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

ASSOCIATED ATTACHMENTS/ENCLOSURES:

Attachment 02.04.03-8T: Dam Rating Curves, Watuaga

(181 Pages including Cover Sheet)

NPG CALCULATION COVERSHEET/CCRIS UPDATE

Page 1

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
L58 090120 002	Calculations (nuclear)	L58 091230 031

Calc Title: Dam Rating Curve, Watauga

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	GEN	CEB	CDQ000020080019	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
J. B. Mauter	(205)298-6074	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Janie B. Mauter Janie B Mauter	12/7/09	Andrew C. Murr	12/7/09
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
Andrew C. Murr	12/7/09	K.R. States	12/23/09

STATEMENT OF PROBLEM/ABSTRACT

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 headwater rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents headwater rating curves for Watauga 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
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: LP4D-C
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO. L58 090120 002	**EDMS TYPE:** Calculations (nuclear)	**EDMS ACCESSION NO (N/A for REV. 0)** N/A

Calc Title: Dam Rating Curves, Watauga

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	CDQ000020080019	N/A	0	

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

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

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
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
W. H. Roberts	632-6465	CEB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
W. H. Roberts W.H. Roberts	1-7-2009	JANIE B. MAUTER	1/7/09
VERIFIER SIGNATURE ANDREW C. MURR MICHAEL T. STALEY	**DATE** 1-7-09 01/08/09 1-19-09	**APPROVAL SIGNATURE** K. R. Spates K.R. SPATES	**DATE** 1/20/09

STATEMENT OF PROBLEM/ABSTRACT

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 headwater rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents headwater rating curves for Watauga Dam.

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

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

NPG CALCULATION COVERSHEET/CCRIS UPDATE

Page 2

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	GEN	CEB	CDQ000020080019	1

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report
				BWSC	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	CDQ000020080053	
D	S	CN	GEN	CEB	CDQ000020080054	

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 CDQ000020080019

Title Dam Rating Curve, Watauga

Revision No.	DESCRIPTION OF REVISION
0	Initial issue Total pages: 101
1	This calculation was revised to address the following: • PER 203951. The verification of the original calculation was completed by personnel who had not completed the required NEDP-7 Job Performance Record (JPR). A verification JPR is now in place for all personnel engaged in verification tasks. Checking 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. NEDP-2 forms have been replaced with correct forms except for the signed coversheet for Revision 0. • Remove Unverified Assumption 3.2.1. Replace with Assumption 3.1.3. • Remove Unverified Assumption 3.2.2. Replace with Assumption 3.1.4. Significant changes to text are marked with a right hand margin revision bar. Administrative changes and typos are excluded. Pages Deleted: None Pages Revised: 1 - 4, 6, 10, 11 New Pages Added: 1a, 5 Total pages Revision 1: 103 Additional Comments: • Rev. 0 coversheet is page 1a. • Coversheet and CCRIS form updated to include EDCN numbers and add/revise calculation references. • Updated page numbers from page 5 through 103 for added page and page text rollover. • Added Verification Form. • Added Reference 14. • Revise page 11 to remove UVAs and add Verified Assumptions. • Updated Form identifiers in the footer of pages 1 through 6.

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: CDQ000020080019	Revision: 1	

TABLE OF CONTENTS

NPG CALCULATION VERIFICATION FORM

Calculation Identifier CDQ000020080019 Revision 1

Method of verification used:

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

Verifier Andrew C. Murr Date 12/7/09

Comments:

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

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

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

NPG COMPUTER INPUT FILE STORAGE INFORMATION SHEET

Document CDQ000020080019	Rev. 1	Plant: GEN	

Subject:
Dam Rating Curve, Watauga

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

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

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

Attachment 9: "Watauga Dam Howell-Bunger Valve Discharge Tables," Tennessee Valley Authority, July 1974 (Ref. 4)
Attachment 10: TVA Water Control Project Manual (Blue Book) for Watauga Dam, TVA River Operations, September, 1999
Attachment 11: TVA Report No. 18-10-1, "Advance Report No. 1 Watauga Model Studies", June 1944 (Ref. 3)
Attachment 12: "South Holston Dam Howell-Bunger Valve Discharge Tables," Tennessee Valley Authority, July 1974 (Ref. 5)
Attachment 13: Selected Watauga Project Drawings (Ref. 1.1 thru 1.10)
Attachment 14: Watauga Tailwater Rating Curve

☐ Microfiche/eFiche

1. Purpose

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 headwater rating curves for each dam provide total dam discharge as a function of headwater elevation. This calculation presents the headwater rating curve for Watauga Dam. This calculation does not evaluate the design loading conditions for the 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 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.

Figure 1 is a plan and elevation view of the dam (a portion of Ref. 1.1, Att. 1). Figure 2 shows sections through the spillway and sluiceway (a portion of Ref. 1.1). For headwaters in the normal operating range, discharge is passed through the turbines, the sluiceway, or the morning glory spillway. Sluice discharge is controlled by two Howell-Bunger valves. During a probable maximum flood (PMF) event headwater will rise above the normal operating range. However, discharge is not expected to pass over the dam because its top elevation was raised in 1983 as part of the dam safety modification program. The modifications were designed to ensure that the dam would not be overtopped during a PMF event (Ref. 2, Att. 2). Consequently, the rating curve developed in this calculation does not include headwater elevations above the top of the modified dam.

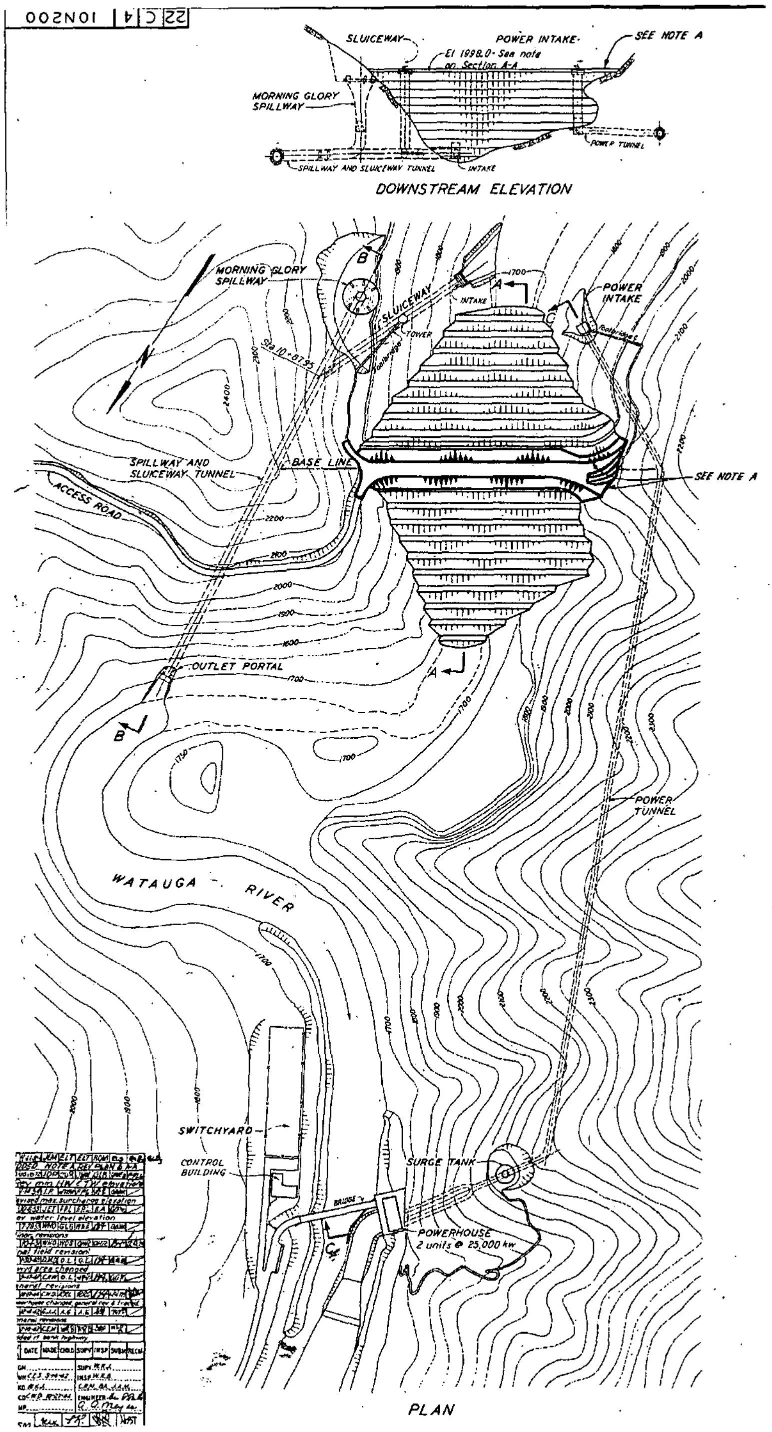
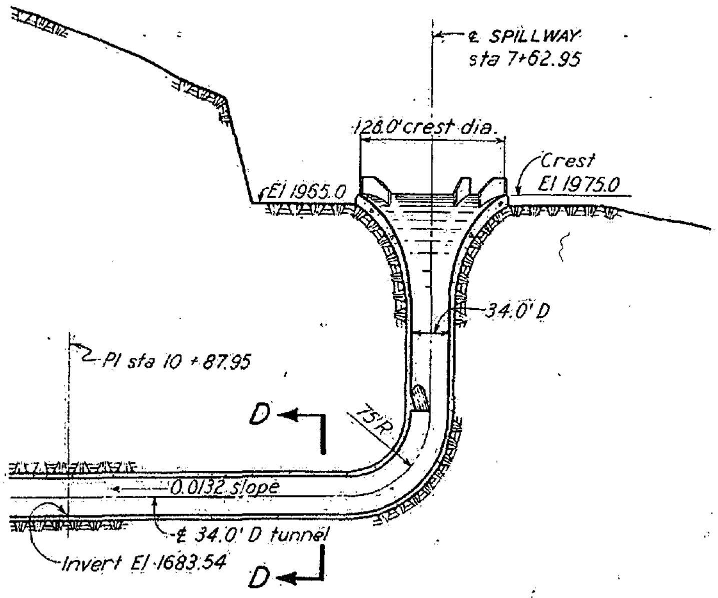
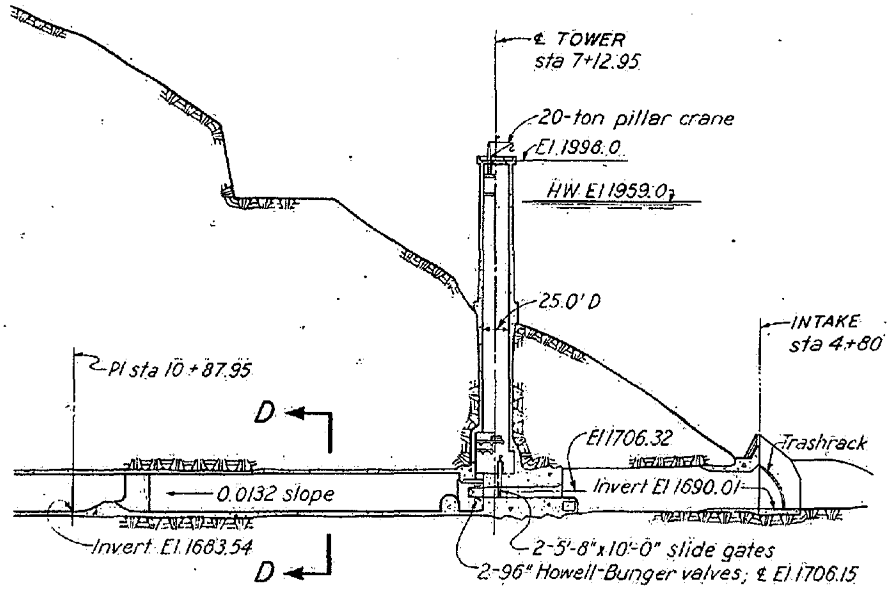


Figure 1 – Watauga Dam, General Plan and Elevation (Ref. 1.1).



SECTION THRU SPILLWAY



SECTION THRU SLUICEWAY

Figure 2 – Watauga Dam, Sections Through Spillway and Sluiceway (Ref. 1.1).

2. References

1.1. TVA Watauga Project drawing no: 10N200, R11
1.2. TVA Watauga Project drawing no: 21W200, R12
1.3. TVA Watauga Project drawing no: 31N201, R4
1.4. TVA Watauga Project drawing no: 51W200, R8
1.5. TVA Watauga Project drawing no: 51N201, R5
1.6. TVA Watauga Project drawing no: 51N203, R2
1.7. TVA Watauga Project drawing no: 51N206, R4
1.8. TVA Watauga Project drawing no: 54W220, R5
1.9. TVA Watauga Project drawing no: 10W250, R6
1.10. TVA Watauga Project drawing no: 46K205, R1
2. TVA Water Control Project Manual (Blue Book) for Watauga Dam, TVA River Operations, September, 1999
3. TVA Report No. 19-10-1, "Advance Report No. 1 Watauga Model Studies", June 1944
4. "Watauga Dam Howell-Bunger Valve Discharge Tables," Tennessee Valley Authority, July 1974
5. "South Holston Dam Howell-Bunger Valve Discharge Tables," Tennessee Valley Authority, July 1974
6. *Applied Hydrology and Sedimentology for Disturbed Areas*, Barfield, Warner and Haan, Oklahoma Technical Press, 1987
7. "Hydraulic Design Criteria", USACE (U. S. Army Engineer Waterways Experiment Station), Eighteenth issue, Vicksburg, MS, 1988
8. *Design of Small Dams*, Third Edition, United States Bureau of Reclamation, 1987
9. *Hydraulic Structures Design Manual 8 Discharge Characteristics*, D. S. Miller, A.A.Balkema Publishers, 1994
10.1. TVA South Holston Project drawing no: 51W200, R6
10.2. TVA South Holston Project drawing no: 54W220, R3
11. *Handbook of Hydraulics* Fifth Edition, King and Brater, McGraw-Hill, 1963
12. TVA files, binder titled "Tailwater Rating Curves by Project - River Scheduling"
13. TVA files, binder titled "South Holston Dam 96" Howell Bunger Valve Rating 6/19/73 KWK ARS"
14. "Basis For Dam Spillway Gate/Outlet Open Configuration For Flood Analyses," Tennessee Valley Authority, May 25, 2009 (EDMS No. L58 090529 800).

3. Assumptions & Methodology

The headwater rating curve developed in these calculations will be used in simulations of probable maximum flood events. Consequently, the rating curve has been calculated well above the normal operating range.

3.1 Assumptions

3.1.1 Assumption: Power generation will continue during flood routing through the reservoir.

Technical Justification: The discharge will be maximized when flow is routed through the generators. The maximum tailwater elevation shown in the Watauga Tailwater Rating Curve (Attachment 6) is 1671' for a discharge of 90,000 cfs (approximately equal to that associated with the maximum considered Watauga headwater). Per drawing 10W250,R6 (see Attachment 1), the switchyard elevation is 1712'. Per drawing 46K205, R1 (see Attachment 1.10), the powerhouse will not flood at elevations below 1685'.

3.1.2 Assumption: The tailwater elevations obtained from the tailwater rating curve presented in Attachment 6 occur at the powerhouse and tailwater elevations at the spillway outlet can be obtained by adding 30' to the elevations from the curve.

Technical Justification: The tailwater rating curve was provided by TVA Flood Risk, which is in the River Operations organization. This is the only rating curve available and is used by TVA during actual flood events as input for river management decisions but a reference describing the basis, assumptions, and methods used to develop it is not available. The elevation range in the tailwater rating curve is 1650' to 1671' which agrees closely with the tailwater range of 1650' to 1673' at the powerhouse shown on drawing 46K205,R1 (see Attachment 1). The tailwater rating curve in Attachment 6 is also a fairly close match to the Powerhouse Tailwater Rating curve shown on inactive drawing 321A477,R0 (Attachment 7). The elevations in the Spillway Tunnel Outlet Tailwater Rating curve shown on drawing 321A47,R0 for a given discharge are approximately 30' higher than the elevation shown on the Powerhouse Tailwater Rating curve for the same discharge. The tailwater rating curve presented in Attachment 6 is used only to verify that the tailwater will not rise high enough at the spillway outlet to affect the discharges past the dam or high enough at the powerhouse to require ceasing turbine discharge during the PMF. Because the difference between the tailwater elevation that would affect discharge and the maximum tailwater elevations obtained from the curve applied as discussed above is large, this rating curve is adequate even if its accuracy is uncertain.

3.1.3 Assumption: Sluiceway valves are considered fully operable and open to allow maximum flow indicated in the Howell-Bunger Valve Discharge Tables (Reference 4).

Technical Justification: For technical justification, see Reference 14, "Basis for Dam Spillway Gate/Outlet Open Configuration for Flood Analyses."

3.1.4 Assumption: The dam will not be overtopped during a PMF event.

Technical Justification: The maximum headwater is based on very conservative estimations of the maximum PMF elevation at the dam. Previous simulations have indicated that the dam is not overtopped during a PMF event. A headwater elevation of 2012 feet is a reasonable upper limit for this dam rating curve. If a SOCH/TRBROUTE analysis requires a PMF Flood elevation higher than the maximum elevation considered, the change will be identified by the SOCH/TRBROUTE analyst and a revision to this dam rating curve calculation will be required.

3.2 Unverified Assumptions

None.

3.3 Methodology

There are three possible routes for discharging through Watauga Dam: 1) through the power intake tunnel exiting at the powerhouse, 2) through the sluiceway intake exiting at the spillway outlet tunnel outlet portal, and 3) through the uncontrolled morning glory spillway exiting at the spillway outlet tunnel outlet portal. Overtopping the dam is not considered a possibility since the top of the dam is at or above elevation 2012' and the currently calculated elevation of the maximum probable flood is 2009.2'.

The calculations consist of computing power tunnel, sluiceway and spillway discharges for headwater elevations ranging from 1975 feet, the spillway crest elevation, to 2012 feet, the minimum dam elevation. The headwater rating curve is a plot of headwater elevation versus total dam discharge. Total discharge, given in "1000 cfs" is the sum of all discharges in cfs past the dam divided by 1000.

Discharge through the power tunnel is taken as 3,000 cfs for all discharges. This value is based on the "Reservoir and Power Data" tables listed on pages 24 through 28 of Reference 2 (see Attachment 2) which shows a maximum sustainable turbine discharge of 3,300 cfs for a reservoir level of 1815' (the lowest listed) and a maximum sustainable turbine discharge of 2,950 cfs for a reservoir level of 1975' (the highest listed). Because the tabulated discharges deviate so little from 3,000 cfs and that value is such a small percentage of the flood flows considered that additional refinement is not necessary, the use of 3,000 cfs at all reservoir levels is justified.

Flow through the sluiceway intake is limited by the discharge capacities of two Howell-Bunger valves located in the 34' diameter sluiceway tunnel before it joins the 34' diameter spillway outlet tunnel. Flow through the valves is determined by the following relationship:

$$Q_{HB} = K^*(HW-Z_{HB})^{0.5} \qquad \text{(Eq. 1)}$$

Where:

$K = 294$

Z_{HB} = centerline elevation of the valves = 1706.15'

See Appendix A for justification for this relationship.

Page 414 of Reference 8 (see Attachment 8) shows 3 conditions of flow which can control the flow through a morning glory spillway: Condition 1 is crest control, condition 2 is tube or orifice control, and condition 3 is full pipe flow.

Flow for Condition 1 is determined by the following relationship which is derived by curve fitting data from model studies presented in Ref. 3:

$$Q_f = 924.1Hc + 410.8Hc^2 - 9.08Hc^3 \qquad \text{(Eq. 2)}$$

Where:

H_c = (HW elevation) – (crest elevation)

See Section 6.3 for derivation of this relationship.

Flow for Condition 2 is determined by the following relationships:

$$Q_{thr} = (R_{thr}/0.204)^2(HW - Z_{thr})^{0.5} \qquad \text{(Eq. 3a)}$$

$$Q_{def} = 7.65^*A_{def}^*(HW - Z_{def})\ \hat{}0.5 \qquad \text{(Eq. 3b)}$$

Where:

R_{thr} = radius at throat = 17'

Z_{thr} = Elevation of throat

A_{def} = area of spillway tunnel at deflector

Z_{def} = Elevation of deflector

See Section 6.4 for derivation of these relationships.

Condition 3 is investigated by determining the energy grade of water exiting the tunnel after flowing through the spillway using the following relationship derived in Appendix B:

$$H' = HW - (Q_{mg}/A)^{\wedge}2/(2*g)*K1-((Q_{mg}+Q_{HB})/A)^{\wedge}2/(2*g)*K3 \qquad \text{(Eq. 4)}$$

Where:

Q_{mg} = flow through the morning glory spillway = least of Q_f, Q_{thr} & Q_{def}

Q_{HB} = flow through the sluiceway

A = area of 34' diameter tunnel

K1 & K3 = loss coefficients derived in Appendix B

If the energy head calculated using Eq. 4 is greater than the actual head (lesser of tailwater elevation and centerline elevation of outlet), the condition of the conduit flowing full will not control flow through the spillway.

4. Design Input and Notation

Sect.	Input Parameter	Symbol	Value	Source
4.1	**Morning Glory Spillway and Tunnel**			
4.1.1	Crest elevation	Z_c	1975 feet	Ref. 1.5
4.1.2	Diameter at crest	D_c	128 feet	Ref. 1.5
4.1.3	Elevation at transition to constant diameter	Z_{thr}	1885.90 feet	Ref. 1.5
4.1.4	Outlet tunnel radius at transition point and below	R	17.0 feet	Ref. 1.5
4.1.5	Elevation of top of elbow		1778.85’	Ref. 1.5
4.1.6	Centerline elevation at bottom of elbow		1703.85’	Ref. 1.5
4.1.7	Radius of elbow centerline		75.0’	Ref. 1.5
4.1.8	Station at bottom of elbow		8+36.96’	Ref. 1.4
4.1.9	Station at intersection with sluiceway centerline		10+87.95’	Ref. 1.4
4.1.10	Station at outlet		23+09’	Ref. 1.4
4.1.11	Invert elevation at outlet		1667.42’	Ref. 1.4
4.1.12	Elevation of maximum projection of deflector	Z_{def}	1885.90 feet	Ref. 1.5
4.1.13	Maximum projection of deflector into vertical spillway tunnel	p	7'-10 3/8"	Ref. 1.5
4.1.14	Length of spillway tunnel from transition to intersection with sluiceway tunnel	L1	see value in Appendix B	Calculated in Appendix B
4.1.15	Length of spillway tunnel from intersection with sluiceway tunnel to outlet	L3	see value in Appendix B	Calculated in Appendix B
4.1.16	Area of 34' diameter tunnel	A	see value in Appendix B	Calculated in Appendix B
4.1.17	Area of conduit at deflector	A_{def}	see value in Appendix B	Calculated in Appendix B
4.1.18	Total head loss coefficient for flow thru spillway above sluiceway tunnel	K1	see value in Appendix B	Calculated in Appendix B
4.1.19	Total head loss coefficient for flow thru spillway below sluiceway tunnel	K3	see value in Appendix B	Calculated in Appendix B
4.1.20	Entrance head loss coefficient for spillway length L1 flowing full	Ke	see value in Appendix B	Calculated in Appendix B
4.1.21	Bend head loss coefficient for spillway length L1 flowing full	Kb	see value in Appendix B	Calculated in Appendix B
4.1.22	Friction head loss coefficient for spillway lengths L1 & L3 flowing full	Kc	see value in Appendix B	Calculated in Appendix B
4.1.23	Sudden expansion head loss coefficient for flow past deflector in spillway length L1	Ks	see value in Appendix B	Calculated in Appendix B
4.1.24	Sudden expansion head loss coefficient for flow past deflector in spillway length L1 modified to use with normal tunnel area.	K's	see value in Appendix B	Calculated in Appendix B
4.1.25	Bend head loss coefficient for spillway length L1 flowing full	Ky	see value in Appendix B	Calculated in Appendix B

4.2	**Sluiceway**			
4.2.1	Tunnel radius	R	17.0’	Ref. 1.1
4.2.2	Elevation of valve centerline	Z_{HB}	1706.15’	Ref. 1.8
4.2.3	Loss coefficient for flow through Howell-Bunger valve	K	294	Calculated in Appendix A
4.3	**Dam**			
4.3.1	Top elevation		2012’	Ref. 1.2

5. Special Requirements/Limiting Conditions

N/A

6. Calculations

6.1 Flow Through Power Tunnel

Q_{gen} = discharge through the power tunnel = 3,000 cfs for all headwater elevations. See Section 3.3 for justification.

6.2 Flow Through Sluiceway

Q_{HB} = discharge through Sluiceway which is controlled by the two Howell-Bunger valves

$$Q_{HB} = K*(HW-1706.15)^{0.5} \qquad \text{(Eq. 1)}$$

where: HW = head water elevation (varies)
K = constant derived in Appendix A = 294
See Appendix A for justification for this relationship.

6.3 Flow Over Spillway Crest

Values scaled from the Spillway Rating Curve shown on Plate 3 of Ref. 3 (see Attachment 3) are listed Table 1.

HW, ft.	H_c, ft.	Q_f, cfs
1975	0	0
1977	2	3300
1978	3	6200
1979	4	9750
1980	5	13800
1981	6	18400
1982	7	23500
1983	8	29000
1984	9	35000
1985	10	41200
1986	11	47750
1987	12	54600
1988	13	61500

Table 1 – Morning-Glory Spillway Model Flow Data

Excel is used to plot the values in Table 1 and determine a polynomial curve to fit the values. The equation for the curve is

Q_f = 924.1Hc + 410.8Hc^2 - 9.08Hc^3 (Eq. 2)

Where:

H_c = (HW elevation) – Z_C

Z_C = crest elevation = 1975’

Figure 3 shows a plot of the values from Table 1 and the derived curve.

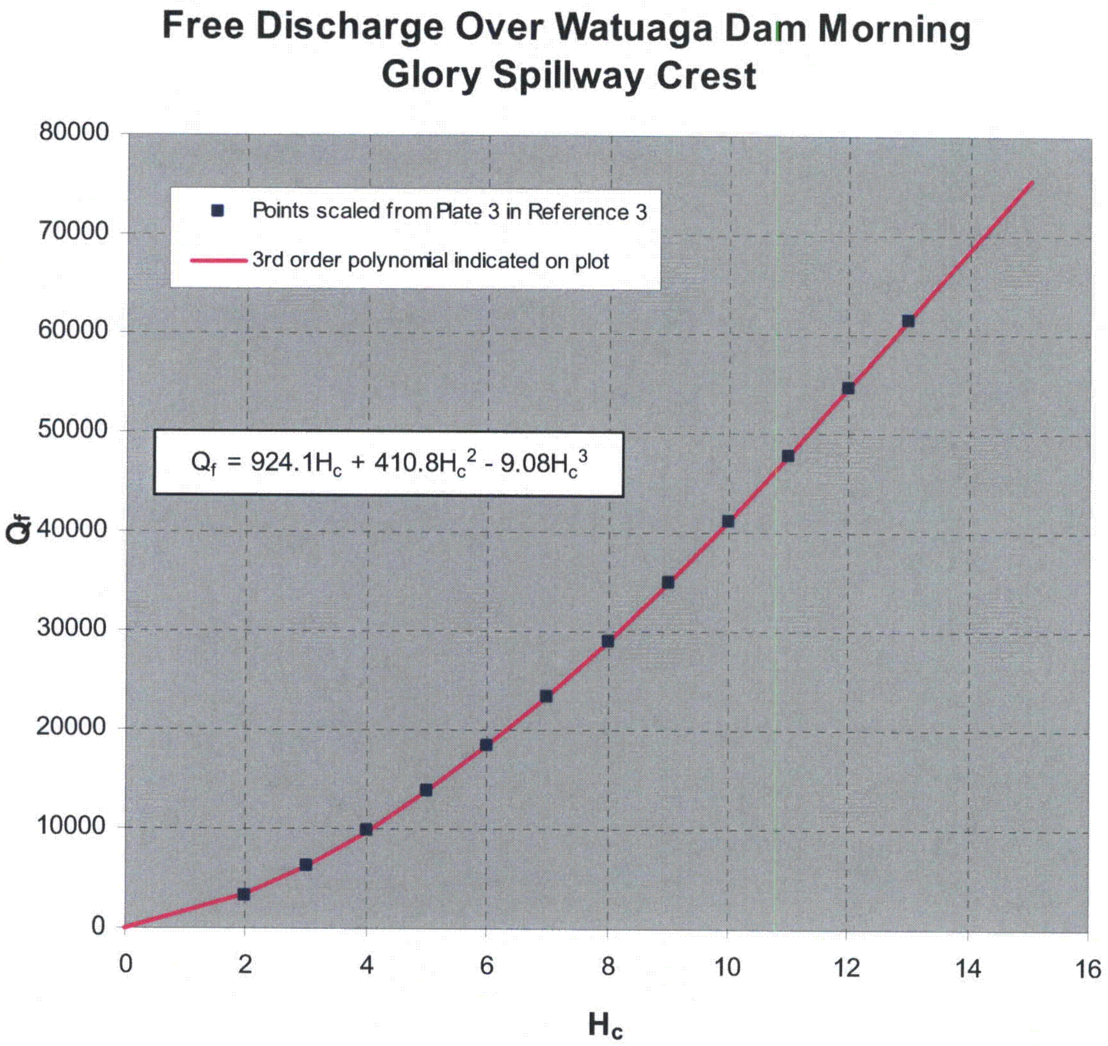


Figure 3 - Morning-Glory Spillway Discharge vs. Head Plot

6.4 Tube Controlled Flow

Equation 29 on page 410 of Ref. 8 is used as the basis for determining flow controlled by the morning-glory throat.

$R = 0.204*(Q_a\text{^}0.5/ H_a\text{^}0.25)$

Rearranging and substituting Q_{thr} for Q_a , R_{thr} for R, and (HW – Z_{thr}) for H_a gives:

$Q_{thr} = (R_{thr}/0.204)\text{^}2*(TW - Z_{thr})\ \text{^}0.5$ (Eq. 3)

Where Z_{thr} is the elevation at the top of the throat and , R_{thr} is the radius of the tunnel at the throat.

The same relationship can be used to determine the throat controlled flow at the section partially blocked by the deflector by substituting A_{def}/π for R^2 and Z_{tdef} for Z_{thr}, which gives:

$Q_{def} = 7.65*A_{def}*(HW - Z_{def})$ ^0.5 (Eq. 3b)

Where Z_{def} is the elevation at the maximum reduction of conduit area by the defector = 1778.85' and A_{def} is the conduit area at that location = 790.5 sq.ft. per calculations an sheet B2.

6.5 Spillway Tunnel Flowing Full

The energy grade of water exiting the tunnel after flowing through the spillway is determined using the Equation 4. See Appendix B for derivation of Equation 4.

H' = HW – (Q_{mg}/A)^2/(2*g)*K1-((Q_{mg} +Q_{HB})/A)^2/(2*g)*K3 (Eq. 4)

Where:

Q_{mg} = flow through the morning glory spillway = least of Q_f, Q_{thr} & Q_{def}

Q_{HB} = flow through the sluiceway

A = area of 34' diameter tunnel

K1 & K3 = loss coefficients derived in Appendix B

If the energy grade calculated using Eq. 4 is greater than the actual head (lesser of tailwater elevation or centerline elevation of outlet), there is more than enough energy to push the flow through the conduit, and the condition of the conduit flowing full will not control flow through the spillway.

6.6 Total Flow Through Spillway

The maximum discharge that can flow through the morning-glory spillway at a given headwater elevation, Q_{mg}, is calculated as the minimum controlled by the crest or the tube. The energy head at the spillway outlet is calculated assuming the spillway tunnel is flowing full with $Q_{mg} + Q_{HB}$ to verify that the conduit flowing full condition does not control.

6.7 Combining Flows and Calculating Rating Curve

The rating curve is a plot of total flows for head water elevations ranging from 1975' to 2012' in one foot increments. The total flow for any headwater elevation is:

$Q = Q_{gen} + Q_{HB} + Q_{mg}$

Where Q_{gen} = 3,000 cfs

Q_{HB} is calculated from Eq.1

Q_{mg} is the minimum of Q_f calculated from Eq. 2 , Q_{thr} calculated from Eq. 3a, or Q_{def} calculated from Eq. 3b

The energy head at the spillway tunnel is also calculated from Eq. 4 and is found to be larger than the maximum tailwater elevation in all cases, thereby demonstrating that the condition of conduit running full does not control the flow.

The Excel spreadsheet used to make the calculations described above is shown in Figure 4.

Calculation of Watauga Dam Rating Curve

Spillway Parameters

Z_c = 1975 feet
Z_{thr} = 1885.9 feet
R_{thr} = 17 feet
Z_{def} = 1778.85 feet

Howell-Bunger Valve Parameters

no. of valves = 2
Z_{HB} = 1706.15 feet
K = 294 $ft^{2.5}/s$

Conduit Parameters

L1 = 475.8
L2 = 1221.1
A = 908
A_{def} = 749
p = 7.86
Ke = 0.05

Kb = 0.135
Kc = 0.000284
K's = 0.0450
Ky = 0.15
K1 = 0.365
K3 = 1.497

HW	Total	Pwr Tunnel	Sluiceway			Morning Glory Spillway			
HW feet	**Discharge 1000 cfs** (Note 1)	Q_{gen} cfs (Note 2)	Q_{HB} cfs (Eq.1)	H_c feet (Note 3)	Q_f cfs (Eq.2)	Q_{thr} cfs (Eq.3a)	Q_{thr} cfs (Eq.3b)	Q_{mg} cfs (Note 4)	H' feet (Eq. 4)*
1975	**12.64**	3000	9641	0	0	65,551	80,251	0	1972
1976	**13.98**	3000	9659	1	1,326	65,917	80,455	1,326	1973
1977	**16.10**	3000	9677	2	3,419	66,282	80,659	3,419	1972
1978	**18.92**	3000	9695	3	6,224	66,645	80,862	6,224	1971
1979	**22.40**	3000	9713	4	9,688	67,006	81,065	9,688	1968
1980	**26.49**	3000	9730	5	13,756	67,365	81,267	13,756	1963
1981	**31.12**	3000	9748	6	18,372	67,722	81,469	18,372	1956
1983	**41.82**	3000	9784	8	29,035	68,430	81,871	29,035	1935
1985	**54.06**	3000	9819	10	41,241	69,131	82,271	41,241	1900
1987	**67.41**	3000	9854	12	54,554	69,825	82,669	54,554	1850
1988	**74.36**	3000	9872	13	61,490	70,170	82,868	61,490	1818
1989	**81.43**	3000	9889	14	68,539	70,513	83,065	68,539	1783
1990	**83.76**	3000	9907	15	75,647	70,854	83,263	70,854	1772
1991	**84.12**	3000	9924	16		71,193	83,460	71,193	1771
1992	**84.47**	3000	9941	17		71,531	83,656	71,531	1770
1994	**85.18**	3000	9976	19		72,202	84,048	72,202	1768
1996	**85.88**	3000	10011	21		72,867	84,437	72,867	1766
1998	**86.57**	3000	10045	23		73,526	84,825	73,526	1764
2000	**87.26**	3000	10080	25		74,179	85,212	74,179	1762
2002	**87.94**	3000	10114	27		74,826	85,596	74,826	1760
2004	**88.62**	3000	10148	29		75,468	85,979	75,468	1758
2006	**89.29**	3000	10182	31		76,104	86,360	76,104	1756
2008	**89.95**	3000	10216	33		76,735	86,739	76,735	1754
2010	**90.61**	3000	10250	35		77,361	87,117	77,361	1752
2012	**91.27**	3000	10283	37		77,982	87,493	77,982	1751

Note 1: $Q = Q_{HB} + Q_{mg} + Q_{gen}$
Note 2: Flow thru power tunnel = approximately 3000 cfs for all HW stages
Note 3: H_c = HW - (Z_c for morning-glory spillway)
Note 4: Q_{mg} = minimum (Q_f , Q_{thr}, Q_{def})
Eq. 1: $Q_{HB} = K*(HW-Z_{HB})$^0.5
Eq. 2: $Q_f = 924.1Hc + 410.8Hc^2 - 9.08Hc^3$
Eq. 3a: $Q_{thr} = 24.03*(R_{thr})$^2*(HW – Z_{thr})^0.5
Eq. 3b: $Q_{def} = 7.65*A_{def}$*(HW – Z_{def})^0.5
Eq. 4: H' = HW – (Q_{mg}/A)^2/(2*g)*k1-((Q_{mg} +Q_{HB})/A)^2/(2*g)*k2
Eq. 5: $Q_{BB} = C_f L H_c^{1.5}$
Eq. 6.a: $C_f = 3.078+0.1201H_c – 0.00556 H_c^2 + 0.0001305H_c^3$ for 0 < Hc < 17.6'
Eq. 6.b: $C_f = 3.549+0.0.0354H_c$ for Hc > 17.6'.

