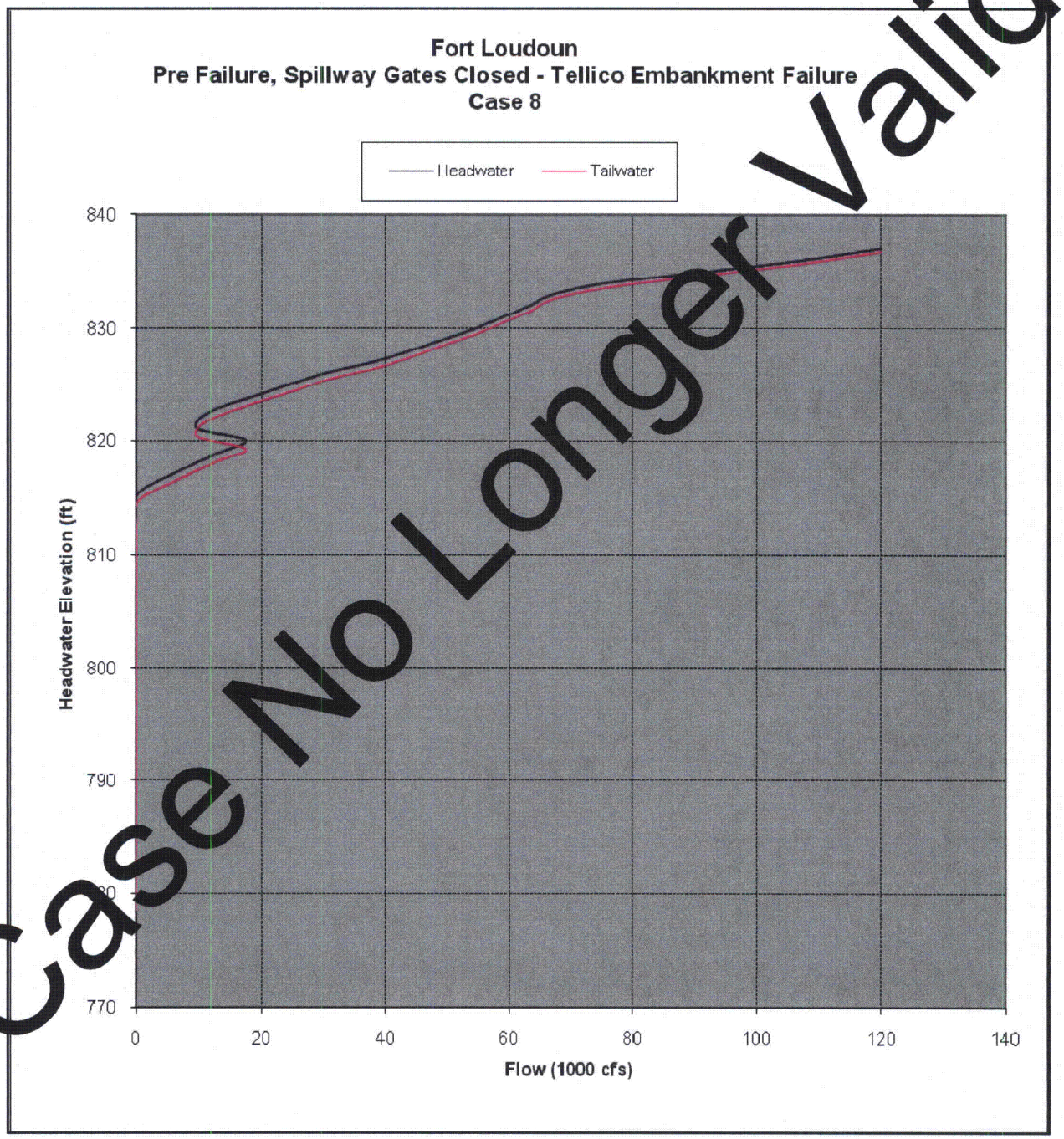
Case No Longer Valid

Figure 22: Case 7 Headwater Rating Curve



Case No Longer Valid

Figure 23: Case 8 Headwater Rating Curve



Case No Longer Valid

Figure 24: Case 9 Headwater Rating Curve

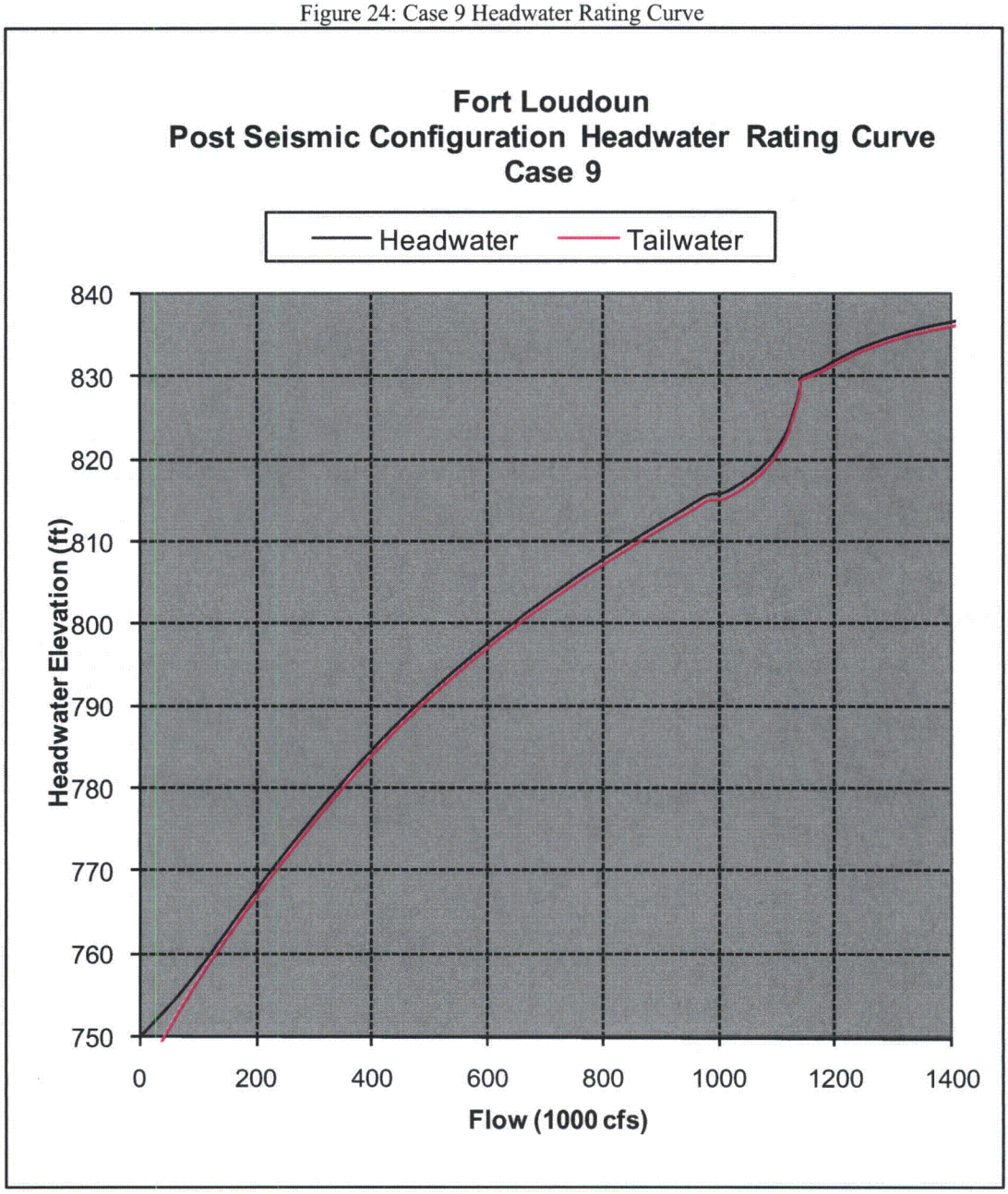


Figure 25: Headwater Rating Curves for Tellico and Fort Loudoun, Combined, for Cases 1 – 4

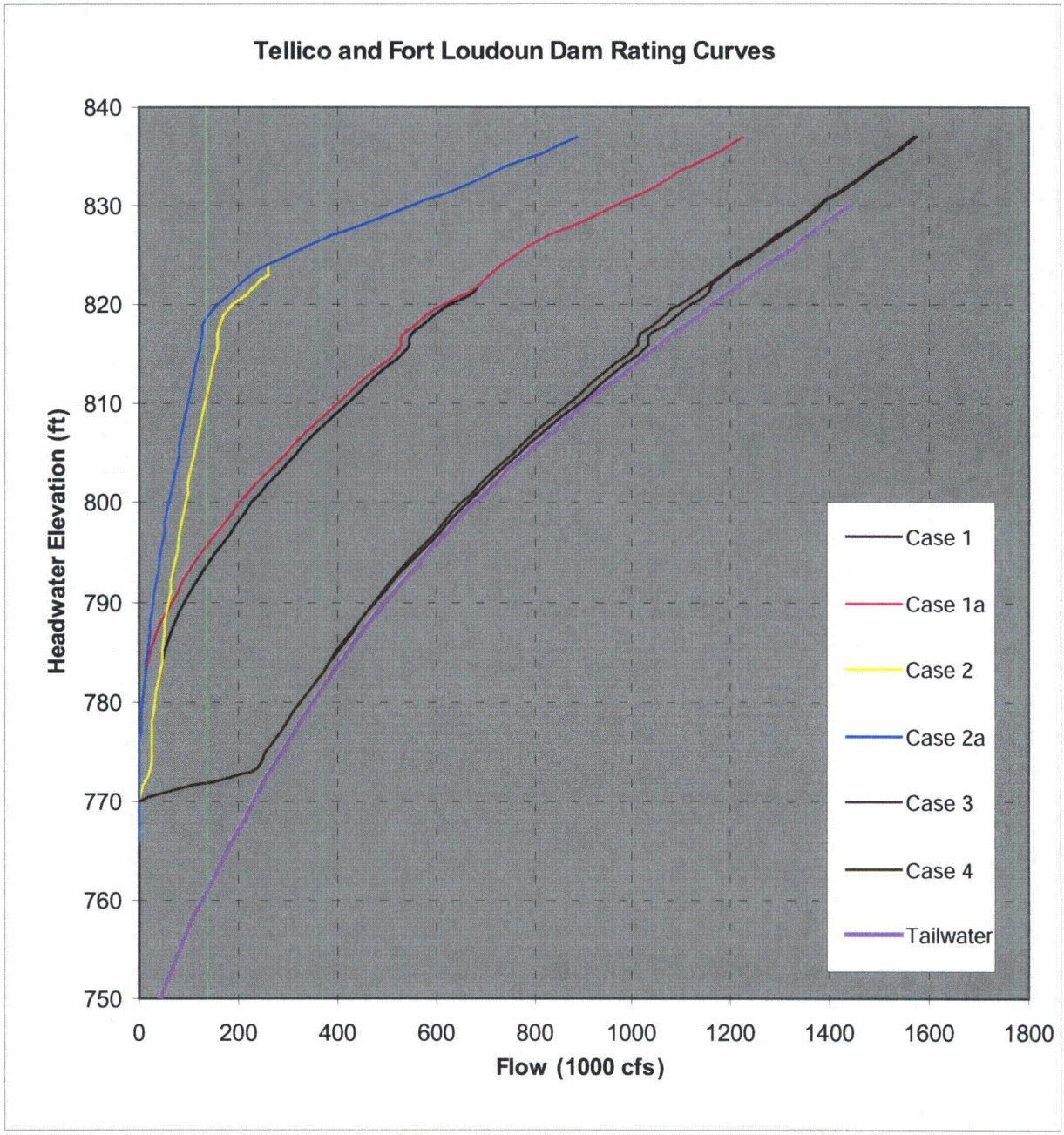
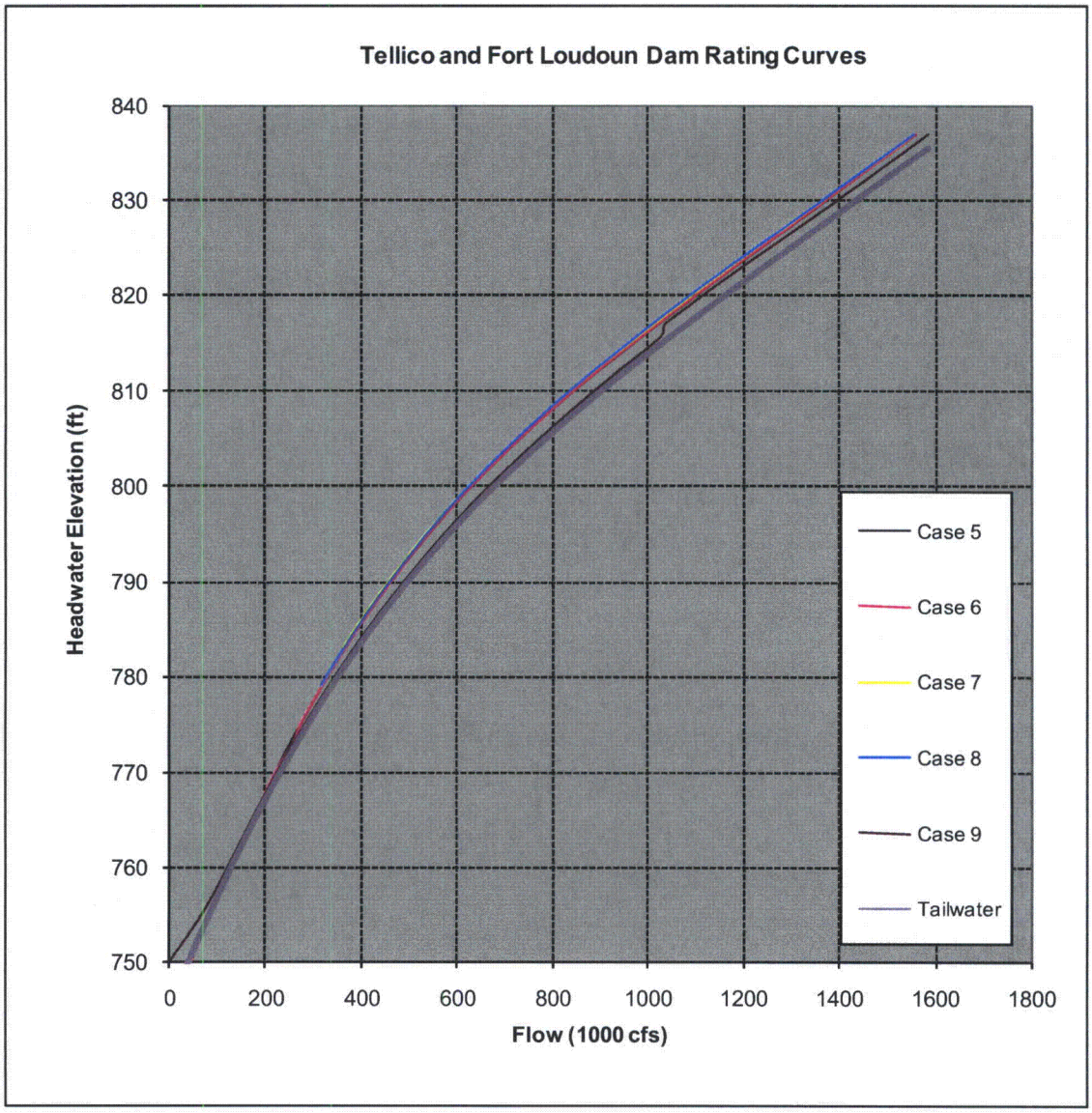
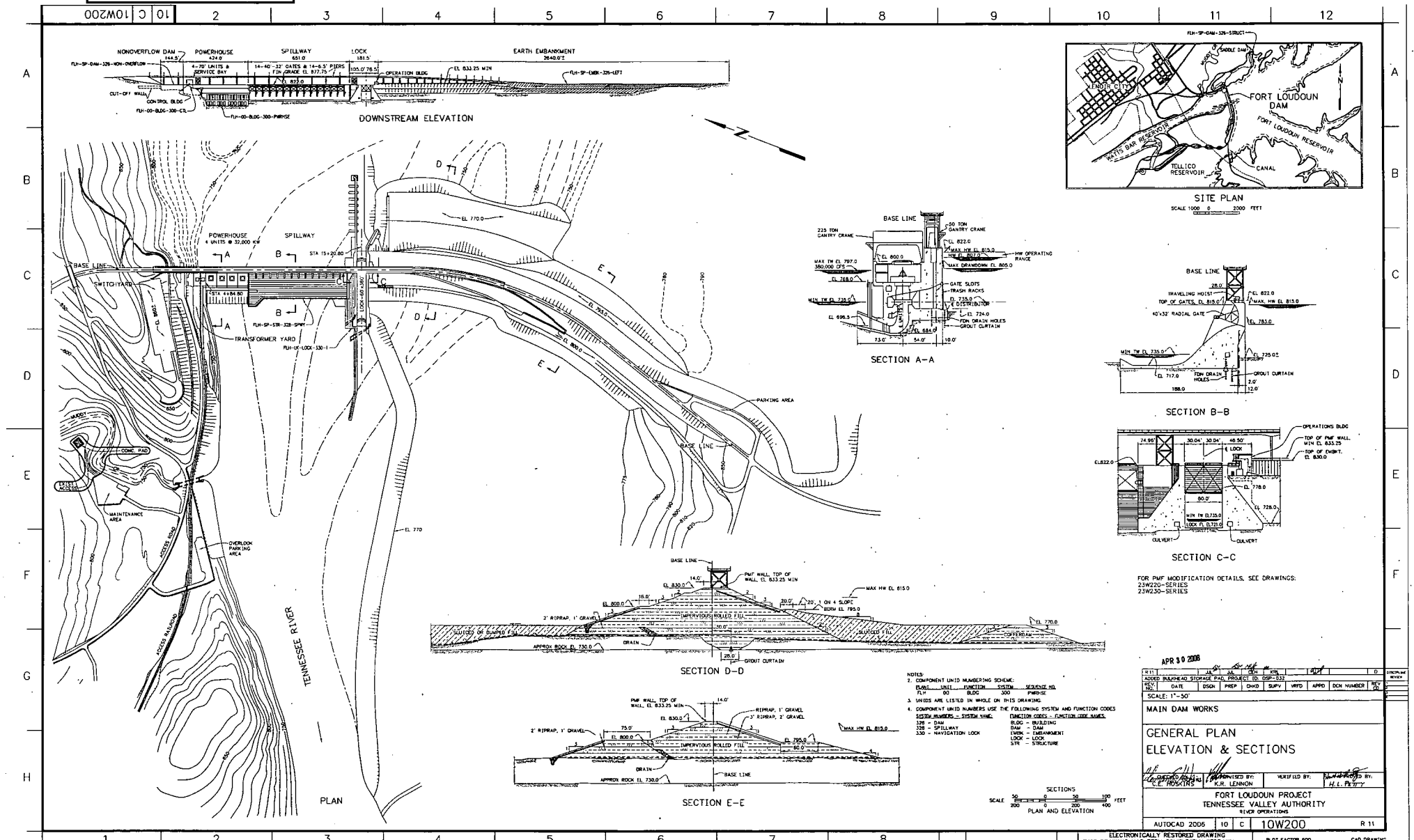


Figure 26 – Headwater Rating Curves for Tellico and Fort Loudoun, Combined, for Cases 5 - 9
Cases 5, 6, 7, and 8 are no longer valid



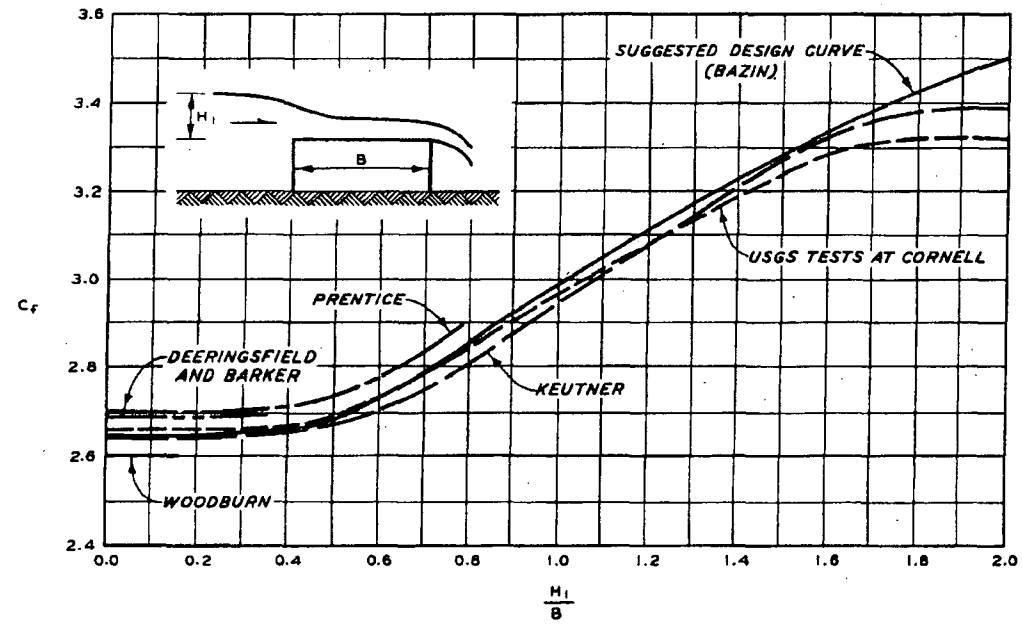
Attachment 1
1 Page
Source: Reference 1

Calculation CDQ000020080009

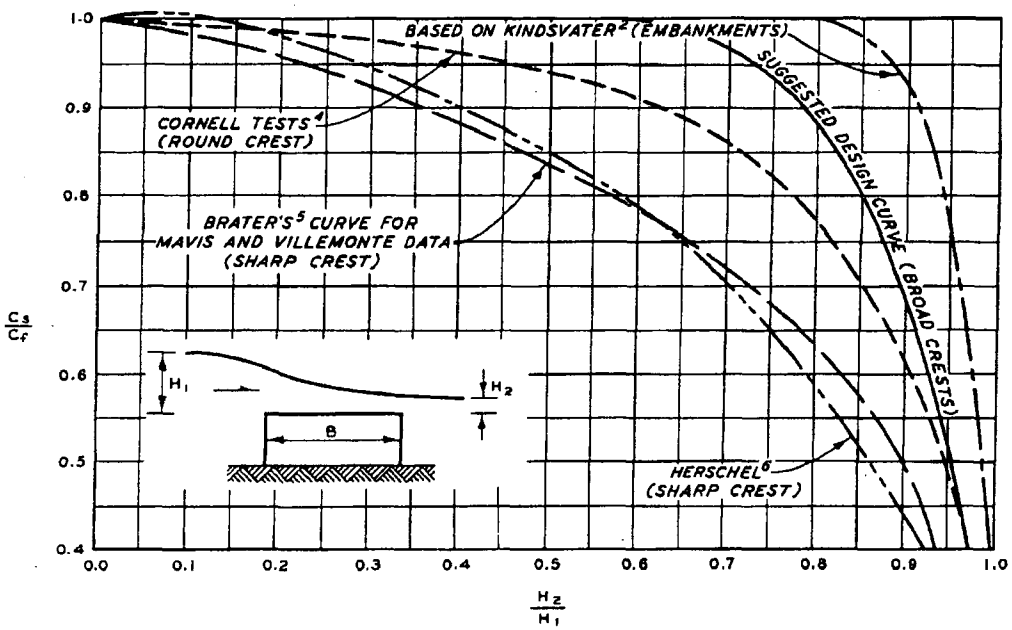


Attachment 2
1 Page
Source: Reference 6

Calculation CDQ000020080009



a. FREE FLOW



b. SUBMERGED FLOW

NOTE: C_F = FREE-FLOW COEFFICIENT
C_S = SUBMERGED-FLOW COEFFICIENT
NEGLIGIBLE VELOCITY OF APPROACH
RAISED NUMBERS ON SUBMERGED FLOW CHART ARE REFERENCE NUMBERS FROM TEXT.

LOW-MONOLITH DIVERSION
DISCHARGE COEFFICIENTS
HYDRAULIC DESIGN CHART 711

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

WES 1-66

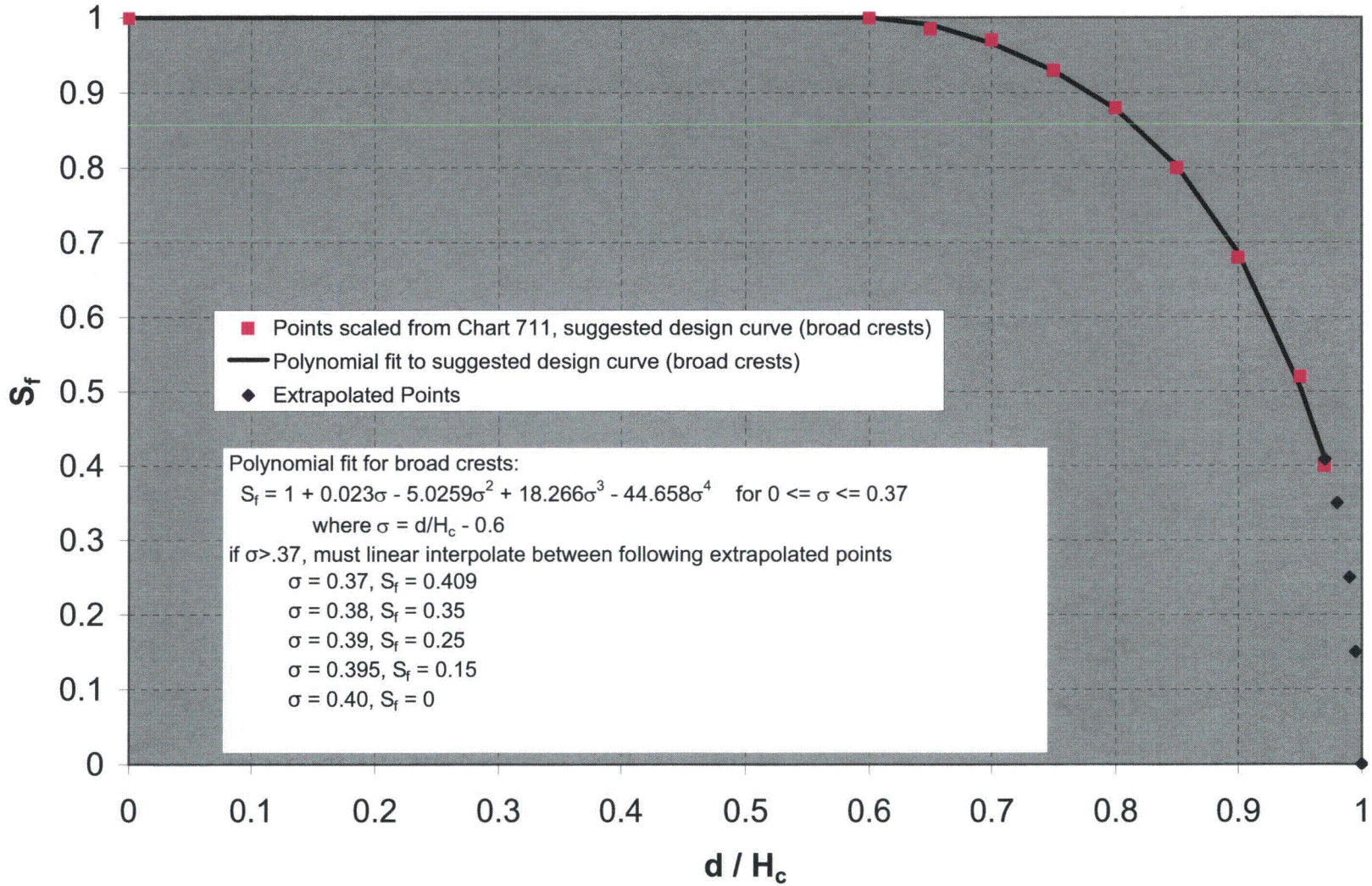
Note:
$H_1=H_c$
$H_2=d$
$C_s/C_f=S_f$

Attachment 3
1 Page
Source: Reference 6

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

Submergence Factors for Weirs from Chart 711 in Hydraulic Design Criteria



Attachment 4-1
4 Total Pages
Source: Reference 7

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

Fort Loudon - Flow Over Tainter Gates

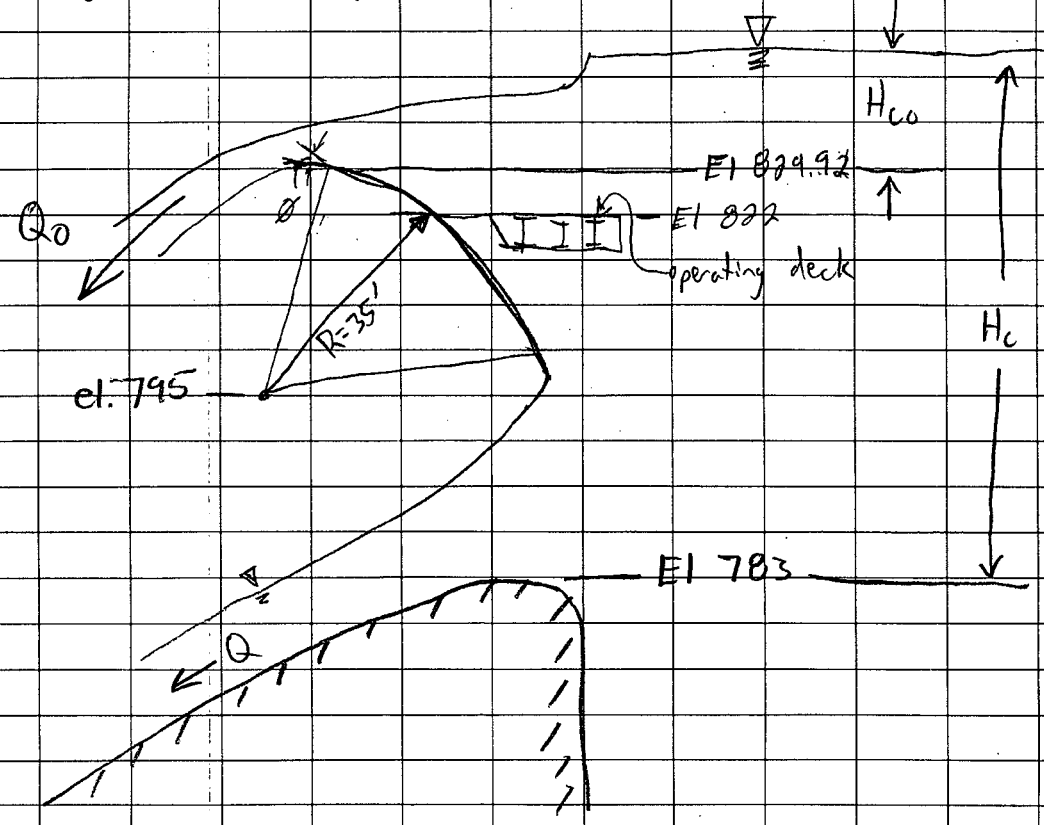
COMPUTED ATT DATE

CHECKED DATE

With reference to the sketch below, discharge over the tops of the open tainter gates is computed as

$$Q_o = C_o L_o H_{co}^{3/2}$$

where L_o = total length of overflowing gates = 14 (40) = 560'



sketch based on drawing 54W 200, R6 (Att A21)

A reasonable approach to specifying C_o is to use discharge coefficients for drum gates which present the same circular surface to overflow. Discharge coefficients for drum gates are available in ref. 7, Figure 6 as

$$C_q = C_q(\theta, H/r) \quad \sim \text{Attachment 4-3}$$

where

C_q = same as C_o above
θ = same as θ above
H = same as H_{co} above
r = gate radius = 35' (same as R above)

Angle ϕ is computed as described in Attachment A9-3:

$$\phi = \tan^{-1}(x_0/y_0) \text{ with } \begin{cases} x_0 = R\cos(\theta - \alpha) \\ y_0 = 829.92 - 795 = 34.92' \end{cases}$$

From Appendix A:

$$R = 35' \quad \theta = 55.537^\circ, \quad \alpha = -30.702^\circ$$

$$\Rightarrow x_0 = 35\cos[55.537 - (-30.702)] = 2.296'$$

$$\Rightarrow \phi = \tan^{-1}\left(\frac{2.296}{34.92}\right) = 3.76^\circ$$

Headwater Rating Curve computed to headwater elevation of 837'

$$\Rightarrow 0 \le H_{co} \le 837 - 829.92 = 7.08'$$

$$\text{and } 0 \le H/r \le 7.08/35 = .20$$

From Ref. 7 $\Rightarrow$ $\underline{3.22 \le C_q \le 3.86}$

For headwater rating - use constant value near low end for all heads

$* \boxed{C_q = 3.3}$ because uncertainties and the magnitude of the overflow discharge do not justify further refinement

Use low End because overflow Q is probably less than drum Q

Reasoning:

- total overflow discharge < 7% of total dam discharge so small variations in C_q have negligible effect on total dam discharge.
- flow under gate causes significant drawdown in water level upstream from gate which should result in less overflow than predicted for an equivalent drum gate.
- Operating deck may impede flow and reduce discharge

Also need C_f for gates closed. Using similar methodology from previous page:

From Appendix A:

$R = 35'$, $\theta = 55.54°$, $\alpha = 20.69°$

$x_0 = 35 \cos(55.54 - 20.69) = 28.72'$

$y_0 = 815 - 795 = 20'$

$\phi = \tan^{-1}\left(\frac{28.72}{20}\right) = 55.15°$

Headwater rating computed to elevation 837'

$0 \le H_{co} \le 837 - 815 = 22'$

and

$0 \le H/r \le \frac{22'}{35} = .629$

from Ref 7 (Att. 4-4) $\Rightarrow 3.8 \le C_q \le 3.5$

use $\boxed{C_f = 3.6}$

Attachment 4-4
4 Total Pages
Source: Reference 7

been able to check the discharge measurements of Bazin. However, the actual values are not so important for the case at hand as is the significance of the trend.

Method of Combining Test Results

The method for combining results from the eleven drum gates tested (Table 2) consisted of first plotting the coefficient of discharge data separately

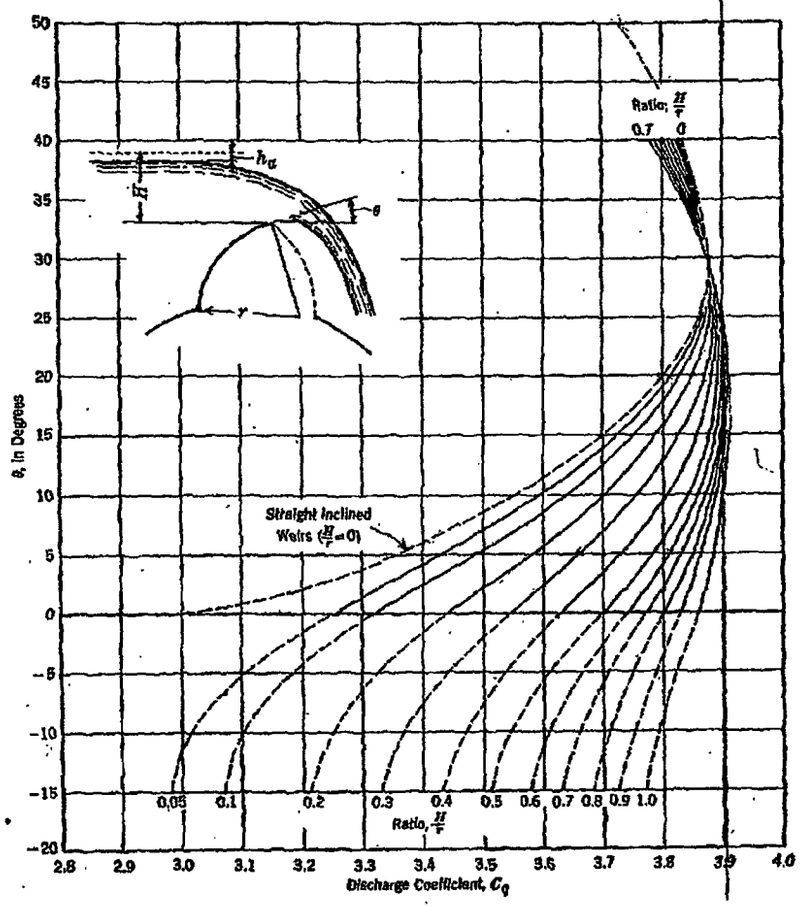


Fig. 6.—General Curves for the Determination of Discharge Coefficients

for each gate as illustrated by the sheet for the Shasta Dam gate (Fig. 5). With the coefficient of discharge as the abscissa and H/r as the ordinate, each curve in Fig. 5 represents a different gate angle θ, which the tangent to the downstre lip of the gate makes with the horizontal. In all cases, H is the

Calculation CDQ000020080009

total head, including the velocity head of approach, measured above the high point of the gate, and r is the radius of the gate. In Fig. 5, C_q is based on the relationship, $Q = C_q L H^{\frac{3}{2}}$. For positive values of θ, the head was measured above the lip of the gate, whereas for negative angles it was observed above the high point, or crest, of the gate proper. The method of measuring the head is illustrated in Fig. 2.

Upon completion of a similar set of curves for each gate tested, the eleven sets of curves were replotted and combined into the chart exhibited as Fig. 6. The results from the various gates showed good general agreement; and the curves in Fig. 6 constitute the general experimental information needed for determining the discharge coefficients for gates in raised or partly raised positions. The supporting points are not shown in Fig. 6, but the individual information for each gate is listed in Table 2.

Analysis of Test Results

The curves in Fig. 6 show a tendency toward reversal, similar to that exhibited by the Bazin curve in Fig. 4, but the points of inflection vary from $\theta = 20°$ to $\theta = 30°$, depending on the value of H/r. Fig. 4 showed the coefficients to vary only slightly with the head, but in this case the coefficients definitely vary with the head.

A matter of significance is the reversal of the (H/r)-order which occurs at 29° (Fig. 6). The coefficient of discharge has but one value, 3.88, when θ approximates 29°; thus, it is insensitive to both the radius and the head on the gate for this angle. The curve for $H/r = 0$ approximates a drum gate of infinite radius and was obtained from the data of Bazin (Fig. 4) by applying a uniform adjustment.

As stated previously, similitude is valid for small negative angles of θ, as well as for positive angles up to 90°; thus, the curves in Fig. 6 are shown and recommended for use down to $\theta = -15°$. As the gate is lowered beyond this angle, the curves double back and converge, finally terminating in the free flow coefficient.

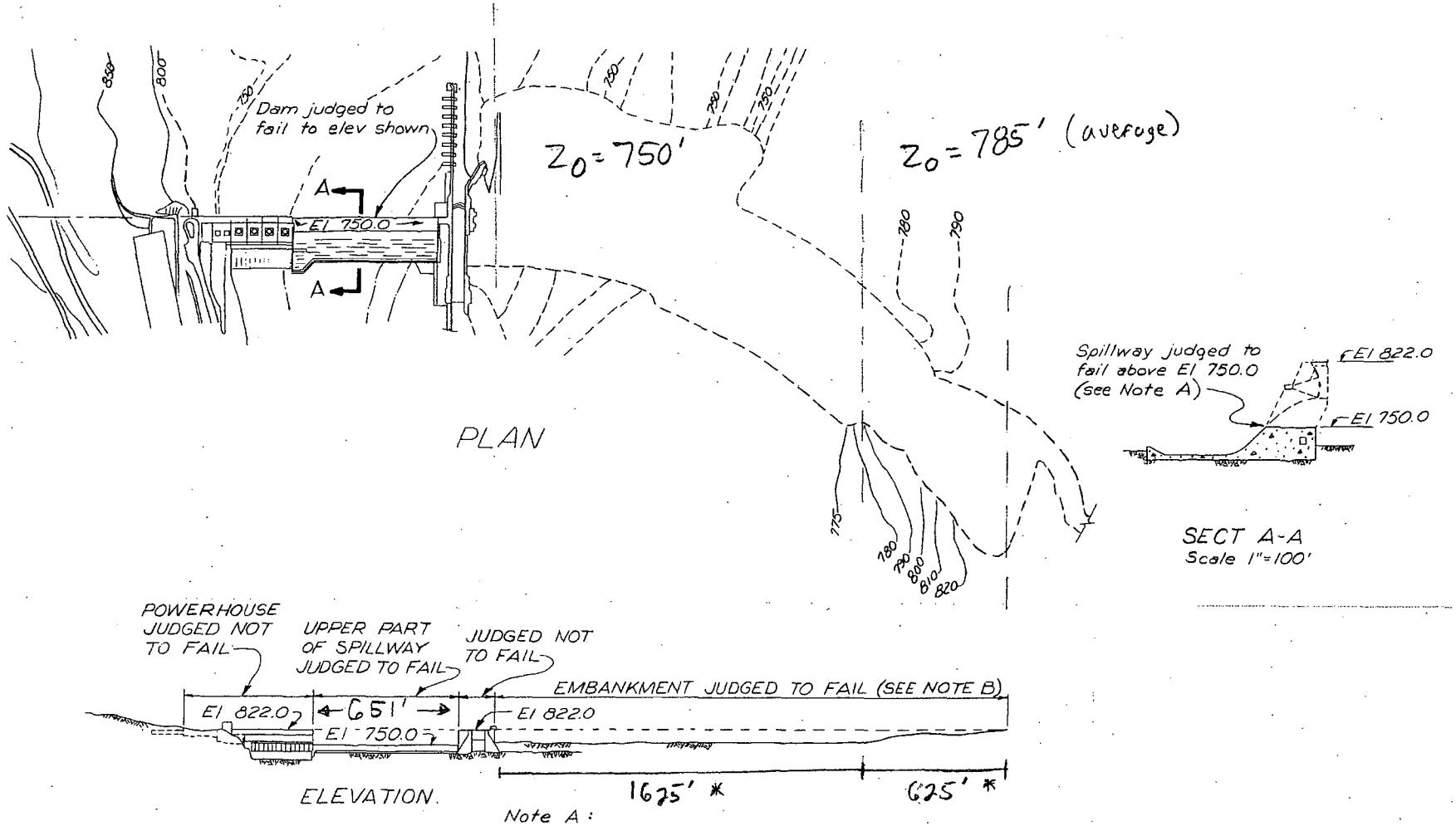
The discharge coefficients in the region between $\theta = -15°$ and the gate completely down are determined by graphical interpolation. Interpolation is accomplished by plotting head-discharge curves for several gate angles between $-15°$ and the maximum positive angle. Also the head-discharge curve is plotted for the free crest. This information is then cross-plotted to obtain values in the transition zone. The method will be explained in the example that follows. It will be discovered that negative angles greater than $-15°$ (with the exception of the free crest) are not particularly important from an operator's standpoint, as a change in gate position has little effect on the discharge in this range.

It must be assumed that the coefficient of discharge is known for at least one value of the head on the free crest (gate completely down) for the particular spillway under consideration. With the coefficient known for one or more heads, the complete coefficient curve for the free crest can be plotted by consulting Fig. 7, in which H_o and C_o are the designed head and the coefficient

Attachment 5
1 Page
Source: Reference 2

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



Note A:
All debris from failed portion of dam judged to be below failure elevation

Note B:
High portion of embankment judged to fail during earthquake. Other portion assumed to erode after failure.

* All distances scaled using spillway

WATTS BAR NUCLEAR PLANT
FINAL SAFETY
ANALYSIS REPORT

FORT LOUDOUN DAM
ASSUMED CONDITION OF DAM
AFTER FAILURE SSE COMBINED WITH
A 25 YEAR FLOOD
Fort Loudoun Dam
Figure 2.4-88

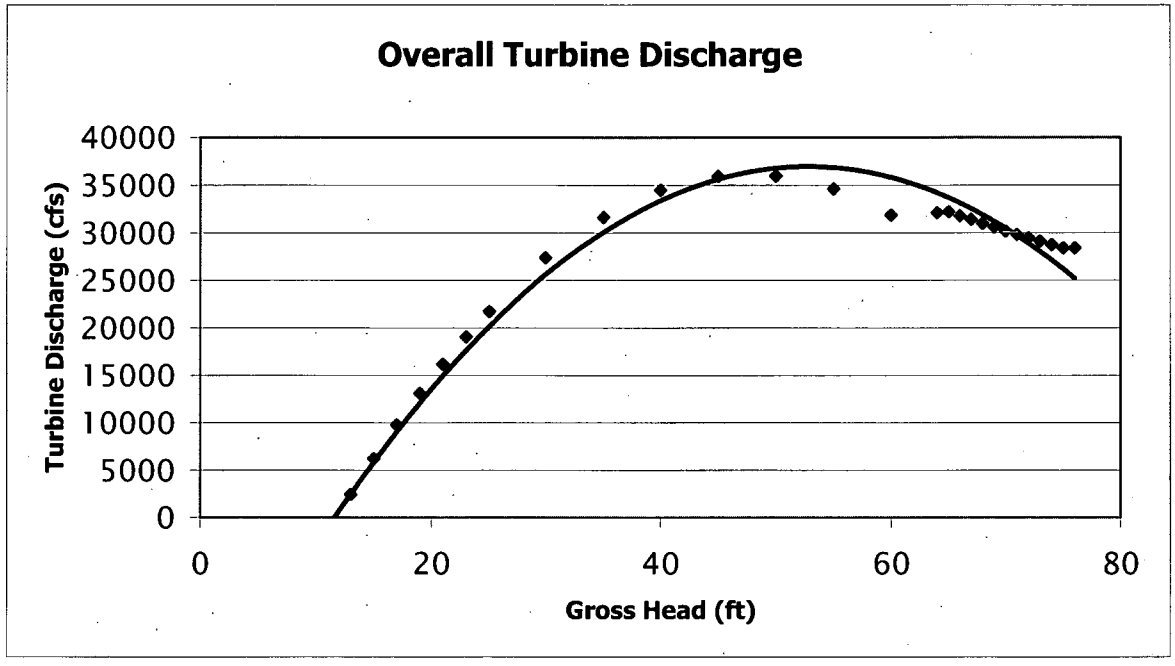
Attachment 6-1
3 Pages
Source: Multiple

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

Overall Turbine Discharge

Gross Head (ft)	Turbine Discharge (cfs)	Source
76	28400	Taken from p. 24 of Fort Loudoun Blue Book
75	28400	
74	28760	
73	29120	
72	29480	
71	29840	
70	30200	
69	30600	
68	31000	
67	31400	
66	31800	
65	32200	
64	32120	
60	31845	Extrapolated from TVA Dwg # 47B901, 47B904, 47B908, 47B912
55	34612	
50	35976	
45	35936	
40	34492	
35	31644	
30	27392	
25	21736	
23	19081	
21	16201	
19	13096	
17	9767	
15	6213	Assume no Discharge
13	2435	
11	-1568	
9	-5796	
7	-10249	
5	-14926	



$Q_T = -21.7981x^2 + 2301.2018x - 23779.5655$

$0 \leq Q_T \geq 32200$

$R^2 = .9885$

Max Headwater Elevation = 822 Feet

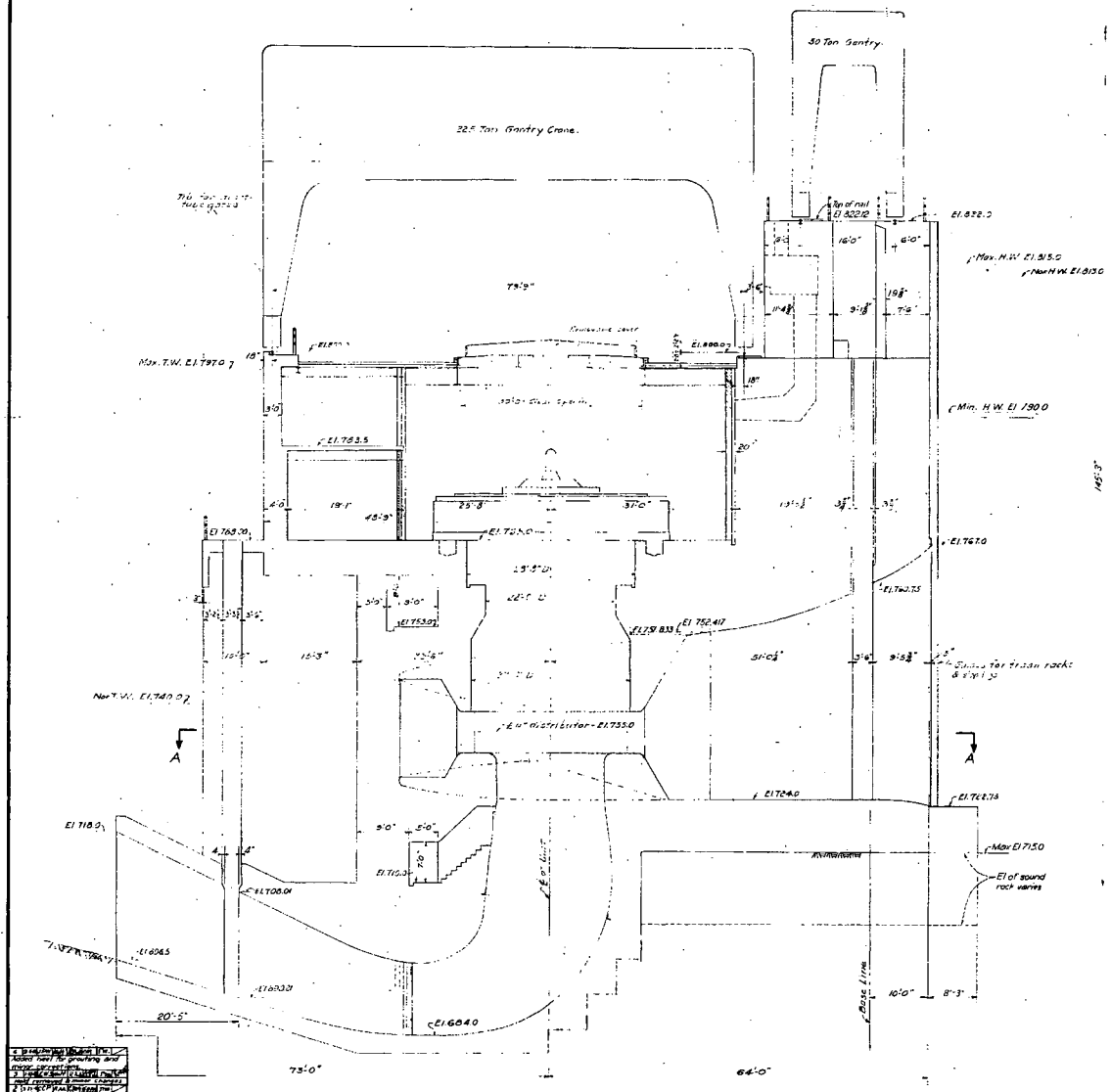
Max Tailwater Elevation = 800 Feet

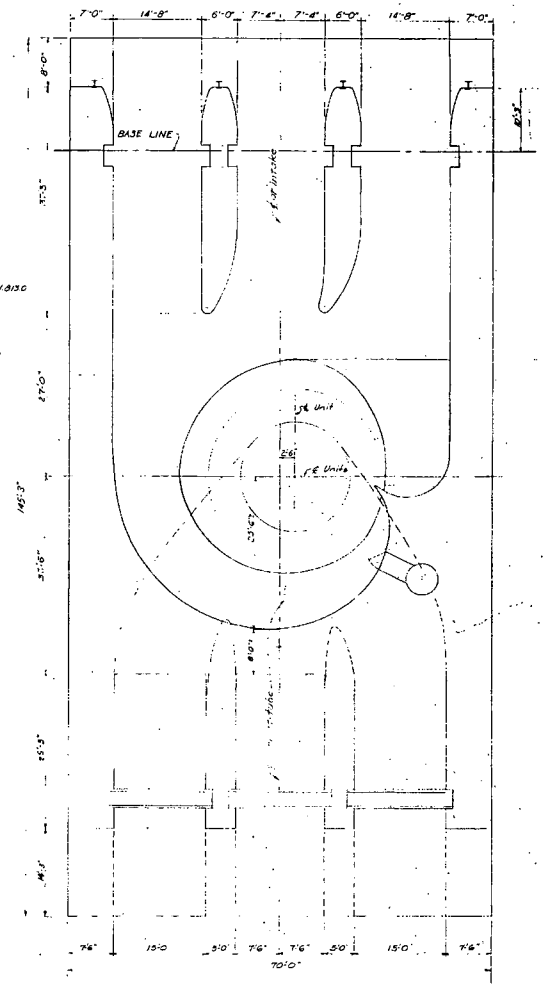
Minimum Gross Head = 15 Feet

Attachment 6-2
3 Pages
Source: Reference 29

Calculation CDQ000020080009

4IN600





NOTES:
For final rock excavation lines, see field office dwgs 213-H-400 to 213-H-447.

Scale: 1/8"=1'-0" Sheet 1 of 6

POWER HOUSE

GENERAL LAYOUT
TYPICAL SECTION

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED | RECOMMENDED | APPROVED

KNOXVILLE | 5-2-41 | 10 | C | 4 | 4IN600R5

RECORD DRAWING AS CONSTRUCTED

APPROVED: PROJECT MANAGER

Attachment 6-3
3 Pages
Source: Reference 36

Calculation CDQ000020080009

RESERVOIR AND POWER DATA

						Best Efficiency			Maximum Sustainable		
Elevation (feet)	Tailwater (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Potential Eis (gWh)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
815	739	15.51	393.0	44.0	76.0	154.7	27,500	5.63	155.0	28,400	5.46
814	739	14.97	377.8	38.0	75.0	154.7	27,500	5.63	155.0	28,400	5.46
813	739	14.60	363.0	32.1	74.0	152.3	27,440	5.55	154.7	28,760	5.38
812	739	14.30	348.5	26.3	73.0	149.9	27,380	5.47	154.4	29,120	5.31
811	739	13.95	334.4	20.7	72.0	147.6	27,320	5.40	154.1	29,480	5.23
810	739	13.56	320.6	15.2	71.0	145.2	27,260	5.33	153.8	29,840	5.16
809	739	13.13	307.3	9.9	70.0	142.8	27,200	5.25	153.5	30,200	5.08
808	739	12.66	294.4	4.9	69.0	139.6	27,000	5.17	152.9	30,600	5.00
807	739	12.14	282.0	.0	68.0	136.3	26,800	5.08	152.2	31,000	4.92

						Best Efficiency			Maximum Sustainable		
Elevation (feet)	Tailwater (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Potential Eis (gWh)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
815	743	15.51	393.0	43.7	72.0	147.6	27,320	5.40	154.1	29,480	5.23
814	743	14.97	377.8	37.7	71.0	145.2	27,260	5.33	153.8	29,840	5.16
813	743	14.60	363.0	31.8	70.0	142.8	27,200	5.25	153.5	30,200	5.08
812	743	14.30	348.5	26.0	69.0	139.6	27,000	5.17	152.9	30,600	5.00
811	743	13.95	334.4	20.5	68.0	136.3	26,800	5.08	152.2	31,000	4.92
810	743	13.56	320.6	15.0	67.0	133.1	26,600	5.00	151.6	31,400	4.83
809	743	13.13	307.3	9.8	66.0	129.8	26,400	4.92	150.9	31,800	4.75
808	743	12.66	294.4	4.8	65.0	126.6	26,200	4.83	150.3	32,200	4.67
807	743	12.14	282.0	.0	64.0	123.5	26,000	4.75	147.3	32,120	4.58

Attachment 7-1
3 Pages
Source: Reference 30

Calculation CDQ000020080009

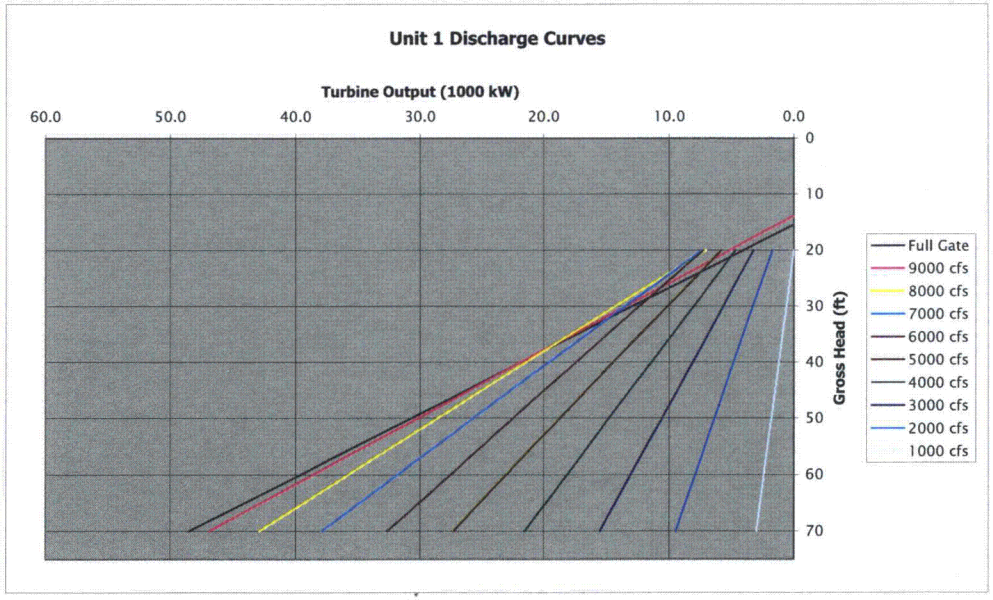
Prepared: ATT
Checked: JCT

Unit 1 Turbine
All values from TVA dwg. 47B901, R0
All data for Gross Head of less than 40 feet is extrapolated

Gross Head	Full Gate	9000 cfs	8000 cfs	7000 cfs	6000 cfs	5000 cfs	4000 cfs	3000 cfs	2000 cfs	1000 cfs
70	48.5	46.9	42.9	37.9	32.6	27.3	21.5	15.5	9.5	3.0
65	44.1	42.7	39.3	34.9	30.1	25.2	19.8	14.3	8.7	2.7
60	39.6	38.5	35.7	31.8	27.5	23.0	18.1	13.0	7.9	2.4
55	35.2	34.4	32.2	28.8	25.0	20.9	16.5	11.8	7.2	2.1
50	30.7	30.2	28.6	25.7	22.5	18.7	14.8	10.6	6.4	1.8
45	26.3	26.0	25.0	22.7	19.9	16.6	13.1	9.3	5.6	1.5
40	21.8	21.8	21.4	19.6	17.4	14.4	11.4	8.1	4.8	1.2
35	17.4	17.6	17.8	16.6	14.9	12.3	9.7	6.9	4.0	0.9
30	12.9	13.4	14.2	13.5	12.3	10.1	8.0	5.6	3.2	0.6
25	8.5	9.3	10.7	10.5	9.8	8.0	6.4	4.4	2.5	0.3
20	4.0	5.1	7.1	7.4	7.3	5.8	4.7	3.2	1.7	0.0
15	-0.4	0.9	3.5	4.4	4.7	3.7	3.0	1.9	0.9	-0.3
10	-4.9	-3.3	-0.1	1.3	2.2	1.5	1.3	0.7	0.1	-0.6

Line Fitting
All lines fit to form y=mx+b

			m	b	Intersection
Full Gate					
	70	48.5	1.123596	15.50562	
	40	21.8			
9000 cfs			m	b	Intersection
	70	46.9	1.195219	13.94422	40
	40	21.8			
8000 cfs			m	b	Intersection
	70	42.9	1.395349	10.13953	37.69231
	40	21.4			
7000 cfs			m	b	Intersection
	70	37.9	1.639344	7.868852	32.14286
	40	19.6			
6000 cfs			m	b	Intersection
	70	32.6	1.973684	5.657895	28.52174
	40	17.4			



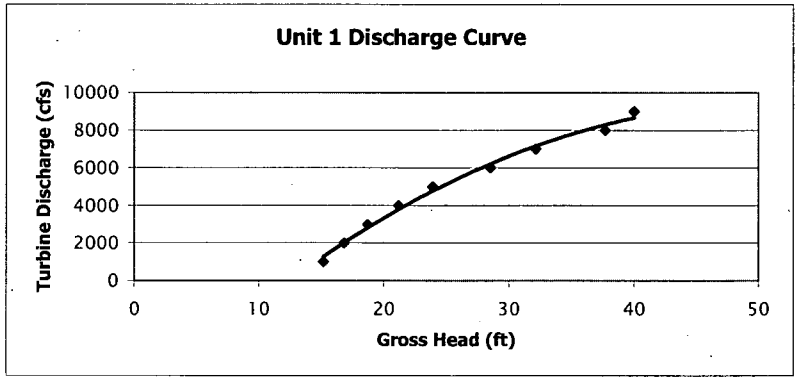
Attachment 7-2
3 Pages
Source: Reference 30

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

			m	b	Intersection
5000 cfs					
	70	27.3	2.325581	6.511628	23.91304
	40	14.4			
4000 cfs			m	b	Intersection
	70	21.5	2.970297	6.138614	21.20482
	40	11.4			
3000 cfs			m	b	Intersection
	70	15.5	4.054054	7.162162	18.70466
	40	8.1			
2000 cfs			m	b	Intersection
	70	9.5	6.382979	9.361702	16.81818
	40	4.8			
1000 cfs			m	b	Intersection
	70	3	16.66667	20	15.18072
	40	1.2			

Discharge (cfs)	Head (ft)
9000	40
8000	37.69231
7000	32.14286
6000	28.52174
5000	23.91304
4000	21.20482
3000	18.70466
2000	16.81818
1000	15.18072

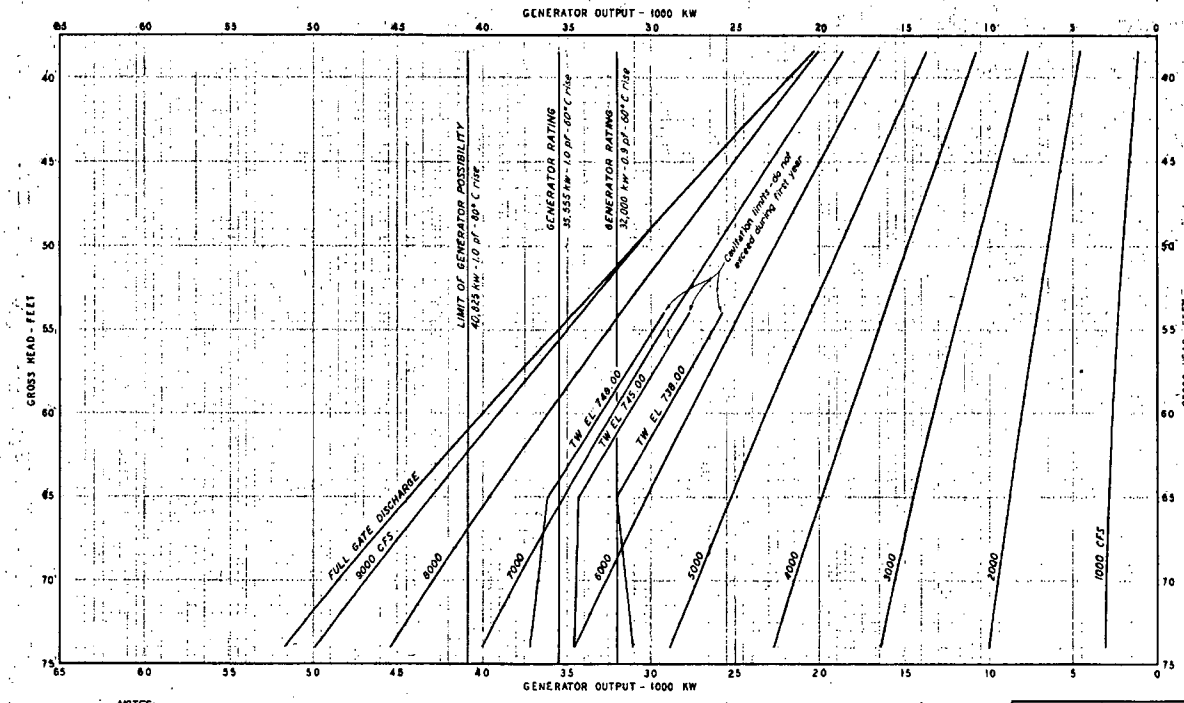


$$Q = -6.3135x^2+645.4279x-7057.4145$$

Attachment 7-3
3 Pages
Source: Reference 30

Calculation CDQ000020080009

EXHIBIT 3



NOTES:
Turbine rated 44,000 hp - 65 ft head - 105.8 rpm.
Furnished by Baldwin Southwark.
Generator rated 35,555 kva - 13,800 volts - 3 phase - 60 cycles - 105.8 rpm - 60° C rise.
Furnished by Allis-Chalmers Mfg Co.
Curves are based on model tests conducted by Baldwin Southwark and modified in accordance with index test conducted 3-12-44.
Tests should be made at other heads and these curves revised accordingly.

POWERHOUSE
UNIT 1

DISCHARGE CURVES
BASED ON INDEX TESTS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED: RECOMMENDED: APPROVED:
KNOXVILLE 4-10-44 10 M 4 47B901R0

MF
RD

Attachment 8-1
3 Pages
Source: Reference 31

Calculation CDQ000020080009

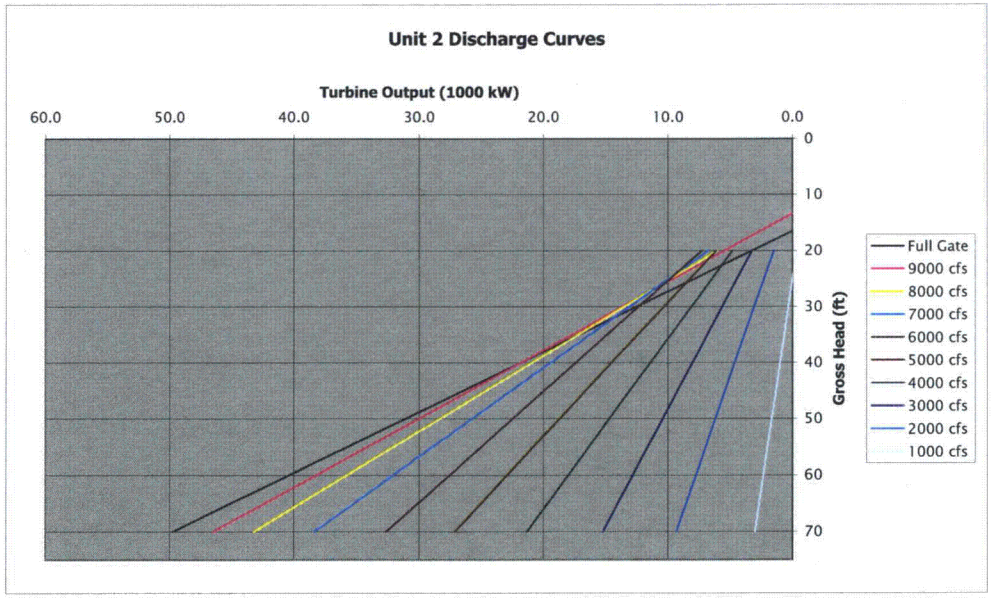
Prepared: ATT
Checked: JCT

Unit 2 Turbine
All values from TVA dwg. 47B904, R0
All data for Gross Head of less than 40 feet is extrapolated

Gross Head	Full Gate	9000 cfs	8000 cfs	7000 cfs	6000 cfs	5000 cfs	4000 cfs	3000 cfs	2000 cfs	1000 cfs
70	49.7	46.4	43.2	38.4	32.6	27.1	21.3	15.2	9.3	3.0
65	45.1	42.3	39.5	35.2	30.1	25.0	19.7	14.0	8.5	2.7
60	40.4	38.2	35.8	32.1	27.5	22.9	18.0	12.8	7.7	2.3
55	35.8	34.1	32.1	28.9	25.0	20.8	16.4	11.6	7.0	2.0
50	31.1	30.0	28.3	25.7	22.5	18.7	14.7	10.4	6.2	1.7
45	26.5	25.9	24.6	22.6	19.9	16.6	13.1	9.2	5.4	1.3
40	21.8	21.8	20.9	19.4	17.4	14.5	11.4	8.0	4.6	1.0
35	17.2	17.7	17.2	16.2	14.9	12.4	9.8	6.8	3.8	0.7
30	12.5	13.6	13.5	13.1	12.3	10.3	8.1	5.6	3.0	0.3
25	7.9	9.5	9.7	9.9	9.8	8.2	6.5	4.4	2.3	0.0
20	3.2	5.4	6.0	6.7	7.3	6.1	4.8	3.2	1.5	-0.3
15	-1.5	1.3	2.3	3.6	4.7	4.0	3.2	2.0	0.7	-0.7
10	-6.1	-2.8	-1.4	0.4	2.2	1.9	1.5	0.8	-0.1	-1.0

Line Fitting
All lines fit to form y=mx+b

			m	b	Intersection
Full Gate					
	70	49.7	1.075269	16.55914	
	40	21.8			
9000 cfs			m	b	Intersection
	70	46.4	1.219512	13.41463	40
	40	21.8			
8000 cfs			m	b	Intersection
	70	43.2	1.345291	11.88341	35.17857
	40	20.9			
7000 cfs			m	b	Intersection
	70	38.4	1.578947	9.368421	31.91011
	40	19.4			
6000 cfs			m	b	Intersection
	70	32.6	1.973684	5.657895	29.6063
	40	17.4			
5000 cfs			m	b	Intersection
	70	27.1	2.380952	5.47619	25.68627
	40	14.5			
4000 cfs			m	b	Intersection



Discharge (cfs)	Head (ft)
9000	40
8000	35.17857

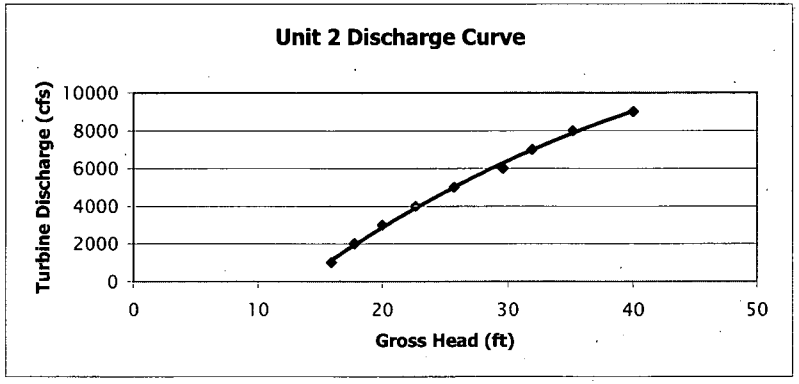
Attachment 8-2
3 Pages
Source: Reference 31

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

	70	21.3	3.030303	5.454545	22.66667
	40	11.4			
3000 cfs			m	b	Intersection
	70	15.2	4.166667	6.666667	20
	40	8			
2000 cfs			m	b	Intersection
	70	9.3	6.382979	10.6383	17.75862
	40	4.6			
1000 cfs			m	b	Intersection
	70	3	15	25	15.90734
	40	1			

7000	31.91011
6000	29.6063
5000	25.68627
4000	22.66667
3000	20
2000	17.75862
1000	15.90734

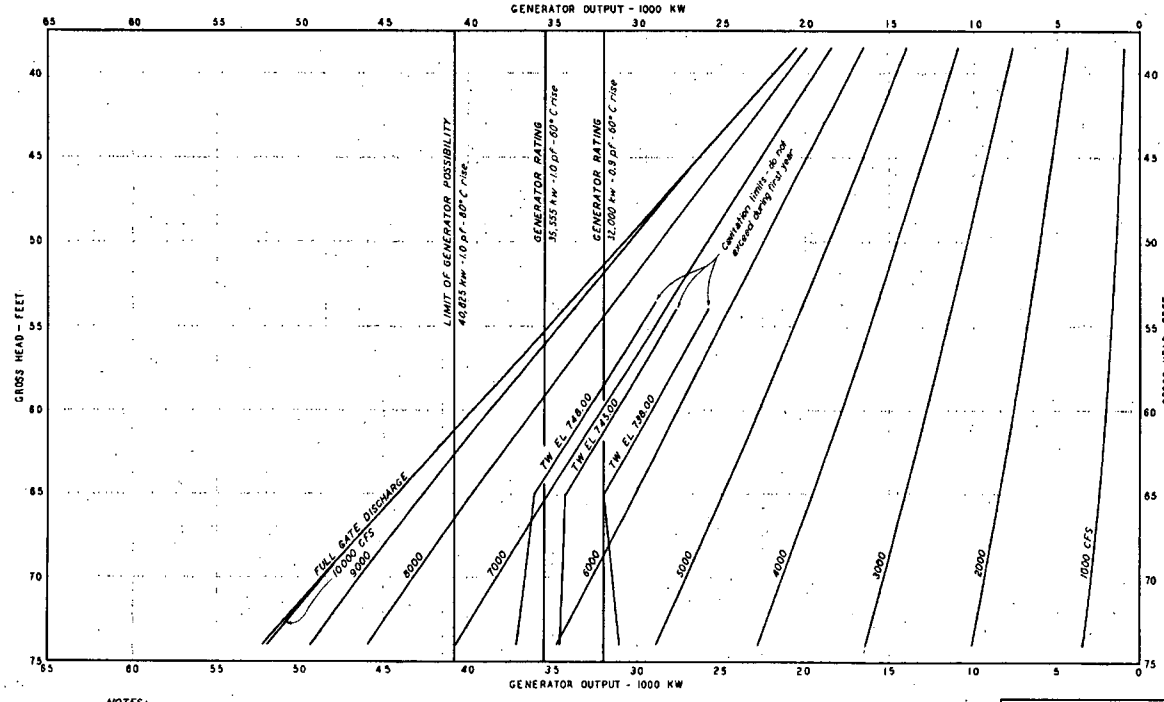


$Q = -4.6707x^2+587.5744x-7017.1789$

Attachment 8-3
3 Pages
Source: Reference 31

Calculation CDQ000020080009

EXHIBIT 7



NOTES:

Turbine rated 44,000 hp - 65 ft head - 105.8 rpm. Furnished by Baldwin-Southwark. Generator rated 35,555 kwe - 12,800 volts - 3 phase - 60 cycles - 105.8 rpm - 60°C rise. Furnished by Allis-Chalmers Mfg Co. Curves are based on model tests conducted by Baldwin-Southwark and modified in accordance with index test conducted 2-29-44. Tests should be made at other heads and these curves revised accordingly.

POWERHOUSE
UNIT 2

DISCHARGE CURVES
BASED ON INDEX TESTS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED: V. Munster
RECOMMENDED: [illegible]
APPROVED: [illegible]

KNOXVILLE | 4-11-44 | 10 | M | 4 | 47890480

MF
RO

Attachment 9-1
3 Pages
Source: Reference 32

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

Unit 3 Turbine
All values from TVA dwg. 47B908, R0
All data for Gross Head of less than 40 feet is extrapolated

Gross Head	Full Gate	9000 cfs	8000 cfs	7000 cfs	6000 cfs	5000 cfs	4000 cfs	3000 cfs	2000 cfs	1000 cfs
70	46.0	45.2	42.5	37.5	32.5	27.0	21.4	15.5	9.3	3.0
65	41.9	41.2	39.0	34.5	29.9	24.8	19.7	14.2	8.5	2.8
60	37.7	37.2	35.4	31.5	27.3	22.7	18.0	13.0	7.7	2.5
55	33.6	33.2	31.9	28.5	24.8	20.5	16.3	11.7	6.9	2.3
50	29.5	29.2	28.3	25.5	22.2	18.3	14.6	10.4	6.1	2.0
45	25.3	25.2	24.8	22.5	19.6	16.2	12.9	9.2	5.3	1.8
40	21.2	21.2	21.2	19.5	17.0	14.0	11.2	7.9	4.5	1.5
35	17.1	17.2	17.7	16.5	14.4	11.8	9.5	6.6	3.7	1.3
30	12.9	13.2	14.1	13.5	11.8	9.7	7.8	5.4	2.9	1.0
25	8.8	9.2	10.6	10.5	9.3	7.5	6.1	4.1	2.1	0.8
20	4.7	5.2	7.0	7.5	6.7	5.3	4.4	2.8	1.3	0.5
15	0.5	1.2	3.5	4.5	4.1	3.2	2.7	1.6	0.5	0.3
10	-3.6	-2.8	-0.1	1.5	1.5	1.0	1.0	0.3	-0.3	0.0

Line Fitting
All lines fit to form y=mx+b

Full Gate		m	b	
70	46	1.209677	14.35484	
40	21.2			

9000 cfs		m	b	Intersection
70	45.2	1.25	13.5	40
40	21.2			

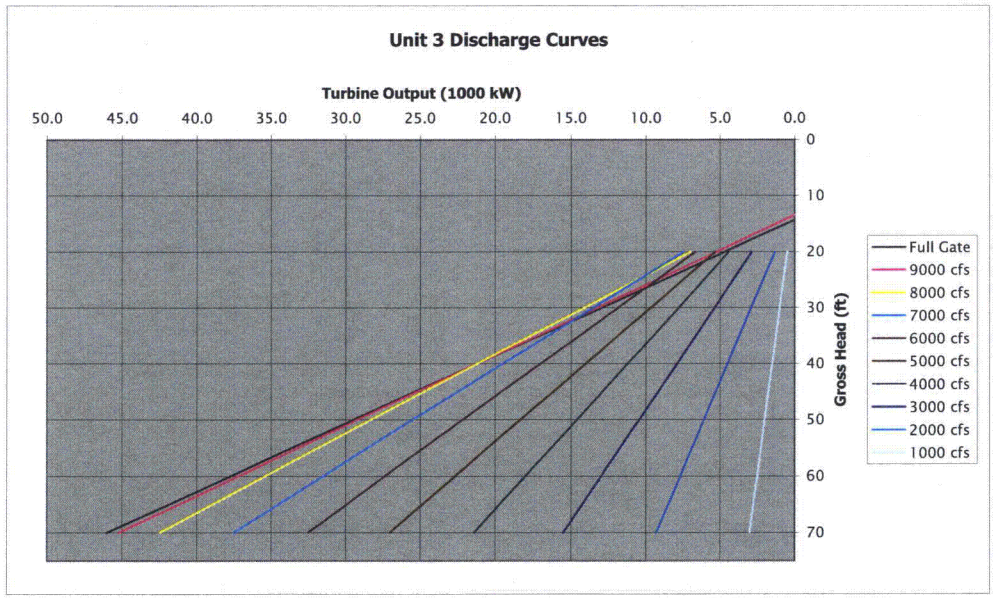
8000 cfs		m	b	Intersection
70	42.5	1.408451	10.14085	40
40	21.2			

7000 cfs		m	b	Intersection
70	37.5	1.666667	7.5	32.5
40	19.5			

6000 cfs		m	b	Intersection
70	32.5	1.935484	7.096774	26.45161
40	17			

5000 cfs		m	b	Intersection
70	27	2.307692	7.692308	21.69492
40	14			

4000 cfs	m	b	Intersection



Discharge (cfs)	Head (ft)
9000	40
8000	40

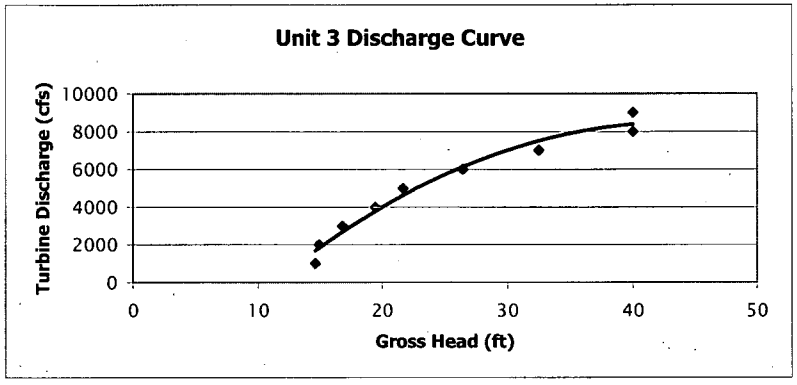
Attachment 9-2
3 Pages
Source: Reference 32

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

	70	21.4	2.941176	7.058824	19.45205
	40	11.2			
3000 cfs			m	b	Intersection
	70	15.5	3.947368	8.815789	16.80233
	40	7.9			
2000 cfs			m	b	Intersection
	70	9.3	6.25	11.875	14.95
	40	4.5			
1000 cfs			m	b	Intersection
	70	3	20	10	14.63519
	40	1.5			

7000	32.5
6000	26.45161
5000	21.69492
4000	19.45205
3000	16.80233
2000	14.95
1000	14.63519

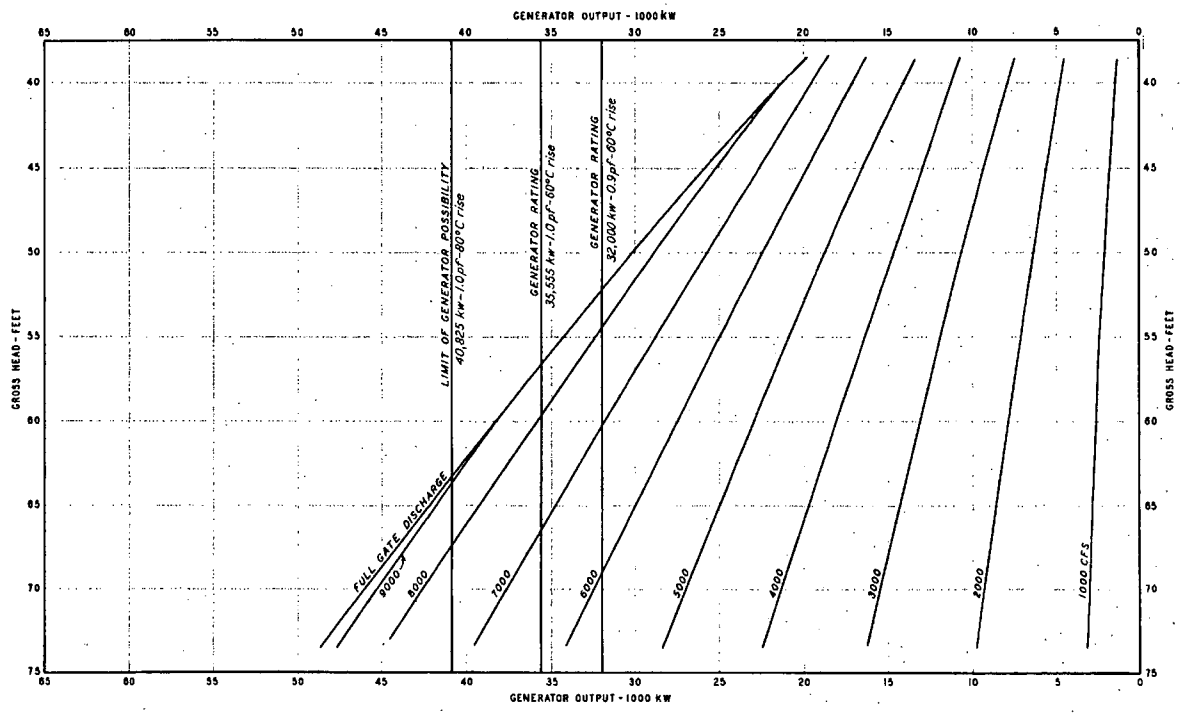


$Q = -8.2565x^2+714.8284x-7002.7668$

Attachment 9-3
3 Pages
Source: Reference 32

Calculation CDQ000020080009

EXHIBIT 3



NOTES:
Turbine rated 44,000 hp-85 ft head-105.8 rpm. Furnished by Baldwin-Southwark.
Generator rated 35,555 kva-13,800 volts-3 phase 60 cycles-105.8 rpm-60°C rise. Furnished by Allis-Chalmers Mfg Co. Curves based on model tests conducted by Baldwin-Southwark and modified in accordance with index test conducted 2-16-49. Tests should be made at other heads and these curves revised accordingly

POWERHOUSE
UNIT 3

DISCHARGE CURVES
BASED ON INDEX TESTS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED | RECOMMENDED | APPROVED

KNOXVILLE | 7-27-49 | 10 | 4 | 478908

MF
RO

Attachment 10-1
3 Pages
Source: Reference 33

Calculation CDQ000020080009

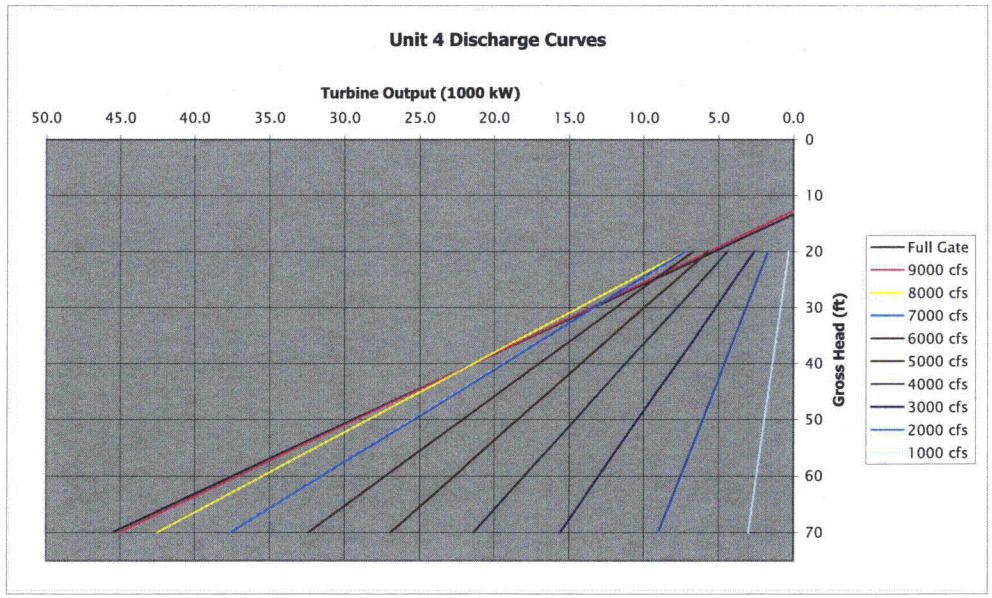
Prepared: ATT
Checked: JCT

Unit 4 Turbine
All values from TVA dwg. 47B912, R1
All data for Gross Head of less than 40 feet is extrapolated

Gross Head	Full Gate	9000 cfs	8000 cfs	7000 cfs	6000 cfs	5000 cfs	4000 cfs	3000 cfs	2000 cfs	1000 cfs
70	45.5	45.0	42.5	37.6	32.4	26.9	21.4	15.6	9.0	3.0
65	41.5	41.1	39.0	34.6	29.8	24.8	19.7	14.3	8.3	2.7
60	37.5	37.1	35.5	31.5	27.3	22.7	18.0	13.0	7.5	2.5
55	33.5	33.2	32.0	28.5	24.7	20.6	16.3	11.7	6.8	2.2
50	29.4	29.3	28.4	25.5	22.1	18.4	14.6	10.4	6.1	1.9
45	25.4	25.3	24.9	22.4	19.6	16.3	12.9	9.1	5.3	1.7
40	21.4	21.4	21.4	19.4	17.0	14.2	11.2	7.8	4.6	1.4
35	17.4	17.5	17.9	16.4	14.4	12.1	9.5	6.5	3.9	1.1
30	13.4	13.5	14.4	13.3	11.9	10.0	7.8	5.2	3.1	0.9
25	9.4	9.6	10.9	10.3	9.3	7.9	6.1	3.9	2.4	0.6
20	5.3	5.7	7.3	7.3	6.7	5.7	4.4	2.6	1.7	0.3
15	1.3	1.7	3.8	4.2	4.2	3.6	2.7	1.3	0.9	0.1
10	-2.7	-2.2	0.3	1.2	1.6	1.5	1.0	0.0	0.2	-0.2

Line Fitting
All lines fit to form y=mx+b

			m	b	Intersection
Full Gate					
	70	45.5	1.244813	13.361	
	40	21.4			
9000 cfs			m	b	Intersection
	70	45	1.271186	12.79661	40
	40	21.4			
8000 cfs			m	b	Intersection
	70	42.5	1.421801	9.57346	40
	40	21.4			
7000 cfs			m	b	Intersection
	70	37.6	1.648352	8.021978	29.83051
	40	19.4			
6000 cfs			m	b	Intersection
	70	32.4	1.948052	6.883117	24.82759
	40	17			
5000 cfs			m	b	Intersection
	70	26.9	2.362205	6.456693	21.05263
	40	14.2			
4000 cfs			m	b	Intersection



Discharge (cfs)	Head (ft)
9000	40
8000	40

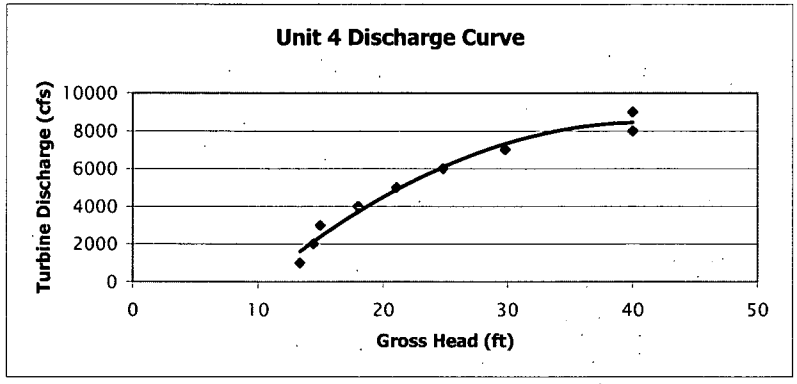
Attachment 10-2
3 Pages
Source: Reference 33

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

	70	21.4	2.941176	7.058824	17.98561
	40	11.2			
3000 cfs			m	b	Intersection
	70	15.6	3.846154	10	14.96933
	40	7.8			
2000 cfs			m	b	Intersection
	70	9	6.818182	8.636364	14.41624
	40	4.6			
1000 cfs			m	b	Intersection
	70	3	18.75	13.75	13.33333
	40	1.4			

7000	29.83051
6000	24.82759
5000	21.05263
4000	17.98561
3000	14.96933
2000	14.41624
1000	13.33333

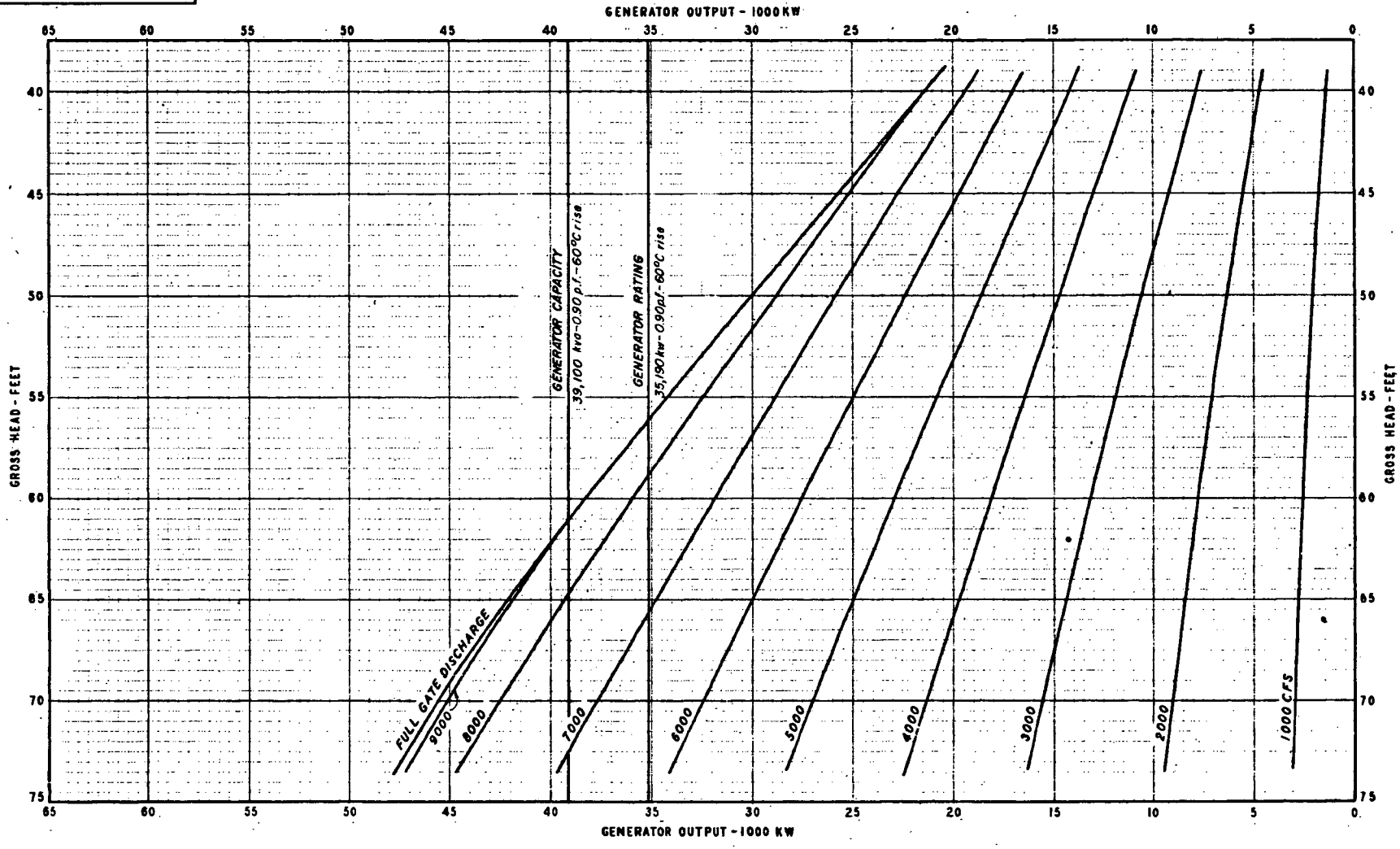


$Q = -8.8373x^2+727.6113x-6523.5280$

Attachment 10-3
3 Pages
Source: Reference 33

Calculation CDQ000020080009

EXHIBIT 7



NOTES:
Turbine rated 44,000 hp - 65 ft head - 105.8 rpm.
Furnished by Baldwin - Southwark.
Generator rated 35,555 kva - 13,800 volts - 3 phase 60 cycle - 105.8 rpm - 60°C rise. Furnished by Allis-Chalmers Mfg Co.
Curves based on model tests conducted by Baldwin-Southward and modified in accordance with index test conducted 2-17-49. Tests should be made at other heads and these curves revised accordingly.
GENERATOR: rerated October 4, 1968 to 39,100 kva, 35,190 kw, 0.90 p.f. 13,800 volts, 60°C rise, 1635 amperes

POWERHOUSE
UNIT 4

DISCHARGE CURVES
BASED ON INDEX TESTS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED C.E. Norris | RECOMMENDED [illegible] | APPROVED A.D. Morris

KNOXVILLE 7-29-49 | 10 | M | 6 | 478912 R1

Attachment 11-1
11 Pages
Source: Multiple

Calculation CDQ000020080009

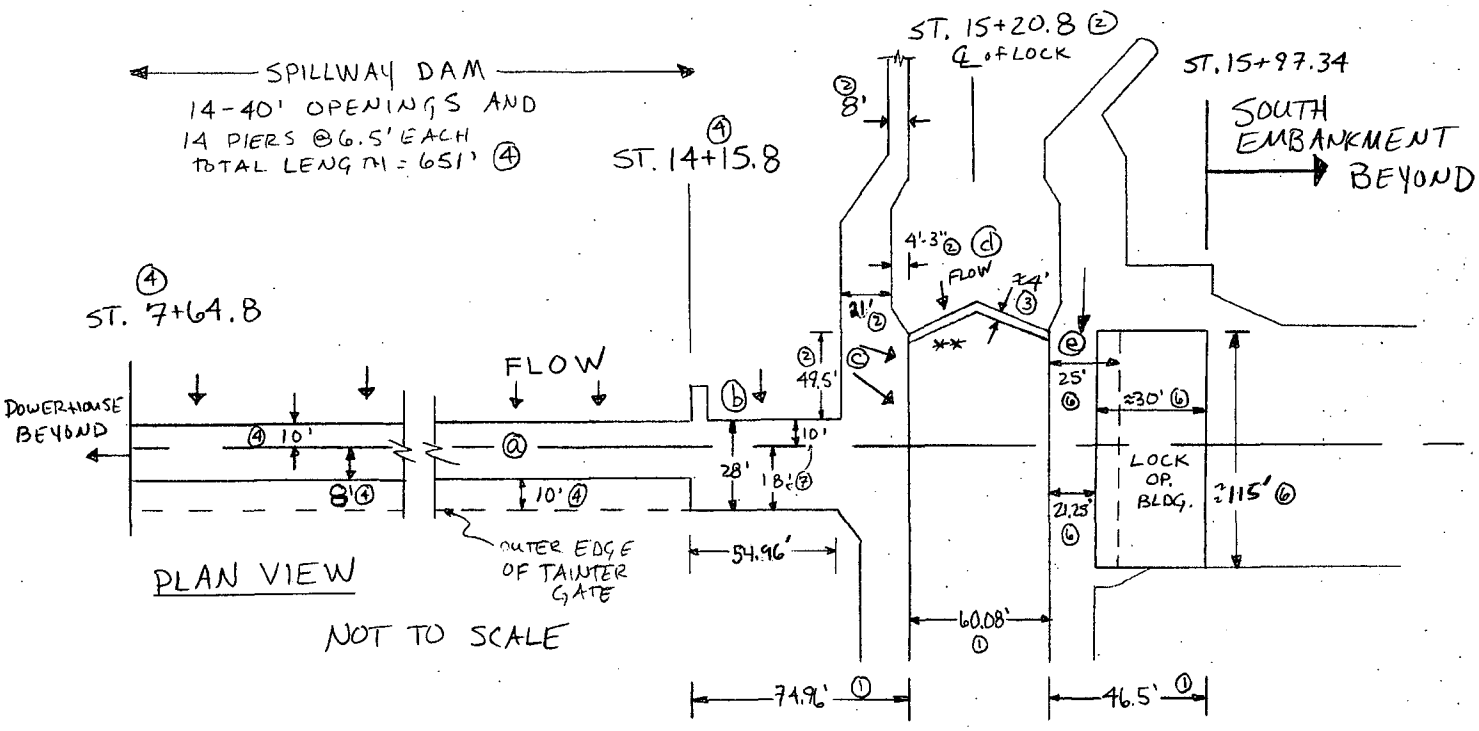
Prepared: ATT
Checked: JCT

(ES-2-78) **TENNESSEE VALLEY AUTHORITY** SHEET ___ OF ___

SUBJECT Spillway and Lock Overflow PROJECT

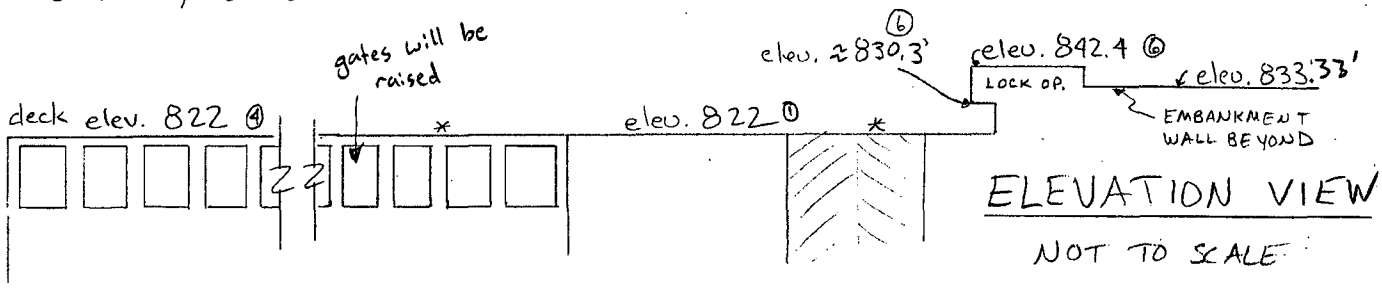
SEM 10-14-08 CDQ0000200 80009

COMPUTED BY DATE CHECKED BY DATE



* ALL RAILINGS WILL BE NEGLECTED.

** LENGTH OF GATE WILL NEGLECT ANGLES.



NOTE THAT SEVEN BRIDGE PIERS @ ≈1' EACH BLOCK FLOW ABOVE THE SPILLWAY DECK AND A BENT FRAME ESTIMATED AS 2' WIDE BLOCKS THE LOCK FLOW. ⑤

DRAWINGS

① 10 W 200 R11 (Ref. 1, Att. 11-4)
② 61 W 220-1 R0 (Ref. 25, Att. 11-5)
③ 21/2.2 (Ref. 9, Att. 11-6)
④ 51 N 200 R2 (Ref. 24, Att. 11-7)
⑤ 80 H 3401 R3 (Ref. 28, Att. 11-8)
⑥ 66 N 201 R7 (Ref. 27, Att. 11-9)
⑦ 61 W 804 R1 (Ref. 26, Att. 11-10)
⑧ 64 W 204, R0 (Ref 34, Att. 11-11)

Attachment 11-2
11 Pages
Source: Multiple

(5-2-78) **TENNESSEE VALLEY AUTHORITY**

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

SUBJECT FORT LOUDOUN DAM, SPILLWAY & LOCK OVERFLOW PROJECT

SEM 10-14-08 CDQ000020080009

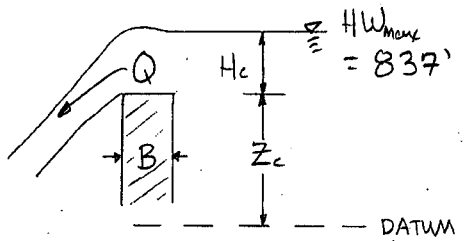
COMPUTED BY DATE CHECKED BY DATE

OVERFLOW PARAMETERS

FOR SIMPLICITY, THE PORTION OF THE LOCK OPERATIONS BUILDING WHICH WOULD BLOCK FLOW ABOVE ELEV. 830.3' WILL BE NEGLECTED. THIS WILL LEAD TO A MORE CONSERVATIVE FLOW ESTIMATE.

OVERFLOW ELEVATION $Z_c = 822'$

C_f DETERMINATION:



ⓐ B = 28' SPILLWAY DECK
ⓑ B = 28' FROM ST. 14+15.8 TO THE LOCK WALL } MAY BE COMBINED
ⓒ B = 24.5' LEFT LOCK WALL
ⓓ B = 4' GATE
ⓔ B = 115' BETWEEN GATE AND LOCK OP. BLDG. (A FLOW BASE "B" EQUAL TO THE LENGTH OF THE LOCK OP. BLDG. WILL BE ASSUMED)

$0 \le H_c \le (837' - 822' = 15')$

FROM Ref. 6, AH. 2

ⓐ	$0 \le H_c/B = 15'/28' = .54$	$2.65 \le C_f \le 2.71$
ⓑ	$0 \le H_c/B = 15'/28' = .54$	$2.65 \le C_f \le 2.71$
ⓒ	$0 \le H_c/B = 15'/24.5' = .61$	$2.65 \le C_f \le 2.77$
ⓓ	$0 \le H_c/B = 15'/4' = 3.75$	$2.65 \le C_f \le 3.33$
ⓔ	$0 \le H_c/B = 15'/115 = .13$	$2.65 \le C_f \le 2.65$

LENGTHS (REMEMBERING BRIDGE PIER BLOCKAGE)

ⓐ + ⓑ; L = 651' + 54.96' − 7(1') − 2(1') = 697'
ⓒ L = 49.5'
ⓓ L = 60.1'
ⓔ L = 25'

SUMMARY OF SPILLWAY DECK AND LOCK OVERFLOW

With gates closed

	Z_c, ft	L, ft	C_f
	822'	697'	2.7
Lock Wall 1	822'	49.5'	2.8
Lock Gates	818.7'	60.1'	3.3
Lock Wall 2	822'	25'	2.65

combine using weighted average

Lock Overflow

Total length = 49.5 + 60.1 + 25 = 134.6'

$$C_f = \left(\frac{49.5}{74.5}\right)2.8 + \left(\frac{25}{74.5}\right)2.65 = 2.75$$

∴ $C_f = 2.75$
$Z_c = 822'$
$L = 74.5'$

Spillway Deck with Gates Raised

$L = 697 - 560' = 137'$

∴ $C_f = 2.7$
$Z_c = 822'$ (spillway deck overflow)
$L = 137$ (length of deck overflow - gate widths)

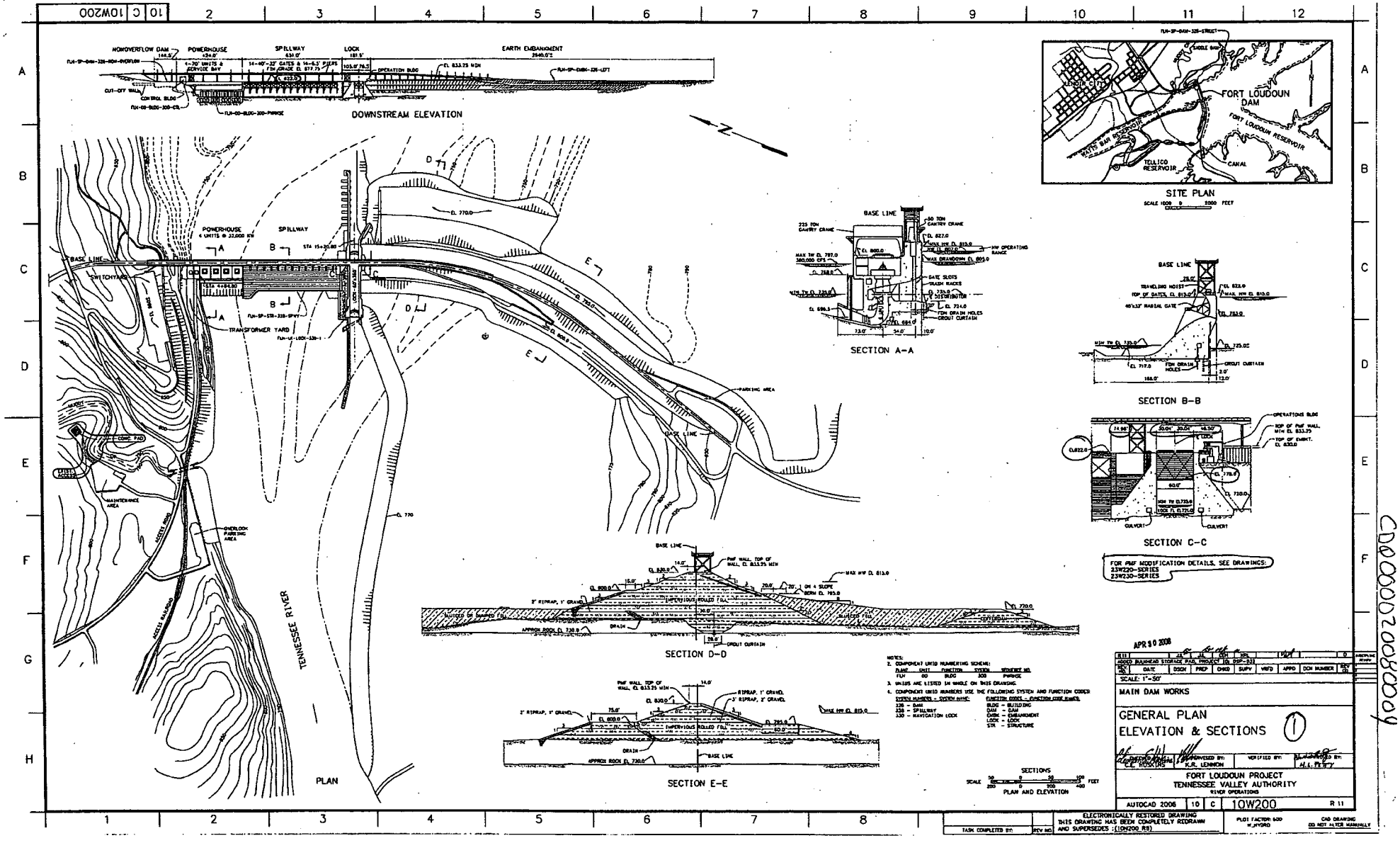
Flow Over tops of Raised gates

∴ $C_f = 3.3$ (See Attachment 4)
$Z_c = 829.92'$ (Appendix A)
$L = 560'$ (14 - 40' wide bays)

Attachment 11-4
11 Pages
Source: Reference 1

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



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Attachment 11-5
11 Pages
Source: Reference 25

Calculation CDQ000020080009

Prepared: ATT
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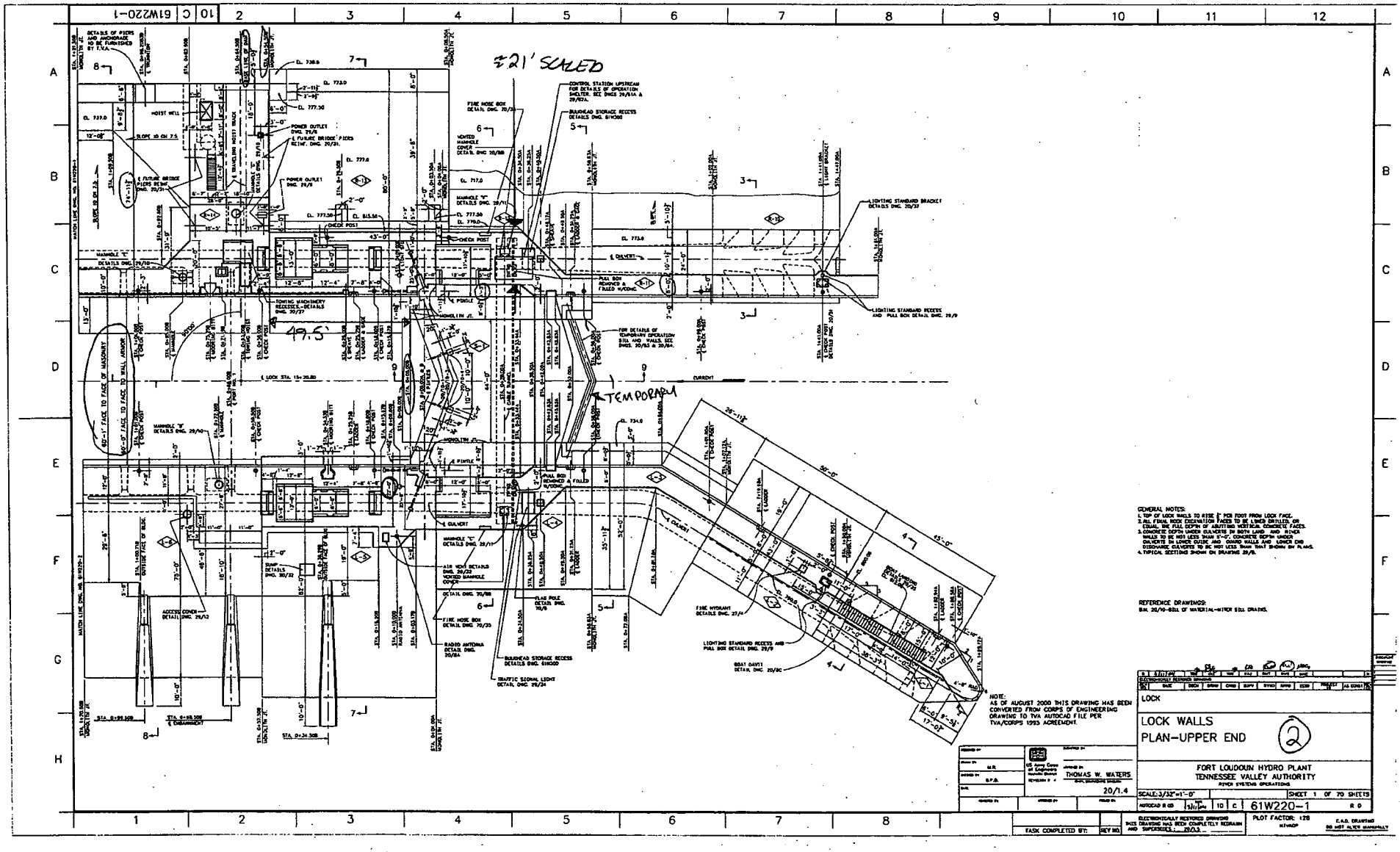

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Attachment 11-6
11 Pages
Source: Reference 9

Calculation CDQ000020080009

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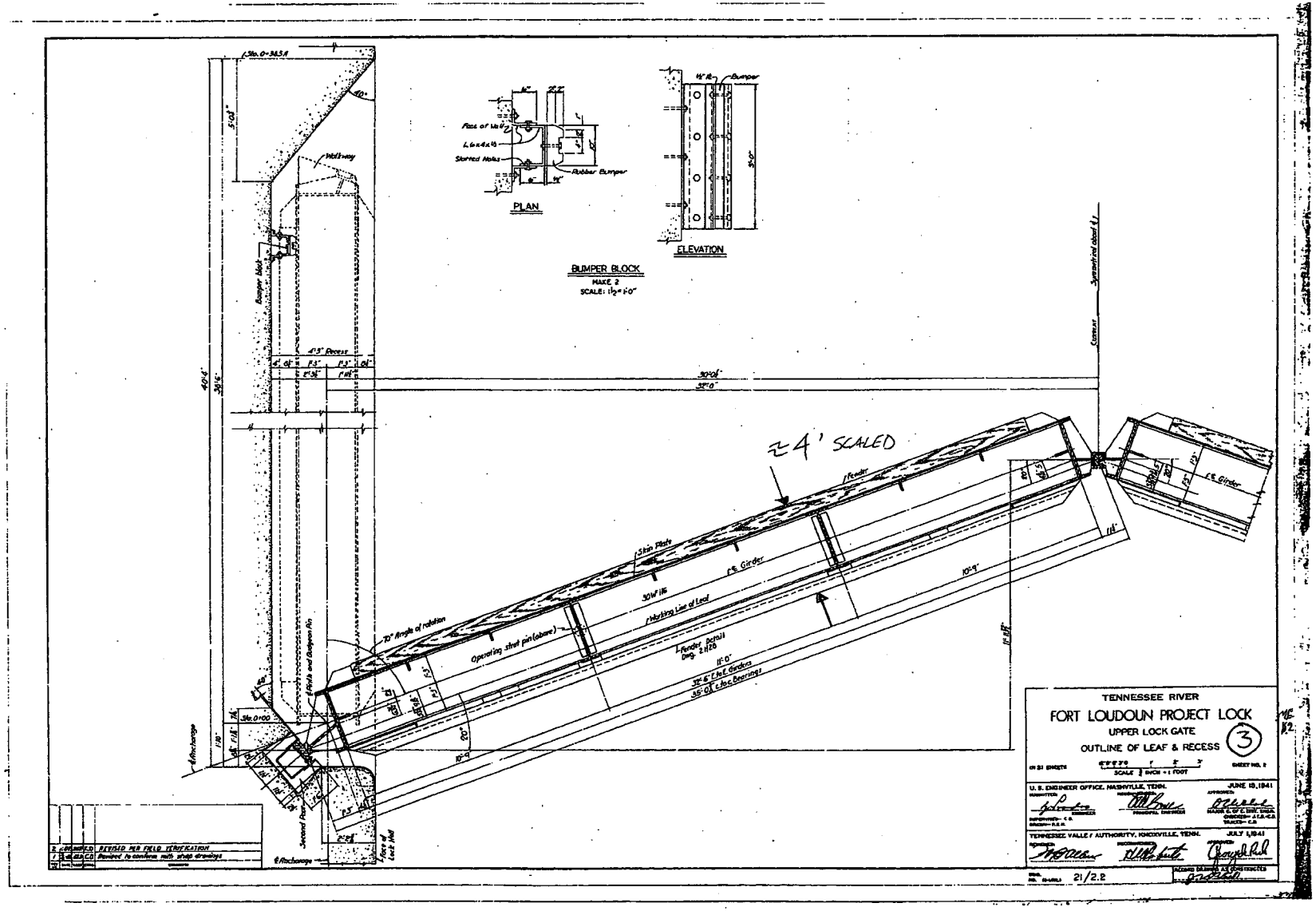

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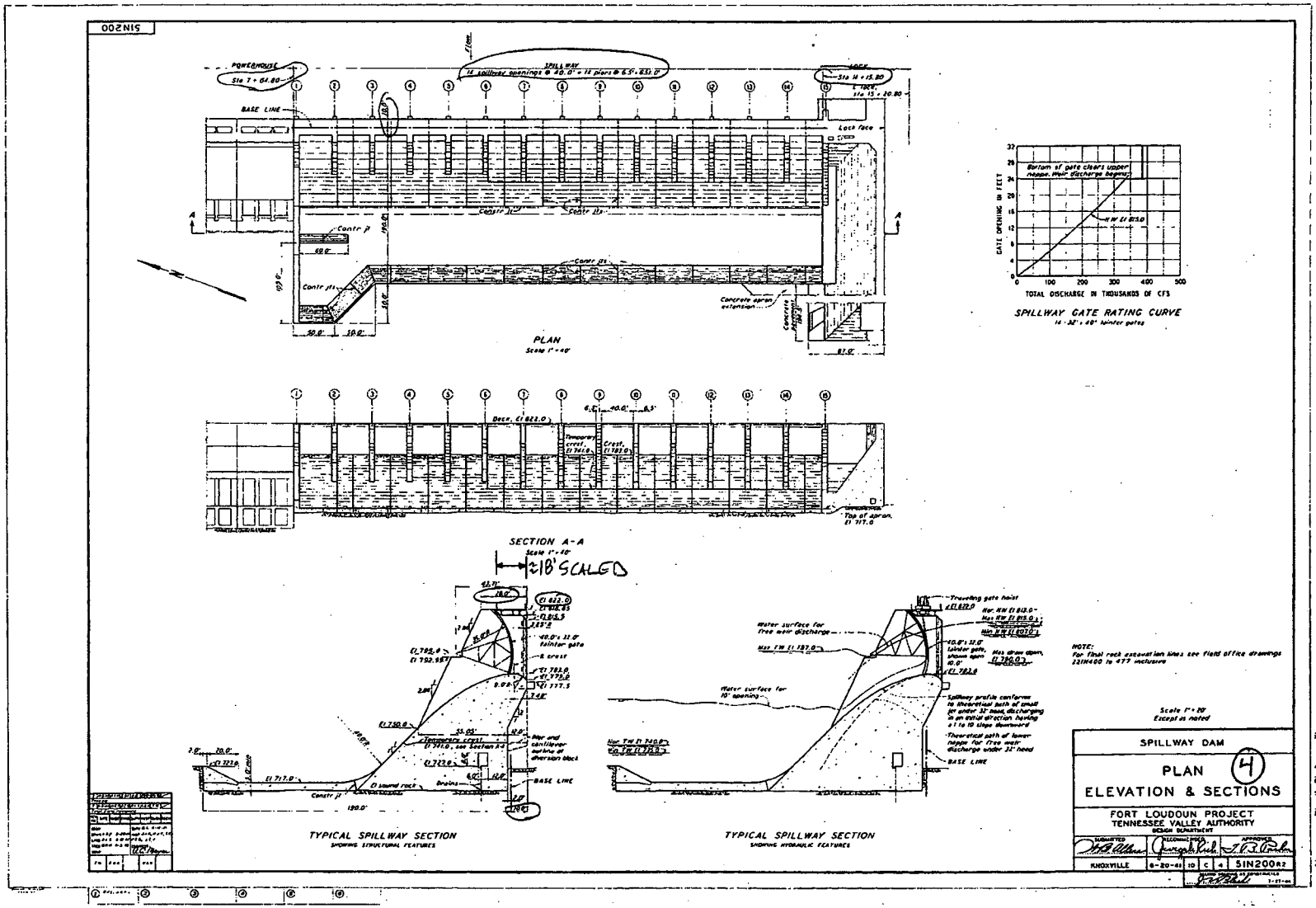
Attachment 11-7
11 Pages
Source: Reference 24

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



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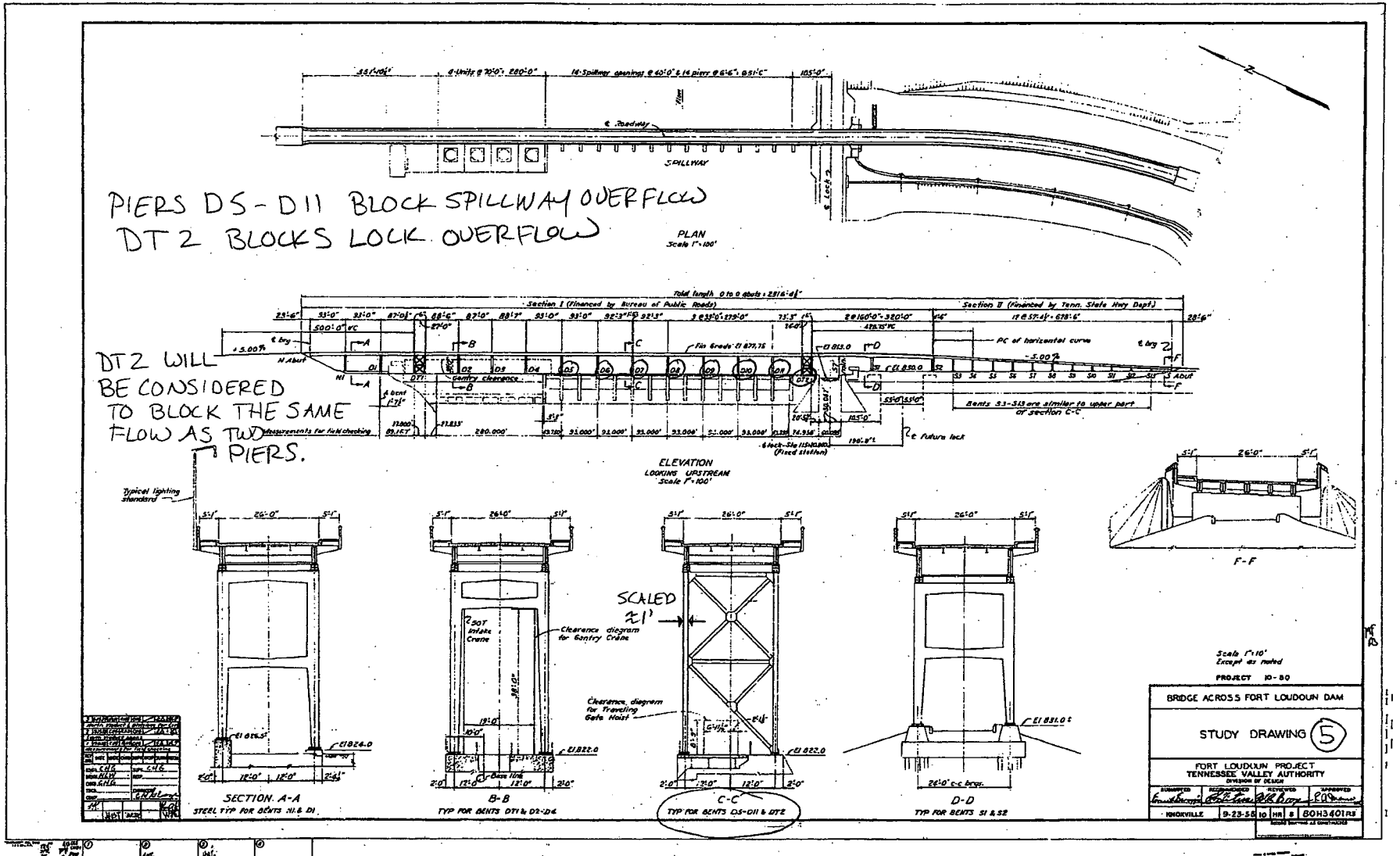
Attachment 11-8
11 Pages
Source: Reference 28

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



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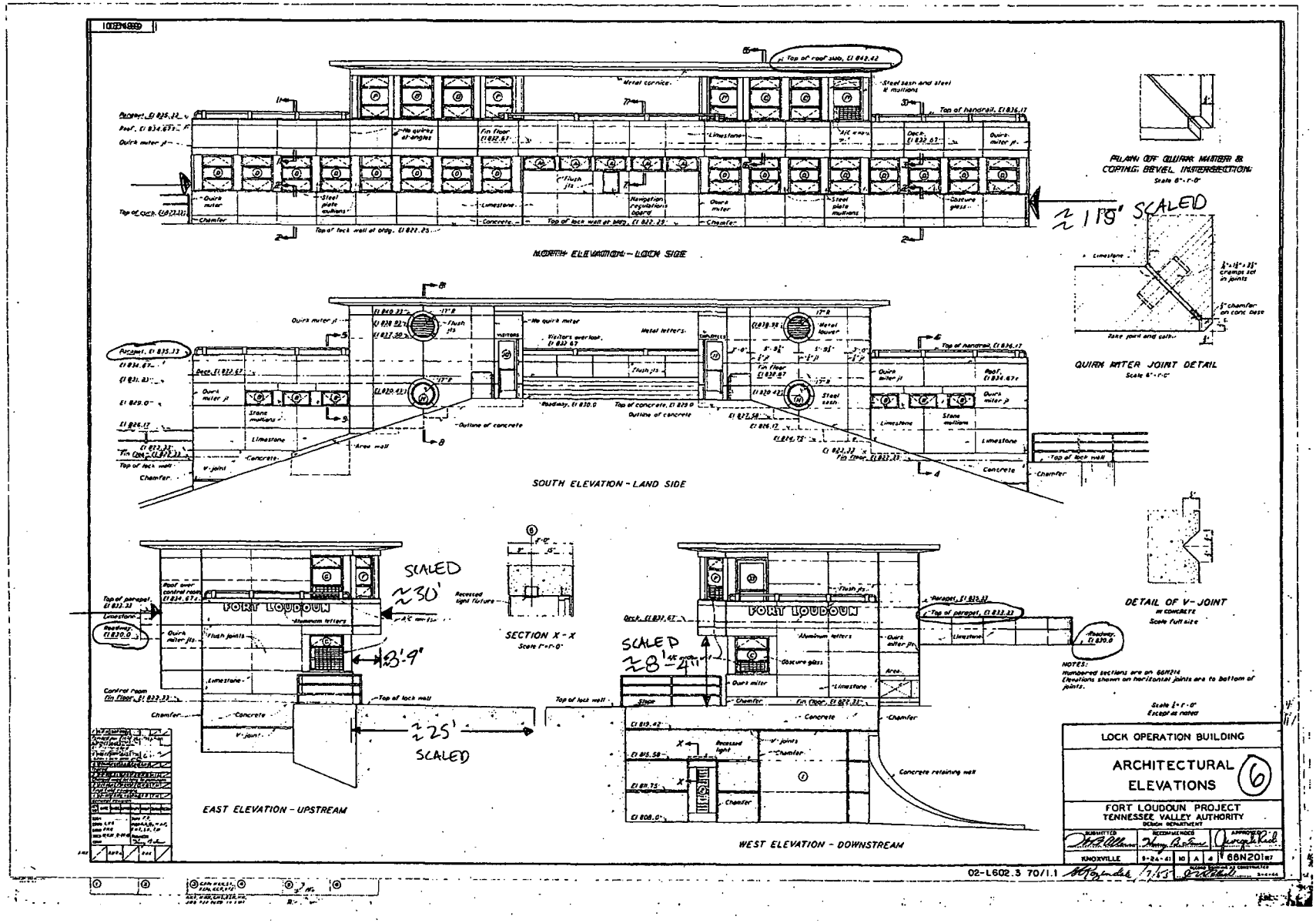
Attachment 11-9
11 Pages
Source: Reference 27

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



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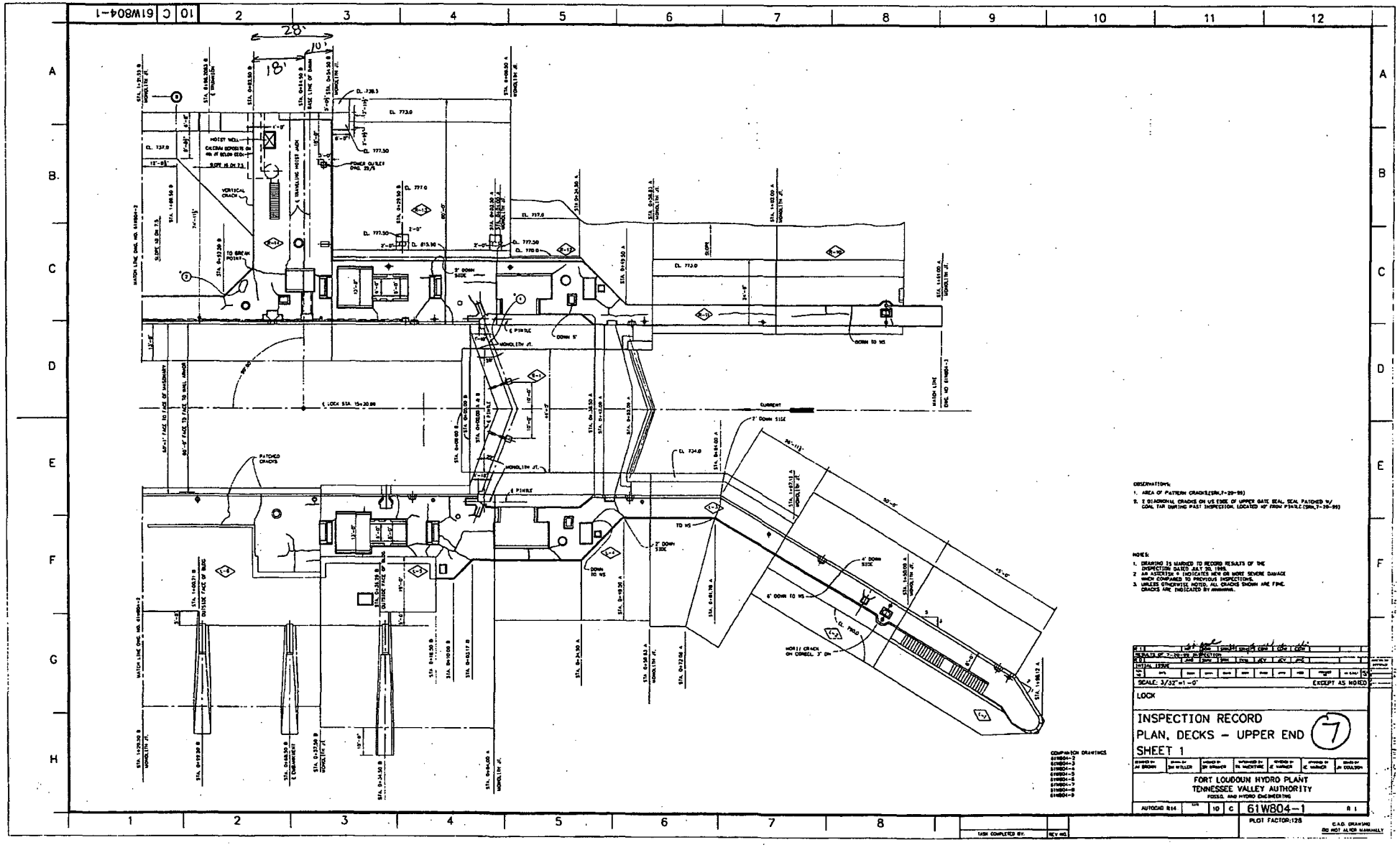
Attachment 11-10
11 Pages
Source: Reference 26

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

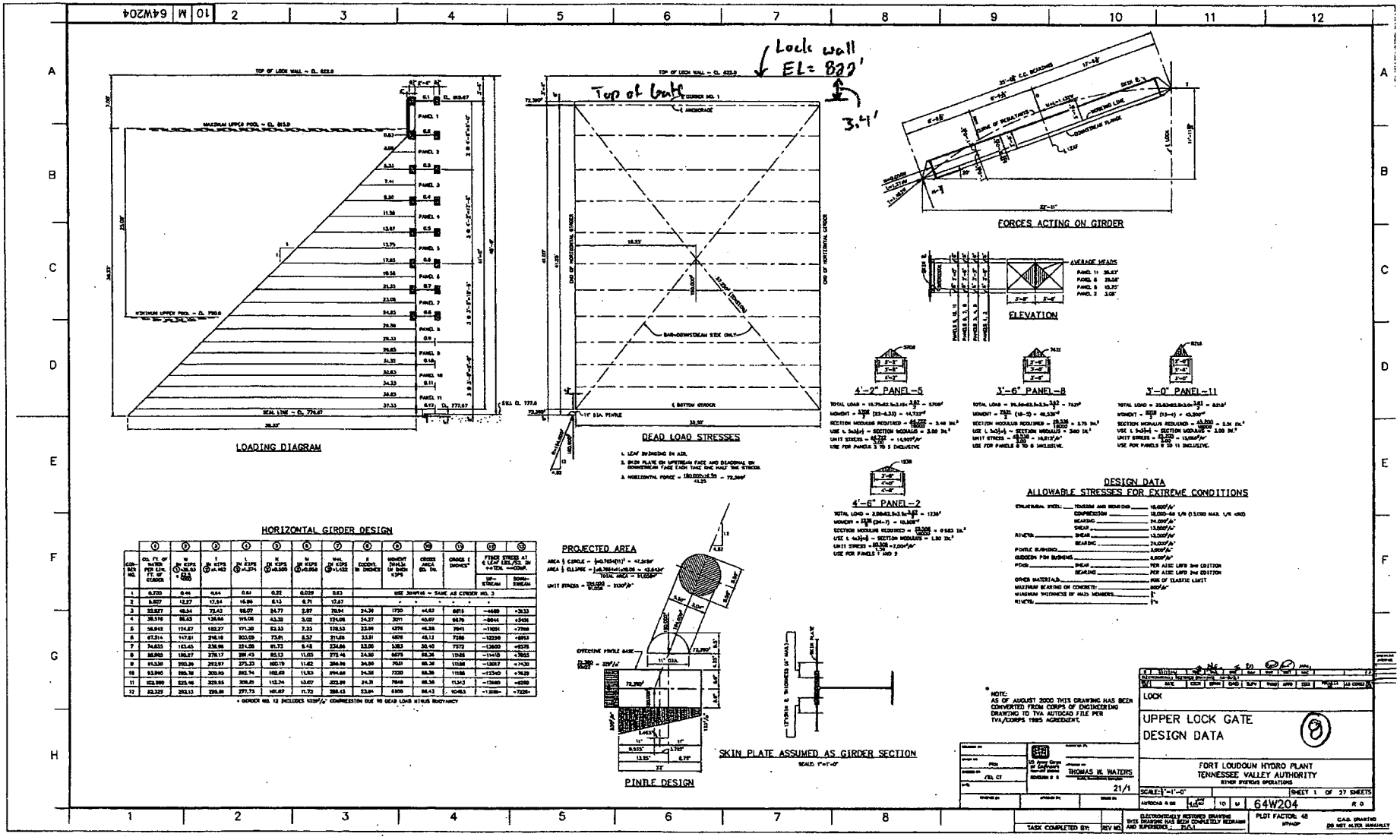


CDQ000020080009

Attachment 11-11
11 Pages
Source: Reference 34

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



Attachment 12-1
11 Pages
Source: Multiple

Calculation CDQ000020080009

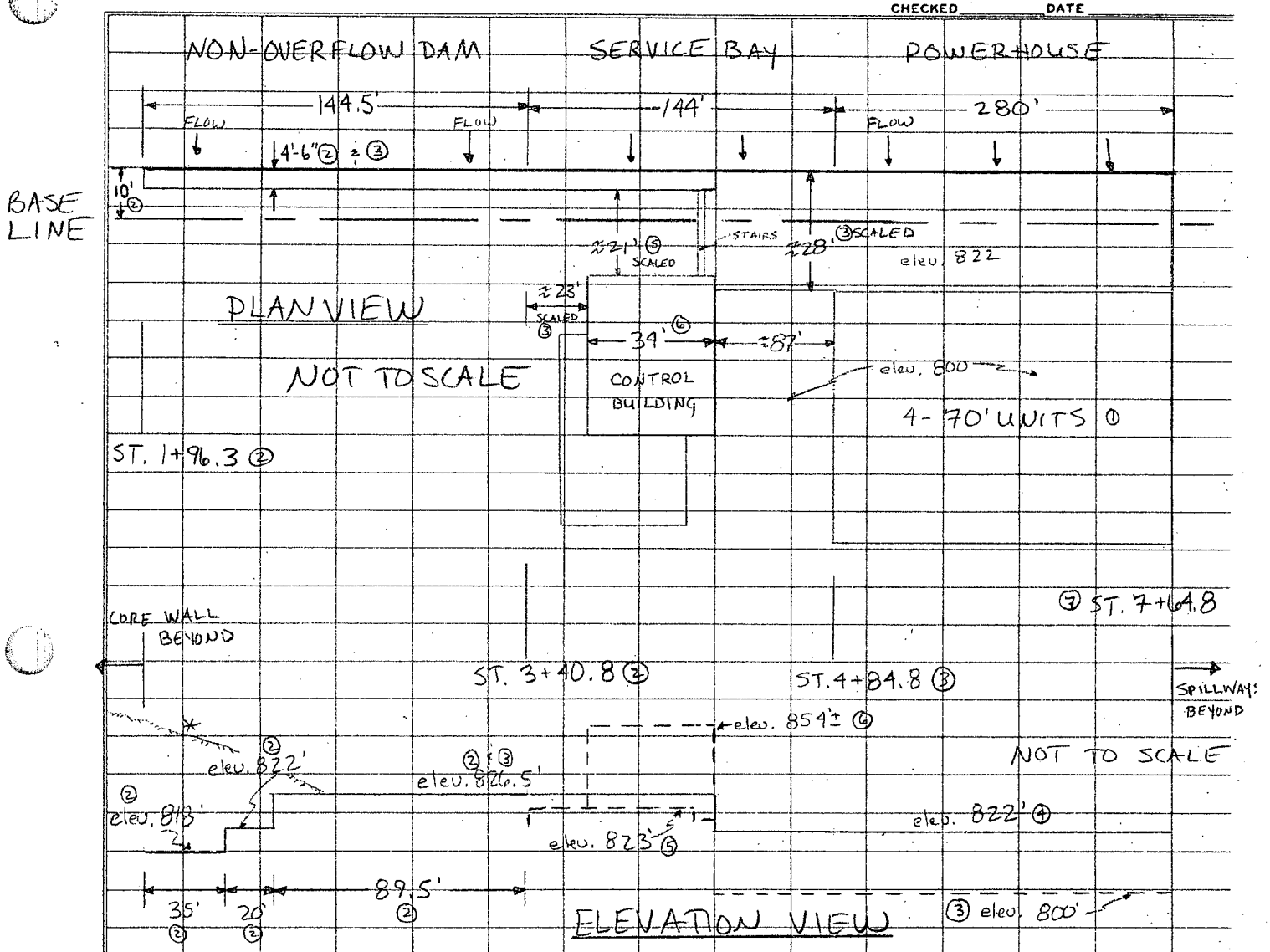
Prepared: ATT
Checked: JCT

T LOUDEN DAM
HEMBANKMENT, SERVICE BAY
AND POWERHOUSE OVERFLOW

CDQ00

COMPUTED J 8

CHECKED DATE



*NOTE THAT THE GROUND SURFACE COVERS A PORTION OF THE NONOVERFLOW DAM. IT WILL BE ASSUMED THAT THE SOIL WILL WASH AWAY TO A POINT AT THE START OF THE CORE WALL. THE SOIL WILL BE CONSIDERED VERTICAL AT THIS POINT. THIS APPROXIMATION SHOULD ACCOUNT FOR THE WASHING AWAY OF SOIL TO THE MAXIMUM FLOOD ELEVATION OF 837'

DRAWINGS

① 10 W 200 R11 (Ref. 1, Att. 12-4); ⑤ 22 W 214 R9 (Ref. 11, Att. 12-8)
② 41 N 508 R4 (Ref. 21, Att. 12-5); ⑥ 46 N 402 R6 (Ref. 23, Att. 12-9)
③ 22 W 200 R10 (Ref. 10, Att. 12-6); ⑦ 51 N 200 R2 (Ref. 24, Att. 12-10)
④ 41 N 615 R1 (Ref. 22, Att. 12-7); ⑧ 80 H 3401 R3 (Ref. 28, Att. 12-11)

Attachment 12-2
11 Pages
Source: Multiple

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

T LOUDOUN DAM
TH EMBANKMENT, SERVICE BAY
AND POWERHOUSE OVERFLOW

CDQ00

COMPUTED S DATE 10/7/03

CHECKED DATE

OVERFLOW PARAMETERS

THE OVERFLOW ELEVATION, Z_c, VARIES AS FOLLOWS:

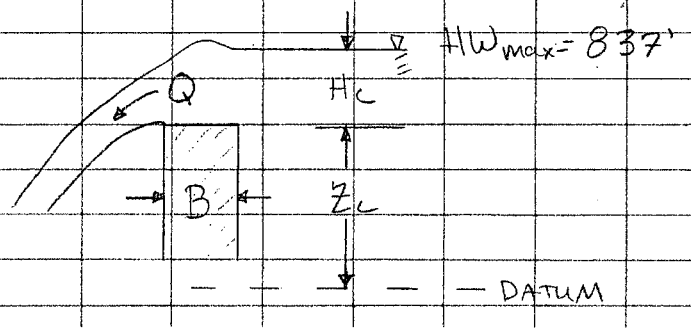
ⓐ $Z_c = 818'$, $B = 4.5'$, $L = 35'$ — FIRST SECTION OF NON OVERFLOW DAM
ⓑ $Z_c = 822'$, $B = 4.5'$, $L = 20'$ — MIDDLE SECTION OF NON OVERFLOW DAM
ⓒ $Z_c = 826.5'$, $B = 4.5'$, $L = 146.5'$ — THIRD SECTION OF N.O. DAM AND SERVICE BAY WALL
ⓓ $Z_c = 822'$, $B = 28'$, $L = 367'$ — POWERHOUSE AND REMAINDER OF SERVICE BAY

$0 \le H_c \le (837' - Z_c)$

			FROM Ref 6, Att. 2	
ⓐ	$0 \le H_c/B \le 837'-818'/4.5' = 4.22$		$2.65 \le C_f \le 3.33$	STANDARD
ⓑ	$0 \le H_c/B \le 837'-822'/4.5' = 3.33$		$2.65 \le C_f \le 3.33$	STANDARD
ⓒ	$0 \le H_c/B \le 837'-826.5'/4.5' = 2.33$		$2.65 \le C_f \le 3.33$	STANDARD
ⓓ	$0 \le H_c/B \le 837'-822'/28' = .54$		$2.65 \le C_f \le 2.72$	

NOTE: THE FLOW OVER THE 21' DECK SECTION BETWEEN THE CONTROL BUILDING AND THE 4'-6" WALL WILL BE NEGLECTED BECAUSE AS THE FLOOD WATER RISES ABOVE ELEV. 823', THE FLOW WILL INITIATE FROM THE AREA BEYOND THE WALL. IN ADDITION, WHEN THE MAX. FLOOD LEVEL IS REACHED, THE FLOW OF CONCERN WILL BE THAT WHICH IS BLOCKED ONLY BY THE CONTROL BUILDING.

IN ADDITION TO THE CONTROL BUILDING, BRIDGE PIERS WILL PARTIALLY BLOCK FLOW. FOR THIS REASON, THE 2.5' WIDTH SCALED FROM ⑧ WILL BE SUBTRACTED FROM THE FLOW WIDTHS FOR EACH SECTION. THE BENT LABLED "DTF" ON THE DRAWING WILL BE CONSIDERED TO BLOCK 5' OF FLOW LENGTH FROM THE POWERHOUSE LENGTH.



Attachment 12-3
11 Pages
Source: Multiple

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

LOUDOUN DAM
NORTH EMBANKMENT, SERVICE BAY
AND POWERHOUSE OVERFLOW

CDQ00

COMPUTED DATE

CHECKED DATE

LENGTHS, ft.

ⓐ L = 35'
ⓑ L = 20'
ⓒ L = 146.5' − (2)(2.5') = 141.5' (FLOOD ELEV. < 826.5')
$ⓒ_2$ L = 146.5' − (2)(2.5') − 34' = 107.5' (FLOOD ELEV. > 826.5')
ⓓ L = 367' − 5' − 3(2.5') = 354.5'

SUMMARY FOR NORTH EMBANKMENT, SERVICE BAY, AND POWERHOUSE OVERFLOW

FLOOD ELEVATION ≤ 826.5' *

Z_c, ft	L, ft	C_f
818'	35'	3.3
822'	20'	3.3
822'	354.5'	2.7

FLOOD ELEVATION > 826.5'

	Z_c, ft.	L, ft.	C_f
North Bank 1	818'	35'	3.3
North Bank 2	822'	20'	3.3
Non Overflow	826.5'	107.5'	3.3
Powerhouse	822'	354.5'	2.7

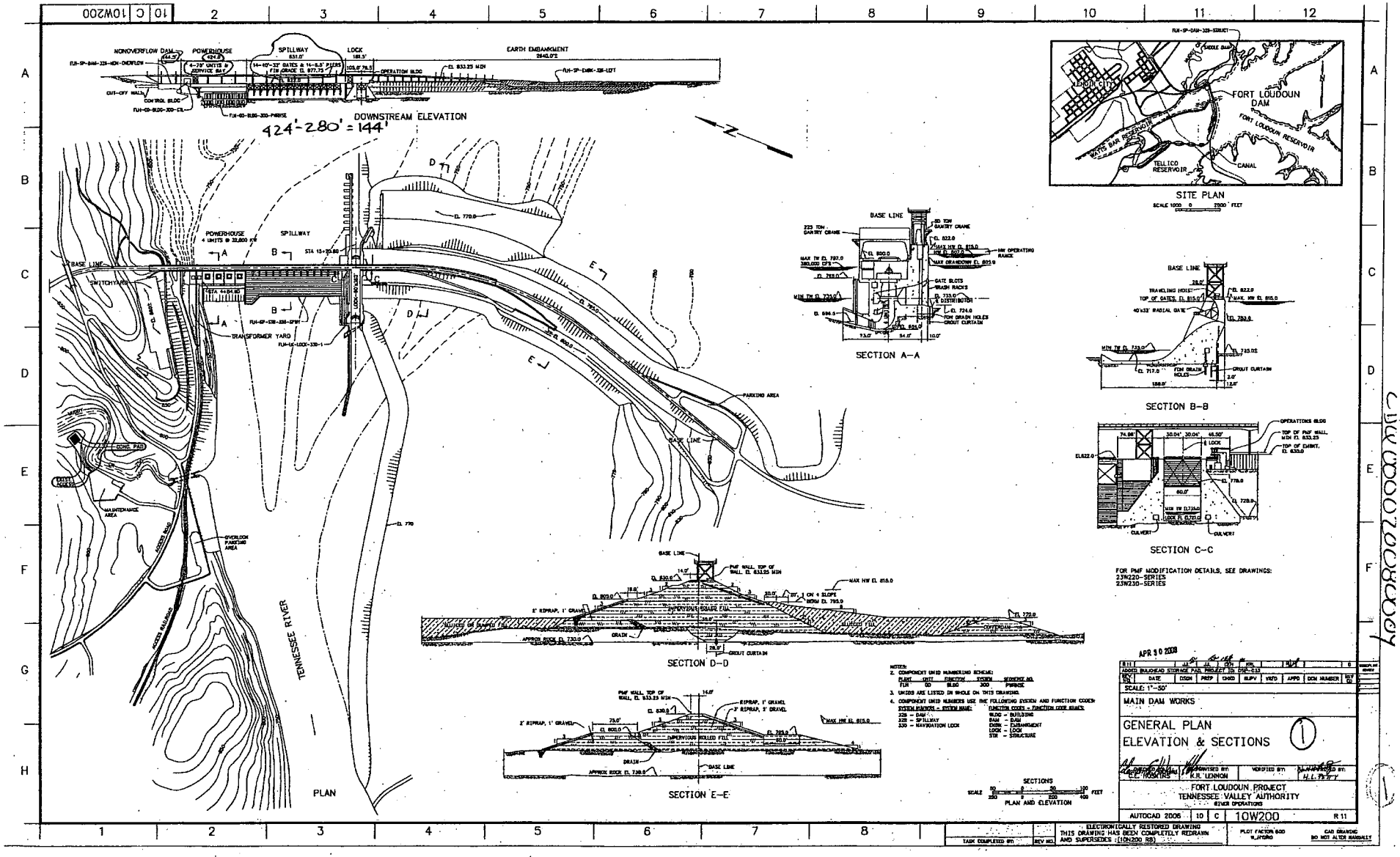
* the North Embankment will be assumed to fail to level of non-overflow dam in all calculations after an elevation of 826.5
∴ no flow over these walls until an elevation of ≈ 827'

- Since the lengths are so small, this assumption should have little affect on final product.

Attachment 12-4
11 Pages
Source: Reference 1

Calculation CDQ000020080009

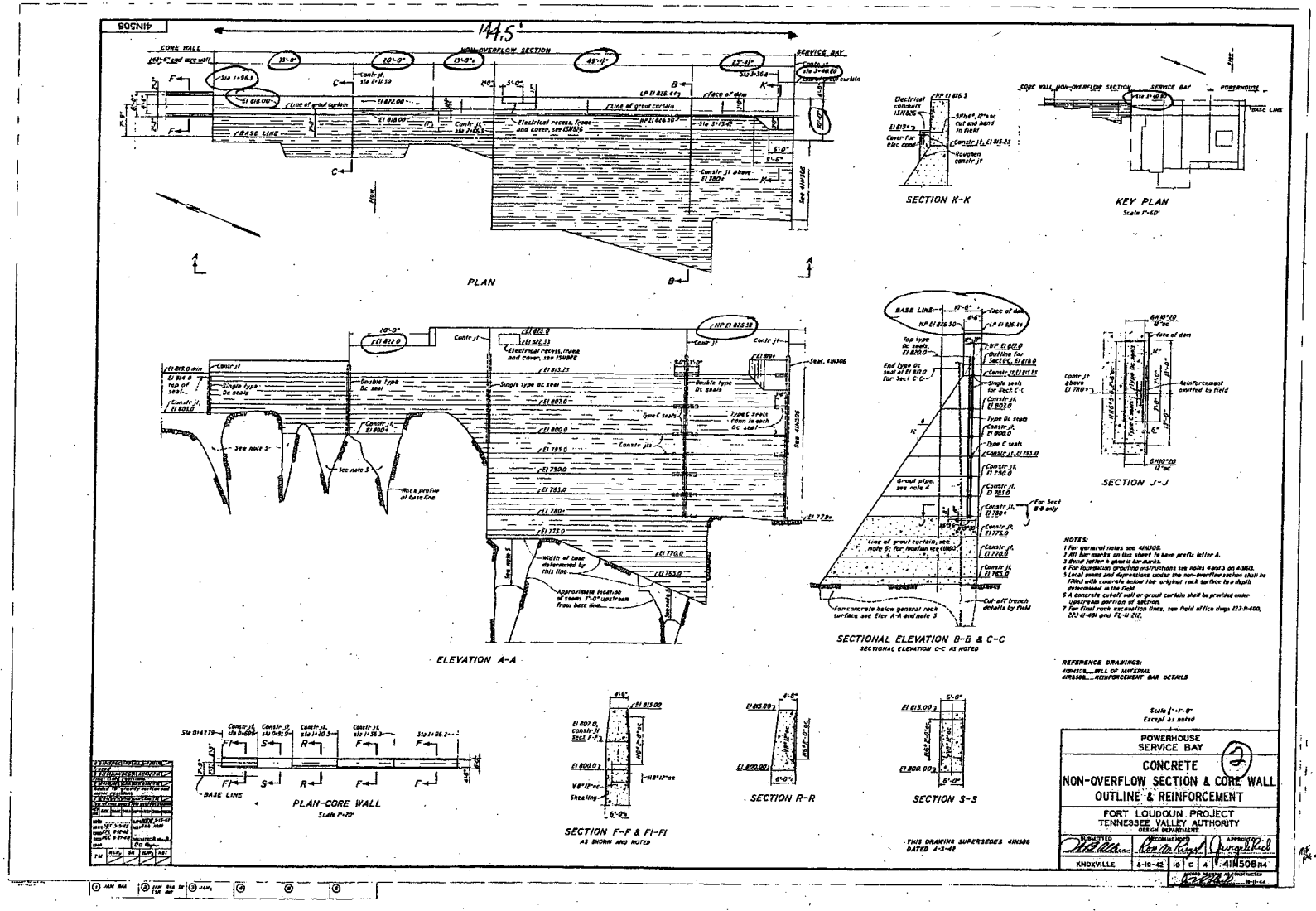
Prepared: ATT
Checked: JCT



Attachment 12-5
11 Pages
Source: Reference 21

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



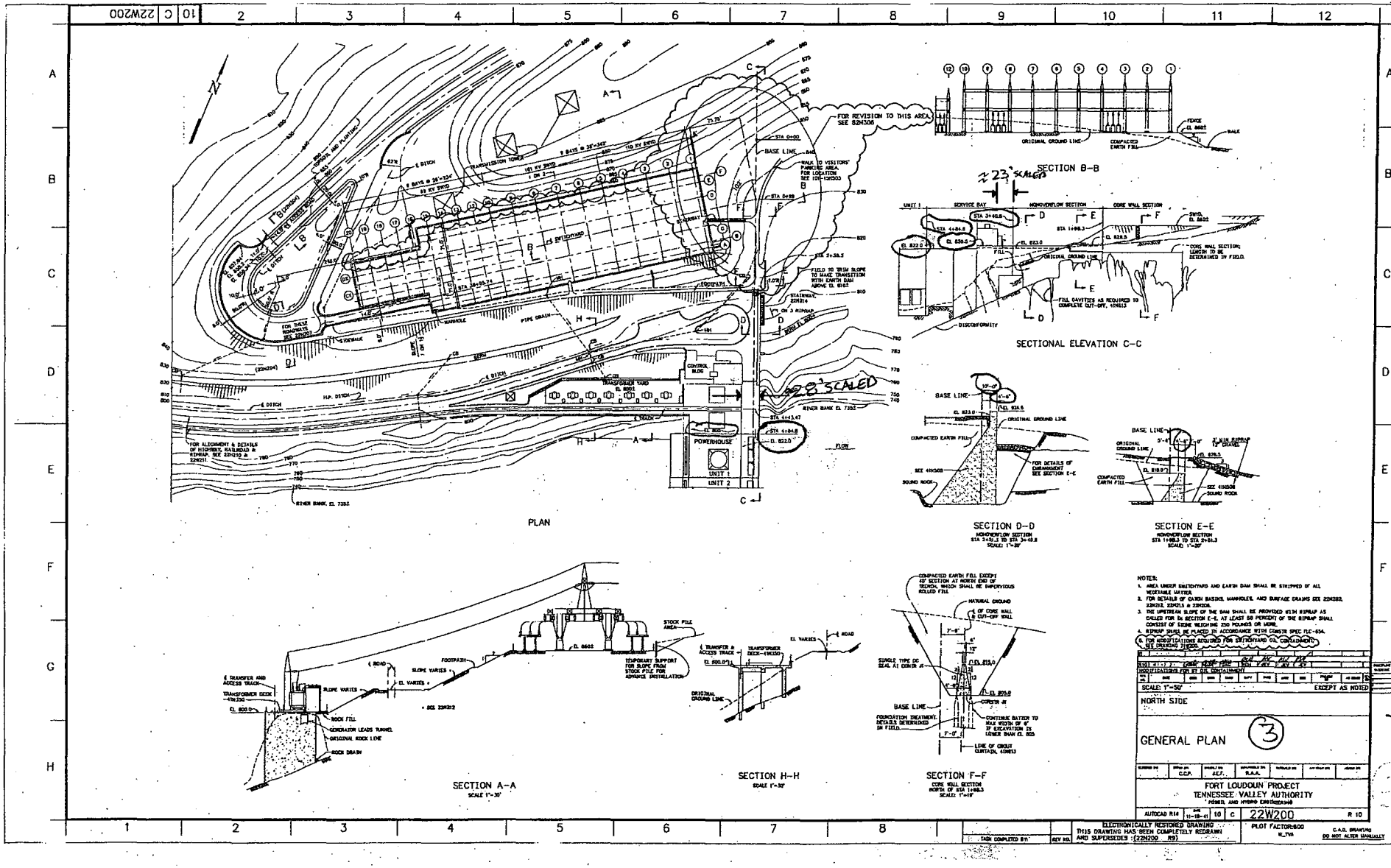
CDQ000020080009

2

Attachment 12-6
11 Pages
Source: Reference 10

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

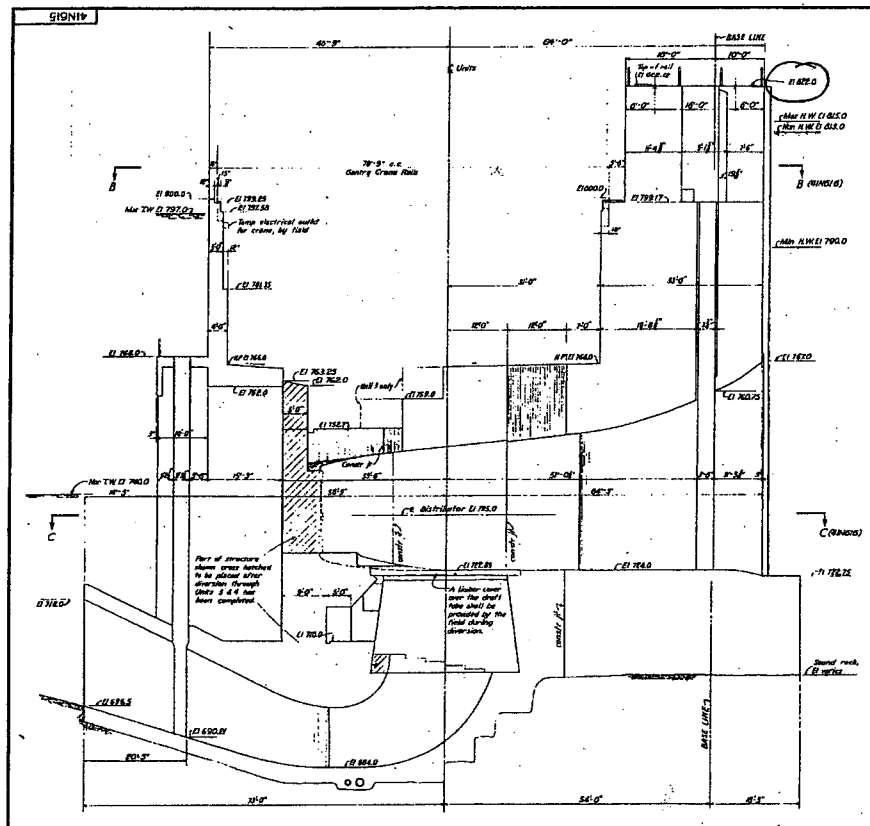


CDQ000020080009

Attachment 12-7
11 Pages
Source: Reference 22

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



NOTES:
For final rock excavation lines, see field office dwgs 213-H-430 to 213-H-447 incl.