* The tailwater elevation at the powerhouse is 1671' when the discharge is 90,000 cfs (approximately equal to the maximum calculated discharge of 91,270 cfs). The tailwater elevation at the spillway outlet is 30' higher than at the power house as discussed in section 3.1.4 All values of H' are > TW elevation = 1671'+30'=1701', therefore conduit flowing full does not control

Figure 4 –Spreadsheet Used to Calculate Dam Rating Curve

7. Results/Conclusions

For convenience, the headwater rating results, separate from the calculation details provided above, are tabulated as total discharge in cfs vs. headwater elevation in feet in Table 2. The headwater rating curve is plotted in Figure 5.

The headwater rating curves developed in this calculation provide Watauga 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 sluiceway Howell-Bunger valves must be opened for maximum flow.

HW Elevation feet	Total Discharge 1000 cfs
1975	12.64
1976	13.98
1977	16.10
1978	18.92
1979	22.40
1980	26.49
1981	31.12
1983	41.82
1985	54.06
1987	67.41
1988	74.36
1989	81.43
1990	83.76
1991	84.12
1992	84.47
1994	85.18
1996	85.88
1998	86.57
2000	87.26
2002	87.94
2004	88.62
2006	89.29
2008	89.95
2010	90.61
2012	91.27

Table 2 – Headwater Rating Results

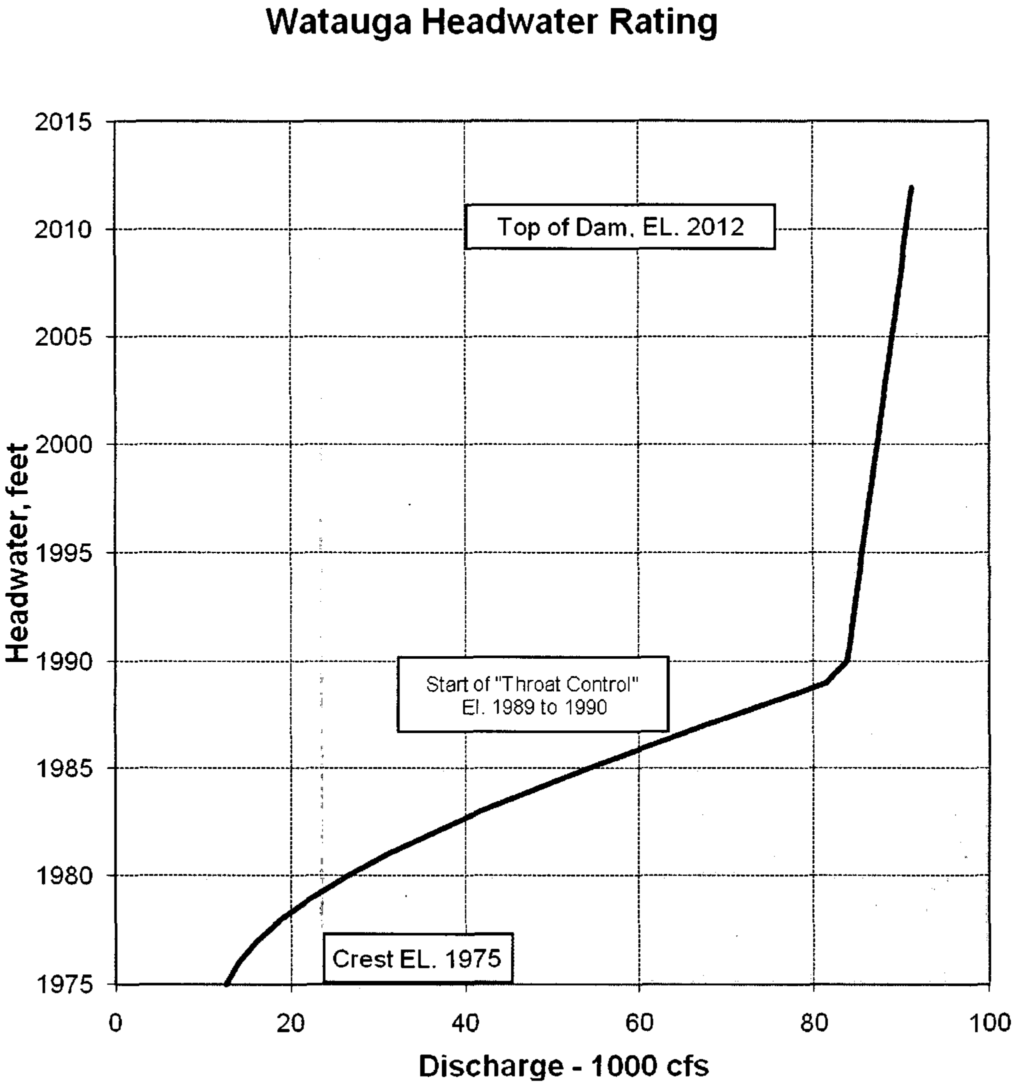


Figure 5 – Headwater Rating Curve

A 489 (EN DES-11-76)

Appendix A

CDQ000020080019

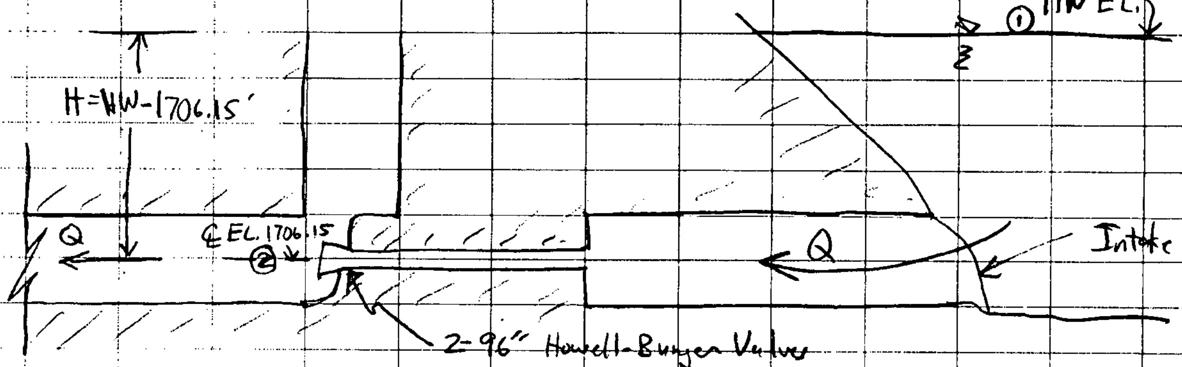
Watuaga Sluice Discharge

SHEET A1 OF

COMPUTED GAS DATE 10/27/2003

CHECKED JBM DATE

Sketch 51W200, R8
54W220, R5



Energy Equation between ① & ②:

$$H = \frac{V_2^2}{2g} + k\frac{V_2^2}{2g}$$ for flow without downstream submergence effects

where
- V_2 = Velocity of jet discharging from Howell-Bunger Valves
- g = acceleration of gravity = 32.2 ft/sec [4.1]
- k = coefficient accounting for all losses from ① to ②

Define discharge, $Q = V_2 A$ where A = a cross-sectional area that need not be specified yet

$$\Rightarrow H = \frac{Q^2}{2gA^2}(1+k) \Rightarrow Q = \frac{A}{\sqrt{1+k}}\sqrt{2gH}$$

or $\underline{Q = K\sqrt{H}}$ with $K = A\sqrt{\frac{2g}{1+k}}$

Reference 4 indicates openings of 7% to 92% for the Howell-Bunger valves at Watauga and K varies with % opening. For HW EL. = 1985, this reference gives Q = 4910 cfs for one valve opened 92%.

$$\Rightarrow K = \frac{Q}{\sqrt{H}} = \frac{4910}{\sqrt{1985-1706.15}} = \underline{294}$$ per valve for 92% opening

(see Attachment A3)

Appendix A

CDQ 0000 2008 0019

SHEET A2 OF

Watauga Sluice Discharge

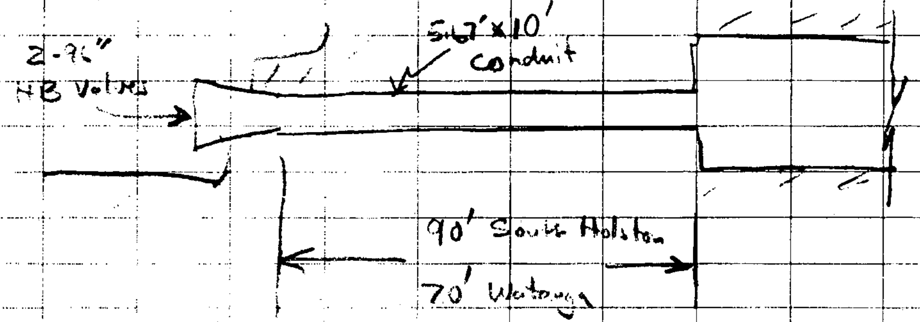
COMPUTED GAS DATE 10/27/2008

CHECKED JBM DATE

This K-value was determined from field measurements of Q made in the South Holston Dam tailrace by the USGS in 1957 and 1973 (summary included as Attachment A4, sheets A4-1 + A4-2). As indicated on Attachment A4, an average value of 293.3 for K was determined for one valve open to 88%, near the maximum discharge opening for the valve (attachments do not explicitly state that only one valve was operating during the measurements but since Reference 5 uses K = 294 to compute discharge for one valve open to 89%, this must have been the case).

An assumption was made by the preparers of Reference 4 that values of K determined for South Holston could be used also for Watauga, with the valve % openings offset by 3% (Reference 4 states that the opening indicators at Watauga read 3% when the Howell-Bunger valves are closed - see Attachment A3).

Attachments A6 and A7 give details on the South Holston sluice for comparison. From a hydraulic point of view, the most significant difference is in the length of the 5.67' x 10' conduits upstream from the valves (high velocity flow in these conduits compared to the upstream tunnels).



Estimate addition headloss at South Holston compared with Watauga:

$$\Delta h_f = f \frac{\Delta L}{D} \frac{Q^2}{2gA^2}$$

where

Δh_f = additional friction loss

ΔL = difference in lengths = 20'

A = area of conduit = 5.67' × 10' = 56.7 ft^2

D = hyd. Dia = $\frac{4A}{P} = \frac{4(56.7 ft^2)}{2(5.67+10)} = 7.24$ ft

P = wetted perimeter of conduit = 2(5.67' + 10')

f = Darcy-Weisbach friction factor

Appendix A
<DQ 0000 2008 0019

SHEET A3 OF

Watauga Sluice Discharge

COMPUTED GAS DATE 10/27/2008
CHECKED JBM DATE

$f = f\left(\frac{\epsilon}{D}\right)$ where ϵ = roughness ≈ 0.00015 for commercial steel (Reference 21) (see sh A7-1)

$$\frac{\epsilon}{D} \approx \frac{0.00015'}{7.24'} = 0.00002$$

For $Q = 4910$ cfs, $V = \frac{Q}{A}$ (velocity) $= \frac{4910}{56.7} = 86.6$ ft/sec

$$\Rightarrow V \cdot (12D') = 86.6 \cdot 12 \cdot 7.24 = 7520$$

$\uparrow$ D in inches

$$\Rightarrow \underline{\underline{f \approx 0.009}}$$

(See Attachment A7 from Reference 21)

$$\Delta h_f = 0.009 \frac{20}{7.24}\left(\frac{4910}{56.7}\right)^2 \frac{1}{2(32.2)} = \underline{\underline{2.9'}}$$

The head required at South Holston to discharge 4910 cfs is

$$H = \frac{Q^2}{K^2} = \left(\frac{4910}{294}\right)^2 = 278.9'$$

which implies that the head required at Watauga to discharge 4910 cfs is $278.9 - 2.9 = 276'$.

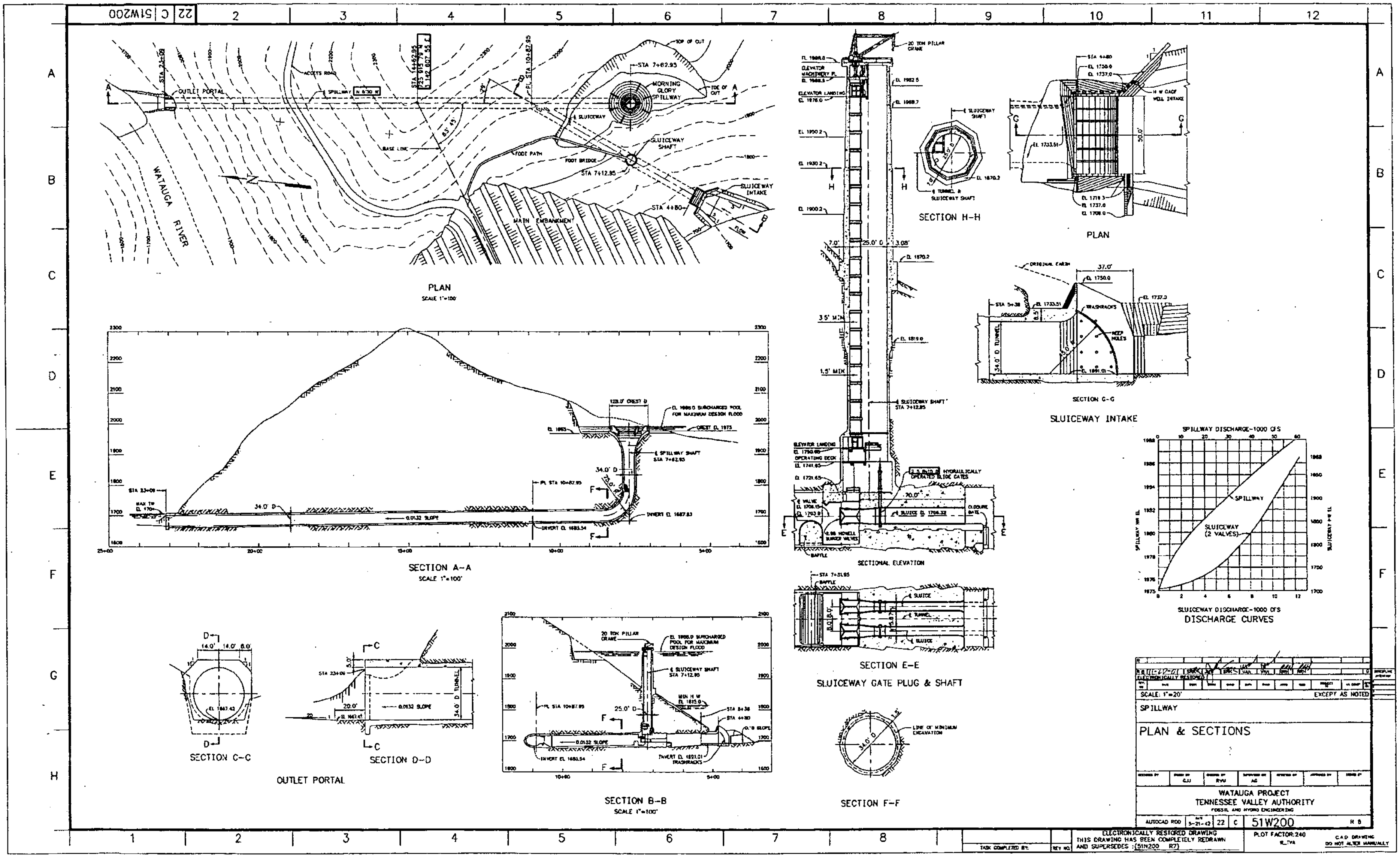
$$\Rightarrow K_{wat} = \frac{Q}{\sqrt{H}} = \frac{4910}{\sqrt{276}} = 295.5$$ which is 0.5% higher than $K_{S.H.}$ (294)

Since current meter measurements of stream discharge are not accurate enough to discern differences of 0.5% in discharge coefficients, use of $K = 294$ for both Watauga and South Holston is justified.

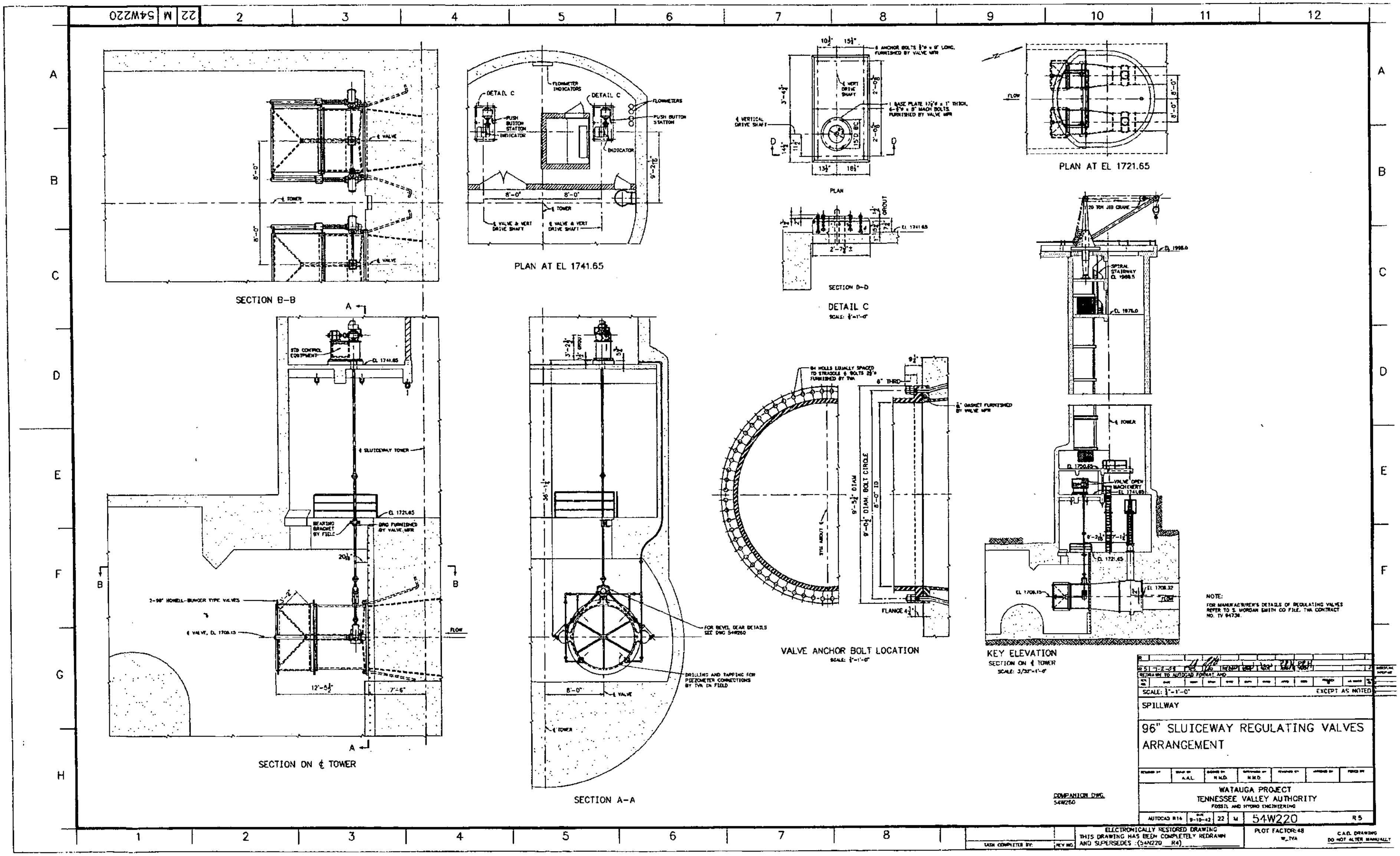
$\Rightarrow$ Conclusion: Use $K = 294$ to compute discharge from $Q = K\sqrt{HW - 1706.15}$

for each H.B. Valve at maximimum opening of 92%

Attachment A1



Attachment A2



sheet A2-1
of 1

Attachment A3
(from Ref. 4)

INSTRUCTIONS FOR USE OF TABLES

1. Purpose of Tables

The purpose of these tables is to provide a means of determining the discharge of the Howell-Bunger valves in the sluice tunnel at Watauga Dam. The tables are based on field discharge measurements and pressure measurements taken at several discharges in the sluice upstream from the Howell-Bunger valves. The tables give the discharge in cubic feet per second for one valve when the reservoir elevation and valve opening are known throughout the complete range of normal operating conditions. These tables supersede the tables dated August 1971.

2. Arrangement and Use of Tables

The tables give the discharge in cubic feet per second per valve for each 5-foot interval of headwater between reservoir elevations 1800 and 1985, and for each 1 percent of valve opening between 7 percent and 92 percent valve positions. Discharges are tabulated only to the nearest 10 cubic feet per second because the accuracy of the field measurements does not warrant greater refinement. It is possible to set any discharge within 40 cubic feet per second by using the tabular values. This tolerance has been accepted by the Division of Water Control Planning and, therefore, *it will not be necessary to interpolate* between tabular entries in these tables.

The reservoir elevation values used in the tables are those given by the recorder in the control room. The valve opening used in the tables is that indicated by the pointer on the valve control mechanism.

The arrangement of tables is such that the discharge over the entire range of valve openings for a 100-foot range of reservoir elevation is on two consecutive pages. For example, discharges are given on pages 2 and 3 for reservoir elevations 1800 through 1900. Discharges should be taken from the table for the tabulated values nearest to those observed. For example, if the reservoir is at elevation 1858.76 and the valve number 1 opening is 76.4 percent, the discharge is found on page 3, in the column headed 1860 opposite a valve opening of 76 percent, as 3220 cubic feet per second. If valve number 2 were set at 56.6 percent at the same time when valve number 1 was operating as given above, the discharge for valve number 2 would be found on page 3, in the column headed 1860 opposite a valve opening of 57 percent, as 2560 cubic feet per second. The total discharge would be the sum of the discharges of the two valves or 5780 cubic feet per second.

3. Valve Opening for Maximum and Minimum Discharge

Maximum discharge for the Howell-Bunger valves at Watauga Dam occurs at 92 percent valve opening. At valve openings greater than 92 percent the discharge becomes less. Therefore, the valves should not be operated beyond 92 percent. No tabular data are presented for such operation.

Minimum valve openings should not be less than 7 percent because of cavitation effects. No tabular values are given for such operation.

4. Adjustment of Valve Opening Indicator

At the time the field measurements were made, the valve opening indicator showed an opening of 3 percent when the valve was closed. In case of repairs to or adjustment of the valve and its control mechanism, the pointer should be reset to zero position so that the tables will still be applicable.

CDQ000020080019

Attachment A3
(from Ref.4)

sheet A3-2 of 2

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985				
56	2830	2860	2900	2930	2970	3000	3040	3070	3100	3140	3170	3200	3230	3270	3300	3330	3360	3390				56
57	2870	2900	2940	2980	3010	3050	3080	3120	3150	3180	3220	3250	3280	3310	3350	3380	3410	3440				57
58	2910	2950	2980	3020	3060	3090	3130	3160	3200	3230	3260	3300	3330	3360	3390	3430	3460	3490				58
59	2950	2990	3030	3060	3100	3140	3170	3210	3240	3280	3310	3340	3380	3410	3440	3480	3510	3540				59
60	3010	3050	3080	3120	3160	3200	3230	3270	3300	3340	3370	3410	3440	3480	3510	3540	3570	3610				60
61	3050	3090	3130	3160	3200	3240	3280	3310	3350	3380	3420	3450	3490	3520	3560	3590	3620	3660				61
62	3090	3130	3170	3210	3250	3280	3320	3360	3390	3430	3470	3500	3540	3570	3610	3640	3670	3710				62
63	3130	3170	3210	3250	3290	3330	3370	3400	3440	3480	3510	3550	3580	3620	3650	3690	3720	3760				63
64	3170	3220	3260	3290	3330	3370	3410	3450	3490	3520	3560	3600	3630	3670	3700	3740	3770	3810				64
65	3200	3240	3280	3320	3360	3400	3440	3480	3520	3550	3590	3630	3660	3700	3740	3770	3810	3840				65
66	3240	3290	3330	3370	3410	3450	3490	3520	3560	3600	3640	3680	3710	3750	3780	3820	3860	3890				66
67	3290	3330	3370	3410	3450	3490	3530	3570	3610	3650	3690	3720	3760	3800	3830	3870	3910	3940				67
68	3330	3370	3410	3450	3490	3540	3580	3620	3650	3690	3730	3770	3810	3850	3880	3920	3950	3990				68
69	3370	3410	3460	3500	3540	3580	3620	3660	3700	3740	3780	3820	3860	3890	3930	3970	4000	4040				69
70	3400	3440	3480	3530	3570	3610	3650	3690	3730	3770	3810	3850	3890	3930	3960	4000	4040	4070				70
71	3420	3470	3510	3560	3600	3640	3680	3720	3760	3800	3840	3880	3920	3960	4000	4030	4070	4110				71
72	3470	3510	3560	3600	3640	3680	3730	3770	3810	3850	3890	3930	3970	4010	4040	4080	4120	4160				72
73	3510	3550	3600	3640	3690	3730	3770	3810	3850	3890	3940	3980	4010	4050	4090	4130	4170	4210				73
74	3550	3600	3640	3690	3730	3770	3820	3860	3900	3940	3980	4020	4060	4100	4140	4180	4220	4260				74
75	3580	3620	3670	3710	3760	3800	3850	3890	3930	3970	4010	4050	4090	4130	4170	4210	4250	4290				75
76	3620	3670	3710	3760	3800	3850	3890	3930	3980	4020	4060	4100	4140	4180	4220	4260	4300	4340				76
77	3660	3710	3750	3800	3850	3890	3930	3980	4020	4060	4110	4150	4190	4230	4270	4310	4350	4390				77
78	3690	3740	3780	3830	3880	3920	3960	4010	4050	4100	4140	4180	4220	4260	4300	4350	4390	4430				78
79	3730	3780	3830	3870	3920	3960	4010	4050	4100	4140	4180	4230	4270	4310	4350	4390	4430	4480				79
80	3760	3810	3850	3900	3950	3990	4040	4080	4130	4170	4220	4260	4300	4340	4390	4430	4470	4510				80
81	3790	3840	3880	3930	3980	4020	4070	4110	4160	4200	4250	4290	4330	4380	4420	4460	4500	4540				81
82	3820	3870	3920	3970	4010	4060	4110	4150	4200	4240	4290	4330	4370	4420	4460	4500	4540	4580				82
83	3860	3910	3950	4000	4050	4100	4140	4190	4240	4280	4330	4370	4410	4460	4500	4540	4580	4630				83
84	3880	3930	3980	4030	4080	4130	4170	4220	4270	4310	4360	4400	4450	4490	4530	4570	4620	4660				84
85	3910	3960	4010	4060	4110	4160	4200	4250	4300	4340	4390	4430	4480	4520	4560	4610	4650	4690				85
86	3950	4000	4050	4100	4150	4200	4250	4300	4340	4390	4430	4480	4520	4570	4610	4660	4700	4740				86
87	3980	4030	4080	4130	4180	4230	4280	4330	4370	4420	4470	4510	4560	4600	4650	4690	4730	4780				87
88	4010	4060	4110	4160	4210	4260	4310	4360	4400	4450	4500	4540	4590	4630	4680	4720	4770	4810				88
89	4040	4090	4140	4190	4240	4290	4340	4390	4430	4480	4530	4570	4620	4670	4710	4750	4800	4840				89
90	4070	4120	4170	4220	4270	4320	4370	4420	4470	4510	4560	4610	4650	4700	4740	4790	4830	4880				90
91	4080	4130	4180	4230	4280	4330	4380	4430	4480	4530	4580	4620	4670	4710	4760	4800	4850	4890				91
*92	4090	4150	4200	4250	4300	4350	4400	4450	4500	4540	4590	4640	4680	4730	4780	4820	4870	4910				92

JULY 1974

* THE MAXIMUM VALVE OPENING
SHOULD NOT EXCEED 92 PERCENT

RESERVOIR ELEVATION 1900 TO 1985
VALVE OPENING, PERCENT 56 TO 92

CDQ000020080019

Attachment A4
(from Ref 13)
INFORMATION
ONLY

sheet A4-1 of 2

TVA 489 (REV-9 47)

Discharge Measurements
USGS
Feb 13, 1957

SHEET ____ OF ____
South Holston
H.B. Valve
COMPUTED KWK DATE 6-26-73
CHECKED ____ DATE ____

Valve NO	Meas NO	GO	Time	Total Q	Turb Q	Sluice Q	$\frac{Q}{\sqrt{H}}$	Hw	H
1	1	88.0	9:30-10:45	7552	3250	4302 ✓	289.8 ✓	1722.04	220.34
	2	88.0	10:50-12:05	7634	"	4384 ✓	295.4 ✓	1721.96	220.26
2	3	8$\overset{7}{8}$.9	1:35-2:45	7575	3250	4325 ✓	291.5 ✓	1721.84	220.14
	4	87.9	2:55-4:05	7649	"	4399	296.5 ✓	1721.77	220.07

avg Q/H^0.5

$$= \frac{289.8+295.4+291.5+296.5}{4}$$

= 293.3

Attachment A4
(from Ref.13)
INFORMATION
ONLY

TVA 489 (REV.9 47)

Discharge Measurements
USGS
6-19-73

SHEET ______ OF ______
South Holston
H.B. Valve
COMPUTED KWK DATE 6-26-73
CHECKED ARS DATE 6-26-73

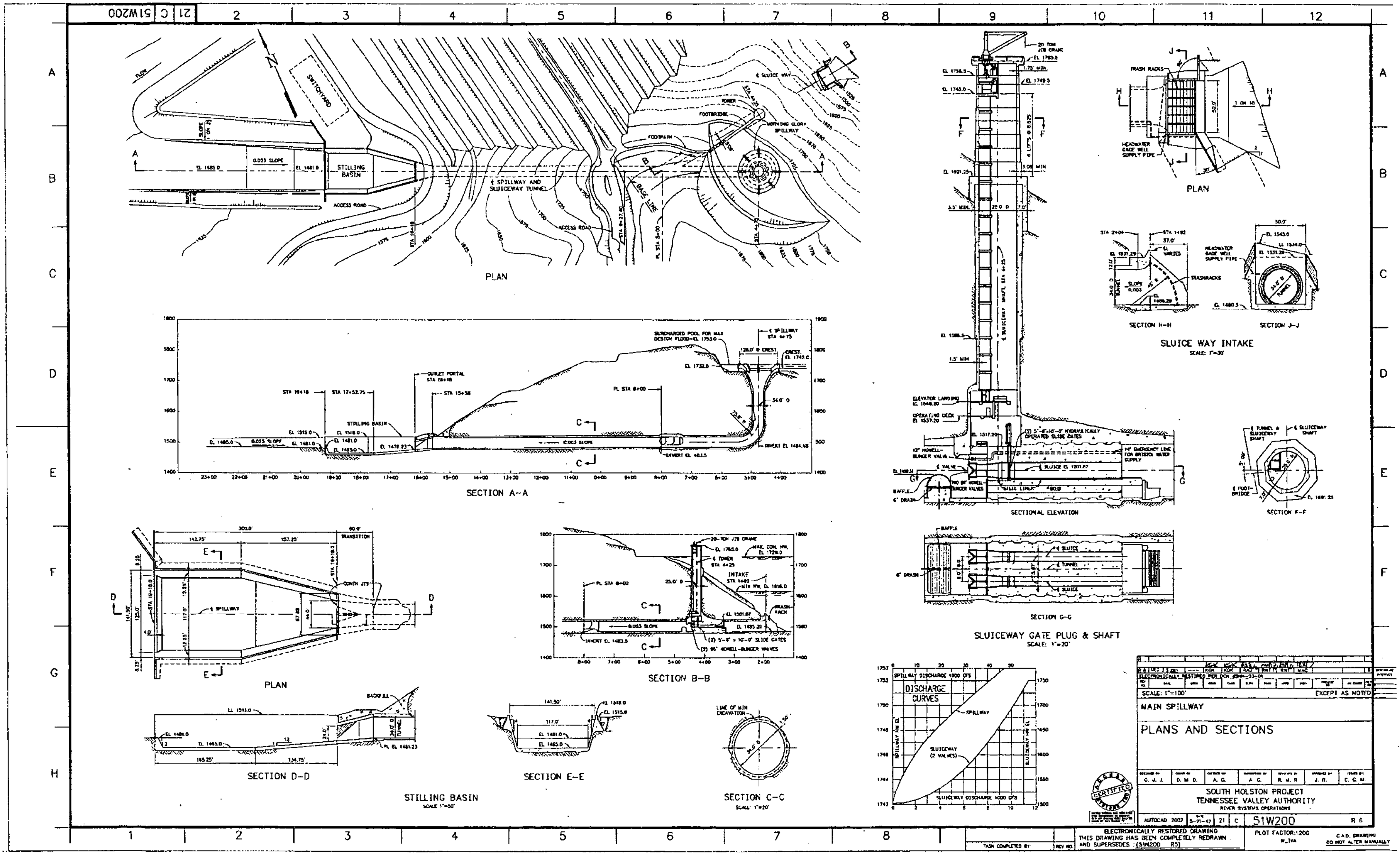
Meas No	GO	Time	Q	Leak Q	Final Q	Q √H	HW	H
218	5%	8:15A-8:55A	216	8.0	208	13.88	1726.1	224.4
219	"	8:15A-9:00A	217	8.0	209	13.95	"	"
220	10%	11:15A-12:00	520	8.0	512	34.18	1726.1	224.4
221	"	11:15A-11:45	540	8.0	532	35.51	"	"
222	40%	2:15P-3:00P	2410	8.0	2402	160.3	1726.2	224.5
223	"	3:00P-4:00P	2380	8.0	2372	158.3	"	"

Leakage thru unit 8.1 cfs.

6.00
15.00
25.00
46.00

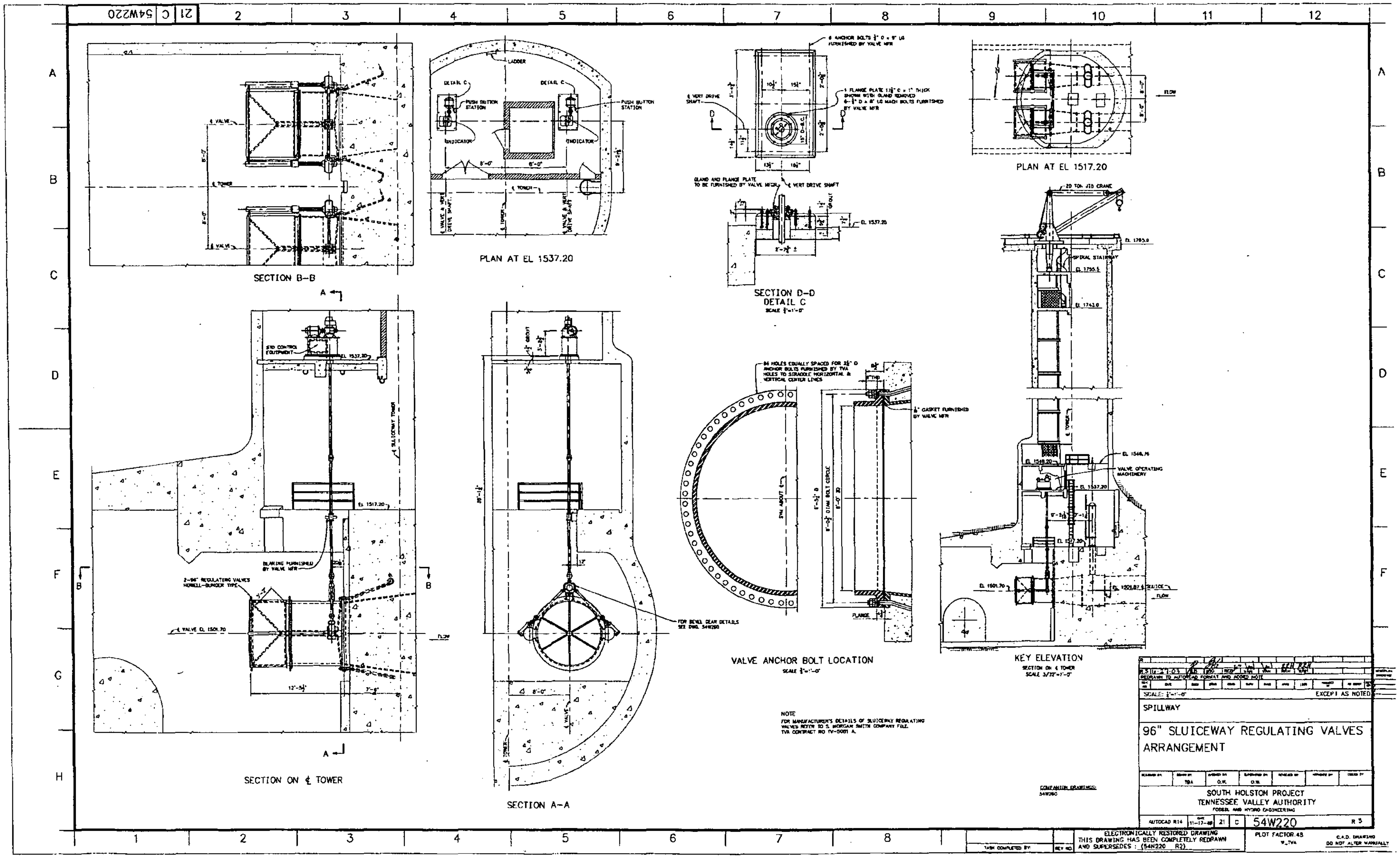
1561.70

Attachment A5



sheet A5-1
of 1

Attachment A6



NOTE
FOR MANUFACTURER'S DETAILS OF SLUICEWAY REGULATING VALVES REFER TO S. MORGAN SMITH COMPANY FILE. TVA CONTRACT NO TV-5081 A.

R3 | 11-27-03 | REDRAWN TO AUTOCAD FORMAT AND ADDED NOTE

SCALE: 3/4"=1'-0" EXCEPT AS NOTED

SPILLWAY

96" SLUICEWAY REGULATING VALVES
ARRANGEMENT

TBA O.W. O.W.

SOUTH HOLSTON PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | 11-17-48 | 21 | C | 54W220 | R3

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES : (54N220 R2)

PLOT FACTOR 48
W_TVA

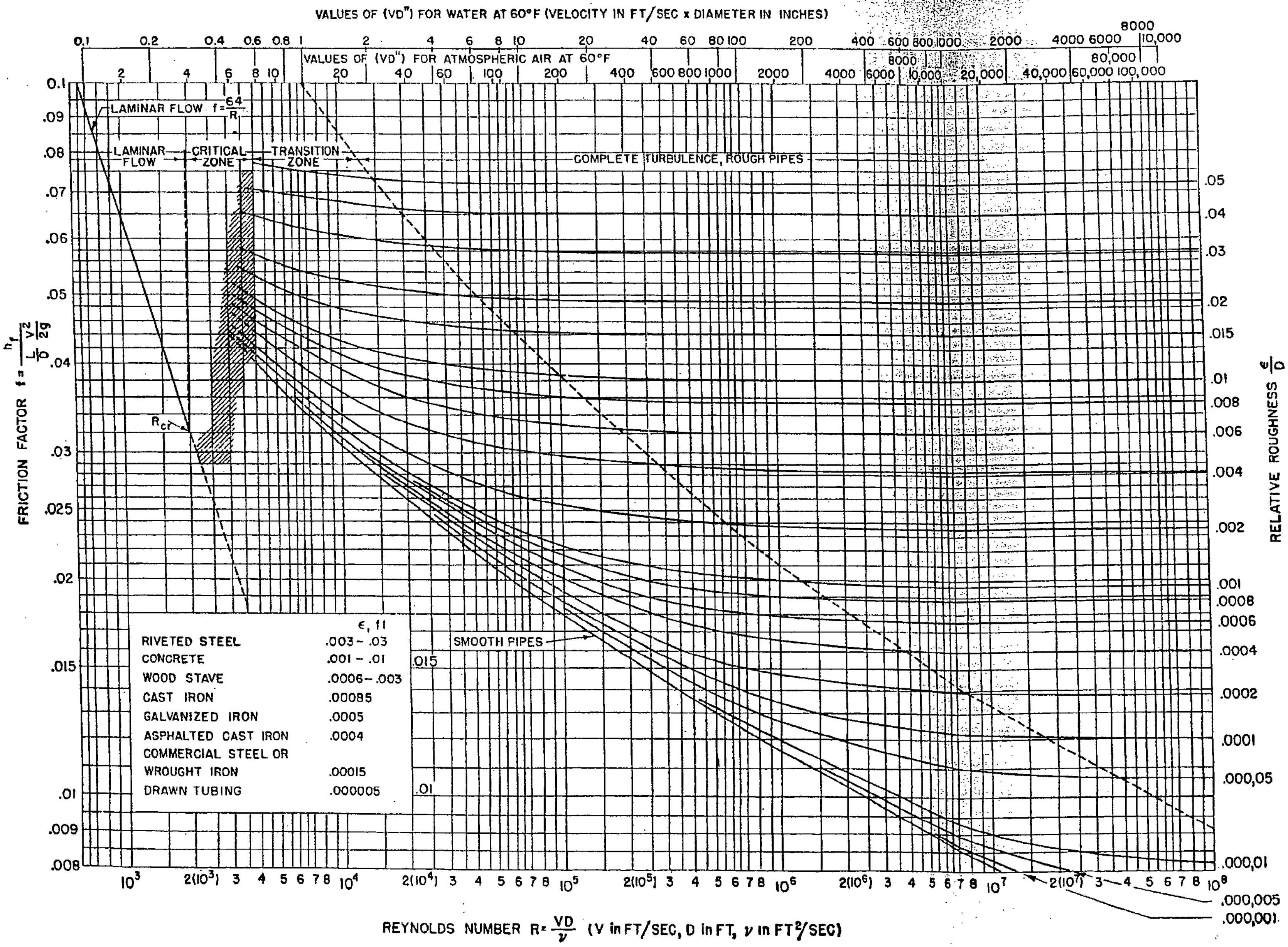
C.A.D. DRAWING
DO NOT ALTER MANUALLY

sheet A6-1
of 1

Attachment A7

(from Ref. 11)

Sheet A7-1 of 1



	ϵ, ft
RIVETED STEEL	.003 ~ .03
CONCRETE	.001 - .01
WOOD STAVE	.0006 ~ .003
CAST IRON	.00085
GALVANIZED IRON	.0005
ASPHALTED CAST IRON	.0004
COMMERCIAL STEEL OR WROUGHT IRON	.00015
DRAWN TUBING	.000005

Fig. 6-4

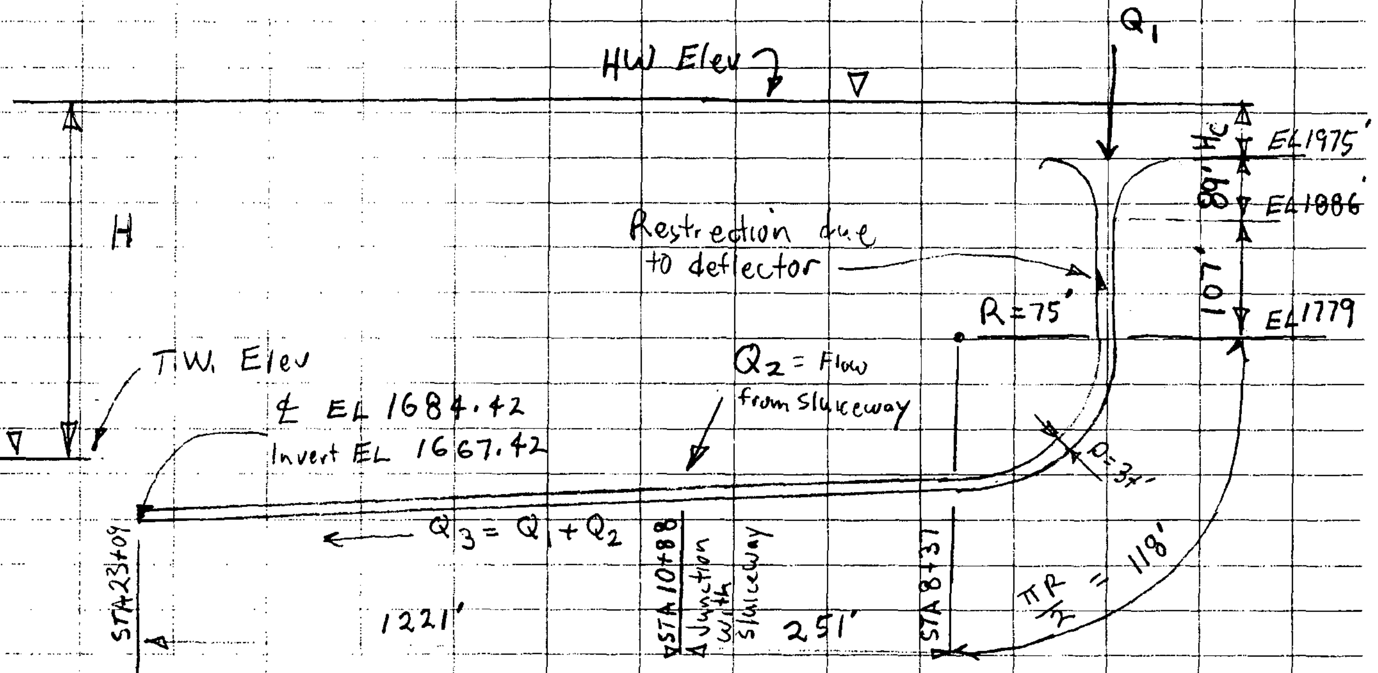
Appendix B

CDQ 0000 2008 0019

COMPUTED WHR DATE 11-7-08

CHECKED JBM DATE

Check Condition of Conduit Flowing Full (sh. 1 of 3)



Proceedure for check

(1) Choose a H W elevation to check

(2) Assume Q_1 = flow thru spillway controlled by the crest or by the throat (small value from crest control or throat control) for the HW elevation
Assume Q_2 = flow thru sluiceway for the H.W elevation.

(3) Calculate energy head at the spillway outlet assuming all tunnels are running full.

(4) If the calculated energy head is greater than the available head at the outlet (lesser elev of TW or ℄ outlet) then the flow over the crest or thru the throat controls.

$$H' = H_c + 1975' - \frac{V_1^2}{2g}\left(K_e + K_b + K_c L_1\right) - \frac{(V_1')^2}{2g} K_s - \frac{V_3^2}{2g}\left(1 + K_Y + K_c L_3\right)$$

where:

K_e = entry loss coef.
K_b = bend loss coef
K_c = friction loss coef
K_s = sudden expansion loss coef
K_Y = coef. for loss at Y junction

V_1' = Velocity at deflector
V_1 = Velocity elsewhere above sluice way
V_3 = Velocity below sluice way
L_1 = Conduit length above sluice way
L_3 = Conduit length below sluiceway

A 489 (EN DES-13-76)

SHEET B2 OF 10

Appendix B
CDQ0000 20080019

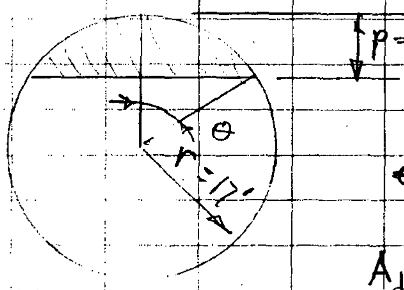
COMPUTED WHR DATE 11-7-08
CHECKED JBM DATE

Check Conduit flowing Full (sh 2 of 3)

Check at HW Elev = 2012'

$H_c = 2012 - 1975 = 37'$
$Q_1 = 78{,}000$ cfs
$Q_2 = 10{,}300$ cfs

Conduit area $= A = \pi r^2 = \pi(17')^2 = 907.9\ ft^2$



$p = 7'\text{-}10\tfrac{3}{8}'' = 7.86'$
(Ref 14)

$\theta = \cos^{-1}\left(\frac{17-7.86}{17}\right) = 1.003$ rad

$A_{def} = \pi r^2 - \theta r^2 + (r(\sin\theta))r(\cos\theta))$

Conduit @ Deflector

$= 749.0\ ft^2$ = area at deflector

$V_1 = 78{,}000/907.9 = 85.9$ ft/sec
$V_1' = 78{,}000/749 = 104.1$ ft/sec
$V_3 = (78{,}000 + 10{,}300)/907.9 = 97.3$ ft/sec

$K_e \simeq 0.05$ per Fig 4.75, p 212 of Ref 9 for $r/d > 0.3$ (see sh B8)
$K_b = 0.135$ per 228-1 of Ref 7 for $r/D = 75/34 = 2.2$ (see sh B10)

$K_c = \frac{5087\, n^2}{d_i^{4/3}}$ per p 233 of Ref 6 where n is Mannings Coef of Roughness (see sh B9)

Conservatively using $n = 0.013$ gives $K_c = \frac{(5087)(0.013)^2}{((34)(12))^{1.333}} = 0.000284$

$K_Y \simeq 0.15$ per Fig 4.40, p. 189 of Ref 9 for $\frac{A_1}{A_3} = 1.0$ + $Q_2/Q_3 = \frac{10.3}{78+10.3} = 0.117$ (see sh B6)

$K_s = \left[1 - \frac{A_1}{A_2}\right]^2$ per Eq 4.20, p. 199 of Ref 9 (see sh. B7)

$= \left[1 - \frac{749}{907.9}\right]^2 = 0.03$

$L_1 = 107' + 118' + 251' = 476'$

$L_2 = 1221'$

Appendix B
CDQ0000 2008 0019

COMPUTED WHR DATE 11-7-08
CHECKED JBM DATE

Checking Conduit Flowing Full (sh 3 of 3)

Check @ HW Elev = 2012' (contd)

$$H' = 37 + 1975 - \left(\frac{85.9}{64.4}\right)^2 \left[0.05 + 0.135 + (0.000284)(476)\right]$$
$$- \left(\frac{104.1}{64}\right)^2 (0.03) - \left(\frac{97.3}{64.4}\right)^2 \left[1 + 0.15 + (0.000284)(1221)\right]$$
$$= 2012' - 261.5' = 1750.5'$$

Derive General Relationship

K_Y is the only loss coefficient used above which varies with flow. But the calculation will be sufficiently accurate if K_Y is assumed to be 0.15 at all flows.

Loss due to expansion @ deflector $\doteq K_s \frac{(V_1')^2}{2g} = 0.03 \frac{(V_1')^2}{2g}$

$$V_1 = V\left(\frac{A}{A_{def}}\right) \quad \therefore \quad K_s' = 0.03\left(\frac{A}{A_{def}}\right)^2 \doteq 0.03\left(\frac{907.9}{749}\right)^2 \doteq 0.045$$

when applied to V_1

$$\therefore H' = H_c + 1975' - \frac{V_1^2}{2g}\left(K_e + K_b + K_c L_1 + K_s'\right) - \frac{V_3^2}{2g}\left(1 + K_Y + K_c L_3\right)$$

Substituting HW for $(H_c + 1975)$, $\frac{Q_{mg}}{A}$ for V_1, $\frac{Q_{mg} + Q_{HB}}{A}$ for V_3, and combining energy loss coefficients gives:

$$\boxed{H' = HW - \left(\frac{Q_{mg}}{A}\right)^2\left(\frac{1}{2g}\right)K_1 - \left(\frac{Q_{mg} + Q_{HB}}{A}\right)^2\left(\frac{1}{2g}\right)K_3} \leftarrow \text{Use as (Eq. 4)}$$

where: H' = Energy grade at conduit exit
HW = Reservior headwater elevation
Q_{mg} = Flow through morning-glory spillway
Q_{HB} = Flow through sluiceway
$K_1 = K_e + K_b + K_c L_1 + K_s'$
$K_3 = 1 + K_Y + K_c L_3$

4.6 DIVIDING AND COMBINING JUNCTIONS

4.6.1 *Introduction*

This section contains loss coefficients given for dividing and combining junctions. The junction geometries included are shown in Figure 4.38. Important geometric parameters are the area ratio, the angle between the legs and the chamfers or radii at the junction of the legs.

The notation used for the junction legs is shown in Figure 4.38. A loss coefficient K_{ij} is defined as the ratio of the total head loss between legs i and j to the mean velocity head in the leg carrying the total flow. The leg carrying the total flow is always referred to as leg 3. In the case of 'T' junctions, leg 1 is the branch and leg 2 is the leg carrying the through flow. Symmetrical 'Y' configurations have only one coefficient since leg 2 can be substituted for leg 1 or vice versa. Loss coefficients are:

Combining flow

$$K_{13} = \frac{\frac{U_1^2}{2g} + h_1 - \frac{U_3^2}{2g} + h_3}{\frac{U_3^2}{2g}} \tag{4.16}$$

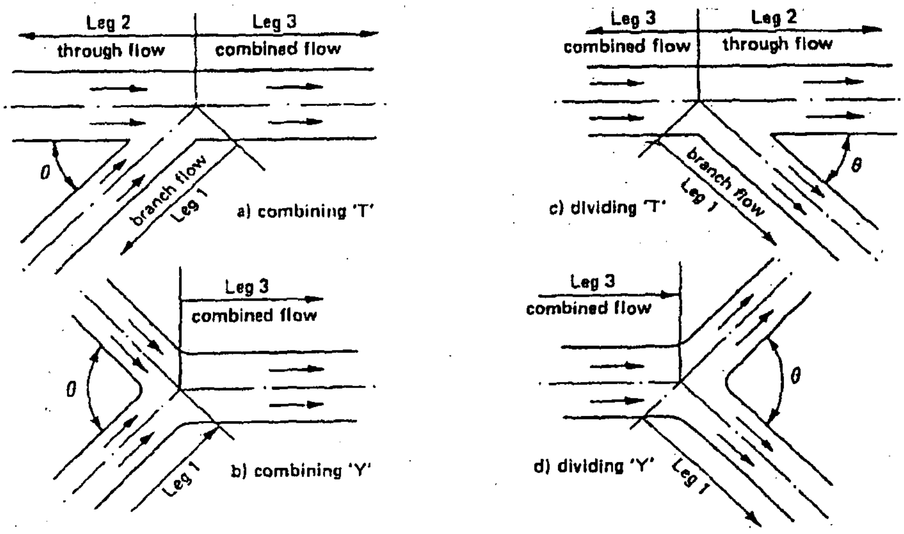


Figure 4.38. Geometric parameters for combining and dividing junctions.

$$K_{23} = \frac{\frac{U_2^2}{2g} + h_2 - \frac{U_3^2}{2g} + h_3}{\frac{U_3^2}{2g}} \tag{4.17}$$

Dividing flow

$$K_{31} = \frac{\frac{U_3^2}{2g} + h_3 - \frac{U_1^2}{2g} + h_1}{\frac{U_3^2}{2g}} \tag{4.18}$$

$$K_{32} = \frac{\frac{U_3^2}{2g} + h_3 - \frac{U_2^2}{2g} + h_2}{\frac{U_3^2}{2g}} \tag{4.19}$$

The loss coefficients apply to junctions with inlet and outlet legs 30 or more diameters long. Conditions are given under which the loss coefficients can be applied to junctions with short inlet and outlet legs.

Chamfers or radii at junctions can reduce one or both of the junction loss coefficents. Guidance is given on where radii are useful in reducing losses. Because of the marked effect of edge sharpness on 'T' junctions and additional inaccuracies introduced in having to measure flow rates in two legs, scatter in experimental results is often quite high compared to other components. Provided there are no reductions in cross-sectional area below the nominal value, loss coefficients of most practical 'sharp-edged' 'T' junctions are unlikely to exceed the loss coefficients for sharp-edged 'T' junctions given in this section.

Cross-sectional shape

Within limits, cross-sectional shape is not important. Data for circular cross-sections can be applied, without serious error, to junctions with rectangular cross-section legs or to 'T' junctions where the branch, leg 1, has a different cross-section from legs 2 and 3.

4.6.2 *Sharp-edged combining 'T's*

Performance charts showing contours of constant loss coefficients for sharp-edged combining tees with legs 2 and 3 of the same area are given for:

- 45° branch angle, K_{13} in Figure 4.39, K_{23} in Figure 4.40.

7)

8)

9)

re
an

ɔn
ıg
ns
in
to
ea
d'
I'

ıs-
ar
nt

p-

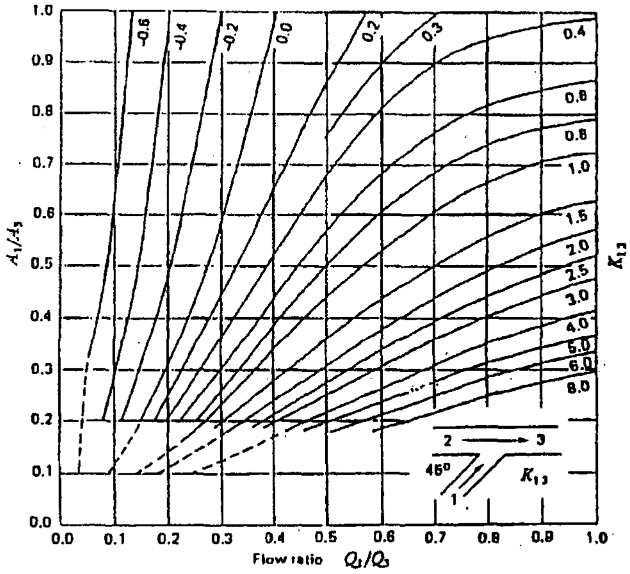


Figure 4.39. Combining flow – branch angle 45° – loss coefficient K_{13}.

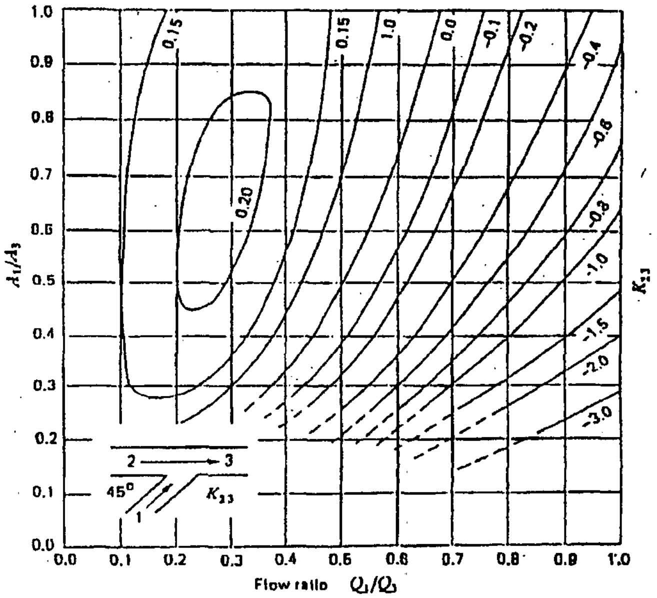


Figure 4.40. Combining flow – branch angle 45° – loss coefficient K_{23}.

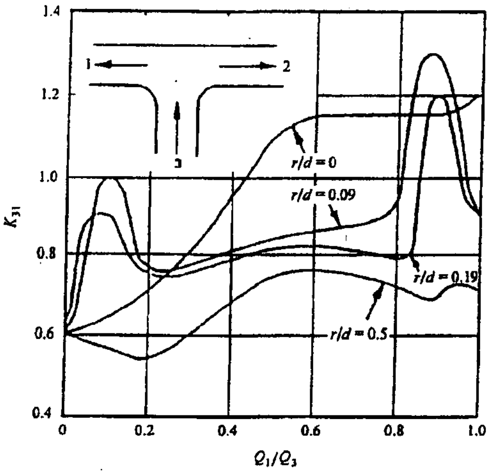


Figure 4.56. Symmetrical dividing 'T' junction with equal area legs.

4.6.8 *Symmetrical dividing junctions*

Loss coefficients, K_{31} , for symmetrically dividing 'T' junctions with the legs of equal area are given in Figure 4.56 for four junction radii.

Performance charts showing contours of constant loss coefficients are given in Figure 4.57 for dividing 'Y' junctions with area $A_1 = A_2$ and $A_1 + A_2 = A_3$ and in Figure 4.58 for dividing 'Y' junctions with $A_1 = A_2 = A_3$.

4.7 VALVES AND GATES

4.7.1 *Introduction*

Valves and gates are used to control the discharge through conduits by dissipating flow energy. This dissipation takes place in a sudden expansion in flow area after the control element. The energy loss due to an abrupt expansion in area can be calculated approximately from the one dimensional continuity, momentum and energy equations in the form:

$$K_s = \left[1 - \left(\frac{A_1}{A_2}\right)\right]^2 \qquad (4.20)$$

where A_1 is the minimum flow area which usually occurs after the control element at what is known as the vena contracta; A_2 is the downstream conduit area.

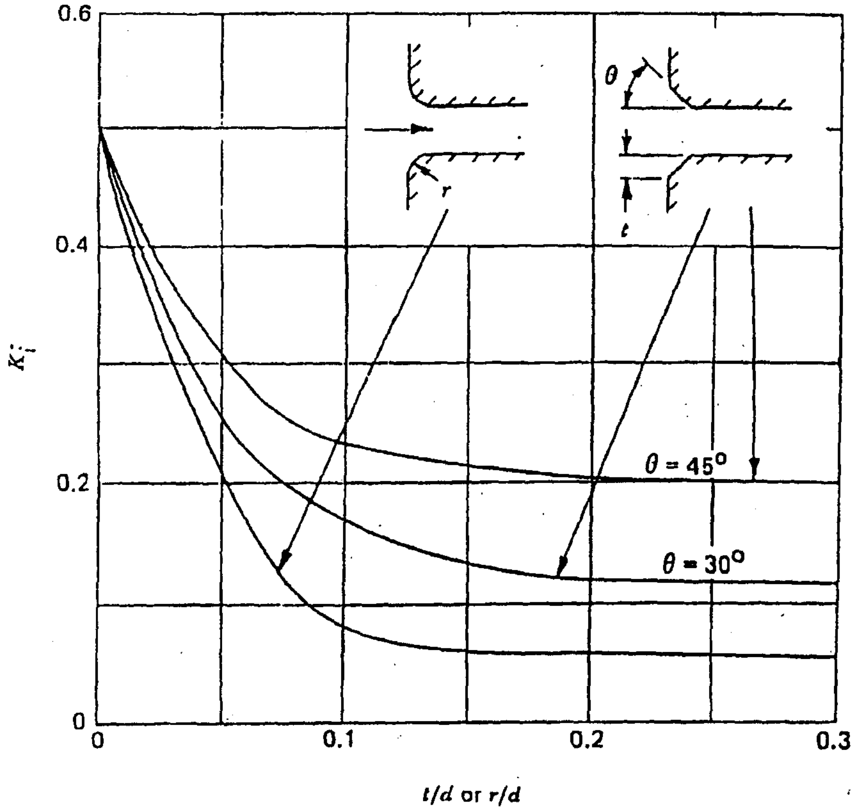


Figure 4.75. Loss coefficients for flush mounted intakes.

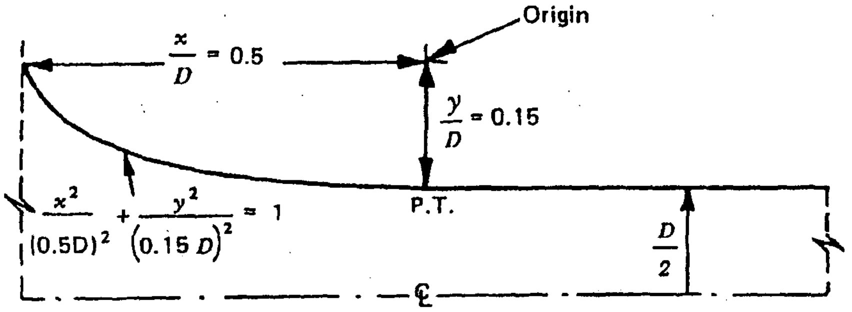


Figure 4.76. Inlet geometry (D = pipe diameter).

CDQ000020080019

INFORMATION ONLY
(from Ref 6)

sheet B9 of 10

PTER 4

(4.3)

e is the
fficient,
ı of the
ıe pipe.
5. Since
quation

(4.4)

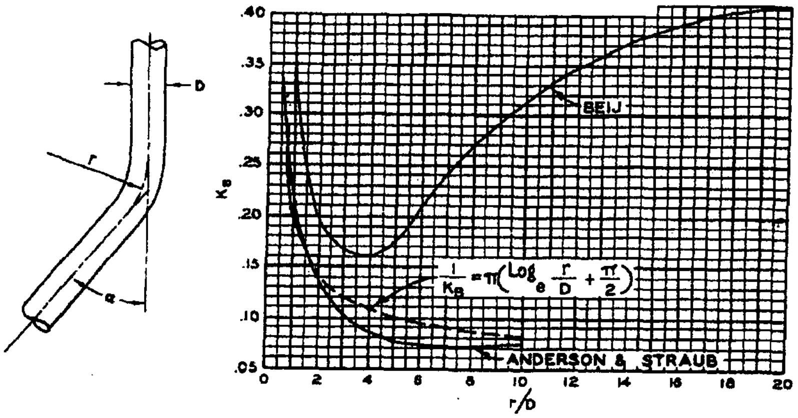
Values
e pipes.
ntrance
).5, res-
should

ng bend

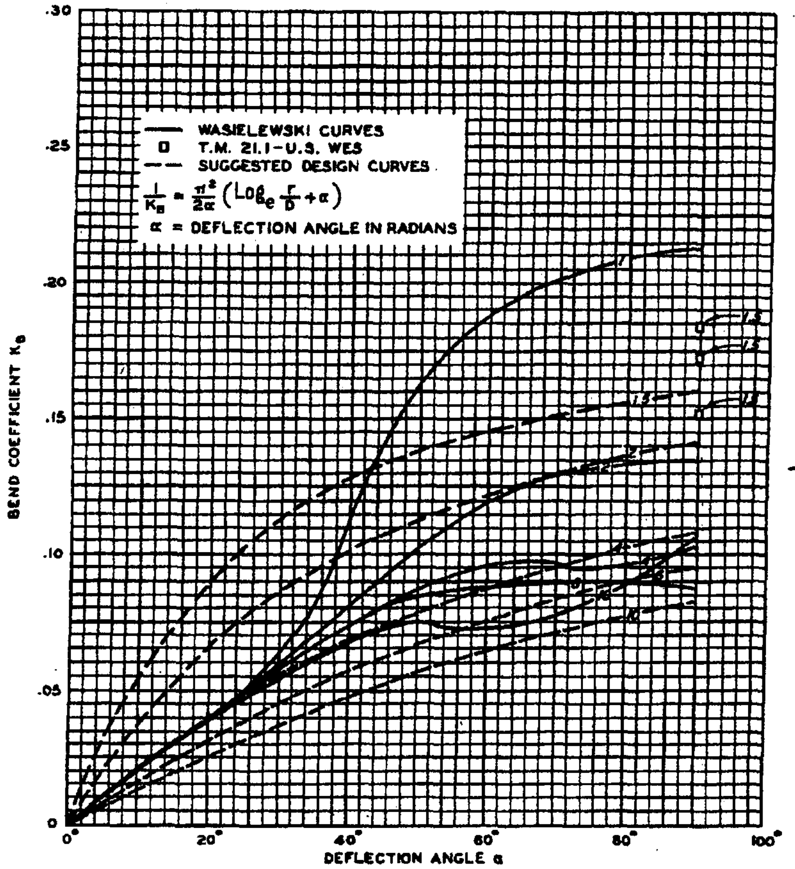
Table 4.1 Head Loss Coefficients for Circular Conduits Flowing Full.

Head Loss Coefficient, K_c, for Circular Pipe Flowing Full $K_c = \frac{5087\ n^2}{d_i^{4/3}}$

Pipe diam. inches	Flow area sq. ft.	Manning's Coefficient of Roughness "n"															
		0.010	0.011	0.012	0.013	0.014	0.015	0.016	0.017	0.018	0.019	0.020	0.021	0.022	0.023	0.024	0.025
6	0.196	0.0467	0.0565	0.0672	0.0789	0.0914	0.1050	0.1194	0.1348	0.1510	0.1680	0.1870	0.2060	0.2260	0.2470	0.2690	0.2920
8	0.349	.0318	.0385	.0458	.0537	.0623	.0715	.0814	.0919	.1030	.1148	.1272	.1400	.1540	.1680	.1830	.1990
10	0.545	.0236	.0286	.0340	.0399	.0463	.0531	.0604	.0682	.0765	.0852	.0944	.1041	.1143	.1249	.1360	.1480
12	0.785	.0185	.0224	.0267	.0313	.0363	.0417	.0474	.0535	.0600	.0668	.0741	.0817	.0896	.0980	.1067	.1157
14	1.069	.0151	.0182	.0217	.0255	.0295	.0339	.0386	.0436	.0488	.0544	.0603	.0665	.0730	.0798	.0868	.0942
15	1.230	.0138	.0166	.0198	.0232	.0270	.0309	.0352	.0397	.0446	.0496	.0550	.0606	.0666	.0727	.0792	.0859
16	1.400	.0126	.0153	.0182	.0213	.0247	.0284	.0323	.0365	.0409	.0455	.0505	.0556	.0611	.0667	.0727	.0789
18	1.770	~~.01078~~	.0130	.0155	.0182	.0211	.0243	.0276	.0312	.0349	.0389	.0431	.0476	.0522	.0570	.0621	.0674
21	2.410	.00878	.01062	.0126	.0148	.0172	.0198	.0225	.0254	.0284	.0317	.0351	.0387	.0425	.0464	.0506	.0549
24	3.140	.00735	.00889	.01058	.0124	.0144	.0165	.0188	.0212	.0238	.0265	.0294	.0324	.0356	.0389	.0423	.0459
27	3.980	.00628	.00760	.00904	.01061	.0123	.0141	.0161	.0181	.0203	.0227	.0251	.0277	.0304	.0332	.0362	.0393
30	4.910	.00546	.00660	.00786	.00922	.01070	.01228	.0140	.0158	.0177	.0197	.0218	.0241	.0264	.0289	.0314	.0341
36	7.070	.00428	.00518	.00616	.00723	.00839	.00963	.01096	.0124	.0139	.0154	.0171	.0189	.0207	.0226	.0246	.0267
42	9.620	.00348	.00422	.00502	.00589	.00683	.00784	.00892	.01007	.01129	.0126	.0139	.0154	.0169	.0184	.0201	.0218
48	12.570	.00292	.00353	.00420	.00493	.00572	.00656	.00747	.00843	.00945	.01053	.01166	.0129	.0141	.0154	.0168	.0182
54	15.900	.00249	.00302	.00359	.00421	.00488	.00561	.00638	.00720	.00808	.00900	.00997	.01099	.0121	.0132	.0144	.0156
60	19.630	.00217	.00262	.00312	.00366	.00424	.00487	.00554	.00622	.00702	.00782	.00866	.00955	.01048	.0115	.0125	.0135



K_B VS r/D FOR 90° BENDS



$\frac{r}{D} = \frac{75}{34} = 2.2$

$K_B \approx 0.135$

BASIC EQUATION = $h_L = K_B V^2/2g$

h_L = HEAD LOSS DUE TO BEND

K_B = BEND LOSS COEFFICIENT

V = VELOCITY IN PIPE

NOTE: FIGURES ON GRAPH INDICATE r/D RATIO.