4

Scale 1/8"=1'-0"

POWER HOUSE
UNITS 3 & 4

GENERAL LAYOUT
TRANSVERSE SECTION
INITIAL CONSTRUCTION

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED: T. Murphy | RECOMMENDED: | APPROVED: 12-3-58

KNOXVILLE | 10 | C | 4 | 41N615 R1

APPROVED: PROJECT MANAGER

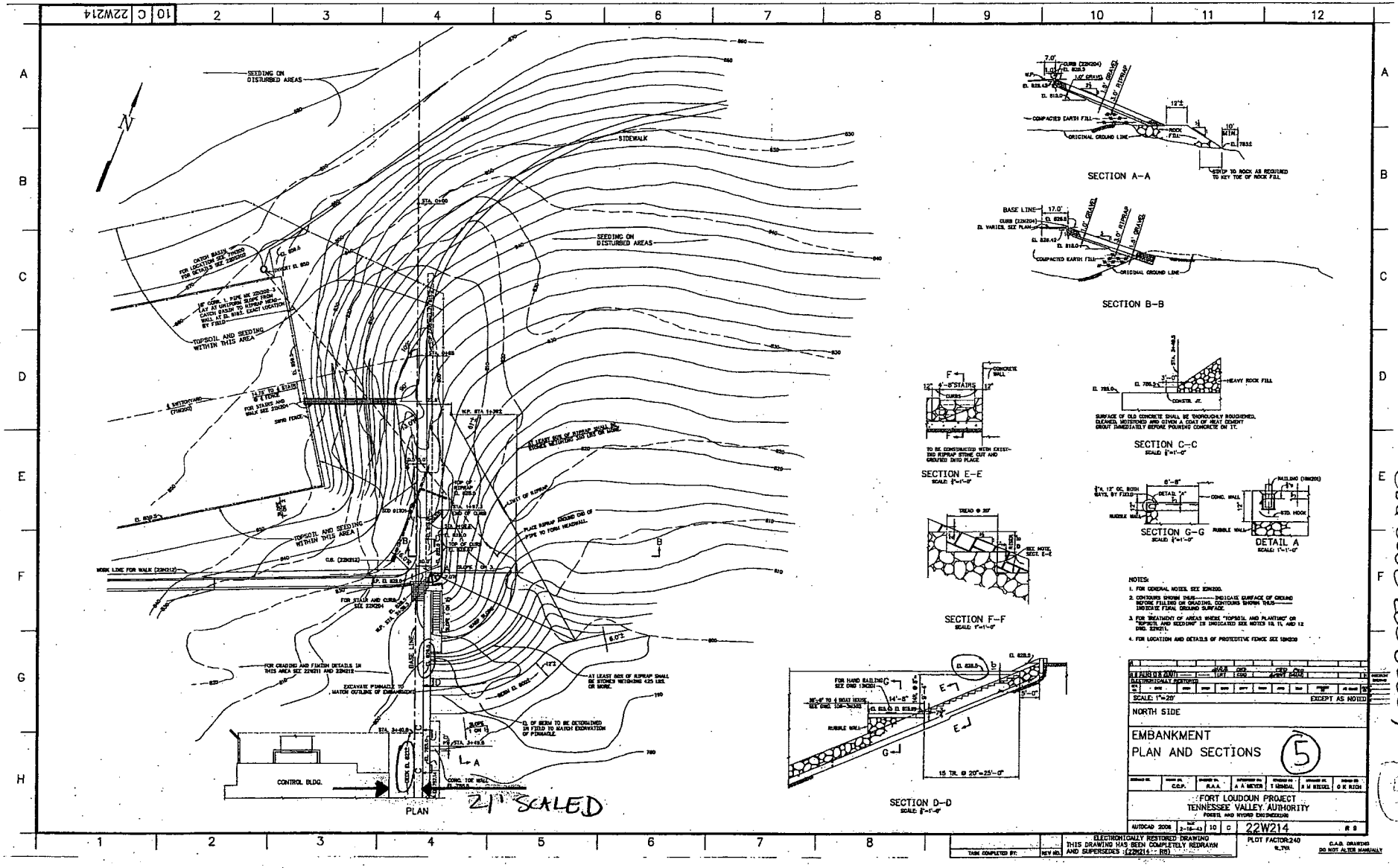
CDQ000020080009

4

Attachment 12-8
11 Pages
Source: Reference 11

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



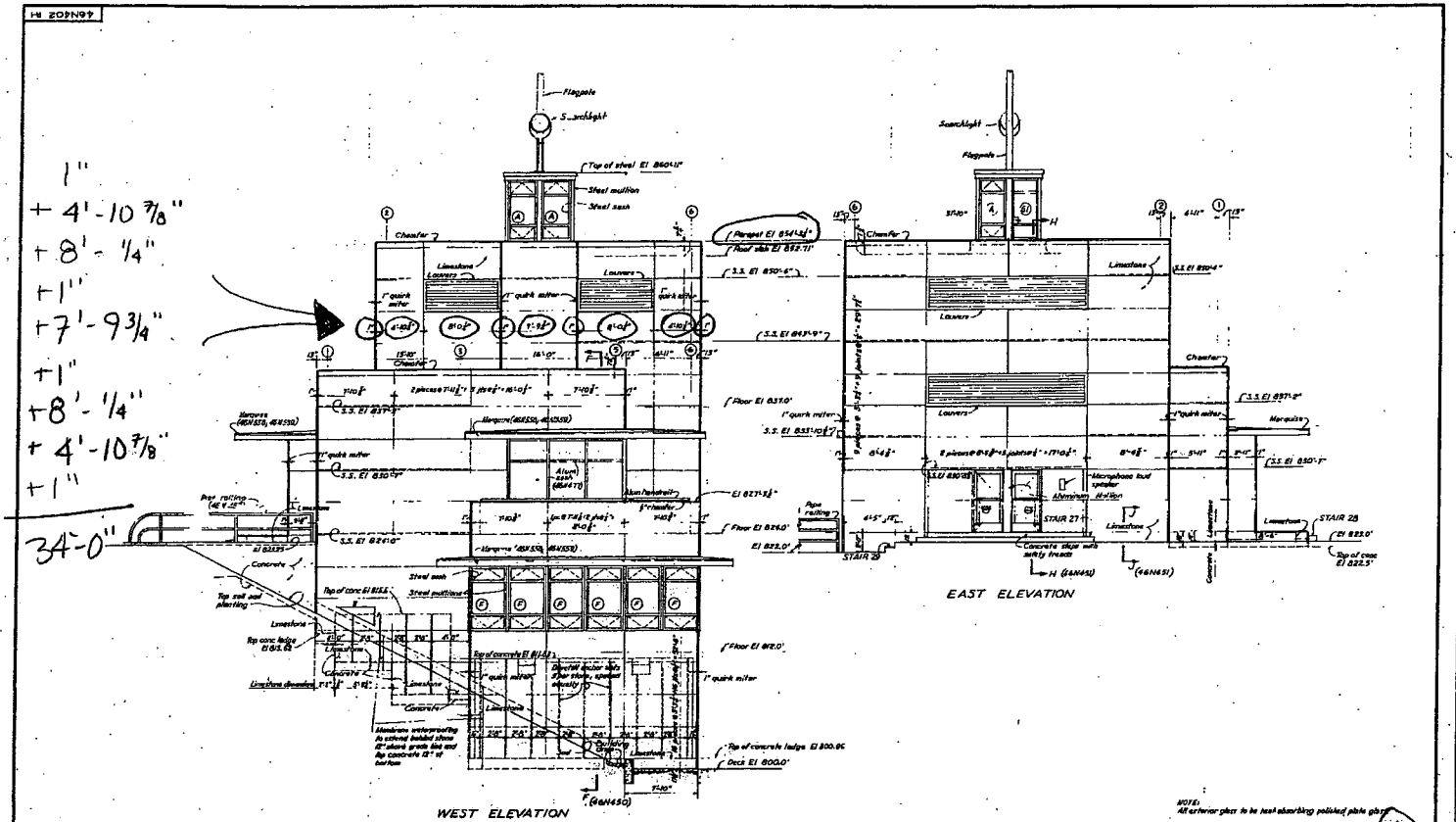
CDQ000020080009

Attachment 12-9
11 Pages
Source: Reference 23

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

1"
+ 4'-10 7/8"
+ 8'- 1/4"
+1"
+7'-9 3/4"
+1"
+8'- 1/4"
+ 4'-10 7/8"
+1"
34'-0"



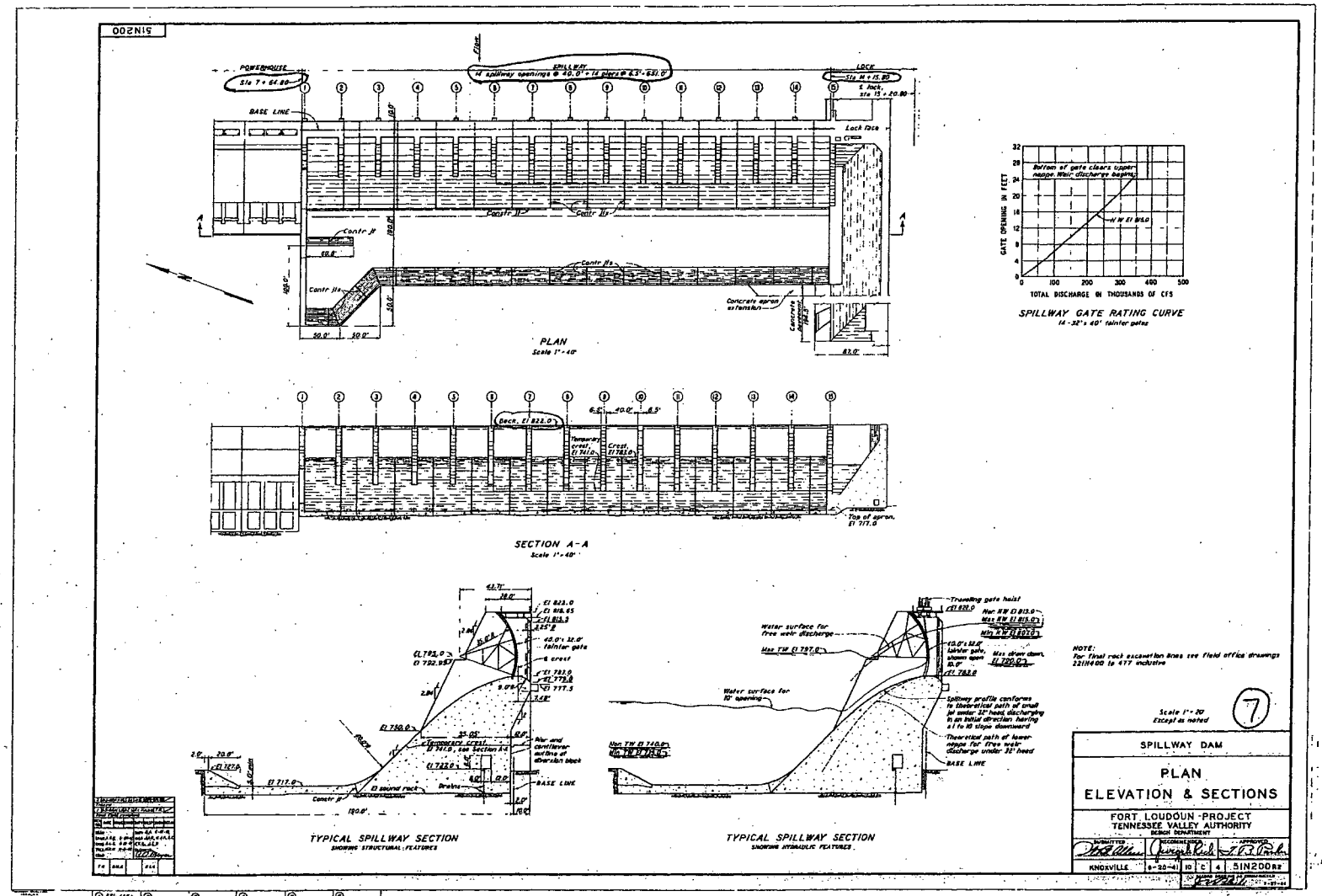
LOW LOW LOW LOW

(6)

Attachment 12-10
11 Pages
Source: Reference 24

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



CDQ000020080009

Attachment 12-11
11 Pages
Source: Reference 28

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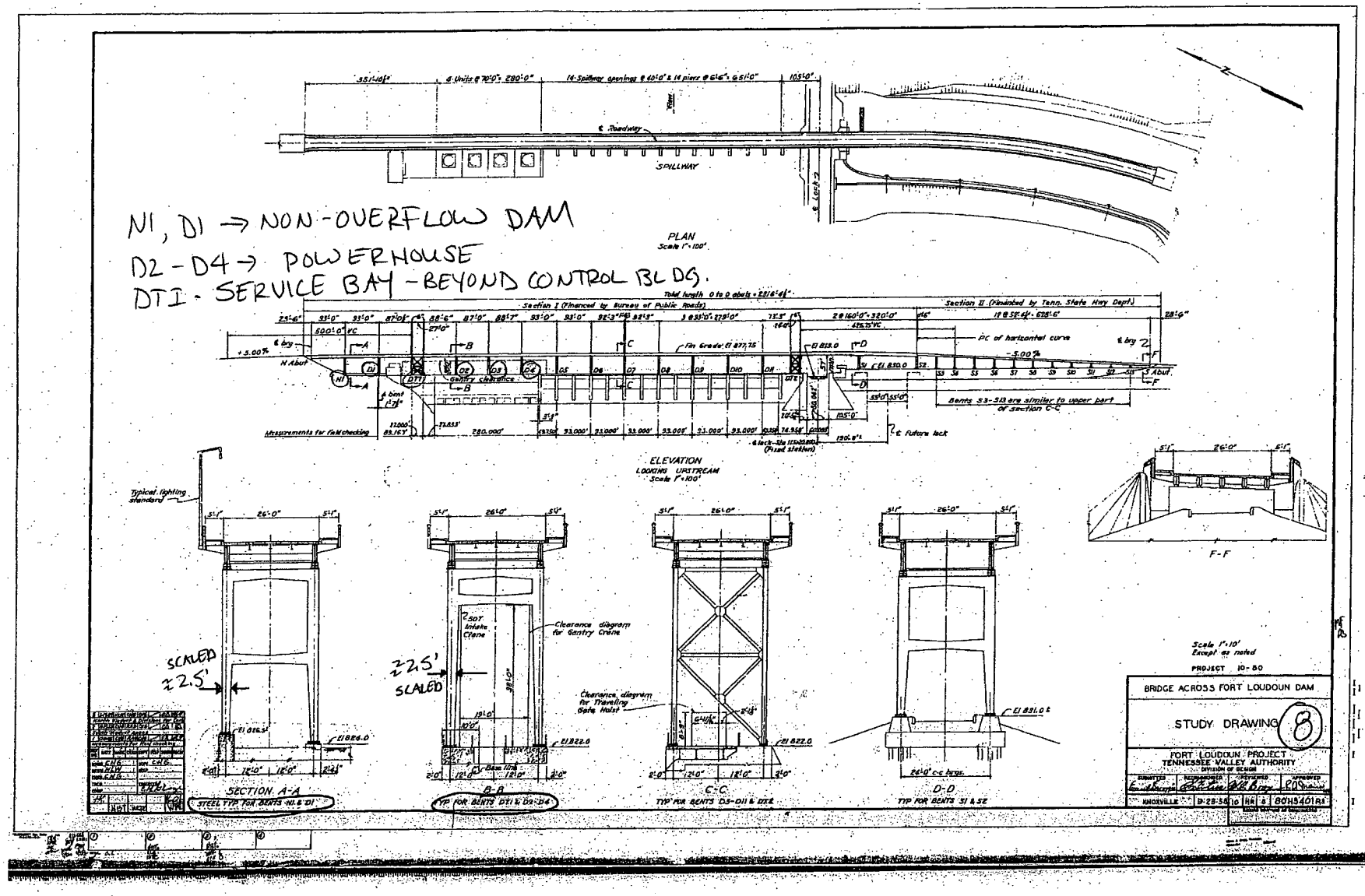


CDQ000020080009

3

Attachment 13-1
5 Pages
Source: Multiple

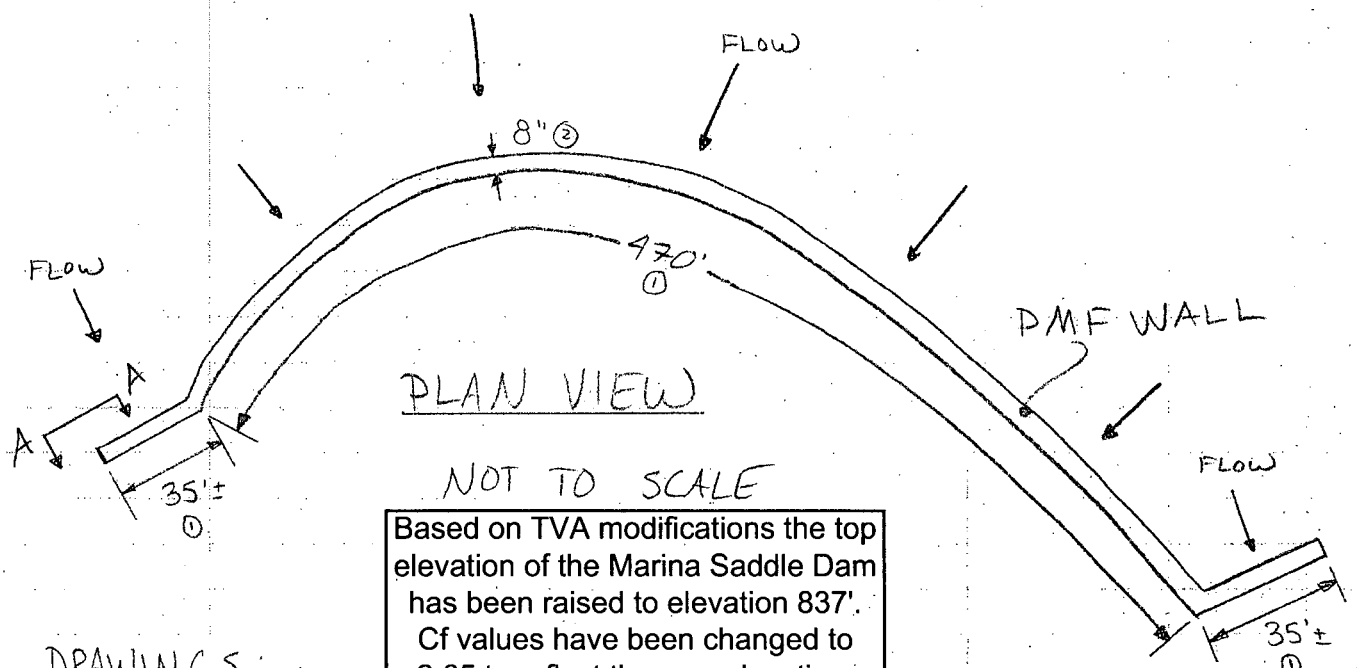
(2-78) TENNESSEE VALLEY AUTHORITY

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

PROJECT: Marina Saddle Dam Overflow

COMPUTED BY: SEM DATE: 10-15-08 CHECKED BY: DATE: CDQ0000200 80009



PLAN VIEW

NOT TO SCALE

Based on TVA modifications the top elevation of the Marina Saddle Dam has been raised to elevation 837'. Cf values have been changed to 2.65 to reflect the new elevation. (Reference 41)

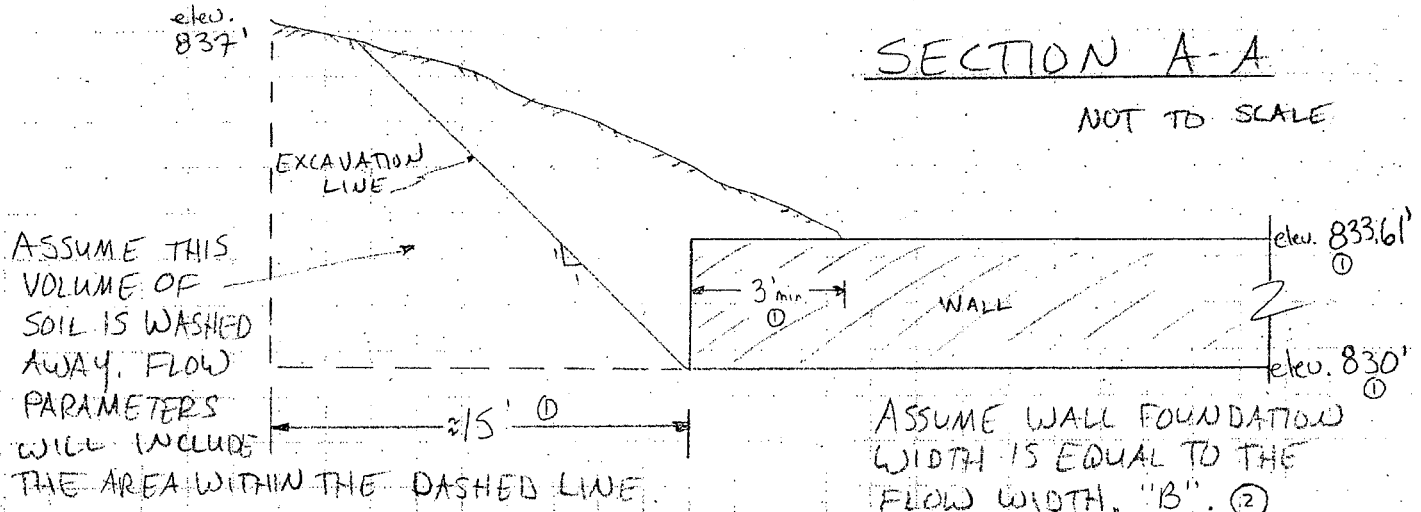
DRAWINGS:

① 23W220-1 R.2 (Ref. 13, Att. 13-4)
② 23W220-2 R.2 (Ref. 14, Att. 13-5)

NOTE THAT IN DRAWING ① THE ELEVATIONS AT THE LEFT END OF THE SADDLE DAM HAVE BEEN EXTRAPOLATED TO MODEL A MAXIMUM FLOOD LEVEL OF 837'. THE FOLLOWING DRAWING DETAILS THE DERIVATION OF FLOW LENGTHS AND Z VALUES AND WILL BE ASSUMED TO APPLY TO BOTH SIDES OF THE SADDLE DAM.

SECTION A-A

NOT TO SCALE



ASSUME WALL FOUNDATION WIDTH IS EQUAL TO THE FLOW WIDTH, "B". ②

Attachment 13-2
5 Pages
Source: Multiple

Calculation CDQ000020080009

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(2-78) TENNESSEE VALLEY AUTHORITY SHEET / OF

SUBJECT FORT LOUDOUN DAM - SADDLE DAM A1 PROJECT MARI

SEM 10/15/08 CDQ00002008009

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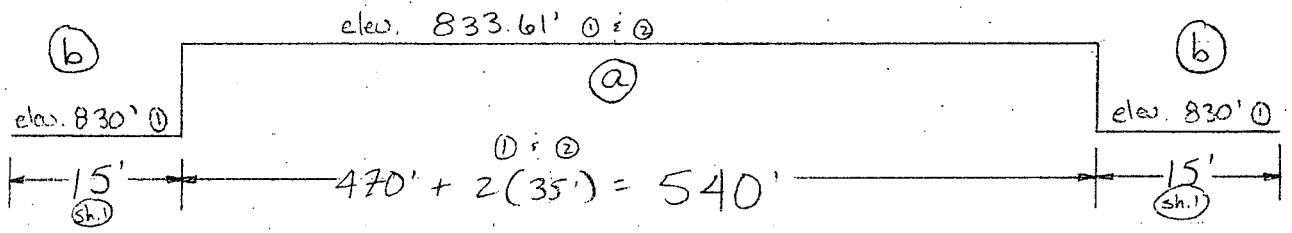
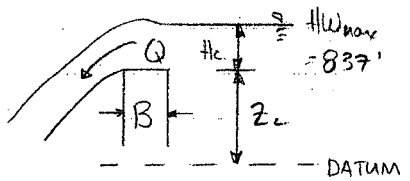
ELEVATION VIEW NOT TO SCALE



OVERFLOW PARAMETERS



ⓐ $B = 8'' = .67'$, $L = 540'$, $Z_c = 833.61'$
ⓑ $B \approx 5'$, $L \approx 30'$, $Z_c = 830'$

$0 \le H_c \le (837' - Z_c)$

ⓐ $0 \le H_c/B \le (837' - 833.61')/.67' = 5.1$
ⓑ $0 \le H_c/B \le (837' - 830')/5' = 1.4$

FROM Ref. 6, Att. 2
$2.65 \le C_f \le 3.33$
$2.65 \le C_f \le 3.23$

SUMMARY OF SADDLE DAM OVERFLOW PARAMETERS

	Z_c, ft.	L, ft.	C_f
Saddle, Sec. 1	833.6'	540'	3.3
Saddle, Sec. 2	830'	30'	3.2

Based on TVA modifications the top elevation of the Marina Saddle Dam has been raised to elevation 837'. Cf values have been changed to 2.65 to reflect the new elevation. (Reference 41)

Upon failure, assume dam erodes to elevation of 815'.

Length of failed dam should be similar to overflow length of 570'.

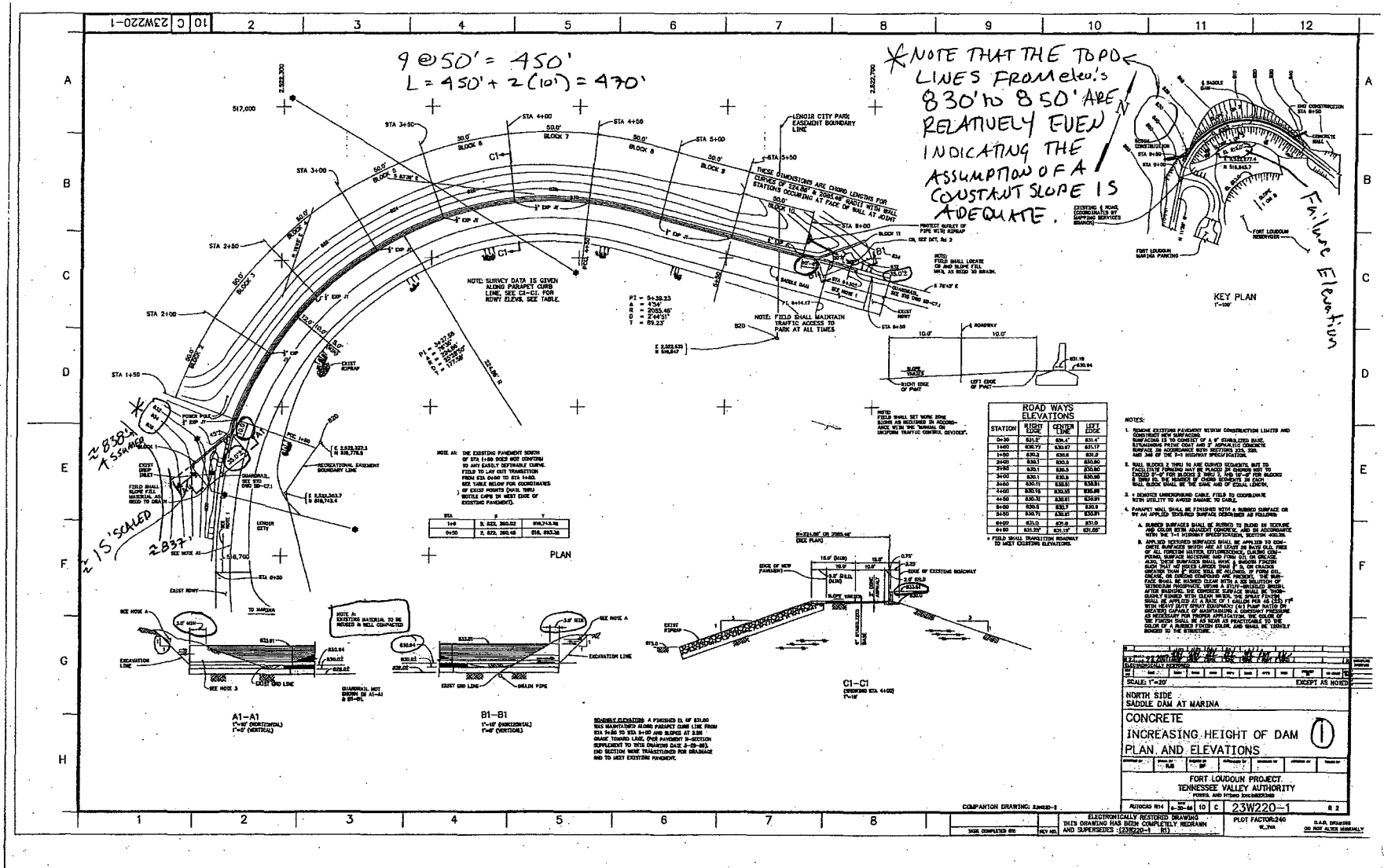
Assume broadcrested weir $\Rightarrow C_f = 2.65$

$\therefore$ $C_f = 2.65$
$L = 570'$
$Z_c = 815'$

Attachment 13-4
5 Pages
Source: Reference 13

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



Attachment 13-5
5 Pages
Source: Reference 14

Calculation CDQ000020080009

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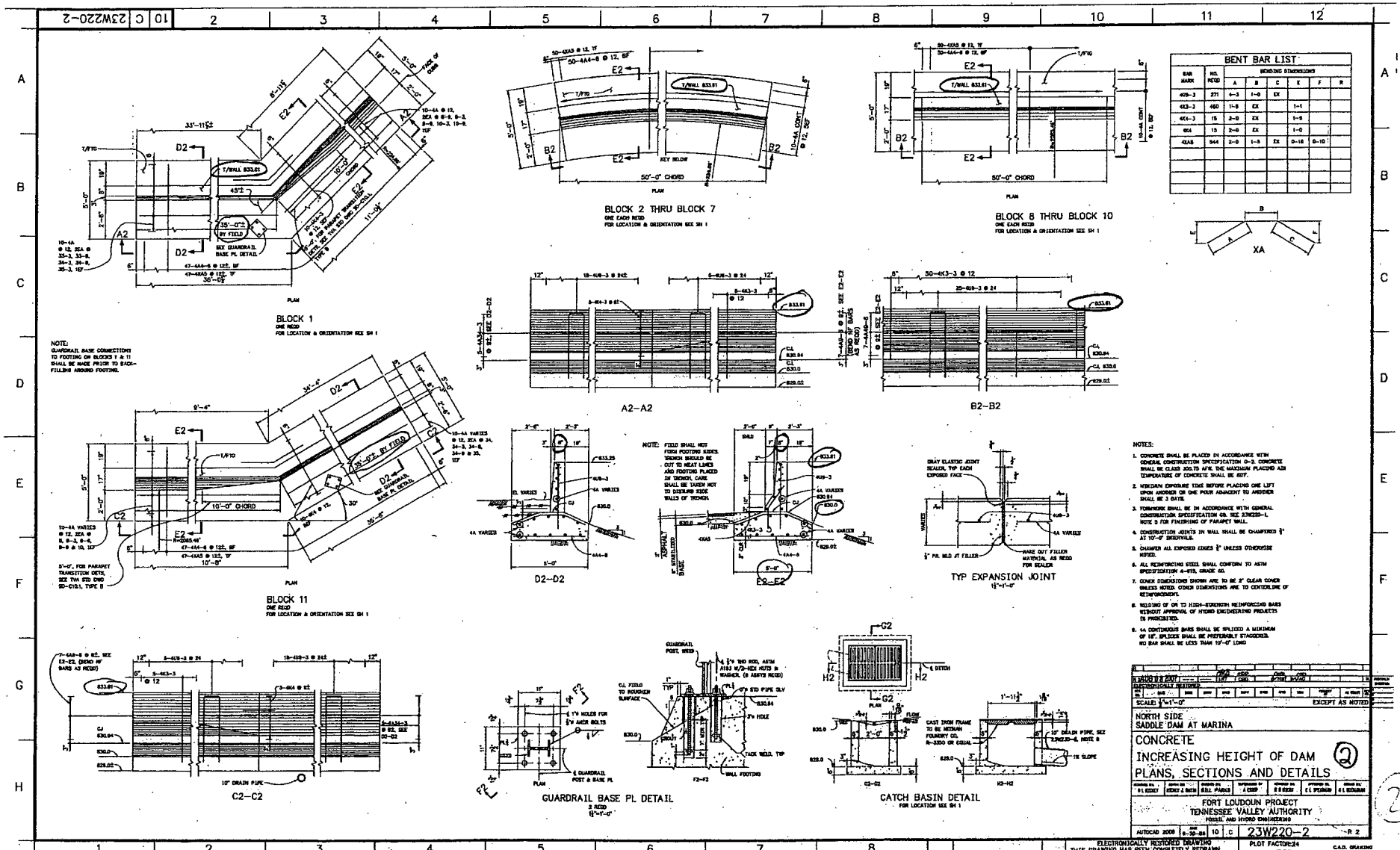
Checked: JCT



Attachment 14-1
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(ES-2-78) **TENNESSEE VALLEY AUTHORITY**

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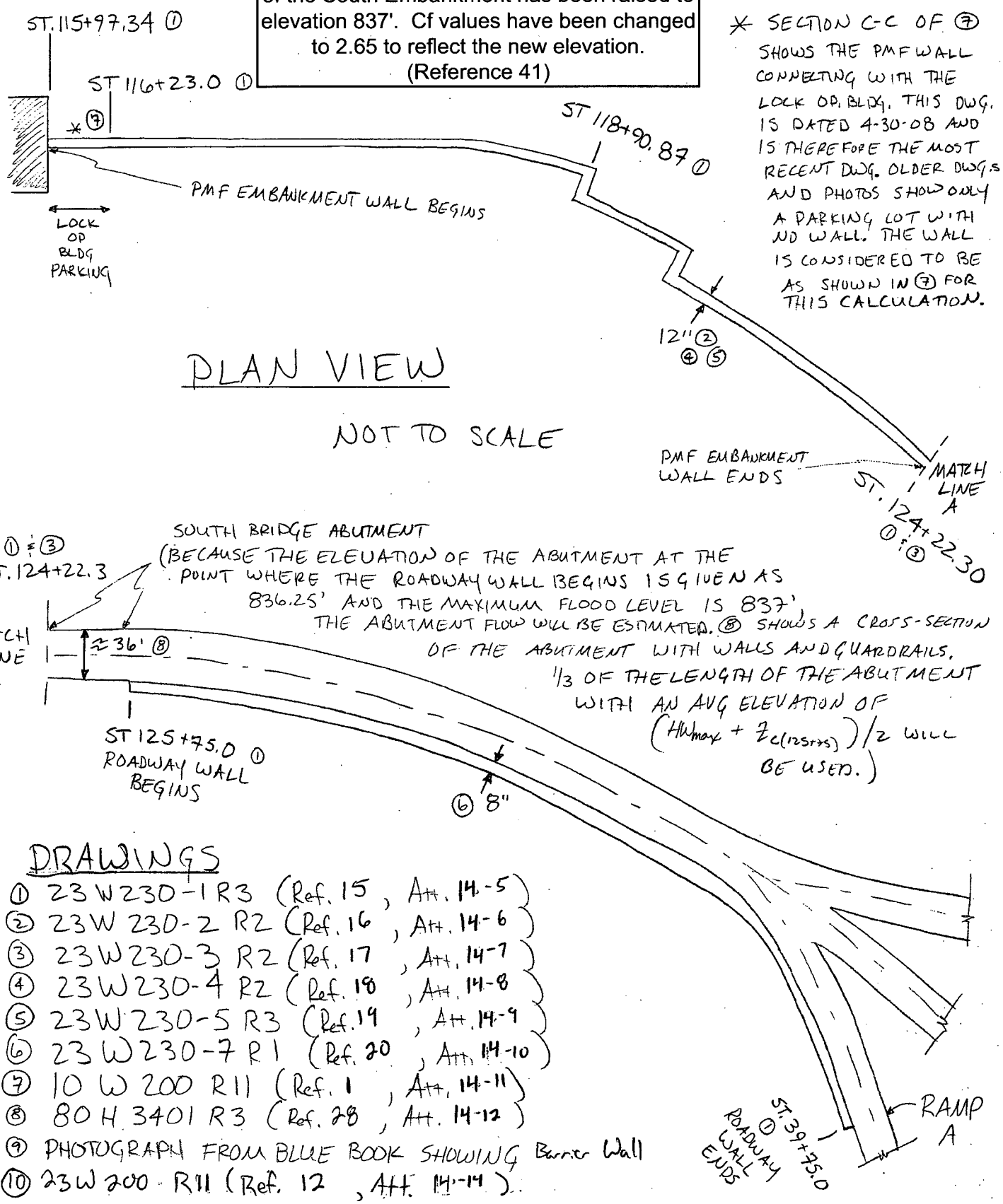
SUBJECT: ORT LOUDOUN DAM - SOUTH EMBANKMENT PROJECT OVE

SEM 10-14-08 CDQ000020080009

COMPUTED BY DATE

Based on TVA modifications the top elevation of the South Embankment has been raised to elevation 837'. Cf values have been changed to 2.65 to reflect the new elevation. (Reference 41)



* SECTION C-C OF ⑦ SHOWS THE PMF WALL CONNECTING WITH THE LOCK OP. BLDG. THIS DWG. IS DATED 4-30-08 AND IS THEREFORE THE MOST RECENT DWG. OLDER DWGS AND PHOTOS SHOW ONLY A PARKING LOT WITH NO WALL. THE WALL IS CONSIDERED TO BE AS SHOWN IN ⑦ FOR THIS CALCULATION.

(BECAUSE THE ELEVATION OF THE ABUTMENT AT THE POINT WHERE THE ROADWAY WALL BEGINS IS GIVEN AS 836.25' AND THE MAXIMUM FLOOD LEVEL IS 837' THE ABUTMENT FLOW WILL BE ESTIMATED. ⑧ SHOWS A CROSS-SECTION OF THE ABUTMENT WITH WALLS AND GUARDRAILS. 1/3 OF THE LENGTH OF THE ABUTMENT WITH AN AVG ELEVATION OF $(HW_{max} + Z_{c(125+75)})/2$ WILL BE USED.)

DRAWINGS

① 23W230-1R3 (Ref. 15, Att. 14-5)
② 23W230-2R2 (Ref. 16, Att. 14-6)
③ 23W230-3R2 (Ref. 17, Att. 14-7)
④ 23W230-4R2 (Ref. 18, Att. 14-8)
⑤ 23W230-5R3 (Ref. 19, Att. 14-9)
⑥ 23W230-7R1 (Ref. 20, Att. 14-10)
⑦ 10W200R11 (Ref. 1, Att. 14-11)
⑧ 80H3401R3 (Ref. 28, Att. 14-12)
⑨ PHOTOGRAPH FROM BLUE BOOK SHOWING Barrier Wall
⑩ 23W200 R11 (Ref. 12, Att. 14-14)

Attachment 14-2
14 Pages
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(DES-2-78) TENNESSEE VALLEY AUTHORIT

Calculation CDQ000020080009

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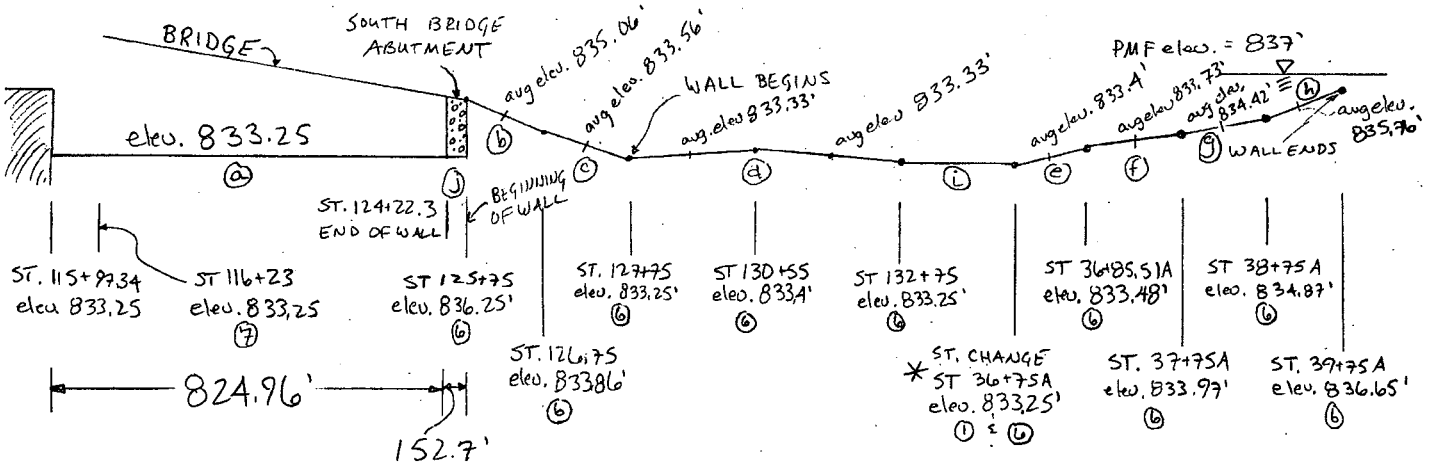
SEM 10-15-08 CDQ000020080009

COMPUTED BY DATE CHECKED BY DATE



ELEVATION VIEW

NOT TO SCALE

* AT ST 135+00 FROM THE DAM DIMENSIONS (S.R. 95) THE STATIONING SWITCHES TO RAMP A DIMENSIONS BEGINNING WITH ST 25+00. THE SUFFIX "A" DENOTES RAMP STATIONING. (1)

OVERFLOW PARAMETERS

THE ELEVATION, Z_c, VARIES ALONG THE LENGTH OF THE EMBANKMENT. FOR SLOPED SECTIONS, THE AVERAGE ELEVATION WILL BE USED.

(a) B = 12", Z_c = 833.25', L = 824.96'
(b) B = 8", Z_c = 835.06', L = 100'
(c) B = 8", Z_c = 833.56', L = 100'
(d) B = 8", Z_c = 833.33', L = 500'
(e) B = 8", Z_c = 833.4', L = 10.51'
(f) B = 8", Z_c = 833.73', L = 89.49'
(g) B = 8", Z_c = 834.42', L = 100'
(h) B = 8", Z_c = 835.76', L = 100'
(i) B = 8", Z_c = 833.25', L = 400'
(j) B = 36", Z_c = 836.63', L = 152.7/3 = 50.9' (See note on sheet 14-1)

Based on TVA modifications the top elevation of the South Embankment has been raised to elevation 837'. Cf values have been changed to 2.65 to reflect the new elevation. (Reference 41)

Attachment 14-3
14 Pages
Source: Multiple

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

(DES-2-78) TENNESSEE VALLEY AUTHORITY

SUBJECT FORT LOUDOUN DAM - SOUTH EMBANKMENT PROJECT OV

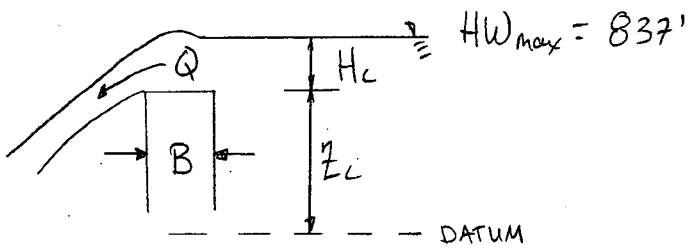
SEM 10-15-08 CDQ000020080009

COMPUTED BY DATE CHECKED BY DATE

$\emptyset \le H_c \le (837' - Z_c)$

FROM Ref. 6, Att. 2

ⓐ	$0 \le H_c/B \le (837' - 833.25')/1' = 3.75$	$2.65 \le C_f \le 3.33$	STANDARD
ⓑ	$0 \le H_c/B \le (837' - 835.06')/.67' = 2.9$	$2.65 \le C_f \le 3.33$	
ⓒ	$0 \le H_c/B \le (837' - 833.56')/.67' = 5.1$	$2.65 \le C_f \le 3.33$	
ⓓ	$0 \le H_c/B \le (837' - 833.33')/.67' = 5.5$	$2.65 \le C_f \le 3.33$	
ⓔ	$0 \le H_c/B \le (837' - 833.41')/.67' = 5.4$	$2.65 \le C_f \le 3.33$	
ⓕ	$0 \le H_c/B \le (837' - 833.73')/.67' = 4.9$	$2.65 \le C_f \le 3.33$	
ⓖ	$0 \le H_c/B \le (837' - 834.42')/.67' = 3.9$	$2.65 \le C_f \le 3.33$	
ⓗ	$0 \le H_c/B \le (837' - 835.76')/.67' = 1.9$	$2.65 \le C_f \le 3.33$	
ⓘ	$0 \le H_c/B \le (837' - 833.25')/.67' = 5.6$	$2.65 \le C_f \le 3.33$	
ⓙ	$0 \le H_c/B \le (837' - 836.63')/36' = .01$	$2.65 \le C_f \le 2.65$	



LENGTHS

ⓐ + ⓘ $L = 824.96' + 400' - 11(1'^{*}) - 2(3'^{*}) = 1207.96'$

ⓑ $L = 100'$

ⓒ $L = 100'$

ⓓ $L = 500'$

ⓔ $L = 10.51'$

ⓕ $L = 89.49'$

ⓖ $L = 100'$

ⓗ $L = 100'$

ⓙ $L = 150.9$

Based on TVA modifications the top elevation of the South Embankment has been raised to elevation 837'. Cf values have been changed to 2.65 to reflect the new elevation. (Reference 41)

* THE BRIDGE BENTS ⑧ WILL RESTRICT FLOW THROUGH SECTION ⓐ.

Attachment 14-4
14 Pages
Source: Multiple

Calculation CDQ000020080009

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(DES-2-78) TENNESSEE VALLEY AUTHORITY

SUBJECT FORT LOUDOUN DAM - SOUTH EMBANKMENT PROJECT OU

SEM 10-15-08 CDQ000020080009

COMPUTED BY DATE CHECKED BY DATE

SUMMARY OF SOUTH EMBANKMENT OVERFLOW

	Z_c, ft	L, ft	C_f	
South Bank Section 1	833.25'	1208'	3.33	combine
	835.1'	100'	3.33	
	833.6'	100'	3.33	
	833.3'	500'	3.33	
	833.4'	10.5	3.33	
	833.7'	89.5'	3.33	
	834.4'	100'	3.33	
	835.8'	100'	3.33	
South Bank Section 2	836.6'	50.9	2.65	

Based on TVA modifications the top elevation of the South Embankment has been raised to elevation 837'. Cf values have been changed to 2.65 to reflect the new elevation. (Reference 41)

Section 1

combined $L = 2208'$
$C_f = 3.33$
$Z_c = 833.3$ ← conservative

Upon Failure:

Assume Embankment will fail to original ground elevation. Drawing 23W200 shows 2 seperate original ground elevations. The failure of the embankment will be divided into 2 equal sections of 1130' each. Section 1 will have an overflow elevation of 754' (scaled from section A-A, 23W200). Section 2 will have an overflow elevation of 770' (section B-B, 23W200). Both sections will be treated as a broad-crested weir with C_f of 2.65

Attachment 14-5
14 Pages
Source: Reference 15

Calculation CDQ000020080009

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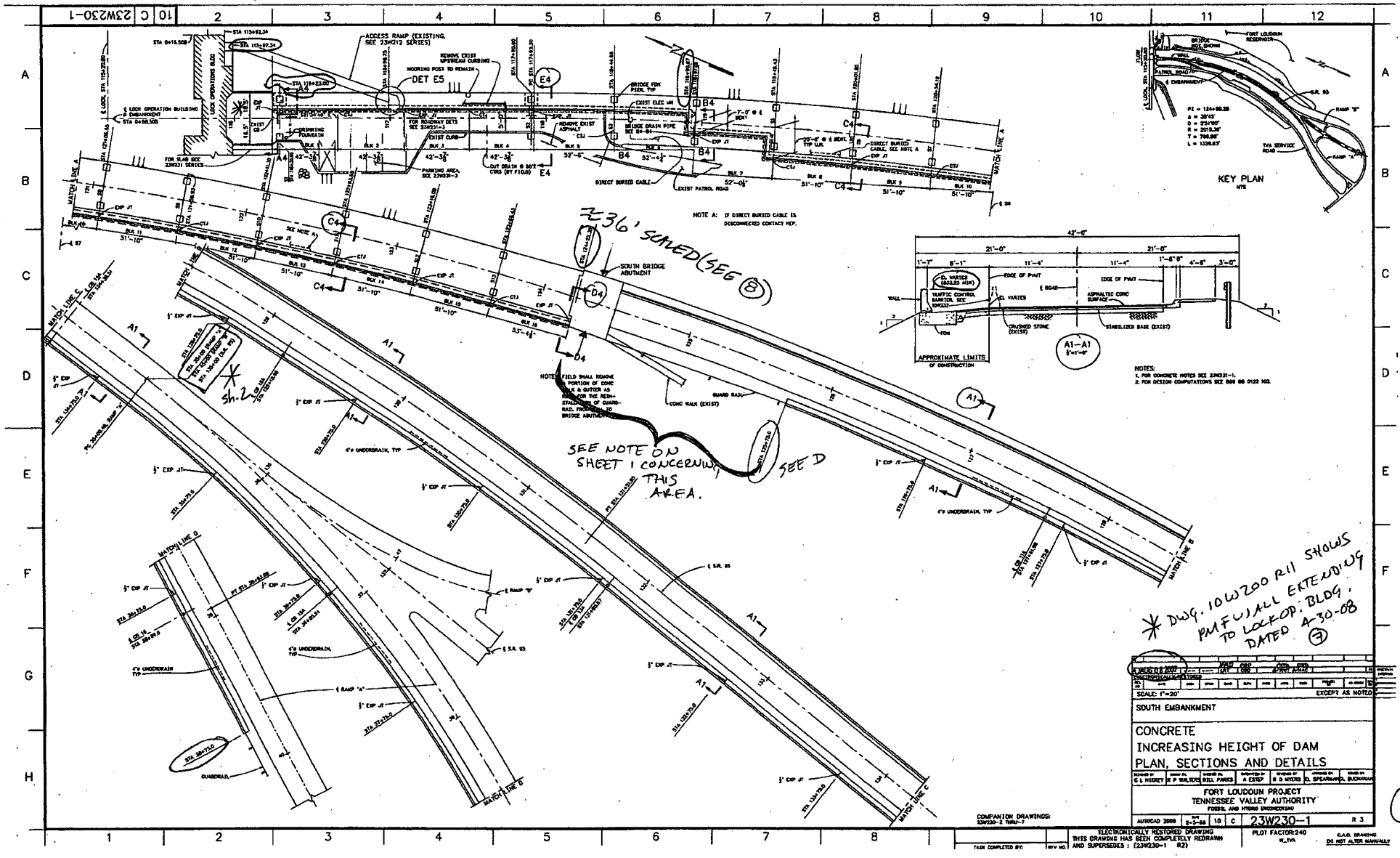

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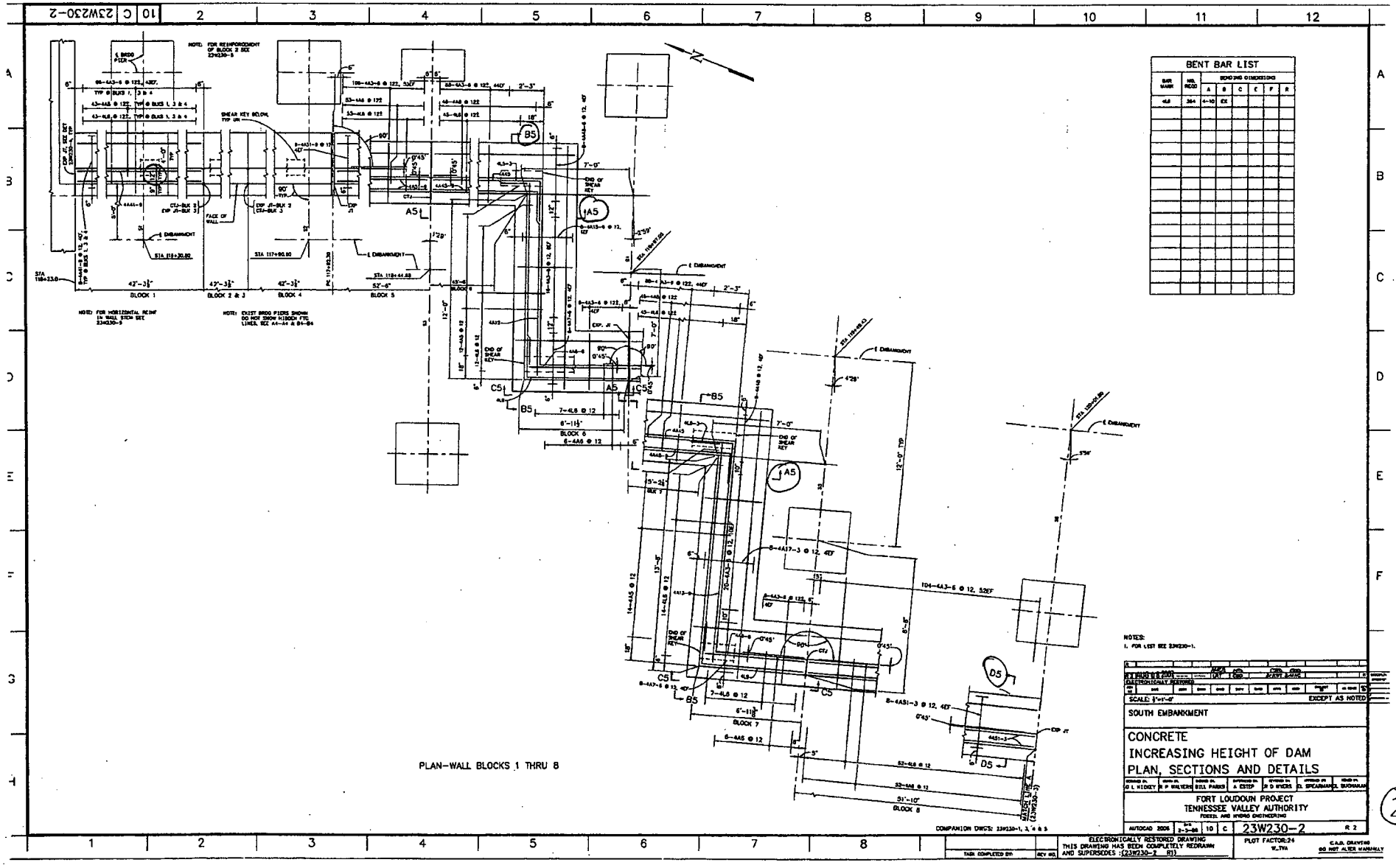
Attachment 14-6
14 Pages
Source: Reference 16

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



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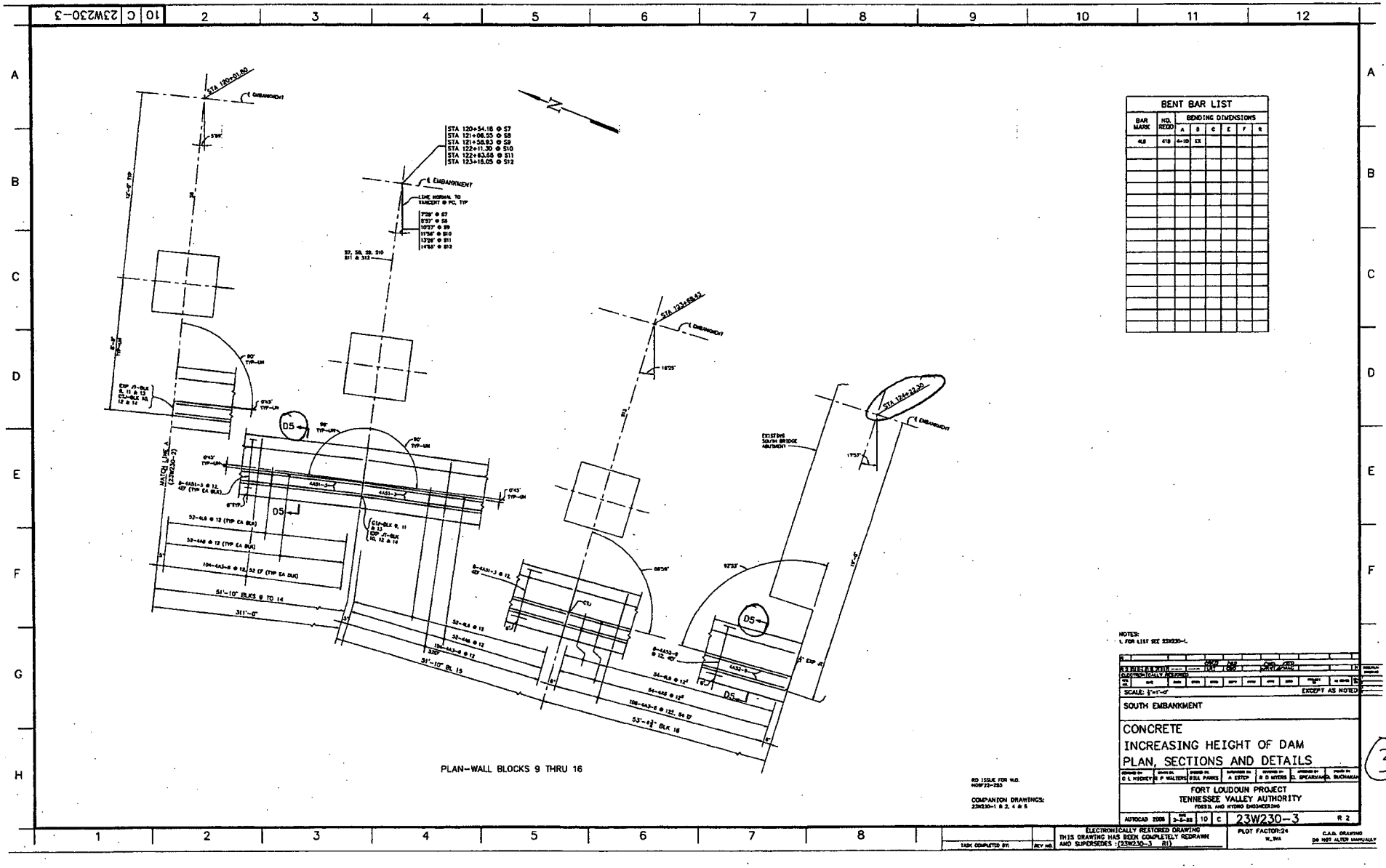
Attachment 14-7
14 Pages
Source: Reference 17

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



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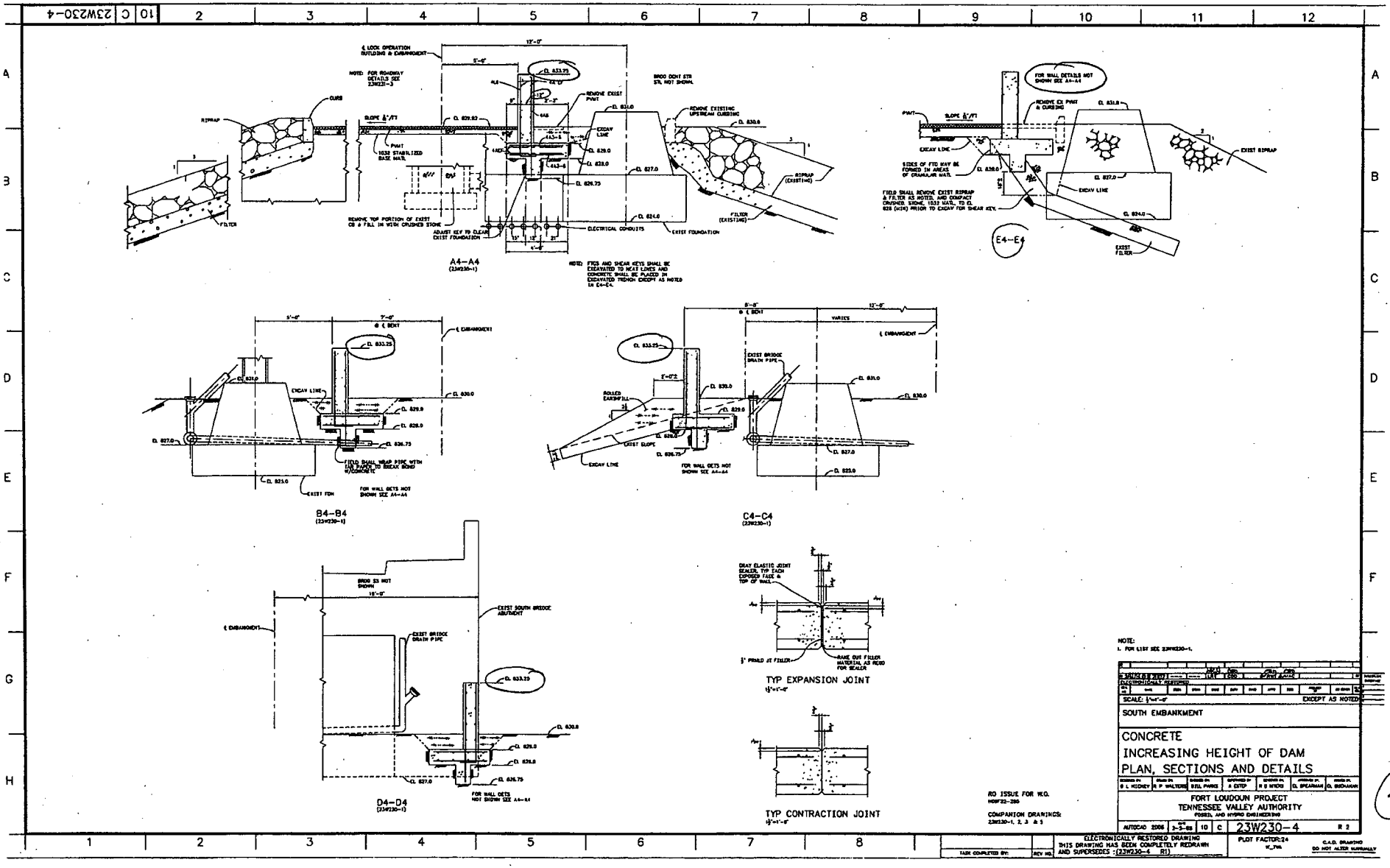
Attachment 14-8
14 Pages
Source: Reference 18

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



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Attachment 14-9
14 Pages
Source: Reference 19

Calculation CDQ000020080009

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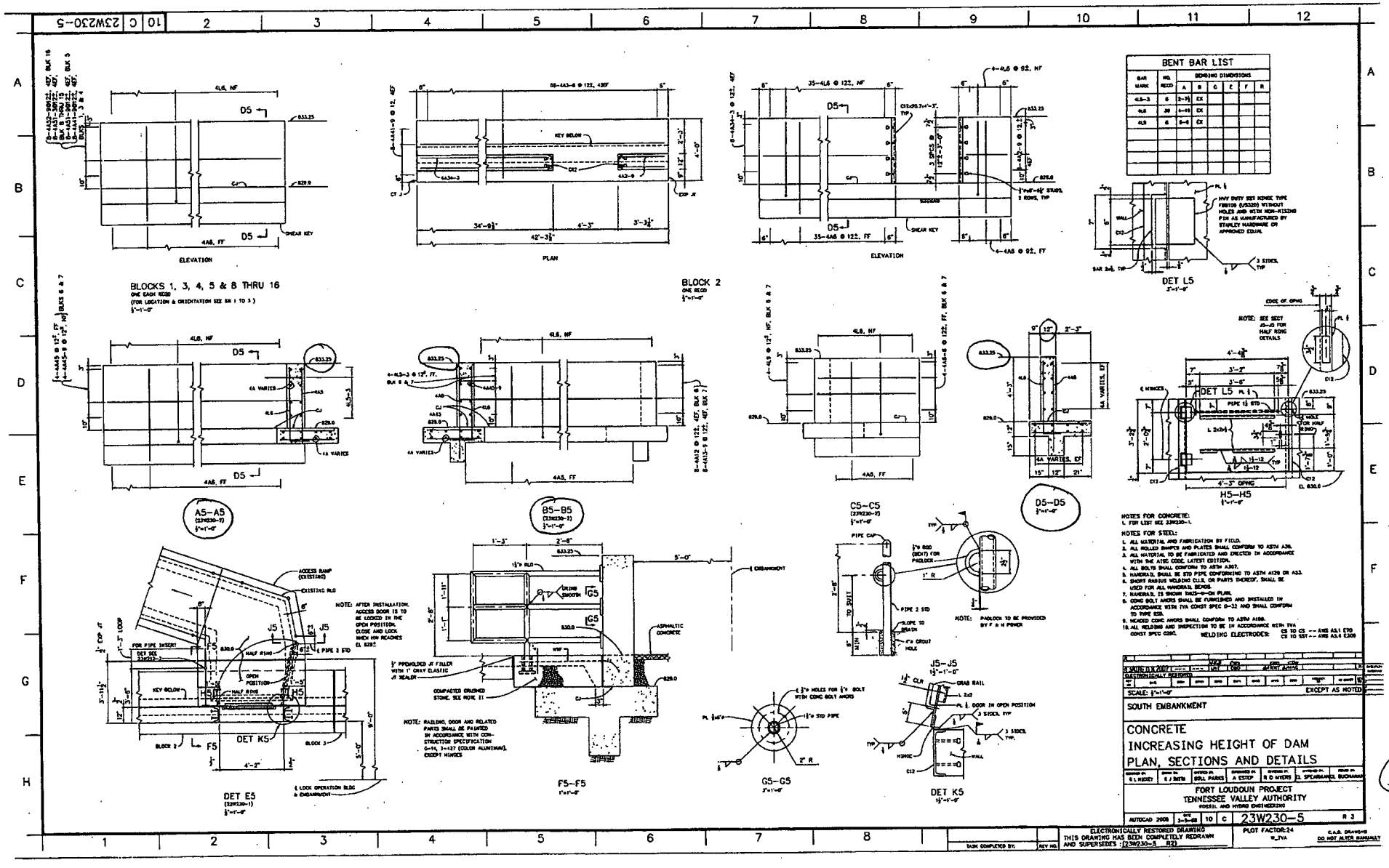

CDQ000020080009

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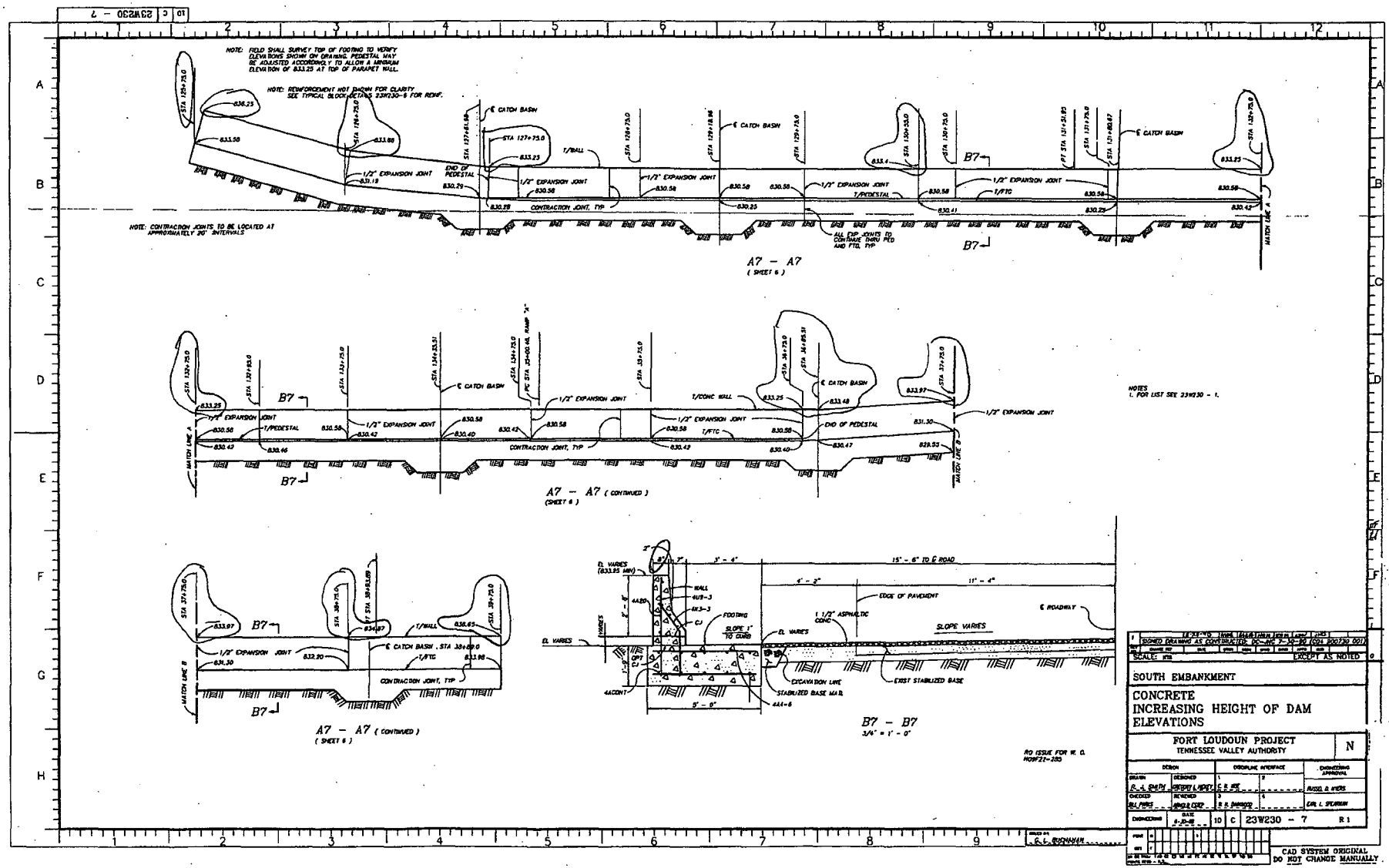
Attachment 14-10
14 Pages
Source: Reference 20

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



CDQ000020080009

6

Attachment 14-11
14 Pages
Source: Reference 1

Calculation CDQ000020080009

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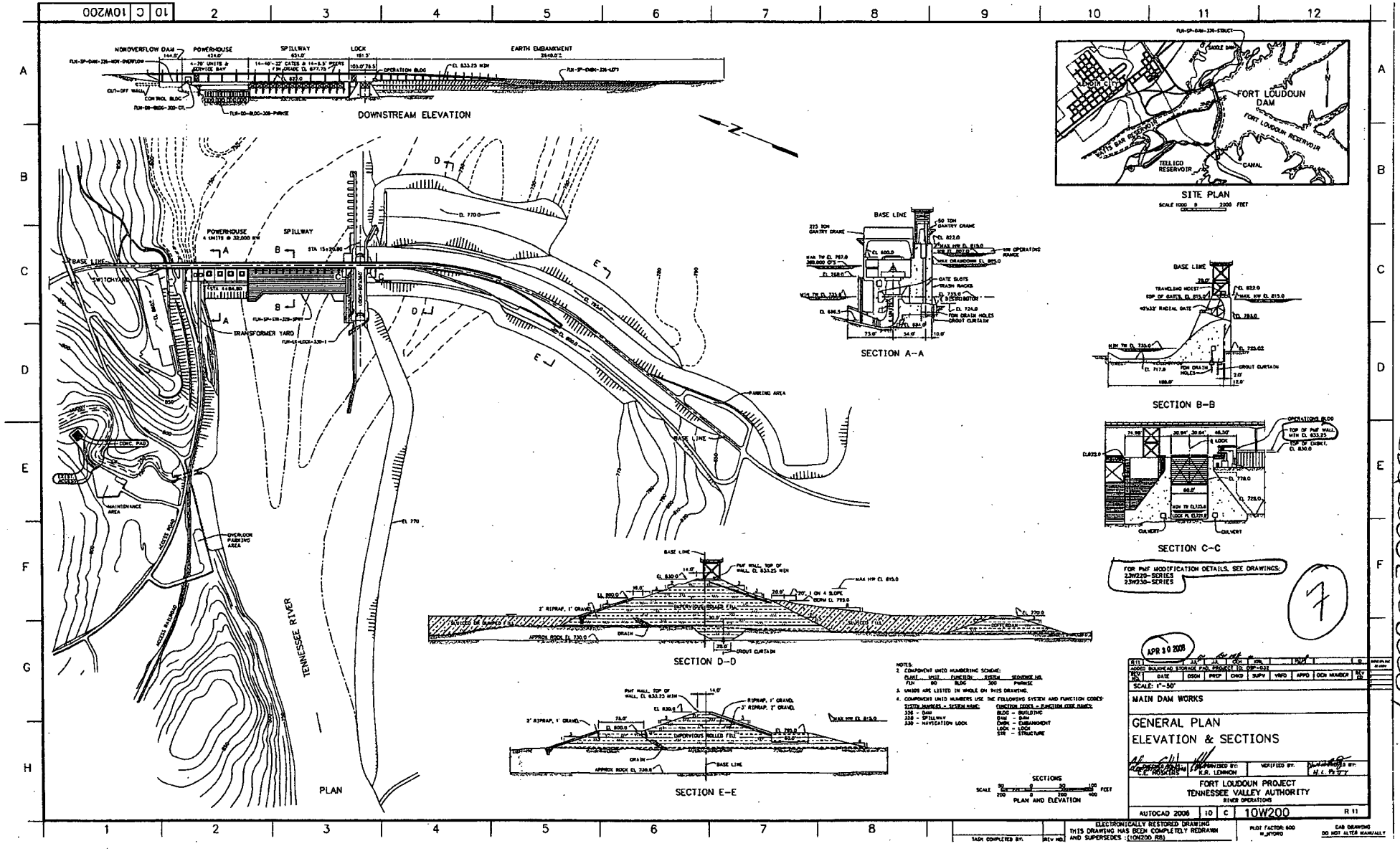
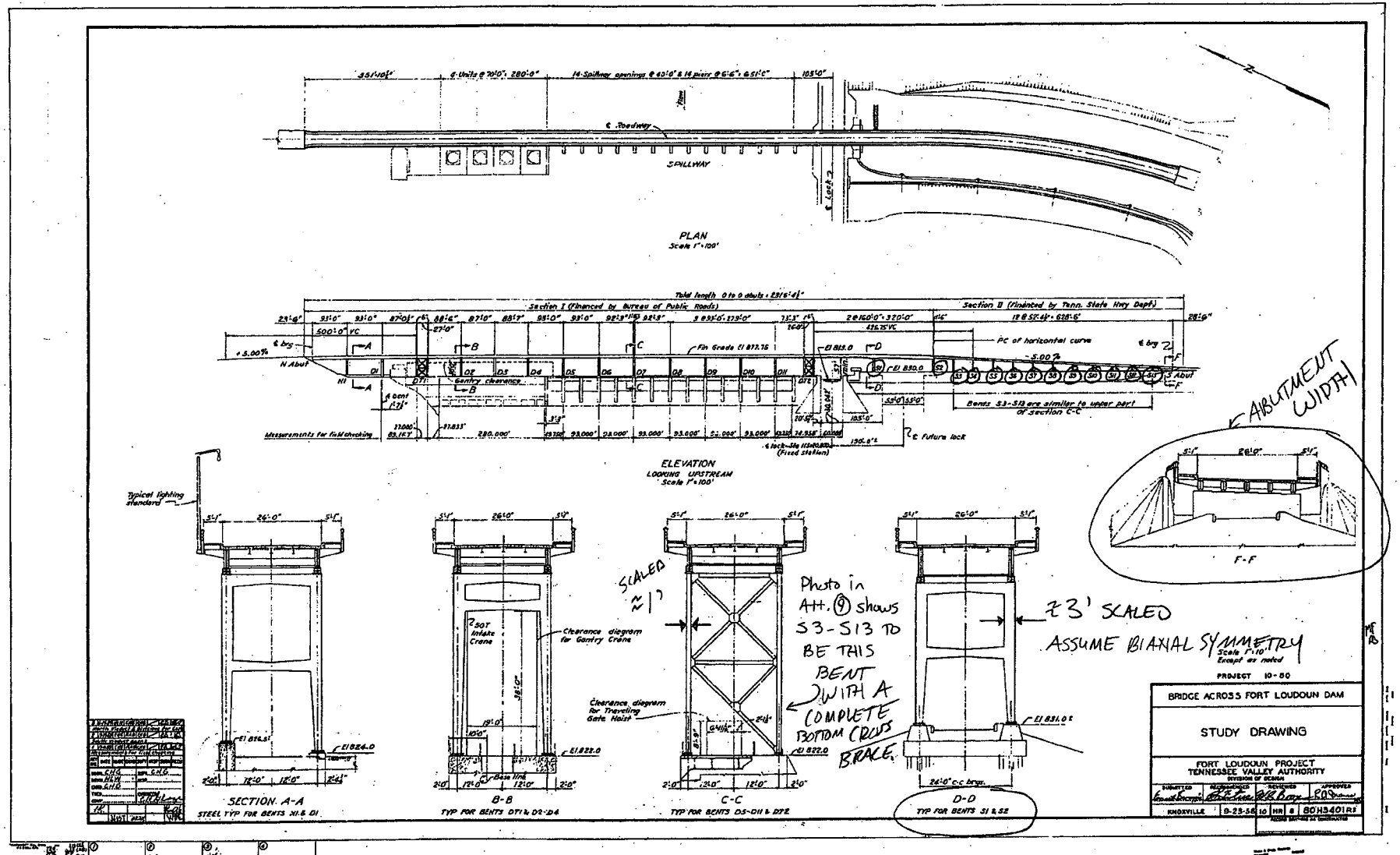


Attachment 14-12
14 Pages
Source: Reference 28

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



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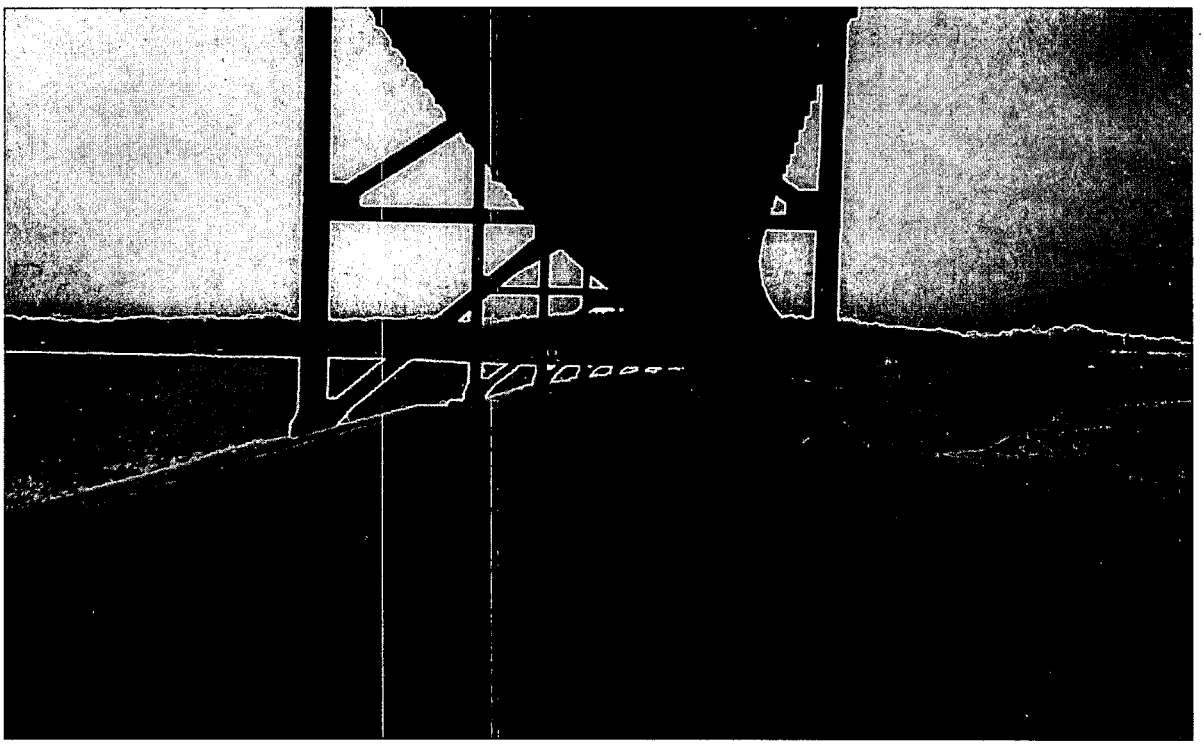


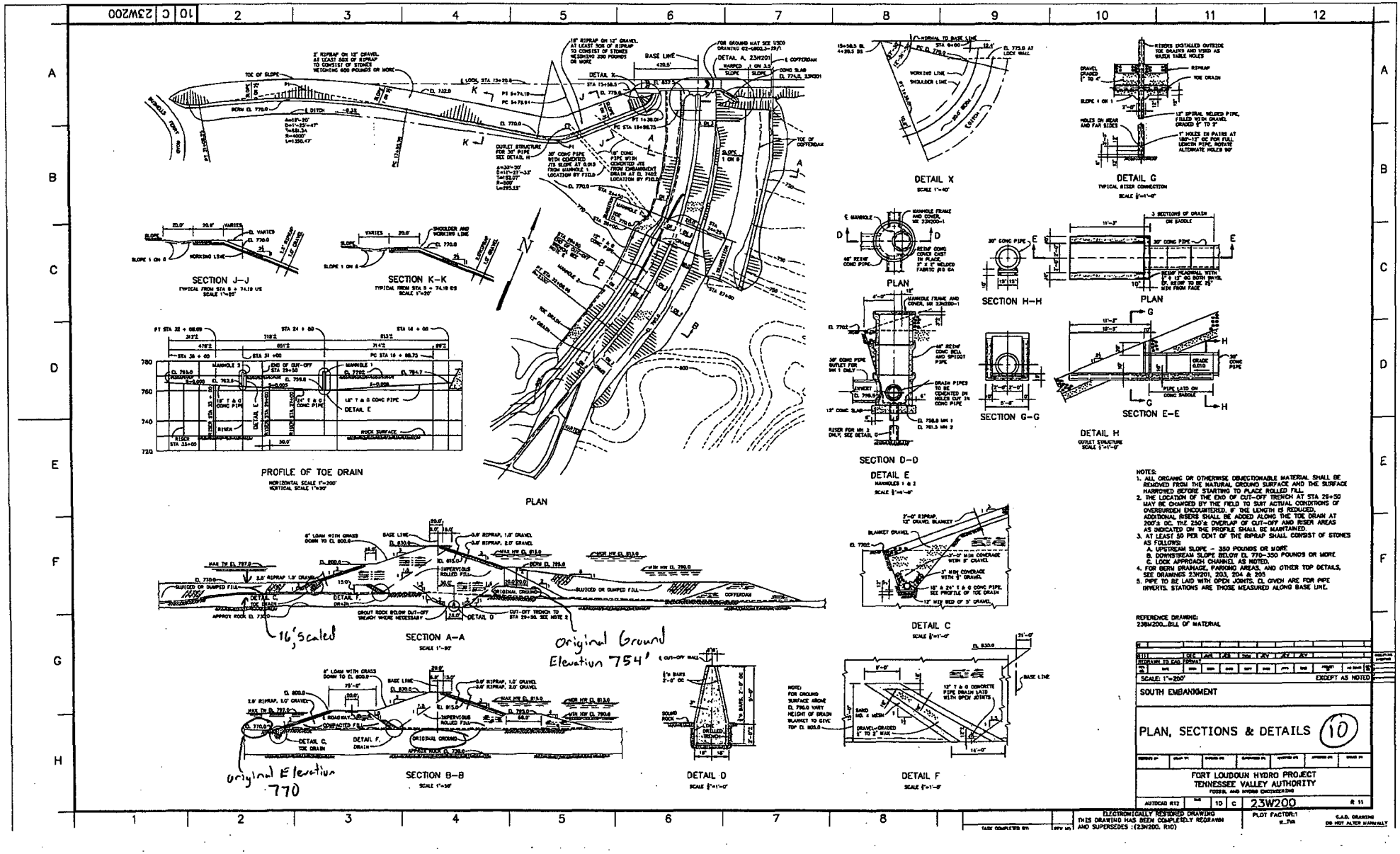
FIGURE 10 : Barrier wall atop south embankment

FIGURE 11 : Barrier wall atop right rim saddle dam (near marina)

Attachment 14-14
14 Pages
Source: Reference 12

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT



Attachment 15-1
1 Page

Calculation CDQ000020080009

Prepared: ATT
Checked: JCT

Fort Loudoun Dam Tailwater Values And Polynomial Fit

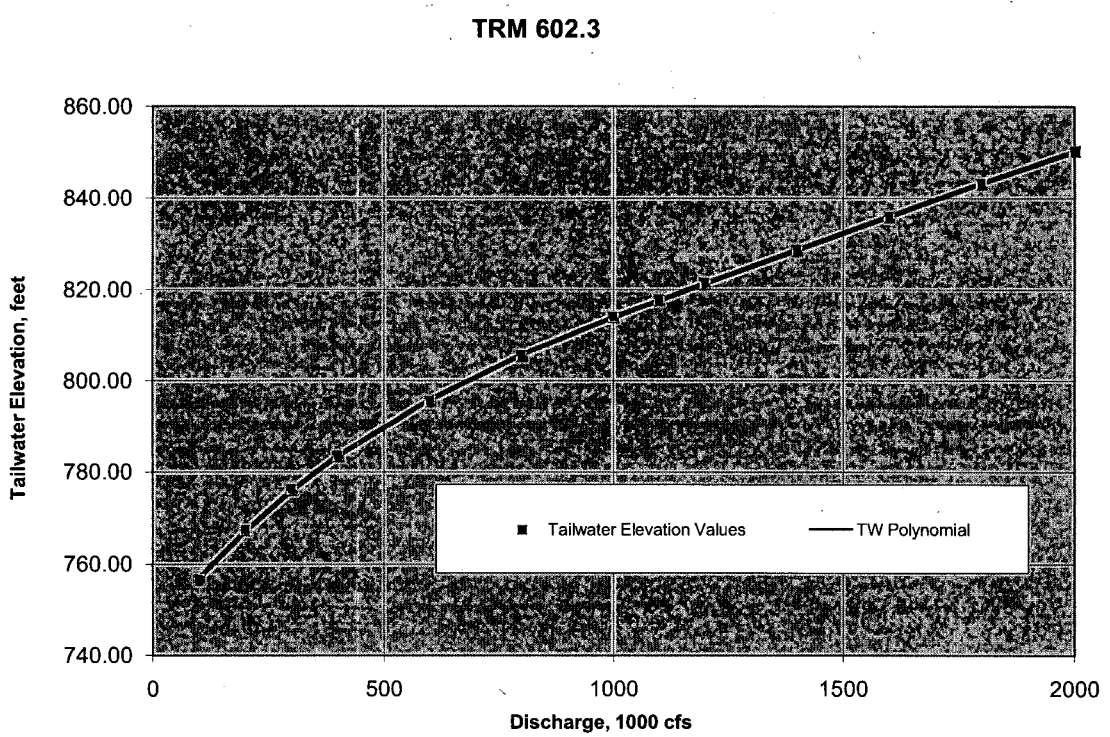
From CDQ000020080037 (Reference 40)

	TRM 602.3 Discharge (1000 cfs)	TW (ft)	TW Polynomial
	100	756.57	756.92
	200	767.51	767.13
	300	776.20	775.92
	400	783.48	783.52
	600	795.51	795.90
	800	805.49	805.65
	1000	813.98	813.86
	1100	817.80	817.65
	1200	821.42	821.35
**	1400	828.66	828.63
**	1600	835.90	835.97
**	1800	843.14	843.30
**	2000	850.38	850.32

* = Points from preliminary SOCH Runs
** = Linearly Extrapolated Points

Polynomial Curve Fit: $TW_{602.3} = 745.07 + 0.1276Q - 0.9492\times10^{-4}Q^2 + 4.350\times10^{-8}Q^3 - 0.7392\times10^{-11}Q^4$

where TW = tailwater elevation in feet and Q = discharge in 1000 cfs



Appendix A: Spillway Discharge Coefficients and Submergence Factors for Watts Bar Dam from 1:35 Scale Model Test Data

TVA has model test data describing the relationships between discharge, headwater, tailwater, and gate opening for most of its spillways. These data, which are the basis for the spillway discharge tables developed for each dam, are used in the dam rating curve calculations. Use of reference book discharge coefficients for standard crests would result in inferior results because TVA's spillway crests are not standard.

Fort Loudoun Dam has fourteen spillway bays, each controlled by a radial (tainter) gate as illustrated in Attachment A1. For initial dam rating curve calculations, the gates are assumed to be opened to their maximum opening position as specified in the Spillway Gate Arrangements table in Reference A1 and included as Attachment A2. As shown in this table, the maximum opening corresponds to reading "U" on the gate position indicators for the spillway. Field measurements of V, the vertical distance between the bottom lip of a raised spillway gate and the spillway crest, are summarized in Attachment A3 (from Reference A2). For gate position indicator reading "U" the average value of V for the fourteen gates is 29.87 feet.

Test data from a 1:35 scale model (circa 1950) are available for free discharge conditions (Reference A3) and for orifice discharge conditions for nine different gate openings varying from V = 1.82 feet to V = 23.83 feet (Reference A4). Orifice discharge data were not collected for gate openings as large as V = 29.87 feet, however, because under normal operating conditions the overflowing nappe will never touch the bottom of a gate open this far. But under the PMF conditions considered for the initial dam rating curves the nappe will touch the gate in this position. Consequently, the data for gate openings V = 23.83, 19.84, 15.86, 11.83, and 7.80 feet are used here to estimate orifice flow discharge characteristics for V = 29.87 feet.

Fort Loudoun, Douglas, and Cherokee Dams all have spillway gates and crests identical to Watts Bar Dam. Consequently, the orifice flow discharge characteristics for these four dams are identical and the orifice relationships provided below apply to all four dams (for the same vertical openings, V, of the gates). The free discharge characteristics vary somewhat with upstream reservoir depth. The free discharge relationships provided below apply to both Watts Bar and Fort Loudoun Dams because they have similar upstream depths, but not to Douglas and Cherokee Dams, which have greater upstream reservoir depths.

A.1 References

A1. "Fort Loudoun Dam Spillway Discharge Tables," River Operations, Tennessee Valley Authority, 2004.
A2. TVA Files, binder "Fort Loudoun, Spillway Rating, 1986"
A3. "Discharge Coefficients for Spillways at TVA Dams," Kenneth W. Kirkpatrick, Paper No. 2855, Transactions of the American Society of Civil Engineers, vol. 22, pp. 190-210, 1957 (Attachment A19)
A4. "Tainter Gate Rating Data Determined from Eight TVA Model Studies," Tennessee Valley Authority, Division of Water Control Planning, Engineering Laboratory, Norris, TN, 1962, RIMS No. L58 080821 001 (Attachment A20)
A5. "Hydraulic Design Criteria," USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988
A6: Dam Rating Curves, Nickajack, TVA Calculation CDQ 000020080014, Appendix A
A7. Open Channel Flow, F. M. Henderson, Macmillan, New York, 1966.
A8. TVA drawing no: 54W200, R6 (Attachments A10 and A21)
A9. TVA drawing no: 51N206, R4 (Attachments A11 and A22)
A10. Dam Rating Curves, Tellico, TVA Calculation CDQ000020080018, Appendix A

A.2 Discharge Equations

Attachment A4 is a definition sketch for flow over the Fort Loudoun Dam spillway. Free discharge occurs for headwater elevations below the elevation at which the overflowing nappe first touches the bottom lip of the gate, or $H_c <= H_{Lmin}$, and is computed using a weir equation (e.g., Reference A5):

$$Q_f = C_f L H_c^{1.5} \quad \text{(A1)}$$

in which Q_f = free discharge (cfs), C_f = free discharge coefficient (($ft^{0.5}/s$ -- varies with H_c), L = length of overflowing section (ft), H_c = head on crest (ft) = HW - Z_c, HW = headwater elevation (ft), and Z_c = top, or crest, elevation of overflowing section (ft).

This equation is modified to account for tailwater submergence as follows:

$$Q_{fs} = Q_f S_f \quad \text{(A2)}$$

in which Q_{fs} = "corrected" free discharge (cfs), S_f = tailwater submergence factor (dimensionless -- varies with d / H_c), d = height of tailwater above crest (ft) = TW - Z_c, and TW = tailwater elevation (ft).

For headwater elevations above the elevation at which the nappe touches the gate lip, or $H_c > H_{Lmin}$, orifice flow occurs and is computed from (e.g., Reference A5):

$$Q_g = C_g G_n L \sqrt{2g(H_c - H_{mp})} \quad \text{(A3)}$$

in which Q_g = orifice discharge (cfs), C_g = orifice discharge coefficient (dimensionless -- varies with gate opening and H_c), G_n = effective gate opening = minimum distance between the gate lip and the crest (ft), g = acceleration of gravity (32.2 ft/s^2 -- common knowledge, Reference A5, sheet. 000-1 for example), and H_{mp} = vertical distance between the mid-point of G_n and the crest.

This equation is modified to account for tailwater submergence as follows:

$$Q_{gs} = S_g Q_g \quad \text{(A4)}$$

in which in which Q_{gs} = "corrected" orifice discharge (cfs) and S_g = tailwater submergence factor (dimensionless -- varies with d / H_c and gate opening, V).

A.3 Model Test Data

The 1:35 scale Watts Bar model test data (References A3 and A4) are used to determine

1.• $C_f(H_c)$ and $S_f(d/H_c)$
2.• H_{Lmin} and $C_g(H_c)$ for V = 29.87 ft.

and the 1:35 scale Nickajack Dam model test data (Reference A6) in conjunction with the 1:72 Tellico Model Data (Reference A10) are used to estimate

3.• $S_g(d/H_c)$ for V = 29.87 ft

Submergence effects on orifice discharge were not evaluated in the Watts Bar model study because under normal operating conditions the tailwater is never high enough to affect orifice discharge. The best data available for estimating submergence effects on orifice discharge through radial gates over a spillway crest are those collected in the model study for Nickajack Dam

(Reference A6) and Tellico Dam (Reference A10). Both dams have somewhat different crest and radial gate parameter values than Fort Loudoun, but its submergence data are normalized in a way that permits their use as an approximation at any dam with radial gates on a spillway crest. The values indicated for the crest and gate configuration in the Kirkpatrick paper (Attachment A19), indicate that submergence will begin to affect discharge at a d/H_c value of 0.4. Nickajack uses a d/H_c of 0.6 as the limiting factor and Tellico uses a d/H_c of 0.2. The average of these two values should produce an adequate estimate of a crest with a limiting d/H_c of 0.4. Use of the averaged Nickajack and Tellico submergence data to estimate submergence effects on orifice discharge at Fort Loudoun is an adequate approximation. Curve fits for $S_g(d/H_c)$ are included as Attachment A5. Note that there was no data for S_g values below 0.35. This data was visually extrapolated to an intersection of (1,0) since the function must pass through this point to be valid. The coordinates defining the curve fits are given in Table A1. The spreadsheets containing the calculations for these data points are included as Attachment A23.

Table A1: Points Defining Curves through averaged Nickajack and Tellico S_g data (Ref. A6, Ref. A10)

H_c/G_n =	1.35		H_c/G_n =	1.50		H_c/G_n =	1.70
d / H_c	S_g		d / H_c	S_g		d / H_c	S_g
0.00	1.000		0.00	1.000		0.00	1.000
0.40	1.000		0.40	1.000		0.40	1.000
0.45	0.990		0.45	0.990		0.45	0.988
0.50	0.984		0.50	0.984		0.50	0.978
0.55	0.973		0.55	0.973		0.55	0.967
0.60	0.961		0.60	0.960		0.60	0.951
0.65	0.938		0.65	0.938		0.65	0.920
0.70	0.902		0.70	0.898		0.70	0.875
0.75	0.856		0.75	0.846		0.75	0.806
0.80	0.794		0.80	0.766		0.80	0.704
0.85	0.697		0.85	0.651		0.85	0.598
0.90	0.570		0.90	0.523		0.90	0.482
0.96	0.350		0.95	0.358		0.94	0.363
0.9875	0.20		0.985	0.20		0.9825	0.20
0.9925	0.10		0.9915	0.10		0.9905	0.10
1.0	0.0		1.0	0.0		1.0	0.0
H_c/G_n =	2.0		H_c/G_n =	2.30			
d / H_c	S_g		d / H_c	S_g			
0.00	1.000		0.00	1.000			
0.40	1.000		0.40	1.000			
0.45	0.986		0.45	0.980			
0.50	0.974		0.50	0.957			
0.55	0.953		0.55	0.929			
0.60	0.917		0.60	0.893			
0.65	0.877		0.65	0.828			
0.70	0.807		0.70	0.748			
0.75	0.714		0.75	0.668			
0.80	0.635		0.80	0.588			
0.85	0.545		0.85	0.505			
0.90	0.444		0.90	0.412			
0.93	0.367		0.92	0.365			
0.98	0.20		0.9775	0.20			
0.9895	0.10		0.9885	0.10			
1.0	0.00		1.0	0.00			

The Watts Bar model test results for $C_f(H_c)$ and $S_f(H_c)$ were published in graphical form in Reference A3 (Attachment A6 and A19). Reference A3 includes results also for orifice discharge but in terms of a different discharge coefficient than the coefficient C_g used here, and Reference A3 includes no information on the relationship between H_{Lmin} and gate opening. However, the

model test data for both orifice and free discharge are tabulated in Reference A4 and these data are used below to estimate H_{Lmin} and $C_g(H_c)$ for V = 29.87 feet and to establish a curve fit for $C_f(H_c)$.

Attachment A6 provides the pages from Reference A3 that are relevant to these calculations. Attachment A7 provides the pages from Reference A4 that are relevant to these calculations. Reference A4 includes a few pages (Attachment A7-4, for example) with penciled corrections by the original author.

Model data are scaled to prototype values using the following scale ratios from Attachment A8 (Reference A7):

1.• V_p/V_m and $H_p/H_m = 35$
2.• $Q_p/Q_m = (35)^{2.5} = 7247.2$

in which H is "head" in feet and represents any water level difference (d of H_c, for example), the p-subscript denotes prototype, and the m-subscript denotes model.

A.4 Geometry

Parameters G_n, H_{mp}, Z_o (gate overflow elevation), and β (angle plotted against discharge coefficient in Reference A5) are computed from crest and gate geometry as described in Attachment A9. Table A2 gives the values of these parameters for V = 7.80, 11.83, 15.86, 19.84, 23.83, and 29.87 feet.

Table A2: Geometrical Parameters for Relevant Gate Openings

V, feet	G_n, feet	H_{mp}, feet	Z_o, feet	β, deg.
0	0	0	815.00	62.10
7.80	7.86	3.89	821.27	77.56
11.83	11.85	5.93	823.76	84.65
15.86	15.89	7.95	825.87	91.37
19.84	19.91	9.93	827.56	97.75
23.83	23.99	11.89	828.85	104.04
29.87	30.314	14.828	829.92	113.65

As an example, the procedure for computing the geometrical parameters for V = 29.87 feet is given here. From Attachment A10 (Reference A8),

1.• R = 35 feet
2.• Z_c = 783 feet
3.• Z_{tr} = 795 feet
4.• z_1 = 795 – 782.636 = 12.364 feet
5.• z_2 =815 - 795 = 20.0 feet

where the parameters are defined in Attachment A9-2. Referring to Attachment A9:

Angle θ:
$$\theta = \sin^{-1}\left(\frac{12.364}{35}\right) + \sin^{-1}\left(\frac{20.0}{35}\right) = 55.537°$$

Angle α:
$$\alpha = \tan^{-1}\left(\frac{795 - 783 - 29.87}{\sqrt{35^2 - (795 - 783 - 29.87)^2}}\right) = -30.702°$$

Overflow elevation Z_o: $Z_o = 795 + 35\sin[55.537 - (-30.702)] = 829.92\,feet$

Gate lip y-coordinate: $y_\ell = 795 - 783 - 29.87 = -17.87\ feet$

Gate lip x-coordinate: $x_\ell = \sqrt{35^2 - (-17.87)^2} = 30.6384\ feet$

From Attachment A11 (Reference A9):

$$y_s^* = f(x_s^*) = 0.045 + \frac{x_s^* - 8.38}{10} + \frac{(x_s^* - 8.38)^2}{127} \quad \text{for } x_s^* \geq 0$$

in which $y_s^* = y_s - 12$ and $x_x^* = 43.708 - x_s$. In terms of y_s and x_s:

$$y_s = f(x_s) = 25.4051 - 83.356\left(\frac{x_s}{127}\right) + 127\left(\frac{x_s}{127}\right)^2 \quad \text{for} \quad x_s \leq 35.328 \text{ feet}$$

and

$$\frac{dy_s}{dx_s} = -0.65635 + \frac{x_s}{63.5}$$

To get effective gate opening, G_n, solve the following equation for x_{sn}:

$$x_{sn} - 30.6384 + \left[25.4051 - 83.356\left(\frac{x_{sn}}{127}\right) + 127\left(\frac{x_{sn}}{127}\right)^2 - (-17.87)\right]\left[-0.65635 + \frac{x_{sn}}{63.5}\right] = 0$$

Solution:

1.• $x_{sn} = 33.818$ feet (by iteration)
2.• $y_{sn} = 25.4051 - 83.356(33.818/127) + 127(33.818/127)^2 = 12.214$
3.• $G_n = \sqrt{(33.818 - 30.6384)^2 + (12.214 - (-17.87))^2} = 30.31\ feet$

and

1.• $H_{mp} = 29.87 - [12.214 - (-17.87)]/2 = 14.83$ feet
2.• $\beta = \frac{\pi}{2} - \tan^{-1}\left(\frac{-17.87}{30.6384}\right) - \tan^{-1}\left(\frac{33.818 - 30.6384}{12.214 - (-17.87)}\right) = 113.65°$

A.5 Determination of $H_{Lmin}(V)$

Attachment A12 shows the model test data (Attachment A7) for H_{Lmin} and a polynomial curve fit to the data (spreadsheet included as Attachment A18). A value of H_{Lmin} for V = 29.87 feet is established by using the polynomial to extrapolate the data. The following is used for the dam rating curve calculations:

H_{Lmin} = 37.94 feet for V = 29.87 feet.

A.6 Determination of $C_f(H_c)$ and $S_f(d/H_c)$

Attachment A13 shows the model test data for free discharge (Attachment A7) and a polynomial curve fit to the data. The "6.866" in the "Definition" was the length of the model crest in feet (Attachment A7). The polynomial indicated in Attachment A13 is used to calculate the free discharge coefficient for flow over the crest for the dam rating curve calculations:

$$C_f = 3.09 + 0.055033H_c - 0.0022844H_c^2 + 5.9044x10^{-5}H_c^3 - 5.507x10^{-7}H_c^4 \quad \text{(A5)}$$

A plot of C_s/C (S_f) vs. d/H (d/H_c) for Watts Bar Dam is provided in Reference A3. The points listed in Attachment A14 were scaled off this plot (Attachment A6) and, as shown on the plot of S_f vs. d/H_c in Attachment A14, the following equation was fit to the scaled points:

$$S_f = \left[1 - \left(\frac{d}{H_c}\right)^{8.3}\right]^{0.55} \quad \text{(A6)}$$

This equation is used for the dam rating calculations.

A.7 Determination of $C_g(H_c)$ for V = 29.87 feet

Attachment A15 shows the calculations and results for extrapolating $C_g(H_c)$ for V = 29.87 feet from the model data for other gate openings. The first column in Attachment A15 indicates the data for which $H_c = H_{Lmin}$, at which H_c is just high enough to touch the bottom of the gate. The discharge indicated for V = 29.87 feet at $H_c = H_{Lmin}$ is the free discharge computed from Equation A1 using $C_f(H_c)$ from the polynomial in Attachment A13. The first three numerical columns list the model data (scaled to prototype dimensions) for V = 7.8, 11.83, 15.86, 19.84, and 23.83 feet as listed in Attachments A7-4 and A7-5. The rows that do not include values of discharge, Q, were added to extrapolate the data. The next two columns after the model data list prototype geometrical parameters. The next column after the geometrical parameters lists the C_g values computed from the data. The last numerical column lists values used for drawing lines through the data points and extending them to H_c = 60 feet (Attachment A16). Values outside the data range were estimated for extrapolation purposes and are labeled as such to the right of the last column.

Attachment A16 shows C_g plotted against H_c for all gate openings. The model data points are shown along with lines drawn through the data and extended to H_c = 60 feet. The estimated curve for V = 29.87 feet starts with the value for $H_c = H_{Lmin}$ and runs approximately parallel to the curve for V = 23.83 feet. Given the absence of data, this extrapolated line segment fit for $C_g(H_c)$ at V = 29.87 feet is used for the dam rating calculations. Table A3 lists the points describing the extrapolated relationship.

Table A3: Points Defining Extrapolated Curve for $C_g(H_c)$ at V = 29.87 feet.

H_c, feet	C_g
37.94	0.794
42	0.720
48	0.711
60	0.711

As justification for the extrapolation, Attachment A17 shows the Fort Loudoun C_g values at H_c = 60 feet plotted against angle β on Hydraulic Design Chart 311-1 from Reference A5 showing U.S. Army Corps of Engineers data for tainter gates on standard

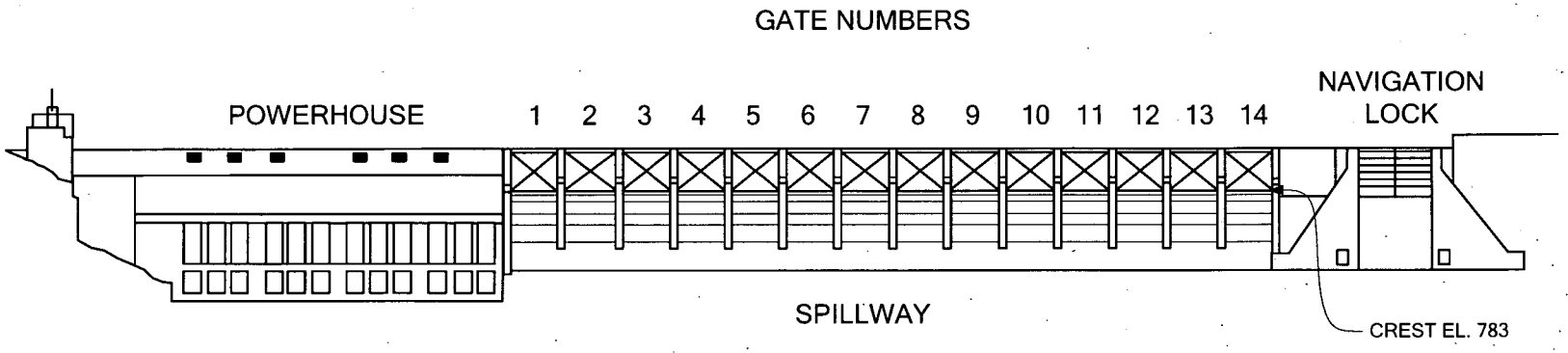
crests. The value of X/H_d for Fort Loudoun is 0.15 (X = 3.43 feet, Attachment A10, and H_d = 23.5 feet, Attachment A7-1). Note the design head used is actually Watts Bar's design head since the crests and configurations are identical. Because TVA's spillway crests are not standard, TVA data always lie to the left of the suggested design curves on this chart. Note that C_g = 0.711 at H_c = 60 feet and V = 29.87 feet (β = 113.65 degrees) is a very reasonable extrapolation of the Watts Bar data curve and appears reasonable compared with the suggested design curves on the chart.

Attachment A1
1 Page
Source: Reference A1

Calculation CDQ000020080009

FORT LOUDOUN DAM

LOCATION OF SPILLWAY GATES



DOWNSTREAM ELEVATION

Attachment A2
1 Page
Source: Reference A1

Calculation CDQ000020080009

FORT LOUDOUN DAM

SPILLWAY GATE ARRANGEMENTS

Gate Arrange-ment	Gate Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
61	14	10	14	10	14	10	14	10	14	10	10	10	10	10
62	14	10	14	10	14	10	14	10	14	10	14	10	10	10
63	14	10	14	10	14	10	14	10	14	10	14	10	14	10
64	14	10	14	10	14	10	14	10	14	10	14	10	14	14
65	14	10	14	10	14	10	14	10	14	10	14	14	14	14
66	14	10	14	10	14	10	14	10	14	14	14	14	14	14
67	14	10	14	10	14	10	14	14	14	14	14	14	14	14
68	14	10	14	10	14	14	14	14	14	14	14	14	14	14
69	14	10	14	14	14	14	14	14	14	14	14	14	14	14
70	14	14	14	14	14	14	14	14	14	14	14	14	14	14
71	18	14	14	14	14	14	14	14	14	14	14	14	14	14
72	18	14	18	14	14	14	14	14	14	14	14	14	14	14
73	18	14	18	14	18	14	14	14	14	14	14	14	14	14
74	18	14	18	14	18	14	18	14	14	14	14	14	14	14
75	18	14	18	14	18	14	18	14	18	14	14	14	14	14
76	18	14	18	14	18	14	18	14	18	14	18	14	14	14
77	18	14	18	14	18	14	18	14	18	14	18	14	18	14
78	18	14	18	14	18	14	18	14	18	14	18	14	18	18
79	18	14	18	14	18	14	18	14	18	14	18	18	18	18
80	18	14	18	14	18	14	18	14	18	18	18	18	18	18
81	18	14	18	14	18	14	18	18	18	18	18	18	18	18
82	18	14	18	14	18	18	18	18	18	18	18	18	18	18
83	18	14	18	18	18	18	18	18	18	18	18	18	18	18
84	18	18	18	18	18	18	18	18	18	18	18	18	18	18
85	22	18	22	18	18	18	18	18	18	18	18	18	18	18
86	22	18	22	18	22	18	22	18	18	18	18	18	18	18
87	22	18	22	18	22	18	22	18	22	18	22	18	18	18
88	22	18	22	18	22	18	22	18	22	18	22	18	22	22
89	22	18	22	18	22	18	22	18	22	22	22	22	22	22
90	22	18	22	18	22	22	22	22	22	22	22	22	22	22

Gate Arrange-ment	Gate Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
91	22	22	22	22	22	22	22	22	22	22	22	22	22	22
92	26	22	26	22	22	22	22	22	22	22	22	22	22	22
93	26	22	26	22	26	22	26	22	22	22	22	22	22	22
94	26	22	26	22	26	22	26	22	26	22	26	22	22	22
95	26	22	26	22	26	22	26	22	26	22	26	22	26	26
96	26	22	26	22	26	22	26	22	26	26	26	26	26	26
97	26	22	26	22	26	26	26	26	26	26	26	26	26	26
98	26	26	26	26	26	26	26	26	26	26	26	26	26	26
99	30	26	30	26	26	26	26	26	26	26	26	26	26	26
100	30	26	30	26	30	26	30	26	26	26	26	26	26	26
101	30	26	30	26	30	26	30	26	30	26	30	26	26	26
102	30	26	30	26	30	26	30	26	30	26	30	26	30	30
103	30	26	30	26	30	26	30	26	30	30	30	30	30	30
104	30	26	30	26	30	30	30	30	30	30	30	30	30	30
105	30	30	30	30	30	30	30	30	30	30	30	30	30	30
106	34	30	34	30	30	30	30	30	30	30	30	30	30	30
107	34	30	34	30	34	30	34	30	30	30	30	30	30	30
108	34	30	34	30	34	30	34	30	34	30	34	30	30	30
109	34	30	34	30	34	30	34	30	34	30	34	30	34	34
110	34	30	34	30	34	30	34	30	34	34	34	34	34	34
111	34	30	34	30	34	34	34	34	34	34	34	34	34	34
112	34	34	34	34	34	34	34	34	34	34	34	34	34	34
113	U	34	U	34	34	34	34	34	34	34	34	34	34	34
114	U	34	U	34	U	34	U	34	34	34	34	34	34	34
115	U	34	U	34	U	34	U	34	U	34	U	34	34	34
116	U	34	U	34	U	34	U	34	U	34	U	34	U	U
117	U	34	U	34	U	34	U	34	U	U	U	U	U	U
118	U	34	U	34	U	U	U	U	U	U	U	U	U	U
119	U	U	U	U	U	U	U	U	U	U	U	U	U	U

GATE OPENINGS

Figures in columns under each gate number refer to gate opening indicator reading
dash (-) indicates closed gate
U indicates gate raised above water surface or to maximimum open position

(DES-11-76)

Calculation No: CDQ000020080009

Attachment A3
1 Page
Source: Reference A2

1985 GATE OPENING MEASUREMENTS — FT. LOUDOUN SPILLWAY GATES

TOR NUMBERS AND CHAIN LINKS

LAGE OF L & R MEASUREMENTS)

TO GATE BOTTOM

COMPUTED JBOYD DATE 8-23-85

CHECKED _____ DATE _____

CHAIN LINK		0	2	6	10	12	18	26	34	42	50	58	74
INDICATOR		0	2	6	8	10	14	18	22	26	30	34	MAX
GATE NUMBER			DISTANCE, (feet) CREST TO GATE BOTTOM (-) = BELOW CREST EL.										
	1	*	.061	1.595	3.245	4.045	6.473	9.753	13.053	16.338	19.583	22.795	30.000
	7	⊙	-0.300 ~~.437~~	1.335	2.995	3.805	6.260	9.570	12.900	16.223	19.510	22.750	29.918
	10		.095	1.750	3.360	4.160	6.868	9.873	13.170	16.448	19.745	22.948	30.025
	12		-0.277	1.353	2.955	3.803	6.255	9.578	12.905	16.223	19.505	23.005	29.905
	13		-0.134	1.533	3.130	3.960	6.340	9.675	13.008	16.295	19.545	22.798	29.923
X	14	⊙	-0.500 ~~-0.184~~	2.260	3.510	4.678	7.131	10.416	13.765	17.060	20.314	23.548	30.000

⊙ slope adjusted, INDICATOR #2 (see 2 of 2)

CHAIN LINK		0	4	8	12	14	20	28	36	44	52	60	74
INDICATOR		0	2	6	8	10	14	18	22	26	30	34	MAX
			DISTANCE, (feet) CREST TO GATE BOTTOM (-) = Below Crest EL.										
	2	*	.828	2.360	4.025	4.830	7.270	10.560	13.865	17.140	20.385	23.590	29.900
	3		.759	1.975	3.928	4.740	7.190	10.495	13.805	17.095	20.345	23.568	29.880
	4		.799	2.380	4.058	4.860	7.310	10.608	13.905	17.188	20.428	23.645	29.920
	5		.686	2.245	3.910	4.718	7.165	10.475	13.788	17.078	20.330	23.560	29.925
X	6		.219	1.810	3.460	4.280	6.685	9.955	13.233	16.505	19.728	22.925	29.875
	8	⊙	-0.800 ~~1.535~~	2.535	4.208	5.008	7.450	10.730	13.985	17.308	20.545	23.768	30.000
	9	⊙	-0.900 ~~1.316~~	2.490	4.130	4.945	7.385	10.678	13.975	17.240	20.480	23.693	29.995
	11		.492	2.146	3.810	4.618	7.085	10.405	13.888	17.035	20.303	23.555	29.993

* see 3 of 3 for like-gate groupings used for 1986 Rating

X SINGLE GATE GROUP

TVA 489 (EN DES-11-76)

SHEET ____ OF ____

Attachment A4
1 Page

Calculation No: CDQ000020080009

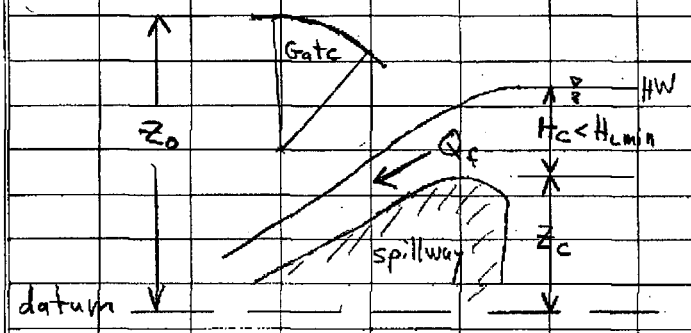
Definition Sketch for Spillway Discharge

COMPUTED GAS

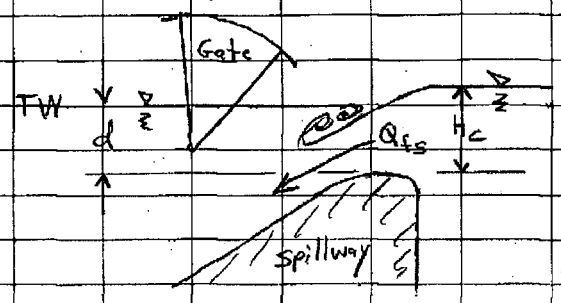
CHECKED ____ DATE ____

Prepared: GAS
Checked: JCT

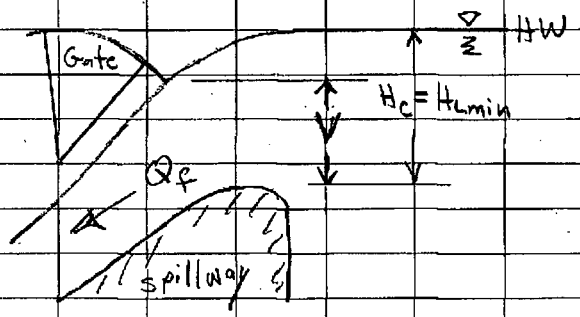
Free Discharge - No Tailwater effect



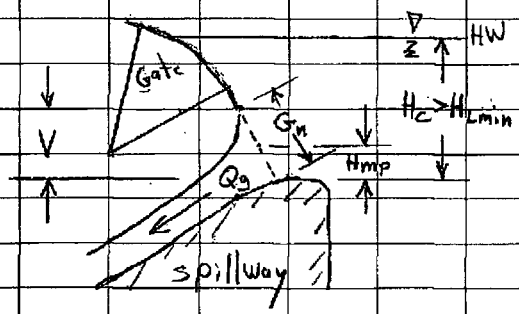
Free Discharge affected by Tailwater



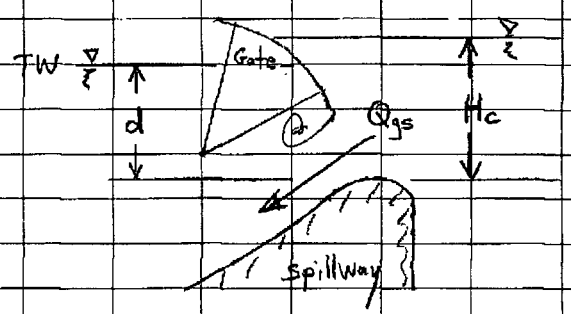
Nappe Touches Gate



Orifice Discharge - No Tailwater Effect



Orifice Discharge affected by Tailwater

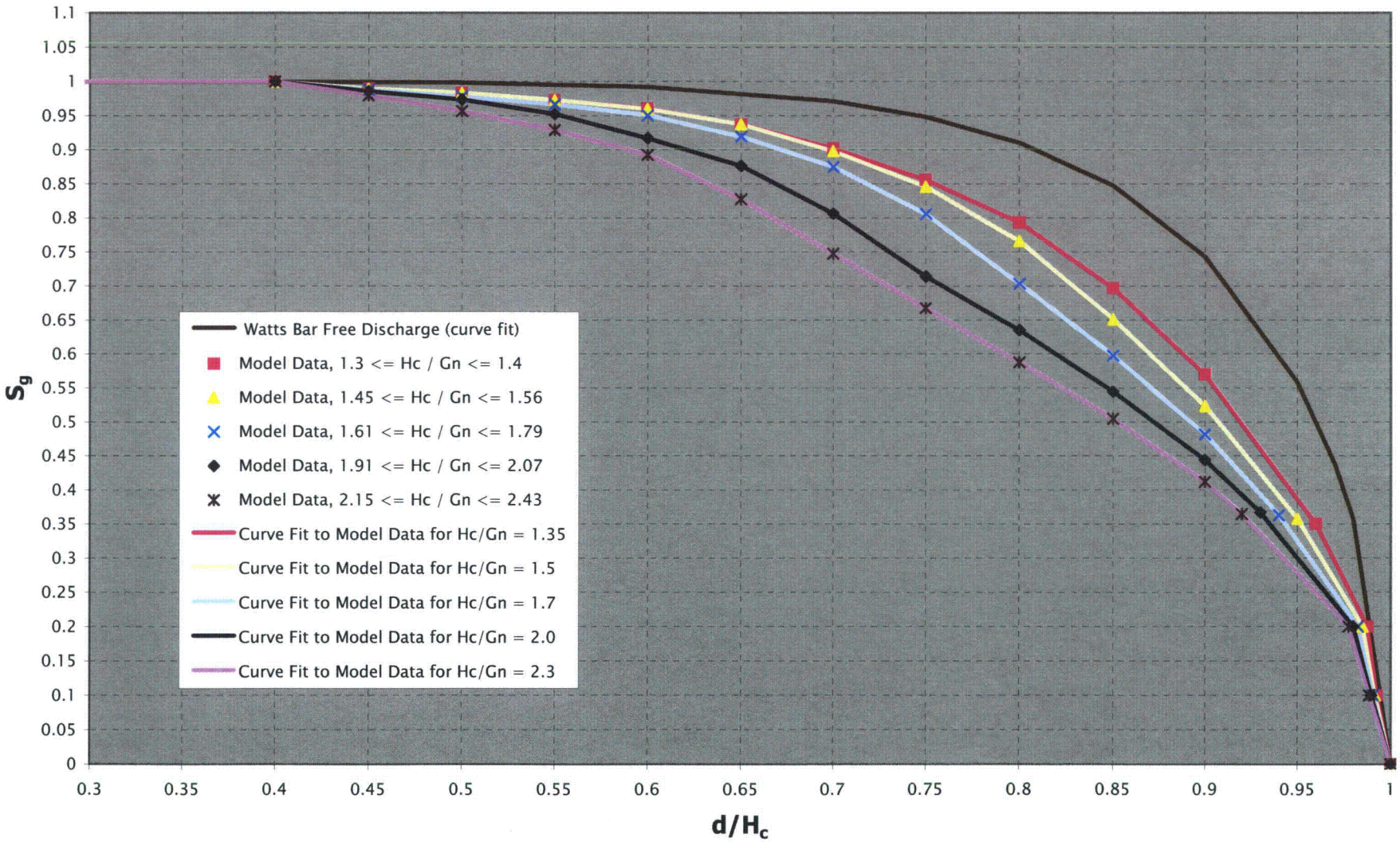


Attachment A5
1 Page
Source: Reference A6 and A10

Calculation No: CDQ000020080009

Prepared: ATT
Checked: JCT

Submergence Factors for Radial Gates on Spillway Crests
Average Between Tellico Dam and Nickajack Model Data
d/H_c >.4



Attachment A6-1
5 Pages
Source: Reference A3

ol. 22, pp. 190-210, 1957

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TRANSACTIONS

Paper No. 2855

DISCHARGE COEFFICIENTS FOR SPILLWAYS AT TVA DAMS

By Kenneth W. Kirkpatrick,[1] A. M. ASCE

Synopsis

Spillway ratings derived from model studies have been used in the preparation of spillway rating tables for the Tennessee Valley Authority dams. As a result of these studies, discharge coefficients for eleven of the Tennessee Valley Authority dams are given in this paper. Coefficients for both submerged and free discharge conditions are presented for discharges over standard spillway crests, irregular spillway crests, and a vertical-lift spillway gate. Discharge coefficients for Tainter gates placed on curved spillway crests are also given for various gate openings under free discharge conditions. In addition, data on the effect of model scale on the discharge coefficient and the effect of closing adjacent spillway bays and gates are presented. The coefficient relationships are shown in a form that may be used by designers as a guide in making determinations of the discharges for future spillways.

Notation

The letter symbols adopted for use in this paper are defined where they first appear, in the illustrations or in the text, and are arranged alphabetically, for convenience of reference, in the Appendix.

Introduction

The Tennessee Valley Authority (TVA) operates a system of nine dams on the Tennessee River and twenty-three on the tributary rivers. The successful operation of such a system requires accurate discharge ratings for each structure. Although enough water is seldom available to make complete ratings for most spillways from measurements conducted on the prototype structure, ratings can be determined from scale model tests. Therefore, the necessary ratings for the TVA spillways have been determined by this means. Model studies have been made at the TVA Hydraulic Laboratory at Norris, Tenn.,

Note.—Published, essentially as printed here, in February, 1955, as *Proceedings-Separate No. 626*. Positions and titles given are those in effect when the paper was approved for publication in *Transactions*.

[1] Hydr. Engr., Hydr. Lab., Tennessee Valley Authority, Norris, Tenn.

Calculation No: CDQ000020080009

on nine different spillway crest shapes equipped with three types of control gates.

Seven of the nine crests were curved sections which approximated the shape of the lower nappe of a sharp-crested weir. The other two crests were flat. The two flat-crested weirs and one of the curved crests were equipped with double-leaf vertical lift gates. Five of the curved crests were equipped with Tainter gates and the other with vertical lift gates.

Data Presented.—Data are presented for the following conditions: (1) Free, ungated flow through a series of spillway bays; (2) submerged, ungated flow through a series of spillway bays; (3) free, ungated flow through a series of spillway bays, with adjacent bays fully open or closed; (4) free flow over a vertical lift gate; (5) submerged flow over a vertical lift gate; (6) flow under a series of Tainter gates set with equal openings; and (7) flow under a series of Tainter gates with adjacent gates closed.

Data are also presented to show the effect of model scale for the condition of free, ungated flow through a series of spillway bays.

General Model Arrangement.—The models were tested in flumes either 3.5 ft wide or 8 ft wide. Models installed in the smaller flume usually consisted of a reproduction of three of the prototype spillway bays. In the larger flume five or six spillway bays were reproduced. Each of these flumes was provided with glass panels for observation purposes. The models placed in the larger flume were constructed at scale ratios of from 1:28.72 to 1:50 with a ratio of approximately 1:35 generally used. Those tested in the smaller flume were built at scale ratios of 1:50, 1:100, and 1:200.

The models were usually provided with concrete crests and concrete piers to insure dimensional stability. Half piers were constructed on the ends of each model. If the model did not completely fill the flume one side was placed against the glass side of the flume and the other against a false wall. The river bed upstream and downstream from the model was reproduced at the elevation of the prototype river bed. Suitable baffling was provided to obtain a uniform distribution of flow in the spillway approach channel. The tailwater level was controlled at the end of the flumes by means of slat gates. Model discharges were determined from readings of a carefully calibrated diaphragm orifice located in the water supply line.

Headwater heights were measured at two piezometers at distances equal to approximately 5 and 8 times the design head upstream from the spillway crest. Tailwater heights were obtained at 2 piezometers at distances equal to approximately 9 and 12 times the design head downstream from the spillway crest—in all cases, sufficiently far enough downstream to eliminate the effect of the spillway apron.

In most studies the headwater and tailwater levels were determined by means of hook gages reading to 0.001 ft. For the 1/200-scale model the heads were measured with a micrometer point gage reading to 0.0001 ft.

Discharge Equations.—The model data have been reduced by the use of two commonly accepted discharge equations. For both free and submerged flow over a spillway crest the equation,

$$Q = C\,L\,H^{3/2} \qquad (1)$$

Attachment A6-2
5 Pages
Source: Reference A3

was used, in which Q is the discharge in cubic feet per second, C is the coefficient of discharge determined from the model tests, L is the length of the crest, and H is the total head as shown in Fig. 1(*a*). Use was made of the same equation in the reduction of the data for free and submerged flows over a vertical gate with D, H, d, and P (Fig. 1(*a*)) being measured from the top of the gate.

For flow under a gate the equation for a rectangular orifice under low head,

$$Q = C\,L\,[H^{3/2} - (D_1 + h)^{3/2}] \qquad (2)$$

was used, in which D_1 is the depth of water to the bottom of the gate as defined in Fig. 1(*b*) and h is the approach velocity head.

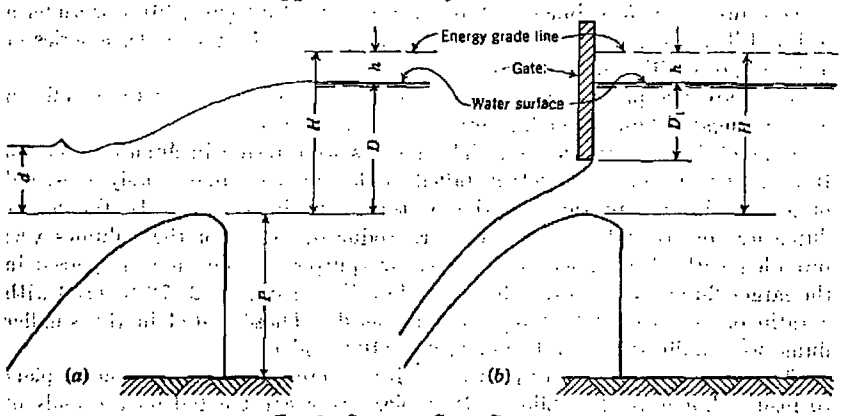

FIG. 1.—SPILLWAY-CREST DIAGRAM

FREE-DISCHARGE COEFFICIENTS, FLOW OVER SPILLWAY CRESTS

It is common practice for engineers to design spillway crests to approximate closely the shape of the lower portion of a jet issuing from a sharp-crested weir, and this type of crest is designated a standard crest.[2] Because the shape of the jet changes with the head on the weir, some particular head must be used for each design. This head for which a particular crest is designed is termed the design head. At this head, pressures approximating atmospheric pressure are developed at the spillway surface. At smaller heads, pressures are greater than atmospheric. Seven of the nine TVA crests for which data are available approximate standard crests in shape whereas the other two crests, which are flat, do not. Fig. 2 shows the basic details and dimensions of each of these crests. Fig. 3 presents the coefficient data obtained on the crests of Fig. 2. Pertinent design data concerning each crest, together with the scale to which each was modeled, appear in Table 1. Eleven spillways are also listed in Table 1. Two pairs of these, the Ocoee No. 3-Apalachia set, and the Douglas-Watts Bar set, both in Tennessee, have crest shapes that are identical within the pair but which were tested for different values of the approach depth, P.

[2] "Hydroelectric Handbook," by W. P. Creager and J. D. Justin, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1950.

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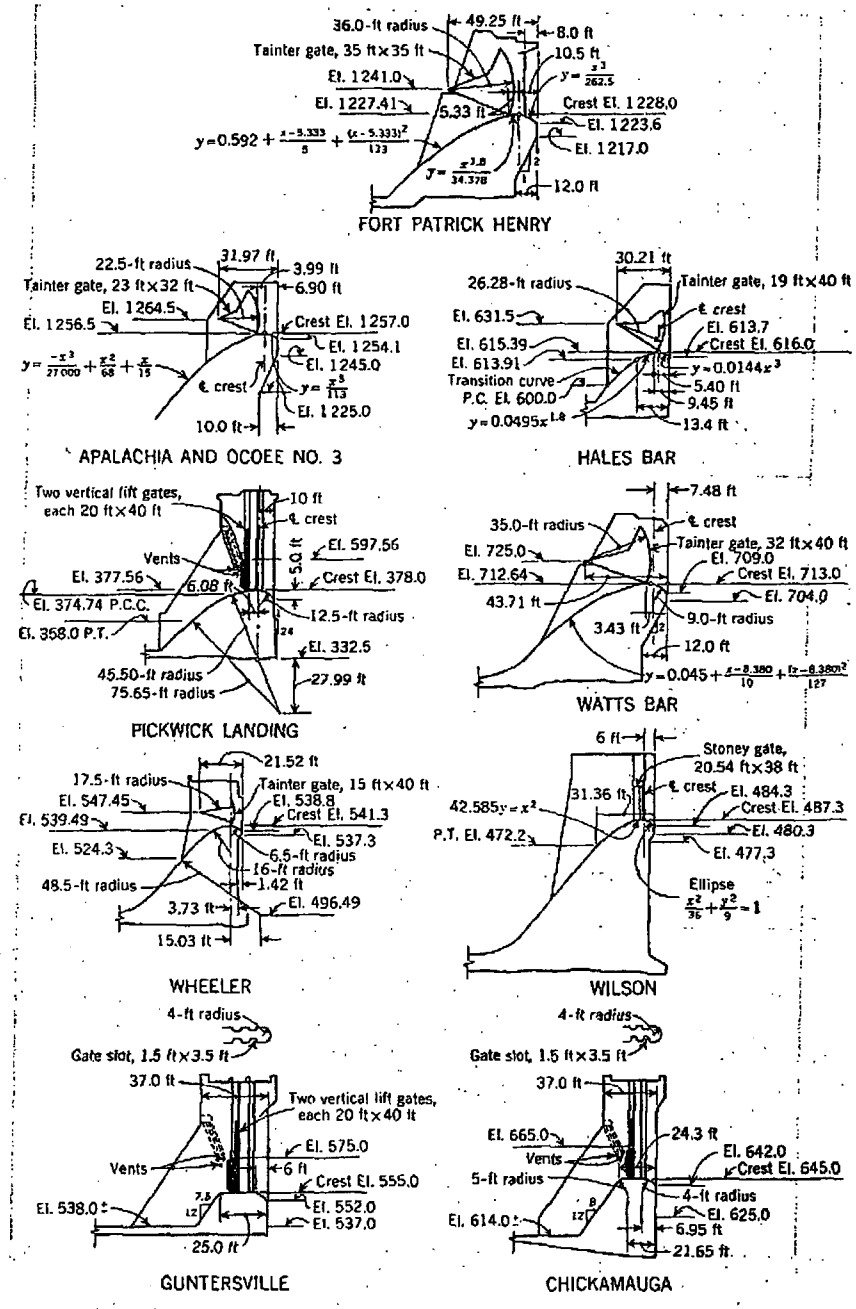

FIG. 2.—TVA SPILLWAY CRESTS (DATA IN FIG. 3)

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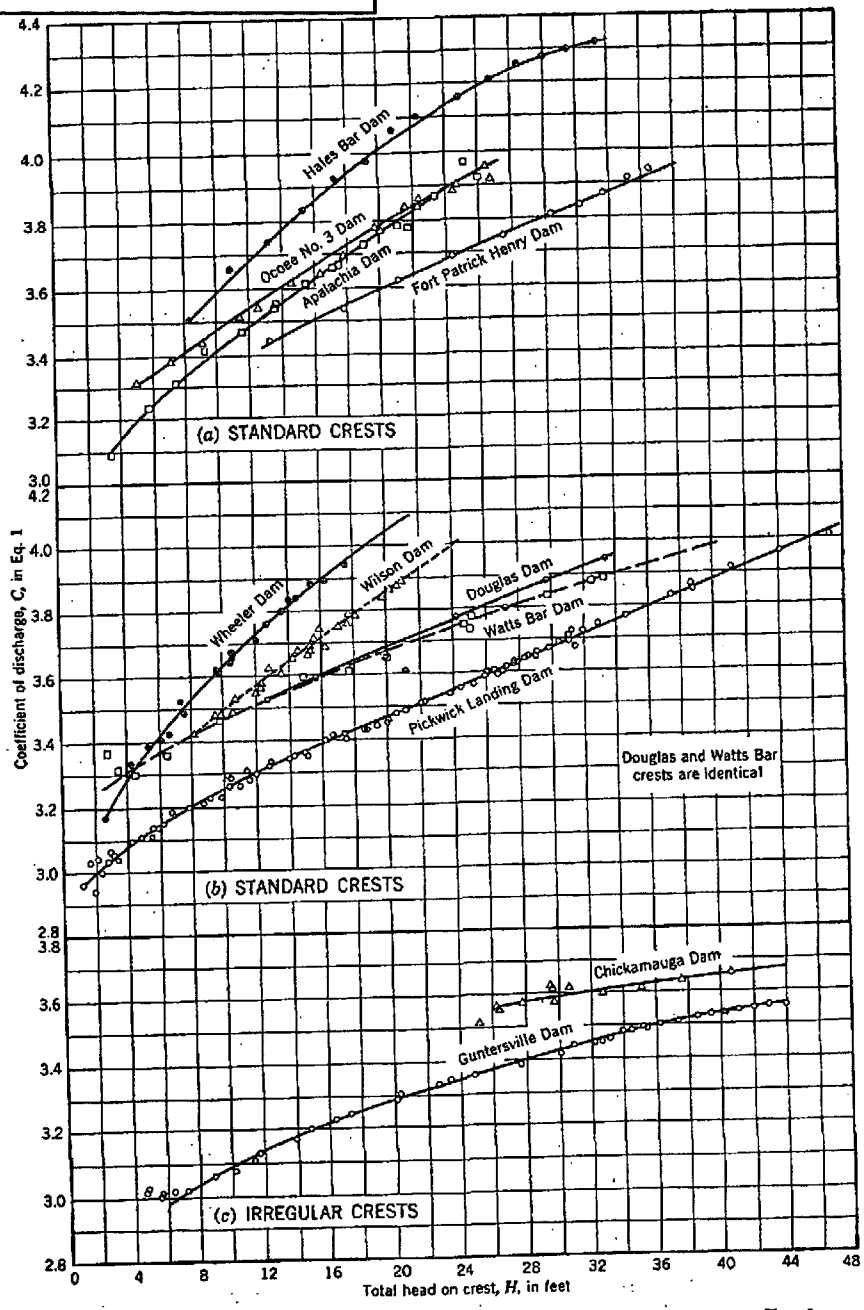

FIG. 3.—DISCHARGE COEFFICIENTS FOR FREE FLOW OVER THE SPILLWAY CRESTS OF FIG. 2

Calculation No: CDQ000020080009

The accuracy of the data is evidenced by the plotting of the data points in Fig. 3. Except in some cases at low heads, the deviation of any plotted point from the coefficient curve does not exceed 0.5%.

Standard Crests.—It has been shown by various authors that the discharge coefficients for all standard crests can be related to each other and that, conversely, the coefficients to be used for a new design can be taken from previous test data.[2,3,4,5] Unfortunately, in most crest designs, due to other design considerations, it is necessary that the shape be varied from the standard form. Nevertheless, satisfactory coefficients can be obtained as sufficient data are now available on a range of crest shapes. By comparison of crest shapes designers may select a coefficient for any particular crest.

Dimensionless plotting provides a means for comparison of crest shapes. This method is used in Fig. 4 on which seven TVA crests which closely approximate standard crests are shown by the solid lines, with the dashed line representing a standard crest shape.[2] The horizontal coordinate, x, and the vertical coordinate, y, of the crest curve have been divided by the design head, H_o.

TABLE 1.—DESIGN DATA FOR ELEVEN MODELS OF TVA SPILLWAYS

Project	Model scale	Design head, H_o, in feet	Upstream depth, P, in feet	$\frac{H_o}{P}$	Pier nose radius, in feet
Hales Bar	1:34.76	18	32	0.56	3.00
Ocoee No. 3	1:28.72	23	67	0.35	3.00
Apalachia	1:28.72	23	97	0.24	3.00
Fort Patrick Henry	1:50	35	43	0.81	3.25
Wheeler	1:34.35	16.5	43	0.38	2.50
Wilson	1:39.4	19	75	0.25	4.00
Douglas	1:35	23.5	133	0.18	3.25
Watts Bar	1:35	23.5	52	0.45	3.25
Pickwick Landing	1:50	31.5	32	0.98	3.75
Chickamauga	1:50		20		4.00
Guntersville	1:50		18		4.00

The design head was determined by fitting the real and standard curves at the crest point ($x = 0$) and at the intersection of the curve with the upstream vertical face. These design-head values are presented in Table 1. The design-head discharge coefficients (C_o) determined from Fig. 3 are shown in Fig. 4.

The TVA crests all fairly closely approximate the standard curve from the upstream spillway face to a point somewhere downstream from the crest which was determined by the position of the gate seal. Below this latter point, the crest shape was modified to fit the trajectory of a jet issuing from under the gate when set at a small opening. The upstream face for a standard crest is vertical. The upstream face of the TVA crests, as shown in Fig. 4, deviates from the vertical. Other experimenters have established the fact that the shape of the upstream face generally has little influence on the discharge coefficient.[3]

[2] "Final Reports of Boulder Canyon Project," *Bulletin No. 3*, Part VI, Hydraulic Investigations, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1947.

[4] "Engineering Hydraulics," edited by Hunter Rouse, John Wiley & Sons, Inc., New York, N. Y., 1950.

[5] "Discharge Coefficients for Irregular Overfall Spillways," by J. N. Bradley, *Engineering Monograph No. 9*, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1952.

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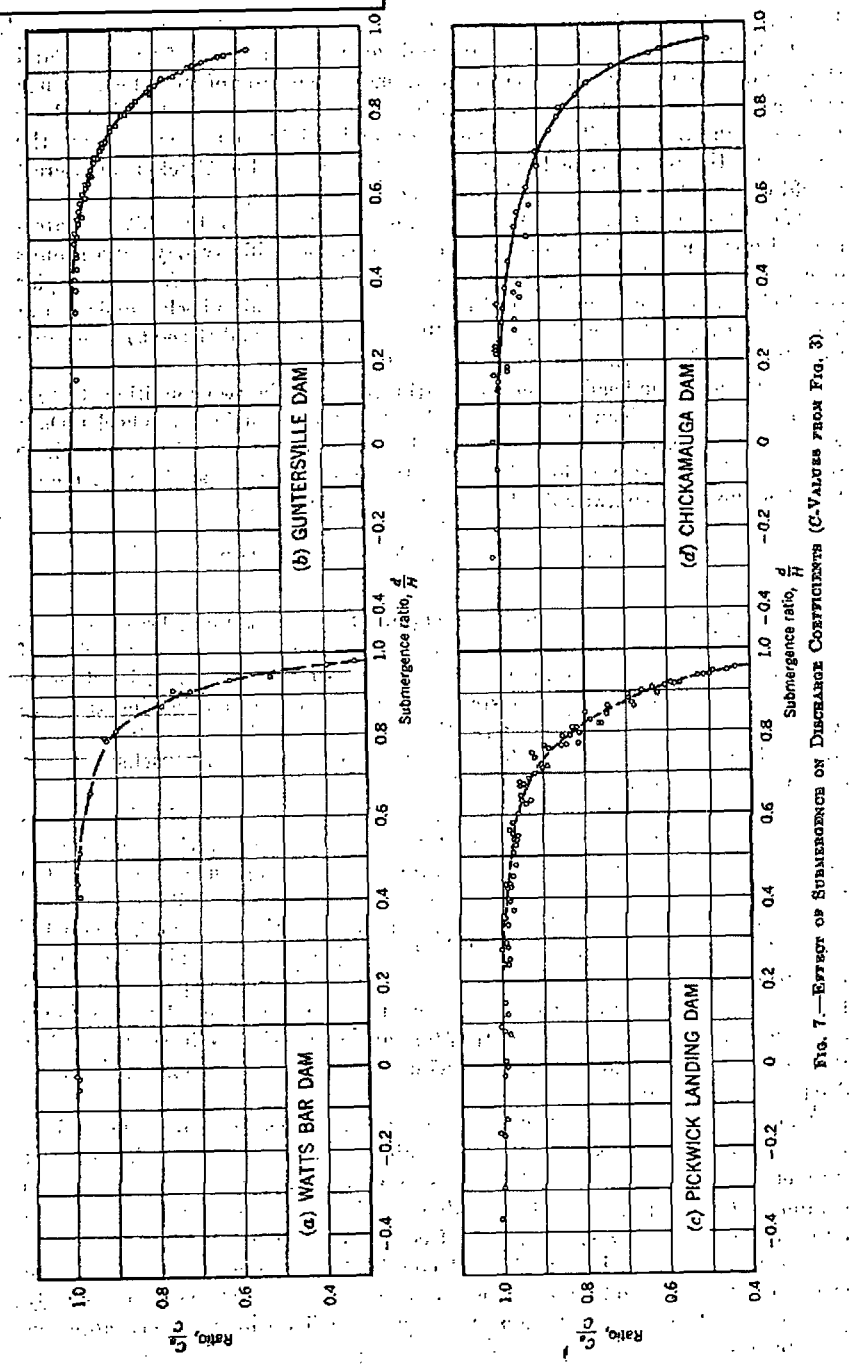

FIG. 7.—EFFECT OF SUBMERGENCE ON DISCHARGE COEFFICIENTS (C-VALUES FROM FIG. 3).

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In Fig. 8 the four curves of Fig. 7 are shown on a single plot. Although the maximum spread between curves is about 10%, this is to be expected considering the wide range of crest shapes used in the tests.

FREE-DISCHARGE COEFFICIENTS FOR FLOW OVER VERTICAL LIFT GATES

The Pickwick Landing vertical lift gates are representative of this type of gate, which has been used on several TVA projects. In Fig. 9(*a*) are shown details of the lower spillway gate leaf. For heads greater than 2 ft, this gate is essentially a sharp-crested weir 40 ft long and 20 ft high with piers 7.5 ft thick at each end of the gate. Air intakes were installed in the sides of the piers just below the top of the gate to ventilate the underside of the nappe.[6] Model tests were conducted with the 1/50-scale, 3-bay spillway model.

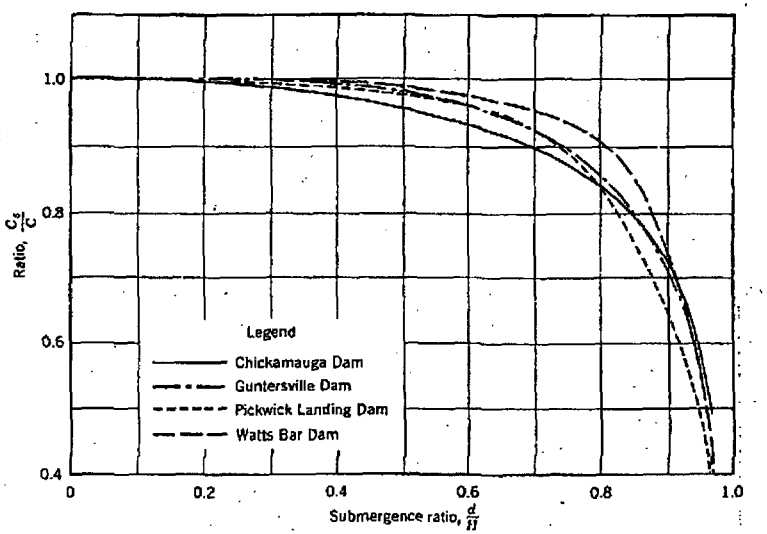

FIG. 8.—COMPARISON OF SUBMERGENCE EFFECTS FOR VARIOUS SPILLWAY CREST SHAPES

In Fig. 9(*b*) is shown the head-coefficient relationship for flow over the crest of the spillway gate. The coefficient, C, was computed from Eq. 1 using the top of the gate as crest elevation. The points define the head-coefficient relationship for heads between 3 ft and 28 ft. Each point was determined from the average of from 3 to 5 separate tests. A constant value of C equal to 3.428 is shown for heads in excess of 12 ft. For heads of from 12 ft to about 4 ft the model test curve shows a gradual rise in the coefficient, with an abrupt drop-off when the heads are approximately 4 ft and less. This curve takes the characteristic form for the coefficients of a sharp-crested weir, the rise and fall in the coefficient curve being due to the nappe clinging to the surface of the weir. This phenomenon is a function of the absolute head. Therefore, similarity between the model and prototype did not exist for prototype heads

[6] "Aeration of Spillways," by G. H. Hickox, *Transactions*, ASCE, Vol. 109, p. 537.

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5 Pages
Source: Reference A3

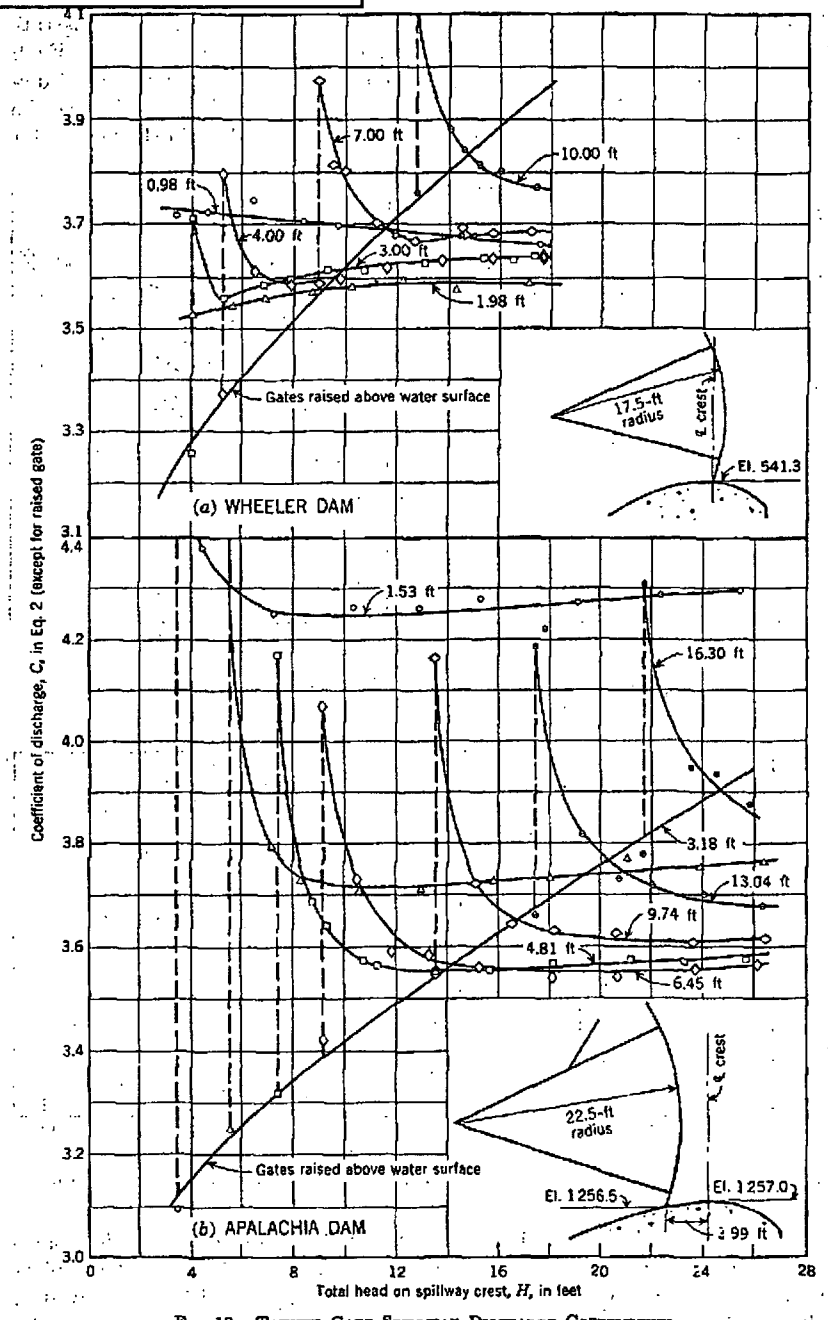


FIG. 12.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

Calculation No: CDQ000020080009

discharge over the gate was thus increased with a consequent lowering of the headwater level.

The flow conditions of plunging nappe and flowing nappe, previously described, also occurred in this type of flow. In this case the change from one to the other is apparent in the data. The dashed line in Fig. 10 indicates the approximate location of the change. At these points the curves show a definite discontinuity in shape. The data of Fig. 10 can be reduced in coeffi-

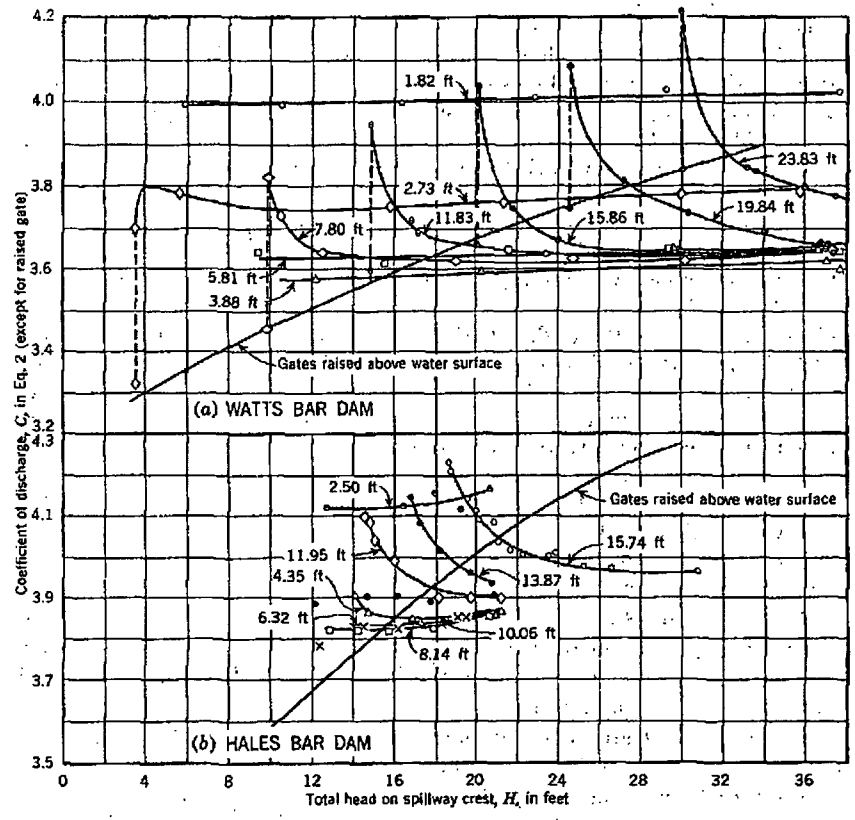


FIG. 13.—TAINTER-GATE SPILLWAY DISCHARGE COEFFICIENTS (DIMENSIONS ON CURVES ARE GATE OPENINGS)

cient form to the single-curve representation shown in Fig. 11. In this illustration, a constant value of C, equal to 3.428, was used in computing the ratio of C_s/C.

DISCHARGE COEFFICIENTS FOR FLOW UNDER TAINTER GATES

The flow under Tainter gates mounted on curved crests is controlled by the geometry of three interrelated variables—the crest shape, the gate, and the gate setting. The major factors which influence the discharge relation-

Tennessee Valley Authority

Tainter Gate Ratings

Basic Model and Prototype Data

	MODEL					PROTOTYPE		
Project	Model Scale	No. of Spill-way Bays	Crest Length L	Approach Width W	Up-stream Depth P	Crest Elev.	Design Head H_o	Pier Nose Radius R
Apalachia	1:28.72	6	6.684	8.00	3.38	1257.0	23.0	3.00
Boone	1:50	5	3.480	(1)	(1)	1350.0	35.0	12.75(2) 11.25(3) 3.50(4)
Ft. Patrick Henry	1:15	1	2.333(5)	2.77(5)	2.29	1228.0	35.0	3.25
Hales Bar	1:34.76	6	6.908(6) 6.905(7)	7.94	0.921	616.0	18.0	3.00
Hiwassee	1:55	7	4.050	8.00	6.35	1503.5		3.00
Watts Bar	1:35	6	6.866	8.00	1.5	713.0	23.5	3.25
Wheeler	1:34.35	6	6.984	7.97	1.253	541.3	16.5	2.50

(1) Variable because approach was reproduced in model.

(2) Right end pier.

(3) Left end pier.

(4) Intermediate piers.

(5) Except as noted on data tabulations.

(6) Gates partially opened.

(7) Gates raised above water surface.

Tennessee Valley Authority

Definition of Symbols

Q = Total discharge in cubic feet per second.

D = Depth of flow above crest in feet.+

D_1 = Depth, bottom of gate to water surface.*

H = Total head above crest, including velocity head of approach in feet.*

H_o = Design head for standard crest, including velocity head of approach, in feet.

h = Velocity head of approach in feet.*

C = Coefficient of discharge for any head.

G.O. = Gate opening - vertical distance above spillway crest in feet.

b = Shortest distance between spillway surface and gate lip in feet.*

L = Length of spillway crest in feet.

P = Depth of model approach channel, crest to river bed, in feet.+

W = Width of model approach in feet.

x = Horizontal distance from upstream face of dam in feet.*

y = Vertical distance above spillway crest in feet.*

Discharge Equations

For flow under a gate:

$$Q = CL\ [H^{3/2} - (D_1 + h)^{3/2}] \qquad (A)$$

For flow over a spillway crest with the spillway gate raised above the water surface:

$$Q = CLH^{3/2} \qquad (B)$$

+See Figure 1(a) on page 4.
*See Figure 1(b) on page 4.

Attachment A7-3
6 Pages
Source: Reference A4

Calculation No: CDQ000020080009

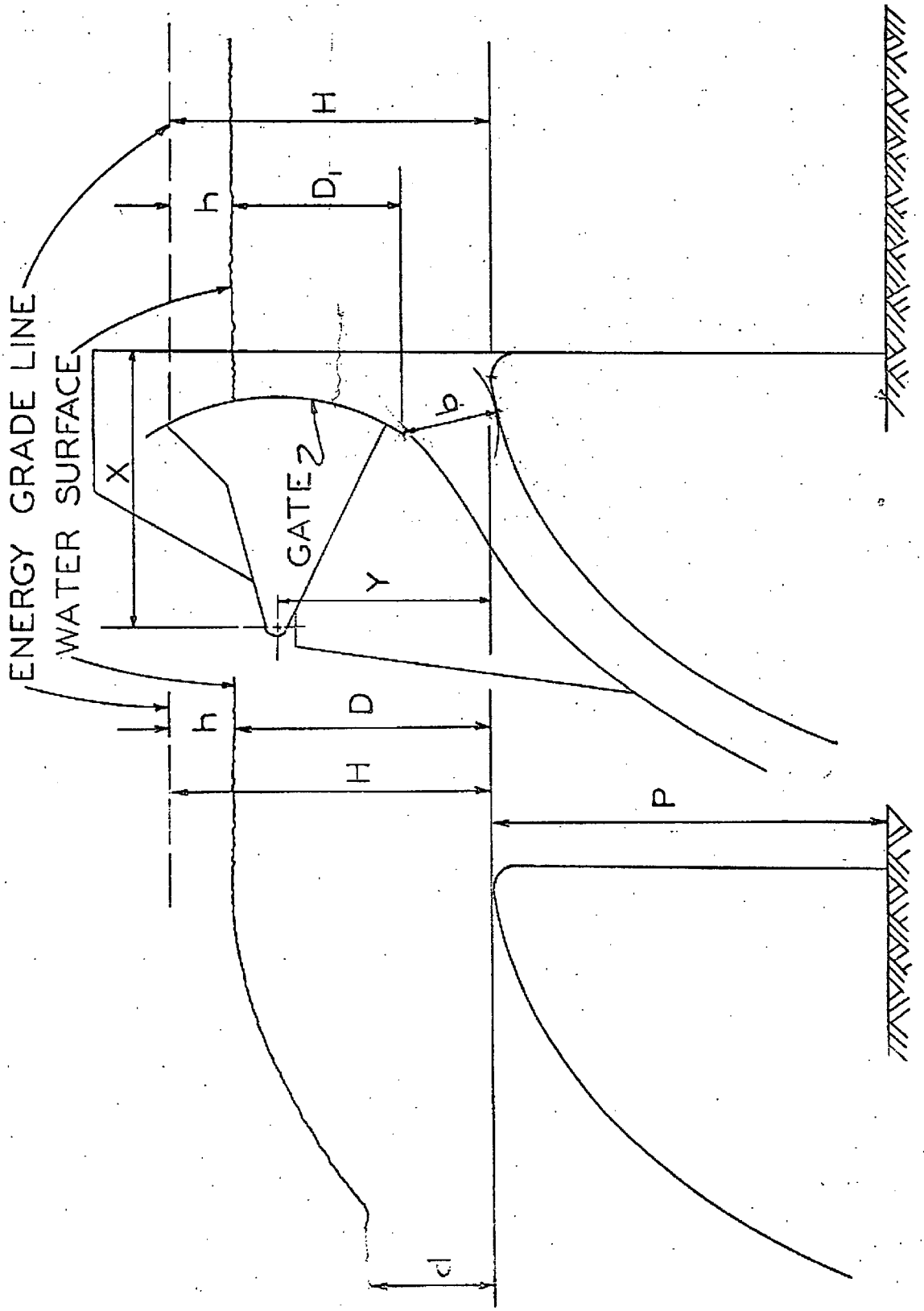


FIGURE 1

Attachment A7-4
6 Pages
Source: Reference A4

Calculation No: CDQ000020080009

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.052	0.168	0.803	0.000	1.82	5.88	5,819	3.99
	0.301	1.119	0.000		10.54	8,110	3.99
	0.463	1.411	0.000		16.20	10,230	3.99
	0.650	1.695	0.000		22.75	12,280	4.01
	0.831	1.932	0.000		29.08	14,000	4.03
	1.068	2,198	0.000		37.38	15,930	4.02
~~0.078~~	0.100	0.719	0.000	~~2.73~~	3.50	5,211	3.31+ ~~3.70~~* 4.96
0.078	1.023	3.024	0.000	2.73	35.80	21,920	3.79
	0.608	2.278	0.000		21.28	16,510	3.76
	0.856	2.746	0.000		29.96	19,900	3.78
	0.451	1.932	0.000		15.78	14,000	3.75
	0.165	1.072	0.000		5.78	7,769	3.78
	0.299 0.127	1.523 1.025	0.000 0.000		10.46 4.44	11,040 7,428	3.72 3.30+ 4.34*
0.111	0.346	2.196	0.000	3.88	12.11	15,910	3.57
	0.576	2.962	0.000		20.16	21,470	3.59
	0.842	3.703	0.001		29.50	26,840	3.65
	1.074	4.161	0.001		37.62	30,160	3.61
	1.056	4.140	0.001		37.00	30,000	3.62
	~~0.183~~ 1.044	~~1.803~~ 4.149	0.0001		36.~~46~~ 58	~~13,070~~ 30,070	~~3.35+~~ 3.65
~~0.166~~	~~1.044~~	~~4.149~~	~~0.001~~	~~5.81~~	~~36.58~~	~~30,070~~	~~3.65~~
0.166	0.271	2.679	0.001	5.81	9.52	19,420	3.63
	1.068	6.182	0.001		37.42	44,800	3.64
	0.837	5.417	0.001		29.33	39,260	3.65
	0.616	4.552	0.001		21.60	32,990	3.65
	0.441	3.688	0.001		15.47	26,730	3.61
0.223	0.280	3.538	0.001	7.80	9.84	25,640	3.46+ 3.82*
	0.356	4.102	0.001		12.50	29,730	3.64
	0.540	5.436	0.002		18.97	39,400	3.62
	0.702	6.396	0.002		24.64	46,350	3.62
	0.858	7.189	0.002		30.10	52,100	3.62
	1.064	8.186	0.002		37.31	59,330	3.65

+Gate lip touching nappe C from Equation B.
*Gate lip touching nappe C from Equation A.

Attachment A7-5
6 Pages
Source: Reference A4

Calculation No: CDQ000020080009

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.338	1.061	11.98	0.005	11.83	37.28	86,820	3.64
	0.854	10.49	0.005		30.06	76,020	3.64
	0.663	8.894	0.004		23.34	64,460	3.64
	0.484	7.141	0.003		17.04	51,750	3.68
	0.420	6.781	0.003		14.81	49,140	3.59+
							3.95*
	0.476	7.102	0.003		16.76	51,470	3.70
	1.050	11.94	0.005		36.92	86,530	3.65
0.453	0.616	10.82	0.006	15.86	21.77	78,410	3.74
	0.565	10.85	0.007		20.02	78,630	3.65+
							4.04*
	0.679	11.48	0.007		24.01	83,200	3.67
	0.840	13.33	0.008		29.68	96,600	3.65
	1.047	15.50	0.009		36.96	112,300	3.66
0.567	0.688	15.07	0.012	19.84	24.50	109,200	3.75+
							4.09*
	0.765	15.39	0.011		27.16	111,500	3.81
	0.854	16.46	0.012		30.31	119,300	3.73
	0.957	17.72	0.013		33.95	128,400	3.69
	1.035	18.60	0.013		36.68	134,800	3.67
0.681	0.833	20.71	0.019	23.83	29.82	150,100	3.84+
							4.21*
	0.937	20.81	0.018		33.42	150,800	3.84
	1.007	21.82	0.018		35.88	158,100	3.80
	1.048	22.36	0.019		37.34	162,000	3.78
	0.928	20.69	0.018		33.11	149,900	3.85

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Attachment A7-6
6 Pages
Source: Reference A4

Calculation No: CDQ000020080009

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.100	0.717	0.000	3.50	5,211	3.31
0.183	1.803	0.000	6.40	13,070	3.35
0.280	3.538	0.001	9.84	25,640	3.46
0.420	6.781	0.003	14.80	49,140	3.59
0.565	10.85	0.007	20.02	78,630	3.65
0.688	15.07	0.012	24.50	109,200	3.75
0.833	20.71	0.019	29.82	150,100	3.84
0.920	24.51	0.025	33.08	177,600	3.89
0.561	10.73	0.007	19.88	77,760	3.65
0.703	15.63	0.012	25.02	113,300	3.77
0.127	10.24	0.000	4.44	7,421	3.30
0.900	23.64	0.024	32.34	171,300	3.88
0.699	15.34	0.012	24.88	111,200	3.73
0.498	8.833	0.005	17.61	64,010	3.61
0.080	0.527	0.000	2.82	3,819	3.40

Attachment A8
1 Page
Source: Reference A7

The state of kinematic similarity can be maintained if, and only if, the corresponding force ratios remain constant. That is, if F_a and F_b are the net forces exerted on the fluid elements at A and B,

$$\frac{(F_a)_p}{(F_a)_m} = \frac{(F_b)_p}{(F_b)_m} \tag{11-3}$$

Each of these net forces may be thought of as an inertia force, mass × acceleration. It is made up of a number of different forces (those due to gravity,

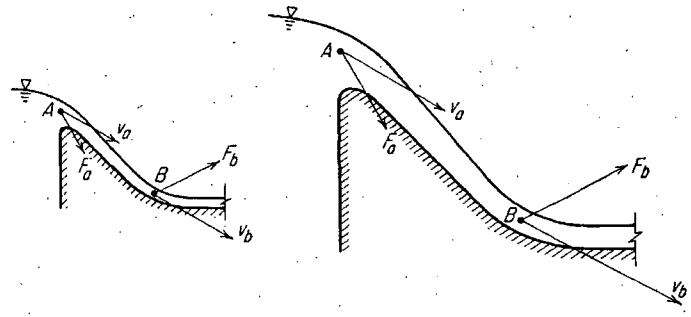


Figure 11-1. *Basic Model-Prototype Relationships*

viscosity, etc.), all of which vary in different ways with v, L, ρ, etc. If each of the ratios in Eq. (11–3) is to be kept constant at all points in the field of flow, then the various components of force must bear a constant ratio to one another. Now it can be shown (Prob. 11.1) that the Froude number is the ratio of inertia force to gravitational force, expressed in general dimensional form; similarly that the Reynolds, Weber, and Cauchy numbers are the ratios of the inertia force to viscous, capillary, and compression forces respectively. The final conclusion is the same as that already drawn from Eq. (11–1): that if a certain type of force is effective in a certain flow situation, the appropriate dimensionless number must be given the same value in the model as in the prototype.

Secondary Scale Ratios

The detailed interpretation of model measurements requires that scale ratios be available for translating model values of various quantities, e.g., velocity, discharge, etc., into the corresponding prototype values. Scales can be deduced for all physical quantities if scales are known for mass, length, time, and the physical properties of prototype and model fluids. It is convenient to introduce here the subscript r to indicate the ratio of prototype : model quantity, e.g., if model lengths are one-tenth those of the protoype, then $L_p/L_m = L_r = 10$, the subscripts p and m indicating prototype and model as before. Now it is always true that the mass ratio $M_r = \rho_r L_r^3$, so we have

Calculation No: CDQ000020080009

scale ratios for mass and length. The time scale T_r is deduced indirectly from the relationship between velocity scale and length scale dictated by the fact that the appropriate dimensionless number, e.g., the Froude number, must be kept constant.

In open channel flow the presence of a free surface means that the Froude number Fr is always significant, indeed dominant. The secondary scale ratios based on the constancy of Fr and its corollary

$$v_r = L_r^{1/2} \tag{11-4}$$

will therefore be applicable, although they may be modified in some case by the action of influences other than gravity. A complete list of scale ratios is therefore as follows

$$\left.\begin{array}{lll} \text{Mass} & M_r & = \rho_r L_r^3 \\ \text{Length} & L_r & = L_r \\ \text{Velocity} & v_r & = L_r^{1/2} \\ \text{Time} & T_r = L_r v_r^{-1} & = L_r^{1/2} \\ \text{Discharge} & Q_r = v_r L_r^2 & = L_r^{2\frac{1}{2}} \\ \text{Force} & F_r = M_r L_r T_r^{-2} & = \rho_r L_r^3 \\ \text{Pressure} & p_r = F_r L_r^{-2} & = \rho_r L_r \end{array}\right\} \tag{11-5}$$

as the reader can verify (Prob. 11.2).

The Influence of Forces Other Than Gravity

Compressibility effects are never significant in open channel flow models. Surface tension effects are appreciable only when radii of curvature of the liquid surface, and the distances from solid boundaries, are very small. They will therefore be negligible in all real prototype situations, and care must be taken to keep them negligible in model situations. This is accomplished by keeping model water depths no less than an inch or two, and similarly for channel widths. Beyond the taking of this precaution, capillary effects do not warrant any further attention.

Viscosity is much more important, and exerts its influence in many different situations. The term *scale effect* can be introduced here; it is the name given to the slight distortions introduced by forces—for example, viscosity—other than the dominant one, such as gravity. Such effects are often slight without being altogether negligible. For example, the flow over a spillway will encounter some slight viscous resistance down the face of the spillway, although resistance will be negligible at the crest itself, where the discharge-head relation is determined.