BEND-LOSS COEFFICIENTS

HYDRAULIC DESIGN CHART 228-1

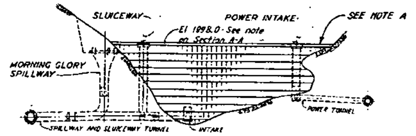
REVISED 8-58 WES 4-1-52

Attachment 1

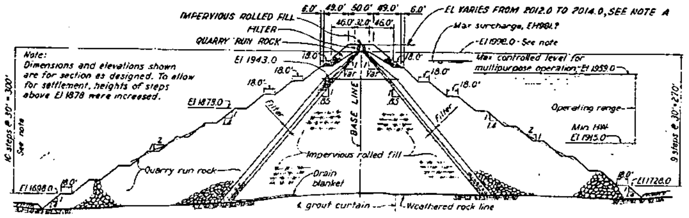
Source: Reference 1.1

Calculation CDQ00002008019

22 C 4 10N200

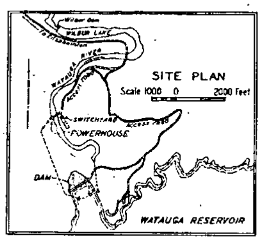


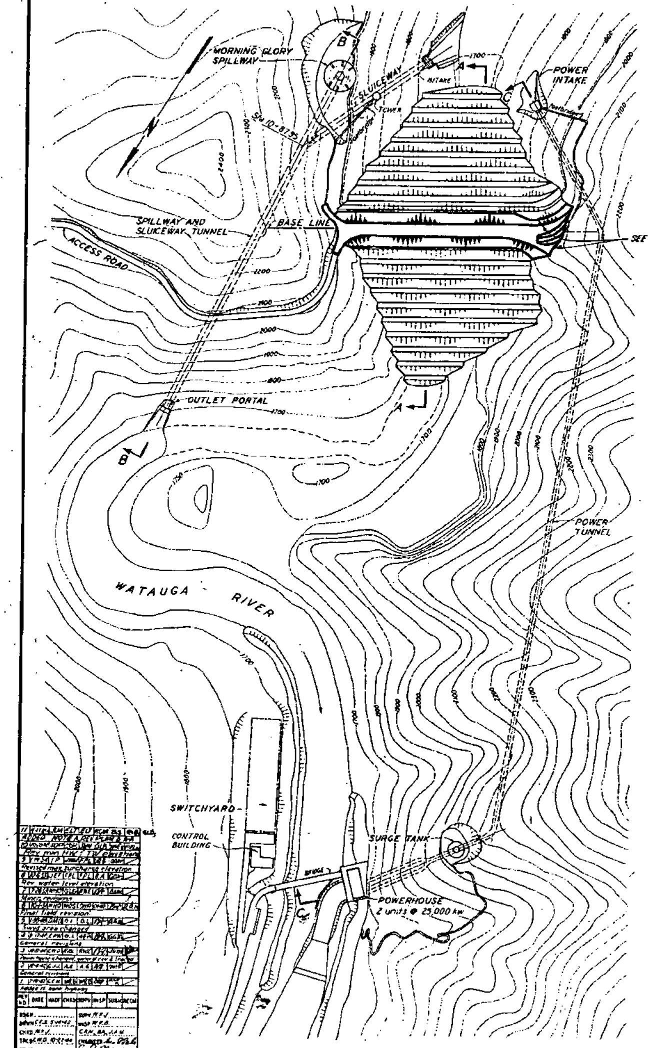
DOWNSTREAM ELEVATION



Note:
Dimensions and elevations shown are for section as designed. To allow for settlement, heights of steps above El 1878 were increased.

SECTION A-A

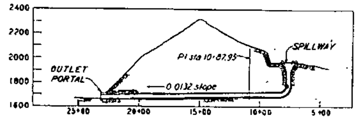




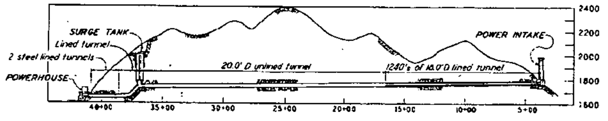
REV NO	DATE	MADE	CHKD	COPY	INSP	SUB	REC
11	[illegible]						
ADDED NOTE A, REV PLAN & A-A							
10	[illegible]						
Rev max HW & TW elevations							
9	[illegible]						
Revised max surcharge elevation							
8	[illegible]						
Rev water level elevation							
7	[illegible]						
Minor revisions							
6	[illegible]						
Final field revision							
5	[illegible]						
Swyd area changed							
4	[illegible]						
General revisions							
3	[illegible]						
Powerhouse changed, [illegible]							
2	[illegible]						
General revisions							
1	[illegible]						
Added rt bank topography							

DRAWN C.E.S.
CHKD M.F.J.
TRCD
SUPV M.F.J.
INSP W.F.B.
C.R.M., B.A., J.A.M.
HSM

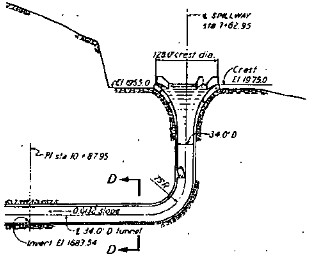
PLAN



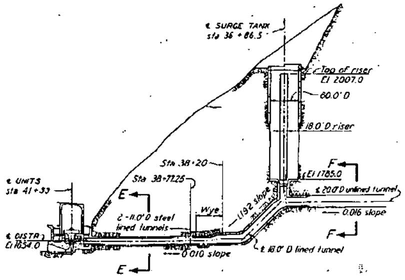
SECTION B-B



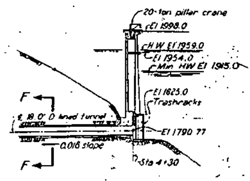
SECTION C-C



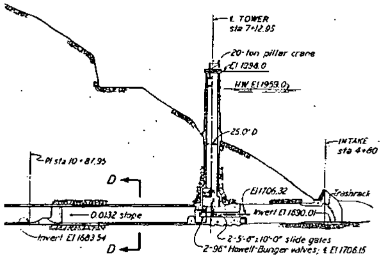
SECTION THRU SPILLWAY



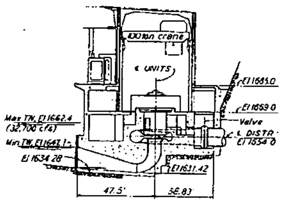
SECTION THRU POWERHOUSE & SURGE TANK



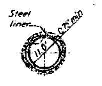
SECTION THRU POWER INTAKE



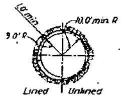
SECTION THRU SLUICEWAY



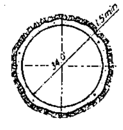
SECTION THRU UNIT



SECTION E-E



SECTION F-F



SECTION D-D

NOTE A:
FOR MODIFICATIONS TO DAM, SEE RAISING TOP OF DAM, PLAN, SECTIONS & DETAILS, DWG 21E210.

Scale 200 0 200 400 Feet
PLAN & DOWNSTREAM ELEVATION

Scale 30 0 30 60 Feet
SECTION THRU UNIT

Scale 20 0 20 40 Feet
SECTIONS D-D, E-E, & F-F

Scale 400 0 400 800 Feet
SECTIONS B-B & C-C

Scale 100 0 100 200 Feet
SECT. A-A, SECTS THRU: SPLWY, POWER INTAKE, PH & SURGE TANK, & SLUICEWAY

PROJECT MANAGER James B. Hays

DAM, CONDUIT & POWERHOUSE

GENERAL PLAN, ELEVATION & SECTIONS

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED M. L. Dickinson NSH
RECOMMENDED George K. Leonard
APPROVED T. B. Parker

KNOXVILLE | 6-5-42 | 22 | C | 4 | 10N200 R11

DRAWING AS CONSTRUCTED W. W. Seamon

① J.A.M.
② J.A.M., M.R.B.
③

Box 402

26 7/8 x 49 1/2"

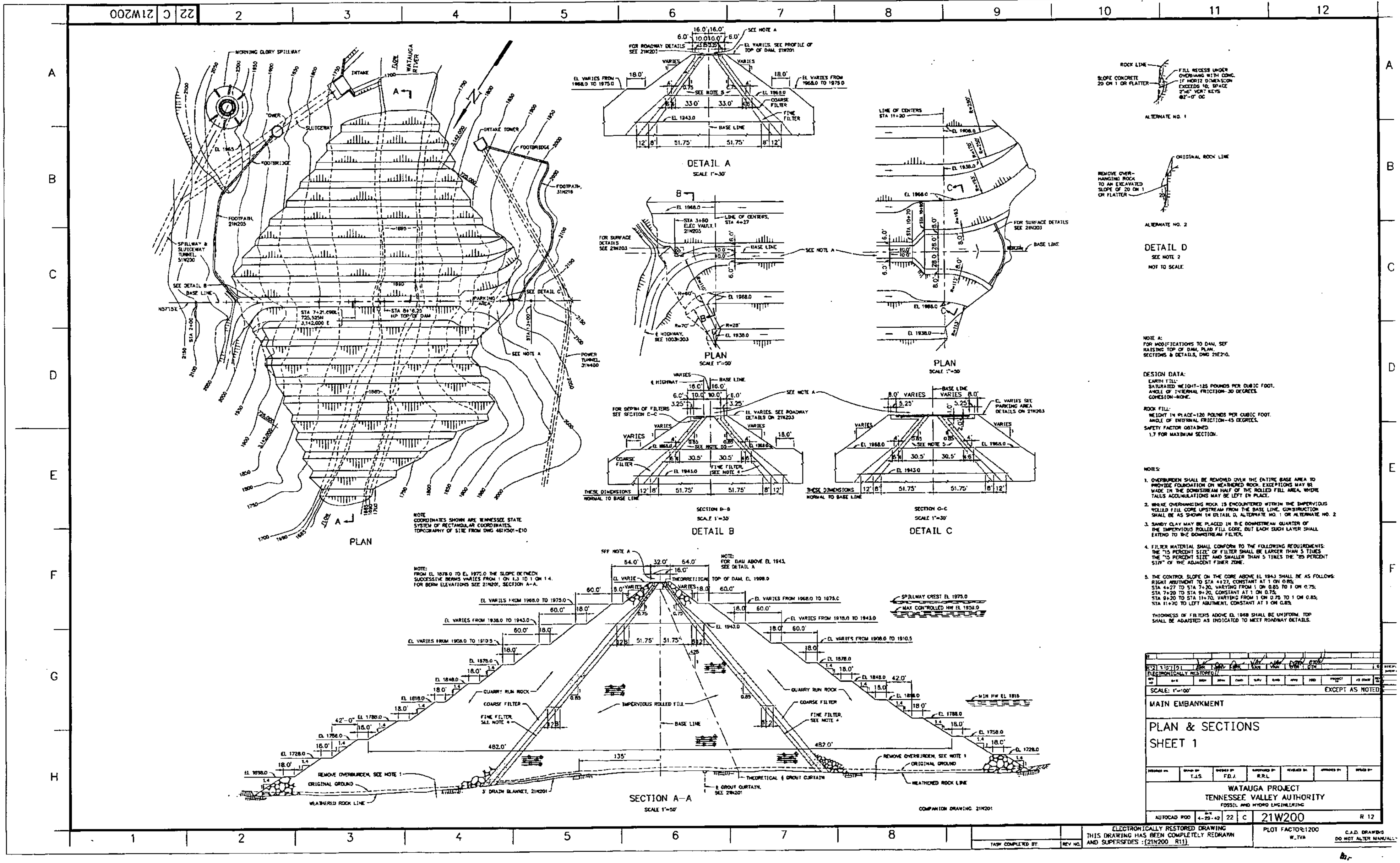
38 E

MF
910
E11

Attachment 1

Source: Reference 1.2

Calculation CDQ00002008019



NOTE

COORDINATES SHOWN ARE TENNESSEE STATE SYSTEM OF RECTANGULAR COORDINATES.
TOPOGRAPHY OF SITE FROM DWG 461K501-E10

NOTE:

FROM EL 1878.0 TO EL 1975.0 THE SLOPE BETWEEN SUCCESSIVE BERMS VARIES FROM 1 ON 1.3 TO 1 ON 1.4.
FOR BERM ELEVATIONS SEE 21N201, SECTION A-A.

NOTE A:

FOR MODIFICATIONS TO DAM, SEE RAISING TOP OF DAM, PLAN, SECTIONS & DETAILS, DWG 21E210.

DESIGN DATA:

EARTH FILL:
SATURATED WEIGHT-125 POUNDS PER CUBIC FOOT.
ANGLE OF INTERNAL FRICTION-30 DEGREES.
COHESION-NONE.

ROCK FILL:
WEIGHT IN PLACE-120 POUNDS PER CUBIC FOOT.
ANGLE OF INTERNAL FRICTION-45 DEGREES.

SAFETY FACTOR OBTAINED:
1.7 FOR MAXIMUM SECTION.

NOTES:

1. OVERBURDEN SHALL BE REMOVED OVER THE ENTIRE BASE AREA TO PROVIDE FOUNDATION ON WEATHERED ROCK. EXCEPTIONS MAY BE MADE IN THE DOWNSTREAM HALF OF THE ROLLED FILL AREA, WHERE TALUS ACCUMULATIONS MAY BE LEFT IN PLACE.
2. WHERE OVERHANGING ROCK IS ENCOUNTERED WITHIN THE IMPERVIOUS ROLLED FILL CORE UPSTREAM FROM THE BASE LINE, CONSTRUCTION SHALL BE AS SHOWN IN DETAIL D, ALTERNATE NO. 1 OR ALTERNATE NO. 2
3. SANDY CLAY MAY BE PLACED IN THE DOWNSTREAM QUARTER OF THE IMPERVIOUS ROLLED FILL CORE, BUT EACH SUCH LAYER SHALL EXTEND TO THE DOWNSTREAM FILTER.
4. FILTER MATERIAL SHALL CONFORM TO THE FOLLOWING REQUIREMENTS: THE "15 PERCENT SIZE" OF FILTER SHALL BE LARGER THAN 5 TIMES THE "15 PERCENT SIZE" AND SMALLER THAN 5 TIMES THE "85 PERCENT SIZE" OF THE ADJACENT FINER ZONE.
5. THE CONTROL SLOPE ON THE CORE ABOVE EL 1943 SHALL BE AS FOLLOWS:
RIGHT ABUTMENT TO STA 4+27, CONSTANT AT 1 ON 0.85;
STA 4+27 TO STA 7+20, VARYING FROM 1 ON 0.85 TO 1 ON 0.75;
STA 7+20 TO STA 9+20, CONSTANT AT 1 ON 0.75;
STA 9+20 TO STA 11+70, VARYING FROM 1 ON 0.75 TO 1 ON 0.85;
STA 11+70 TO LEFT ABUTMENT, CONSTANT AT 1 ON 0.85;

THICKNESS OF FILTERS ABOVE EL 1968 SHALL BE UNIFORM. TOP SHALL BE ADJUSTED AS INDICATED TO MEET ROADWAY DETAILS.

R12 | 3-10-91 | | GRK | JMV | GRK | VAN | VAN | DTN | DTN
ELECTRONICALLY RESTORED

SCALE: 1"=100' EXCEPT AS NOTED

MAIN EMBANKMENT

PLAN & SECTIONS
SHEET 1

DRAWN BY T.J.S. | CHECKED BY F.D.J. | SUPERVISED BY R.R.L.

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R00 | 4-29-42 | 22 | C | 21W200 | R 12

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(21N200 R11)

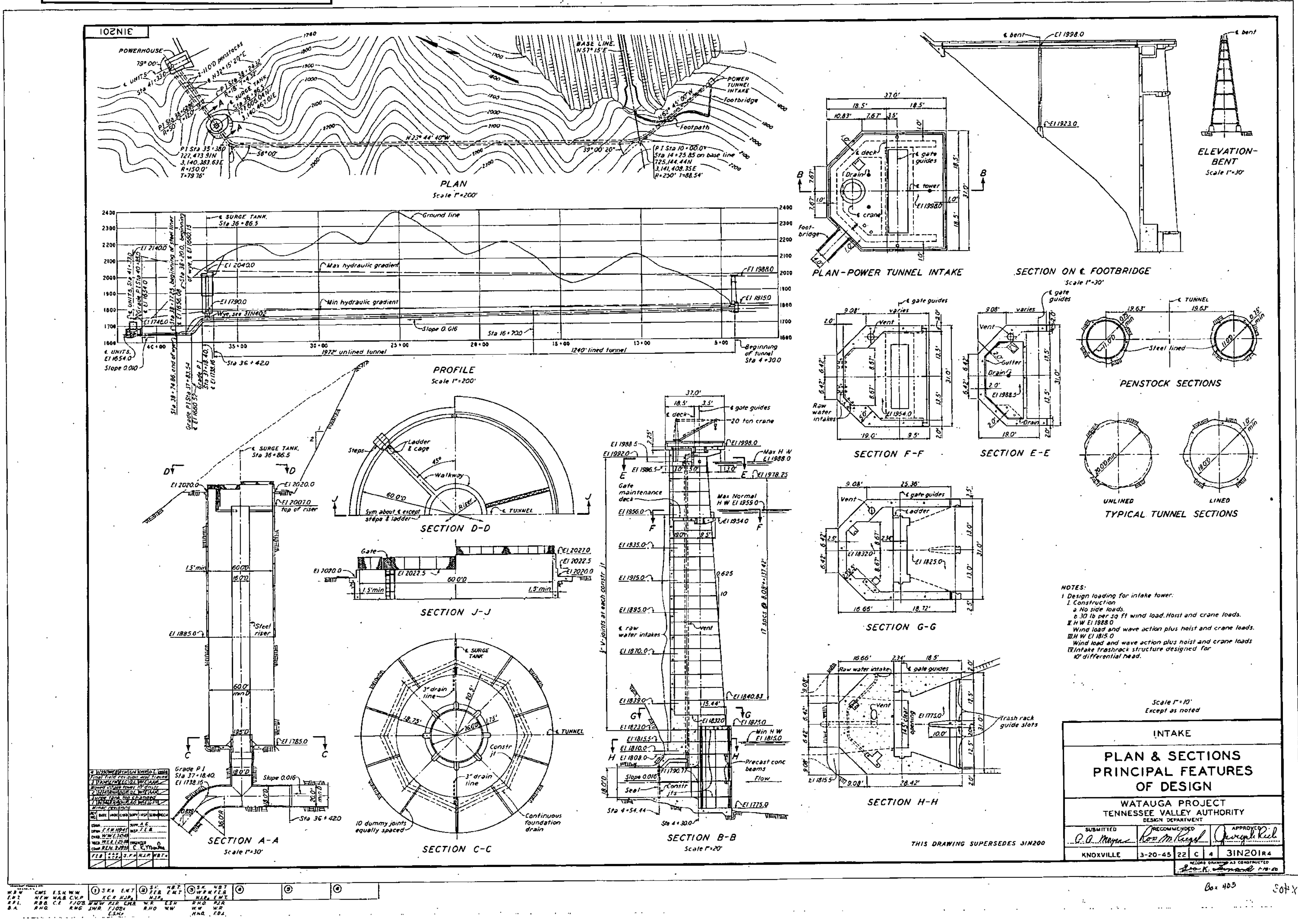
PLOT FACTOR:1200
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Attachment 1

Source: Reference 1.3

Calculation CDQ00002008019



NOTES:

1 Design loading for intake tower:
  I. Construction
    a. No side loads.
    b. 30 lb per sq ft wind load. Hoist and crane loads.
  II. H W El 1988.0
    Wind load and wave action plus hoist and crane loads.
  III. H W El 1815.0
    Wind load and wave action plus hoist and crane loads
  IV. Intake trashrack structure designed for
    10' differential head.

Scale 1"=10'
Except as noted

INTAKE

PLAN & SECTIONS
PRINCIPAL FEATURES
OF DESIGN

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
C. A. Meyer	Ross M Riegel	George Rich

KNOXVILLE 3-20-45 22 C 4 31N201R4

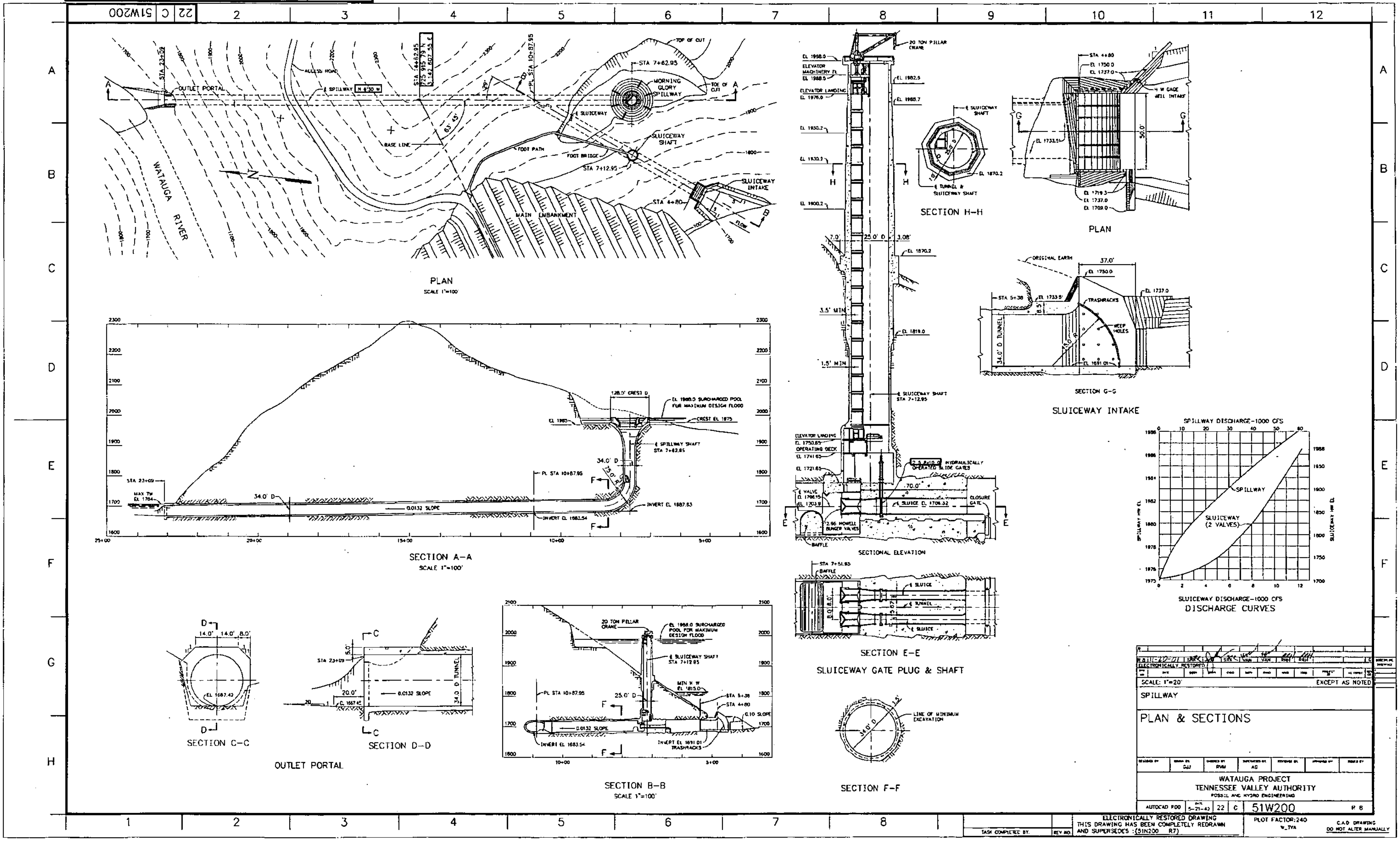
RECORD DRAWING AS CONSTRUCTED
Geo K. Leonard

Box 405

Attachment 1

Source: Reference 1.4

Calculation CDQ00002008019



Attachment 1

Source: Reference 1.5

Calculation CDQ00002008019

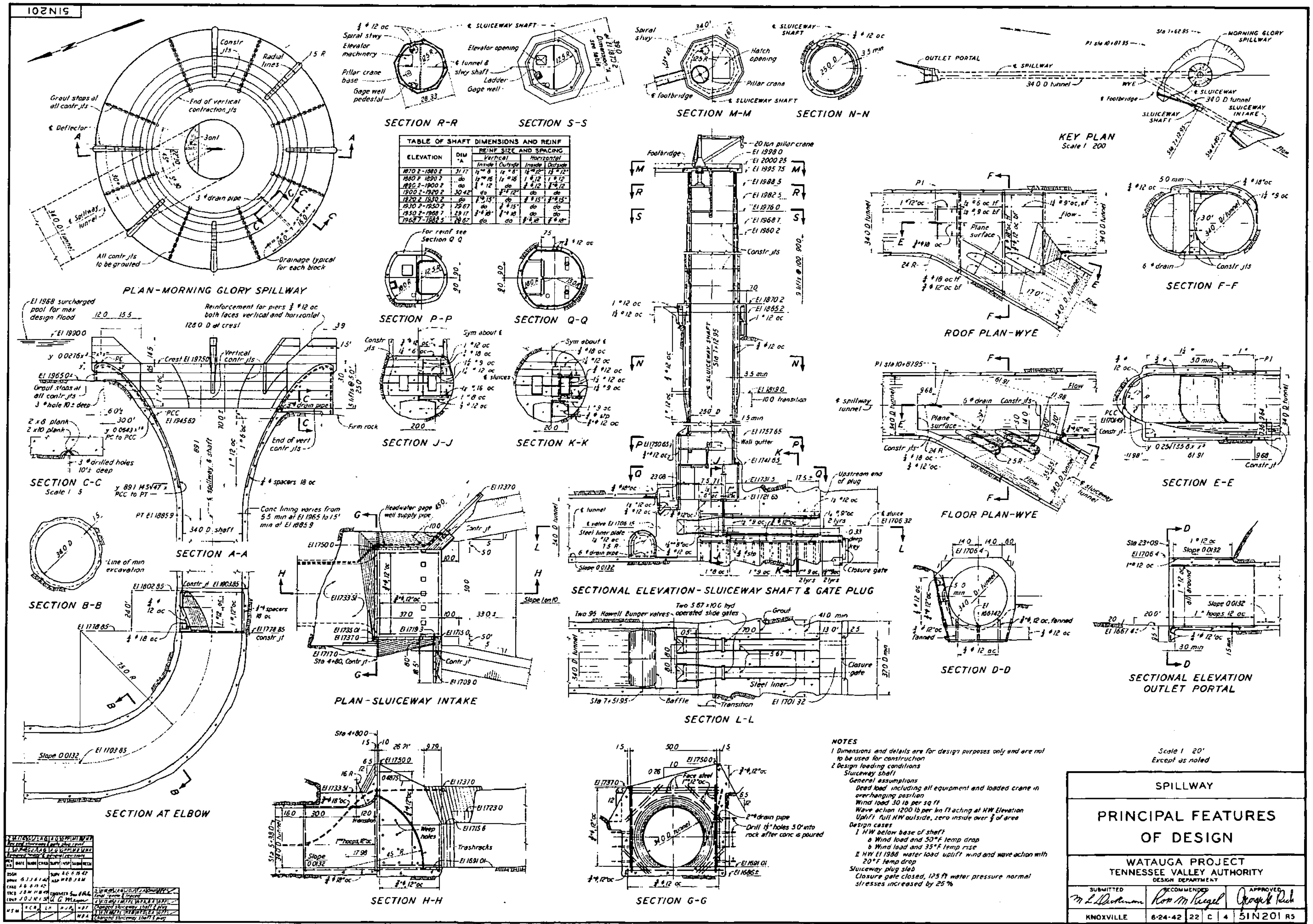


TABLE OF SHAFT DIMENSIONS AND REINF					
ELEVATION	DIM "A"	REINF SIZE AND SPACING			
		Vertical		Horizontal	
		Inside	Outside	Inside	Outside
1870 2-1880 2	31 17	1¼ ■ 8	1¼ ■ 8"	1¼ ■ 12"	1¼ ■ 12"
1880 2-1890 2	do	1¼ ■ 16	1¼ ■ 16	1 ● 12	1 ● 12
1890 2-1900 2	do	⅞ ● 12	do	⅞ ● 12	⅞ ● 12
1900 2-1920 2	30 42	do	⅞ ● 12"	do	do
1920 2-1930 2	do	⅞ ● 15"	do	⅞ ● 15"	⅞ ● 15"
1930 2-1950 2	29 67	do	⅞ ● 15"	do	do
1950 2-1968 7	29 17	¾ ● 18"	¾ ● 18	do	do
1968 7-1982 5	29 67	do	do	¾ ● 18	¾ ● 18"

NOTES

1 Dimensions and details are for design purposes only and are not to be used for construction

2 Design loading conditions
  - Sluiceway shaft
    - General assumptions
      - Dead load including all equipment and loaded crane in overhanging position
      - Wind load 30 lb per sq ft
      - Wave action 1200 lb per lin ft acting at HW Elevation
      - Uplift full HW outside, zero inside over ⅔ of area
    - Design cases
      - I HW below base of shaft
        - a Wind load and 50°F temp drop
        - b Wind load and 35°F temp rise
      - II HW El 1988 water load uplift wind and wave action with 20°F temp drop
  - Sluiceway plug slab
    - Closure gate closed, 125 ft water pressure normal stresses increased by 25%

Scale 1 20'
Except as noted

SPILLWAY

PRINCIPAL FEATURES
OF DESIGN

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
M L Dickinson	Ross M Riegel	George K Rich

KNOXVILLE | 6-24-42 | 22 | C | 4 | 51N201 R5

RECORD DRAW NO AS CONSTRUCTED

Attachment 1

Source: Reference 1.6

Calculation CDQ00002008019

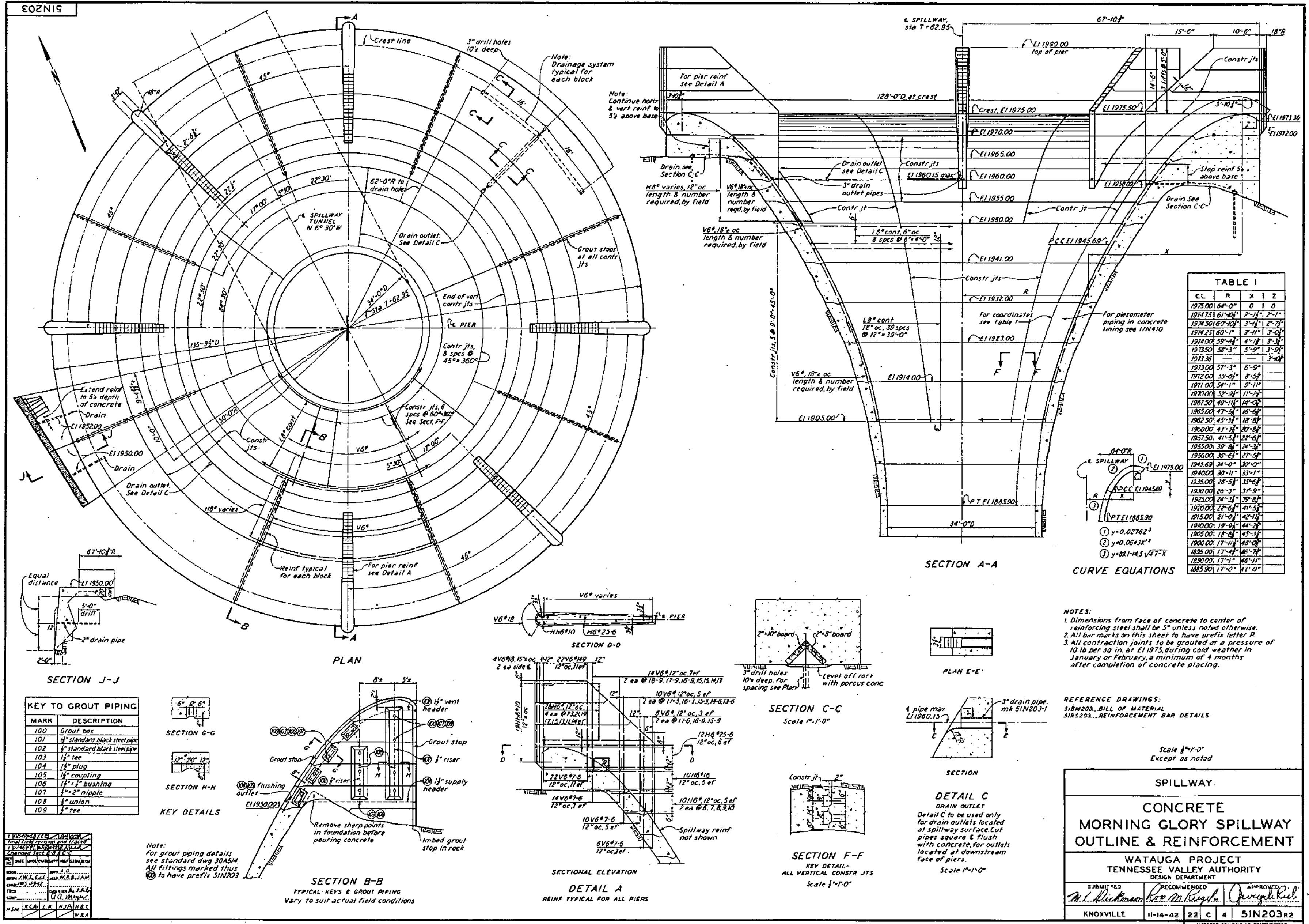


TABLE I

EL	R	X	Z
1975.00	64'-0"	0	0
1974.75	61'-10½"	2'-1½"	2'-1"
1974.50	60'-10½"	3'-1½"	2'-7½"
1974.25	60'-1"	3'-11"	3'-0½"
1974.00	59'-4¼"	4'-7¾"	3'-3¾"
1973.50	58'-3"	5'-9"	3'-9½"
1973.36	—	—	3'-10½"
1973.00	57'-3"	6'-9"	
1972.00	55'-6½"	8'-5½"	
1971.00	54'-1"	9'-11"	
1970.00	52'-9¼"	11'-2¾"	
1967.50	49'-11¼"	14'-0¾"	
1965.00	47'-5¼"	16'-6¾"	
1962.50	45'-3¼"	18'-8¾"	
1960.00	43'-3¼"	20'-8¾"	
1957.50	41'-5¼"	22'-6¾"	
1955.00	39'-8¼"	24'-3¾"	
1950.00	36'-6½"	27'-5½"	
1945.69	34'-0"	30'-0"	
1940.00	30'-11"	33'-1"	
1935.00	28'-5¼"	35'-6¾"	
1930.00	26'-3"	37'-9"	
1925.00	24'-3¼"	39'-8¾"	
1920.00	22'-6¼"	41'-5¾"	
1915.00	21'-0¼"	42'-11¾"	
1910.00	19'-9¼"	44'-2¾"	
1905.00	18'-8¼"	45'-3¾"	
1900.00	17'-11¼"	46'-0¾"	
1895.00	17'-4¼"	46'-7¾"	
1890.00	17'-1"	46'-11"	
1885.90	17'-0"	47'-0"	

KEY TO GROUT PIPING

MARK	DESCRIPTION
100	Grout box
101	1½" standard black steel pipe
102	½" standard black steel pipe
103	1½" tee
104	1½" plug
105	1½" coupling
106	1½" x ½" bushing
107	½" x 2" nipple
108	½" union
109	½" tee

NOTES:

1. Dimensions from face of concrete to center of reinforcing steel shall be 5" unless noted otherwise.
2. All bar marks on this sheet to have prefix letter P.
3. All contraction joints to be grouted at a pressure of 10 lb per sq in. at El 1975, during cold weather in January or February, a minimum of 4 months after completion of concrete placing.