The only perfect way of dealing with the effect of viscosity is to keep both

Attachment A9-1
5 Pages

Calculation No: CDQ000020080009

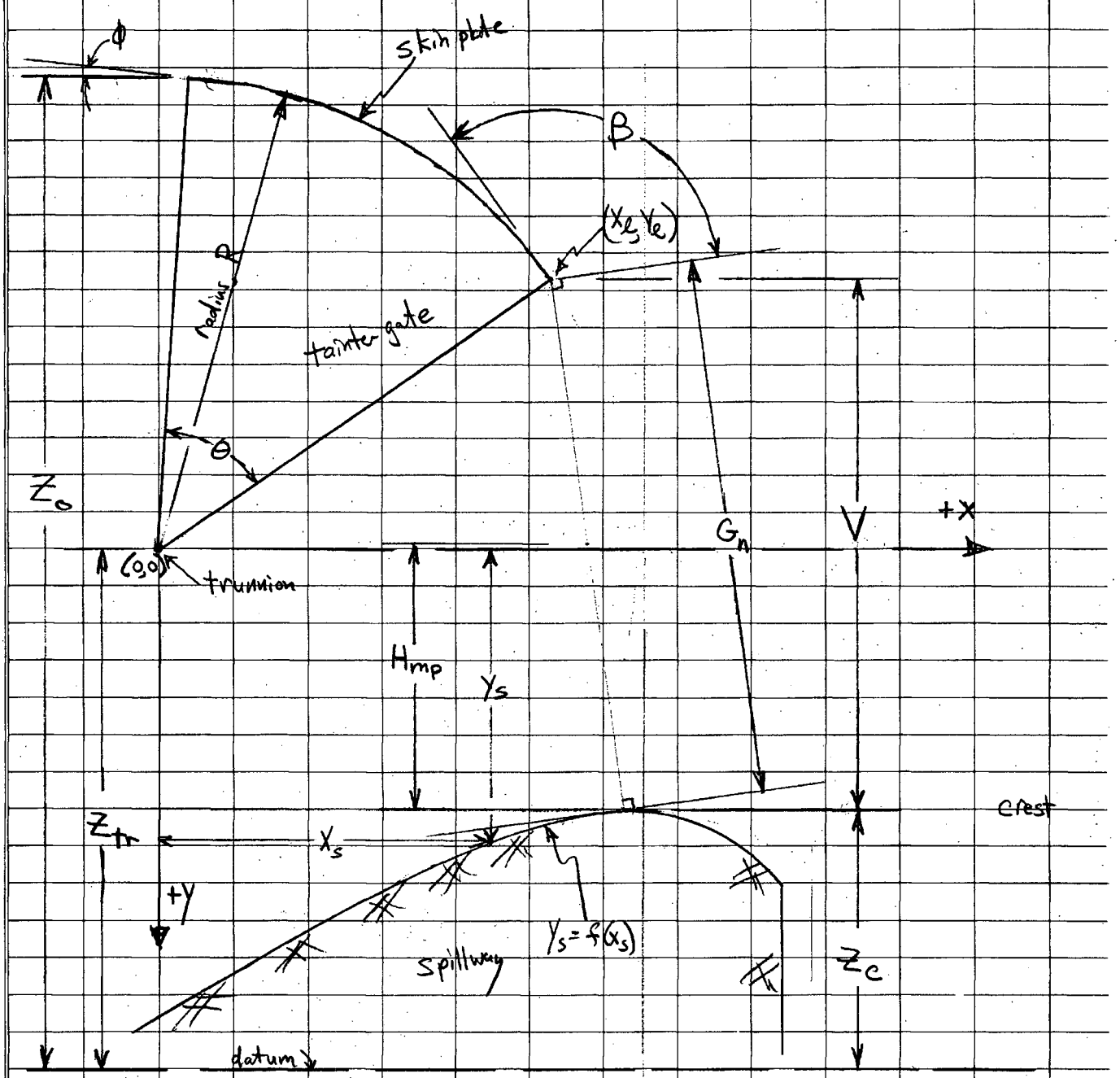
Prepared: GAS
Checked: JCT

Way Discharge Calculations
Geometry for Flow Under an Open Tainter Gate

COMPUTED GAS

CHECKED _____ DATE _____

Definition Sketch



Attachment A9-2
5 Pages

Calculation No: CDQ000020080009

Prepared: GAS
Checked: JCT

Gate Geometry

COMPUTED GA

CHECKED _____ DATE _____

Variables

V = vertical distance between the bottom of the open gate and the crest

Z_c = crest elevation

Z_{tr} = trunnion elevation

Z_o = overflow elevation

R = radius of the tainter gate

G_n = minimum distance between the gate lip and the crest

H_{mp} = vertical distance between the mid-point of G_n and the crest

β = angle formed by the tangent to the gate lip and the tangent to the crest curve at the nearest point of the crest curve

Θ = angle of the sector of a circle formed by two lines connecting the trunnion axis to the bottom and top of the radial gate.

x, y = coordinates relative to trunnion axis (y positive downward)

x_s, y_s = coordinates of spillway surface defined by $y_s = f(x_s)$

x_ℓ, y_ℓ = coordinates of the gate lip relative to trunnion axis

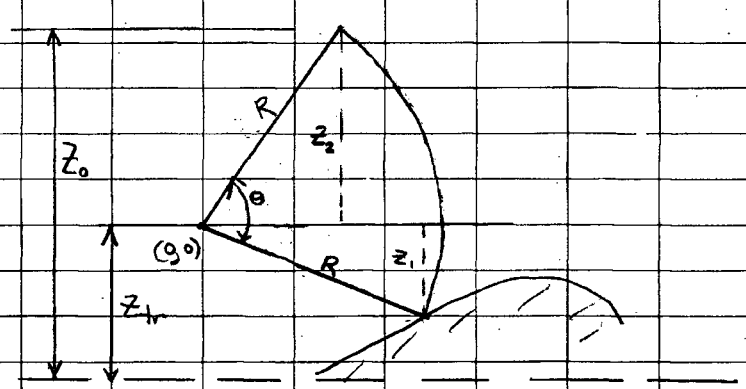
notes: { y positive downward for all coordinates
all coordinates relative to trunnion axis

Φ = angle formed by the tangent to the gate top and horizontal

Angle, Θ

$$\Theta = \sin^{-1}\left(\frac{Z_2}{R}\right) + \sin^{-1}\left(\frac{Z_1}{R}\right)$$

Z_1 & Z_2 are determined from drawings



Closed Gate

Attachment A9-3
5 Pages

Calculation No: CDQ000020080009

Gate Geometry

Prepared: GAS
Checked: JCT

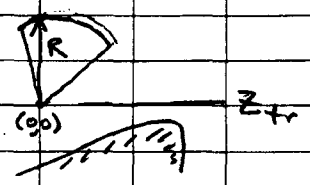
COMPUTED GA

CHECKED DATE

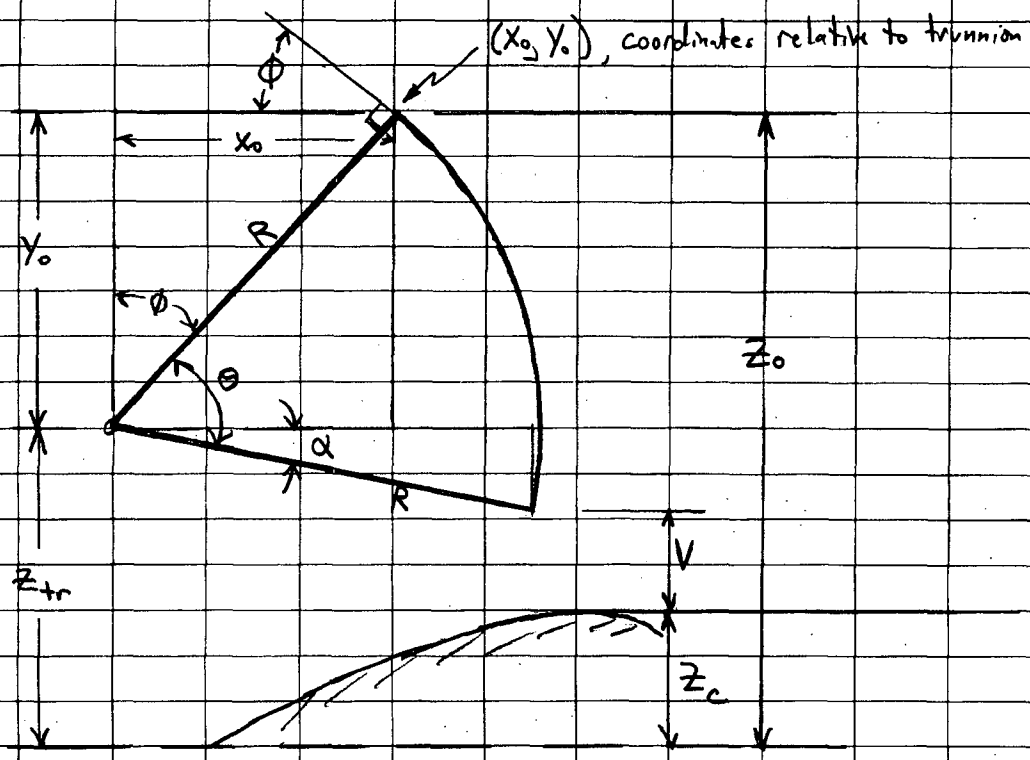
Overflow Elevation, Z_o and Angle, Φ

For a gate opened so far that its upper edge is downstream of the trunnion:

$$Z_o = Z_{tr} + R$$



For a gate opened less:



$$\alpha = \tan^{-1}\left(\frac{Z_{tr} - (Z_{cr} + V)}{\sqrt{R^2 - (Z_{tr} - Z_{cr} - V)^2}}\right)$$

V given

$$\boxed{Z_o = Z_{tr} + R\sin(\theta - \alpha)}$$

and $\boxed{\Phi = \tan^{-1}\left(\frac{X_o}{Y_o}\right)}$ with $\begin{cases} Y_o = Z_o - Z_{tr} \\ X_o = R\cos(\theta - \alpha) \end{cases}$

Attachment A9-4
5 Pages

Calculation No: CDQ000020080009

way Gate Geometry

COMPUTED GAS

Prepared: GAS
Checked: JCT

CHECKED DATE

Gate Opening, G_n

Gate lip coordinates: $\begin{cases} Y_\ell = Z_{tr} - Z_{co} - V \\ X_\ell = \sqrt{R^2 - Y_\ell^2} \end{cases}$

Distance between gate lip and any point on spillway surface is

$$\ell = \sqrt{(X_s - X_\ell)^2 + (Y_s - Y_\ell)^2} \equiv \sqrt{(X_s - X_\ell)^2 + [f(X_s) - Y_\ell]^2}$$

G_n is the minimum distance. ℓ is minimum when $\frac{d\ell}{dX_s} = 0$

$$\frac{d\ell}{dX_s} = \frac{1}{2}\left\{(X_{sn} - X_\ell)^2 + [f(X_{sn}) - Y_\ell]^2\right\}^{-1/2} \cdot \left\{2(X_{sn} - X_\ell) + 2[f(X_{sn}) - Y_\ell]\frac{df(X_{sn})}{dX_s}\right\} = 0$$

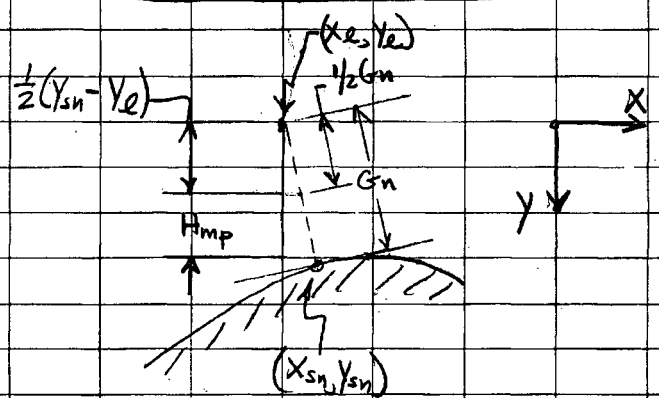
$$\Rightarrow 0 = \frac{(X_{sn} - X_\ell) + [f(X_{sn}) - Y_\ell]\frac{df(X_{sn})}{dX_s}}{\ell_{minimum}}$$

where $X_{sn} = X_s$ for minimum ℓ, $\ell_{minimum} \equiv G_n$.

Solve: $X_{sn} - X_\ell + [f(X_{sn}) - Y_\ell]\frac{df(X_{sn})}{dX_s} = 0$ for X_{sn}

Then: $Y_{sn} = f(X_{sn})$ and $\boxed{G_n = \sqrt{(X_{sn} - X_\ell)^2 + (Y_{sn} - Y_\ell)^2}}$

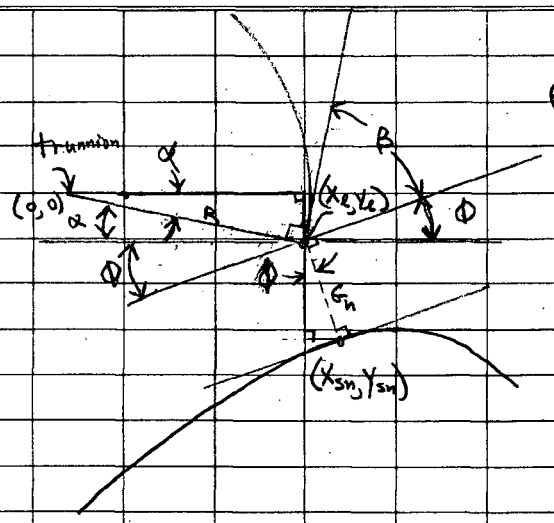
Mid-Point Head, H_{mp}



$H_{mp} = Z_{tr} - Z_c - Y_\ell - \frac{1}{2}(Y_{sn} - Y_\ell)$

$\Rightarrow \boxed{H_{mp} = V - \frac{1}{2}(Y_{sn} - Y_\ell)}$

Angle, B



$$\beta + \frac{\pi}{2} + \alpha + \Phi = \pi$$

$$\beta + \Phi = \frac{\pi}{2} - \alpha$$

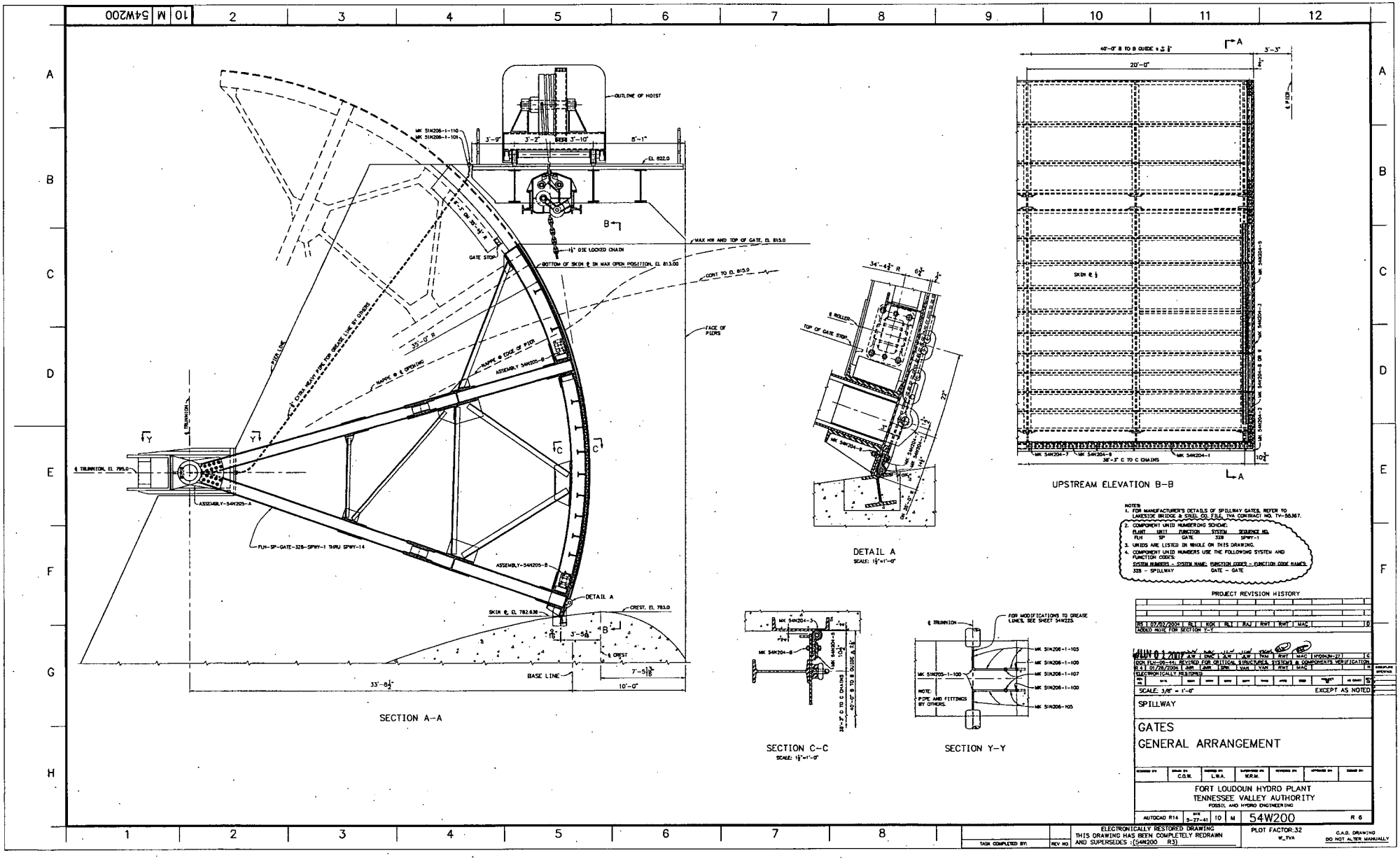
$$\beta = \frac{\pi}{2} - \alpha - \Phi$$

$$\left.\begin{aligned} \alpha &= \tan^{-1}\left(\frac{Y_e}{X_e}\right) \\ \Phi &= \tan^{-1}\left(\frac{X_{sn} - X_e}{Y_{sn} - Y_e}\right) \end{aligned}\right\}$$

$$\boxed{\beta = \frac{\pi}{2} - \tan^{-1}\left(\frac{Y_e}{X_e}\right) - \tan^{-1}\left(\frac{X_{sn} - X_e}{Y_{sn} - Y_e}\right)}$$

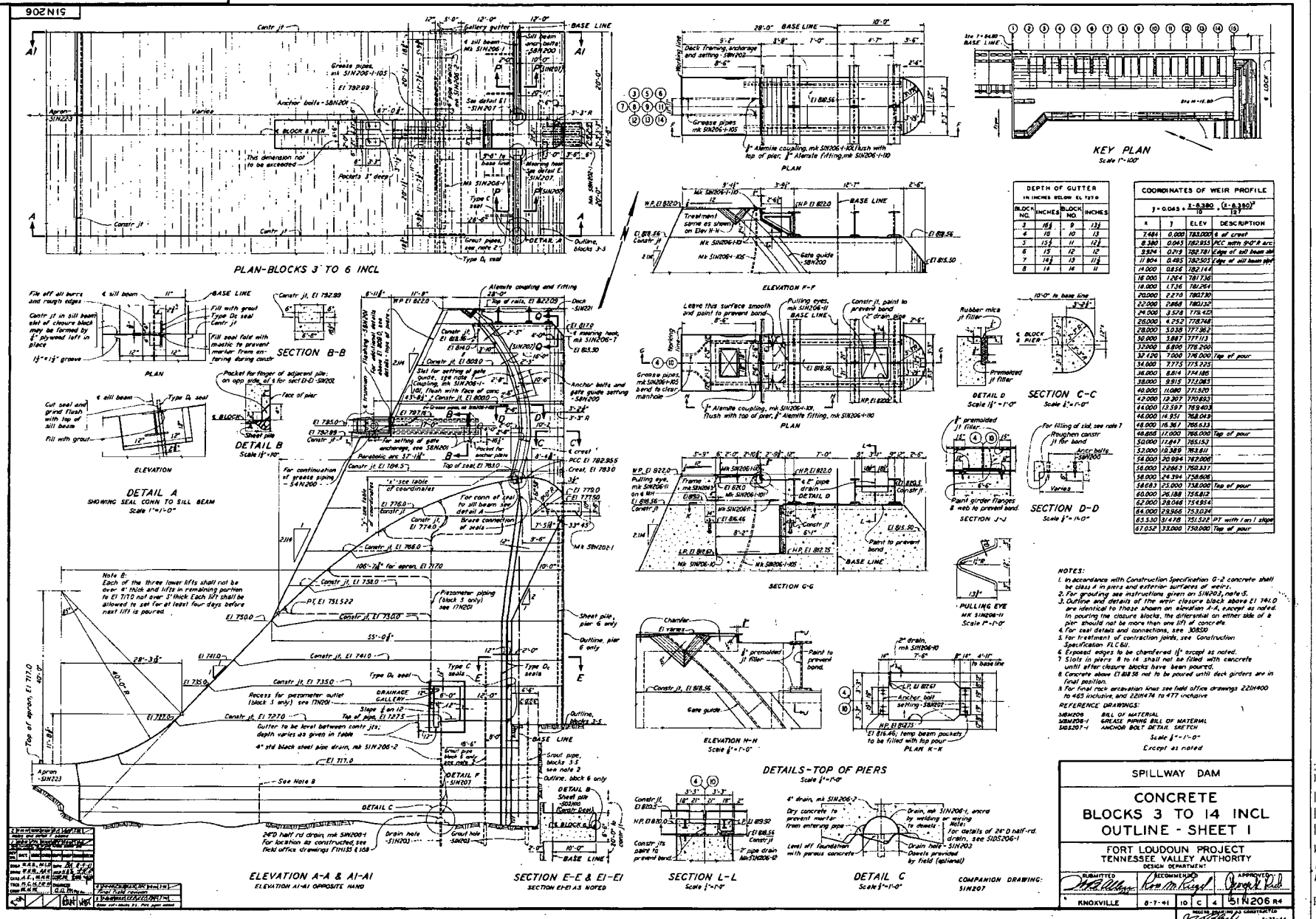
Attachment A10
1 Page
Source: Reference A8

Calculation CDQ000020080009



Attachment A11
1 Page
Source: Reference A9

Calculation CDQ000020080009



DEPTH OF GUTTER IN INCHES BELOW EL 737.0			
BLOCK NO.	INCHES	BLOCK NO.	INCHES
3	16½	9	13½
4	10	10	13
5	13½	11	12½
6	15	12	12
7	14½	13	11½
8	14	14	11

COORDINATES OF WEIR PROFILE			
$y = 0.045 \times \frac{(x-8.380)}{10} \times \frac{(x-8.380)^2}{127}$			
x	y	ELEV	DESCRIPTION
7.484	0.000	783.000	℄ of crest
8.380	0.045	782.955	PCC with 9'-0" R arc
9.524	0.219	782.781	Edge of sill beam slot
11.904	0.493	782.507	Edge of sill beam slot
14.000	0.856	782.144	
16.000	1.264	781.736	
18.000	1.736	781.264	
20.000	2.270	780.730	
22.000	2.868	780.132	
24.000	3.528	779.472	
26.000	4.252	778.748	
28.000	5.038	777.962	
30.000	5.887	777.113	
32.000	6.800	776.200	
32.120	7.000	776.000	Top of pour
34.000	7.775	775.225	
36.000	8.814	774.186	
38.000	9.915	773.085	
40.000	11.080	771.920	
42.000	12.307	770.693	
44.000	13.597	769.403	
46.000	14.951	768.049	
48.000	16.367	766.633	
48.666	17.000	766.000	Top of pour
50.000	17.847	765.153	
52.000	19.389	763.611	
54.000	20.994	762.006	
56.000	22.663	760.337	
58.000	24.394	758.606	
58.683	25.000	758.000	Top of pour
60.000	26.188	756.812	
62.000	28.046	754.954	
64.000	29.966	753.034	
65.330	31.478	751.522	PT with 1 on 1 slope
67.032	33.000	750.000	Top of pour

NOTES:

1. In accordance with Construction Specification G-2 concrete shall be class A in piers and exterior surfaces of weirs.
2. For grouting see instructions given on 5IN203, note 5.
3. Outline and details of the weir closure block above El 741.0 are identical to those shown on elevation A-A, except as noted. In pouring the closure blocks, the differential on either side of a pier should not be more than one lift of concrete.
4. For seal details and connections, see 30B50
5. For treatment of contraction joints, see Construction Specification FLC 611.
6. Exposed edges to be chamfered 1½" except as noted.
7. Slots in piers 8 to 14 shall not be filled with concrete until after closure blocks have been poured.
8. Concrete above El 818.56 not to be poured until deck girders are in final position.
9. For final rock excavation lines see field office drawings 221H400 to 465 inclusive, and 221H474 to 477 inclusive

REFERENCE DRAWINGS:

5IN206	BILL OF MATERIAL
5IN206-1	GREASE PIPING BILL OF MATERIAL
5IN207-1	ANCHOR BOLT DETAIL SKETCH

Scale 1/2"=1'-0"
Except as noted

Refile in Box 75

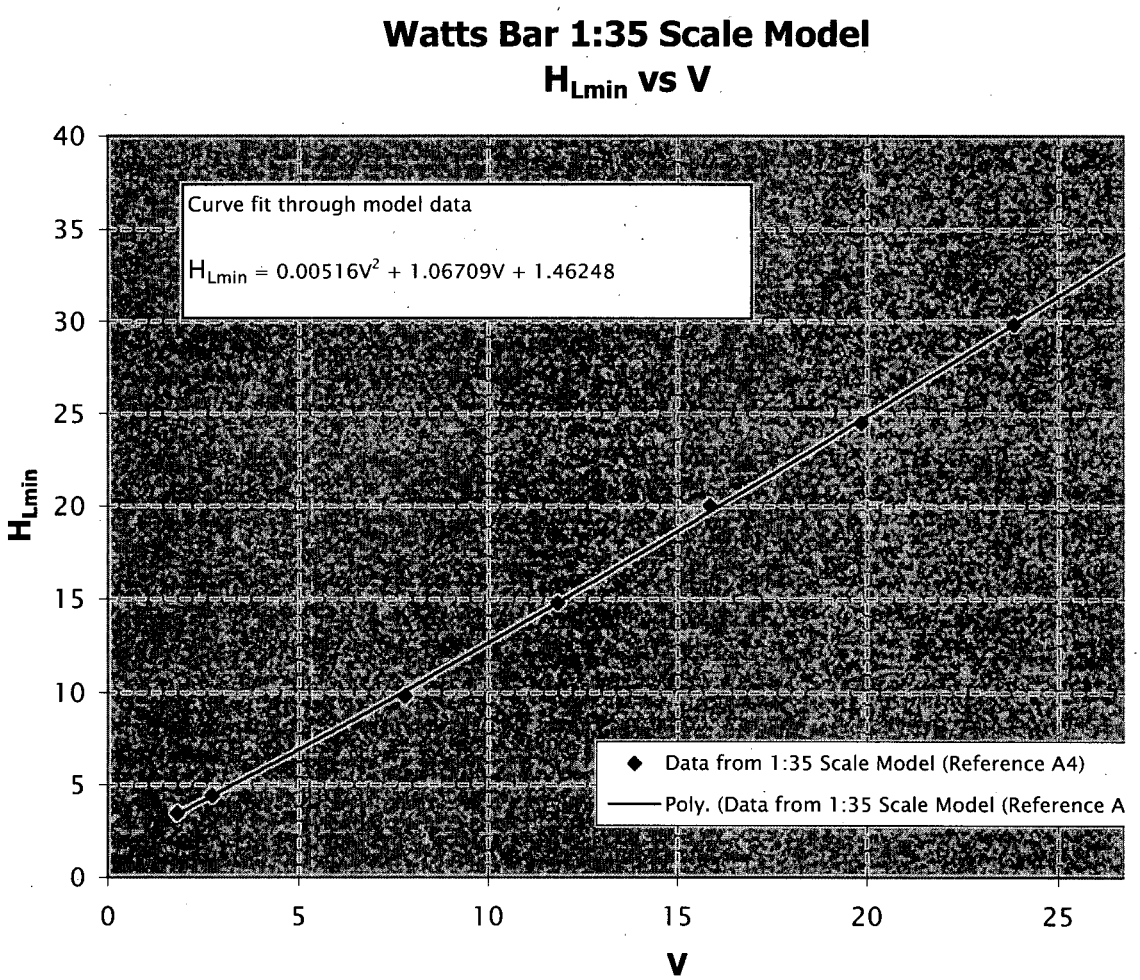
Attachment A12
1 Page
Source: Reference A4

Calculation No: CDQ000020080009

Prepared: ATT
Checked: JCT

Watts Bar Project
Tainter Gates Partially Opened
Data from 1:35 scale model (Reference A4)
EQUIVALENT PROTOTYPE

V	H_{Lmin} (data)	H_{Lmin} (fit)	
feet	feet	feet	
1.82	3.5	3.42	
2.73	4.44	4.41	
7.80	9.84	10.10	
11.83	14.8	14.81	
15.86	20.02	19.68	
19.84	24.5	24.66	
23.83	29.82	29.82	
29.87		**37.94**	extrapolated using polynomial shown on plot



Attachment A13
1 Page
Source: Reference A4

Watts Bar Model Data for Headwater Ratings.xls Free Discharge

Calculation No: CDQ000020080009

Prepared: ATT
Checked: JCT

Watts Bar Project
Tainter Gates Raised Above the Water Surface
Data from 1:35 scale model (Reference A4)
(equivalent prototype)

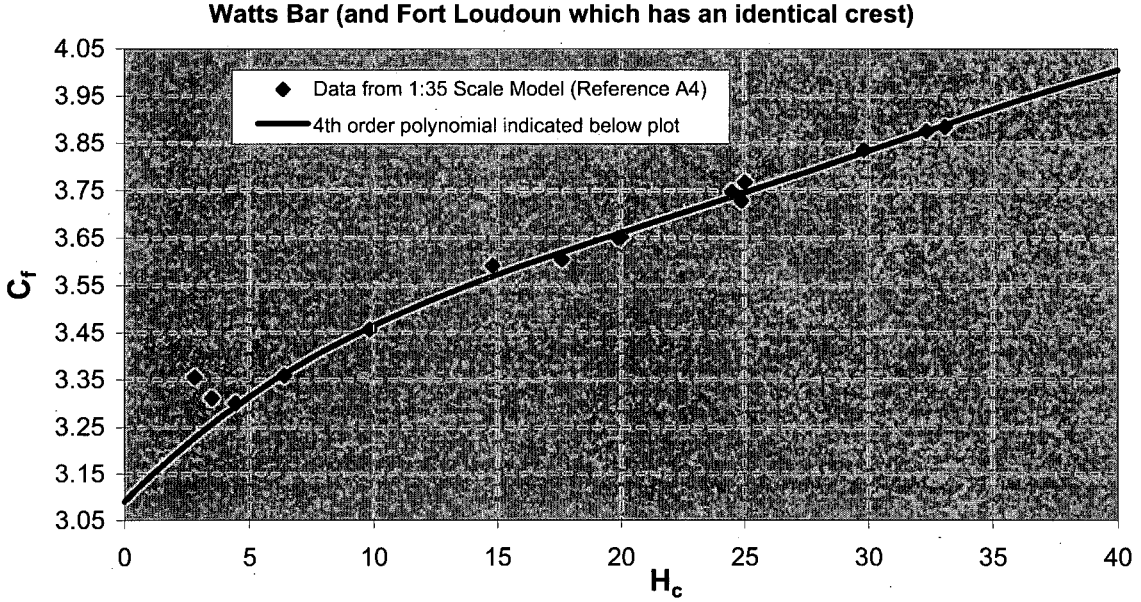
H_c	Q	C_f
ft.	cfs	
2.82	3,819	3.36
3.50	5,211	3.31
4.44	7,421	3.30
6.40	13,070	3.36
9.84	25,640	3.46
14.80	49,140	3.59
17.61	64,010	3.60
19.88	77,760	3.65
20.02	78,630	3.65
24.50	109,200	3.75
24.88	111,200	3.73
25.02	113,300	3.77
29.82	150,100	3.84
32.34	171,300	3.88
33.08	177,600	3.88

Definition: $C_f = Q/(35*6.866*H_c^{1.5})$

H_c	4th-order curve fit (see plot)
ft.	C_f
0	3.090
0.25	3.104
0.5	3.117
0.75	3.130
1	3.143
2	3.191
3	3.236
4	3.277
6	3.350
8	3.412
10	3.465
12	3.512
14	3.554
16	3.591
19	3.644
22	3.695
25	3.746
28	3.798
31	3.851
34	3.905
37	3.958
40	4.005

Free Discharge Coefficient, $C_f(H_c)$

Watts Bar (and Fort Loudoun which has an identical crest)



$$C_f = -5.5070x10^{-7}H_c^4 + 5.9044x^{-5}H_c^3 - .0022844H_c^2 + .055033H_c + 3.09$$

Attachment A14
1 Page
Source: Reference A3

Watts Bar Model Data for Headwater Ratings.xls Free Discharge

Calculation No: CDQ000020080009

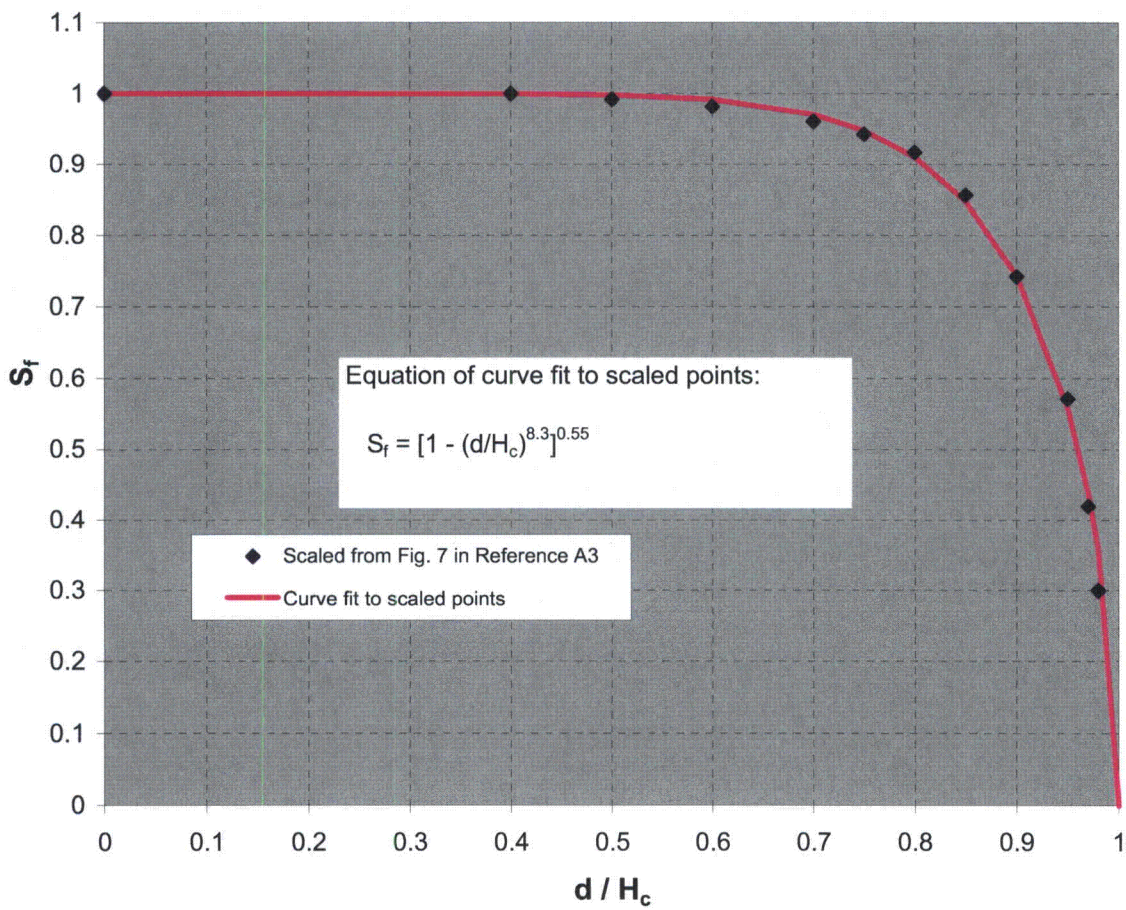
Prepared: ATT
Checked: JCT

Data Scaled from plot of Cs/C vs d/H in Reference A3

d / H_c	S_f	Curve fit to S_f	exponents (see chart)
0	1.000	1.000	8.3
0.4	1.000	1.000	0.55
0.5	0.992	0.998	
0.6	0.982	0.992	
0.7	0.961	0.971	
0.75	0.943	0.948	
0.8	0.917	0.910	
0.85	0.856	0.848	
0.9	0.742	0.743	
0.95	0.571	0.558	
0.97	0.420	0.439	
0.98	0.300	0.358	
1		0.000	

Submergence Effect on Free Discharge, $S_f(d/H_c)$

Watts Bar (and Fort Loudoun which has an identical crest)



Attachment A15
1 Page
Source: Reference A4

Calculation No: CDQ000020080009

Prepared: ATT
Checked: JCT

Watts Bar Project, Tainter Gates Partially Opened
Data from 1:35 scale model as published in Reference A4
"Tainter Gate Rating Data Determined from Eight TVA Model Studies," Norris, Tennessee, March 1962

Model Scale = 35 g = 32.2 ft/s2
L_{model} = 6.866 ft Attachment A7-1
$L_{prototype}$ = 240.31 ft $35*L_{model}$

Definition: $C_g = Q / \{G_n*L*sqrt[2*g*(H_c-H_{mp})]\}$

	Model Test Data In Prototype Dimensions			Geometry			
	V	H_c	Q	G_n	H_{mp}	C_g	C_g Line
	ft	ft	cfs	ft	ft		
$H_c=H_{Lmin}$	7.80	9.84	25640	7.865	3.881	0.692	0.692
	7.80	12.50	29730	7.865	3.881	0.668	0.668
	7.80	18.97	39400	7.865	3.881	0.669	0.669
	7.80	24.64	46350	7.865	3.881	0.671	0.671
	7.80	30.10	52100	7.865	3.881	0.671	0.671
	7.80	37.31	59330	7.865	3.881	0.677	0.671
	7.80	60.00					0.671 (1)
$H_c=H_{Lmin}$	11.83	14.81	49140	11.868	5.906	0.720	0.720
	11.83	16.76	51470	11.868	5.906	0.683	0.683
	11.83	17.04	51750	11.868	5.906	0.678	0.678
	11.83	23.34	64460	11.868	5.906	0.675	0.675
	11.83	30.06	76020	11.868	5.906	0.676	0.676
	11.83	36.92	86530	11.868	5.906	0.679	0.678
	11.83	37.28	86820	11.868	5.906	0.677	0.678
	11.83	60.00					0.678 (1)
$H_c=H_{Lmin}$	15.86	20.02	78630	15.904	7.921	0.737	0.737
	15.86	21.77	78410	15.904	7.921	0.687	0.687
	15.86	24.01	83200	15.904	7.921	0.676	0.676
	15.86	29.68	96600	15.904	7.921	0.675	0.675
	15.86	36.96	112300	15.904	7.921	0.679	0.680
	15.86	60					0.680 (1)
$H_c=H_{Lmin}$	19.84	24.50	109200	19.919	9.906	0.744	0.744
	19.84	27.16	111500	19.919	9.906	0.699	0.699
	19.84	30.31	119300	19.919	9.906	0.688	0.688
	19.84	33.95	128400	19.919	9.906	0.682	0.682
	19.84	36.68	134800	19.919	9.906	0.678	0.678
	19.84	60					0.678 (1)
$H_c=H_{Lmin}$	23.83	29.82	150100	23.994	11.892	0.766	0.766
	23.83	33.11	149900	23.994	11.892	0.703	0.703
	23.83	33.42	150800	23.994	11.892	0.702	0.702
	23.83	35.88	158100	23.994	11.892	0.698	0.698
	23.83	37.34	162000	23.994	11.892	0.694	0.694
	23.83	40					0.690 (1)
	23.83	60					0.690 (1)
$H_c=H_{Lmin}$	29.87	37.94	223129	30.314	14.828	0.794	0.794
	29.87	42					0.720 (1)
	29.87	48					0.711 (1)
	29.87	60					0.711 (1)

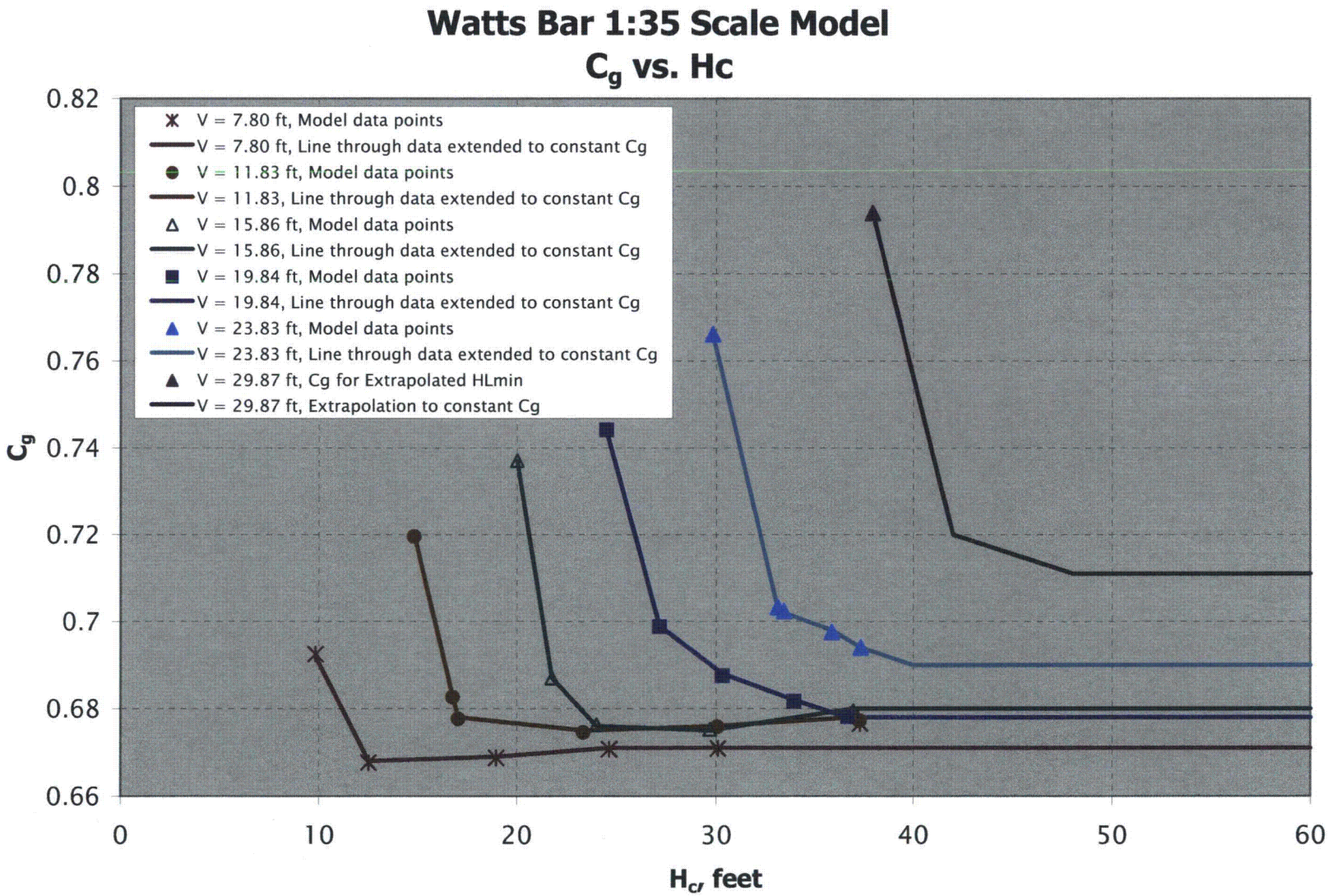
(1) Value of Cg is estimated; no model data, so no value for Q; geometrical parameters not needed

from: A18 - Watts Bar Model Data for Headwater Ratings.xls, Gated Discharge

Attachment A16
1 Page
Source: Reference A4

Calculation No: CDQ000020080009

Prepared: ATT
Checked: JCT



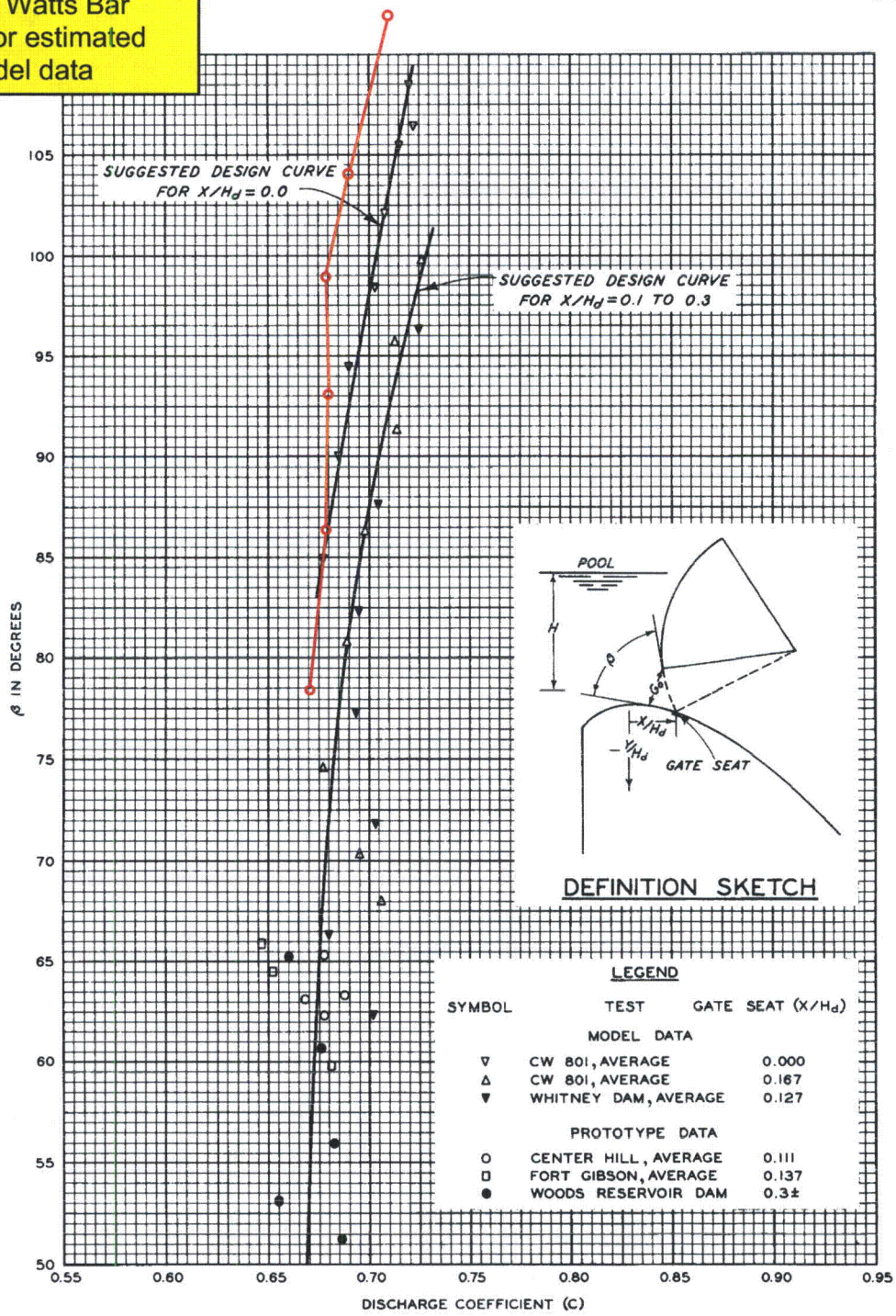
from: A18 – Watts Bar Model Data for Headwater Ratings.xls, Cg vs. Hc

Attachment A17
1 Page
Source: Reference A5

Red circles indicate Watts Bar values determined or estimated from 1:35 scale model data

Calculation No: CDQ000020080009

Prepared: ATT
Checked: JCT



FORMULA

$$Q = CG_oB\sqrt{2gH}$$

WHERE:

G_o = NET GATE OPENING
B = GATE WIDTH
H = HEAD TO CENTER OF GATE OPENING

TAINTER GATES ON SPILLWAY CRESTS

DISCHARGE COEFFICIENTS

HYDRAULIC DESIGN CHART 311-1

WES 3-56

Appendix B: Hydrostatic Loads on the Spillway Tainter Gates

The Hydrostatic loads on the spillway tainter gates for Fort Loudoun Dam can be found in the following calculations.

B1 References

B1. "Watts Bar Dam – Flood and Earthquake Analysis on Radial Spillway Gates, pages 76-100" Tennessee Valley Authority, HEPE3WBHSQN-WBNBLNBFN.

B2 Calculations

Reference B1 evaluates the structural capacity of the radial spillway gates at Watts Bar Dam. This reference was used as a basis for evaluating the margin between the forces on the closed gates (FR_{closed}) when the headwater elevation is at the top of the gate (815.00 feet) and when the gates are completely open (FR_{open}) and the headwater elevation is at 837.00 feet. The margin is defined at the ratio of FR_{open} to FR_{closed}. The calculation of these forces and the results of this comparison are shown in Figure B1.

Fort Loudoun Hydrostatic Forces on Gates

Comparison of forces when gates are closed and HW is at 815.00 feet (top of gate) vs. when gates are fully open and HW at an elevation of 837.00 feet.

Attribute	Symbol	Value	Unit
top elev	Zo	815.00	ft
trun elev	Ztr	795.00	ft
sill elev	Zsill	782.64	ft
radius	R	35.00	ft
length	L	40.00	ft
angle up	α2	34.85	deg
angle lwr	α	20.68	deg
angle tot	θ	55.53	deg
area of lower slice	Aslice1	593.62	ft^2
proj area	AProjected	1294.40	ft^2
Desgn LdH	FRx	1306867.66	lbs
Result elv	Z1	793.43	ft
Result ang deg		2.58	deg
Result ang rad		0.04	rad
Result Dsgn	Horiz	1305546.59	lbs
Area slice upper	Aslice2	372.55	ft^2
Area triangle	Atriangle	287.23	ft^2
project vert	x1	6.28	ft
vert weight water	FRy	100392.74	lbs
Resultant load - Gates Closed	FR_{closed}	**1310718.04**	lbs
vert open fm calc	calc App A	29.87	ft
max hw	calc	837.00	ft
lwr lip elev	Z2	812.51	ft
bot angle	α3	30.02	deg
top elev	Zo	829.89	ft
project area for h lc	AProjected	695.38	ft^2
Flood LdH	FRx	685489.96	lbs
Height over gate	y1	7.11	ft
Height ratio to orig		1.68	(ratio)
project vert	x2	27.59	ft
Flood LdV1		489297.97	lbs
Flood lLdV2		377252.62	lbs
Total Flood LdV	FRy	866550.59	lbs
Resultant load - Gates Fully Open	FR_{open}	**1104901.08**	lbs
Margin	FR_{open}/FR_{closed}	**0.84**	(ratio)

Figure B1: Fort Loudoun Spillway Gate Margin Evaluation

BWSC BARGE WAGGONER SUMNER & CANNON, INC.

Project: Hydro Static Force on Gate
Description: Diagram
Project No. _____ Sheet No. _____ of _____
Designer: _____ Date: _____
Checker: _____ Date: _____

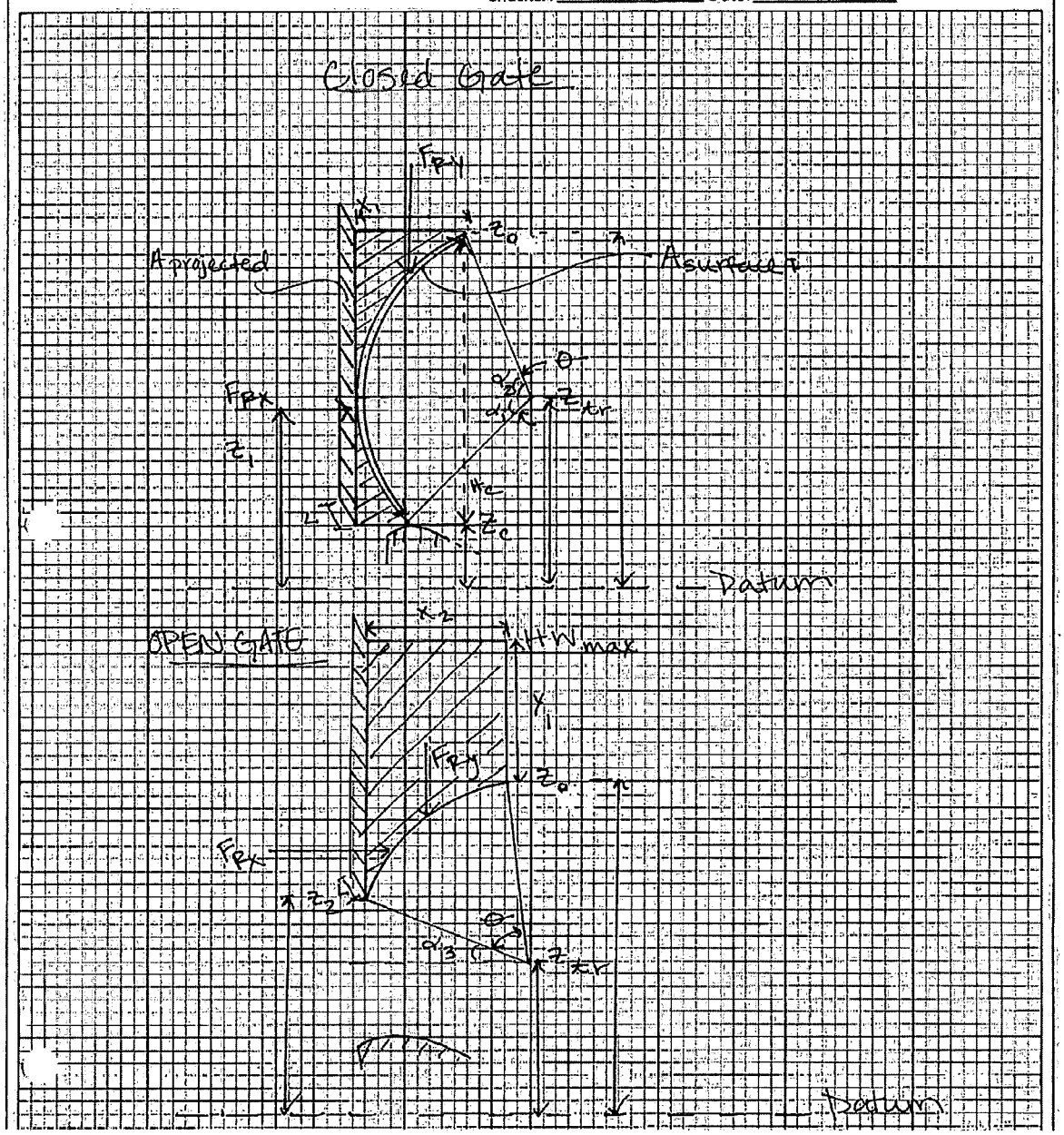
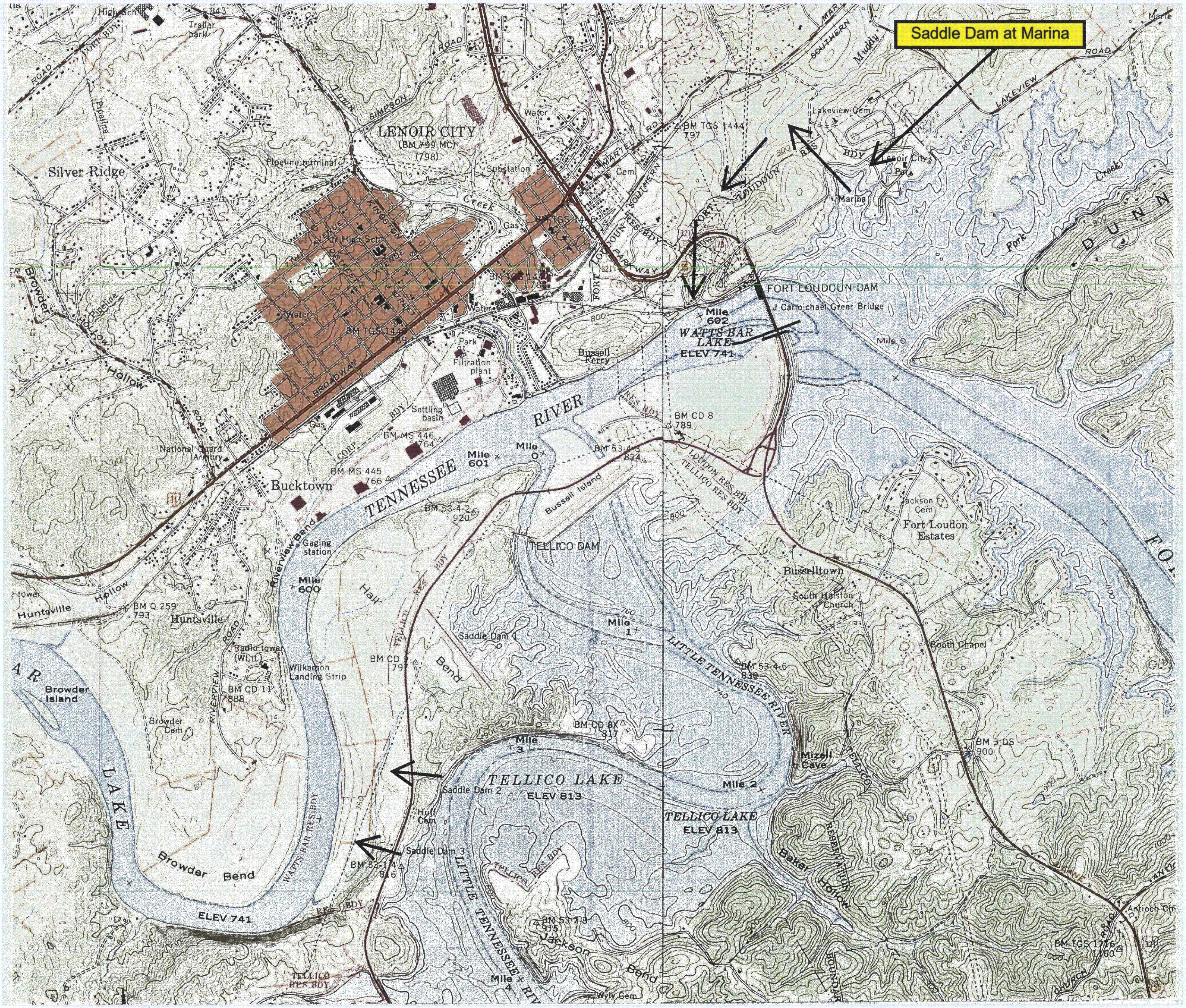


Figure B2: Diagram of Hydrostatic Forces



Saddle Dam at Marina
LENOIR CITY
Silver Ridge
FORT LOUDOUN DAM
J Carmichael Greer Bridge
WATTS BAR LAKE
ELEV 741
TENNESSEE RIVER
TELLICO DAM
Bussell Island
Saddle Dam 1
Saddle Dam 2
Saddle Dam 3
TELLICO LAKE
ELEV 813
LITTLE TENNESSEE RIVER
Bucktown
Huntsville
Browder Island
Browder Bend
LAKE
Fort Loudon Estates
Busselltown
Mizell Cave
Baker Hollow
Jackson Bend
Marina
Lenoir City Park
Mile 602
Mile 601
Mile 600

TVA 10697 (DNE-6-86)

DNE CALCULATIONS

TITLE Ft. Loudoun - Concrete Stability Analysis For SSE and ½ SSE + ½ PMF	PLANT/UNIT SQN, WBN, BLN, BFN
PREPARING ORGANIZATION DPE & C	KEY NOUNS (Consult RIMS DESCRIPTORS LIST) Sequoyah NP, Ft. Loudoun Dam, SSE + 25yr. Flood, ½ SSE + ½ PMF
BRANCH/PROJECT IDENTIFIERS HEP ES FLH SQN WBN BLN BFN ESSENT. CALCS A 5	Each time these calculations are issued, preparers must ensure that the original (R0) RIMS accession number is filled in.

Rev	(for RIMS' use)	RIMS accession number
R0	870415C0032 (58)	B66 '870316 003
R1	880525E0010 (60)	B25 '88 0520 302
R _		
R _		

APPLICABLE DESIGN DOCUMENT(S)

SAR SECTION(S) | UNID SYSTEM(S)

751-7082

Safety-related? Yes ☑ No ☐

Revision 0	R1	R2	R3
ECN No. (or indicate Not Applicable) N/A	N/A		
Prepared L.F. Schlomer	C.D. Wagner		
Checked C. D. Wagner	L.F. Schlomer		
Reviewed Archie T. Dean	Archie T. Dean		
Approved W. C. Brattney	C.M. Johnson		
Date 3/23/87	5/20/88		
List all pages added by this revision.	46 pg. add		
List all pages deleted by this revision.	—		
List all pages changed by this revision.	4-6, 9, 10, 19-23		

Use form TVA 10534 if more space required.

Statement of Problem

Determine effect of seismic event concurrent with major flood on typical powerhouse and spillway blocks. Analyze powerhouse for ½ SSE + ½ PMF and spillway for ½ SSE + ½ PMF and SSE + 25 yr. flood.

Abstract

These calculations contain an unverified assumption(s) that must be verified later. Yes ☐ No ☑

Concrete stability analysis on typical powerhouse and spillway blocks for ½ SSE + ½ PMF on both and SSE + 25 yr. flood on spillway block.

Note:

These calculations were accomplished over a period from 1972 through 1977 in support of the Sequoyah Nuclear Plant FSAR. At the request of DNE in March of 1987, they have been reviewed, verified, and put into RIMS to satisfy the nuclear calculation verification program.

☐ Microfilm and store calculations in RIMS Service Center. Microfilm and destroy. ☐

☑ Microfilm and return calculations to: L.F. Schlomer Address: W3 C173 C-K

cc: RIMS, SL 26 C-K

1175

TVA

Title: Ft Loudoun - Concrete Stability Analysis For SSE and ½ SSE + ½ PMF

REVISION LOG

Revision No.	DESCRIPTION OF REVISION	Date Approved
1	Change RIMS reference number to Cals reference number.	5/20/88

TVA 10534 (EN DES-4-78)

CALCULATION DESIGN VERIFICATION (INDEPENDENT REVIEW) FORM

HEPE5 FLH SQN-WBN BLN BFN
Calculation No.

1
Revision

Method of design verification (independent review) used (check method used):

1. Design Review ✓
2. Alternate Calculation
3. Qualification Test

Justification (explain below):

Method 1: In the design review method, justify the technical adequacy of the calculation and explain how the adequacy was verified (calculation is similar to another, based on accepted handbook methods, appropriate sensitivity studies included for confidence, etc.).

Method 2: In the alternate calculation method, identify the pages where the alternate calculation has been included in the calculation package and explain why this method is adequate.

Method 3: In the qualification test method, identify the QA documented source(s) where testing adequately demonstrates the adequacy of this calculation and explain.

There were no revisions to calculations. This revision corrects a RIMS reference number used on several pages in these calculations that was furnished by CEB concerning seismic analysis. This review addresses this R1 revision only.

Harold C. Buttrey
Design Verifier
(Independent Reviewer)

4/19/88
Date

HEPE5FLHSQN-WBNBLNBFN SHEET A OF

Index - Spillway and Powerhouse Ft. Loudoun Dam
Earthquake Stability Analysis
For SSE + 25 Yr. Flood and ½ SSE + ½ PMF

COMPUTED LFS DATE 3-9-87
CHECKED DATE

Sheet #

1-14	Stability Analysis Spillway Block, ½ SSE + ½ PMF, Gates Open - Base EL 700.
12-14	Summary of Stability Analysis for Spillway Block, ½ SSE + ½ PMF, Gates Open - Base EL 700.
15-33	Stability Analysis Powerhouse Block, ½ SSE + ½ PMF - Base EL 715.
27 & 31-33	Summary of Stability Analysis for Powerhouse Block, ½ SSE + ½ PMF - Base EL 715.
34-40	Stability Analysis Spillway Block, HW-EL 815 and TW-EL 753, Gates Open 4 Feet - Base EL 700.
37-40	Summary of Stability Analysis for Spillway Block, HW-EL 815 and TW-EL 753, Gates Open 4 Feet - Base EL 700.
41-42	Summary of Stability Analysis for Spillway Block, SSE + 25 yr. Flood, Gates Open 4 Feet - Base EL 700.
43	Summary Sheet Showing Assumed Condition of Dam After Failure - SSE + 25 Yr. Flood.

TVA 11030 (WRI-7-75)

HEPE5FLHSQN-WBNBLNBFN SHEET B OF

Index - Spillway and Powerhouse Ft. Loudoun Dam
Earthquake Stability Analysis
For SSE + 25 Yr. Flood and 1/2 SSE + 1/2 PMF

COMPUTED LFS DATE 3-9-87
CHECKED _____ DATE _____

SHEET #

44 Summary of Stability Analysis for Powerhouse and Spillway Blocks, 1/2 SSE + 1/2 PMF.

45 Summary of Stability Analysis for Main Embankment, Slip Circle, 1/2 SSE + 1/2 PMF.

TVA 11030 (WM-7-75)

1179

TVA 4811 (REV. 8 47)

SHEET 1 OF 1

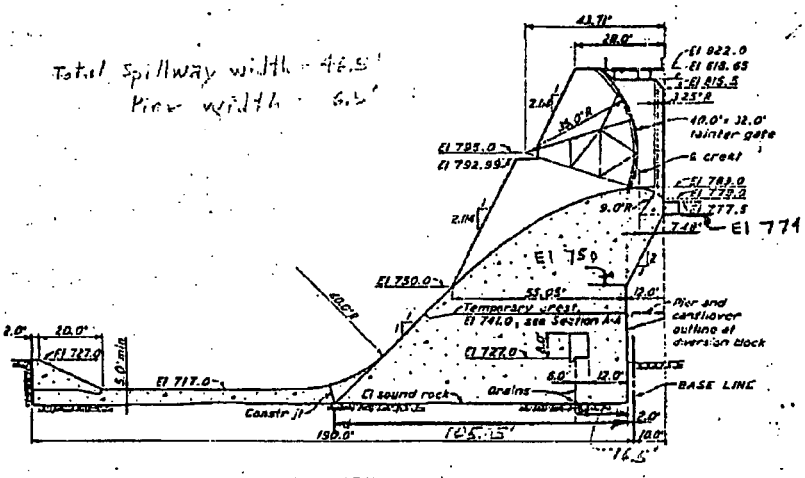
Fort Loudoun - Spillway - O.B.E.
Base El 700 ; HW El 817 , TW El 793
Spillway Gates Open

HEPE5FLHSQN-WBNBLNBFN

Fort Loudoun - Spillway
O.B.E. Stability

COMPUTED GNA DATE 6-23-72
CHECKED RKK DATE 6-27-72

Total Spillway width = 46.5'
Pier width = 6.5'



TYPICAL SPILLWAY SECTION
SHOWING STRUCTURAL FEATURES

refer to Fort Loudoun Design Computations, by A.A. Hans, 4-27-71, sheet 2

$$\underline{D.L.} = \frac{39,233\,K}{}$$

$$x = -\frac{105.05}{} - 12 + \frac{1777.617}{39,233} = -18.02'$$ u.s. of CG of base

Bouyant Force on Spillway: Refer to Watts Bar O.B.E., GNA, 4-10-72, Sheet 4, Spillway

Force	arm	moment (12' u.s. of base)
-258 K	6.45'	1660
-610 K	7.1'	4330
F = -868 K	(6.9')	5990

x = -57.62' from C.L. (upst.)

TVA 489 (REV. 9 47)

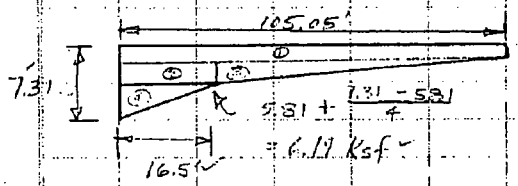
SHEET 2 OF 2

Fort Loudoun Spillway - O.B.E.
Base El 700, HW El 817, TW El 793
Spillway Gates Open

Fort Loudoun
O.B.E. Stability

COMPUTED GNA DATE 6-26-72
HEPE5FLHSQN-WBNBLNBFN CHECKED RBR DATE 6-27-72

Uplift:



93(.0625) = 5.81 Ksf

	Force	Arm	Moment (about c.g.)
① (105.05)(5.81) =	- 611	0	0
② (0.38)(16.5) =	- 6.26	-44.27	+ 277
③ ½(.78)(8.53) =	- 16.29	47.02 6.5'	+ 764 109'
④ ½(1.12)(16.5) =	- 9.25	-6.50 47.02'	60 434'
	642.95	(1.714) 1.28'	1101 K 821'

F = 642.95 x 46.5 = -29,950 K ↑ M = 51,250 'K ↺

Vert TW: F = ½ (93)²(.0625)(46.5) = 12,550 K ↓

X = 52.52 - 93/3 = 21.52'

Horiz HW:

F = ½ (117)²(.0625)(46.5) = 19,900 →

a = 117/3 = 39'

Deduct for open Gates:

F = - ½ (34)²(.0625)(40) = - 1943 K ←

a = 99.33'

Horiz TW:

F = ½ (93)²(.0625)(46.5) = -12,550 K ←

a = 93/3 = 31'

Deduct water over crest

F = ½ (10)²(.0625)(40) = 125 K ← ✓

a = 86.33' M = 10,800 'K

TVA 489 (REV. 9 47)

Fort Loudoun Spillway - OBE
Base El 700, HW El 817 TW El 793
Spillway Gates Open

Fort Loudoun
O.B.E. Stability

COMPUTED GNA DATE 6-27-72
CHECKED PDR DATE 6-27-72

HEPE5FLHSQN-WBNBLNBFN

Summary of non-earthquake Forces:

Item	V	H	arm	Moment (about CG)	
D.L.	+ 39 233		-13.82	- 739,000	738,305
Buoyant force	- 868		-57.62	+ 50,000	50,114
Uplift	- ~~24,950~~ 29,868		-1.714 1.718	+ 51,250	32,177
Vert TW	+ 12,550		+21.52	+ 270,000	270,463
Horiz HW		+ 19,900	+39.0'	+ 776,000	779,758
Open Gates		+ 1,443	+94.33	+ 136,000	- 136,307
Horiz TW		- 12,550 + 125	+ 310	- 389,500	- 389,608
Debit above line		6004	(56)	+ 10,800	119,038
	20,965	= 119,038			
	21,065				
	21,065				
S =	20,965	+ 117,250 (52.52)			
	4890	4,500,000			
	4,884	4,492,200			

f_d = 4.31 - 1.37 dk = + 2.94 ksf = 20.2 psi (comp) - OK
f_u = 4.31 + ~~1.37~~ = ~~5.68~~ ksf = ~~39.1~~ psi

FORT LOUDOUN SEISMIC ANALYSIS — SPILLWAY SECTION
GROUND ACCELERATION = 0.09G — Horizontal — OPERATING BASIS EARTHQUAKE

R M S R E S P O N S E

DAMPING= 5.00%

MASS POINT	DEFLECTION	SHEAR	MOMENT	ACCELERATION
BASE	0.0	0.26157E 04	0.15879E 06	0.90000E-01
1	0.20291E-04	0.26157E 04	0.14083E 06	0.90000E-01
2	0.54727E-04	0.25668E 04	0.11576E 06	0.90000E-01
3	0.98029E-04	0.24252E 04	0.92164E 05	0.90000E-01
4	0.14152E-03	0.22349E 04	0.74794E 05	0.90000E-01
5	0.19224E-03	0.20342E 04	0.59001E 05	0.90000E-01
6	0.24260E-03	0.18118E 04	0.46696E 05	0.93199E-01
7	0.34230E-03	0.15151E 04	0.29037E 05	0.12257E 00
8	0.45789E-03	0.10831E 04	0.16355E 05	0.15658E 00
9	0.57678E-03	0.67451E 03	0.90282E 04	0.19541E 00
10	0.70533E-03	0.43943E 03	0.55294E 04	0.24661E 00
11	0.77231E-03	0.34232E 03	0.41045E 04	0.27700E 00
12	0.95002E-03	0.26018E 03	0.13140E 04	0.36648E 00
13	0.11211E-02	0.12246E 03	0.0	0.45798E 00

HEPE5FLHSQN-WBNBLNBFN

~~SEE RIMS CEB 830902 002~~ R1

SEE CALS-NO. CSG-87-017

CDW 4-12-88
LFS 4-13-88

0

1183

SPILLWAY SECTION
OPERATING BASIS EARTHQUAKE 06/14/72

N S E

%

SHEAR	MOMENT	ACCELERATION
26157E 04	0.15879E 06	0.90000E-01
26157E 04	0.14083E 06	0.90000E-01
25668E 04	0.11576E 06	0.90000E-01
24252E 04	0.92164E 05	0.90000E-01
22349E 04	0.74794E 05	0.90000E-01
20342E 04	0.59001E 05	0.90000E-01
18118E 04	0.46696E 05	0.93199E-01
15151E 04	0.29037E 05	0.12257E 00
10831E 04	0.16355E 05	0.15658E 00
17451E 03	0.90282E 04	0.19541E 00
13943E 03	0.55294E 04	0.24661E 00
14232E 03	0.41045E 04	0.27700E 00
16018E 03	0.13140E 04	0.36648E 00
12246E 03	0.0	0.45798E 00

FLHSQN-WBNBLNBFN

~~CEB B30902 00~~ R1

No. CSG - 87-017

CDW 4-12-88
LFS 4-13-88

2

1184

FORT LOUDOUN SEISMIC ANALYSIS
GROUND ACCELERATION = 0.06G - Vertical

SPILLWAY SECTION
OPERATING BASIS EARTHQUAKE

R M S R E S P O N S E

DAMPING= 5.00%

MASS POINT	DEFLECTION	VERTICAL LOAD	ACCELERATION
BASE	0.0	0.15768E 04	0.60000E-01
1	0.44377E-05	0.15768E 04	0.60000E-01
2	0.10595E-04	0.15314E 04	0.60000E-01
3	0.17012E-04	0.14111E 04	0.60000E-01
4	0.22530E-04	0.12602E 04	0.60000E-01
5	0.27891E-04	0.11082E 04	0.60000E-01
6	0.32354E-04	0.94855E 03	0.60000E-01
7	0.39215E-04	0.74450E 03	0.69816E-01
8	0.44728E-04	0.47754E 03	0.79630E-01
9	0.48598E-04	0.25575E 03	0.86521E-01
10	0.55474E-04	0.14570E 03	0.98762E-01
11	0.58178E-04	0.10583E 03	0.10358E 00
12	0.63756E-04	0.74550E 02	0.11351E 00
13	0.66729E-04	0.31782E 02	0.11880E 00

HEPE5FLHSQN-WBNBLNBFN

SEE RIMS CER 830902 006

SEE CALS - NO. CSG - 87 - 017

R1

CDW 4-12-88
LPS 4-12-88

0

1185

SPILLWAY SECTION
OPERATING BASIS EARTHQUAKE 06/14/72

N S E

Z

ICAL LOAD	ACCELERATION
5768E 04	0.60000E-01
5768E 04	0.60000E-01
5314E 04	0.60000E-01
4111E 04	0.60000E-01
2602E 04	0.60000E-01
1082E 04	0.60000E-01
4855E 03	0.60000E-01
4450E 03	0.69816E-01
7754E 03	0.79630E-01
5575E 03	0.86521E-01
4570E 03	0.98762E-01
0583E 03	0.10358E 00
4550E 02	0.11351E 00
1782E 02	0.11880E 00

E5FLHSQN-WBNBLNBFN

TMS CEB 830902 006

ALS - NO. CSG - 87 - 017

R1

CDW 4-12-88
LPS 4-13-88

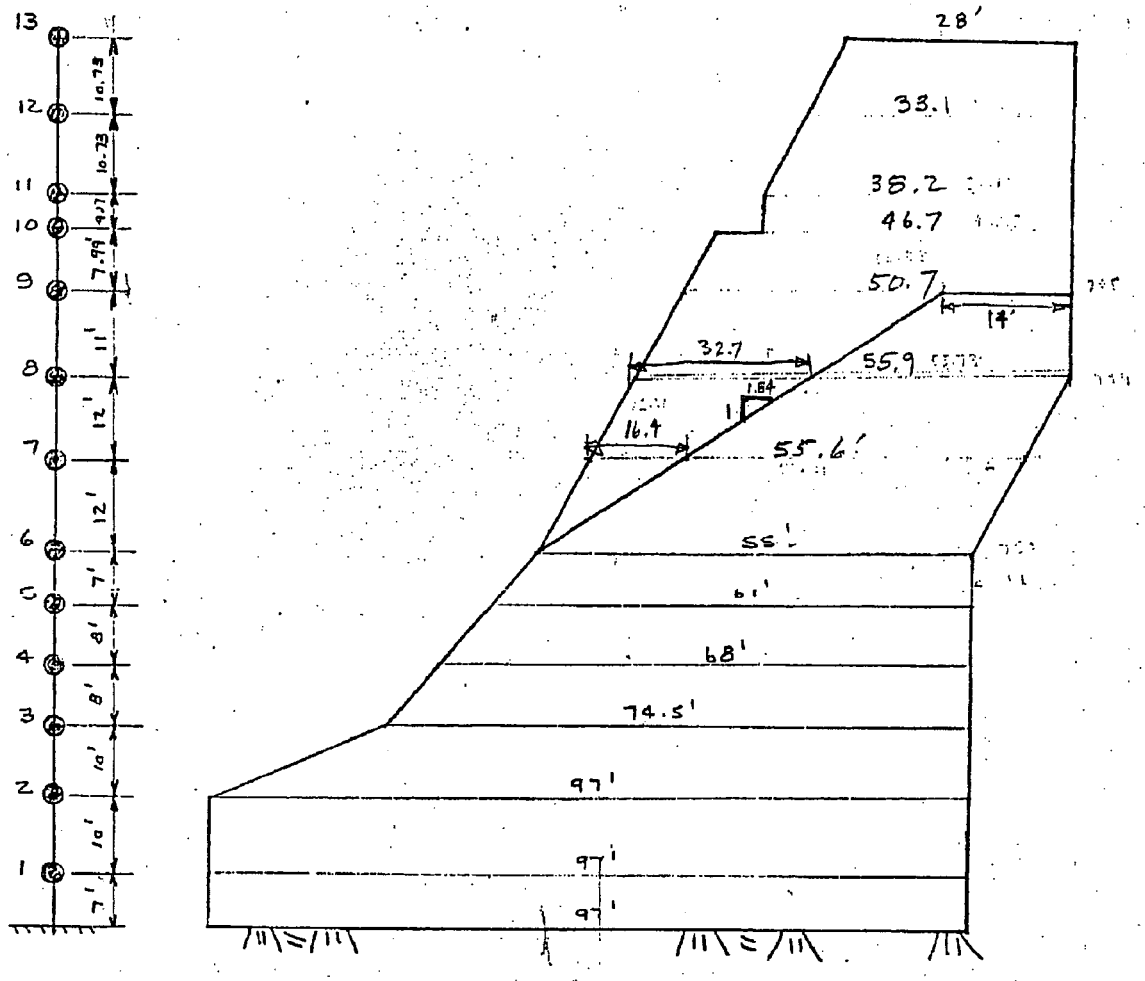
2

118b

TVA 489G (DES-1-63) TENNESSEE VALLEY AUTHORITY SHEET 6 OF

SUBJECT HEPE5FLHSQN-WBNBLNBFN PROJECT

COMPUTED BY DATE CHECKED BY DATE



SCALE 1" = 20'

~~SEE RIMS CEB 830901 003~~

SEE CALS - NO. CSG-87-017

CDW 4-12-88
LFS 4-13-88

R1

1 1 8 7

TVA 489 (REV-9 47)

SHEET 7 OF 7

Fort Loudoun - OBE Stability
HW El 817, TW El 773, Base El 700
Spillway Gates Open

Fort Loudoun
OBE Stability

COMPUTED GNM DATE 6-27-72

HEPE5FLHSQN-WBNBLNBFN CHECKED [illegible] DATE 6-30-72

Horiz Inertia Force:

F = 2616 k →
M = 158,000 'k (158,790)

Vertical Earthquake Force:

Mass Pt	Force	arm	Moment	
1	45.10	4.02	182.51	
2	120.30	4.02	483.61	
3	150.10	15.27	2304.27	
4	152.00	18.52	2815.04	
5	159.65	22.02	3515.49	
6	209.05	25.02	5105.33	
7	266.96	25.32	~~6759.43~~	9618.57
8	221.79	36.42	~~8077.59~~	[illegible]
9	110.05	39.17	~~4310.66~~	[illegible]
10	39.87	41.12	1641.45	
11	31.28	45.42	1420.74	
12	42.77	47.97	2051.68	
13	31.78	50.52	1605.53	
	F = -1577 k ↑	(25.54)	40,273 'k	↺ about [illegible]
		45.21 C.G.	[illegible]	
		28.76'		

TVA-489 (REV. 9-47)

SHEET 5 OF 8

Fort Loudoun - Spillway - OBE
HW El 817, TW El 793, Base El 700
Spillway Gates open

Fort Loudoun Spillway
OBE - Stability

COMPUTED GNA DATE 6-28-72
CHECKED PEC DATE 6-30-72

HEPE5FLHSQN-WBNBLNBFN

Hydrodynamic Force (HW):

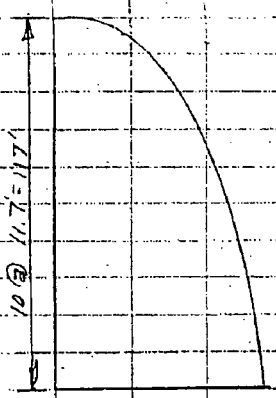
$n=1 \quad T_n = \frac{4(117)}{4720} = 0.099'$

$S_1' = 0.22'$

For First mode only:

$\frac{y}{H}=0 \quad P = \frac{8(.0625)(117)(.22)}{\pi^2} = 1.30'$

= .1	=	.988 ×	1.30 =	1.29
= .2	=	.951 ×	" =	1.24
= .3	=	.891 ×	" =	1.16
= .4	=	.809 ×	" =	1.05
= .5	=	.707 ×	" =	0.92
= .6	=	.588 ×	" =	0.77
= .7	=	.454 ×	" =	0.59
= .8	=	.309 ×	" =	~~0.45~~ 0.40
= .9	=	.156 ×	" =	0.20
= 1.0	=	.00 ×	" =	0.00



	Force	Arm	Moment
1.3(11.7) =	15.2	5.85'	88.92
1.27 " =	14.9	17.55	261.50
1.20 " =	14.0	29.25	409.50
1.11 " =	13.0	40.95	532.35
0.99 " =	11.6	52.65	610.74
0.85 " =	10.0	69.35	693.50
0.68 " =	8.0	76.05	608.40
0.52 " =	6.1	87.75	~~535.28~~
0.33 " =	3.9	99.45	~~387.86~~
0.10 " =	1.2	111.15	~~144.50~~
	98.0 K →	(43.0')	4223 K ↺
F = 98×46.5 =	4557 K ←	(42.6')	M = 196500 K ↺

Deduct (open Gates) 40 × 104 = 416

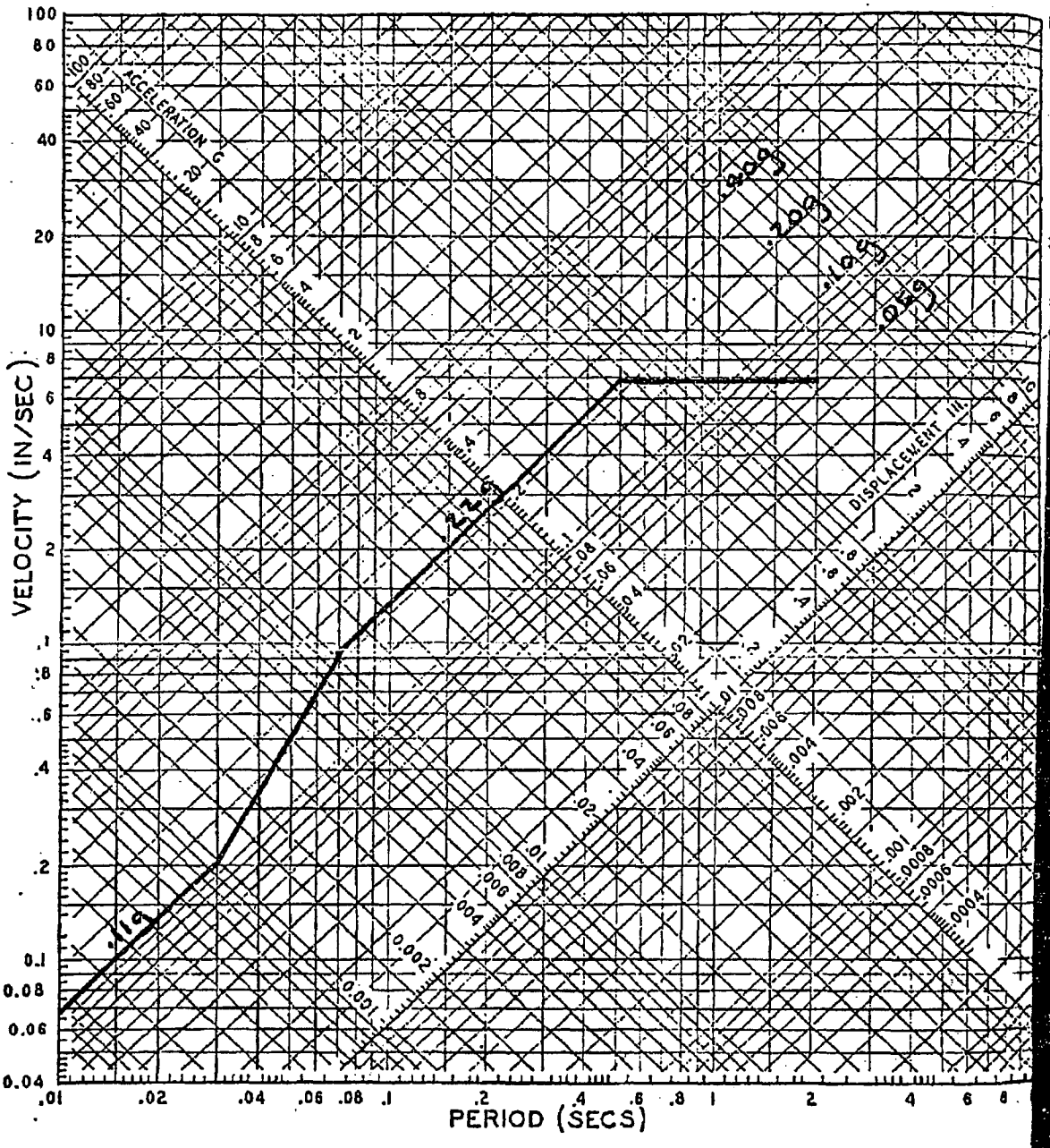
F = (46.5)(10.7) = -497 K ←

(972)(40) = 39,040

M = (104)(446) = -47200 ↻

Sheet 9

HEPE5FLHSQN-WBNBLNBFN

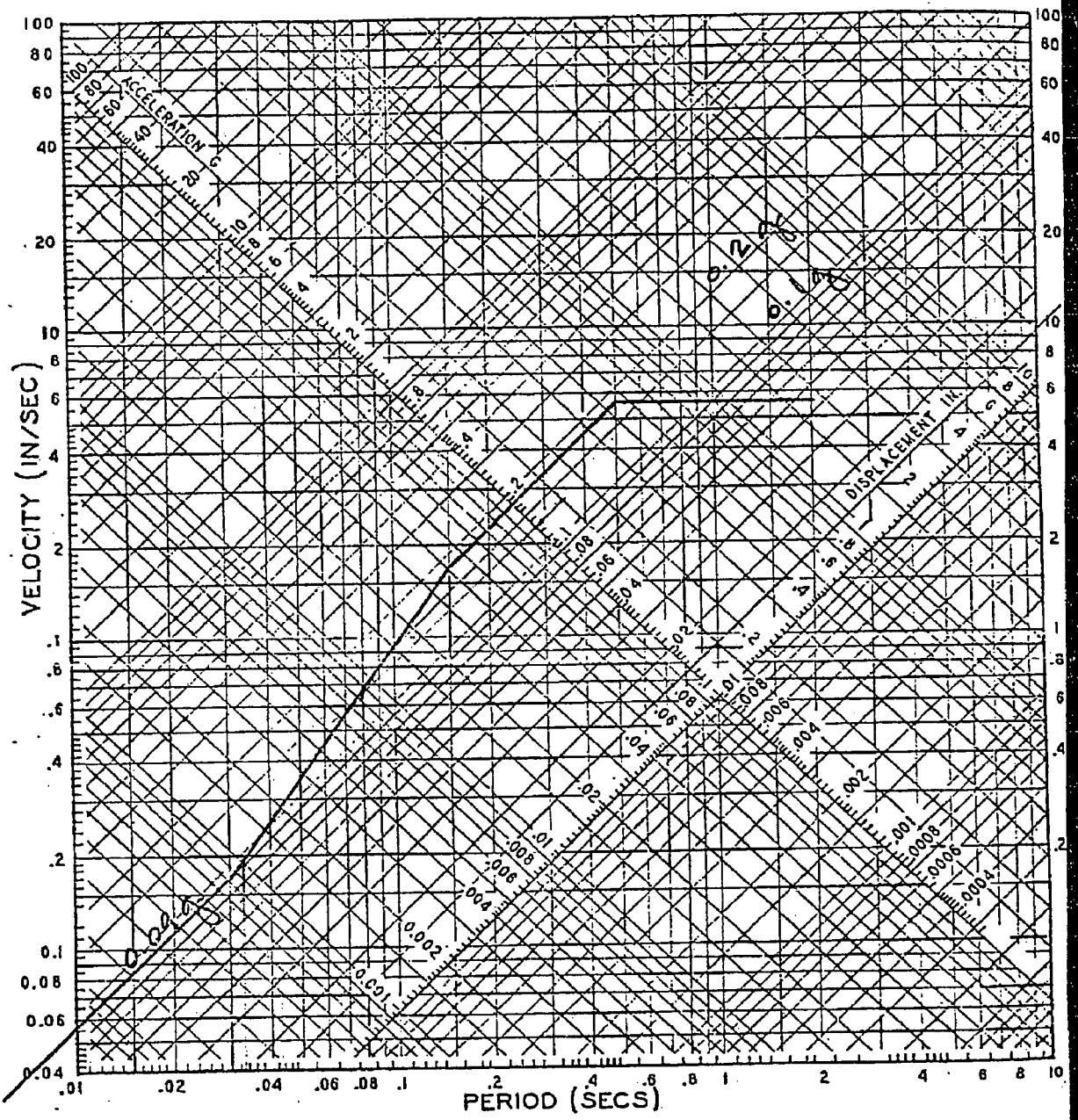


FORT LOUDOUN DAM - SPILLWAY
HYDRODYNAMIC SPECTRUM
OPERATING BASIS EARTHQUAKE

~~SEE RIMS CEB 8309020006~~
SEE CALS - NO. ESG - 87-017
CL'D LPS 4-13-88 CDW 4-11-88

1190

Sheet 10



OPERATING BASIS EARTHQUAKE

HYDRODYNAMIC SPECTRUM

HEPE5FLHSQN-WBNBLNBFN

~~SEE RIMS CEB 830402 006~~

SEE CALS - NO. CSG-87-017

CDW 4-12-88
LLS 4-13-88

R1

TVA 489 (REV. 0 47)

SHEET 6 OF 11

Fort Loudoun - Spillway - OBE
HW El 817, TW 713, Base 700
Spillway Gates open

Fort Loudoun
OBE - Stability

COMPUTED GNA DATE 6-28-72
CHECKED RBR DATE 6-30-72

HEPE5FLHSQN-WBNBLNBFN

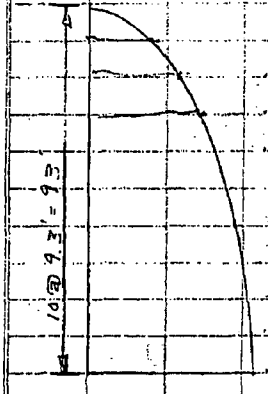
Hydrodynamic Force (TW):

$$T_1 = \frac{4(93)}{4720} = 0.079$$

$S_1 = 0.13$

For First mode only:

@ $\frac{Y}{H}$ = 0.0	$P = \frac{8(66.5)(93)(.13)}{\pi^2}$	= 0.612	
.1	= .988 (.612)	= 0.605	
.2	= .951 "	= 0.582	
.3	= .891 "	= 0.545	
.4	= .809 "	= 0.495	
.5	= .707 "	= 0.432	
.6	= .588 "	= 0.360	
.7	= .454 "	= 0.278	
.8	= .309 "	= 0.189	
.9	= .156 "	= 0.095	
1.0	= 0.00 "	= 0.00	



		Force	Arm	Moment
.048 (1.3)	=	0.15	88.35	39.76
.142 "	=	1.32	79.05	104.35
.239 "	=	2.18	69.75	152.06
.319 "	=	2.97	60.45	179.59
.396 "	=	3.68	51.15	188.23
.469 "	=	4.31	41.85	180.37
.520 "	=	4.84	32.55	157.54
.564 "	=	5.25	23.25	122.06
.594 "	=	5.52	13.95	77.00
.609 "		5.66	4.65	26.32
		36.12		1227.23

F = 1682 K → M = 57,066 'K ↺

Deduct for open gates

0.05 × 40 = 18 39.76 × (40) = 1590

F = − ~~21~~ K M = − ~~1849~~ 'K ↻

Fort Loudoun · Spillway - OBE
HW El 817, TW 793, Base 700
Spillway Gates Open

Fort Loudoun
OBE - Stability

COMPUTED GNA DATE 6-28-72
CHECKED RJR DATE 6-30-72

HEPE5FLHSQN-WBNBLNBFN

Summary of All Forces:

Item	V	H	arm	Moment (at CG)
from Sht. 3	21,065	6009		119,038
Horiz Inertia		2616		158,000
Vert. "	-1577	4524		40,273
Hydrodyn. HW		4557		196,500
open Gates		416 - 497		- 47,200
Hydrodyn. TW		1682		57,066
open Gates		18 - 21		- 1549

$\Sigma V = 19{,}488$ k ↓ $\Sigma H = 14{,}341$ → (26.78) $\Sigma M = 521{,}828$ k ↺

Resultant is 25.4 inside base

$$f = \frac{19{,}488}{4885} \pm \frac{521{,}828(52.525)}{4{,}492{,}208}$$

$f_u = 3.99 \pm 6.11 = -2.12$ ksf = -14.7 psi (tension)

$f_L = 10.10$ ksf = 70.2 psi (compression)

$$\frac{\Sigma H}{\Sigma V} = \frac{14{,}341}{19{,}488} = 0.74$$

$$\frac{\Sigma H}{A} = \frac{14{,}341(1000)}{4885(144)} = 20.4 \text{ psi}$$

$$Q = \frac{.65(19488) + 144(4885)(.25)}{14{,}341} = 13.1$$

Stress for Q = 1 : Considering entire base area

$$S = \frac{14{,}341 - 12{,}667}{4885} = 0.343 \text{ ksf} = 2.38 \text{ psi}$$

Stress for Q = 1 : considering portion of Base in comp. only

$$S = \frac{1674}{3595} = 0.466 \text{ ksf} = 3.24 \text{ psi}$$

1 1 9 3

TVA 489 (REV-9 47)

SHEET 8 OF 13

Fort Loudoun Spillway - OBE
HW El 817, TW 793, Base El 700
Spillway Gates Open

Fort Loudoun
OBE - Stability

COMPUTED GNA DATE 6-29-72
CHECKED [illegible] DATE 6-30-72

HEPE5FLHSQN-WBNBLNBFN

$$f_{max} = \frac{19,188}{3(35.71)(66.5)} = 5.42 \text{ ksf} = 37.7 \text{ psi}$$

F.S. against OT:

Item	Force	Arm	M_R	M_{OT}
DL (W)	37,233	71.34	2,798,882	
Powerhouse DL	868	110.14		95,602
Uplift (U)	29,868	53.8		1,606,898
Vert TW (V)	12,566	31.0	389,608	
Horiz HW				775,788
open Gates				− 136,307
Horiz TW			389,608	
− Induct Open Gates			− 10,800	
Horiz Inertia		81.17		158,890
Vert Inertia	1577 (18.04)			123,200
Hydrodyn HW				196,500
− open Gates				− 47,240
Hydrodyn TW				57,066
− open Gates				− 1,549
			$\Sigma M_R = 3,567,298$	$\Sigma M_{OT} = 2,827,698$

$$F.S._{OT} = \frac{3,567,298}{2,827,698} = 1.26 \text{ ok}$$

1 1 9 4

TVA 489 (REV. 9 47)

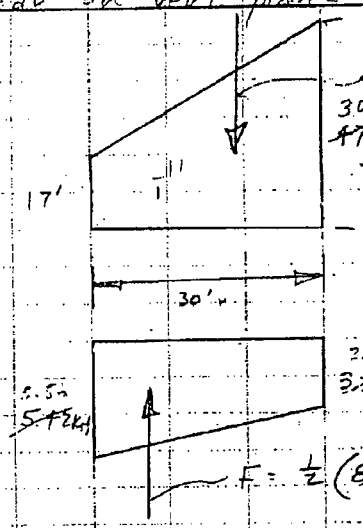
Fort Loudoun Spillway - OBE
Base El 700, HW El 917, TW El 793
Spillway Gates open

Fort Loudoun
O.B.E.

COMPUTED GNA DATE 6-29-72
CHECKED KBK DATE 6-30-72

HEPESFLHSQN-WBNBLNBFN

Shear on Vert plane through toe: approximate using bouyant wt. of concrete



$F = \frac{1}{2}(8.79)(30)(46.5)(.08175)$ 47 30 = 3900 2871

$F = \frac{1}{2}(8.79)(30)(46.5) = 6160$ K ↑ 8.12 6.210

$V = 6100 - 3900 = 2200$ K 6210 2900 3340

avg Shear $v = \frac{2200000}{30\ 47(46.5)(144)} = 7.0$ psi 3340 900 16.6

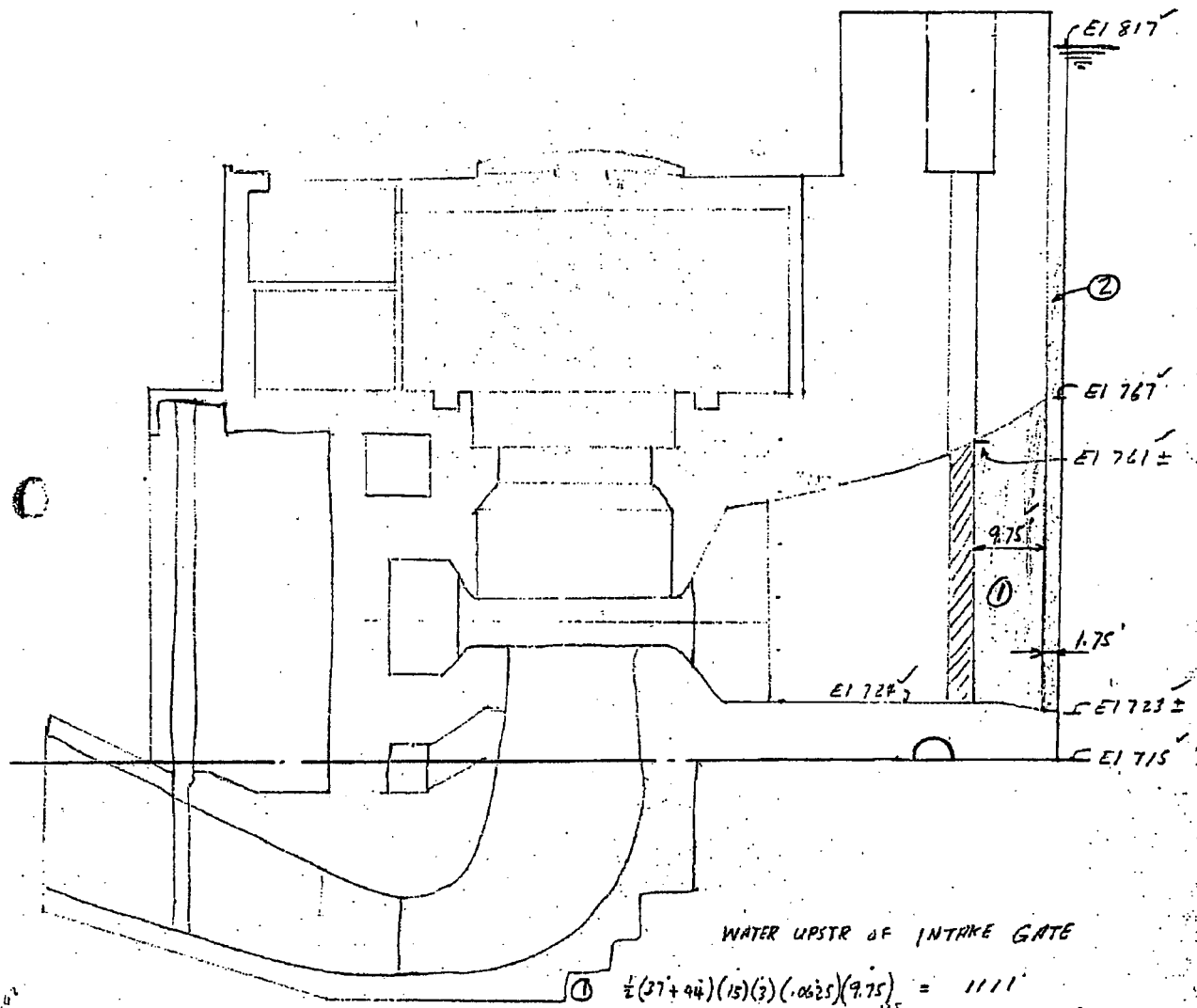
TVA 488 A (DEC-3-39) TENNESSEE VALLEY AUTHORITY SHEET 1 OF 15

SUBJECT POWERHOUSE - STABILITY PROJECT FT LOUDOUN

HW EL 817 , TW EL 793 BASE EL 715

COMPUTED BY RBR DATE 6-27-72 CHECKED BY GNA DATE 6-30-72

HEPE5FLHSQN-WBNBLNBFN



WATER UPSTR OF INTAKE GATE

1 $\frac{1}{2}(37+44)(15)(3)(.0625)(9.75) = 1111'$

ARM $= (1.75 + 9.75) - \frac{9.75}{3}\left[\frac{2(44)+37}{44+37}\right] = 6.48'$

SECT THRU POWERHOUSE
NOT TO SCALE

2 $(94)(1.75)(70)(0.0625) = 720'$

ARM $= \frac{1.75}{2} = 0.88'$

TVA 469 (REV. 9 47)

SHEET 2 OF 16

POWERHOUSE - STABILITY

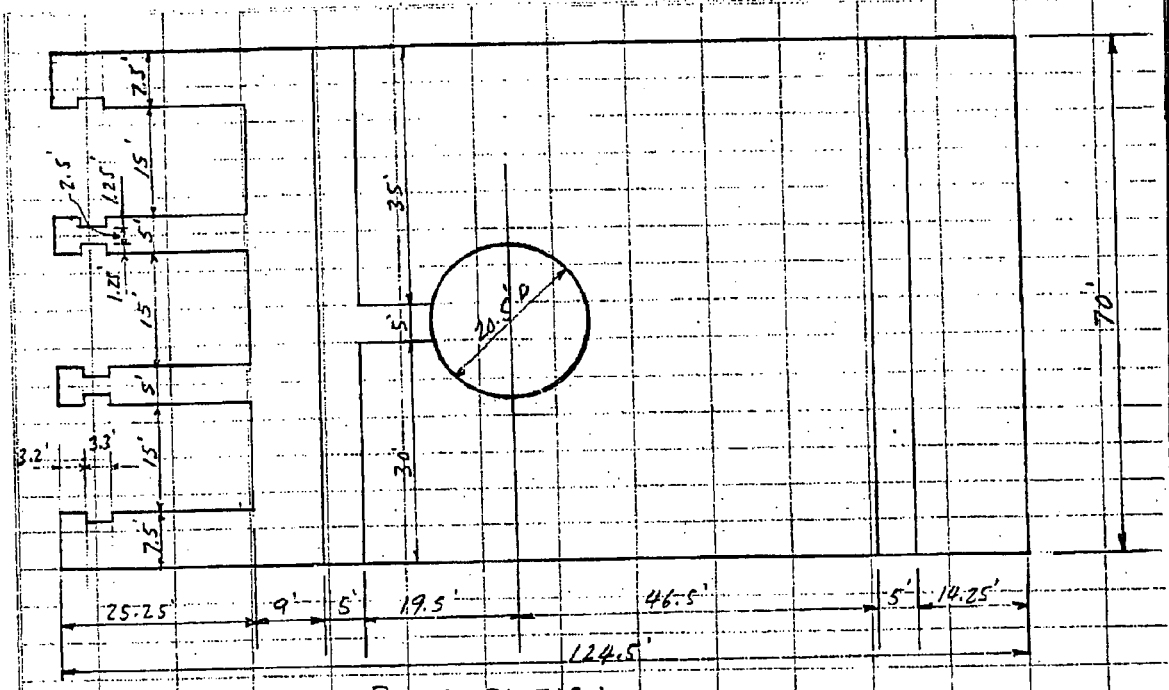
HW EL 817, TW EL 793

BASE EL 715

FT LOUDOUN

COMPUTED RBR DATE 6-27-72

HEPE5FLHSQN-WBNBLNBFN CHECKED GNA DATE 6-30-72



PLAN EL 715 ±

AREA AND C.G.

ITEM	AREA	ARM	MOMENT AT HEEL
(70)(124.5)	8715	62.25	542509
- (70)(5)	- 350	17.75	- 6213
- (3.14)(10.25)²	- 330	65.75	- 21691
- (5)(9.25)	- 46	80.63	- 3729
- (70)(5)	- 350	87.75	- 30713
- (5)(15)(25.25)	- 1136	111.87	- 127113
- (2)(1.25)(3.3)	- 25	119.65	- 2961
	6478	(54.04)	350089

TVA 489 (REV-9 47)

SHEET 3 OF 17

POWERHOUSE - STABILITY — FT LOUDOUN

HWEL 817 , TWEL 793

BASE EL 715

COMPUTED RBR DATE 6-28-72

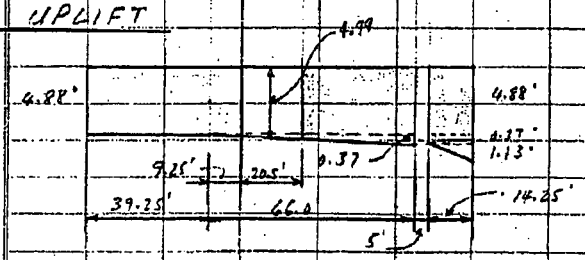
HEPESFLHSQN-WBNBLIIBFII CHECKED GVH DATE 6-30-72

MOMENT OF INERTIA

$8715\left[\left(\frac{124.5}{12}\right)^2 + (8.21)^2\right]$	=		11 844 483
$350\left[\left(\frac{5}{12}\right)^2 + (36.29)^2\right]$	=	−	461 667
$330\left[\left(\frac{10.25}{4}\right)^2 + (11.71)^2\right]$	=	−	53 919
$46\left[\left(\frac{9.25}{12}\right)^2 + (26.59)^2\right]$	=	−	32 851
$350\left[\left(\frac{5}{12}\right)^2 + (33.71)^2\right]$	=	−	398 457
$1136\left[\left(\frac{25.25}{12}\right)^2 + (57.83)^2\right]$	=	−	3 859 491
$25\left[\left(\frac{3.3}{12}\right)^2 + (65.61)^2\right]$	=	−	107 639
Σ	=		6 930 459

FROM DESIGN BOOK E-41-4 FT LOUDOUN PROJECT
SH 3 BY LAVIK DATED 1-16-42 (SH 157 IN BOOK)
DEAD LOAD = 59 700 K MOMENT AT HEEL = 3043000 K'
RESULTANT IS 51' DNSTR OF HEEL

UPLIFT



				M ABT HEEL
(4.88)(6478)	=	31 613	54.04	1 708 347
½(0.37)(66.0)(70)	=	855	41.25	35 256
(0.37)(14.25)(70)	=	369	7.13	2632
½(1.13)(14.25)(70)	=	564	4.75	2677
−(4.99)(330)	=	−1647	65.75	−108 271
		31 754	(51.67)	1 640 641

1 1 9 8

TVA 489 (REV-9 47)

SHEET 10 OF 18

POWERHOUSE - STABILITY — FT LOUDOUN

HW EL 817, TW EL 793

BASE EL 715

COMPUTED RBR DATE 6-28-72

HEPE5FLHSQN-WBNBLNBFN CHECKED GNA DATE 6-30-72

SUMMATION OF NON EARTHQUAKE FORCES

ITEM		H	V	ARM	MOMT HEEL
D.L.			↓ 59700		3 043 000
UPLIFT			↑ 31754		- 1 640 641
HW UPSTR OF INTAKE GATE			↓ 1111	6.48	7199
" " " " "			↓ 720	.88	634
HW $\frac{1}{2}(102)^2(0.0625)(70)$	←	22759		34.0	773 798
TW $\frac{1}{2}(78)^2(0.0625)(70)$	→	13309		26.0	- 346 028
Σ =	←	9450	↓ 29777	(61.72)	1 837 962

$e = 61.72 - 54.04 = 7.68'$ DNSTR FROM CG

$f_u = \frac{29777}{6478} - \frac{29777(7.68)(54.04)}{6\,930\,459} = 4.60 - 1.78 = 2.82$ KSF

$= 19.6$ psi COMPR

$f_d = 4.60 + (0.0329974)(70.96) = 4.60 + 2.32 = 6.92$ KSF

$= 48.1$ psi COMPR

TVA 466 A (DEC-3-39) TENNESSEE VALLEY AUTHORITY SHEET 19. OF

SUBJECT FORT LOUDON DAM - POWERHOUSE SECTION PROJECT WBNP HEPE5FLHSQN-WBNBLNBFN

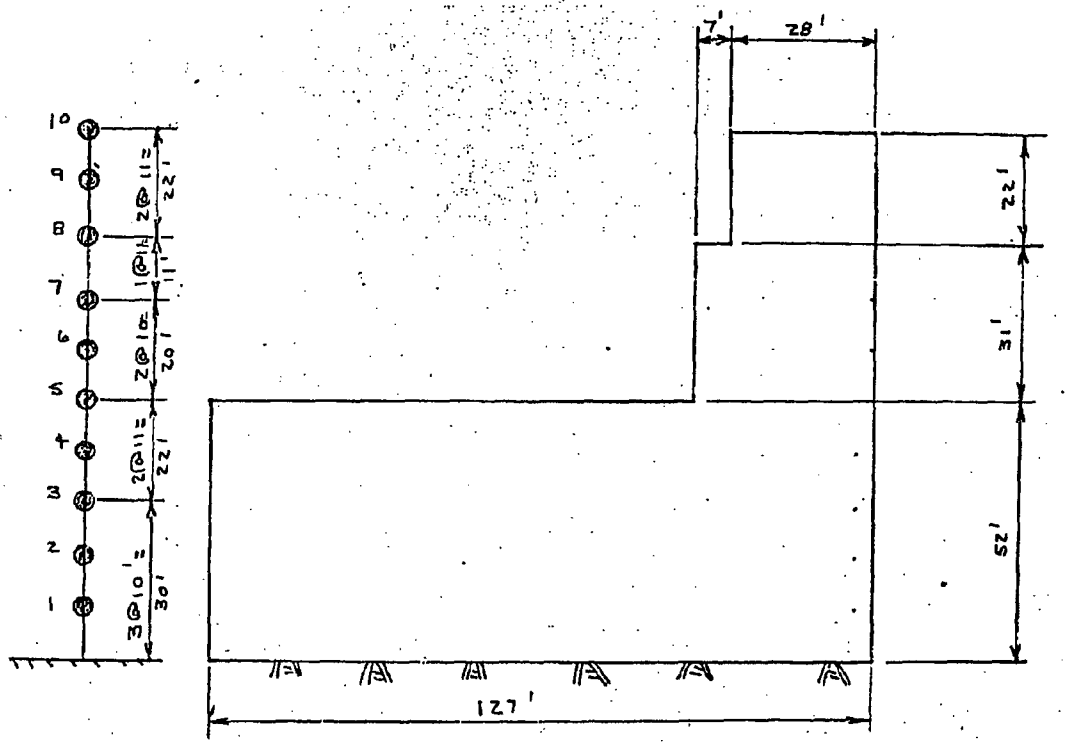
COMPUTED BY STONE DATE 6-07-72 CHECKED BY DATE

CONSIDER 5' WIDE SECTION TO INCLUDE PIERS.

$f_c' = 4000$ psi

$E = 3.830000$ psi

$\gamma = 150$ lb/ft^3



ELEMENTS 1 TO 5 : A = 635 FT^2 & I = 853492.9 FT^4

ELEMENTS 6 TO 8 : A = 175 FT^2 & I = 17864.6 FT^4

ELEMENTS 9 AND 10 : A = 140 FT^2 & I = 9146.7

~~SEE RIMS CEB 83-0902-006~~

SEE CALS - NO. CSG-87-017

R1

CDW 4-12-88
LFS 4-13-88

1 2 0 0

FORT LOUDOUN DAM — POWERHOUSE SECTION

GROUND ACCELERATION = 0.09G — OPERATING BASIS EARTHQUAKE

Horizontal

R M S R E S P O N S E

DAMPING= 5.00%

MASS POINT	DEFLECTION	SHEAR	MOMENT	ACCELERATION
BASE	0.0	0.45376E 03	0.23475E 05	0.90000E-01
1	0.34554E-04	0.45376E 03	0.19350E 05	0.90000E-01
2	0.71154E-04	0.42950E 03	0.15580E 05	0.90000E-01
3	0.10741E-03	0.38226E 03	0.12337E 05	0.90000E-01
4	0.14459E-03	0.31469E 03	0.94251E 04	0.10552E 00
5	0.17714E-03	0.23830E 03	0.70466E 04	0.11762E 00
6	0.26306E-03	0.20000E 03	0.51014E 04	0.12358E 00
7	0.39507E-03	0.18237E 03	0.33029E 04	0.13711E 00
8	0.57379E-03	0.15249E 03	0.16334E 04	0.18776E 00
9	0.77741E-03	0.10586E 03	0.47023E 03	0.27442E 00
10	0.97569E-03	0.42749E 02	0.0	0.37009E 00

HEPE5FLHSQN-WBNBLNBFN

~~SEE RIMS CEB 830902 003~~

SEE CALS - NO. CSG - 87 - 017 R1

CDW 4-12-88

LFS 4-13-88

FORT LOUDOUN DAM
GROUND ACCELERATION = 0.06G

POWERHOUSE SECTION
OPERATING BASIS EARTHQUAKE

Vertical
RMS RESPONSE

DAMPING= 5.00%

MASS POINT	DEFLECTION	VERTICAL LOAD	ACCELERATION
BASE	0.0	0.50109E 03	0.60000E-01
1	0.14308E-04	0.50109E 03	0.60000E-01
2	0.27958E-04	0.47801E 03	0.60000E-01
3	0.40320E-04	0.43291E 03	0.68294E-01
4	0.51772E-04	0.36460E 03	0.87693E-01
5	0.60338E-04	0.27272E 03	0.10220E 00
6	0.81658E-04	0.20577E 03	0.13831E 00
7	0.99216E-04	0.16946E 03	0.16805E 00
8	0.11325E-03	0.12314E 03	0.19183E 00
9	0.12369E-03	0.73290E 02	0.20951E 00
10	0.12724E-03	0.24892E 02	0.21552E 00

HEPE5FLHSQN-WBNBLNBFN

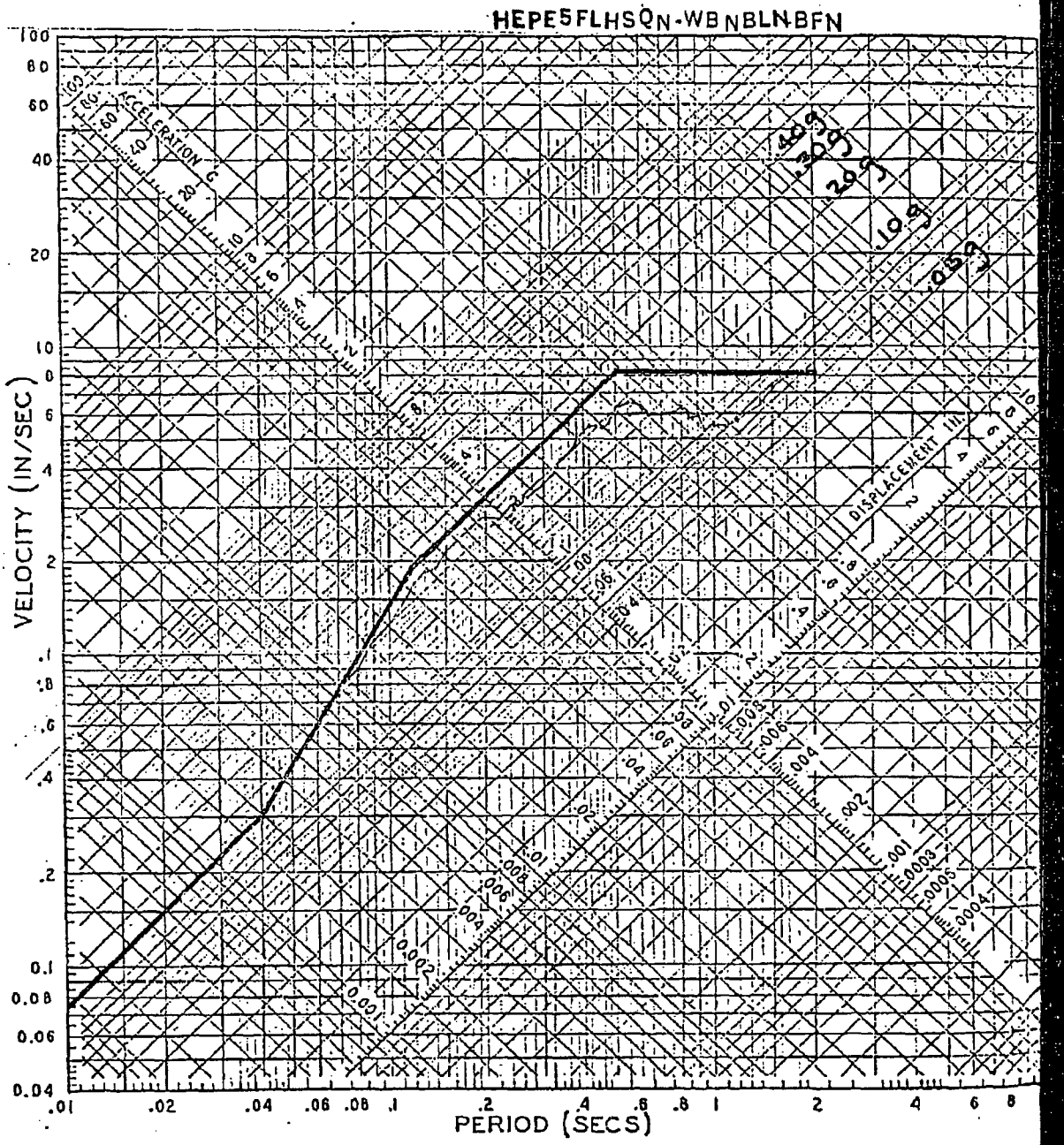
~~SEE RIMS CEB 830902 006~~

SEE CALS - NO. CSG - 87 - 017

R1

CDW 4-12-88
LFS 4-13-88

Sheet 22



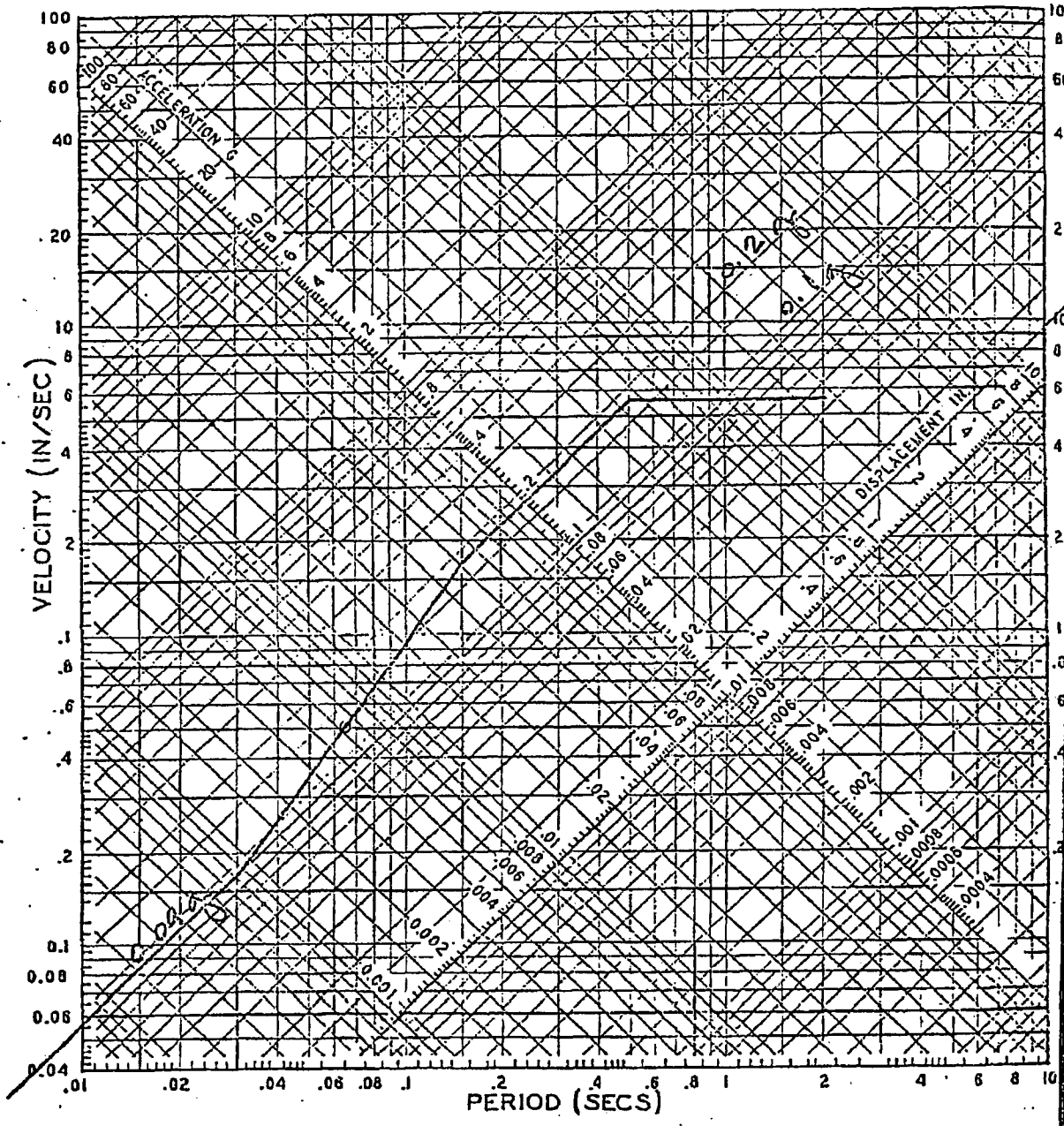
FORT LOUDOUN DAM - POWERHOUSE
HYDRODYNAMIC SPRECTRUM
OPERATING BASIS EARTHQUAKE

~~SEE RIMS CEB 830902 006~~
SEE CALS-NO. CSG-87-017 CPW 4-12-88

R1

1 2 0 3

Sheet 23



OPERATING BASIS EARTHQUAKE

HYDRODYNAMIC SPECTRUM

HEPE5FLHSQN-WBNBLNBFN

~~SEE RIMS CE.8 830902 006~~

SEE CALS - NO. CSG - 87-017

CDW 4-12-88
LFS 4 13-88

R1

1 2 0 4

TVA 489 (REV. 9 47)

SHEET 5 OF 24

POWERHOUSE - STABILITY - OBE — FT LOUDOUN

HWEL 817, TWEL 793

BASE EL 715

COMPUTED RBR DATE 6-30-72

HEPE5FLHSQN-WBNBLNBFN CHECKED GNA DATE 7-5-72

DYNAMIC FORCES

HORIZ

FROM COMPUTER PRINTOUT FOR 5' SECTION,

HORIZ FORCE = 453.76 K

" MOMENT = 23475 'K

FOR 70' SECTION: HORIZ FORCE = $\frac{453.76}{5} \times 70 =$ 6353 K

" MOMENT = $\frac{23475}{5} \times 70 =$ 328650 'K

VERT

MASS POINT	FORCE	ARM	MOMENT ABT HEEL
1	23.08	63.5	1465.58
2	45.10	63.5	2863.85
3	68.31	63.5	4337.69
4	91.88	63.5	5834.38
5	66.95	63.5	4251.33
6	36.31	17.5	635.43
7	46.32	17.5	810.60
8	49.85	17.5	872.38
9	48.40	14.0	677.60
10	24.89	14.0	348.46
Σ	501.09		22097.30
Σ × 70/5 =	7015.26	(44.1)	309362.2

TVA 489 (REV. 9-47)

POWERHOUSE - STABILITY - OBE — FT LOUDOUN

HW EL 817, TW EL 793

BASE EL 715

COMPUTED RBR DATE 6-30-72

HEPE5FLHSQN-WBNBLNBFN CHECKED GNA DATE 7-6-72

HYDRODYNAMIC FORCES (HW)

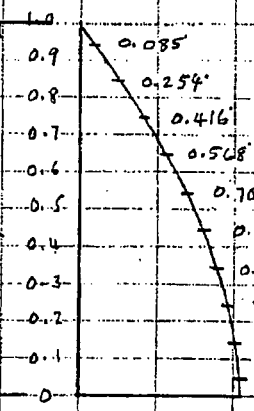
$$t = \frac{4H}{4720} = \frac{4(102)}{4720} = 0.0865^{\cdot}$$

FROM HYDRODYNAMIC SPECTRUM $S = 0.21^{\cdot}$

CONSIDER FIRST MODE ONLY

@ Y/H = 0 $\quad P = \frac{(0.0635)(102)(8)(1)(0.21)}{\pi^2} = 1.09^{\cdot}$

@ Y/H =	0.1	P =	0.988 (1.09)	= 1.08
"	0.2	" =	0.951 (1.09)	= 1.04
"	0.3	" =	0.891 (1.09)	= 0.971
"	0.4	" =	0.809 (1.09)	= 0.882
"	0.5	" =	0.707 (1.09)	= 0.771
"	0.6	" =	0.588 (1.09)	= 0.641
"	0.7	" =	0.454 (1.09)	= 0.495
"	0.8	" =	0.309 (1.09)	= 0.337
"	0.9	" =	0.156 (1.09)	= 0.170
"	1.0	" =	0 (1.09)	= 0



			FORCE	ARM	MOMENT
(10.2)	(1.085)	=	11.07	5.1	56.44
	(1.06)	=	10.81	15.3	165.42
	(1.01)	=	10.30	25.5	262.70
	(0.927)	=	9.46	35.7	337.56
	(0.827)	=	8.44	45.9	387.18
	(0.706)	=	7.20	56.1	403.99
	(0.568)	=	5.79	66.3	384.12
	(0.416)	=	4.24	76.5	324.60
	(0.254)	=	2.59	86.7	224.62
	(0.085)	=	0.87	96.9	84.01
	Σ		70.77		2630.64
Σ × 70		=	4954		184145

TVA 483 (REV. 9 47)

SHEET 7 OF 26

POWERHOUSE - STABILITY - OBE

FT LOUDOUN

HW EL 817, TW EL 793

BASE EL 715

HEPE5FLHSQN-WBNBLNBFN

COMPUTED RBR DATE 6-30-72

CHECKED CVA DATE 7-6-72

HYDRODYNAMIC FORCES (TW)

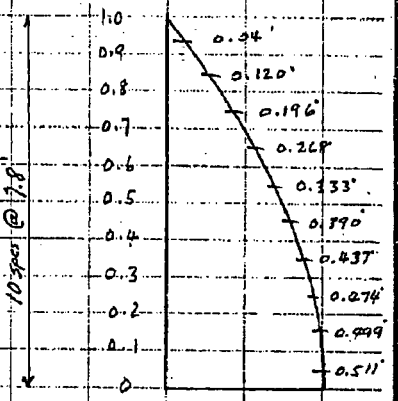
$t_1 = \frac{4(78)}{4720} = 0.066'$

FROM HYDRODYNAMIC SPECTRUM $S = 0.13'$

CONSIDER FIRST MODE ONLY

@ Y/H = 0 $P = \frac{(0.0625)(78)(8)(1)(0.13)}{\pi^2} = 0.514'$

@ Y/H = 0.1	P = 0.988 (0.514)	= 0.508'	
0.2	0.951	= 0.489'	
0.3	0.891	= 0.458'	
0.4	0.809	= 0.416'	
0.5	0.707	= 0.363'	
0.6	0.588	= 0.302'	
0.7	0.454	= 0.233'	
0.8	0.309	= 0.159'	
0.9	0.156	= 0.080'	
1.0	0	=	



		FORCE	ARM	MOMENT
(7.8)(0.511)	=	3.99'	3.9'	15.54'
(0.499')	=	3.89'	11.7	45.54'
(0.474')	=	3.69'	19.5	72.10'
(0.437')	=	3.41'	27.3	93.05'
(0.390')	=	3.04'	35.1	106.77'
(0.333')	=	2.60'	42.9	111.43'
(0.268')	=	2.09'	50.7	105.98'
(0.196')	=	1.53'	58.5	89.43'
(0.120')	=	0.94	66.3	62.06'
(0.04')	=	0.31'	74.1	23.12'
	Σ =	25.49'		725.02'
Σ x 70	=	1784'		50751'

1207

TVA 489 (REV. 9 47)

SHEET 8 OF 27

POWERHOUSE - STABILITY - OBE — FT LOUDOUN

HWEL 817, TWEL 793

BASE EL 715

COMPUTED RBR DATE 7-3-72

HEPE5FLHSQN-WBNBLNBFN

CHECKED GNA DATE 7-6-72

SUMMATION OF ALL FORCES

ITEM		H	V	M ABT HEEL
Σ FROM SH 4	←	9450	↓ 29777	1,837,962
DYNAMIC FORCES	←	6353		328650
			↑ 7015	− 309362
HYDRODYNAMIC FORCES	←	4954		184145
	←	1784		50751
Σ	←	22541	↓ 22762 (91.91)	2,092,146

$e = 91.91 - 54.04 = 37.87'$ DNSTR FROM C.G.

$f_u = \frac{22762}{6478} - \frac{22762(37.87)(54.04)}{6,930,459} = 3.51 - 6.72 = -3.21$ KSF

$= 22.3$ psi TENSION

$f_d = 3.51 + (0.126378)(70.46) = 3.51 + 8.76 = 12.27$ KSF

$= 85.2$ psi COMPR.

$\frac{\Sigma H}{\Sigma V} = \frac{22541}{22762} = 0.99$

$\frac{\Sigma H}{A} = \frac{22541}{6478} = 3.48$ KSF $= 24.2$ psi

$Q = \frac{0.65\,(22762) + 0.25\,(6478)(149)}{22541} = 11.6$

(14795) (23504)

S FOR Q = 1 (USING ENTIRE BASE AREA)

$S = \frac{22541 - 14795}{6478} = 1.2$ KSF $= 8.3$ psi

1208

TVA 489 (REV-9 47)

SHEET 9 OF 28

POWERHOUSE - STABILITY - OBE — FT. LOUDOUN

HWEL 817, TWEL 793

BASE EL 715

COMPUTED RBR DATE 7-3-72

HEPESFLHSQN-WBNBLNBFN CHECKED NA DATE 7-6-72

STRESS FOR NO TENSION IN BASE

ASSUME 31' TO CRACK

LOCATE CG.

		AREA	X	Ax
		6478	59.04	350089
(14.25)(70)	=	- 998	7.13	- 7112
(11.75)(70)	=	- 823	25.13	- 20669
		4657	(69.21)	322308

69.21 - 31.0 = 38.21' FROM CRACK

COMPUTE I_{CG}

	I_o	A	d	Ad^2	$(I_o + Ad^2)$ I_{CG}
	6930459	6478	15.17	1490775	8421234
$\frac{70}{12}(14.25)^3$	- 16860	- 998	62.08	- 3846219	- 3863099
$\frac{70}{12}(11.75)^3$	- 9463	- 823	44.08	- 1599127	- 1608590
					2949545

e = 91.91 - 69.21 = 22.7'

$$\bar{X} = \frac{I}{eA} = \frac{2949545}{(22.7)(4657)} = 27.9' \text{ FROM CRACK}$$

1204

TVA 489 (REV-8 47)

SHEET 10 OF 29

POWERHOUSE - STABILITY - OBE

FT LOUDOUN

HW EL 817 TW EL 793

BASE EL 715

COMPUTED RBR DATE 7-3-72

HEPE5FLHSON-WBNBLNBFN

CHECKED LFS DATE 3-9-97

TRY A 36' CRACK

LOCATE CG

	AREA	X	Ax
	6478	54.04	350089
(14.25)(70)	- 998	7.13	- 7112 OK
(16.75)(70)	- 1173	27.63	- 32396 OK
	4307	(72.11)	310581

72.11 - 36 = 36.11' FROM CRACK

COMPUTE I_{CG}

	I_o	A	d	Ad^2	$(I_o + Ad^2)$ I_{CG}
	6930459	6478	18.07	2115228	9045687
$\frac{70}{12}(14.75)^3$	- 16880	- 998	64.98	- 4213956	- 4230836
$\frac{70}{12}(16.75)^3$	- 27413	- 1173	44.48	- 2320746	- 2348159
					2466692

$e = 91.91 - 72.11 = 19.8$

$\bar{x} = \frac{2466692}{(19.8)(4307)} = 28.93'$ FROM CRACK

TVA 489 (REV. 9 47)

SHEET 11 OF 30

POWERHOUSE - STABILITY - OBE — FT LOUDOUN

H.W. EL 817 T.W. EL 793

BASE EL 715

COMPUTED RBR DATE 7-3-72

CHECKED LFS DATE 3-9-87

HEPE5FLHSQN:WBNBLNBEN

TRY A 46' CRACK

LOCATE CG

	AREA	X	AX
	6478	54.04	350089
(14.25)(70)	- 998	7.13	- 7112
(26.75)(70)	- 1873	32.63	- 61100 OK
	3607	(78.15)	281877

78.15 - 46 = 32.15 FROM CRACK

COMPUTE I_{CG}

	I_o	A	d	Ad^2	I_{CG}
	6930459	6478	24.11	3765610	10696069
$\frac{70}{12}(14.25)^3$	- 16880	- 998	71.02	- 5033753	- 5050633
$\frac{70}{12}(26.75)^3$	- 111658	- 1873	45.52	- 3880988	- 3992646
					1652790

e = 91.91 - 78.15 = 13.76

$$\bar{X} = \frac{1652790}{(13.76)(3607)} = 33.30 \text{ FT FROM CRACK}$$

TVA 469 (REV. 9-47)

POWERHOUSE - STABILITY - OBE — FT LOUDOUN

HW EL 817, TW EL 783

BASE EL 715

COMPUTED RBR DATE 7-3-72

HEPE5FLHSQN-WBNBLNBFN

CHECKED GNA DATE 7-6-72

TRY A 45' CRACK

LOCATE C.G.

		AREA	X	Ax
		6478	54.04	350089
(14.25)(70)	-	998	7.13	- 7112
(25.75)(70)	-	1803	32.13	- 57914
		3677	(77.53)	285063

77.53 - 45.0 = 32.53' FROM CRACK

COMPUTE I_{CG}

		I_o		A	d	Ad^2	I_{CG}
		6930459		6478	23.49	3574431	10504890
$\frac{70}{12}(14.25)^3$	-	16880	-	998	70.40	- 4946248	- 4963128
$\frac{70}{12}(25.75)^3$	-	99598	-	1803	45.40	- 3716271	- 3815869
							1725893

$e = 91.91 - 77.53 = 14.38$

$\bar{x} = \frac{I_{CG}}{eA} = \frac{1725893}{(14.38)(3677)} = 32.64'$ FROM CRACK

CLOSE ENOUGH

MAX S: $\frac{22762}{3677} + \frac{22762(14.38)(79.5 - 32.53)}{1725893}$ (46.97)

$= 6.19 + 8.91 = 15.1$ KSF $= 104.86$ psi

S FOR Q = 1 (USING CRACKED BASE)

$S = \frac{2254 - 14795}{3677} = \frac{7746}{3677} = 2.1$ KSF $= 14.6$ psi

TVA 489 (REV. 9 47)

SHEET 13 OF 32

POWERHOUSE - STABILITY OBE

HW EL 817 TW EL 793

BASE EL 715

FT LOUDOUN

COMPUTED RBR DATE 7-3-72

CHECKED CNA DATE 7-6-72

HEPE5FLHSON:WBNBLNBFN

FACTOR OF SAFETY ~~AGAINST OVERTURNING~~

ITEM	FORCE	ARM	MOMENTS OVERTURNING	MOMENTS RESISTING
D.L	59700	73.5		4 387 950
UPLIFT	31754	72.83	2 312 644	
VERT HW	1111	118.02		131 120
" "	720	123.62		89 006
HORIZ HW	22759	-	773 798	
TW	13309	-		346 028
DYNAMIC FORCES	6353	-	328 650	
	7015	80.40	564 006	
HYDRODYNAMIC FORCES	4954	-	184 145	
	1784	-	50 751	
			4 213 994	4 954 104

$$FS = \frac{4954104}{4213994} = 1.18$$

Study of Maximum shear for Earthquake of 13.5g 243 32A

for .13.5g Assumed

516
− 307
209 100

13.5 / 18 × E0 Force & Moment 209

HEPE5FLHSQN-WBNBLNBFN

DL	39,233	39,233	−738,365	DL
U	− 21,900	4,075	+206,000	U
TW_V	+ 4,075	43,308	+142,000	TW_V
Eq.V	− 2,365	34,265	+68,000	Eq.V
		19,043	+740,000	HW
	21,900		−25,450	Deduct open gate
	2,365		+238,000 OK	Eq.H
	24,265		+13,500	TW_{eq}
			−72,200	TW_H
			−11,350	Hydrodynamic deduct open gate

333,135 / 19043 = 52.52 / 43 = 43.15

8.77
9.52
× 3
28.56
26.31

−738,365 DL
25,450 Deduct open gate
72,200 TW_H
11,350 Hydrodynamic deduct open
847,365

740,000 HW vpl.ft
206,000
142,000 TW_V
68000 Eq.V
238,000 Eq.H
273,000 HU_{eq}
1,667,000
847,365
819,635
13,500 TW_{eq}
833,135 ΣM

15% in comp.
~~27.2%~~
28,000
2(19,043)
(28.56)(46.5)
26.31

31.1 KSF
~~28.7 KSF~~
216
~~200~~ psi

Computed By GNA 10-10-72
Checked By LFS 3-9-87

1214

TVA 489 (REV. 8 47)

SHEET 14 OF 33

POWERHOUSE - STABILITY - OBE

FT LOUDOUN

HW EL 817 TW EL 793

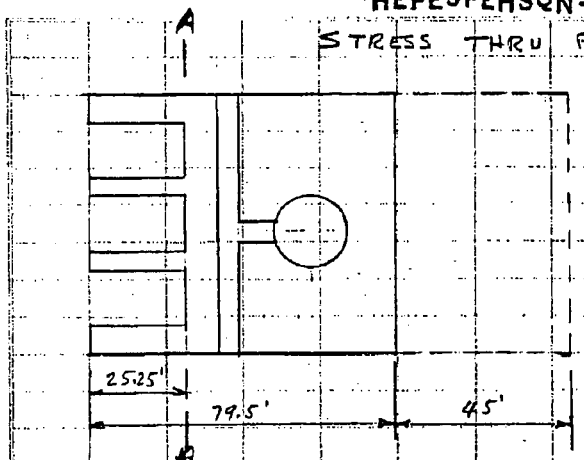
BASE EL 715

COMPUTED RBR DATE 7-3-72

HEPE5FLHSQN-WBNBLI1BFII

CHECKED GNA DATE 7-6-72

STRESS THRU PLANE A-A



EL 793, MAX TW

EL 768

SUBMERGED PIERS

$WT = [(25.25)(25) - 6(1.25)(3.3)](53)(0.0875) = 2813^k$

6 GOG'S.

EL 715

15.1' KSF

$10.3' = \frac{15.1 \times 54.25}{79.5}$

$UPWARD\ LOAD = \frac{1}{2}(15.1 + 10.3)(606.5) = 7703^k$

$NET\ LOAD = 7703 - 2813 = 4890^k$

$v = \frac{4890^k}{(25)(53)^{\square}} = 3.69^k\ KSF = 25.6^k\ psi$

1215

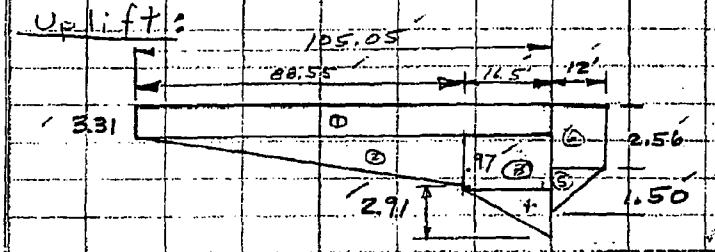
Ft Loudoun Spillway - OBE
HW El 815, TW El 753, Base El 700
Gates Open 4'
(TW El Based on 25 yr Summer flow
80,000 CFS - Loudoun + Little Tenn)

Ft Loudoun
Spillway - OBE
COMPUTED GNA DATE 10-5-72
CHECKED RBK DATE 10-10-72

Refer to Ft Loudoun - Spillway, OBE, GNA, 6-23-72, sht 1-9

D.L. = 39,233 K ↓
M = -738,365 'K @ C.G. of Base

Uplift:



Force			Arm		Moment @ CG
① (105.05)(3.31)	=	348 ↑	0		0
② ½(88.55)(0.97)	=	43 ↑	+6.5	+	279
③ (0.97)(16.5)	=	16 ↑	+44.27	+	708
④ ½(2.91)(16.5)	=	24 ↑	+47.02	+	1130
⑤ ½(12)(1.5)	=	9 ↑	+56.52	+	509
⑥ (12)(2.56)	=	30.8 ↑	+58.52	+	1800
	= 470.8 X 46.5				ΣM = 4426 x 46.5
	F = -21,900 k ↑		@ 9.45'		M_{CG} = +206,000 'k

Horiz HW:

$$F = \frac{1}{2}(115)^2(.0625)(46.5) = 19{,}250 \leftarrow$$

$$M = \frac{115}{3}(19{,}250) = 740{,}000 \text{ 'k}$$

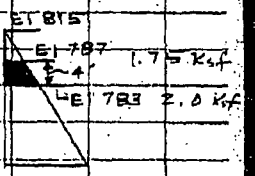
Deduct for open gates:

$$F = (40)\left(\frac{1.75+2.0}{2}\right)(4) = -300 \text{ K} \rightarrow$$

$$M = (300)\left[83 + \frac{1.75(4)(2) + (.25)(2)(1.33)}{7.5}\right]$$

84.95

$$M = -25{,}450 \circlearrowright$$



TVA 488 (REV. 5-47)

SHEET 11 OF 35

Ft Loudoun Spillway - OBE
HW El 815, TW El 753, Base El 700
Gate: Open 4'

Ft. Loudoun Spillway - OBE.

COMPUTED GNA DATE 10-5-72

HEPE5FLHSQN-WBNBLNBFN

CHECKED RCK DATE 10-10-72

Horiz TW:

$F = \frac{1}{2}(53)^2(.0625)(46.5) = -4080\ k \rightarrow$ ✓

$M = (4080)\left(\frac{53}{3}\right) = -72{,}200\ 'k$ ✓

Vert TW:

$F = \frac{1}{2}(53)^2(.0625)(46.5) = 4075\ k \uparrow$ ✓

$M = 4075\left(52.52 - \frac{53}{3}\right) = -142{,}200$ ✓

Horiz Inertiz:

$F = 2{,}616\ k \leftarrow$ ✓

$M = 158{,}790\ 'k$ ✓

Vert. Inertiz:

$F = -1572\ k \uparrow$ ✓

$M = 45{,}347\ 'k$ ✓

Hydrodynamic (HW): refer to Ft Loudoun, GNA, 6-28-72 Sheet 5

Y_n	P =		
0	1.28	✓	
.1	1.26	✓	
.2	1.22	✓	1.24
.3	1.14	✓	1.18
.4	1.04	✓	1.09
.5	0.91	✓	0.975
.6	0.75	✓	0.83
.7	0.58	✓	0.665
.8	0.40	✓	0.49
.9	0.20	✓	0.30
1.0	0.00	✓	0.10

1217

TVA 466 (REV. 5-47)

SHEET 12 OF 36

HW 815, TW El 753, Base El 700

Spillway Gates open 4'

Ft Loudoun

Spillway - O.B.E.

COMPUTED GWR DATE 10-6-72

CHECKED [illegible] DATE 10-10-72

HEPE5FLHSQN-WBNBLNBFN

Hydrodynamic (HW):

Force		Sum	Moment
(11.5)(1.27) =	14.6	5.75	84.0
" (1.24) =	14.3	17.25	247.0
" (1.18) =	13.6	28.75	391.0
" (1.09) =	12.5	40.25	503.0
" (0.975) =	11.2	51.75	580.0
" (0.83) =	9.5	63.25	600.0
" (0.66) =	7.6	79.75	568.0
" (0.49) =	5.5	86.25	474.0
" (0.30) =	3.45	97.75	336.0
" (0.10) =	1.15	109.25	126.0
	93.40		3909 × 46.5

F = 93.4 (46.5) = 4340 K ←

M = + 182,000 'k

Deduct for Gates open

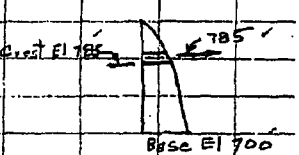
F = $\frac{4}{115}$ (5.5)(46.5) = − 89 K ←

M = 85(89) = −7565 'k

Hydrodynamic (TW):

T = $\frac{4(40)}{4720}$ = .0339

S = .11



X_H	F = $\frac{E(.1625)(40)(.11)}{\pi^2}$				
0			= .182	0.295	
.1	.988	(.182)	= .180	0.292	
.2	.951	"	= .173	0.281	
.3	.891	"	= .162	0.263	
.4	.809	"	= .147	0.239	
.5	.707	"	= .129	0.208	
.6	.588	"	= .107	0.173	
.7	.454	"	= .083	0.134	
.8	.309	"	= .056	0.091	
.9	.156	"	= .028	0.046	
1.0	.00	"	= .000	0	

TVA 489 (REV. 9 47)

SHEET 13 OF 37

HW El 815, TW El 753, Base El 700 — Ft Loudoun Spillway - OBE

Spillway Gates open

COMPUTED GNA DATE 10-6-72

HEPE5FLHSQN-WBNBI.NBFN

CHECKED PLP DATE 10-11-72

Hydrodynamic (TW):

				Force		Arm		Moment	
5.3	(0.290)	4.0	(.181)	= 0.72	1.56	2	3.65	1.4	4.13
"	(0.287)	"	(.177)	= 0.70	1.52	6	7.95	4.20	12.1
"	(0.272)	"	(.167)	= 0.66	1.44	10	13.25	6.60	19.1
"	(0.261)	"	(.155)	= 0.62	1.38	14	18.55	8.7	25.6
"	(0.234)	"	(.135)	= 0.55	1.19	18	23.85	9.9	28.4
"	(0.191)	"	(.118)	= 0.47	1.01	22	29.15	10.3	29.4
"	(0.174)	"	(.095)	= 0.38	0.82	26	34.45	9.9	28.2
"	(0.115)	"	(.070)	= 0.28	0.6	30	39.75	8.9	23.8
"	(0.083)	"	(.042)	= 0.17	0.37	34	45.05	5.8	16.7
"	(0.2[illegible])	"	(.014)	= 0.06	0.12	38	50.35	2.3	6.03
				4.61	x46.5			67.5	x46.5
				F = 214 K ←				M = +3140 ↻	
					10.01				19346
				F = (10.01)(46.5) = 465 K				M = (19346)(46.5) = 900 K'	

Summary:

	Force		Moment c.g.
D.L.	+ 89,233 ↓ ✓		− 738,365 ✓
Uplift	− 21,900 ↑ ✓		+ 206,000 ✓
Vert TW	+ 4,075 ↓ ✓		+ 142,000 ✓
Vert Inertia	− 1,577 ↑ ✓		+ 45,347 ✓
Horiz HW		+ 19,350 ← ✓	+ 740,000 ✓
Deduct gen Gates		− 300 → ✓	− 25,450 ✓
Horiz Inertia		+ 2,616 ← ✓	+ 158,790 ✓
Hydrodynamic HW		+ 4340 ←	+ 182,000 ✓
" TW		+ 214 ←	+ 3140
Horiz TW		− 4080 → ✓	− 72,200 ✓
Deduct for open Gates (Hydrodynamic HW)		+ 89 → ✓	− 7565 ✓
	ΣV = 19,831 K ↓	ΣH = 21,951 ←	+ 633,697 ↻

$f = \frac{19,831}{(105.05)(46.5)}\left(1 \pm \frac{6(31.9)}{105.05}\right)$

$e = \frac{31.9}{32.5}$ (Resultant falls 20.62' inside base)

57% of base in comp

$f = 4.05\ (1 \pm 1.82)$

$f_u = -3.87\ \text{Ksf} = -23\ \text{psi}$ (tension)

$f_d = 11.4\ \text{Ksf} = 79\ \text{psi}$ (comp)

1 2 1 4

TVA 489 (REV. 9-47)

SHEET 14 OF 38

Ft Loudoun Spillway · OBE
HW El 815, TW El 753, Base El 700
Gates open 4'

Ft Loudoun Spillway OBE

COMPUTED GNA DATE 10-6-72

HEPE5FLHSQN-WBNBLNBFN

CHECKED RGR DATE 10-11-72

$$\frac{\Sigma H}{\Sigma V} = \frac{21,951}{19,831} = 1.11$$

$$\frac{\Sigma H}{A} = \frac{21,951}{46.5(105.05)} = 4.45 \text{ Ksf} = 31.2 \text{ psi}$$

Stress for Q = 1 : Entire Base

$$S = \frac{21,951 - .65(19,831)}{(46.5)(105.05)} = 1.85 \text{ Ksf} = 12.8 \text{ psi}$$

Stress for Q = 1 : Portion of Base in Comp.

$$S = \frac{9051}{46.5(4.67)(8)} = 3.15 \text{ Ksf} = 21.8 \text{ psi}$$

Max Comp. Stress :

$$S = \frac{2(19,831)}{(46.5)(3)(2.67)} = 13.8 \text{ Ksf} = 96 \text{ psi}$$

F.S. against O.T. :

ITEM	FORCE	ARM	OT MOM	RESISTING MOM
D.L	39233	71.30		2798382
UPLIFT	71950	61.77	1,352,000	
VERT TW	4077	17.17		72,000
VERT INERTIA	1577	81.38	128,179	
HORIZ HW	1925		740,000	
DEDUCTION FOR OPEN GATE	300		- 25450	
HORIZ INERTIA	2616		153,790	
HYDRODYNAMIC HW	454		182,000	
" TW	467		7,000	
HORIZ TW	4083			72200
DEDUCT FOR OPEN GATE (HYDRODYNAMIC HW)	84		- 7565	
			2,536,954	2,943,082

$$FS = \frac{2943082}{2536954} = 1.16$$

1220

TVA 489 (REV. 9-71)

SHEET 15 OF 39

Fort Loudoun

Base El 700; HW El 815; TW El 753

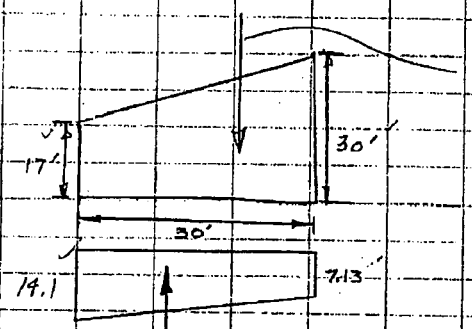
Spillway OBE

COMPUTED GNA DATE 10-11-72

HEPE5FLHSQN-WBNBLNBFN

CHECKED LFS DATE 3-9-97

Shear on Vert plane through toe: refer to Ft Loudoun, O.B.E.; G.N.A.; Spillway, 6-29-72, sht 9



$\frac{14.1}{60.66} = \frac{x}{30.66}$

$x =$

$F = \frac{1}{2}(21.23)(30)(46.5) = 14{,}850\ K$

$V = 14{,}850 - 2870 = 11{,}980\ K$

$v = \frac{11{,}980}{(30)(46.5)} = 8.6\ ksf = 59.7\ psi$

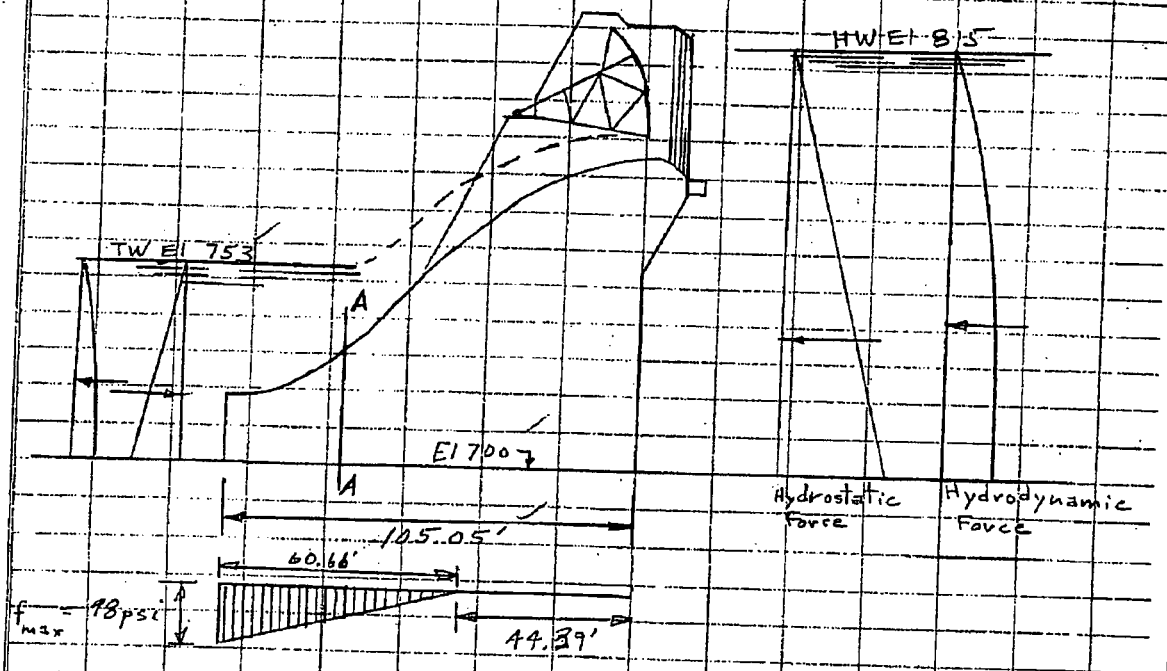
TVA 489 (REV. 9 47)

HEPE5FLHSON-WBNALNBEN SHEET 16 OF 40

Ft Loudoun Spillway - OBE
HW 815; TW 753; Base El 700
Gates open 4'
Summary of Analysis

Ft Loudoun
Spillway - OBE

COMPUTED GNA DATE 10-11-72
CHECKED LFS DATE 5-7-87



Base Pressure

ΣH	ΣV	$\frac{\Sigma H}{\Sigma V}$	$\frac{\Sigma H}{A}$	Portion of Base in Comp. S for @ = 1	f_{max}	% Base in Comp.	FS_{OT}	Vert Shear on Plane A - A
22,202	19,831	1.12	32 psi	23 psi	98 psi	58%	1.16	60 psi

Ft Loudoun Spillway - DBE (.18g)
HW El 815, TW El 753, Base El 700
Spillway Gates Open 4'

Ft Loudoun
Spillway - D.B.E.

COMPUTED GNA DATE 10-10-72
CHECKED RSR DATE 10-11-72

HEPE5FLHSON·WBNBLNBFN

All forces & Moments will be the same except the Seismic forces & Moment and the hydrodynamic forces & moments which will merely twice those computed for the O.B.E. (GNA, 10-6-72, Ft Loudoun Spillway, sheet 13):

Summary:

	Force		Moment cg
D.L.	+ 39,233 ↓		- 738,365
Uplift	- 21,900 ↑		+ 206,000
Vert TW	+ 9,075 ↓		+ 142,000
Vert Inertia	- 3,154 ↑		+ 90,694
Horiz HW		+ 19,250 →	+ 740,000
Deduct open gates		- 300 →	- 25,450
Horiz Inertia		+ 5,232 →	+ 317,580
Hydrodynamic HW		+ 8,680 →	+ 364,000
Hydrodynamic TW		+ 930 →	+ 18,000
Horiz TW		- 4,080 →	- 72,200
Deduct for open gates (Hydrodynamic HW)		- 178 →	- 15,130
	ΣV = + 18,254 ↓	ΣH = 29,534 K →	ΣM = 1,027,129 'K ↺

$e_{cg} = \frac{1,027,129}{18,254} = 56.2'$

Resultant Falls 3.68' outside base.

$f = \frac{18,254}{105.05(46.5)}\left(1 + \frac{6(56.2)}{105.05}\right)$

$f = 3.74(1 \pm 3.21)$

$f_u = -8.27 \text{ Ksf} = -57.5 \text{ psi}$ (Tension)

$f_d = +15.75 \text{ Ksf} = +109 \text{ psi}$ (Comp.)

$\frac{\Sigma H}{\Sigma V} = \frac{29,534}{18,254} = 1.62$

$\frac{\Sigma H}{A} = \frac{29,534}{(105.05)(46.5)} = 6.05 \text{ Ksf} = 42 \text{ psi}$

1 2 2 3

TVA 489 (REV. 9 47)

Ft. Loudoun Spillway - D.B.E. (.18g)
HW El 815, TW El 753, Base El 700
Spillway Gates Open 4'

Ft Loudoun
Spillway - DBE

COMPUTED GNA DATE 10-11-72
CHECKED RBK DATE 10-11-72

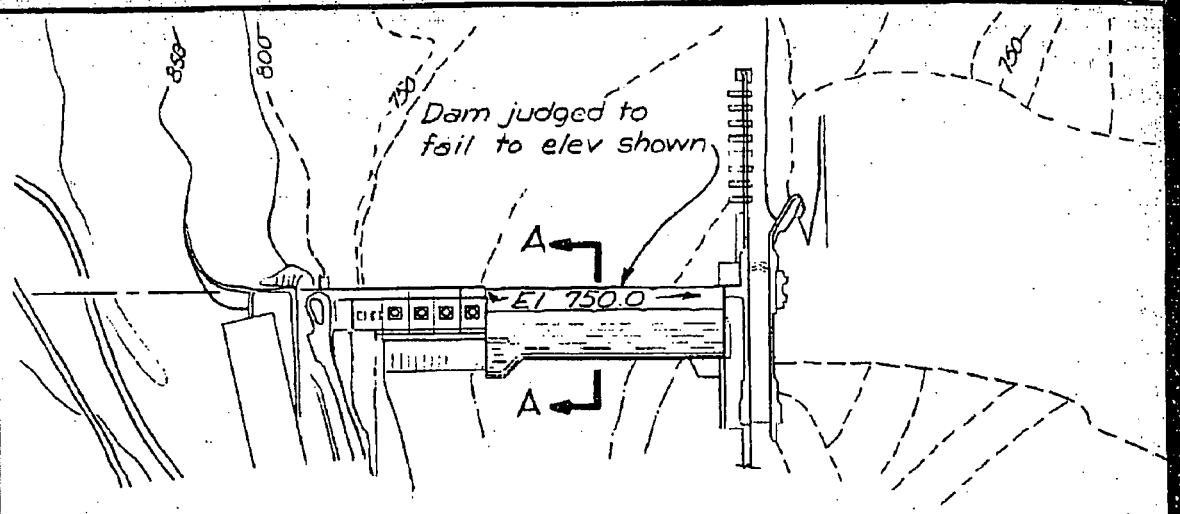
HEPE5FLHSQN-WBNBLNBFN

Stress for Q = 1: Entire base area

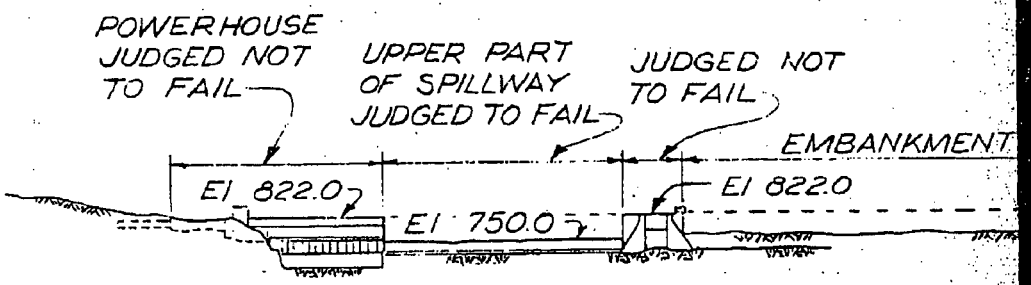
$$S = \frac{29,534 - .65(18,254)}{(105.05)(46.5)} = \frac{17,684}{4885} = 3.62 \text{ ksf} = 25.2 \text{ psi}$$

F.S. of will be less than 1

1 2 2 4



PLAN



ELEVATION

Note A:
All debris from fa
of dam judged to
failure elevation.
Note B:
High portion of em
to fail during earth
assumed to erode

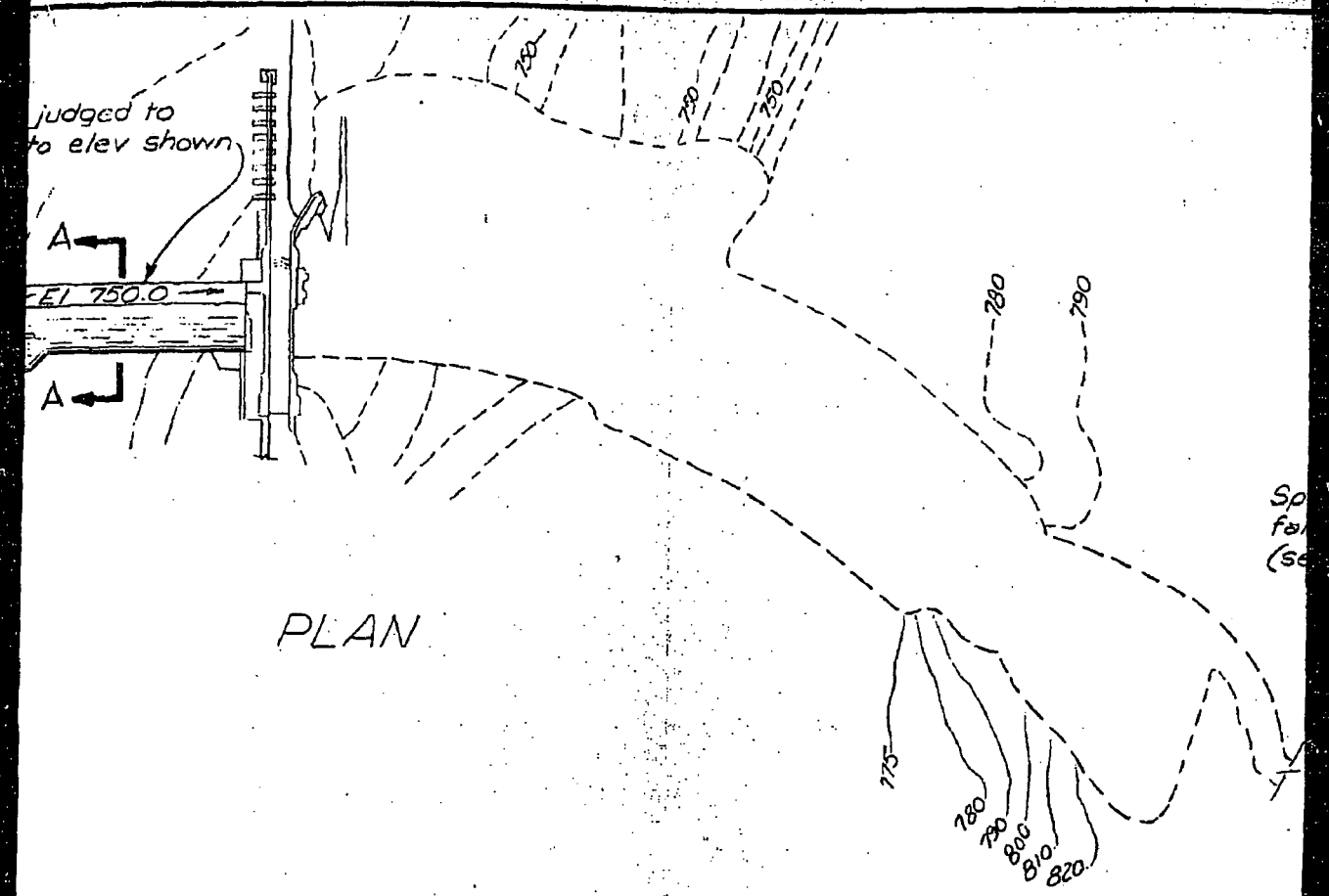
This drawing shows judged mode of failure

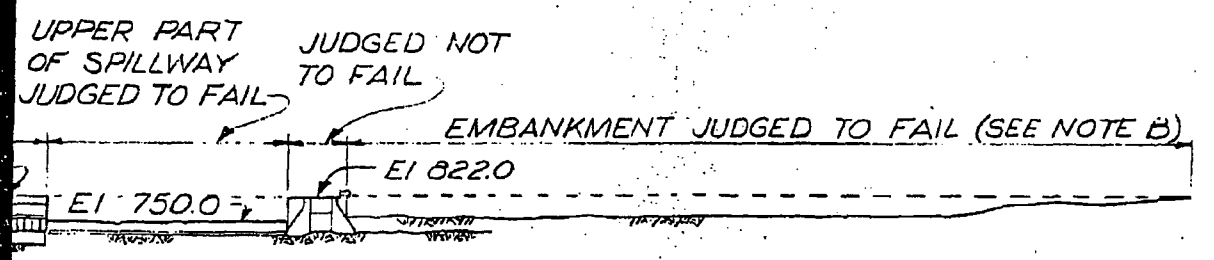
LFS 3-16-87

See memo Lacy to Buehler dated 10-16-72

LFS 3-18-87

1 2 2 5





ELEVATION

Note A:
All debris from failed portion of dam judged to be below failure elevation.

Note B:
High portion of embankment judged to fail during earthquake. Other portion assumed to erode after failure.

to Buehler

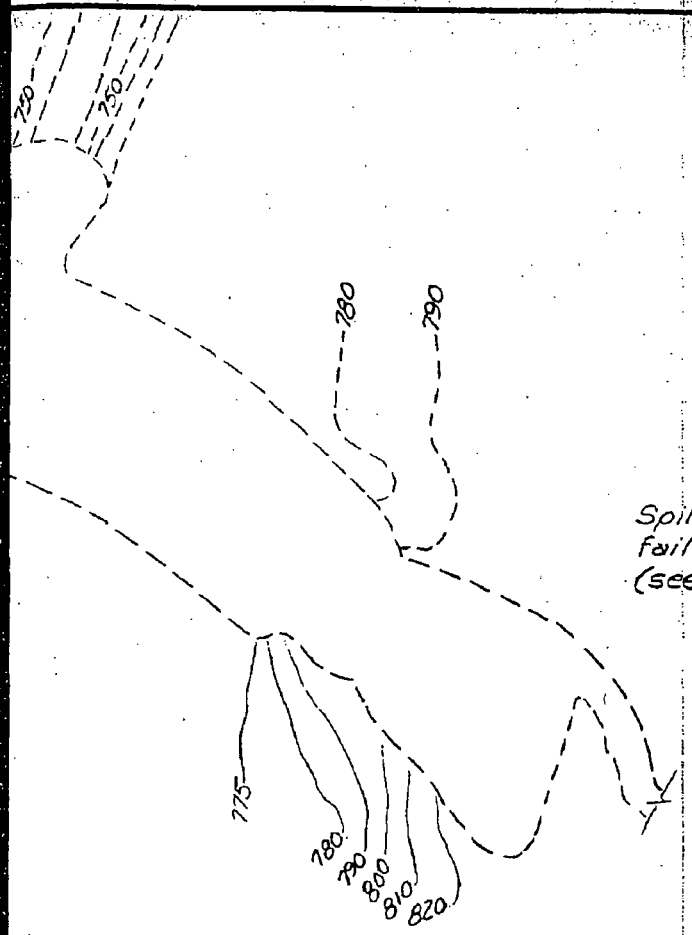
2

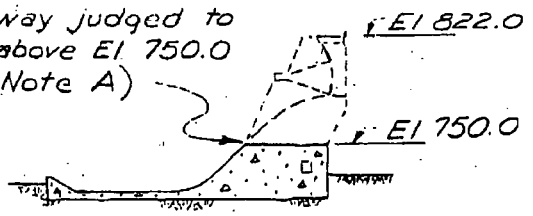
1226

EXHIBIT 10

SHEET 43

HEPE5FLHSQN-WBNBLNBFN





SECT A-A
Scale 1"=100'

JUDGED TO FAIL (SEE NOTE B)

Scale 1"=400'
Except as noted

iled portion
be below

nbankment judged
nquake. Other portion
after failure.

FORT LOUDOUN DAM

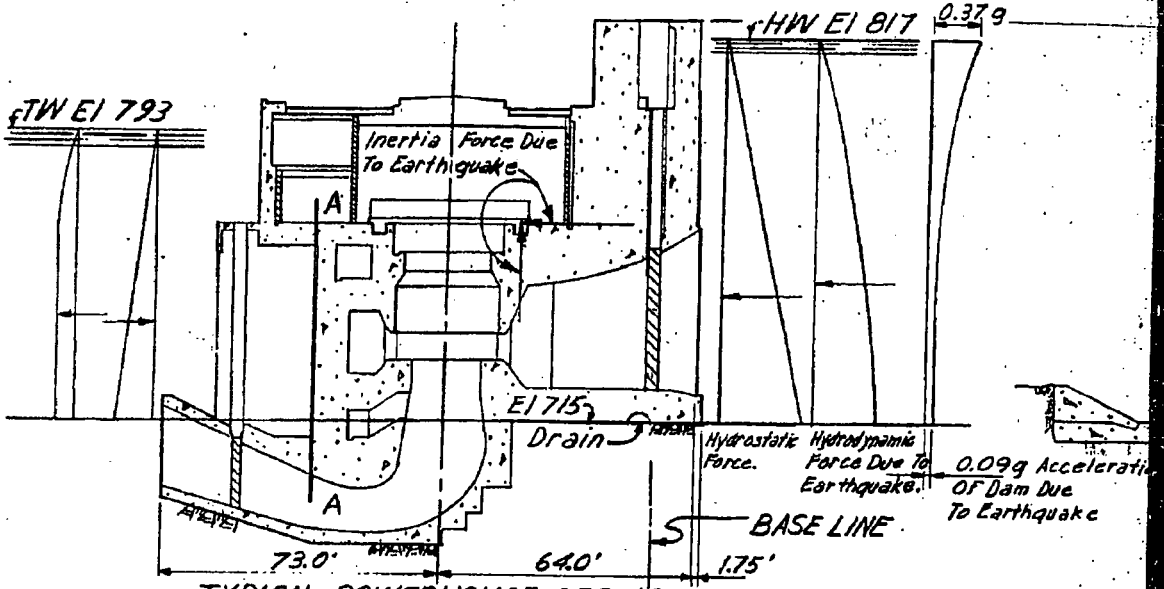
ASSUMED CONDITION OF DAM AFTER FAILURE
DBE COMBINED WITH A 25 YR FLOOD

FORT LOUDOUN DAM
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

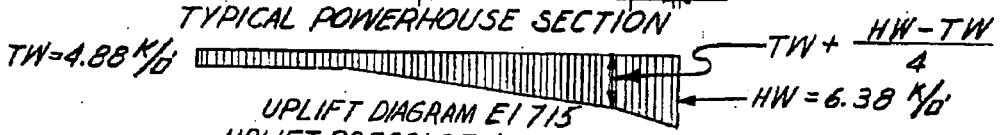
SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE

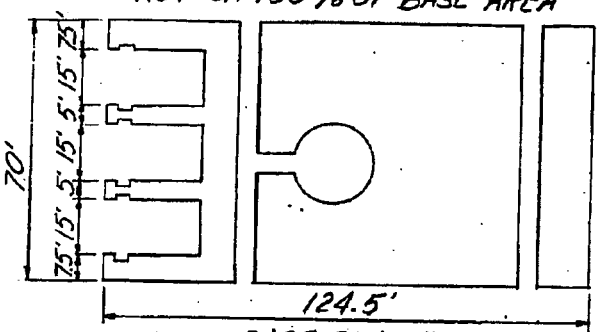
1227



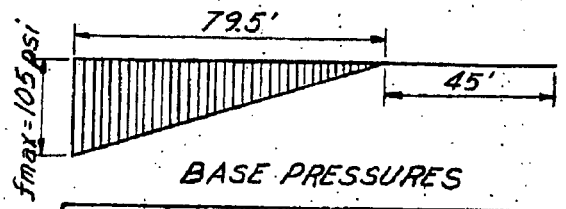
TYPICAL POWERHOUSE SECTION



UPLIFT DIAGRAM El 715
UPLIFT PRESSURE ASSUMED TO ACT ON 100 % OF BASE AREA



BASE PLAN El 715



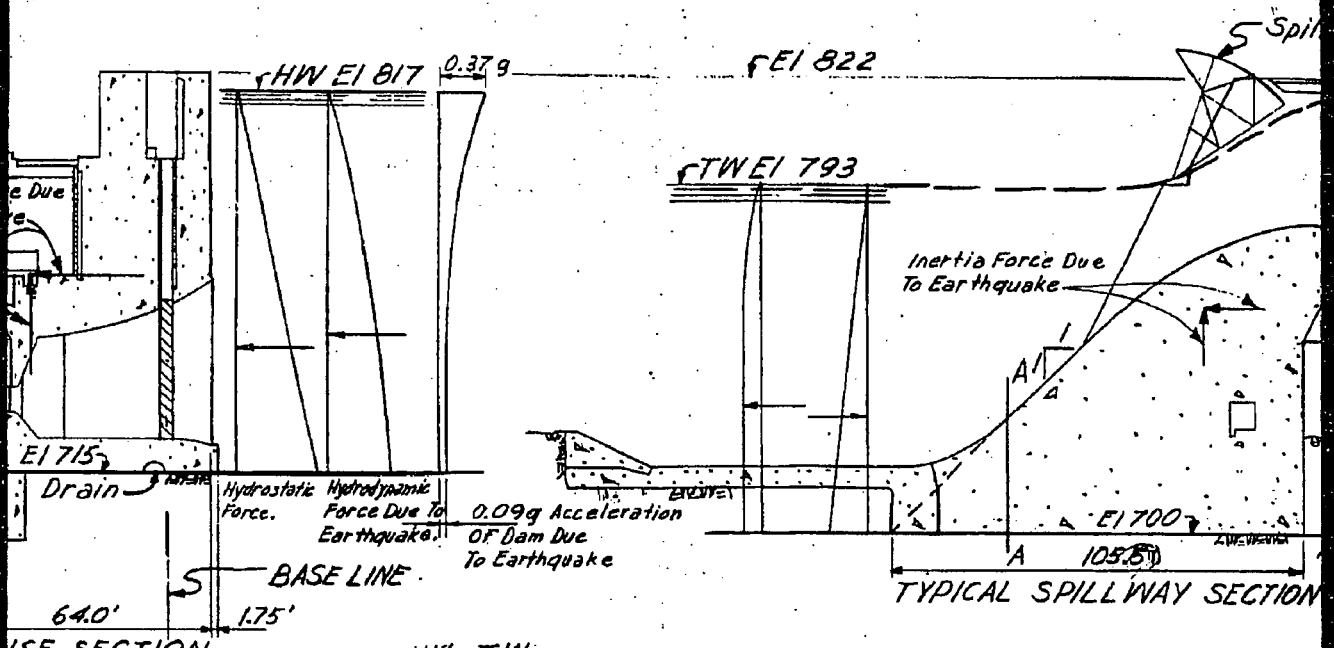
BASE PRESSURES

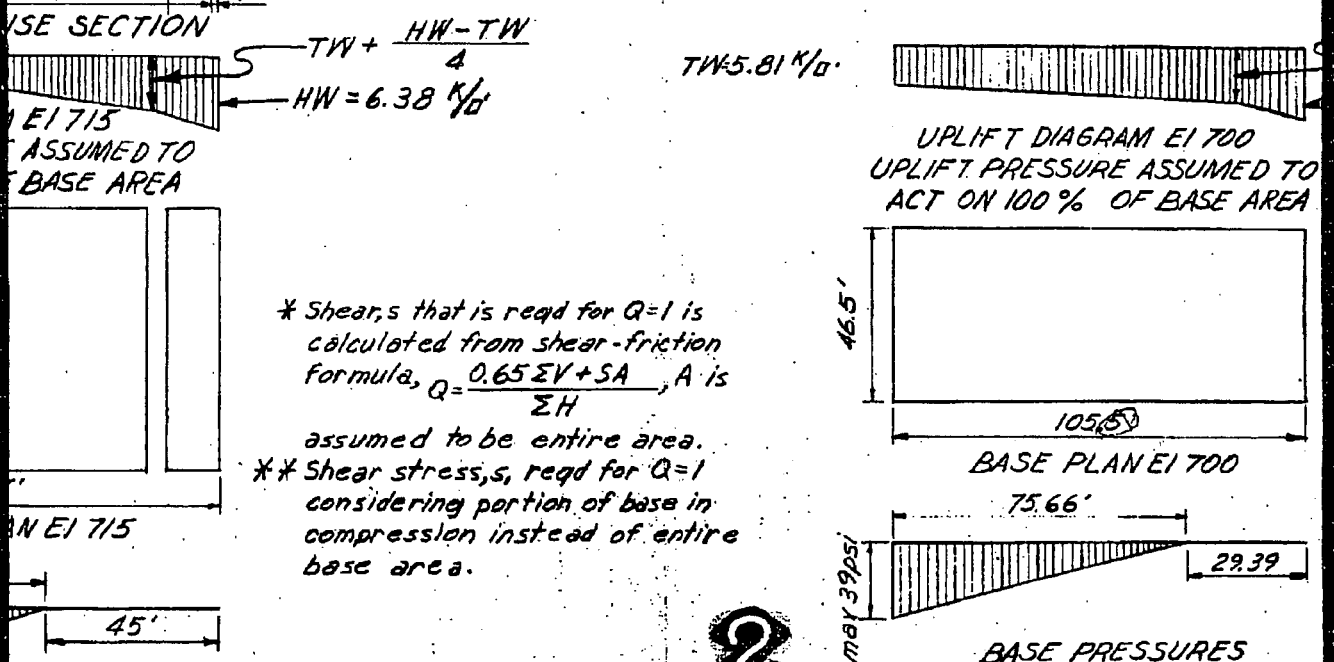
* Shear, s that is reqd for Q=
calculated from shear-fri
formula, $Q = \frac{0.65\,\Sigma V + SA}{\Sigma H}$
assumed to be entire ar
** Shear stress, s, reqd for Q
considering portion of bas
compression instead of e
base area.

ΣV	ΣH	$\frac{\Sigma H}{\Sigma V}$	Avg shear	S reqd for Q=1	f max	$FS = \frac{\Sigma MR}{\Sigma Mo}$	Vertical shear on plane A-A	Σ
22,762K	22,541K	0.99	24.2 psi (entire base)	8.3 psi * (14.6 psi) **	105 psi	1.18	26 psi	19,4

DRAWN	GAA				
DRAWN	HES				
CHKD	RBR				
TRACED					
COMP					

1 2 2 8





* Shear, s that is reqd for Q=1 is calculated from shear-friction formula, $Q = \frac{0.65\Sigma V + SA}{\Sigma H}$, A is assumed to be entire area.

** Shear stress, s, reqd for Q=1 considering portion of base in compression instead of entire base area.

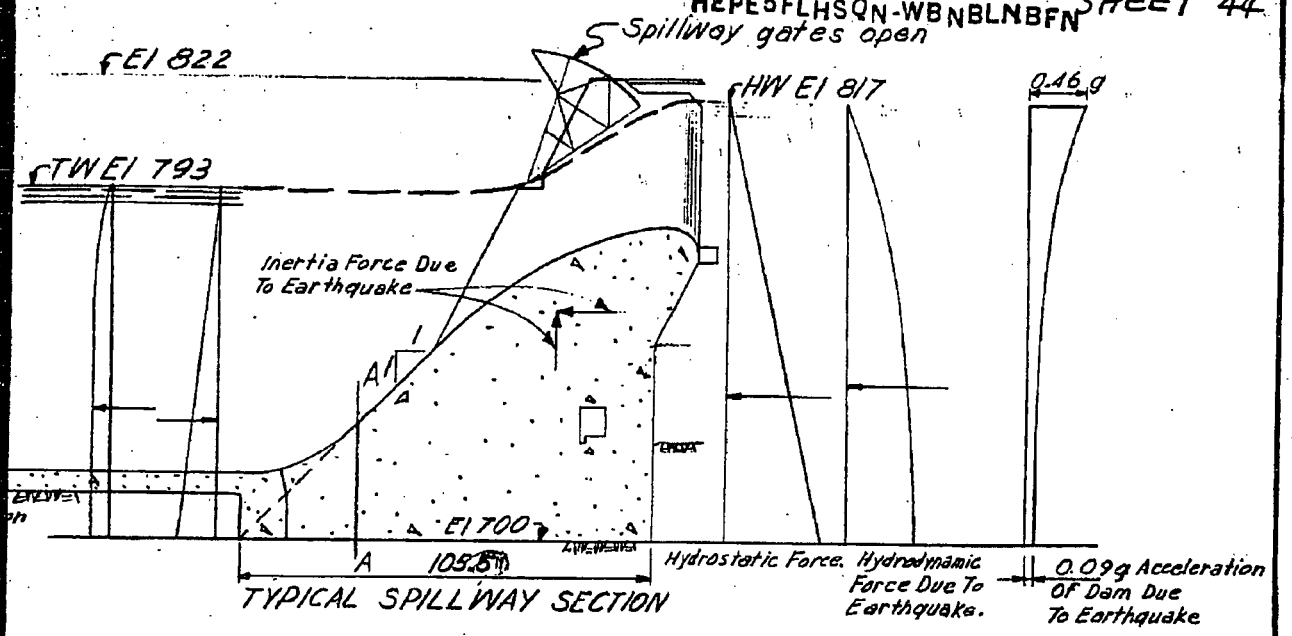
2

SSURES

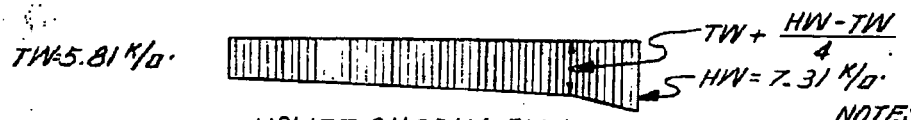
Avg shear	S reqd for Q=1	f max	F.S. $\frac{\Sigma M_R}{\Sigma M_O}$	Vertical shear on plane A-A
24.2psi (entire base)	8.3psi * (14.6psi)**	105psi	1.18	26 psi

ΣV	ΣH	$\frac{\Sigma H}{\Sigma V}$	Avg shear	S reqd for Q=1	f max	F.S. $\frac{\Sigma M}{\Sigma M}$
19,488K	14,382K	0.75	20psi (entire base)	2.38psi* (3.30psi)**	39psi	1.26

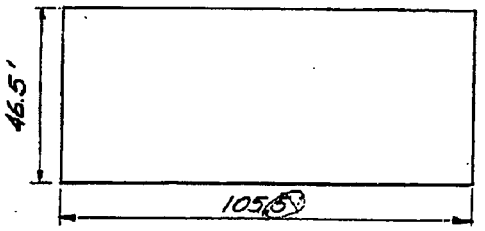
1 2 2 9



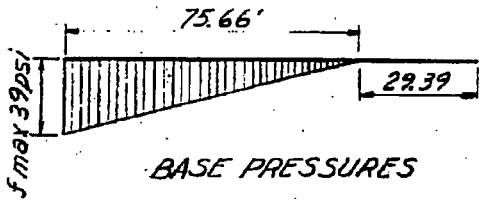
TYPICAL SPILLWAY SECTION



UPLIFT DIAGRAM EI 700
UPLIFT PRESSURE ASSUMED TO ACT ON 100 % OF BASE AREA



BASE PLAN EI 700



BASE PRESSURES

NOTES:

1. Vertical acceleration of powerhouse and spillway at base assumed to be 0.06g. By dynamic analysis, amplification of acceleration above the base was determined to be 0.22g at top for the powerhouse section and 0.12g at the top for the spillway.
2. Horizontal acceleration of powerhouse and spillway at base assumed to be 0.09g. By dynamic analysis, amplification of acceleration above the base was determined to be 0.37g at the top for the powerhouse section and 0.46g at the top for the spillway.
3. Spillway gates assumed open for this analysis.

Scale 1" = 40'

	ΣH	ΣH/ΣV	Avg shear	S reqd for Q=1	fmax	F.S. = ΣMR/ΣMo	Vertical shear on plane A-A
8K	14,382K	0.75	20 psi (entire base)	2.38psi* (3.30psi)**	39psi	1.26	17psi

POWERHOUSE & SPILLWAY

RESULTS OF ANALYSIS FOR OPERATING BASIS EARTHQUAKE

FORT LOUDOUN
TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED | RECOMMENDED | APPROVED

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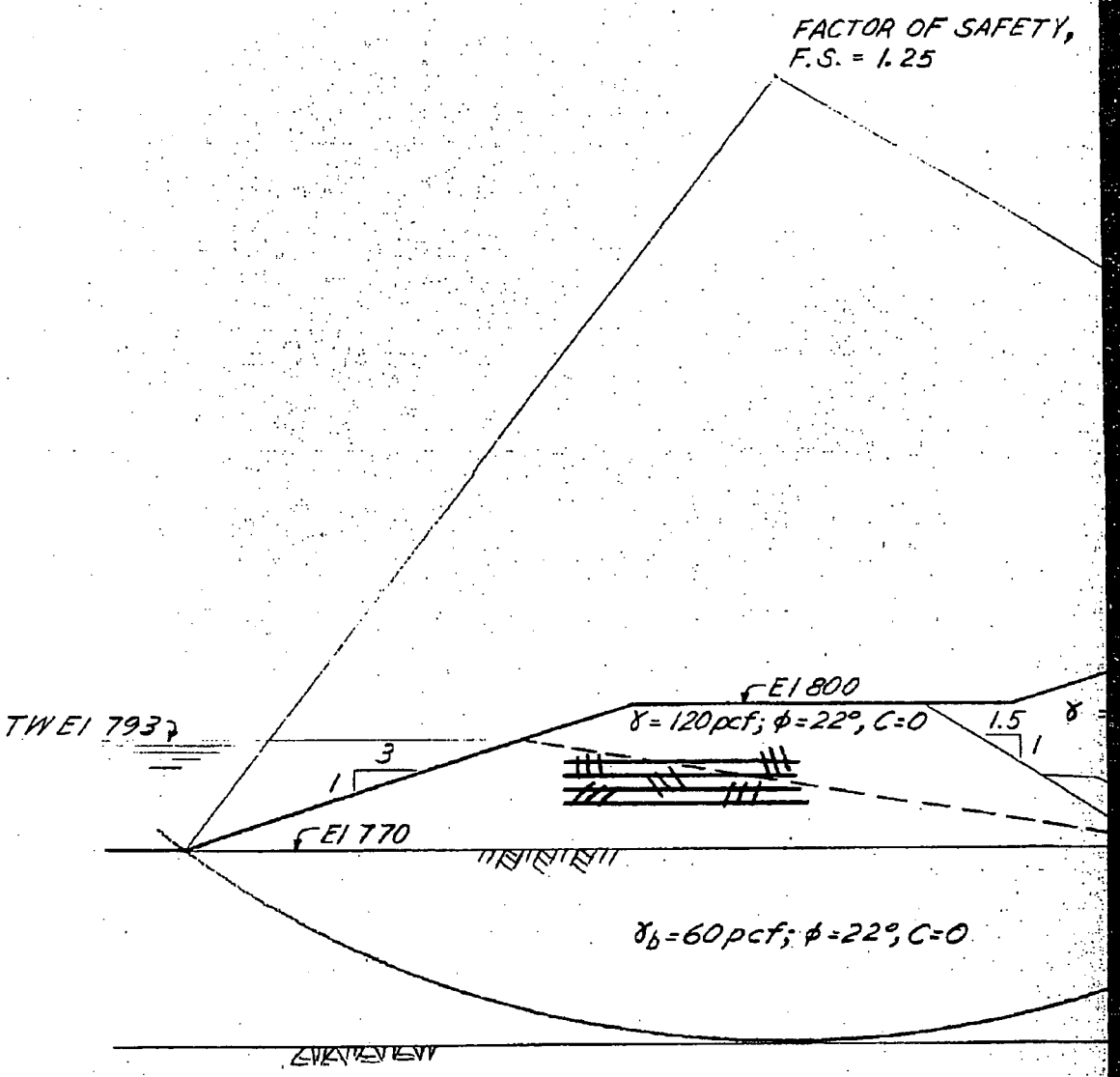
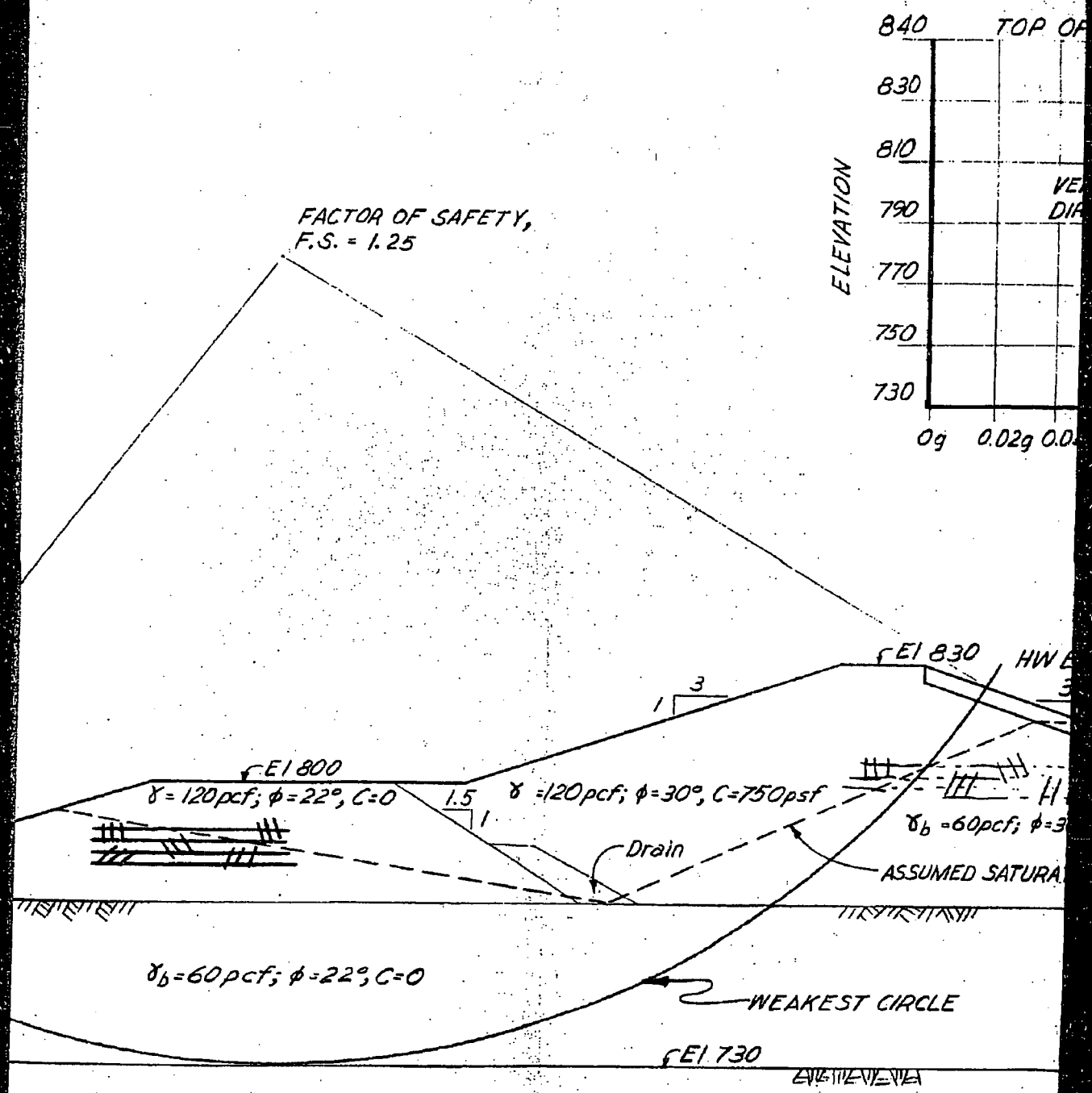


TYPICAL EMBANKM

REV NO	DATE	NAME	CHKD	SUPV	N.S.P	SUBM	RECM
DSGN. RBR				SUPV.			
DRWN. AES				N.S.P.			
CHKD. N/A							
TRCD.				DWG/VCLER			
COMP.							

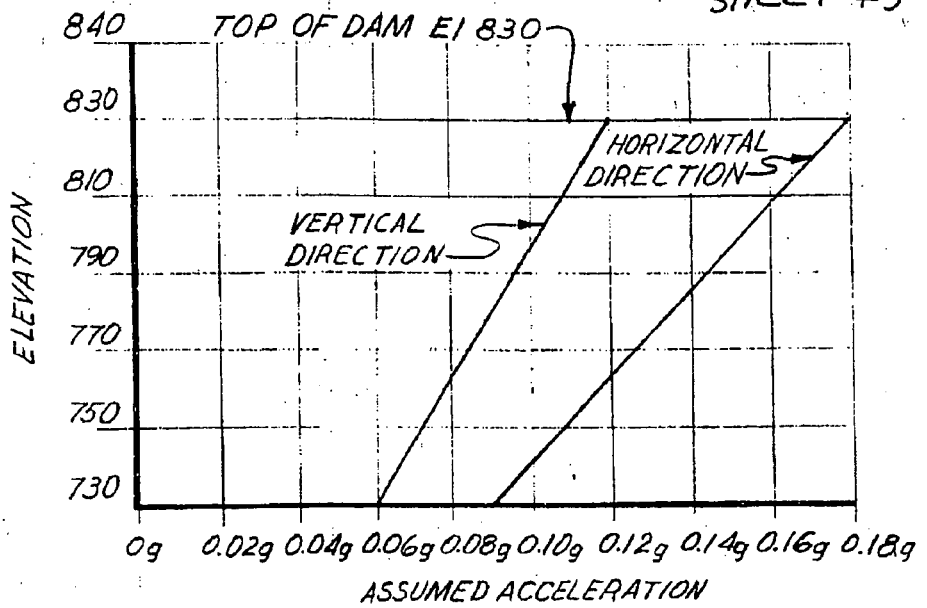


TYPICAL EMBANKMENT SECTION

2

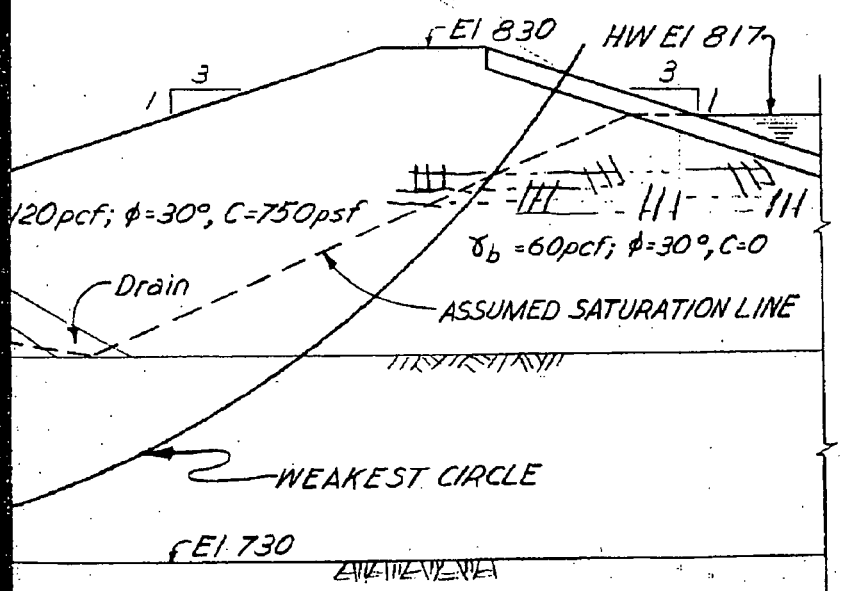
HEPE5FLHSON-WBNBLNBFN

SHEET 45



NOTES:

1. Analysis was made using the standard slip circle method.
2. Shear strengths of materials same as used in original analysis.



MENT SECTION

3

Scale 1"=30'

EMBANKMENT

RESULTS OF ANALYSIS FOR OPERATING BASIS EARTHQUAKE

FORT LOUDOUN

TENNESSEE VALLEY AUTHORITY
DIVISION OF ENGINEERING DESIGN

SUBMITTED	RECOMMENDED	APPROVED

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THIS SHT. ADDED PER REV. 1

SHEET 46 OF

Ft. Loudoun - Concrete Stability Analysis For SSE and ½ SSE + ½ PME

SQN, WBN, BLN, BFN

COMPUTED _____ DATE _____

HEPESFLHSQN-WBNBLNBFN

CHECKED _____ DATE _____

THIS IS THE LAST PAGE OF THE CALCULATION

TVA 11030 (9-81)

1 2 3 4

TENNESSEE VALLEY AUTHORITY
RIVER SYSTEM OPERATIONS & ENVIRONMENT
RIVER OPERATIONS

FORT LOUDOUN DAM

SPILLWAY DISCHARGE TABLES

NOVEMBER 2004

CONTENTS

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Instructions for Use of Tables	1
Location of Spillway Gates	3
Spillway Gate Arrangement Tables	4
Spillway Discharge Tables	6-23
Headwater Range	
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804 - 806	8
806 - 808	10
808 - 810	12
810 - 812	14
812 - 814	16
814 - 816	18
816 - 818	20
818 - 820	22

INSTRUCTIONS FOR USE OF TABLES

1. Tables Update

These tables supersede the tables dated September 1996. They differ from those tables only in a few minor details. The September 1996 tables superseded the tables dated January 1986. Those tables were revised to increase the maximum headwater elevation covered in the tables from 817 feet to 820 feet. The computer code SPILLQ generated the tabulated discharges.

Whenever the gate lifting chains are replaced or their ends are reversed, the gate opening indicators must be reset, the opening heights under the spillway gates at every indicator position must be re-measured, and the spillway tables must be re-computed. As described below, the spillway gates at Fort Loudoun Dam are set by "dogging" the gate lifting chains at discrete positions marked by indicator pointers. When the chains are replaced, or the ends of the chains are reversed, the opening heights under the gates change for every indicator position and discharges computed assuming the previous opening heights are no longer correct. The gate openings on which these tables are based were measured in 1985.

2. Purpose of Tables

These tables provide a means for setting required spillway discharges and for determining the discharge when a specific arrangement of gates is in use. The tabulated discharges are based on test results from scale models.

The specific gate arrangements in the tables were determined by considering erosion data obtained from spillway model studies together with incremental discharge values for satisfactory spillway operation.

3. Range of Tables

The tables cover a discharge range from 0 to 494,900 cubic feet per second. Headwater elevations range from 802 feet to 820 feet. The tailwater does not affect the discharges from this spillway.

4. Arrangement of Tables

The tables show spillway discharges in cubic feet per second. Headwater elevations in 0.1-foot increments are shown at the top of each column. The headwater range is shown at the bottom of each page.

The discharge is tabulated under the headwater elevations for specific arrangements of gate openings, which are indicated by number in the left and right columns of each page. The numbered arrangements are defined in the tables of Spillway Gate Arrangements on pages 4 and 5. Reference to these tables and to the drawing showing the location of the gates on page 3 will determine the gate opening to which each gate is to be set for any particular discharge given in the tables.

5. Discharge Intervals

The tables have been prepared so that the incremental discharge between tabulated values for consecutive gate arrangements is generally less than 5 percent of the tabulated discharge. The incremental discharge between tabulated values of consecutive headwater elevations is generally less than 1 percent. These increments are exceeded in some cases near the extreme ends of the tables where operation is relatively infrequent. In general it is possible to set any required discharge within 2-1/2 percent and to know the actual discharge for any given set of conditions within 1 percent. These tolerances are considered acceptable and therefore it will not be necessary to interpolate between values given in these tables.

When the exact headwater elevation does not appear in the tables, the discharge for the headwater elevation closest to it is used. For example, the column headed 812.2 is used for actual headwater elevations between 812.15 feet and 812.24 feet inclusive. When the actual headwater elevation is exactly halfway between tabular values, the larger value is used.

6. Raising and Lowering Gates

The gates are raised and lowered by traveling hoists that lift the gates by chains attached to each end of the gates. Gate openings are set by dogging each chain by means of a dogging arrangement located just below the deck of the dam. Fastened to the dogging device is a gate opening indicator pointer that revolves as the gate is raised or lowered. This indicator pointer can be observed from either end of the traveling hoist. Gate opening positions have been marked on the gate opening indicator dials and correspond to the openings described in the tables of Spillway Gate Arrangements on pages 4 and 5. Gate opening indicator readings do not represent gate opening in feet but only provide a gate opening position that will give the desired discharge when used with the tables of Spillway Gate Arrangements. Gate opening indicator readings cannot be interchanged between gates since a given indicator reading on one gate will not necessarily give the same discharge as the same indicator reading on another gate.

7. Special Instruction – Preventing Flow Over Top of Spillway Gates When Headwater Elevation is Above 815 feet

If the headwater elevation exceeds 815 feet (actually, 814.8 feet to provide a 0.2-foot margin of safety) the spillway gates must be set to one of the gate arrangements listed in the tables to prevent flow over the tops of the gates. The minimum gate openings are those corresponding to the lowest numbered gate arrangement for which a discharge value is provided in the tables.

8. Use of Tables

The tables can be used in two ways: (1) to determine the arrangement of gates needed to pass a required discharge at a given headwater elevation, and (2) to determine the discharge for a given arrangement of gates and headwater elevation.

Example 1 -- What gate arrangement is necessary to pass a discharge of 21,000 cubic feet per second with the headwater at elevation 808.94 feet?

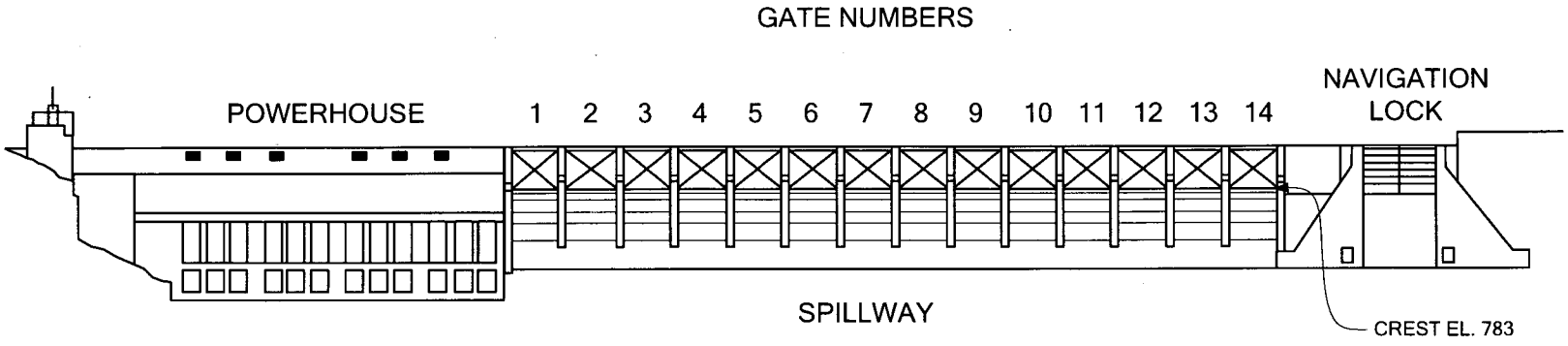
The first step is to find the table in which the headwater elevation appears. Referring to the contents page, we find that headwater elevations between 808 feet and 810 feet are found on pages 12 and 13. The headwater elevation closest to 808.94 feet is 808.9 feet. In the column headed 808.9 the discharge nearest to the required 21,000 cubic feet per second is 20,540 cubic feet per second located in the upper half of page 12. By tracing the horizontal line in which 20,540 cubic feet per second appears, to either side of the page, we find that gate arrangement 18 is the one for producing the discharge closest to 21,000 cubic feet per second at headwater elevation 808.94 feet. Referring to page 4 it is found that the gates should be set with the gate opening indicators reading as follows: Gates 3, 5, 7, 9, 10, 11, 12, 13, and 14 at indicator reading 6.

After all the gates are set, changes in the headwater elevation may require changes in the gate arrangement to maintain the desired discharge. For example, if the headwater should fall to 808.12 feet, the discharge will be found in the column headed 808.1. In this column the discharge closest to 21,000 cubic feet per second is 21,320 cubic feet per second for gate arrangement 19. To change to gate arrangement 19 from gate arrangement 18, gate 8 would be opened to an indicator reading of 2.

Example 2 -- Suppose the operating records show that the headwater is at elevation 812.35 feet, and gate arrangement 97 is in use. The headwater is found on pages 16 and 17, which are marked "Headwater 812 to 814." The elevation given is exactly halfway between elevation 812.3 feet and 812.4 feet. The larger value, 812.4 feet, is used. In the column headed 812.4 opposite gate arrangement 97, the discharge is found to be 229,500 cubic feet per second.

FORT LOUDOUN DAM

LOCATION OF SPILLWAY GATES



DOWNSTREAM ELEVATION

FORT LOUDOUN DAM

SPILLWAY GATE ARRANGEMENTS

Gate Arrange-ment	Gate Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-	-	2	-	-	-	-	-	-	-	-	-	-	-
2	-	-	6	-	-	-	-	-	-	-	-	-	-	-
3	-	-	6	-	2	-	-	-	-	-	-	-	-	-
4	-	-	6	-	6	-	-	-	-	-	-	-	-	-
5	-	-	6	-	6	-	2	-	-	-	-	-	-	-
6	-	-	6	-	6	-	6	-	-	-	-	-	-	-
7	-	-	6	-	6	-	6	-	2	-	-	-	-	-
8	-	-	6	-	6	-	6	-	6	-	-	-	-	-
9	-	-	6	-	6	-	6	-	6	-	2	-	-	-
10	-	-	6	-	6	-	6	-	6	-	6	-	-	-
11	-	-	6	-	6	-	6	-	6	-	6	-	2	-
12	-	-	6	-	6	-	6	-	6	-	6	-	6	-
13	-	-	6	-	6	-	6	-	6	-	6	-	6	2
14	-	-	6	-	6	-	6	-	6	-	6	-	6	6
15	-	-	6	-	6	-	6	-	6	-	6	2	6	6
16	-	-	6	-	6	-	6	-	6	-	6	6	6	6
17	-	-	6	-	6	-	6	-	6	2	6	6	6	6
18	-	-	6	-	6	-	6	-	6	6	6	6	6	6
19	-	-	6	-	6	-	6	2	6	6	6	6	6	6
20	-	-	6	-	6	-	6	6	6	6	6	6	6	6
21	-	-	6	-	6	2	6	6	6	6	6	6	6	6
22	-	-	6	-	6	6	6	6	6	6	6	6	6	6
23	-	-	6	2	6	6	6	6	6	6	6	6	6	6
24	-	-	6	6	6	6	6	6	6	6	6	6	6	6
25	-	2	6	6	6	6	6	6	6	6	6	6	6	6
26	-	6	6	6	6	6	6	6	6	6	6	6	6	6
27	2	6	6	6	6	6	6	6	6	6	6	6	6	6
28	6	6	6	6	6	6	6	6	6	6	6	6	6	6
29	8	6	6	6	6	6	6	6	6	6	6	6	6	6
30	8	6	8	6	6	6	6	6	6	6	6	6	6	6

Gate Arrange-ment	Gate Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
31	8	6	8	6	8	6	6	6	6	6	6	6	6	6
32	8	6	8	6	8	6	8	6	6	6	6	6	6	6
33	8	6	8	6	8	6	8	6	8	6	6	6	6	6
34	8	6	8	6	8	6	8	6	8	6	8	6	6	6
35	8	6	8	6	8	6	8	6	8	6	8	6	8	6
36	8	6	8	6	8	6	8	6	8	6	8	6	8	8
37	8	6	8	6	8	6	8	6	8	6	8	8	8	8
38	8	6	8	6	8	6	8	6	8	8	8	8	8	8
39	8	6	8	6	8	6	8	8	8	8	8	8	8	8
40	8	6	8	6	8	8	8	8	8	8	8	8	8	8
41	8	6	8	8	8	8	8	8	8	8	8	8	8	8
42	8	8	8	8	8	8	8	8	8	8	8	8	8	8
43	10	8	8	8	8	8	8	8	8	8	8	8	8	8
44	10	8	10	8	8	8	8	8	8	8	8	8	8	8
45	10	8	10	8	10	8	8	8	8	8	8	8	8	8
46	10	8	10	8	10	8	10	8	8	8	8	8	8	8
47	10	8	10	8	10	8	10	8	10	8	8	8	8	8
48	10	8	10	8	10	8	10	8	10	8	10	8	8	8
49	10	8	10	8	10	8	10	8	10	8	10	8	10	8
50	10	8	10	8	10	8	10	8	10	8	10	8	10	10
51	10	8	10	8	10	8	10	8	10	8	10	10	10	10
52	10	8	10	8	10	8	10	8	10	10	10	10	10	10
53	10	8	10	8	10	8	10	10	10	10	10	10	10	10
54	10	8	10	8	10	10	10	10	10	10	10	10	10	10
55	10	8	10	10	10	10	10	10	10	10	10	10	10	10
56	10	10	10	10	10	10	10	10	10	10	10	10	10	10
57	14	10	10	10	10	10	10	10	10	10	10	10	10	10
58	14	10	14	10	10	10	10	10	10	10	10	10	10	10
59	14	10	14	10	14	10	10	10	10	10	10	10	10	10
60	14	10	14	10	14	10	14	10	10	10	10	10	10	10

GATE OPENINGS

Figures in columns under each gate number refer to gate opening indicator reading
dash (-) indicates closed gate
U indicates gate raised above water surface or to maximimum open position

FORT LOUDOUN DAM

SPILLWAY GATE ARRANGEMENTS

Gate Arrange-ment	Gate Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
61	14	10	14	10	14	10	14	10	14	10	10	10	10	10
62	14	10	14	10	14	10	14	10	14	10	14	10	10	10
63	14	10	14	10	14	10	14	10	14	10	14	10	14	10
64	14	10	14	10	14	10	14	10	14	10	14	10	14	14
65	14	10	14	10	14	10	14	10	14	10	14	14	14	14
66	14	10	14	10	14	10	14	10	14	14	14	14	14	14
67	14	10	14	10	14	10	14	14	14	14	14	14	14	14
68	14	10	14	10	14	14	14	14	14	14	14	14	14	14
69	14	10	14	14	14	14	14	14	14	14	14	14	14	14
70	14	14	14	14	14	14	14	14	14	14	14	14	14	14
71	18	14	14	14	14	14	14	14	14	14	14	14	14	14
72	18	14	18	14	14	14	14	14	14	14	14	14	14	14
73	18	14	18	14	18	14	14	14	14	14	14	14	14	14
74	18	14	18	14	18	14	18	14	14	14	14	14	14	14
75	18	14	18	14	18	14	18	14	18	14	14	14	14	14
76	18	14	18	14	18	14	18	14	18	14	18	14	14	14
77	18	14	18	14	18	14	18	14	18	14	18	14	18	14
78	18	14	18	14	18	14	18	14	18	14	18	14	18	18
79	18	14	18	14	18	14	18	14	18	14	18	18	18	18
80	18	14	18	14	18	14	18	14	18	18	18	18	18	18
81	18	14	18	14	18	14	18	18	18	18	18	18	18	18
82	18	14	18	14	18	18	18	18	18	18	18	18	18	18
83	18	14	18	18	18	18	18	18	18	18	18	18	18	18
84	18	18	18	18	18	18	18	18	18	18	18	18	18	18
85	22	18	22	18	18	18	18	18	18	18	18	18	18	18
86	22	18	22	18	22	18	22	18	18	18	18	18	18	18
87	22	18	22	18	22	18	22	18	22	18	22	18	18	18
88	22	18	22	18	22	18	22	18	22	18	22	18	22	22
89	22	18	22	18	22	18	22	18	22	22	22	22	22	22
90	22	18	22	18	22	22	22	22	22	22	22	22	22	22

Gate Arrange-ment	Gate Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
91	22	22	22	22	22	22	22	22	22	22	22	22	22	22
92	26	22	26	22	22	22	22	22	22	22	22	22	22	22
93	26	22	26	22	26	22	26	22	22	22	22	22	22	22
94	26	22	26	22	26	22	26	22	26	22	26	22	22	22
95	26	22	26	22	26	22	26	22	26	22	26	22	26	26
96	26	22	26	22	26	22	26	22	26	26	26	26	26	26
97	26	22	26	22	26	26	26	26	26	26	26	26	26	26
98	26	26	26	26	26	26	26	26	26	26	26	26	26	26
99	30	26	30	26	26	26	26	26	26	26	26	26	26	26
100	30	26	30	26	30	26	30	26	26	26	26	26	26	26
101	30	26	30	26	30	26	30	26	30	26	30	26	26	26
102	30	26	30	26	30	26	30	26	30	26	30	26	30	30
103	30	26	30	26	30	26	30	26	30	30	30	30	30	30
104	30	26	30	26	30	30	30	30	30	30	30	30	30	30
105	30	30	30	30	30	30	30	30	30	30	30	30	30	30
106	34	30	34	30	30	30	30	30	30	30	30	30	30	30
107	34	30	34	30	34	30	34	30	30	30	30	30	30	30
108	34	30	34	30	34	30	34	30	34	30	34	30	30	30
109	34	30	34	30	34	30	34	30	34	30	34	30	34	34
110	34	30	34	30	34	30	34	30	34	34	34	34	34	34
111	34	30	34	30	34	34	34	34	34	34	34	34	34	34
112	34	34	34	34	34	34	34	34	34	34	34	34	34	34
113	U	34	U	34	34	34	34	34	34	34	34	34	34	34
114	U	34	U	34	U	34	U	34	34	34	34	34	34	34
115	U	34	U	34	U	34	U	34	U	34	U	34	34	34
116	U	34	U	34	U	34	U	34	U	34	U	34	U	U
117	U	34	U	34	U	34	U	34	U	U	U	U	U	U
118	U	34	U	34	U	U	U	U	U	U	U	U	U	U
119	U	U	U	U	U	U	U	U	U	U	U	U	U	U

GATE OPENINGS

Figures in columns under each gate number refer to gate opening indicator reading
dash (-) indicates closed gate
U indicates gate raised above water surface or to maximimum open position

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	802.0	802.1	802.2	802.3	802.4	802.5	802.6	802.7	802.8	802.9	803.0	803.1	803.2	803.3	803.4	803.5	803.6	803.7	803.8	803.9	804.0	
1	950	950	950	960	960	960	960	970	970	970	970	980	980	980	980	980	990	990	990	990	1,000	1
2	2,220	2,220	2,230	2,230	2,240	2,250	2,250	2,260	2,260	2,270	2,280	2,280	2,290	2,290	2,300	2,310	2,310	2,320	2,320	2,330	2,340	2
3	3,160	3,170	3,180	3,190	3,200	3,210	3,220	3,220	3,230	3,240	3,250	3,260	3,270	3,270	3,280	3,290	3,300	3,310	3,320	3,320	3,330	3
4	4,430	4,440	4,460	4,470	4,480	4,490	4,510	4,520	4,530	4,540	4,550	4,570	4,580	4,590	4,600	4,610	4,630	4,640	4,650	4,660	4,670	4
5	4,650	4,660	4,680	4,690	4,700	4,710	4,730	4,740	4,750	4,770	4,780	4,790	4,800	4,820	4,830	4,840	4,850	4,870	4,880	4,890	4,900	5
6	6,020	6,040	6,050	6,070	6,090	6,100	6,120	6,140	6,150	6,170	6,180	6,200	6,220	6,230	6,250	6,260	6,280	6,300	6,310	6,330	6,340	6
7	6,970	6,990	7,010	7,020	7,040	7,060	7,080	7,100	7,120	7,140	7,160	7,180	7,190	7,210	7,230	7,250	7,270	7,290	7,300	7,320	7,340	7
8	8,240	8,260	8,280	8,300	8,330	8,350	8,370	8,390	8,420	8,440	8,460	8,480	8,510	8,530	8,550	8,570	8,590	8,620	8,640	8,660	8,680	8
9	9,180	9,210	9,230	9,260	9,280	9,310	9,330	9,360	9,380	9,410	9,430	9,460	9,480	9,510	9,530	9,560	9,580	9,610	9,630	9,650	9,680	9
10	10,450	10,480	10,510	10,540	10,570	10,600	10,620	10,650	10,680	10,710	10,740	10,770	10,790	10,820	10,850	10,880	10,910	10,930	10,960	10,990	11,020	10
11	10,670	10,700	10,730	10,760	10,790	10,820	10,850	10,880	10,900	10,930	10,960	10,990	11,020	11,050	11,080	11,110	11,130	11,160	11,190	11,220	11,250	11
12	12,040	12,070	12,110	12,140	12,170	12,210	12,240	12,270	12,300	12,340	12,370	12,400	12,430	12,470	12,500	12,530	12,560	12,590	12,630	12,660	12,690	12
13	12,880	12,910	12,950	12,990	13,020	13,060	13,090	13,130	13,160	13,200	13,230	13,260	13,300	13,330	13,370	13,400	13,440	13,470	13,500	13,540	13,570	13
14	14,240	14,280	14,320	14,360	14,390	14,430	14,470	14,510	14,550	14,590	14,630	14,670	14,700	14,740	14,780	14,820	14,860	14,890	14,930	14,970	15,010	14
15	14,470	14,510	14,550	14,590	14,630	14,670	14,710	14,750	14,790	14,830	14,870	14,910	14,950	14,980	15,020	15,060	15,100	15,140	15,180	15,220	15,250	15
16	15,850	15,900	15,940	15,980	16,030	16,070	16,110	16,160	16,200	16,240	16,290	16,330	16,370	16,410	16,460	16,500	16,540	16,580	16,620	16,670	16,710	16
17	16,090	16,140	16,180	16,230	16,270	16,310	16,360	16,400	16,450	16,490	16,530	16,580	16,620	16,660	16,700	16,750	16,790	16,830	16,880	16,920	16,960	17
18	17,470	17,520	17,570	17,620	17,670	17,710	17,760	17,810	17,860	17,900	17,950	18,000	18,040	18,090	18,140	18,180	18,230	18,280	18,320	18,370	18,410	18
19	18,440	18,490	18,540	18,590	18,650	18,700	18,750	18,800	18,850	18,890	18,940	18,990	19,040	19,090	19,140	19,190	19,240	19,290	19,340	19,380	19,430	19
20	19,730	19,780	19,840	19,890	19,950	20,000	20,050	20,110	20,160	20,210	20,270	20,320	20,370	20,420	20,480	20,530	20,580	20,630	20,690	20,740	20,790	20
21	20,250	20,310	20,360	20,420	20,480	20,530	20,590	20,640	20,700	20,750	20,800	20,860	20,910	20,970	21,020	21,080	21,130	21,180	21,240	21,290	21,340	21
22	21,590	21,650	21,710	21,760	21,820	21,880	21,940	22,000	22,060	22,120	22,170	22,230	22,290	22,350	22,410	22,460	22,520	22,580	22,630	22,690	22,750	22
23	22,560	22,620	22,680	22,750	22,810	22,870	22,930	22,990	23,050	23,110	23,170	23,230	23,290	23,350	23,410	23,470	23,530	23,590	23,650	23,710	23,770	23
24	23,850	23,910	23,980	24,040	24,110	24,170	24,240	24,300	24,370	24,430	24,500	24,560	24,620	24,690	24,750	24,810	24,880	24,940	25,000	25,070	25,130	24
25	24,810	24,870	24,940	25,010	25,080	25,150	25,210	25,280	25,350	25,410	25,480	25,550	25,610	25,680	25,750	25,810	25,880	25,940	26,010	26,070	26,140	25
26	26,080	26,150	26,230	26,300	26,370	26,440	26,510	26,580	26,650	26,720	26,790	26,860	26,930	27,000	27,070	27,140	27,210	27,280	27,350	27,420	27,490	26
27	26,310	26,380	26,460	26,530	26,600	26,670	26,740	26,820	26,890	26,960	27,030	27,100	27,170	27,240	27,310	27,380	27,450	27,520	27,590	27,660	27,730	27
28	27,690	27,760	27,840	27,920	27,990	28,070	28,140	28,220	28,290	28,370	28,440	28,520	28,590	28,660	28,740	28,810	28,890	28,960	29,030	29,100	29,180	28
29	28,960	29,040	29,120	29,200	29,280	29,360	29,440	29,520	29,600	29,680	29,760	29,840	29,910	29,990	30,070	30,150	30,220	30,300	30,380	30,450	30,530	29
30	30,290	30,380	30,460	30,550	30,630	30,720	30,800	30,880	30,960	31,050	31,130	31,210	31,290	31,380	31,460	31,540	31,620	31,700	31,780	31,860	31,940	30
31	31,630	31,710	31,800	31,890	31,980	32,070	32,150	32,240	32,330	32,420	32,500	32,590	32,670	32,760	32,850	32,930	33,020	33,100	33,190	33,270	33,360	31
32	32,910	33,010	33,100	33,190	33,280	33,370	33,470	33,560	33,650	33,740	33,830	33,920	34,010	34,100	34,190	34,280	34,370	34,450	34,540	34,630	34,720	32
33	34,240	34,340	34,440	34,530	34,630	34,730	34,820	34,920	35,010	35,110	35,200	35,300	35,390	35,480	35,580	35,670	35,760	35,860	35,950	36,040	36,130	33
34	35,580	35,680	35,780	35,880	35,980	36,080	36,180	36,280	36,380	36,470	36,570	36,670	36,770	36,870	36,970	37,060	37,160	37,260	37,350	37,450	37,540	34
35	36,860	36,970	37,070	37,180	37,280	37,390	37,490	37,590	37,690	37,800	37,900	38,000	38,100	38,210	38,310	38,410	38,510	38,610	38,710	38,810	38,910	35
36	37,820	37,930	38,040	38,150	38,250	38,360	38,470	38,570	38,680	38,780	38,890	38,990	39,100	39,200	39,310	39,410	39,520	39,620	39,720	39,820	39,930	36
37	39,110	39,220	39,340	39,450	39,560	39,670	39,780	39,890	40,000	40,110	40,220	40,330	40,430	40,540	40,650	40,760	40,860	40,970	41,080	41,180	41,290	37
38	40,400	40,520	40,630	40,750	40,860	40,980	41,090	41,200	41,320	41,430	41,540	41,660	41,770	41,880	41,990	42,100	42,210	42,320	42,430	42,540	42,650	38
39	41,730	41,850	41,970	42,090	42,210	42,330	42,450	42,560	42,680	42,800	42,920	43,030	43,150	43,260	43,380	43,500	43,610	43,720	43,840	43,950	44,070	39
40	43,020	43,150	43,270	43,390	43,520	43,640	43,760	43,880	44,010	44,130	44,250	44,370	44,490	44,610	44,730	44,850	44,960	45,080	45,200	45,320	45,440	40
41	44,350	44,480	44,610	44,740	44,860	44,990	45,120	45,240	45,370	45,490	45,620	45,740	45,870	45,990	46,120	46,240	46,360	46,480	46,610	46,730	46,850	41
42	45,690	45,820	45,950	46,080	46,210	46,340	46,470	46,600	46,730	46,860	46,990	47,120	47,250	47,380	47,500	47,630	47,760	47,890	48,010	48,140	48,260	42
43	46,310	46,450	46,580	46,710	46,850	46,980	47,110	47,240	47,380	47,510	47,640	47,770	47,900	48,030	48,160	48,290	48,420	48,550	48,670	48,800	48,930	43
44	47,000	47,140	47,270	47,410	47,540	47,680	47,810	47,950	48,080	48,220	48,350	48,480	48,610	48,750	48,880	49,010	49,140	49,270	49,400	49,530	49,660	44
45	47,690	47,830	47,970	48,100	48,240	48,380	48,520	48,650	48,790	48,920	49,060	49,200	49,330	49,460	49,600	49,730	49,870	50,000	50,130	50,260	50,400	45
46	48,320	48,460	48,600	48,740	48,880	49,020	49,160	49,300	49,440	49,580	49,710	49,850	49,990	50,120	50,260	50,400	50,530	50,670	50,800	50,940	51,070	46
47	49,010	49,150	49,300	49,440	49,580	49,720	49,860	50,000	50,150	50,290	50,430	50,560	50,700	50,840	50,980	51,120	51,260	51,390	51,530	51,670	51,800	47
48	49,700	49,840	49,990	50,130	50,280	50,420	50,570	50,710	50,850	50,990	51,140	51,280	51,420	51,560	51,700	51,840	51,980	52,120	52,260	52,400	52,540	48
49	50,330	50,480	50,630	50,770	50,920	51,070	51,210	51,360	51,500	51,650	51,790	51,930	52,080	52,220	52,360	52,500	52,650	52,790	52,930	53,070	53,210	49
50	51,280	51,440	51,590	51,740	51,890	52,030	52,180	52,330	52,480	52,630	52,770	52,920	53,070	53,210	53,360	53,500	53,650	53,790	53,940	54,080	54,220	50
51	51,920	52,070	52,220	52,380	52,530	52,680	52,830	52,980	53,130	53,280	53,430	53,580	53,730	53,870	54,020	54,170	54,320	54,460	54,610	54,750	54,900	51
52	52,550	52,710	52,860	53,020	53,170	53,320	53,480	53,630	53,780	53,930	54,080	54,230	54,380	54,530	54,680	54,830	54,980	55,130	55,280	55,420	55,570	52
53	53,240	53,400	53,550	53,710	53,870	54,020	54,180	54,330	54,490	54,640	54,790	54,950	55,100	55,250	55,400	55,550	55,710	55,860	56,010	56,160	56,300	53
54	53,900	54,060	54,220	54,380	54,540	54,700	54,850	55,010	55,170	55,320	55,480	55,630	55,790	55,940	56,100	56,250	56,400	56,560	56,710	56,860	57,010	54
55	54,590	54,750	54,920	55,080	55,240	55,400	55,560	55,720	55,870	56,030	56,190	56,350	56,500	56,660	56,820	56,970	57,130	57,280	57,440	57,590	57,740	55
56	55,280	55,440	55,610	55,770	55,930	56,100	56,260	56,420	56,580	56,740	56,900	57,060	57,220	57,380	57,540	57,690	57,850	58,010	58,160	58,320	58,480	56
57	57,290	57,460	57,630	57,800	57,970	58,140	58,310	58,480	58,640	58,810	58,980	59,150	59,310	59,480	59,640	59,810	59,970	60,130	60,300	60,460	60,620	57
58	59,210	59,390	59,570	59,750	59,930	60,100	60,280	60,450	60,630	60,800	60,980	61,150	61,320	61,500	61,670	61,840	62,010	62,180	62,350	62,520	62,690	58
59	61,130	61,320	61,510	61,690	61,880	62,070	62,250	62,430	62,620	62,800	62,980	63,160	63,340	63,520	63,700	63,880	64,050	64,230	64,410	64,580	64,760	59
60	63,170	63,360	63,560	63,750	63,950	64,140	64,330	64,520	64,710	64,900	65,090	65,280	65,460	65,650	65,840	66,020	66,210	66,390	66,580	66,760	66,940	60

FORT LOUDOUN DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	802.0	802.1	802.2	802.3	802.4	802.5	802.6	802.7	802.8	802.9	803.0	803.1	803.2	803.3	803.4	803.5	803.6	803.7	803.8	803.9	804.0	
61	65,090	65,290	65,500	65,700	65,900	66,110	66,300	66,500	66,700	66,890	67,090	67,280	67,480	67,670	67,860	68,060	68,250	68,440	68,630	68,820	69,010	61
62	67,010	67,220	67,440	67,650	67,860	68,070	68,280	68,480	68,680	68,890	69,090	69,290	69,490	69,690	69,890	70,090	70,290	70,490	70,690	70,880	71,080	62
63	69,050	69,270	69,490	69,710	69,930	70,150	70,360	70,570	70,780	70,990	71,200	71,410	71,620	71,820	72,030	72,240	72,440	72,650	72,850	73,060	73,260	63
64	70,950	71,180	71,410	71,640	71,870	72,090	72,310	72,530	72,750	72,970	73,180	73,400	73,610	73,830	74,040	74,250	74,470	74,680	74,890	75,100	75,310	64
65	72,990	73,230	73,470	73,700	73,940	74,170	74,400	74,620	74,850	75,070	75,290	75,520	75,740	75,960	76,180	76,400	76,620	76,840	77,060	77,270	77,490	65
66	75,030	75,280	75,520	75,760	76,010	76,250	76,480	76,710	76,940	77,170	77,400	77,630	77,860	78,090	78,320	78,550	78,770	79,000	79,220	79,450	79,670	66
67	76,950	77,210	77,460	77,710	77,960	78,210	78,450	78,690	78,930	79,170	79,400	79,640	79,880	80,110	80,350	80,580	80,810	81,050	81,280	81,510	81,740	67
68	78,900	79,170	79,420	79,680	79,940	80,190	80,440	80,690	80,930	81,180	81,420	81,670	81,910	82,150	82,390	82,630	82,870	83,110	83,350	83,590	83,830	68
69	80,830	81,090	81,360	81,630	81,900	82,160	82,410	82,670	82,920	83,170	83,420	83,670	83,920	84,170	84,420	84,670	84,920	85,160	85,410	85,650	85,900	69
70	82,750	83,020	83,300	83,580	83,850	84,120	84,380	84,650	84,910	85,160	85,420	85,680	85,940	86,190	86,450	86,700	86,960	87,210	87,460	87,710	87,970	70
71	84,990	85,280	85,570	85,860	86,140	86,430	86,700	86,970	87,240	87,510	87,780	88,050	88,320	88,590	88,850	89,120	89,380	89,650	89,910	90,170	90,430	71
72	87,260	87,560	87,860	88,160	88,450	88,740	89,030	89,310	89,590	89,880	90,160	90,440	90,720	91,000	91,270	91,550	91,830	92,100	92,380	92,650	92,920	72
73	89,530	89,830	90,140	90,450	90,760	91,060	91,360	91,650	91,950	92,240	92,530	92,820	93,120	93,410	93,690	93,980	94,270	94,560	94,840	95,130	95,410	73
74	91,830	92,150	92,470	92,790	93,110	93,420	93,730	94,040	94,340	94,650	94,950	95,260	95,560	95,860	96,160	96,460	96,760	97,050	97,350	97,650	97,940	74
75	94,100	94,430	94,760	95,090	95,420	95,740	96,060	96,380	96,700	97,010	97,330	97,640	97,960	98,270	98,580	98,890	99,200	99,510	99,820	100,100	100,400	75
76	96,360	96,700	97,040	97,380	97,720	98,060	98,390	98,720	99,050	99,380	99,700	100,000	100,400	100,700	101,000	101,300	101,600	102,000	102,300	102,600	102,900	76
77	98,670	99,020	99,370	99,730	100,100	100,400	100,800	101,100	101,400	101,800	102,100	102,500	102,800	103,100	103,500	103,800	104,100	104,500	104,800	105,100	105,500	77
78	100,900	101,200	101,600	102,000	102,300	102,700	103,000	103,400	103,700	104,100	104,400	104,800	105,100	105,500	105,800	106,200	106,500	106,900	107,200	107,500	107,900	78
79	103,200	103,600	103,900	104,300	104,700	105,000	105,400	105,800	106,100	106,500	106,900	107,200	107,600	107,900	108,300	108,600	109,000	109,400	109,700	110,100	110,400	79
80	105,500	105,900	106,300	106,600	107,000	107,400	107,800	108,200	108,500	108,900	109,300	109,600	110,000	110,400	110,800	111,100	111,500	111,800	112,200	112,600	112,900	80
81	107,800	108,100	108,500	108,900	109,300	109,700	110,100	110,500	110,900	111,300	111,700	112,000	112,400	112,800	113,200	113,600	113,900	114,300	114,700	115,100	115,400	81
82	110,000	110,500	110,900	111,300	111,700	112,100	112,500	112,900	113,300	113,700	114,100	114,500	114,800	115,200	115,600	116,000	116,400	116,800	117,200	117,600	117,900	82
83	112,300	112,700	113,100	113,600	114,000	114,400	114,800	115,200	115,600	116,000	116,400	116,800	117,200	117,600	118,000	118,500	118,800	119,200	119,600	120,000	120,400	83
84	114,600	115,000	115,400	115,900	116,300	116,700	117,100	117,600	118,000	118,400	118,800	119,200	119,600	120,100	120,500	120,900	121,300	121,700	122,100	122,500	122,900	84
85	118,900	119,400	119,800	120,200	120,700	121,100	121,500	122,000	122,400	122,800	123,200	123,700	124,100	124,500	124,900	125,400	125,800	126,200	126,600	127,000	127,400	85
86	123,400	123,800	124,200	124,700	125,100	125,600	126,000	126,400	126,900	127,300	127,800	128,200	128,600	129,100	129,500	129,900	130,400	130,800	131,200	131,600	132,100	86
87	127,900	128,300	128,700	129,100	129,600	130,000	130,500	130,900	131,400	131,800	132,300	132,700	133,200	133,600	134,100	134,500	134,900	135,400	135,800	136,200	136,700	87
88	132,200	132,600	133,000	133,500	133,900	134,400	134,900	135,300	135,800	136,300	136,700	137,200	137,600	138,100	138,500	139,000	139,400	139,900	140,300	140,800	141,200	88
89	136,600	137,000	137,500	137,900	138,400	138,900	139,300	139,800	140,300	140,800	141,200	141,700	142,200	142,600	143,100	143,500	144,000	144,500	144,900	145,400	145,800	89
90	141,000	141,500	141,900	142,300	142,800	143,300	143,800	144,300	144,800	145,200	145,700	146,200	146,700	147,100	147,600	148,100	148,500	149,000	149,500	149,900	150,400	90
91	145,500	145,900	146,300	146,700	147,300	147,800	148,300	148,800	149,300	149,700	150,200	150,700	151,200	151,700	152,200	152,600	153,100	153,600	154,100	154,500	155,000	91
92	148,800	149,400	149,900	150,500	151,100	151,800	152,400	153,000	153,600	154,300	154,900	155,500	156,100	156,700	157,200	157,800	158,300	158,800	159,300	159,800	160,300	92
93	152,200	152,900	153,600	154,300	155,100	155,800	156,600	157,400	158,100	158,900	159,700	160,400	161,200	161,800	162,400	163,000	163,600	164,100	164,700	165,300	165,800	93
94	155,000	155,800	156,700	157,500	158,400	159,300	160,200	161,100	162,000	162,900	163,800	164,700	165,600	166,400	167,100	167,800	168,600	169,300	170,000	170,700	171,400	94
95	158,400	159,400	160,400	161,400	162,400	163,400	164,500	165,500	166,500	167,600	168,600	169,600	170,700	171,500	172,300	173,100	173,800	174,600	175,300	176,100	176,800	95
96	162,500	163,600	164,700	165,800	167,000	168,100	169,300	170,500	171,600	172,800	174,000	175,200	176,300	177,200	177,900	178,700	179,400	180,100	180,800	181,500	182,200	96
97	165,700	167,000	168,200	169,500	170,800	172,100	173,400	174,700	176,000	177,300	178,600	179,900	181,200	182,300	183,100	184,000	184,700	185,500	186,200	187,000	187,800	97
98	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	186,800	187,800	188,800	189,700	190,600	191,500	192,400	193,300	98
99	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	186,900	188,000	189,100	190,100	191,100	192,100	193,100	194,100	99
100	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,000	188,100	189,300	190,400	191,500	192,600	193,700	194,800	100
101	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,000	188,100	189,300	190,400	191,500	192,600	193,700	194,800	101
102	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,000	188,300	189,600	190,800	191,900	193,100	194,300	195,500	102
103	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,400	192,800	194,200	195,600	197,000	103
104	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	104
105	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	105
106	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	106
107	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	107
108	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	108
109	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	109
110	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	110
111	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	111
112	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	112
113	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	113
114	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	114
115	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	115
116	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	116
117	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	117
118	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	118
119	168,500	169,900	171,300	172,700	174,100	175,600	177,000	178,400	179,900	181,300	182,800	184,200	185,700	187,100	188,600	190,100	191,600	193,000	194,500	196,000	197,500	119

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	804.0	804.1	804.2	804.3	804.4	804.5	804.6	804.7	804.8	804.9	805.0	805.1	805.2	805.3	805.4	805.5	805.6	805.7	805.8	805.9	806.0	
1	1,000	1,000	1,000	1,000	1,010	1,010	1,010	1,010	1,020	1,020	1,020	1,020	1,030	1,030	1,030	1,030	1,030	1,040	1,040	1,040	1,040	1
2	2,340	2,340	2,350	2,350	2,360	2,370	2,370	2,380	2,380	2,390	2,390	2,400	2,410	2,410	2,420	2,420	2,430	2,430	2,440	2,450	2,450	2
3	3,330	3,340	3,350	3,360	3,370	3,370	3,380	3,390	3,400	3,410	3,410	3,420	3,430	3,440	3,450	3,450	3,460	3,470	3,480	3,490	3,490	3
4	4,670	4,680	4,700	4,710	4,720	4,730	4,740	4,750	4,770	4,780	4,790	4,800	4,810	4,820	4,830	4,850	4,860	4,870	4,880	4,890	4,900	4
5	4,900	4,910	4,930	4,940	4,950	4,960	4,970	4,990	5,000	5,010	5,020	5,030	5,050	5,060	5,070	5,080	5,090	5,110	5,120	5,130	5,140	5
6	6,340	6,360	6,380	6,390	6,410	6,420	6,440	6,450	6,470	6,490	6,500	6,520	6,530	6,550	6,560	6,580	6,590	6,610	6,620	6,640	6,650	6
7	7,340	7,360	7,380	7,400	7,410	7,430	7,450	7,470	7,490	7,500	7,520	7,540	7,560	7,570	7,590	7,610	7,630	7,640	7,660	7,680	7,700	7
8	8,680	8,700	8,720	8,750	8,770	8,790	8,810	8,830	8,850	8,870	8,890	8,920	8,940	8,960	8,980	9,000	9,020	9,040	9,060	9,080	9,100	8
9	9,680	9,700	9,730	9,750	9,770	9,800	9,820	9,840	9,870	9,890	9,920	9,940	9,960	9,990	10,010	10,030	10,060	10,080	10,100	10,120	10,150	9
10	11,020	11,040	11,070	11,100	11,130	11,150	11,180	11,210	11,240	11,260	11,290	11,320	11,340	11,370	11,400	11,420	11,450	11,480	11,500	11,530	11,550	10
11	11,250	11,270	11,300	11,330	11,360	11,390	11,410	11,440	11,470	11,500	11,520	11,550	11,580	11,610	11,630	11,660	11,690	11,710	11,740	11,770	11,790	11
12	12,690	12,720	12,750	12,780	12,810	12,850	12,880	12,910	12,940	12,970	13,000	13,030	13,060	13,090	13,120	13,160	13,190	13,220	13,250	13,280	13,310	12
13	13,570	13,610	13,640	13,670	13,710	13,740	13,770	13,810	13,840	13,870	13,910	13,940	13,970	14,000	14,040	14,070	14,100	14,130	14,170	14,200	14,230	13
14	15,010	15,040	15,080	15,120	15,160	15,190	15,230	15,270	15,300	15,340	15,380	15,410	15,450	15,490	15,520	15,560	15,590	15,630	15,670	15,700	15,740	14
15	15,250	15,290	15,330	15,370	15,400	15,440	15,480	15,520	15,550	15,590	15,630	15,670	15,700	15,740	15,780	15,810	15,850	15,890	15,920	15,960	16,000	15
16	16,710	16,750	16,790	16,830	16,870	16,910	16,960	17,000	17,040	17,080	17,120	17,160	17,200	17,240	17,280	17,320	17,360	17,400	17,440	17,480	17,520	16
17	16,960	17,000	17,040	17,090	17,130	17,170	17,210	17,250	17,290	17,340	17,380	17,420	17,460	17,500	17,540	17,580	17,620	17,660	17,700	17,740	17,780	17
18	18,410	18,460	18,510	18,550	18,600	18,640	18,690	18,730	18,780	18,820	18,870	18,910	18,960	19,000	19,040	19,090	19,130	19,180	19,220	19,270	19,310	18
19	19,430	19,480	19,530	19,580	19,630	19,670	19,720	19,770	19,820	19,860	19,910	19,960	20,000	20,050	20,100	20,140	20,190	20,240	20,280	20,330	20,380	19
20	20,790	20,840	20,890	20,950	21,000	21,050	21,100	21,150	21,200	21,250	21,300	21,350	21,400	21,450	21,500	21,550	21,600	21,650	21,700	21,750	21,800	20
21	21,340	21,400	21,450	21,500	21,550	21,610	21,660	21,710	21,760	21,810	21,870	21,920	21,970	22,020	22,070	22,120	22,180	22,230	22,280	22,330	22,380	21
22	22,750	22,800	22,860	22,920	22,970	23,030	23,090	23,140	23,200	23,250	23,310	23,360	23,420	23,470	23,530	23,580	23,640	23,690	23,750	23,800	23,850	22
23	23,770	23,830	23,890	23,950	24,010	24,070	24,120	24,180	24,240	24,300	24,360	24,410	24,470	24,530	24,590	24,640	24,700	24,760	24,810	24,870	24,930	23
24	25,130	25,190	25,250	25,320	25,380	25,440	25,500	25,560	25,630	25,690	25,750	25,810	25,870	25,930	25,990	26,050	26,110	26,170	26,230	26,290	26,350	24
25	26,140	26,200	26,270	26,330	26,400	26,460	26,530	26,590	26,650	26,720	26,780	26,850	26,910	26,970	27,030	27,100	27,160	27,220	27,280	27,350	27,410	25
26	27,490	27,560	27,620	27,690	27,760	27,830	27,900	27,960	28,030	28,100	28,160	28,230	28,300	28,360	28,430	28,500	28,560	28,630	28,690	28,760	28,830	26
27	27,730	27,800	27,870	27,940	28,000	28,070	28,140	28,210	28,280	28,340	28,410	28,480	28,550	28,610	28,680	28,750	28,810	28,880	28,950	29,010	29,080	27
28	29,180	29,250	29,320	29,390	29,470	29,540	29,610	29,680	29,750	29,820	29,890	29,970	30,040	30,110	30,180	30,250	30,320	30,390	30,460	30,530	30,600	28
29	30,530	30,610	30,680	30,760	30,830	30,910	30,980	31,060	31,130	31,210	31,280	31,360	31,430	31,510	31,580	31,650	31,730	31,800	31,870	31,950	32,020	29
30	31,940	32,020	32,100	32,180	32,260	32,340	32,420	32,500	32,580	32,660	32,740	32,810	32,890	32,970	33,050	33,120	33,200	33,280	33,360	33,430	33,510	30
31	33,360	33,440	33,520	33,610	33,690	33,770	33,860	33,940	34,020	34,110	34,190	34,270	34,350	34,430	34,510	34,600	34,680	34,760	34,840	34,920	35,000	31
32	34,720	34,810	34,890	34,980	35,070	35,160	35,240	35,330	35,420	35,500	35,590	35,670	35,760	35,840	35,930	36,010	36,100	36,180	36,270	36,350	36,440	32
33	36,130	36,220	36,320	36,410	36,500	36,590	36,680	36,770	36,860	36,950	37,040	37,130	37,220	37,310	37,400	37,490	37,570	37,660	37,750	37,840	37,930	33
34	37,540	37,640	37,740	37,830	37,930	38,020	38,120	38,210	38,300	38,400	38,490	38,590	38,680	38,770	38,860	38,960	39,050	39,140	39,230	39,320	39,420	34
35	38,910	39,010	39,110	39,210	39,300	39,400	39,500	39,600	39,700	39,790	39,890	39,990	40,090	40,180	40,280	40,370	40,470	40,570	40,660	40,760	40,850	35
36	39,930	40,030	40,130	40,230	40,330	40,440	40,540	40,640	40,740	40,840	40,940	41,040	41,140	41,240	41,340	41,430	41,530	41,630	41,730	41,830	41,920	36
37	41,290	41,400	41,500	41,610	41,710	41,820	41,920	42,030	42,130	42,230	42,340	42,440	42,540	42,650	42,750	42,850	42,950	43,060	43,160	43,260	43,360	37
38	42,650	42,760	42,870	42,980	43,090	43,200	43,310	43,420	43,520	43,630	43,740	43,850	43,950	44,060	44,160	44,270	44,380	44,480	44,590	44,690	44,800	38
39	44,070	44,180	44,290	44,410	44,520	44,630	44,740	44,860	44,970	45,080	45,190	45,300	45,410	45,520	45,630	45,740	45,850	45,960	46,070	46,180	46,290	39
40	45,440	45,550	45,670	45,790	45,900	46,020	46,140	46,250	46,370	46,480	46,600	46,710	46,830	46,940	47,050	47,170	47,280	47,390	47,500	47,620	47,730	40
41	46,850	46,970	47,090	47,210	47,330	47,450	47,570	47,690	47,810	47,930	48,050	48,170	48,290	48,400	48,520	48,640	48,750	48,870	48,990	49,100	49,220	41
42	48,260	48,390	48,510	48,640	48,760	48,890	49,010	49,130	49,260	49,380	49,500	49,620	49,750	49,870	49,990	50,110	50,230	50,350	50,470	50,590	50,710	42
43	48,930	49,060	49,180	49,310	49,440	49,560	49,690	49,810	49,940	50,060	50,190	50,310	50,430	50,560	50,680	50,800	50,930	51,050	51,170	51,290	51,410	43
44	49,660	49,790	49,920	50,050	50,180	50,310	50,430	50,560	50,690	50,810	50,940	51,070	51,190	51,320	51,440	51,570	51,690	51,820	51,940	52,070	52,190	44
45	50,400	50,530	50,660	50,790	50,920	51,050	51,180	51,310	51,440	51,570	51,700	51,820	51,950	52,080	52,210	52,330	52,460	52,590	52,710	52,840	52,960	45
46	51,070	51,200	51,340	51,470	51,600	51,730	51,870	52,000	52,130	52,260	52,390	52,520	52,650	52,780	52,910	53,040	53,170	53,290	53,420	53,550	53,680	46
47	51,800	51,940	52,070	52,210	52,340	52,480	52,610	52,740	52,880	53,010	53,140	53,280	53,410	53,540	53,670	53,800	53,930	54,060	54,190	54,320	54,450	47
48	52,540	52,670	52,810	52,950	53,080	53,220	53,360	53,490	53,630	53,760	53,900	54,030	54,170	54,300	54,430	54,570	54,700	54,830	54,960	55,100	55,230	48
49	53,210	53,350	53,490	53,630	53,770	53,900	54,040	54,180	54,320	54,450	54,590	54,730	54,860	55,000	55,130	55,270	55,400	55,540	55,670	55,810	55,940	49
50	54,220	54,370	54,510	54,650	54,790	54,930	55,070	55,220	55,360	55,500	55,640	55,770	55,910	56,050	56,190	56,330	56,460	56,600	56,740	56,880	57,010	50
51	54,900	55,040	55,190	55,330	55,470	55,620	55,760	55,900	56,050	56,190	56,330	56,470	56,610	56,750	56,890	57,030	57,170	57,310	57,450	57,590	57,720	51
52	55,570	55,720	55,860	56,010	56,160	56,300	56,450	56,590	56,730	56,880	57,020	57,160	57,310	57,450	57,590	57,730	57,870	58,010	58,160	58,300	58,440	52
53	56,300	56,450	56,600	56,750	56,900	57,050	57,190	57,340	57,480	57,630	57,780	57,920	58,070	58,210	58,350	58,500	58,640	58,780	58,930	59,070	59,210	53
54	57,010	57,160	57,310	57,460	57,610	57,760	57,910	58,060	58,210	58,350	58,500	58,650	58,800	58,940	59,090	59,230	59,380	59,520	59,670	59,810	59,960	54
55	57,740	57,900	58,050	58,200	58,350	58,510	58,660	58,810	58,960	59,110	59,260	59,410	59,550	59,700	59,850	60,000	60,150	60,290	60,440	60,590	60,730	55
56	58,480	58,630	58,790	58,940	59,100	59,250	59,400	59,560	59,710	59,860	60,010	60,160	60,310	60,460	60,610	60,760	60,910	61,060	61,210	61,360	61,510	56
57	60,620	60,780	60,950	61,110	61,270	61,430	61,590	61,750	61,910	62,070	62,220	62,380	62,540	62,700	62,850	63,010	63,160	63,320	63,480	63,630	63,780	57
58	62,690	62,860	63,030	63,200	63,360	63,530	63,700	63,860	64,030	64,200	64,360	64,520	64,690	64,850	65,020	65,180	65,340	65,500	65,660	65,820	65,990	58
59	64,760	64,940	65,110	65,290	65,460	65,630	65,810	65,980	66,150	66,320	66,500	66,670	66,840	67,010	67,180	67,350	67,520	67,680	67,850	68,020	68,190	59
60	66,940	67,120	67,310	67,490	67,670	67,850	68,030	68,210	68,390	68,570	68,740	68,920	69,100	69,280	69,450	69,630	69,800	69,980	70,150	70,330	70,500	60

FORT LOUDOUN DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	804.0	804.1	804.2	804.3	804.4	804.5	804.6	804.7	804.8	804.9	805.0	805.1	805.2	805.3	805.4	805.5	805.6	805.7	805.8	805.9	806.0	
61	69,010	69,200	69,390	69,580	69,760	69,950	70,140	70,320	70,510	70,700	70,880	71,060	71,250	71,430	71,610	71,800	71,980	72,160	72,340	72,520	72,700	61
62	71,080	71,280	71,470	71,670	71,860	72,050	72,250	72,440	72,630	72,820	73,020	73,210	73,400	73,590	73,780	73,970	74,150	74,340	74,530	74,720	74,900	62
63	73,260	73,460	73,660	73,870	74,070	74,270	74,470	74,670	74,870	75,070	75,260	75,460	75,660	75,850	76,050	76,250	76,440	76,640	76,830	77,020	77,220	63
64	75,310	75,520	75,730	75,940	76,140	76,350	76,560	76,760	76,970	77,180	77,380	77,580	77,790	77,990	78,190	78,390	78,600	78,800	79,000	79,200	79,400	64
65	77,490	77,710	77,920	78,140	78,350	78,570	78,780	78,990	79,200	79,420	79,630	79,840	80,050	80,260	80,470	80,670	80,880	81,090	81,300	81,500	81,710	65
66	79,670	79,890	80,120	80,340	80,560	80,780	81,000	81,220	81,440	81,660	81,880	82,090	82,310	82,530	82,740	82,960	83,170	83,380	83,600	83,810	84,020	66
67	81,740	81,970	82,200	82,430	82,660	82,880	83,110	83,340	83,560	83,790	84,010	84,240	84,460	84,680	84,900	85,120	85,350	85,570	85,790	86,000	86,220	67
68	83,830	84,060	84,300	84,540	84,770	85,000	85,240	85,470	85,700	85,930	86,160	86,390	86,620	86,850	87,080	87,310	87,540	87,760	87,990	88,210	88,440	68
69	85,900	86,140	86,380	86,620	86,870	87,110	87,350	87,590	87,830	88,060	88,300	88,540	88,770	89,010	89,240	89,480	89,710	89,950	90,180	90,410	90,640	69
70	87,970	88,220	88,470	88,710	88,960	89,210	89,460	89,700	89,950	90,190	90,440	90,680	90,920	91,170	91,410	91,650	91,890	92,130	92,370	92,600	92,840	70
71	90,430	90,690	90,950	91,210	91,470	91,730	91,990	92,240	92,500	92,760	93,010	93,260	93,520	93,770	94,020	94,270	94,520	94,770	95,020	95,260	95,510	71
72	92,920	93,190	93,470	93,740	94,010	94,280	94,540	94,810	95,080	95,340	95,610	95,880	96,140	96,400	96,660	96,920	97,180	97,440	97,700	97,960	98,220	72
73	95,410	95,690	95,980	96,260	96,540	96,820	97,100	97,380	97,660	97,930	98,210	98,490	98,760	99,040	99,310	99,580	99,850	100,100	100,400	100,700	100,900	73
74	97,940	98,240	98,530	98,820	99,110	99,410	99,700	99,990	100,300	100,600	100,800	101,100	101,400	101,700	102,000	102,300	102,500	102,800	103,100	103,400	103,700	74
75	100,400	100,700	101,000	101,300	101,600	101,900	102,300	102,600	102,900	103,200	103,400	103,700	104,000	104,300	104,600	104,900	105,200	105,500	105,800	106,100	106,400	75
76	102,900	103,200	103,600	103,900	104,200	104,500	104,800	105,100	105,400	105,700	106,000	106,400	106,700	107,000	107,300	107,600	107,900	108,200	108,500	108,800	109,100	76
77	105,500	105,800	106,100	106,400	106,800	107,100	107,400	107,700	108,000	108,400	108,700	109,000	109,300	109,600	110,000	110,300	110,600	110,900	111,200	111,500	111,800	77
78	107,900	108,200	108,600	108,900	109,200	109,600	109,900	110,200	110,600	110,900	111,200	111,500	111,900	112,200	112,500	112,800	113,200	113,500	113,800	114,100	114,400	78
79	110,400	110,800	111,100	111,500	111,800	112,100	112,500	112,800	113,200	113,500	113,900	114,200	114,500	114,900	115,200	115,500	115,900	116,200	116,500	116,900	117,200	79
80	112,900	113,300	113,700	114,000	114,400	114,700	115,100	115,400	115,800	116,100	116,500	116,800	117,200	117,500	117,900	118,200	118,600	118,900	119,200	119,600	119,900	80
81	115,400	115,800	116,200	116,500	116,900	117,300	117,600	118,000	118,400	118,700	119,100	119,500	119,800	120,200	120,500	120,900	121,200	121,600	121,900	122,300	122,600	81
82	117,900	118,300	118,700	119,100	119,500	119,800	120,200	120,600	121,000	121,400	121,700	122,100	122,500	122,800	123,200	123,600	123,900	124,300	124,600	125,000	125,400	82
83	120,400	120,800	121,200	121,600	122,000	122,400	122,800	123,200	123,600	123,900	124,300	124,700	125,100	125,500	125,800	126,200	126,600	127,000	127,300	127,700	128,100	83
84	122,900	123,300	123,700	124,100	124,500	124,900	125,300	125,700	126,100	126,500	126,900	127,300	127,700	128,100	128,500	128,900	129,300	129,600	130,000	130,400	130,800	84
85	127,400	127,900	128,300	128,700	129,100	129,500	129,900	130,300	130,800	131,200	131,600	132,000	132,400	132,800	133,200	133,600	134,000	134,400	134,800	135,200	135,600	85
86	132,100	132,500	132,900	133,300	133,800	134,200	134,600	135,000	135,500	135,900	136,300	136,700	137,100	137,600	138,000	138,400	138,800	139,300	139,700	140,100	140,500	86
87	136,700	137,100	137,500	138,000	138,400	138,800	139,300	139,700	140,100	140,600	141,000	141,400	141,800	142,300	142,700	143,200	143,600	144,100	144,500	144,900	145,400	87
88	141,200	141,600	142,100	142,500	143,000	143,400	143,900	144,300	144,800	145,200	145,600	146,100	146,500	147,000	147,400	147,900	148,400	148,800	149,300	149,800	150,200	88
89	145,800	146,200	146,700	147,200	147,600	148,100	148,600	149,000	149,500	150,000	150,400	150,900	151,300	151,800	152,300	152,800	153,300	153,800	154,300	154,800	155,200	89
90	150,400	150,800	151,300	151,800	152,200	152,700	153,200	153,700	154,200	154,600	155,100	155,600	156,100	156,500	157,100	157,600	158,100	158,600	159,100	159,600	160,100	90
91	155,000	155,400	155,900	156,400	156,900	157,400	157,800	158,300	158,800	159,300	159,800	160,300	160,700	161,200	161,800	162,300	162,800	163,400	163,900	164,400	165,000	91
92	160,300	160,900	161,400	161,900	162,300	162,800	163,200	163,700	164,100	164,500	165,000	165,400	165,800	166,300	166,800	167,300	167,800	168,300	168,900	169,400	169,900	92
93	165,800	166,400	166,900	167,500	167,900	168,300	168,700	169,100	169,500	169,900	170,300	170,600	171,000	171,500	172,000	172,400	172,900	173,400	173,900	174,400	174,900	93
94	171,400	172,100	172,800	173,500	173,900	174,200	174,600	174,900	175,200	175,600	175,900	176,200	176,600	177,000	177,400	177,800	178,300	178,700	179,200	179,600	180,000	94
95	176,800	177,600	178,300	179,000	179,300	179,600	179,900	180,200	180,500	180,800	181,100	181,300	181,600	182,000	182,400	182,800	183,200	183,700	184,100	184,500	184,900	95
96	182,200	182,900	183,600	184,200	184,500	184,700	185,000	185,300	185,500	185,800	186,000	186,200	186,500	186,800	187,200	187,700	188,100	188,500	188,900	189,400	189,800	96
97	187,800	188,500	189,200	189,900	190,100	190,300	190,500	190,800	191,000	191,200	191,400	191,600	191,700	192,000	192,400	192,800	193,200	193,600	194,000	194,400	194,800	97
98	193,300	194,300	195,100	195,900	196,100	196,200	196,400	196,600	196,700	196,900	197,000	197,200	197,300	197,500	197,900	198,200	198,600	198,900	199,300	199,600	199,900	98
99	194,100	195,100	196,000	196,900	197,300	197,600	198,000	198,300	198,700	199,000	199,400	199,700	200,000	200,400	200,900	201,400	202,000	202,500	203,000	203,500	204,000	99
100	194,800	195,900	197,000	197,900	198,500	199,000	199,600	200,100	200,700	201,200	201,800	202,300	202,800	203,400	204,100	204,800	205,500	206,200	206,900	207,500	208,200	100
101	194,800	195,900	197,000	198,000	198,700	199,500	200,200	201,000	201,700	202,500	203,200	204,000	204,700	205,500	206,400	207,200	208,100	209,000	209,900	210,800	211,700	101
102	195,500	196,700	197,900	199,100	200,100	201,000	201,900	202,900	203,800	204,800	205,700	206,600	207,600	208,600	209,600	210,600	211,700	212,700	213,800	214,900	215,900	102
103	197,000	198,400	199,800	201,200	202,300	203,400	204,500	205,700	206,800	207,900	209,100	210,200	211,300	212,500	213,700	214,800	216,000	217,300	218,500	219,700	220,900	103
104	197,500	199,000	200,500	202,000	203,300	204,600	206,000	207,300	208,600	209,900	211,300	212,600	213,900	215,300	216,700	218,000	219,400	220,800	222,200	223,500	224,900	104
105	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	105
106	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	106
107	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	107
108	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	108
109	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	109
110	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	110
111	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	111
112	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	112
113	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	113
114	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	114
115	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	115
116	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	116
117	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	117
118	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	118
119	197,500	199,000	200,500	202,000	203,500	205,100	206,600	208,100	209,600	211,200	212,700	214,300	215,800	217,400	218,900	220,500	222,100	223,600	225,200	226,800	228,400	119

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	806.0	806.1	806.2	806.3	806.4	806.5	806.6	806.7	806.8	806.9	807.0	807.1	807.2	807.3	807.4	807.5	807.6	807.7	807.8	807.9	808.0	
1	1,040	1,050	1,050	1,050	1,050	1,060	1,060	1,060	1,060	1,060	1,070	1,070	1,070	1,070	1,080	1,080	1,080	1,080	1,080	1,090	1,090	1
2	2,450	2,460	2,460	2,470	2,470	2,480	2,480	2,490	2,490	2,500	2,510	2,510	2,520	2,520	2,530	2,530	2,540	2,540	2,550	2,550	2,560	2
3	3,490	3,500	3,510	3,520	3,530	3,530	3,540	3,550	3,560	3,560	3,570	3,580	3,590	3,600	3,600	3,610	3,620	3,630	3,630	3,640	3,650	3
4	4,900	4,910	4,920	4,930	4,950	4,960	4,970	4,980	4,990	5,000	5,010	5,020	5,030	5,040	5,060	5,070	5,080	5,090	5,100	5,110	5,120	4
5	5,140	5,150	5,160	5,180	5,190	5,200	5,210	5,220	5,230	5,250	5,260	5,270	5,280	5,290	5,300	5,310	5,320	5,340	5,350	5,360	5,370	5
6	6,650	6,670	6,680	6,700	6,710	6,730	6,740	6,760	6,770	6,790	6,800	6,820	6,830	6,850	6,860	6,880	6,890	6,910	6,920	6,930	6,950	6
7	7,700	7,710	7,730	7,750	7,770	7,780	7,800	7,820	7,830	7,850	7,870	7,890	7,900	7,920	7,940	7,950	7,970	7,990	8,000	8,020	8,040	7
8	9,100	9,120	9,150	9,170	9,190	9,210	9,230	9,250	9,270	9,290	9,310	9,330	9,350	9,370	9,390	9,410	9,430	9,450	9,470	9,490	9,510	8
9	10,150	10,170	10,190	10,220	10,240	10,260	10,280	10,310	10,330	10,350	10,370	10,400	10,420	10,440	10,460	10,490	10,510	10,530	10,550	10,570	10,600	9
10	11,550	11,580	11,610	11,630	11,660	11,690	11,710	11,740	11,760	11,790	11,810	11,840	11,870	11,890	11,920	11,940	11,970	11,990	12,020	12,040	12,070	10
11	11,790	11,820	11,850	11,870	11,900	11,930	11,950	11,980	12,010	12,030	12,060	12,090	12,110	12,140	12,160	12,190	12,220	12,240	12,270	12,290	12,320	11
12	13,310	13,340	13,370	13,400	13,430	13,460	13,490	13,520	13,550	13,580	13,610	13,630	13,660	13,690	13,720	13,750	13,780	13,810	13,840	13,870	13,900	12
13	14,230	14,260	14,300	14,330	14,360	14,390	14,420	14,450	14,490	14,520	14,550	14,580	14,610	14,640	14,670	14,710	14,740	14,770	14,800	14,830	14,860	13
14	15,740	15,770	15,810	15,840	15,880	15,910	15,950	15,990	16,020	16,060	16,090	16,120	16,160	16,190	16,230	16,260	16,300	16,330	16,370	16,400	16,440	14
15	16,000	16,030	16,070	16,100	16,140	16,180	16,210	16,250	16,280	16,320	16,350	16,390	16,420	16,460	16,500	16,530	16,570	16,600	16,640	16,670	16,700	15
16	17,520	17,560	17,600	17,640	17,680	17,720	17,760	17,800	17,830	17,870	17,910	17,950	17,990	18,030	18,070	18,110	18,140	18,180	18,220	18,260	18,300	16
17	17,780	17,820	17,860	17,900	17,940	17,980	18,020	18,060	18,100	18,140	18,180	18,220	18,260	18,300	18,340	18,380	18,420	18,460	18,490	18,530	18,570	17
18	19,310	19,350	19,400	19,440	19,480	19,530	19,570	19,610	19,660	19,700	19,740	19,780	19,830	19,870	19,910	19,950	20,000	20,040	20,080	20,120	20,160	18
19	20,380	20,420	20,470	20,510	20,560	20,600	20,650	20,700	20,740	20,790	20,830	20,880	20,920	20,970	21,010	21,050	21,100	21,140	21,190	21,230	21,280	19
20	21,800	21,850	21,900	21,950	22,000	22,050	22,100	22,140	22,190	22,240	22,290	22,340	22,390	22,430	22,480	22,530	22,580	22,620	22,670	22,720	22,770	20
21	22,380	22,430	22,480	22,530	22,580	22,630	22,680	22,730	22,780	22,830	22,880	22,930	22,980	23,030	23,080	23,130	23,170	23,220	23,270	23,320	23,370	21
22	23,850	23,910	23,960	24,010	24,070	24,120	24,180	24,230	24,280	24,330	24,390	24,440	24,490	24,550	24,600	24,650	24,700	24,750	24,810	24,860	24,910	22
23	24,930	24,980	25,040	25,090	25,150	25,210	25,260	25,320	25,370	25,430	25,480	25,540	25,590	25,650	25,700	25,760	25,810	25,870	25,920	25,970	26,030	23
24	26,350	26,410	26,470	26,530	26,590	26,650	26,710	26,770	26,820	26,880	26,940	27,000	27,060	27,120	27,170	27,230	27,290	27,350	27,400	27,460	27,520	24
25	27,410	27,470	27,530	27,590	27,660	27,720	27,780	27,840	27,900	27,960	28,020	28,080	28,140	28,200	28,260	28,320	28,380	28,440	28,500	28,560	28,620	25
26	28,830	28,890	28,960	29,020	29,090	29,150	29,210	29,280	29,340	29,410	29,470	29,530	29,600	29,660	29,730	29,790	29,850	29,910	29,980	30,040	30,100	26
27	29,080	29,140	29,210	29,270	29,340	29,400	29,470	29,530	29,600	29,660	29,730	29,790	29,860	29,920	29,980	30,050	30,110	30,180	30,240	30,300	30,370	27
28	30,600	30,660	30,730	30,800	30,870	30,940	31,010	31,080	31,140	31,210	31,280	31,350	31,420	31,480	31,550	31,620	31,680	31,750	31,820	31,880	31,950	28
29	32,020	32,090	32,160	32,240	32,310	32,380	32,450	32,520	32,600	32,670	32,740	32,810	32,880	32,950	33,020	33,090	33,160	33,230	33,300	33,370	33,440	29
30	33,510	33,590	33,660	33,740	33,810	33,890	33,970	34,040	34,120	34,190	34,270	34,340	34,420	34,490	34,560	34,640	34,710	34,790	34,860	34,930	35,010	30
31	35,000	35,080	35,160	35,240	35,320	35,400	35,480	35,560	35,640	35,720	35,790	35,870	35,950	36,030	36,110	36,180	36,260	36,340	36,420	36,490	36,570	31
32	36,440	36,520	36,600	36,690	36,770	36,850	36,930	37,020	37,100	37,180	37,260	37,350	37,430	37,510	37,590	37,670	37,750	37,830	37,910	37,990	38,070	32
33	37,930	38,010	38,100	38,190	38,270	38,360	38,450	38,530	38,620	38,710	38,790	38,880	38,960	39,050	39,130	39,220	39,300	39,390	39,470	39,550	39,640	33
34	39,420	39,510	39,600	39,690	39,780	39,870	39,960	40,050	40,140	40,230	40,320	40,410	40,500	40,590	40,670	40,760	40,850	40,940	41,030	41,110	41,200	34
35	40,850	40,950	41,040	41,130	41,230	41,320	41,420	41,510	41,600	41,700	41,790	41,880	41,970	42,070	42,160	42,250	42,340	42,430	42,520	42,610	42,710	35
36	41,920	42,020	42,120	42,220	42,310	42,410	42,510	42,600	42,700	42,790	42,890	42,980	43,080	43,170	43,270	43,360	43,460	43,550	43,640	43,740	43,830	36
37	43,360	43,460	43,560	43,660	43,760	43,860	43,960	44,060	44,160	44,260	44,360	44,460	44,560	44,650	44,750	44,850	44,950	45,040	45,140	45,240	45,340	37
38	44,800	44,900	45,000	45,110	45,210	45,320	45,420	45,520	45,620	45,730	45,830	45,930	46,030	46,130	46,240	46,340	46,440	46,540	46,640	46,740	46,840	38
39	46,290	46,390	46,500	46,610	46,720	46,820	46,930	47,040	47,140	47,250	47,360	47,460	47,570	47,670	47,780	47,880	47,990	48,090	48,200	48,300	48,400	39
40	47,730	47,840	47,950	48,060	48,170	48,280	48,400	48,510	48,620	48,730	48,830	48,940	49,050	49,160	49,270	49,380	49,490	49,590	49,700	49,810	49,920	40
41	49,220	49,330	49,450	49,560	49,680	49,790	49,910	50,020	50,140	50,250	50,360	50,480	50,590	50,700	50,810	50,920	51,040	51,150	51,260	51,370	51,480	41
42	50,710	50,830	50,950	51,070	51,190	51,300	51,420	51,540	51,660	51,770	51,890	52,010	52,120	52,240	52,350	52,470	52,590	52,700	52,810	52,930	53,040	42
43	51,410	51,530	51,660	51,780	51,900	52,020	52,140	52,250	52,370	52,490	52,610	52,730	52,850	52,970	53,080	53,200	53,320	53,430	53,550	53,670	53,780	43
44	52,190	52,310	52,430	52,560	52,680	52,800	52,920	53,040	53,170	53,290	53,410	53,530	53,650	53,770	53,890	54,010	54,130	54,240	54,360	54,480	54,600	44
45	52,960	53,090	53,210	53,340	53,460	53,590	53,710	53,830	53,960	54,080	54,200	54,330	54,450	54,570	54,690	54,810	54,930	55,050	55,170	55,290	55,410	45
46	53,680	53,800	53,930	54,060	54,180	54,310	54,430	54,560	54,680	54,810	54,930	55,060	55,180	55,300	55,430	55,550	55,670	55,800	55,920	56,040	56,160	46
47	54,450	54,580	54,710	54,840	54,970	55,090	55,220	55,350	55,480	55,600	55,730	55,860	55,980	56,110	56,230	56,360	56,480	56,610	56,730	56,850	56,980	47
48	55,230	55,360	55,490	55,620	55,750	55,880	56,010	56,140	56,270	56,400	56,530	56,650	56,780	56,910	57,040	57,160	57,290	57,420	57,540	57,670	57,790	48
49	55,940	56,070	56,200	56,340	56,470	56,600	56,730	56,860	56,990	57,120	57,260	57,390	57,510	57,640	57,770	57,900	58,030	58,160	58,290	58,410	58,540	49
50	57,010	57,150	57,280	57,420	57,550	57,690	57,820	57,960	58,090	58,220	58,360	58,490	58,620	58,750	58,880	59,020	59,150	59,280	59,410	59,540	59,670	50
51	57,720	57,860	58,000	58,140	58,270	58,410	58,540	58,680	58,820	58,950	59,090	59,220	59,350	59,490	59,620	59,750	59,890	60,020	60,150	60,290	60,420	51
52	58,440	58,570	58,710	58,850	58,990	59,130	59,270	59,400	59,540	59,680	59,820	59,950	60,090	60,220	60,360	60,490	60,630	60,760	60,900	61,030	61,160	52
53	59,210	59,350	59,490	59,630	59,770	59,920	60,060	60,190	60,330	60,470	60,610	60,750	60,890	61,030	61,160	61,300	61,440	61,570	61,710	61,840	61,980	53
54	59,960	60,100	60,240	60,390	60,530	60,670	60,810	60,950	61,100	61,240	61,380	61,520	61,660	61,800	61,940	62,070	62,210	62,350	62,490	62,630	62,760	54
55	60,730	60,880	61,020	61,170	61,310	61,460	61,600	61,740	61,890	62,030	62,170	62,310	62,460	62,600	62,740	62,880	63,020	63,160	63,300	63,440	63,580	55
56	61,510	61,660	61,800	61,950	62,100	62,240	62,390	62,530	62,680	62,820	62,970	63,110	63,260	63,400	63,540	63,690	63,830	63,970	64,110	64,250	64,400	56
57	63,780	63,940	64,090	64,250	64,400	64,550	64,700	64,850	65,010	65,160	65,310	65,460	65,610	65,760	65,910	66,060	66,200	66,350	66,500	66,650	66,800	57
58	65,990	66,150	66,310	66,470	66,620	66,780	66,940	67,100	67,260	67,420	67,570	67,730	67,890	68,040	68,200	68,350	68,510	68,660	68,820	68,970	69,120	58
59	68,190	68,350	68,520	68,690	68,850	69,020	69,180	69,350	69,510	69,670	69,840	70,000	70,160	70,320	70,490	70,650	70,810	70,970	71,130	71,290	71,450	59
60	70,500	70,670	70,850	71,020	71,190	71,360	71,530	71,700	71,870	72,040	72,210	72,380	72,550	72,720	72,890	73,060	73,220	73,390	73,560	73,720	73,890	60

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	806.0	806.1	806.2	806.3	806.4	806.5	806.6	806.7	806.8	806.9	807.0	807.1	807.2	807.3	807.4	807.5	807.6	807.7	807.8	807.9	808.0	
61	72,700	72,880	73,060	73,240	73,420	73,590	73,770	73,950	74,130	74,300	74,480	74,650	74,830	75,000	75,180	75,350	75,520	75,700	75,870	76,040	76,210	61
62	74,900	75,090	75,270	75,460	75,640	75,830	76,010	76,200	76,380	76,560	76,740	76,920	77,110	77,290	77,470	77,650	77,830	78,000	78,180	78,360	78,540	62
63	77,220	77,410	77,600	77,790	77,980	78,170	78,360	78,550	78,740	78,930	79,120	79,310	79,490	79,680	79,870	80,050	80,240	80,420	80,610	80,790	80,980	63
64	79,400	79,590	79,790	79,990	80,190	80,380	80,580	80,780	80,970	81,170	81,360	81,560	81,750	81,940	82,130	82,330	82,520	82,710	82,900	83,090	83,280	64
65	81,710	81,910	82,120	82,320	82,530	82,730	82,930	83,130	83,340	83,540	83,740	83,940	84,140	84,340	84,540	84,730	84,930	85,130	85,330	85,520	85,720	65
66	84,020	84,230	84,440	84,660	84,870	85,070	85,280	85,490	85,700	85,910	86,110	86,320	86,530	86,730	86,940	87,140	87,350	87,550	87,750	87,960	88,160	66
67	86,220	86,440	86,660	86,880	87,090	87,310	87,520	87,740	87,950	88,170	88,380	88,590	88,800	89,020	89,230	89,440	89,650	89,860	90,070	90,280	90,480	67
68	88,440	88,660	88,890	89,110	89,330	89,560	89,780	90,000	90,220	90,440	90,660	90,880	91,090	91,310	91,530	91,750	91,960	92,180	92,390	92,610	92,820	68
69	90,640	90,870	91,100	91,330	91,560	91,790	92,020	92,240	92,470	92,700	92,920	93,150	93,370	93,600	93,820	94,040	94,260	94,490	94,710	94,930	95,150	69
70	92,840	93,080	93,320	93,550	93,790	94,020	94,260	94,490	94,720	94,950	95,190	95,420	95,650	95,880	96,110	96,340	96,570	96,790	97,020	97,250	97,480	70
71	95,510	95,750	96,000	96,240	96,490	96,730	96,970	97,220	97,460	97,700	97,940	98,180	98,420	98,660	98,900	99,130	99,370	99,610	99,840	100,100	100,300	71
72	98,220	98,470	98,730	98,980	99,240	99,490	99,740	99,990	100,200	100,500	100,700	101,000	101,200	101,500	101,700	102,000	102,200	102,500	102,700	103,000	103,200	72
73	100,900	101,200	101,500	101,700	102,000	102,200	102,500	102,800	103,000	103,300	103,500	103,800	104,100	104,300	104,600	104,800	105,100	105,300	105,600	105,800	106,100	73
74	103,700	103,900	104,200	104,500	104,800	105,000	105,300	105,600	105,800	106,100	106,400	106,600	106,900	107,200	107,400	107,700	108,000	108,200	108,500	108,700	109,000	74
75	106,400	106,700	106,900	107,200	107,500	107,800	108,100	108,300	108,600	108,900	109,200	109,500	109,700	110,000	110,300	110,500	110,800	111,100	111,400	111,600	111,900	75
76	109,100	109,400	109,700	110,000	110,300	110,500	110,800	111,100	111,400	111,700	112,000	112,300	112,500	112,800	113,100	113,400	113,700	114,000	114,200	114,500	114,800	76
77	111,800	112,100	112,400	112,700	113,000	113,300	113,600	113,900	114,200	114,500	114,800	115,100	115,400	115,700	116,000	116,300	116,500	116,800	117,100	117,400	117,700	77
78	114,400	114,800	115,100	115,400	115,700	116,000	116,300	116,600	116,900	117,200	117,500	117,800	118,100	118,400	118,700	119,000	119,300	119,600	119,900	120,200	120,500	78
79	117,200	117,500	117,800	118,200	118,500	118,800	119,100	119,400	119,700	120,000	120,400	120,700	121,000	121,300	121,600	121,900	122,200	122,500	122,800	123,100	123,400	79
80	119,900	120,200	120,600	120,900	121,200	121,600	121,900	122,200	122,500	122,900	123,200	123,500	123,800	124,100	124,400	124,800	125,100	125,400	125,700	126,000	126,300	80
81	122,600	123,000	123,300	123,700	124,000	124,300	124,700	125,000	125,300	125,600	126,000	126,300	126,600	127,000	127,300	127,600	127,900	128,300	128,600	128,900	129,200	81
82	125,400	125,700	126,100	126,400	126,800	127,100	127,400	127,800	128,100	128,500	128,800	129,100	129,500	129,800	130,100	130,500	130,800	131,100	131,500	131,800	132,100	82
83	128,100	128,400	128,800	129,200	129,500	129,900	130,200	130,600	130,900	131,300	131,600	131,900	132,300	132,600	133,000	133,300	133,700	134,000	134,300	134,700	135,000	83
84	130,800	131,100	131,500	131,900	132,300	132,600	133,000	133,300	133,700	134,100	134,400	134,800	135,100	135,500	135,800	136,200	136,500	136,900	137,200	137,600	137,900	84
85	135,600	136,000	136,400	136,800	137,200	137,600	137,900	138,300	138,700	139,100	139,500	139,800	140,200	140,600	141,000	141,300	141,700	142,100	142,500	142,800	143,200	85
86	140,500	141,000	141,400	141,800	142,200	142,600	143,000	143,400	143,800	144,200	144,600	145,000	145,400	145,800	146,200	146,600	147,000	147,400	147,800	148,200	148,600	86
87	145,400	145,800	146,300	146,700	147,100	147,500	148,000	148,400	148,800	149,300	149,700	150,100	150,500	150,900	151,400	151,800	152,200	152,600	153,000	153,400	153,900	87
88	150,200	150,700	151,200	151,600	152,100	152,500	153,000	153,400	153,900	154,300	154,800	155,200	155,600	156,100	156,500	157,000	157,400	157,800	158,300	158,700	159,200	88
89	155,200	155,700	156,200	156,700	157,200	157,600	158,100	158,600	159,100	159,500	160,000	160,500	160,900	161,400	161,800	162,300	162,800	163,200	163,700	164,100	164,600	89
90	160,100	160,600	161,100	161,600	162,100	162,600	163,100	163,600	164,100	164,600	165,100	165,600	166,100	166,500	167,000	167,500	168,000	168,500	169,000	169,400	169,900	90
91	165,000	165,500	166,000	166,500	167,100	167,600	168,100	168,600	169,100	169,600	170,200	170,700	171,200	171,700	172,200	172,700	173,200	173,700	174,200	174,700	175,200	91
92	169,900	170,400	170,900	171,400	171,900	172,400	172,900	173,400	174,000	174,500	175,000	175,500	176,000	176,500	177,000	177,500	178,000	178,500	179,000	179,500	180,000	92
93	174,900	175,300	175,800	176,300	176,800	177,400	177,900	178,400	178,900	179,400	179,900	180,500	181,000	181,500	182,000	182,500	183,000	183,500	184,000	184,500	185,000	93
94	180,000	180,500	180,900	181,300	181,800	182,400	182,900	183,400	183,900	184,500	185,000	185,500	186,000	186,500	187,000	187,500	188,000	188,500	189,000	189,500	190,000	94
95	184,900	185,300	185,700	186,100	186,700	187,200	187,700	188,300	188,800	189,300	189,800	190,300	190,800	191,300	191,900	192,400	192,900	193,400	193,900	194,400	194,900	95
96	189,800	190,200	190,600	191,000	191,600	192,100	192,600	193,100	193,700	194,200	194,700	195,200	195,700	196,200	196,700	197,200	197,700	198,200	198,700	199,200	199,700	96
97	194,800	195,200	195,500	196,000	196,500	197,000	197,600	198,100	198,600	199,100	199,700	200,200	200,700	201,200	201,700	202,200	202,700	203,200	203,700	204,200	204,700	97
98	199,900	200,300	200,600	201,000	201,500	202,000	202,600	203,100	203,600	204,200	204,700	205,200	205,700	206,200	206,700	207,200	207,700	208,200	208,700	209,200	209,700	98
99	204,000	204,500	205,000	205,600	206,300	207,000	207,600	208,300	209,000	209,700	210,400	211,000	211,700	212,400	213,000	213,500	214,100	214,600	215,200	215,700	216,200	99
100	208,200	208,900	209,600	210,300	211,200	212,000	212,900	213,700	214,500	215,400	216,200	217,000	217,900	218,700	219,400	220,000	220,600	221,200	221,800	222,400	222,900	100
101	211,700	212,600	213,500	214,400	215,400	216,400	217,400	218,400	219,400	220,300	221,300	222,300	223,300	224,300	225,200	225,900	226,700	227,400	228,200	229,000	229,700	101
102	215,900	217,000	218,000	219,100	220,300	221,400	222,500	223,700	224,800	226,000	227,100	228,300	229,400	230,600	231,500	232,300	233,100	233,900	234,700	235,500	236,300	102
103	220,900	222,100	223,300	224,500	225,800	227,100	228,400	229,800	231,100	232,400	233,700	235,000	236,300	237,700	238,600	239,300	240,000	240,800	241,500	242,200	243,000	103
104	224,900	226,300	227,700	229,100	230,600	232,000	233,500	235,000	236,400	237,900	239,400	240,800	242,300	243,800	244,900	245,800	246,600	247,400	248,100	248,900	249,700	104
105	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	250,700	251,700	252,700	253,600	254,600	255,500	256,500	105
106	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	250,800	251,900	253,000	254,100	255,100	256,200	257,200	106
107	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	250,800	252,100	253,300	254,500	255,700	256,900	258,100	107
108	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	250,800	252,100	253,300	254,500	255,700	256,900	258,100	108
109	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	250,900	252,300	253,700	255,000	256,200	257,600	258,900	109
110	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,300	255,800	257,400	258,900	260,500	110
111	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	111
112	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	112
113	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	113
114	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	114
115	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	115
116	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	116
117	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	117
118	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	118
119	228,400	230,000	231,600	233,200	234,800	236,400	238,000	239,600	241,200	242,900	244,500	246,100	247,800	249,400	251,100	252,700	254,400	256,100	257,700	259,400	261,100	119

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	808.0	808.1	808.2	808.3	808.4	808.5	808.6	808.7	808.8	808.9	809.0	809.1	809.2	809.3	809.4	809.5	809.6	809.7	809.8	809.9	810.0	
1	1,090	1,090	1,090	1,100	1,100	1,100	1,100	1,100	1,110	1,110	1,110	1,110	1,110	1,120	1,120	1,120	1,120	1,130	1,130	1,130	1,130	1
2	2,560	2,570	2,570	2,580	2,580	2,590	2,590	2,600	2,600	2,610	2,610	2,620	2,620	2,630	2,630	2,640	2,640	2,650	2,650	2,660	2,660	2
3	3,650	3,660	3,660	3,670	3,680	3,690	3,690	3,700	3,710	3,720	3,720	3,730	3,740	3,750	3,750	3,760	3,770	3,770	3,780	3,790	3,800	3
4	5,120	5,130	5,140	5,150	5,160	5,170	5,180	5,190	5,200	5,220	5,230	5,240	5,250	5,260	5,270	5,280	5,290	5,300	5,310	5,320	5,330	4
5	5,370	5,380	5,390	5,400	5,410	5,430	5,440	5,450	5,460	5,470	5,480	5,490	5,500	5,510	5,520	5,540	5,550	5,560	5,570	5,580	5,590	5
6	6,950	6,960	6,980	6,990	7,010	7,020	7,030	7,050	7,060	7,080	7,090	7,110	7,120	7,130	7,150	7,160	7,180	7,190	7,200	7,220	7,230	6
7	8,040	8,050	8,070	8,090	8,100	8,120	8,140	8,150	8,170	8,190	8,200	8,220	8,230	8,250	8,270	8,280	8,300	8,320	8,330	8,350	8,360	7
8	9,510	9,530	9,550	9,570	9,590	9,610	9,630	9,650	9,670	9,680	9,700	9,720	9,740	9,760	9,780	9,800	9,820	9,840	9,860	9,880	9,900	8
9	10,600	10,620	10,640	10,660	10,680	10,710	10,730	10,750	10,770	10,790	10,810	10,840	10,860	10,880	10,900	10,920	10,940	10,960	10,990	11,010	11,030	9
10	12,070	12,090	12,120	12,140	12,170	12,190	12,220	12,240	12,270	12,290	12,320	12,340	12,370	12,390	12,420	12,440	12,460	12,490	12,510	12,540	12,560	10
11	12,320	12,340	12,370	12,390	12,420	12,450	12,470	12,500	12,520	12,550	12,570	12,600	12,620	12,650	12,670	12,700	12,720	12,750	12,770	12,800	12,820	11
12	13,900	13,930	13,950	13,980	14,010	14,040	14,070	14,100	14,130	14,150	14,180	14,210	14,240	14,270	14,300	14,320	14,350	14,380	14,410	14,440	14,460	12
13	14,860	14,890	14,920	14,950	14,980	15,010	15,040	15,080	15,110	15,140	15,170	15,200	15,230	15,260	15,290	15,320	15,350	15,380	15,410	15,440	15,470	13
14	16,440	16,470	16,500	16,540	16,570	16,610	16,640	16,670	16,710	16,740	16,770	16,810	16,840	16,870	16,910	16,940	16,970	17,010	17,040	17,070	17,110	14
15	16,700	16,740	16,770	16,810	16,840	16,880	16,910	16,950	16,980	17,010	17,050	17,080	17,120	17,150	17,180	17,220	17,250	17,280	17,320	17,350	17,390	15
16	18,300	18,330	18,370	18,410	18,450	18,490	18,520	18,560	18,600	18,640	18,670	18,710	18,750	18,780	18,820	18,860	18,890	18,930	18,970	19,010	19,040	16
17	18,570	18,610	18,650	18,690	18,730	18,760	18,800	18,840	18,880	18,920	18,950	18,990	19,030	19,070	19,100	19,140	19,180	19,220	19,250	19,290	19,330	17
18	20,160	20,210	20,250	20,290	20,330	20,370	20,410	20,450	20,500	20,540	20,580	20,620	20,660	20,700	20,740	20,780	20,820	20,860	20,900	20,940	20,980	18
19	21,280	21,320	21,360	21,410	21,450	21,500	21,540	21,580	21,630	21,670	21,710	21,760	21,800	21,840	21,880	21,930	21,970	22,010	22,060	22,100	22,140	19
20	22,770	22,810	22,860	22,910	22,960	23,000	23,050	23,100	23,140	23,190	23,230	23,280	23,330	23,370	23,420	23,470	23,510	23,560	23,600	23,650	23,690	20
21	23,370	23,420	23,470	23,510	23,560	23,610	23,660	23,710	23,750	23,800	23,850	23,900	23,940	23,990	24,040	24,080	24,130	24,180	24,230	24,270	24,320	21
22	24,910	24,960	25,010	25,060	25,120	25,170	25,220	25,270	25,320	25,370	25,420	25,470	25,520	25,570	25,620	25,670	25,720	25,770	25,820	25,870	25,920	22
23	26,030	26,080	26,140	26,190	26,240	26,300	26,350	26,400	26,460	26,510	26,560	26,610	26,670	26,720	26,770	26,830	26,880	26,930	26,980	27,030	27,090	23
24	27,520	27,580	27,630	27,690	27,750	27,800	27,860	27,920	27,970	28,030	28,080	28,140	28,200	28,250	28,310	28,360	28,420	28,470	28,530	28,580	28,640	24
25	28,620	28,680	28,740	28,800	28,860	28,920	28,980	29,030	29,090	29,150	29,210	29,270	29,330	29,380	29,440	29,500	29,560	29,610	29,670	29,730	29,790	25
26	30,100	30,170	30,230	30,290	30,350	30,410	30,480	30,540	30,600	30,660	30,720	30,780	30,840	30,910	30,970	31,030	31,090	31,150	31,210	31,270	31,330	26
27	30,370	30,430	30,490	30,550	30,620	30,680	30,740	30,800	30,870	30,930	30,990	31,050	31,110	31,170	31,240	31,300	31,360	31,420	31,480	31,540	31,600	27
28	31,950	32,020	32,080	32,150	32,220	32,280	32,350	32,410	32,480	32,540	32,610	32,670	32,740	32,800	32,870	32,930	33,000	33,060	33,120	33,190	33,250	28
29	33,440	33,510	33,580	33,650	33,720	33,790	33,860	33,930	33,990	34,060	34,130	34,200	34,270	34,340	34,400	34,470	34,540	34,610	34,670	34,740	34,810	29
30	35,010	35,080	35,150	35,230	35,300	35,370	35,440	35,520	35,590	35,660	35,730	35,800	35,870	35,950	36,020	36,090	36,160	36,230	36,300	36,370	36,440	30
31	36,570	36,650	36,720	36,800	36,880	36,950	37,030	37,100	37,180	37,260	37,330	37,410	37,480	37,560	37,630	37,710	37,780	37,850	37,930	38,000	38,080	31
32	38,070	38,150	38,230	38,310	38,390	38,470	38,550	38,630	38,710	38,790	38,870	38,950	39,020	39,100	39,180	39,260	39,340	39,410	39,490	39,570	39,640	32
33	39,640	39,720	39,810	39,890	39,970	40,050	40,140	40,220	40,300	40,380	40,470	40,550	40,630	40,710	40,790	40,880	40,960	41,040	41,120	41,200	41,280	33
34	41,200	41,290	41,380	41,460	41,550	41,640	41,720	41,810	41,900	41,980	42,070	42,150	42,240	42,320	42,410	42,490	42,580	42,660	42,750	42,830	42,910	34
35	42,710	42,800	42,890	42,980	43,070	43,160	43,250	43,340	43,430	43,510	43,600	43,690	43,780	43,870	43,960	44,040	44,130	44,220	44,310	44,400	44,480	35
36	43,830	43,920	44,020	44,110	44,200	44,300	44,390	44,480	44,570	44,660	44,750	44,850	44,940	45,030	45,120	45,210	45,300	45,390	45,480	45,570	45,660	36
37	45,340	45,430	45,530	45,620	45,720	45,820	45,910	46,010	46,100	46,200	46,290	46,390	46,480	46,570	46,670	46,760	46,860	46,950	47,040	47,130	47,230	37
38	46,840	46,940	47,040	47,140	47,240	47,340	47,430	47,530	47,630	47,730	47,830	47,930	48,020	48,120	48,220	48,310	48,410	48,510	48,600	48,700	48,800	38
39	48,400	48,510	48,610	48,710	48,820	48,920	49,020	49,120	49,220	49,330	49,430	49,530	49,630	49,730	49,830	49,930	50,030	50,130	50,230	50,330	50,430	39
40	49,920	50,020	50,130	50,240	50,340	50,450	50,550	50,660	50,760	50,870	50,970	51,080	51,180	51,290	51,390	51,490	51,600	51,700	51,800	51,910	52,010	40
41	51,480	51,590	51,700	51,810	51,920	52,030	52,140	52,250	52,360	52,470	52,570	52,680	52,790	52,900	53,000	53,110	53,220	53,330	53,430	53,540	53,640	41
42	53,040	53,160	53,270	53,390	53,500	53,610	53,720	53,840	53,950	54,060	54,170	54,280	54,400	54,510	54,620	54,730	54,840	54,950	55,060	55,170	55,280	42
43	53,780	53,900	54,010	54,130	54,240	54,360	54,470	54,590	54,700	54,820	54,930	55,040	55,160	55,270	55,380	55,490	55,610	55,720	55,830	55,940	56,050	43
44	54,600	54,720	54,830	54,950	55,070	55,180	55,300	55,420	55,530	55,650	55,760	55,880	55,990	56,110	56,220	56,340	56,450	56,570	56,680	56,790	56,910	44
45	55,410	55,530	55,650	55,770	55,890	56,010	56,130	56,250	56,360	56,480	56,600	56,720	56,830	56,950	57,070	57,180	57,300	57,410	57,530	57,650	57,760	45
46	56,160	56,280	56,400	56,530	56,650	56,770	56,890	57,010	57,130	57,250	57,360	57,480	57,600	57,720	57,840	57,960	58,070	58,190	58,310	58,430	58,540	46
47	56,980	57,100	57,220	57,350	57,470	57,590	57,710	57,840	57,960	58,080	58,200	58,320	58,440	58,560	58,680	58,800	58,920	59,040	59,160	59,280	59,400	47
48	57,790	57,920	58,040	58,170	58,290	58,420	58,540	58,670	58,790	58,910	59,040	59,160	59,280	59,400	59,520	59,650	59,770	59,890	60,010	60,130	60,250	48
49	58,540	58,670	58,800	58,920	59,050	59,170	59,300	59,430	59,550	59,680	59,800	59,920	60,050	60,170	60,300	60,420	60,540	60,670	60,790	60,910	61,030	49
50	59,670	59,800	59,930	60,060	60,190	60,320	60,440	60,570	60,700	60,830	60,950	61,080	61,210	61,330	61,460	61,590	61,710	61,840	61,960	62,090	62,210	50
51	60,420	60,550	60,680	60,810	60,940	61,070	61,200	61,330	61,460	61,590	61,720	61,850	61,980	62,110	62,230	62,360	62,490	62,620	62,740	62,870	63,000	51
52	61,160	61,300	61,430	61,560	61,700	61,830	61,960	62,090	62,220	62,350	62,480	62,610	62,750	62,880	63,000	63,130	63,260	63,390	63,520	63,650	63,780	52
53	61,980	62,120	62,250	62,390	62,520	62,650	62,790	62,920	63,050	63,190	63,320	63,450	63,580	63,720	63,850	63,980	64,110	64,240	64,370	64,500	64,630	53
54	62,760	62,900	63,040	63,170	63,310	63,450	63,580	63,720	63,850	63,990	64,120	64,260	64,390	64,520	64,660	64,790	64,920	65,060	65,190	65,320	65,450	54
55	63,580	63,720	63,860	64,000	64,130	64,270	64,410	64,550	64,680	64,820	64,960	65,090	65,230	65,360	65,500	65,640	65,770	65,900	66,040	66,170	66,310	55
56	64,400	64,540	64,680	64,820	64,960	65,100	65,240	65,380	65,520	65,650	65,790	65,930	66,070	66,210	66,340	66,480	66,620	66,750	66,890	67,020	67,160	56
57	66,800	66,940	67,090	67,240	67,380	67,530	67,670	67,820	67,960	68,110	68,250	68,400	68,540	68,680	68,830	68,970	69,110	69,250	69,400	69,540	69,680	57
58	69,120	69,280	69,430	69,580	69,730	69,880	70,040	70,190	70,340	70,490	70,640	70,790	70,940	71,090	71,240	71,380	71,530	71,680	71,830	71,980	72,120	58
59	71,450	71,610	71,770	71,930	72,080	72,240	72,400	72,560	72,710	72,870	73,020	73,180	73,340	73,490	73,650	73,800	73,950	74,110	74,260	74,410	74,570	59
60	73,890	74,050	74,220	74,380	74,550	74,710	74,870	75,040	75,200	75,360	75,520	75,690	75,850	76,010	76,170	76,330	76,490	76,650	76,810	76,970	77,130	60

FORT LOUDOUN DAM

SPILLWAY DISCHARGE

IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	808.0	808.1	808.2	808.3	808.4	808.5	808.6	808.7	808.8	808.9	809.0	809.1	809.2	809.3	809.4	809.5	809.6	809.7	809.8	809.9	810.0	
61	76,210	76,380	76,560	76,730	76,900	77,070	77,240	77,400	77,570	77,740	77,910	78,080	78,240	78,410	78,580	78,740	78,910	79,080	79,240	79,410	79,570	61
62	78,540	78,720	78,890	79,070	79,250	79,420	79,600	79,770	79,950	80,120	80,300	80,470	80,640	80,820	80,990	81,160	81,330	81,500	81,670	81,840	82,020	62
63	80,980	81,160	81,340	81,530	81,710	81,890	82,070	82,250	82,430	82,610	82,790	82,970	83,150	83,330	83,510	83,690	83,870	84,040	84,220	84,400	84,570	63
64	83,280	83,470	83,660	83,850	84,040	84,220	84,410	84,600	84,790	84,970	85,160	85,340	85,530	85,710	85,900	86,080	86,260	86,450	86,630	86,810	86,990	64
65	85,720	85,920	86,110	86,310	86,500	86,690	86,890	87,080	87,270	87,460	87,660	87,850	88,040	88,230	88,420	88,610	88,800	88,990	89,180	89,360	89,550	65
66	88,160	88,360	88,560	88,760	88,960	89,160	89,360	89,560	89,760	89,960	90,150	90,350	90,550	90,750	90,940	91,140	91,330	91,530	91,720	91,920	92,110	66
67	90,480	90,690	90,900	91,110	91,310	91,520	91,720	91,930	92,130	92,340	92,540	92,740	92,950	93,150	93,350	93,550	93,750	93,950	94,150	94,350	94,550	67
68	92,820	93,040	93,250	93,460	93,670	93,890	94,100	94,310	94,520	94,730	94,940	95,150	95,360	95,560	95,770	95,980	96,190	96,390	96,600	96,800	97,010	68
69	95,150	95,370	95,590	95,810	96,030	96,240	96,460	96,680	96,890	97,110	97,320	97,540	97,750	97,970	98,180	98,390	98,610	98,820	99,030	99,240	99,450	69
70	97,480	97,700	97,930	98,150	98,380	98,600	98,820	99,050	99,270	99,490	99,710	99,930	100,200	100,400	100,600	100,800	101,000	101,200	101,500	101,700	101,900	70
71	100,300	100,500	100,800	101,000	101,200	101,500	101,700	101,900	102,200	102,400	102,600	102,900	103,100	103,300	103,500	103,800	104,000	104,200	104,400	104,700	104,900	71
72	103,200	103,400	103,700	103,900	104,200	104,400	104,700	104,900	105,100	105,400	105,600	105,800	106,100	106,300	106,600	106,800	107,000	107,300	107,500	107,700	108,000	72
73	106,100	106,300	106,600	106,900	107,100	107,400	107,600	107,800	108,100	108,300	108,600	108,800	109,100	109,300	109,600	109,800	110,100	110,300	110,500	110,800	111,000	73
74	109,000	109,300	109,500	109,800	110,000	110,300	110,600	110,800	111,100	111,300	111,600	111,800	112,100	112,300	112,600	112,800	113,100	113,300	113,600	113,800	114,100	74
75	111,900	112,200	112,400	112,700	113,000	113,200	113,500	113,800	114,000	114,300	114,600	114,800	115,100	115,300	115,600	115,900	116,100	116,400	116,600	116,900	117,200	75
76	114,800	115,100	115,300	115,600	115,900	116,200	116,400	116,700	117,000	117,300	117,500	117,800	118,100	118,300	118,600	118,900	119,200	119,400	119,700	120,000	120,200	76
77	117,700	118,000	118,300	118,600	118,800	119,100	119,400	119,700	120,000	120,200	120,500	120,800	121,100	121,400	121,600	121,900	122,200	122,500	122,700	123,000	123,300	77
78	120,500	120,800	121,100	121,400	121,700	122,000	122,300	122,600	122,800	123,100	123,400	123,700	124,000	124,300	124,600	124,900	125,100	125,400	125,700	126,000	126,300	78
79	123,400	123,700	124,000	124,300	124,600	124,900	125,200	125,500	125,800	126,100	126,400	126,700	127,000	127,300	127,600	127,900	128,200	128,500	128,800	129,100	129,300	79
80	126,300	126,600	127,000	127,300	127,600	127,900	128,200	128,500	128,800	129,100	129,400	129,700	130,000	130,300	130,600	130,900	131,200	131,500	131,800	132,100	132,400	80
81	129,200	129,500	129,900	130,200	130,500	130,800	131,100	131,400	131,800	132,100	132,400	132,700	133,000	133,300	133,600	133,900	134,300	134,600	134,900	135,200	135,500	81
82	132,100	132,500	132,800	133,100	133,400	133,800	134,100	134,400	134,700	135,100	135,400	135,700	136,000	136,300	136,700	137,000	137,300	137,600	137,900	138,200	138,600	82
83	135,000	135,400	135,700	136,000	136,400	136,700	137,000	137,400	137,700	138,000	138,400	138,700	139,000	139,300	139,700	140,000	140,300	140,600	141,000	141,300	141,600	83
84	137,900	138,300	138,600	139,000	139,300	139,600	140,000	140,300	140,700	141,000	141,300	141,700	142,000	142,300	142,700	143,000	143,400	143,700	144,000	144,300	144,700	84
85	143,200	143,600	143,900	144,300	144,700	145,000	145,400	145,700	146,100	146,500	146,800	147,200	147,500	147,900	148,300	148,600	149,000	149,300	149,700	150,000	150,400	85
86	148,600	148,900	149,300	149,700	150,100	150,500	150,900	151,300	151,600	152,000	152,400	152,800	153,200	153,500	153,900	154,300	154,700	155,000	155,400	155,800	156,200	86
87	153,900	154,300	154,700	155,100	155,500	155,900	156,300	156,700	157,100	157,500	157,900	158,300	158,700	159,100	159,500	159,900	160,300	160,700	161,100	161,500	161,900	87
88	159,200	159,600	160,000	160,500	160,900	161,300	161,700	162,200	162,600	163,000	163,400	163,900	164,300	164,700	165,100	165,500	166,000	166,400	166,800	167,200	167,600	88
89	164,600	165,100	165,500	166,000	166,400	166,900	167,300	167,800	168,200	168,700	169,100	169,500	170,000	170,400	170,900	171,300	171,700	172,200	172,600	173,000	173,400	89
90	169,900	170,400	170,900	171,300	171,800	172,300	172,800	173,200	173,700	174,200	174,600	175,100	175,600	176,000	176,500	176,900	177,400	177,800	178,300	178,700	179,200	90
91	175,200	175,700	176,200	176,700	177,200	177,700	178,200	178,700	179,200	179,700	180,100	180,600	181,100	181,600	182,100	182,600	183,000	183,500	184,000	184,400	184,900	91
92	180,000	180,500	181,000	181,500	182,000	182,500	183,100	183,600	184,100	184,500	185,000	185,500	186,000	186,500	187,000	187,500	188,000	188,500	189,000	189,500	190,000	92
93	185,000	185,500	186,000	186,500	187,000	187,500	188,000	188,500	189,100	189,600	190,100	190,600	191,100	191,600	192,100	192,600	193,100	193,600	194,100	194,700	195,200	93
94	190,000	190,500	191,000	191,500	192,000	192,500	193,000	193,600	194,100	194,600	195,100	195,600	196,100	196,600	197,100	197,600	198,200	198,700	199,200	199,800	200,300	94
95	194,900	195,400	195,800	196,400	196,900	197,400	197,900	198,400	198,900	199,500	200,000	200,500	201,000	201,500	202,100	202,600	203,200	203,700	204,300	204,800	205,400	95
96	199,700	200,200	200,700	201,200	201,800	202,300	202,900	203,400	203,900	204,500	205,000	205,500	206,100	206,600	207,200	207,800	208,300	208,900	209,500	210,100	210,600	96
97	204,700	205,200	205,700	206,200	206,700	207,300	207,800	208,400	208,900	209,400	210,000	210,500	211,100	211,600	212,200	212,800	213,400	214,000	214,600	215,200	215,800	97
98	209,700	210,200	210,700	211,200	211,700	212,300	212,800	213,400	213,900	214,500	215,000	215,500	216,100	216,600	217,200	217,800	218,500	219,100	219,700	220,300	220,900	98
99	216,200	216,800	217,300	217,900	218,500	218,900	219,400	219,900	220,300	220,800	221,300	221,700	222,200	222,600	223,200	223,800	224,400	224,900	225,500	226,100	226,700	99
100	222,900	223,500	224,100	224,700	225,300	225,700	226,100	226,500	226,900	227,300	227,700	228,100	228,400	228,800	229,300	229,900	230,400	231,000	231,500	232,000	232,600	100
101	229,700	230,500	231,200	232,000	232,700	233,000	233,400	233,700	234,000	234,300	234,600	234,900	235,200	235,500	235,900	236,400	236,900	237,300	237,800	238,200	238,700	101
102	236,300	237,100	237,900	238,700	239,400	239,600	239,800	240,100	240,300	240,500	240,800	241,000	241,300	241,500	241,800	242,300	242,700	243,100	243,600	244,000	244,400	102
103	243,000	243,700	244,400	245,100	245,700	245,900	246,000	246,200	246,400	246,500	246,700	246,900	247,000	247,200	247,500	248,000	248,400	248,800	249,200	249,600	250,000	103
104	249,700	250,500	251,300	252,000	252,600	252,700	252,800	252,900	253,000	253,100	253,200	253,300	253,300	253,400	253,700	254,000	254,400	254,800	255,200	255,500	255,900	104
105	256,500	257,400	258,400	259,300	260,000	260,000	260,100	260,100	260,100	260,100	260,100	260,100	260,100	260,100	260,300	260,600	260,900	261,200	261,500	261,800	262,100	105
106	257,200	258,300	259,400	260,400	261,300	261,500	261,800	262,000	262,300	262,500	262,800	263,000	263,300	263,500	263,900	264,400	264,900	265,400	265,900	266,400	266,900	106
107	258,100	259,300	260,500	261,600	262,600	263,100	263,600	264,100	264,600	265,000	265,500	266,000	266,500	267,000	267,600	268,300	269,000	269,700	270,400	271,100	271,800	107
108	258,100	259,300	260,500	261,600	262,700	263,400	264,100	264,900	265,600	266,400	267,100	267,900	268,600	269,400	270,200	271,200	272,100	273,100	274,000	274,900	275,900	108
109	258,900	260,200	261,500	262,800	264,100	265,100	266,100	267,000	268,000	269,000	270,000	271,000	272,000	273,000	274,000	275,100	276,300	277,400	278,600	279,700	280,900	109
110	260,500	262,100	263,600	265,200	266,700	267,900	269,100	270,300	271,500	272,700	274,000	275,200	276,400	277,700	278,900	280,200	281,500	282,800	284,100	285,400	286,700	110
111	261,100	262,800	264,500	266,100	267,800	269,200	270,700	272,200	273,600	275,100	276,500	278,000	279,500	281,000	282,500	284,000	285,500	287,000	288,500	290,100	291,600	111
112	261,100	262,800	264,500	266,100	267,800	269,500	271,300	273,000	274,700	276,400	278,100	279,900	281,600	283,300	285,100	286,800	288,600	290,300	292,100	293,900	295,600	112
113	261,100	262,800	264,500	266,100	267,800	269,500	271,300	273,000	274,700	276,400	278,100	279,900	281,600	283,300	285,100	286,800	288,600	290,300	292,100	293,900	295,600	113
114	261,100	262,800	264,500	266,100	267,800	269,500	271,300	273,000	274,700	276,400	278,100	279,900	281,600	283,300	285,100	286,800	288,600	290,300	292,100	293,900	295,600	114
115	261,100	262,800	264,500	266,100	267,800	269,500	271,300	273,000	274,700	276,400	278,100	279,900	281,600	283,300	285,100	286,800	288,600	290,300	292,100	293,900	295,600	115
116	261,100	262,800	264,500	266,100	267,800	269,500	271,300	273,000	274,700	276,400	278,100	279,900	281,600	283,300	285,100	286,800	288,600	290,300	292,100	293,900	295,600	116
117	261,100	262,800	264,500	266,100	267,800	269,500	271,300	273,000	274,700	276,400	278,100	279,900	281,600	283,300	285,100	286,800	288,600	290,300	292,100	293,900	295,600	117
118	261,100	262,800	264,500	266,100	267,800	269,500	271,300	273,000	274,700	276,400	278,100	279,900	281,600	283,300	285,100	286,800	288,600	290,300	292,100	293,900	295,600	118
119	261,100	262,800	264,500	266,100	267,800	269,500	271,300	273,000	274,700	276,400	278,100	279,900	281,600	283,300	285,100	286,800	288,600	290,300	292,100	293,900	295,600	119

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	810.0	810.1	810.2	810.3	810.4	810.5	810.6	810.7	810.8	810.9	811.0	811.1	811.2	811.3	811.4	811.5	811.6	811.7	811.8	811.9	812.0	
1	1,130	1,130	1,140	1,140	1,140	1,140	1,140	1,150	1,150	1,150	1,150	1,150	1,160	1,160	1,160	1,160	1,170	1,170	1,170	1,170	1,170	1
2	2,660	2,670	2,670	2,680	2,690	2,690	2,700	2,700	2,710	2,710	2,720	2,720	2,730	2,730	2,740	2,740	2,750	2,750	2,760	2,760	2,770	2
3	3,800	3,800	3,810	3,820	3,830	3,830	3,840	3,850	3,850	3,860	3,870	3,880	3,880	3,890	3,900	3,900	3,910	3,920	3,920	3,930	3,940	3
4	5,330	5,340	5,350	5,360	5,370	5,380	5,390	5,400	5,410	5,420	5,430	5,440	5,450	5,460	5,470	5,480	5,490	5,500	5,510	5,520	5,530	4
5	5,590	5,600	5,610	5,620	5,630	5,640	5,650	5,660	5,670	5,680	5,700	5,710	5,720	5,730	5,740	5,750	5,760	5,770	5,780	5,790	5,800	5
6	7,230	7,250	7,260	7,270	7,290	7,300	7,310	7,330	7,340	7,360	7,370	7,380	7,400	7,410	7,420	7,440	7,450	7,460	7,480	7,490	7,500	6
7	8,360	8,380	8,400	8,410	8,430	8,440	8,460	8,470	8,490	8,510	8,520	8,540	8,550	8,570	8,580	8,600	8,620	8,630	8,650	8,660	8,680	7
8	9,900	9,920	9,930	9,950	9,970	9,990	10,010	10,030	10,050	10,070	10,080	10,100	10,120	10,140	10,160	10,180	10,200	10,210	10,230	10,250	10,270	8
9	11,030	11,050	11,070	11,090	11,110	11,130	11,150	11,170	11,200	11,220	11,240	11,260	11,280	11,300	11,320	11,340	11,360	11,380	11,400	11,420	11,440	9
10	12,560	12,580	12,610	12,630	12,660	12,680	12,700	12,730	12,750	12,780	12,800	12,820	12,850	12,870	12,890	12,920	12,940	12,960	12,990	13,010	13,030	10
11	12,820	12,850	12,870	12,890	12,920	12,940	12,970	12,990	13,020	13,040	13,060	13,090	13,110	13,140	13,160	13,180	13,210	13,230	13,260	13,280	13,300	11
12	14,460	14,490	14,520	14,550	14,570	14,600	14,630	14,660	14,680	14,710	14,740	14,770	14,790	14,820	14,850	14,870	14,900	14,930	14,950	14,980	15,010	12
13	15,470	15,490	15,520	15,550	15,580	15,610	15,640	15,670	15,700	15,730	15,760	15,790	15,820	15,850	15,870	15,900	15,930	15,960	15,990	16,020	16,050	13
14	17,110	17,140	17,170	17,200	17,240	17,270	17,300	17,330	17,370	17,400	17,430	17,460	17,500	17,530	17,560	17,590	17,620	17,650	17,690	17,720	17,750	14
15	17,390	17,420	17,450	17,490	17,520	17,550	17,580	17,620	17,650	17,680	17,720	17,750	17,780	17,810	17,850	17,880	17,910	17,940	17,980	18,010	18,040	15
16	19,040	19,080	19,110	19,150	19,190	19,220	19,260	19,300	19,330	19,370	19,400	19,440	19,470	19,510	19,550	19,580	19,620	19,650	19,690	19,720	19,760	16
17	19,330	19,360	19,400	19,440	19,470	19,510	19,550	19,580	19,620	19,660	19,690	19,730	19,770	19,800	19,840	19,880	19,910	19,950	19,980	20,020	20,050	17
18	20,980	21,020	21,060	21,100	21,140	21,180	21,220	21,260	21,300	21,340	21,380	21,420	21,460	21,500	21,540	21,580	21,620	21,660	21,690	21,730	21,770	18
19	22,140	22,180	22,220	22,270	22,310	22,350	22,390	22,430	22,480	22,520	22,560	22,600	22,640	22,680	22,730	22,770	22,810	22,850	22,890	22,930	22,970	19
20	23,690	23,740	23,780	23,830	23,870	23,920	23,960	24,010	24,050	24,100	24,140	24,190	24,230	24,280	24,320	24,370	24,410	24,450	24,500	24,540	24,590	20
21	24,320	24,370	24,410	24,460	24,500	24,550	24,600	24,640	24,690	24,730	24,780	24,830	24,870	24,920	24,960	25,010	25,050	25,100	25,140	25,190	25,230	21
22	25,920	25,970	26,020	26,070	26,120	26,170	26,220	26,270	26,320	26,370	26,410	26,460	26,510	26,560	26,610	26,660	26,710	26,750	26,800	26,850	26,900	22
23	27,090	27,140	27,190	27,240	27,290	27,340	27,390	27,450	27,500	27,550	27,600	27,650	27,700	27,750	27,800	27,850	27,900	27,950	28,000	28,050	28,100	23
24	28,640	28,690	28,750	28,800	28,860	28,910	28,970	29,020	29,070	29,130	29,180	29,240	29,290	29,340	29,400	29,450	29,500	29,560	29,610	29,660	29,720	24
25	29,790	29,840	29,900	29,960	30,010	30,070	30,130	30,180	30,240	30,290	30,350	30,410	30,460	30,520	30,570	30,630	30,690	30,740	30,800	30,850	30,910	25
26	31,330	31,390	31,450	31,510	31,570	31,630	31,690	31,750	31,810	31,870	31,920	31,980	32,040	32,100	32,160	32,220	32,280	32,330	32,390	32,450	32,510	26
27	31,600	31,660	31,720	31,780	31,840	31,900	31,960	32,020	32,080	32,140	32,200	32,260	32,320	32,380	32,440	32,500	32,560	32,620	32,670	32,730	32,790	27
28	33,250	33,310	33,380	33,440	33,500	33,570	33,630	33,690	33,760	33,820	33,880	33,940	34,010	34,070	34,130	34,190	34,260	34,320	34,380	34,440	34,500	28
29	34,810	34,870	34,940	35,010	35,070	35,140	35,210	35,270	35,340	35,400	35,470	35,540	35,600	35,670	35,730	35,800	35,860	35,930	35,990	36,060	36,120	29
30	36,440	36,510	36,580	36,650	36,720	36,790	36,860	36,930	37,000	37,070	37,140	37,210	37,280	37,340	37,410	37,480	37,550	37,620	37,690	37,750	37,820	30
31	38,080	38,150	38,220	38,300	38,370	38,440	38,520	38,590	38,660	38,730	38,810	38,880	38,950	39,020	39,100	39,170	39,240	39,310	39,380	39,450	39,520	31
32	39,640	39,720	39,800	39,880	39,950	40,030	40,100	40,180	40,260	40,330	40,410	40,480	40,560	40,630	40,710	40,780	40,860	40,930	41,010	41,080	41,160	32
33	41,280	41,360	41,440	41,520	41,600	41,680	41,760	41,840	41,920	42,000	42,080	42,150	42,230	42,310	42,390	42,470	42,550	42,620	42,700	42,780	42,860	33
34	42,910	43,000	43,080	43,160	43,250	43,330	43,410	43,500	43,580	43,660	43,740	43,830	43,910	43,990	44,070	44,150	44,240	44,320	44,400	44,480	44,560	34
35	44,480	44,570	44,660	44,740	44,830	44,920	45,000	45,090	45,170	45,260	45,340	45,430	45,520	45,600	45,690	45,770	45,850	45,940	46,020	46,110	46,190	35
36	45,660	45,750	45,840	45,930	46,020	46,100	46,190	46,280	46,370	46,460	46,550	46,630	46,720	46,810	46,900	46,980	47,070	47,160	47,240	47,330	47,420	36
37	47,230	47,320	47,410	47,510	47,600	47,690	47,780	47,870	47,960	48,060	48,150	48,240	48,330	48,420	48,510	48,600	48,690	48,780	48,870	48,960	49,050	37
38	48,800	48,890	48,990	49,080	49,180	49,270	49,370	49,460	49,560	49,650	49,750	49,840	49,930	50,030	50,120	50,210	50,310	50,400	50,490	50,590	50,680	38
39	50,430	50,530	50,630	50,730	50,830	50,930	51,020	51,120	51,220	51,320	51,420	51,510	51,610	51,710	51,800	51,900	52,000	52,090	52,190	52,280	52,380	39
40	52,010	52,110	52,220	52,320	52,420	52,520	52,620	52,720	52,820	52,930	53,030	53,130	53,230	53,330	53,430	53,530	53,630	53,730	53,830	53,920	54,020	40
41	53,640	53,750	53,860	53,960	54,070	54,170	54,280	54,380	54,490	54,590	54,700	54,800	54,900	55,010	55,110	55,210	55,320	55,420	55,520	55,620	55,730	41
42	55,280	55,390	55,500	55,610	55,720	55,820	55,930	56,040	56,150	56,260	56,360	56,470	56,580	56,690	56,790	56,900	57,000	57,110	57,220	57,320	57,430	42
43	56,050	56,160	56,270	56,380	56,500	56,610	56,720	56,830	56,930	57,040	57,150	57,260	57,370	57,480	57,590	57,700	57,800	57,910	58,020	58,130	58,230	43
44	56,910	57,020	57,130	57,240	57,360	57,470	57,580	57,690	57,800	57,920	58,030	58,140	58,250	58,360	58,470	58,580	58,690	58,800	58,910	59,020	59,120	44
45	57,760	57,880	57,990	58,100	58,220	58,330	58,450	58,560	58,670	58,790	58,900	59,010	59,120	59,240	59,350	59,460	59,570	59,680	59,790	59,900	60,020	45
46	58,540	58,660	58,780	58,890	59,010	59,120	59,240	59,350	59,470	59,580	59,700	59,810	59,930	60,040	60,150	60,270	60,380	60,490	60,610	60,720	60,830	46
47	59,400	59,520	59,630	59,750	59,870	59,990	60,100	60,220	60,340	60,450	60,570	60,690	60,800	60,920	61,030	61,150	61,260	61,380	61,490	61,610	61,720	47
48	60,250	60,370	60,490	60,610	60,730	60,850	60,970	61,090	61,210	61,330	61,440	61,560	61,680	61,800	61,910	62,030	62,150	62,260	62,380	62,500	62,610	48
49	61,030	61,160	61,280	61,400	61,520	61,640	61,760	61,880	62,000	62,120	62,240	62,360	62,480	62,600	62,720	62,840	62,960	63,070	63,190	63,310	63,430	49
50	62,210	62,340	62,460	62,590	62,710	62,830	62,960	63,080	63,200	63,330	63,450	63,570	63,690	63,810	63,930	64,060	64,180	64,300	64,420	64,540	64,660	50
51	63,000	63,120	63,250	63,370	63,500	63,620	63,750	63,870	64,000	64,120	64,250	64,370	64,490	64,620	64,740	64,860	64,980	65,110	65,230	65,350	65,470	51
52	63,780	63,910	64,030	64,160	64,290	64,410	64,540	64,670	64,790	64,920	65,040	65,170	65,290	65,420	65,540	65,670	65,790	65,920	66,040	66,160	66,290	52
53	64,630	64,760	64,890	65,020	65,150	65,280	65,410	65,530	65,660	65,790	65,920	66,040	66,170	66,300	66,420	66,550	66,680	66,800	66,930	67,050	67,180	53
54	65,450	65,580	65,710	65,850	65,980	66,110	66,240	66,370	66,500	66,630	66,750	66,880	67,010	67,140	67,270	67,400	67,520	67,650	67,780	67,910	68,030	54
55	66,310	66,440	66,570	66,710	66,840	66,970	67,100	67,230	67,370	67,500	67,630	67,760	67,890	68,020	68,150	68,280	68,410	68,540	68,670	68,800	68,920	55
56	67,160	67,300	67,430	67,570	67,700	67,830	67,970	68,100	68,230	68,370	68,500	68,630	68,770	68,900	69,030	69,160	69,290	69,420	69,550	69,680	69,820	56
57	69,680	69,820	69,960	70,100	70,240	70,380	70,520	70,660	70,800	70,940	71,080	71,210	71,350	71,490	71,630	71,760	71,900	72,040	72,170	72,310	72,450	57
58	72,120	72,270	72,420	72,560	72,710	72,850	73,000	73,140	73,290	73,430	73,580	73,720	73,860	74,010	74,150	74,290	74,440	74,580	74,720	74,860	75,000	58
59	74,570	74,720	74,870	75,020	75,180	75,330	75,480	75,630	75,780	75,930	76,080	76,230	76,380	76,530	76,680	76,820	76,970	77,120	77,270	77,410	77,560	59
60	77,130	77,280	77,440	77,600	77,760	77,910	78,070	78,230	78,380	78,540	78,690	78,850	79,000	79,160	79,310	79,470	79,620	79,770	79,930	80,080	80,230	60

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	810.0	810.1	810.2	810.3	810.4	810.5	810.6	810.7	810.8	810.9	811.0	811.1	811.2	811.3	811.4	811.5	811.6	811.7	811.8	811.9	812.0	
61	79,570	79,730	79,900	80,060	80,220	80,390	80,550	80,710	80,870	81,040	81,200	81,360	81,520	81,680	81,840	82,000	82,160	82,320	82,470	82,630	82,790	61
62	82,020	82,190	82,350	82,520	82,690	82,860	83,030	83,200	83,360	83,530	83,700	83,870	84,030	84,200	84,360	84,530	84,690	84,860	85,020	85,190	85,350	62
63	84,570	84,750	84,920	85,100	85,270	85,450	85,620	85,800	85,970	86,140	86,310	86,490	86,660	86,830	87,000	87,170	87,340	87,510	87,680	87,850	88,020	63
64	86,990	87,170	87,360	87,540	87,720	87,900	88,080	88,260	88,430	88,610	88,790	88,970	89,150	89,320	89,500	89,680	89,850	90,030	90,200	90,380	90,550	64
65	89,550	89,740	89,920	90,110	90,300	90,480	90,670	90,850	91,040	91,220	91,410	91,590	91,770	91,960	92,140	92,320	92,500	92,680	92,860	93,040	93,220	65
66	92,110	92,300	92,490	92,690	92,880	93,070	93,260	93,450	93,640	93,830	94,020	94,210	94,400	94,590	94,780	94,960	95,150	95,340	95,520	95,710	95,900	66
67	94,550	94,750	94,950	95,150	95,350	95,540	95,740	95,940	96,130	96,330	96,520	96,720	96,910	97,110	97,300	97,490	97,690	97,880	98,070	98,260	98,450	67
68	97,010	97,210	97,420	97,620	97,820	98,030	98,230	98,430	98,630	98,830	99,030	99,230	99,430	99,630	99,830	100,000	100,200	100,400	100,600	100,800	101,000	68
69	99,450	99,660	99,870	100,100	100,300	100,500	100,700	100,900	101,100	101,300	101,500	101,700	101,900	102,200	102,400	102,600	102,800	103,000	103,200	103,400	103,600	69
70	101,900	102,100	102,300	102,500	102,800	103,000	103,200	103,400	103,600	103,800	104,000	104,300	104,500	104,700	104,900	105,100	105,300	105,500	105,700	105,900	106,100	70
71	104,900	105,100	105,300	105,600	105,800	106,000	106,200	106,500	106,700	106,900	107,100	107,300	107,600	107,800	108,000	108,200	108,400	108,600	108,900	109,100	109,300	71
72	108,000	108,200	108,400	108,700	108,900	109,100	109,300	109,600	109,800	110,000	110,300	110,500	110,700	110,900	111,200	111,400	111,600	111,800	112,100	112,300	112,500	72
73	111,000	111,300	111,500	111,700	112,000	112,200	112,500	112,700	112,900	113,200	113,400	113,600	113,900	114,100	114,300	114,600	114,800	115,000	115,300	115,500	115,700	73
74	114,100	114,300	114,600	114,800	115,100	115,300	115,600	115,800	116,100	116,300	116,600	116,800	117,000	117,300	117,500	117,800	118,000	118,200	118,500	118,700	119,000	74
75	117,200	117,400	117,700	117,900	118,200	118,400	118,700	118,900	119,200	119,400	119,700	120,000	120,200	120,500	120,700	121,000	121,200	121,400	121,700	121,900	122,200	75
76	120,200	120,500	120,800	121,000	121,300	121,500	121,800	122,100	122,300	122,600	122,800	123,100	123,400	123,600	123,900	124,100	124,400	124,600	124,900	125,200	125,400	76
77	123,300	123,600	123,800	124,100	124,400	124,700	124,900	125,200	125,500	125,700	126,000	126,300	126,500	126,800	127,100	127,300	127,600	127,900	128,100	128,400	128,600	77
78	126,300	126,600	126,800	127,100	127,400	127,700	127,900	128,200	128,500	128,800	129,100	129,300	129,600	129,900	130,200	130,400	130,700	131,000	131,200	131,500	131,800	78
79	129,300	129,600	129,900	130,200	130,500	130,800	131,100	131,400	131,600	131,900	132,200	132,500	132,800	133,100	133,300	133,600	133,900	134,200	134,400	134,700	135,000	79
80	132,400	132,700	133,000	133,300	133,600	133,900	134,200	134,500	134,800	135,100	135,400	135,600	135,900	136,200	136,500	136,800	137,100	137,400	137,700	137,900	138,200	80
81	135,500	135,800	136,100	136,400	136,700	137,000	137,300	137,600	137,900	138,200	138,500	138,800	139,100	139,400	139,700	140,000	140,300	140,600	140,900	141,200	141,500	81
82	138,600	138,900	139,200	139,500	139,800	140,100	140,400	140,700	141,000	141,300	141,700	142,000	142,300	142,600	142,900	143,200	143,500	143,800	144,100	144,400	144,700	82
83	141,600	141,900	142,300	142,600	142,900	143,200	143,500	143,900	144,200	144,500	144,800	145,100	145,400	145,700	146,100	146,400	146,700	147,000	147,300	147,600	147,900	83
84	144,700	145,000	145,300	145,700	146,000	146,300	146,600	147,000	147,300	147,600	147,900	148,300	148,600	148,900	149,200	149,600	149,900	150,200	150,500	150,800	151,100	84
85	150,400	150,700	151,100	151,400	151,800	152,100	152,400	152,800	153,100	153,500	153,800	154,200	154,500	154,800	155,200	155,500	155,800	156,200	156,500	156,800	157,200	85
86	156,200	156,500	156,900	157,300	157,600	158,000	158,300	158,700	159,100	159,400	159,800	160,100	160,500	160,900	161,200	161,600	161,900	162,300	162,600	163,000	163,300	86
87	161,900	162,300	162,700	163,100	163,400	163,800	164,200	164,600	164,900	165,300	165,700	166,100	166,500	166,800	167,200	167,600	167,900	168,300	168,700	169,100	169,400	87
88	167,600	168,000	168,400	168,800	169,200	169,600	170,000	170,400	170,800	171,200	171,600	172,000	172,400	172,800	173,200	173,500	173,900	174,300	174,700	175,100	175,500	88
89	173,400	173,900	174,300	174,700	175,100	175,600	176,000	176,400	176,800	177,200	177,600	178,000	178,400	178,800	179,300	179,700	180,100	180,500	180,900	181,300	181,700	89
90	179,200	179,600	180,100	180,500	181,000	181,400	181,800	182,200	182,700	183,100	183,500	184,000	184,400	184,800	185,200	185,700	186,100	186,500	186,900	187,400	187,800	90
91	184,900	185,400	185,800	186,300	186,800	187,200	187,700	188,100	188,600	189,000	189,500	189,900	190,300	190,800	191,200	191,700	192,100	192,600	193,000	193,400	193,900	91
92	190,000	190,500	191,000	191,400	191,900	192,400	192,900	193,300	193,800	194,300	194,700	195,200	195,700	196,100	196,600	197,100	197,500	198,000	198,400	198,900	199,400	92
93	195,200	195,700	196,200	196,700	197,200	197,700	198,200	198,700	199,200	199,600	200,100	200,600	201,100	201,600	202,100	202,600	203,100	203,500	204,000	204,500	205,000	93
94	200,300	200,800	201,300	201,900	202,400	202,900	203,400	203,900	204,400	205,000	205,500	206,000	206,500	207,000	207,500	208,000	208,500	209,000	209,500	210,000	210,500	94
95	205,400	205,900	206,500	207,000	207,600	208,100	208,600	209,200	209,700	210,200	210,800	211,300	211,800	212,400	212,900	213,400	213,900	214,500	215,000	215,500	216,000	95
96	210,600	211,200	211,800	212,300	212,900	213,500	214,000	214,600	215,100	215,700	216,200	216,800	217,300	217,900	218,400	219,000	219,500	220,100	220,600	221,200	221,700	96
97	215,800	216,400	217,000	217,600	218,100	218,700	219,300	219,900	220,500	221,000	221,600	222,200	222,800	223,300	223,900	224,500	225,000	225,600	226,200	226,700	227,300	97
98	220,900	221,500	222,100	222,700	223,300	224,000	224,600	225,200	225,800	226,400	226,900	227,500	228,100	228,700	229,300	229,900	230,500	231,100	231,700	232,300	232,800	98
99	226,700	227,200	227,800	228,400	228,900	229,500	230,100	230,700	231,300	231,900	232,500	233,100	233,700	234,300	234,900	235,500	236,000	236,600	237,200	237,800	238,400	99
100	232,600	233,100	233,600	234,100	234,700	235,300	235,900	236,500	237,100	237,600	238,200	238,800	239,400	240,000	240,600	241,200	241,700	242,300	242,900	243,500	244,000	100
101	238,700	239,100	239,600	240,000	240,500	241,100	241,700	242,300	242,900	243,500	244,100	244,600	245,200	245,800	246,400	247,000	247,500	248,100	248,700	249,200	249,800	101
102	244,400	244,800	245,200	245,600	246,100	246,700	247,300	247,800	248,400	249,000	249,600	250,200	250,800	251,300	251,900	252,500	253,100	253,600	254,200	254,700	255,300	102
103	250,000	250,400	250,900	251,300	251,700	252,300	252,900	253,500	254,100	254,700	255,200	255,800	256,400	257,000	257,500	258,100	258,600	259,200	259,800	260,300	260,900	103
104	255,900	256,300	256,600	257,000	257,400	258,000	258,600	259,200	259,800	260,400	260,900	261,500	262,100	262,600	263,200	263,800	264,300	264,900	265,400	266,000	266,500	104
105	262,100	262,300	262,600	262,900	263,300	263,900	264,400	265,000	265,600	266,200	266,700	267,300	267,900	268,400	269,000	269,600	270,100	270,700	271,200	271,800	272,300	105
106	266,900	267,400	267,800	268,300	268,900	269,700	270,400	271,200	271,900	272,700	273,400	274,200	274,900	275,600	276,400	277,100	277,800	278,400	279,000	279,600	280,200	106
107	271,800	272,500	273,200	273,900	274,700	275,600	276,600	277,500	278,400	279,400	280,300	281,200	282,100	283,100	284,000	284,900	285,700	286,300	287,000	287,600	288,200	107
108	275,900	276,800	277,800	278,700	279,700	280,800	281,900	283,000	284,200	285,300	286,400	287,500	288,600	289,700	290,800	291,900	292,900	293,700	294,500	295,300	296,200	108
109	280,900	282,000	283,200	284,300	285,500	286,800	288,000	289,300	290,600	291,900	293,100	294,400	295,700	297,000	298,300	299,600	300,700	301,500	302,400	303,300	304,100	109
110	286,700	288,100	289,400	290,700	292,100	293,500	295,000	296,400	297,900	299,300	300,800	302,300	303,700	305,200	306,700	308,100	309,300	310,100	310,800	311,600	312,400	110
111	291,600	293,100	294,600	296,200	297,700	299,400	301,000	302,600	304,200	305,900	307,500	309,200	310,800	312,500	314,100	315,800	317,100	318,000	318,800	319,600	320,400	111
112	295,600	297,400	299,200	301,000	302,800	304,600	306,400	308,200	310,000	311,800	313,600	315,400	317,300	319,100	320,900	322,800	324,300	325,400	326,400	327,300	328,300	112
113	295,600	297,400	299,200	301,000	302,800	304,600	306,400	308,200	310,000	311,800	313,600	315,400	317,300	319,100	320,900	322,800	324,400	325,500	326,700	327,800	329,000	113
114	295,600	297,400	299,200	301,000	302,800	304,600	306,400	308,200	310,000	311,800	313,600	315,400	317,300	319,100	320,900	322,800	324,400	325,800	327,000	328,300	329,600	114
115	295,600	297,400	299,200	301,000	302,800	304,600	306,400	308,200	310,000	311,800	313,600	315,400	317,300	319,100	320,900	322,800	324,400	325,800	327,000	328,300	329,600	115
116	295,600	297,400	299,200	301,000	302,800	304,600	306,400	308,200	310,000	311,800	313,600	315,400	317,300	319,100	320,900	322,800	324,500	326,000	327,400	328,800	330,200	116
117	295,600	297,400	299,200	301,000	302,800	304,600	306,400	308,200	310,000	311,800	313,600	315,400	317,300	319,100	320,900	322,800	324,600	326,400	328,100	329,800	331,500	117
118	295,600	297,400	299,200	301,000	302,800	304,600	306,400	308,200	310,000	311,800	313,600	315,400	317,300	319,100	320,900	322,800	324,600	326,500	328,300	330,200	332,000	118
119	295,600	297,400	299,200	301,000	302,800	304,600	306,400	308,200	310,000	311,800	313,600	315,400	317,300	319,100	320,900	322,800	324,600	326,500	328,300	330,200	332,000	119