REFERENCE DRAWINGS:

51BM203...BILL OF MATERIAL
51RS203...REINFORCEMENT BAR DETAILS

Scale ⅛"=1'-0"
Except as noted

SPILLWAY

CONCRETE
MORNING GLORY SPILLWAY
OUTLINE & REINFORCEMENT

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
M. L. Dickinson	Ross M. Riegel	George Rich

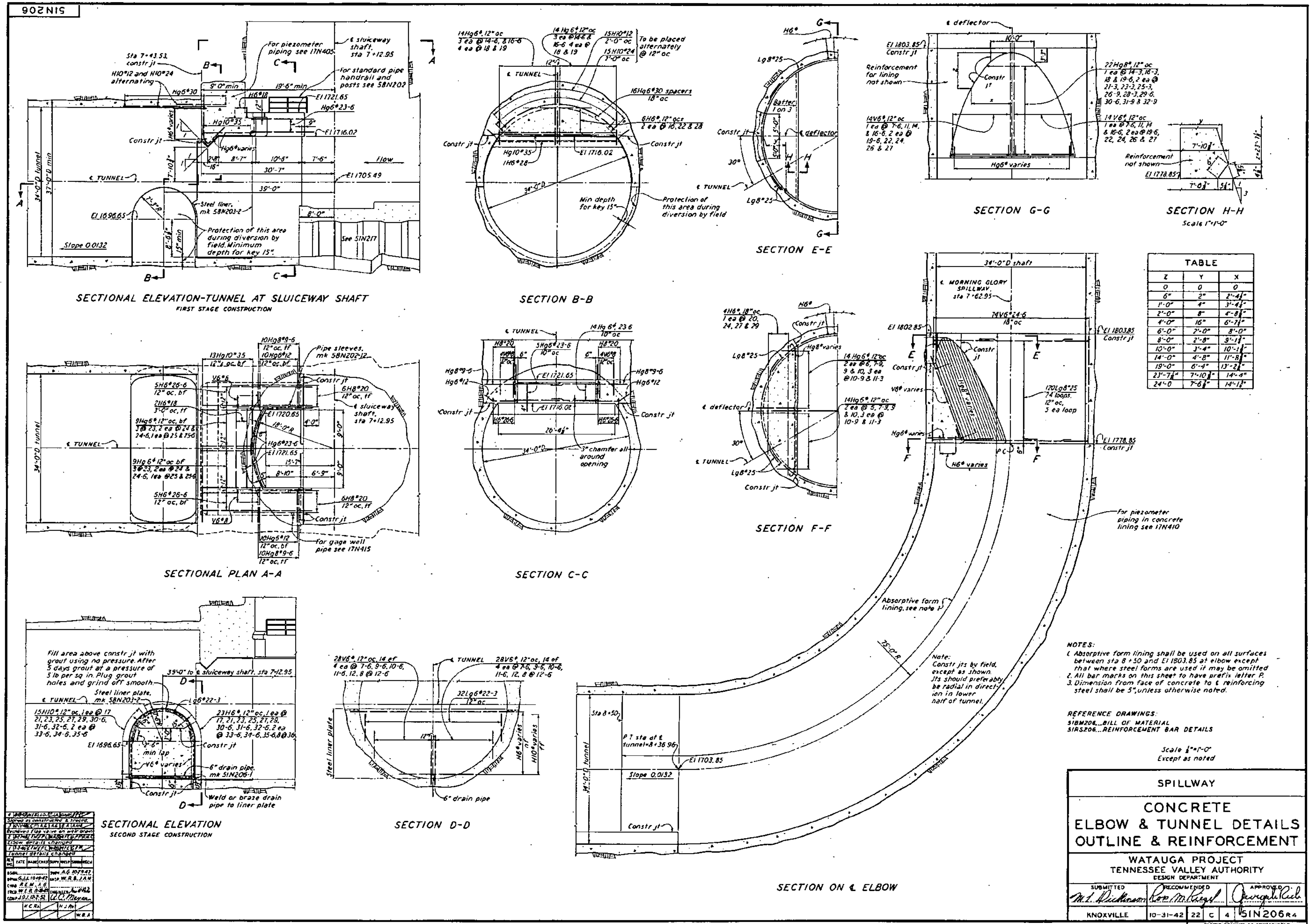
KNOXVILLE	11-14-42	22	C	4	51N203R2

RECORD DRAWING AS CONSTRUCTED
Leonard

Attachment 1

Source: Reference 1.7

Calculation CDQ00002008019



SECTIONAL ELEVATION–TUNNEL AT SLUICEWAY SHAFT

FIRST STAGE CONSTRUCTION

SECTION B-B

SECTION E-E

SECTION G-G

SECTION H-H

Scale 1"=1'-0"

SECTIONAL PLAN A-A

SECTION C-C

SECTION F-F

SECTIONAL ELEVATION

SECOND STAGE CONSTRUCTION

SECTION D-D

SECTION ON ℄ ELBOW

TABLE		
Z	Y	X
0	0	0
6"	2"	2'-4¼"
1'-0"	4"	3'-4¾"
2'-0"	8"	4'-8¼"
4'-0"	16"	6'-7¼"
6'-0"	2'-0"	8'-0"
8'-0"	2'-8"	9'-1¾"
10'-0"	3'-4"	10'-1¼"
14'-0"	4'-8"	11'-8¼"
19'-0"	6'-4"	13'-2¼"
23'-7⅛"	7'-10⅜"	14'-4"
24'-0	7'-6⅜"	14'-1⅜"

NOTES:

1. Absorptive form lining shall be used on all surfaces between sta 8+50 and El 1803.85 at elbow except that where steel forms are used it may be omitted
2. All bar marks on this sheet to have prefix letter P.
3. Dimension from face of concrete to ℄ reinforcing steel shall be 5", unless otherwise noted.

REFERENCE DRAWINGS:

51BM206...BILL OF MATERIAL

51RS206...REINFORCEMENT BAR DETAILS

Scale ¼"=1'-0"

Except as noted

SPILLWAY

CONCRETE
ELBOW & TUNNEL DETAILS
OUTLINE & REINFORCEMENT

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
M.L. Dickinson	Roe M. Riegel	George Rich

KNOXVILLE	10-31-42	22	C	4	51N206 R4

RECORD DRAWING AS CONSTRUCTED

12-29-49

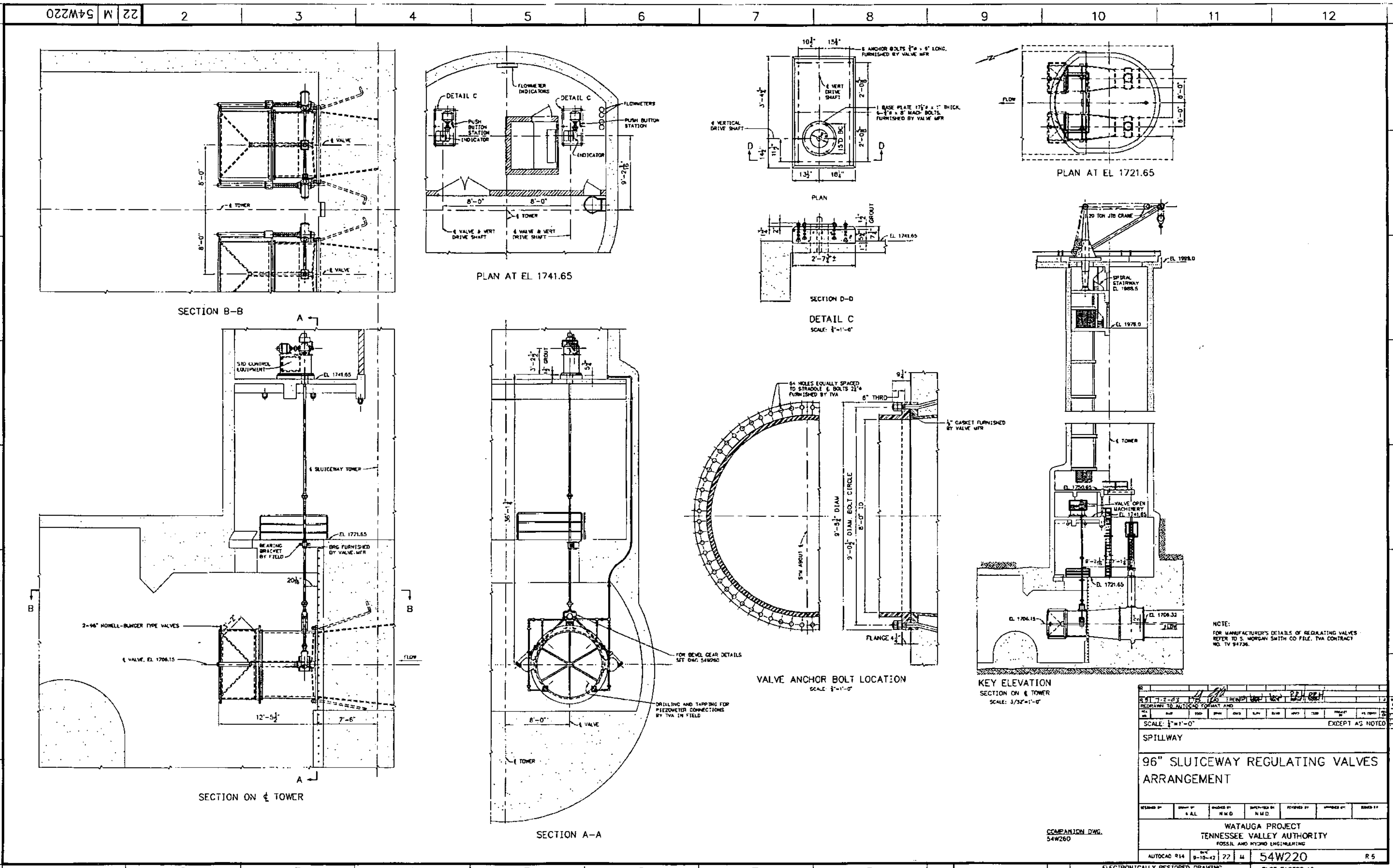
8-18-49 JEB 12-31-52

MF R4

Attachment 1

Source: Reference 1.8

Calculation CDQ00002008019



SECTION B-B

PLAN AT EL 1741.65

DETAIL C
SCALE: 3/4"=1'-0"

PLAN AT EL 1721.65

SECTION ON ℄ TOWER

SECTION A-A

VALVE ANCHOR BOLT LOCATION
SCALE: 3/4"=1'-0"

KEY ELEVATION
SECTION ON ℄ TOWER
SCALE: 3/32"=1'-0"

NOTE:
FOR MANUFACTURER'S DETAILS OF REGULATING VALVES REFER TO S. MORGAN SMITH CO FILE. TVA CONTRACT NO. TV 94736.

COMPANION DWG.
54W260

R5 7-2-03 REDRAWN TO AUTOCAD FORMAT AND

SCALE: 1/4"=1'-0" EXCEPT AS NOTED

SPILLWAY

96" SLUICEWAY REGULATING VALVES ARRANGEMENT

DRAWN BY K.A.L. CHECKED BY N.M.D. SUPERVISED BY N.M.D.

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | 9-10-42 | 22 | M | 54W220 | R5

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN AND SUPERSEDES :(54N220 R4)

TASK COMPLETED BY: REV NO.

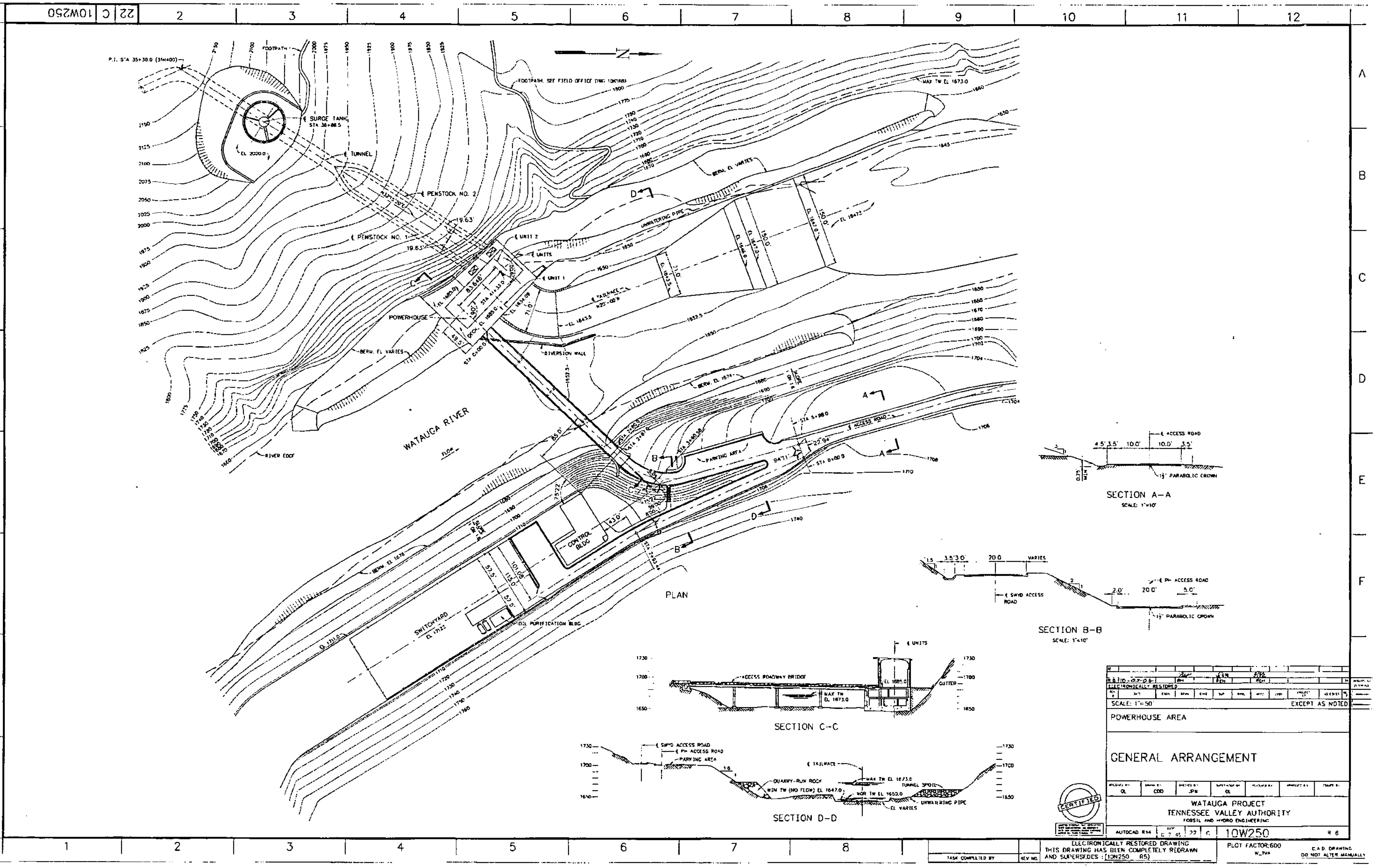
PLOT FACTOR:48
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Attachment 1

Source: Reference 1.9

Calculation CDQ00002008019



R6 10-03-04

ELECTRONICALLY RESTORED

SCALE: 1"=50' EXCEPT AS NOTED

POWERHOUSE AREA

GENERAL ARRANGEMENT

OL | CDD | JPW | OL

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R14 | C 7 45 | 22 | C | 10W250 | R 6

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES : (10W250 R5)

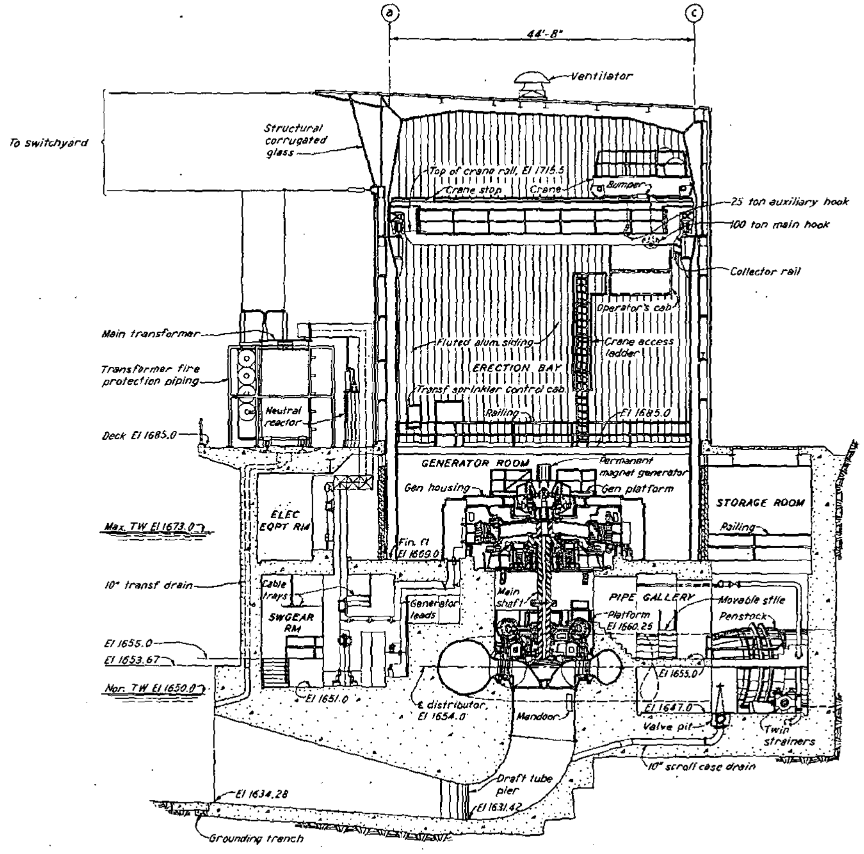
PLOT FACTOR:600
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

Attachment 1

Source: Reference 1.10

Calculation CDQ00002008019



Scale ½" = 1'-0"

1	5-24-50	R.K.M.	S.A.D.	R.K.A.	H.A.G.		
Traced							
REV NO	DATE	MADE	CHKD	SUPV	INSP	CL.DM	RECM

DSGN. ______ SUPV. R.A.O.
DRWN. T.R.E. INSP. W.C.S.
CHKD. R.T.C.
TRCD. M.E.M. 5-24-50 ENGINEER
COMP. ______

S.K.	A.A.M.B.	G.P.P.		R.J.P.

POWERHOUSE

EQUIPMENT
TRANSVERSE SECTION
THRU UNIT 2

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

RECOMMENDED	REVIEWED	APPROVED
Henry B. Fox	W.F. Allen	R.A. Monroe

KNOXVILLE	12-6-48	22	A	4	46K205R1

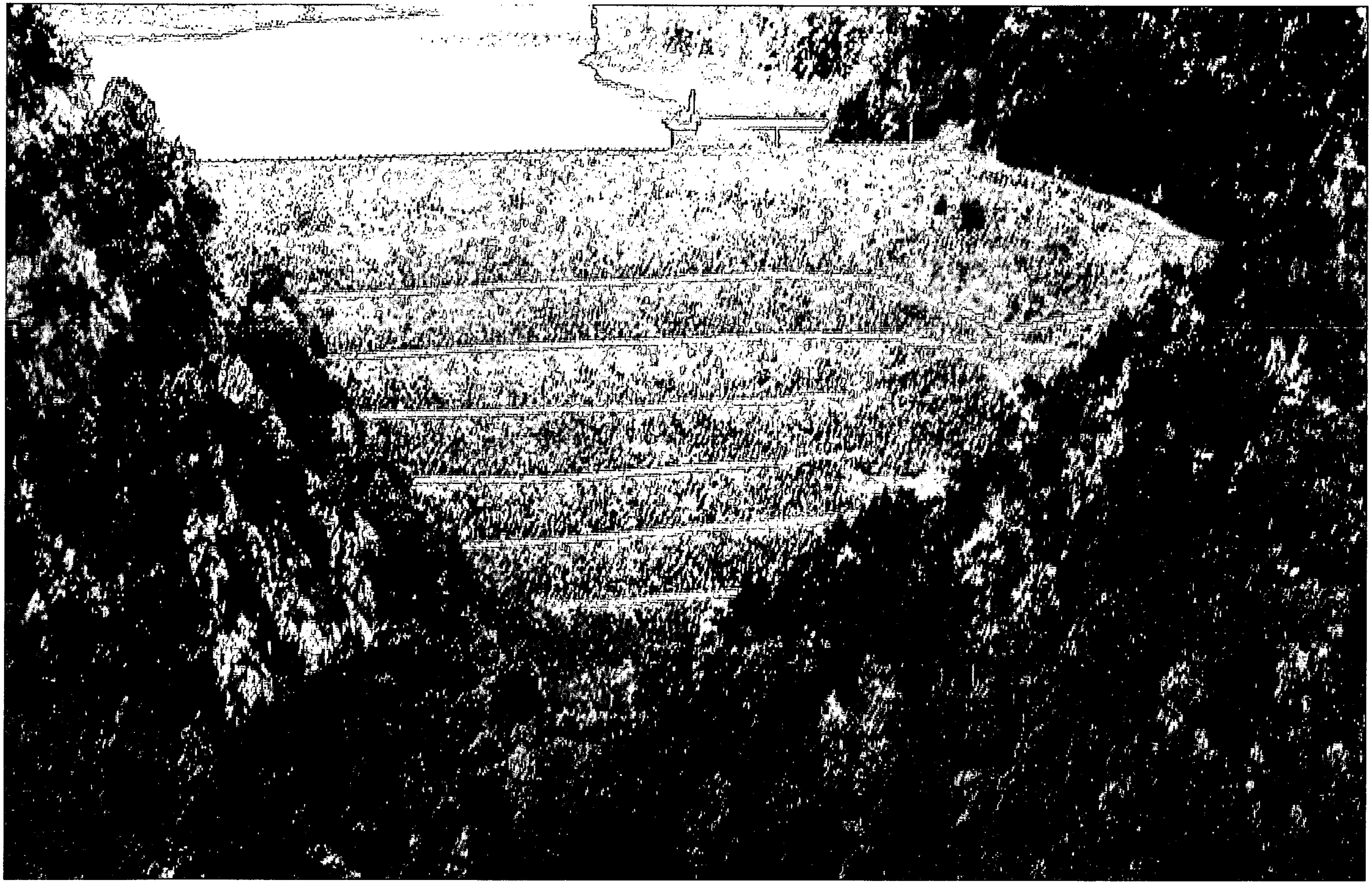
MF
R1

E.C., P.J.R., W.R.M., E.M.T., H.W.P. Jr., D.W., O.C., W.R.B., E.E.M., C.V.P., L.W.S., W.N., C.L.H., B.S.M., R.F., C.W.B., F.J.O'R., Holm

Attachment 2-1

Calculation No: CDQ000020080019

WATAUGA DAM



January 2000

STREAMFLOW (CONT.)

Near Elizabethton, Tennessee, October 1902 to December 1908; drainage area	474 sq. miles
At Siam, Tennessee, March 1946 to May 1946; drainage area	480 sq. miles
At Elizabethton, Tennessee, October 1925 to July 1949; July 1953 to date; drainage area	692 sq. miles
Maximum natural flood at dam site (estimated ,August 1940)	71,500 cfs
Maximum regulated flood since closure of dam (February ,1957)	8945 cfs
Average unregulated flow at dam site: (estimated ,1903-1999)	716 cfs
Minimum daily natural flow at dam site (estimated , 1954)	39 cfs

RESERVOIR

Counties affected:	
State of Tennessee	Carter, Johnson
Reservoir land at May 1996:	
Fee simple	5,496 ac.
Easements	2,419 ac.
Total	7,915 ac.
Transferred	3,688 ac.
Operating levels at dam:	
Probable maximum flood elevation	el. 2009.2
500 year flood elevation	el. 1974.5
100 year flood elevation	el. 1967.0
Maximum used for design (130,000 cfs)	el. 1988.0
Spillway crest (area 7,00 ac.)	el. 1975.0
Summer pool (area 6,430 c.)	el. 1959.0
Winter pool (area 4,690 c.)	el. 1915.0
Backwater, length at normal maximum pool level	16.3 miles
Shoreline, length at normal maximum pool level:	
Main shore	104 miles
Islands	2 miles
Total	106 miles
Original river area (to el. 1975 crossing)	313 ac.
Storage (flat pool assumption):	
Total volume:	
At spillway crest (el. 1975)	677,000 ac.-ft
At normal maximum pool (el. 1959)	568,700 ac.-ft
At normal minimum pool (el. 1915)	323,000 ac.-ft
January 1 to January 25 (el. 1975-1940)	223,000 ac.-ft
April 15 (el. 1975-1959)	108,300 ac.-ft
Useful controlled storage (el. 1975-1915)	354,000 ac.-ft

TAILWATER (At Powerhouse)

Maximum used for design	el. 1664.0
Full plant operation (1 unit)	el. 1651.3
One unit operating at best efficiency	el. 1649.8
Minimum level	el. 1647.1

HEAD (Gross)

Maximum static (el. 1975-1647.1)	327.9 ft
Normal maximum operating (el. 1959-1650)	309.0 ft
Average operating	286.0 ft
Minimum operating (el. 1815-1652)	163.0 ft

RESERVOIR ADJUSTMENTS

Clearing (estimated)	1,663 ac.
Highways:	
Access	5.7 miles
State	10.1 miles
County and tertiary	39.1 miles
Total	54.9 miles
Bridges, highway	3
Families affected	761
Graves	1,281
Utilities adjusted or constructed	66.4 miles

DAM

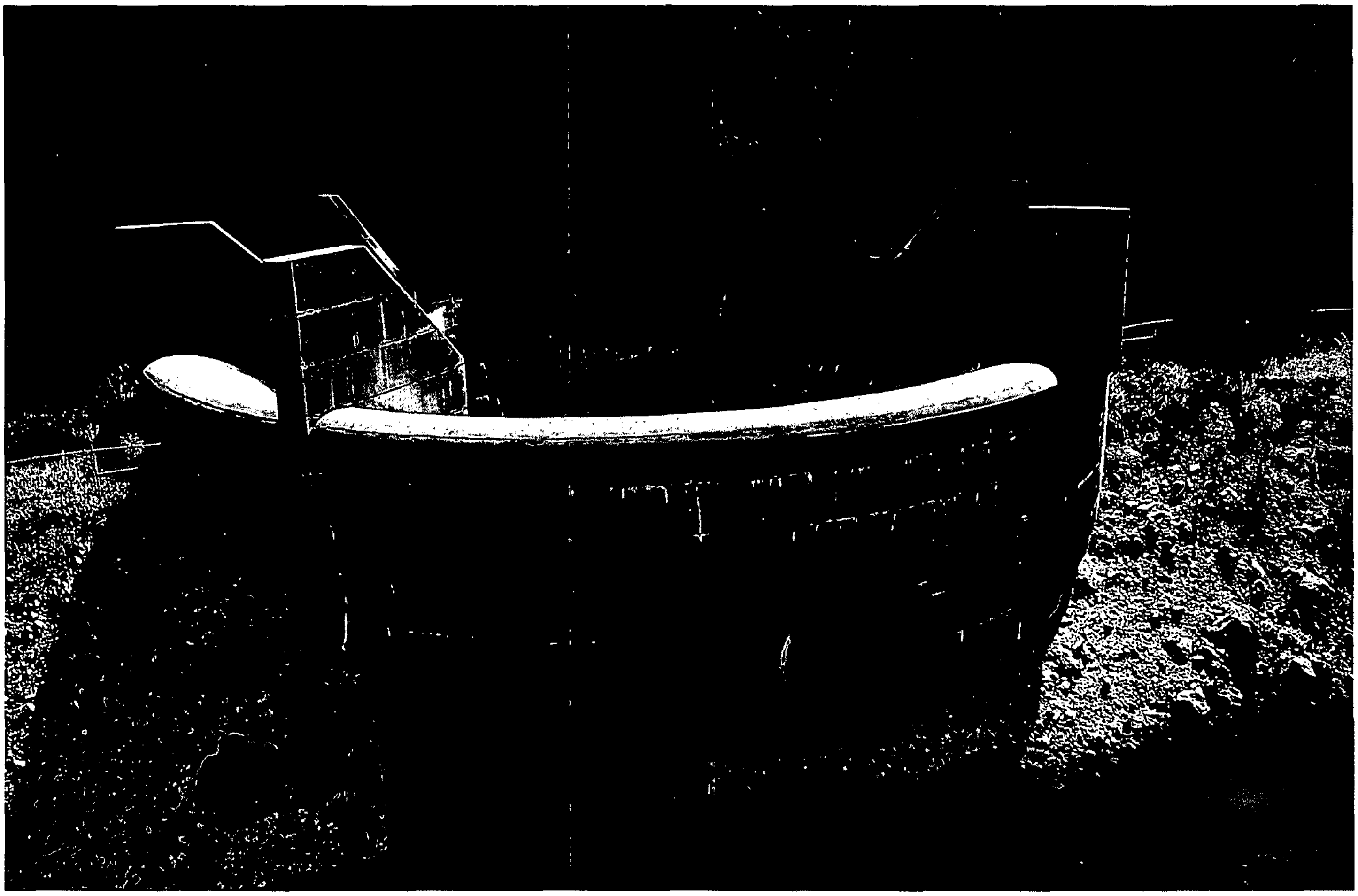
Material and type	Rockfill and impervious rolled earthfill embankment
Length	900 ft
Maximum height	318 ft
Maximum width at base	1260 ft
Top of embankment (original)	el. 1998.0
Top of embankment (modified for PMF)	varies from el. 2012.0 to 2014.0
Top width	32 ft
Foundation	Unicoi quartzite and Shady dolomite

OUTLETWORKS

SPILLWAY

Location	Right abutment
Material and type	Concrete, uncontrolled morning-glory spillway with concrete-lined shaft and discharge tunnel
Crest diameter	128 ft
Crest length, clear	385 ft
Crest level	el. 1975.0
Shaft and tunnel diameter	34 ft
Length:	
Shaft and elbow	313 ft
Tunnel	1,472 ft
Invert of tunnel outlet	el. 1667.4
Discharge capacity, HW el. 1988 (design level)	62,000 cfs

FIGURE 6 - Morning-glory Spillway Intake - Right Bank, September 1999



RESERVOIR AND POWER DATA

Watauga

				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1975	7.20	677.0	324.3	61.3	2,610	23.50	68.0	2,950	23.04
1974	7.10	669.8	323.3	61.3	2,610	23.50	68.0	2,950	23.04
1973	7.02	662.8	322.3	61.3	2,610	23.50	68.0	2,950	23.04
1972	6.95	655.8	321.3	61.3	2,610	23.50	68.0	2,950	23.04
1971	6.90	648.9	320.3	61.3	2,610	23.50	68.0	2,950	23.04
1970	6.86	642.0	319.3	60.9	2,590	23.45	68.0	2,950	23.01
1969	6.83	635.1	318.3	60.3	2,580	23.38	68.0	2,960	22.98
1968	6.80	628.3	317.3	59.7	2,560	23.32	68.0	2,960	22.94
1967	6.77	621.5	316.3	59.1	2,540	23.25	68.0	2,970	22.90
1966	6.74	614.8	315.3	58.6	2,520	23.18	68.0	2,970	22.86
1965	6.70	608.1	314.3	58.0	2,510	23.12	68.0	2,980	22.83
1964	6.67	601.4	313.3	57.4	2,490	23.05	68.0	2,980	22.79
1963	6.63	594.7	312.2	56.8	2,470	22.98	68.0	2,990	22.75
1962	6.60	588.1	311.2	56.2	2,450	22.92	68.0	2,990	22.71
1961	6.56	581.5	310.2	55.6	2,430	22.85	68.0	3,000	22.68
1960	6.53	575.0	309.2	55.5	2,430	22.78	67.8	3,010	22.57
1959	6.49	568.5	308.2	55.4	2,440	22.72	67.6	3,010	22.45
1958	6.45	562.0	307.2	55.4	2,450	22.65	67.4	3,020	22.33
1957	6.40	555.6	306.2	55.4	2,450	22.58	67.2	3,030	22.21
1956	6.36	549.2	305.2	55.4	2,460	22.51	67.0	3,040	22.09
1955	6.31	542.9	304.2	55.3	2,460	22.45	66.8	3,040	21.97
1954	6.26	536.6	303.2	55.3	2,470	22.38	66.6	3,050	21.85
1953	6.21	530.4	302.2	55.3	2,480	22.31	66.4	3,060	21.72
1952	6.15	524.2	301.2	55.2	2,480	22.25	66.2	3,070	21.60
1951	6.09	518.1	300.2	55.2	2,490	22.18	66.0	3,070	21.48
1950	6.03	512.0	299.2	55.2	2,500	22.11	65.8	3,080	21.37
1949	5.98	506.0	298.2	55.3	2,510	22.03	65.7	3,090	21.25
1948	5.92	500.0	297.2	55.3	2,520	21.95	65.5	3,100	21.14
1947	5.87	494.1	296.2	55.4	2,530	21.88	65.3	3,100	21.03
1946	5.82	488.3	295.2	55.4	2,540	21.80	65.1	3,110	20.91
1945	5.78	482.5	294.2	55.5	2,550	21.73	64.9	3,120	20.80
1944	5.74	476.7	293.1	55.5	2,570	21.65	64.7	3,130	20.69
1943	5.71	471.0	292.1	55.6	2,580	21.58	64.5	3,130	20.57

NOTE: Energy in storage values not included in this data

RESERVOIR AND POWER DATA

Watauga

				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1942	5.68	465.3	291.1	55.6	2,590	21.50	64.3	3,140	20.46
1941	5.66	459.6	290.1	55.7	2,600	21.43	64.1	3,150	20.35
1940	5.64	454.0	289.1	55.7	2,610	21.36	63.9	3,160	20.24
1939	5.62	448.4	288.1	55.8	2,620	21.30	63.7	3,160	20.12
1938	5.59	442.8	287.1	55.8	2,630	21.24	63.5	3,170	20.01
1937	5.57	437.2	286.1	55.9	2,640	21.17	63.2	3,180	19.90
1936	5.54	431.6	285.1	55.9	2,650	21.11	63.0	3,190	19.78
1935	5.51	426.1	284.1	56.0	2,660	21.05	62.8	3,190	19.67
1934	5.48	420.6	283.1	56.0	2,670	20.99	62.6	3,200	19.56
1933	5.44	415.1	282.1	56.1	2,680	20.92	62.4	3,210	19.44
1932	5.40	409.7	281.1	56.1	2,690	20.86	62.1	3,220	19.33
1931	5.36	404.3	280.1	56.2	2,700	20.80	61.9	3,220	19.22
1930	5.32	399.0	279.1	56.2	2,710	20.73	61.7	3,230	19.11
1929	5.27	393.7	278.1	56.2	2,720	20.67	61.5	3,240	19.01
1928	5.23	388.4	277.1	56.3	2,730	20.61	61.3	3,250	18.90
1927	5.18	383.2	276.1	56.3	2,740	20.55	61.2	3,250	18.80
1926	5.14	378.1	275.0	56.3	2,750	20.48	61.0	3,260	18.69
1925	5.10	373.0	274.0	56.3	2,760	20.42	60.8	3,270	18.59
1924	5.06	367.9	273.0	56.3	2,770	20.36	60.6	3,280	18.48
1923	5.01	362.8	272.0	56.4	2,780	20.29	60.4	3,280	18.38
1922	4.97	357.9	271.0	56.4	2,790	20.23	60.2	3,290	18.27
1921	4.93	352.9	270.0	56.4	2,800	20.17	60.0	3,300	18.17
1920	4.89	348.0	269.0	56.2	2,800	20.10	59.8	3,300	18.11
1919	4.85	343.1	268.0	56.0	2,800	20.02	59.6	3,300	18.05
1918	4.81	338.3	267.0	55.9	2,810	19.95	59.4	3,300	17.99
1917	4.77	333.5	266.0	55.7	2,810	19.88	59.2	3,300	17.93
1916	4.73	328.7	265.0	55.5	2,810	19.81	59.0	3,300	17.86
1915	4.70	324.0	264.0	55.3	2,810	19.74	58.8	3,300	17.80
1914	4.66	319.4	263.0	55.1	2,820	19.67	58.6	3,300	17.74
1913	4.62	314.7	262.0	55.0	2,820	19.59	58.4	3,300	17.68
1912	4.59	310.1	261.0	54.8	2,820	19.52	58.2	3,300	17.62
1911	4.55	305.5	260.0	54.6	2,820	19.45	58.0	3,300	17.56
1910	4.52	301.0	259.0	54.4	2,830	19.38	57.8	3,300	17.50