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	812.0	812.1	812.2	812.3	812.4	812.5	812.6	812.7	812.8	812.9	813.0	813.1	813.2	813.3	813.4	813.5	813.6	813.7	813.8	813.9	814.0	
1	1,170	1,180	1,180	1,180	1,180	1,180	1,190	1,190	1,190	1,190	1,190	1,200	1,200	1,200	1,200	1,200	1,210	1,210	1,210	1,210	1,210	1
2	2,770	2,770	2,780	2,780	2,790	2,790	2,790	2,800	2,800	2,810	2,810	2,820	2,820	2,830	2,830	2,840	2,840	2,850	2,850	2,860	2,860	2
3	3,940	3,950	3,950	3,960	3,970	3,970	3,980	3,990	3,990	4,000	4,010	4,010	4,020	4,030	4,040	4,040	4,050	4,060	4,060	4,070	4,080	3
4	5,530	5,540	5,550	5,560	5,570	5,580	5,590	5,600	5,610	5,620	5,630	5,640	5,650	5,660	5,670	5,680	5,690	5,700	5,710	5,720	5,730	4
5	5,800	5,810	5,820	5,830	5,840	5,850	5,860	5,870	5,880	5,890	5,900	5,910	5,920	5,930	5,940	5,950	5,960	5,970	5,980	5,990	6,000	5
6	7,500	7,520	7,530	7,540	7,560	7,570	7,580	7,600	7,610	7,620	7,640	7,650	7,660	7,680	7,690	7,700	7,710	7,730	7,740	7,750	7,770	6
7	8,680	8,690	8,710	8,720	8,740	8,750	8,770	8,780	8,800	8,810	8,830	8,850	8,860	8,880	8,890	8,910	8,920	8,940	8,950	8,970	8,980	7
8	10,270	10,290	10,310	10,320	10,340	10,360	10,380	10,400	10,410	10,430	10,450	10,470	10,490	10,500	10,520	10,540	10,560	10,580	10,590	10,610	10,630	8
9	11,440	11,460	11,480	11,500	11,520	11,540	11,560	11,580	11,600	11,620	11,640	11,660	11,680	11,700	11,720	11,740	11,760	11,780	11,800	11,820	11,840	9
10	13,030	13,060	13,080	13,100	13,130	13,150	13,170	13,200	13,220	13,240	13,270	13,290	13,310	13,330	13,360	13,380	13,400	13,420	13,450	13,470	13,490	10
11	13,300	13,330	13,350	13,370	13,400	13,420	13,450	13,470	13,490	13,520	13,540	13,560	13,590	13,610	13,630	13,660	13,680	13,700	13,720	13,750	13,770	11
12	15,010	15,030	15,060	15,090	15,110	15,140	15,170	15,190	15,220	15,250	15,270	15,300	15,330	15,350	15,380	15,400	15,430	15,460	15,480	15,510	15,530	12
13	16,050	16,080	16,100	16,130	16,160	16,190	16,220	16,250	16,270	16,300	16,330	16,360	16,390	16,410	16,440	16,470	16,500	16,520	16,550	16,580	16,610	13
14	17,750	17,780	17,810	17,840	17,880	17,910	17,940	17,970	18,000	18,030	18,060	18,090	18,130	18,160	18,190	18,220	18,250	18,280	18,310	18,340	18,370	14
15	18,040	18,070	18,100	18,140	18,170	18,200	18,230	18,260	18,300	18,330	18,360	18,390	18,420	18,450	18,480	18,520	18,550	18,580	18,610	18,640	18,670	15
16	19,760	19,790	19,830	19,860	19,900	19,930	19,970	20,000	20,040	20,070	20,110	20,140	20,180	20,210	20,250	20,280	20,310	20,350	20,380	20,420	20,450	16
17	20,050	20,090	20,130	20,160	20,200	20,230	20,270	20,300	20,340	20,370	20,410	20,440	20,480	20,510	20,550	20,580	20,620	20,650	20,690	20,720	20,760	17
18	21,770	21,810	21,850	21,890	21,930	21,970	22,000	22,040	22,080	22,120	22,160	22,190	22,230	22,270	22,310	22,350	22,380	22,420	22,460	22,500	22,530	18
19	22,970	23,010	23,050	23,090	23,130	23,180	23,220	23,260	23,300	23,340	23,380	23,420	23,460	23,500	23,540	23,580	23,620	23,660	23,700	23,730	23,770	19
20	24,590	24,630	24,670	24,720	24,760	24,800	24,850	24,890	24,930	24,980	25,020	25,060	25,100	25,150	25,190	25,230	25,280	25,320	25,360	25,400	25,450	20
21	25,230	25,280	25,320	25,370	25,410	25,460	25,500	25,550	25,590	25,630	25,680	25,720	25,770	25,810	25,850	25,900	25,940	25,990	26,030	26,070	26,120	21
22	26,900	26,950	26,990	27,040	27,090	27,140	27,180	27,230	27,280	27,330	27,370	27,420	27,470	27,510	27,560	27,610	27,650	27,700	27,750	27,790	27,840	22
23	28,100	28,150	28,200	28,250	28,300	28,350	28,400	28,450	28,500	28,550	28,600	28,650	28,700	28,750	28,790	28,840	28,890	28,940	28,990	29,040	29,090	23
24	29,720	29,770	29,820	29,870	29,930	29,980	30,030	30,080	30,140	30,190	30,240	30,290	30,340	30,400	30,450	30,500	30,550	30,600	30,650	30,710	30,760	24
25	30,910	30,960	31,020	31,070	31,120	31,180	31,230	31,290	31,340	31,400	31,450	31,500	31,560	31,610	31,670	31,720	31,770	31,830	31,880	31,930	31,990	25
26	32,510	32,570	32,620	32,680	32,740	32,800	32,850	32,910	32,970	33,030	33,080	33,140	33,200	33,250	33,310	33,370	33,420	33,480	33,530	33,590	33,650	26
27	32,790	32,850	32,910	32,970	33,020	33,080	33,140	33,200	33,250	33,310	33,370	33,430	33,480	33,540	33,600	33,660	33,710	33,770	33,830	33,880	33,940	27
28	34,500	34,560	34,620	34,690	34,750	34,810	34,870	34,930	34,990	35,050	35,110	35,170	35,230	35,290	35,350	35,410	35,470	35,530	35,590	35,650	35,710	28
29	36,120	36,180	36,250	36,310	36,380	36,440	36,510	36,570	36,630	36,700	36,760	36,820	36,890	36,950	37,010	37,070	37,140	37,200	37,260	37,330	37,390	29
30	37,820	37,890	37,960	38,030	38,090	38,160	38,230	38,290	38,360	38,430	38,490	38,560	38,630	38,690	38,760	38,830	38,890	38,960	39,020	39,090	39,150	30
31	39,520	39,600	39,670	39,740	39,810	39,880	39,950	40,020	40,090	40,160	40,230	40,300	40,370	40,440	40,510	40,580	40,650	40,710	40,780	40,850	40,920	31
32	41,160	41,230	41,300	41,380	41,450	41,520	41,600	41,670	41,740	41,820	41,890	41,960	42,040	42,110	42,180	42,250	42,330	42,400	42,470	42,540	42,610	32
33	42,860	42,940	43,010	43,090	43,170	43,240	43,320	43,400	43,470	43,550	43,630	43,700	43,780	43,850	43,930	44,000	44,080	44,160	44,230	44,310	44,380	33
34	44,560	44,640	44,720	44,800	44,880	44,960	45,040	45,120	45,200	45,280	45,360	45,440	45,520	45,600	45,680	45,760	45,830	45,910	45,990	46,070	46,150	34
35	46,190	46,280	46,360	46,440	46,530	46,610	46,690	46,770	46,860	46,940	47,020	47,100	47,190	47,270	47,350	47,430	47,510	47,600	47,680	47,760	47,840	35
36	47,420	47,500	47,590	47,670	47,760	47,840	47,930	48,020	48,100	48,190	48,270	48,350	48,440	48,520	48,610	48,690	48,780	48,860	48,940	49,030	49,110	36
37	49,050	49,140	49,230	49,310	49,400	49,490	49,580	49,670	49,760	49,840	49,930	50,020	50,110	50,190	50,280	50,370	50,460	50,540	50,630	50,720	50,800	37
38	50,680	50,770	50,860	50,960	51,050	51,140	51,230	51,320	51,410	51,500	51,590	51,680	51,780	51,870	51,960	52,050	52,140	52,230	52,310	52,400	52,490	38
39	52,380	52,480	52,570	52,670	52,760	52,860	52,950	53,050	53,140	53,230	53,330	53,420	53,520	53,610	53,700	53,800	53,890	53,980	54,080	54,170	54,260	39
40	54,020	54,120	54,220	54,320	54,420	54,520	54,610	54,710	54,810	54,910	55,000	55,100	55,200	55,290	55,390	55,490	55,580	55,680	55,770	55,870	55,970	40
41	55,730	55,830	55,930	56,030	56,130	56,230	56,340	56,440	56,540	56,640	56,740	56,840	56,940	57,040	57,140	57,240	57,340	57,440	57,530	57,630	57,730	41
42	57,430	57,530	57,640	57,740	57,850	57,950	58,060	58,160	58,270	58,370	58,470	58,580	58,680	58,780	58,890	58,990	59,090	59,190	59,300	59,400	59,500	42
43	58,230	58,340	58,450	58,550	58,660	58,770	58,870	58,980	59,080	59,190	59,290	59,400	59,500	59,610	59,710	59,820	59,920	60,020	60,130	60,230	60,340	43
44	59,120	59,230	59,340	59,450	59,560	59,670	59,770	59,880	59,990	60,100	60,200	60,310	60,420	60,520	60,630	60,730	60,840	60,950	61,050	61,160	61,260	44
45	60,020	60,130	60,240	60,350	60,460	60,570	60,680	60,780	60,890	61,000	61,110	61,220	61,330	61,440	61,540	61,650	61,760	61,870	61,970	62,080	62,190	45
46	60,830	60,940	61,050	61,170	61,280	61,390	61,500	61,610	61,720	61,830	61,940	62,050	62,160	62,270	62,380	62,490	62,600	62,710	62,820	62,930	63,030	46
47	61,720	61,840	61,950	62,060	62,180	62,290	62,400	62,510	62,630	62,740	62,850	62,960	63,070	63,190	63,300	63,410	63,520	63,630	63,740	63,850	63,960	47
48	62,610	62,730	62,840	62,960	63,070	63,190	63,300	63,420	63,530	63,650	63,760	63,870	63,990	64,100	64,210	64,330	64,440	64,550	64,660	64,780	64,890	48
49	63,430	63,540	63,660	63,780	63,900	64,010	64,130	64,240	64,360	64,480	64,590	64,710	64,820	64,940	65,050	65,160	65,280	65,390	65,510	65,620	65,730	49
50	64,660	64,780	64,900	65,020	65,140	65,250	65,370	65,490	65,610	65,730	65,850	65,960	66,080	66,200	66,310	66,430	66,550	66,660	66,780	66,900	67,010	50
51	65,470	65,590	65,710	65,840	65,960	66,080	66,200	66,320	66,440	66,560	66,680	66,800	66,910	67,030	67,150	67,270	67,390	67,510	67,620	67,740	67,860	51
52	66,290	66,410	66,530	66,660	66,780	66,900	67,020	67,140	67,260	67,390	67,510	67,630	67,750	67,870	67,990	68,110	68,230	68,350	68,470	68,590	68,710	52
53	67,180	67,300	67,430	67,550	67,680	67,800	67,920	68,050	68,170	68,290	68,420	68,540	68,660	68,780	68,900	69,030	69,150	69,270	69,390	69,510	69,630	53
54	68,030	68,160	68,290	68,410	68,540	68,660	68,790	68,910	69,040	69,160	69,290	69,410	69,540	69,660	69,780	69,910	70,030	70,150	70,280	70,400	70,520	54
55	68,920	69,050	69,180	69,310	69,440	69,560	69,690	69,820	69,940	70,070	70,200	70,320	70,450	70,570	70,700	70,820	70,950	71,070	71,200	71,320	71,450	55
56	69,820	69,950	70,080	70,200	70,330	70,460	70,590	70,720	70,850	70,980	71,110	71,230	71,360	71,490	71,620	71,740	71,870	71,990	72,120	72,250	72,370	56
57	72,450	72,580	72,720	72,850	72,990	73,120	73,260	73,390	73,520	73,660	73,790	73,920	74,060	74,190	74,320	74,450	74,590	74,720	74,850	74,980	75,110	57
58	75,000	75,140	75,290	75,430	75,570	75,710	75,850	75,990	76,130	76,260	76,400	76,540	76,680	76,820	76,960	77,090	77,230	77,370	77,500	77,640	77,780	58
59	77,560	77,710	77,850	78,000	78,150	78,290	78,440	78,580	78,730	78,870	79,020	79,160	79,300	79,450	79,590	79,730	79,880	80,020	80,160	80,300	80,440	59
60	80,230	80,390	80,540	80,690	80,840	80,990	81,140	81,290	81,440	81,590	81,740	81,890	82,040	82,190	82,340	82,490	82,640	82,780	82,930	83,080	83,230	60

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	812.0	812.1	812.2	812.3	812.4	812.5	812.6	812.7	812.8	812.9	813.0	813.1	813.2	813.3	813.4	813.5	813.6	813.7	813.8	813.9	814.0	
61	82,790	82,950	83,110	83,260	83,420	83,580	83,730	83,890	84,050	84,200	84,360	84,510	84,670	84,820	84,970	85,130	85,280	85,430	85,590	85,740	85,890	61
62	85,350	85,510	85,680	85,840	86,000	86,160	86,320	86,490	86,650	86,810	86,970	87,130	87,290	87,450	87,610	87,770	87,930	88,080	88,240	88,400	88,560	62
63	88,020	88,190	88,360	88,530	88,690	88,860	89,030	89,200	89,360	89,530	89,700	89,860	90,030	90,190	90,360	90,520	90,690	90,850	91,010	91,180	91,340	63
64	90,550	90,730	90,900	91,070	91,250	91,420	91,590	91,770	91,940	92,110	92,280	92,450	92,620	92,790	92,960	93,130	93,300	93,470	93,640	93,810	93,980	64
65	93,220	93,400	93,580	93,760	93,940	94,120	94,300	94,480	94,650	94,830	95,010	95,180	95,360	95,540	95,710	95,890	96,060	96,240	96,410	96,590	96,760	65
66	95,900	96,080	96,270	96,450	96,640	96,820	97,000	97,190	97,370	97,550	97,740	97,920	98,100	98,280	98,460	98,640	98,820	99,000	99,180	99,360	99,540	66
67	98,450	98,650	98,840	99,030	99,220	99,410	99,590	99,780	99,970	100,200	100,300	100,500	100,700	100,900	101,100	101,300	101,500	101,700	101,800	102,000	102,200	67
68	101,000	101,200	101,400	101,600	101,800	102,000	102,200	102,400	102,600	102,800	103,000	103,200	103,400	103,500	103,700	103,900	104,100	104,300	104,500	104,700	104,900	68
69	103,600	103,800	104,000	104,200	104,400	104,600	104,800	105,000	105,200	105,400	105,600	105,800	106,000	106,200	106,400	106,600	106,800	107,000	107,200	107,400	107,500	69
70	106,100	106,300	106,600	106,800	107,000	107,200	107,400	107,600	107,800	108,000	108,200	108,400	108,600	108,800	109,000	109,200	109,400	109,600	109,800	110,000	110,200	70
71	109,300	109,500	109,700	109,900	110,100	110,400	110,600	110,800	111,000	111,200	111,400	111,600	111,800	112,000	112,300	112,500	112,700	112,900	113,100	113,300	113,500	71
72	112,500	112,700	113,000	113,200	113,400	113,600	113,800	114,100	114,300	114,500	114,700	114,900	115,200	115,400	115,600	115,800	116,000	116,200	116,500	116,700	116,900	72
73	115,700	116,000	116,200	116,400	116,700	116,900	117,100	117,300	117,600	117,800	118,000	118,200	118,500	118,700	118,900	119,100	119,400	119,600	119,800	120,000	120,300	73
74	119,000	119,200	119,400	119,700	119,900	120,200	120,400	120,600	120,900	121,100	121,300	121,600	121,800	122,000	122,300	122,500	122,700	123,000	123,200	123,400	123,600	74
75	122,200	122,400	122,700	122,900	123,200	123,400	123,700	123,900	124,100	124,400	124,600	124,900	125,100	125,400	125,600	125,800	126,100	126,300	126,500	126,800	127,000	75
76	125,400	125,700	125,900	126,200	126,400	126,700	126,900	127,200	127,400	127,700	127,900	128,200	128,400	128,700	128,900	129,200	129,400	129,700	129,900	130,200	130,400	76
77	128,600	128,900	129,200	129,400	129,700	129,900	130,200	130,500	130,700	131,000	131,200	131,500	131,700	132,000	132,300	132,500	132,800	133,000	133,300	133,500	133,800	77
78	131,800	132,000	132,300	132,600	132,900	133,100	133,400	133,700	133,900	134,200	134,400	134,700	135,000	135,200	135,500	135,800	136,000	136,300	136,500	136,800	137,100	78
79	135,000	135,300	135,600	135,800	136,100	136,400	136,700	136,900	137,200	137,500	137,700	138,000	138,300	138,600	138,800	139,100	139,400	139,600	139,900	140,200	140,400	79
80	138,200	138,500	138,800	139,100	139,400	139,600	139,900	140,200	140,500	140,800	141,100	141,300	141,600	141,900	142,200	142,400	142,700	143,000	143,300	143,500	143,800	80
81	141,500	141,800	142,000	142,300	142,600	142,900	143,200	143,500	143,800	144,100	144,400	144,600	144,900	145,200	145,500	145,800	146,100	146,300	146,600	146,900	147,200	81
82	144,700	145,000	145,300	145,600	145,900	146,200	146,500	146,800	147,100	147,400	147,700	148,000	148,300	148,500	148,800	149,100	149,400	149,700	150,000	150,300	150,600	82
83	147,900	148,200	148,500	148,800	149,100	149,400	149,800	150,100	150,400	150,700	151,000	151,300	151,600	151,900	152,200	152,500	152,800	153,100	153,400	153,700	154,000	83
84	151,100	151,500	151,800	152,100	152,400	152,700	153,000	153,300	153,600	154,000	154,300	154,600	154,900	155,200	155,500	155,800	156,100	156,400	156,700	157,000	157,300	84
85	157,200	157,500	157,800	158,200	158,500	158,800	159,200	159,500	159,800	160,100	160,500	160,800	161,100	161,500	161,800	162,100	162,400	162,700	163,100	163,400	163,700	85
86	163,300	163,700	164,000	164,400	164,700	165,100	165,400	165,800	166,100	166,400	166,800	167,100	167,500	167,800	168,200	168,500	168,800	169,200	169,500	169,800	170,200	86
87	169,400	169,800	170,200	170,500	170,900	171,200	171,600	172,000	172,300	172,700	173,100	173,400	173,800	174,100	174,500	174,800	175,200	175,600	175,900	176,300	176,600	87
88	175,500	175,900	176,200	176,600	177,000	177,400	177,800	178,200	178,500	178,900	179,300	179,700	180,000	180,400	180,800	181,200	181,500	181,900	182,300	182,600	183,000	88
89	181,700	182,100	182,500	182,900	183,300	183,700	184,100	184,500	184,900	185,300	185,600	186,000	186,400	186,800	187,200	187,600	188,000	188,400	188,800	189,100	189,500	89
90	187,800	188,200	188,600	189,000	189,400	189,900	190,300	190,700	191,100	191,500	191,900	192,300	192,700	193,100	193,500	193,900	194,400	194,800	195,200	195,600	196,000	90
91	193,900	194,300	194,700	195,200	195,600	196,000	196,500	196,900	197,300	197,700	198,200	198,600	199,000	199,500	199,900	200,300	200,700	201,100	201,600	202,000	202,400	91
92	199,400	199,800	200,300	200,700	201,200	201,600	202,100	202,500	203,000	203,400	203,900	204,300	204,800	205,200	205,600	206,100	206,500	207,000	207,400	207,800	208,300	92
93	205,000	205,400	205,900	206,400	206,900	207,300	207,800	208,300	208,800	209,200	209,700	210,200	210,600	211,100	211,600	212,000	212,500	212,900	213,400	213,800	214,300	93
94	210,500	211,000	211,500	212,000	212,500	213,000	213,500	214,000	214,500	215,000	215,400	215,900	216,400	216,900	217,400	217,900	218,300	218,800	219,300	219,800	220,200	94
95	216,000	216,500	217,100	217,600	218,100	218,600	219,100	219,600	220,100	220,600	221,200	221,700	222,200	222,700	223,200	223,700	224,200	224,700	225,200	225,700	226,100	95
96	221,700	222,300	222,800	223,300	223,900	224,400	224,900	225,500	226,000	226,500	227,100	227,600	228,100	228,600	229,200	229,700	230,200	230,700	231,200	231,700	232,200	96
97	227,300	227,900	228,400	229,000	229,500	230,100	230,600	231,200	231,800	232,300	232,900	233,400	234,000	234,500	235,000	235,600	236,100	236,600	237,200	237,700	238,200	97
98	232,800	233,400	234,000	234,600	235,200	235,700	236,300	236,900	237,500	238,000	238,600	239,200	239,700	240,300	240,900	241,400	242,000	242,500	243,100	243,600	244,200	98
99	238,400	238,900	239,500	240,100	240,700	241,200	241,800	242,400	243,000	243,500	244,100	244,700	245,300	245,800	246,400	247,000	247,500	248,100	248,700	249,200	249,800	99
100	244,000	244,600	245,200	245,700	246,300	246,900	247,500	248,100	248,600	249,200	249,800	250,400	250,900	251,500	252,100	252,700	253,300	253,800	254,400	255,000	255,600	100
101	249,800	250,400	250,900	251,500	252,100	252,600	253,200	253,800	254,400	254,900	255,500	256,100	256,600	257,200	257,800	258,400	259,000	259,600	260,200	260,800	261,300	101
102	255,300	255,900	256,400	257,000	257,500	258,100	258,700	259,300	259,900	260,400	261,000	261,600	262,200	262,700	263,300	263,900	264,500	265,100	265,800	266,400	267,000	102
103	260,900	261,400	262,000	262,500	263,100	263,700	264,300	264,900	265,500	266,100	266,700	267,200	267,800	268,400	269,000	269,600	270,300	270,900	271,500	272,100	272,800	103
104	266,500	267,100	267,600	268,200	268,700	269,300	269,900	270,500	271,100	271,700	272,300	272,900	273,500	274,100	274,700	275,300	276,000	276,600	277,200	277,900	278,500	104
105	272,300	272,800	273,400	273,900	274,500	275,100	275,700	276,300	276,800	277,400	278,000	278,600	279,200	279,800	280,300	281,000	281,700	282,300	283,000	283,600	284,300	105
106	280,200	280,700	281,300	281,900	282,500	283,100	283,700	284,200	284,700	285,200	285,600	286,100	286,600	287,100	287,500	288,100	288,600	289,200	289,800	290,400	291,000	106
107	288,200	288,900	289,500	290,100	290,800	291,400	291,900	292,300	292,700	293,100	293,500	293,900	294,200	294,600	294,900	295,400	295,800	296,400	296,900	297,500	298,000	107
108	296,200	297,000	297,800	298,600	299,400	300,300	300,900	301,200	301,500	301,700	302,000	302,300	302,500	302,800	303,000	303,300	303,600	304,100	304,500	304,900	305,400	108
109	304,100	305,000	305,800	306,700	307,500	308,300	308,800	309,000	309,200	309,400	309,500	309,700	309,800	310,000	310,100	310,200	310,500	310,900	311,300	311,700	312,000	109
110	312,400	313,100	313,900	314,600	315,300	316,000	316,400	316,500	316,600	316,600	316,700	316,800	316,800	316,800	316,800	316,900	317,100	317,500	317,900	318,200	318,600	110
111	320,400	321,200	322,000	322,800	323,600	324,300	324,600	324,600	324,600	324,600	324,500	324,500	324,400	324,300	324,200	324,200	324,200	324,600	324,900	325,200	325,500	111
112	328,300	329,300	330,300	331,300	332,300	333,200	333,600	333,400	333,300	333,200	333,100	332,900	332,700	332,500	332,300	332,100	332,000	332,200	332,400	332,700	332,900	112
113	329,000	330,100	331,200	332,300	333,400	334,500	335,100	335,300	335,400	335,600	335,700	335,800	335,900	336,000	336,100	336,200	336,400	336,900	337,300	337,800	338,200	113
114	329,600	330,900	332,100	333,400	334,700	335,900	336,700	337,200	337,600	338,100	338,500	338,900	339,300	339,700	340,100	340,500	341,000	341,700	342,400	343,100	343,800	114
115	329,600	330,900	332,100	333,400	334,700	335,900	336,800	337,600	338,300	339,100	339,800	340,600	341,300	342,000	342,700	343,400	344,300	345,200	346,200	347,200	348,200	115
116	330,200	331,700	333,100	334,500	335,900	337,400	338,600	339,600	340,700	341,700	342,700	343,700	344,800	345,800	346,800	347,800	348,900	350,100	351,300	352,500	353,700	116
117	331,500	333,200	335,000	336,700	338,400	340,200	341,700	343,000	344,300	345,600	346,900	348,200	349,500	350,800	352,100	353,400	354,800	356,200	357,600	359,000	360,400	117
118	332,000	333,900	335,800	337,700	339,500	341,400	343,200	344,800	346,400	348,000	349,600	351,200	352,800	354,400	356,000	357,600	359,300	360,900	362,600	364,200	365,900	118
119	332,000	333,900	335,800	337,700	339,500	341,400	343,300	345,200	347,100	349,000	350,900	352,900	354,800	356,700	358,600	360,600	362,500	364,400	366,400	368,300	370,300	119

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	814.0	814.1	814.2	814.3	814.4	814.5	814.6	814.7	814.8	814.9	815.0	815.1	815.2	815.3	815.4	815.5	815.6	815.7	815.8	815.9	816.0	
1	1,210	1,220	1,220	1,220	1,220	1,220	1,230	1,230	1,230													1
2	2,860	2,870	2,870	2,880	2,880	2,890	2,890	2,900	2,900													2
3	4,080	4,080	4,090	4,100	4,100	4,110	4,120	4,120	4,130													3
4	5,730	5,730	5,740	5,750	5,760	5,770	5,780	5,790	5,800													4
5	6,000	6,010	6,020	6,030	6,040	6,050	6,060	6,070	6,080													5
6	7,770	7,780	7,790	7,810	7,820	7,830	7,840	7,860	7,870													6
7	8,980	9,000	9,010	9,020	9,040	9,050	9,070	9,080	9,100													7
8	10,630	10,650	10,660	10,680	10,700	10,720	10,740	10,750	10,770													8
9	11,840	11,860	11,880	11,900	11,920	11,940	11,960	11,980	12,000													9
10	13,490	13,510	13,540	13,560	13,580	13,600	13,630	13,650	13,670													10
11	13,770	13,790	13,820	13,840	13,860	13,880	13,910	13,930	13,950													11
12	15,530	15,560	15,590	15,610	15,640	15,660	15,690	15,710	15,740													12
13	16,610	16,640	16,660	16,690	16,720	16,750	16,770	16,800	16,830													13
14	18,370	18,400	18,430	18,460	18,490	18,520	18,550	18,590	18,620													14
15	18,670	18,700	18,730	18,760	18,800	18,830	18,860	18,890	18,920													15
16	20,450	20,480	20,520	20,550	20,590	20,620	20,650	20,690	20,720													16
17	20,760	20,790	20,820	20,860	20,890	20,930	20,960	21,000	21,030													17
18	22,530	22,570	22,610	22,650	22,680	22,720	22,760	22,790	22,830													18
19	23,770	23,810	23,850	23,890	23,930	23,970	24,010	24,050	24,090													19
20	25,450	25,490	25,530	25,570	25,610	25,660	25,700	25,740	25,780													20
21	26,120	26,160	26,200	26,250	26,290	26,330	26,370	26,420	26,460													21
22	27,840	27,890	27,930	27,980	28,020	28,070	28,120	28,160	28,210													22
23	29,090	29,130	29,180	29,230	29,280	29,330	29,370	29,420	29,470													23
24	30,760	30,810	30,860	30,910	30,960	31,010	31,060	31,110	31,160													24
25	31,990	32,040	32,090	32,150	32,200	32,250	32,300	32,360	32,410													25
26	33,650	33,700	33,760	33,810	33,870	33,930	33,980	34,040	34,090													26
27	33,940	34,000	34,050	34,110	34,160	34,220	34,280	34,330	34,390	34,440	34,500											27
28	35,710	35,770	35,830	35,890	35,950	36,010	36,060	36,120	36,180	36,240	36,300	36,360	36,410	36,470	36,530	36,590	36,650	36,700	36,760	36,820	36,880	28
29	37,390	37,450	37,510	37,570	37,640	37,700	37,760	37,820	37,880	37,940	38,010	38,070	38,130	38,190	38,250	38,310	38,370	38,430	38,490	38,550	38,610	29
30	39,150	39,220	39,290	39,350	39,420	39,480	39,550	39,610	39,670	39,740	39,800	39,870	39,930	40,000	40,060	40,120	40,190	40,250	40,320	40,380	40,440	30
31	40,920	40,990	41,060	41,130	41,200	41,260	41,330	41,400	41,470	41,530	41,600	41,670	41,740	41,800	41,870	41,940	42,010	42,070	42,140	42,210	42,270	31
32	42,610	42,680	42,760	42,830	42,900	42,970	43,040	43,110	43,180	43,250	43,320	43,390	43,460	43,530	43,600	43,670	43,740	43,810	43,880	43,950	44,020	32
33	44,380	44,450	44,530	44,600	44,680	44,750	44,830	44,900	44,970	45,050	45,120	45,200	45,270	45,340	45,420	45,490	45,560	45,630	45,710	45,780	45,850	33
34	46,150	46,230	46,300	46,380	46,460	46,540	46,610	46,690	46,770	46,840	46,920	47,000	47,070	47,150	47,230	47,300	47,380	47,450	47,530	47,610	47,680	34
35	47,840	47,920	48,000	48,080	48,160	48,240	48,320	48,400	48,480	48,560	48,640	48,720	48,800	48,880	48,960	49,040	49,120	49,200	49,270	49,350	49,430	35
36	49,110	49,190	49,280	49,360	49,440	49,520	49,610	49,690	49,770	49,850	49,940	50,020	50,100	50,180	50,260	50,340	50,420	50,500	50,590	50,670	50,750	36
37	50,800	50,890	50,970	51,060	51,150	51,230	51,320	51,400	51,490	51,570	51,660	51,740	51,830	51,910	51,990	52,080	52,160	52,250	52,330	52,410	52,500	37
38	52,490	52,580	52,670	52,760	52,850	52,940	53,030	53,110	53,200	53,290	53,380	53,470	53,550	53,640	53,730	53,810	53,900	53,990	54,070	54,160	54,250	38
39	54,260	54,350	54,440	54,540	54,630	54,720	54,810	54,900	54,990	55,090	55,180	55,270	55,360	55,450	55,540	55,630	55,720	55,810	55,900	55,990	56,080	39
40	55,970	56,060	56,160	56,250	56,350	56,440	56,530	56,630	56,720	56,820	56,910	57,000	57,100	57,190	57,280	57,380	57,470	57,560	57,660	57,750	57,840	40
41	57,730	57,830	57,930	58,030	58,120	58,220	58,320	58,420	58,520	58,610	58,710	58,810	58,900	59,000	59,100	59,190	59,290	59,380	59,480	59,580	59,670	41
42	59,500	59,600	59,700	59,800	59,900	60,010	60,110	60,210	60,310	60,410	60,510	60,610	60,710	60,810	60,910	61,010	61,110	61,200	61,300	61,400	61,500	42
43	60,340	60,440	60,540	60,640	60,750	60,850	60,950	61,050	61,160	61,260	61,360	61,460	61,560	61,660	61,760	61,870	61,970	62,070	62,170	62,270	62,370	43
44	61,260	61,370	61,470	61,580	61,680	61,780	61,890	61,990	62,100	62,200	62,300	62,410	62,510	62,610	62,710	62,820	62,920	63,020	63,120	63,230	63,330	44
45	62,190	62,290	62,400	62,510	62,610	62,720	62,830	62,930	63,040	63,140	63,250	63,350	63,460	63,560	63,670	63,770	63,870	63,980	64,080	64,180	64,290	45
46	63,030	63,140	63,250	63,360	63,470	63,570	63,680	63,790	63,900	64,000	64,110	64,210	64,320	64,430	64,530	64,640	64,740	64,850	64,950	65,060	65,160	46
47	63,960	64,070	64,180	64,290	64,400	64,510	64,620	64,730	64,840	64,940	65,050	65,160	65,270	65,380	65,480	65,590	65,700	65,800	65,910	66,020	66,130	47
48	64,890	65,000	65,110	65,220	65,330	65,440	65,550	65,670	65,780	65,890	66,000	66,110	66,220	66,320	66,430	66,540	66,650	66,760	66,870	66,980	67,090	48
49	65,730	65,850	65,960	66,070	66,190	66,300	66,410	66,520	66,630	66,750	66,860	66,970	67,080	67,190	67,300	67,410	67,520	67,630	67,740	67,850	67,960	49
50	67,010	67,130	67,240	67,360	67,470	67,590	67,700	67,820	67,930	68,050	68,160	68,270	68,390	68,500	68,610	68,730	68,840	68,950	69,060	69,180	69,290	50
51	67,860	67,980	68,090	68,210	68,330	68,440	68,560	68,670	68,790	68,910	69,020	69,140	69,250	69,370	69,480	69,600	69,710	69,820	69,940	70,050	70,160	51
52	68,710	68,820	68,940	69,060	69,180	69,300	69,410	69,530	69,650	69,770	69,880	70,000	70,120	70,230	70,350	70,460	70,580	70,700	70,810	70,930	71,040	52
53	69,630	69,750	69,870	69,990	70,110	70,230	70,350	70,470	70,590	70,710	70,830	70,940	71,060	71,180	71,300	71,420	71,530	71,650	71,770	71,880	72,000	53
54	70,520	70,640	70,760	70,890	71,010	71,130	71,250	71,370	71,490	71,610	71,730	71,850	71,970	72,090	72,210	72,330	72,450	72,570	72,690	72,800	72,920	54
55	71,450	71,570	71,690	71,820	71,940	72,060	72,190	72,310	72,430	72,550	72,670	72,800	72,920	73,040	73,160	73,280	73,400	73,520	73,640	73,760	73,880	55
56	72,370	72,500	72,620	72,750	72,870	73,000	73,120	73,250	73,370	73,490	73,620	73,740	73,860	73,990	74,110	74,230	74,360	74,480	74,600	74,720	74,840	56
57	75,110	75,240	75,370	75,500	75,630	75,760	75,890	76,020	76,150	76,280	76,410	76,540	76,670	76,790	76,920	77,050	77,180	77,300	77,430	77,560	77,680	57
58	77,780	77,910	78,050	78,180	78,320	78,460	78,590	78,730	78,860	78,990	79,130	79,260	79,400	79,530	79,660	79,790	79,930	80,060	80,190	80,320	80,460	58
59	80,440	80,590	80,730	80,870	81,010	81,150	81,290	81,430	81,570	81,710	81,850	81,990	82,120	82,260	82,400	82,540	82,680	82,810	82,950	83,090	83,230	59
60	83,230	83,370	83,520	83,660	83,810	83,960	84,100	84,250	84,390	84,540	84,680	84,830	84,970	85,110	85,260	85,400	85,540	85,690	85,830	85,970	86,110	60

See special instruction for preventing gate overflow on page 2.

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	814.0	814.1	814.2	814.3	814.4	814.5	814.6	814.7	814.8	814.9	815.0	815.1	815.2	815.3	815.4	815.5	815.6	815.7	815.8	815.9	816.0	
61	85,890	86,040	86,200	86,350	86,500	86,650	86,800	86,950	87,100	87,250	87,400	87,550	87,700	87,850	88,000	88,150	88,290	88,440	88,590	88,740	88,880	61
62	88,560	88,720	88,870	89,030	89,190	89,340	89,500	89,650	89,810	89,960	90,120	90,270	90,430	90,580	90,740	90,890	91,040	91,200	91,350	91,500	91,650	62
63	91,340	91,500	91,660	91,830	91,990	92,150	92,310	92,470	92,630	92,790	92,950	93,110	93,270	93,430	93,590	93,750	93,910	94,070	94,230	94,380	94,540	63
64	93,980	94,150	94,310	94,480	94,650	94,810	94,980	95,150	95,310	95,480	95,640	95,810	95,970	96,140	96,300	96,470	96,630	96,790	96,960	97,120	97,280	64
65	96,760	96,930	97,110	97,280	97,450	97,620	97,790	97,970	98,140	98,310	98,480	98,650	98,820	98,990	99,160	99,330	99,500	99,660	99,830	100,000	100,200	65
66	99,540	99,720	99,900	100,100	100,300	100,400	100,600	100,800	101,000	101,100	101,300	101,500	101,700	101,800	102,000	102,200	102,400	102,500	102,700	102,900	103,100	66
67	102,200	102,400	102,600	102,800	102,900	103,100	103,300	103,500	103,700	103,900	104,000	104,200	104,400	104,600	104,800	104,900	105,100	105,300	105,500	105,600	105,800	67
68	104,900	105,100	105,300	105,400	105,600	105,800	106,000	106,200	106,400	106,600	106,800	106,900	107,100	107,300	107,500	107,700	107,900	108,000	108,200	108,400	108,600	68
69	107,500	107,700	107,900	108,100	108,300	108,500	108,700	108,900	109,100	109,300	109,500	109,700	109,900	110,000	110,200	110,400	110,600	110,800	111,000	111,200	111,400	69
70	110,200	110,400	110,600	110,800	111,000	111,200	111,400	111,600	111,800	112,000	112,200	112,400	112,600	112,800	113,000	113,200	113,400	113,600	113,800	113,900	114,100	70
71	113,500	113,700	113,900	114,100	114,300	114,500	114,700	114,900	115,200	115,400	115,600	115,800	116,000	116,200	116,400	116,600	116,800	117,000	117,200	117,400	117,600	71
72	116,900	117,100	117,300	117,500	117,700	118,000	118,200	118,400	118,600	118,800	119,000	119,200	119,400	119,600	119,900	120,100	120,300	120,500	120,700	120,900	121,100	72
73	120,300	120,500	120,700	120,900	121,200	121,400	121,600	121,800	122,000	122,200	122,500	122,700	122,900	123,100	123,300	123,600	123,800	124,000	124,200	124,400	124,600	73
74	123,600	123,900	124,100	124,300	124,600	124,800	125,000	125,200	125,500	125,700	125,900	126,100	126,400	126,600	126,800	127,000	127,300	127,500	127,700	127,900	128,100	74
75	127,000	127,300	127,500	127,700	128,000	128,200	128,400	128,700	128,900	129,100	129,400	129,600	129,800	130,100	130,300	130,500	130,800	131,000	131,200	131,400	131,700	75
76	130,400	130,600	130,900	131,100	131,400	131,600	131,900	132,100	132,300	132,600	132,800	133,100	133,300	133,500	133,800	134,000	134,300	134,500	134,700	135,000	135,200	76
77	133,800	134,000	134,300	134,500	134,800	135,000	135,300	135,500	135,800	136,000	136,300	136,500	136,800	137,000	137,300	137,500	137,700	138,000	138,200	138,500	138,700	77
78	137,100	137,300	137,600	137,800	138,100	138,400	138,600	138,900	139,100	139,400	139,600	139,900	140,100	140,400	140,600	140,900	141,100	141,400	141,700	141,900	142,200	78
79	140,400	140,700	141,000	141,200	141,500	141,800	142,000	142,300	142,600	142,800	143,100	143,300	143,600	143,900	144,100	144,400	144,600	144,900	145,200	145,400	145,700	79
80	143,800	144,100	144,400	144,600	144,900	145,200	145,400	145,700	146,000	146,300	146,500	146,800	147,100	147,300	147,600	147,900	148,100	148,400	148,700	148,900	149,200	80
81	147,200	147,500	147,800	148,000	148,300	148,600	148,900	149,200	149,400	149,700	150,000	150,300	150,500	150,800	151,100	151,400	151,600	151,900	152,200	152,400	152,700	81
82	150,600	150,900	151,200	151,400	151,700	152,000	152,300	152,600	152,900	153,200	153,400	153,700	154,000	154,300	154,600	154,800	155,100	155,400	155,700	156,000	156,200	82
83	154,000	154,300	154,500	154,800	155,100	155,400	155,700	156,000	156,300	156,600	156,900	157,200	157,500	157,800	158,000	158,300	158,600	158,900	159,200	159,500	159,800	83
84	157,300	157,600	157,900	158,200	158,500	158,800	159,100	159,400	159,700	160,000	160,300	160,600	160,900	161,200	161,500	161,800	162,100	162,400	162,700	163,000	163,300	84
85	163,700	164,000	164,300	164,700	165,000	165,300	165,600	165,900	166,200	166,600	166,900	167,200	167,500	167,800	168,100	168,400	168,700	169,100	169,400	169,700	170,000	85
86	170,200	170,500	170,900	171,200	171,500	171,900	172,200	172,500	172,900	173,200	173,500	173,800	174,200	174,500	174,800	175,200	175,500	175,800	176,100	176,500	176,800	86
87	176,600	177,000	177,300	177,700	178,000	178,400	178,700	179,100	179,400	179,800	180,100	180,500	180,800	181,100	181,500	181,800	182,200	182,500	182,900	183,200	183,500	87
88	183,000	183,400	183,700	184,100	184,500	184,800	185,200	185,600	185,900	186,300	186,700	187,000	187,400	187,700	188,100	188,500	188,800	189,200	189,500	189,900	190,200	88
89	189,500	189,900	190,300	190,700	191,100	191,400	191,800	192,200	192,600	193,000	193,300	193,700	194,100	194,500	194,800	195,200	195,600	196,000	196,300	196,700	197,100	89
90	196,000	196,400	196,800	197,200	197,600	198,000	198,400	198,700	199,100	199,500	199,900	200,300	200,700	201,100	201,500	201,900	202,300	202,700	203,000	203,400	203,800	90
91	202,400	202,800	203,200	203,600	204,100	204,500	204,900	205,300	205,700	206,100	206,500	206,900	207,300	207,800	208,200	208,600	209,000	209,400	209,800	210,200	210,600	91
92	208,300	208,700	209,100	209,600	210,000	210,400	210,900	211,300	211,700	212,200	212,600	213,000	213,400	213,900	214,300	214,700	215,100	215,500	216,000	216,400	216,800	92
93	214,300	214,700	215,200	215,700	216,100	216,500	217,000	217,400	217,900	218,300	218,800	219,200	219,700	220,100	220,500	221,000	221,400	221,900	222,300	222,700	223,200	93
94	220,200	220,700	221,200	221,700	222,100	222,600	223,100	223,500	224,000	224,400	224,900	225,400	225,800	226,300	226,700	227,200	227,600	228,100	228,600	229,000	229,500	94
95	226,100	226,600	227,100	227,600	228,100	228,600	229,100	229,500	230,000	230,500	231,000	231,500	231,900	232,400	232,900	233,400	233,800	234,300	234,800	235,200	235,700	95
96	232,200	232,700	233,300	233,800	234,300	234,800	235,300	235,800	236,300	236,800	237,200	237,700	238,200	238,700	239,200	239,700	240,200	240,700	241,200	241,700	242,100	96
97	238,200	238,800	239,300	239,800	240,300	240,800	241,400	241,900	242,400	242,900	243,400	243,900	244,400	244,900	245,400	245,900	246,500	247,000	247,500	248,000	248,500	97
98	244,200	244,700	245,300	245,800	246,300	246,900	247,400	247,900	248,500	249,000	249,500	250,100	250,600	251,100	251,600	252,200	252,700	253,200	253,700	254,200	254,800	98
99	249,800	250,400	250,900	251,500	252,000	252,600	253,100	253,700	254,200	254,800	255,300	255,800	256,400	256,900	257,500	258,000	258,500	259,100	259,600	260,100	260,700	99
100	255,600	256,200	256,700	257,300	257,900	258,400	259,000	259,600	260,100	260,700	261,200	261,800	262,400	262,900	263,500	264,000	264,600	265,100	265,700	266,200	266,800	100
101	261,300	261,900	262,500	263,100	263,700	264,300	264,900	265,400	266,000	266,600	267,200	267,700	268,300	268,900	269,400	270,000	270,600	271,100	271,700	272,300	272,800	101
102	267,000	267,600	268,200	268,800	269,400	270,000	270,600	271,200	271,700	272,300	272,900	273,500	274,100	274,700	275,300	275,800	276,400	277,000	277,600	278,200	278,700	102
103	272,800	273,400	274,000	274,600	275,200	275,900	276,500	277,100	277,700	278,300	278,900	279,500	280,100	280,700	281,300	281,900	282,500	283,100	283,700	284,300	284,900	103
104	278,500	279,100	279,800	280,400	281,000	281,700	282,300	282,900	283,500	284,200	284,800	285,400	286,000	286,600	287,200	287,900	288,500	289,100	289,700	290,300	290,900	104
105	284,300	284,900	285,600	286,200	286,900	287,500	288,100	288,800	289,400	290,100	290,700	291,300	292,000	292,600	293,200	293,800	294,500	295,100	295,700	296,300	296,900	105
106	291,000	291,600	292,200	292,800	293,400	294,000	294,600	295,200	295,800	296,500	297,100	297,700	298,300	299,000	299,600	300,200	300,800	301,400	302,000	302,700	303,300	106
107	298,000	298,500	299,100	299,600	300,100	300,600	301,200	301,800	302,500	303,100	303,700	304,300	304,900	305,600	306,200	306,800	307,400	308,000	308,600	309,200	309,800	107
108	305,400	305,800	306,200	306,600	307,000	307,400	307,900	308,600	309,200	309,800	310,400	311,000	311,600	312,200	312,900	313,500	314,100	314,700	315,300	315,800	316,400	108
109	312,000	312,400	312,800	313,100	313,500	313,900	314,300	315,000	315,600	316,200	316,800	317,400	318,000	318,600	319,200	319,800	320,400	321,000	321,600	322,200	322,700	109
110	318,600	319,000	319,300	319,700	320,000	320,400	320,900	321,500	322,100	322,700	323,300	323,900	324,500	325,100	325,700	326,300	326,900	327,400	328,000	328,600	329,200	110
111	325,500	325,800	326,100	326,400	326,700	327,000	327,500	328,100	328,700	329,300	329,900	330,400	331,000	331,600	332,200	332,800	333,400	333,900	334,500	335,100	335,600	111
112	332,900	333,000	333,200	333,400	333,600	333,800	334,200	334,800	335,400	336,000	336,600	337,200	337,700	338,300	338,900	339,500	340,000	340,600	341,200	341,700	342,300	112
113	338,200	338,600	339,100	339,500	339,900	340,400	341,000	341,800	342,600	343,400	344,100	344,900	345,700	346,500	347,300	348,000	348,800	349,600	350,300	351,100	351,900	113
114	343,800	344,400	345,100	345,800	346,500	347,200	348,000	349,000	350,000	351,000	352,000	353,000	354,000	354,900	355,900	356,900	357,900	358,900	359,900	360,800	361,800	114
115	348,200	349,200	350,100	351,100	352,100	353,100	354,200	355,400	356,600	357,800	359,000	360,100	361,300	362,500	363,700	364,900	366,100	367,300	368,500	369,700	370,900	115
116	353,700	354,900	356,200	357,400	358,600	359,800	361,100	362,500	363,900	365,300	366,700	368,100	369,500	370,800	372,200	373,600	375,000	376,400	377,800	379,200	380,600	116
117	360,400	361,800	363,200	364,700	366,100	367,500	369,000	370,600	372,200	373,800	375,400	377,000	378,600	380,200	381,800	383,400	385,000	386,600	388,200	389,800	391,400	117
118	365,900	367,500	369,200	370,900	372,500	374,200	375,900	377,700	379,500	381,300	383,100	384,900	386,700	388,500	390,400	392,200	394,000	395,800	397,600	399,500	401,300	118
119	370,300	372,300	374,200	376,200	378,200	380,100	382,100	384,100	386,100	388,100	390,100	392,100	394,100	396,100	398,200	400,200	402,200	404,200	406,300	408,300	410,400	119

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	816.0	816.1	816.2	816.3	816.4	816.5	816.6	816.7	816.8	816.9	817.0	817.1	817.2	817.3	817.4	817.5	817.6	817.7	817.8	817.9	818.0	
26																						26
27																						27
28	36, 880	36, 930	36, 990	37, 050																		28
29	38, 610	38, 670	38, 730	38, 790																		29
30	40, 440	40, 510	40, 570	40, 630																		30
31	42, 270	42, 340	42, 410	42, 470																		31
32	44, 020	44, 090	44, 160	44, 230																		32
33	45, 850	45, 920	46, 000	46, 070																		33
34	47, 680	47, 760	47, 830	47, 910																		34
35	49, 430	49, 510	49, 590	49, 670																		35
36	50, 750	50, 830	50, 910	50, 990																		36
37	52, 500	52, 580	52, 660	52, 750																		37
38	54, 250	54, 330	54, 420	54, 510	54, 590	54, 680	54, 760															38
39	56, 080	56, 170	56, 260	56, 340	56, 430	56, 520	56, 610															39
40	57, 840	57, 930	58, 030	58, 120	58, 210	58, 300	58, 390	58, 480	58, 570	58, 670	58, 760											40
41	59, 670	59, 770	59, 860	59, 960	60, 050	60, 150	60, 240	60, 330	60, 430	60, 520	60, 620											41
42	61, 500	61, 600	61, 700	61, 790	61, 890	61, 990	62, 090	62, 190	62, 280	62, 380	62, 480	62, 570	62, 670	62, 770	62, 860	62, 960	63, 060					42
43	62, 370	62, 470	62, 570	62, 670	62, 770	62, 860	62, 960	63, 060	63, 160	63, 260	63, 360	63, 460	63, 550	63, 650	63, 750	63, 850	63, 950					43
44	63, 330	63, 430	63, 530	63, 630	63, 730	63, 830	63, 930	64, 030	64, 130	64, 240	64, 340	64, 440	64, 530	64, 630	64, 730	64, 830	64, 930					44
45	64, 290	64, 390	64, 490	64, 600	64, 700	64, 800	64, 900	65, 010	65, 110	65, 210	65, 310	65, 410	65, 520	65, 620	65, 720	65, 820	65, 920					45
46	65, 160	65, 270	65, 370	65, 480	65, 580	65, 690	65, 790	65, 890	66, 000	66, 100	66, 200	66, 310	66, 410	66, 510	66, 610	66, 720	66, 820					46
47	66, 130	66, 230	66, 340	66, 440	66, 550	66, 660	66, 760	66, 870	66, 970	67, 080	67, 180	67, 290	67, 390	67, 490	67, 600	67, 700	67, 810					47
48	67, 090	67, 190	67, 300	67, 410	67, 520	67, 620	67, 730	67, 840	67, 940	68, 050	68, 160	68, 260	68, 370	68, 480	68, 580	68, 690	68, 790					48
49	67, 960	68, 070	68, 180	68, 290	68, 400	68, 510	68, 620	68, 730	68, 830	68, 940	69, 050	69, 160	69, 260	69, 370	69, 480	69, 590	69, 690					49
50	69, 290	69, 400	69, 510	69, 620	69, 730	69, 840	69, 960	70, 070	70, 180	70, 290	70, 400	70, 510	70, 620	70, 730	70, 840	70, 950	71, 060					50
51	70, 160	70, 280	70, 390	70, 500	70, 620	70, 730	70, 840	70, 950	71, 070	71, 180	71, 290	71, 400	71, 510	71, 620	71, 730	71, 840	71, 960					51
52	71, 040	71, 160	71, 270	71, 380	71, 500	71, 610	71, 730	71, 840	71, 950	72, 070	72, 180	72, 290	72, 410	72, 520	72, 630	72, 740	72, 860	72, 970	73, 080	73, 190		52
53	72, 000	72, 120	72, 230	72, 350	72, 470	72, 580	72, 700	72, 810	72, 930	73, 040	73, 160	73, 270	73, 390	73, 500	73, 620	73, 730	73, 840	73, 960	74, 070	74, 180		53
54	72, 920	73, 040	73, 160	73, 280	73, 390	73, 510	73, 630	73, 740	73, 860	73, 980	74, 090	74, 210	74, 330	74, 440	74, 560	74, 670	74, 790	74, 900	75, 020	75, 130	75, 250	54
55	73, 880	74, 000	74, 120	74, 240	74, 360	74, 480	74, 600	74, 720	74, 830	74, 950	75, 070	75, 190	75, 310	75, 420	75, 540	75, 660	75, 780	75, 890	76, 010	76, 120	76, 240	55
56	74, 840	74, 960	75, 090	75, 210	75, 330	75, 450	75, 570	75, 690	75, 810	75, 930	76, 050	76, 170	76, 290	76, 410	76, 520	76, 640	76, 760	76, 880	77, 000	77, 120	77, 230	56
57	77, 680	77, 810	77, 940	78, 060	78, 190	78, 320	78, 440	78, 570	78, 690	78, 820	78, 940	79, 060	79, 190	79, 310	79, 440	79, 560	79, 680	79, 810	79, 930	80, 050	80, 180	57
58	80, 460	80, 590	80, 720	80, 850	80, 980	81, 110	81, 240	81, 370	81, 500	81, 630	81, 760	81, 890	82, 020	82, 150	82, 280	82, 410	82, 540	82, 660	82, 790	82, 920	83, 050	58
59	83, 230	83, 360	83, 500	83, 640	83, 770	83, 910	84, 040	84, 180	84, 310	84, 450	84, 580	84, 720	84, 850	84, 990	85, 120	85, 250	85, 390	85, 520	85, 650	85, 790	85, 920	59
60	86, 110	86, 250	86, 400	86, 540	86, 680	86, 820	86, 960	87, 100	87, 240	87, 380	87, 520	87, 660	87, 800	87, 940	88, 080	88, 220	88, 360	88, 490	88, 630	88, 770	88, 910	60
61	88, 880	89, 030	89, 180	89, 320	89, 470	89, 620	89, 760	89, 910	90, 050	90, 200	90, 340	90, 490	90, 630	90, 780	90, 920	91, 060	91, 210	91, 350	91, 490	91, 640	91, 780	61
62	91, 650	91, 810	91, 960	92, 110	92, 260	92, 410	92, 560	92, 710	92, 860	93, 010	93, 160	93, 310	93, 460	93, 610	93, 760	93, 910	94, 060	94, 210	94, 350	94, 500	94, 650	62
63	94, 540	94, 700	94, 860	95, 010	95, 170	95, 320	95, 480	95, 640	95, 790	95, 950	96, 100	96, 260	96, 410	96, 560	96, 720	96, 870	97, 030	97, 180	97, 330	97, 480	97, 640	63
64	97, 280	97, 440	97, 610	97, 770	97, 930	98, 090	98, 250	98, 410	98, 570	98, 730	98, 890	99, 050	99, 210	99, 370	99, 530	99, 690	99, 850	100, 000	100, 200	100, 300	100, 500	64
65	100, 200	100, 300	100, 500	100, 700	100, 800	101, 000	101, 200	101, 300	101, 500	101, 700	101, 800	102, 000	102, 200	102, 300	102, 500	102, 700	102, 800	103, 000	103, 100	103, 300	103, 500	65
66	103, 100	103, 200	103, 400	103, 600	103, 700	103, 900	104, 100	104, 300	104, 400	104, 600	104, 800	104, 900	105, 100	105, 300	105, 400	105, 600	105, 800	106, 000	106, 100	106, 300	106, 500	66
67	105, 800	106, 000	106, 200	106, 400	106, 500	106, 700	106, 900	107, 100	107, 200	107, 400	107, 600	107, 800	107, 900	108, 100	108, 300	108, 500	108, 600	108, 800	109, 000	109, 200	109, 300	67
68	108, 600	108, 800	109, 000	109, 100	109, 300	109, 500	109, 700	109, 900	110, 100	110, 200	110, 400	110, 600	110, 800	111, 000	111, 100	111, 300	111, 500	111, 700	111, 800	112, 000	112, 200	68
69	111, 400	111, 600	111, 700	111, 900	112, 100	112, 300	112, 500	112, 700	112, 900	113, 100	113, 200	113, 400	113, 600	113, 800	114, 000	114, 200	114, 300	114, 500	114, 700	114, 900	115, 100	69
70	114, 100	114, 300	114, 500	114, 700	114, 900	115, 100	115, 300	115, 500	115, 700	115, 900	116, 100	116, 200	116, 400	116, 600	116, 800	117, 000	117, 200	117, 400	117, 600	117, 800	117, 900	70
71	117, 600	117, 800	118, 000	118, 200	118, 400	118, 600	118, 800	119, 000	119, 200	119, 400	119, 600	119, 800	120, 000	120, 100	120, 300	120, 500	120, 700	120, 900	121, 100	121, 300	121, 500	71
72	121, 100	121, 300	121, 500	121, 700	121, 900	122, 100	122, 300	122, 500	122, 700	123, 000	123, 200	123, 400	123, 600	123, 800	124, 000	124, 200	124, 400	124, 600	124, 800	125, 000	125, 200	72
73	124, 600	124, 800	125, 100	125, 300	125, 500	125, 700	125, 900	126, 100	126, 300	126, 500	126, 800	127, 000	127, 200	127, 400	127, 600	127, 800	128, 000	128, 200	128, 400	128, 600	128, 800	73
74	128, 100	128, 400	128, 600	128, 800	129, 000	129, 300	129, 500	129, 700	129, 900	130, 100	130, 300	130, 600	130, 800	131, 000	131, 200	131, 400	131, 600	131, 900	132, 100	132, 300	132, 500	74
75	131, 700	131, 900	132, 100	132, 400	132, 600	132, 800	133, 000	133, 300	133, 500	133, 700	133, 900	134, 200	134, 400	134, 600	134, 800	135, 100	135, 300	135, 500	135, 700	136, 000	136, 200	75
76	135, 200	135, 400	135, 700	135, 900	136, 100	136, 400	136, 600	136, 800	137, 100	137, 300	137, 500	137, 800	138, 000	138, 200	138, 500	138, 700	138, 900	139, 200	139, 400	139, 600	139, 800	76
77	138, 700	139, 000	139, 200	139, 400	139, 700	139, 900	140, 200	140, 400	140, 700	140, 900	141, 100	141, 400	141, 600	141, 800	142, 100	142, 300	142, 600	142, 800	143, 000	143, 300	143, 500	77
78	142, 200	142, 400	142, 600	142, 900	143, 100	143, 400	143, 600	143, 900	144, 100	144, 400	144, 600	144, 900	145, 100	145, 400	145, 600	145, 900	146, 100	146, 300	146, 600	146, 800	147, 100	78
79	145, 700	145, 900	146, 200	146, 400	146, 700	146, 900	147, 200	147, 500	147, 700	148, 000	148, 200	148, 500	148, 700	149, 000	149, 200	149, 500	149, 700	150, 000	150, 200	150, 500	150, 700	79
80	149, 200	149, 500	149, 700	150, 000	150, 200	150, 500	150, 800	151, 000	151, 300	151, 500	151, 800	152, 100	152, 300	152, 600	152, 800	153, 100	153, 400	153, 600	153, 900	154, 100	154, 400	80
81	152, 700	153, 000	153, 300	153, 500	153, 800	154, 100	154, 300	154, 600	154, 900	155, 100	155, 400	155, 700	155, 900	156, 200	156, 500	156, 700	157, 000	157, 300	157, 500	157, 800	158, 000	81
82	156, 200	156, 500	156, 800	157, 100	157, 400	157, 600	157, 900	158, 200	158, 500	158, 700	159, 000	159, 300	159, 500	159, 800	160, 100	160, 400	160, 600	160, 900	161, 200	161, 400	161, 700	82
83	159, 800	160, 100	160, 300	160, 600	160, 900	161, 200	161, 500	161, 800	162, 000	162, 300	162, 600	162, 900	163, 200	163, 400	163, 700	164, 000	164, 300	164, 600	164, 800	165, 100	165, 400	83
84	163, 300	163, 600	163, 900	164, 200	164, 500	164, 800	165, 000	165, 300	165, 600	165, 900	166, 200	166, 500	166, 800	167, 100	167, 300	167, 600	167, 900	168, 200	168, 500	168, 800	169, 000	84
85	170, 000	170, 300	170, 600	170, 900	171, 200	171, 500	171, 800	172, 100	172, 400	172, 700	173, 000	173, 300	173, 600	173, 900	174, 200	174, 500	174, 800	175, 100	175, 400	175, 700	176, 000	85

See special instruction for preventing gate overflow on page 2.

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	816.0	816.1	816.2	816.3	816.4	816.5	816.6	816.7	816.8	816.9	817.0	817.1	817.2	817.3	817.4	817.5	817.6	817.7	817.8	817.9	818.0	
86	176,800	177,100	177,400	177,700	178,100	178,400	178,700	179,000	179,300	179,700	180,000	180,300	180,600	180,900	181,200	181,600	181,900	182,200	182,500	182,800	183,100	86
87	183,500	183,900	184,200	184,500	184,900	185,200	185,600	185,900	186,200	186,600	186,900	187,200	187,600	187,900	188,200	188,600	188,900	189,200	189,500	189,900	190,200	87
88	190,200	190,600	190,900	191,300	191,700	192,000	192,400	192,700	193,100	193,400	193,800	194,100	194,400	194,800	195,100	195,500	195,800	196,200	196,500	196,900	197,200	88
89	197,100	197,400	197,800	198,200	198,600	198,900	199,300	199,700	200,000	200,400	200,700	201,100	201,500	201,800	202,200	202,600	202,900	203,300	203,600	204,000	204,300	89
90	203,800	204,200	204,600	205,000	205,400	205,700	206,100	206,500	206,900	207,300	207,600	208,000	208,400	208,800	209,100	209,500	209,900	210,300	210,600	211,000	211,400	90
91	210,600	211,000	211,400	211,800	212,200	212,600	213,000	213,400	213,800	214,200	214,600	214,900	215,300	215,700	216,100	216,500	216,900	217,300	217,700	218,100	218,500	91
92	216,800	217,200	217,600	218,000	218,500	218,900	219,300	219,700	220,100	220,500	220,900	221,300	221,800	222,200	222,600	223,000	223,400	223,800	224,200	224,600	225,000	92
93	223,200	223,600	224,000	224,500	224,900	225,300	225,800	226,200	226,600	227,000	227,500	227,900	228,300	228,700	229,200	229,600	230,000	230,400	230,800	231,300	231,700	93
94	229,500	229,900	230,400	230,800	231,300	231,700	232,200	232,600	233,000	233,500	233,900	234,400	234,800	235,300	235,700	236,100	236,600	237,000	237,400	237,900	238,300	94
95	235,700	236,200	236,600	237,100	237,600	238,000	238,500	239,000	239,400	239,900	240,300	240,800	241,200	241,700	242,200	242,600	243,100	243,500	244,000	244,400	244,900	95
96	242,100	242,600	243,100	243,600	244,100	244,500	245,000	245,500	246,000	246,500	246,900	247,400	247,900	248,400	248,800	249,300	249,800	250,200	250,700	251,200	251,600	96
97	248,500	249,000	249,500	250,000	250,500	251,000	251,500	251,900	252,400	252,900	253,400	253,900	254,400	254,900	255,400	255,900	256,400	256,800	257,300	257,800	258,300	97
98	254,800	255,300	255,800	256,300	256,800	257,300	257,900	258,400	258,900	259,400	259,900	260,400	260,900	261,400	261,900	262,400	262,900	263,400	263,900	264,400	264,900	98
99	260,700	261,200	261,700	262,300	262,800	263,300	263,800	264,400	264,900	265,400	265,900	266,500	267,000	267,500	268,000	268,500	269,100	269,600	270,100	270,600	271,100	99
100	266,800	267,300	267,900	268,400	268,900	269,500	270,000	270,600	271,100	271,600	272,200	272,700	273,200	273,800	274,300	274,800	275,400	275,900	276,400	277,000	277,500	100
101	272,800	273,400	273,900	274,500	275,000	275,600	276,200	276,700	277,300	277,800	278,400	278,900	279,500	280,000	280,500	281,100	281,600	282,200	282,700	283,300	283,800	101
102	278,700	279,300	279,900	280,500	281,000	281,600	282,200	282,700	283,300	283,800	284,400	285,000	285,500	286,100	286,600	287,200	287,800	288,300	288,900	289,400	290,000	102
103	284,900	285,400	286,000	286,600	287,200	287,800	288,400	288,900	289,500	290,100	290,700	291,300	291,800	292,400	293,000	293,600	294,100	294,700	295,300	295,900	296,400	103
104	290,900	291,500	292,100	292,700	293,300	293,900	294,500	295,100	295,700	296,300	296,900	297,400	298,000	298,600	299,200	299,800	300,400	301,000	301,600	302,200	302,700	104
105	296,900	297,600	298,200	298,800	299,400	300,000	300,600	301,200	301,800	302,400	303,000	303,600	304,200	304,800	305,400	306,100	306,700	307,300	307,900	308,500	309,100	105
106	303,300	303,900	304,500	305,100	305,700	306,300	306,900	307,500	308,100	308,700	309,300	309,900	310,500	311,100	311,700	312,300	312,900	313,500	314,200	314,800	315,400	106
107	309,800	310,400	311,000	311,600	312,200	312,800	313,400	314,000	314,600	315,200	315,800	316,400	317,000	317,600	318,200	318,800	319,400	320,000	320,700	321,300	321,900	107
108	316,400	317,000	317,600	318,200	318,800	319,400	320,000	320,600	321,200	321,800	322,300	322,900	323,500	324,100	324,700	325,300	325,900	326,500	327,200	327,800	328,400	108
109	322,700	323,300	323,900	324,500	325,100	325,600	326,200	326,800	327,400	328,000	328,600	329,200	329,800	330,400	331,000	331,600	332,200	332,800	333,500	334,100	334,700	109
110	329,200	329,700	330,300	330,900	331,400	332,000	332,600	333,200	333,800	334,400	335,000	335,600	336,200	336,800	337,400	338,000	338,700	339,300	340,000	340,600	341,300	110
111	335,600	336,200	336,800	337,300	337,900	338,400	339,000	339,600	340,200	340,800	341,400	342,000	342,700	343,300	343,900	344,500	345,100	345,700	346,400	347,100	347,700	111
112	342,300	342,800	343,400	343,900	344,500	345,000	345,600	346,200	346,800	347,400	348,000	348,600	349,200	349,800	350,400	350,900	351,600	352,200	352,900	353,600	354,200	112
113	351,900	352,600	353,400	354,200	354,900	355,700	356,400	357,300	358,100	358,900	359,700	360,500	361,300	362,100	362,900	363,700	364,500	365,400	366,200	367,100	368,000	113
114	361,800	362,800	363,800	364,800	365,700	366,700	367,700	368,700	369,700	370,700	371,800	372,800	373,800	374,800	375,800	376,900	377,900	379,000	380,100	381,100	382,200	114
115	370,900	372,100	373,300	374,500	375,700	376,800	378,100	379,300	380,500	381,800	383,000	384,300	385,500	386,700	388,000	389,200	390,500	391,800	393,100	394,400	395,700	115
116	380,600	382,000	383,400	384,800	386,200	387,600	389,100	390,500	391,900	393,400	394,800	396,300	397,700	399,200	400,600	402,100	403,600	405,100	406,600	408,100	409,500	116
117	391,400	393,100	394,700	396,300	397,900	399,600	401,200	402,800	404,500	406,100	407,800	409,400	411,100	412,800	414,400	416,100	417,800	419,500	421,200	422,900	424,600	117
118	401,300	403,100	405,000	406,800	408,700	410,500	412,400	414,200	416,100	418,000	419,800	421,700	423,600	425,400	427,300	429,200	431,100	433,000	434,900	436,800	438,800	118
119	410,400	412,400	414,500	416,500	418,600	420,700	422,700	424,800	426,900	429,000	431,100	433,200	435,300	437,400	439,500	441,600	443,700	445,800	447,900	450,100	452,200	119

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	818.0	818.1	818.2	818.3	818.4	818.5	818.6	818.7	818.8	818.9	819.0	819.1	819.2	819.3	819.4	819.5	819.6	819.7	819.8	819.9	820.0	
51																						51
52																						52
53																						53
54	75, 250	75, 360	75, 480	75, 590																		54
55	76, 240	76, 360	76, 470	76, 590																		55
56	77, 230	77, 350	77, 470	77, 590																		56
57	80, 180	80, 300	80, 420	80, 540																		57
58	83, 050	83, 170	83, 300	83, 430																		58
59	85, 920	86, 050	86, 180	86, 320																		59
60	88, 910	89, 040	89, 180	89, 320																		60
61	91, 780	91, 920	92, 060	92, 200																		61
62	94, 650	94, 800	94, 940	95, 090																		62
63	97, 640	97, 790	97, 940	98, 090																		63
64	100, 500	100, 600	100, 800	100, 900																		64
65	103, 500	103, 600	103, 800	104, 000																		65
66	106, 500	106, 600	106, 800	107, 000	107, 100	107, 300																66
67	109, 300	109, 500	109, 700	109, 800	110, 000	110, 200																67
68	112, 200	112, 400	112, 600	112, 700	112, 900	113, 100	113, 300	113, 400	113, 600	113, 800												68
69	115, 100	115, 300	115, 400	115, 600	115, 800	116, 000	116, 200	116, 300	116, 500	116, 700												69
70	117, 900	118, 100	118, 300	118, 500	118, 700	118, 900	119, 100	119, 200	119, 400	119, 600	119, 800	120, 000	120, 200	120, 300	120, 500	120, 700	120, 900	121, 100	121, 300	121, 400	121, 600	70
71	121, 500	121, 700	121, 900	122, 100	122, 300	122, 500	122, 700	122, 900	123, 000	123, 200	123, 400	123, 600	123, 800	124, 000	124, 200	124, 400	124, 600	124, 800	124, 900	125, 100	125, 300	71
72	125, 200	125, 400	125, 600	125, 800	126, 000	126, 200	126, 400	126, 600	126, 800	127, 000	127, 200	127, 400	127, 600	127, 800	128, 000	128, 100	128, 300	128, 500	128, 700	128, 900	129, 100	72
73	128, 800	129, 100	129, 300	129, 500	129, 700	129, 900	130, 100	130, 300	130, 500	130, 700	130, 900	131, 100	131, 300	131, 500	131, 700	131, 900	132, 100	132, 300	132, 500	132, 700	132, 900	73
74	132, 500	132, 700	132, 900	133, 100	133, 400	133, 600	133, 800	134, 000	134, 200	134, 400	134, 600	134, 800	135, 000	135, 300	135, 500	135, 700	135, 900	136, 100	136, 300	136, 500	136, 700	74
75	136, 200	136, 400	136, 600	136, 800	137, 100	137, 300	137, 500	137, 700	137, 900	138, 100	138, 400	138, 600	138, 800	139, 000	139, 200	139, 400	139, 700	139, 900	140, 100	140, 300	140, 500	75
76	139, 800	140, 100	140, 300	140, 500	140, 800	141, 000	141, 200	141, 400	141, 700	141, 900	142, 100	142, 300	142, 600	142, 800	143, 000	143, 200	143, 400	143, 700	143, 900	144, 100	144, 300	76
77	143, 500	143, 700	144, 000	144, 200	144, 400	144, 700	144, 900	145, 100	145, 400	145, 600	145, 800	146, 100	146, 300	146, 500	146, 700	147, 000	147, 200	147, 400	147, 700	147, 900	148, 100	77
78	147, 100	147, 300	147, 500	147, 800	148, 000	148, 300	148, 500	148, 700	149, 000	149, 200	149, 500	149, 700	149, 900	150, 200	150, 400	150, 600	150, 900	151, 100	151, 300	151, 600	151, 800	78
79	150, 700	151, 000	151, 200	151, 500	151, 700	152, 000	152, 200	152, 400	152, 700	152, 900	153, 200	153, 400	153, 700	153, 900	154, 200	154, 400	154, 600	154, 900	155, 100	155, 400	155, 600	79
80	154, 400	154, 600	154, 900	155, 100	155, 400	155, 600	155, 900	156, 200	156, 400	156, 700	156, 900	157, 200	157, 400	157, 700	157, 900	158, 200	158, 400	158, 700	158, 900	159, 100	159, 400	80
81	158, 000	158, 300	158, 600	158, 800	159, 100	159, 300	159, 600	159, 900	160, 100	160, 400	160, 600	160, 900	161, 200	161, 400	161, 700	161, 900	162, 200	162, 400	162, 700	162, 900	163, 200	81
82	161, 700	162, 000	162, 200	162, 500	162, 800	163, 000	163, 300	163, 600	163, 800	164, 100	164, 400	164, 600	164, 900	165, 200	165, 400	165, 700	166, 000	166, 200	166, 500	166, 700	167, 000	82
83	165, 400	165, 700	165, 900	166, 200	166, 500	166, 800	167, 000	167, 300	167, 600	167, 800	168, 100	168, 400	168, 700	168, 900	169, 200	169, 500	169, 700	170, 000	170, 300	170, 500	170, 800	83
84	169, 000	169, 300	169, 600	169, 900	170, 200	170, 500	170, 700	171, 000	171, 300	171, 600	171, 900	172, 100	172, 400	172, 700	173, 000	173, 200	173, 500	173, 800	174, 100	174, 300	174, 600	84
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86	183, 100	183, 400	183, 800	184, 100	184, 400	184, 700	185, 000	185, 300	185, 600	185, 900	186, 200	186, 500	186, 800	187, 100	187, 500	187, 800	188, 100	188, 400	188, 700	189, 000	189, 300	86
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92	225, 000	225, 400	225, 800	226, 200	226, 600	227, 000	227, 400	227, 800	228, 200	228, 600	229, 000	229, 400	229, 800	230, 200	230, 600	231, 000	231, 300	231, 700	232, 100	232, 500	232, 900	92
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96	251, 600	252, 100	252, 600	253, 000	253, 500	254, 000	254, 400	254, 900	255, 300	255, 800	256, 200	256, 700	257, 200	257, 600	258, 100	258, 500	259, 000	259, 400	259, 900	260, 300	260, 800	96
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103	296, 400	297, 000	297, 600	298, 100	298, 700	299, 300	299, 900	300, 400	301, 000	301, 600	302, 200	302, 700	303, 300	303, 900	304, 400	305, 000	305, 600	306, 100	306, 700	307, 300	307, 800	103
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110	341, 300	341, 900	342, 600	343, 200	343, 800	344, 500	345, 100	345, 800	346, 400	347, 000	347, 700	348, 300	348, 900	349, 600	350, 200	350, 800	351, 500	352, 100	352, 700	353, 300	353, 900	110

See special instruction for preventing gate overflow on page 2.

FORT LOUDOUN DAM
SPILLWAY DISCHARGE
IN CUBIC FEET PER SECOND

GATE ARRANGE-MENT	HEADWATER ELEVATION																					GATE ARRANGE-MENT
	818.0	818.1	818.2	818.3	818.4	818.5	818.6	818.7	818.8	818.9	819.0	819.1	819.2	819.3	819.4	819.5	819.6	819.7	819.8	819.9	820.0	
111	347,700	348,400	349,000	349,700	350,300	351,000	351,600	352,300	352,900	353,600	354,200	354,800	355,500	356,100	356,700	357,400	358,000	358,600	359,300	359,900	360,500	111
112	354,200	354,900	355,600	356,200	356,900	357,500	358,200	358,900	359,500	360,200	360,800	361,400	362,100	362,700	363,400	364,000	364,600	365,300	365,900	366,500	367,200	112
113	368,000	368,900	369,700	370,600	371,500	372,300	373,200	374,000	374,900	375,800	376,600	377,500	378,300	379,200	380,000	380,900	381,700	382,600	383,400	384,300	385,100	113
114	382,200	383,300	384,400	385,500	386,600	387,600	388,700	389,800	390,900	392,000	393,000	394,100	395,200	396,300	397,300	398,400	399,500	400,600	401,700	402,700	403,800	114
115	395,700	397,000	398,300	399,600	400,800	402,100	403,400	404,700	406,000	407,300	408,600	409,900	411,200	412,500	413,800	415,100	416,400	417,700	419,000	420,300	421,600	115
116	409,500	411,000	412,500	414,000	415,500	417,000	418,600	420,100	421,600	423,100	424,600	426,100	427,600	429,100	430,600	432,200	433,700	435,200	436,700	438,200	439,800	116
117	424,600	426,300	428,000	429,700	431,400	433,200	434,900	436,600	438,300	440,100	441,800	443,500	445,300	447,000	448,800	450,500	452,200	454,000	455,700	457,500	459,200	117
118	438,800	440,700	442,600	444,500	446,500	448,400	450,400	452,300	454,200	456,200	458,100	460,100	462,100	464,000	466,000	468,000	469,900	471,700	473,500	475,300	477,100	118
119	452,200	454,300	456,500	458,600	460,800	462,900	465,100	467,200	469,400	471,600	473,700	475,900	478,100	480,300	482,500	484,700	486,800	488,800	490,900	492,900	494,900	119

3. Free earth support analyses which compensate for toe fixity by including a bending moment reduction factor are liable to be misleading; fixed earth support methods should always be used.

4. Design analyses should be suitable for practical design use. In view of the approximations involved in "idealizing" geologic sections and assessing soil properties, design computations should not depend on arithmetical accuracy to several decimal places.

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RATING CURVES FOR FLOW OVER DRUM GATES

By Joseph N. Bradley,[1] A. M. ASCE

With Discussion by Messrs. Guido Wyss; Sam Shulits; Bob Buehler; F. B. Campbell and A. A. McCool; and Joseph N. Bradley

Synopsis

With water becoming more valuable in the western states each year, there is an increasing demand for better methods of measurement and additional rating structures. This condition applies not only to the requirements for main canals and laterals of irrigation works but also to the regulation and measurement of flow at dams. In fact, the need has reached the point at which operators are desirous of metering the flow at nearly all control devices in irrigation systems, and in other water supply or control systems.

The primary purpose of this paper is to point out that there are numerous control structures in existence that will serve a dual purpose—that of a metering station as well as that of a regulating device. Examples of such structures include spillways, with or without gates; outlet works for dams using gates or valves; and canal regulating structures using gates. With the accumulation of information from hydraulic model studies made by the Bureau of Reclamation (USBR), United States Department of the Interior, it is now possible to prepare reasonably accurate rating curves for many such structures without the construction of models and without access to the prototypes. The method is especially useful for the rating of existing structures. This paper describes the method as it applies to the rating of drum gates and the paper is concluded with an engineering example. The method is also applicable to the rating of the Volet gate used in France, the bascule gate manufactured in the United States, and others in which the sector of a circle is hinged at or near the crest of a spillway.

Note.—Published, essentially as printed here, in February, 1953, as *Proceedings-Separate No. 169*. Positions and titles given are those in effect when the paper or discussion was received for publication.

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Introduction

The drum gate is a type of gate that floats in a chamber and is buoyed into position by regulating the water level in that chamber. A medium-sized gate of this type is shown in Fig. 1. To use drum gates as metering devices, it is essential that each gate be equipped with an accurate position indicator. This indicator may consist of an arm or pointer connected directly to one of the gate pins, and is usually located inside an adjacent pier. The scale, which commonly indicates "position of high point of gate," may be a cast-metal arc mounted on the wall under the pointer, or a scale painted on the wall.

This paper presents a method of computing rating curves for all positions of the gate with an accuracy comparable to that which can be obtained from an average current-meter traverse of the river. The information required for rating a drum gate consists of the over-all dimensions of the gate and overflow crest, the information contained in this paper, and the coefficient of discharge

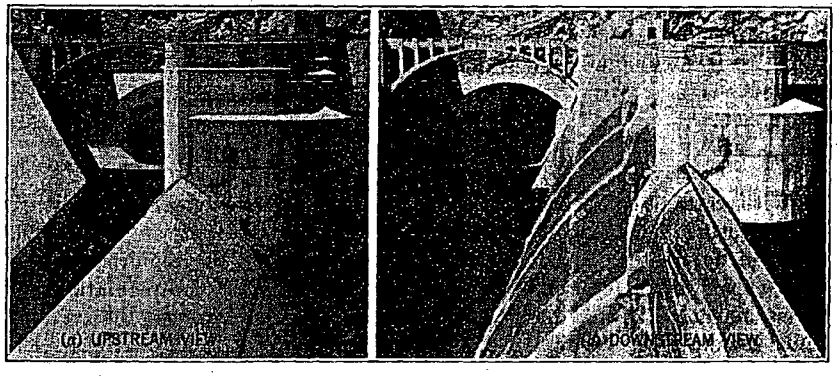


Fig. 1.—Drum Gate, 100 Ft by 16 Ft, at Hoover Dam (Arizona-Nevada)

for any appreciable head on the spillway with the gate in the completely lowered position. Should the coefficient data be lacking, the coefficient of discharge for the designed head can be estimated for nearly any overflow section by a method previously published.[2]

The method of rating described here is not intended to replace the measurements taken at river gaging stations. However, it has the following advantages: (1) The gates can be set in a few minutes to pass a desired discharge and (2) in time of flood, the gaging station may be out of order but the gate calibration is as accurate as usual. The flood that passed over Grand Coulee Dam (Washington) in 1948 is an example. The river gage, in the pier of a bridge downstream, was in error because of a drawdown in the water surface, adjacent to the pier, at the higher flows. Current-meter measurements were also attempted during the flood, but the swiftness of the current and other difficulties rendered these only partially successful. As a result, the discharge at the peak of the flood, which was finally estimated as 638,000

[2] "Discha[illegible]efficients for Irregular Overfall Spillway Sections," by J. N. Bradley, *Engineering Monograph N*[illegible] Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo., March, 1952.

sec-ft, is questionable. Measurement of the flow over the drum gates, which is now possible, would have afforded a continuous record and one that would be as accurate for floods as for normal flows.

Characteristics of the Drum Gate

As a measuring device, the drum gate resembles a sharp-crested weir with a curved upstream face over the greater part of its travel. With an adequate positioning indicator, the drum gate can serve as a very satisfactory metering device.

When the drum gate simulates a sharp-crested weir—that is, when a line drawn tangent to the downstream lip of the gate makes a positive angle with the horizontal, as in Fig. 2(*a*), four principal factors are involved. These factors are H, the total head above the high point of the gate; θ, the angle made by a line drawn tangent to the downstream lip of the gate and the horizontal; r, the radius of the gate or an equivalent radius, should the curvature of the

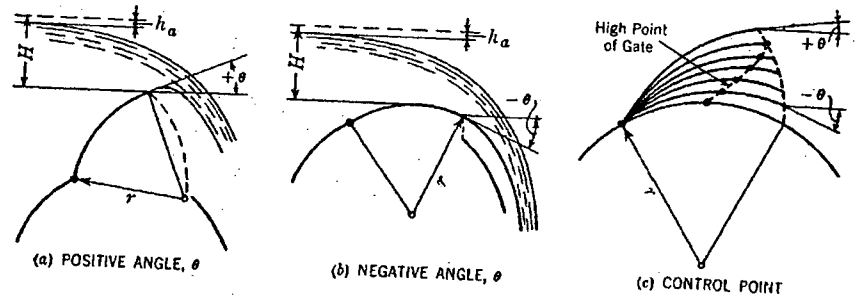


Fig. 2.—Drum-Gate Positions

gate involve a parabola; and C_q, the coefficient of discharge in $Q = C_q L H^{\frac{3}{2}}$, in which Q is the discharge in second-feet, and L is the length of the gate.

The depth of approach was not included as a variable because drum-gate installations studied were for medium and high dams at which approach effects were negligible. When the approach depth, measured below the high point of the gate, is equal to or greater than twice the head on the gate, it has been shown[3] that a further increase in approach depth produces very little increase in the coefficient of discharge. Most drum-gate installations satisfy this condition, especially when the gate is in a raised position. Therefore, with adequate approach depth the four variables H, θ, r, and C_q completely define the flow over this type of gate for positive angles of θ, Fig. 2(*a*).

For negative values of θ, Fig. 2(*b*), the downstream lip of the gate no longer controls the flow. Rather, the control point shifts upstream to the vicinity of the high point of the gate for each setting as illustrated in Fig. 2(*c*), and flow conditions gradually approach those of the free crest (as the gate is lowered). Although other factors enter the problem, the similitude also holds for this case down to an angle of approximately $-15°$.

[3] "Studies of Crests for Overfall Dams," *Bulletin No. 3*, Pt. VI, Boulder Canyon Final Reports, Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo., 1948.

Sources of Information

The data for this drum-gate study were obtained from hydraulic models of various sizes and scales. The experiments were performed over a period of about eighteen years. The spillway drum gates tested, the principal dimensions of each, the model scale, the laboratory where the tests were conducted, and other information are given in Table 1. Gates for the first three dams

TABLE 1.—Principal Dimensions of Drum Gates Tested

Dam	No. of gates	Length of gate, in ft	Height of gate, in ft	Radius of gate, in ft	Approach depth, in ft	Maximum head on crest,[a] in ft	Model scale	Hydraulic laboratory
Grand Coulee (Washington)	11	135	28	66.25	360	31.65	1:30	Fort Collins (Colo.)
Bhakra (India)	2	135	28	66.25	410	28	1:80	Customhouse (Denver, Colo.)
Shasta (California)	3	110	28	66.25	460	28	1:68	Customhouse
Hamilton (Texas)	1	300	28	74.17	50	32	1:30	Fort Collins
Hoover, Shape 4-M3[b] (Ariz.-Nev.)	4	100	16	26.8	50	26.6	1:20	Montrose, Colo.
Hoover, Shape 8-M5[b] (Ariz.-Nev.)	4	100	16	36.0	50	26.6	1:20	Montrose
Hoover, Shape 7-C4[b] (Ariz.-Nev.)	4	100	16	26.0	50	26.6	1:60	Fort Collins
Friant (California)	3	100	18	47.0	140	19.0	1:25	Fort Collins
Norris (Tennessee)	3	100	14	34.0	200	27.0	1:72	Fort Collins
Madden (Canal Zone)	4	100	18	30.0	120	30.0	1:72	Fort Collins
Capilano (British Columbia)	1	70	23	71.0	200	23.0	1:60	Denver Federal Center

[a] Gate down. [b] Refers to the shape of the spillway cross section.

listed in the table—Grand Coulee Dam (Washington), Bhakra Dam (India), and Shasta Dam (California)—are identical except for the length and number. The models of each were tested at different times by different personnel. The results of the tests are nearly identical, which fact indicates the consistency possible in this type of test. Although identical gates are of value in indicating the consistency of results, test results on dissimilar gates are desirable because they can give assurance that all factors involved in the establishment of similitude have been considered. The study includes only eleven gates (Table 1), but the dimensions of these vary over a fairly wide range, and the consistency indicated in compiling the results was quite satisfactory.

Cross sections of representative examples of the spillway overflow sections and drum gates listed in Table 1 are shown in Fig. 3. For Hoover Dam, Shape 4-M3 is shown. The data relating the coefficient, C_q, to the head for the model drum gates tested are tabulated in Table 2.

Results of Bazin on Straight Inclined Weirs

The straight inclined weir is comparable to a drum gate, having infinite radius, thus the results of Bazin serve as an introduction to this study.

Bazin, in his classical experiments, studied inclined sharp-crested weirs.[4] The angle of the weir was varied in increments from 14° to 90° with the horizontal, and each weir was 3.7 ft high (vertical dimension). The head on the crest of the weirs ranged from 0.32 ft to 1.48 ft. The results, presented in Fig. 4, show θ plotted against the Bazin coefficient, C_b (in the formula, $Q = C_b L h \sqrt{2 g h}$), in which h does not include the velocity head of approach (h_a). The

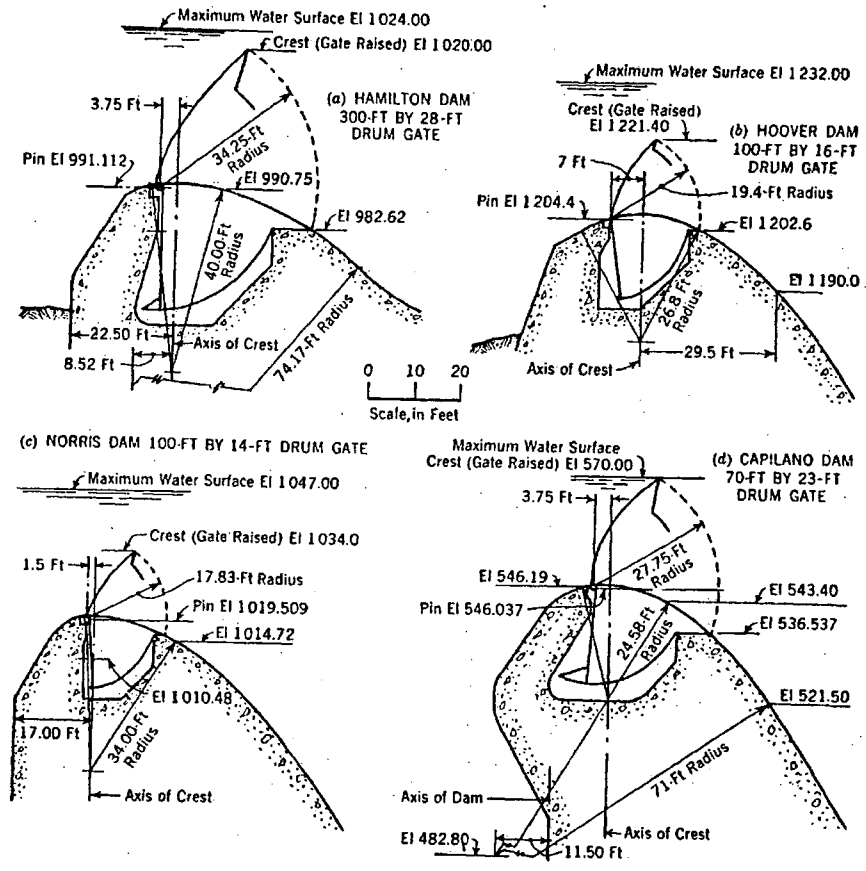


Fig. 3.—Examples of Drum-Gate Cross Sections

angle θ is also plotted with respect to C_q (in the expression, $Q = C_q L H^{\frac{3}{2}}$) in which H is the total head. This latter expression will be used throughout the paper.

By reference to Fig. 4 it can be observed (1) that the coefficient, C_q, varies only slightly with the observed head on the weir, (2) that there is a rather

[4] "Recent Experiments on the Flow of Water over Weirs," by H. Bazin, *Annales des Ponts et Chaussées*, October, 1888. (Translation by Arthur Marichal and John C. Trautwine, Jr., *Proceedings*, Engineers' Club of Philadelphia, Pa., Vol. IX, No. 4, 1892, p. 316.)

TABLE 2.—Drum-Gate Coefficients[a]

Grand Coulee Dam (Washington)		Bhakra Dam (India)		Shasta Dam (California)		Hamilton Dam (Texas)	
Reservoir elevation, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e	Total head on gate, in feet	Coefficient, C_e
Gate Elevation[b] 1260.0		Gate Elevation[b] 1552.0		Gate Elevation[b] 1037.0		Gate Elevation[b] 992.0	
1295	3.920	1580	3.680	1075	3.895	35	3.710
1290	3.842	1575	3.645	1070	3.835	30	3.645
1285	3.745	1570	3.550	1065	3.760	25	3.580
1280	3.635	1565	3.420	1060	3.675	20	3.500
1275	3.510	1560	3.275	1055	3.575	15	3.400
1270	3.352	1555	3.120	1050	3.465	10	3.290
1265	3.220			1045	3.335	5	3.160
Gate Elevation 1263.51		Gate Elevation 1557.0		Gate Elevation 1039.0		Gate Elevation 995.52	
1295	3.530	1580	3.430	1075	3.637	30	3.400
1290	3.442	1575	3.380	1070	3.565	25	3.310
1285	3.360	1570	3.295	1065	3.490	20	3.223
1280	3.280	1565	3.170	1060	3.417	15	3.150
1275	3.220	1560	3.040	1055	3.340	10	3.085
1270	3.182			1050	3.250	5	3.010
Gate Elevation 1267.02		Gate Elevation 1562.0		Gate Elevation 1041.0		Gate Elevation 999.0	
1295	3.530	1580	3.550	1075	3.550	25	3.450
1290	3.457	1576	3.355	1070	3.494	20	3.390
1285	3.380	1572	3.290	1065	3.432	15	3.300
1280	3.300	1568	3.345	1060	3.365	10	3.195
1275	3.213	1564	3.465	1055	3.290	5	3.080
1270	3.120						
Gate Elevation 1270.48		Gate Elevation 1567.0		Gate Elevation 1045.0		Gate Elevation 1006.0	
1295	3.600	1580	3.665	1075	3.637	18	3.640
1290	3.530	1577	3.650	1070	3.565	15	3.635
1285	3.462	1573	3.600	1065	3.490	12	3.605
1280	3.410	1570	3.535	1060	3.415	9	3.560
1275	3.375			1055	3.330	6	3.505
				1050	3.220		
Gate Elevation 1274.01		Gate Elevation 1572.0		Gate Elevation 1050.0		Gate Elevation 1013.0	
1300	3.725	1580	3.780	1075	3.717	12	3.718
1295	3.695	1579	3.755	1070	3.670	10	3.690
1290	3.662	1578	3.690	1065	3.615	8	3.645
1285	3.630	1577	3.500	1060	3.560	6	3.595
1280	3.600	1576	3.150	1055	3.495	4	3.530
Gate Elevation 1277.50				Gate Elevation 1055.0		Gate Elevation 1020.0	
1295	3.750			1075	3.854	6	3.630
1290	3.738			1070	3.827	5	3.610
1285	3.740			1065	3.800	4	3.540
1280	3.765			1060	3.780	3.5	3.400
				1055	3.763		
Gate Elevation 1281.02				Gate Elevation 1060.0			
1295	3.730			1075	3.645		
1292	3.708			1072	3.683		
1288	3.705			1069	3.740		
1285	3.725			1066	3.815		
				1063	3.920		
Gate Elevation 1284.50				Gate Elevation 1065.0			
1300	3.840			1076	3.810		
1296	3.830			1074	3.865		
1292	3.875			1072	3.910		
1288	3.950			1070	3.950		
Gate Elevation 1288.0							
1296	3.750						
1294	3.720						
1292	3.670						
1290	3.580						

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

TABLE 2.[a]—(*Continued*)

Friant Dam (California)		Norris Dam (Tennessee)		Madden Dam (Canal Zone)		Capilano Dam (British Columbia)	
Reservoir elevation, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e	Total head on gate, in feet	Coefficient, C_e	Reservoir elevation, in feet	Coefficient, C_e
Gate Elevation[b] 560.0		Gate Elevation[b] 1020.0		Gate Elevation[b] 232.0		Gate Elevation[b] 547.0	
580	3.650	1055	3.915	35	3.900	580	3.775
577	3.625	1050	3.845	30	3.770	575	3.705
574	3.550	1045	3.765	25	3.660	570	3.625
571	3.460	1040	3.670	20	3.560	565	3.530
568	3.340	1035	3.550	15	3.460	560	3.415
565	3.175	1030	3.390	10	3.365	555	3.250
562	2.965	1025	3.125	5	3.280		
Gate Elevation 561.5		Gate Elevation 1022.0		Gate Elevation 236.0		Gate Elevation 555.4	
580	3.340	1055	3.785	30	3.810	580	3.615
577	3.300	1050	3.725	25	3.750	577	3.580
574	3.250	1045	3.655	20	3.675	574	3.540
571	3.200	1040	3.570	15	3.590	571	3.485
568	3.125	1035	3.460	10	3.500	568	3.420
564	2.950	1030	3.300	5	3.410	565	3.320
		1025	3.000				
Gate Elevation 563.0		Gate Elevation 1024.0		Gate Elevation 240.0		Gate Elevation 561.1	
580	3.320	1055	3.760	30	3.960	583	3.560
577	3.280	1050	3.720	25	3.890	580	3.530
574	3.240	1045	3.670	20	3.835	577	3.490
571	3.175	1040	3.605	15	3.800	574	3.435
568	3.080	1035	3.520	10	3.775	571	3.355
565	2.960	1030	3.380	5	3.740	568	3.130
		1025	3.000				
Gate Elevation 566.0		Gate Elevation 1026.0		Gate Elevation 245.0		Gate Elevation 568.5	
580	3.450	1055	3.835	25	3.900	583	3.785
577	3.410	1050	3.810	20	3.900	580	3.850
574	3.340	1045	3.780	15	3.890	577	3.890
571	3.240	1040	3.740	10	3.910	574	3.925
568	3.085	1035	3.685	5	3.935		
		1030	3.580				
Gate Elevation 569.0		Gate Elevation 1028.0		Gate Elevation 250.0			
580	3.625	1055	3.890	20	3.750		
578	3.605	1050	3.880	15	3.780		
576	3.575	1045	3.865	10	3.860		
574	3.550	1040	3.845	5	3.980		
572	3.500	1035	3.815				
570	3.400	1030	3.745				
Gate Elevation 572.0		Gate Elevation 1030.0					
580	3.725	1055	3.890				
578	3.720	1050	3.890				
576	3.680	1045	3.885				
574	3.620	1040	3.880				
		1035	3.875				
Gate Elevation 573.0		Gate Elevation 1032.0					
580	3.760	1055	3.870				
578	3.760	1050	3.875				
576	3.765	1045	3.880				
575	3.780	1040	3.895				
574	3.900	1035	3.920				
Gate Elevation 575.0		Gate Elevation 1034.0					
580	3.780	1055	3.815				
578	3.790	1050	3.835				
577	3.840	1045	3.855				
576	3.950	1040	3.885				
		1036	3.945				

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

TABLE 2.[a]—(*Continued*)

Hoover Dam (Arizona-Nevada) Shape 4-M3		Hoover Dam (Arizona-Nevada) Shape 8-M5		Hoover Dam (Arizona-Nevada) Shape 7-C4	
Total head on gate, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q	Total head on gate, in feet	Coefficient, C_q
Gate Elevation[b] 1205.4		Gate Elevation[b] 1205.4		Gate Elevation[b] 1205.4	
26	3.670	28	3.735	26	3.665
22	3.605	25	3.705	22	3.615
18	3.540	20	3.650	18	3.540
14	3.472	15	3.565	14	3.450
10	3.405	10	3.460	10	3.360
6	3.338	5	3.335	6	3.200
Gate Elevation 1209.4		Gate Elevation 1209.4		Gate Elevation 1209.0	
20	3.675	24	3.590	23	3.725
17	3.645	20	3.540	19	3.650
14	3.615	16	3.492	15	3.580
11	3.585	12	3.428	11	3.508
8	3.555	8	3.330	7	3.415
Gate Elevation 1213.4		Gate Elevation 1213.4		Gate Elevation 1213.0	
20	3.880	20	3.765	19	3.800
17	3.875	16	3.765	16	3.845
14	3.875	12	3.725	13	3.825
11	3.870	8	3.668	10	3.750
8	3.870	4	3.600	7	3.640
Gate Elevation 1217.4		Gate Elevation 1217.4		Gate Elevation 1217.0	
14	3.960	15	3.900	15	3.960
12	3.980	12	3.890	13	3.930
10	4.010	9	3.900	11	3.935
8	4.075	6	3.930	9	3.970
				7	4.020
Gate Elevation 1221.4		Gate Elevation 1221.4		Gate Elevation 1221.4	
10	3.890	11	3.830	14	3.815
8	3.930	9	3.840	12	3.820
6	4.020	7	3.875	10	3.823
5	4.100	5	3.935	8	3.825

[a] Coordinates of curves prepared by plotting original data. [b] Gate down.

sharp reversal in the curve when the angle θ approaches 28°, and (3) that the coefficient of discharge is a maximum at this angle. As the angle θ is increased from 28° to 90°, contraction of the jet gradually reduces the coefficient to approximately 3.33, which occurs when the weir is vertical. As θ is decreased from 28° to 0° the coefficient is gradually reduced—either by approach conditions, friction, or both—to that for a broad-crested weir, which may be some value between 2.8 and 3.1. As the principal difference between the drum gate and the straight inclined weir lies in the curvature of the gate, the trends for the two should be similar.

An inconsistency exists in Fig. 4—namely, the coefficient of discharge for a vertical sharp-crested weir should approximate 3.33, but Fig. 4 shows that Bazin obtained 3.45. This conclusion is supported by the fact that the USBR, Ernest W. Schoder, M.ASCE, and Kenneth B. Turner,[5] and others have not

[5] "Precise Weir Measurements," by Ernest W. Schoder and Kenneth B. Turner, *Transactions*, ASCE, Vol. 93, 1929, p. 999.

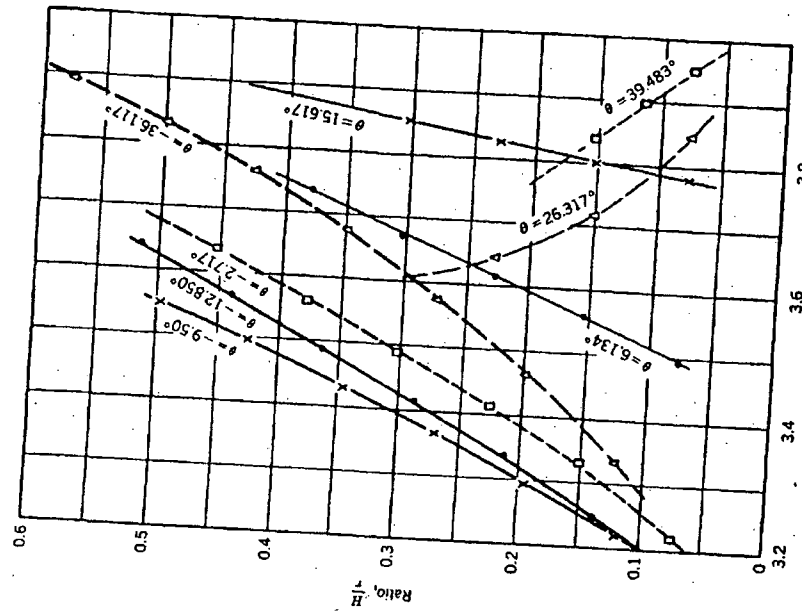


Fig. 5.—Dimensionless Plotting of Data from Model of Shasta Dam Drum Gate

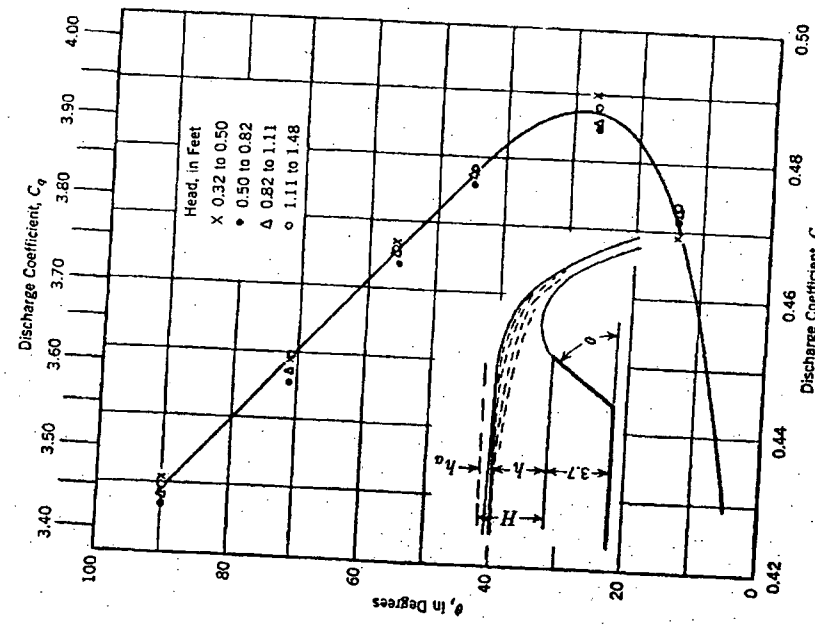


Fig. 4.—Results of Bazin's Experiments on Sloping Weirs

been able to check the discharge measurements of Bazin. However, the actual values are not so important for the case at hand as is the significance of the trend.

Method of Combining Test Results

The method for combining results from the eleven drum gates tested (Table 2) consisted of first plotting the coefficient of discharge data separately

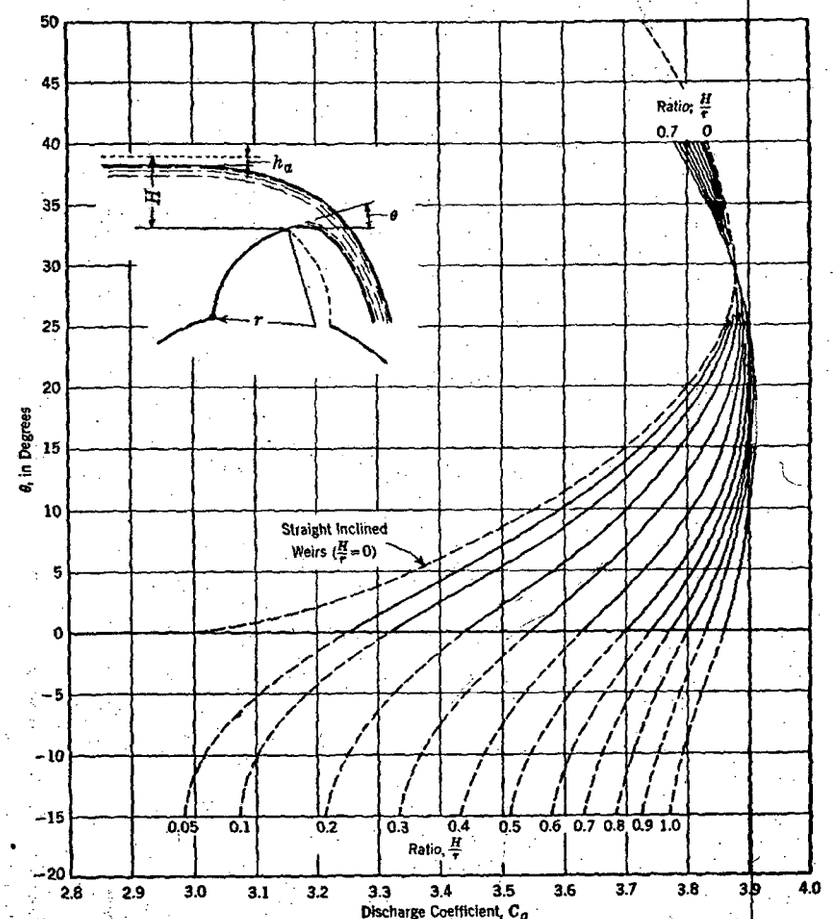


Fig. 6.—General Curves for the Determination of Discharge Coefficients

for each gate as illustrated by the sheet for the Shasta Dam gate (Fig. 5). With the coefficient of discharge as the abscissa and H/r as the ordinate, each curve in Fig. 5 represents a different gate angle θ, which the tangent to the downstream lip of the gate makes with the horizontal. In all cases, H is the

total head, including the velocity head of approach, measured above the high point of the gate, and r is the radius of the gate. In Fig. 5, C_q is based on the relationship, $Q = C_q L H^{\frac{3}{2}}$. For positive values of θ, the head was measured above the lip of the gate, whereas for negative angles it was observed above the high point, or crest, of the gate proper. The method of measuring the head is illustrated in Fig. 2.

Upon completion of a similar set of curves for each gate tested, the eleven sets of curves were replotted and combined into the chart exhibited as Fig. 6. The results from the various gates showed good general agreement; and the curves in Fig. 6 constitute the general experimental information needed for determining the discharge coefficients for gates in raised or partly raised positions. The supporting points are not shown in Fig. 6, but the individual information for each gate is listed in Table 2.

Analysis of Test Results

The curves in Fig. 6 show a tendency toward reversal, similar to that exhibited by the Bazin curve in Fig. 4, but the points of inflection vary from $\theta = 20°$ to $\theta = 30°$, depending on the value of H/r. Fig. 4 showed the coefficients to vary only slightly with the head, but in this case the coefficients definitely vary with the head.

A matter of significance is the reversal of the (H/r)-order which occurs at 29° (Fig. 6). The coefficient of discharge has but one value, 3.88, when θ approximates 29°; thus, it is insensitive to both the radius and the head on the gate for this angle. The curve for $H/r = 0$ approximates a drum gate of infinite radius and was obtained from the data of Bazin (Fig. 4) by applying a uniform adjustment.

As stated previously, similitude is valid for small negative angles of θ, as well as for positive angles up to 90°; thus, the curves in Fig. 6 are shown and recommended for use down to $\theta = -15°$. As the gate is lowered beyond this angle, the curves double back and converge, finally terminating in the free flow coefficient.

The discharge coefficients in the region between $\theta = -15°$ and the gate completely down are determined by graphical interpolation. Interpolation is accomplished by plotting head-discharge curves for several gate angles between $-15°$ and the maximum positive angle. Also the head-discharge curve is plotted for the free crest. This information is then cross-plotted to obtain values in the transition zone. The method will be explained in the example that follows. It will be discovered that negative angles greater than $-15°$ (with the exception of the free crest) are not particularly important from an operator's standpoint, as a change in gate position has little effect on the discharge in this range.

It must be assumed that the coefficient of discharge is known for at least one value of the head on the free crest (gate completely down) for the particular spillway under consideration. With the coefficient known for one or more heads, the complete coefficient curve for the free crest can be plotted by consulting Fig. 7, in which H_o and C_o are the designed head and the coefficient

for the designed head, respectively. This chart was reproduced from a previous publication[2] and represents a curve well supported by tests of some fifty overfall spillway crests having wide variation in shape and operating conditions.

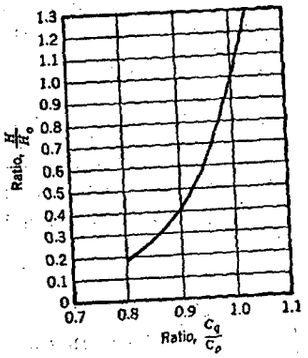


Fig. 7.—Coefficients of Discharge for Other Than the Designed Head

Application of Results

From the plan and section of the Black Canyon Diversion Dam (Idaho), shown in Figs. 8 and 9, assume that it becomes necessary to compute and construct a rating curve for one drum gate for each 0.5 ft of gate elevation. The scale on the gate position indicator is calibrated to show the elevation of the high point of the gate, and the gate has a constant radius of 21.0 ft. The gate is 64 ft long. The coefficient of discharge for the free crest is $C_o = 3.48$ for the designed head (H_o) of 14.5 ft.

With the coefficient of discharge known for free flow at the designed head, the entire free-flow coefficient curve can be established by consulting Fig. 7. The free-flow coefficient curve for Black Canyon Dam spillway (for which $H_o = 14.5$ ft

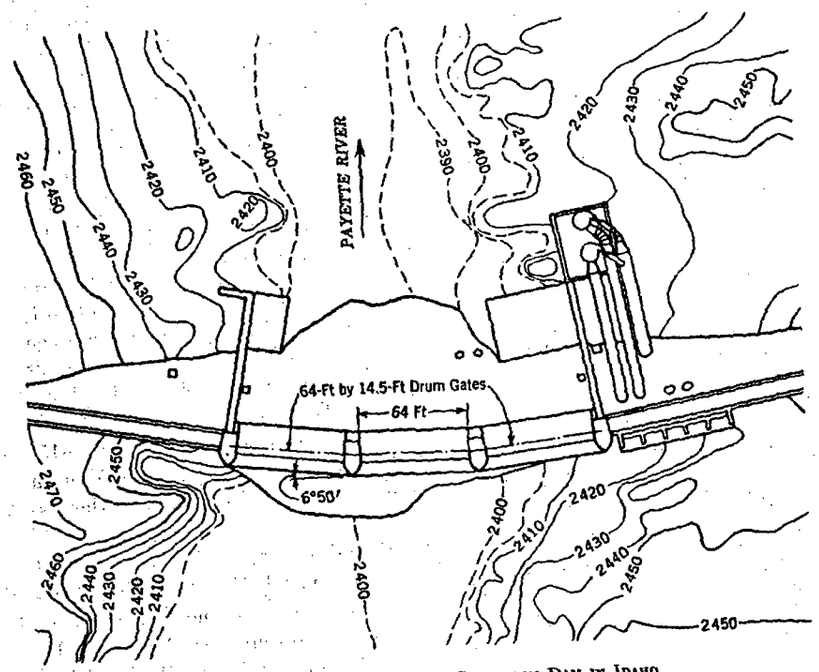


Fig. 8.—Plan of Black Canyon Diversion Dam in Idaho

and $C_o = 3.48$) is constructed by arbitrarily assuming several values of H/H_o and reading the corresponding values of C/C_o from Fig. 7. The method is illustrated in Table 3, and the head-coefficient curve for free flow (gate down), obtained in this manner, is shown in Fig. 10.

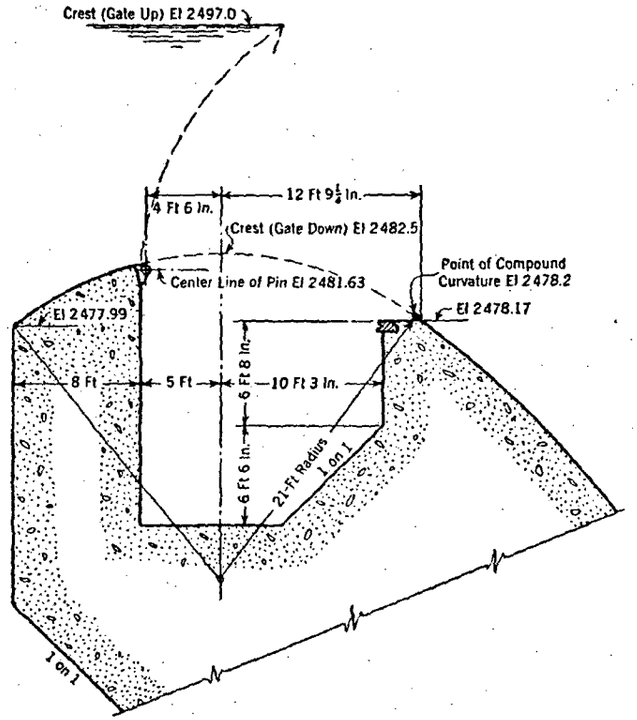


Fig. 9.—Spillway Crest Detail, Black Canyon Dam in Idaho

TABLE 3.—Head and Discharge Computations for a Free Crest (Black Canyon Dam in Idaho)

Total head, H, in ft	Reservoir elevation, in ft	Ratio,[a] H/H_o	Ratio,[b] C_q/C_o	Coefficient, C_q	Q, in cu ft per sec[c]
(1)	(2)	(3)	(4)	(5)	(6)
17	2499.5	1.172	1.020	3.55	15,950
16	2498.5	1.104	1.012	3.52	14,420
14.5	2497.0	1.0	1.0	3.48	12,296
12	2494.5	0.827	0.980	3.41	9,072
10	2492.5	0.690	0.960	3.34	6,759
8	2490.5	0.552	0.940	3.27	4,736
6	2488.5	0.414	0.905	3.135	2,949
4	2486.5	0.276	0.850	2.957	1,514
3	2485.5	0.207	0.815	2.835	943
2	2484.5	0.138	0.760	2.642	478

[a] $H_o = 14.5$ ft. [b] $C_o = 3.48$. [c] The discharge for one gate: $Q = C_q L H^{3/2}$, in which $L = 64.0$ ft.

Before considering the rating of the spillway with gates in raised positions, it is necessary to construct a diagram such as that shown in Fig. 11 to relate gate elevation to the angle θ for the Black Canyon Dam gate. The tabulation in Fig. 11 shows the angle θ for corresponding elevations of the downstream lip of the gate at intervals of 2 ft.

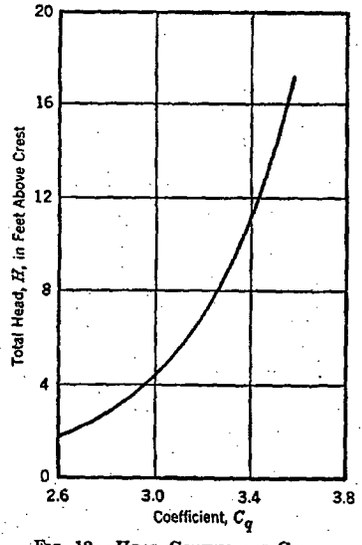


Fig. 10.—Head-Coefficient Curve, Black Canyon Dam, in Idaho

Beginning with the maximum positive angle of the gate, which is 34.883°, the computations may be begun by choosing a representative number of reservoir elevations as indicated in Col. 2, Table 4. The difference between the reservoir elevation and the high point of the gate (which is the downstream lip in this case) constitutes the total head on the gate, and values of head are recorded in Col. 3. Col. 4 shows these same heads divided by the radius of the gate, which is 21.0 ft.

Entering the curves in Fig. 6 with the values in Col. 4, Table 4, for $\theta = +34.883°$, the discharge coefficients, listed in Col. 5 of the set of computations designated "A," are obtained. The remainder of the procedure outlined in Cols. 6 and 7, Table 4, consists of computing the discharge for one gate from the expression, $Q = C_q L H^{\frac{3}{2}}$. A similar procedure of computation is repeated for other positive angles of θ as in sets B, C, and D of Table 4.

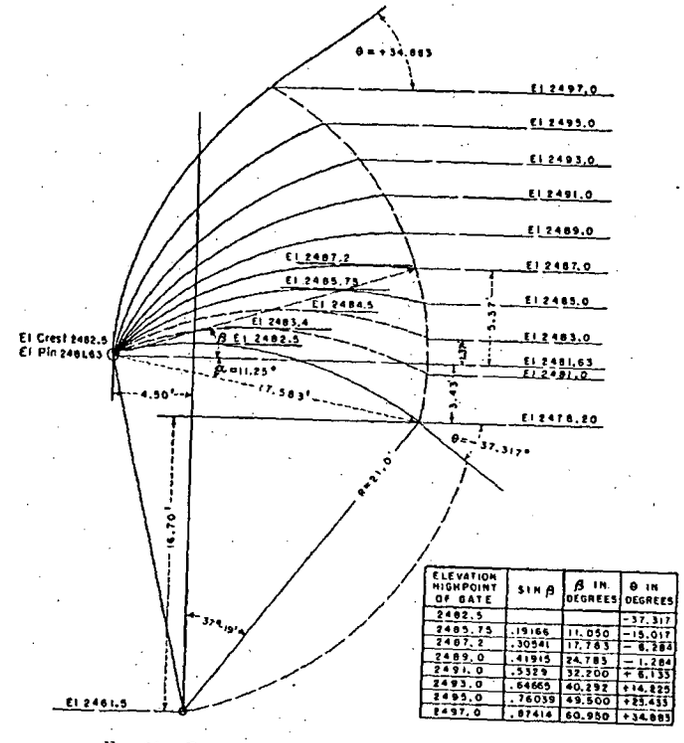
As the angle θ is given negative values, the procedure for determining the discharge remains the same for angles between 0 and $-15°$, except that the head on the gate is measured above the high point rather than above the lip. Discharge computations for negative angles of the gate down to $-15.017°$ are tabulated in E, F, and G of Table 4.

Plotting values of discharge, reservoir elevation, and gate elevation from Table 4 results in the seven curves in Fig. 12 for which the points are denoted by circles. The extreme lower curve, on which the points are identified by x-marks, represents the discharge of the free crest with the gate completely down. The latter values were obtained from Table 3.

The discharge values shown in Fig. 12 are for one gate only. When more than one gate is in operation, the discharges from the separate gates may be totaled providing the gates are each raised the same amount. The experimental models contained from one to four gates (with the exception of that of Grand Coulee Dam, which contained eleven) so a reasonable allowance for pier effect on the discharge is already present in the results.

The intervals between the eight curves identified by points (Fig. 12) are too great for rating purposes, especially the gap between gate elevations, 2485.75 ft and 2482.5 ft. This is remedied by cross-plotting the eight curves

for various constant values of the discharge as shown in Fig. 13. Fortunately, the result is a straight-line variation for any constant value of discharge. The lines in Fig. 13 are not quite parallel and there is no assurance that they will be straight for every drum gate. Nevertheless, this will not detract appreci-



Elevation Highpoint of Gate	Sin β	β in Degrees	θ in Degrees
2482.5			−37.317
2485.75	.19166	11.050	−15.017
2487.2	.30541	17.763	−6.284
2489.0	.41915	24.785	−1.284
2491.0	.5329	32.200	+6.133
2493.0	.64665	40.292	+14.225
2495.0	.76039	49.500	+23.433
2497.0	.87414	60.950	+34.883

Fig. 11.—Relationship of Gate Elevation to Angle θ

ably from the accuracy obtained. Interpolated information from Fig. 13 is then utilized to construct the additional curves in Fig. 12. If all curves are considered, Fig. 12 shows the completed rating for the Black Canyon Dam spillway for 0.5-ft gate intervals. For intermediate values, straight-line interpolation is permissible.

Conclusions

This paper has demonstrated how an existing control structure, such as the Black Canyon Dam spillway, can also serve as a rating station. The accuracy of rating curves obtained by the method is estimated to approach that of an average current-meter traverse of the river providing that (1) the gate position indicators are made as large as possible and are accurately cali-

brated, (2) the reservoir gage can be read to within 0.05 ft, (3) nearly atmospheric pressure exists under the sheet of water after it springs from the gate, and (4) all gates are set at approximately the same elevation.

TABLE 4.—HEAD AND DISCHARGE COMPUTATIONS FOR DRUM GATES IN RAISED POSITIONS

Set (1)	Reservoir elevation, in ft (2)	H, in ft[a] (3)	Ratio, $\frac{H}{r}$ (4)	Coefficients, C_q (5)	$H^{\frac{3}{2}}$, in ft (6)	Q, in cu ft per sec[b] (7)
GATE ELEVATION 2497.0; $\theta = +34.88°$						
A	2498.0	1	0.048	3.86	1	247
	2499.0	2	0.095	3.86	2.828	699
	2500.0	3	0.143	3.86	5.196	1.283
GATE ELEVATION 2495.0; $\theta = +23.43°$						
B	2496.0	1	0.048	3.85	1	246
	2497.0	2	0.095	3.86	2.828	698
	2498.0	3	0.143	3.87	5.196	1,284
	2499.0	4	0.190	3.87	8.00	1,979
	2500.0	5	0.238	3.88	11.18	2,770
GATE ELEVATION 2493.0; $\theta = +14.22°$						
C	2494.0	1	0.048	3.69	1	236
	2495.0	2	0.095	3.73	2.828	675
	2496.0	3	0.143	3.75	5.196	1,247
	2498.0	5	0.238	3.80	11.18	2,719
	2500.0	7	0.333	3.84	18.52	4,552
GATE ELEVATION 2491.0; $\theta = +6.13°$						
D	2492.0	1	0.048	3.47	1	222
	2493.0	2	0.095	3.51	2.828	635
	2494.0	3	0.143	3.57	5.196	1,187
	2496.0	5	0.235	3.63	11.18	2,597
	2498.0	7	0.333	3.70	18.52	4,386
	2500.0	9	0.429	3.77	27.00	6,515
GATE ELEVATION 2489.0; $\theta = -1.28°$						
E	2490.0	1	0.048	3.21	1	205
	2491.0	2	0.095	3.28	2.828	594
	2492.0	3	0.143	3.34	5.196	1,111
	2494.0	5	0.238	3.45	11.18	2,469
	2496.0	7	0.333	3.545	18.52	4,202
	2498.0	9	0.429	3.63	27.00	6,273
	2500.0	11	0.524	3.695	36.48	8,627
GATE ELEVATION 2487.2; $\theta = -8.28°$						
F	2488.0	0.8	0.038	3.02	0.716	138
	2489.0	1.8	0.086	3.10	2.415	479
	2490.0	2.8	0.133	3.17	4.685	950
	2492.0	4.8	0.229	3.31	10.52	2,229
	2494.0	6.8	0.324	3.43	17.73	3,892
	2496.0	8.8	0.419	3.51	26.10	5,863
	2498.0	10.8	0.515	3.58	35.49	8,131
	2500.0	12.8	0.610	3.635	45.79	10,653
GATE ELEVATION 2485.75; $\theta = -15.02°$						
G	2487.0	1.25	0.060	3.00	1.398	268
	2488.0	2.25	0.107	3.07	3.375	663
	2489.0	3.25	0.155	3.15	5.859	1,181
	2491.0	5.25	0.250	3.275	12.03	2,522
	2493.0	7.25	0.345	3.375	19.52	4,216
	2495.0	9.25	0.440	3.465	28.13	6,238
	2497.0	11.25	0.536	3.54	37.73	8,548
	2499.0	13.25	0.631	3.595	48.23	11,097

[a] H is the total head on the gate. [b] The discharge for one gate: $Q = C_q L H^{\frac{3}{2}}$.

In connection with provision (3), the blunt piers on the Black Canyon Dam spillway, Figs. 8 and 9, provide effective aeration under the overfalling sheet of water for all but very small heads with gate completely raised. In the case of provision (4), uniform operation of the gates is also most desirable from the standpoint of stilling basin operation for minimum erosion downstream.

Discharge measurements on the prototype are desirable whenever possible as a check on the accuracy of the foregoing method. Sufficient observations should be taken, however, to establish the fact that the prototype information is consistent and reliable.

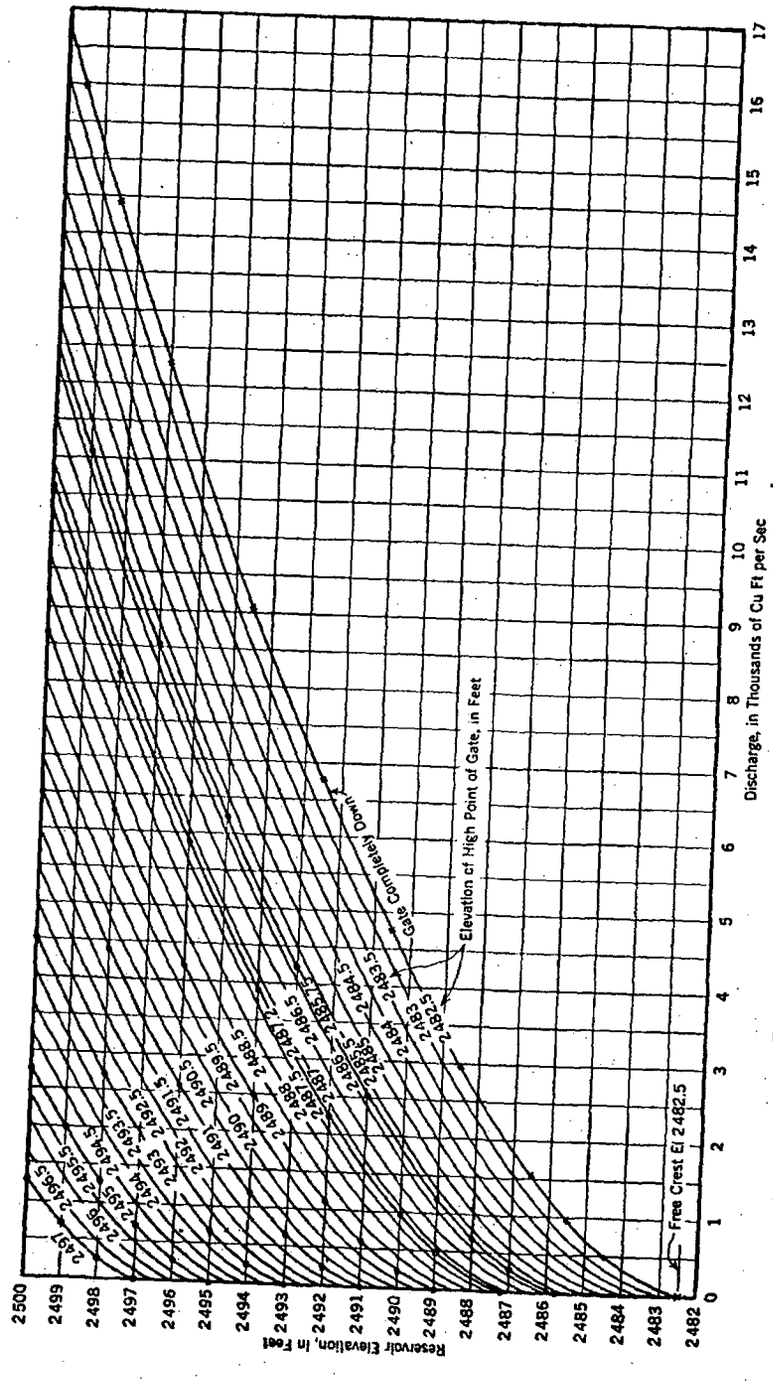


FIG. 12.—RATING CURVES FOR BLACK CANYON DAM DRUM-GATE SPILLWAY IN IDAHO

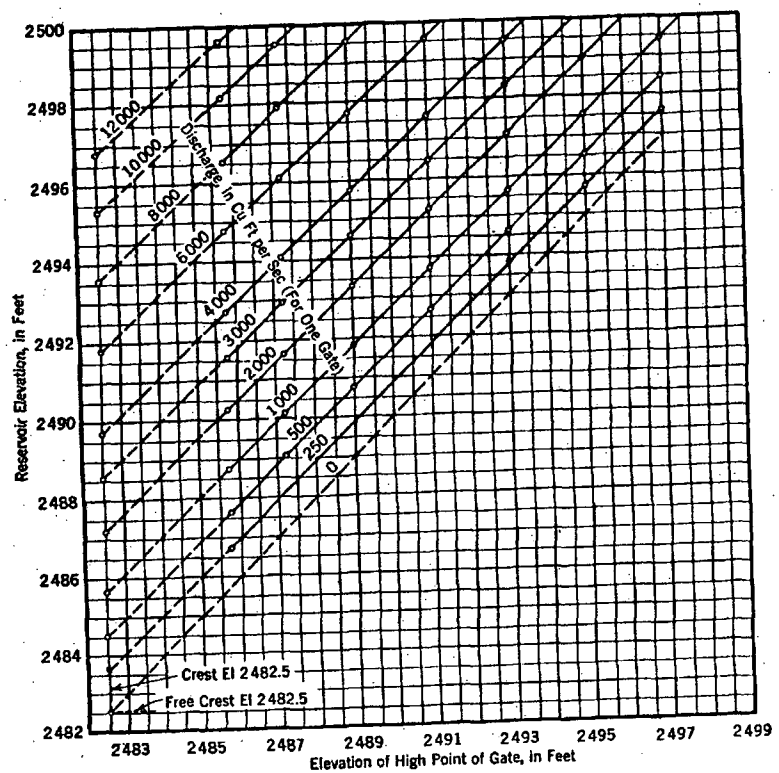


FIG. 13.—CROSS-PLOTTED INITIAL RATING CURVES, BLACK CANYON DAM IN IDAHO

ACKNOWLEDGMENTS

The writer wishes to thank C. E. Blee, M. ASCE, chief engineer of the Tennessee Valley Authority for the use of the data on the Norris Dam Spillway; Hal Birkeland, M. ASCE, of the International Engineering Corporation, for obtaining permission to include the Bhakra and Capilano Dam spillways in the paper; and the chief engineer of the Panama Canal for use of the data on the Madden Dam spillway. The writer is also grateful to the Bureau of Reclamation for the use of the remainder of the experimental information. He also wishes to thank his engineering associates, H. M. Martin, M. ASCE, D. J. Hebert, and A. J. Peterka, A. M. ASCE, for their most helpful comments and suggestions.

DISCUSSION

GUIDO WYSS[6].—The information presented by Mr. Bradley is of utmost value for determining the quantities of discharge over drum gates under various heads for any gate position. This information will permit operators in the field to adjust the gate position from corresponding chart values in such a manner as to obtain the desired flow. The use of drum gates as an actual metering device for spillway quantity discharges is unique and the results obtained are more practicable and reliable than those obtained by stream gaging, especially when this gaging is conducted during periods of high floods.

It would have been interesting if the author had presented an investigation of the flow, profiles of the upper and lower nappe surfaces, as well as the actual water pressures on the upstream plate of the drum gate by use of charts. This would afford an opportunity to obtain the true loading conditions on the gate during the cycle of operation from fully-raised gate to fully-lowered gate. This information would be important in the determination of the buoyancy and loading criteria of the gate structure.

SAM SHULITS,[7] M. ASCE.—An outstanding contribution to the design and operation of drum gates has been presented in this report of the author's work at the USBR. The paper and its complement[2] fill a great need.

Since 1928, when the Freeman Scholarships were established, there has been a tremendous development of hydraulic model research in the laboratories of the United States. Although these laboratories are unexcelled in size and quality, many hydraulic engineers have pondered the procession of models (spillways, stilling pools, and river reaches) in the period from 1928 to 1953 with few, if any, summaries or proposals for design to reduce the dependence on models. In Mr. Bradley's work there is strong evidence that the laboratories will produce correlations and syntheses—not more models.

When it is realized that many of the most famous and productive laboratories in the United States did not exist prior to 1928, the lack of correlation and synthesis for general use is understandable. The hope is that other works of similar quality will be added to engineering literature.

BOB BUEHLER,[8] A. M. ASCE.—An interesting and clever use of data has resulted in a method by which records of gate settings at dams can be made a substitute for missing stream-flow records and can be used to augment existing records. The construction of a dam and reservoir often floods an established stream gage. Unless the gage is replaced below the dam or upstream from the reservoir, subsequent stream flow usually is not accurately known. Sometimes a series of dams (each causing the water to back up to the dam above) prevents continuing established gages at the strategic points where they had been

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located. The less accurate—and more costly—slope stations are not completely satisfactory alternatives to the single-line rating stations.

If the spillway of a dam can be rated with an accuracy comparable to the accuracy obtainable with a gage (as demonstrated by Mr. Bradley for certain spillway types), and if allowance is made for flow through other water outlets such as turbines, locks, and sluices, the structure is then superior in some respects to the gage. For example, the rating of the dam should be permanent, whereas the rating of a gage usually requires frequent checking.

Mr. Bradley's method for rating drum gates not only allows records for ordinary stream flow to be supplemented, but also probably gives a more accurate determination of extreme flood rates than do most gages. He has made an important contribution to the planning and design of drum-gated structures.

The author has presented a method for rating a spillway at all heads provided the coefficient for one appreciable head is known. He also states that a coefficient for the designed head can be estimated for most spillways by a method previously published.[3] The writer, on the other hand, offers a method by which an ogee spillway can be rated, provided its profile shape is known. The method is based on an equation derived by R. N. Brudenell, A. M. ASCE, incidental to studies made on radial gates.[9] Mr. Brudenell's equation is

$$Q = \frac{3.97\, L\, H^{1.62}}{H_D^{0.12}} \qquad (1)$$

in which Q is the spillway discharge, in cubic feet per second; L denotes the length of the spillway, in feet; H is the total head on the spillway crest, in feet;

TABLE 5.—FREE DISCHARGES FOR BLACK CANYON DAM IN IDAHO

Total head, in feet	Discharge, in cubic feet per second[a]	Using Eq. 1		Using Fig. 14	
		Discharge, in cubic feet per second	Difference, in percent	Discharge, in cubic feet per second	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)
17	15,950	15,847	−0.65	15,910	−0.25
16	14,420	14,363	−0.39	14,421	−0.01
14.5[b]	12,296	12,247[c]	−0.40	12,296	0
12	9,072	9,013	−0.65	9,049	−0.25
10	6,759	6,708	−0.75	6,735	−0.36
8	4,736	4,673	−1.33	4,692	−0.93
6	2,949	2,932	−0.58	2,944	−0.20
4	1,514	1,521	+0.46	1,527	+0.86
3	943	954	+1.17	958	+1.59
2	478	494	+3.35	496	+3.76

[a] From Col. 6, Table 3. [b] Head at which $C_e = 3.48$. [c] C_e would be 3.466 for this discharge.

and H_D represents the design head in feet. The design head is that head which produces a standard lower nappe that agrees closely with the spillway profile.

[9] "Flow over Rounded Crests," by R. N. Brudenell, *Engineering News-Record*, July 18, 1935, p. 95.

Eq. 1 was intended to be used with heads greater than $H_D/4$, although the equation has been found to agree closely with model data for somewhat lower heads. Without knowing any coefficients, Eq. 1 gives discharges that agree closely with those obtained by Mr. Bradley for Black Canyon Dam. In the case of Black Canyon Dam, Mr. Bradley used one known coefficient and the curve of Fig. 7. Free-flow discharges computed by the two methods are shown in Cols. 2 and 3, Table 5. The procedure by which Eq. 1 was applied will be described subsequently.

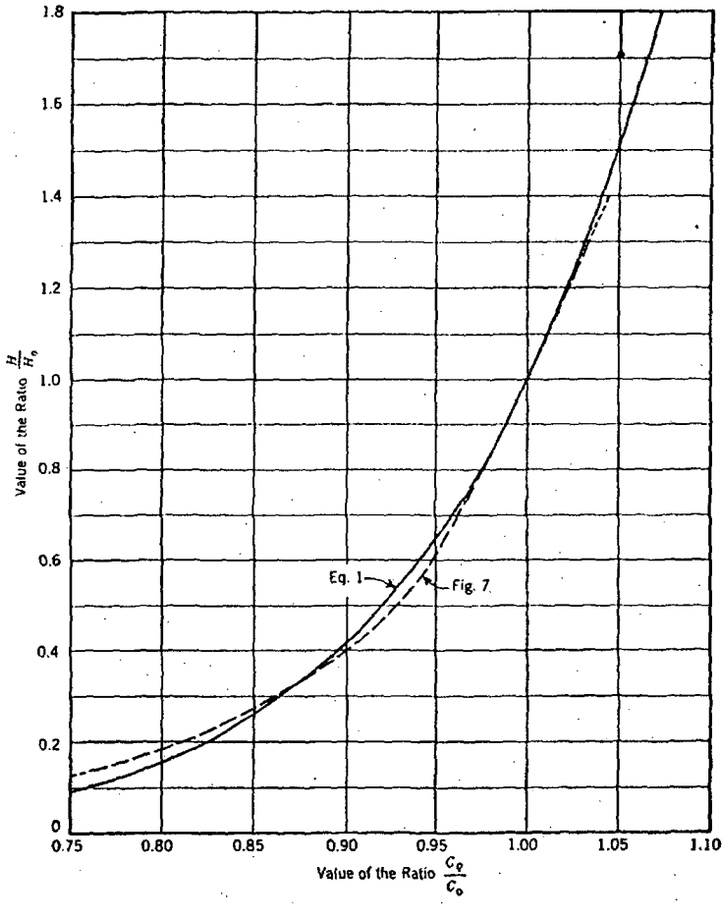


FIG. 14.—COMPARISON OF VALUES OBTAINED FROM FIG. 7 AND EQ. 1

It is assumed that in choosing Black Canyon Dam for his example, the author knew that his method would yield discharges close to known values. The good agreement for all except the low heads shows that, in this example, Eq. 1 (using only the shape of the spillway) also produces suitable results.

This good agreement suggests, too, that there must be a close relationship between the curve in Fig. 7 and a similar curve that can be derived from Eq. 1. To examine the relationship, theoretical discharge coefficients were computed by using

$$Q = C_q\, L\, H^{3/2} \qquad (2)$$

and Eq. 1, from which

$$C_q = \frac{3.97\ H^{1.62}}{H^{0.12}{}_D\ H^{3/2}} \qquad (3)$$

The design head, H_D, was found (by a method to be described subsequently) to be 45 ft for Black Canyon Dam, and this value was used in making the test. Thus, for $H_D = 45$ ft,

$$C_q = \frac{2.5143\ H^{1.62}}{H^{3/2}} \qquad (4)$$

For several assumed values of total head, H, varying from 2 ft to 58.5 ft, corresponding C_q-values were computed. The resulting C_q of 3.97 for a head of 45 ft (H_o) was taken arbitrarily as the known coefficient, C_o. Then the (H/H_o)-ratios and the (C_q/C_o)-ratios were computed for all other heads in the assumed range. The resulting curve is the solid line in Fig. 14. The dashed curve is from Fig. 7. The agreement is close—as expected. Still using H_D equal to 45 ft, the remainder of the process was repeated using the coefficient for the 25-ft head as C_o, and then using the coefficient for the 12-ft head as C_o. There was no discernible difference in the curves resulting from the three separate selections. A similar procedure, using H_D equal to 20 ft in Eq. 1, also showed no differences from Fig. 14. It can probably be proved that there should be no difference.

The curve derived from Eq. 1 then was applied to the Black Canyon Dam spillway, assuming (as did the author) that the coefficient is 3.48 at a 14.5-ft head. The resultant free discharges are shown in Col. 5, Table 5.

The free-flow coefficients in Table 2 invite further comparisons with Eq. 1 for the four projects for which spillway profiles are given in Fig. 3. It should be remembered that this comparison tests the use of only the spillway shape as a guide to free discharge for the entire range of heads. Col. 4, Table 6, shows that for appreciable heads the maximum error in the four cases is approximately 2% (Hamilton Dam). Observed coefficients in model tests often scatter as much.

The same coefficients permit testing the curve in Fig. 7 for all eleven spillways. This test is not as severe, however, because it is necessary to assume one known coefficient at which head agreement becomes perfect. At near-by higher and lower heads, large divergences would not be expected. Col. 6, Table 6, shows that for appreciable heads the maximum error is slightly greater than 2% (Hoover Dam, shape 8-M5). The base coefficient selected to obtain C_q from the (C_q/C_o)-ratios is designated by a footnote for each project. These arbitrary selections were made for medium high heads.

The solid-line curve in Fig. 14 also was tested in this manner. The same coefficient at each project was assumed to be known as when the curve in Fig. 7 was tested. Col. 8, Table 6, shows that for appreciable heads the maximum error is slightly more than 2% (Madden Dam).

These comparisons show that the direct application of Eq. 1, Fig. 7 (or Fig. 14) (derived from Eq. 1), all give highly accurate free-flow spillway dis-

TABLE 6.—COMPARISON OF FREE-FLOW SPILLWAY COEFFICIENTS

Total head, in feet	Coefficient obtained from model test	Using Eq. 1		Using Fig. 7		Using Fig. 14	
		C_q	Difference, in percent	C_q	Difference, in percent	C_q	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Grand Coulee Dam (Washington)							
35	3.920			3.914	− 0.15	3.902	−0.46
30	3.842			3.831	− 0.29	3.827	−0.39
25	3.745			3.745[a]	0	3.745[a]	0
20	3.635			3.655	+ 0.55	3.651	+0.44
15	3.510			3.550	+ 1.14	3.524	+0.40
10	3.352			3.370	+ 0.54	3.356	+0.12
5	3.220			3.138	− 2.54	3.168	−1.62
Bhakra Dam (India)							
28	3.680			3.736	+ 1.52	3.732	+1.41
23	3.645			3.645[a]	0	3.645[a]	0
18	3.550			3.547	− 0.08	3.543	−0.20
13	3.420			3.434	+ 0.41	3.404	−0.47
8	3.275			3.215	− 1.83	3.208	−2.04
3	3.120			2.748	−11.92	2.854	−8.53
Shasta Dam (California)							
38	3.895			3.910	+ 0.39	3.899	+0.10
33	3.835			3.839	+ 0.10	3.831	−0.10
28	3.760			3.760[a]	0	3.760[a]	0
23	3.675			3.677	+ 0.05	3.674	−0.03
18	3.575			3.591	+ 0.45	3.568	−0.20
13	3.465			3.455	− 0.29	3.429	−1.04
8	3.335			3.215	− 3.60	3.230	−3.15
Hamilton Dam (Texas) H_D = 52 Ft							
35	3.710	3.785	+2.02	3.741	+ 0.84	3.730	+0.54
30	3.645	3.716	+1.95	3.662	+ 0.47	3.659	+0.38
25	3.580	3.635	+1.54	3.580[a]	0	3.580[a]	0
20	3.500	3.539	+1.11	3.494	− 0.17	3.490	−0.29
15	3.400	3.420	+0.59	3.394	− 0.18	3.369	−0.91
10	3.290	3.258	−0.97	3.222	− 2.07	3.208	−2.50
5	3.160	2.997	−5.16	3.000	− 5.06	3.029	−4.14
Friant Dam (California)							
20	3.650			3.717	+ 1.84	3.706	+1.53
17	3.625			3.639	+ 0.39	3.632	+0.19
14	3.550			3.550[a]	0	3.550[a]	0
11	3.460			3.458	− 0.06	3.452	−0.23
8	3.340			3.348	+ 0.24	3.319	−0.63
5	3.175			3.142	− 1.04	3.131	−1.38
2	2.965			2.723	− 8.15	2.812	−5.16

[a] Coefficient assumed to be known.

TABLE 6.—(*Continued*)

Total head, in feet	Coefficient obtained from model test	Using Eq. 1		Using Fig. 7		Using Fig. 14	
		C_e	Difference, in percent	C_e	Difference, in percent	C_e	Difference, in percent
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Norris Dam (Tennessee) H_D = 35 Ft							
35	3.915	3.969	+1.38	3.934	+ 0.49	3.923	+0.20
30	3.845	3.897	+1.35	3.852	+ 0.18	3.848	+0.08
25	3.765	3.812	+1.25	3.765[a]	0	3.765[a]	0
20	3.670	3.711	+1.12	3.675	+ 0.14	3.671	+0.03
15	3.550	3.586	+1.01	3.569	+ 0.53	3.543	−0.20
10	3.390	3.416	+0.77	3.388	− 0.06	3.373	−0.50
5	3.125	3.143	+0.58	3.155	+ 0.96	3.185	+1.92
Madden Dam (Canal Zone)							
35	3.900			3.825	− 1.92	3.814	−2.20
30	3.770			3.744	− 0.69	3.740	−0.80
25	3.660			3.660[a]	0	3.660[a]	0
20	3.560			3.572	+ 0.34	3.568	+0.22
15	3.460			3.470	+ 0.29	3.444	−0.46
10	3.365			3.294	− 2.11	3.279	−2.55
5	3.280			3.067	− 6.49	3.096	−5.61
Capilano Dam (British Columbia) H_D = 48 Ft							
33	3.775	3.797	+0.58	3.783	+ 0.21	3.775	0
28	3.705	3.720	+0.40	3.705[a]	0	3.705[a]	0
23	3.625	3.634	+0.25	3.623	− 0.05	3.620	−0.14
18	3.530	3.529	−0.03	3.538	+ 0.23	3.516	−0.40
13	3.415	3.394	−0.62	3.405	− 0.29	3.379	−1.05
8	3.250	3.201	−1.51	3.168	− 2.52	3.183	−2.06
Hoover Dam (Arizona-Nevada) Shape 4-M3, H_D = 50 Ft							
26	3.670	3.670	0	3.681	+ 0.30	3.677	+0.19
22	3.605	3.597	−0.22	3.605[a]	0	3.605[a]	0
18	3.540	3.512	−0.79	3.526	− 0.40	3.522	−0.51
14	3.472	3.408	−1.84	3.439	− 0.95	3.414	−1.67
10	3.405	3.273	−3.88	3.306	− 2.91	3.280	−3.67
6	3.338	3.077	−7.82	3.064	− 8.21	3.082	−7.67
Hoover Dam Shape 8-M5							
28	3.735			3.814	+ 2.12	3.800	+1.74
25	3.705			3.752	+ 1.27	3.749	+1.19
20	3.650			3.650[a]	0	3.650[a]	0
15	3.565			3.537	− 0.78	3.530	−0.98
10	3.460			3.387	− 2.11	3.358	−2.94
5	3.335			3.059	− 8.28	3.088	−7.41
Hoover Dam Shape 7-C4							
26	3.665			3.691	+ 0.71	3.687	+0.60
22	3.615			3.615[a]	0	3.615[a]	0
18	3.540			3.535	− 0.14	3.532	−0.23
14	3.450			3.449	− 0.03	3.423	−0.78
10	3.360			3.315	− 1.34	3.290	−2.08
6	3.200			3.073	− 3.97	3.091	−3.41

charges for ogee dams at all but low heads. Eq. 1, applied directly to the spillway shape, has the advantage that no coefficients need be known or estimated in advance.

The comparisons in Table 6 show a tendency toward errors of some importance at low heads when Eq. 1 or its companion curve in Fig. 14 is used, as well as when Fig. 7 is used. In most cases the errors are negative. These errors are of little concern in planning the safety of a structure against extreme floods, or in considering most other operations such as emptying the reservoir. The errors nonetheless affect the analytical rating of drum gates in the lowered or slightly raised positions. The free-flow coefficients help to determine the direction of the general curves at the large negative angles shown in Fig. 6. Free discharges form the base curve of the rating curves in Fig. 12 and help define the curvature of the low ends of the cross-plot curves in Fig. 13. Low to ordinary heads, corresponding to normal stream flow, can exist for a large part of the time at dams whose reservoir capacities are small. Further study of data for low heads might lead to valuable refinements.

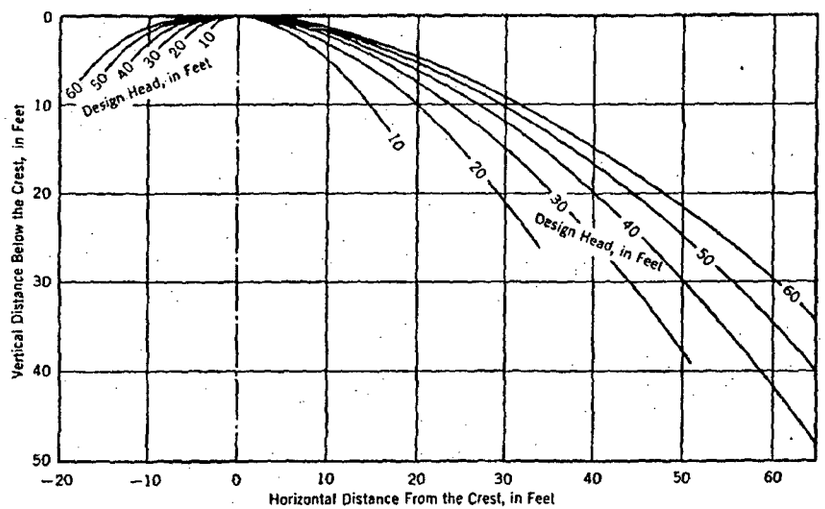


Fig. 15.—Standard Spillway Shapes

Application of Eq. 1.—Since the factor H_D in Eq. 1 represents the head at which a standard lower nappe shape is a reasonable approximation of the spillway shape (as designed or built), it is only necessary to find this head to apply the formula. Spillway coordinates for a standard crest having a vertical upstream face have been used to find this head.[10] These coordinates are shown in Table 7. The last column in Table 7 refers the horizontal (x) coordinates to the spillway crest because this form is the simplest to apply. In Table 7, y is the distance below the crest elevation.

Using these dimensionless coordinates, standard spillway shapes were plotted (Fig. 15) for values of H_D from 10 ft to 60 ft. In Fig. 15 negative

[10] "Hydroelectric Handbook," by William P. Creager and Joel D. Justin, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1950, p. 362.

horizontal distances indicate the distance upstream from the crest. The spillway shape as designed or built is then drawn on transparent paper. This paper is laid over Fig. 15, and the value of H_D which gives the best fit is selected. In deciding the best fit it may be found that the profile upstream from the crest indicates one value and the downstream profile indicates a different value. The higher of the two indicated values of H_D should be used. For example, the shape of Black Canyon Dam spillway upstream from the crest indicated a value of approximately 45 ft for H_D. The downstream shape indicated a value of approximately 25 ft. The larger value was used.

TABLE 7.—COORDINATES OF A STANDARD SPILLWAY CREST

Value of $\frac{x}{H_D}$	Value of $\frac{y}{H_D}$	Value of $\frac{x}{H_D}$ referred to crest
0	0.126	−0.3
0.1	0.036	−0.2
0.2	0.007	−0.1
0.3	0	0
0.4	0.007	0.1
0.6	0.063	0.3
0.8	0.153	0.5
1.0	0.267	0.7
1.2	0.410	0.9
1.4	0.590	1.1
1.7	0.920	1.4
2.0	1.31	1.7

The determination of the H_D-value which gives a reasonable fit requires a certain amount of judgment. When the profile upstream from the crest is the criterion, the lip of the dam will sometimes be the determinant. Sometimes, however, the lip droops sharply downward and indicates a lower value than other parts of the upstream profile. When the downstream shape is the criterion, good results have been obtained by assigning a value of H_D based on the average fit in the zone between points on the spillway where tangents range from 20° to 35° from the horizontal. The exact value of H_D is not too important. Since it enters Eq. 1 in the 0.12 power, a difference of 10% in its value affects the discharge by only 1.15%.

The writer's application of Eq. 1 has been limited to fairly high dams. Although the total head used in Eq. 1 should include the approach velocity, the accuracy of Eq. 1 when used for low dams, where approach velocity is large, has not been tested.

So far as is known, the application of standard nappe shapes (for which discharge coefficients are known) to actual spillways on a basis of reasonable best fit was first suggested by W. M. Borlund.[11] Mr. Borlund used a curve of observed C_q-value plotted against H/H_o. In 1942, C. E. Kindsvater, M. ASCE, suggested a similar procedure in which the curve of C_q versus H/H_o was derived from Eq. 1. Mr. Kindsvater's work (not published) should give results comparable to those obtained herein.

The material presented is regarded as an excellent check on that part of Mr. Bradley's work which relates to free discharge over an ogee spillway.

F. B. CAMPBELL,[12] M. ASCE, AND A. A. MCCOOL,[13] J. M. ASCE.—The experimental data on discharge coefficients for flow over drum gates are a welcome addition to the published information on flow over spillways, or the observation and recording of the flow of streams. A paper by Robert E. Horton has been a guide for the estimation of flows over spillways since its publication.[14] The basic information for the discharge over curved crests which fit the under side of a nappe from a sharp-crested weir can be deduced from investigations made by Bazin,[15,16] although the published record of these experiments has not been generally available to engineers in the United States. The investigations conducted by the USBR (proposed by E. W. Lane, M. ASCE) embraced and extended the scope of Bazin's work which is often used as the basis for overflow spillway shapes.[3] Although good estimates for discharge over free-overflow crests can be accomplished rather simply, the problem becomes complicated when flow through partly opened crest gates is involved.

The commonly used types of crest gates are vertical lift gates, tainter or radial gates, and drum gates. The coefficient for a partly opened vertical lift gate depends on the location of the plane of the skin plate or lip with respect to the axis of the curved crest. The discharge coefficient for tainter gates is affected by the radius of the skin plate, the elevation of the trunnion with respect to the crest, and the location of the gate seat with respect to the axis as well as the crest curvature. To complicate any investigations further, observers define the gate opening variously as (1) the length of the arc from the gate seat to the gate lip, (2) the vertical distance from the lip to the face, and (3) the distance from the lip to the face measured normal to the face. The last method is believed to give the proper dimension, whereas the foregoing considerations are geometrical. The effective head for a partly opened vertical lift or tainter gate depends on the pressures on the face of the concrete and the pressures within the issuing jet. The author has given a good outline of the geometrical variables and the head-measurement method for analyzing partly raised drum gates.

The drum gate has the very attractive feature of requiring no mechanical hoisting equipment for operation. Many of the dams constructed by the USBR have spillways controlled by drum gates. For example the Arrowrock Dam in Idaho (constructed in 1915) and the Tieton Dam in Washington (constructed in 1925) are both equipped with drum gates. B. F. Thomas and D. A. Watt credit H. M. Crittenden with the design of what is apparently the first drum gate.[17] The gates were installed in Dam No. 1 on the Osage River in Missouri in 1911. However, the refinements of the modern drum gate have been developed principally by the USBR.

The discharge coefficients presented by the author are based on model studies. There should be opportunity to check the coefficients for relatively low heads with partly raised gates in the prototype by current-meter measure-

[11] "Flow over Rounded Crest Weirs," by W. M. Borlund, thesis presented to the University of Colorado, at Boulder, Colo., in 1938, in partial fulfilment of the requirement for the degree of Master of Science.

[12] Chf. Hydr. Engr., Analysis Branch, Corps of Engrs., U. S. Waterways Experiment Station, Vicksburg, Miss.

[13] Hydr. [illegible] U. S. Waterways Experiment Station, Vicksburg, Miss.

[14] "Weir Experiments, Coefficients and Formulas," by Robert E. Horton, *Water Supply and Irrigation Paper No. 200, Coast and Geodetic Survey, U. S. Dept. of Commerce, Washington, D. C.*, 1907 (revision of Paper No. 150).

[15] "Recent Experiments on the Flow of Water over Weirs," by H. Bazin, *Annales des Ponts et Chaussées*, October, 1888. (Translation by Arthur Marichal and John C. Trautwine, Jr., *Proceedings*, Engineers' Club of Philadelphia, Pa., Vol. VII, No. 5, 1890, p. 259.)

[16] *Ibid.*, Vol. IX, No. 3, 1892, p. 231.

[17] "The Improvement of Rivers," by B. F. Thomas and D. A. Watt, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1913.

ments. Only on rare occasions with large floods is it possible to verify the coefficients for high prototype heads over the drum gates in the lowered position. The author's mention of the failure to obtain discharge measurements during the 1948 flood over the Grand Coulee Dam spillway emphasizes the importance of this condition. The writers have studied the basic data for high heads over the drum gate in the lowered position.

It becomes evident from a study of Table 2 that the ratio of gate radius to maximum head has a wide range. The writers use the ratio r/H_D, in which H_D is the design head for the spillway. This is the inverse of the ratio used by Mr. Bradley, used so that circular arcs can be traced on dimensionless profiles of x/H_D and y/H_D.

A comparison has been made of the coefficients for various (r/H_D)-values with the gate down. Only the high-overflow sections with negligible velocity of approach were selected from Table 2 for a study of discharge coefficients. Table 8 shows the value of the discharge coefficients for the condition when the drum gate is down. The percentage difference of the coefficient from that of the Madden Dam coefficient is also shown. It is expected that the accuracy of the discharge measurements and thus the coefficient of discharge is less than 1%.

TABLE 8.—COMPARISON OF DISCHARGE COEFFICIENT WITH THE GATE DOWN

Dam	Radius of gate, in feet[a]	Maximum head on crest, in feet[a]	Ratio, $\frac{r}{H_D}$	Coefficient,[b] C_q	Difference, in percent, from Madden Dam
Madden (Canal Zone)	30.0	30.0	1.00	3.77	0.0
Norris (Tennessee)	34.0	27.0	1.26	3.80	0.8
Grand Coulee (Washington)	66.2	31.6	2.09	3.87	2.6
Shasta (California)	66.2	28.0	2.37	3.76	−0.3
Friant (California)	47.0	19.0	2.47	3.64	−3.5
Capilano (British Columbia)	71.0	23.0	3.08	3.62	−4.0

[a] From Table 1. [b] From Table 2.

The dams for which the data are listed in Table 8 are in the approximate chronological order of the time of their design conception.

Because of the increase in the ratio of r/H_D (Table 8), it is of interest to plot the profile for the lower surface of the nappe from a sharp-crested weir with an approach slope of 2 on 3 in terms of x/H_D and y/H_D and to superimpose on it the arcs of circles with radii of r/H_D equal to 1, 2, and 3, as is done in Fig. 16. The center of the radius is located on the axis of the crest. It can be seen that the arc represented by r/H_D equal to 1 is a fair approximation of the true nappe shape. The arcs of r/H_D equal to 2 and 3 indicate a very flat curvature in comparison to the shape of the nappe.

One is tempted to assume, for a crest with a ratio $r/H_D = 3$, that the coefficient would be that for one third the design head of a crest with $4/H_D = 1$.

Model studies for Madden Dam reported by Richard R. Randolph, Jr.,[18] indicate that the coefficient for such a condition is approximately 3.40. Such a coefficient is not in agreement with that for Capilano Dam with r/H_D equal to 3.62 at full head. The lack of agreement does not necessarily vitiate the initial assumption. The difference in the coefficient may be caused by the

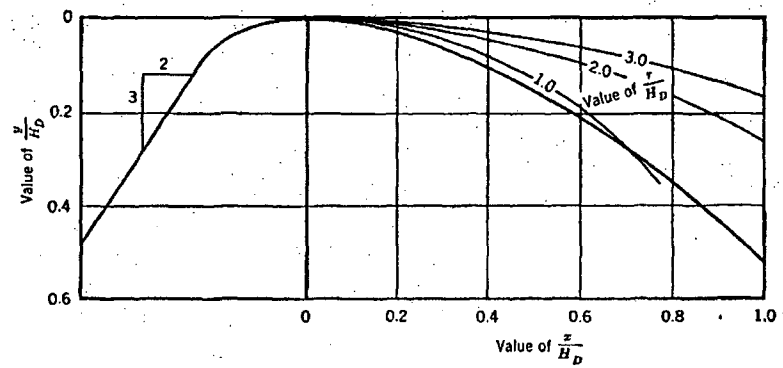


FIG. 16.—LOWER SURFACE OF NAPPE FROM SLOPING WEIR COMPARED WITH CIRCULAR ARCS

difference in shape of the two crests upstream from the circular arc. Furthermore, the scale ratio of the Madden Dam model was only 1:78, and a 10-ft prototype head would be 0.128 ft on the model, which is near the lower limit of reliability for conformity of the discharge coefficient.

JOSEPH N. BRADLEY,[19] A.M. ASCE.—Mr. Shulits' statements regarding the lack of correlation in laboratory studies are well founded, and the writer is in complete agreement with his views.

Mr. Buehler's analysis for the determination of the designed head, H_D, for overflow sections formed by a single radius, or for a shape that conforms closely to a single radius, gives satisfactory results. The comparison of discharge coefficients for free flow over various dams, using Eq. 3 with the method offered in the paper, is gratifying. Mr. Buehler's method certainly has merit because following the determination of H_D, coefficients of discharge can be computed directly for all heads.

Messrs. Campbell and McCool undertook to show that a definite relationship exists between the coefficient of discharge at the designed head and the ratio r/H_D for overflow shapes. This relationship is valid if the overflow shape can be approximated by an arc of a single radius and if the approach conditions are favorable—that is, if the approach depth below the crest is at least twice H_D. This method results in a coefficient of discharge for the designed head only. When overflow sections are encountered where a single radius does not approximate the overflow shape, or when the approach conditions are unusual, an engineering monograph[2] may prove helpful.

[18] "Hydraulic Tests on the Spillway of the Madden Dam," by Richard R. Randolph, Jr., *Transactions*, ASCE, Vol. 103, 1938, p. 1091.

[19] Hydr. Engr., Bureau of Reclamation, U. S. Dept. of the Interior, Denver, Colo.

Mr. Wyss suggested that pressures and water surfaces for drum gates at various positions and reservoir levels would be useful to designers in computing gate loadings. A limited amount of information is available, and this will be presented.

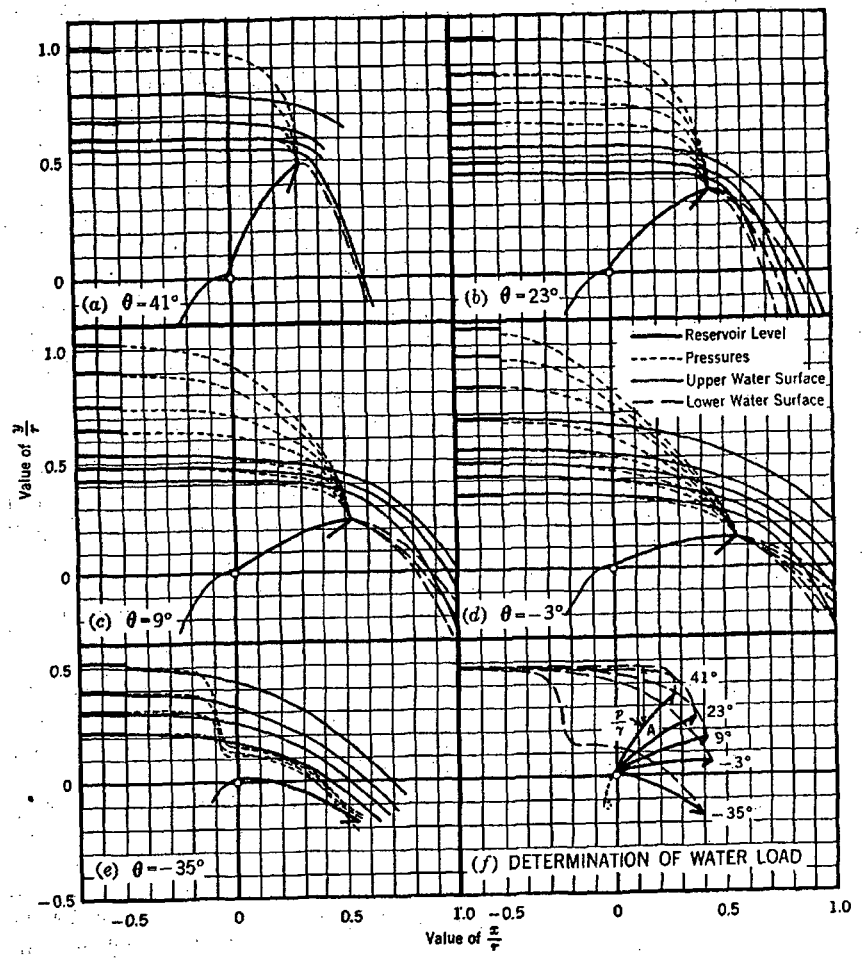


Fig. 17.—Pressure and Water-Surface Profiles

Because there was good correlation among the discharge coefficients, it was reasoned that the pressures and related flow patterns would also be well correlated through the same variables.

Pressures and water-surface profiles are plotted in dimensionless coordinates (in terms of the radius of the gate) in Fig. 17. Five positions of the gate are shown for various reservoir levels producing flow over the gate. Pressures and water surfaces are shown for some levels whereas only pressures are

available for others. The broken lines represent pressure, measured vertically, for the reservoir levels indicated at the left of the charts. Upper water-surface profiles are shown by solid lines, and lower water-surface profiles are identified by dash lines. The charts represent a composite, in graphical form, of information from model tests performed on the Grand Coulee, Hamilton, Norris, Friant, and Hoover dams.

To determine graphically the most adverse water load on a particular gate, it is necessary to investigate the pressures for several gate positions. Assuming that the first position is $\theta = 41°$, the gate is drawn in this position on a piece of transparent paper to the same scale as that used in Fig. 17. The maximum expected reservoir is indicated for this gate position on the left side of the transparent sheet.

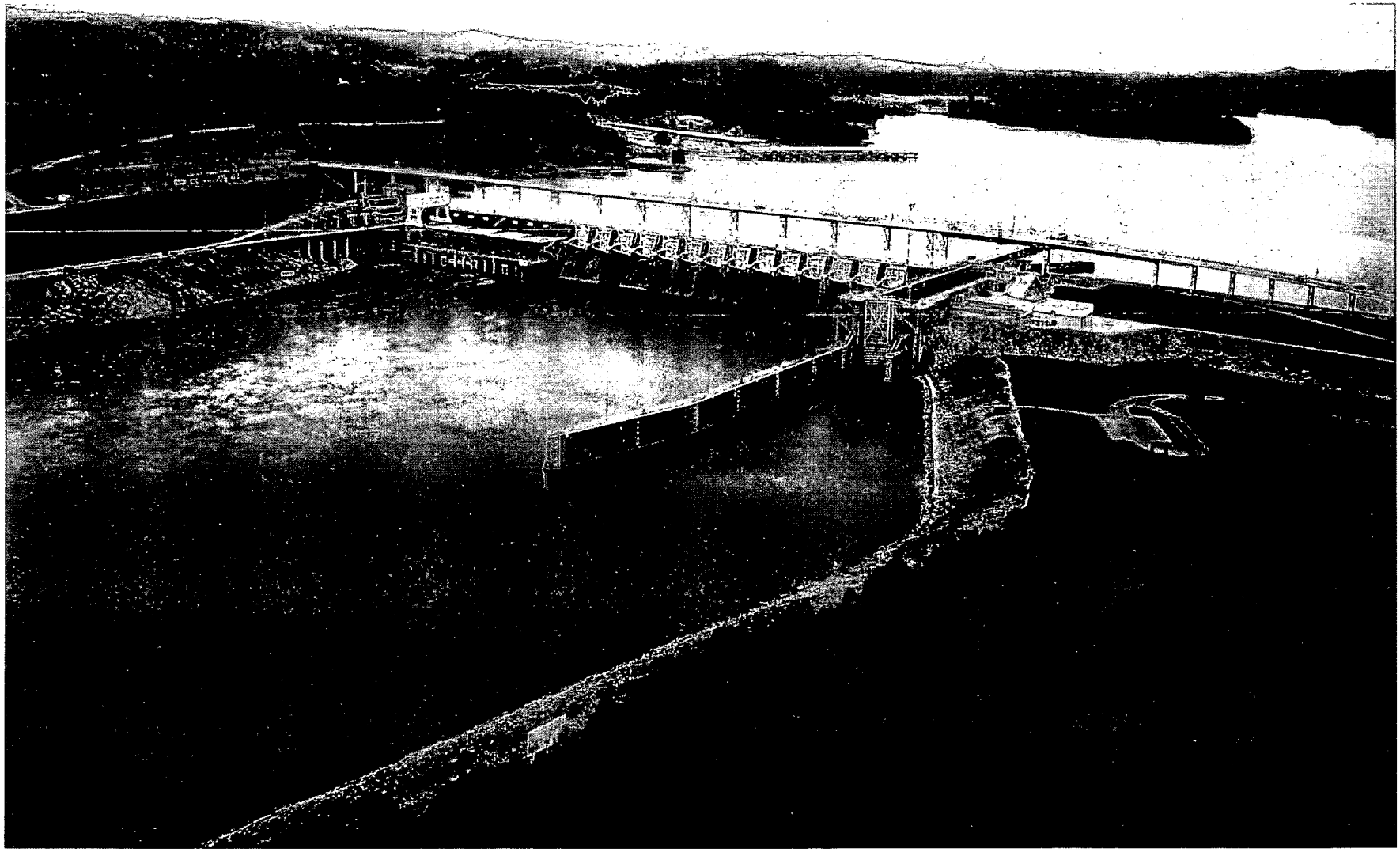
The transparent sheet is then placed over Fig. 17(*a*), disregarding the origin of coordinates, and matching only the downstream tips of the two gates. The downstream part of all drum gates, regardless of size or radius, will coincide for any given value of θ. The height of the gate, or length of arc, can be expected to vary; this will have a negligible effect on pressures or water-surface profiles in the majority of cases. Should the gate under investigation differ from the height shown in Fig. 17(*a*), a small increase or decrease in the approach-depth results.

Beginning with the chosen reservoir level, the pressure curve is traced from Fig. 17(*a*) onto the transparent paper. It may be necessary to interpolate between two of the pressure curves. The result will be similar to that shown in Fig. 17(*f*).

A similar procedure is then followed for gate positions of 23°, 9°, −3°, and −35°, utilizing Figs. 17(*b*), 17(*c*), 17(*d*), and 17(*e*), respectively. The result is a composite plot similar to that shown in Fig. 17(*f*). It should be noted that the pressures shown for negative angles of the gate are not as reliable as those for positive angles. Fortunately, the greater water loads occur for positive angles.

Water loads can be determined by scaling the pressures vertically over the gate as indicated by point A in Fig. 17(*f*). If a gate angle other than those shown is desired, interpolation can be made directly on the sheet corresponding to Fig. 17(*f*). Following the establishment of the maximum-pressure curve, values of x/r and y/r are scaled from the sheet corresponding to Fig. 17(*f*) and are transferred to dimensional values by multiplying by r. Should water-surface profiles be desired, the same method of tracing and scaling can be used.

FORT LOUDOUN DAM



July 1998

RESERVOIR OPERATION OVERVIEW

Fort Loudoun Dam is a multipurpose main river project, the uppermost of 9 such projects located on the Tennessee River which provide a navigable waterway from the mouth of the river at Paducah, Kentucky to the source of the river above Knoxville, Tennessee, some 652 river miles apart. Fort Loudoun was constructed in the early 1940's as part of the War effort. In addition to completing the navigation link along the Tennessee River, Fort Loudoun provides significant flood reduction benefits for downstream locations including Chattanooga, Tennessee, and also contributes hydroelectric generation. Fort Loudoun Lake is fed by releases from TVA'S Douglas and Cherokee Lakes in addition to the unregulated inflow from a significant local drainage area which includes portions of the Great Smoky Mountains. Inflow to Fort Loudoun also is contributed by Tellico Lake, a TVA project on the Little Tennessee River which is connected to Fort Loudoun Lake via an unregulated canal.

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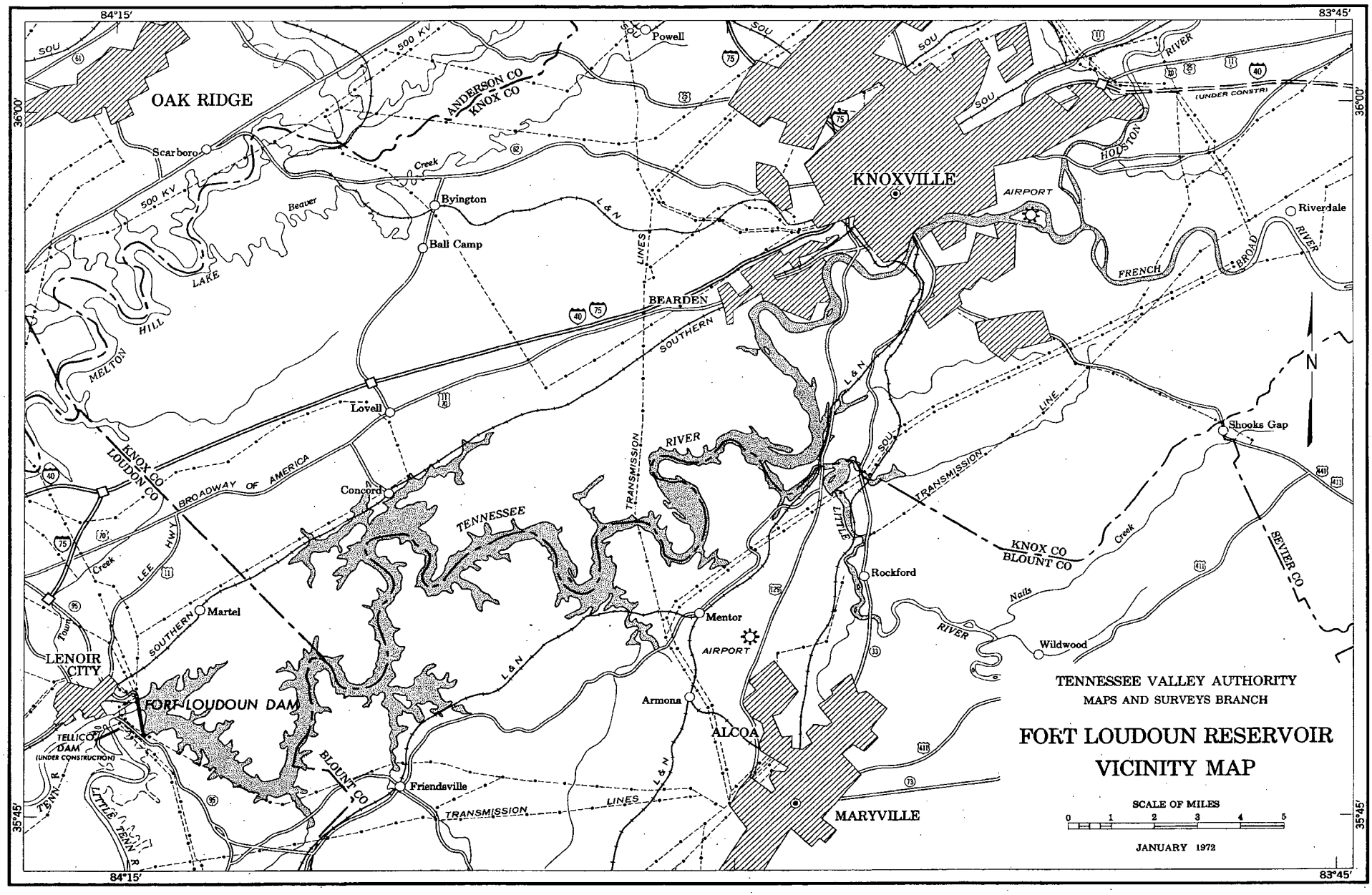

84°15'
83°45'
36°00'
35°45'
OAK RIDGE
Scarboro
Powell
ANDERSON CO
KNOX CO
500 KV
Beaver
Creek
Byington
Ball Camp
LAKE
HILL
MELTON
L & N
LINES
SOUTHERN
BEARDEN
KNOXVILLE
AIRPORT
HOLSTON
RIVER
(UNDER CONSTR)
Riverdale
FRENCH
BROAD
RIVER
N
Lovell
KNOX CO
LOUDON CO
BROADWAY OF AMERICA
Concord
TENNESSEE
RIVER
TRANSMISSION
LINE
Shooks Gap
LITTLE
KNOX CO
BLOUNT CO
Creek
SEVIER CO
Rockford
Nails
RIVER
Wildwood
Mentor
AIRPORT
Martel
LEE HWY
Tound
LENOIR CITY
FORT LOUDOUN DAM
TELLICO DAM
(UNDER CONSTRUCTION)
TENN. R.
LITTLE TENN. R.
BLOUNT CO
Armona
ALCOA
Friendsville
TRANSMISSION LINES
MARYVILLE
TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH
FORT LOUDOUN RESERVOIR
VICINITY MAP
SCALE OF MILES
0 1 2 3 4 5
JANUARY 1972

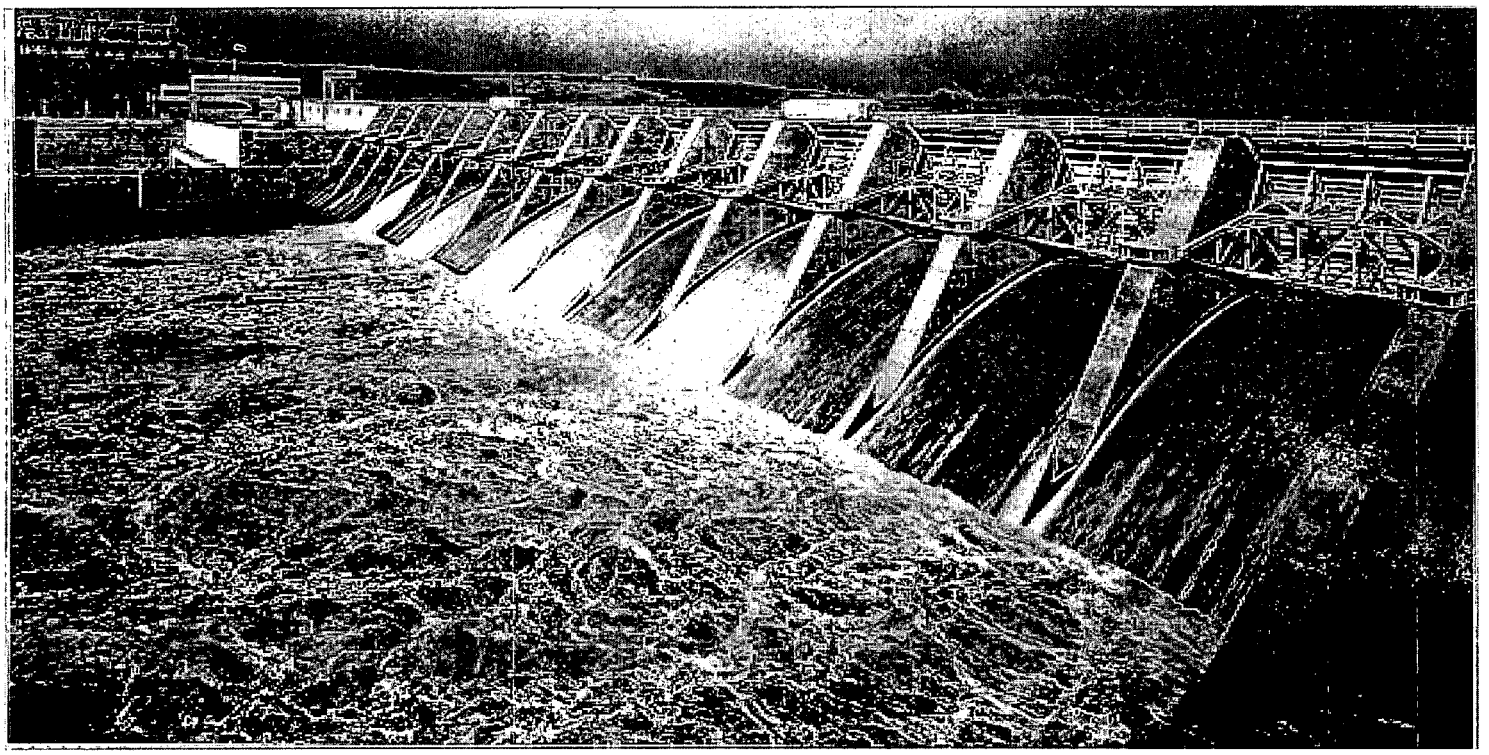


FIGURE 1: Radial gates controlling spillway discharge, 1943

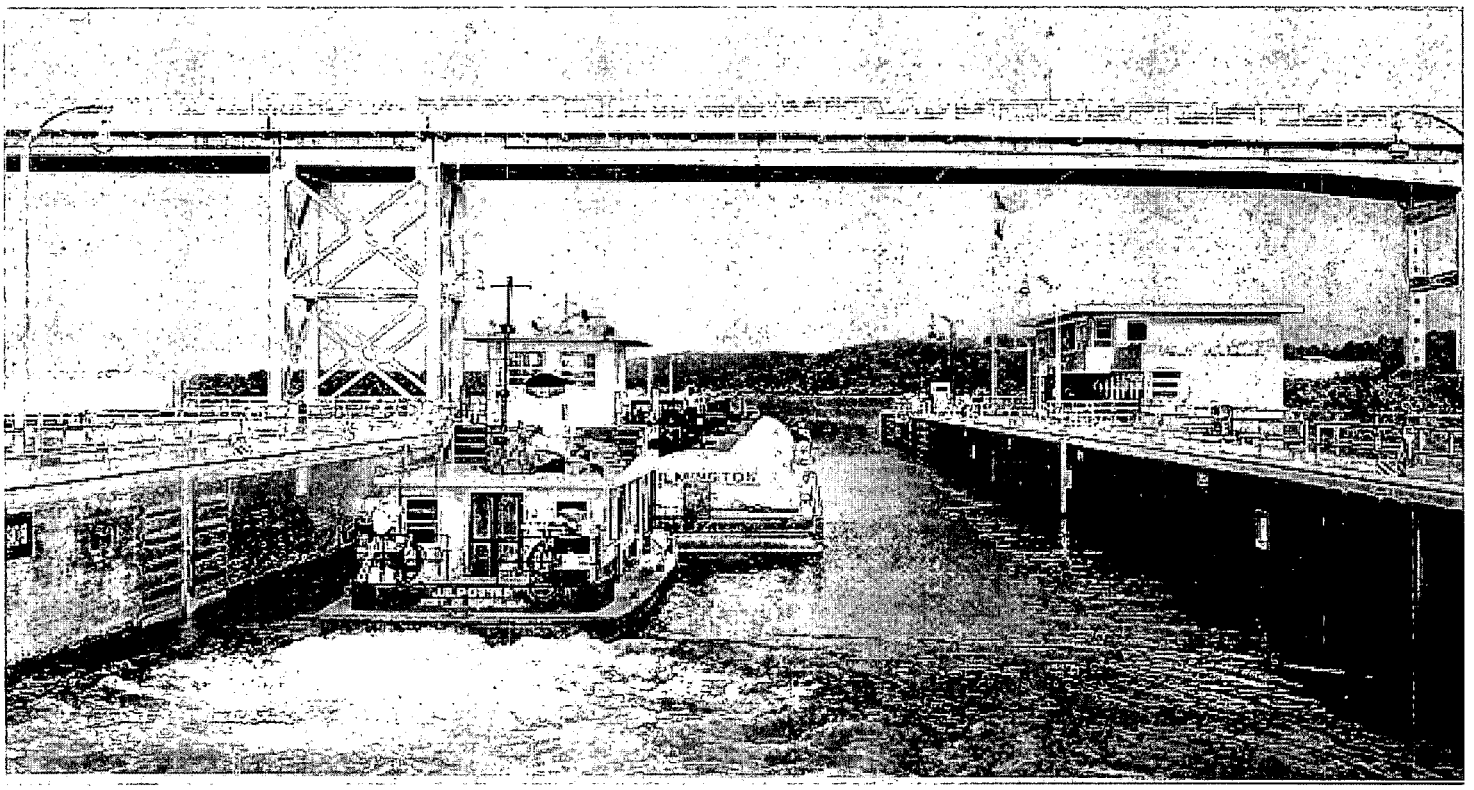


FIGURE 2: Navigation lock has single lift of 80 feet, 1943

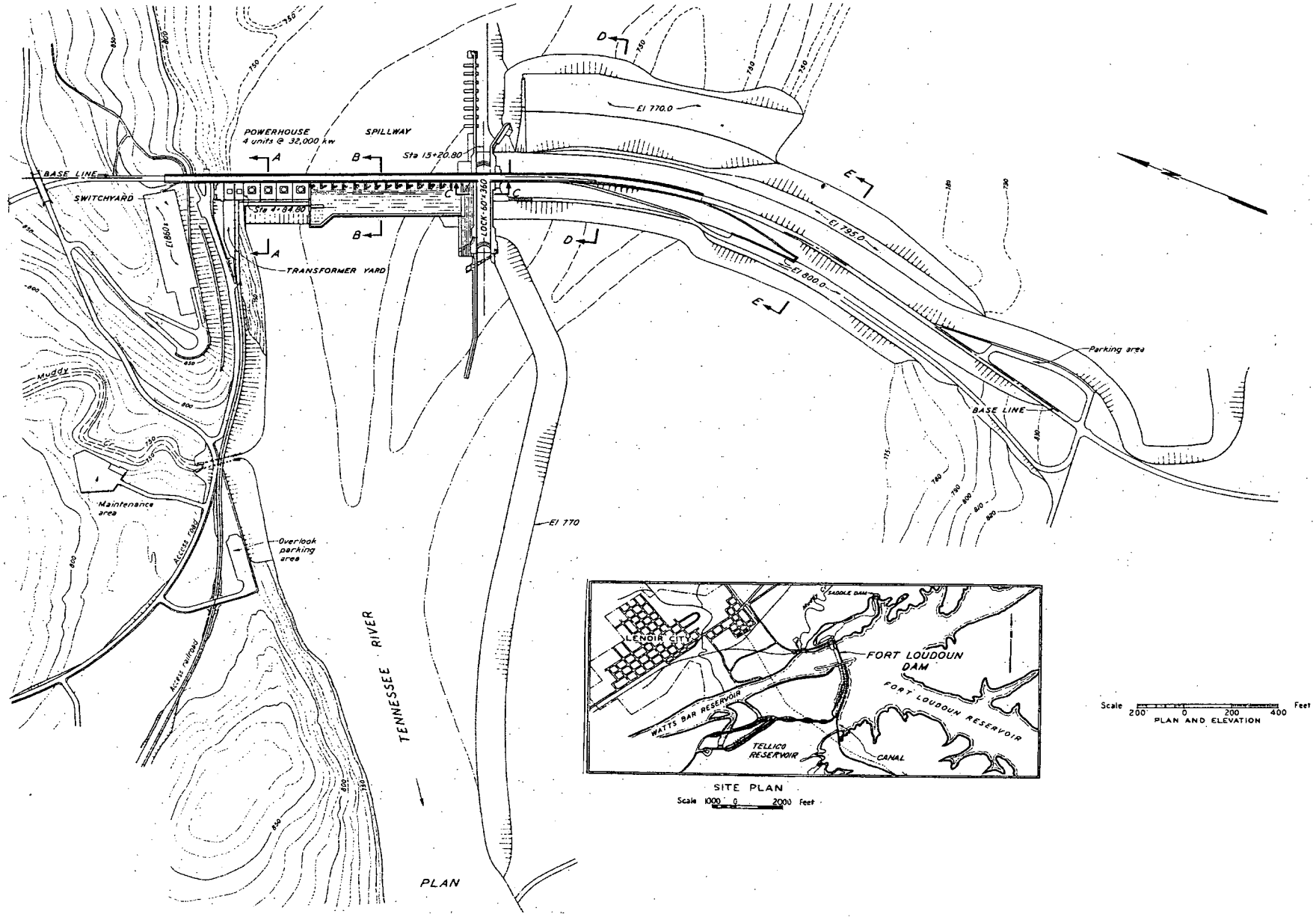


FIGURE 3: General Plan

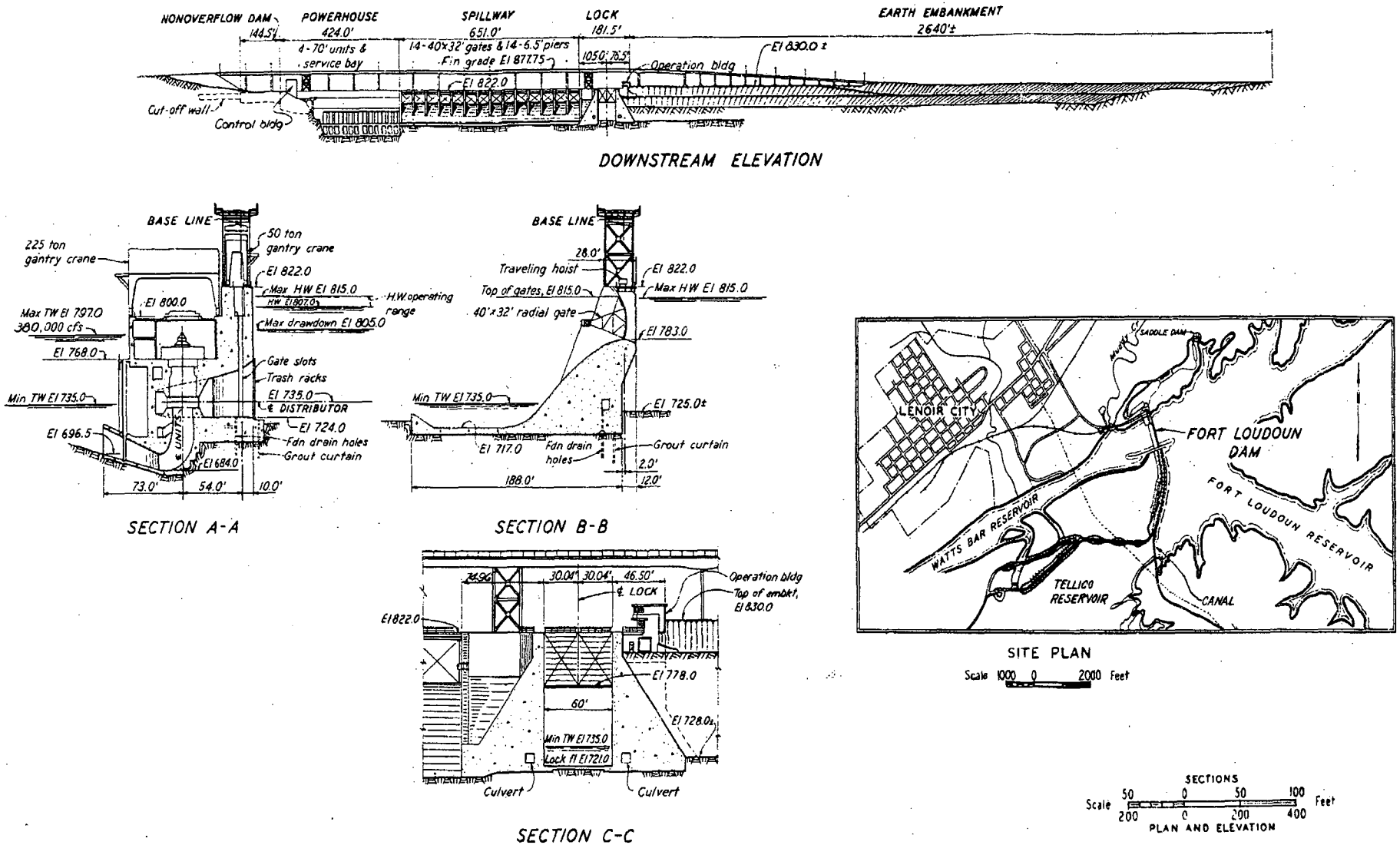


FIGURE 4: Site Plan Downstream Elevation and Sections A-A, B-B, and C-C

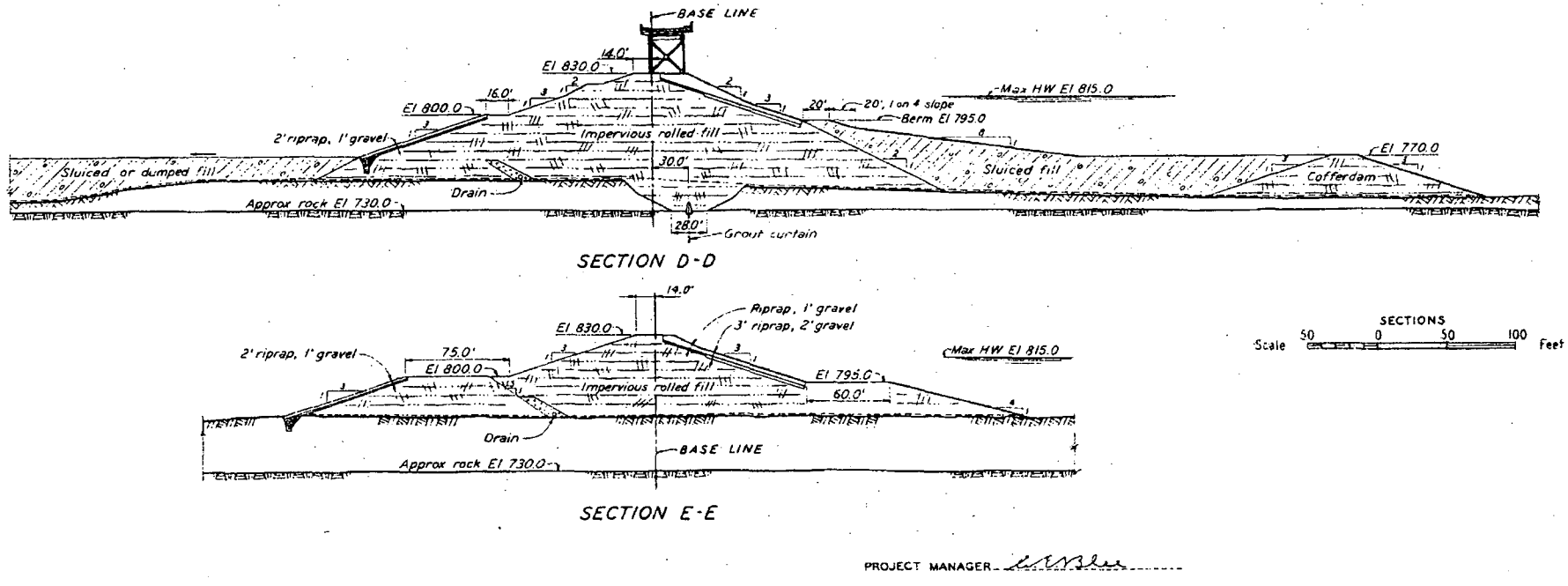
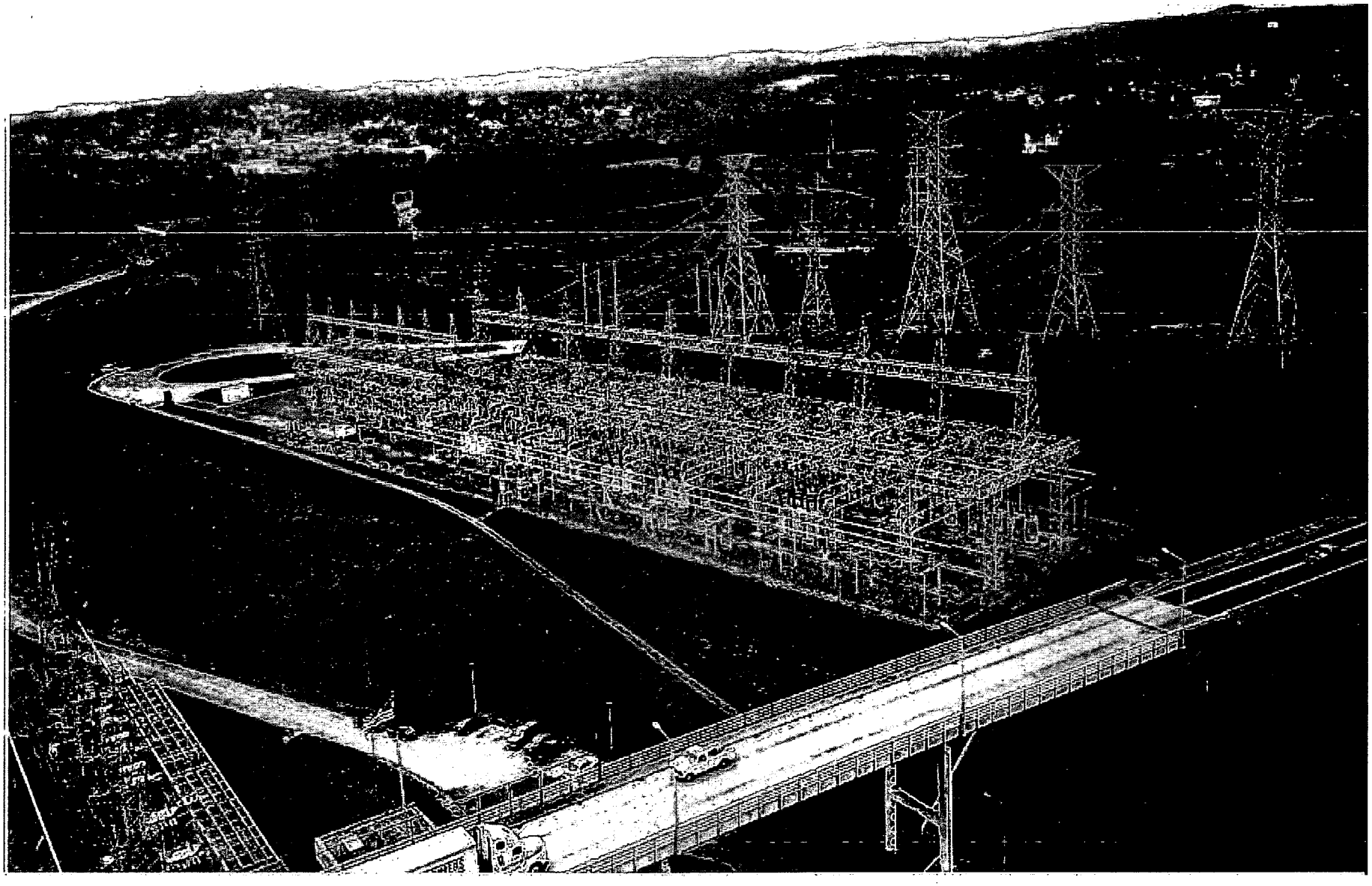


FIGURE 5: Sections D-D & E-E

FIGURE 6: Fort Loudoun Switch Yard



FORT LOUDOUN PROJECT

SUMMARY OF PRINCIPAL FEATURES

LOCATION

On Tennessee River at river mile 602.3; in Loudon County, Tennessee; 72.4 miles upstream from Watts Bar Dam; 1 mile upstream from Lenoir City and mouth of Little Tennessee River; 45.4 miles downstream from Knoxville, Tennessee; 1/2 mile from main line of Southern Railway.

NOTE

Elevations are based on the U.S.C. & G.S. 1936 Supplementary Adjustment.

CHRONOLOGY

Initial appropriation by Congress	April 18, 1940
Authorized by TVA Board of Directors	July 3, 1940
Construction started	July 8, 1940
First cofferdam started	October 15, 1940
First excavation	December 1940
First concrete in permanent structures	June 1941
Units 3 and 4 authorized by TVA Board of Directors	January 15, 1942
Work on units 3 and 4 stopped by order of War Production Board	October 1942
Dam closure	August 2, 1943
Lock opened to traffic	October 10, 1943
Unit 2 in commercial operation	November 9, 1943
Unit 1 in commercial operation	January 15, 1944
Work resumed on units 3 and 4	July 1, 1947
Unit 3 in commercial operation	October 17, 1948
Unit 4 in commercial operation	January 27, 1949
Highway bridge across dam:	
Started	January 1960
Opened to traffic	July 22, 1961
Safety Modifications for probable maximum flood	September 1989
Reservoir release improvements	June 1995

PROJECT COST

Initial project, including lock and 2 units	$36,209,067
Addition of units 3 and 4	4,793,890
Safety Modifications for probable Maximum Flood	1,012,750
Reservoir Release Improvements	$750,000
Total, including switchyard	$42,765,707

STREAMFLOW

Drainage area at dam:
- Total ..... 9,550 sq. miles
- Uncontrolled (below Cherokee and Douglas Dams) ..... 1,581 sq. miles

Gaging station discharge records (for complete records see Data Services Branch files):
- Knoxville, Tennessee, October 1899 to date; drainage area at:
  - Point of gage reading ..... 8,913 sq. miles
  - Point of discharge measurement ..... 8,934 sq. miles

Maximum known flood at dam site;
- Natural (1867) ..... 315,000 cfs
- Regulated (May 1984) ..... 140,100 cfs

Average unregulated flow at dam site, including Little Tennessee River (1903 -1998) ..... 18,700 cfs

Minimum daily natural flow at dam site, (1925), approx ..... 1,600 cfs

RESERVOIR

Counties affected:
- State of Tennessee ..... Loudon, Blount, Knox
- Note: ..... A free-flowing navigable canal connects Fort Loudoun Reservoir with the Tellico Reservoir on the Little Tennessee River.

Reservoir land at September 29,1998:
- Fee simple ..... 1,583 ac.
- Easements (Needs Updated) ..... 3,835 ac.
- Total ..... 5,418 ac.
- Transferred ..... 958 ac.

Operating levels at dam:
- Probable maximum flood elevation (PMF) ..... *el. 833.5
- 500 year flood elevation ..... *el. 817.0
- 100 year flood elevation ..... *el. 816.0
- Winter flood guide level ..... el. 807.0
- Summer flood guide level ..... el. 813.0
- Maximum used for design (390,000 cfs) ..... el. 815.0
- Top of gates (area 15,500 ac.) ..... el. 815.0
- Normal minimum pool (area 12,200 ac.) ..... el. 807.0

Backwater, length at normal maximum pool level:
- Tennessee River ..... 49.9 miles
- French Broad River ..... 6.5 miles
- Holston River ..... 4.4 miles
- Total ..... 60.8 miles

**These elevations are valid at the dam and may change significantly upstream of the dam.*

RESERVOIR (CONT.)

Shoreline, length at normal maximum pool level:
- Main shore ..... 358.8 miles
- Islands ..... 19.4 miles
- Total ..... 378.2 miles

Original river area (to el. 815 crossing) ..... 4,420 ac.
Storage (flat pool assumption):
- Total volume:
  - At top of gates (el. 815) ..... 393,000 ac.-ft
  - At normal maximum pool (el. 813) ..... 363,000 ac.-ft
  - At normal minimum pool (el. 807) ..... 282,000 ac.-ft
- Controlled flood storage:
  - January 1 to April 1 (el. 815-807) ..... 111,000 ac.-ft

TAILWATER

Maximum used for design ..... el. 797.0
Maximum known flood (1867) ..... el. 787.4
Full plant operation (4 units) ..... el. 742.0
One unit operating at best efficiency ..... el. 736.7
Minimum level ..... el. 735.0

HEAD (Gross)

Maximum static (el. 815-735) ..... 80 ft
Normal operating range ..... 56 to 75 ft
Average operating ..... 71 ft

RESERVOIR ADJUSTMENTS

Clearing ..... 3,146 ac
Preparation of sailing line ..... 550 ac.
Drainage of isolated pools ..... 92,300 cu. yd
Highways:
- Access ..... 2.9 miles
- State ..... 0.9 miles
- County and tertiary ..... 62.6 miles
- Total ..... 66.4 miles

Railroads:
- Access ..... 1.5 miles
- Other ..... 8.4 miles
- Total ..... 9.9 miles

Bridge adjustments (highway 3,816 ft:
railroad 795 ft) ..... 27 bridges
Concrete box culverts 69
Utilities adjusted or constructed ..... 42 miles
Families relocated 317
Graves ..... 890 agreements; 878 removals

NAVIGATION FACILITIES

NAVIGATION CHANNEL

Length of channel for 9-ft navigable
depth (to Knoxville) ..... 44.7 sailing miles
Minimum navigation level at Knoxville ..... el. 807
Length of dredged navigable channel:
Below look ..... 6.3 miles
Upper end of pool ..... 1.1 miles

NAVIGATION CANAL

A 3000-ft-long by 500-ft-wide canal connects Tellico Reservoir on the Little Tennessee River with Ft. Loudoun (See Figure 7.)

NAVIGATION LOCK (See Figure 8)

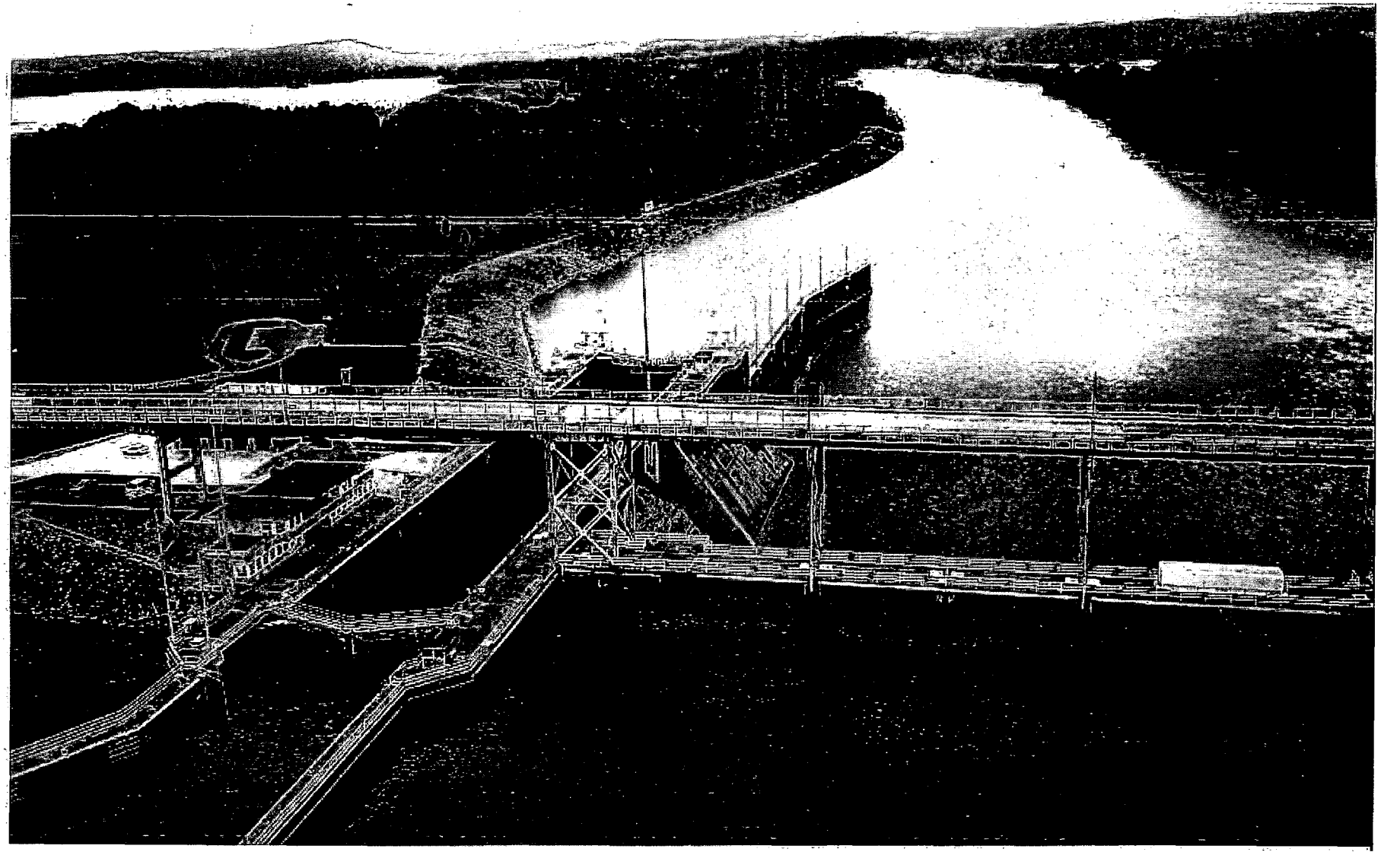
Location ..... At left (south) end of spillway
Lock chamber, clear ..... 60 by 360 ft
Lift: Maximum (el. 735-816) ..... 80 ft
Normal (el. 741-813) ..... 72 ft
Gate sills ..... Upper, el. 778.0; lower, el. 723.2
Minimum depth over
sills ..... Upper, 27.0 ft; lower, 11.8 ft
Top of upper approach walls ..... el. 822.0
Top of chamber walls ..... el. 822.0
Top of lower approach walls ..... el. 772.8
Estimated lockage time (checking to
regaining speed) ..... 45 min
Vertical clearance under bridge (min.) ..... 57 ft
Provision for:
future lock ..... Space available for 110 - by 600-ft lock to left (south) of present lock
Lock gate top ..... Upper, el. 819.11; lower, el. 819.31
Lock gate height ..... Upper, 42.44 ft; lower, 96.64 ft

Canal between Ft. Loudoun & Tellico

FIGURE 7

Navigation Lock

FIGURE 8



DAMS

MAIN DAM

Material and type ..... Concrete gravity nonoverflow dam and spillway; concrete powerhouse ; intake, navigation lock; impervious rolled earthfill embankment

Lengths:
- Nonoverflow dam ..... 145 ft
- Spillway ..... 651 ft
- Powerhouse intake and service bay ..... 424 ft
- Navigation lock ..... 182 ft
- Cutoff wall, right (north) bank ..... 148 ft
- Earth embankment ..... 2,640 ft
- Total ..... 4,190 ft

Maximum height, foundation to deck level ..... 122 ft

Maximum width at base:
- Spillway section only ..... 105 ft
- Including apron ..... 188 ft

Deck level ..... el. 822.0

Top of earth embankment ..... el. 830.0

Outlet facilities:
- Spillway clear opening (14 openings at 40 ft) ..... 560 ft
- Spillway crest level ..... el. 783.0
- Crest gates ..... 14 radial gates, 40 ft wide, 32 ft high, separated by 6.5-ft-thick piers
- Traveling hoists ..... Two 60-ton hoists
- Spillway capacity, HW el. 815 (top of gates) ..... 390,000 cfs

Highway ..... 26 ft wide, on bridge over dam

Foundation ..... Limestone and shale

SADDLE DAM

Location ..... Right rim 0.5 mile from main dam

Material and type ..... Impervious rolled earthfill embankment

Length ..... 460 ft

Maximum height ..... 25 ft

Top of embankment, 30 ft wide ..... el. 830.0

Highway ..... 20 ft

Foundation ..... Earth

POWER FACILITIES

INTAKES

Number ..... 4 (each with 3 bays)
Dimensions of one
rack opening ..... 19.42 ft wide by 44.25 ft high
Gross area at racks ..... 2,575 sq. ft per unit
Gates ..... Two sets of 3 each wheel gates, 37 ft 9 in. high by 14.67 ft clear opening, in 2 sections
Stoplogs ..... One set of 7 sections, 44.4 ft high
Crane ..... 50-ton gantry and lifting beam

POWERHOUSE

Generating capacity, 4-unit total (Original Capacity) ..... 135,590 kW
Type of construction ..... Semioutdoor, reinforced concrete and steel
Principal outside dimensions including:
service bay ..... 424 ft long by 137 ft wide by 142 ft high
Service bay ..... 144 ft long by 125 ft wide
Draft tubes:
Type ..... Elbow, 3 openings
Horizontal length (centerline of turbine to downstream face) ..... 73.0 ft
Vertical distance from distributor centerline to draft tube floor ..... 51.0 ft
Net area at outlet opening per unit ..... 968 sq. ft
Gates ..... One set of 3 steel slide gates, 18 ft 3 in. high by 15 ft clear opening
Crane ..... One 25-ton hook on jib of powerhouse gantry
Erecting crane ..... 225-ton gantry with two 112.5-ton main hooks and two 25-ton auxiliary hooks

POWER FACILITIES (CONT)

HYDRAULIC TURBINES

Number 4
Manufacturer ..... Baldwin-Lima-Hamilton Corp.
Type ..... Kaplan adjustable-blade propeller
Rated capacity (each) ..... 44,000 hp at 65-ft net head
Rated speed ..... 105.8 r/min
Maximum runaway speed ..... 282 r/min
Specific speed at rating 120
Value of sigma at rating 0.69
Diameter of runner ..... 222 in
Diameter of guide vane circle ..... 276.500 in
Diameter of lower pit ..... 27.0 ft
Spacing of turbines, center to center of units ..... 70 ft
Draft tubes (see Powerhouse) ..... Elbow type
Governors ..... Woodward, cabinet actuator type
Heaviest assembly to be lifted by crane ..... 431,900 lb

GENERATORS

Generating Capacity 4 unit Total 135,590KW
Number 4
Manufacturer ..... Allis-Chalmers Manufacturing Co.
Type ..... Enclosed, water-cooled, vertical-shaft
Original Rating:
Units 1,2,3 &4
original rating ..... 35,555 kVA , 32,000 kW, 1487 A, 60° C rise, 0.9 pf, 13.8 kV, 3 phase, 60 Hz
Original Capacity:
Unit 1,2,3 &4
original capacity ..... 40,825 kVA, 36,742 kW, 1710 A, 80° C rise

Note: Units 2, 3, and 4 rewound and rerated July 1, 1972, June 1, 1973, and November 1, 1968, respectively.
Rating, Units 2,3 ..... 38,000 kVA, 34,200 kW, 1590 A, 60°C rise, 0.9 pf, 13.8 kV, 3 phase, Hz
Rating: Unit 4 39,100 kVA, 35,190 kW, 1635 A, 60°C rise, 0.9 pf, 13.8 kV, 3 phase, 60 Hz
Efficiency (guaranteed original values):
At rated kVA, 1.0 pf ..... 97.4 percent
At 75% kVA, 0.9 pf ..... 97.0 percent
Flywheel effect ..... 40,100,000 lb-ft^2
Thrust bearing ..... Kingsbury, dia. 93 in., max. load 855 tons
Neutral reactor ..... 0.75 ohm, 5000 A, 1 min
Exciters:
Main ..... 350 kW, 250 V
Pilot ..... 20 kW, 250 V

POWER FACILITIES (CONT)

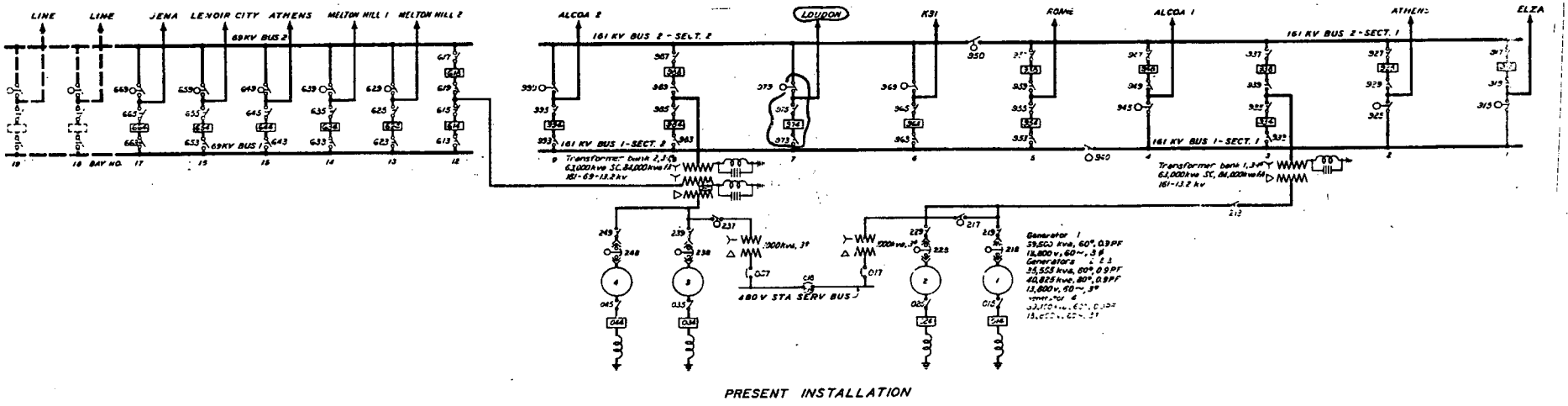
GENERATORS (CONT.)

Weight of heaviest crane lift, rotor ..... 182 tons
Diameter over air housing, less trim ..... 477 in.
Diameter of stator bore ..... 298 in.
Top of pilot exciter:
Above stator soleplates ..... 136.12 in.
Above generator floor ..... 139.49 in.

GENERATOR & TURBINE MODERNIZATION

This project will modernize the power train and involves replacing principal components such as the runners , main transformers, generator leads, and stator windings for the generator air coolers. Principal components to be rehabilitated are the kaplan servo , turbine/generator bearings and shaft, thrust runner, wicket gates, brakes ,and main exciter . This project is scheduled to start in June 2002 and complete in July 2010.

FIGURE 9: SINGLE LINE DIAGRAM OF MAIN CONNECTIONS



ELECTRIC CONTROLS

From control room in powerhouse:
Fort Loudoun generators, transformers, switchyard, sources of auxiliary power, unit auxiliaries, and starting of turbines by direct control; Fontana and Melton Hill hydro plants by supervisory control; Lenoir City primary substation by overhead cable pair.

TRANSMISSION PLANT

Step-up transformers: See Transmission Plant Data.
Intersystem transformers: See Transmission Plant Data.

161-kV circuit breakers:
- 8 1200-A, 10,000,000-kVA, 3/20-Hz, pneu, Westinghouse
- 4 1600-A, 15,000,000-kVA, 3/20-Hz, pneu, Westinghouse

69-kV circuit breakers:
- 3 1200-A, 1,500,000-kVA, 5/20-Hz, pneu, Allis-Chalmers
- 4 600-A, 1,500,000-kVA, 5/20-Hz, pneu, Allis-Chalmers

Structures:
- 9 161-kV switchyard bays, 38 ft wide
- 6 69-kV switchyard bays, 26 ft wide
- 6 transformer structures for 2 transformer banks

TRANSMISSION PLANT DATA

Plant	Location	Phase	Serial Number	MVA Rating		Voltage kV	Cooling	Tap Changer	Oil Preservation System	Oil Volume Gal.	Configuration	Impedance %			Contract Number	Manufacturer	Yr of Manuf
				55 deg	65 deg							H-X	H-Y	X-Y			
Ft. Loudoun	Bank 1	A	737482	21	N/A	161/13.2	OA	DETC	Gas-Blanketed	7510	Wye/Delta	12.83	N/A	N/A	TV-80837	Moloney	1943
Ft. Loudoun	Bank 1	B	704487	21	N/A	161/13.2	OA	DETC	Gas-Blanketed	7510	Wye/Delta	12.80	N/A	N/A	TV-55069	Moloney	1941
Ft. Loudoun	Bank 1	C	737481	21	N/A	161/13.2	OA	DETC	Gas-Blanketed	7510	Wye/Delta	12.83	N/A	N/A	TV-80837	Moloney	1943
Ft. Loudoun	Bank 2	A	2010478354	21/28	N/A	161/69/13.2	OA/FA	DETC & OLTC	Gas-Blanketed	6660	Wye/Wye/Delta	13.50	13.10	8.70	TV-94915	Allis Chalmers	1947
Ft. Loudoun	Bank 2	B	2010478352	21/28	N/A	161/69/13.2	OA/FA	DETC & OLTC	Gas-Blanketed	6660	Wye/Wye/Delta	13.40	13.00	8.60	TV-94915	Allis Chalmers	1947
Ft. Loudoun	Bank 2	C	2010478353	21/28	N/A	161/69/13.2	OA/FA	DETC & OLTC	Gas-Blanketed	6660	Wye/Wye/Delta	13.30	13.10	8.70	TV-94915	Allis Chalmers	1947
Ft. Loudoun	Bank 2	Spare	2010478351	21/28	N/A	161/69/13.2	OA/FA	DETC & OLTC	Gas-Blanketed	6660	Wye/Wye/Delta	13.40	13.00	8.70	TV-94915	Allis Chalmers	1947

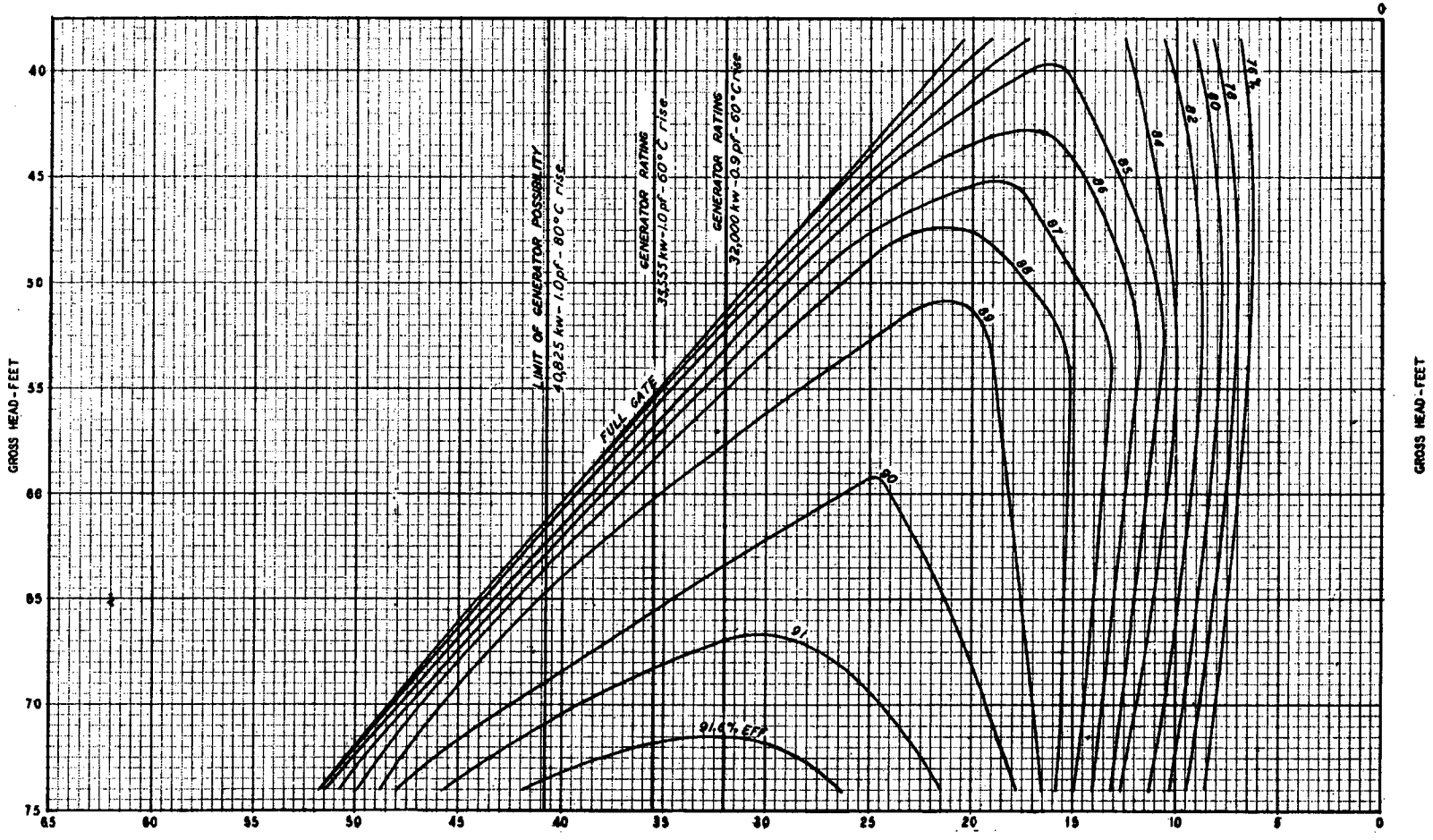
Note: H=High voltage winding
Y=Tertiary winding
X=Low voltage winding

Bank 1 originally installed at Watts Bar Steam Plant

RESERVOIR AND POWER DATA

						Best Efficiency			Maximum Sustainable		
Elevation (feet)	Tailwater (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Potential Eis (gWh)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
815	739	15.51	393.0	44.0	76.0	154.7	27,500	5.63	155.0	28,400	5.46
814	739	14.97	377.8	38.0	75.0	154.7	27,500	5.63	155.0	28,400	5.46
813	739	14.60	363.0	32.1	74.0	152.3	27,440	5.55	154.7	28,760	5.38
812	739	14.30	348.5	26.3	73.0	149.9	27,380	5.47	154.4	29,120	5.31
811	739	13.95	334.4	20.7	72.0	147.6	27,320	5.40	154.1	29,480	5.23
810	739	13.56	320.6	15.2	71.0	145.2	27,260	5.33	153.8	29,840	5.16
809	739	13.13	307.3	9.9	70.0	142.8	27,200	5.25	153.5	30,200	5.08
808	739	12.66	294.4	4.9	69.0	139.6	27,000	5.17	152.9	30,600	5.00
807	739	12.14	282.0	.0	68.0	136.3	26,800	5.08	152.2	31,000	4.92

						Best Efficiency			Maximum Sustainable		
Elevation (feet)	Tailwater (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Potential Eis (gWh)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
815	743	15.51	393.0	43.7	72.0	147.6	27,320	5.40	154.1	29,480	5.23
814	743	14.97	377.8	37.7	71.0	145.2	27,260	5.33	153.8	29,840	5.16
813	743	14.60	363.0	31.8	70.0	142.8	27,200	5.25	153.5	30,200	5.08
812	743	14.30	348.5	26.0	69.0	139.6	27,000	5.17	152.9	30,600	5.00
811	743	13.95	334.4	20.5	68.0	136.3	26,800	5.08	152.2	31,000	4.92
810	743	13.56	320.6	15.0	67.0	133.1	26,600	5.00	151.6	31,400	4.83
809	743	13.13	307.3	9.8	66.0	129.8	26,400	4.92	150.9	31,800	4.75
808	743	12.66	294.4	4.8	65.0	126.6	26,200	4.83	150.3	32,200	4.67
807	743	12.14	282.0	.0	64.0	123.5	26,000	4.75	147.3	32,120	4.58



Curves are based on model tests conducted by Baldwin-Southwark and modified in accordance with index test conducted 3,1-2,44.

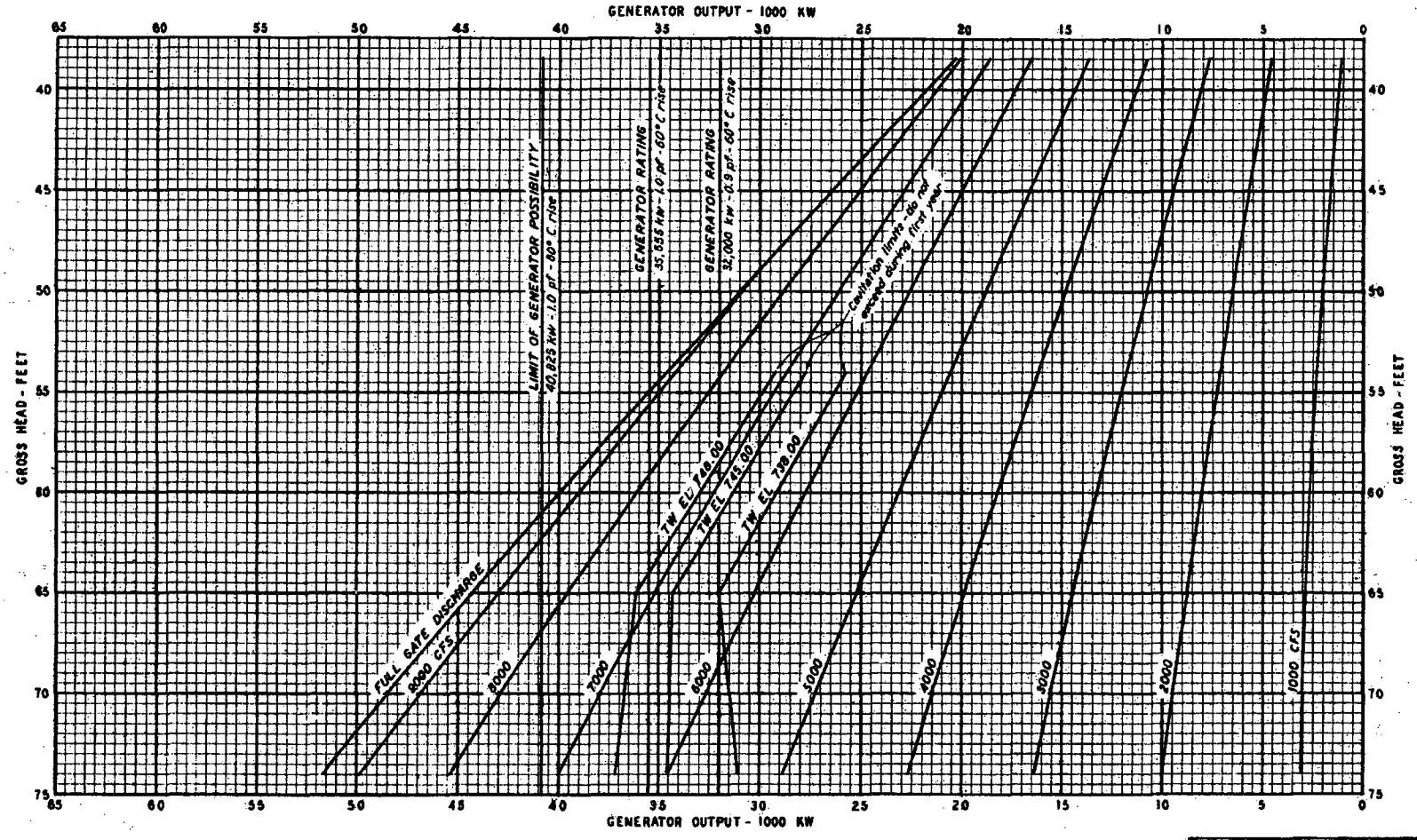
POWERHOUSE
UNIT I

OPERATING CHARACTERISTICS
OF 35,555 KVA
GENERATING UNIT

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DENOIR DEPARTMENT

DESIGNED F. Meundel | DRAWN | APPROVED

KNOXVILLE, 12-15-44 | 10 | 14 | 4 | 478902 Rev



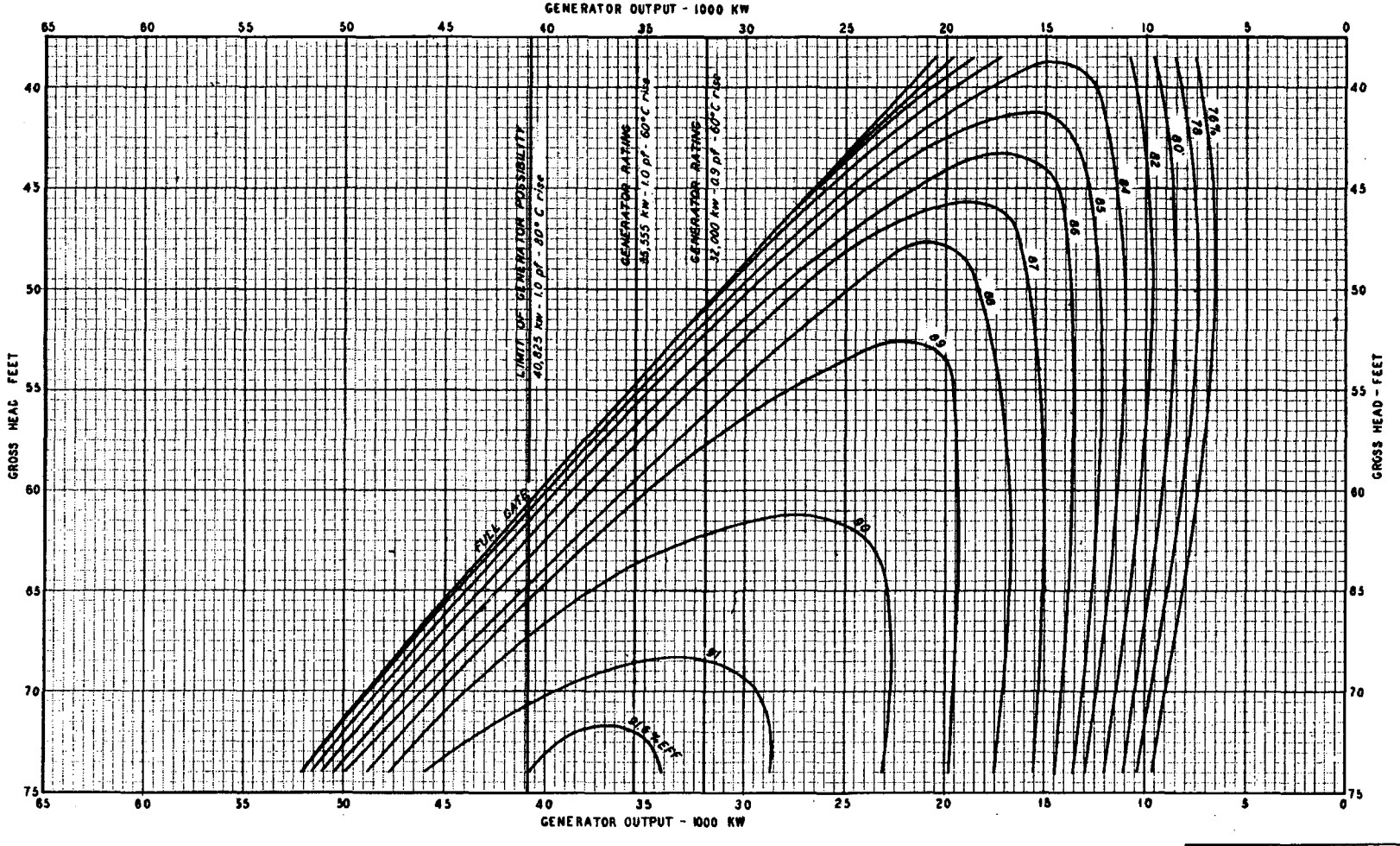
Curves are based on model tests conducted by Baldwin Southwark and modified in accordance with index test conducted 3-1,2-44.

POWERHOUSE
UNIT 1

DISCHARGE CURVES BASED ON INDEX TESTS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
KNOXVILLE	4-10-44	10 M 4 47B901R0



Curves are based on model tests conducted by Baldwin-Southwark and modified in accordance with index test conducted 2-29-44.

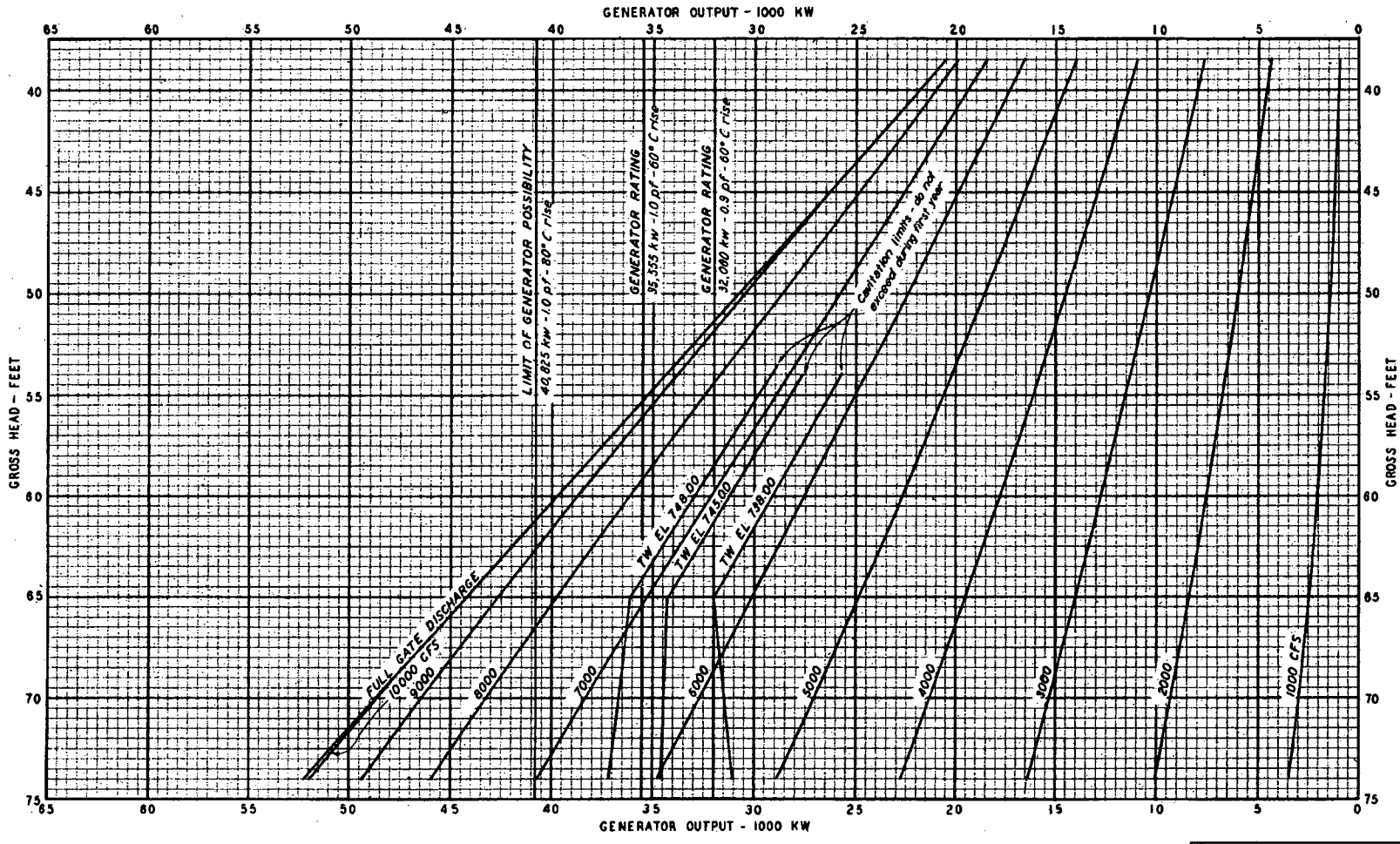
POWERHOUSE
UNIT 2

OPERATING CHARACTERISTICS OF 40,000 KVA GENERATING UNIT

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	DRAWN	APPROVED

KNOXVILLE	10-19-44	10	M	4	478905 RO



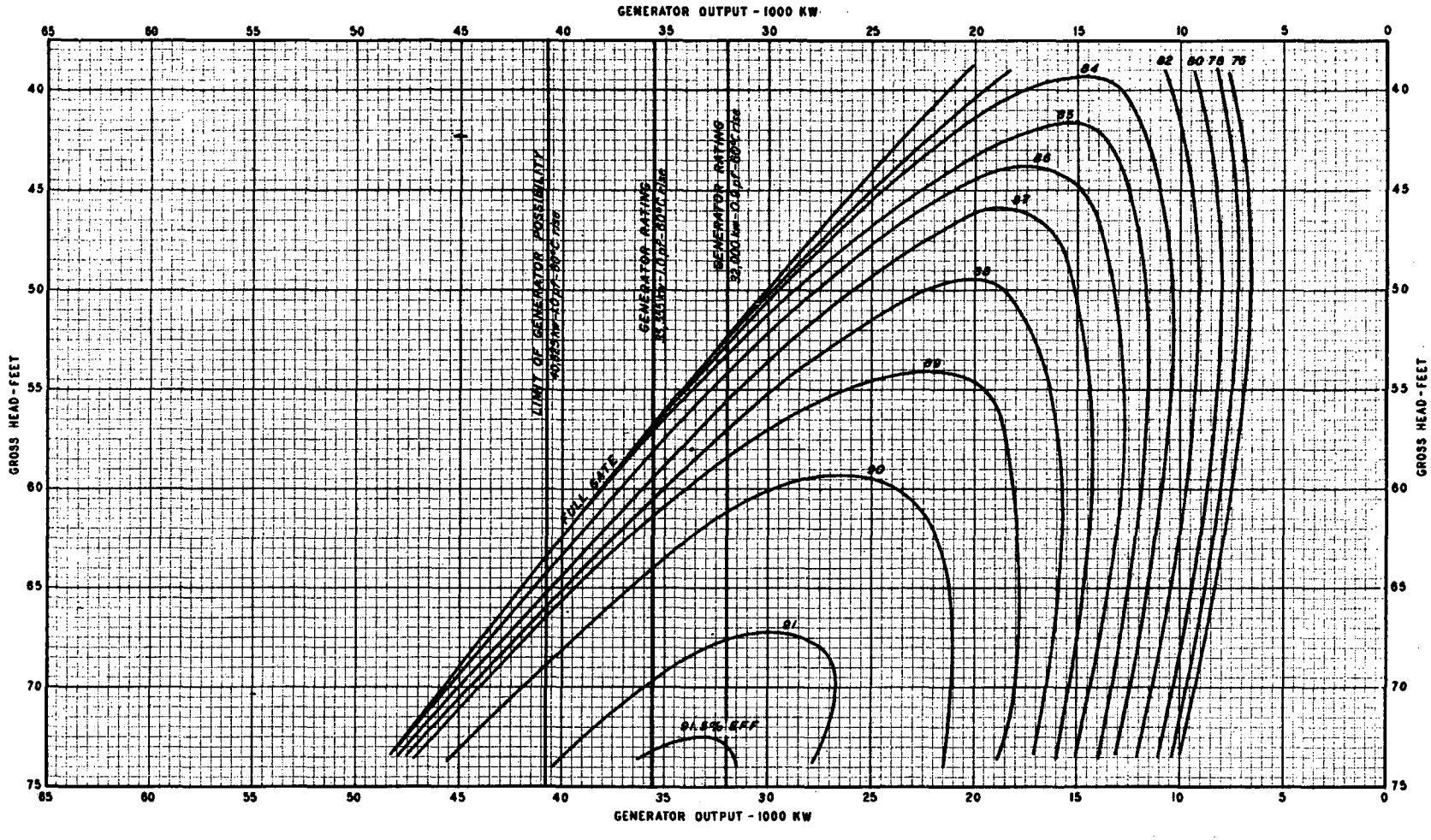
Curves are based on model tests conducted by Baldwin-Southwark and modified in accordance with index test conducted 2-29-44.

POWERHOUSE
UNIT 2

DISCHARGE CURVES BASED ON INDEX TESTS

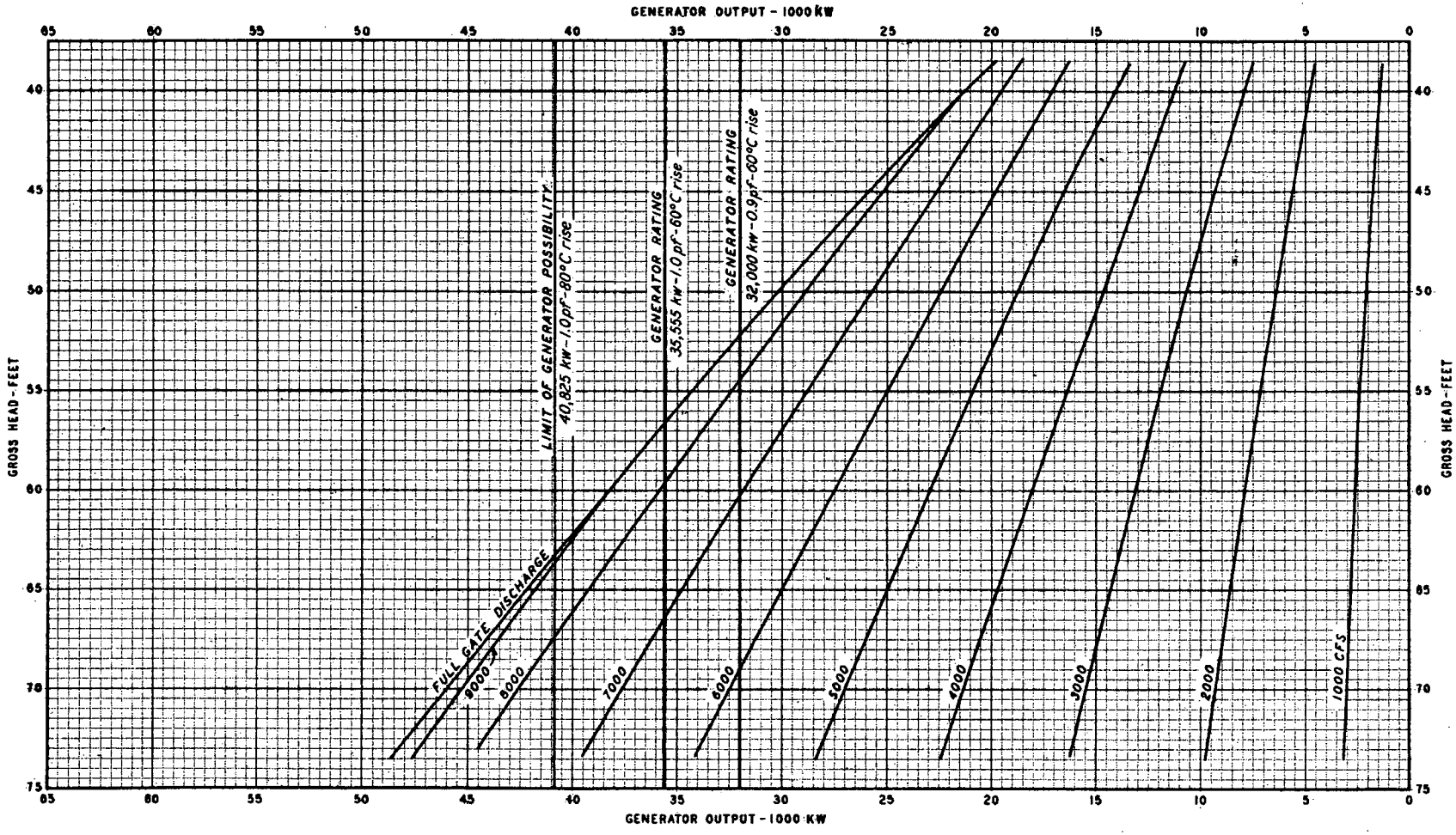
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY

SUBMITTED	DESIGN DEPARTMENT	APPROVED
F. Munchel		
KNOXVILLE	2-11-44	10 M 4 47B904R0



Curves based on model tests conducted by Baldwin-Southwerk and modified in accordance with index test conducted 2-16-49.

POWERHOUSE UNIT 3	
OPERATING CHARACTERISTICS OF 35,555 KVA GENERATING UNIT	
FORT LOUDOUN PROJECT TENNESSEE VALLEY AUTHORITY DIVISION OF DESIGN	
SUBMITTED	RECOMMENDED / APPROVED
KNOXVILLE	7-29-49 10 M 4 478909



Curves based on model tests conducted by Baldwin-Southwark and modified in accordance with index test conducted 2-16-49.

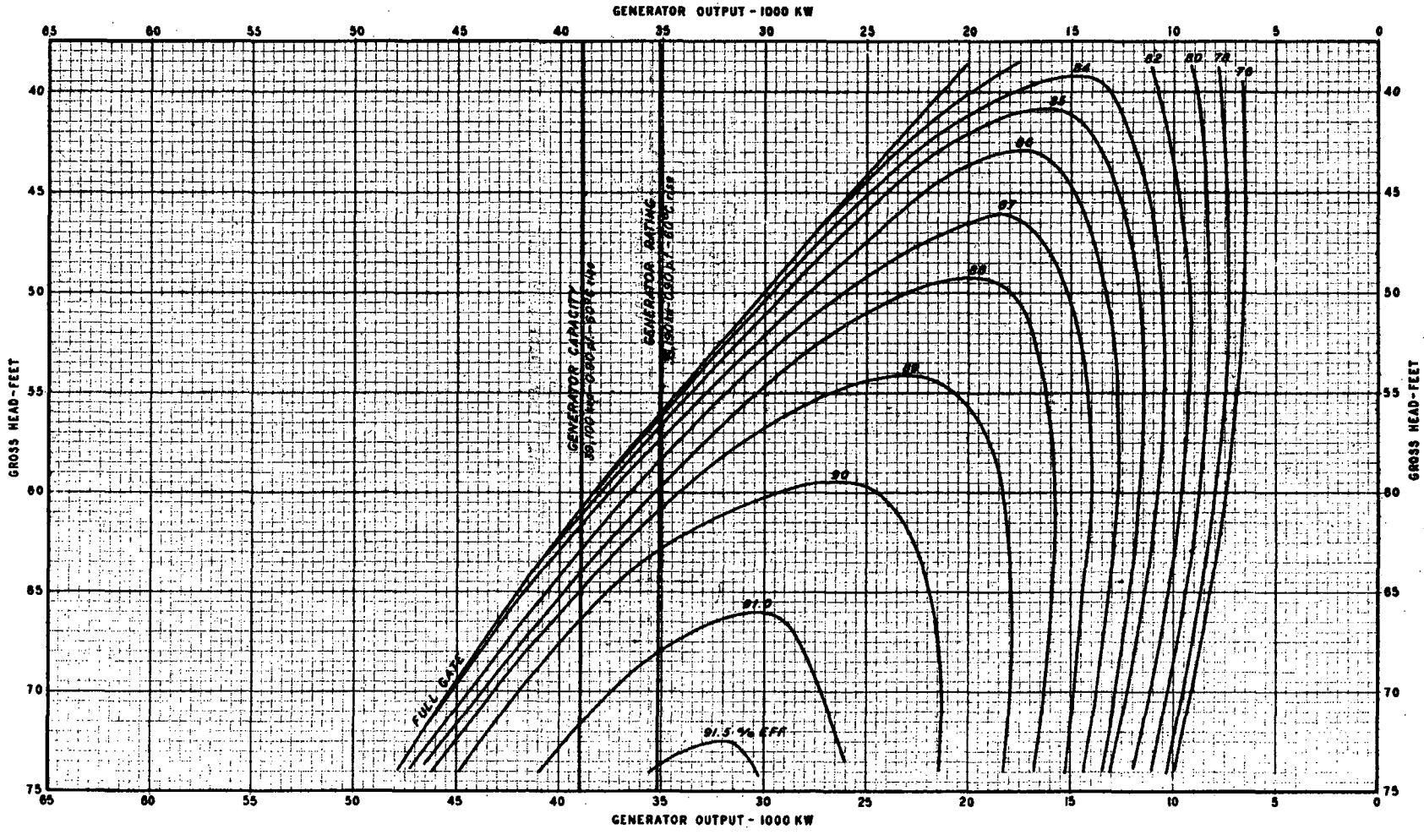
POWERHOUSE
UNIT 3

DISCHARGE CURVES
BASED ON INDEX TESTS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
R.E. Monroe	W. Williams	R.E. Monroe

KNOXVILLE 7-22-49 10 M 6 478908



Curves based on model tests conducted by Baldwin-Southwerk and modified in accordance with index test conducted 2-17-40.

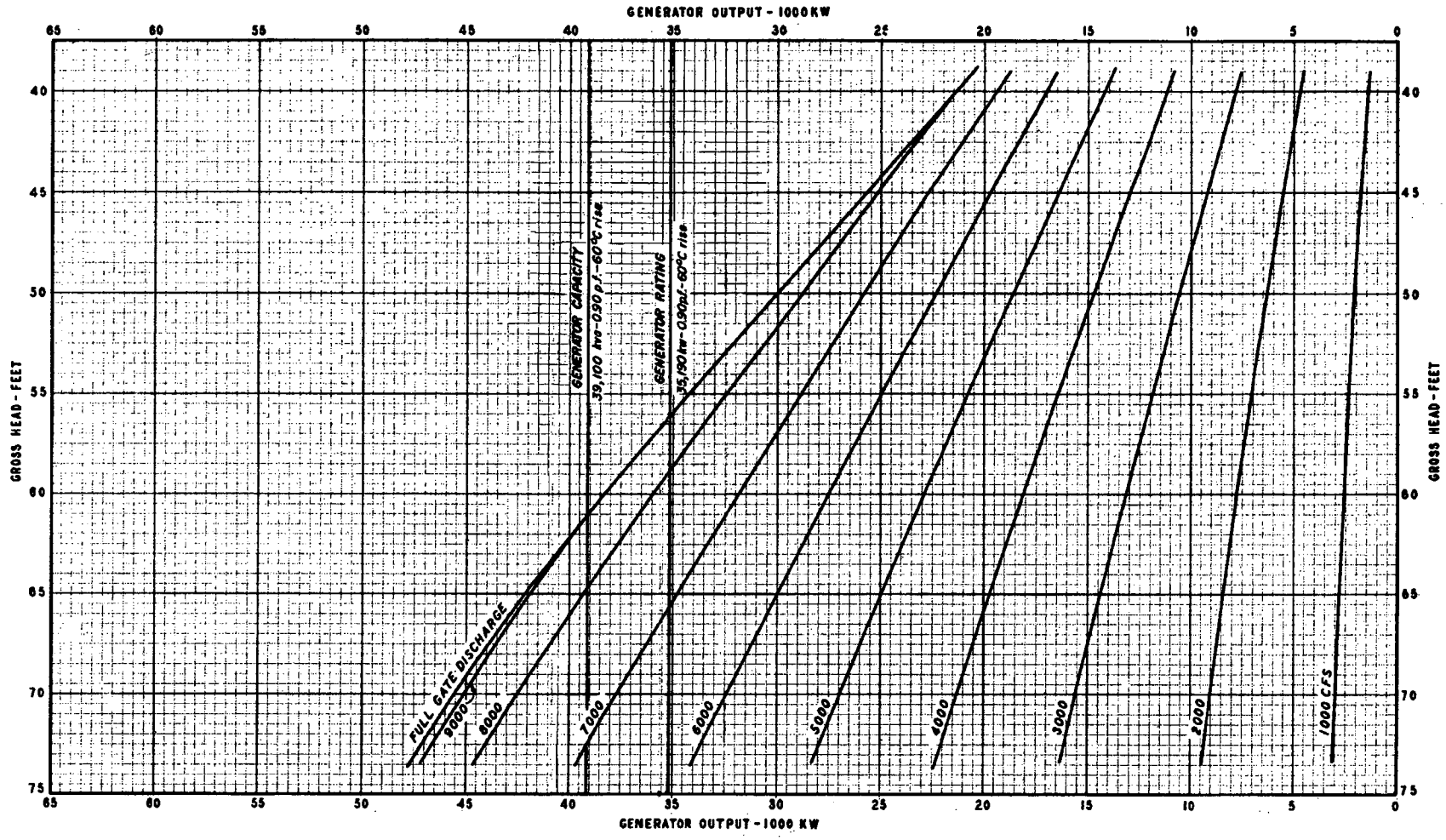
POWERHOUSE
UNIT 4

OPERATING CHARACTERISTICS OF 39,100 KVA GENERATING UNIT

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
C. F. Perry	[illegible]	B. A. Monroe

KNOXVILLE 7-23-49 10 M 4 478913



Curves based on model tests conducted by Baldwin-Southward and modified in accordance with index test conducted 2-17-49.

POWERHOUSE
UNIT 4

DISCHARGE CURVES
BASED ON INDEX TESTS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

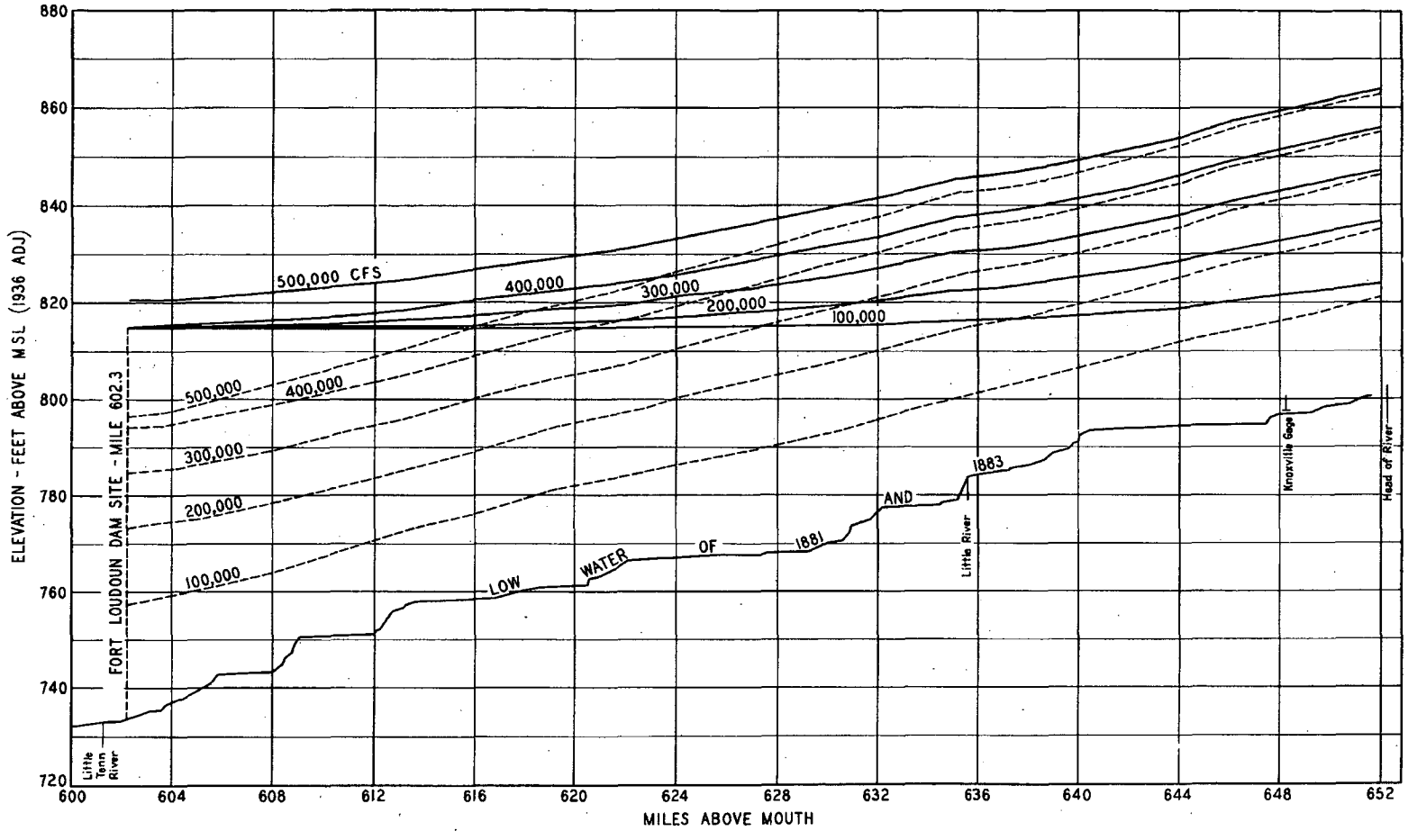
SUBMITTED | CHIEF ENGINEER | APPROVED

KNOXVILLE | 7-29-49 | 10 | 34 | 4 | 478012 R1

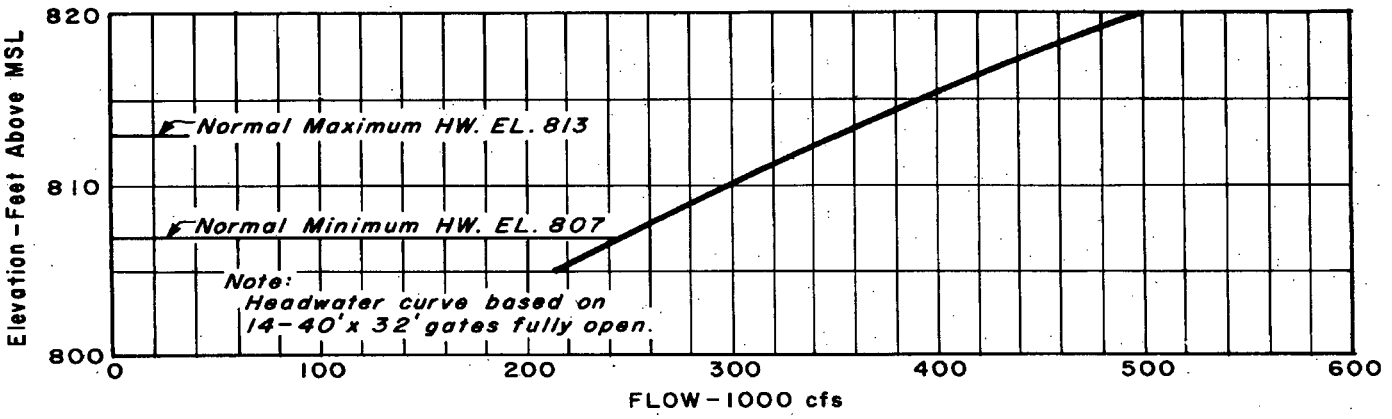
Fort Loudoun Spill Compilations

Volumes are average daily in day-second-feet, except as shown.
Maximum spill, date of maximum, and number of days of spill in each spill period, in this order. "Total Days" is for calendar years and does not always equal the sum of the days in periods because of extension of periods into adjacent years.
All spill is through the spillway.
Maximum hourly average discharge to date was 140,000 cfs from 9 a.m. thru 1 p.m. on 5/8/84.

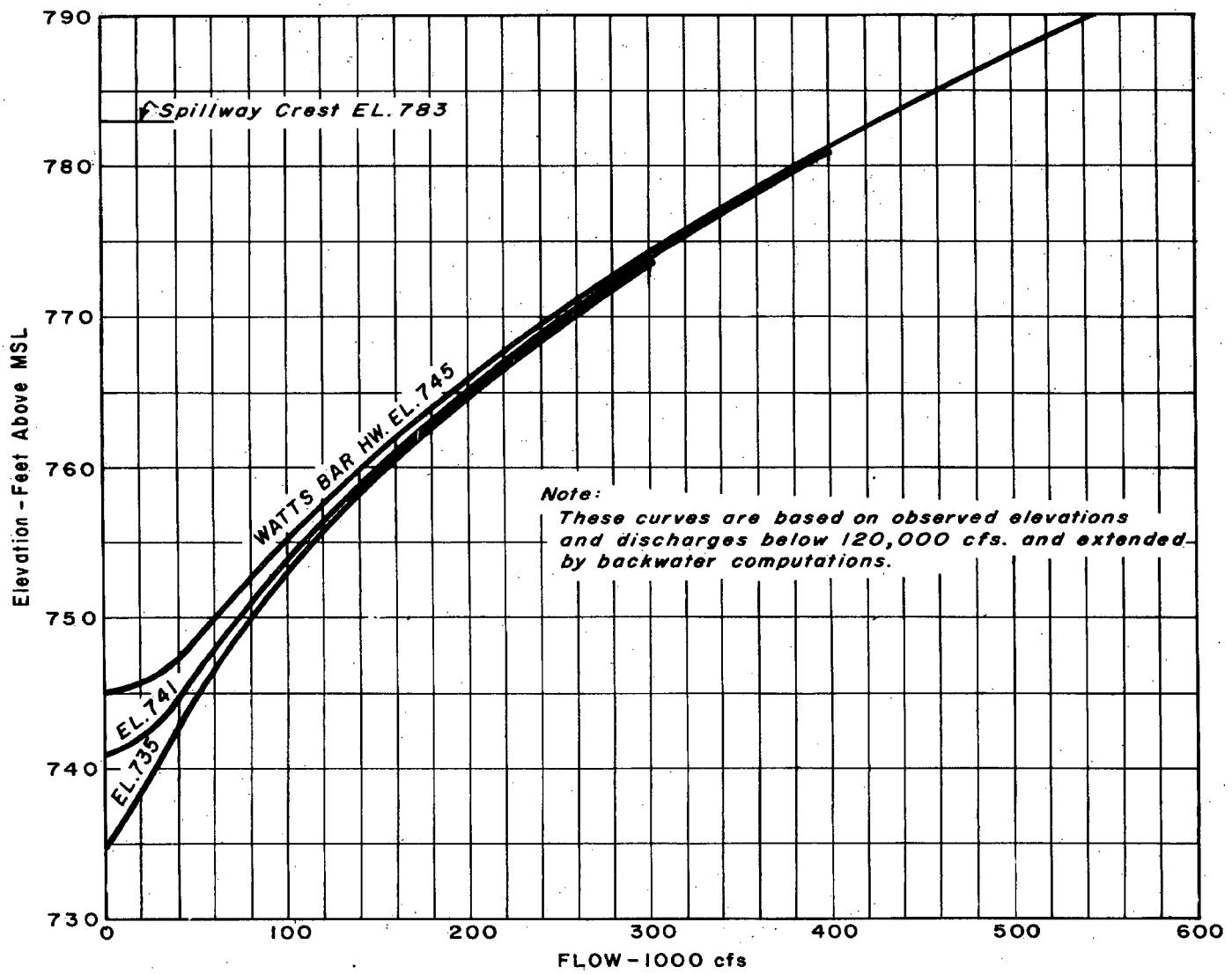
YEAR	MAXIMUM AVERAGE DAILY DISCHARGE (TURBINE + SPILL)	DATE	NUMBER OF PERIODS	TOTAL DAYS	
1982	51700	2/11	3	43	16500---1/12---6; 18600---2/4-5---22; 11900---12-15-18---15
1983	41662	5/23	6	18	12975---4/6---2; 7642---4/25---2; 11316---5/22---5; 5300---6/5-6---4; 2937---12/27---2; 6500---12/30---3
1984	134824	5/8	1	13	110416---5/8---13
1985	46737	2/2	1	3	14308---2/2---3
1986	32204	12/9	0	0	
1987	41788	3/3	1	5	8438---3/3---5
1988	23346	2/5	0	0	
1989	59625	6/19	9	89	16133---1/14---7; 8775---2/25---14; 26217---6/19---12; 5688---6/29---1; 13888---7/6---6; 5750---7/11---3; 15800---10/1---7; 13129---11/25---26; 12300---12/23-24---13
1990	79875	2/19	5	64	12425---1/10---11; 8300---1/25---3; 45987---2/19---38; 30825---3/21---7; 10067---12/28---9
1991	66942	12/3	6	51	9866---1/1---9; 20216---2/22---18;22208---4/2---7; 35471---12/3---7; 14562---12/11---11; 10895---12/24---4
1992	65567	12/25	3	27	14592---1/7---7; 7070---2/28---5; 33963---12/25---36
1993	54217	3/30	3	31	21858---1/14---36; 22259---3/30---7; 12758---12/7---3
1994	116746	3/28	4	99	7417---1/13---14; 38530---2/26---33; 84408---3/28---34; 4000---8/23-9/7---18
1995	49325	1/18	7	57	16800---1/18-19---13; 15875---2/18---8; 2846---2/27---2; 14629---3/10---8; 8700---11/14---9; 8500---12/5---12 3800---12/12---5
1996	67842	1/30	2	54	43779---1/28---33; 9833---12/4---21
1997	63227	3/2	5	42	14566---1/10---7; 7229---1/22---4; 7396---2/1---6; 26654---3/7---20; 19429---6/15---5



NOTE:
These backwater curves represent the estimated water surface elevations within Fort Loudoun reach for flows at the dam site as designated. These flows have been reduced progressively upstream in proportion to the respective drainage areas in an attempt to simulate an average actual flood.
The dashed lines represent flows under natural conditions existing in 1936. The solid lines represent backwater above Fort Loudoun dam site for the pool elevation 815.0.



HEADWATER RATING CURVE



TAILWATER RATING CURVE

FORT LOUDOUN DAM

RIVER SYSTEM OPERATIONS

TVA OPERATED RESERVOIR SYSTEM

ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE

FROM DATE OF RESERVOIR CLOSURE THROUGH 1998

FORT LOUDOUN

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
1	816.07	1994	MAR.	28	1	745.20 *	1943	AUG.	2
2	815.14	1984	MAY	8	2	805.54	1954	JAN.	18
3	815.00	1943	SEP.	11	3	805.72	1944	JAN.	20
4	815.00	1945	MAY	14	4	805.77	1947	JAN.	19
5	814.99	1997	MAY	4	5	806.16	1951	JAN.	10
6	814.95	1969	MAY	8	6	806.17	1961	DEC.	20
7	814.89	1971	JUNE	16	7	806.20	1950	FEB.	27
8	814.85	1949	JULY	14	8	806.20	1962	FEB.	25
9	814.85	1998	APR.	19	9	806.29	1949	JAN.	19
10	814.74	1958	APR.	25	10	806.39	1963	MAR.	25
11	814.72	1989	JUNE	17	11	806.43	1964	MAR.	9
12	814.71	1953	JUNE	26	12	806.55	1967	MAR.	8
13	814.68	1964	APR.	28	13	806.58	1955	JAN.	3
14	814.67	1968	MAY	8	14	806.62	1946	JAN.	9
15	814.66	1960	MAY	17	15	806.63	1952	DEC.	29
16	814.62	1956	APR.	18	16	806.64	1965	FEB.	17
17	814.58	1944	APR.	12	17	806.65	1960	MAR.	21
18	814.48	1952	MAY	19	18	806.66	1970	DEC.	30
19	814.44	1950	MAY	14	19	806.68	1945	FEB.	7
20	814.41	1946	APR.	14	20	806.68	1953	DEC.	16
21	814.41	1965	APR.	29	21	806.68	1968	FEB.	19
22	814.39	1955	JULY	12	22	806.70	1958	MAR.	3
23	814.27	1961	APR.	20	23	806.74	1956	JAN.	10
24	814.26	1951	APR.	30	24	806.74	1959	MAR.	11
25	814.08	1967	MAY	25	25	806.82	1966	FEB.	7
26	814.07	1959	MAY	13	26	806.84	1969	FEB.	8
27	814.06	1947	MAY	26	27	806.85	1971	MAR.	18
28	814.06	1957	NOV.	5	28	806.87	1957	JAN.	16
29	814.05	1970	APR.	27	29	806.87	1972	JAN.	27
30	814.00	1973	MAR.	17	30	806.87	1975	JAN.	8
31	813.95	1966	MAY	13	31	806.90	1948	JAN.	19

RIVER SYSTEM OPERATIONS

TVA OPERATED RESERVOIR SYSTEM

ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE

FROM DATE OF RESERVOIR CLOSURE THROUGH 1998

FORT LOUDOUN

MAXIMUM					MINIMUM				
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
32	813.91	1962	APR.	19	32	806.90	1974	JAN.	8
33	813.89	1948	APR.	25	33	806.92	1973	MAR.	1
34	813.87	1954	JUNE	29	34	806.92	1976	JAN.	5
35	813.60	1963	MAR.	13	35	807.00	1977	FEB.	9
36	813.47	1983	APR.	25	36	807.00	1978	MAR.	24
37	813.40	1982	AUG.	1	37	807.00	1979	JAN.	16
38	813.38	1991	DEC.	3	38	807.00	1984	FEB.	27
39	813.36	1972	JULY	4	39	807.07	1980	JAN.	10
40	813.35	1974	MAY	31	40	807.14	1997	FEB.	17
41	813.34	1996	AUG.	1	41	807.18	1989	DEC.	7
42	813.31	1987	MAY	22	42	807.21	1985	JAN.	11
43	813.29	1977	JUNE	22	43	807.22	1982	JAN.	28
44	813.29	1981	JUNE	6	44	807.22	1983	DEC.	6
45	813.29	1990	MAY	4	45	807.25	1987	MAR.	27
46	813.25	1978	JULY	1	46	807.27	1981	FEB.	17
47	813.22	1988	JULY	15	47	807.27	1994	MAR.	7
48	813.22	1993	SEP.	21	48	807.30	1998	MAR.	4
49	813.20	1975	MAR.	14	49	807.32	1990	MAR.	1
50	813.19	1995	MAY	29	50	807.32	1991	DEC.	19
51	813.15	1976	JULY	14	51	807.36	1993	FEB.	15
52	813.15	1980	JULY	30	52	807.41	1988	DEC.	29
53	813.12	1985	OCT.	22	53	807.41	1992	JAN.	15
54	813.10	1979	MAY	12	54	807.43	1986	MAR.	7
55	813.09	1992	JULY	3	55	807.48	1996	DEC.	11
56	813.07	1986	SEP.	13	56	807.68	1995	JAN.	23

* CLOSURE

TOP-OF-GATES ELEVATION 815

MAXIMUM, MINIMIUM, MEDIAN, AND MEAN

Adjusted Flow by Weeks

Fort Loudoun
Years = 1903-1998
AVERAGE WEEKLY CFS

WEEK ENDING	WEEK NO.	MAXIMUM	YR	MINIMUM	YR	MEDIAN	MEAN
JAN 7	1	82,000	1974	4,130	1940	20,900	25,200
JAN 14	2	101,000	1946	4,090	1981	20,700	24,900
JAN 21	3	124,000	1947	4,760	1981	21,200	25,200
JAN 28	4	88,700	1954	3,820	1940	25,800	28,600
FEB 4	5	174,000	1957	4,150	1940	23,800	29,800
FEB 11	6	103,000	1957	6,600	1934	24,000	30,600
FEB 18	7	95,600	1966	5,940	1934	26,500	32,100
FEB 25	8	80,200	1961	5,840	1934	28,000	31,400
MAR 4	9	90,700	1997	6,930	1941	27,300	31,300
MAR 11	10	100,000	1917	10,600	1931	31,300	33,500
MAR 18	11	141,000	1963	9,580	1931	28,200	35,100
MAR 25	12	102,000	1980	8,960	1988	28,700	33,000
APR 1	13	165,000	1994	8,430	1988	28,000	35,700
APR 8	14	130,000	1977	9,150	1910	25,900	32,300
APR 15	15	88,000	1994	8,350	1986	25,100	28,200
APR 22	16	119,000	1998	7,920	1986	23,100	25,300
APR 29	17	51,900	1958	7,160	1986	22,200	23,200
MAY 6	18	56,400	1958	5,850	1986	19,700	22,500
MAY 13	19	154,000	1984	5,770	1986	18,900	22,300
MAY 20	20	41,900	1929	7,140	1941	18,000	19,200
MAY 27	21	51,700	1929	5,760	1941	16,400	18,200
JUN 3	22	62,500	1973	4,670	1988	15,300	17,500
JUN 10	23	59,000	1909	3,810	1988	13,800	16,400
JUN 17	24	47,500	1989	3,060	1988	13,000	15,400
JUN 24	25	47,300	1989	3,310	1988	12,700	13,800
JUL 1	26	42,400	1928	3,560	1988	12,100	12,800
JUL 8	27	41,400	1989	2,930	1988	11,200	12,500
JUL 15	28	48,700	1916	4,100	1952	11,100	13,400
JUL 22	29	87,200	1916	1,780	1956	10,200	13,400
JUL 29	30	52,500	1938	2,800	1952	10,200	12,000
AUG 5	31	42,700	1971	2,390	1986	10,000	11,800
AUG 12	32	28,900	1916	2,910	1925	10,400	11,100
AUG 19	33	61,000	1940	2,350	1954	9,710	12,200
AUG 26	34	32,100	1920	2,770	1987	8,730	10,500
SEP 2	35	47,000	1940	1,940	1953	7,760	10,100
SEP 9	36	60,400	1928	2,060	1954	7,360	9,290
SEP 16	37	24,700	1928	1,690	1954	6,890	8,050
SEP 23	38	33,900	1906	2,330	1956	6,670	7,930
SEP 30	39	43,800	1989	2,370	1952	6,960	8,710
OCT 7	40	52,100	1989	2,120	1952	6,370	9,760
OCT 14	41	33,600	1976	1,760	1954	6,600	7,910
OCT 21	42	38,700	1964	1,490	1954	6,560	8,860
OCT 28	43	38,400	1918	2,540	1953	6,850	8,980
NOV 4	44	77,100	1918	1,850	1954	7,290	9,910

MAXIMUM, MINIMIUM, MEDIAN, AND MEAN (CONT.)

Adjusted Flow by Weeks

Fort Loudoun
Years = 1903-1998
AVERAGE WEEKLY CFS

WEEK ENDING	WEEK NO.	MAXIMUM	YR	MINIMUM	YR	MEDIAN	MEAN
NOV 11	45	68,900	1977	1,950	1953	7,260	9,840
NOV 18	46	39,100	1929	1,920	1953	8,090	10,400
NOV 25	47	74,900	1906	3,870	1954	9,790	12,300
DEC 2	48	61,400	1948	3,330	1953	10,200	13,900
DEC 9	49	54,100	1991	3,020	1958	12,800	16,000
DEC 16	50	90,500	1972	3,810	1939	15,100	18,000
DEC 23	51	83,100	1961	3,520	1958	13,200	18,200
DEC 31	52	89,600	1926	4,980	1965	19,400	22,200

AVERAGE FLOW: 1903 - 1998 = 18700 CFS

MAXIMUM, MINIMUM, MEDIAN, AND MEAN (CONT.)

ADJUSTED FLOWS COMPUTED BY:

Fort Loudoun including Tellico
(12,176 square miles)

1/1/03 - 12/31/04 Flows were computed by increasing the Fort Loudoun natural flows at the Tellico Dam site on the Little Tennessee River. Tellico natural flows were computed by : Tellico = 1.717 x Fontana natural flow.Fort Loudoun = 1.081 x Knoxville flow (USGS).

1/1/05 - 9/30/22 Flows were computed by increasing the Fort Loudoun natural flows (as above) by natural flows at the Tellico Dam site. Tellico natural flows computed by : Tellico = 1.047 x McGhee (USGS). Drainage areas : USGS gage @ Knoxville, 8,931 square miles; USGS gage at McGhee, 2,442 square miles.

10/1/23 - 12/31/38 Flows were computed from USGS gage at Loudoun by : Fort Loudoun extension = .997 x Loudoun. Drainage area at Loudoun = 12,220 square miles.

1/1/39 - 8/26/57 Flows were computed by increasing the corrected flow for Fort Loudoun Dam and Calderwood Dam by the local inflows between Fort Loudoun Dam Extension Site. These local inflows were computed by increasing the local inflows between At Calderwood and At McGhee gages in proportion to the local drainage area, (764/581).

8/27/57 - 12/31/65 Flows were computed by increasing the corrected flows for Fort Loudoun Dam, plus Chilhowee Dam by the local inflows between Fort Loudoun Dam , Chilhowee Dam, and the Fort Loudoun Extension site. These local inflows were computed by increasing the local inflows between Chilhowee and McGhee gage in proportion to the local drainage area, (650/467).

1/1/66 - 12/31/71 Flows were computed by increasing the sum of the adjusted flows for Fort Loudoun Dam and Chilhowee Dam by the local flows between Chilhowee Dam and Tellico Dam site.

MAXIMUM, MINIMUM, MEDIAN, AND MEAN (CONT.)

1/1/72 - 12/24/79 Flows for the former McGhee gage location were computed by increasing the flow at Sewee Creek near Decatur by the drainage area ratio of (348/117) to obtain the Chilhowee and Fort Loudoun including Tellico Dam - Tellico River at Tellico Plains. Flow at the McGhee location was then increased by the drainage area ratio (650/467) to obtain the Chilhowee Dam to Tellico Dam site local . Drainage areas : Tellico River at Tellico Plains, Tennessee (USGS) gage, 117 sq. mi.; Former McGhee gage site (USGS) gage, 2443 sq. mi.; Chilhowee Dam, 1976 sq. mi.; Fort Loudoun plus Tellico Dam site, 12,176 sq. mi.

12/25/79 - Current Discharge at Fort Loudoun Dam and Tellico Dam were corrected for storage changes at all upstream plants.

1/1/03 - 12/31/20 Flows computed from Cherokee and Douglas natural flows by; Fort Loudoun = 1.2135 x (Cherokee + Douglas). The constant was determined from 1921 - 1939 average natural flow data at Fort Loudoun, Cherokee, and Douglas.

1/1/21 - 9/30/22 Flows computed by : 1.081 x Knoxville flow (USGS). Drainage area : Knoxville, 8,931 square miles.

10/1/22 - 9/30/38 Flows computed by : 0.978 x (Loudoun - McGhee) (USGS). Drainage areas : Loudoun, 12,220 square miles ; McGhee, 2,442 square miles.

10/1/38 - 12/31/38 Same as 1/1/21 - 9/30/22.

MAXIMUM, MINIMUM, MEDIAN, AND MEAN (CONT.)

ADJUSTED FLOWS COMPUTED BY :

Fort Loudoun w/o Tellico

1/1/39 - 12/4/41 Flows were computed by correcting USGS records of the at Knoxville, Tennessee gage for storage change in Walters Reservoir and adding a local inflow computed by reducing the local inflow between gages at Knoxville, at McGhee, and at Loudoun by drainage area ratio 637/864 (based on drainage area of 8,913 sq. mi. for Knoxville).

12/5/41 - 8/5/43 Additional corrections were made in Knoxville flows for storage changes in Cherokee Reservoir, in Douglas Reservoir, February 19,1943, and Fort Loudoun Reservoir, 8/2/43.

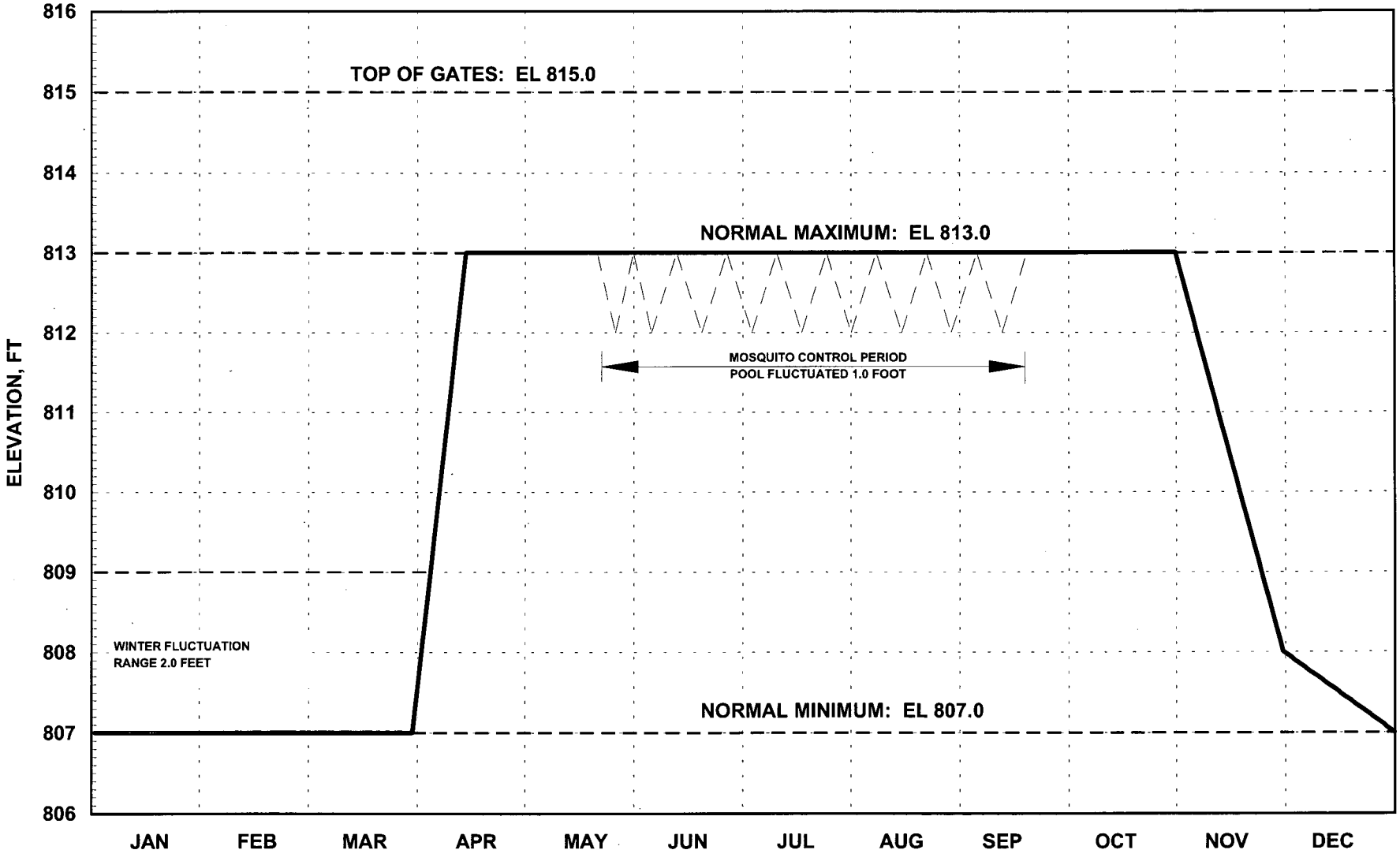
8/5/43 - 12/21/79 Discharges at Fort Loudoun Dam reported by TVA were corrected for storage change in Walters, Cherokee, Douglas and Fort Loudoun Reservoirs . Additional corrections were made for storage changes in the following reservoirs beginning with the date indicated.

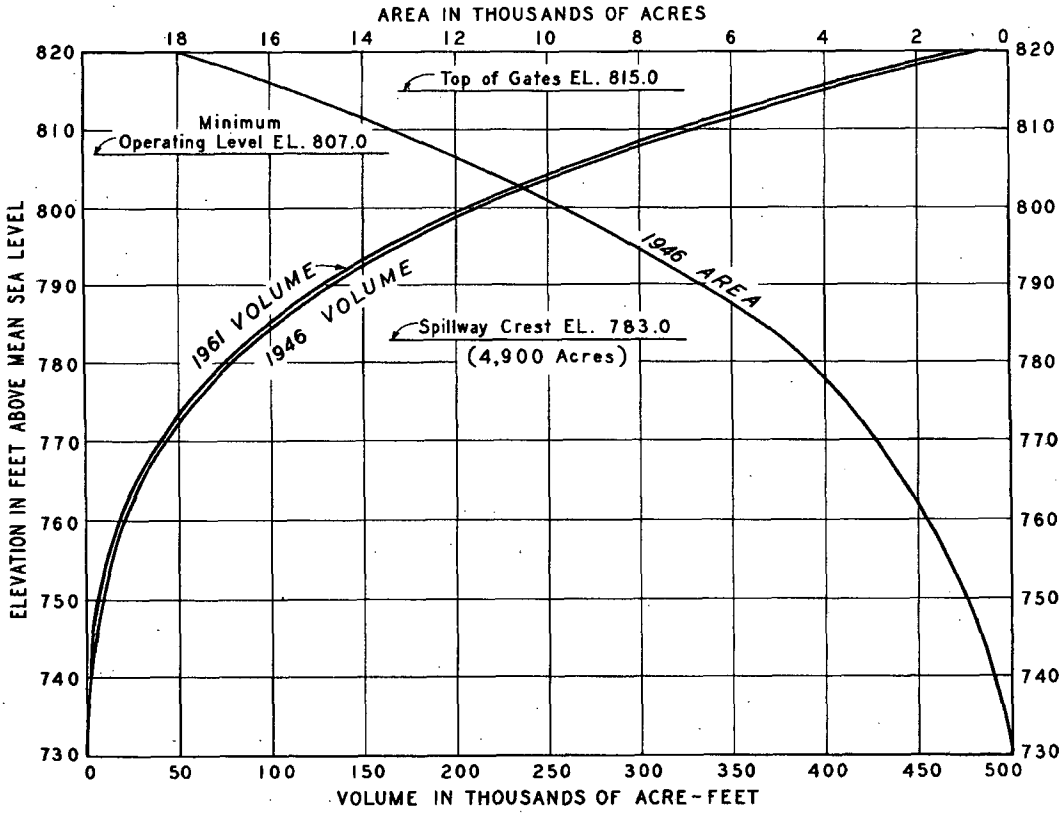
12/1/48 Watauga
11/20/50 South Holston
12/16/52 Boone
10/27/53 Fort Patrick Henry

10/1/55 - 12/31/57 An additional correction was made for storage changes in the water supply reservoir at John Sevier Steam Plant.

12/25/79 Since closure of Tellico Dam , Fort Loudoun (w/o Tellico) adjusted flows have not been computed.

ANNUAL OPERATING CYCLE





ELEV FT	1946 AREA AC	VOLUME			
		1946 AC-FT	1951 AC-FT	1956 AC-FT	1961 AC-FT
820	18,000	485,000	483,000	482,000	477,000
815	15,500	401,000	399,000	398,000	393,000
813	14,600	371,000	369,000	368,000	363,000
807	12,200	290,000	289,000	287,000	282,000
802	10,200	234,000	233,000	232,000	227,000
796	8,340	179,000	178,000	177,000	172,000
790	6,680	133,000	133,000	132,000	128,000
780	4,230	79,200	78,800	78,500	75,700
770	2,880	43,800	43,700	43,600	41,600
760	1,790	20,700	20,400	20,200	19,600
750	966	7,930	7,550	6,950	7,450
740	324	1,620	1,350	810	1,690
730	0	0	0	0	0

NOTES:

Reservoir areas were measured on a composite map prepared by Hydraulic Data Branch with contours drawn at 10' intervals and scale 1"=500'. The map was prepared from TVA land maps with contours at elevations 790, 796, 802, 807, 813, 815 and 820. Contours were made to conform to elevations on TVA sediment range cross sections located at one-half to five-mile intervals. The 1946 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 1936 Supplementary Adjustment.

Area of original river within reservoir = 4,420 acres.

Drainage area at dam = 9,550 square miles.

Dam closure August 2, 1943.

THIS DRAWING SUPERSEDES 10-DA-1-321G424R1

SAFETY MODIFICATIONS FOR MAXIMUM PROBABLE FLOOD

CHRONOLOGY

Safety analysis studies for Fort Loudoun to evaluate the safety hydrologic deficiencies caused by a Probable Maximum Flood (PMF) were essentially completed in fiscal year (FY) 1986. The recommended proposal to measure the height of the embankments and armor a portion of the south embankment was programmed in the FY 1988 Operating Plan and approved by the TVA Board of Directors. Budget underruns in the overall dam safety programs enabled an early design start in the latter part of FY1987. Construction mobilization began in February 1988 and construction was completed in September 1989.

COST OF MODIFICATION

Engineering and Design cost for the capital safety modifications to Fort Loudoun Dam were approximately $255,250 . The construction cost were approximately $757,500.The total project cost was approximately $1,012,750.

CONTROLLING FEATURES

Modifications for the PMF consisted of barrier walls atop the south embankment paving adjacent to the navigation lock, upstream armor adjacent to the Lock Operations Building, and a barrier wall atop the right rim saddle dam near the marina. The height of the Fort Loudoun south embankment and saddle dam was raised 3.25 feet and 2.67 feet, respectively. Armoring part of the south embankment adjacent to the navigation Lock to prevent erosion due to overtopping the Lock Landwall was also necessary.(See Figures 10,11 & 12.)

SAFETY MODIFICATIONS FOR MAXIMUM PROBABLE FLOOD (CONT.)

MODIFICATIONS FOR PMF

QUANTITIES

Fort Loudoun South Embankment & Barrier Wall atop Right Rim Saddle Dam :

Excavation	3,250 cu. yd
Concrete	2,144 cu. yd
Rolled fill	1,885 cu. yd
Crushed stone	2,290 tons
Riprap	1,800 tons

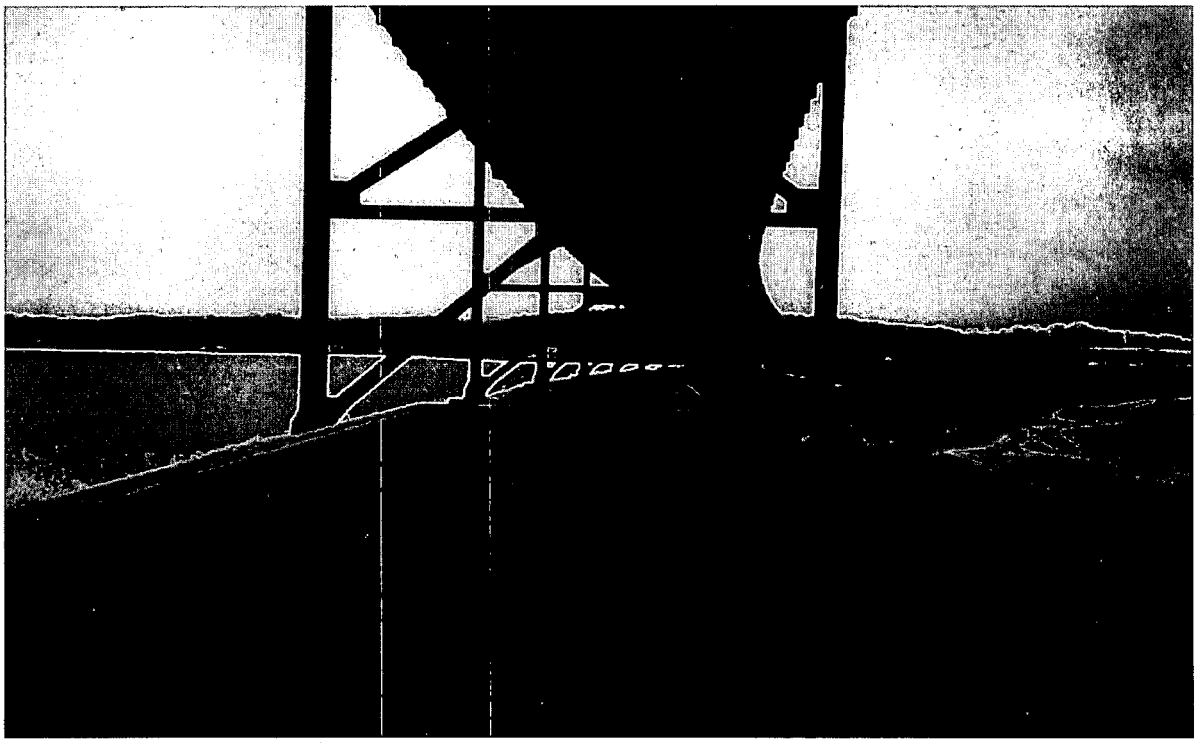


FIGURE 10 : Barrier wall atop south embankment

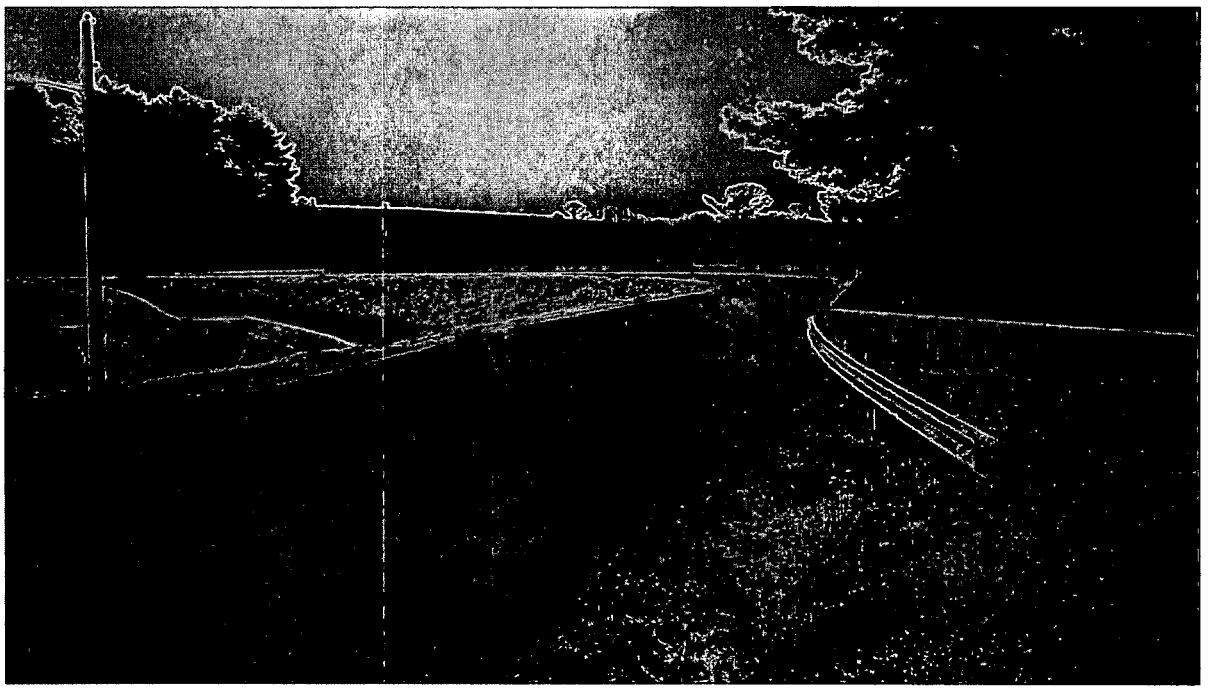


FIGURE 11 : Barrier wall atop right rim saddle dam (near marina)

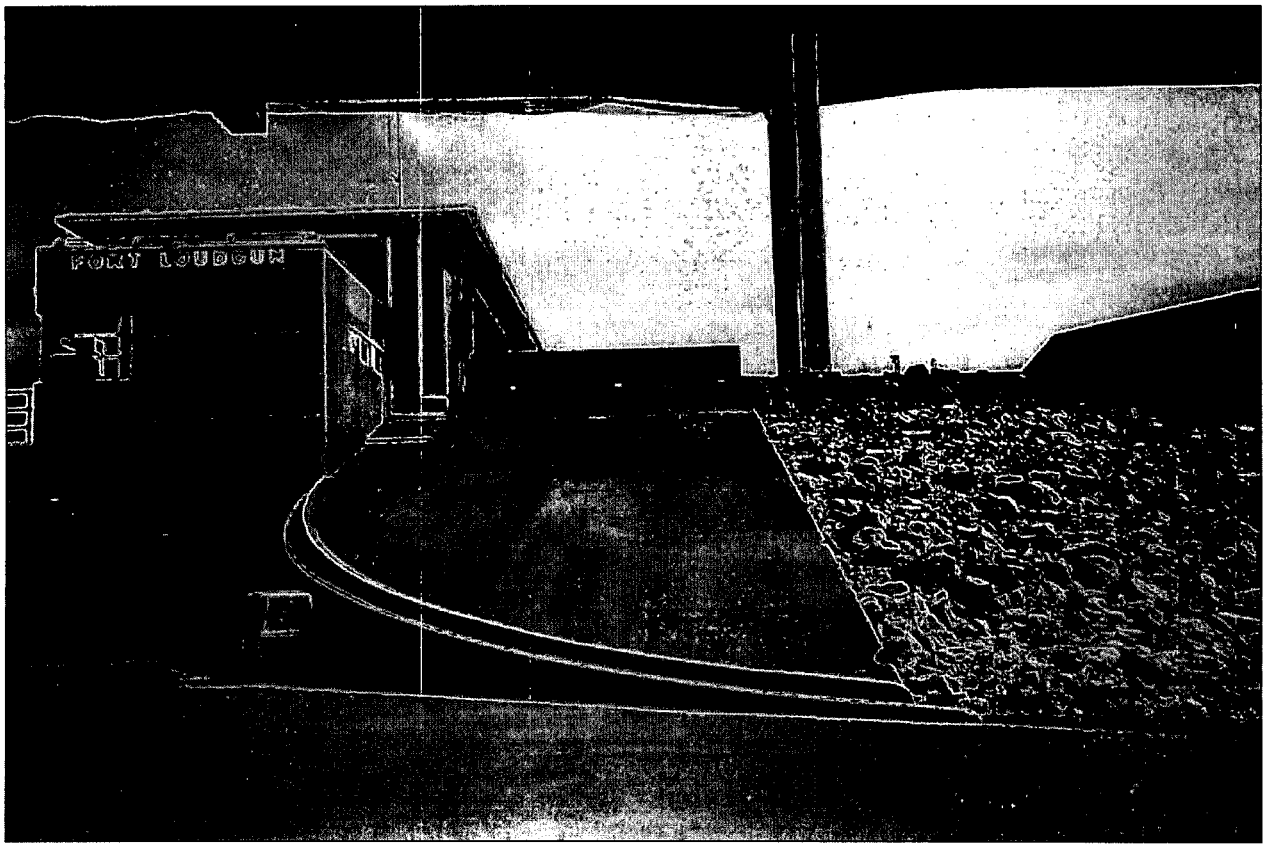


FIGURE 12: Embankment paving adjacent to navigation Lock

HOUSING FACILITIES
(Original Project)

Permanent houses built ..... None
Dormitories built:
Men (128 total capacity) 4
Women (26 total capacity) 2
Public buildings constructed included a cafeteria, hospital (10 beds), community and recreation building, and observation building.

ORIGINAL CONSTRUCTION DATA

PERSONNEL

	Initial Project		
	Total	Dam Construction Only	Units 3-4
Peak employed	3,000	2,650	160
Total man-hours	19,519,463	13,746,341	474,453
Number of injuries	195	139	8
Days lost	29,934	27,197	3,397
Fatalities	2	2	0
Accident frequency	10.0	10.1	16.9
Accident severity	1,534	1,979	7,160

QUANTITIES

	Initial Project	Units 3-4
Dam, lock, and power facilities:		
Earth excavation	1,633,000 cu. yd	-
Rock excavation	365,000 cu. yd	-
Unclassified excavation	291,000 cu. yd	-
Dredging	649,000 cu. yd	-
Rolled earthfill	1,382,000 cu. yd	-
Compacted earthfill	642,000 cu. yd	-
Blanket fill	294,000 cu. yd	-
Unclassified fill	1,154,000 cu. yd	-
Riprap	122,000 cu. yd	-
Concrete	582,000 cu. yd	4,700 cu. yd
Reinforcing steel	5,390 tons	175 tons
Structural steel	2,480 tons	150 tons
Formwork	1,814,000 sq. ft	-
Foundation grouting	1,067,000 cu. ft	-
Drilling for grouting	804,000 lin ft	-
Highway and railroad:		
Excavation	1,560,000 cu. yd	-

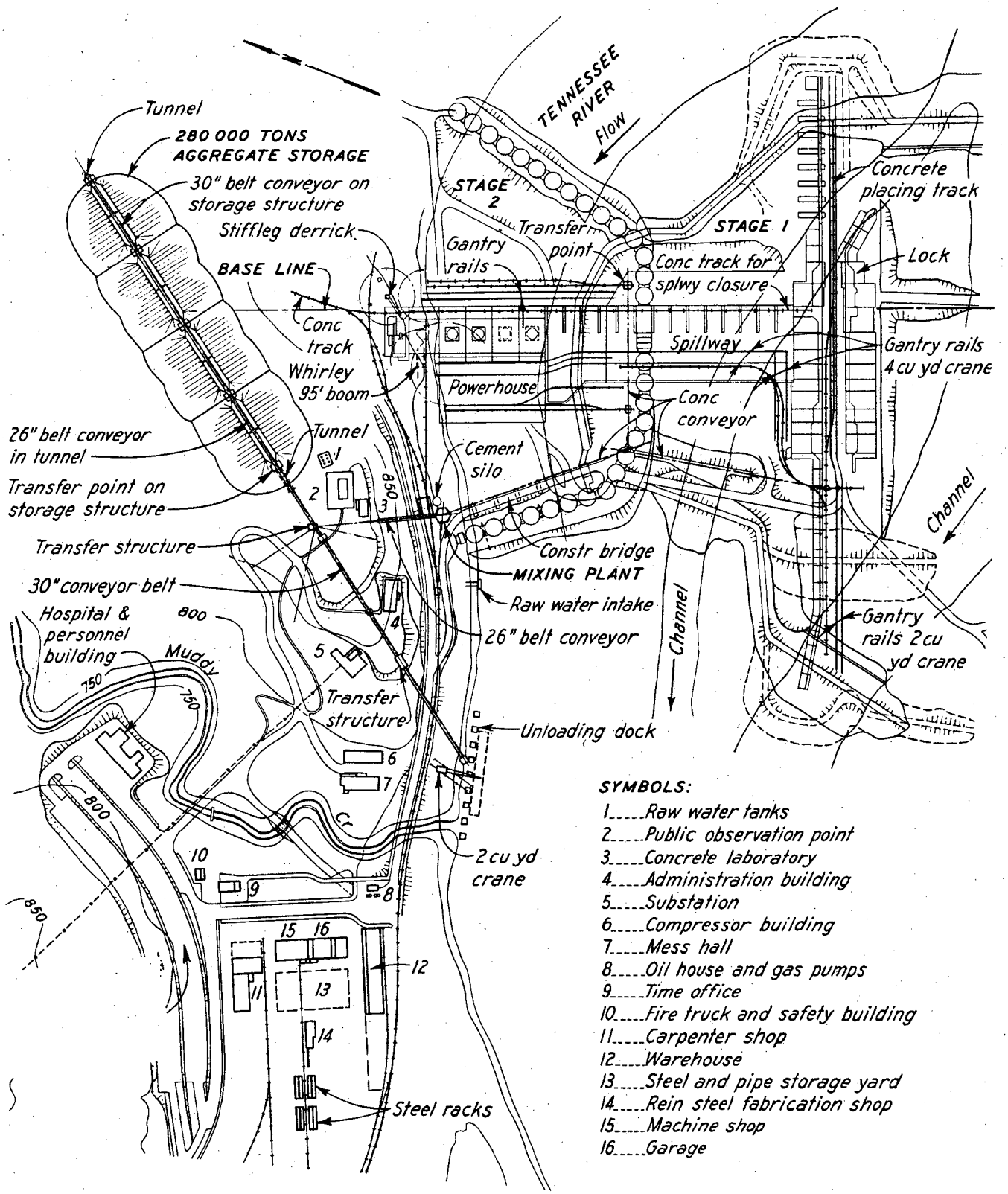
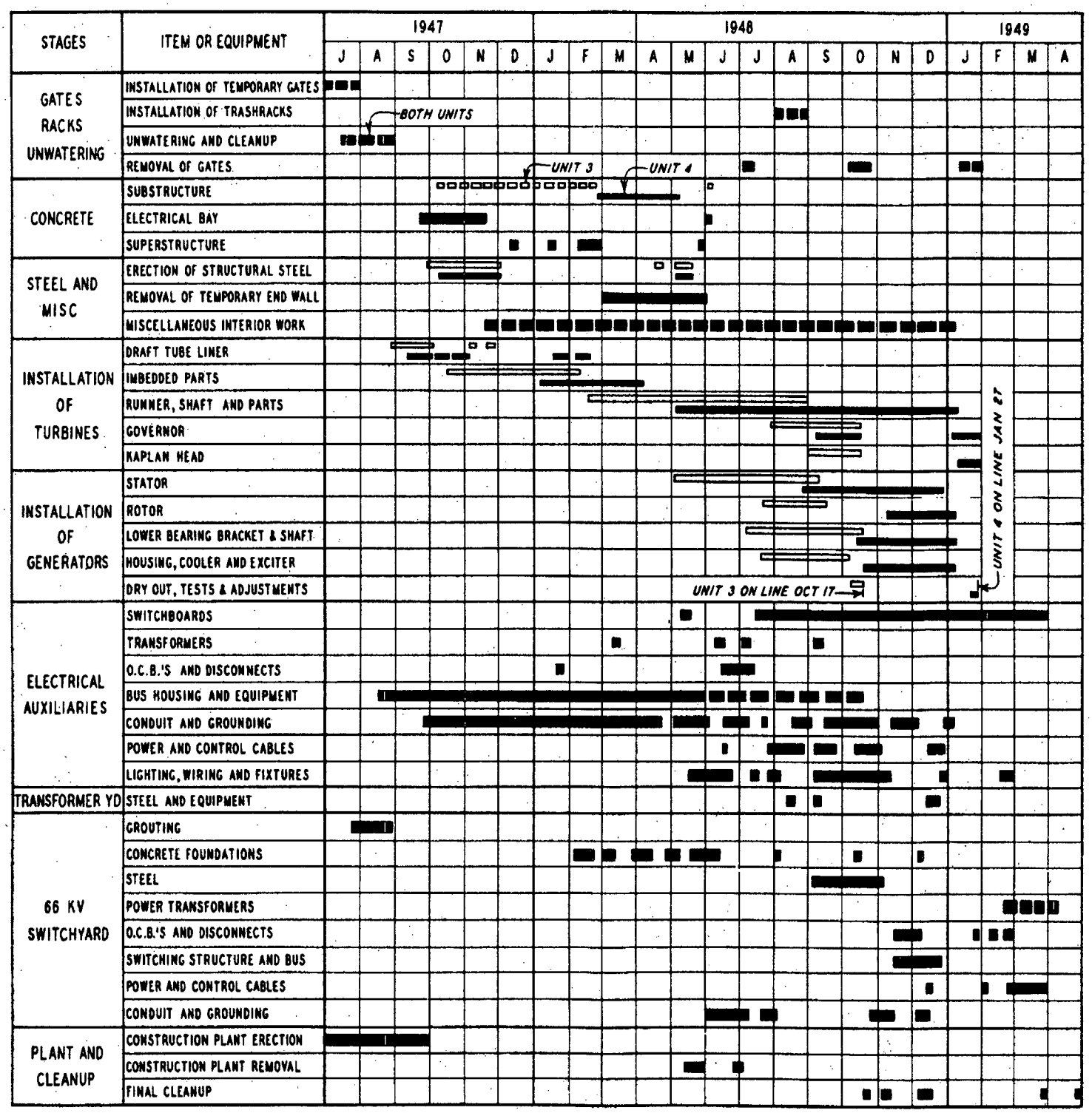
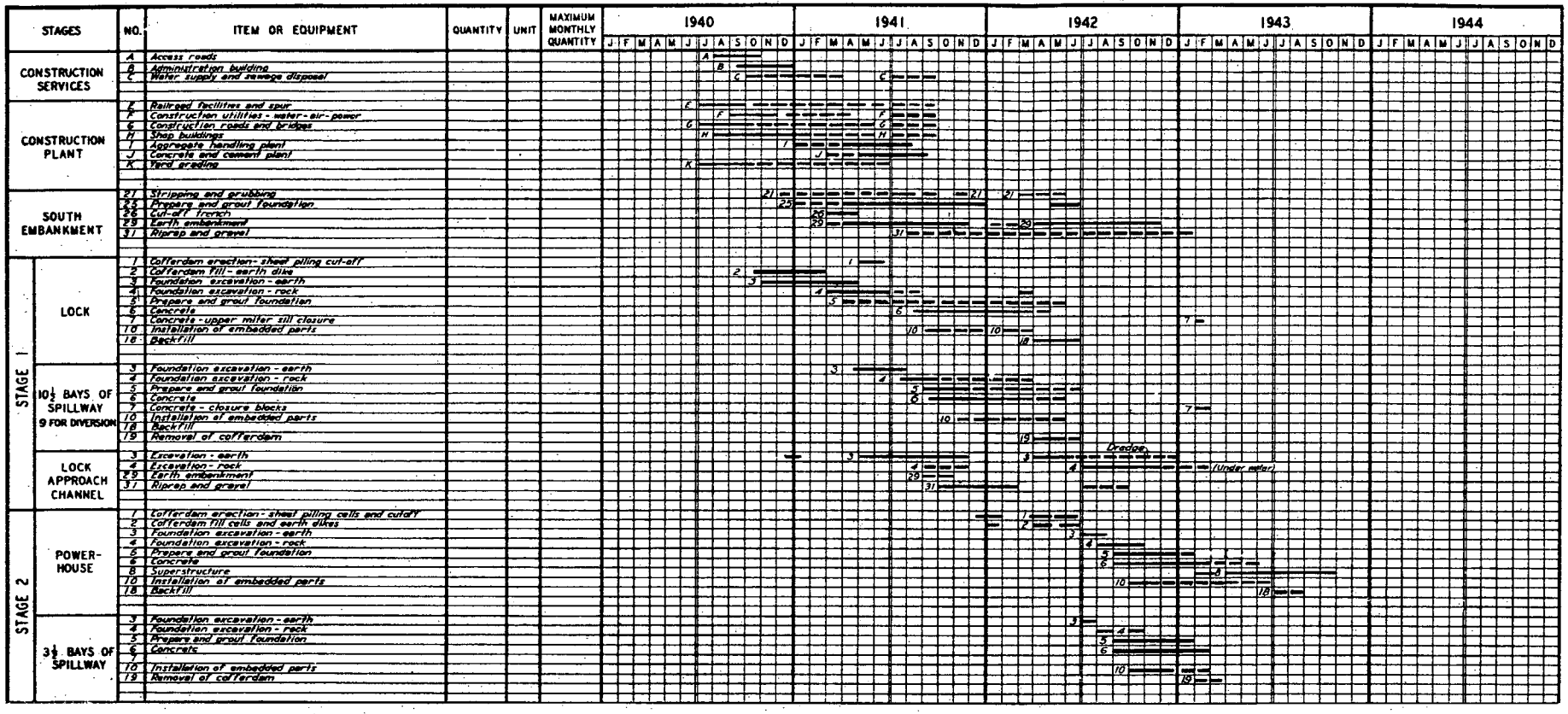


FIGURE 13: Construction Plant Layout



CONSTRUCTION SCHEDULE - UNITS 3 & 4



To show dates when Units 1 & 2 went on line (date on Units 3 & 4 removed) and Reservoir filling revised. Otherwise as revised

REVISED TO 7-4-45

THIS DRAWING SUPERSEDES 102N2

GENERAL

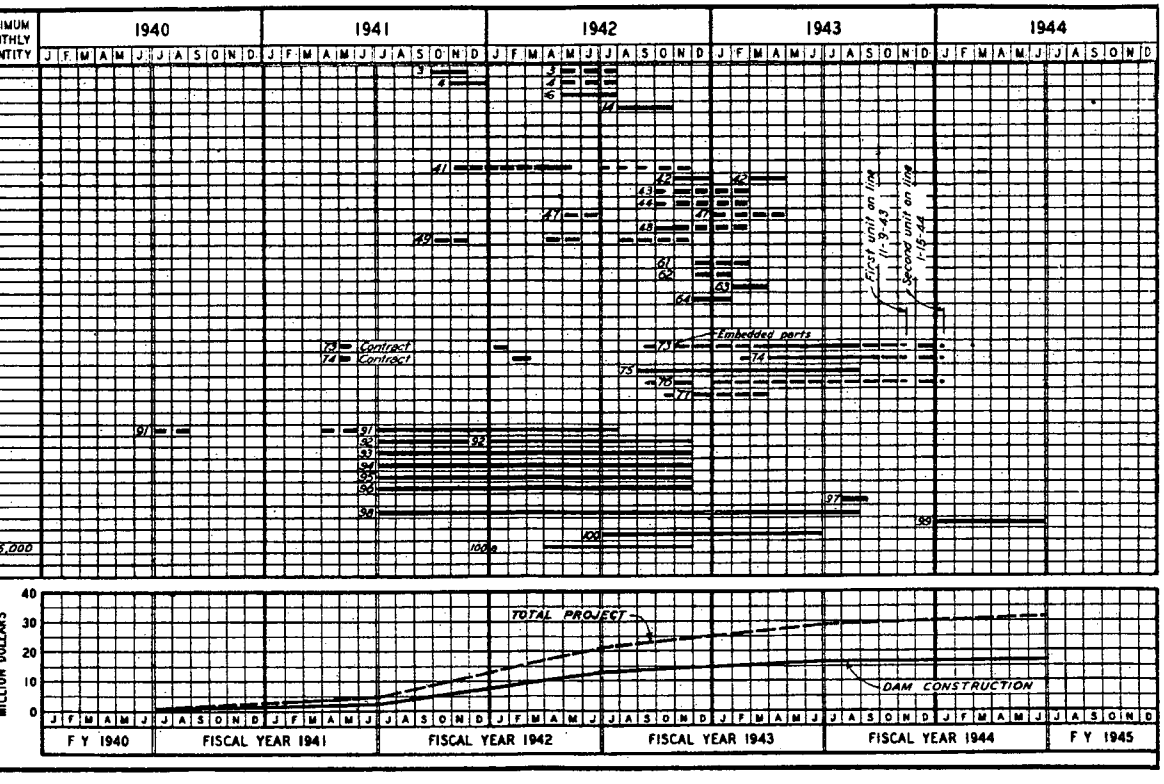
CONSTRUCTION SCHEDULE

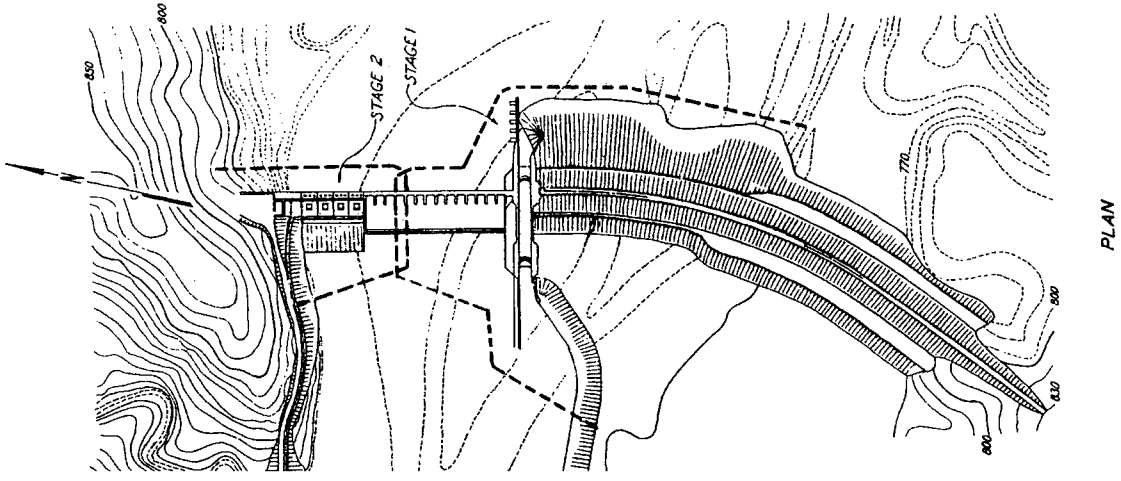
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
4-4-41		

KNOXVILLE	4-4-41	10	CP	3	102N3R4

STAGES	NO.	ITEM OR EQUIPMENT	QUANTITY	UNIT	MAXIMUM MONTHLY QUANTITY
SWITCHYARD	3	Earth excavation			
	4	Rock excavation			
	6	Concrete			
	14	Structural steel			
	18	Backfill			
	30	Earth fill			
INSTALLATION GATES AND MACHINERY	41	Lock gates and operating mechanism			
	42	Gates - spillway (Tainter)			
	43	Gates - intake			
	44	Gates - draft tube			
	47	Spillway deck girders			
	48	Trash racks			
	49	Lock segmental valves & oper eqpt - incl culvert liner			
INSTALLATION CRANES	61	Spillway gate operating equipment			
	62	Crane - intake			
	63	Crane - powerhouse			
	64	Crane - draft tube			
	66	Crane - unloading			
INSTALLATION POWERHOUSE MACHINERY	73	Turbines			
	74	Generators			
	75	Switchyard			
	76	Mechanical equipment			
	77	Powerhouse structural steel			
GENERAL	91	Land acquisition			
	92	Reservoir clearing			
	93	Backwater protection			
	94	Highway and railroad relocation			
	95	Family removal and cemetery relocation			
	96	Utilities			
	97	Filling reservoir			
	98	Switching structure and transmission line			
	99	Cleanup and removal			
	100	Channel excavation			
	100a	Excavation of islands below dam (dredging)	600,000	Cu yd	46,000





To show dates when Units 1 & 2 went on line (data on Units 3 & 4 removed) and Reservoir filling revised. Otherwise as revised

REVISED TO 7-4-45

THIS DRAWING SUPERSEDES 102N2

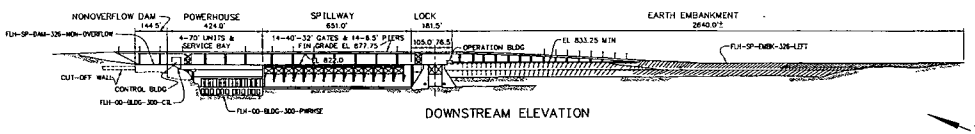
GENERAL

CONSTRUCTION SCHEDULE

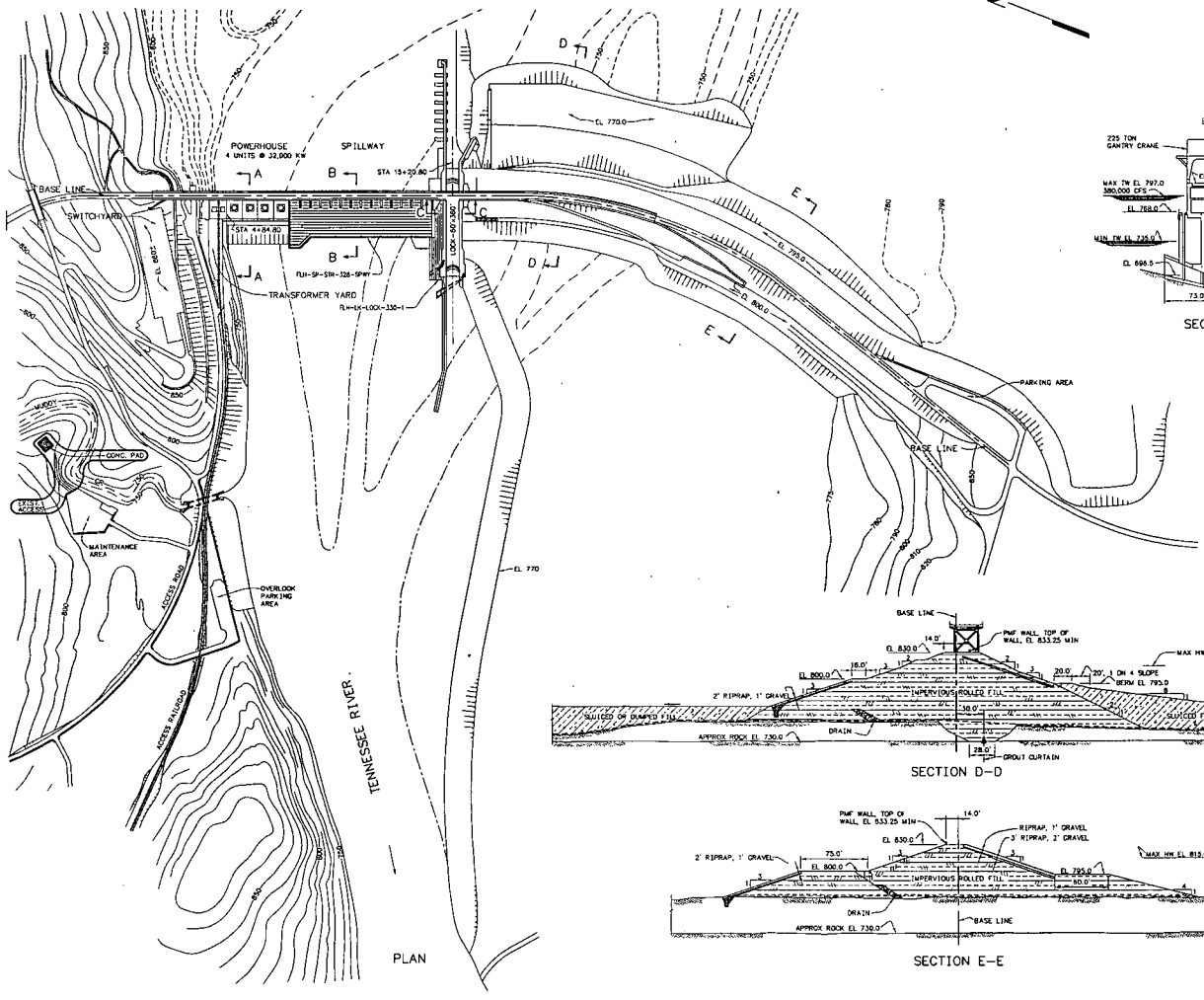
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
4-4-41		

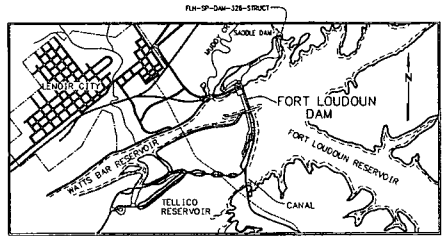
KNOXVILLE	4-4-41	10	CP	3	102N3R4



DOWNSTREAM ELEVATION

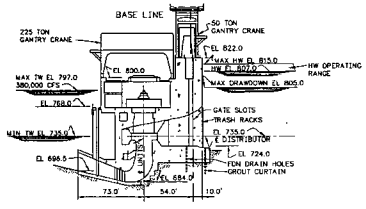


PLAN

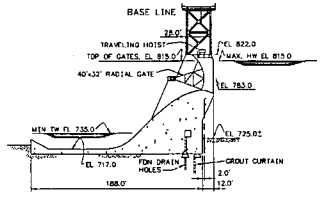


SITE PLAN

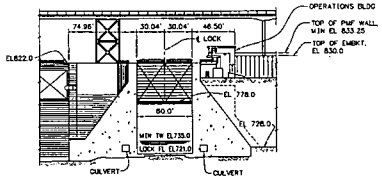
SCALE 1000 0 2000 FEET



SECTION A–A

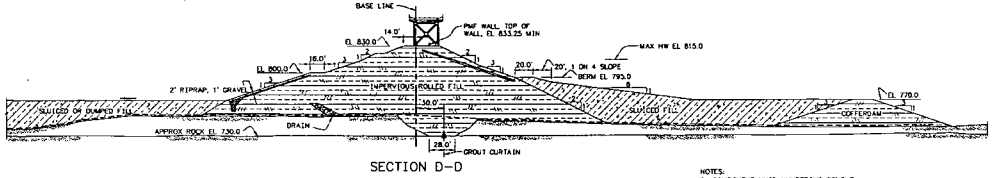


SECTION B–B



SECTION C–C

FOR PMF MODIFICATION DETAILS, SEE DRAWINGS:
23W220–SERIES
23W230–SERIES



SECTION D–D

SECTION E–E

NOTES:

2. COMPONENT UNID NUMBERING SCHEME:

PLANT	UNIT	FUNCTION	SYSTEM	SEQUENCE NO.
FLH	00	BLDG	300	PWRHSE

3. UNIDS ARE LISTED IN WHOLE ON THIS DRAWING.
4. COMPONENT UNID NUMBERS USE THE FOLLOWING SYSTEM AND FUNCTION CODES:

SYSTEM NUMBERS – SYSTEM NAME:
328 – DAM
328 – SPILLWAY
330 – NAVIGATION LOCK

FUNCTION CODES – FUNCTION CODE NAMES:
BLDG – BUILDING
DAM – DAM
EMBK – EMBANKMENT
LOCK – LOCK
STR – STRUCTURE

SECTIONS
SCALE 50 0 50 100 FEET
200 0 200 400
PLAN AND ELEVATION

APR 30 2008

REV NO.	DATE	DSGN	PREP	CHKD	SUPV	VRFD	APPD	DCN NUMBER	REV CD
R11									D
ADDED BULKHEAD STORAGE PAD, PROJECT ID: DSP-032									

SCALE: 1"=50'

MAIN DAM WORKS

GENERAL PLAN
ELEVATION & SECTIONS

DESIGNED BY: C.C. HOSKINS | REVISED BY: K.R. LENNON | VERIFIED BY: H.L. PATTY

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
RIVER OPERATIONS

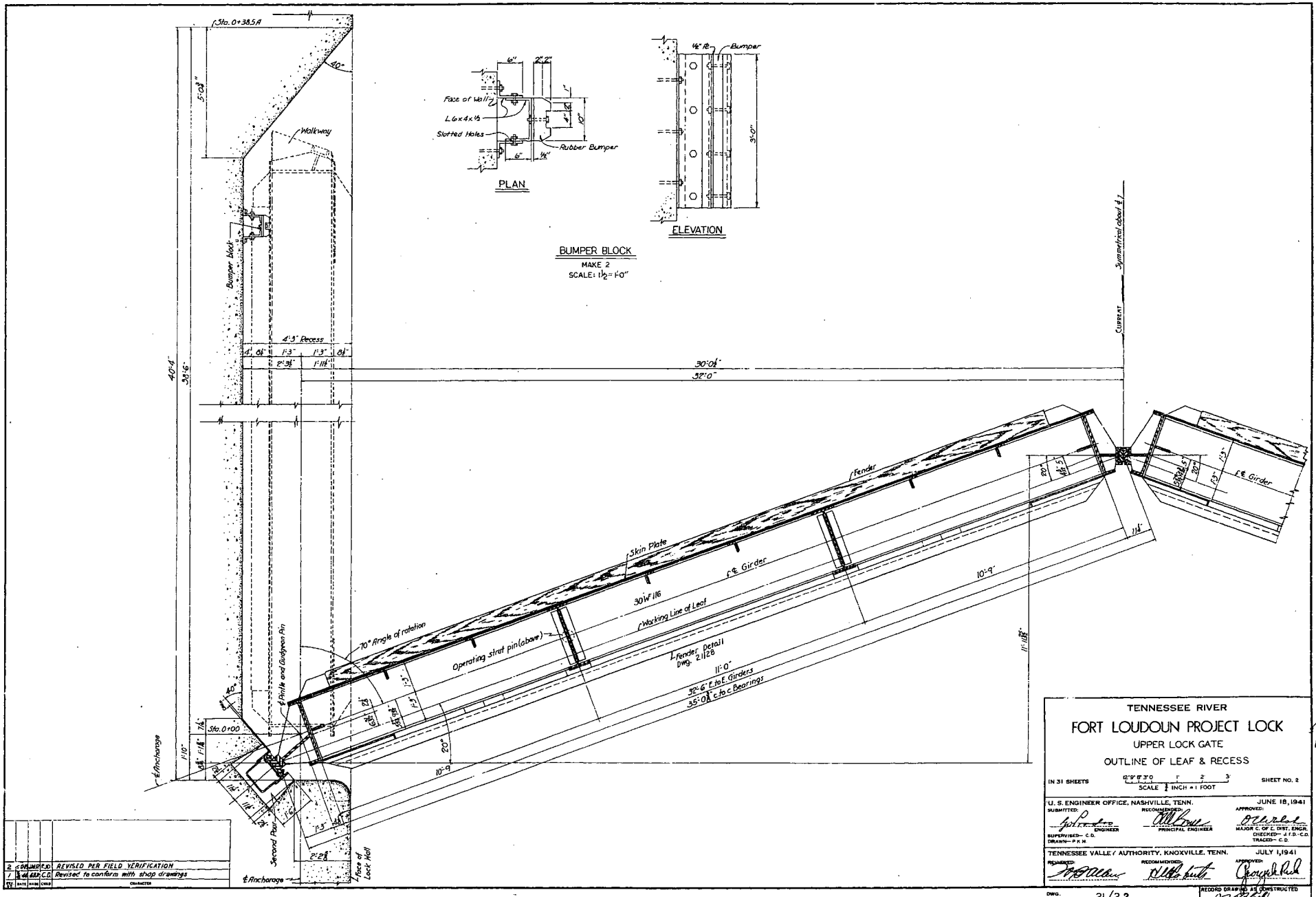
AUTOCAD 2006 | 10 | C | 10W200 | R 11

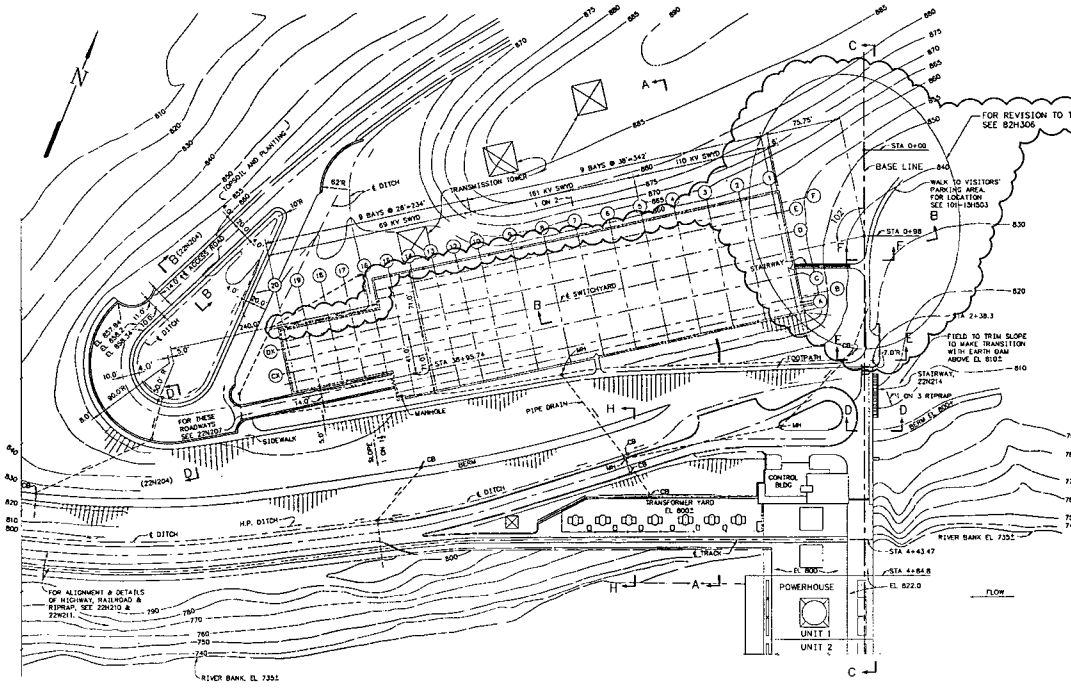
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES : (10N200 R8)

TASK COMPLETED BY: | REV NO.