NOTE: Energy in storage values not included in this data

RESERVOIR AND POWER DATA

Watauga

				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1909	4.48	296.5	258.0	54.2	2,830	19.31	57.6	3,300	17.44
1908	4.45	292.0	257.0	54.1	2,830	19.24	57.4	3,300	17.38
1907	4.40	287.6	256.0	53.9	2,840	19.16	57.2	3,300	17.32
1906	4.36	283.2	255.0	53.7	2,840	19.09	57.0	3,300	17.26
1905	4.31	278.9	254.0	53.5	2,840	19.02	56.8	3,300	17.20
1904	4.26	274.6	253.0	53.3	2,840	18.95	56.6	3,300	17.14
1903	4.21	270.4	252.0	53.2	2,850	18.88	56.4	3,300	17.08
1902	4.15	266.2	251.0	53.0	2,850	18.80	56.2	3,300	17.02
1901	4.09	262.1	250.0	52.8	2,850	18.73	56.0	3,300	16.96
1900	4.03	258.0	249.0	52.6	2,860	18.66	55.8	3,300	16.89
1899	3.97	254.0	248.0	52.4	2,860	18.59	55.6	3,300	16.83
1898	3.91	250.1	247.0	52.3	2,860	18.52	55.4	3,300	16.77
1897	3.86	246.2	246.0	52.1	2,860	18.45	55.2	3,300	16.71
1896	3.82	242.3	245.0	51.9	2,870	18.37	55.0	3,300	16.65
1895	3.78	238.5	244.0	51.7	2,870	18.30	54.8	3,300	16.59
1894	3.74	234.8	243.0	51.5	2,870	18.23	54.6	3,300	16.53
1893	3.71	231.0	242.0	51.3	2,880	18.16	54.4	3,300	16.47
1892	3.69	227.3	241.0	51.2	2,880	18.09	54.2	3,300	16.41
1891	3.67	223.7	240.0	51.0	2,880	18.02	54.0	3,300	16.35
1890	3.66	220.0	239.0	50.8	2,880	17.94	53.8	3,300	16.29
1889	3.65	216.3	238.0	50.6	2,890	17.87	53.6	3,300	16.23
1888	3.63	212.7	237.0	50.4	2,890	17.80	53.4	3,300	16.17
1887	3.62	209.1	236.0	50.3	2,890	17.73	53.2	3,300	16.11
1886	3.59	205.5	235.0	50.1	2,890	17.66	53.0	3,300	16.05
1885	3.57	201.9	234.0	49.9	2,900	17.58	52.8	3,300	15.98
1884	3.54	198.3	233.0	49.7	2,900	17.51	52.6	3,300	15.92
1883	3.51	194.8	232.0	49.5	2,900	17.44	52.4	3,300	15.86
1882	3.48	191.3	231.0	49.4	2,910	17.37	52.2	3,300	15.80
1881	3.44	187.8	230.0	49.2	2,910	17.30	52.0	3,300	15.74
1880	3.40	184.4	229.0	49.0	2,910	17.23	51.8	3,300	15.68
1879	3.36	181.0	228.0	48.8	2,910	17.15	51.6	3,300	15.62
1878	3.31	177.7	227.0	48.6	2,920	17.08	51.4	3,300	15.56
1877	3.26	174.4	226.0	48.5	2,920	17.01	51.2	3,300	15.50

NOTE: Energy in storage values not included in this data

RESERVOIR AND POWER DATA

Watauga

				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1876	3.21	171.2	225.0	48.3	2,920	16.94	51.0	3,300	15.44
1875	3.15	168.0	224.0	48.1	2,930	16.87	50.8	3,300	15.38
1874	3.10	164.9	223.0	47.9	2,930	16.80	50.6	3,300	15.32
1873	3.04	161.8	222.0	47.7	2,930	16.72	50.4	3,300	15.26
1872	2.99	158.8	221.0	47.6	2,930	16.65	50.2	3,300	15.20
1871	2.94	155.8	220.0	47.4	2,940	16.58	50.0	3,300	15.14
1870	2.89	152.9	219.0	47.2	2,940	16.51	49.8	3,300	15.07
1869	2.85	150.0	218.0	47.0	2,940	16.44	49.6	3,300	15.01
1868	2.80	147.2	217.0	46.8	2,950	16.37	49.4	3,300	14.95
1867	2.76	144.4	216.0	46.7	2,950	16.29	49.2	3,300	14.89
1866	2.72	141.7	215.0	46.5	2,950	16.22	49.0	3,300	14.83
1865	2.68	139.0	214.0	46.3	2,950	16.15	48.8	3,300	14.77
1864	2.65	136.3	213.0	46.1	2,960	16.08	48.6	3,300	14.71
1863	2.61	133.7	212.0	45.9	2,960	16.01	48.4	3,300	14.65
1862	2.58	131.1	211.0	45.8	2,960	15.93	48.2	3,300	14.59
1861	2.55	128.5	210.0	45.6	2,960	15.86	48.0	3,300	14.53
1860	2.52	126.0	209.0	45.4	2,970	15.79	47.8	3,300	14.47
1859	2.49	123.5	208.0	45.2	2,970	15.72	47.6	3,300	14.41
1858	2.46	121.0	207.0	45.0	2,970	15.65	47.4	3,300	14.35
1857	2.42	118.6	206.0	44.8	2,980	15.58	47.2	3,300	14.29
1856	2.37	116.2	205.0	44.7	2,980	15.50	47.0	3,300	14.23
1855	2.32	113.8	204.0	44.5	2,980	15.43	46.8	3,300	14.17
1854	2.27	111.5	203.0	44.3	2,980	15.36	46.6	3,300	14.10
1853	2.21	109.3	202.0	44.1	2,990	15.29	46.4	3,300	14.04
1852	2.14	107.1	201.0	43.9	2,990	15.22	46.2	3,300	13.98
1851	2.07	105.0	200.0	43.8	2,990	15.15	46.0	3,300	13.92
1850	1.99	103.0	199.0	43.6	3,000	15.07	45.8	3,300	13.86
1849	1.92	101.0	198.0	43.4	3,000	15.00	45.6	3,300	13.80
1848	1.85	99.2	197.0	43.2	3,000	14.93	45.4	3,300	13.74
1847	1.79	97.3	196.0	43.0	3,000	14.86	45.2	3,300	13.68
1846	1.73	95.6	195.0	42.9	3,010	14.79	45.0	3,300	13.62
1845	1.68	93.9	194.0	42.7	3,010	14.71	44.8	3,300	13.56
1844	1.64	92.2	193.0	42.5	3,010	14.64	44.6	3,300	13.50

NOTE: Energy in storage values not included in this data

RESERVOIR AND POWER DATA

Watauga

Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Best Efficiency			Maximum Sustainable		
				Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1843	1.60	90.6	192.0	42.3	3,010	14.57	44.4	3,300	13.44
1842	1.57	89.0	191.0	42.1	3,020	14.50	44.2	3,300	13.38
1841	1.55	87.4	190.0	42.0	3,020	14.43	44.0	3,300	13.32
1840	1.53	85.9	189.0	41.8	3,020	14.36	43.8	3,300	13.26
1839	1.52	84.4	188.0	41.6	3,030	14.28	43.6	3,300	13.19
1838	1.51	82.9	187.0	41.4	3,030	14.21	43.4	3,300	13.13
1837	1.49	81.4	186.0	41.2	3,030	14.14	43.2	3,300	13.07
1836	1.48	79.9	185.0	41.1	3,030	14.07	43.0	3,300	13.01
1835	1.46	78.4	184.0	40.9	3,040	14.00	42.8	3,300	12.95
1834	1.45	77.0	183.0	40.7	3,040	13.93	42.6	3,300	12.89
1833	1.43	75.5	182.0	40.5	3,040	13.85	42.4	3,300	12.83
1832	1.41	74.1	181.0	40.3	3,050	13.78	42.2	3,300	12.77
1831	1.40	72.7	180.0	40.2	3,050	13.71	42.0	3,300	12.71
1830	1.38	71.3	179.0	40.0	3,050	13.64	41.8	3,300	12.65
1829	1.37	69.9	178.0	39.8	3,050	13.57	41.6	3,300	12.59
1828	1.35	68.6	177.0	39.6	3,060	13.49	41.4	3,300	12.53
1827	1.34	67.2	176.0	39.4	3,060	13.42	41.2	3,300	12.47
1826	1.32	65.9	175.0	39.3	3,060	13.35	41.0	3,300	12.41
1825	1.31	64.6	174.0	39.1	3,070	13.28	40.8	3,300	12.35
1824	1.29	63.3	173.0	38.9	3,070	13.21	40.6	3,300	12.29
1823	1.28	62.0	172.0	38.7	3,070	13.14	40.4	3,300	12.22
1822	1.27	60.7	171.0	38.5	3,070	13.06	40.1	3,300	12.16
1821	1.26	59.5	170.0	38.3	3,080	12.99	39.9	3,300	12.10
1820	1.25	58.2	169.0	38.2	3,080	12.92	39.7	3,300	12.04
1819	1.24	57.0	168.0	38.0	3,080	12.85	39.5	3,300	11.98
1818	1.23	55.7	167.0	37.8	3,080	12.78	39.3	3,300	11.92
1817	1.22	54.5	166.0	37.6	3,090	12.71	39.1	3,300	11.86
1816	1.20	53.3	165.0	37.4	3,090	12.63	38.9	3,300	11.80
1815	1.19	52.1	164.0	37.3	3,090	12.56	38.7	3,300	11.74

NOTE: Energy in storage values not included in this data

Tennessee Valley Authority
Division of Water Control Planning
Hydraulic Data Branch

Report No. 19-10-1

Advance Report No. 1

WATAUGA MODEL STUDIES

Knoxville, Tennessee
June 1944

ADVANCE REPORT NO. 1

WATAUGA MODEL STUDIES

SUMMARY

This report presents the results of tests made on models of the spillway for the Watauga project. The spillway and Howell-Bunger outlet valves for the Watauga and South Holston projects have many features in common. Advance Report No. 1, South Holston Model Studies, describes tests made on the South Holston project. The results of these tests are all applicable to the Watauga project with the exception of the discharge rating curve, the deflector at the foot of the vertical shaft, and the stilling basin. Additional studies peculiar to the Watauga project are summarized as follows:

An 8-foot deflector at the foot of the vertical shaft, placed at an angle of 30 degrees with the tunnel, gives satisfactory flow conditions in the tunnel. Plate 1 shows the location of this deflector.

No negative pressures of any consequence occurred on the spillway face. There were no excessive pressures on the deflector.

The portal design as shown on Plate 1 appeared to be satisfactory. It appeared that no additional structures were necessary to prevent dangerous erosion.

SPILLWAY OPERATION

The development of the spillway for the Watauga project was, in general, the same as for the South Holston project. Reference is made to Advance Report No. 1, South Holston Model Studies, for details. The deflector at the base of the vertical shaft of the Watauga spillway differed from that for the South Holston spillway. The same deflectors were tested as for the South Holston spillway with the same result for the 10-foot one, namely, filling of the shaft for the higher discharges. The 5-foot and 6-1/2-foot deflectors were too small to be effective. The 8-foot deflector at the bottom of the vertical shaft, located 30 degrees to the right of the tunnel, gave satisfactory performance. Moving the deflector to either side of this position caused uneven flow and standing waves in the tunnel. Figure 1 shows flow in the tunnel without the deflector, and Figure 2 shows the same flow with the deflector in its recommended position. Figure 3 shows the flow with the deflector 20 degrees to the left of the tunnel. The improvement caused by proper location of the deflector is clearly shown by these photographs.

Piezometers were located on the 1:100 scale model of the Watauga model, as shown on Plate 2. A summary of the pressures observed for various discharges is given in Table 1.

Calibration of Spillway

The spillway discharges measured on the South Holston model are also applicable to the Watauga model. Plate 3 is a curve showing the relationship between reservoir elevation and spillway discharge.

HOWELL-BUNGER VALVE OPERATION

Reference is made to Advance Report No. 1, South Holston Model Studies, for details of the structures required below the Howell-Bunger valves, both immediately below the valves, and at the Y.

EROSION STUDIES AT TUNNEL PORTAL

Tests were made on a 1:51 scale model of the Watauga tunnel outlet, as shown on Plate 1, to determine whether special treatment or structures would be necessary to prevent serious erosion at the tunnel portal. Performance without a stilling basin appeared to be satisfactory. There was no eddy action to cause serious erosion at the portal structure although deep erosion occurred in the river bed downstream. Plate 1 shows a cross section immediately below the portal as it existed after ten minutes of model operation with a spillway discharge of 60,000 cubic feet per second. The maximum erosion at the structure for this discharge was 8 feet. It seems likely that a 10-foot cut-off wall at the portal would prevent damage for a considerable period of time.

ACKNOWLEDGMENTS

This investigation was conducted by the Hydraulic Data Branch under the direction of Albert S. Fry, Chief of Branch. The tests were made and the report prepared in the Hydraulic Laboratory at Norris under the supervision of G. H. Hickox, Head, Hydraulic Laboratory Section. A. J. Peterka and B. R. Blackwell were in charge of the testing. They were assisted by the entire laboratory staff. The report was prepared by B. R. Blackwell.

TABLE 1

PRESSURE IN SPILLWAY

Piezometer pressures are expressed in feet of water.

Piezometer Number	Discharge in Cubic Feet Per Second							
	60,000	50,000	45,000	40,000	35,000	30,000	20,000	10,000
1	6	5	5	5	4	4	4	3
2	3	2	2	2	1	2	0	0
3	3	1	0	-1	-1	-1	0	0
4	9	6	6	6	4	2	1	1
5	10	3	2	3	2	2	0	0
6	3	4	4	4	4	4	4	3
7	2	2	2	2	2	2	1	1
8	-1	0	0	0	0	0	0	1
9	18	20	12	3	0	0	0	0
10	9	4	6	5	4	4	9	0
11a	47	31	32	7	1	2	1	1
11b	38	23	22	19	4	3	2	2
11c	28	17	27	23	20	2	1	1
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	68	70	64	56	35	14	1	-5
15	83	69	60	55	48	42	30	18
16	69	55	47	41	34	29	17	1
17	18	17	16	15	13	12	9	4

Note: Piezometer locations are shown on Plate 2.

4

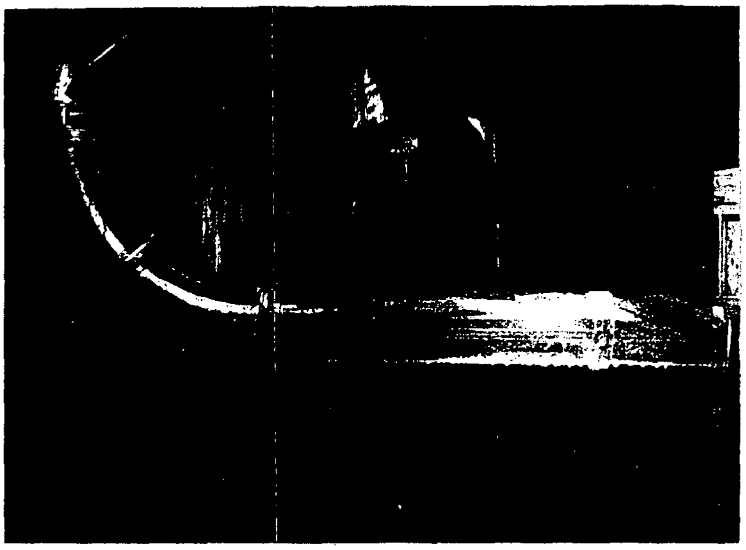


Figure 1.--Spiral flow in elbow and tunnel with no deflector in the spillway shaft. Discharge, 40,000 cubic feet per second.

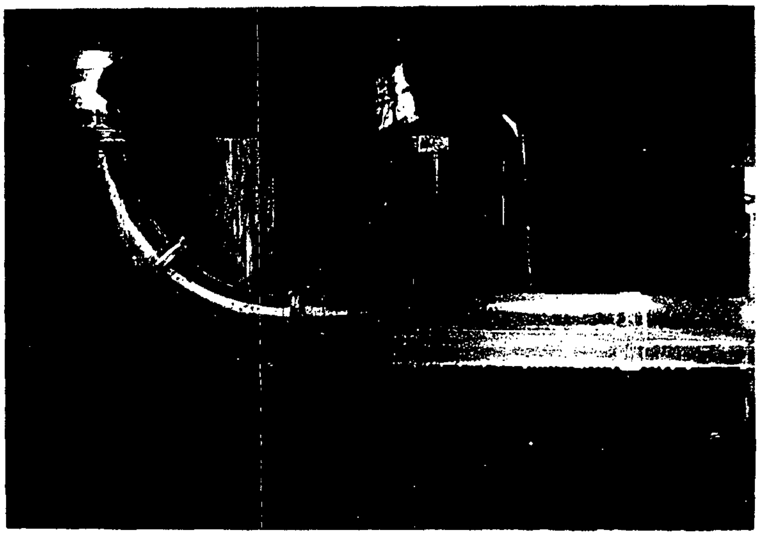


Figure 2.--Smooth uniform flow in elbow and tunnel with the 8-foot deflector in the spillway shaft at an angle of 30 degrees to the right of the tunnel. Discharge, 40,000 cubic feet per second.

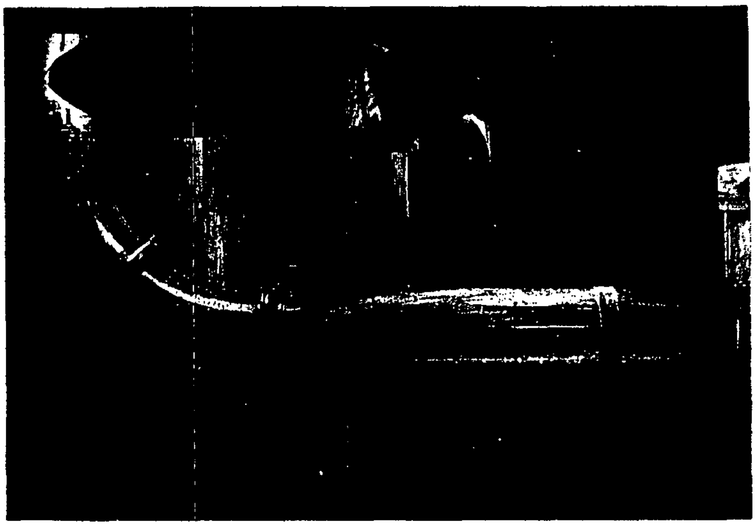
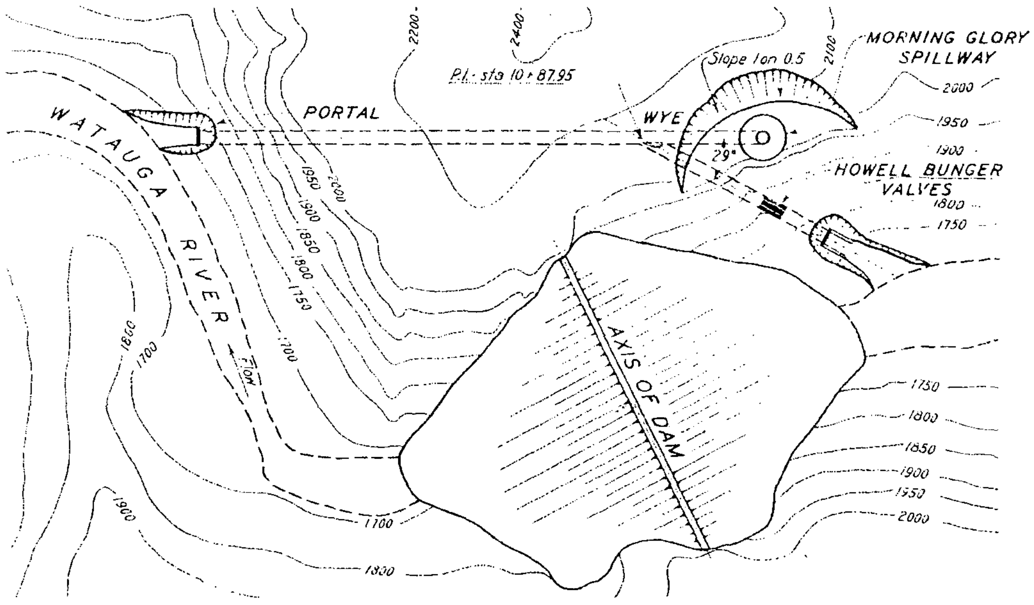
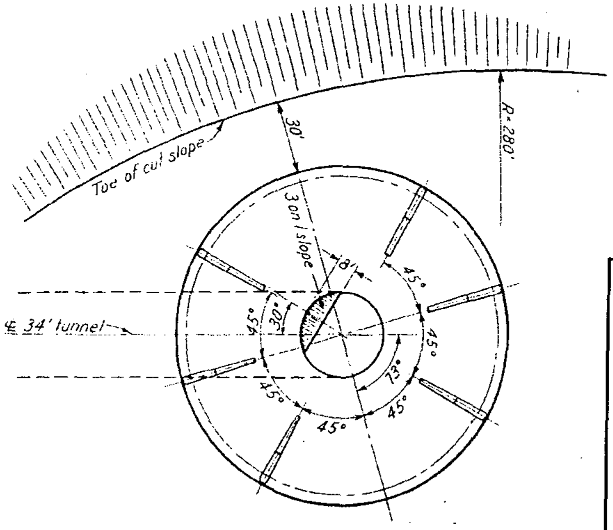


Figure 3.--Spiral flow in elbow and tunnel with the 8-foot deflector 20 degrees to the left of the tunnel. Discharge, 40,000 cubic feet per second.



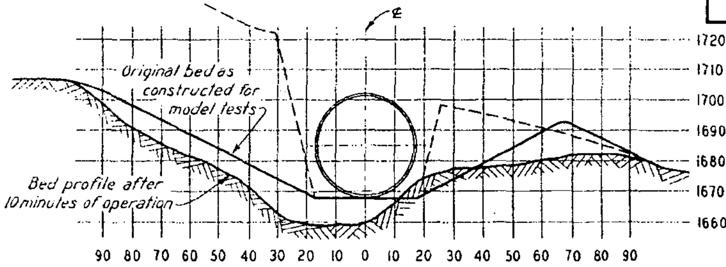
GENERAL LAYOUT

Scale 0 200 400 600 Feet



PLAN

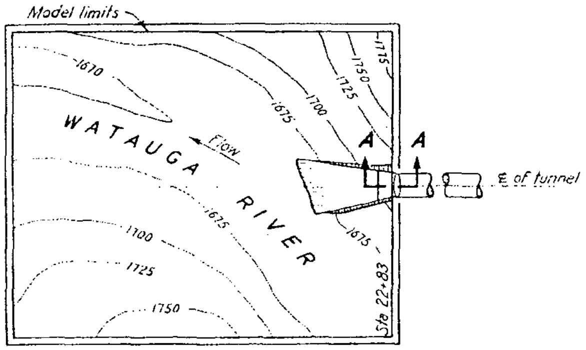
SCHEME AL



BED PROFILES AT STA 22 + 83

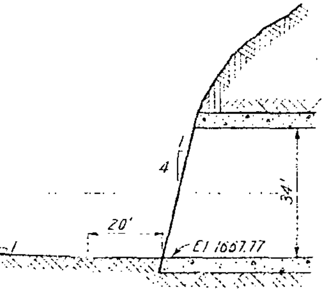
DISCHARGE = 60 000 CFS

TEST NO. 216



MODEL LAYOUT

Scale 0 100 200 300 Feet



SECTION A-A

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

WATAUGA PROJECT HYDRAULIC MODEL STUDIES

SPILLWAY AND TUNNEL

MODEL DETAILS AND TEST RESULTS

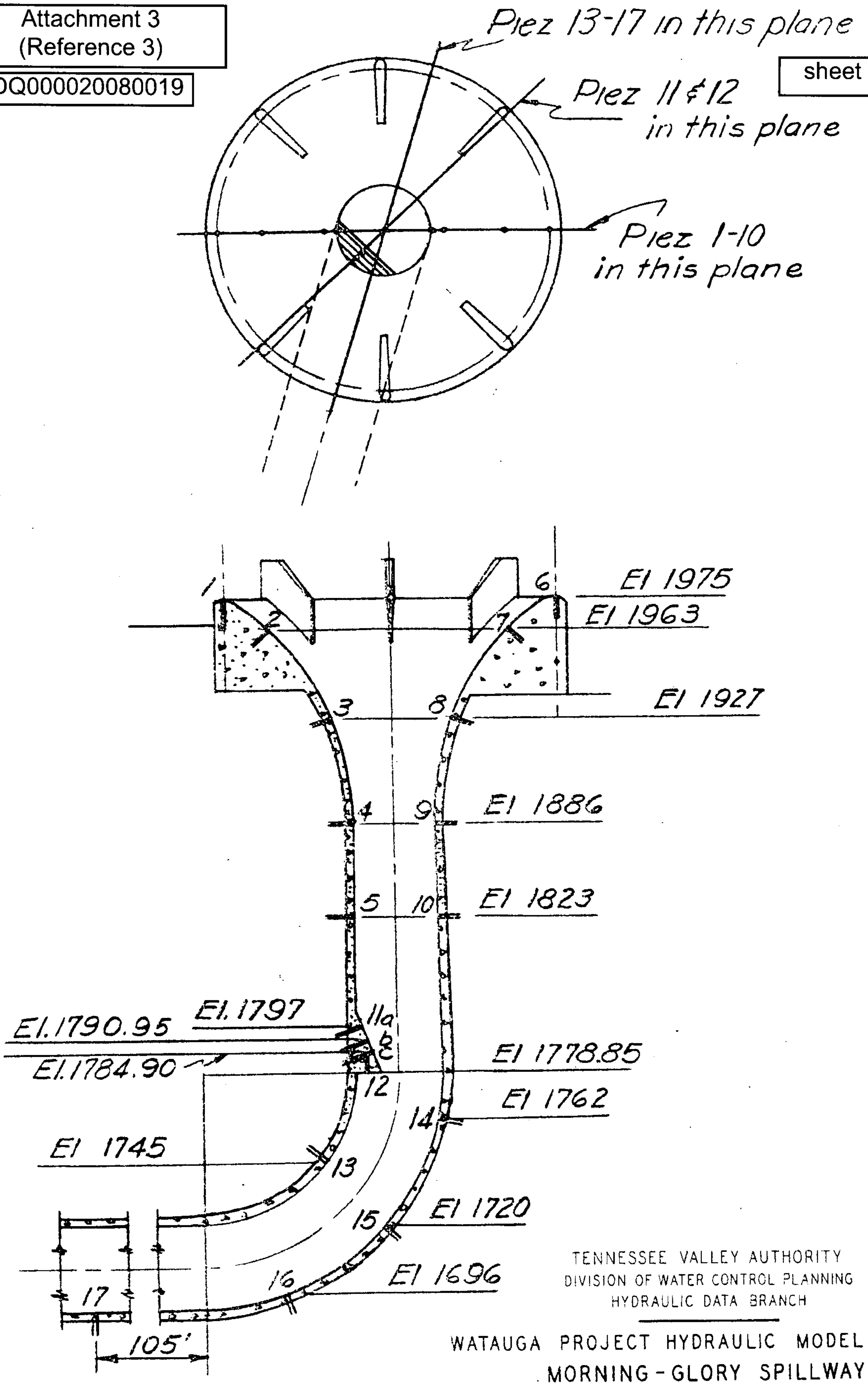
MODEL SCALES 1:34, 1:51, AND 1:100

PLATE 1

Attachment 3
(Reference 3)

Attachment 3
(Reference 3)

sheet 3-8 of 9



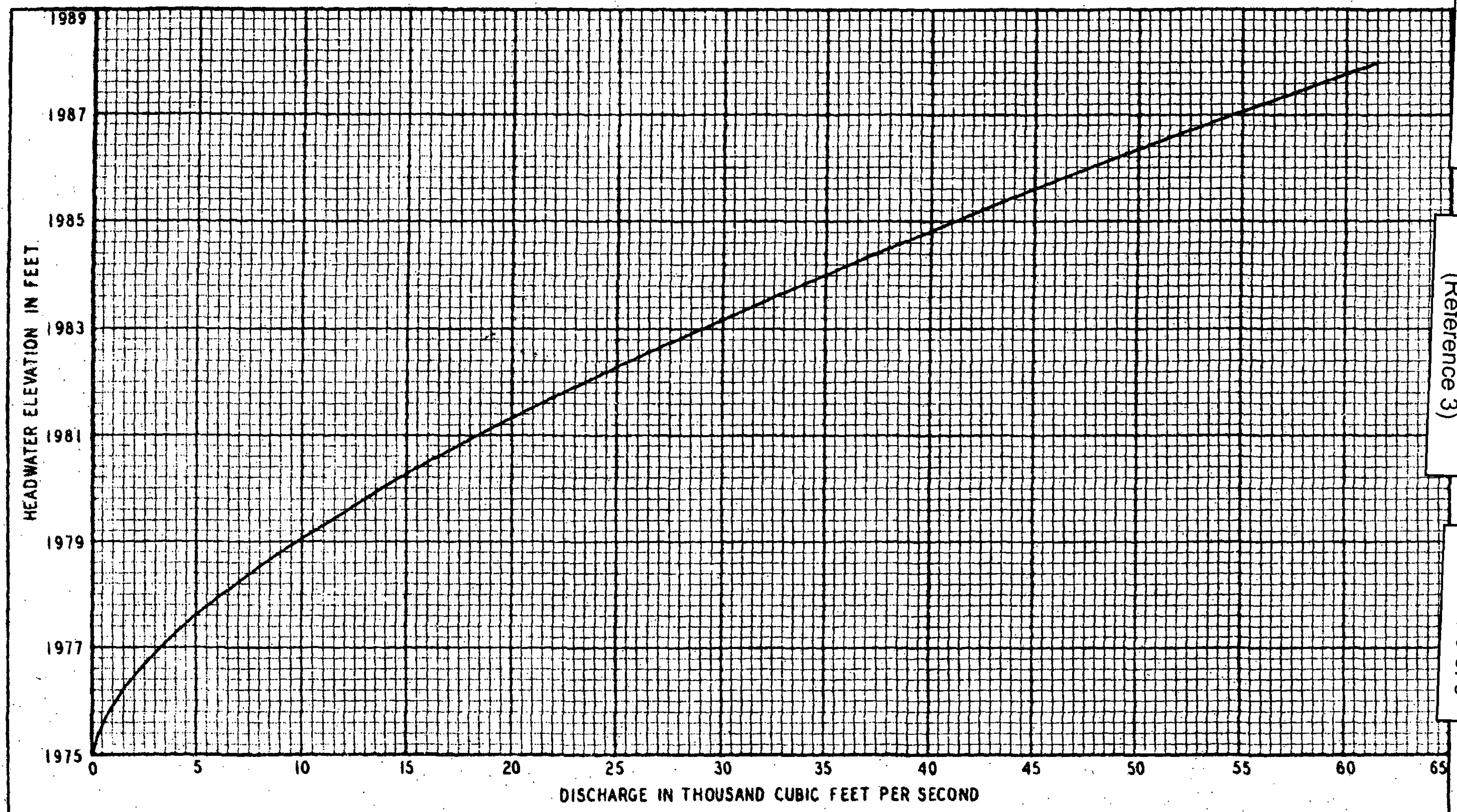
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

WATAUGA PROJECT HYDRAULIC MODEL STUDIES
MORNING-GLORY SPILLWAY
PIEZOMETER LOCATIONS
MODEL SCALE 1:100

CDQ000020080019

Attachment 3
(Reference 3)

sheet 3-9 of 9



TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

WATAUGA PROJECT HYDRAULIC MODEL STUDIES
MORNING-GLORY SPILLWAY
SPILLWAY RATING CURVE

PLATE 3

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

WATAUGA DAM
HOWELL-BUNGER VALVE DISCHARGE TABLES

JULY 1974

INSTRUCTIONS FOR USE OF TABLES

1. Purpose of Tables

The purpose of these tables is to provide a means of determining the discharge of the Howell-Bunger valves in the sluice tunnel at Watauga Dam. The tables are based on field discharge measurements and pressure measurements taken at several discharges in the sluice upstream from the Howell-Bunger valves. The tables give the discharge in cubic feet per second for one valve when the reservoir elevation and valve opening are known throughout the complete range of normal operating conditions. These tables supersede the tables dated August 1971.

2. Arrangement and Use of Tables

The tables give the discharge in cubic feet per second per valve for each 5-foot interval of headwater between reservoir elevations 1800 and 1985, and for each 1 percent of valve opening between 7 percent and 92 percent valve positions. Discharges are tabulated only to the nearest 10 cubic feet per second because the accuracy of the field measurements does not warrant greater refinement. It is possible to set any discharge within 40 cubic feet per second by using the tabular values. This tolerance has been accepted by the Division of Water Control Planning and, therefore, *it will not be necessary to interpolate* between tabular entries in these tables.

The reservoir elevation values used in the tables are those given by the recorder in the control room. The valve opening used in the tables is that indicated by the pointer on the valve control mechanism.

The arrangement of tables is such that the discharge over the entire range of valve openings for a 100-foot range of reservoir elevation is on two consecutive pages. For example, discharges are given on pages 2 and 3 for reservoir elevations 1800 through 1900. Discharges should be taken from the table for the tabulated values nearest to those observed. For example, if the reservoir is at elevation 1858.76 and the valve number 1 opening is 76.4 percent, the discharge is found on page 3, in the column headed 1860 opposite a valve opening of 76 percent, as 3220 cubic feet per second. If valve number 2 were set at 56.6 percent at the same time when valve number 1 was operating as given above, the discharge for valve number 2 would be found on page 3, in the column headed 1860 opposite a valve opening of 57 percent, as 2560 cubic feet per second. The total discharge would be the sum of the discharges of the two valves or 5780 cubic feet per second.

3. Valve Opening for Maximum and Minimum Discharge

Maximum discharge for the Howell-Bunger valves at Watauga Dam occurs at 92 percent valve opening. At valve openings greater than 92 percent the discharge becomes less. Therefore, the valves should not be operated beyond 92 percent. No tabular data are presented for such operation.

Minimum valve openings should not be less than 7 percent because of cavitation effects. No tabular values are given for such operation.

4. Adjustment of Valve Opening Indicator

At the time the field measurements were made, the valve opening indicator showed an opening of 3 percent when the valve was closed. In case of repairs to or adjustment of the valve and its control mechanism, the pointer should be reset to zero position so that the tables will still be applicable.

Calculation No: CDQ000020080019

Attachment 4

sheet 4-3 of 6

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1800	1805	1810	1815	1820	1825	1830	1835	1840	1845	1850	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	
6																						6
* 7	130	130	130	140	140	140	150	150	150	150	160	160	160	170	170	170	170	180	180	180	180	7
8	150	160	160	170	170	170	180	180	190	190	190	200	200	200	200	210	210	210	220	220	220	8
9	190	200	200	210	210	220	220	230	230	240	240	240	250	250	260	260	260	270	270	270	280	9
10	220	230	240	240	250	250	260	260	270	270	280	280	290	290	300	300	310	310	310	320	320	10
11	270	270	280	290	290	300	300	310	320	320	330	330	340	350	350	360	360	370	370	380	380	11
12	310	310	320	330	340	340	350	360	370	370	380	390	390	400	400	410	420	420	430	430	440	12
13	340	350	360	370	380	390	400	400	410	420	430	430	440	450	460	460	470	480	480	490	500	13
14	390	400	410	420	430	440	450	450	460	470	480	490	500	500	510	520	530	530	540	550	560	14
15	430	440	450	470	480	490	500	510	520	530	530	540	550	560	570	580	590	600	600	610	620	15
16	480	490	500	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	16
17	530	540	550	570	580	590	600	620	630	640	650	660	670	680	690	700	710	720	730	740	750	17
18	570	590	600	620	630	650	660	670	690	700	710	720	740	750	760	770	780	790	800	810	830	18
19	620	640	650	670	680	700	710	730	740	760	770	780	800	810	820	830	850	860	870	880	890	19
20	660	680	700	720	730	750	760	780	790	810	820	840	850	860	880	890	900	920	930	940	960	20
21	710	720	740	760	780	790	810	830	840	860	870	890	900	920	930	950	960	970	990	1000	1010	21
22	750	770	790	810	820	840	860	880	890	910	930	940	960	970	990	1000	1020	1030	1050	1060	1080	22
23	790	810	830	850	870	890	910	930	940	960	980	990	1010	1030	1040	1060	1070	1090	1110	1120	1130	23
24	830	850	870	890	910	930	950	970	990	1000	1020	1040	1060	1070	1090	1110	1120	1140	1160	1170	1190	24
25	860	880	910	930	950	970	990	1010	1030	1050	1070	1090	1100	1120	1140	1160	1170	1190	1210	1220	1240	25
26	900	920	950	970	990	1010	1030	1050	1070	1090	1110	1130	1150	1170	1190	1210	1220	1240	1260	1280	1290	26
27	930	960	980	1010	1030	1050	1070	1100	1120	1140	1160	1180	1200	1220	1240	1250	1270	1290	1310	1330	1340	27
28	970	990	1020	1040	1070	1090	1110	1140	1160	1180	1200	1220	1240	1260	1280	1300	1320	1340	1360	1370	1390	28
29	1010	1030	1060	1080	1110	1130	1160	1180	1200	1230	1250	1270	1290	1310	1330	1350	1370	1390	1410	1430	1450	29
30	1050	1070	1100	1130	1150	1180	1200	1230	1250	1270	1300	1320	1340	1360	1380	1400	1420	1440	1460	1480	1500	30
31	1090	1120	1150	1170	1200	1230	1250	1280	1300	1330	1350	1370	1400	1420	1440	1460	1480	1500	1530	1550	1570	31
32	1130	1160	1190	1220	1240	1270	1300	1320	1350	1370	1400	1420	1440	1470	1490	1510	1540	1560	1580	1600	1620	32
33	1160	1190	1220	1250	1280	1310	1340	1360	1390	1410	1440	1460	1490	1510	1540	1560	1580	1600	1630	1650	1670	33
34	1200	1230	1260	1290	1320	1350	1380	1410	1430	1460	1490	1510	1540	1560	1590	1610	1630	1660	1680	1700	1730	34
35	1240	1270	1300	1340	1370	1400	1420	1450	1480	1510	1540	1560	1590	1610	1640	1660	1690	1710	1740	1760	1780	35
36	1280	1310	1350	1380	1410	1440	1470	1500	1530	1560	1580	1610	1640	1660	1690	1720	1740	1770	1790	1810	1840	36
37	1320	1350	1390	1420	1450	1480	1510	1540	1570	1600	1630	1660	1690	1710	1740	1770	1790	1820	1840	1870	1890	37
38	1360	1390	1430	1460	1490	1530	1560	1590	1620	1650	1680	1710	1740	1760	1790	1820	1850	1870	1900	1920	1950	38
39	1390	1430	1470	1500	1540	1570	1600	1630	1670	1700	1730	1760	1790	1810	1840	1870	1900	1930	1950	1980	2000	39
40	1430	1470	1510	1540	1580	1610	1650	1680	1710	1740	1780	1810	1840	1870	1890	1920	1950	1980	2010	2030	2060	40
41	1470	1510	1550	1590	1620	1660	1690	1730	1760	1790	1820	1850	1890	1920	1950	1980	2000	2030	2060	2090	2120	41
42	1500	1540	1580	1620	1650	1690	1720	1760	1790	1830	1860	1890	1920	1950	1980	2010	2040	2070	2100	2130	2160	42
43	1540	1580	1620	1650	1690	1730	1760	1800	1830	1870	1900	1930	1970	2000	2030	2060	2090	2120	2150	2180	2210	43
44	1570	1620	1660	1700	1730	1770	1810	1840	1880	1910	1950	1980	2020	2050	2080	2110	2140	2170	2200	2230	2260	44
45	1610	1650	1690	1730	1770	1810	1850	1880	1920	1960	1990	2030	2060	2090	2120	2160	2190	2220	2250	2280	2310	45
46	1640	1690	1730	1770	1810	1850	1890	1920	1960	2000	2030	2070	2100	2140	2170	2200	2230	2270	2300	2330	2360	46
47	1680	1720	1760	1800	1850	1890	1930	1960	2000	2040	2070	2110	2150	2180	2210	2250	2280	2310	2350	2380	2410	47
48	1700	1750	1790	1840	1880	1920	1960	2000	2040	2070	2110	2150	2180	2220	2250	2290	2320	2350	2390	2420	2450	48
49	1740	1780	1830	1870	1920	1960	2000	2040	2080	2120	2150	2190	2230	2260	2300	2330	2370	2400	2430	2470	2500	49
50	1770	1820	1860	1910	1950	1990	2040	2080	2120	2160	2190	2230	2270	2310	2340	2380	2410	2450	2480	2510	2550	50
51	1800	1850	1900	1940	1980	2030	2070	2110	2150	2190	2230	2270	2310	2340	2380	2420	2450	2490	2520	2560	2590	51
52	1830	1880	1930	1970	2020	2060	2100	2150	2190	2230	2270	2310	2340	2380	2420	2460	2490	2530	2560	2600	2630	52
53	1870	1920	1970	2010	2060	2100	2150	2190	2230	2270	2310	2350	2390	2430	2470	2510	2540	2580	2620	2650	2690	53
54	1900	1950	2000	2040	2090	2140	2180	2220	2270	2310	2350	2390	2430	2470	2510	2550	2580	2620	2660	2690	2730	54
55	1930	1980	2030	2080	2120	2170	2210	2260	2300	2340	2390	2430	2470	2510	2550	2590	2620	2660	2700	2730	2770	55

JULY 1974

* THE MINIMUM ALLOWABLE
VALVE OPENING IS 7 PERCENT

RESERVOIR ELEVATION 1800 TO 1900
VALVE OPENING, PERCENT 7 TO 55

Calculation No: CDQ000020080019

Attachment 4

sheet 4-4 of 6

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1800	1805	1810	1815	1620	1825	1830	1835	1840	1845	1850	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	
56	1970	2020	2070	2120	2170	2210	2260	2300	2350	2390	2430	2480	2520	2560	2600	2640	2680	2710	2750	2790	2830	56
57	2000	2050	2100	2150	2200	2250	2290	2340	2380	2430	2470	2510	2560	2600	2640	2680	2720	2750	2790	2830	2870	57
58	2020	2080	2130	2180	2230	2280	2330	2370	2420	2460	2510	2550	2590	2630	2680	2720	2760	2790	2830	2870	2910	58
59	2050	2110	2160	2210	2260	2310	2360	2410	2450	2500	2540	2590	2630	2670	2710	2750	2800	2840	2870	2910	2950	59
60	2090	2150	2200	2250	2300	2350	2400	2450	2500	2550	2590	2640	2680	2720	2760	2810	2850	2890	2930	2970	3010	60
61	2120	2180	2230	2280	2340	2390	2440	2490	2530	2580	2630	2670	2720	2760	2800	2850	2890	2930	2970	3010	3050	61
62	2150	2210	2260	2320	2370	2420	2470	2520	2570	2620	2660	2710	2750	2800	2840	2880	2930	2970	3010	3050	3090	62
63	2180	2240	2290	2350	2400	2450	2500	2550	2600	2650	2700	2750	2790	2840	2880	2920	2970	3010	3050	3090	3130	63
64	2210	2270	2320	2380	2430	2490	2540	2590	2640	2690	2730	2780	2830	2870	2920	2960	3010	3050	3090	3130	3170	64
65	2230	2290	2340	2400	2450	2510	2560	2610	2660	2710	2760	2810	2850	2900	2940	2990	3030	3080	3120	3160	3200	65
66	2260	2320	2370	2430	2490	2540	2590	2640	2700	2750	2790	2840	2890	2940	2980	3030	3070	3120	3160	3200	3240	66
67	2290	2350	2400	2460	2520	2570	2630	2680	2730	2780	2830	2880	2930	2970	3020	3070	3110	3160	3200	3240	3290	67
68	2320	2380	2440	2490	2550	2610	2660	2710	2760	2820	2870	2920	2960	3010	3060	3110	3150	3200	3240	3280	3330	68
69	2340	2410	2470	2520	2580	2640	2690	2750	2800	2850	2900	2950	3000	3050	3100	3140	3190	3240	3280	3330	3370	69
70	2360	2430	2490	2550	2600	2660	2720	2770	2820	2880	2930	2980	3030	3080	3120	3170	3220	3260	3310	3350	3400	70
71	2380	2450	2510	2570	2620	2680	2740	2790	2850	2900	2950	3000	3050	3100	3150	3200	3240	3290	3340	3380	3420	71
72	2410	2480	2540	2600	2660	2710	2770	2830	2880	2930	2990	3040	3090	3140	3190	3240	3280	3330	3380	3420	3470	72
73	2440	2510	2570	2630	2690	2750	2800	2860	2920	2970	3020	3070	3130	3180	3230	3270	3320	3370	3420	3460	3510	73
74	2470	2540	2600	2660	2720	2780	2840	2890	2950	3000	3060	3110	3160	3210	3260	3310	3360	3410	3460	3500	3550	74
75	2490	2560	2620	2680	2740	2800	2860	2920	2970	3030	3080	3140	3190	3240	3290	3340	3390	3440	3480	3530	3580	75
76	2520	2580	2650	2710	2770	2830	2890	2950	3010	3060	3120	3170	3220	3280	3330	3380	3430	3480	3530	3570	3620	76
77	2550	2610	2680	2740	2810	2870	2930	2990	3040	3100	3150	3210	3260	3310	3370	3420	3470	3520	3570	3610	3660	77
78	2570	2630	2700	2760	2830	2890	2950	3010	3070	3120	3180	3230	3290	3340	3390	3440	3490	3540	3590	3640	3690	78
79	2600	2660	2730	2800	2860	2920	2980	3040	3100	3160	3210	3270	3320	3380	3430	3480	3530	3580	3630	3680	3730	79
80	2620	2680	2750	2820	2880	2940	3000	3060	3120	3180	3240	3290	3350	3400	3460	3510	3560	3610	3660	3710	3760	80
81	2630	2700	2770	2840	2900	2970	3030	3090	3150	3200	3260	3320	3370	3430	3480	3530	3590	3640	3690	3740	3790	81
82	2660	2730	2800	2860	2930	2990	3050	3120	3180	3230	3290	3350	3400	3460	3510	3570	3620	3670	3720	3770	3820	82
83	2680	2750	2820	2890	2960	3020	3080	3140	3200	3260	3320	3380	3440	3490	3550	3600	3650	3700	3760	3810	3860	83
84	2700	2770	2840	2910	2980	3040	3100	3170	3230	3290	3350	3400	3460	3520	3570	3630	3680	3730	3780	3830	3880	84
85	2720	2790	2860	2930	3000	3060	3130	3190	3250	3310	3370	3430	3490	3540	3600	3650	3700	3760	3810	3860	3910	85
86	2750	2820	2890	2960	3030	3100	3160	3220	3290	3350	3410	3460	3520	3580	3640	3690	3740	3800	3850	3900	3950	86
87	2770	2840	2910	2980	3050	3120	3180	3250	3310	3370	3430	3490	3550	3600	3660	3720	3770	3820	3880	3930	3980	87
88	2790	2860	2930	3000	3070	3140	3200	3270	3330	3390	3450	3510	3570	3630	3690	3740	3800	3850	3900	3960	4010	88
89	2810	2880	2960	3030	3090	3160	3230	3290	3350	3420	3480	3540	3600	3650	3710	3770	3820	3880	3930	3990	4040	89
90	2830	2900	2980	3050	3120	3180	3250	3310	3380	3440	3500	3560	3620	3680	3740	3790	3850	3900	3960	4010	4070	90
91	2840	2910	2990	3060	3130	3190	3260	3330	3390	3450	3510	3570	3630	3690	3750	3810	3860	3920	3970	4030	4080	91
*92	2850	2920	3000	3070	3140	3210	3270	3340	3400	3460	3530	3590	3650	3710	3760	3820	3880	3930	3990	4040	4090	92

JULY 1974

* THE MAXIMUM VALVE OPENING
SHOULD NOT EXCEED 92 PERCENT

RESERVOIR ELEVATION 1800 TO 1900
VALVE OPENING, PERCENT 56 TO 92

Calculation No: CDQ000020080019

Attachment 4

sheet 4-5 of 6

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985				
6																						6
* 7	180	180	190	190	190	190	200	200	200	200	200	210	210	210	210	210	220	220				7
8	220	230	230	230	230	240	240	240	240	250	250	250	250	260	260	260	260	270				8
9	280	280	290	290	290	300	300	300	310	310	310	320	320	320	320	330	330	330				9
10	320	330	330	340	340	340	350	350	350	360	360	370	370	370	380	380	380	390				10
11	380	390	390	400	400	410	410	410	420	420	430	430	440	440	450	450	450	460				11
12	440	450	450	460	460	470	470	480	480	490	490	500	500	510	510	520	520	530				12
13	500	500	510	510	520	530	530	540	540	550	560	560	570	570	580	580	590	590				13
14	560	560	570	580	580	590	600	610	610	620	620	630	640	640	650	660	660	670				14
15	620	630	640	640	650	660	670	670	680	690	700	700	710	720	720	730	740	740				15
16	690	700	710	720	720	730	740	750	760	760	770	780	790	800	800	810	820	830				16
17	750	760	770	780	790	800	810	820	830	840	850	850	860	870	880	890	900	910				17
18	830	840	850	860	870	880	890	900	910	920	930	940	940	950	960	970	980	990				18
19	890	910	920	930	940	950	960	970	980	990	1000	1010	1020	1030	1040	1050	1060	1070				19
20	960	970	980	990	1000	1010	1030	1040	1050	1060	1070	1080	1090	1100	1110	1120	1140	1150				20
21	1010	1030	1040	1050	1070	1080	1090	1100	1110	1130	1140	1150	1160	1170	1180	1200	1210	1220				21
22	1080	1090	1100	1120	1130	1140	1160	1170	1180	1190	1210	1220	1230	1240	1260	1270	1280	1290				22
23	1130	1150	1160	1180	1190	1210	1220	1230	1250	1260	1270	1290	1300	1310	1320	1340	1350	1360				23
24	1190	1200	1220	1230	1250	1260	1270	1290	1300	1320	1330	1340	1360	1370	1380	1400	1410	1420				24
25	1240	1250	1270	1290	1300	1320	1330	1350	1360	1380	1390	1400	1420	1430	1450	1460	1470	1490				25
26	1290	1310	1330	1340	1360	1370	1390	1410	1420	1440	1450	1470	1480	1490	1510	1520	1540	1550				26
27	1340	1360	1380	1390	1410	1430	1440	1460	1480	1490	1510	1520	1540	1550	1570	1580	1600	1610				27
28	1390	1410	1430	1450	1460	1480	1500	1510	1530	1550	1560	1580	1590	1610	1620	1640	1650	1670				28
29	1450	1470	1480	1500	1520	1540	1560	1570	1590	1610	1620	1640	1660	1670	1690	1710	1720	1740				29
30	1500	1520	1540	1560	1580	1600	1620	1630	1650	1670	1690	1700	1720	1740	1750	1770	1790	1800				30
31	1570	1590	1610	1630	1650	1660	1680	1700	1720	1740	1760	1770	1790	1810	1830	1840	1860	1880				31
32	1620	1640	1660	1680	1700	1720	1740	1760	1780	1800	1820	1840	1860	1870	1890	1910	1930	1950				32
33	1670	1690	1710	1730	1750	1780	1800	1820	1840	1850	1870	1890	1910	1930	1950	1970	1990	2000				33
34	1730	1750	1770	1790	1810	1830	1860	1880	1900	1920	1940	1960	1980	1990	2010	2030	2050	2070				34
35	1780	1800	1830	1850	1870	1890	1920	1940	1960	1980	2000	2020	2040	2060	2080	2100	2120	2140				35
36	1840	1860	1880	1910	1930	1950	1970	2000	2020	2040	2060	2080	2100	2120	2140	2160	2180	2200				36
37	1890	1920	1940	1970	1990	2010	2030	2060	2080	2100	2120	2150	2170	2190	2210	2230	2250	2270				37
38	1950	1970	2000	2020	2050	2070	2090	2120	2140	2160	2190	2210	2230	2250	2270	2300	2320	2340				38
39	2000	2030	2060	2080	2110	2130	2150	2180	2200	2230	2250	2270	2290	2320	2340	2360	2380	2400				39
40	2060	2090	2110	2140	2160	2190	2210	2240	2260	2290	2310	2330	2360	2380	2400	2430	2450	2470				40
41	2120	2140	2170	2200	2220	2250	2270	2300	2320	2350	2370	2400	2420	2450	2470	2490	2520	2540				41
42	2160	2190	2210	2240	2270	2290	2320	2340	2370	2400	2420	2450	2470	2490	2520	2540	2560	2590				42
43	2210	2240	2260	2290	2320	2340	2370	2400	2420	2450	2480	2500	2530	2550	2570	2600	2620	2650				43
44	2260	2290	2320	2350	2380	2400	2430	2460	2480	2510	2540	2560	2590	2610	2640	2660	2690	2710				44
45	2310	2340	2370	2400	2430	2460	2480	2510	2540	2570	2590	2620	2640	2670	2700	2720	2750	2770				45
46	2360	2390	2420	2450	2480	2510	2540	2560	2590	2620	2650	2670	2700	2730	2750	2780	2800	2830				46
47	2410	2440	2470	2500	2530	2560	2590	2620	2650	2670	2700	2730	2760	2780	2810	2840	2860	2890				47
48	2450	2480	2510	2540	2570	2600	2630	2660	2690	2720	2750	2780	2800	2830	2860	2890	2910	2940				48
49	2500	2530	2560	2590	2620	2660	2690	2720	2740	2770	2800	2830	2860	2890	2920	2940	2970	3000				49
50	2550	2580	2610	2640	2680	2710	2740	2770	2800	2830	2860	2890	2920	2940	2970	3000	3030	3060				50
51	2590	2620	2660	2690	2720	2750	2780	2810	2840	2870	2900	2930	2960	2990	3020	3050	3080	3110				51
52	2630	2670	2700	2730	2760	2800	2830	2860	2890	2920	2950	2980	3010	3040	3070	3100	3130	3160				52
53	2690	2720	2760	2790	2820	2860	2890	2920	2950	2980	3010	3040	3070	3110	3130	3160	3190	3220				53
54	2730	2760	2800	2830	2870	2900	2930	2960	3000	3030	3060	3090	3120	3150	3180	3210	3240	3270				54
55	2770	2810	2840	2880	2910	2940	2980	3010	3040	3080	3110	3140	3170	3200	3230	3260	3290	3320				55

JULY 1974

* THE MINIMUM ALLOWABLE
GATE OPENING IS 7 PERCENT

RESERVOIR ELEVATION 1900 TO 1985
VALVE OPENING, PERCENT 7 TO 55

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY **ENGINEERING LABORATORY**

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985				
56	2830	2860	2900	2930	2970	3000	3040	3070	3100	3140	3170	3200	3230	3270	3300	3330	3360	3390				56
57	2870	2900	2940	2980	3010	3050	3080	3120	3150	3180	3220	3250	3280	3310	3350	3380	3410	3440				57
58	2910	2950	2980	3020	3060	3090	3130	3160	3200	3230	3260	3300	3330	3360	3390	3430	3460	3490				58
59	2950	2990	3030	3060	3100	3140	3170	3210	3240	3280	3310	3340	3380	3410	3440	3480	3510	3540				59
60	3010	3050	3080	3120	3160	3200	3230	3270	3300	3340	3370	3410	3440	3480	3510	3540	3570	3610				60
61	3050	3090	3130	3160	3200	3240	3280	3310	3350	3380	3420	3450	3490	3520	3560	3590	3620	3660				61
62	3090	3130	3170	3210	3250	3280	3320	3360	3390	3430	3470	3500	3540	3570	3610	3640	3670	3710				62
63	3130	3170	3210	3250	3290	3330	3370	3400	3440	3480	3510	3550	3580	3620	3650	3690	3720	3760				63
64	3170	3220	3260	3290	3330	3370	3410	3450	3490	3520	3560	3600	3630	3670	3700	3740	3770	3810				64
65	3200	3240	3280	3320	3360	3400	3440	3480	3520	3550	3590	3630	3660	3700	3740	3770	3810	3840				65
66	3240	3290	3330	3370	3410	3450	3490	3520	3560	3600	3640	3680	3710	3750	3780	3820	3860	3890				66
67	3290	3330	3370	3410	3450	3490	3530	3570	3610	3650	3690	3720	3760	3800	3830	3870	3910	3940				67
68	3330	3370	3410	3450	3490	3540	3580	3620	3650	3690	3730	3770	3810	3850	3880	3920	3950	3990				68
69	3370	3410	3460	3500	3540	3580	3620	3660	3700	3740	3780	3820	3860	3890	3930	3970	4000	4040				69
70	3400	3440	3480	3530	3570	3610	3650	3690	3730	3770	3810	3850	3890	3930	3960	4000	4040	4070				70
71	3420	3470	3510	3560	3600	3640	3680	3720	3760	3800	3840	3880	3920	3960	4000	4030	4070	4110				71
72	3470	3510	3560	3600	3640	3680	3730	3770	3810	3850	3890	3930	3970	4010	4040	4080	4120	4160				72
73	3510	3550	3600	3640	3690	3730	3770	3810	3850	3890	3940	3980	4010	4050	4090	4130	4170	4210				73
74	3550	3600	3640	3690	3730	3770	3820	3860	3900	3940	3980	4020	4060	4100	4140	4180	4220	4260				74
75	3580	3620	3670	3710	3760	3800	3850	3890	3930	3970	4010	4050	4090	4130	4170	4210	4250	4290				75
76	3620	3670	3710	3760	3800	3850	3890	3930	3980	4020	4060	4100	4140	4180	4220	4260	4300	4340				76
77	3660	3710	3750	3800	3850	3890	3930	3980	4020	4060	4110	4150	4190	4230	4270	4310	4350	4390				77
78	3690	3740	3780	3830	3880	3920	3960	4010	4050	4100	4140	4180	4220	4260	4300	4350	4390	4430				78
79	3730	3780	3830	3870	3920	3960	4010	4050	4100	4140	4180	4230	4270	4310	4350	4390	4430	4480				79
80	3760	3810	3850	3900	3950	3990	4040	4080	4130	4170	4220	4260	4300	4340	4390	4430	4470	4510				80
81	3790	3840	3880	3930	3980	4020	4070	4110	4160	4200	4250	4290	4330	4380	4420	4460	4500	4540				81
82	3820	3870	3920	3970	4010	4060	4110	4150	4200	4240	4290	4330	4370	4420	4460	4500	4540	4580				82
83	3860	3910	3950	4000	4050	4100	4140	4190	4240	4280	4330	4370	4410	4460	4500	4540	4580	4630				83
84	3880	3930	3980	4030	4080	4130	4170	4220	4270	4310	4360	4400	4450	4490	4530	4570	4620	4660				84
85	3910	3960	4010	4060	4110	4160	4200	4250	4300	4340	4390	4430	4480	4520	4560	4610	4650	4690				85
86	3950	4000	4050	4100	4150	4200	4250	4300	4340	4390	4430	4480	4520	4570	4610	4660	4700	4740				86
87	3980	4030	4080	4130	4180	4230	4280	4330	4370	4420	4470	4510	4560	4600	4650	4690	4730	4780				87
88	4010	4060	4110	4160	4210	4260	4310	4360	4400	4450	4500	4540	4590	4630	4680	4720	4770	4810				88
89	4040	4090	4140	4190	4240	4290	4340	4390	4430	4480	4530	4570	4620	4670	4710	4750	4800	4840				89
90	4070	4120	4170	4220	4270	4320	4370	4420	4470	4510	4560	4610	4650	4700	4740	4790	4830	4880				90
91	4080	4130	4180	4230	4280	4330	4380	4430	4480	4530	4580	4620	4670	4710	4760	4800	4850	4890				91
*92	4090	4150	4200	4250	4300	4350	4400	4450	4500	4540	4590	4640	4680	4730	4780	4820	4870	4910				92

JULY 1974

* THE MAXIMUM VALVE OPENING
SHOULD NOT EXCEED 92 PERCENT

RESERVOIR ELEVATION 1900 TO 1985
VALVE OPENING, PERCENT 56 TO 92

Attachment 5-1

Calculation No: CDQ000020080019

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE TABLES

JULY 1974

INSTRUCTIONS FOR USE OF TABLES

1. Purpose of Tables

The purpose of these tables is to provide a means of determining the discharge of the Howell-Bunger valves in the sluice tunnel at South Holston Dam. The tables are based on field discharge measurements and pressure measurements taken at several discharges in the sluice upstream from the Howell-Bunger valves. The tables give the discharge in cubic feet per second for one valve when the reservoir elevation and valve opening are known throughout the complete range of normal operating conditions. These tables supersede the tables dated April 1959.

2. Arrangement and Use of Tables

The tables give the discharge in cubic feet per second per valve for each 5-foot interval of headwater between reservoir elevations 1600 and 1755, and for each 1 percent of valve opening between 5 percent and 89 percent valve positions. Discharges are tabulated only to the nearest 10 cubic feet per second because the accuracy of the field measurements does not warrant greater refinement. It is possible to set any discharge within 40 cubic feet per second by using the tabular values. This tolerance has been accepted by the Division of Water Control Planning, and therefore, *it will not be necessary to interpolate* between tabular entries in these tables.

The reservoir elevation values used in the tables are those given by the recorder in the control room. The valve opening used in the tables is that indicated by the pointer on the valve control mechanism.

The arrangement of tables is such that the discharge over the entire range of valve openings for a 100-foot range of reservoir elevation is on two consecutive pages. For example, discharges are given on pages 2 and 3 for reservoir elevations 1600 through 1700. Discharges should be taken from the table for the tabulated values nearest to those observed. For example, if the reservoir is at elevation 1658.76 and the valve number 1 opening is 76.4 percent, the discharge is found on page 3, in the column headed 1660 opposite a valve opening of 76 percent, as 3370 cubic feet per second. If valve number 2 were set at 56.6 percent at the same time when valve number 1 was operating as given above, the discharge for valve number 2 would be found on page 3, in the column headed 1660 opposite a valve opening of 57 percent, as 2720 cubic feet per second. The total discharge would be the sum of the discharges of the two valves or 6090 cubic feet per second.

3. Valve Opening for Maximum and Minimum Discharge

Maximum discharge for the Howell-Bunger valves at South Holston Dam occurs at 89 percent valve opening. At valve openings greater than 89 percent the discharge becomes less. Therefore, the valves should not be operated beyond 89 percent. No tabular data are presented for such operation.

Minimum valve openings should not be less than 5 percent because of cavitation effects. No tabular values are given for such operation.

4. Adjustment of Valve Opening Indicator

At the time the field measurements were made, the valve opening indicator showed an opening of 0 percent when the valve was closed. In case of repairs to or adjustment of the valve and its control mechanism, the pointer should be reset to this position so that the tables will still be applicable.

July 1974

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1600	1605	1610	1615	1620	1625	1630	1635	1640	1645	1650	1655	1660	1665	1670	1675	1680	1685	1690	1695	1700	
1																						1
2																						2
3																						3
4																						4
* 5	140	140	140	150	150	150	160	160	160	170	170	170	170	180	180	180	180	190	190	190	190	5
6	180	180	190	190	200	200	200	210	210	220	220	220	230	230	230	240	240	240	250	250	250	6
7	230	240	240	250	250	260	260	270	270	280	280	290	290	300	300	310	310	310	320	320	330	7
8	270	280	290	290	300	300	310	320	320	330	330	340	340	350	360	360	370	370	380	380	390	8
9	310	320	330	340	340	350	360	360	370	380	380	390	400	400	410	420	420	430	430	440	440	9
10	350	360	370	380	390	400	400	410	420	430	430	440	450	450	460	470	480	480	490	490	500	10
11	400	410	420	430	440	440	450	460	470	480	490	500	500	510	520	530	530	540	550	560	560	11
12	440	450	460	470	490	500	510	510	520	530	540	550	560	570	580	590	600	600	610	620	630	12
13	490	500	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	13
14	540	550	560	580	590	600	610	630	640	650	660	670	680	690	700	710	720	730	740	750	760	14
15	590	600	620	630	640	660	670	680	700	710	720	730	750	760	770	780	790	800	810	820	840	15
16	640	650	670	680	700	710	730	740	750	770	780	790	810	820	830	850	860	870	880	890	900	16
17	680	700	710	730	750	760	780	790	810	820	840	850	860	880	890	900	920	930	940	950	970	17
18	720	740	760	780	790	810	830	840	860	870	890	900	920	930	950	960	970	990	1000	1010	1030	18
19	770	790	800	820	840	860	880	890	910	930	940	960	970	990	1000	1020	1030	1050	1060	1070	1090	19
20	810	830	850	870	890	900	920	940	960	980	990	1010	1030	1040	1060	1070	1090	1100	1120	1130	1150	20
21	840	870	890	910	930	950	970	980	1000	1020	1040	1050	1070	1090	1110	1120	1140	1150	1170	1180	1200	21
22	880	900	930	950	970	990	1010	1030	1050	1070	1080	1100	1120	1140	1150	1170	1190	1200	1220	1240	1250	22
23	920	940	970	990	1010	1030	1050	1070	1090	1110	1130	1150	1170	1190	1210	1220	1240	1260	1270	1290	1310	23
24	960	980	1000	1030	1050	1070	1090	1110	1130	1160	1180	1190	1210	1230	1250	1270	1290	1310	1320	1340	1360	24
25	990	1020	1040	1060	1090	1110	1130	1150	1180	1200	1220	1240	1260	1280	1300	1320	1340	1350	1370	1390	1410	25
26	1030	1060	1080	1110	1130	1150	1180	1200	1220	1240	1270	1290	1310	1330	1350	1370	1390	1410	1430	1450	1460	26
27	1070	1100	1120	1150	1170	1200	1220	1250	1270	1290	1320	1340	1360	1380	1400	1420	1440	1460	1480	1500	1520	27
28	1120	1140	1170	1200	1220	1250	1270	1300	1320	1350	1370	1390	1420	1440	1460	1480	1500	1520	1540	1560	1580	28
29	1160	1180	1210	1240	1270	1290	1320	1350	1370	1390	1420	1440	1470	1490	1510	1530	1560	1580	1600	1620	1640	29
30	1190	1220	1250	1280	1310	1330	1360	1390	1410	1440	1460	1490	1510	1530	1560	1580	1600	1620	1650	1670	1690	30
31	1230	1260	1290	1320	1350	1380	1400	1430	1460	1480	1510	1540	1560	1580	1610	1630	1660	1680	1700	1720	1750	31
32	1270	1300	1330	1360	1390	1420	1450	1480	1510	1530	1560	1580	1610	1640	1660	1690	1710	1730	1760	1780	1800	32
33	1310	1340	1370	1410	1440	1470	1500	1520	1550	1580	1610	1630	1660	1690	1710	1740	1760	1790	1810	1840	1860	33
34	1350	1380	1420	1450	1480	1510	1540	1570	1600	1630	1660	1680	1710	1740	1760	1790	1820	1840	1870	1890	1920	34
35	1390	1420	1460	1490	1520	1550	1590	1620	1650	1680	1700	1730	1760	1790	1820	1840	1870	1900	1920	1950	1970	35
36	1430	1460	1500	1530	1570	1600	1630	1660	1690	1720	1750	1780	1810	1840	1870	1900	1920	1950	1980	2000	2030	36
37	1470	1500	1540	1580	1610	1640	1680	1710	1740	1770	1800	1830	1860	1890	1920	1950	1980	2000	2030	2060	2080	37
38	1510	1540	1580	1620	1650	1690	1720	1750	1790	1820	1850	1880	1910	1940	1970	2000	2030	2060	2090	2110	2140	38
39	1540	1580	1610	1650	1690	1720	1760	1790	1820	1860	1890	1920	1950	1980	2010	2040	2070	2100	2130	2160	2180	39
40	1570	1610	1650	1690	1720	1760	1800	1830	1860	1900	1930	1960	1990	2030	2060	2090	2120	2150	2170	2200	2230	40
41	1610	1650	1690	1730	1770	1800	1840	1880	1910	1950	1980	2010	2040	2080	2110	2140	2170	2200	2230	2260	2290	41
42	1650	1690	1730	1770	1810	1840	1880	1920	1950	1990	2020	2060	2090	2120	2150	2190	2220	2250	2280	2310	2340	42
43	1680	1720	1760	1800	1840	1880	1920	1960	1990	2030	2060	2100	2130	2170	2200	2230	2260	2290	2330	2360	2390	43
44	1720	1760	1800	1840	1880	1920	1960	2000	2030	2070	2110	2140	2180	2210	2240	2280	2310	2340	2370	2410	2440	44
45	1740	1790	1830	1870	1910	1950	1990	2030	2070	2110	2140	2180	2210	2250	2280	2320	2350	2380	2420	2450	2480	45
46	1780	1820	1870	1910	1950	1990	2030	2070	2110	2150	2190	2220	2260	2290	2330	2360	2400	2430	2460	2500	2530	46
47	1810	1860	1900	1950	1990	2030	2070	2110	2150	2190	2230	2270	2300	2340	2370	2410	2440	2480	2510	2540	2580	47
48	1840	1890	1940	1980	2020	2070	2110	2150	2190	2230	2270	2300	2340	2380	2410	2450	2480	2520	2550	2590	2620	48
49	1870	1920	1970	2010	2060	2100	2140	2180	2220	2260	2300	2340	2380	2420	2450	2490	2520	2560	2590	2630	2660	49
50	1910	1960	2010	2050	2100	2140	2190	2230	2270	2310	2350	2390	2430	2470	2500	2540	2580	2610	2650	2680	2720	50