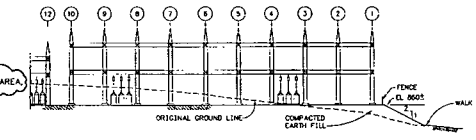
PLOT FACTOR: 600
W_HYDRO

CAD DRAWING
DO NOT ALTER MANUALLY

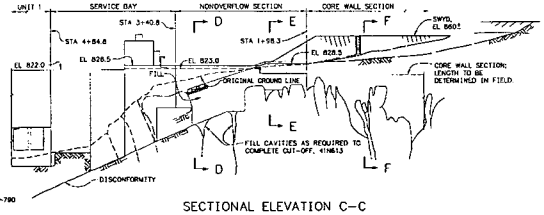

Sta. 0+38.5 A
40°
5'-0 3/8"
Walkway
Bumper Block
4'-3" Recess
4" 8 1/2" 1'-3" 1'-3" 8 1/2"
2'-3 1/2" 1'-11 1/2"
40'-4"
38'-6"
30'-0 1/2"
32'-0"
Face of Wall
L 6x4x1/2
Slotted Holes
Rubber Bumper
PLAN
Bumper
ELEVATION
BUMPER BLOCK
MAKE 2
SCALE: 1 1/2" = 1'-0"
Symmetrical about ℄
Clipper at
Fender
Skin Plate
℄ Girder
30 WF 116
Working Line of Leaf
70° Angle of rotation
Operating strut pin (above)
Fender Detail Dwg. 2/128
11'-0"
32'-6" E. to E. Girders
35'-0 1/2" c. to c. Bearings
℄ Pintle and Gudgeon Pin
Sta. 0+00
℄ Anchorage
Second Pair
Face of Lock Wall
20°
10'-9
11'-10 1/2"
TENNESSEE RIVER
FORT LOUDOUN PROJECT LOCK
UPPER LOCK GATE
OUTLINE OF LEAF & RECESS
IN 31 SHEETS
SCALE 1/4 INCH = 1 FOOT
SHEET NO. 2
U. S. ENGINEER OFFICE, NASHVILLE, TENN.
JUNE 18, 1941
SUBMITTED: ENGINEER
RECOMMENDED: PRINCIPAL ENGINEER
APPROVED: MAJOR C. OF E. DIST. ENGR.
SUPERVISED— C.D.
DRAWN— P.K.H.
CHECKED— J.F.D.-C.D.
TRACED— C.D.
TENNESSEE VALLEY AUTHORITY, KNOXVILLE, TENN.
JULY 1, 1941
REMARKED:
RECOMMENDED:
APPROVED:
2 REVISED PER FIELD VERIFICATION
1 Revised to conform with shop drawings
RECORD DRAWING AS CONSTRUCTED
DWG. NO. 21/2.2



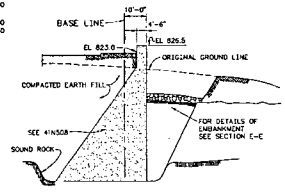
PLAN



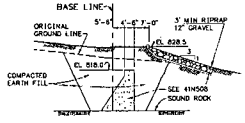
SECTION B-B



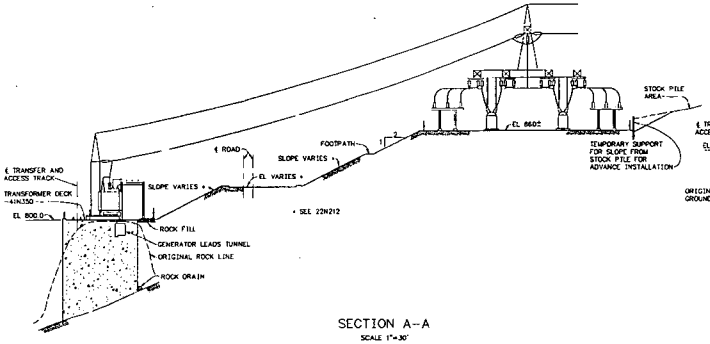
SECTIONAL ELEVATION C-C



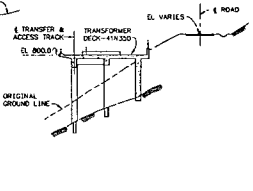
SECTION D-D
NONOVERFLOW SECTION
STA 2+51.3 TO STA 3+40.8
SCALE: 1"=20'



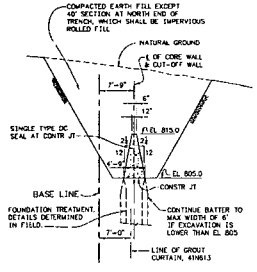
SECTION E-E
NONOVERFLOW SECTION
STA 1+98.3 TO STA 2+51.3
SCALE: 1"=20'



SECTION A-A
SCALE 1"=30'



SECTION H-H
SCALE 1"=30'



SECTION F-F
CORE WALL SECTION
NORTH OF STA 1+98.3
SCALE: 1"=10'

NOTES:

1. AREA UNDER SWITCHYARD AND EARTH DAM SHALL BE STRIPPED OF ALL VEGETABLE MATTER.
2. FOR DETAILS OF CATCH BASINS, MANHOLES, AND SURFACE DRAINS SEE 22N202, 22N212, 22N213 & 22N206.
3. THE UPSTREAM SLOPE OF THE DAM SHALL BE PROVIDED WITH RIPRAP AS CALLED FOR IN SECTION E-E. AT LEAST 50 PERCENT OF THE RIPRAP SHALL CONSIST OF STONE WEIGHING 350 POUNDS OR MORE.
4. RIPRAP SHALL BE PLACED IN ACCORDANCE WITH CONSTR SPEC FLC-654.
5. FOR MODIFICATIONS REQUIRED FOR SWITCHYARD OIL CONTAINMENT SEE DRAWING 22N200

REV NO.	DATE	DRN	DWG	DJP	PWD	APPD	FEED	PROJECT	AE COMP	%
R										
R10	[illegible]	CWF	[illegible]	RCH	JEV	JEV	JEV			

MODIFICATIONS FOR SY OIL CONTAINMENT

SCALE: 1"=50' EXCEPT AS NOTED

NORTH SIDE

GENERAL PLAN

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISOR BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
	C.C.P.	J.E.F.	R.A.K.			

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | DATE 11-15-41 | 10 | C | 22W200 | R 10

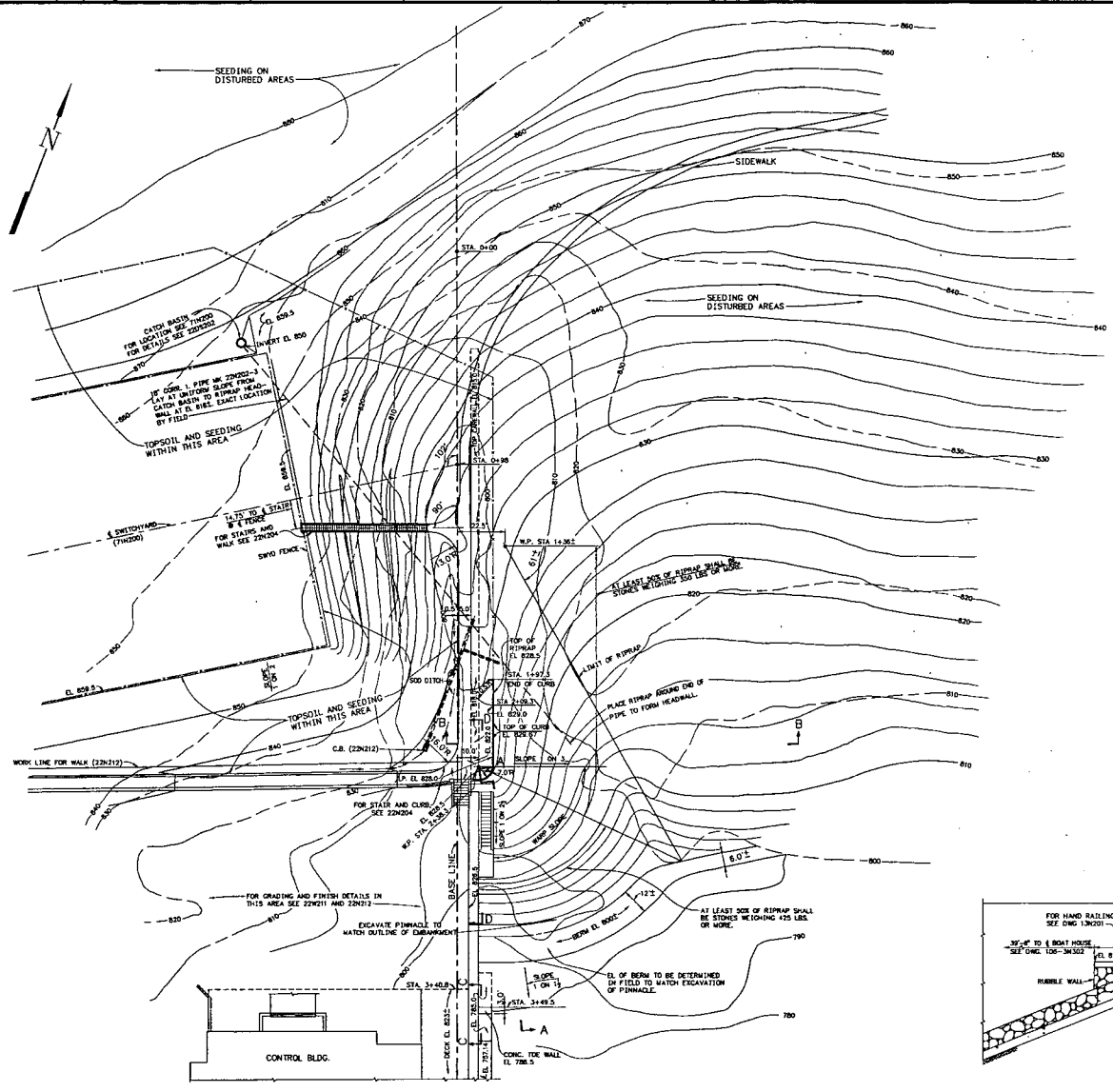
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(22N200 R9)

TASK COMPLETED BY: | REV. NO.

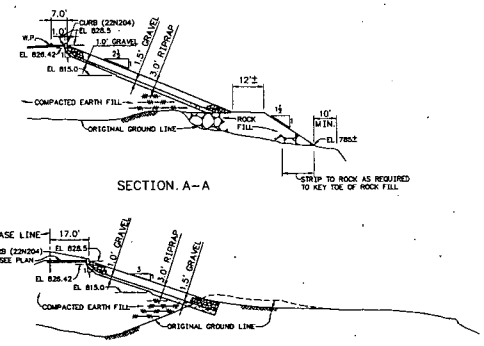
PLOT FACTOR:600
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

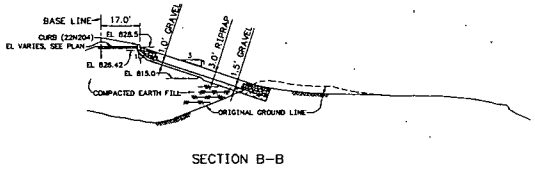
10 | C | 22W200



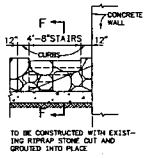
PLAN



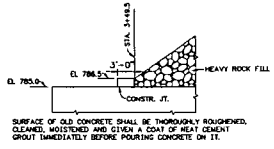
SECTION. A–A



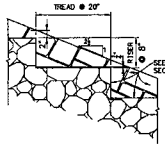
SECTION B–B



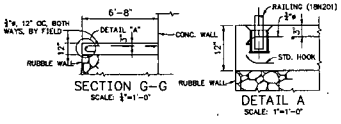
SECTION E–E
SCALE: 1/4"=1'-0"



SECTION C–C
SCALE: 1/4"=1'-0"

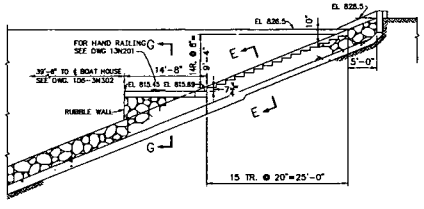


SECTION F–F
SCALE: 1"=1'-0"



SECTION G–G
SCALE: 1/4"=1'-0"

DETAIL A
SCALE: 1"=1'-0"



SECTION D–D
SCALE: 1/4"=1'-0"

NOTES:

1. FOR GENERAL NOTES, SEE 22N200.
2. CONTOURS SHOWN THUS------INDICATE SURFACE OF GROUND BEFORE FILLING OR GRADING. CONTOURS SHOWN THUS------ INDICATE FINAL GROUND SURFACE.
3. FOR TREATMENT OF AREAS WHERE "TOPSOIL AND PLANTING" OR "TOPSOIL AND SEEDING" IS INDICATED SEE NOTES 10, 11, AND 12 DWG. 22W211.
4. FOR LOCATION AND DETAILS OF PROTECTIVE FENCE SEE 18N200

R												
R 8 AUG 08 2001												
ELECTRONICALLY RESTORED												
REV. NO.	DATE	DRAWN	DESIGN	CHECK	SUPV	PROJ	APPR	LEAD	PROJECT NO.	CE CHIEF		REVISION WORK

SCALE: 1"=20' EXCEPT AS NOTED

NORTH SIDE

EMBANKMENT PLAN AND SECTIONS

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
	C.C.P.	R.A.A.	A. A. MEYER	T. MUNDAL	R. M. RIEGEL	G. K. RICH

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

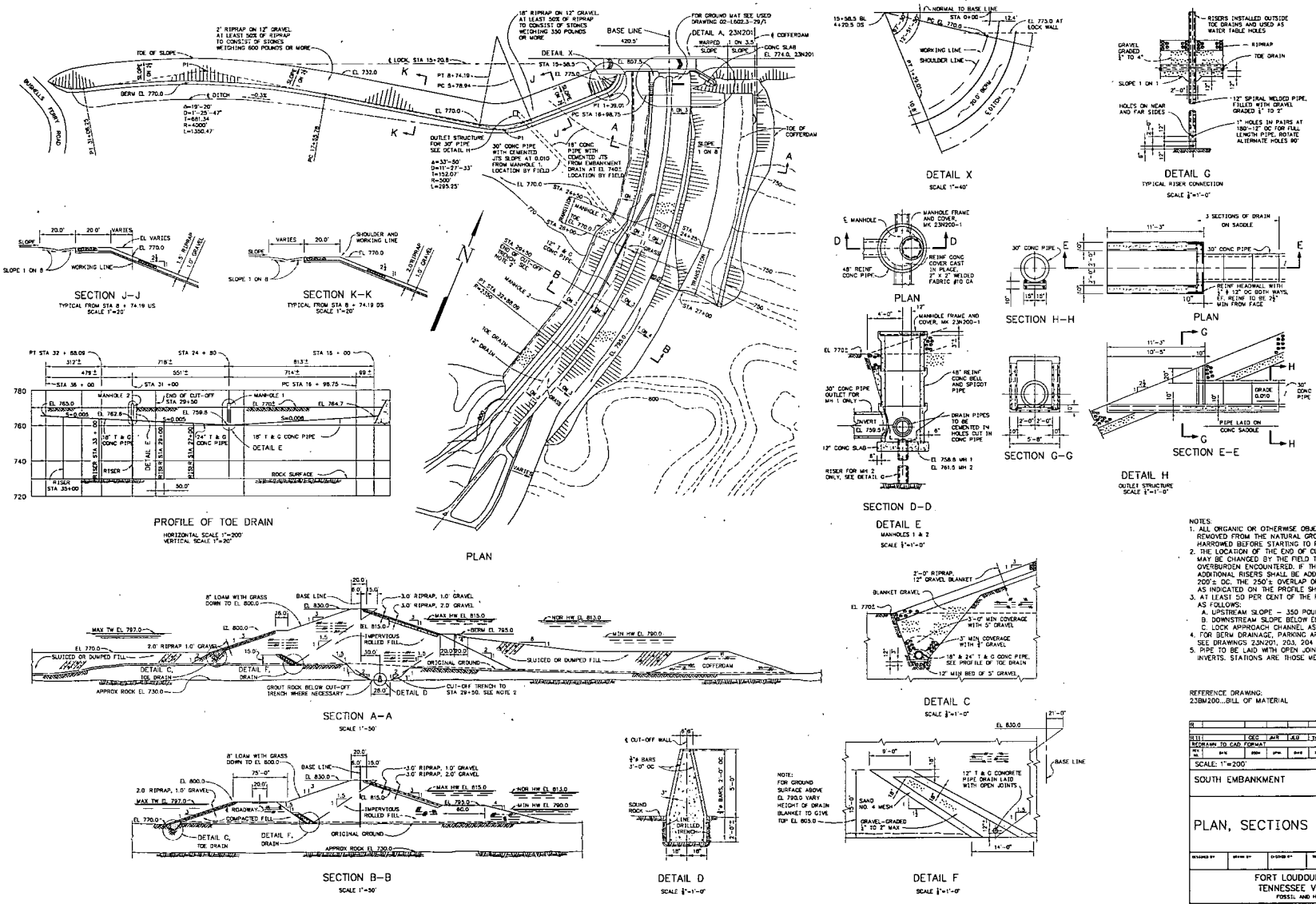
AUTOCAD 2006 | 2-16-43 | 10 | C | 22W214 | R 9

TASK COMPLETED BY: | REV NO. | ELECTRONICALLY RESTORED DRAWING THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(22N214 R8)

PLOT FACTOR:240
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

10 | C | 22W214



NOTES:

1. ALL ORGANIC OR OTHERWISE OBJECTIONABLE MATERIAL SHALL BE REMOVED FROM THE NATURAL GROUND SURFACE AND THE SURFACE HARROWED BEFORE STARTING TO PLACE ROLLED FILL.
2. THE LOCATION OF THE END OF CUT-OFF TRENCH AT STA 29+50 MAY BE CHANGED BY THE FIELD TO SUIT ACTUAL CONDITIONS OF OVERBURDEN ENCOUNTERED. IF THE LENGTH IS REDUCED, ADDITIONAL RISERS SHALL BE ADDED ALONG THE TOE DRAIN AT 200'± OC. THE 250'± OVERLAP OF CUT-OFF AND RISER AREAS AS INDICATED ON THE PROFILE SHALL BE MAINTAINED.
3. AT LEAST 50 PER CENT OF THE RIPRAP SHALL CONSIST OF STONES AS FOLLOWS:
   A. UPSTREAM SLOPE – 350 POUNDS OR MORE
   B. DOWNSTREAM SLOPE BELOW EL 770–350 POUNDS OR MORE
   C. LOCK APPROACH CHANNEL AS NOTED.
4. FOR BERM DRAINAGE, PARKING AREAS, AND OTHER TOP DETAILS, SEE DRAWINGS 23N201, 203, 204 & 205
5. PIPE TO BE LAID WITH OPEN JOINTS. EL GIVEN ARE FOR PIPE INVERTS. STATIONS ARE THOSE MEASURED ALONG BASE LINE.

REFERENCE DRAWING:
23BM200...BILL OF MATERIAL

REV	DATE	DSGN	DFTG	CHKD	SUPV	PVRD	APPD	ISSD	PROJECT ID	AE CONST	REV
R											
R11		CEC	AJR	LEG	TSM	JEY	JEV	JEY			
REDRAWN TO CAD FORMAT											

SCALE: 1"=200' EXCEPT AS NOTED

SOUTH EMBANKMENT

PLAN, SECTIONS & DETAILS

DESIGNED BY | DRAWN BY | CHECKED BY | SUPERVISED BY | REVIEWED BY | APPROVED BY | ISSUED BY

FORT LOUDOUN HYDRO PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

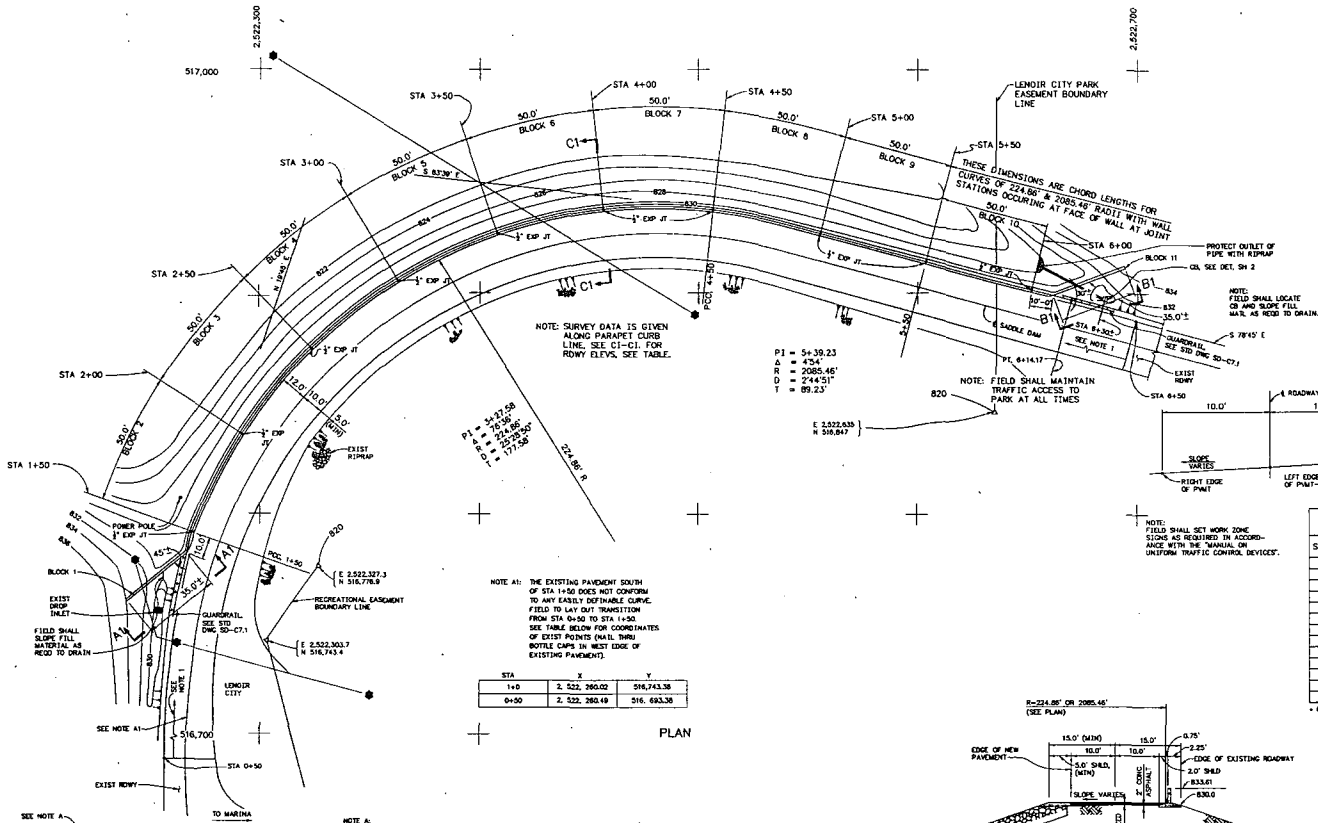
AUTOCAD R12 | 10 | C | 23W200 | R 11

TASK COMPLETED BY: | REV NO | ELECTRONICALLY RESTORED DRAWING THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES : (23W200, R10)

PLOT FACTOR:1
W_TVA

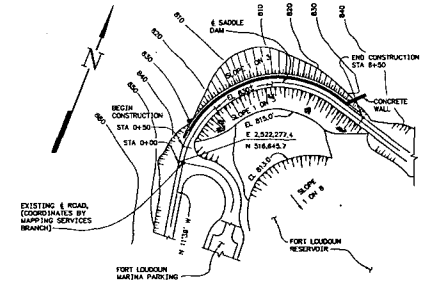
C.A.D. DRAWING
DO NOT ALTER MANUALLY

23W200 | C | 10

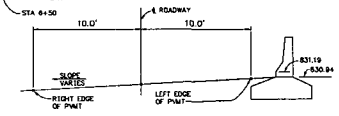


STA	X	Y
1+0	2, 522, 260.02	516,743.38
0+50	2, 522, 260.49	516, 693.38

PLAN



KEY PLAN
1"=100'



NOTE: FIELD SHALL SET WORK ZONE SIGNS AS REQUIRED IN ACCORDANCE WITH THE "MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES".

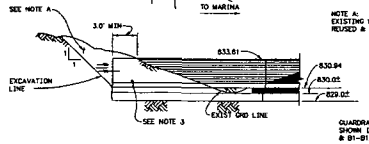
ROAD WAYS ELEVATIONS

STATION	RIGHT EDGE	CENTER LINE	LEFT EDGE
0+50	831.27	831.4*	831.4*
1+00	830.77	830.97	831.17
1+50	830.2	830.8	831.0
2+00	830.1	830.5	830.90
2+50	830.1	830.5	830.90
3+00	830.1	830.5	830.90
3+50	830.11	830.51	830.91
4+00	830.15	830.55	830.95
4+50	830.31	830.61	830.91
5+00	830.5	830.7	830.9
5+50	830.71	830.81	830.91
6+00	831.0	831.0	831.0
6+50	831.25*	831.15*	831.05*

* FIELD SHALL TRANSITION ROADWAY TO MEET EXISTING ELEVATIONS.

NOTES:

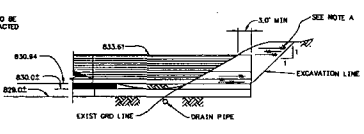
1. REMOVE EXISTING PAVEMENT WITHIN CONSTRUCTION LIMITS AND CONSTRUCT NEW SURFACING. SURFACING IS TO CONSIST OF A 8" STABILIZED BASE, BITUMINOUS PRIME COAT AND 2" ASPHALTIC CONCRETE SURFACE IN ACCORDANCE WITH SECTIONS 225, 320, AND 346 OF THE T-1 HIGHWAY SPECIFICATION.
2. WALL BLOCKS 2 THRU 10 ARE CURVED SEGMENTS, BUT TO FACILITATE FORMING MAY BE PLACED IN CHORDS NOT TO EXCEED 5'-0" FOR BLOCKS 2 THRU 7, AND 10'-0" FOR BLOCKS 8 THRU 10. THE NUMBER OF CHORD SEGMENTS IN EACH WALL BLOCK SHALL BE THE SAME AND OF EQUAL LENGTH.
3. * DENOTES UNDERGROUND CABLE. FIELD TO COORDINATE WITH UTILITY TO AVOID DAMAGE TO CABLE.
4. PARAPET WALL SHALL BE FINISHED WITH A RUBBED SURFACE OR BY AN APPLIED TEXTURED SURFACE DESCRIBED AS FOLLOWS:
   A. RUBBED SURFACES SHALL BE RUBBED TO BLEND IN TEXTURE AND COLOR WITH ADJACENT CONCRETE, AND IN ACCORDANCE WITH THE T-1 HIGHWAY SPECIFICATION, SECTION 401.28.
   B. APPLIED TEXTURED SURFACES SHALL BE APPLIED TO CONCRETE SURFACES WHICH ARE AT LEAST 28 DAYS OLD, FREE OF ALL FOREIGN MATTER, EFFLORESCENCE, CURING COMPOUND, SURFACE MOISTURE AND FORM OIL OR GREASE. ALSO, THESE SURFACES SHALL HAVE A SMOOTH FINISH SUCH THAT NO HOLES LARGER THAN ¼" D. OR CRACKS GREATER THAN ¼" WIDE WILL BE ALLOWED. IF FORM OIL, GREASE, OR CURING COMPOUND ARE PRESENT, THE SURFACE SHALL BE WASHED CLEAN WITH A 5% SOLUTION OF TRISODIUM PHOSPHATE, USING A STIFF-BRISTLED BRUSH. AFTER WASHING, THE CONCRETE SURFACE SHALL BE THOROUGHLY RINSED WITH CLEAN WATER. THE SPRAY FINISH SHALL BE APPLIED AT A RATE OF 1 GALLON PER 45 (SQ FT) WITH HEAVY DUTY SPRAY EQUIPMENT (4:1 PUMP RATIO OR GREATER) CAPABLE OF MAINTAINING A CONSTANT PRESSURE AS NECESSARY FOR PROPER APPLICATION. THE COLOR OF THE FINISH SHALL BE AS NEAR AS PRACTICABLE TO THE COLOR OF A RUBBED FINISH COLOR AND SHALL BE TIGHTLY BONDED TO THE STRUCTURE.



A1-A1
1"=10' (HORIZONTAL)
1"=5' (VERTICAL)

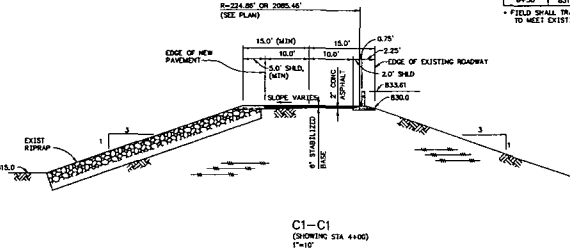
NOTE A: EXISTING MATERIAL TO BE REUSED & WELL COMPACTED

GUARDRAIL NOT SHOWN IN A1-A1 & B1-B1.



B1-B1
1"=10' (HORIZONTAL)
1"=5' (VERTICAL)

ROADWAY ELEVATIONS: A FINISHED EL OF 831.00 WAS MAINTAINED ALONG PARAPET CURB LINE FROM STA 1+50 TO STA 5+00 AND SLOPED AT 2.5% GRADE TOWARD LAKE, (PER PAVEMENT X-SECTION SUPPLEMENT TO THIS DRAWING DATE 3-28-86). END SECTION WERE TRANSITIONED FOR DRAINAGE AND TO MEET EXISTING PAVEMENT.



C1-C1
(SHOWING STA 4+00)
1"=10'

COMPANION DRAWING: 23W220-2

R1									
R0	2 2 2001	RJS	BP	BP	RJS	BP	BP	RJS	
ELECTRONICALLY RESTORED									
NO.	DATE	DRAWN	CHECKED	DESIGN	SUPV	PROJ	APPD	DWG	PROJECT NO.	AS BUILT	TO

SCALE: 1"=20' EXCEPT AS NOTED

NORTH SIDE
SADDLE DAM AT MARINA

CONCRETE
INCREASING HEIGHT OF DAM
PLAN AND ELEVATIONS

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
	RJS	BP				

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

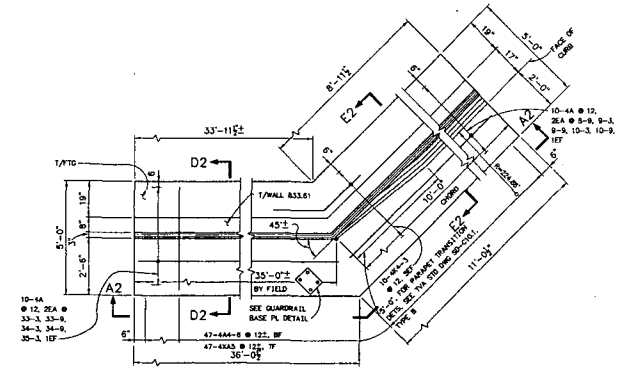
AUTOCAD R14	DATE 6-30-86	10	C	23W220-1	R 2

TASK COMPLETED BY: | REV NO

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES : (23W220-1 R1)

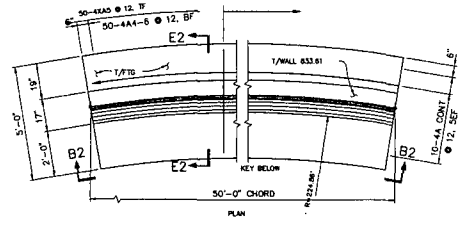
PLOT FACTOR:240
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

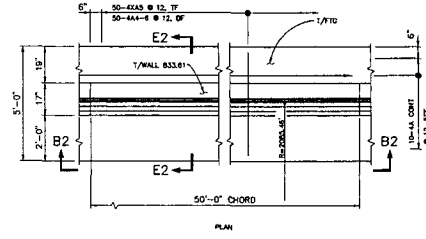


BLOCK 1
ONE REQD
FOR LOCATION & ORIENTATION SEE SH 1

NOTE:
GUARDRAIL BASE CONNECTIONS TO FOOTING ON BLOCKS 1 & 11 SHALL BE MADE PRIOR TO BACK-FILLING AROUND FOOTING.



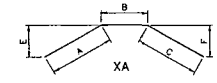
BLOCK 2 THRU BLOCK 7
ONE EACH REQD
FOR LOCATION & ORIENTATION SEE SH 1

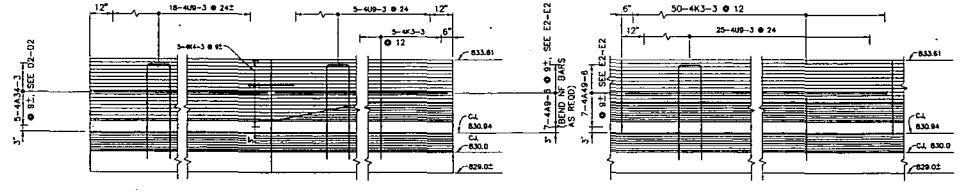


BLOCK 8 THRU BLOCK 10
ONE EACH REQD
FOR LOCATION & ORIENTATION SEE SH 1

BENT BAR LIST

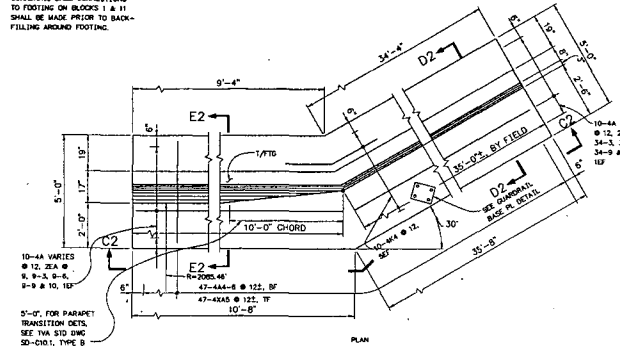
BAR MARK	NO. REQD	BENDING DIMENSIONS A	B	C	E	F	R
4U9-3	271	4-3	1-0	EX			
4K3-3	480	1-6	EX		1-1		
4K4-3	15	2-0	EX		1-5		
4K4	15	2-0	EX		1-0		
4X5	544	2-0	1-5	EX	0-10	0-10	



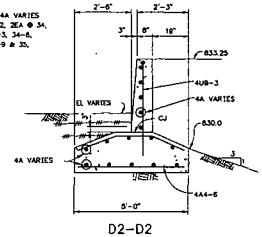


A2–A2

B2–B2

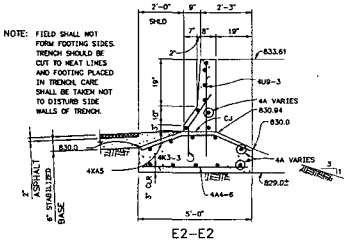


BLOCK 11
ONE REQD
FOR LOCATION & ORIENTATION SEE SH 1

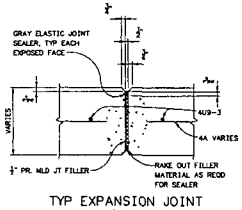


D2–D2

NOTE: FIELD SHALL NOT FORM FOOTING SIDES. TRENCH SHOULD BE CUT TO NEAT LINES AND FOOTING PLACED IN TRENCH. CARE SHALL BE TAKEN NOT TO DISTURB SIDE WALLS OF TRENCH.



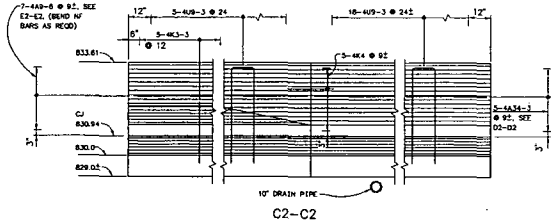
E2–E2



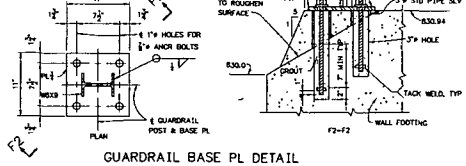
TYP EXPANSION JOINT
1½"=1'-0"

NOTES:

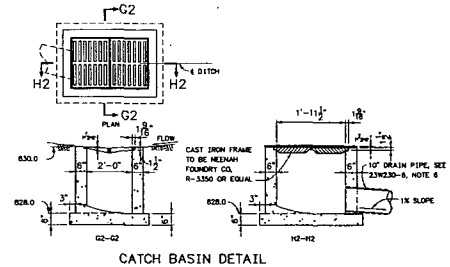
1. CONCRETE SHALL BE PLACED IN ACCORDANCE WITH GENERAL CONSTRUCTION SPECIFICATION G-2. CONCRETE SHALL BE CLASS 300.75 AFW. THE MAXIMUM PLACING AIR TEMPERATURE OF CONCRETE SHALL BE 80°F.
2. MINIMUM EXPOSURE TIME BEFORE PLACING ONE LIFT UPON ANOTHER OR ONE POUR ADJACENT TO ANOTHER SHALL BE 3 DAYS.
3. FORMWORK SHALL BE IN ACCORDANCE WITH GENERAL CONSTRUCTION SPECIFICATION G8. SEE 23W220-1, NOTE 3 FOR FINISHING OF PARAPET WALL.
4. CONSTRUCTION JOINTS IN WALL SHALL BE CHAMFERED ¾" AT 10'-0" INTERVALS.
5. CHAMFER ALL EXPOSED EDGES ¾" UNLESS OTHERWISE NOTED.
6. ALL REINFORCING STEEL SHALL CONFORM TO ASTM SPECIFICATION A-615, GRADE 60.
7. COVER DIMENSIONS SHOWN ARE TO BE 2" CLEAR COVER UNLESS NOTED. OTHER DIMENSIONS ARE TO CENTERLINE OF REINFORCEMENT.
8. WELDING OF OR TO HIGH-STRENGTH REINFORCING BARS WITHOUT APPROVAL OF HYDRO ENGINEERING PROJECTS IS PROHIBITED.
9. 4A CONTINUOUS BARS SHALL BE SPLICED A MINIMUM OF 18". SPLICES SHALL BE PREFERABLY STAGGERED. NO BAR SHALL BE LESS THAN 10'-0" LONG



C2–C2



GUARDRAIL BASE PL DETAIL
2 REQD
1½"=1'-0"



CATCH BASIN DETAIL
FOR LOCATION SEE SH 1

SCALE: ½"=1'-0" EXCEPT AS NOTED

NORTH SIDE
SADDLE DAM AT MARINA

CONCRETE
INCREASING HEIGHT OF DAM
PLANS, SECTIONS AND DETAILS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

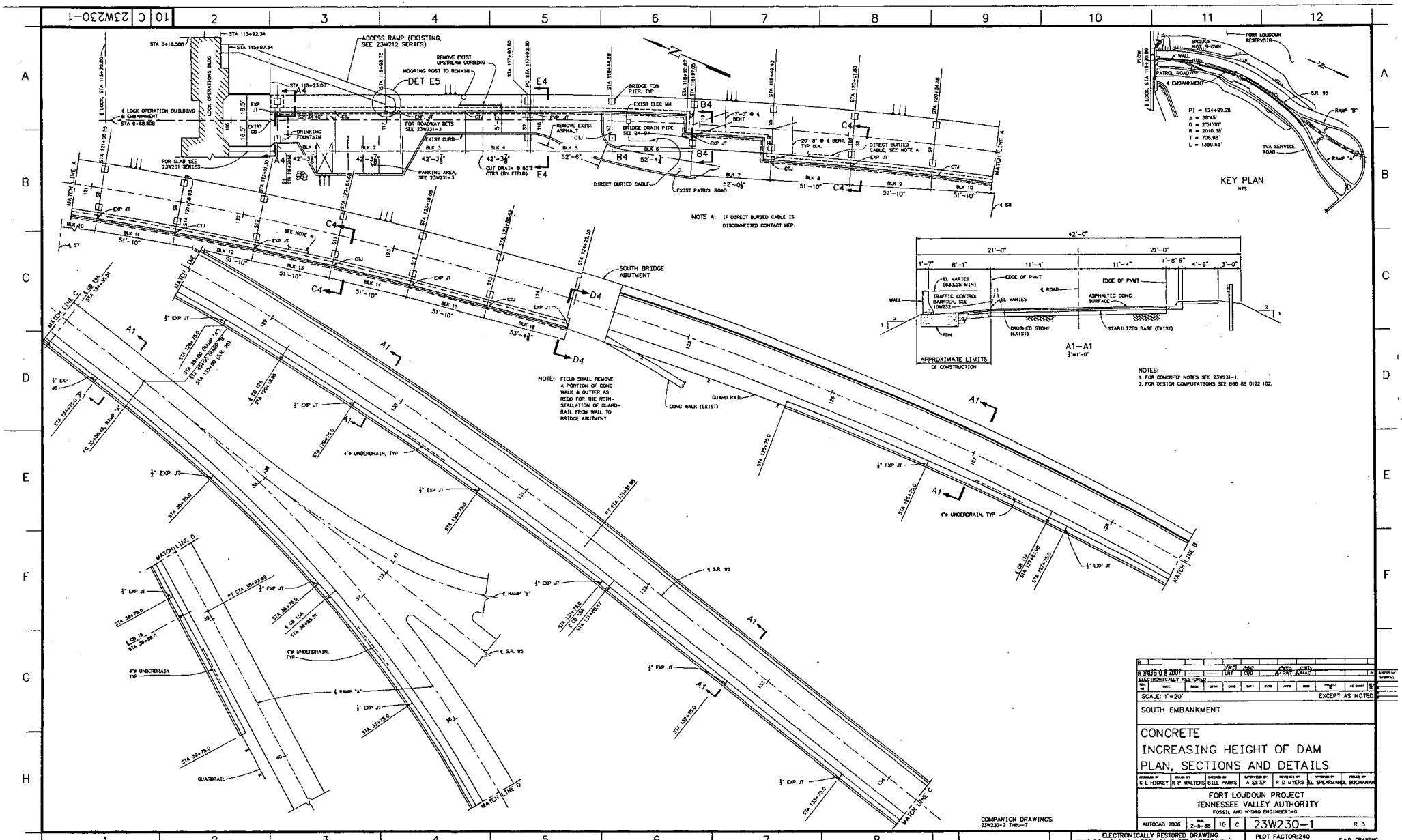
AUTOCAD 2006 | 6-30-88 | 10 | C | 23W220-2 | R 2

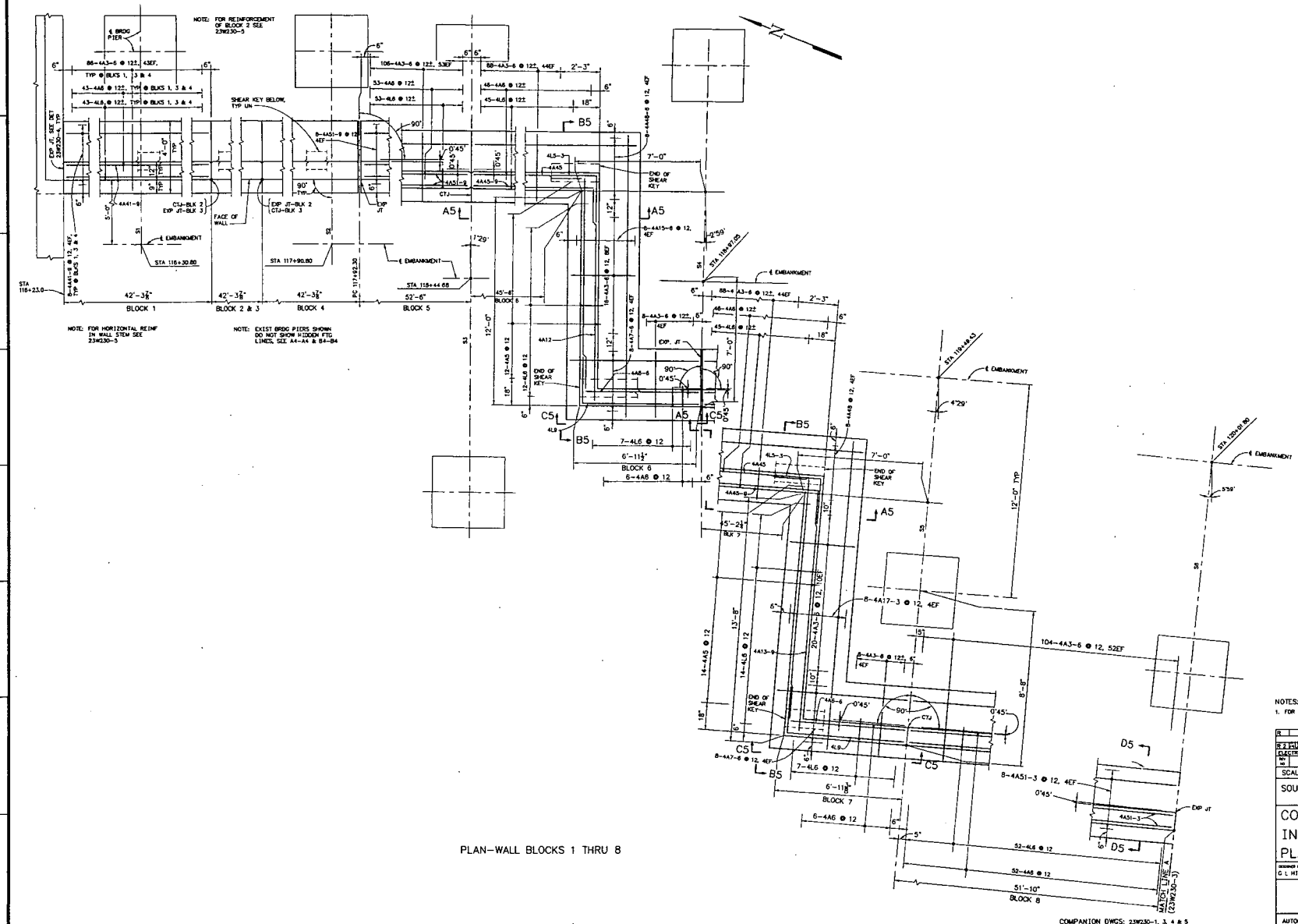
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES : (23W220-2 R1)

TASK COMPLETED BY: | REV NO.

PLOT FACTOR:24
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY


ACCESS RAMP (EXISTING, SEE 23W212 SERIES)
DET E5
SOUTH BRIDGE ABUTMENT
NOTE A: IF DIRECT BURIED CABLE IS DISCONNECTED CONTACT HEP.
NOTE: FIELD SHALL REMOVE A PORTION OF CONC WALK & GUTTER AS REQD FOR THE REINSTALLATION OF GUARDRAIL FROM WALL TO BRIDGE ABUTMENT
KEY PLAN
NTS
A1–A1
APPROXIMATE LIMITS OF CONSTRUCTION
NOTES:
1. FOR CONCRETE NOTES SEE 23W231-1.
2. FOR DESIGN COMPUTATIONS SEE 866 88 0122 102.
COMPANION DRAWINGS: 23W230-2 THRU-7
SCALE: 1"=20'
EXCEPT AS NOTED
SOUTH EMBANKMENT
CONCRETE
INCREASING HEIGHT OF DAM
PLAN, SECTIONS AND DETAILS
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING
AUTOCAD 2006
23W230-1
R 3
PLOT FACTOR:240
W_TVA
C.A.D. DRAWING
DO NOT ALTER MANUALLY
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES : (23W230-1 R2)
TASK COMPLETED BY:
REV NO.



PLAN-WALL BLOCKS 1 THRU 8

COMPANION DWGS: 23W230-1, 3, 4 & 5

BENT BAR LIST

BAR MARK	NO. REQD	BENDING DIMENSIONS A	B	C	E	F	R
4L8	364	4-10	EX				

NOTES:
1. FOR LIST SEE 23W230-1.

R 2 AUG 08 2001 — ELECTRONICALLY RESTORED

SCALE: 1"=1'-0" EXCEPT AS NOTED

SOUTH EMBANKMENT

CONCRETE
INCREASING HEIGHT OF DAM
PLAN, SECTIONS AND DETAILS

DESIGNED BY: G. L. HICKEY | DRAWN BY: R. P. WALTERS | CHECKED BY: BILL PARKS | SUPERVISED BY: A. ESTEP | REVIEWED BY: R. D. MYERS | APPROVED BY: EL SPEARMAN | ISSUED BY: D. BUCHANAN

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

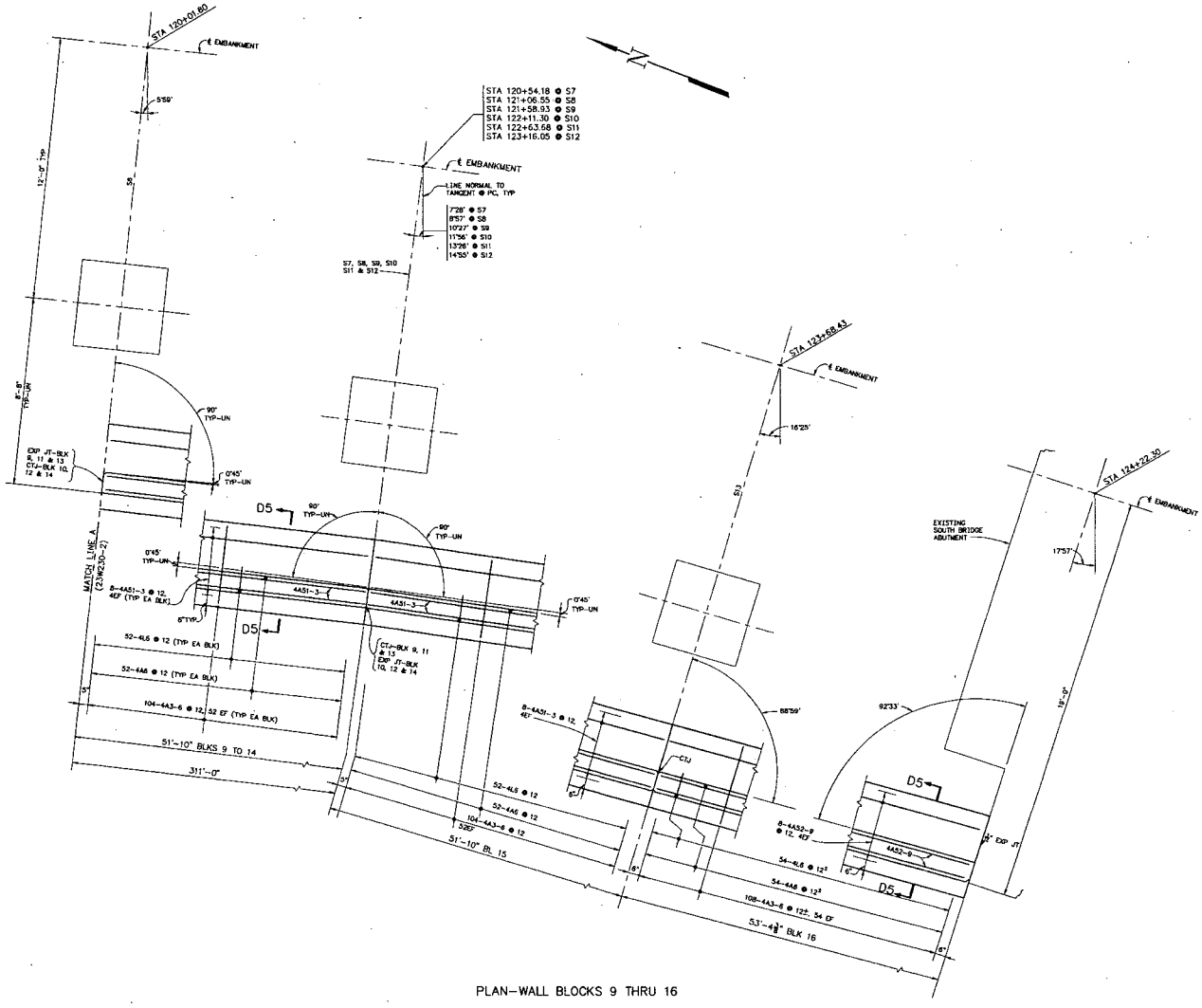
AUTOCAD 2006 | DATE 2-5-88 | 10 | C | 23W230-2 | R 2

TASK COMPLETED BY: | REV NO.

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(23W230-2 R1)

PLOT FACTOR:24
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY



PLAN-WALL BLOCKS 9 THRU 16

BENT BAR LIST							
BAR MARK	NO REQD	BENDING DIMENSIONS					
		A	B	C	E	F	R
4L6	418	4-10	EX				

NOTES:
1. FOR LIST SEE 23W230-1.

R 2 AUG 08 2007 ELECTRONICALLY RESTORED

SCALE: 1"=1'-0" EXCEPT AS NOTED

SOUTH EMBANKMENT

CONCRETE
INCREASING HEIGHT OF DAM
PLAN, SECTIONS AND DETAILS

G L HICKEY | R P WALTERS | BILL PARKS | A ESTEP | R D MYERS | EL SPEARMAN | BUCHANAN

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD 2006 | 2-5-88 | 10 | C | 23W230-3 | R 2

RO ISSUE FOR W.O. H05F22-285

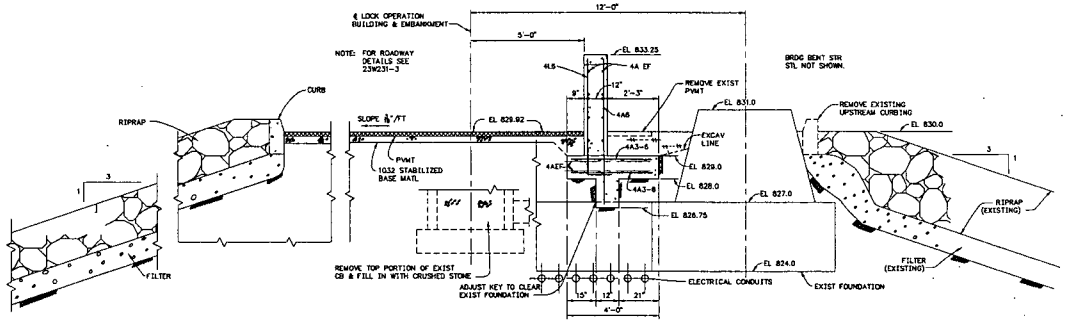
COMPANION DRAWINGS: 23W230-1 & 2, 4 & 5

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(23W230-3 R1)

TASK COMPLETED BY: | REV NO.

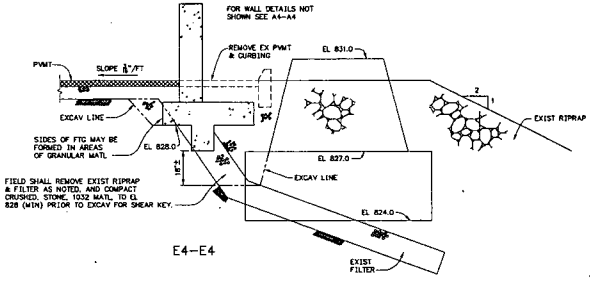
PLOT FACTOR:24
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

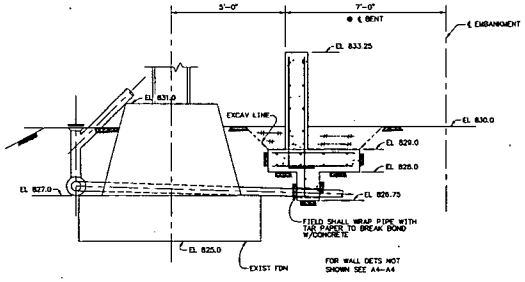


A4-A4
(23W230-1)

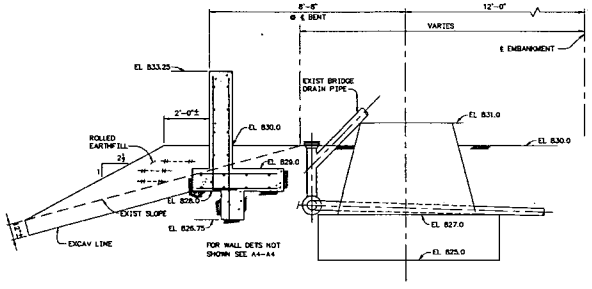
NOTE: FTGS AND SHEAR KEYS SHALL BE EXCAVATED TO NEAT LINES AND CONCRETE SHALL BE PLACED IN EXCAVATED TRENCH EXCEPT AS NOTED IN C4-E4.



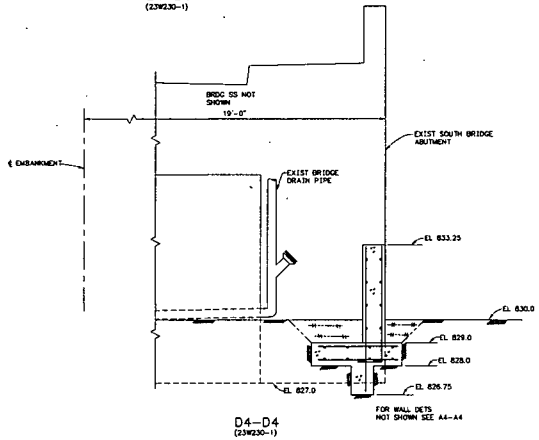
E4-E4



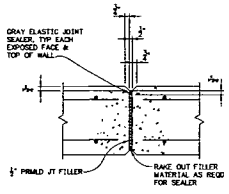
B4-B4
(23W230-1)



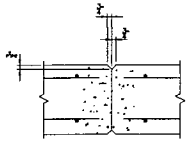
C4-C4
(23W230-1)



D4-D4
(23W230-1)



TYP EXPANSION JOINT
1½"=1'-0"



TYP CONTRACTION JOINT
1½"=1'-0"

RO ISSUE FOR W.O.
H08F22-285

COMPANION DRAWINGS:
23W230-1, 2, 3 & 5

NOTE:
1. FOR LIST SEE 23W230-1.

REV	DATE	DRWN	DSGN	CHKD	DSPY	RVWD	APPD	ISSD	PROJECT ID	LA CONST	
R	2 AUG 01 2007	---	---	SEE LAT	CBD		CBD PRNT ALMAC	CBD			R

ELECTRONICALLY RESTORED

SCALE: 1/8"=1'-0" EXCEPT AS NOTED

SOUTH EMBANKMENT

CONCRETE
INCREASING HEIGHT OF DAM
PLAN, SECTIONS AND DETAILS

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	DRAWN BY
G L HICKEY	R P WALTERS	BILL PARKS	A ESTEP	R D MYERS	EL SPEARMAN	G. BUCHANAN

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

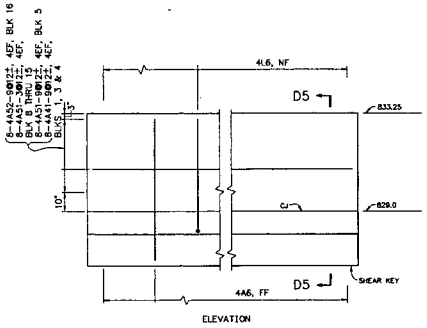
AUTOCAD 2006 | DATE 2-5-08 | 10 | C | 23W230-4 | R 2

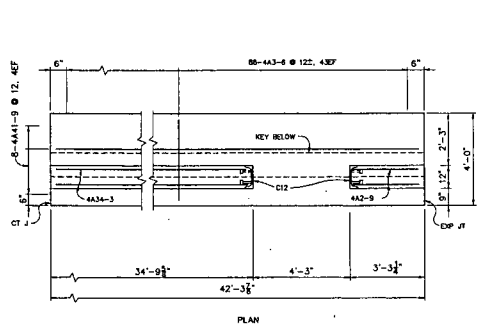
TASK COMPLETED BY: | REV NO.

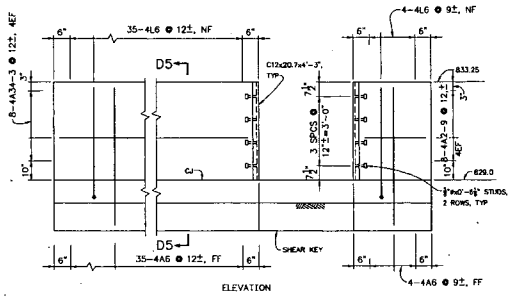
ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(23W230-4 R1)

PLOT FACTOR:24
W_TVA

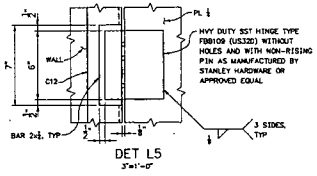
C.A.D. DRAWING
DO NOT ALTER MANUALLY





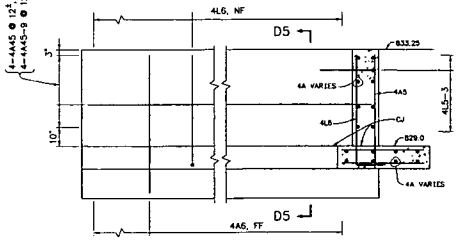


BENT BAR LIST							
BAR MARK	NO. REQD	BENDING DIMENSIONS					
		A	B	C	E	F	R
4L5-3	8	2'-7 1/2	EX				
4L6	39	4'-10	EX				
4L9	8	6'-6	EX				



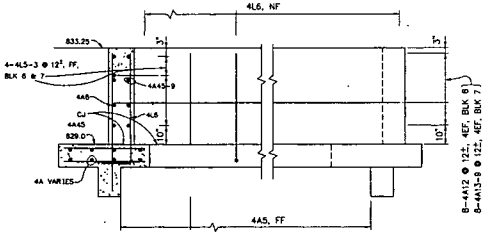
DET L5
3"=1'-0"

BLOCKS 1, 3, 4, 5 & 8 THRU 16
ONE EACH REQD
(FOR LOCATION & ORIENTATION SEE SH 1 TO 3)
1/4"=1'-0"

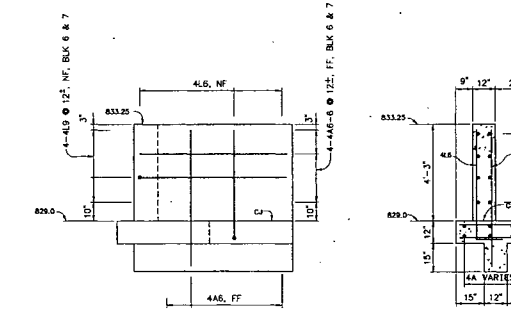


A5-A5
(23W230-2)
1/4"=1'-0"

BLOCK 2
ONE REQD
1/4"=1'-0"

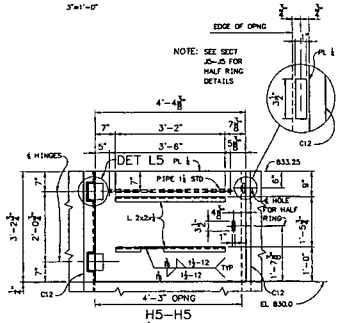


B5-B5
(23W230-2)
1/4"=1'-0"

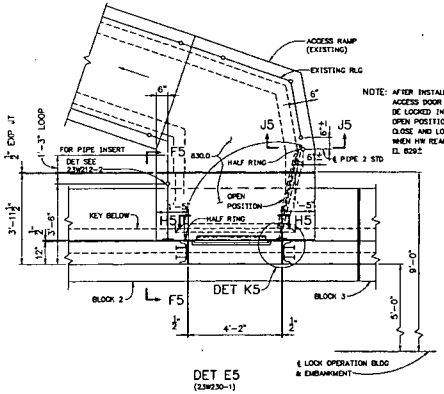


C5-C5
(23W230-2)
1/4"=1'-0"

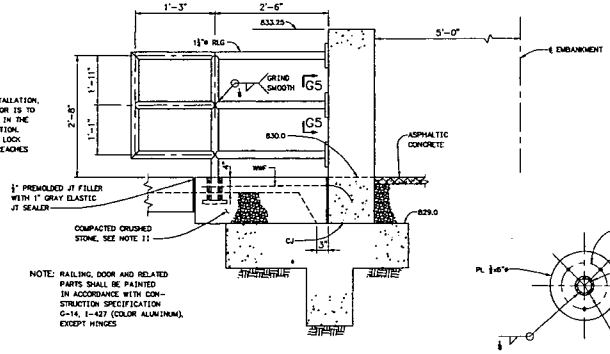
D5-D5
1/4"=1'-0"



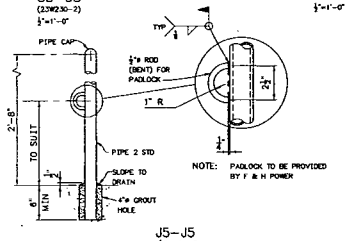
H5-H5
1/4"=1'-0"

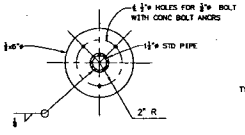


DET E5
(23W230-1)
1/4"=1'-0"

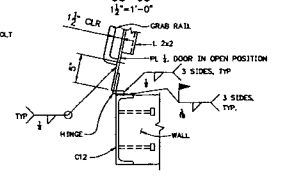


F5-F5
1"=1'-0"





G5-G5
3"=1'-0"



DET K5
1 1/2"=1'-0"

NOTES FOR CONCRETE:
1. FOR LIST SEE 23W230-1.

NOTES FOR STEEL:
1. ALL MATERIAL AND FABRICATION BY FIELD.
2. ALL ROLLED SHAPES AND PLATES SHALL CONFORM TO ASTM A36.
3. ALL MATERIAL TO BE FABRICATED AND ERECTED IN ACCORDANCE WITH THE AISC CODE, LATEST EDITION.
4. ALL BOLTS SHALL CONFORM TO ASTM A307.
5. HANDRAIL SHALL BE STD PIPE CONFORMING TO ASTM A120 OR A53.
6. SHORT RADIUS WELDING ELLS, OR PARTS THEREOF, SHALL BE USED FOR ALL HANDRAIL BENDS.
7. HANDRAIL IS SHOWN THUS-o-ON PLAN.
8. CONC BOLT ANCRS SHALL BE FURNISHED AND INSTALLED IN ACCORDANCE WITH TVA CONST SPEC C-32 AND SHALL CONFORM TO TYPE SSD.
9. HEADED CONC ANCRS SHALL CONFORM TO ASTM A108.
10. ALL WELDING AND INSPECTION TO BE IN ACCORDANCE WITH TVA CONST SPEC G29C.

WELDING ELECTRODES: CS TO CS — AWS A5.1 E70; CS TO SST — AWS A5.4 E308

REV	DATE	DESIGN	DRAWN	CHKD	TECH	ENGR	APPR	CODE	PROJECT NO	AS CHKD	
R	3 AUG 0 8 2007	---	---	---	TGT	CSG			FRT	JAC	
ELECTRONICALLY RESTORED											

SCALE: 1/4"=1'-0" EXCEPT AS NOTED

SOUTH EMBANKMENT

CONCRETE
INCREASING HEIGHT OF DAM
PLAN, SECTIONS AND DETAILS

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
C L HICKEY	R J SMITH	BILL PARKS	A ESTEP	R D MYERS	EL SPEARMAN	CL BUCHANAN

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD 2006 | DATE 2-5-88 | 10 | C | 23W230-5 | R 3

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(23W230-5 R2)

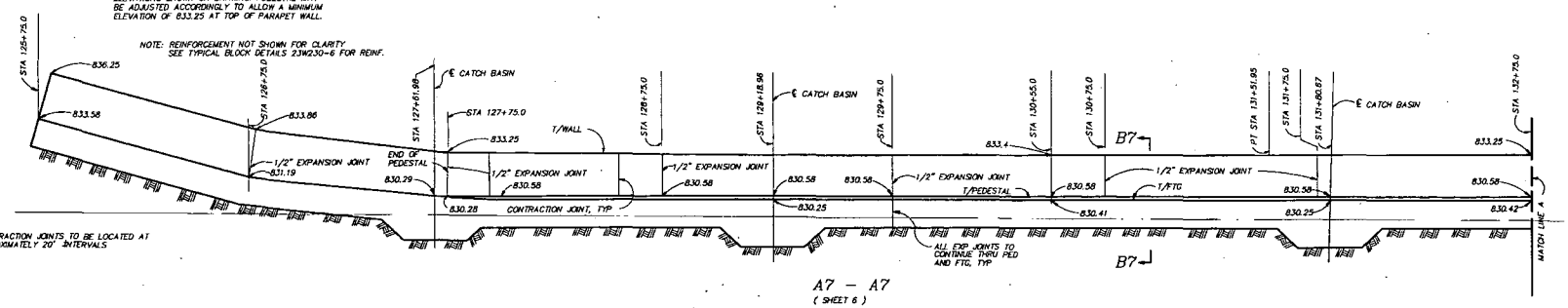
TASK COMPLETED BY: | REV NO.

PLOT FACTOR:24
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

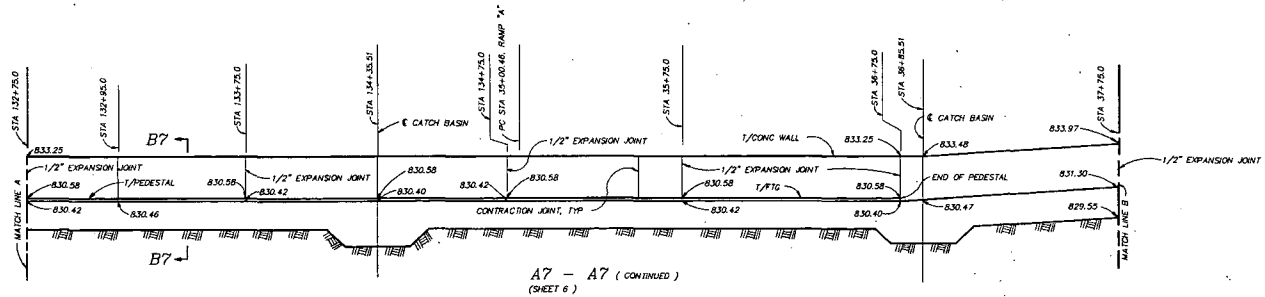
NOTE: FIELD SHALL SURVEY TOP OF FOOTING TO VERIFY ELEVATIONS SHOWN ON DRAWING. PEDESTAL MAY BE ADJUSTED ACCORDINGLY TO ALLOW A MINIMUM ELEVATION OF 833.25 AT TOP OF PARAPET WALL.

NOTE: REINFORCEMENT NOT SHOWN FOR CLARITY SEE TYPICAL BLOCK DETAILS 23W230-6 FOR REINF.



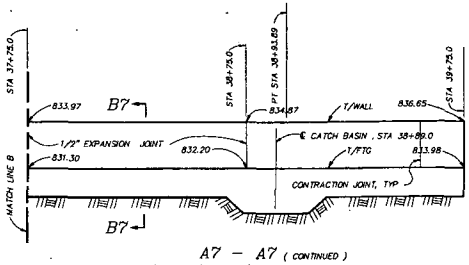
NOTE: CONTRACTION JOINTS TO BE LOCATED AT APPROXIMATELY 20' INTERVALS

A7 – A7
(SHEET 6)

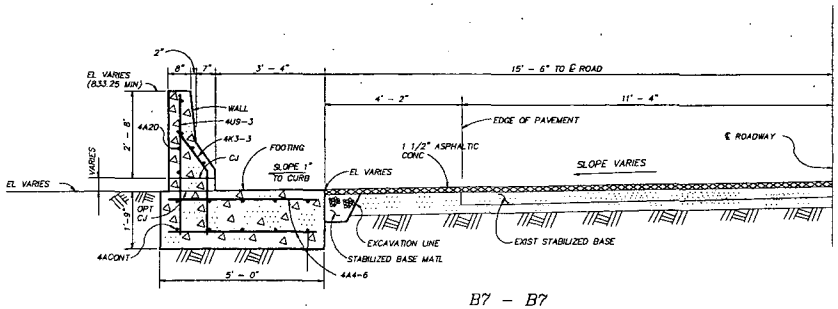


A7 – A7 (CONTINUED)
(SHEET 6)

NOTES
1. FOR LIST SEE 23W230 – 1.



A7 – A7 (CONTINUED)
(SHEET 6)



B7 – B7
3/4" = 1' – 0"

RO ISSUE FOR W. O. H08F22-285

REV	CHANGE REF	DATE	DRWN	DSGN	CHKD	RVWD	APPD	ISSD
1		8-28-96	GWH	GWH	JRH	WRB	KDH	JHG

SIGNED DRAWING AS CONSTRUCTED. DC-JHC 7-30-90 (C04 900730 001)

SCALE: NTS — EXCEPT AS NOTED

SOUTH EMBANKMENT

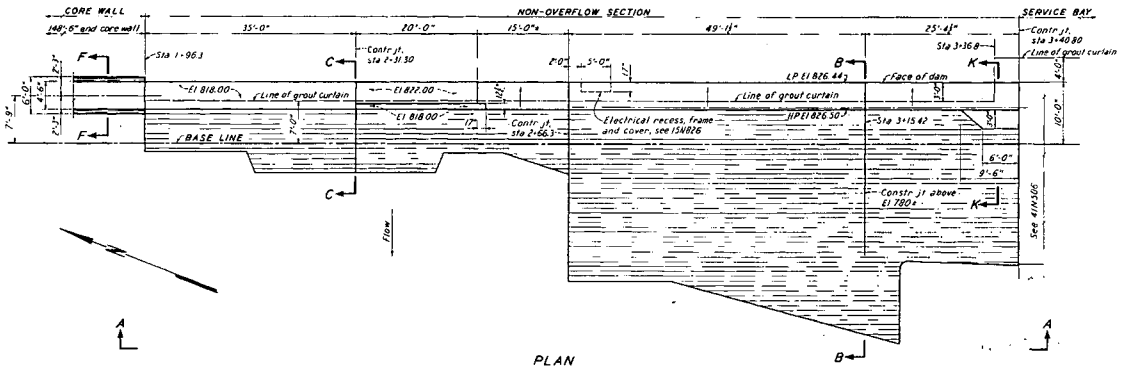
CONCRETE
INCREASING HEIGHT OF DAM
ELEVATIONS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY — N

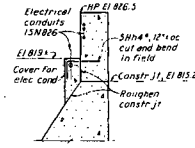
DESIGN		DISCIPLINE INTERFACE		ENGINEERING APPROVAL
DRAWN: R. J. SMITH	DESIGNED: GREGORY L. HOBSEY	1: C. R. WISE	2:	RUSSEL D. MYERS
CHECKED: BILL PARKS	REVIEWED: ARNOLD CLYDE	3: W. H. DAWWOOD	4:	EARL L. SPEARMAN
ENGINEERING	DATE: 8-30-96	10	C	23W230 – 7 R1

MADE BY: G. L. BUCHANAN

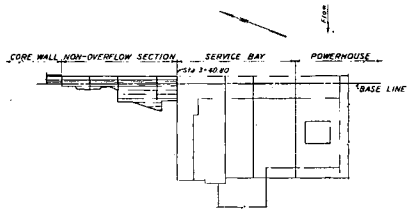
CAD SYSTEM ORIGINAL
DO NOT CHANGE MANUALLY



PLAN

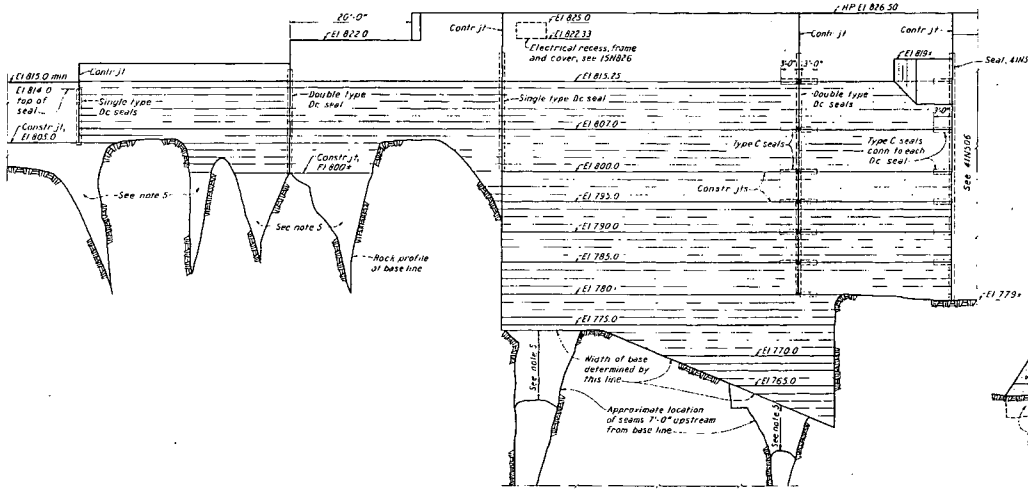


SECTION K-K

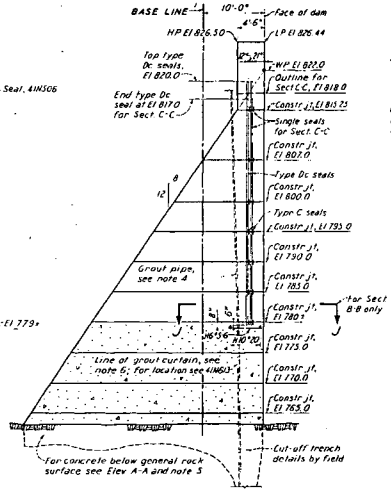


KEY PLAN

Scale 1"=60'

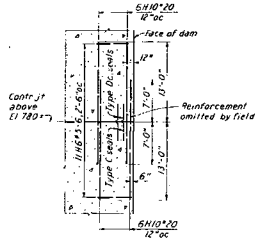


ELEVATION A-A



SECTIONAL ELEVATION B-B & C-C

SECTIONAL ELEVATION C-C AS NOTED



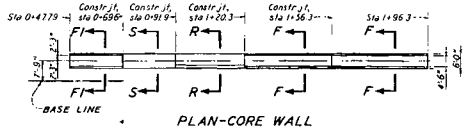
SECTION J-J

NOTES:

1. For general notes see 41N500.
2. All bar marks on this sheet to have prefix letter A.
3. Bend letter h given in bar marks.
4. For foundation grouting instructions see notes 4 and 5 on 41N613.
5. Local seams and depressions under the non-overflow section shall be filled with concrete below the original rock surface to a depth determined in the field.
6. A concrete cutoff wall or grout curtain shall be provided under upstream portion of section.
7. For final rock excavation lines, see field office dwgs 223-H-400, 223-H-401 and FL-H-212.

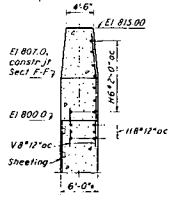
REFERENCE DRAWINGS:

41BM508__BILL OF MATERIAL
41RS508__REINFORCEMENT BAR DETAILS



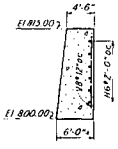
PLAN-CORE WALL

Scale 1"=20'

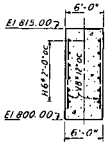


SECTION F-F & F1-F1

AS SHOWN AND NOTED



SECTION R-R



SECTION S-S

THIS DRAWING SUPERSEDES 41N508 DATED 4-3-42

Scale 1/8"=1'-0" Except as noted

POWERHOUSE
SERVICE BAY

CONCRETE NON-OVERFLOW SECTION & CORE WALL OUTLINE & REINFORCEMENT

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE	5-19-42	10	C	4	41N508 R4

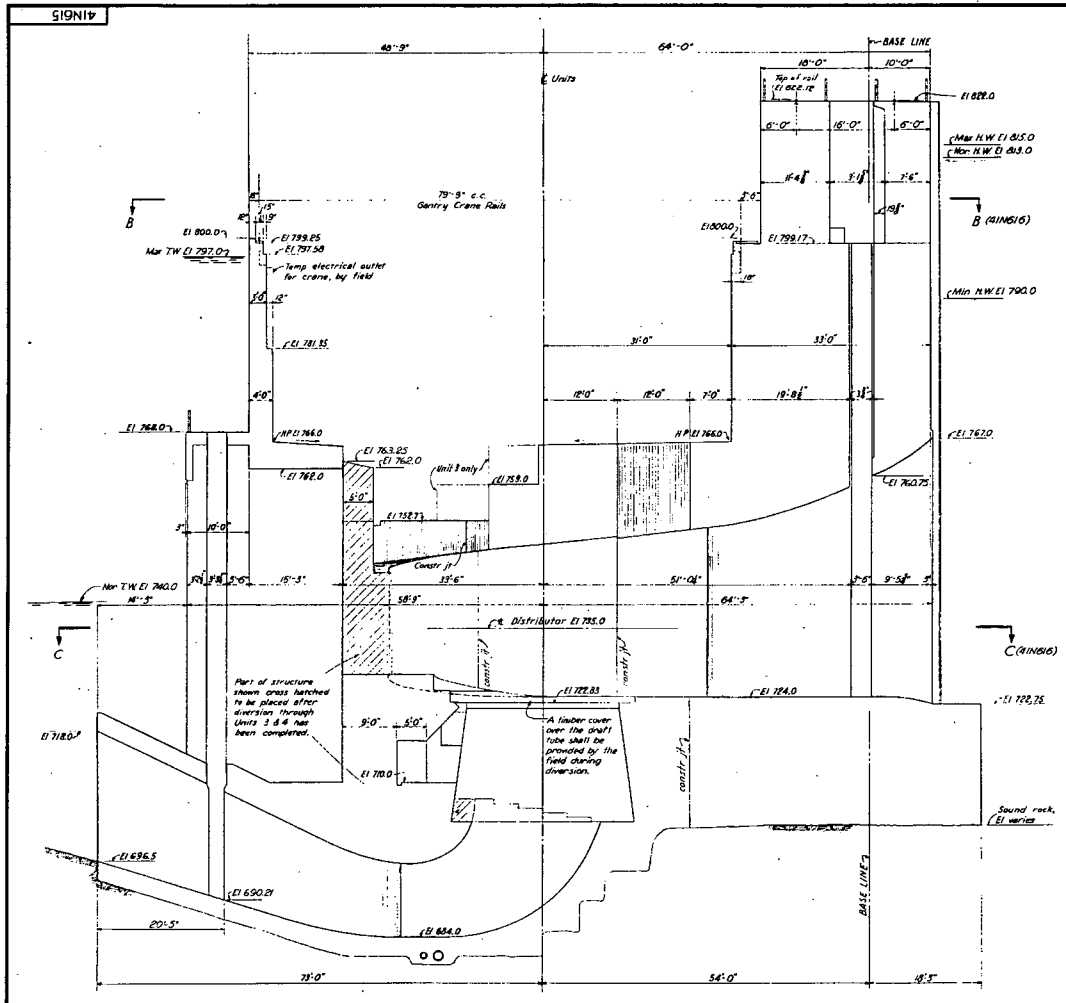
RECORD DRAWING AS CONSTRUCTED 10-11-44

REV. NO.	DATE	MADE	CHKD	DSPT	APP	TRACED
4	10-11-44	JAM				
3	12-4-42	JAM	SK			
2	11-20-42	JAM	SK			
1	10-20-42	JAM	SK			

Added 10' gravity section and minor revisions
Top of non-overflow section shown
DSGN OBT 3-9-42 DSP WWW 5-12-42
CHKD FPL 3-12-42 APP FAA JAM
TRC RGC 9-27-42 ENGINEER R. W. Ruff
CDP Do Rep
T M KCR SK MJK HBT

① JAM RAA ② JAM RAA SK ESM HBT ③ JAM ④ ⑤ ⑥

41N615



TRANSVERSE SECTION ON ℄ UNIT

NOTES:
For final rock excavation lines, see field office drwgs 213-H-430 to 213-H-447 incl.

Scale ⅛"=1'-0"

POWER HOUSE
UNITS 3 & 4

GENERAL LAYOUT
TRANSVERSE SECTION
INITIAL CONSTRUCTION

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
T. Mundal	George Reid	T. B. Parker
KNOXVILLE	10-5-48	

10 C 4 41N615 R1

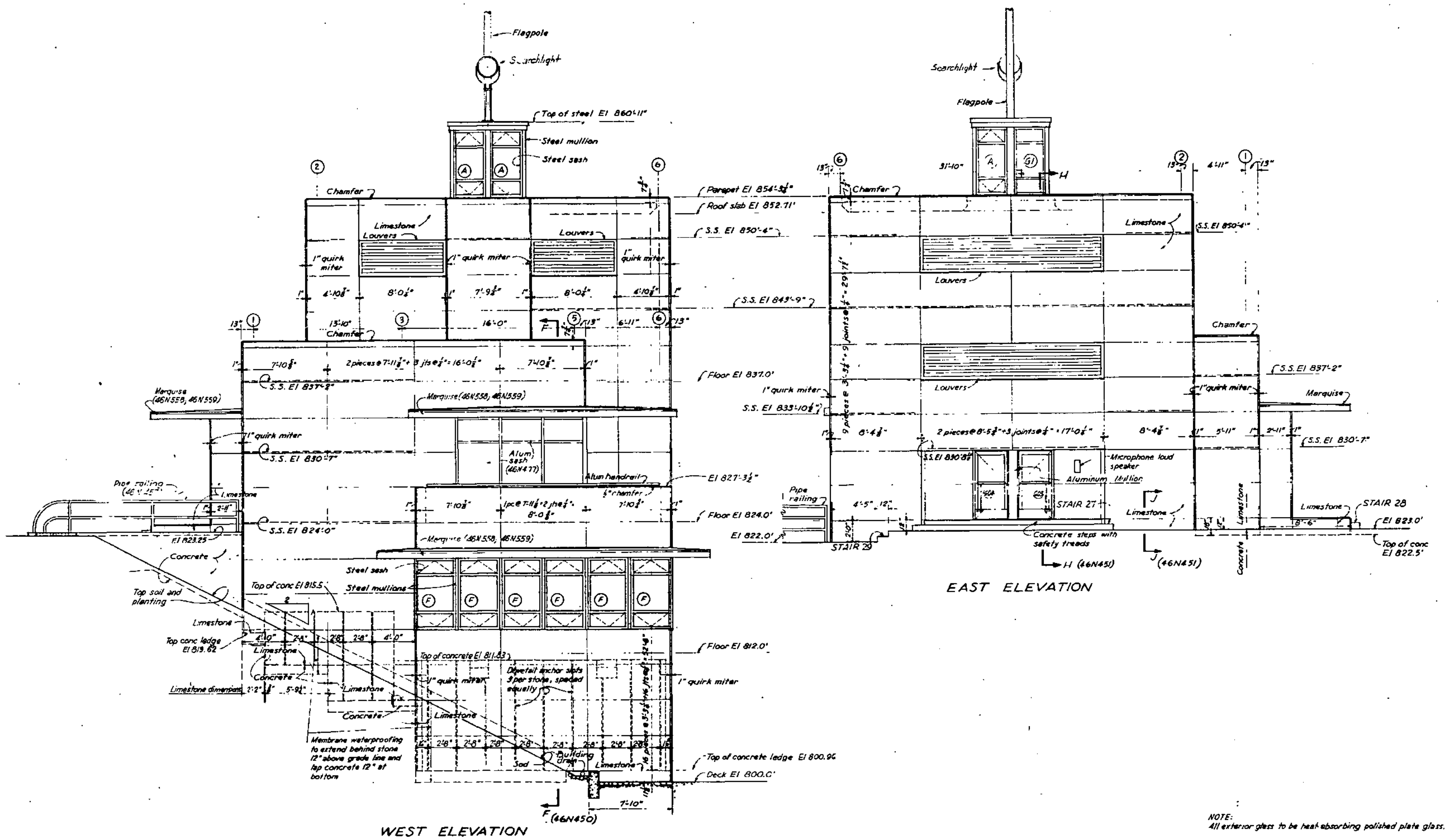
AS BUILT DRAWING AS CONSTRUCTED
R. H. Reid 12-18-44

APPROVED: _____
PROJECT MANAGER

Final Field Inspection						
NO.	DATE	NAME	CHKD	SUPV	INSP	DWN	RECM
DGN							
DWN							
CHKD							
TRCD							
COMP							

① JRB	②	③	④	⑤	⑥

46N402 R-1



NOTE:
All exterior glass to be heat absorbing polished plate glass.

Scale ⅛" = 1'-0"

REGIONAL STUDIES DEPT R. A. Wank BY M.B.

COMPANION DRAWINGS 46N400, 46N401

POWERHOUSE

ARCHITECTURAL
EAST & WEST ELEVATIONS

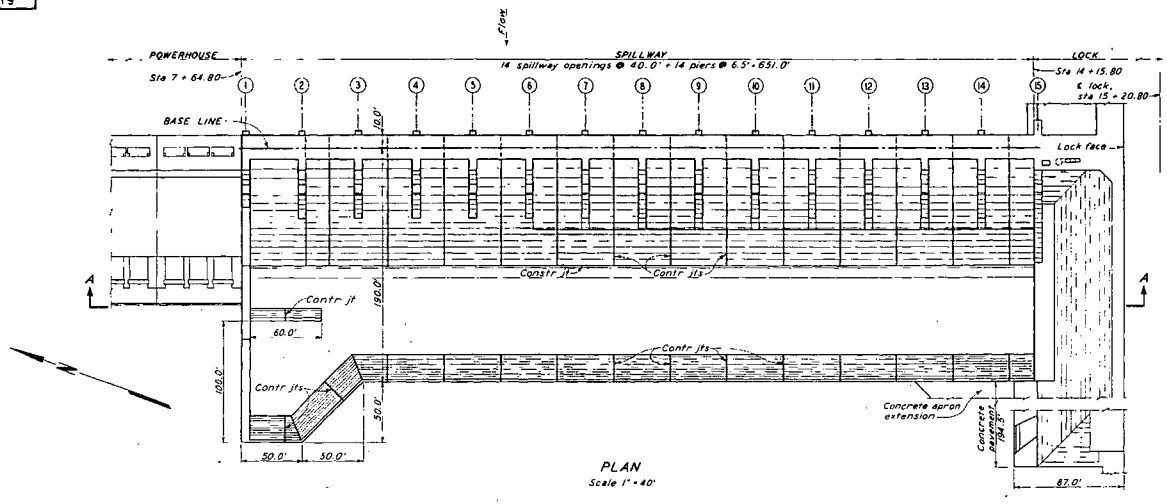
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	[signature]

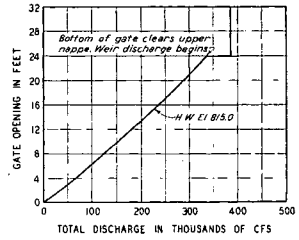
KNOXVILLE	3-28-42	10	A	4	46N402 R6

RECORD DRAWING AS CONSTRUCTED - UNITS 3 & 4 10-13-49
RECORD DRAWING AS CONSTRUCTED 3-8-44

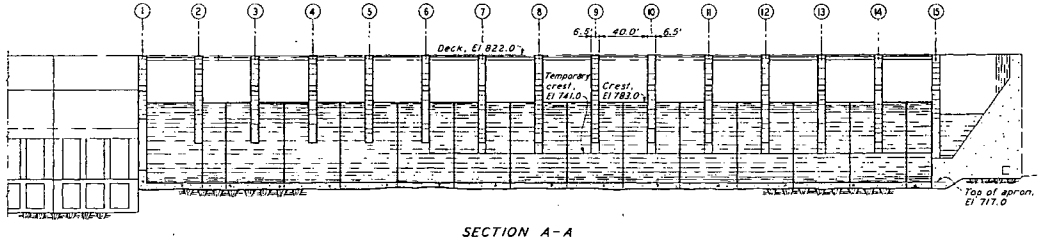
5IN200



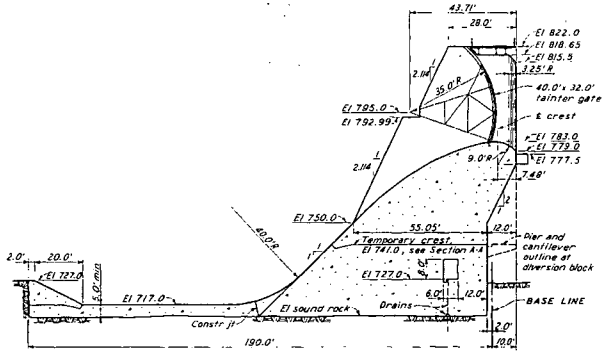
PLAN
Scale 1" = 40'



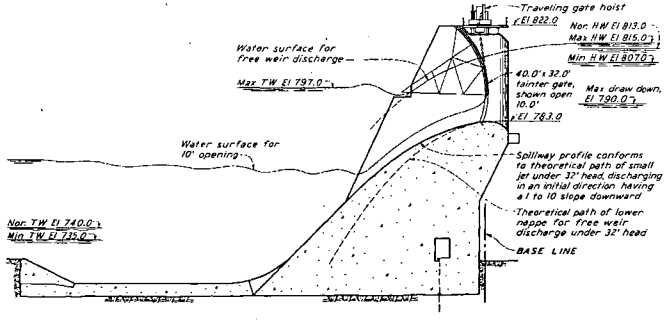
SPILLWAY GATE RATING CURVE
14 - 32' x 40' tainter gates



SECTION A-A
Scale 1" = 40'



TYPICAL SPILLWAY SECTION
SHOWING STRUCTURAL FEATURES



TYPICAL SPILLWAY SECTION
SHOWING HYDRAULIC FEATURES

NOTE:
For final rock excavation lines see field office drawings 221H400 to 477 inclusive

Scale 1" = 20'
Except as noted

SPILLWAY DAM

PLAN
ELEVATION & SECTIONS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE	8-20-41	10	C	4	5IN200R2

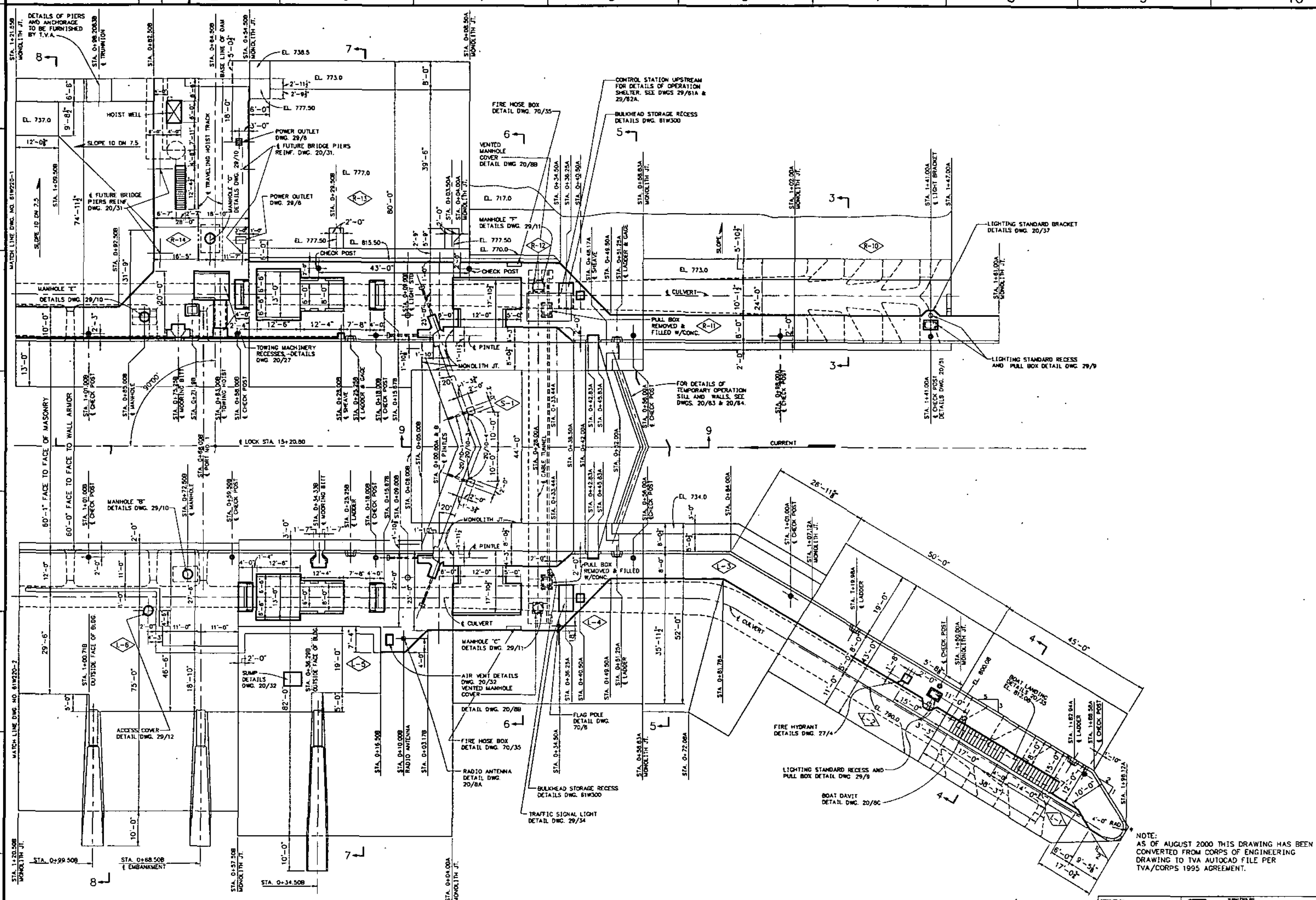
RECORD DRAWING AS CONSTRUCTED
7-27-46

Final Field revisions

NO	DATE	NAME	CHKD	SUPV	INSP	SUBM	RECM
DSGN				SUPV			
DRWN				INSP			
CHKD							
TRCD							
CONC							

F.W. Meyer

F.N. F.W.D. P.L.C.



GENERAL NOTES:

1. TOP OF LOCK WALLS TO RISE ⅛" PER FOOT FROM LOCK FACE.
2. ALL FINAL ROCK EXCAVATION FACES TO BE LINED DRILLED, OR EQUAL, THE FULL DEPTH OF ABUTTING VERTICAL CONCRETE FACES.
3. CONCRETE DEPTH UNDER CULVERTS IN BOTH LAND AND RIVER WALLS TO BE NOT LESS THAN 5'-0". CONCRETE DEPTH UNDER CULVERTS IN LOWER GUIDE AND GUARD WALLS AND LOWER END DISCHARGE CULVERTS TO BE NOT LESS THAN THAT SHOWN ON PLANS.
4. TYPICAL SECTIONS SHOWN ON DRAWING 20/9.

REFERENCE DRAWINGS:

B.M. 20/10—BILL OF MATERIAL—MITER SILL DRAINS.

NOTE:
AS OF AUGUST 2000 THIS DRAWING HAS BEEN CONVERTED FROM CORPS OF ENGINEERING DRAWING TO TVA AUTOCAD FILE PER TVA/CORPS 1995 AGREEMENT.

REV NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST
0	3/11/04									

ELECTRONICALLY RESTORED DRAWING

LOCK

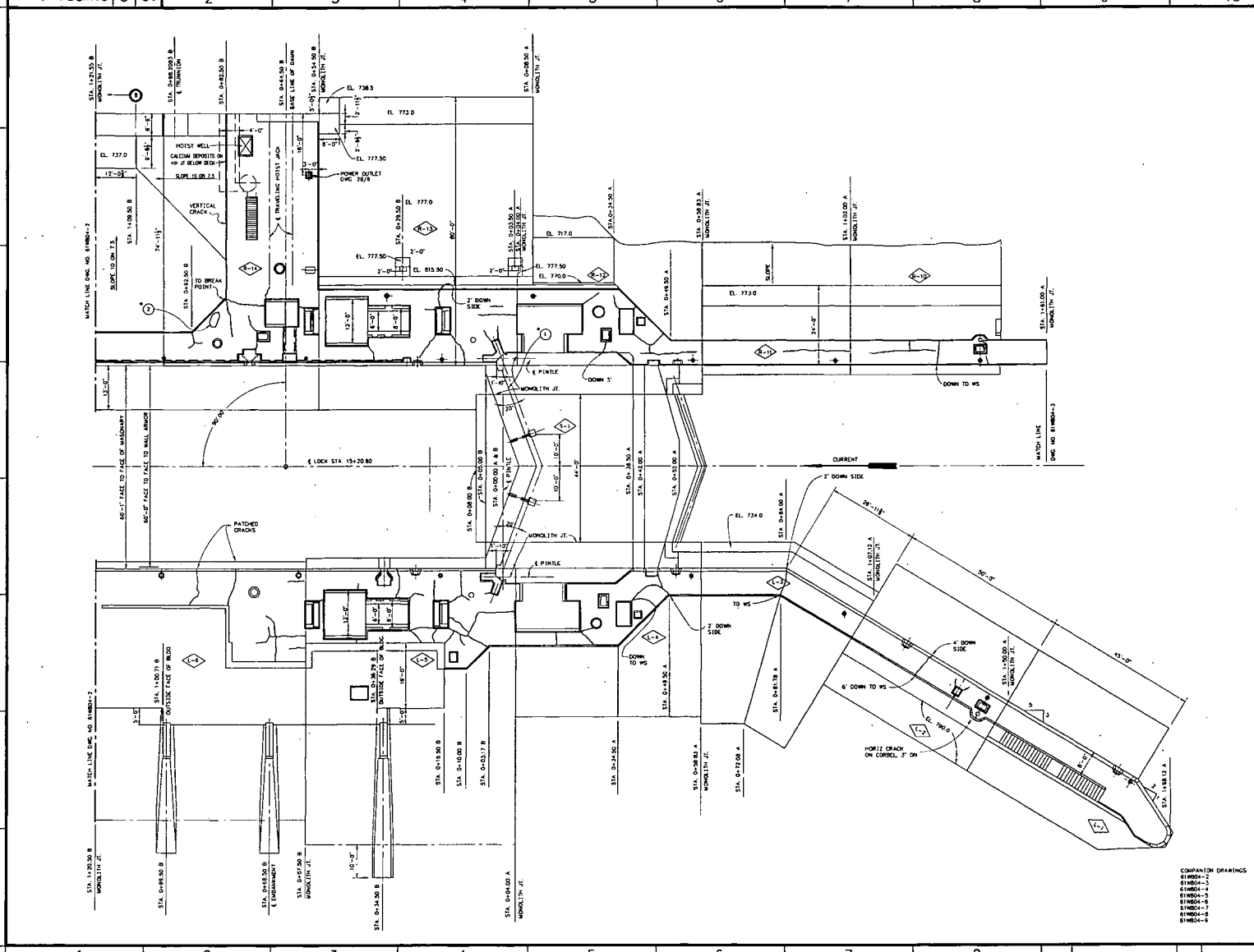
LOCK WALLS
PLAN—UPPER END

FORT LOUDOUN HYDRO PLANT
TENNESSEE VALLEY AUTHORITY
RIVER SYSTEMS OPERATIONS

DRAWN BY: M.R.
CHECKED BY: C.P.D.
US Army Corps of Engineers, Nashville District
REVISION R 4
APPROVED BY: THOMAS W. WATERS, CHIEF, ENGINEERING DIVISION
20/1.4

SCALE: 3/32"=1'-0" | SHEET 1 OF 70 SHEETS
AUTOCAD R 00 | 3/11/04 | 10 | C | 61W220-1 | R 0

TASK COMPLETED BY: | REV NO.
ELECTRONICALLY RESTORED DRAWING THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES: 20/1.5
PLOT FACTOR: 128
NTVAOP
C.A.D. DRAWING DO NOT ALTER MANUALLY



OBSERVATIONS:

1. AREA OF PATTERN CRACKS.(SRK,7-20-99)
2. 2 DIAGONAL CRACKS ON US EDGE OF UPPER GATE SEAL. SEAL PATCHED W/ COAL TAR DURING PAST INSPECTION. LOCATED 10' FROM PINTLE.(SRK,7-20-99)

NOTES:

1. DRAWING IS MARKED TO RECORD RESULTS OF THE INSPECTION DATED JULY 20, 1999
2. AN ASTERISK * INDICATES NEW OR MORE SEVERE DAMAGE WHEN COMPARED TO PREVIOUS INSPECTIONS
3. UNLESS OTHERWISE NOTED, ALL CRACKS SHOWN ARE FINE. CRACKS ARE INDICATED BY AAAAAAAA.

COMPANION DRAWINGS
61W804-2
61W804-3
61W804-4
61W804-5
61W804-6
61W804-7
61W804-8
61W804-9

REV.	DATE	DRAWN	DESIGN	PRINCIPAL	SUPV.	PLANNER	APPROVED	PLANNER	PROJECT ENGR.	VICE PRESIDENT
R 1				SRK	SRK	CDH	CDH	CDH		
REVISITS OF 7-20-99 INSPECTION										
R 0		JAB	SRK	SRK	DLV	JEV	JEV	JHC		
INITIAL ISSUE										

SCALE: 3/32"=1'-0" EXCEPT AS NOTED

LOCK

INSPECTION RECORD
PLAN, DECKS - UPPER END
SHEET 1

DRAWN BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
JM BROWN	SM MILLER	SR KRAMER	TH MCINTYRE	JE VARNER	JE VARNER	JH COLSON

FORT LOUDOUN HYDRO PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

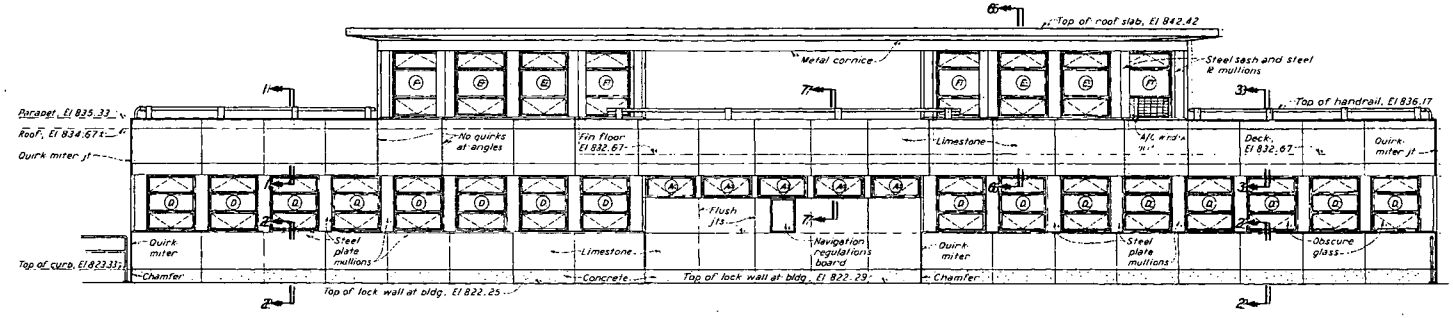
AUTOCAD R14 | SHEET 10 | C | 61W804-1 | R 1

PLOT FACTOR:128

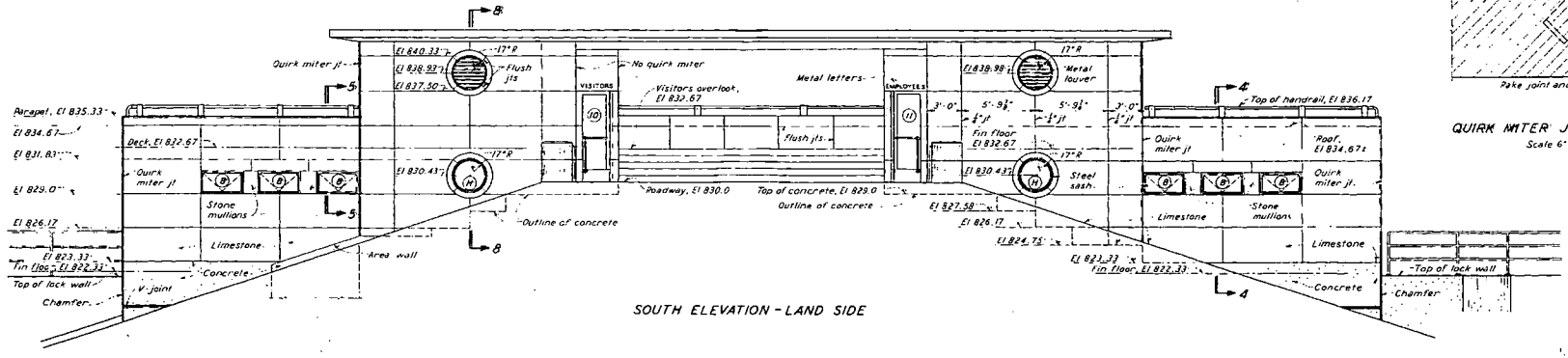
C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: | REV. NO.

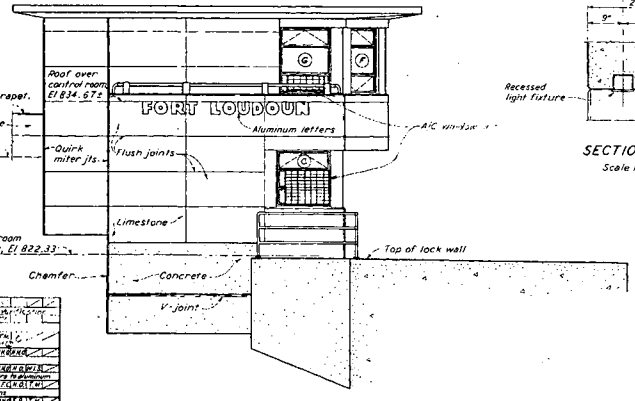
61W804-1 | 10 | C



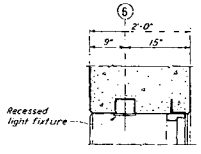
NORTH ELEVATION – LOCK SIDE



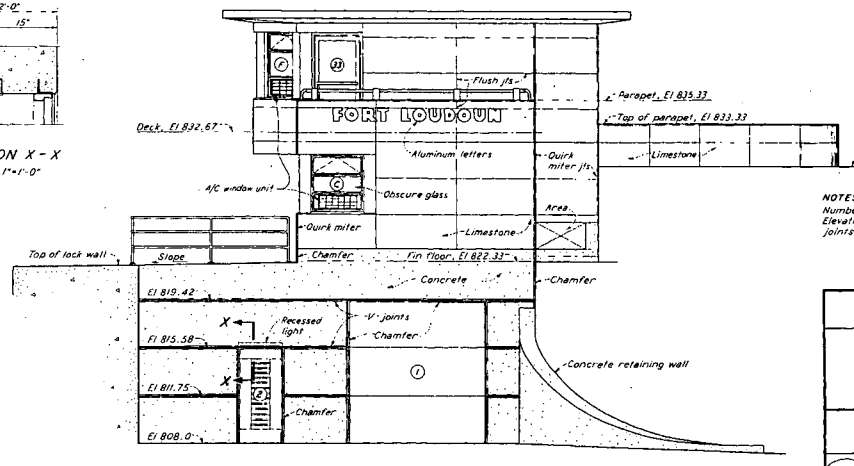
SOUTH ELEVATION – LAND SIDE



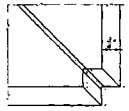
EAST ELEVATION – UPSTREAM



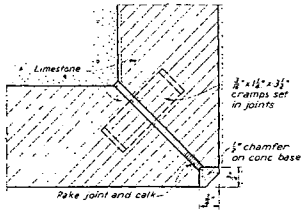
SECTION X – X
Scale 1"=1'-0"



WEST ELEVATION – DOWNSTREAM



PLAN OF QUIRK MITER & COPING BEVEL INTERSECTION
Scale 6"=1'-0"



QUIRK MITER JOINT DETAIL
Scale 6"=1'-0"

DETAIL OF V-JOINT
IN CONCRETE
Scale full size

NOTES:
Numbered sections are on 66N214
Elevations shown on horizontal joints are to bottom of joints.

Scale ¼"=1'-0"
Except as noted

REV NO	DATE	MODE	CHKD	SUPV	PROP	DESIGN	RECOM
7	10-21-41	SUPPLEMENTAL					
6	10-21-41	Revised per Field Memo					
5	6-10-41	Revised					
4	5-15-41	Revised					
3	1-28-41	Revised per Field Memo					
2	12-17-40	Revised per Field Memo					
1	12-4-40	Revised per Field Memo					
0	9-24-40	Issued for Bids					
Traced							
2	2-8-40	Changed wood letters to aluminum					
1	11-1-40	Changed letters & Corrected					
Final field revisions							
1	10-17-40	Revised					
General revision							

DSGN L.V.S. SUPV F.E.
DRWN L.V.S. INSP A.A.M., H.J.R., E.W.T., S.E., T.W.
CHKD F.R.D.
TRCD M.E.W. 8-14-40 ENGINEER Harry B. Tour
CONT.

LOCK OPERATION BUILDING

ARCHITECTURAL ELEVATIONS

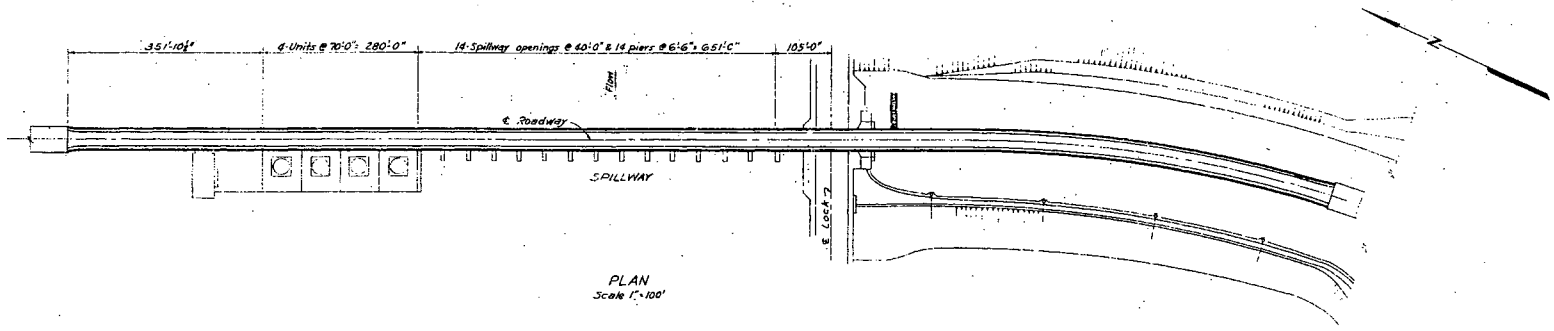
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

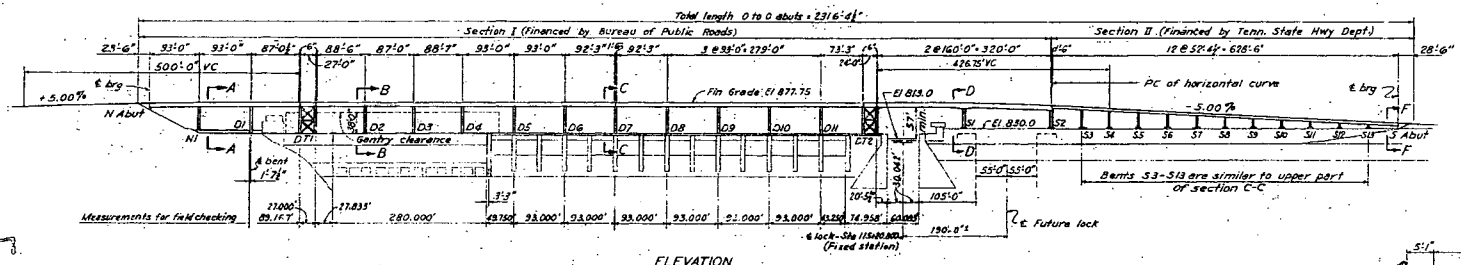
SUBMITTED	RECOMMENDED	APPROVED
A.B. Allison	Harry B. Tour	George Reich

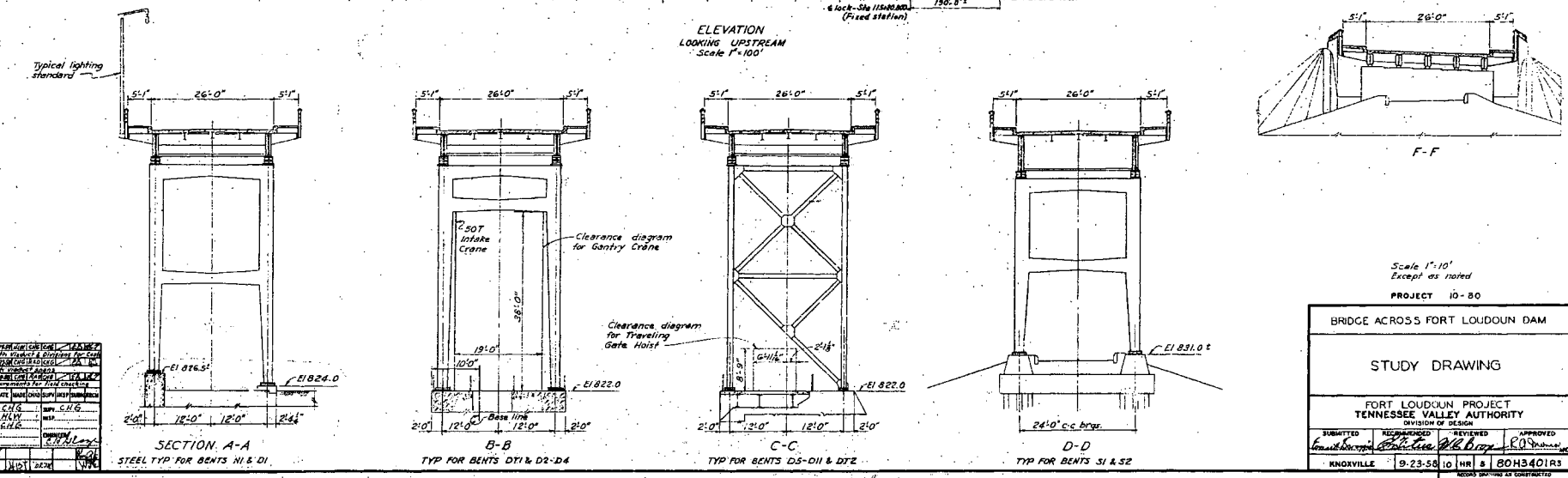
KNOXVILLE	9-24-41	10	A	4	66N201R7

RECORD DRAWING AS CONSTRUCTED 3-4-46

02-L602.3 70/1.1 7/1/55







Scale 1" = 10'
Except as noted

PROJECT 10-80

BRIDGE ACROSS FORT LOUDOUN DAM

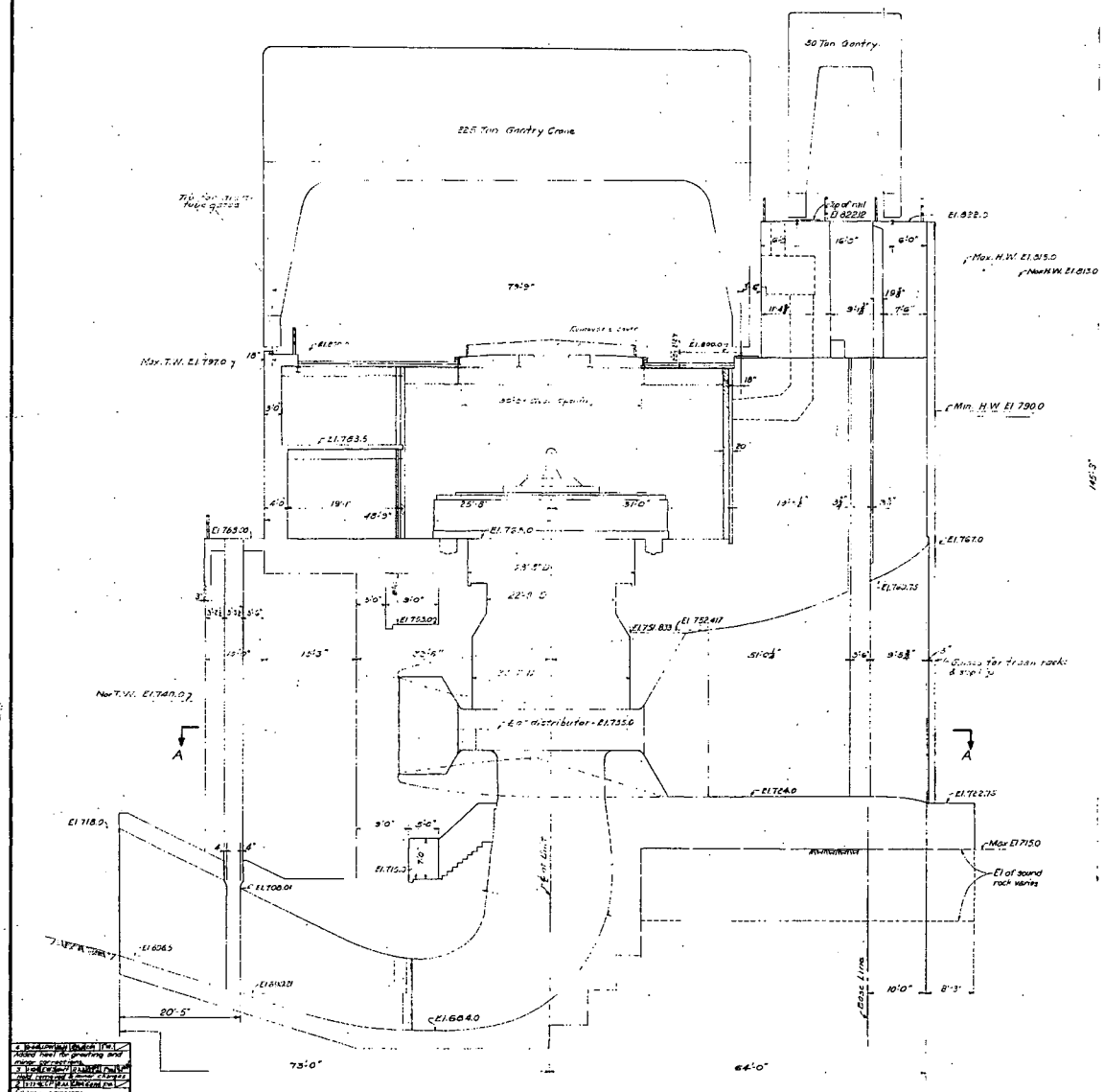
STUDY DRAWING

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

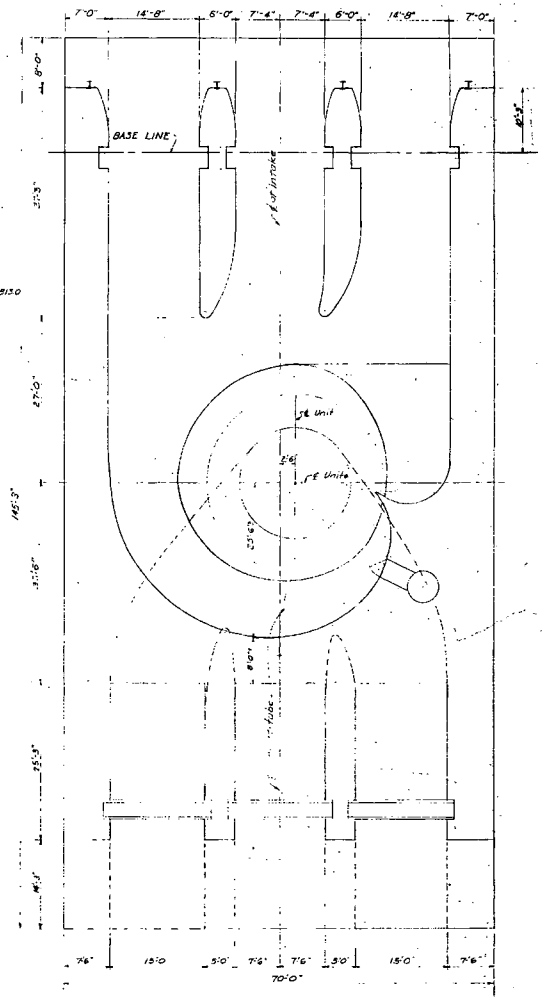
SUBMITTED	RECOMMENDED	REVIEWED	APPROVED
KNOXVILLE	9-23-58	10 HR S	80H3401R3

RECORD DRAWING AS CONSTRUCTED

41N600



TYPICAL SECTION



SECTIONAL PLAN A-A

NOTES:
For final rock excavation lines, see field office dwgs 213-H-400 to 213-H-447.

Scale: 3/8"=1'-0"

Sheet 1 of 6

POWER HOUSE

GENERAL LAYOUT
TYPICAL SECTION

~~FORT LOUDOUN~~ PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

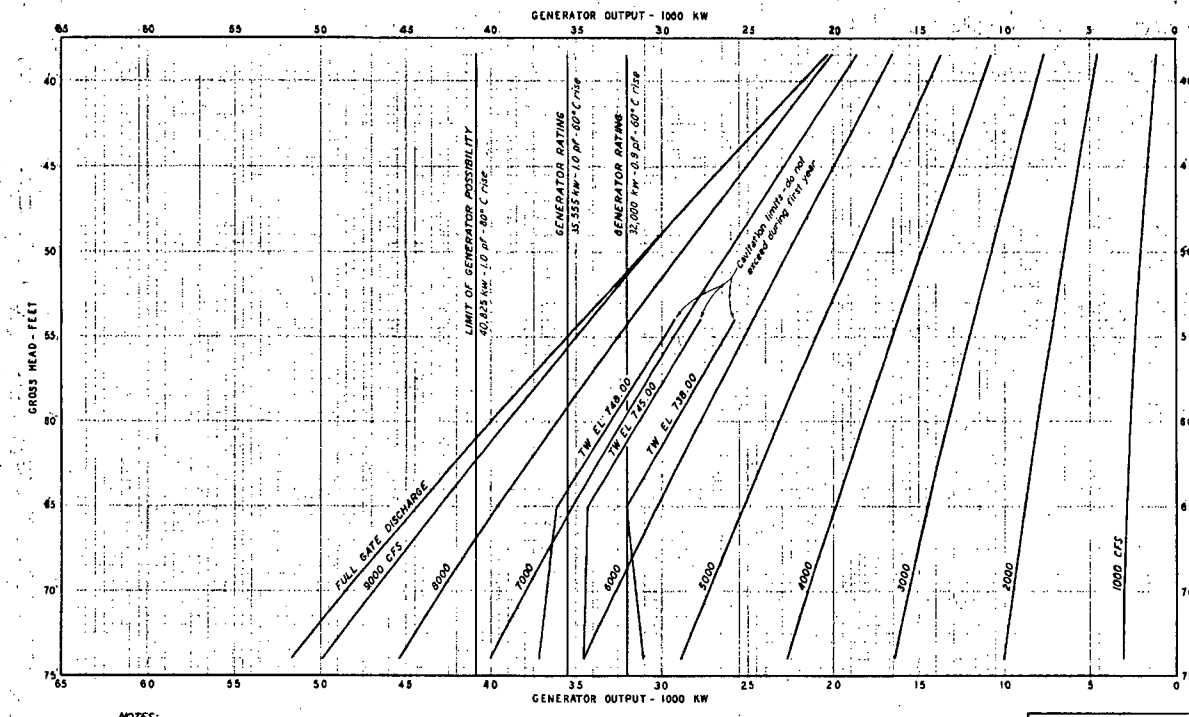
SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE | 5-2-41 | 10 | C | 4 | 41N600R5

RECORD DRAWING AS CONSTRUCTED

APPROVED: PROJECT MANAGER

EXHIBIT 3



NOTES:
Turbine rated 44,000 hp - 65 ft head - 105.8 rpm.
Furnished by Baldwin Southwark.
Generator rated 35,555 kva - 13,800 volts - 3 phase - 60 cycles - 105.8 rpm - 60° C rise.
Furnished by Allis - Chalmers Mfg Co.
Curves are based on model tests conducted by Baldwin Southwark and modified in accordance with index test conducted 3-1,2-44.
Tests should be made at other heads and these curves revised accordingly.

POWERHOUSE
UNIT 1

DISCHARGE CURVES
BASED ON INDEX TESTS

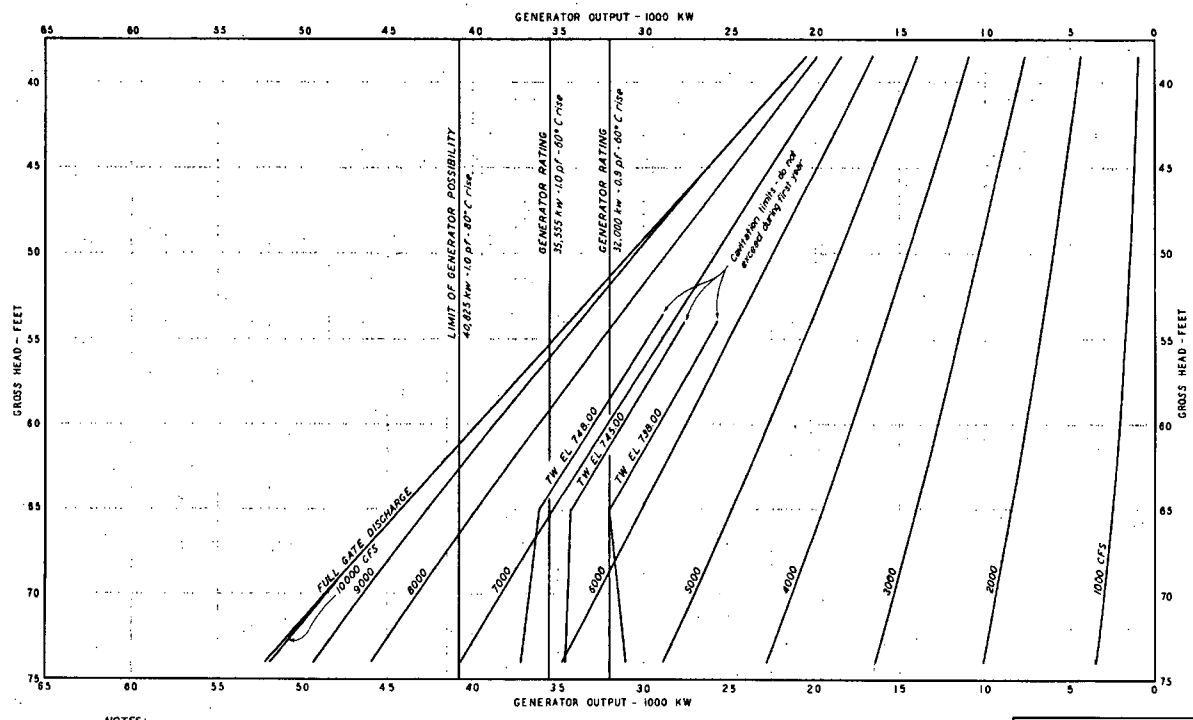
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE	4-10-44	10	M	4	47890180

MF
RD

EXHIBIT 7



NOTES:

Turbine rated 44,000 hp - 65 ft head - 105.8 rpm. Furnished by Baldwin-Southwerk. Generator rated 35,555 kw - 13,800 volts - 3 phase - 60 cycles - 105.8 rpm - 80°C rise. Furnished by Allis-Chalmers Mfg Co. Curves are based on model tests conducted by Baldwin-Southwerk and modified in accordance with index test conducted 2-29-44. Tests should be made at other heads and these curves revised accordingly.

DRN	J.R.C.	SURV	C.L.N.		
DSN	J.R.H.	MAP			
CHK	C.L.N.				
TRCE	R.E.M.				
CHR					

POWERHOUSE
UNIT 2

DISCHARGE CURVES
BASED ON INDEX TESTS

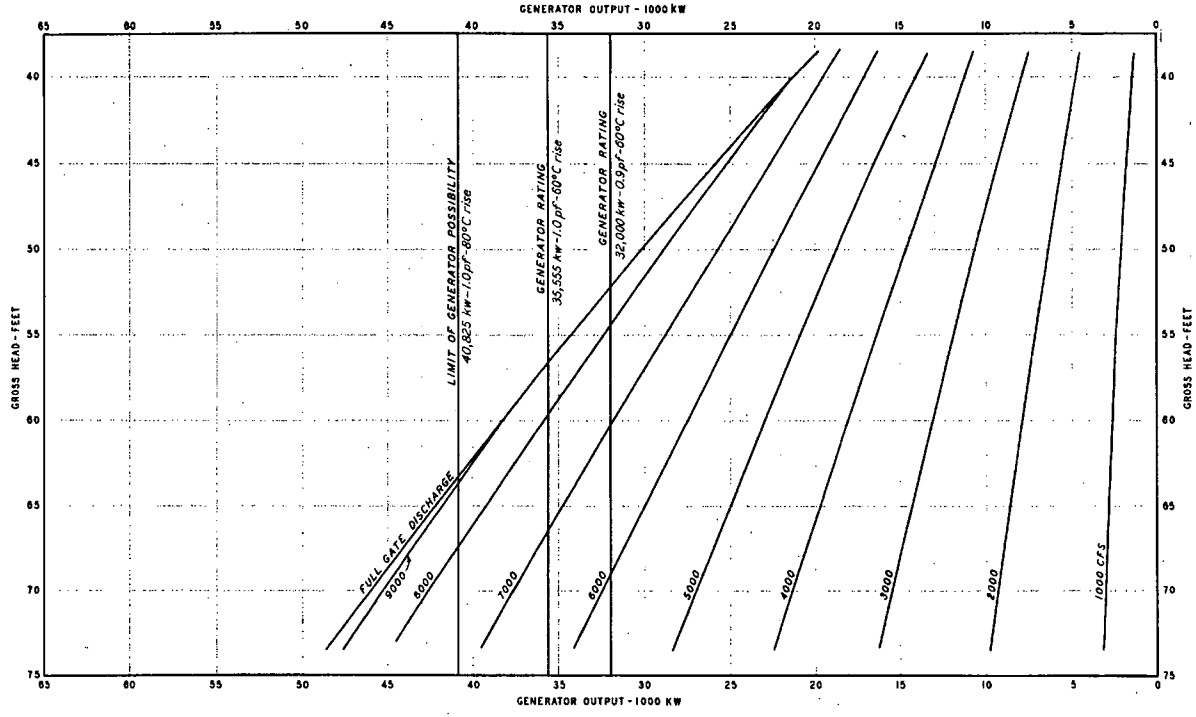
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
F. Munsel	[illegible]	[illegible]

KNOXVILLE	6-11-46	10	M	4	47890480

MF
RO

EXHIBIT 3



NOTES:
Turbine rated 44,000 hp-65 ft head-105.8 rpm. Furnished by Baldwin-Southwark.
Generator rated 35,555 kva-13,800 volts-3 phase 60 cycles-105.8 rpm-60°C rise. Furnished by Allis-Chalmers Mfg Co. Curves based on model tests conducted by Baldwin-Southwark and modified in accordance with index test conducted 2-15-49. Tests should be made at other heads and these curves revised accordingly

NO.	DATE	REVISION	CHK	APP	REVISION

NAME: EA
DATE: 2-17-49
CHKD.
TRCD.
COMP.

POWERHOUSE
UNIT 3

DISCHARGE CURVES
BASED ON INDEX TESTS

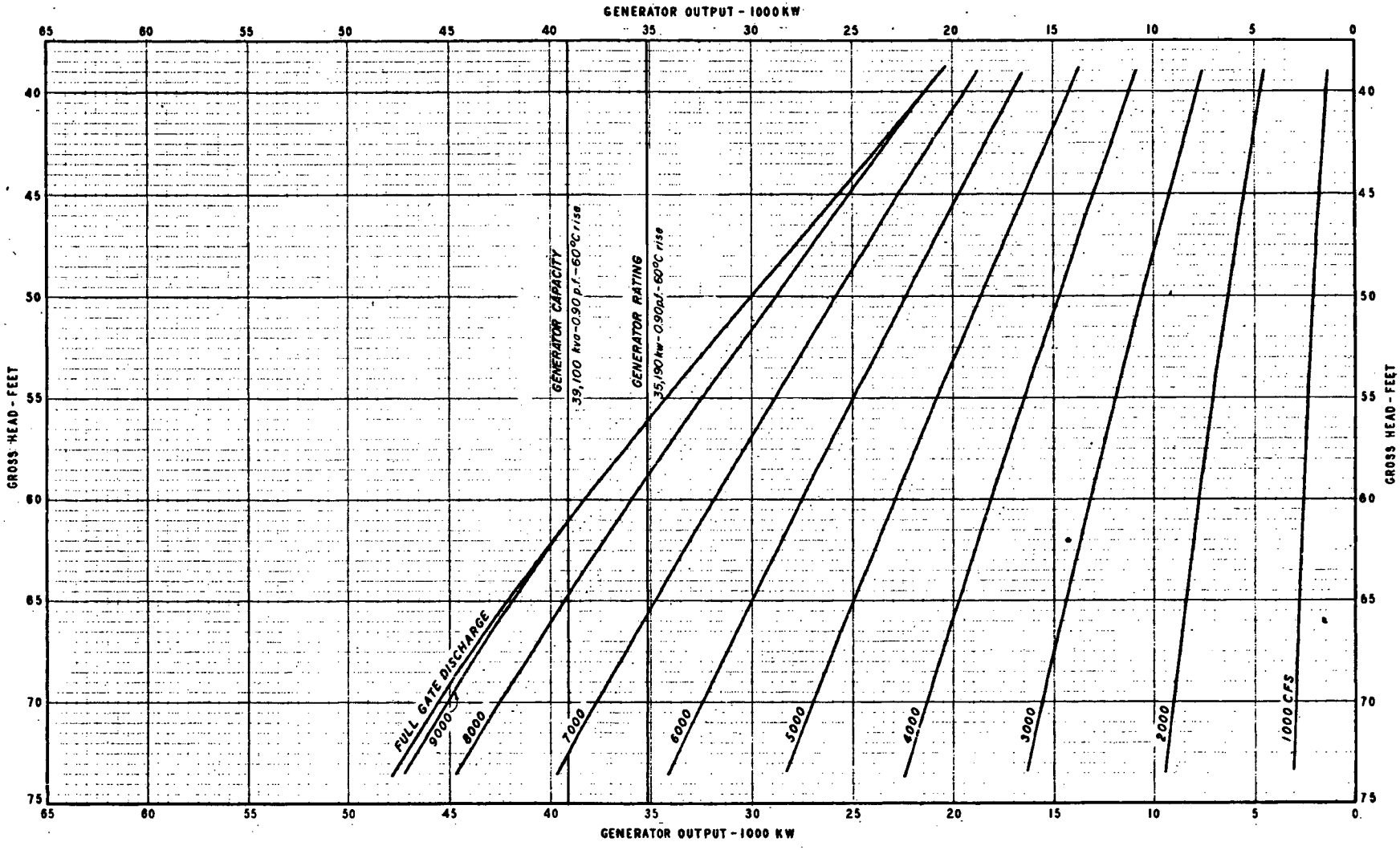
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED: [signature]
RECOMMENDED:
APPROVED: [signature]

KNOXVILLE | 7-27-49 | 10 | M | 4 | 478906

MF
RO

EXHIBIT 7



NOTES:

Turbine rated 44,000 hp - 65 ft head - 105.8 rpm. Furnished by Baldwin - Southwark.
Generator rated 35,555 kva - 13,900 volts - 3 phase 60 cycle - 105.8 rpm - 60°C rise. Furnished by Allis-Chalmers Mfg. Co.
Curves based on model tests conducted by Baldwin-Southward and modified in accordance with index test conducted 2-17-49. Tests should be made at other heads and these curves revised accordingly.
GENERATOR: rerated October 4, 1968 to 39,100 kva, 35,190 kw, 0.90 p.f. 13,800 volts, 60°C rise, 1635 amperes

POWERHOUSE
UNIT 4

DISCHARGE CURVES BASED ON INDEX TESTS

FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

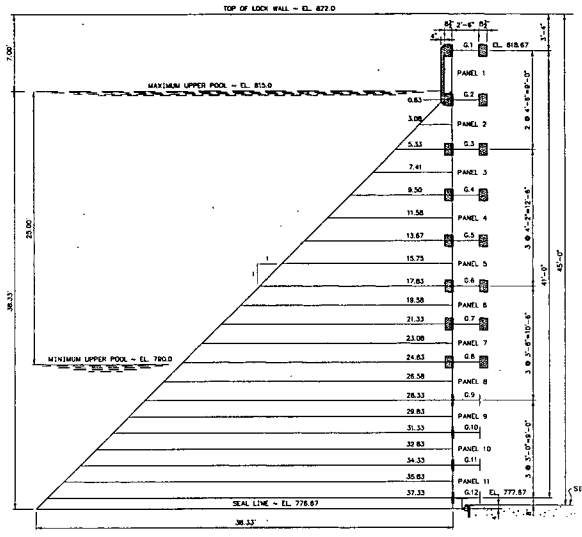
SUBMITTED C.F. Morris | RECOMMENDED W. Williams | APPROVED A.D. Moore

KNOXVILLE 7-29-49 | 10 | M | 4 | 478912R1

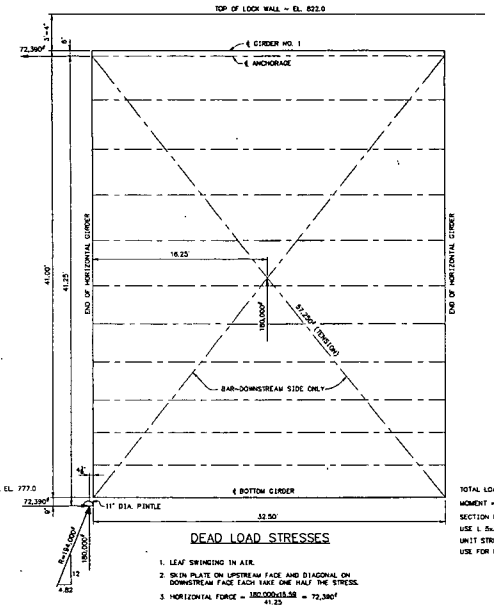
GEN. RATING CHART

NO.	DATE	MADE	CHECKED	SUPV.	DRFT.	SUBM.	APPR.

DRAWN J.E.A. SUPV. CHIEF
CALCD. TRCD. CHIEF

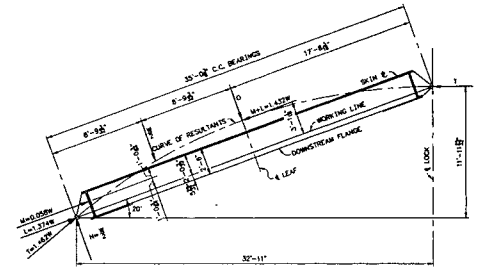


LOADING DIAGRAM

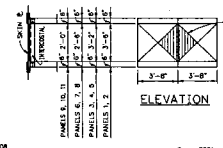


DEAD LOAD STRESSES

1. LEAF SWINGING IN AIR.
2. SKIN PLATE ON UPSTREAM FACE AND DIAGONAL ON DOWNSTREAM FACE EACH HAVE ONE HALF THE STRESS.
3. HORIZONTAL FORCE = $\frac{180,000 \times 15.58}{41.25}$ = 72,390#



FORCES ACTING ON GIRDER



ELEVATION

4'-2" PANEL-5

TOTAL LOAD = $15.73 \times 82.5 \times 3.18 \times \frac{3.67}{2}$ = 5708#

MOMENT = $\frac{5708}{2}$ (22-6.33) = 44,722'#

SECTION MODULUS REQUIRED = $\frac{44,722}{18000}$ = 2.48 IN.³

USE L 4x3½x½ ~ SECTION MODULUS = 3.00 IN.³

UNIT STRESS = $\frac{44,722}{3.00}$ = 14,907#/in²

USE FOR PANELS 3 TO 5 INCLUSIVE.

3'-6" PANEL-8

TOTAL LOAD = $28.58 \times 82.5 \times 2.5 \times \frac{3.67}{2}$ = 7621#

MOMENT = $\frac{7621}{2}$ (18-5) = 49,536'#

SECTION MODULUS REQUIRED = $\frac{49,536}{18000}$ = 2.75 IN.³

USE L 5x3½x½ ~ SECTION MODULUS = 3.00 IN.³

UNIT STRESS = $\frac{49,536}{3.00}$ = 16,512#/in²

USE FOR PANELS 6 TO 8 INCLUSIVE.

3'-0" PANEL-11

TOTAL LOAD = $35.83 \times 82.5 \times 2.0 \times \frac{3.67}{2}$ = 8218#

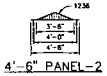
MOMENT = $\frac{8218}{2}$ (15-4) = 45,200'#

SECTION MODULUS REQUIRED = $\frac{45,200}{18000}$ = 2.51 IN.³

USE L 5x3½x½ ~ SECTION MODULUS = 3.00 IN.³

UNIT STRESS = $\frac{45,200}{3.00}$ = 15,068#/in²

USE FOR PANELS 9 TO 11 INCLUSIVE.



4'-6" PANEL-2

TOTAL LOAD = $3.08 \times 82.5 \times 3.5 \times \frac{3.67}{2}$ = 1236#

MOMENT = $\frac{1236}{2}$ (24-7) = 10,506'#

SECTION MODULUS REQUIRED = $\frac{10,506}{18000}$ = 0.583 IN.³

USE L 4x3½x½ ~ SECTION MODULUS = 1.50 IN.³

UNIT STRESS = $\frac{10,506}{1.50}$ = 7,004#/in²

USE FOR PANELS 1 AND 2

DESIGN DATA
ALLOWABLE STRESSES FOR EXTREME CONDITIONS

STRUCTURAL STEEL: TENSION AND BENDING	18,000#/in²
COMPRESSION	18,000-80 l/R (15,000 MAX. l/R <50)
BEARING	24,000#/in²
SHEAR	13,500#/in²
RIVETS: SHEAR	13,500#/in²
BEARING	24,000#/in²
PINTLE BUSHING	3,000#/in²
QUICKOM PIN BUSHING	8,000#/in²
PINS: SHEAR	PER AISC LRFD 2nd EDITION
BEARING	PER AISC LRFD 2nd EDITION
OTHER MATERIALS:	60% OF ELASTIC LIMIT
MAXIMUM BEARING ON CONCRETE:	800#/in²
MINIMUM THICKNESS OF MAIN MEMBERS:	¼"
RIVETS:	⅞"ø

HORIZONTAL GIRDER DESIGN

	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬
GIRDER NO.	CU. FT. OF WATER PER LIN. FT. OF GIRDER	W IN KIPS (1) x35.03 ÷ 62.3 ÷ 1000	I IN KIPS (2) x1.462	L IN KIPS (2) x1.374	N IN KIPS (2) x0.500	M IN KIPS (2) x0.058	M+L IN KIPS (2) x1.432	X ECCENT. IN INCHES	MOMENT (M+L)X IN INCH KIPS	GROSS AREA SQ. IN.	GROSS I INCHES*	FIBER STRESS AT ℄ LEAF LBS./SQ. IN +=TEN. −=COMP. UP-STREAM	DOWN-STREAM
1	0.200	0.44	0.64	0.61	0.22	0.029	0.63	USE 30WT16 ~ SAME AS GIRDER NO. 3					
2	5.607	12.27	17.94	16.88	6.13	0.71	17.57	-	-	-	-	-	-
3	22.627	49.54	72.43	68.07	24.77	2.87	70.94	24.39	1730	44.62	6816	−4689	+3133
4	39.576	86.65	126.68	119.06	43.32	5.02	124.08	24.27	3011	45.07	6876	−8044	+5451
5	56.942	124.67	182.27	171.30	62.33	7.23	178.53	23.96	4278	46.28	7041	−11051	+7709
6	87.514	147.81	216.10	203.09	73.91	8.57	211.66	23.51	4976	48.13	7288	−12259	+8913
7	74.655	163.45	238.96	224.58	81.73	9.48	234.06	23.00	5383	50.40	7572	−12600	+9376
8	88.905	190.27	278.17	261.43	95.13	11.03	272.46	24.50	6675	68.36	11186	−11410	+7055
9	91.530	200.39	292.97	275.33	100.19	11.62	286.96	24.50	7031	68.36	11188	−12017	+7430
10	93.990	205.78	300.85	282.74	102.89	11.93	294.68	24.50	7220	68.36	11186	−12340	+7629
11	102.990	225.48	329.65	309.81	112.74	13.07	322.89	24.31	7849	69.38	11343	−13180	+8280
12	92.325	202.13	295.31	277.73	101.07	11.72	289.45	23.84	6900	68.42	10483	−13181*	+7226*

* GIRDER NO. 12 INCLUDES 1029#/in² COMPRESSION DUE TO DEAD LOAD MINUS BUOYANCY

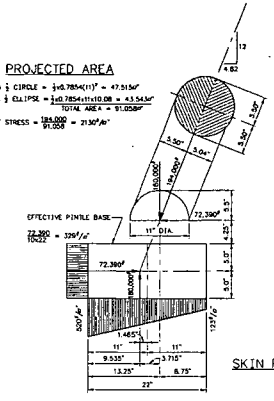
PROJECTED AREA

AREA ½ CIRCLE = ½x0.7854x(11)² = 47.515in²

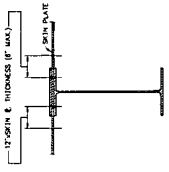
AREA ½ ELLIPSE = ½x0.7854x11x10.08 = 43.543in²

TOTAL AREA = 91.058in²

UNIT STRESS = $\frac{194,000}{91.058}$ = 2130#/in²



PINTLE DESIGN



SKIN PLATE ASSUMED AS GIRDER SECTION

SCALE: 1"=1'-0"

* NOTE:
AS OF AUGUST 2000 THIS DRAWING HAS BEEN CONVERTED FROM CORPS OF ENGINEERING DRAWING TO TVA AUTOCAD FILE PER TVA/CORPS 1995 AGREEMENT.

REV	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST REV
0	5/11/94	TWP	TLC	TWP	RJJ	RWT	RWT	MAC		

ELECTRONICALLY RESTORED DRAWING AS-BUILT

LOCK

UPPER LOCK GATE
DESIGN DATA

FORT LOUDOUN HYDRO PLANT
TENNESSEE VALLEY AUTHORITY
RIVER SYSTEMS OPERATIONS

DESIGNED BY: PKN
DRAWN BY: PKN
CHECKED BY: JTD, CT
DATE:
US Army Corps of Engineers Nashville District
REVISION R 0
SUBMITTED BY: THOMAS W. WATERS
DSGN. BRANCH DIVISION
21/1
REVIEWED BY:
APPROVED BY:
ISSUED BY:

SCALE: 1"=1'-0" | SHEET 1 OF 27 SHEETS

AUTOCAD R 00 | 10 | M | 64W204 | R 0

TASK COMPLETED BY: | REV NO.

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES 21/1

PLOT FACTOR: 48
NTVADP

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Trans. ASCE, Vol. 22, pp. 190-210, 1957

AMERICAN SOCIETY OF CIVIL ENGINEERS

Founded November 5, 1852

TRANSACTIONS

Paper No. 2855

DISCHARGE COEFFICIENTS FOR SPILLWAYS AT TVA DAMS

By Kenneth W. Kirkpatrick,[1] A. M. ASCE

Synopsis

Spillway ratings derived from model studies have been used in the preparation of spillway rating tables for the Tennessee Valley Authority dams. As a result of these studies, discharge coefficients for eleven of the Tennessee Valley Authority dams are given in this paper. Coefficients for both submerged and free discharge conditions are presented for discharges over standard spillway crests, irregular spillway crests, and a vertical-lift spillway gate. Discharge coefficients for Tainter gates placed on curved spillway crests are also given for various gate openings under free discharge conditions. In addition, data on the effect of model scale on the discharge coefficient and the effect of closing adjacent spillway bays and gates are presented. The coefficient relationships are shown in a form that may be used by designers as a guide in making determinations of the discharges for future spillways.

Notation

The letter symbols adopted for use in this paper are defined where they first appear, in the illustrations or in the text, and are arranged alphabetically, for convenience of reference, in the Appendix.

Introduction

The Tennessee Valley Authority (TVA) operates a system of nine dams on the Tennessee River and twenty-three on the tributary rivers. The successful operation of such a system requires accurate discharge ratings for each structure. Although enough water is seldom available to make complete ratings for most spillways from measurements conducted on the prototype structure, ratings can be determined from scale model tests. Therefore, the necessary ratings for the TVA spillways have been determined by this means. Model studies have been made at the TVA Hydraulic Laboratory at Norris, Tenn.,

Note.—Published, essentially as printed here, in February, 1955, as *Proceedings-Separate No. 626*. Positions and titles given are those in effect when the paper was approved for publication in *Transactions*.

[1] Hydr. Engr., Hydr. Lab., Tennessee Valley Authority, Norris, Tenn.

on nine different spillway crest shapes equipped with three types of control gates.

Seven of the nine crests were curved sections which approximated the shape of the lower nappe of a sharp-crested weir. The other two crests were flat. The two flat-crested weirs and one of the curved crests were equipped with double-leaf vertical lift gates. Five of the curved crests were equipped with Tainter gates and the other with vertical lift gates.

Data Presented.—Data are presented for the following conditions: (1) Free, ungated flow through a series of spillway bays; (2) submerged, ungated flow through a series of spillway bays; (3) free, ungated flow through a series of spillway bays, with adjacent bays fully open or closed; (4) free flow over a vertical lift gate; (5) submerged flow over a vertical lift gate; (6) flow under a series of Tainter gates set with equal openings; and (7) flow under a series of Tainter gates with adjacent gates closed.

Data are also presented to show the effect of model scale for the condition of free, ungated flow through a series of spillway bays.

General Model Arrangement.—The models were tested in flumes either 3.5 ft wide or 8 ft wide. Models installed in the smaller flume usually consisted of a reproduction of three of the prototype spillway bays. In the larger flume five or six spillway bays were reproduced. Each of these flumes was provided with glass panels for observation purposes. The models placed in the larger flume were constructed at scale ratios of from 1:28.72 to 1:50 with a ratio of approximately 1:35 generally used. Those tested in the smaller flume were built at scale ratios of 1:50, 1:100, and 1:200.

The models were usually provided with concrete crests and concrete piers to insure dimensional stability. Half piers were constructed on the ends of each model. If the model did not completely fill the flume one side was placed against the glass side of the flume and the other against a false wall. The river bed upstream and downstream from the model was reproduced at the elevation of the prototype river bed. Suitable baffling was provided to obtain a uniform distribution of flow in the spillway approach channel. The tailwater level was controlled at the end of the flumes by means of slat gates. Model discharges were determined from readings of a carefully calibrated diaphragm orifice located in the water supply line.

Headwater heights were measured at two piezometers at distances equal to approximately 5 and 8 times the design head upstream from the spillway crest. Tailwater heights were obtained at 2 piezometers at distances equal to approximately 9 and 12 times the design head downstream from the spillway crest—in all cases, sufficiently far enough downstream to eliminate the effect of the spillway apron.

In most studies the headwater and tailwater levels were determined by means of hook gages reading to 0.001 ft. For the 1/200-scale model the heads were measured with a micrometer point gage reading to 0.0001 ft.

Discharge Equations.—The model data have been reduced by the use of two commonly accepted discharge equations. For both free and submerged flow over a spillway crest the equation,

$$Q = C\,L\,H^{3/2} \qquad (1)$$

was used, in which Q is the discharge in cubic feet per second, C is the coefficient of discharge determined from the model tests, L is the length of the crest, and H is the total head as shown in Fig. 1(*a*). Use was made of the same equation in the reduction of the data for free and submerged flows over a vertical gate with D, H, d, and P (Fig. 1(*a*)) being measured from the top of the gate.

For flow under a gate the equation for a rectangular orifice under low head,

$$Q = C\,L\,[H^{3/2} - (D_1 + h)^{3/2}] \qquad (2)$$

was used, in which D_1 is the depth of water to the bottom of the gate as defined in Fig. 1(*b*) and h is the approach velocity head.

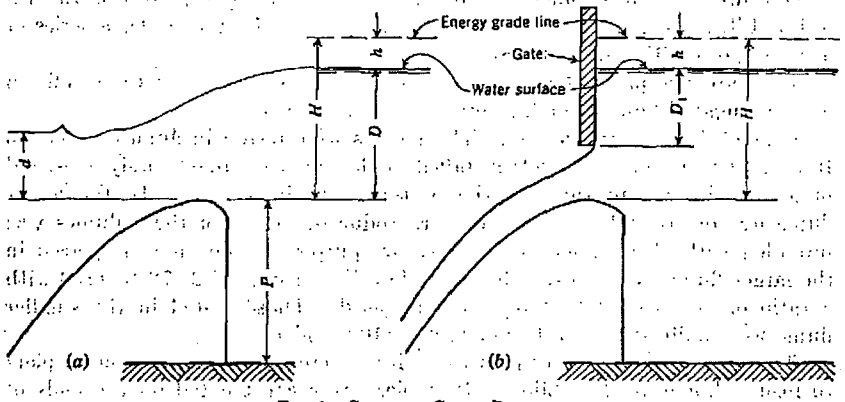


Fig. 1.—Spillway-Crest Diagram

Free-Discharge Coefficients, Flow over Spillway Crests

It is common practice for engineers to design spillway crests to approximate closely the shape of the lower portion of a jet issuing from a sharp-crested weir, and this type of crest is designated a standard crest.[2] Because the shape of the jet changes with the head on the weir, some particular head must be used for each design. This head for which a particular crest is designed is termed the design head. At this head, pressures approximating atmospheric pressure are developed at the spillway surface. At smaller heads, pressures are greater than atmospheric. Seven of the nine TVA crests for which data are available, approximate standard crests in shape whereas the other two crests, which are flat, do not. Fig. 2 shows the basic details and dimensions of each of these crests. Fig. 3 presents the coefficient data obtained on the crests of Fig. 2. Pertinent design data concerning each crest, together with the scale to which each was modeled, appear in Table 1. Eleven spillways are also listed in Table 1. Two pairs of these, the Ocoee No. 3-Apalachia set, and the Douglas-Watts Bar set, both in Tennessee, have crest shapes that are identical within the pair but which were tested for different values of the approach depth, P.

[2] "Hydroelectric Handbook," by W. P. Creager and J. D. Justin, John Wiley & Sons, Inc., New York, N. Y., 2d Ed., 1950.

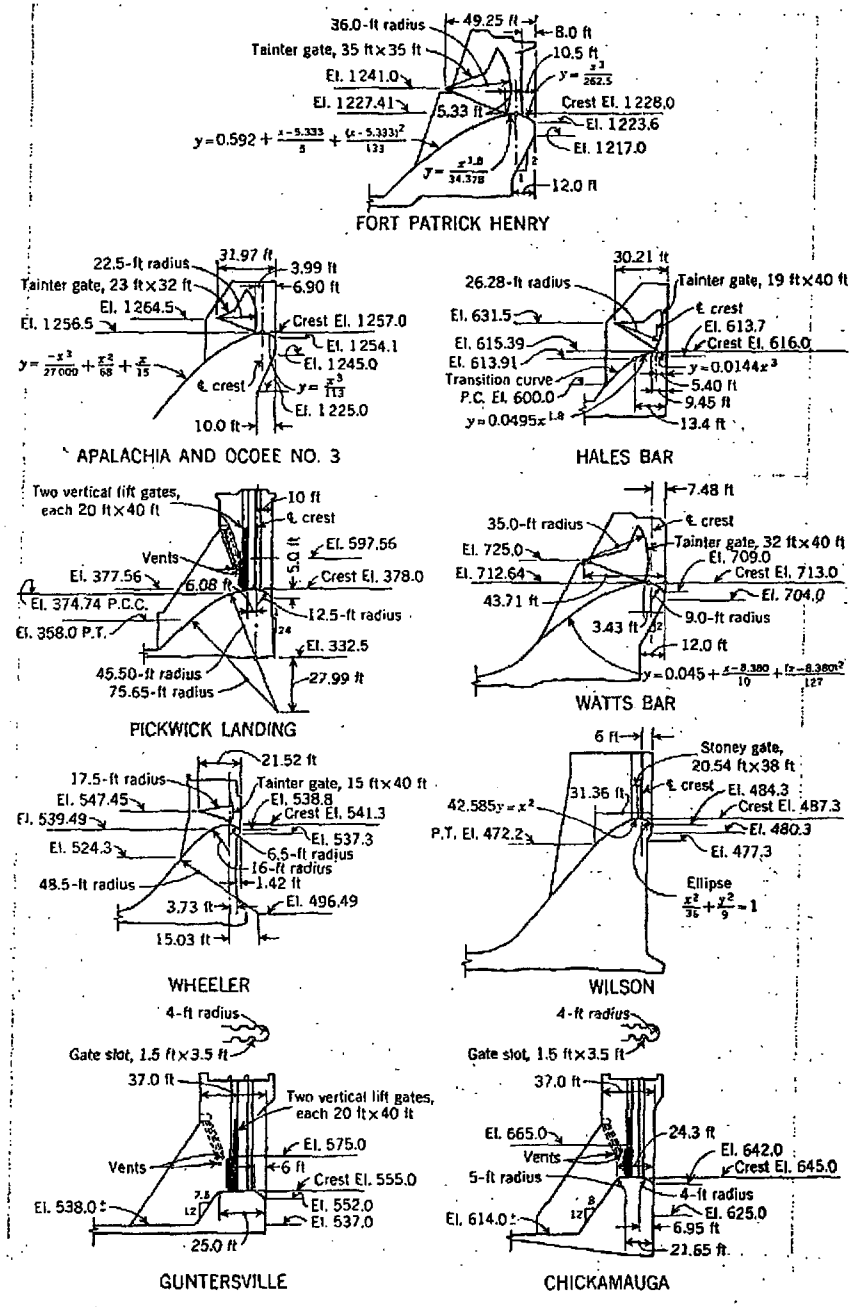


Fig. 2.—TVA Spillway Crests (Data in Fig. 3)

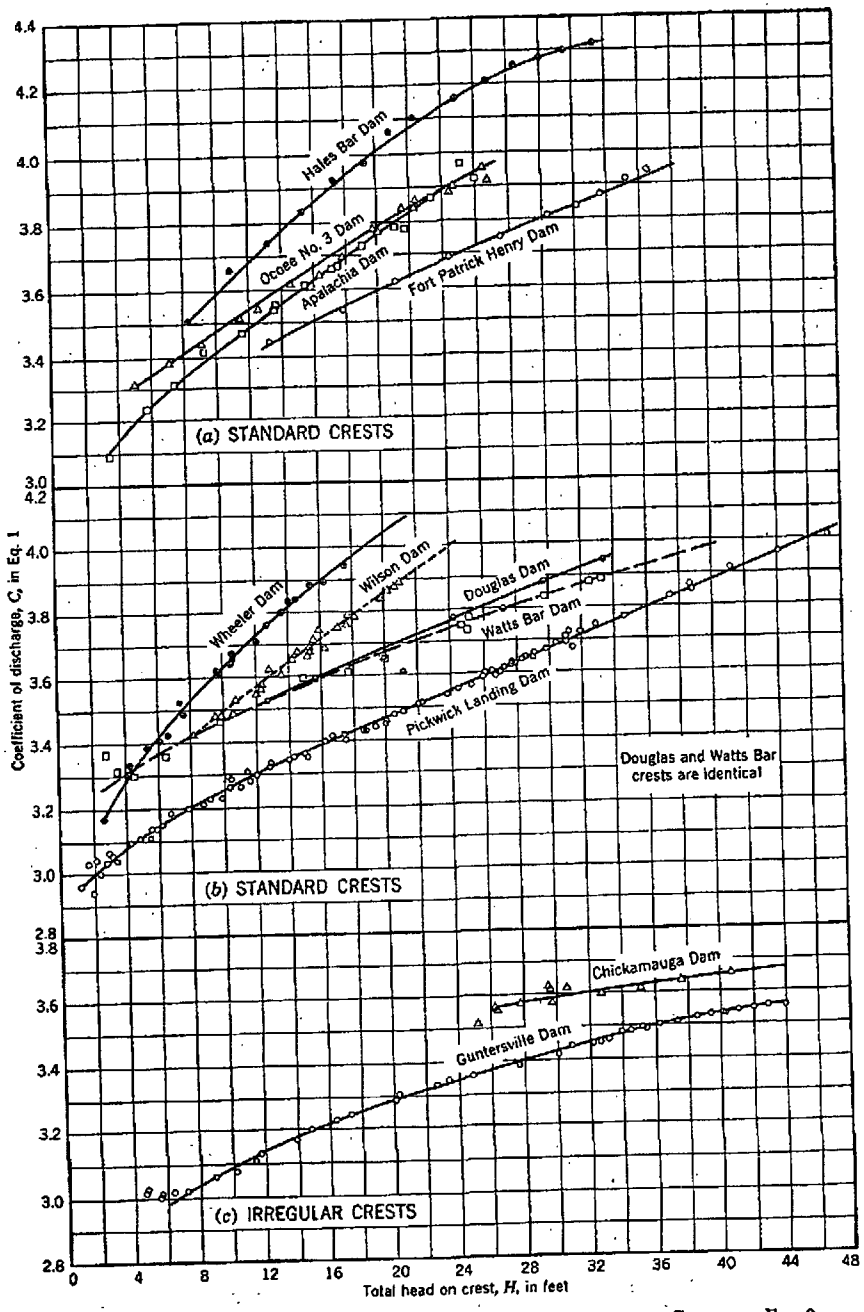


FIG. 3.—DISCHARGE COEFFICIENTS FOR FREE FLOW OVER THE SPILLWAY CRESTS OF FIG. 2

The accuracy of the data is evidenced by the plotting of the data points in Fig. 3. Except in some cases at low heads, the deviation of any plotted point from the coefficient curve does not exceed 0.5%.

Standard Crests.—It has been shown by various authors that the discharge coefficients for all standard crests can be related to each other and that, conversely, the coefficients to be used for a new design can be taken from previous test data.[2,3,4,5] Unfortunately, in most crest designs, due to other design considerations, it is necessary that the shape be varied from the standard form. Nevertheless, satisfactory coefficients can be obtained as sufficient data are now available on a range of crest shapes. By comparison of crest shapes designers may select a coefficient for any particular crest.

Dimensionless plotting provides a means for comparison of crest shapes. This method is used in Fig. 4 on which seven TVA crests which closely approximate standard crests are shown by the solid lines, with the dashed line representing a standard crest shape.[2] The horizontal coordinate, x, and the vertical coordinate, y, of the crest curve have been divided by the design head, H_o.

TABLE 1.—DESIGN DATA FOR ELEVEN MODELS OF TVA SPILLWAYS

Project	Model scale	Design head, H_o, in feet	Upstream depth, P, in feet	$\frac{H_o}{P}$	Pier nose radius, in feet
Hales Bar	1:34.76	18	32	0.56	3.00
Ocoee No. 3	1:28.72	23	67	0.35	3.00
Apalachia	1:28.72	23	97	0.24	3.00
Fort Patrick Henry	1:50	35	43	0.81	3.25
Wheeler	1:34.35	16.5	43	0.38	2.50
Wilson	1:39.4	19	75	0.25	4.00
Douglas	1:35	23.5	133	0.18	3.25
Watts Bar	1:35	23.5	52	0.45	3.25
Pickwick Landing	1:50	31.5	32	0.98	3.75
Chickamauga	1:50		20		4.00
Guntersville	1:50		18		4.00

The design head was determined by fitting the real and standard curves at the crest point ($x = 0$) and at the intersection of the curve with the upstream vertical face. These design-head values are presented in Table 1. The design-head discharge coefficients (C_o) determined from Fig. 3 are shown in Fig. 4.

The TVA crests all fairly closely approximate the standard curve from the upstream spillway face to a point somewhere downstream from the crest which was determined by the position of the gate seal. Below this latter point, the crest shape was modified to fit the trajectory of a jet issuing from under the gate when set at a small opening. The upstream face for a standard crest is vertical. The upstream face of the TVA crests, as shown in Fig. 4, deviates from the vertical. Other experimenters have established the fact that the shape of the upstream face generally has little influence on the discharge coefficient.[3]

[3] "Final Reports of Boulder Canyon Project," *Bulletin No. 3*, Part VI, Hydraulic Investigations, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1947.

[4] "Engineering Hydraulics," edited by Hunter Rouse, John Wiley & Sons, Inc., New York, N. Y., 1950.

[5] "Discharge Coefficients for Irregular Overfall Spillways," by J. N. Bradley, *Engineering Monograph No. 9*, Bureau of Reclamation, U. S. Dept. of the Interior, Washington, D. C., 1952.

Fig. 4 indicates that the shape of the curve from the crest to a point somewhere in the neighborhood of $x/H_o = 0.5$ materially affects the coefficient. As the curve is raised above the standard curve, the coefficient is decreased. This can be seen by comparing the (y/H_o)-values at $x/H_o = 0.5$ with C_o. The comparative crests in Fig. 4 have been placed in the order of decreasing (Y/H_o)-values. No reasonable correlation of C_o with either upstream shape of H_o/P can be determined.

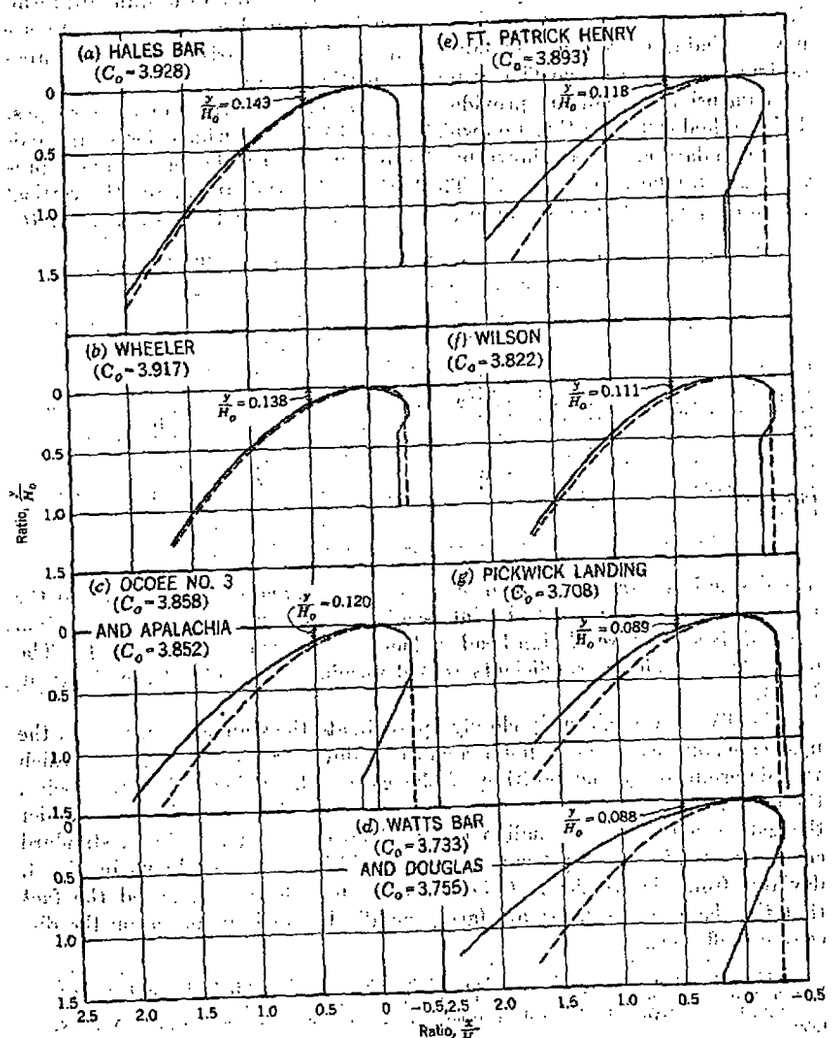


Fig. 4.—Comparative Crests (H_o/P Shown in Table 1)

The relationships between the discharge coefficient and the ratio of any head to the design head, H/H_o, are shown in Fig. 5. In Fig. 5(a) the value of C is plotted against H/H_o for the four crests—Apalachia, Ocoee No. 3, Hales Bar (Tennessee), and Fort Patrick Henry (Tennessee)—that most closely follow the standard crest shape. The maximum variation of the individual points from

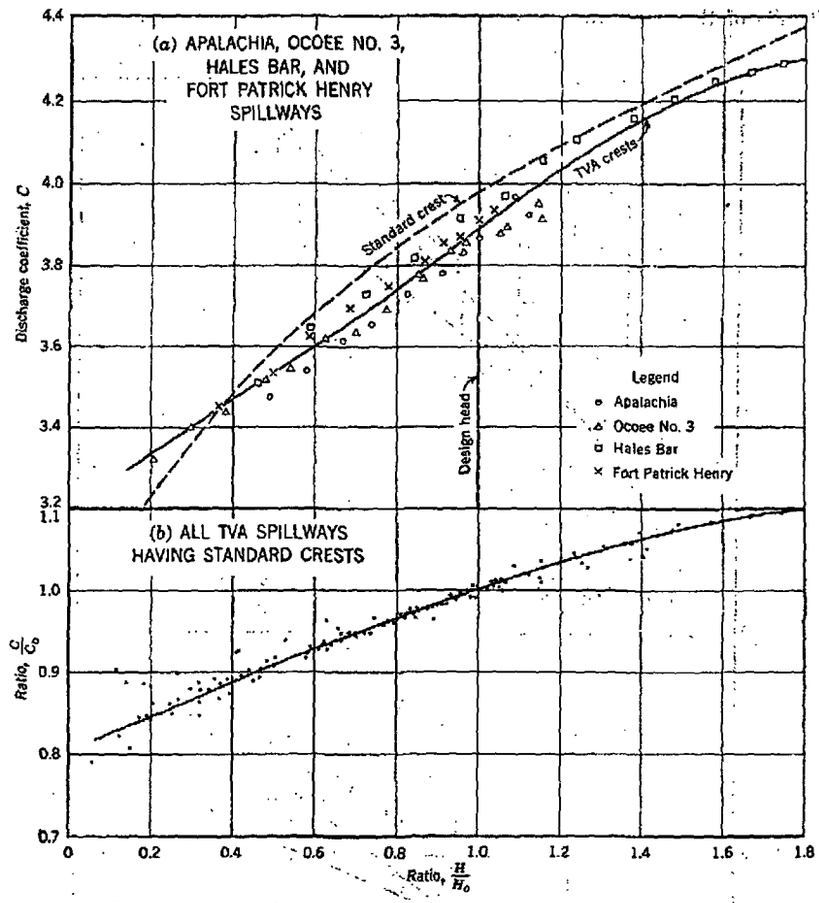


Fig. 5.—Discharge Coefficients for Spillways Having Standard Crests

the average curve for TVA crests is 0.5%. The standard-crest curve shown by the dashed line in Fig. 5 is that of W. P. Creager and J. D. Justin.[2] This curve is approximately 2% higher than the TVA curve. Fig. 5(b) is a dimensionless plot of the data from Figs. 3(a) and 3(b). The deviation of the points from the average curve is greater than in Fig. 5(a) because all crests are included, but for design purposes the curve should be useful. Actually, the

curve is more firmly established than it may appear because the curve itself obliterates several test points.

Irregular Spillway Crests.—The designation "irregular spillway crests" is used to distinguish between standard spillway crests and other crest forms. Only two of the TVA spillways, those at Chickamauga, Tenn., and Guntersville, Ala., have irregular spillway crests. Both are trapezoidal in cross section. Details of these spillway crests and the discharge coefficients computed using

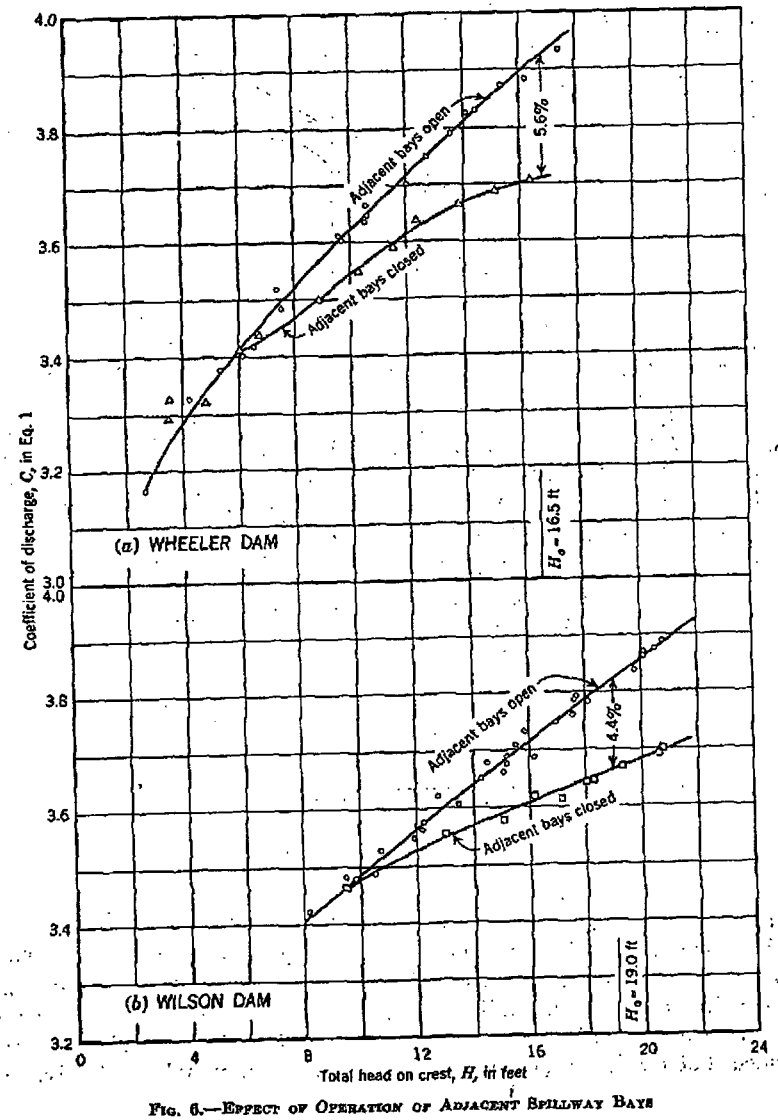


FIG. 6.—EFFECT OF OPERATION OF ADJACENT SPILLWAY BAYS

Eq. 1 from the model-study data are shown in Fig. 3(*c*). The two crests differ chiefly in the shape of the upstream and downstream edges of the crest and the height above the apron. Over the range of the tests of the Chickamauga spillway the coefficients are consistently from 3% to 5% greater than those for the Guntersville spillway. The additional height of the crest above the apron and the rounding of the near upstream edge of the Chickamauga crest would operate to increase the discharge coefficients.

The Effect of Operating Adjacent Spillway Bays.—In the TVA water-control operations, it is necessary to operate single spillway bays and groups of consecutive spillway bays. Because a greater contraction forms at a pier situated next to a closed bay, models of the Wilson and Wheeler spillways in Tennessee were tested with adjacent spillway bays open and closed to determine the difference in contraction effects at the piers.

Fig. 6 shows the head-coefficient relationships for the two conditions tested. The discharge coefficient at the design head was 5.6% higher at Wheeler Dam with adjacent bays opened and 4.4% higher at Wilson Dam than with these bays closed. These relationships show the importance of spillway pier contraction effects in spillway discharge determinations.

SUBMERGENCE DISCHARGE COEFFICIENTS FOR FLOW OVER SPILLWAY CRESTS

Chickamauga Dam, Guntersville Dam, Pickwick Landing Dam (Tennessee), and Watts Bar Dam are subject to submergence of the crest at periods of high discharge. To determine the effect of this submergence model tests were conducted by establishing a constant rate of discharge and varying the tailwater elevation to determine the relationship between the headwater and tailwater elevations. This procedure was repeated for several discharge rates covering the operating range at the dam.

Two flow conditions were observed in the model tests which are characterized as "plunging nappe" and "flowing nappe." In the condition of plunging nappe the discharge issuing from the spillway plunges down into the tailwater and appears to follow the boundary surface of the spillway.

In the condition of flowing nappe the flow is nearly horizontal, producing an undulating surface flow in the tailrace channel. The plunging nappe usually occurs with low submergence whereas the flowing nappe occurs with high submergence. When the headwater and tailwater head relationship at a constant rate of discharge was plotted for each series of tests, it was found that the change from plunging nappe to flowing nappe had no apparent effect on the discharge coefficient.

The results from these tests on the four spillways have been plotted in Fig. 7 in the dimensionless form, d/H, against C_s/C, in which d is the depth of submergence and H is the total head above the crest. The coefficient, C_s, was computed from Eq. 1 using the H-value for the submerged conditions; C was determined using the H-value for the free-flow condition.

No systematic variation of C_s/C could be determined for any variable except the (d/H)-ratio for any of the conditions tested. However, no relatively low discharges were tested because in practice the TVA installations can never be submerged at low discharges.

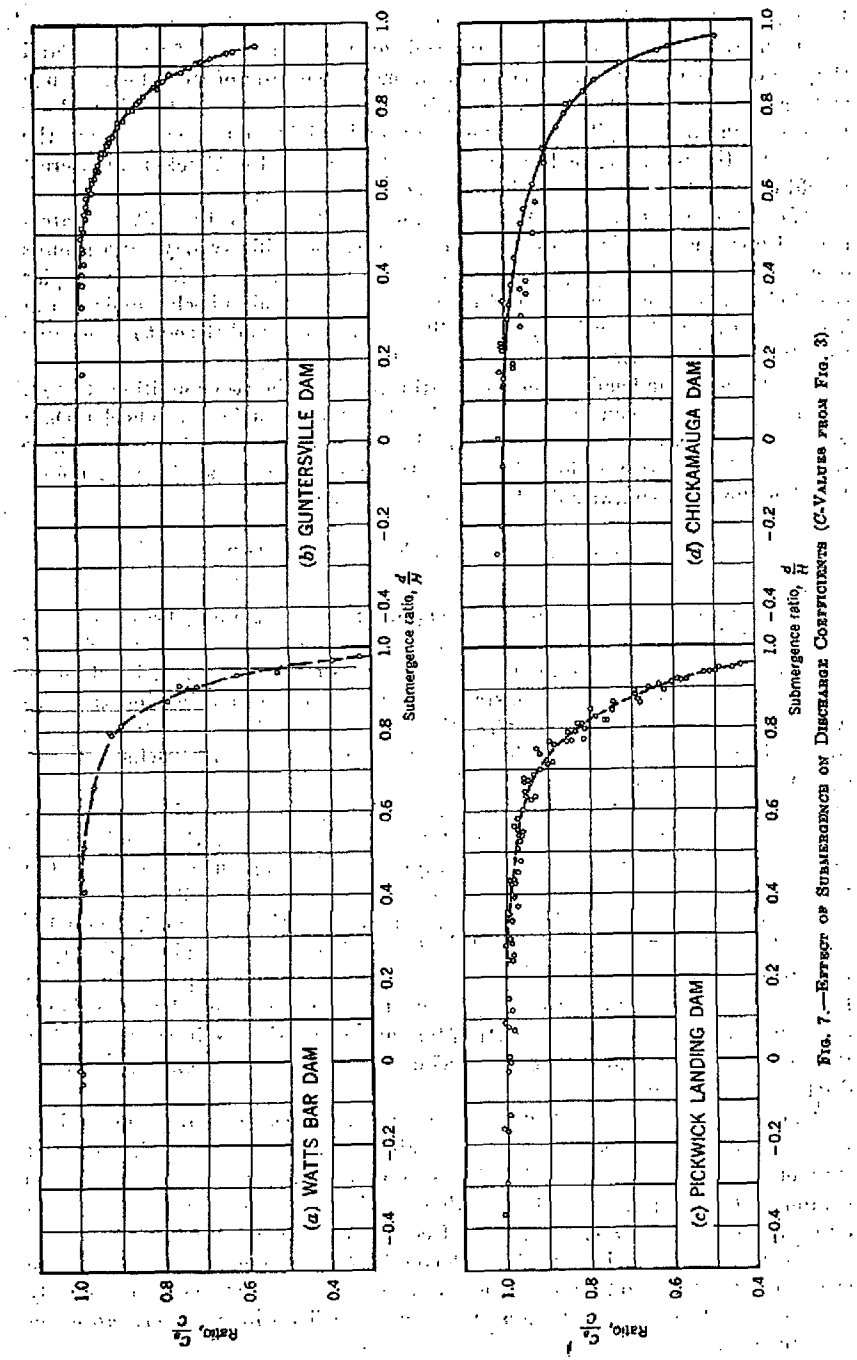


FIG. 7.—EFFECT OF SUBMERGENCE ON DISCHARGE COEFFICIENTS (C-VALUES FROM FIG. 3)

In Fig. 8 the four curves of Fig. 7 are shown on a single plot. Although the maximum spread between curves is about 10%, this is to be expected considering the wide range of crest shapes used in the tests.

FREE-DISCHARGE COEFFICIENTS FOR FLOW OVER VERTICAL LIFT GATES

The Pickwick Landing vertical lift gates are representative of this type of gate, which has been used on several TVA projects. In Fig. 9(*a*) are shown details of the lower spillway gate leaf. For heads greater than 2 ft, this gate is essentially a sharp-crested weir 40 ft long and 20 ft high with piers 7.5 ft thick at each end of the gate. Air intakes were installed in the sides of the piers just below the top of the gate to ventilate the underside of the nappe.[6] Model tests were conducted with the 1/50-scale, 3-bay spillway model.

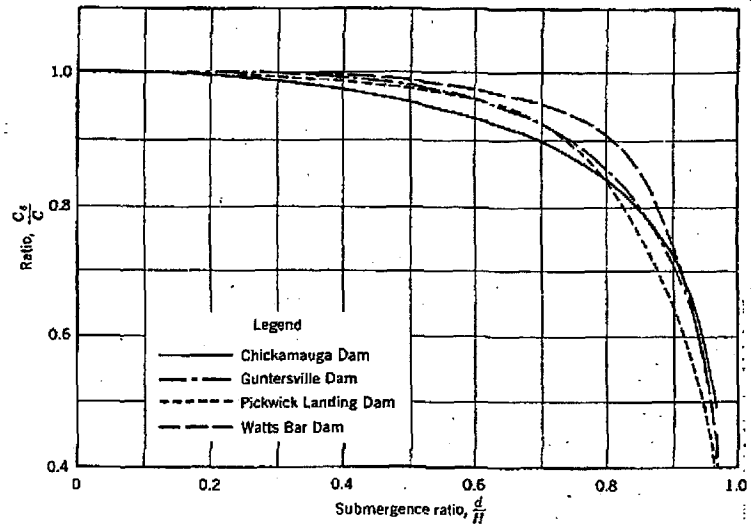


FIG. 8.—COMPARISON OF SUBMERGENCE EFFECTS FOR VARIOUS SPILLWAY CREST SHAPES

In Fig. 9(*b*) is shown the head-coefficient relationship for flow over the crest of the spillway gate. The coefficient, C, was computed from Eq. 1 using the top of the gate as crest elevation. The points define the head-coefficient relationship for heads between 3 ft and 28 ft. Each point was determined from the average of from 3 to 5 separate tests. A constant value of C equal to 3.428 is shown for heads in excess of 12 ft. For heads of from 12 ft to about 4 ft the model test curve shows a gradual rise in the coefficient, with an abrupt drop-off when the heads are approximately 4 ft and less. This curve takes the characteristic form for the coefficients of a sharp-crested weir, the rise and fall in the coefficient curve being due to the nappe clinging to the surface of the weir. This phenomenon is a function of the absolute head. Therefore, similarity between the model and prototype did not exist for prototype heads

[6] "Aeration of Spillways," by G. H. Hickox, *Transactions*, ASCE, Vol. 109, p. 537.

of less than 12 ft. Because the gate has a 10-in.-wide flat top, at low heads the prototype can be expected to exhibit discharge characteristics similar to those of the model. However, for a head in excess of about 2 ft the prototype can be expected to act similarly to a sharp-crested weir and to have a flat coefficient curve.

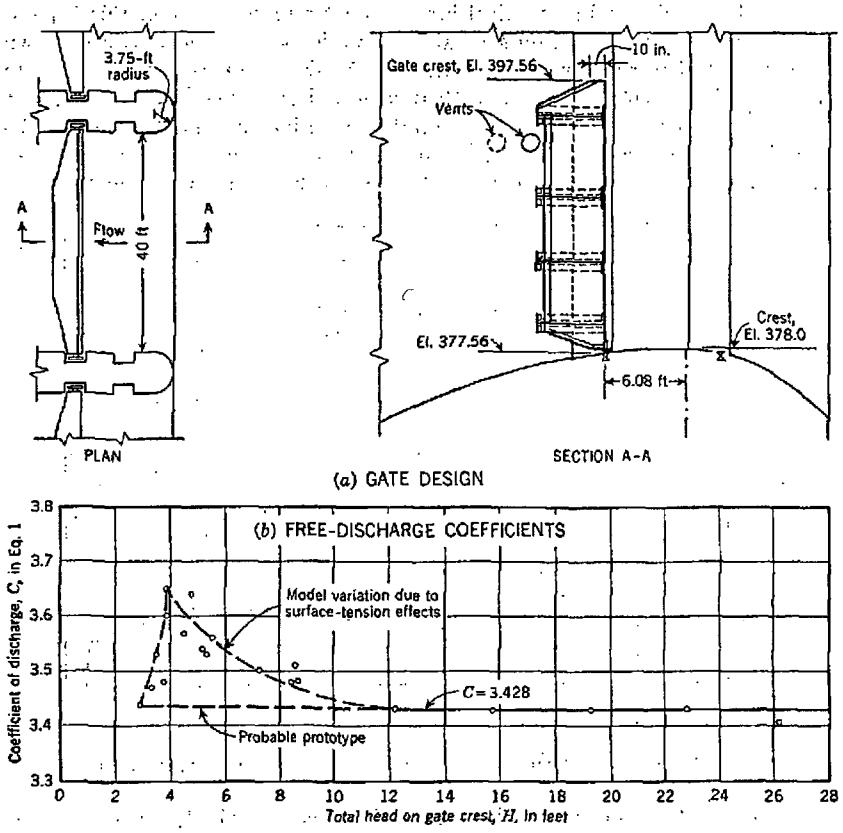


Fig. 9.—Vertical Lift Gate, Pickwick Landing Dam

Submergence Discharge Coefficients for Flow over a Vertical Lift Gate

To obtain data on the effect of the submergence of flow over vertical-lift gates, model tests were conducted in a manner similar to that used in determining submergence effects on spillway crests. The coefficient, C_s, was computed from Eq. 1 in a manner similar to that used for the spillway crest data but using the top of gate as the crest elevation. Fig. 10 shows a plot of the headwater-tailwater relationships that have been determined. The data presented in Fig. 10 represent the rating of a three-bay, 1/50-scale model of the Pickwick Landing Dam. The total equivalent prototype crest width was

117.8 ft. The discharge was for three spillway bays. These curves illustrate the characteristic flow phenomena associated with this type of gate. Each constant-discharge curve begins with a horizontal line where the head-discharge relationship is not affected by the tailwater level. Just before the tailwater elevation reaches the gate crest level there is a drop in the headwater

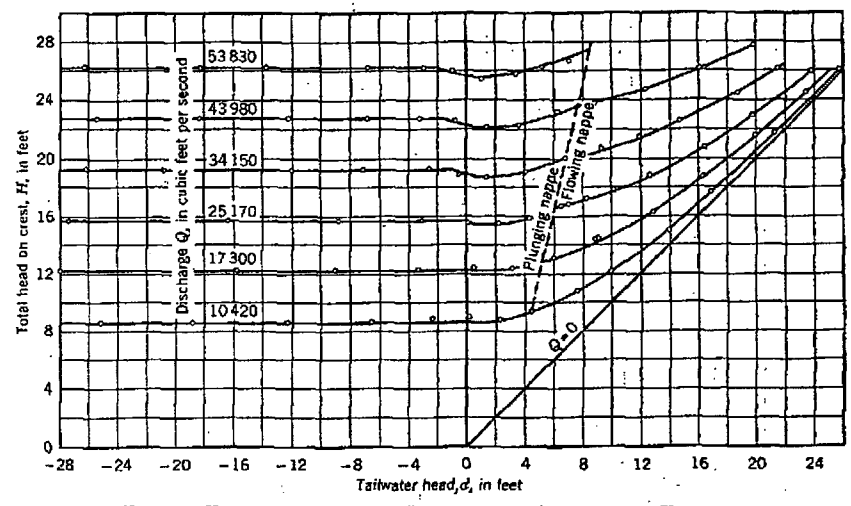


Fig. 10.—Headwater-Tailwater Relations for Flow over a Vertical Lift Gate (Profile Sketch in Fig. 11)

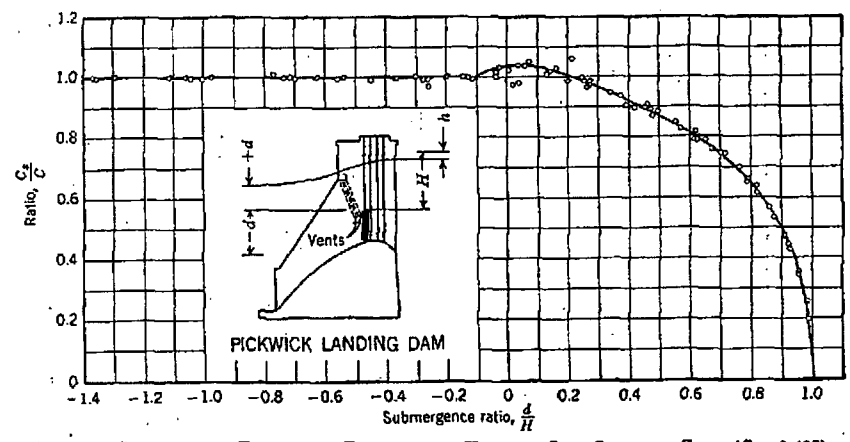


Fig. 11.—Submergence Effect for Flow over a Vertical Lift Spillway Gate ($C = 2.428$)

level for an increase in the tailwater level. Observations of the model operation showed that at this point the air vents, located in the sides of the piers just below the crest of the spillway gate, became submerged by the tailwater, reducing the contraction of the lower nappe issuing from the gate crest. The

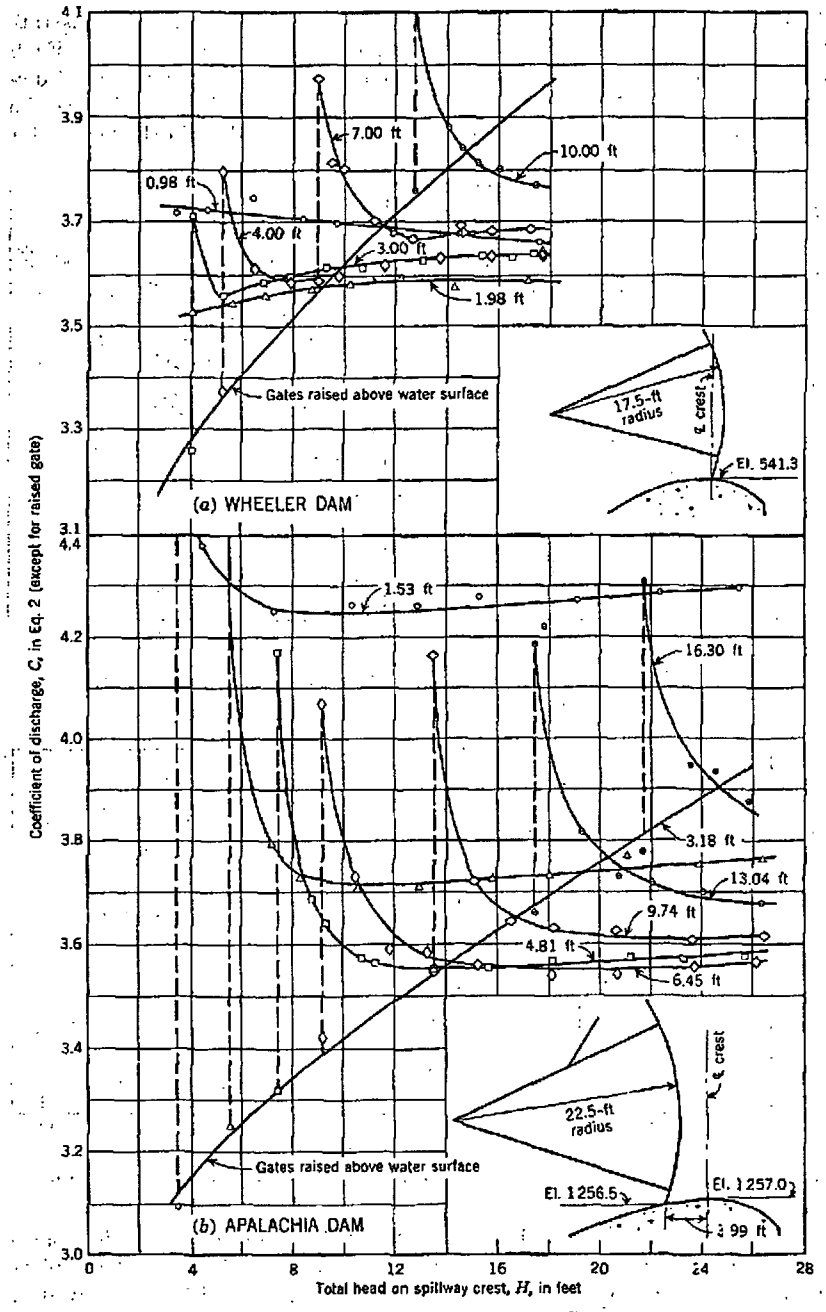


Fig. 12.—Tainter-Gate Spillway Discharge Coefficients (Dimensions on Curves Are Gate Openings)

discharge over the gate was thus increased with a consequent lowering of the headwater level.

The flow conditions of plunging nappe and flowing nappe, previously described, also occurred in this type of flow. In this case the change from one to the other is apparent in the data. The dashed line in Fig. 10 indicates the approximate location of the change. At these points the curves show a definite discontinuity in shape. The data of Fig. 10 can be reduced in coefficient form to the single-curve representation shown in Fig. 11. In this illustration, a constant value of C, equal to 3.428, was used in computing the ratio of C_s/C.

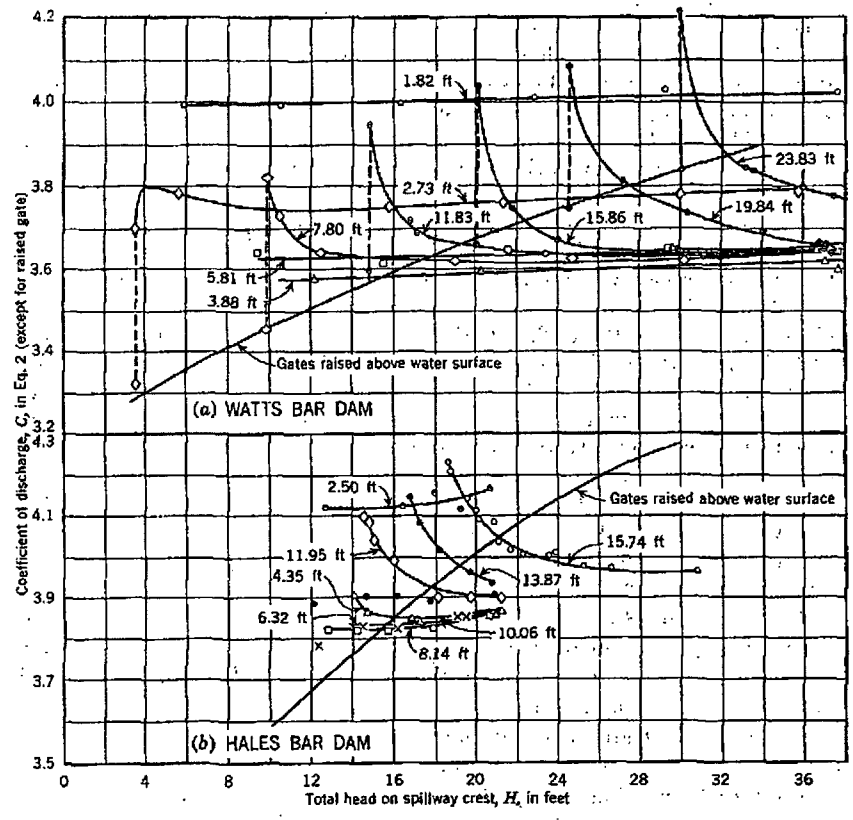


Fig. 13.—Tainter-Gate Spillway Discharge Coefficients (Dimensions on Curves Are Gate Openings)

Discharge Coefficients for Flow Under Tainter Gates

The flow under Tainter gates mounted on curved crests is controlled by the geometry of three interrelated variables—the crest shape, the gate, and the gate setting. The major factors which influence the discharge relation-

ships are the position of the gate seal point with respect to the highest point of the spillway crest and the curvature of the upstream face of the gate. In obtaining the model data on the various TVA Tainter-gate installations no attempt has been made to determine the quantitative effect of these factors taken individually. The data presented in Figs. 12 and 13 for the gate settings at Wheeler Dam, Apalachia Dam, Watts Bar Dam, and Hales Bar Dam are not, therefore, applicable to other installations unless the several variables involved are similar.

Data on Tainter-gate coefficients previously published have, in most cases, been based on flow along a horizontal surface although many of these gates are installed on curved crests. The tests reported herein are for Tainter gates mounted on curved spillway crests where the pressure distribution differs considerably from that in a horizontal channel. The coefficients obtained from tests on a horizontal channel are not applicable to installations on curved crests.

The discharge coefficients for Figs. 12 and 13 were computed using Eq. 2, with the heads measured above the crest elevation. The curves designated "Gates raised above water surface" are the free-discharge curves taken from Figs. 3(*a*) and 3(*b*) for which *C*-values were computed using Eq. 1. The points connected by the dashed lines represent the point at which the water touched the bottom edge of the gate. The difference in the *C*-values is, of course, due to the use of Eq. 2 for the gate curve. The Hales Bar tests were not conducted in a manner that allowed the determination of the point of contact of the gate with the free water surface.

The gate opening was measured as the vertical distance above the crest. This definition leads to the somewhat peculiar variation in the coefficients for small gate openings. In Fig. 12(*a*) the data for Wheeler Dam are presented. The Wheeler gate was positioned, as shown in the insert, with the seal at the high point on the crest. With this design, except at the smallest opening, the coefficient curves for each gate position followed the general pattern of an increase in *C* for an increase in gate opening. In Fig. 12(*b*) the data for Apalachia Dam indicate that, when the gate seal is 3.99 ft downstream and 0.50 ft below the highest point on the crest, the coefficients for gate openings of less than 6.45 ft are increased materially with a decrease in gate opening. This is caused by an arbitrary use in Eq. 2 of an *H*-value as measured above the crest rather than as measured above the elevation of the spillway surface below the gate. Thus, although the *H*-value is consistently too small at the smaller gate openings, the effect becomes more appreciable and results in the increase in *C*.

Tainter-Gate Discharge Coefficients with Adjacent Gates Opened or Closed

The results of tests on the six-spillway-bay model of Wheeler Dam with one gate in operation and with six gates in operation are shown in Fig. 14. In operating with all six gates the contraction effect of the end piers was the same as that for the intermediate piers because the model was constructed

with half piers against the sidewalls of the flume. This operation thus represented the case in which all adjacent bays are open.

Effect of Model Scale on Free-Discharge Coefficients

In developing discharge ratings for prototype structures from model data, it is important that the scale at which the model is built be such that the coefficients determined are applicable to the prototype structure. One author has presented data to indicate that with an increase in the model size the discharge coefficients increase.[7] To study this relationship, a series of precise

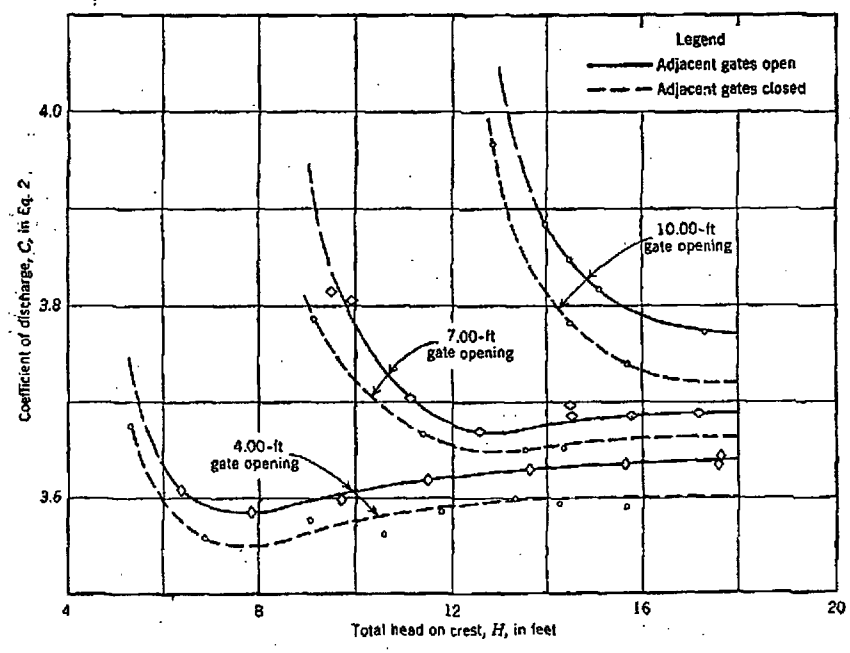


Fig. 14.—Tainter-Gate Discharge Coefficients, *C*, Wheeler Dam

tests was made at the TVA Hydraulic Laboratory under the joint sponsorship of the American Society for Engineering Education, the University of Tennessee (Knoxville) and the TVA.[8] In this study three models of Pickwick Landing spillway were constructed to scales of 1:50, 1:100, and 1:200. Each model consisted of a reproduction of three spillway bays. The shape of the spillway crest and the piers of Pickwick Landing Dam are shown in Figs. 2 and 9(*a*). Similar techniques were used in all tests with one exception. Hook gages reading to 0.0001 ft were used for the 1/200-scale

[7] "Überfallversuche in Berschiedener Modellgrosse," by F. Eisner, The Prussian Experiment Station for Hydraulic Structures and Shipbuilding, Berlin, 1933.

[8] "A Study of the Effect of Model Size on Spillway Coefficients," by C. R. Ownbey, thesis presented in 1949 to the University of Tennessee at Knoxville, in partial fulfilment of the requirements for the degree of Master of Science.

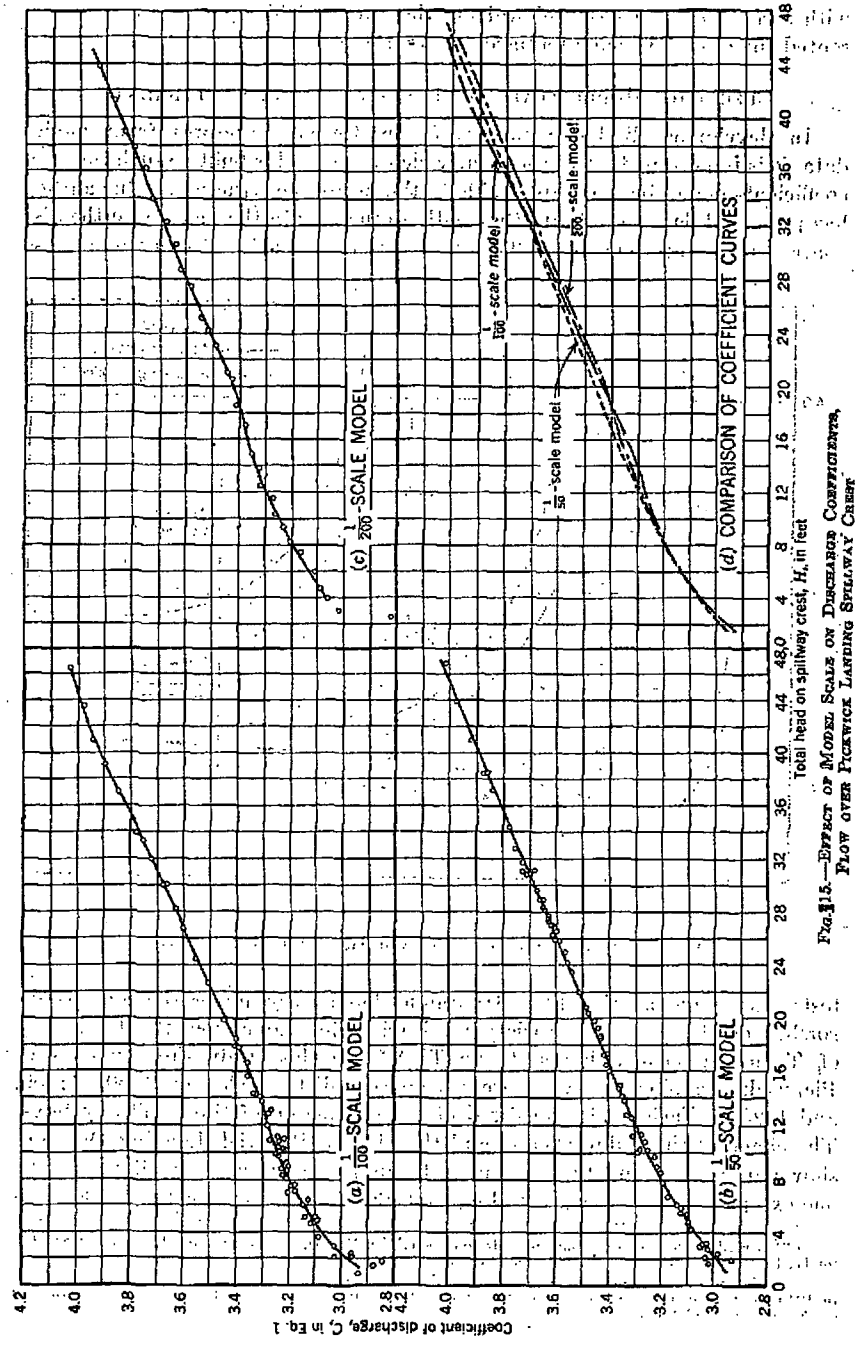


FIG. 15.—EFFECT OF MODEL SCALE ON DISCHARGE COEFFICIENTS, FLOW OVER PICKWICK LANDING SPILLWAY CREST

tests, and gages reading to 0.001 ft were used in the 1/50-scale tests and 1/100-scale tests.

Discharge coefficients for free flow over the crest of each model are shown in Figs. 15(*a*), 15(*b*), and 15(*c*). The coefficients of discharge were computed using Eq. 1. Each curve was drawn through the average of the plotted points.

A comparison of the three coefficient curves is shown in Fig. 15(*d*). The maximum spread of the curves does not exceed 2%. For prototype heads between 2 ft and 8 ft, the three coefficient curves are almost identical. At 13 ft the coefficient curve for the 1/100-scale model is approximately 1% lower than those for the 1/50-scale model and the 1/200-scale model. At 43 ft the curve for the 1/100-scale model is 1% higher than the data for the 1/50-scale model, and that of the 1/200-scale model is 1% lower than that of the 1/50-scale model. Because there is no consistent relationship between the coefficient curves, it is logical to conclude that these variations are merely the result of experimental error and that the model scale did not affect the stage-coefficient relationship. The close agreement of the coefficient curves at the three scales supports the validity of the preparation of prototype ratings based on model tests.

ACKNOWLEDGMENTS

The model studies were made under the general direction of Albert S. Fry, M. ASCE, chief of the Hydraulic Data Branch of the TVA, and under the immediate supervision of G. H. Hickox, M. ASCE, former head of the TVA Hydraulic Laboratory, and Rex A. Elder, M. ASCE, head of the TVA Hydraulic Laboratory. The assistance of Jack C. Jones, J. M. ASCE, is acknowledged in making the computations and preparing the illustrations in this paper. The writer also acknowledges the many helpful suggestions made by Mr. Hickox and Mr. Elder.

APPENDIX. NOTATION

The following letter symbols, adopted for use in the paper and for the guidance of discussers, conform essentially with American Standard Letter Symbols for Hydraulics (ASA-Z10.2-1942), prepared by a committee of the American Standards Association with Society representation, and approved by the Association in 1942:

C = coefficient of discharge for any head:
- C_o = coefficient of discharge for the design head;
- C_s = coefficient of discharge for submerged flow;

D = depth of flow above the crest, in feet (Fig. 1(*a*));
D_1 = depth, bottom of gate to water surface, in feet (Fig. 1(*b*));
d = submergence tailwater, measured above the crest, in feet (Fig. 1(*a*));
g = acceleration due to gravity, in feet per second per second;

H = total head above the crest, including the velocity head of approach, in feet (Fig. 1);
H_e = design head for a standard crest, including the velocity head of approach, in feet;
h = velocity head of approach, $v^2/2g$, in feet (Fig. 1);
L = spillway crest length, in feet;
P = depth of the approach channel, crest to river bed, in feet (Fig. 1(*a*));
Q = total discharge, in cubic feet per second;
v = average velocity of approach, in feet per second; and
X, Y = crest coordinates, in feet.

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Paper No. 2856

WATER CONTROL IN CENTRAL AND SOUTHERN FLORIDA

By Harold A. Scott,[1] M. ASCE

Synopsis

This paper describes the historical efforts made to provide drainage and water control for central and southern Florida. Distribution and utilization of water in the comprehensive plan for flood control and multiple purposes are described. The need for a secondary water-control plan is emphasized.

Introduction

The area described in this paper (Fig. 1) lies south of an east-west line through Lake Harney (about 35 miles north of Cocoa) in Florida in the St. Johns River basin and east of the ridge that extends through Haines City and Sebring. The ridge divides the waters which flow into the Atlantic Ocean and those which flow into the Gulf of Mexico. Water-control problems are quite common throughout the area, although there are a few variations in topography and soil. The area consists of approximately 15,000 sq miles of groveland, pastures, rich agricultural lands, lakes, and marshlands. Elevations range from approximately 7 ft in the vicinity of Miami and 15 ft around Lake Okeechobee to 80 ft in the area of the headwaters of the Kissimmee River basin. (All stages and elevations throughout this paper refer to mean sea level data.) However, the lands of a large part of the area are extremely flat, and natural water courses are not common. Except for the St. Johns River, the Kissimmee River, Fisheating Creek, and a few minor streams, most of the water control is accomplished by man-made canals and drainage districts. Soils in the area vary from sand to peat with a small amount of marl. The areas with higher elevations in the St. Johns and Kissimmee River basins consist of sand mixed with a small amount of organic material in the upper 6 in. to 12 in. In the low areas and marshes, deposits of peat of thicknesses ranging to several feet are found. The Everglades is covered with a layer of peat of thickness ranging to approximately 15 ft at Lake Okeechobee and gradually diminishing to zero at

Note.—Published, essentially as printed here, in October, 1954, as *Proceedings-Separate No. 581*. Positions and titles given are those in effect when the paper was approved for publication in *Transactions*.
[1] Cons. Engr., Reynolds, Smith, and Hills, Jacksonville, Fla.

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Tennessee Valley Authority
Division of Water Control Planning
Engineering Laboratory

TAINTER GATE RATING DATA
DETERMINED FROM EIGHT TVA MODEL STUDIES

Norris, Tennessee
March 1962

TAINTER GATE RATING DATA

DETERMINED FROM EIGHT TVA MODEL STUDIES

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Tainter Gate Ratings

Basic Model and Prototype Data

	MODEL					PROTOTYPE		
Project	Model Scale	No. of Spill-way Bays	Crest Length L	Approach Width W	Up-stream Depth P	Crest Elev.	Design Head H_o	Pier Nose Radius R
Apalachia	1:28.72	6	6.684	8.00	3.38	1257.0	23.0	3.00
Boone	1:50	5	3.480	(1)	(1)	1350.0	35.0	12.75(2) 11.25(3) 3.50(4)
Ft. Patrick Henry	1:15	1	2.333(5)	2.77(5)	2.29	1228.0	35.0	3.25
Hales Bar	1:34.76	6	6.908(6) 6.905(7)	7.94	0.921	616.0	18.0	3.00
Hiwassee	1:55	7	4.050	8.00	6.35	1503.5		3.00
Watts Bar	1:35	6	6.866	8.00	1.5	713.0	23.5	3.25
Wheeler	1:34.35	6	6.984	7.97	1.253	541.3	16.5	2.50

(1) Variable because approach was reproduced in model.

(2) Right end pier.

(3) Left end pier.

(4) Intermediate piers.

(5) Except as noted on data tabulations.

(6) Gates partially opened.

(7) Gates raised above water surface.

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Definition of Symbols

Q = Total discharge in cubic feet per second.

D = Depth of flow above crest in feet.+

D_1 = Depth, bottom of gate to water surface.*

H = Total head above crest, including velocity head of approach in feet.*

H_o = Design head for standard crest, including velocity head of approach, in feet.

h = Velocity head of approach in feet.*

C = Coefficient of discharge for any head.

G.O. = Gate opening - vertical distance above spillway crest in feet.

b = Shortest distance between spillway surface and gate lip in feet.*

L = Length of spillway crest in feet.

P = Depth of model approach channel, crest to river bed, in feet.+

W = Width of model approach in feet.

x = Horizontal distance from upstream face of dam in feet.*

y = Vertical distance above spillway crest in feet.*

Discharge Equations

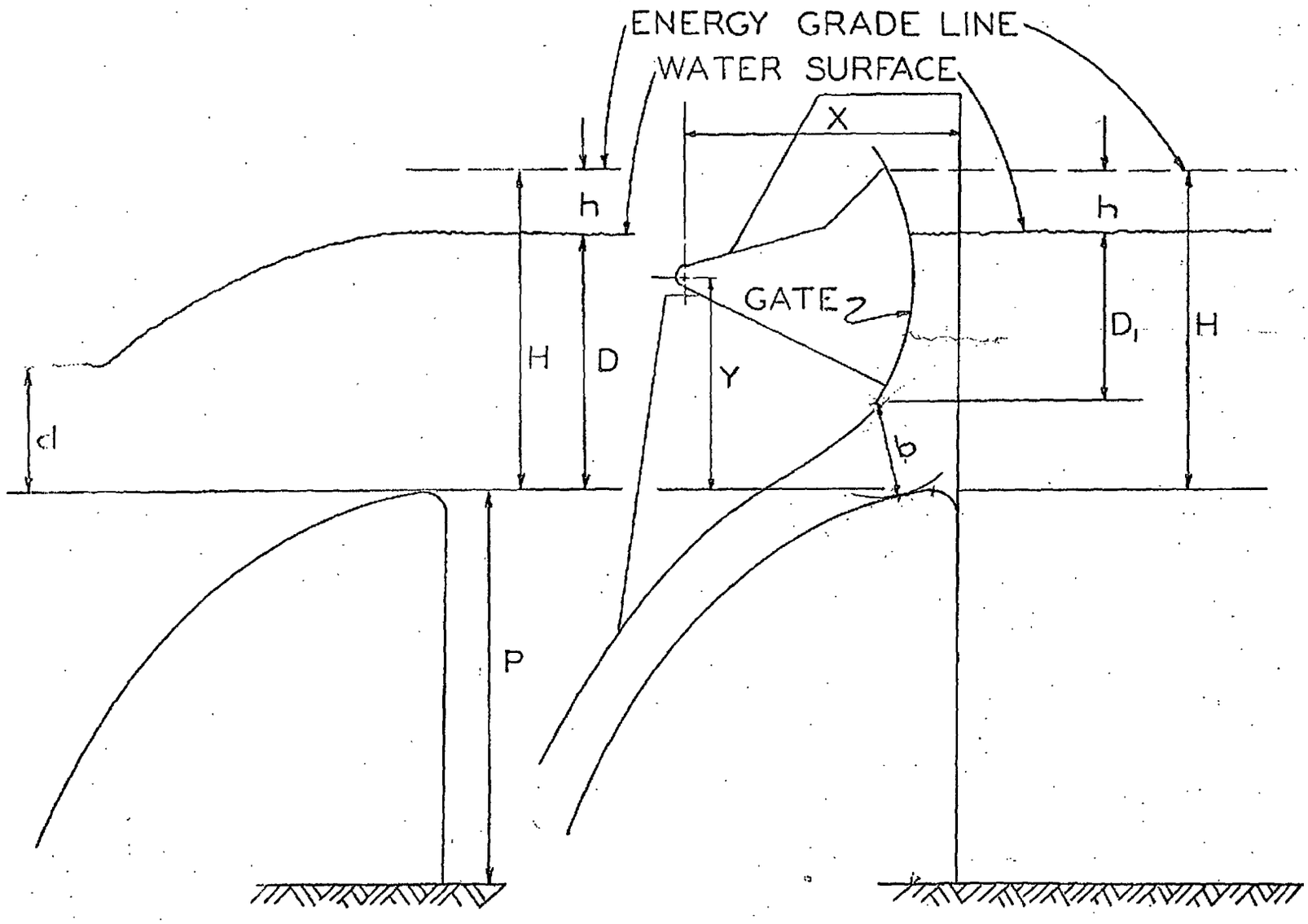
For flow under a gate:

$$Q = CL \left[H^{3/2} - (D_1 + h)^{3/2}\right] \qquad (A)$$

For flow over a spillway crest with the spillway gate raised above the water surface:

$$Q = CLH^{3/2} \qquad (B)$$

+See Figure 1(a) on page 4.
*See Figure 1(b) on page 4.



[a] FIGURE 1 [b]

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Apalachia Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.0532	0.117	0.826	0.000	1.53	3.36	3,650	3.09+ 5.19*
	0.154	0.828	0.000		4.42	3,660	4.38
	0.251	1.071	0.000		7.21	4,734	4.25
	0.358	1.305	0.000		10.28	5,769	4.26
	0.449	1.472	0.000		12.90	6,507	4.26
	0.533	1.618	0.000		15.31	7,152	4.28
	0.663	1.812	0.000		19.04	8,010	4.27
	0.778	1.973	0.000		22.34	8,721	4.28
	0.886	2.115	0.000		25.45	9,349	4.29
0.1107	0.190	1.796	0.000	3.18	5.46	7,939	3.25+ 4.43*
	0.246	1.838	0.000		7.07	8,125	3.80
	0.287	1.994	0.000		8.24	8,814	3.73
	0.367	2.302	0.000		10.54	10,180	3.71
	0.450	2.595	0.000		12.92	11,470	3.72
	0.549	2.916	0.000		15.77	12,890	3.73
	0.627	3.137	0.000		18.01	13,870	3.73
	0.732	3.451	0.000		21.02	15,250	3.77
	0.831	3.681	0.000		23.87	16,270	3.76
	0.917	3.888	0.000		26.34	17,190	3.76
0.1676	0.257	2.888	0.000	4.81	7.38	12,770	3.32+ 4.17*
	0.303	2.890	0.000		8.70	12,770	3.69
	0.393	3.330	0.000		11.29	14,720	3.57
	0.469	3.709	0.000		13.47	16,400	3.57
	0.545	4.066	0.000		15.65	17,970	3.56
	0.631	4.444	0.000		18.12	19,640	3.57
	0.739	4.866	0.000		21.22	21,510	3.57
	0.373	3.221	0.000		10.71	14,240	3.57
	0.322	2.977	0.000		9.25	13,160	3.64
	0.811	5.124	0.000		23.29	22,650	3.57
	0.894	5.418	0.000		25.68	23,950	3.58

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Apalachia Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.2247	0.364	4.184	0.000	6.45	10.45	18,490	3.73
	0.318	4.098	0.000		9.13	18,110	3.42+ 4.08*
	0.411	4.399	0.000		11.80	19,450	3.59
	0.461	4.752	0.000		13.24	21,010	3.58
	0.531	5.181	0.000		15.25	22,900	3.56
	0.627	5.742	0.001		18.04	25,380	3.54
	0.718	6.224	0.001		20.65	27,510	3.55
	0.825	6.771	0.001		23.72	29,930	3.56
	0.911	7.179	0.001		26.19	31,730	3.56
0.3393	0.469	7.647	0.001	9.74	13.50	33,800	3.55+ 4.16*
	0.526	7.490	0.001		15.14	33,110	3.72
	0.574	7.832	0.001		16.51	34,620	3.65
	0.631	8.344	0.001		18.15	36,880	3.63
	0.717	9.089	0.001		20.62	40,180	3.63
	0.821	9.882	0.001		23.61	43,680	3.61
	0.919	10.58	0.002		26.42	46,770	3.62
0.4541	0.604	11.54	0.002	13.04	17.40	51,010	3.66+ 4.19*
	0.617	11.84	0.002		17.78	52,340	4.22
	0.720	11.84	0.002		20.74	52,340	3.73
	0.668	11.42	0.002		19.24	50,480	3.81
	0.765	12.34	0.002		22.03	54,550	3.72
	0.838	13.10	0.002		24.12	57,910	3.70
	0.915	13.84	0.003		26.36	61,180	3.68
0.5677	0.751	16.55	0.004	16.30	21.68	73,160	3.77+ 4.31*
	0.895	17.14	0.004		25.82	75,770	3.87
	0.849	16.72	0.004		24.50	73,910	3.94
	0.815	16.24	0.004		23.52	71,790	3.95

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Apalachia Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D ft.	Q cfs	h ft.	H ft.	Q cfs	C
0.117	0.826	0.000	3.36	3,651	3.09
0.190	1.796	0.000	5.46	7,939	3.25
0.257	2.888	0.000	7.38	12,770	3.32
0.318	4.098	0.000	9.13	18,110	3.42
0.397	5.813	0.001	11.42	25,700	3.46
0.466	7.542	0.001	13.41	33,340	3.54
0.536	9.512	0.001	15.43	42,050	3.62
0.592	11.17	0.002	17.06	49,380	3.65
0.659	13.39	0.003	19.00	59,190	3.72
0.728	15.80	0.004	21.01	69,840	3.77
0.800	18.66	0.005	23.12	82,480	3.86
0.866	21.57	0.006	25.05	95,350	3.96
0.894	22.44	0.007	25.87	99,190	3.93
0.469	7.647	0.001	13.50	33,800	3.55
0.604	11.54	0.002	17.40	51,010	3.66
0.751	16.55	0.004	21.68	73,160	3.77

Tennessee Valley Authority

Boone Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.040	0.085	0.2810		2.00	4.25	4,968	3.26+ 5.28*
	0.149	0.3552			7.45	6,279	4.74
	0.234	0.4567			11.70	8,073	4.72
	0.274	0.4937			13.70	8,727	4.70
	0.351	0.5661			17.55	10,010	4.70
	0.428	0.6285			21.40	11,110	4.72
	0.504	0.6857			25.20	12,120	4.73
	0.581	0.7385			29.05	13,050	4.72
	0.626	0.7663			31.30	13,550	4.71
	0.700	0.8087			35.00	14,300	4.69
	0.110	0.3020			5.50	5,339	4.82
0.500	0.617	6.250		25.00	30.85	110,500	3.70+ 4.04*
	0.680	6.598	Negligible		34.00	116,600	3.92
	0.721	6.715			36.03	118,700	3.80
	0.633	6.456			33.15	114,100	3.91
0.400	0.493	4.355		20.00	24.65	76,990	3.61+ 3.93*
	0.558	4.638			27.90	81,990	3.77
	0.615	4.906			30.75	86,730	3.69
	0.685	5.279			34.25	93,320	3.66
	0.708	5.425			35.40	95,900	3.67
0.300	0.379	2.964		15.00	18.95	52,400	3.65+ 4.04*
	0.459	3.175			22.95	56,130	3.68
	0.517	3.453			25.85	61,040	3.67
	0.575	3.726			28.75	65,870	3.67
	0.648	4.044			32.40	71,490	3.67
	0.724	4.344			36.20	76,790	3.67

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Boone Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.200	0.270	1.672		10.00	13.50	29,560	3.42+ 3.94*
	0.334	1.856			16.70	32,810	3.71
	0.409	2.133			20.45	37,710	3.69
	0.469	2.413			23.45	42,660	3.82
	0.539	2.626			26.95	46,420	3.80
	0.592	2.790			29.60	49,320	3.82
	0.670	2.896			33.50	51,200	3.68
	0.723	3.035			36.15	53,650	3.69
0.100	0.152	0.7015	Negligible	5.00	7.60	12,400	3.40+ 4.25*
	0.218	0.8119			10.90	14,350	3.81
	0.264	0.9232			13.20	16,320	3.83
	0.334	1.061			16.70	18,760	3.82
	0.391	1.174			19.55	20,750	3.86
	0.474	1.311			23.70	23,180	3.86
	0.599	1.496			29.95	26,450	3.87
	0.537	1.403			26.85	24,800	3.85
	0.630	1.537			31.50	27,170	3.87
	0.719	1.654			35.95	29,240	3.87
	0.177	0.7320			8.85	12,940	3.96
	0.234	0.8555			11.70	15,120	3.84
	0.299	0.9897			14.95	17,500	3.81

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Boone Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.323	2.312	Negligible	16.15	40,870	3.62
0.367	2.928		18.35	51,760	3.79
0.432	3.575		21.60	63,200	3.62
0.492	4.399		24.60	77,770	3.66
0.545	5.166		27.25	91,320	3.69
0.609	6.155		30.45	108,800	3.72
0.664	7.044		33.20	124.500	3.74
0.706	7.809		35.30	138,000	3.78
0.252	1.522		12.60	26,910	3.46
0.190	0.9783		9.50	17,290	3.39
0.135	0.5736		6.75	10,140	3.33
0.088	0.2952		4.40	5,220	3.25
0.048	0.1170		2.40	2,068	3.21

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.200	2.214	4.040	0.000	3.00	33.21	3,520	3.97
	2.530	4.332	0.000		37.95	3,775	3.97
	1.714	3.511	0.000		25.71	3,060	3.95
	1.412	3.156	0.000		21.18	2,750	3.94
	1.110	2.755	0.000		16.65	2,401	3.92
	0.683	2.076	0.000		10.24	1,809	3.89
	0.556	1.831	0.000		8.34	1,596	3.88
	0.500	1.711	0.000		7.50	1,491	3.88
	0.424	1.552	0.000		6.36	1,352	3.91
	0.350	1.515	0.000		5.25	1,320	4.36
	0.362	1.510	0.000		5.43	1,316	4.24
	0.360	1.578	0.000		5.40	1,375	4.45
0.333	1.464	4.895	0.003	5.00	22.00	4,266	3.69
	1.133	4.218	0.003		17.04	3,676	3.68
	0.917	3.692	0.003		13.80	3,217	3.66
	0.742	3.217	0.002		11.16	2,803	3.65
	1.692	5.331	0.004		25.44	4,646	3.70
	1.913	5.716	0.004		28.76	4,981	3.71
0.667	1.226	7.822	0.010	10.00	18.54	6,816	3.55
	2.108	11.21	0.013		31.82	9,768	3.60
	1.556	9.169	0.012		23.52	7,990	3.55
	1.915	10.59	0.013		28.92	9,230	3.60
	0.995	6.828	0.009		15.06	5,950	3.61
	2.186	11.46	0.013		32.99	9,986	3.60
1.133	1.625	15.23	0.030	17.00	24.83	13,270	3.73
	1.947	17.28	0.034		29.72	15,060	3.69
	2.124	18.33	0.035		32.39	15,970	3.68
	2.361	19.68	0.036		35.96	17,150	3.68
1.400	1.966	21.05	0.049	21.00	30.22	18,340	3.79
	2.105	22.08	0.051		32.34	19,240	3.77
	2.359	23.67	0.052		36.16	20,630	3.72
	1.925	20.72	0.049		29.61	18,060	3.80
	1.925	20.83	0.049		29.61	18,150	3.82
	1.828	20.11	0.048		28.14	17,520	3.84
	1.807	20.03	0.048		27.82	17,460	3.87
	1.786	19.94	0.048		27.51	17,380	3.89
	1.766	19.92	0.049		27.22	17,360	3.92

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
1.667	2.326	27.84	0.073	25.00	35.98	24,260	3.86
	2.296	27.65	0.073		35.49	24,100	3.88
	2.253	27.40	0.073		34.89	23,880	3.89
	2.233	27.26	0.073		34.59	23,760	3.91
	2.179	26.96	0.073		33.78	23,493	3.94
	2.144	26.74	0.073		33.26	23,300	3.96
	1.995	27.89	0.086		31.22	24,304	4.37
0.867	2.396	15.55	0.022	13.00	36.27	13,550	3.65
	2.036	13.99	0.021		30.86	12,190	3.63
	1.756	12.66	0.020		26.64	11,030	3.62
	1.408	10.85	0.018		21.39	9,455	3.62
	1.281	10.15	0.016		19.46	8,845	3.64
	1.070	9.504	0.016		16.29	8,282	3.96
	1.149	9.582	0.016		17.48	8,350	3.75
	1.136	9.548	0.016		17.28	8,320	3.77
0.533	1.141	6.240	0.007	8.00	17.22	5,438	3.58
	1.466	7.389	0.008		22.11	6,439	3.61
	1.797	8.391	0.008		27.08	7,312	3.63
	2.378	9.885	0.009		35.80	8,614	3.64
0.433	1.991	7.402	0.006	6.50	29.96	6,450	3.66
	1.595	6.497	0.006		24.02	5,662	3.65
	1.238	5.544	0.005		18.64	4,831	3.62
	0.765	4.036	0.004		11.54	3,517	3.61

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
1.274	13.09	0.027	19.52	11,410	3.78
1.440	16.17	0.038	22.17	14,090	3.86
1.691	21.55	0.059	26.25	18,780	3.99
1.890	26.26	0.080	29.55	22,880	4.07
1.972	28.34	0.090	30.93	24,700	4.10
0.9916	8.551	0.014	15.09	7,451	3.63
0.8044	6.045	0.008	12.18	5,268	3.54
0.5831	3.578	0.003	8.79	3,118	3.42
0.3610	1.673	0.001	5.43	1,458	3.29

This is for special 1:15 model tests in which Fort Pat crest was replaced with a standard crest for comparison purposes.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.200	2.325	2.486	1.430	3.069	0.001	4.388
				3.048	0.001	4.374
				2.124	0.001	3.605
				1.282	0.001	2.734
				0.577	0.001	1.700
				0.283	0.000	0.999
0.203	2.325	2.808	0.550	0.601	0.001	1.714
				1.361	0.001	2.757
				2.240	0.001	3.600
				2.771	0.001	4.016
0.200	2.325	2.808	0.550	0.217	0.000	0.745
				0.402	0.001	1.309
				0.934	0.001	2.210
				1.882	0.001	3.244
				2.720	0.001	3.912
0.200	2.325	2.822	-0.077	1.389	0.001	2.652
				2.444	0.001	3.590
				1.945	0.001	3.180
				0.539	0.001	1.556
0.701	2.320	2.410	1.924	2.959	0.017	15.14
				2.374	0.017	13.27
				1.856	0.015	11.32
				0.970	0.009	6.688
				1.393	0.013	9.186
0.700	2.320	2.732	1.044	0.952	0.008	6.469
				1.525	0.012	9.396
				2.189	0.015	11.95
				3.047	0.015	14.52
0.700	2.320	2.746	0.417	0.795	0.007	5.691
				0.893	0.008	6.140
				1.488	0.012	9.080
				2.150	0.014	11.50
				2.727	0.014	13.25
1.199	2.320	2.333	2.418	1.305	0.027	12.94
				1.434	0.029	13.97
				1.641	0.035	16.00
				2.117	0.043	20.00
				2.765	0.048	24.40

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b	L	x	y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
1.199	2.320	2.655	1.538	2.746	0.045	23.29
				2.337	0.042	20.77
				1.787	0.036	16.90
				1.444	0.028	13.89
1.199	2.320	2.669	0.911	1.500	0.030	14.34
				1.803	0.036	16.92
				2.389	0.042	20.84
				2.851	0.043	23.43
1.698	2.320	2.579	2.032	1.926	0.065	23.58
				2.173	0.073	26.47
				2.465	0.080	29.47
1.701	2.320	2.593	1.405	1.798	0.063	22.55
				1.978	0.067	24.25
				2.278	0.076	27.62
				2.456	0.080	29.49
0.199	2.328	2.397	1.897	0.546	0.001	1.699
				1.129	0.001	2.698
				1.944	0.002	3.668
				2.949	0.002	4.594
0.199	2.328	2.917	1.118	2.835	0.001	4.102
				2.103	0.001	3.501
				1.276	0.001	2.661
				0.620	0.001	1.731
0.197	2.329	3.100	0.200	0.651	0.001	1.703
				1.461	0.001	2.693
				2.470	0.001	3.565
				3.099	0.001	4.013
0.198	2.329	3.018	-0.421	0.570	0.001	1.583
				1.439	0.001	2.645
				1.950	0.001	3.112
				2.549	0.001	3.534
0.200	2.328	3.018	-0.421	0.298	0.000	1.219
				0.424	0.001	1.346
				1.022	0.001	2.217

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

b	L	Trunnion Locations x	Trunnion Locations y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.699	2.328	2.397	2.397	1.000	0.010	7.197
				1.338	0.013	9.270
				1.623	0.016	10.78
				2.074	0.018	12.86
				2.547	0.019	14.64
				2.862	0.019	15.71
0.699	2.328	2.917	1.618	1.007	0.010	7.094
				1.585	0.014	9.894
				2.199	0.016	12.31
				2.848	0.017	14.48
0.699	2.328	3.100	0.700	0.923	0.010	7.094
				1.036	0.010	7.133
				1.619	0.013	9.609
				2.163	0.014	11.60
				2.894	0.015	13.76
0.701	2.328	3.018	0.079	1.028	0.010	7.107
				1.663	0.012	9.609
				2.234	0.013	11.46
				2.911	0.014	13.52
1.199	2.328	2.917	2.118	1.628	0.035	16.08
				1.944	0.040	18.41
				2.349	0.044	21.30
				2.804	0.046	24.13
1.198	2.328	3.100	1.200	1.641	0.034	15.90
				1.972	0.036	18.05
				2.323	0.040	20.31
				2.797	0.042	22.93
1.200	2.328	3.018	0.579	1.483	0.036	15.88
				1.629	0.034	15.87
				2.001	0.037	18.08
				2.292	0.039	19.86
				2.571	0.040	21.43
1.699	2.328	2.917	2.618	2.016	0.083	27.31
				2.158	0.078	27.28
				2.217	0.079	27.83

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

b	L	Trunnion Locations x	Trunnion Locations y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.200	2.333	3.115	1.451	0.415	0.001	1.557
				1.081	0.001	2.723
				1.882	0.002	3.677
				3.083	0.002	4.760
0.200	2.333	3.456	0.578	0.471	0.001	1.594
				1.164	0.001	2.630
				1.905	0.001	3.417
				2.679	0.001	4.084
0.198	2.333	3.437	-0.357	0.497	0.001	1.587
				0.923	0.001	2.201
				1.692	0.001	3.010
				2.584	0.001	3.737
0.194	2.333	3.224	-0.946	0.379	0.001	1.745
				0.620	0.001	1.733
				1.002	0.001	2.201
				1.550	0.001	2.727
				2.047	0.001	3.150
0.697	2.333	3.222	-1.940	1.372	0.015	9.915
				1.947	0.018	12.53
				2.472	0.019	14.44
				3.039	0.019	16.29
0.700	2.333	3.563	1.067	1.382	0.014	9.453
				1.976	0.016	11.74
				2.462	0.016	13.39
				2.983	0.017	14.93
0.697	2.333	3.544	0.132	1.086	0.016	9.420
				1.467	0.013	9.439
				1.940	0.014	11.09
				2.459	0.015	12.60
				2.972	0.015	14.07
0.701	2.333	3.331	-0.457	1.345	0.013	8.977
				1.739	0.014	10.31
				2.232	0.014	11.86
				2.497	0.014	12.57

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

Trunnion Locations						
b ft.	L ft.	x ft.	y ft.	D ft.	h ft.	Q cfs
1.200	2.333	3.329	2.428	1.886	0.048	20.08
				2.113	0.050	21.53
				2.332	0.052	23.08
				2.666	0.054	25.26
1.198	2.333	3.670	1.555	1.863	0.045	19.30
				2.134	0.046	20.66
				2.402	0.047	22.31
				2.784	0.048	24.40
1.199	2.333	3.651	0.620	1.881	0.043	18.94
				2.192	0.043	20.46
				2.514	0.044	22.19
				2.816	0.045	23.85
1.201	2.333	3.438	0.031	1.698	0.053	20.27
				2.010	0.043	19.44
				2.234	0.043	20.61
				2.548	0.043	22.13
				2.837	0.043	23.40
1.990	2.335	3.670	1.004	0.441	0.001	1.877
				0.442	0.001	2.247
				0.949	0.001	2.695
				1.779	0.002	3.678
				2.959	0.002	4.741
0.199	2.335	3.872	0.090	0.512	0.001	1.880
				1.156	0.001	2.735
				2.046	0.001	3.614
				2.860	0.001	4.279
0.198	2.335	3.709	-0.832	0.443	0.001	1.705
				0.834	0.001	2.233
				1.289	0.001	2.726
				2.138	0.001	3.473
0.701	2.334	3.851	1.470	1.409	0.018	10.65
				1.510	0.018	11.05
				1.795	0.019	12.16
				2.417	0.019	14.41
				2.962	0.019	16.10

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Fort Patrick Henry Project

Tainter Gates Partially Opened

Gate Trunnion at Various Locations

MODEL TEST DATA

b	L	Trunnion Locations x	Trunnion Locations y	D	h	Q
ft.	ft.	ft.	ft.	ft.	ft.	cfs
0.700	2.334	4.053	0.556	1.495	0.015	10.34
				2.064	0.016	12.28
				2.457	0.017	13.45
				2.838	0.017	14.59
0.697	2.334	3.890	-0.366	1.208	0.021	11.16
				1.530	0.014	10.10
				1.911	0.015	11.31
				2.208	0.015	12.06
				2.602	0.015	13.12
1.199	2.334	4.033	1.936	1.825	0.065	22.95
				2.071	0.054	22.37
				2.210	0.055	23.16
				2.404	0.055	24.20
				2.585	0.056	25.33
				2.731	0.056	26.10
1.198	2.334	4.235	1.022	1.924	0.051	21.00
				2.020	0.051	21.22
				2.225	0.050	22.02
				2.467	0.050	23.22
				2.704	0.050	24.42
1.199	2.334	4.072	0.100	2.141	0.046	21.14
				2.260	0.048	21.83
				2.577	0.046	23.06
				2.797	0.046	23.94
0.199	2.338	4.101	0.677	0.518	0.001	2.247
				1.082	0.002	3.019
				1.928	0.002	3.914
				2.748	0.002	4.626
0.200	2.338	4.233	-0.250	0.492	0.002	2.673
				0.512	0.001	2.118
				1.293	0.002	3.054
				2.007	0.002	3.692
				2.678	0.002	4.247

Width of model approach channel (W) = 2.74 ft.
Model layout is shown on page 44.

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.4529	0.595	11.53	0.014	15.74	21.17	82,140	4.04
	0.666	12.52	0.015		23.67	89,190	4.00
	0.869	15.01	0.018		30.83	106,900	3.96
	0.527	10.81	0.014		18.81	77,010	4.21
	0.561	11.17	0.014		19.99	79,570	4.11
	0.526	10.84	0.014		18.77	77,220	4.23
	0.612	11.74	0.014		21.76	83,630	4.02
	0.548	11.02	0.014		19.54	78,500	4.14
	0.588	11.55	0.014		20.93	82,280	4.08
	0.565	11.18	0.014		20.13	79,640	4.09
	0.669	12.59	0.016		23.81	89,700	4.01
	0.628	11.97	0.015		22.35	85,270	4.01
	0.712	13.10	0.016		25.31	93,320	3.98
	0.751	13.59	0.016		26.66	96,810	3.97
0.3991	0.588	10.18	0.011	13.87	20.82	72,520	3.94
	0.558	9.824	0.011		19.78	69,980	3.96
	0.517	9.346	0.010		18.32	66,580	4.02
	0.486	8.994	0.010		17.24	64,070	4.08
	0.475	8.946	0.010		16.86	63,730	4.14
0.3438	0.604	9.169	0.009	11.95	21.31	65,320	3.90
	0.562	8.706	0.008		19.81	62,020	3.90
	0.518	8.191	0.008		18.28	58,350	3.90
	0.457	7.560	0.007		16.13	53,850	3.99
	0.430	7.269	0.007		15.19	51,780	4.04
	0.414	7.135	0.007		14.63	50,830	4.10
	0.422	7.235	0.007		14.91	51,540	4.09
0.2894	0.483	6.723	0.006	10.06	17.00	47,890	3.85
	0.605	7.928	0.007		21.27	56,480	3.88
	0.403	5.938	0.005		14.18	42,300	3.91
	0.493	6.809	0.006		17.35	48,500	3.84
	0.419	6.049	0.005		14.74	43,090	3.86
	0.592	7.776	0.007		20.82	55,390	3.86

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.1818	0.354	3.650	0.002	6.319	12.37	26,000	3.78
	0.547	4.915	0.003		19.12	35,010	3.86
	0.462	4.393	0.002		16.13	31,290	3.83
	0.413	4.096	0.002		14.43	29,180	3.83
	0.488	4.574	0.003		17.07	32,580	3.85
	0.580	5.095	0.003		20.27	36,290	3.86
	0.559	4.972	0.003		19.54	35,420	3.85
0.2342	0.410	5.019	0.003	8.141	14.36	35,750	3.83
	0.368	4.636	0.003		12.90	33,020	3.83
	0.450	5.354	0.004		15.78	38,140	3.82
	0.590	6.461	0.004		20.65	46,030	3.86
0.1251	0.601	3.719	0.002	4.348	20.96	26,490	3.91
	0.512	3.382	0.001		17.83	24,090	3.89
	0.422	3.034	0.001		14.70	21,610	3.90
	0.348	2.693	0.001		12.13	19,180	3.89
	0.466	3.215	0.001		16.23	22,900	3.90
0.0720	0.475	2.039	0.000	2.503	16.51	14,530	4.12
	0.555	2.216	0.001		19.33	15,790	4.12
	0.596	2.330	0.001		20.75	16,600	4.17
	0.518	2.153	0.001		18.04	15,340	4.16
	0.365	1.762	0.000		12.69	12,550	4.12

Tennessee Valley Authority

Hales Bar Project

Tainter Gates Raised Above the Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.896	27.80	0.058	33.16	198,000	4.32
0.851	25.43	0.051	31.35	181,100	4.30
0.817	23.66	0.046	30.00	168,500	4.27
0.775	21.62	0.040	28.33	154,000	4.26
0.731	19.44	0.034	26.59	138,500	4.21
0.684	17.26	0.028	24.75	122,900	4.16
0.579	12.93	0.018	20.75	92,100	4.06
0.537	11.24	0.015	19.19	80,060	3.97
0.617	14.47	0.022	22.21	103,100	4.10
0.483	9.387	0.011	17.17	66,870	3.92
0.430	7.647	0.008	15.22	54,470	3.82
0.372	5.957	0.005	13.10	42,400	3.72
0.306	4.321	0.003	10.74	30,780	3.64
0.242	2.919	0.002	8.48	20,790	3.51
0.654	15.88	0.025	23.60	113,100	4.11
0.568	12.39	0.017	20.33	88,260	4.01

Tennessee Valley Authority

Hiwassee Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.0213	0.280	0.3292		1.17	15.40	7,385	4.96
	0.185	0.2692			10.18	6,039	5.03
	0.070	0.1636			3.85	3,670	5.24
	0.310	0.3456			17.05 ~~1.71~~	7,753	4.96
	0.449	0.4161			24.70	9,335	4.92
	0.385	0.3849			21.18	8,635	4.92
	0.048	0.1296			2.64	2,907	5.25
	0.051	0.1372			2.80	3,078	5.38
	0.052	0.1415			2.86	3.174	5.46
	0.051	0.1404			2.80	3,150	5.51
	0.056	0.1520			3.08	3,410	5.61
	0.063	0.1568			3.46	3,518	5.37
	0.077	0.1725			4.24	3,870	5.20
	0.084	0.1812			4.62	4,065	5.27
	0.124	0.2188			6.82	4,909	5.15
	0.229	0.3010	Negligible		12.60	6,753	5.06
	0.322	0.3555			17.71	7,975	5.01
0.0421	0.142	0.3687		2.32	7.81	8,271	4.16
	0.100	0.3133			5.50	7,029	4.39
	0.196	0.4123			10.78	9,250	3.86
	0.277	0.5273			15.24	11,830	4.08
	0.385	0.6276			21.18	14,080	4.08
	0.473	0.6983			26.02	15,670	4.08
	0.203	0.4465			11.16	10,020	4.10
0.0767	0.120	0.5475		4.22	6.60	12,280	4.13
	0.188	0.6886			10.34	15,450	3.82
	0.261	0.8201			14.36	18,400	3.72
	0.318	0.9188			17.49	20,610	3.72
	0.374	1.003			20.57	22,500	3.71
	0.440	1.094			24.20	24,540	3.69
0.0762	0.172	0.6546		4.19	9.46	14,690	3.88
	0.203	0.7079			11.16	15,880	3.78

Tennessee Valley Authority

Hiwassee Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.1302	0.229	1.222		7.16	12.60	27,410	3.85
	0.277	1.344			15.24	30,150	3.71
	0.389	1.612			21.40	36,160	3.59
	0.447	1.751			24.59	39,280	3.59
	0.483	1.833			26.57	41,120	3.59
	0.425	1.703			23.38	38,210	3.60
	0.346	1.512			19.03	33,920	3.62
0.1293	0.300	1.382		7.11	16.50	31,000	3.65
	0.347	1.505			19.08	33,760	3.62
	0.477	1.817			26.24	40,760	3.62
	0.237	1.229			13.04	27,570	3.80
	0.248	1.255			13.64	28,150	3.76
0.187	0.402	2.282	Negligible	10.28	22.11	51,190	3.63
	0.350	2.130			19.25	47,780	3.72
	0.320	2.057			17.60	46,150	3.83
	0.452	2.438			24.86	54,690	3.59
	0.491	2.563			27.00	57,500	3.59
0.186	0.317	2.041		10.23	17.44	45,790	3.84
	0.320	2.037			17.60	45,700	3.81
0.238	0.445	3.051		13.09	24.48	68,450	3.72
	0.491	3.213			27.00	72,080	3.66
	0.381	2.908			20.96	65,240	3.96
	0.388	2.909			21.34	65,260	4.04
0.294	0.501	4.033		16.17	27.56	90,480	3.82
	0.422	3.993			23.21	89,580	4.32
	0.422	3.989			23.21	89,490	4.31
	0.460	3.989			25.30	89,490	4.03
	0.465	3.989			25.58	89,490	4.00

Tennessee Valley Authority

Hiwassee Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.199	1.224		10.94	27,460	3.40
0.238	1.616		13.09	36,250	3.44
0.303	2.348		16.66	52,680	3.48
0.353	3.002		19.42	67,350	3.54
0.463	4.673		25.46	104,800	3.66
0.083	0.3053		4.56	6,849	3.15
0.081	0.2932		4.46	6,578	3.13
0.150	0.7790		8.25	17,480	3.31
0.113	0.4982		6.22	11,180	3.24
0.147	0.7553		8.08	16,940	3.31
0.157	0.8340		8.64	18,710	3.31
0.217	1.404	Negligible	11.94	31,500	3.43
0.252	1.769		13.86	39,690	3.45
0.283	2.116		15.56	47,470	3.47
0.293	2.244		16.12	50,340	3.49
0.319	2.548		17.54	57,160	3.49
0.371	3.254		20.40	73,000	3.56
0.289	2.200		15.90	49,350	3.50
0.498	5.274		27.39	118,300	3.71
0.314	2.498		17.27	56,040	3.50
0.426	4.059		23.43	91,060	3.60
0.054	0.1572		2.97	3,527	3.11
0.120	0.5475		6.60	12,280	3.25
0.347	2.893		19.08	64,900	3.49
0.347	2.911		19.08	65,310	3.52
0.422	3.993		23.21	89,580	3.60
0.280	2.082		15.40	46,710	3.47
0.048	0.1296		2.64	2,907	3.05
0.081	0.2886		4.46	6,474	3.08

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.052	0.168	0.803	0.000	1.82	5.88	5,819	3.99
	0.301	1.119	0.000		10.54	8,110	3.99
	0.463	1.411	0.000		16.20	10,230	3.99
	0.650	1.695	0.000		22.75	12,280	4.01
	0.831	1.932	0.000		29.08	14,000	4.03
	1.068	2,198	0.000		37.38	15,930	4.02
~~0.078~~	0.100	0.719	0.000	~~2.73~~	3.50	5,211	3.31+ ~~3.70~~* 4.96
0.078	1.023	3.024	0.000	2.73	35.80	21,920	3.79
	0.608	2.278	0.000		21.28	16,510	3.76
	0.856	2.746	0.000		29.96	19,900	3.78
	0.451	1.932	0.000		15.78	14,000	3.75
	0.165	1.072	0.000		5.78	7,769	3.78
	0.299	1.523	0.000		10.46	11,040	3.72
	0.127	1.025	0.000		4.44	7,428	3.30+ 4.34*
0.111	0.346	2.196	0.000	3.88	12.11	15,910	3.57
	0.576	2.962	0.000		20.16	21,470	3.59
	0.842	3.703	0.001		29.50	26,840	3.65
	1.074	4.161	0.001		37.62	30,160	3.61
	1.056	4.140	0.001		37.00	30,000	3.62
	~~0.183~~ 1.044	~~1.803~~ 4.149	0.001		~~36.46~~ 36.58	~~13,070~~ 30,070	~~3.35+~~ 3.65
~~0.166~~	~~1.044~~	~~4.149~~	~~0.001~~	~~5.81~~	~~36.58~~	~~30,070~~	~~3.65~~
0.166	0.271	2.679	0.001	5.81	9.52	19,420	3.63
	1.068	6.182	0.001		37.42	44,800	3.64
	0.837	5.417	0.001		29.33	39,260	3.65
	0.616	4.552	0.001		21.60	32,990	3.65
	0.441	3.688	0.001		15.47	26,730	3.61
0.223	0.280	3.538	0.001	7.80	9.84	25,640	3.46+ 3.82*
	0.356	4.102	0.001		12.50	29,730	3.64
	0.540	5.436	0.002		18.97	39,400	3.62
	0.702	6.396	0.002		24.64	46,350	3.62
	0.858	7.189	0.002		30.10	52,100	3.62
	1.064	8.186	0.002		37.31	59,330	3.65

+Gate lip touching nappe C from Equation B.
*Gate lip touching nappe C from Equation A.

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.338	1.061	11.98	0.005	11.83	37.28	86,820	3.64
	0.854	10.49	0.005		30.06	76,020	3.64
	0.663	8.894	0.004		23.34	64,460	3.64
	0.484	7.141	0.003		17.04	51,750	3.68
	0.420	6.781	0.003		14.8~~0~~1	49,140	3.59+
							3.95*
	0.476	7.102	0.003		16.76	51,470	3.70
	1.050	11.94	0.005		36.92	86,530	3.65
0.453	0.616	10.82	0.006	15.86	21.77	78,410	3.74
	0.565	10.85	0.007		20.02	78,630	3.65+
							4.04*
	0.679	11.48	0.007		24.01	83,200	3.67
	0.840	13.33	0.008		29.68	96,600	3.65
	1.047	15.50	0.009		36.96	112,300	3.66
0.567	0.688	15.07	0.012	19.84	24.50	109,200	3.75+
							4.09*
	0.765	15.39	0.011		27.16	111,500	3.81
	0.854	16.46	0.012		30.31	119,300	3.73
	0.957	17.72	0.013		33.95	128,400	3.69
	1.035	18.60	0.013		36.68	134,800	3.67
0.681	0.833	20.71	0.019	23.83	29.82	150,100	3.84+
							4.21*
	0.937	20.81	0.018		33.42	150,800	3.84
	1.007	21.82	0.018		35.88	158,100	3.80
	1.048	22.36	0.019		37.34	162,000	3.78
	0.928	20.69	0.018		33.11	149,900	3.85

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Watts Bar Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.100	0.717	0.000	3.50	5,211	3.31
0.183	1.803	0.000	6.40	13,070	3.35
0.280	3.538	0.001	9.84	25,640	3.46
0.420	6.781	0.003	14.80	49,140	3.59
0.565	10.85	0.007	20.02	78,630	3.65
0.688	15.07	0.012	24.50	109,200	3.75
0.833	20.71	0.019	29.82	150,100	3.84
0.920	24.51	0.025	33.08	177,600	3.89
0.561	10.73	0.007	19.88	77,760	3.65
0.703	15.63	0.012	25.02	113,300	3.77
0.127	10.24	0.000	4.44	7,421	3.30
0.900	23.64	0.024	32.34	171,300	3.88
0.699	15.34	0.012	24.88	111,200	3.73
0.498	8.833	0.005	17.61	64,010	3.61
0.080	0.527	0.000	2.82	3,819	3.40

Tennessee Valley Authority

Wheeler Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G. O. ft.	H ft.	Q cfs	C
0.0286	0.096	0.3164	0.000	0.98	3.30	2,188	3.71
	0.131	0.3794	0.000		4.50	2,624	3.72
	0.240	0.5280	0.000		8.24	3,651	3.71
	0.279	0.5704	0.000		9.58	3,945	3.70
	0.417	0.6987	0.000		14.32	4,832	3.68
	0.344	0.6346	0.000		11.82	4,389	3.70
	0.184	0.4629	0.000		6.32	3,201	3.74
	0.508	0.7730	0.000		17.45	5,346	3.66
0.0575	0.160	0.7723	0.000	1.98	5.50	5,341	3.54
	0.197	0.8797	0.000		6.77	6,083	3.56
	0.114	0.6192	0.000		3.92	4,282	3.53
	0.251	1.015	0.000		8.62	7,019	3.57
	0.294	1.112	0.000		10.10	7,690	3.59
	0.355	1.235	0.000		12.19	8,541	3.59
	0.412	1.338	0.000		14.15	9,253	3.58
	0.497	1.480	0.000		17.07	10,230	3.59
0.0875	0.116	0.8990	0.000	3.00	3.98	6,220	3.26+ 3.71*
	0.151	1.061	0.000		5.19	7,340	3.56
	0.195	1.273	0.000		6.70	8,803	3.58
	0.229	1.416	0.000		7.87	9,792	3.59
	0.269	1.568	0.000		9.24	10,840	3.61
	0.310	1.706	0.000		10.65	11,800	3.61
	0.379	1.922	0.000		13.02	13,290	3.63
	0.447	2.116	0.000		15.35	14,630	3.64
	0.478	2.196	0.000		16.42	15,190	3.64
	0.504	2.261	0.000		17.31	15,640	3.64
0.1166	0.151	1.385	0.000	4.00	5.19	9,578	3.38+ 3.79*
	0.186	1.560	0.000		6.39	10,790	3.61
	0.228	1.796	0.000		7.83	12,420	3.59
	0.283	2.080	0.000		9.72	14,380	3.60
	0.334	2.320	0.001		11.51	16,040	3.62
	0.396	2.576	0.001		13.64	17,810	3.63
	0.454	2.793	0.001		15.63	19,310	3.64
	0.512	2.997	0.001		17.62	20,730	3.64
	0.511	2.990	0.001		17.59	20,680	3.64

*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

Wheeler Project

Tainter Gates Partially Opened

MODEL TEST DATA				EQUIVALENT PROTOTYPE			
G.O. ft.	D ft.	Q cfs	h ft.	G.O. ft.	H ft.	Q cfs	C
0.2037	0.258	3.299	0.001	7.00	8.90	22,810	3.58+ 3.98*
	0.276	3.358	0.001		9.51	23,220	3.82
	0.288	3.467	0.001		9.93	23,980	3.80
	0.322	3.684	0.001		11.10	25,480	3.70
	0.365	4.007	0.002		12.61	27,710	3.67
	0.418	4.430	0.002		14.43	30,640	3.70
	0.456	4.677	0.002		15.73	32,340	3.68
	0.497	4.945	0.002		17.14	34,200	3.69
	0.421	4.434	0.002		14.53	30,660	3.68
0.2912	0.365	5.866	0.003	10.00	12.64	40,570	3.76+ 4.16*
	0.404	5.977	0.003		13.98	41,330	3.88
	0.418	6.081	0.003		14.46	42,050	3.85
	0.436	6.243	0.003		15.08	43,170	3.82
	0.461	6.502	0.004		15.97	44,960	3.81
	0.500	6.841	0.004		17.31	47,310	3.77

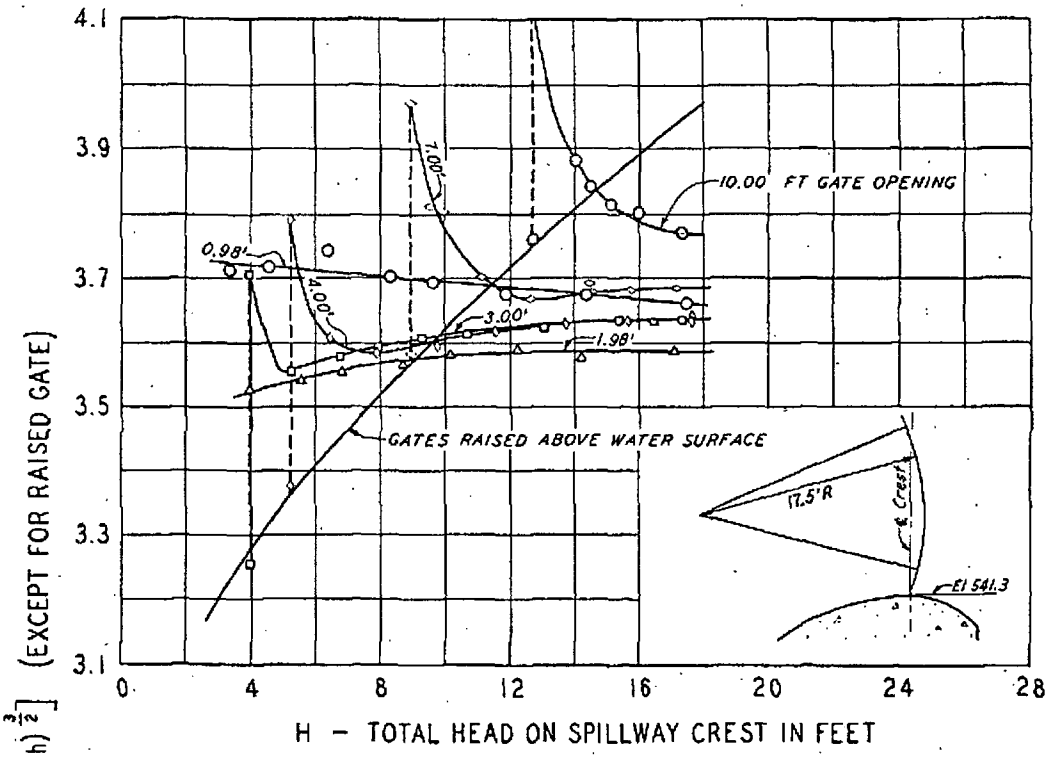
*Gate lip touching nappe C from Equation A.
+Gate lip touching nappe C from Equation B.

Tennessee Valley Authority

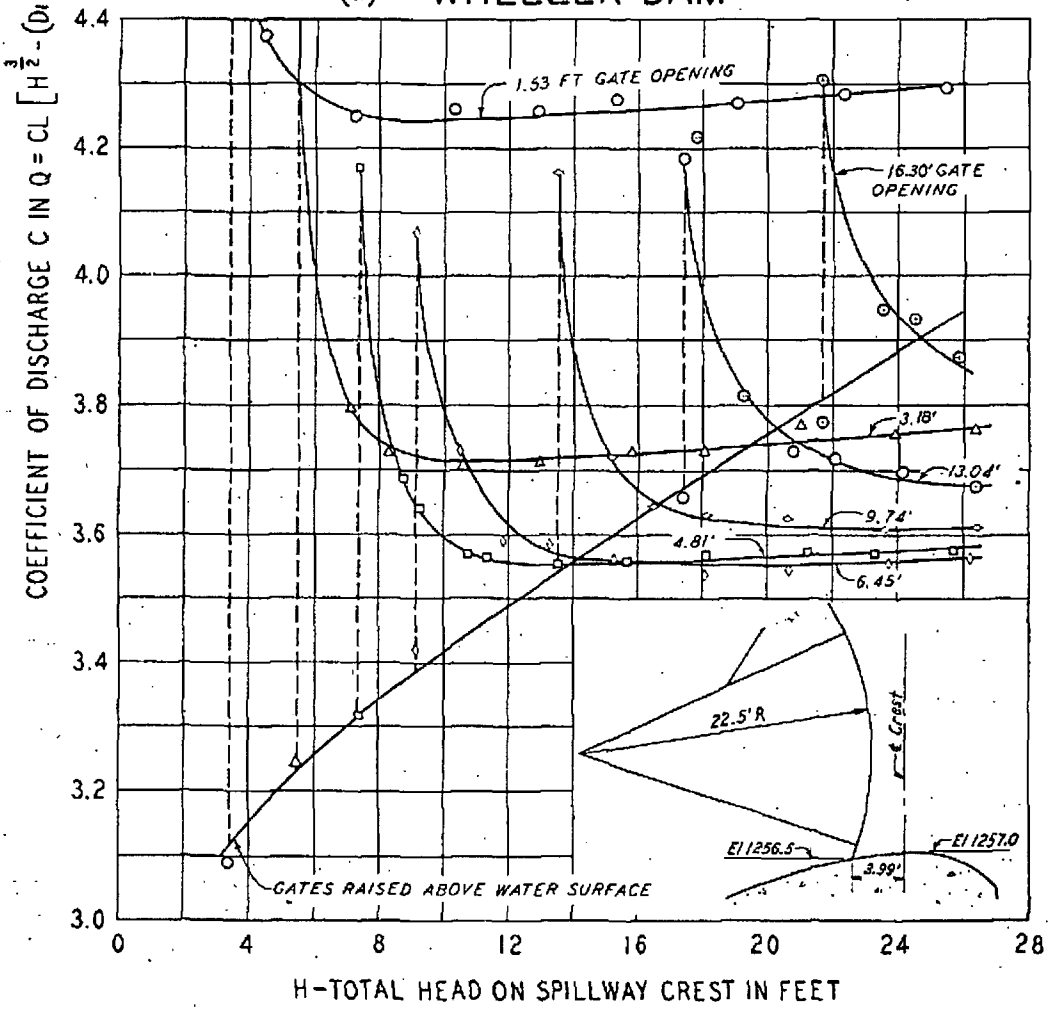
Wheeler Project

Tainter Gates Raised Above Water Surface

MODEL TEST DATA			EQUIVALENT PROTOTYPE		
D	Q	h	H	Q	C
ft.	cfs	ft.	ft.	cfs	
0.178	1.786	0.000	6.11	12,350	3.41
0.214	2.444	0.001	7.39	16,900	3.51
0.281	3.788	0.002	9.72	26,200	3.60
0.307	4.386	0.002	10.58	30,330	3.67
0.347	5,348	0.003	12.02	36,980	3.70
0.390	6.559	0.004	13.53	45,360	3.80
0.440	8,038	0.006	15.32	55,590	3.86
0.405	6.998	0.004	14.05	48,400	3.83
0.366	5.892	0.003	12.68	40,750	3.76
0.191	1.996	0.000	6.56	13,800	3.42
0.218	2.490	0.001	7.52	17,220	3.48
0.279	3.742	0.002	9.65	25,880	3.60
0.306	4.366	0.002	10.58	30,190	3.66
0.416	7.316	0.005	14.46	50,590	3.83
0.465	8.775	0.006	16.18	60,680	3.89
0.499	9.914	0.009	17.45	68,560	3.92
0.305	4.314	0.002	10.55	29,830	3.63
0.076	0.464	0.000	2.61	3,209	3.16
0.123	1.004	0.000	4.23	6,943	3.34
0.155	1.444	0.000	5.32	9,986	3.39
0.116	0.8990	0.000	3.98	6,220	3.26
0.151	1.385	0.000	5.19	9,578	3.38
0.258	3.299	0.001	8.90	22,810	3.58
0.365	5.866	0.003	12.64	40,570	3.76



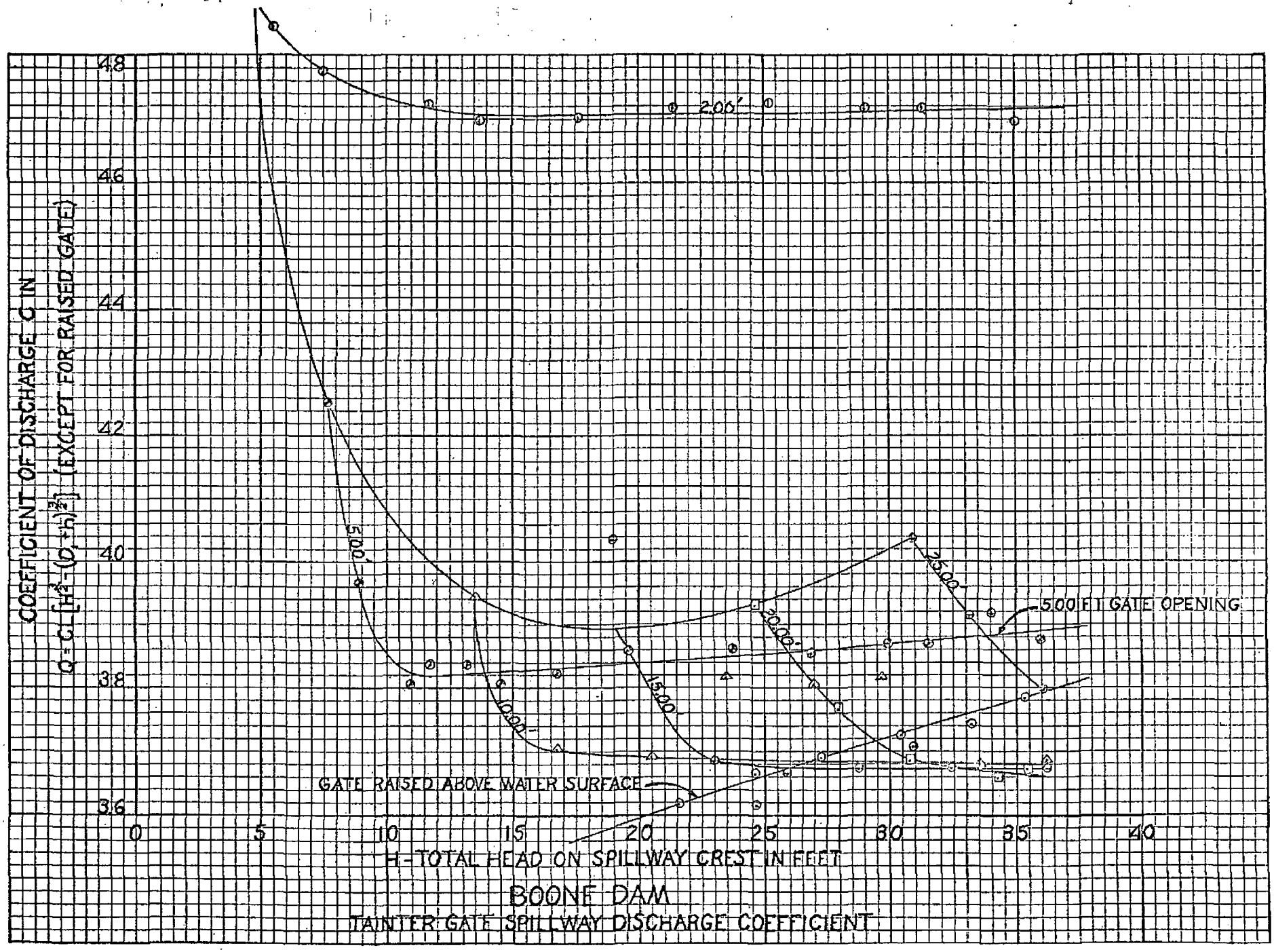
(a) WHEELER DAM



(b) APALACHIA DAM

TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

K+E 10 X 10 TO THE INCH 359-5
KEUFFEL & ESSER CO. MADE IN U.S.A.



BOONE DAM
TAINTER GATE SPILLWAY DISCHARGE COEFFICIENT

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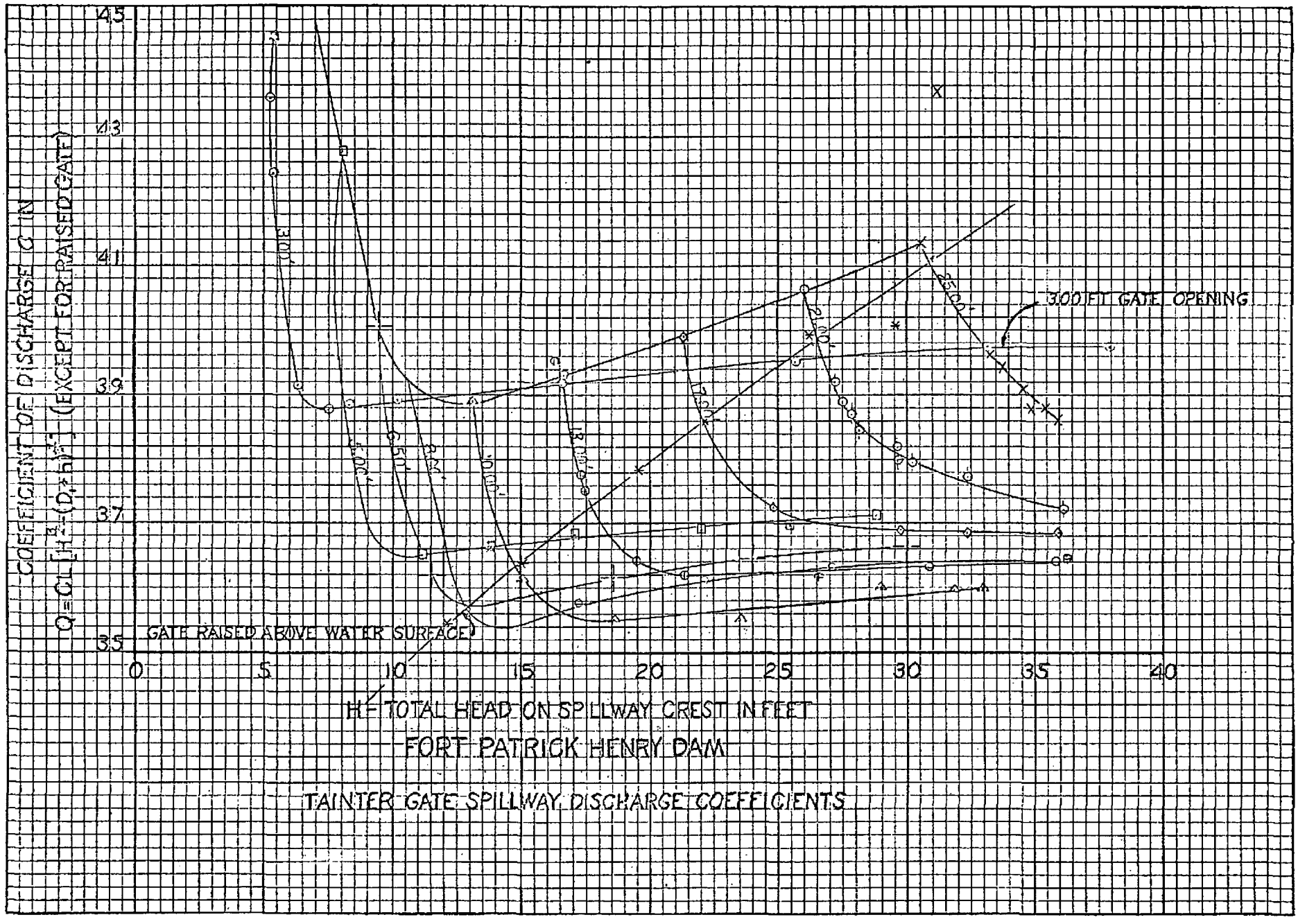
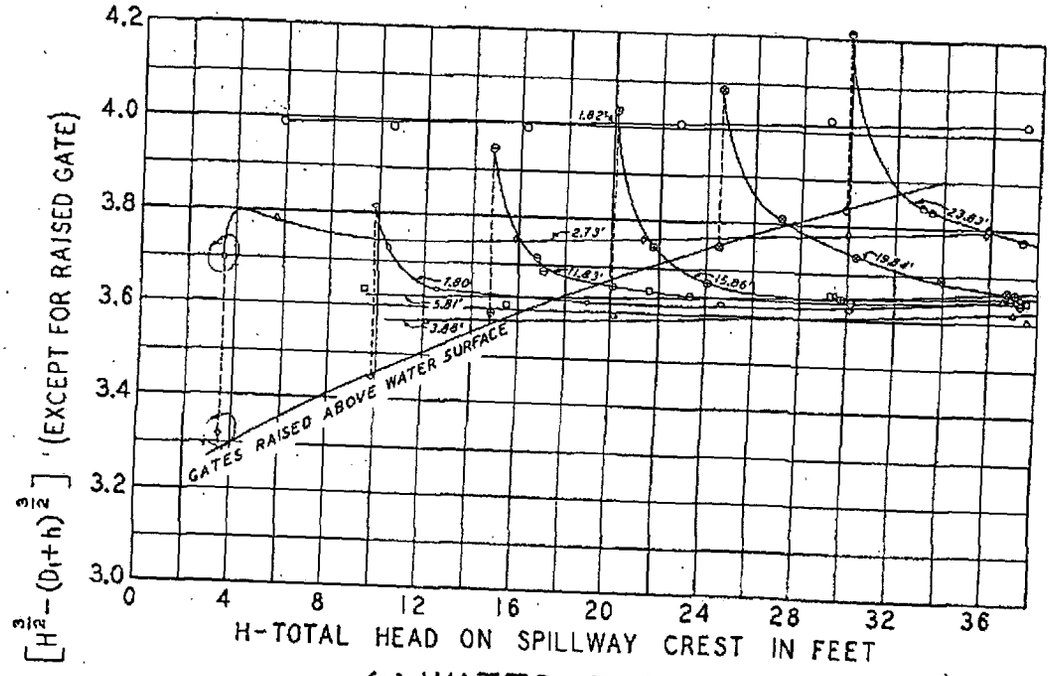
KEUFFEL & ESSER CO. MADE IN U.S.A.

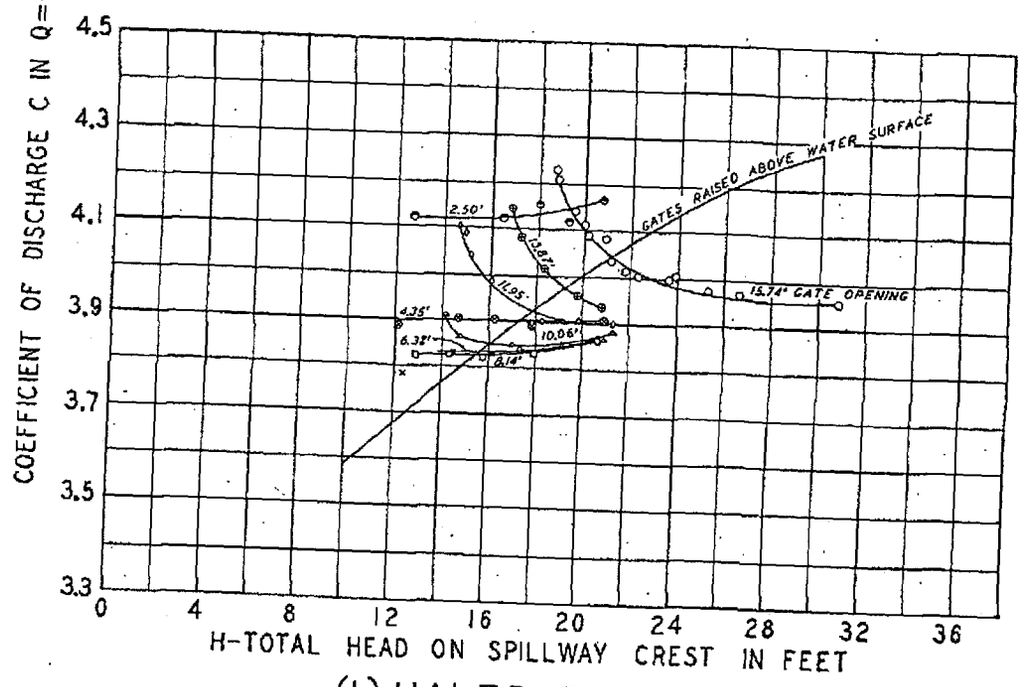


FORT PATRICK HENRY DAM

TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS

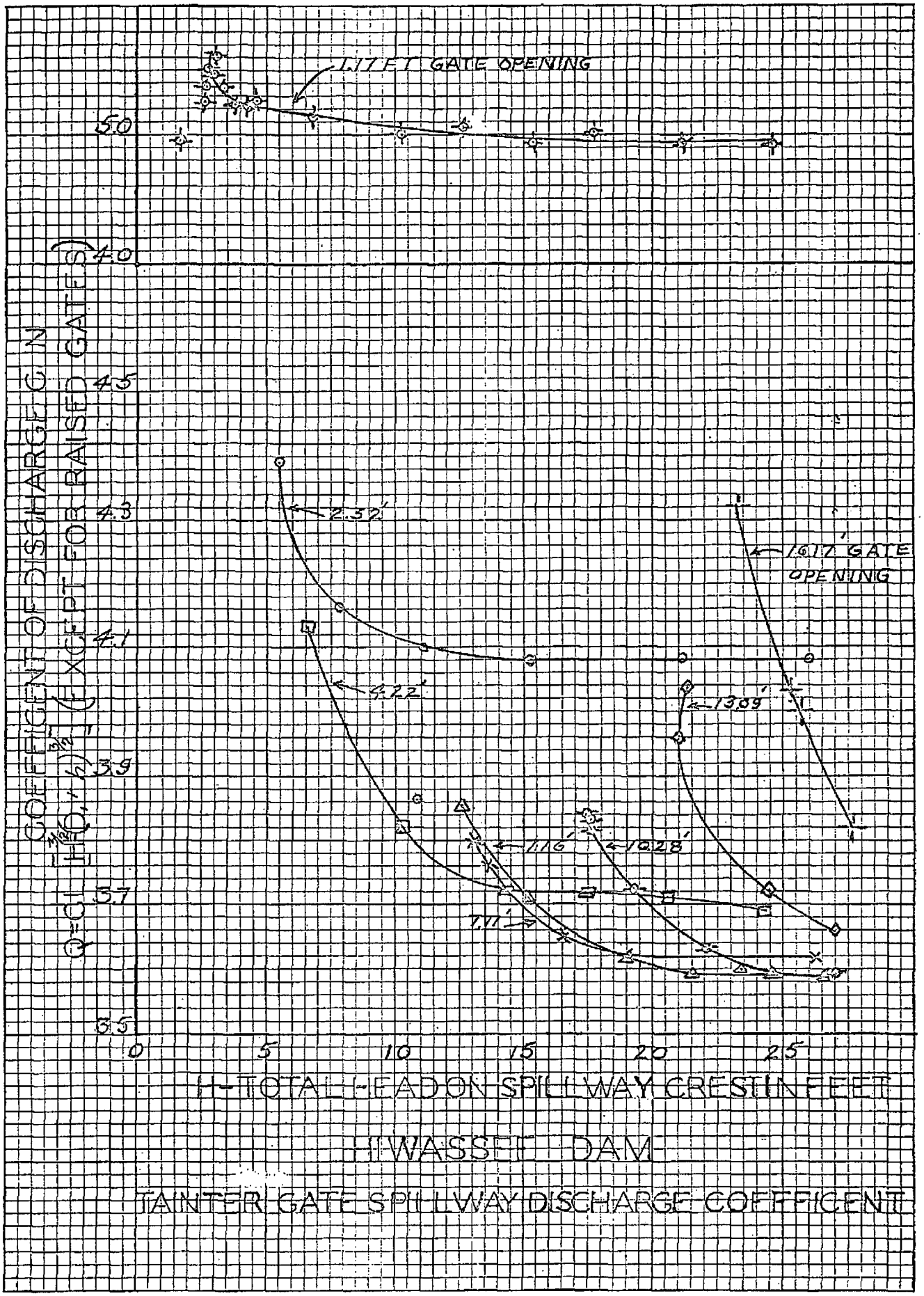


(a) WATTS BAR DAM

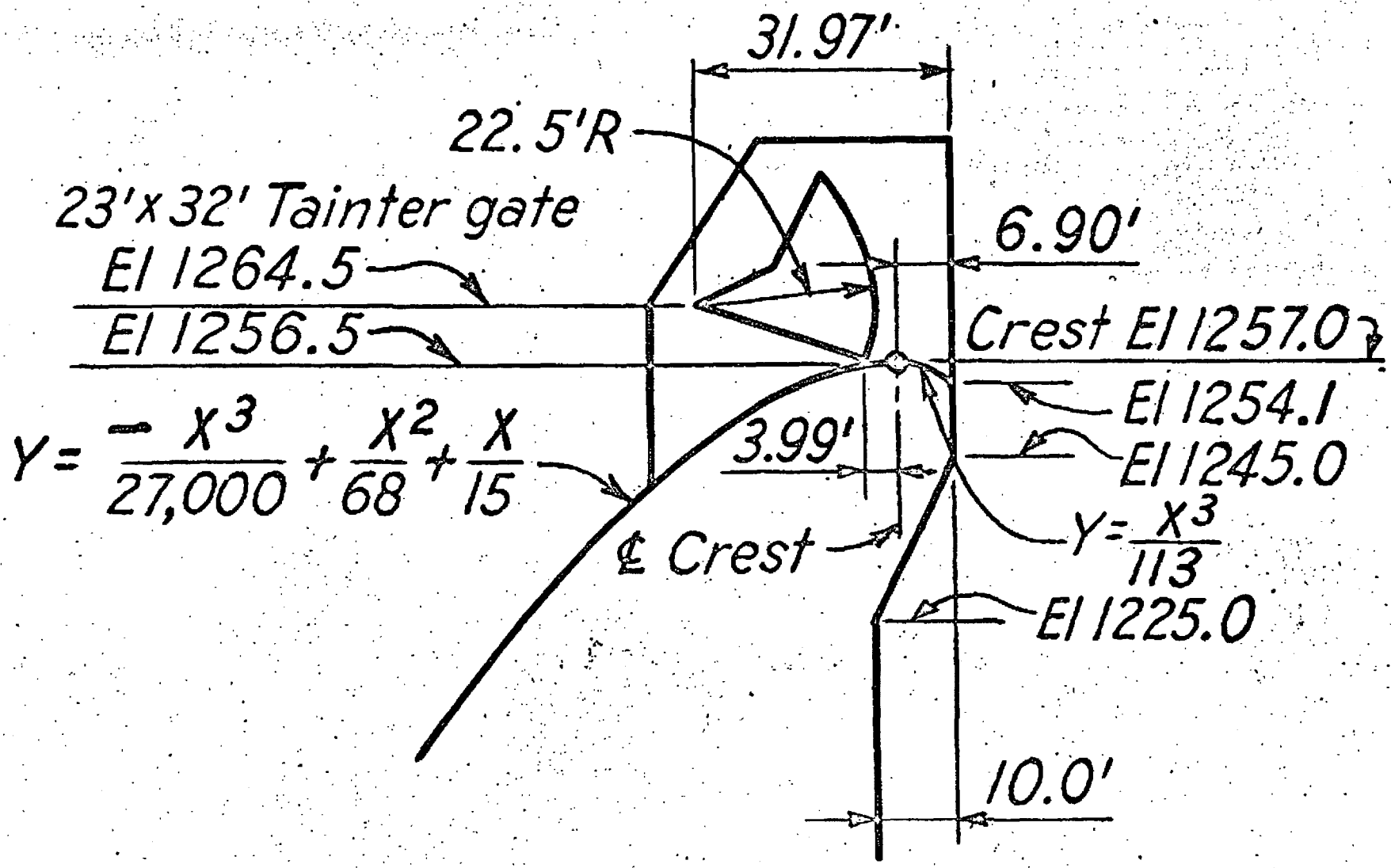


(b) HALES BAR DAM

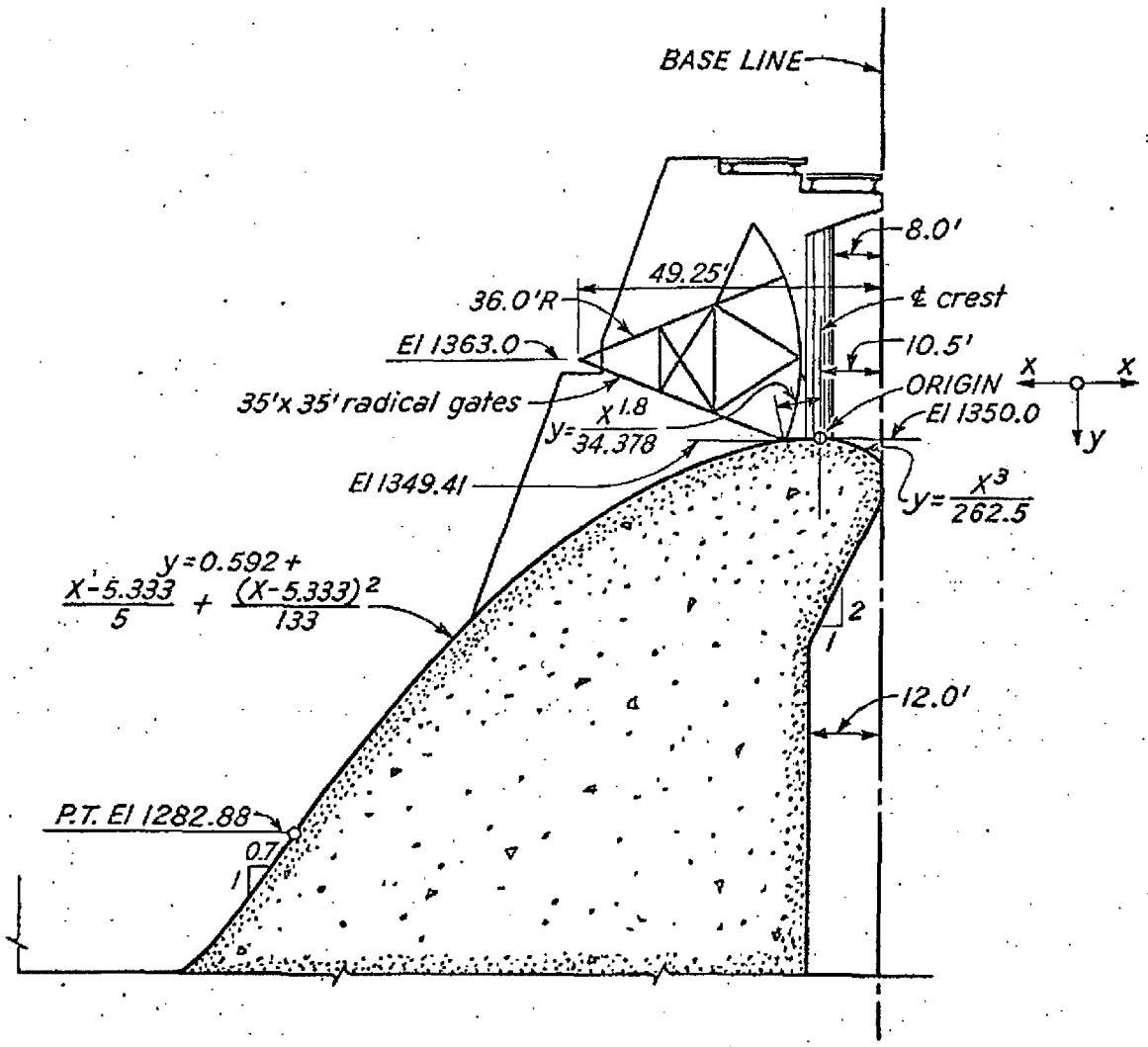
TAINTER GATE SPILLWAY DISCHARGE COEFFICIENTS



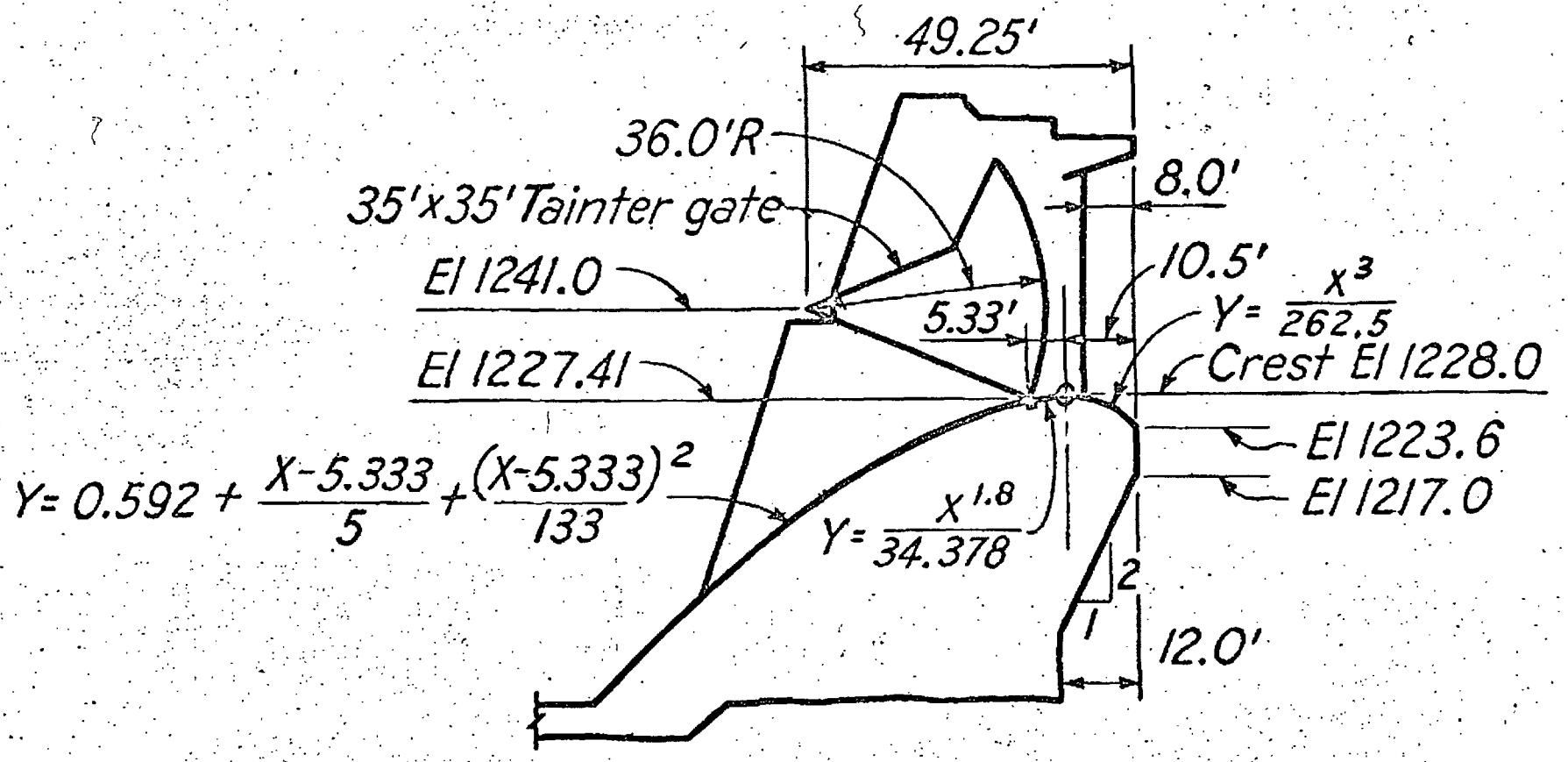
K+E 10 X 10 TO THE INCH 359-5 KEUFFEL & ESSER CO. MADE IN U.S.A.



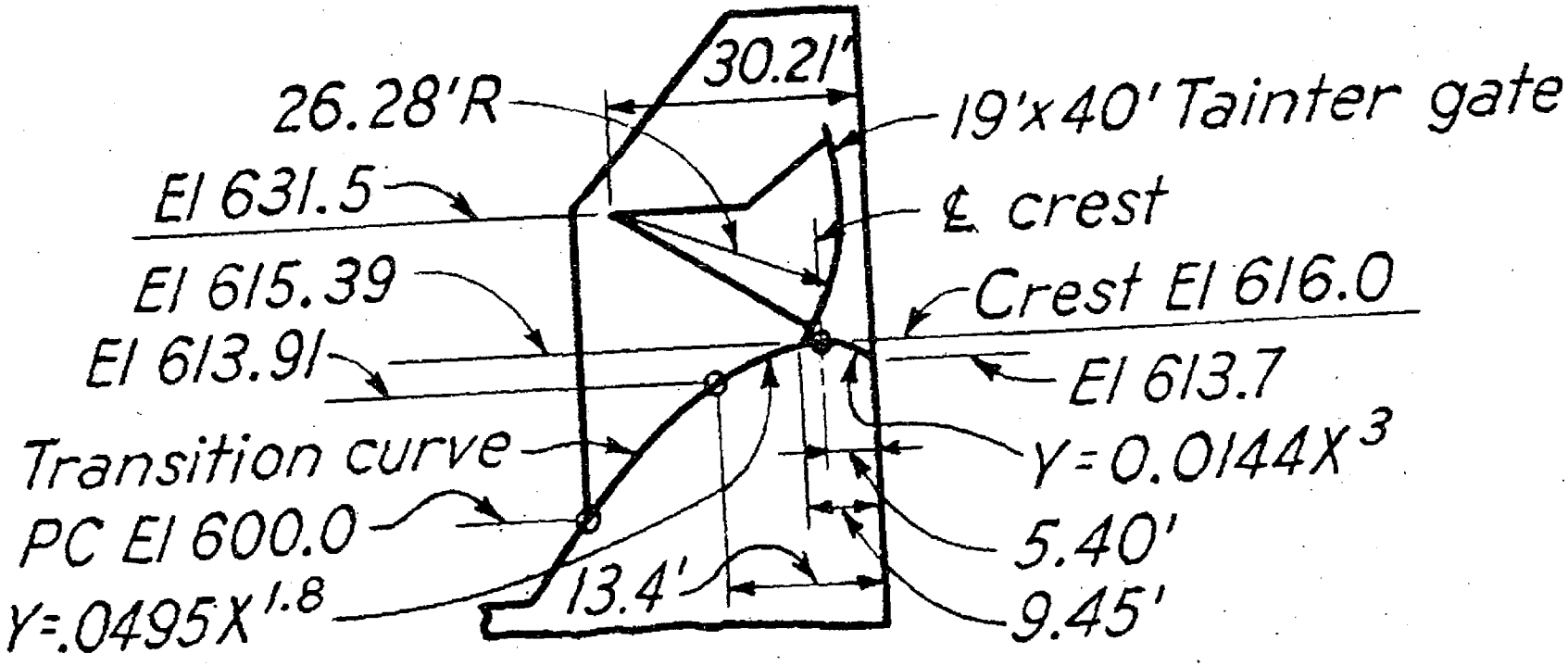
APALACHIA PROJECT



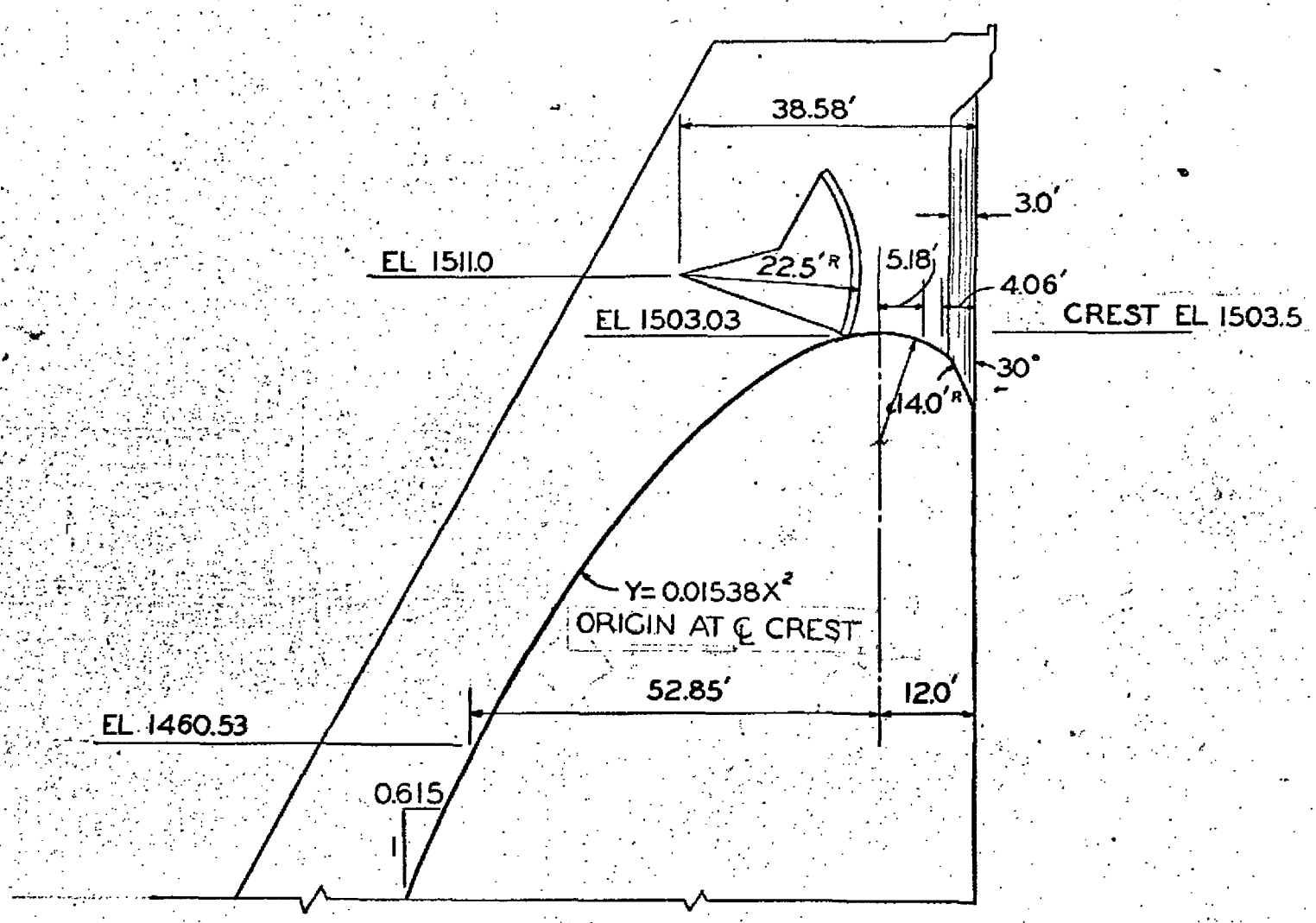
BOONE PROJECT



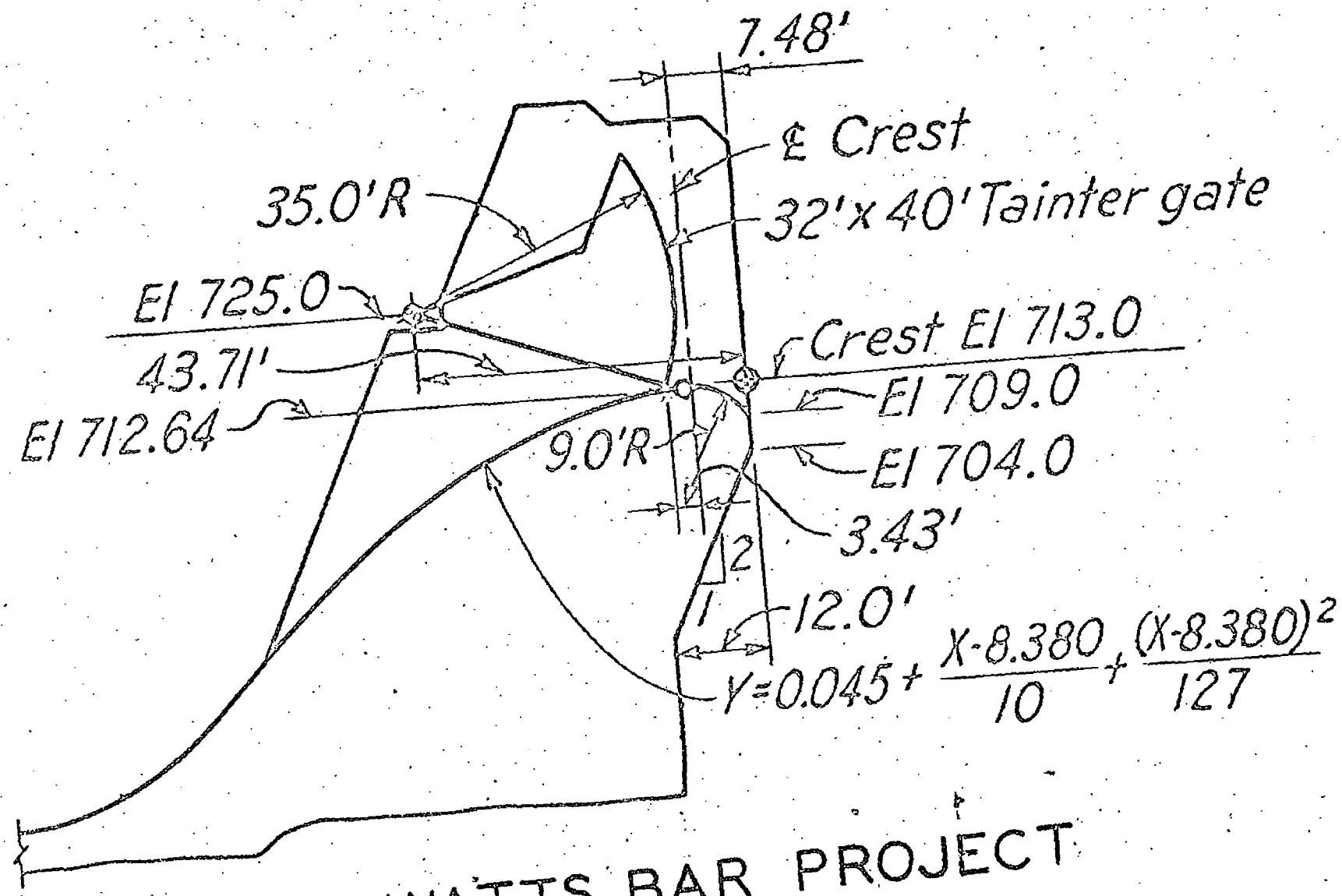
FORT PATRICK HENRY PROJECT



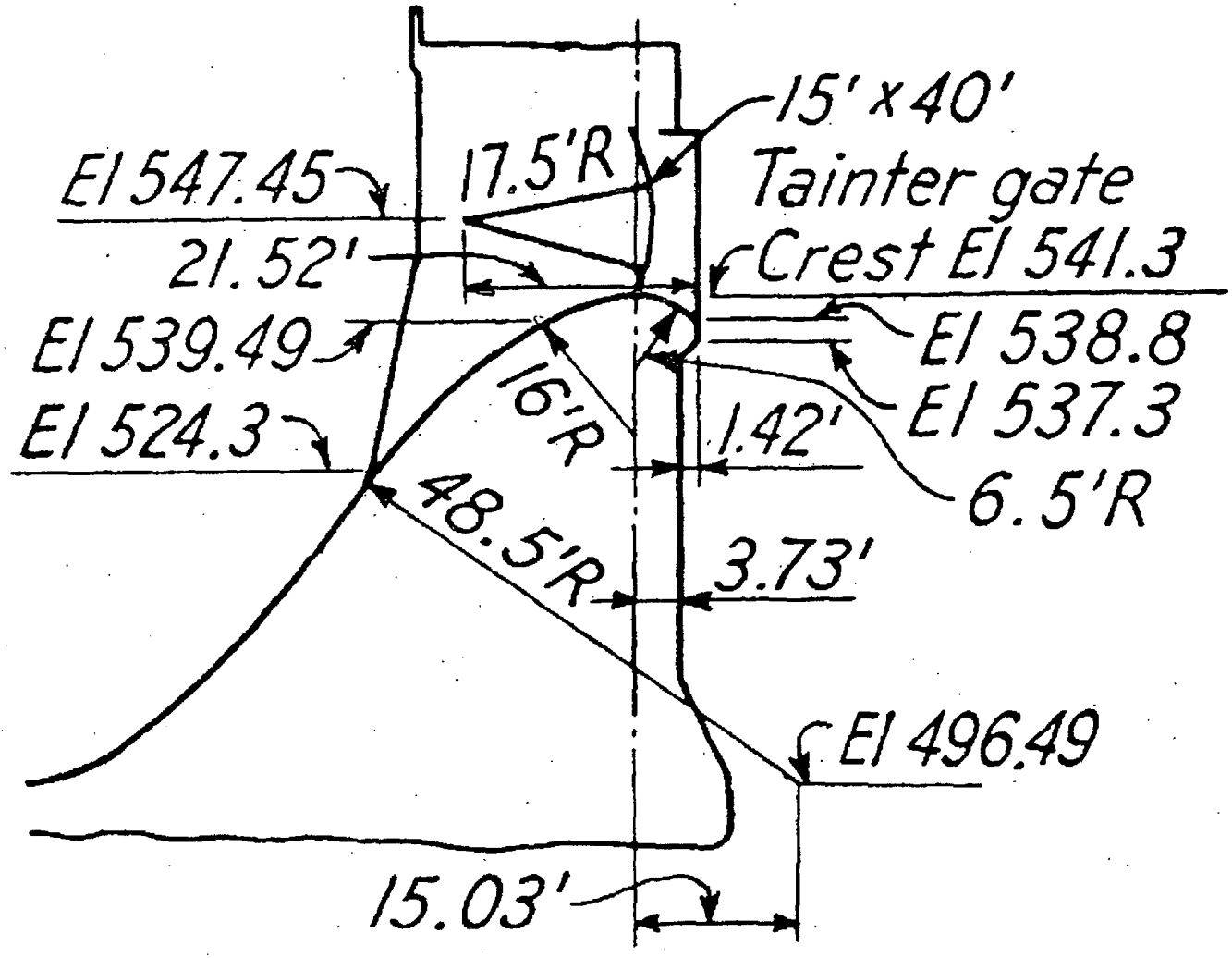
HALES BAR PROJECT



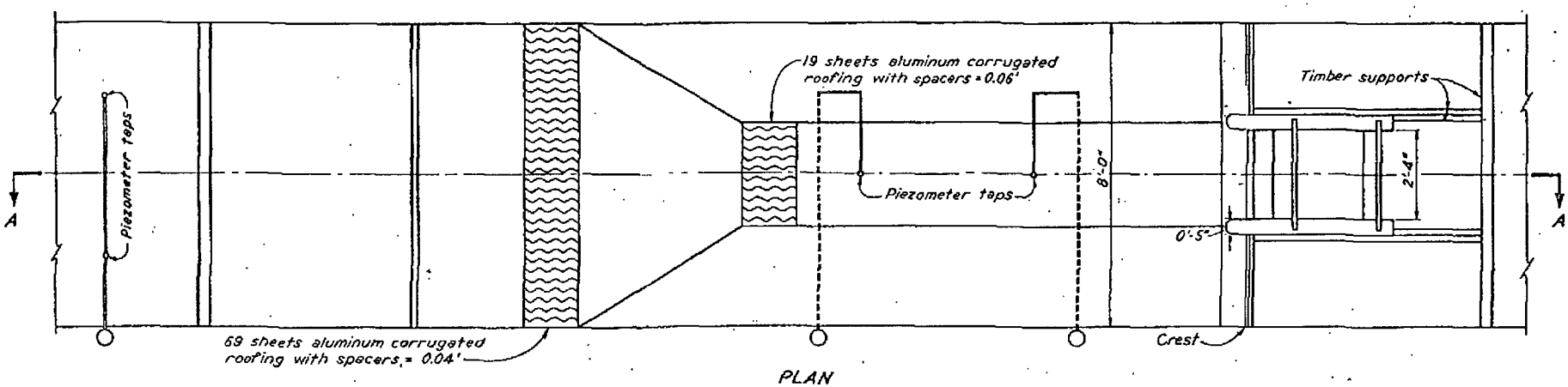
HIWASSEE PROJECT



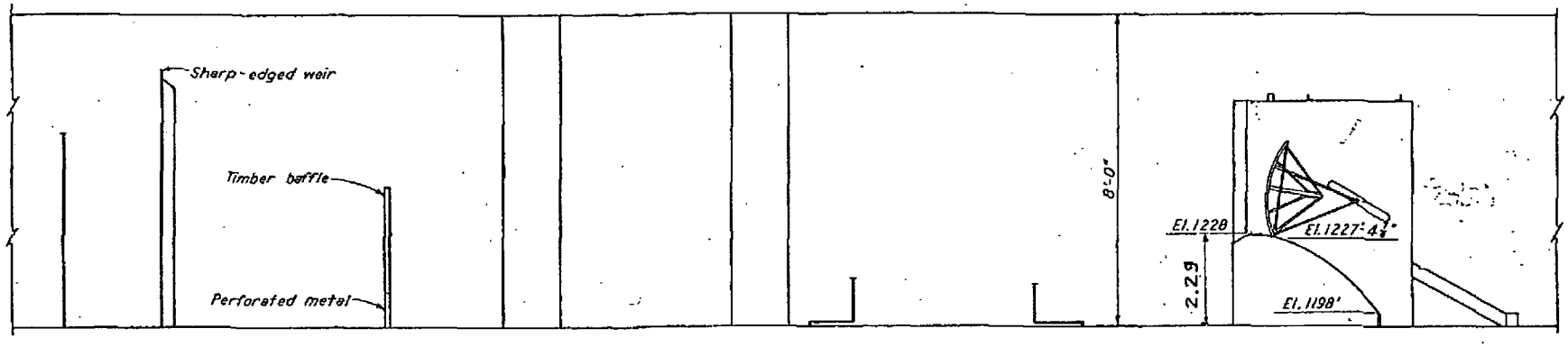
WATTS BAR PROJECT



WHEELER PROJECT



PLAN



SECTION A-A

Scales

1" Model 0 1 2 3 4 5 6 7 8 9 10 Feet

Prototype 0 20 40 60 80 100 Feet

NOTE:

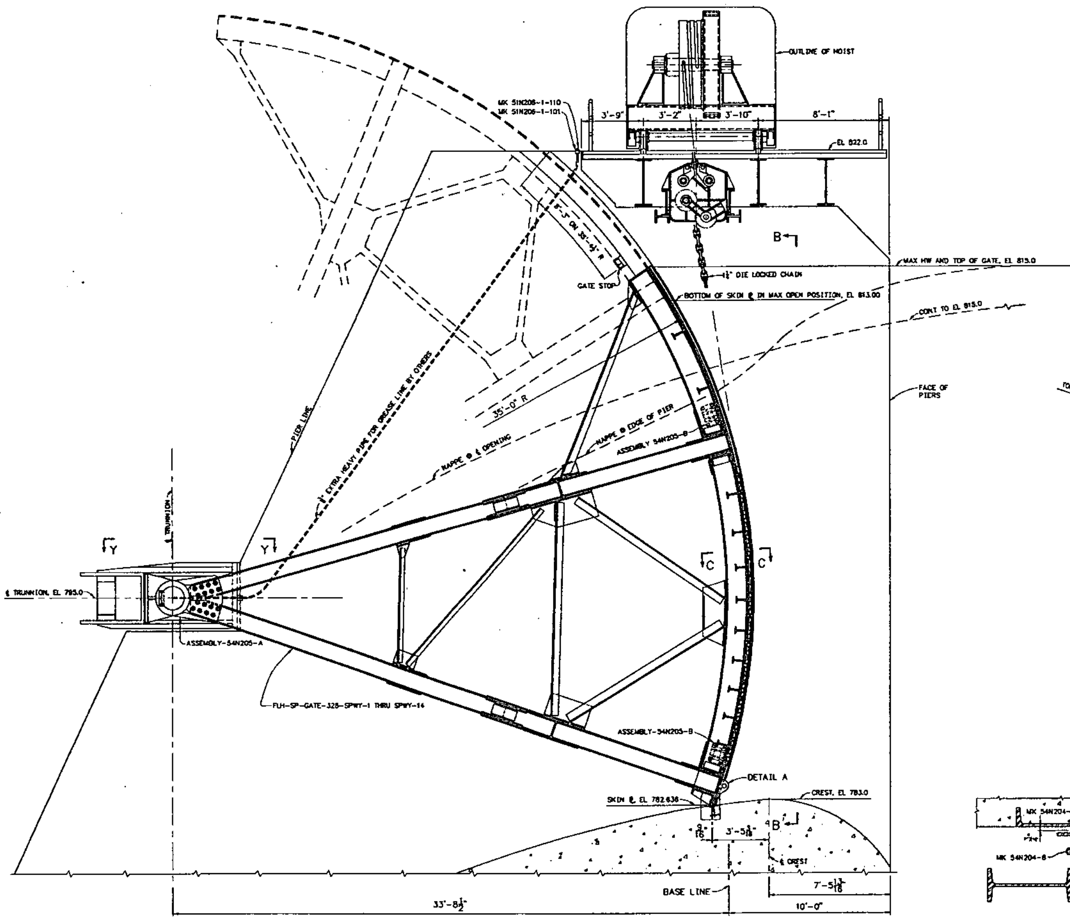
Elevations refer to the prototype.
Dimensions refer to the model.

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

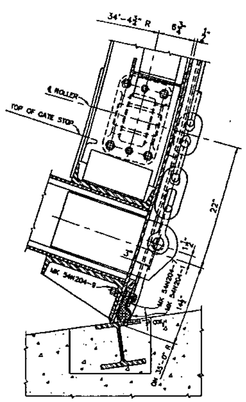
FORT PATRICK HENRY PROJECT
HYDRAULIC MODEL STUDIES

1:15 SCALE MODEL LAYOUT

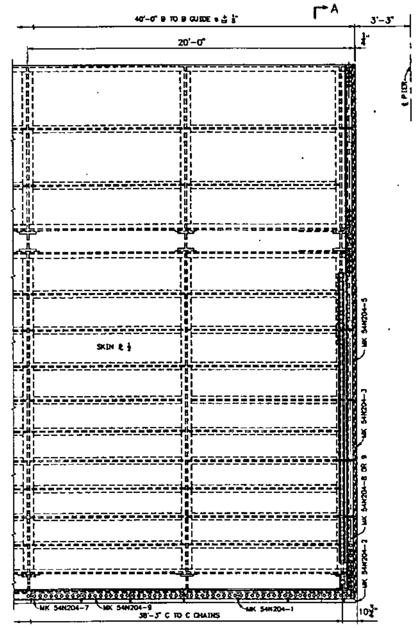
44



SECTION A-A



DETAIL A
SCALE: 1 1/2"=1'-0"



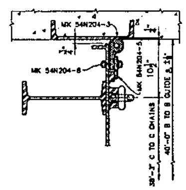
UPSTREAM ELEVATION B-B

NOTES:
1. FOR MANUFACTURER'S DETAILS OF SPILLWAY GATES, REFER TO LAKESIDE BRIDGE & STEEL CO. FILE, TVA CONTRACT NO. TV-55367.
2. COMPONENT UNID NUMBERING SCHEME:

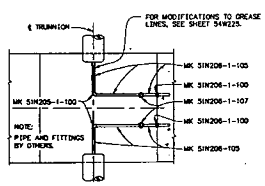
PLANT	UNIT	FUNCTION	SYSTEM	SEQUENCE NO.
FLH	SP	GATE	328	SPWY-1

3. UNIDS ARE LISTED IN WHOLE ON THIS DRAWING.
4. COMPONENT UNID NUMBERS USE THE FOLLOWING SYSTEM AND FUNCTION CODES:

SYSTEM NUMBERS - SYSTEM NAME:	FUNCTION CODES - FUNCTION CODE NAMES:
328 - SPILLWAY	GATE - GATE



SECTION C-C
SCALE: 1 1/2"=1'-0"



SECTION Y-Y

PROJECT REVISION HISTORY

R5	07/02/2004	RLI	KOK	RLI	RAJ	RWT	RWT	MAC		D
ADDED NOTE FOR SECTION Y-Y										
JUN 01 2007		JLW	DMC	JLW	JLW	TKM	RWT	MAC	HYD043M-27	C
DCN FLH-06-44; REVISED FOR CRITICAL STRUCTURES, SYSTEMS & COMPONENTS VERIFICATION										
R 4	01/28/2004	JMR	JMR	SRK	VAN	VAN	RWT	MAC		H
ELECTRONICALLY RESTORED										

SCALE: 3/8" = 1'-0" EXCEPT AS NOTED

SPILLWAY

GATES
GENERAL ARRANGEMENT

DESIGNED BY:	DRAWN BY:	CHECKED BY:	SUPERVISED BY:	REVIEWED BY:	APPROVED BY:	ISSUED BY:
	C.O.W.	L.W.A.	W.R.M.			

FORT LOUDOUN HYDRO PLANT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

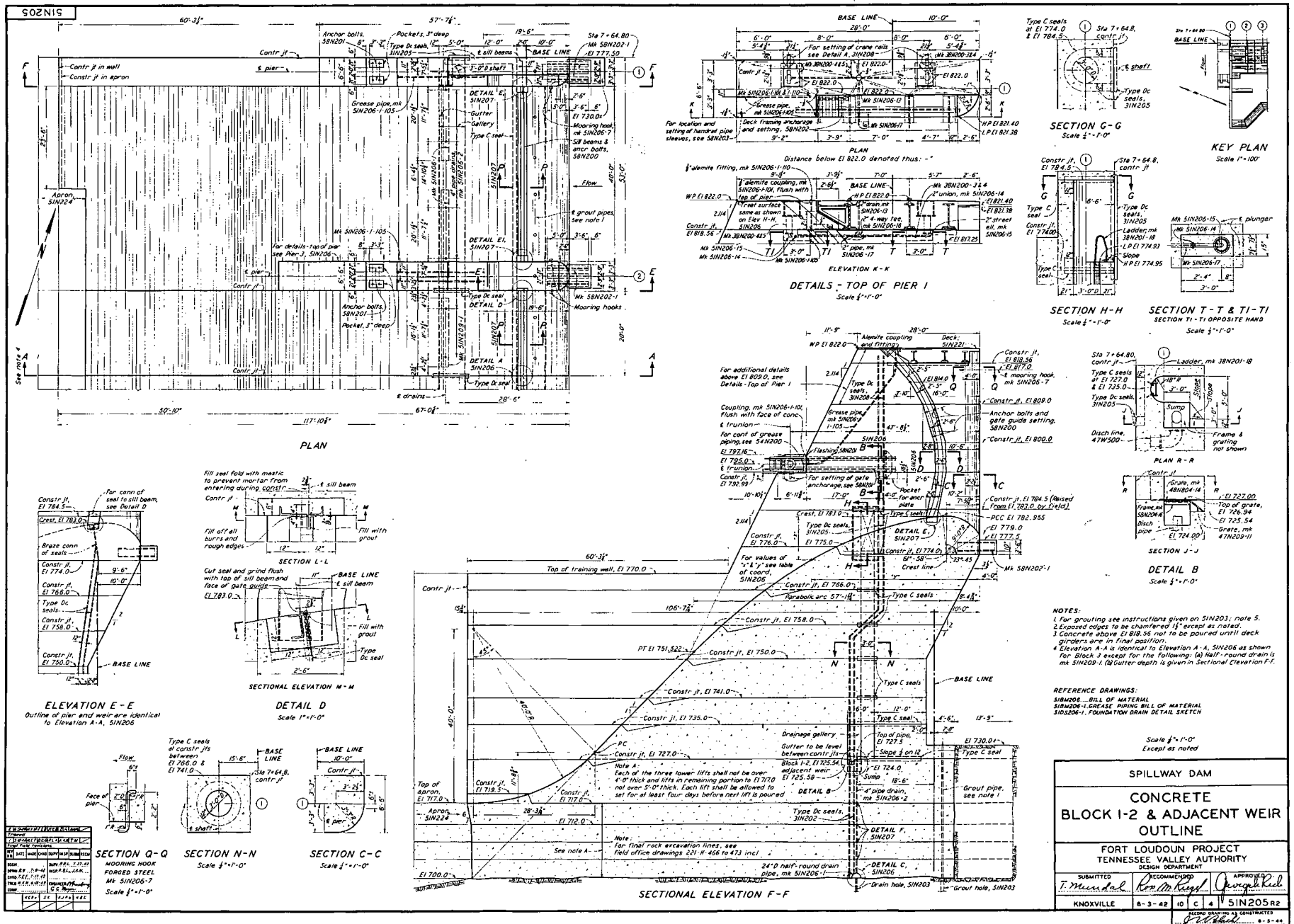
AUTOCAD R14 | DATE 5-27-41 | 10 | M | 54W200 | R 6

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES :(54N200 R3)

TASK COMPLETED BY: | REV NO.

PLOT FACTOR:32
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY


5IN205
PLAN
DETAILS - TOP OF PIER I
Scale ½"=1'-0"
ELEVATION K-K
SECTION G-G
Scale ½"=1'-0"
KEY PLAN
Scale 1"=100'
SECTION H-H
Scale ½"=1'-0"
SECTION T-T & TI-TI
SECTION TI-TI OPPOSITE HAND
Scale ½"=1'-0"
PLAN R-R
SECTION J-J
DETAIL B
Scale ½"=1'-0"
ELEVATION E-E
Outline of pier and weir are identical to Elevation A-A, 5IN206
SECTION L-L
SECTIONAL ELEVATION M-M
DETAIL D
Scale 1"=1'-0"
SECTION Q-Q
MOORING HOOK
FORGED STEEL
Mk 5IN206-7
Scale ½"=1'-0"
SECTION N-N
Scale ½"=1'-0"
SECTION C-C
Scale ½"=1'-0"
SECTIONAL ELEVATION F-F
NOTES:
1. For grouting see instructions given on 5IN203; note 5.
2. Exposed edges to be chamfered 1½" except as noted.
3. Concrete above El 818.56 not to be poured until deck girders are in final position.
4. Elevation A-A is identical to Elevation A-A, 5IN206 as shown for Block 3 except for the following: (a) Half-round drain is mk 5IN209-1. (b) Gutter depth is given in Sectional Elevation F-F.
REFERENCE DRAWINGS:
5IBM206 - BILL OF MATERIAL
5IBM206-1 GREASE PIPING BILL OF MATERIAL
5IDS206-1 FOUNDATION DRAIN DETAIL SKETCH
Scale ½"=1'-0"
Except as noted
SPILLWAY DAM
CONCRETE
BLOCK 1-2 & ADJACENT WEIR
OUTLINE
FORT LOUDOUN PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
KNOXVILLE
8-3-42
10
C
4
5IN205R2