JULY 1974

* THE MINIMUM ALLOWABLE
VALVE OPENING IS 5 PERCENT

RESERVOIR ELEVATION 1600 TO 1700
VALVE OPENING. PERCENT 5 TO 50

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1600	1605	1610	1615	1620	1625	1630	1635	1640	1645	1650	1655	1660	1665	1670	1675	1680	1685	1690	1695	1700	
51	1940	1990	2040	2090	2130	2180	2220	2260	2300	2350	2390	2430	2470	2500	2540	2580	2620	2650	2690	2730	2760	51
52	1970	2020	2070	2120	2160	2210	2250	2300	2340	2380	2420	2460	2500	2540	2580	2620	2660	2690	2730	2770	2800	52
53	2010	2060	2110	2160	2210	2250	2300	2340	2390	2430	2470	2510	2550	2590	2630	2670	2710	2750	2790	2820	2860	53
54	2040	2090	2140	2190	2240	2290	2330	2380	2420	2470	2510	2550	2590	2630	2670	2710	2750	2790	2830	2860	2900	54
55	2070	2120	2180	2220	2270	2320	2370	2410	2460	2500	2550	2590	2630	2670	2710	2750	2790	2830	2870	2910	2940	55
56	2100	2150	2210	2260	2310	2350	2400	2450	2490	2540	2580	2620	2670	2710	2750	2790	2830	2870	2910	2950	2990	56
57	2140	2200	2250	2300	2350	2400	2450	2490	2540	2590	2630	2670	2720	2760	2800	2840	2880	2920	2960	3000	3040	57
58	2170	2230	2280	2330	2380	2430	2480	2530	2580	2620	2670	2710	2760	2800	2840	2880	2920	2970	3010	3040	3080	58
59	2200	2260	2310	2360	2410	2470	2510	2560	2610	2660	2700	2750	2790	2840	2880	2920	2960	3010	3050	3090	3130	59
60	2230	2290	2340	2390	2450	2500	2550	2600	2650	2690	2740	2790	2830	2880	2920	2960	3000	3050	3090	3130	3170	60
61	2260	2320	2370	2430	2480	2530	2580	2630	2680	2730	2780	2820	2870	2910	2960	3000	3040	3090	3130	3170	3210	61
62	2280	2340	2390	2450	2500	2550	2610	2660	2700	2750	2800	2850	2890	2940	2980	3030	3070	3110	3160	3200	3240	62
63	2310	2370	2420	2480	2530	2590	2640	2690	2740	2790	2840	2880	2930	2980	3020	3070	3110	3150	3200	3240	3280	63
64	2340	2400	2460	2510	2570	2620	2670	2720	2780	2830	2870	2920	2970	3020	3060	3110	3150	3200	3240	3280	3320	64
65	2370	2430	2490	2540	2600	2650	2710	2760	2810	2860	2910	2960	3010	3050	3100	3150	3190	3240	3280	3320	3370	65
66	2400	2460	2520	2580	2630	2690	2740	2790	2850	2900	2950	3000	3040	3090	3140	3190	3230	3280	3320	3360	3410	66
67	2420	2480	2540	2600	2650	2710	2760	2820	2870	2920	2970	3020	3070	3120	3170	3210	3260	3300	3350	3390	3440	67
68	2440	2500	2560	2620	2680	2730	2790	2840	2890	2940	3000	3050	3100	3140	3190	3240	3280	3330	3380	3420	3460	68
69	2470	2530	2590	2650	2710	2760	2820	2870	2930	2980	3030	3080	3130	3180	3230	3280	3320	3370	3420	3460	3510	69
70	2500	2560	2620	2680	2740	2800	2850	2910	2960	3020	3070	3120	3170	3220	3270	3320	3360	3410	3460	3500	3550	70
71	2530	2590	2650	2710	2770	2830	2890	2940	3000	3050	3110	3160	3210	3260	3310	3360	3400	3450	3500	3550	3590	71
72	2550	2610	2670	2740	2800	2850	2910	2970	3020	3080	3130	3180	3230	3280	3330	3380	3430	3480	3530	3570	3620	72
73	2580	2640	2710	2770	2830	2890	2950	3000	3060	3110	3170	3220	3270	3320	3370	3420	3470	3520	3570	3610	3660	73
74	2610	2670	2740	2800	2860	2920	2980	3040	3090	3150	3200	3260	3310	3360	3410	3460	3510	3560	3610	3660	3700	74
75	2630	2690	2760	2820	2880	2940	3000	3060	3120	3170	3230	3280	3330	3390	3440	3490	3540	3590	3640	3680	3730	75
76	2660	2720	2790	2850	2910	2980	3040	3090	3150	3210	3260	3320	3370	3420	3480	3530	3580	3630	3680	3730	3770	76
77	2680	2740	2810	2870	2940	3000	3060	3120	3180	3230	3290	3340	3400	3450	3500	3550	3610	3660	3710	3750	3800	77
78	2700	2760	2830	2900	2960	3020	3080	3140	3200	3260	3310	3370	3420	3480	3530	3580	3630	3680	3730	3780	3830	78
79	2720	2790	2860	2920	2990	3050	3110	3170	3230	3290	3340	3400	3450	3510	3560	3610	3670	3720	3770	3820	3870	79
80	2750	2820	2880	2950	3010	3080	3140	3200	3260	3320	3370	3430	3490	3540	3590	3650	3700	3750	3800	3850	3900	80
81	2770	2840	2900	2970	3030	3100	3160	3220	3280	3340	3400	3450	3510	3570	3620	3670	3730	3780	3830	3880	3930	81
82	2790	2860	2920	2990	3060	3120	3180	3240	3300	3360	3420	3480	3540	3590	3650	3700	3750	3800	3860	3910	3960	82
83	2820	2890	2960	3020	3090	3150	3220	3280	3340	3400	3460	3520	3570	3630	3680	3740	3790	3850	3900	3950	4000	83
84	2840	2910	2980	3040	3110	3180	3240	3300	3360	3420	3480	3540	3600	3650	3710	3770	3820	3870	3920	3980	4030	84
85	2860	2930	3000	3070	3130	3200	3260	3330	3390	3450	3510	3570	3620	3680	3740	3790	3850	3900	3950	4000	4060	85
86	2880	2950	3020	3090	3150	3220	3280	3350	3410	3470	3530	3590	3650	3710	3760	3820	3870	3930	3980	4030	4080	86
87	2900	2970	3040	3110	3180	3240	3310	3370	3430	3500	3560	3620	3670	3730	3790	3840	3900	3950	4010	4060	4110	87
88	2900	2980	3050	3120	3190	3250	3320	3380	3450	3510	3570	3630	3690	3740	3800	3860	3910	3970	4020	4070	4130	88
*89	2910	2990	3060	3130	3200	3260	3330	3390	3460	3520	3580	3640	3700	3760	3810	3870	3930	3980	4030	4090	4140	89

JULY 1974

* THE MAXIMUM VALVE OPENING SHOULD NOT EXCEED 89 PERCENT

RESERVOIR ELEVATION 1600 TO 1700
VALVE OPENING, PERCENT 51 TO 89

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY | **ENGINEERING LABORATORY**

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1700	1705	1710	1715	1720	1725	1730	1735	1740	1745	1750	1755										
1																						1
2																						2
3																						3
4																						4
*5	190	200	200	200	200	210	210	210	210	220	220	220										5
6	250	260	260	260	270	270	270	270	280	280	280	290										6
7	330	330	330	340	340	350	350	350	360	360	370	370										7
8	390	390	400	400	400	410	410	420	420	430	430	440										8
9	440	450	460	460	470	470	480	480	490	490	500	500										9
10	500	510	510	520	530	530	540	540	550	560	560	570										10
11	560	570	580	580	590	600	600	610	620	620	630	640										11
12	630	640	640	650	660	670	670	680	690	700	700	710										12
13	700	710	710	720	730	740	750	760	760	770	780	790										13
14	760	770	780	790	800	810	820	830	840	850	850	860										14
15	840	850	860	870	880	890	900	910	920	920	930	940										15
16	900	920	930	940	950	960	970	980	990	1000	1010	1020										16
17	970	980	990	1000	1010	1030	1040	1050	1060	1070	1080	1090										17
18	1030	1040	1050	1060	1080	1090	1100	1110	1130	1140	1150	1160										18
19	1090	1100	1120	1130	1140	1160	1170	1180	1190	1210	1220	1230										19
20	1150	1160	1180	1190	1200	1220	1230	1240	1260	1270	1280	1300										20
21	1200	1210	1230	1240	1260	1270	1290	1300	1320	1330	1340	1360										21
22	1250	1270	1280	1300	1310	1330	1340	1360	1370	1390	1400	1420										22
23	1310	1320	1340	1360	1370	1390	1400	1420	1430	1450	1460	1480										23
24	1360	1380	1390	1410	1430	1440	1460	1470	1490	1510	1520	1540										24
25	1410	1430	1440	1460	1480	1490	1510	1530	1540	1560	1580	1590										25
26	1460	1480	1500	1520	1540	1550	1570	1590	1610	1620	1640	1660										26
27	1520	1540	1560	1580	1600	1610	1630	1650	1670	1680	1700	1720										27
28	1580	1600	1620	1640	1660	1680	1700	1720	1740	1750	1770	1790										28
29	1640	1660	1680	1700	1720	1740	1760	1780	1800	1820	1840	1850										29
30	1690	1710	1730	1750	1770	1790	1810	1830	1850	1870	1890	1910										30
31	1750	1770	1790	1810	1830	1850	1870	1890	1910	1930	1950	1570										31
32	1800	1830	1850	1870	1890	1910	1930	1960	1980	2000	2020	2040										32
33	1860	1880	1910	1930	1950	1970	1990	2020	2040	2060	2080	2100										33
34	1920	1940	1960	1990	2010	2030	2050	2080	2100	2120	2140	2160										34
35	1970	2000	2020	2040	2070	2090	2120	2140	2160	2180	2210	2230										35
36	2030	2050	2080	2100	2130	2150	2180	2200	2220	2250	2270	2290										36
37	2080	2110	2140	2160	2190	2210	2240	2260	2280	2310	2330	2360										37
38	2140	2170	2190	2220	2250	2270	2300	2320	2350	2370	2400	2420										38
39	2180	2210	2240	2260	2290	2320	2340	2370	2390	2420	2440	2470										39
40	2230	2260	2290	2310	2340	2370	2390	2420	2450	2470	2500	2520										40
41	2290	2320	2350	2370	2400	2430	2460	2480	2510	2530	2560	2590										41
42	2340	2370	2400	2420	2450	2480	2510	2540	2560	2590	2620	2640										42
43	2390	2420	2450	2480	2500	2530	2560	2590	2620	2640	2670	2700										43
44	2440	2470	2500	2530	2560	2590	2610	2640	2670	2700	2730	2750										44
45	2480	2510	2540	2570	2600	2630	2660	2690	2720	2750	2770	2800										45
46	2530	2560	2590	2620	2650	2680	2710	2740	2770	2800	2830	2860										46
47	2580	2610	2640	2670	2700	2730	2770	2800	2820	2850	2880	2910										47
48	2620	2650	2680	2720	2750	2780	2810	2840	2870	2900	2930	2960										48
49	2660	2690	2730	2760	2790	2820	2860	2890	2920	2950	2980	3010										49
50	2720	2750	2790	2820	2850	2880	2920	2950	2980	3010	3040	3070										50

JULY 1974

* THE MINIMUM ALLOWABLE
VALVE OPENING IS 5 PERCENT

RESERVOIR ELEVATION 1700 TO 1755
VALVE OPENING PERCENT 5 TO 50

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY **ENGINEERING LABORATORY**

VALVE OPENING PERCENT	RESERVOIR ELEVATION												VALVE OPENING PERCENT
	1700	1705	1710	1715	1720	1725	1730	1735	1740	1745	1750	1755	
51	2760	2790	2830	2860	2900	2930	2960	2990	3030	3060	3090	3120	51
52	2800	2840	2870	2910	2940	2970	3010	3040	3070	3100	3140	3170	52
53	2860	2890	2930	2960	3000	3030	3070	3100	3130	3170	3200	3230	53
54	2900	2940	2970	3010	3040	3080	3110	3150	3180	3210	3250	3280	54
55	2940	2980	3020	3050	3090	3120	3160	3190	3230	3260	3290	3330	55
56	2990	3020	3060	3100	3130	3170	3200	3240	3270	3310	3340	3370	56
57	3040	3080	3120	3150	3190	3230	3260	3300	3330	3370	3400	3440	57
58	3080	3120	3160	3200	3240	3270	3310	3350	3380	3420	3450	3490	58
59	3130	3170	3200	3240	3280	3320	3350	3390	3430	3460	3500	3530	59
60	3170	3210	3250	3290	3320	3360	3400	3440	3470	3510	3550	3580	60
61	3210	3250	3290	3330	3370	3410	3440	3480	3520	3560	3590	3630	61
62	3240	3280	3320	3360	3400	3440	3480	3510	3550	3590	3620	3660	62
63	3280	3320	3360	3400	3440	3480	3520	3560	3600	3630	3670	3710	63
64	3320	3360	3410	3450	3490	3530	3570	3600	3640	3680	3720	3760	64
65	3370	3410	3450	3490	3530	3570	3610	3650	3690	3730	3770	3800	65
66	3410	3450	3490	3530	3580	3620	3660	3700	3740	3770	3810	3850	66
67	3440	3480	3520	3560	3610	3650	3690	3730	3770	3810	3840	3880	67
68	3460	3510	3550	3590	3630	3680	3720	3760	3800	3840	3880	3920	68
69	3510	3550	3590	3640	3680	3720	3760	3800	3840	3880	3920	3960	69
70	3550	3590	3640	3680	3720	3770	3810	3850	3890	3930	3970	4010	70
71	3590	3640	3680	3720	3770	3810	3850	3890	3940	3980	4020	4060	71
72	3620	3660	3710	3750	3800	3840	3880	3930	3970	4010	4050	4090	72
73	3660	3710	3750	3800	3840	3890	3930	3970	4010	4060	4100	4140	73
74	3700	3750	3800	3840	3890	3930	3970	4020	4060	4100	4140	4190	74
75	3730	3780	3820	3870	3920	3960	4000	4050	4090	4130	4180	4220	75
76	3770	3820	3870	3910	3960	4000	4050	4090	4140	4180	4220	4270	76
77	3800	3850	3900	3940	3990	4030	4080	4120	4170	4210	4250	4300	77
78	3830	3880	3930	3970	4020	4060	4110	4150	4200	4240	4290	4330	78
79	3870	3910	3960	4010	4060	4100	4150	4190	4240	4280	4330	4370	79
80	3900	3950	4000	4050	4090	4140	4190	4230	4280	4320	4360	4410	80
81	3930	3980	4030	4070	4120	4170	4220	4260	4310	4350	4400	4440	81
82	3960	4010	4060	4100	4150	4200	4250	4290	4340	4380	4430	4470	82
83	4000	4050	4100	4150	4200	4240	4290	4340	4380	4430	4480	4520	83
84	4030	4080	4130	4180	4230	4270	4320	4370	4410	4460	4510	4550	84
85	4060	4110	4160	4210	4260	4300	4350	4400	4450	4490	4540	4580	85
86	4080	4130	4190	4240	4280	4330	4380	4430	4480	4520	4570	4620	86
87	4110	4160	4210	4260	4310	4360	4410	4460	4510	4550	4600	4650	87
88	4130	4180	4230	4280	4330	4380	4430	4480	4520	4570	4620	4660	88
*89	4140	4190	4240	4290	4340	4390	4440	4490	4540	4590	4630	4680	89

JULY 1974

*THE MAXIMUM VALVE OPENING SHOULD NOT EXCEED 89 PERCENT

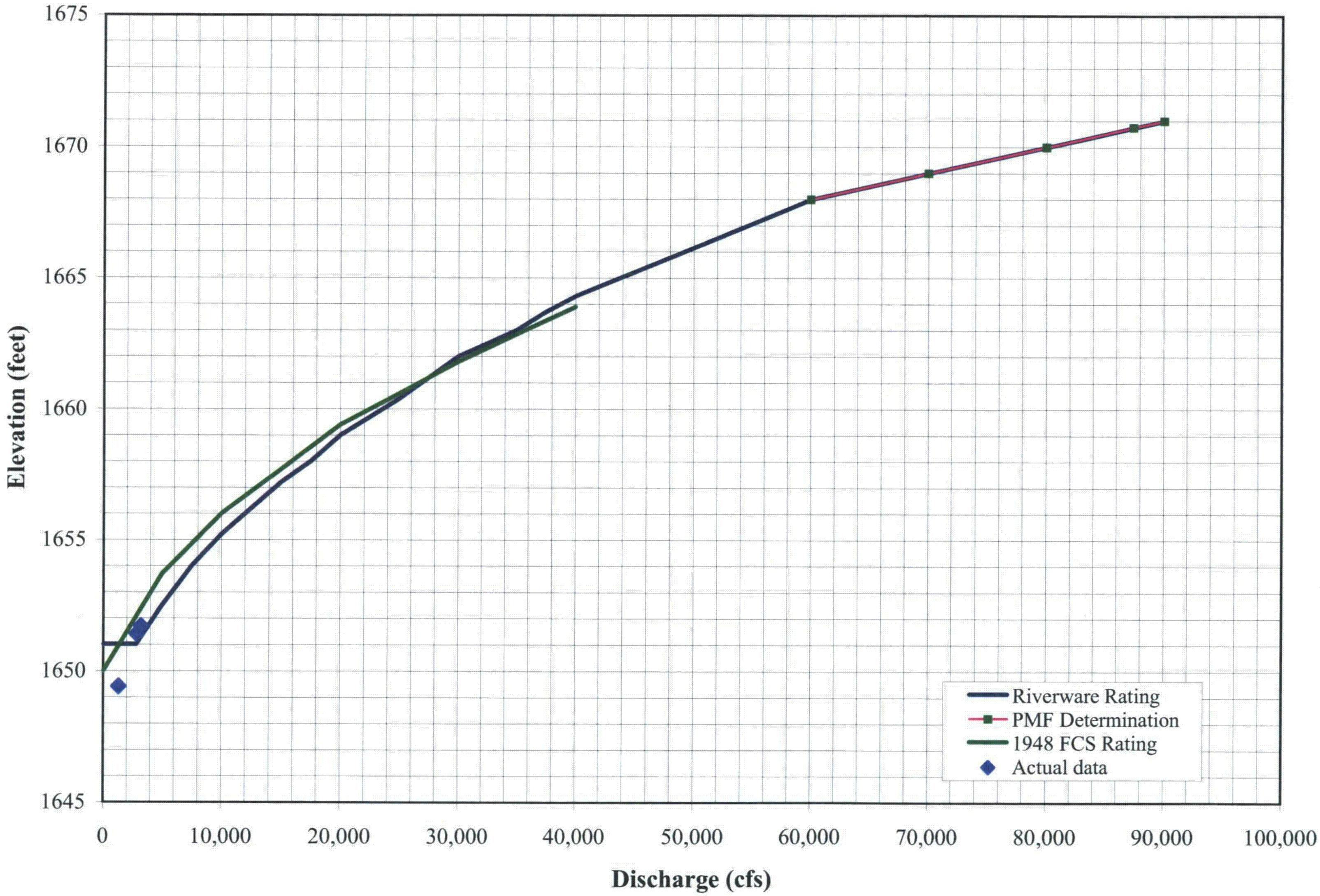
RESERVOIR ELEVATION 1700 TO 1755
VALVE OPENING, PERCENT 51 TO 89

CDQ000020080019

Attachment 6

sheet 6-1 of 3

Watauga Tailwater Rating



Watauga Tailwater Rating

Actual da
1300
2820
3200

Riverware Rating

Q*1000	Q	Elevation
0	0	1651
2.8	2,800	1651
5	5,000	1652.5
7.5	7,500	1654
10	10,000	1655.2
12.5	12,500	1656.2
15	15,000	1657.2
17.5	17,500	1658
20	20,000	1659
22.5	22,500	1659.7
25	25,000	1660.4
27.5	27,500	1661.2
30	30,000	1662
32.5	32,500	1662.5
35	35,000	1663
37.5	37,500	1663.7
40	40,000	1664.3
60	60,000	1668
70	70,000	1669
80	80,000	1670
90	90,000	1671

Flood Control Section 1948

Q	Elevation	
0	1650	
5,000	1653.7	
10,000	1656	
20,000	1659.4	
30,000	1661.8	
40,000	1663.9	
60,000	1668	
70,000	1669	
80,000	1670	
87,400	1670.75	**PMF**
90,000	1671	

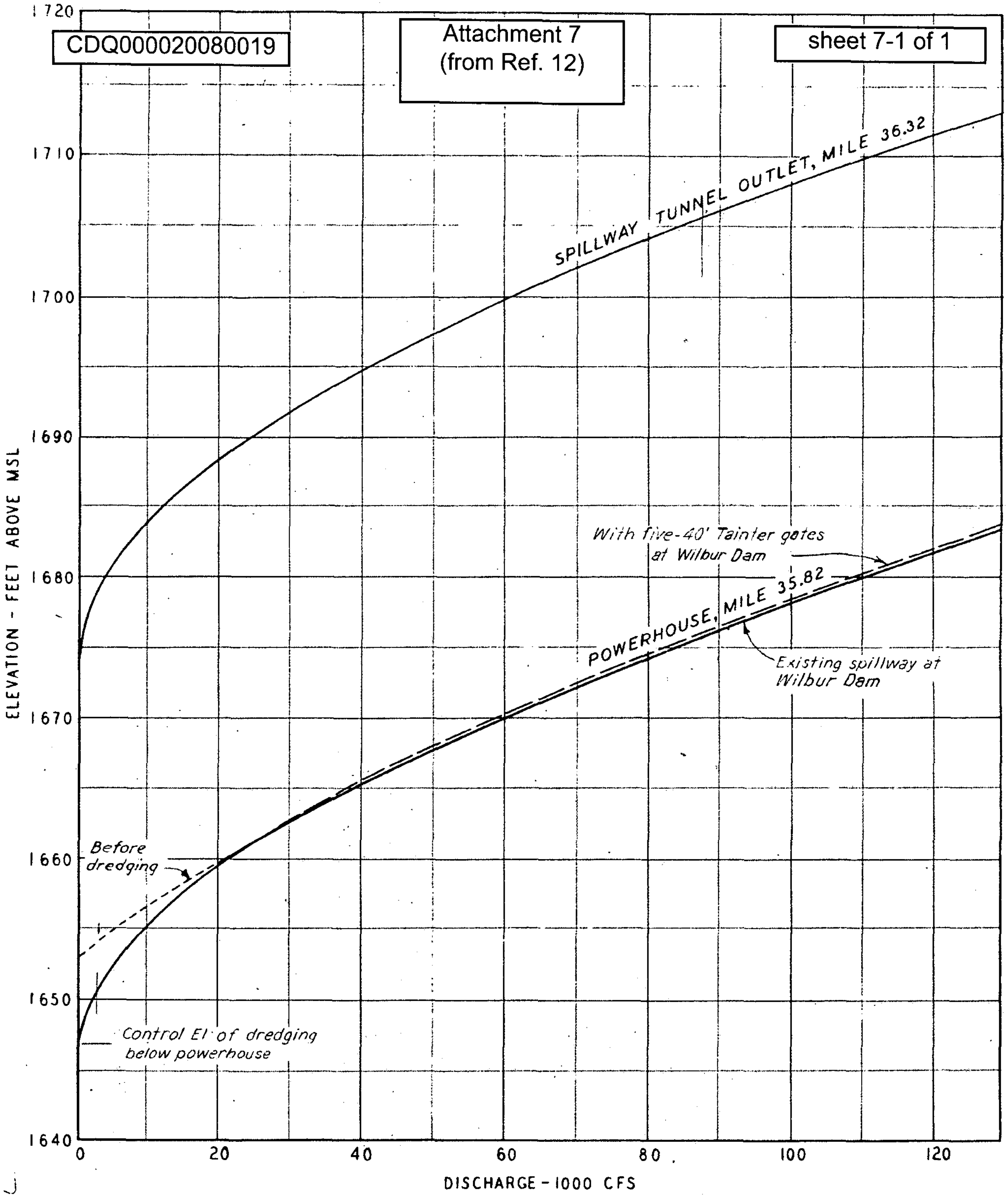
ta

1649.4
1651.4
1651.7

CDQ000020080019

Attachment 7
(from Ref. 12)

sheet 7-1 of 1



NOTE:

Spillway crest at Wilbur Dam is at El 1640.6

THIS DWG SUPERSEDES 22-PP-1-321A331

REV. NO.	DATE	MADE	CHKD	SUPV.	INSP.

DRWN. BJG
TRCD. VLJ
CHKD.

COMPUTED BJG
ENGINEER B.J. Buckles

WATAUGA RIVER

TAILWATER RATING CURVES

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
WATER CONTROL PLANNING DEPARTMENT

SUBMITTED E. J. Rutter
RECOMMENDED J. H. Kimball
APPROVED

KNOXVILLE | 7-1-44 | 22 | PP | 1 | 321A477 R0

FU 138-10.023

for the hydraulic-jump basin will be smaller and spaced closer together than those for the impact block basin.

This example shows that the impact block basin is considerably smaller than the hydraulic-jump basin. However, the impact block basin should be limited to uses where the drop distance does not exceed 20 feet. Furthermore, as previously explained, the foundation for an impact block basin must be of better quality because of the concentrated forces involved. The hydraulic-jump basin, therefore, has a much wider application.

The slotted-grating dissipator is not suitable in this case because the Froude number of 5.3 is greater than 4.5, which is the tested limit for a practical slotted-grating design.

9.26. *Drop Inlet (Shaft or Morning Glory) Spillways.*—(a) *General Characteristics.*—Typical floor conditions and discharge characteristics of a drop inlet spillway are shown on figure 9-55. The discharge curve shows that crest control (condition 1) will prevail for heads between the ordinates of *a* and *g*; orifice or tube control (condition 2) will govern for heads between the ordinates of *g* and *h*; and the spillway conduit will flow full for heads above the ordinate of *h* (condition 3).

The flow characteristics of a drop inlet spillway vary according to the proportional sizes of the different elements. Changing the diameter of the crest will change the curve *ab* on figure 9-55 so that the ordinate of *g* on curve *cd* will be either higher or lower. For a larger diameter crest, greater outflows can be discharged over the weir at low heads, the transition will fill up, and tube control will occur with a lesser head on the crest. Similarly, by altering the size of the throat of the tube, the position of curve *cd* will change, indicating the heads above which tube control will prevail. If the transition is made of such size that curve *cd* is moved to coincide with or lie to the right of point *j*, the control will shift directly from the crest to the downstream end of the conduit. The details of the hydraulic flow characteristics are discussed in the following subsections.

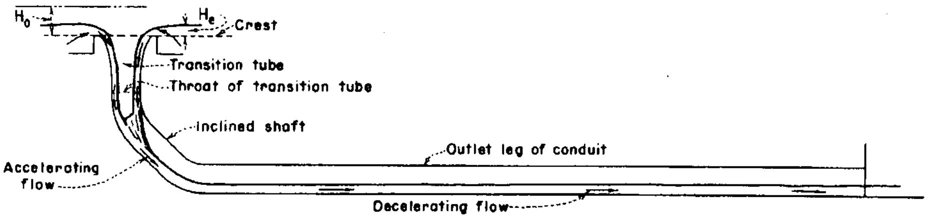
(b) *Crest Discharge.*—For small heads, flow over the drop inlet spillway is governed by the characteristics of crest discharge. The vertical transition beyond the crest will flow partly full and the flow will cling to the sides of the shaft. As the discharge over the crest increases, the overflowing annular nappe will become thicker and, eventually, the nappe flow will converge into a solid vertical jet. The point where the annular nappe joins the solid jet is called the crotch. After the solid jet forms, a "boil" will occupy the region above the crotch; both the crotch and the top of the boil become progressively higher with large discharges. For high heads the crotch and boil may almost flood out, showing only a slight depression and eddy at the surface.

Until the nappe converges to form a solid jet, free-discharging weir flow prevails. After the crotch and boil form, submergence begins to affect the weir flow and, ultimately, the crest will drown out. Flow is then governed either by the contracted jet formed by the overflow entrance, or by the shape and size of the vertical transition if it does not conform to the jet shape. Vortex action must be minimized to maintain converging flow into the drop inlet. Guide piers are often installed along the crest for this purpose [13, 14].

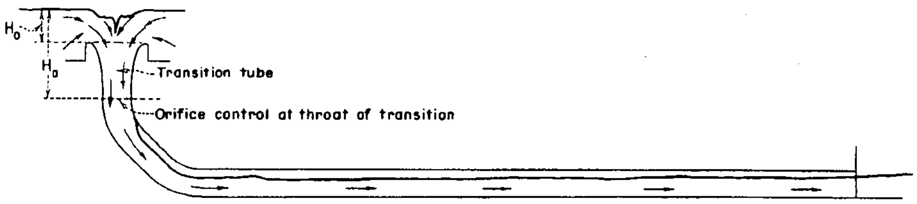
If the crest profile and transition conform to the shape of the lower nappe of a jet flowing over a sharp-crested circular weir, the discharge for flow over the crest and through the transition can be expressed as $Q = CLH^{3/2}$ (see eq. (3)); where H is the head measured either to the apex of the undernappe of the overflow, to the spring point of the circular sharp-crested weir, or to some other established point on the overflow. Similarly, the choice of the length, L, is related to some specific point of measurement such as the length of the circle at the apex, along the periphery at the upstream face of the crest, or along some other chosen reference line. C will change with different definitions of L and H. If L is taken at the outside periphery of the overflow crest (the origin of the coordinates on figure 9-56) and if the head is measured to the apex of the overflow shape, equation (3) can be written:

$$Q = C_o(2\pi R_s)H_o^{3/2} \qquad (28)$$

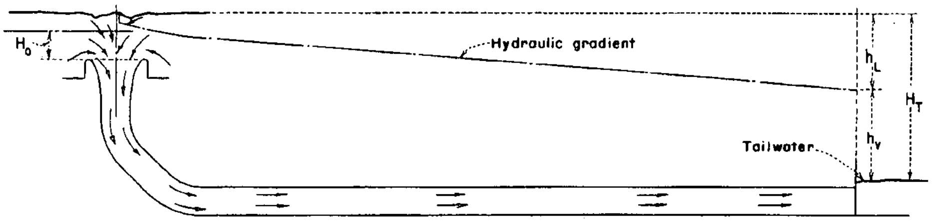
It is apparent that the discharge coefficient for a circular crest differs from that for a straight crest because of the effects of submergence and back pressure incident to the joining of the converging flows. Thus, C_0 must be related to both H_o and R_s, and can be expressed in terms of H_o/R_s. The relationship of C_o, as determined from model tests [24], to H_o/R_s for three conditions of approach depth is plotted on figure 9-57. These coefficients are valid only if the crest profile and transition shape conform to that of the jet flowing over a



CONDITION I. CREST CONTROL



CONDITION 2. TUBE OR ORIFICE CONTROL



CONDITION 3. FULL PIPE FLOW

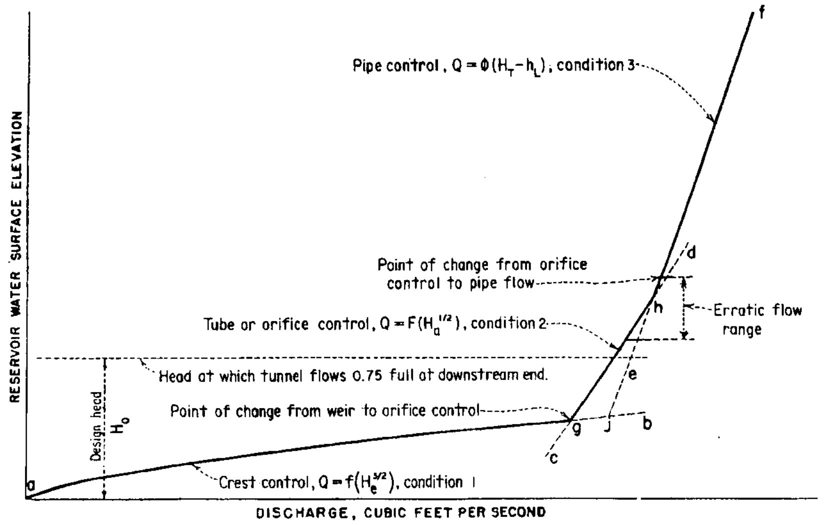


Figure 9-55.—Nature of flow and discharge characteristics of a morning glory spillway. 288-D-2439.

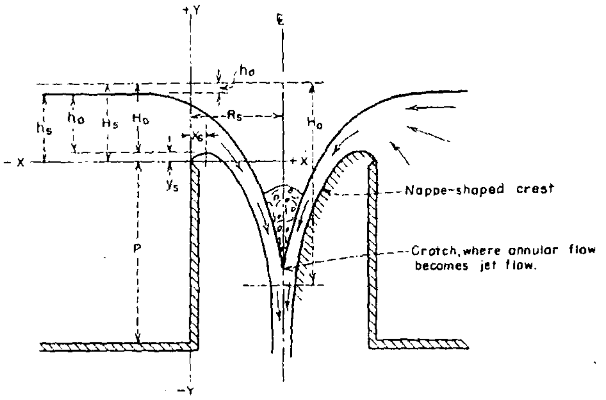


Figure 9-56.—Elements of nappe-shaped profile for circular weir. 288-D-2440.

sharp-crested circular weir at H_o head and if aeration is provided so that subatmospheric pressures do not exist along the lower nappe surface contact.

When the crest outline and transition shape conform to the profile of the nappe shape for an H_o head over the crest, free flow prevails for H_o/R_s up to approximately 0.45, and weir control governs. As H_o/R_s increases above 0.45, the weir partly submerges, and flow showing characteristics of a submerged weir is the controlling condition. When the H_o/R_s ratio approaches 1.0, the water surface above the weir is completely submerged. For this and higher stages of H_o/R_s, the flow phenomenon is that of orifice flow. The weir formula, $Q = CLH^{3/2}$, is used as the measure of flow through the drop inlet entrance regardless of the submergence, by using a coefficient that reflects the flow conditions through the various H_o/R_s ranges. Thus, from figure 9-57 it can be seen that the weir coefficient only changes slightly from that normally indicated for $H_o/R_s <$ 0.45, but reduces rapidly for the higher H_o/R_s values.

It should be noted that for most conditions of flow over a circular weir, the discharge coefficient increases with a reduction in the approach depth; whereas, the opposite is true for a straight weir. For both weirs, a shallower approach lessens the upward vertical velocity component and, consequently, suppresses the contraction of the nappe. However, for the circular weir, the submergence effect is reduced because of a depressed upper nappe surface, giving the jet a quicker downward impetus, which lowers the position of the crotch and increases the discharge.

Discharge coefficients for partial heads of H_e on the crest can be determined from figure 9-58 to prepare a discharge-head relationship. The designer must be cautious in applying the above criteria because subatmospheric pressure or submergence effects may alter the flow conditions differently for various profile shapes. This criteria, therefore, should not be applied for flow conditions where $H_e/R_s > 0.4$.

(c) *Crest Profiles.*—Values of coordinates that define the shape of the lower surface of a nappe flowing over an aerated sharp-crested circular weir for various conditions of P/R_s and H_s/R_s are shown in tables 9-5, 9-6, and 9-7. These data are based on experimental tests [24] conducted by the Bureau of Reclamation. The relationships of H_s to H_o are shown on figure 9-59. Typical upper and lower nappe profiles for various values of H_s/R_s are plotted on figure 9-60 in terms of X/H_s and Y/H_s for the condition of $P/R_s = 2.0$.

Figure 9-61 shows typical lower nappe profiles, plotted for various values of H_s for a given value of R_s. In contrast to the straight weir where the nappe springs farther from the crest as the head increases, it can be seen from figure 9-61 that the lower nappe profile for the circular crest springs farther only in the region of the high point of the trace, and then only for H_s/R_s values up to about 0.5.

The profiles become increasingly suppressed for larger H_s/R_s values. Below the high point of the profile, the traces cross and the shapes for the higher heads fall inside those for the lower heads. Thus, if the crest profile is designed for heads where H_s/R_s exceeds about 0.25 to 0.3, it appears that subatmospheric pressure will occur along some portion for the profile when heads are less than the designed maximum. If subatmospheric pressures are to be avoided along the crest profile, the crest shape selected should give support to the overflow nappe for the smaller H_s/R_s ratios. Figure 9-62 shows the approximate increase in radius required to minimize subatmospheric pressures on the crest. The crest shape for the enlarged crest radius is then based on $H'_s/R'_s = 0.3$.

(d) *Transition Design.*—The diameter of a jet issuing from a horizontal orifice can be determined for any point below the water surface if it is assumed that the continuity equation, $Q = av$, is valid and if friction and other losses are neglected.

For a circular jet the area is equal to πR^2. The discharge is equal to $av = \pi R^2 \sqrt{2gH_a}$. Solving for R,

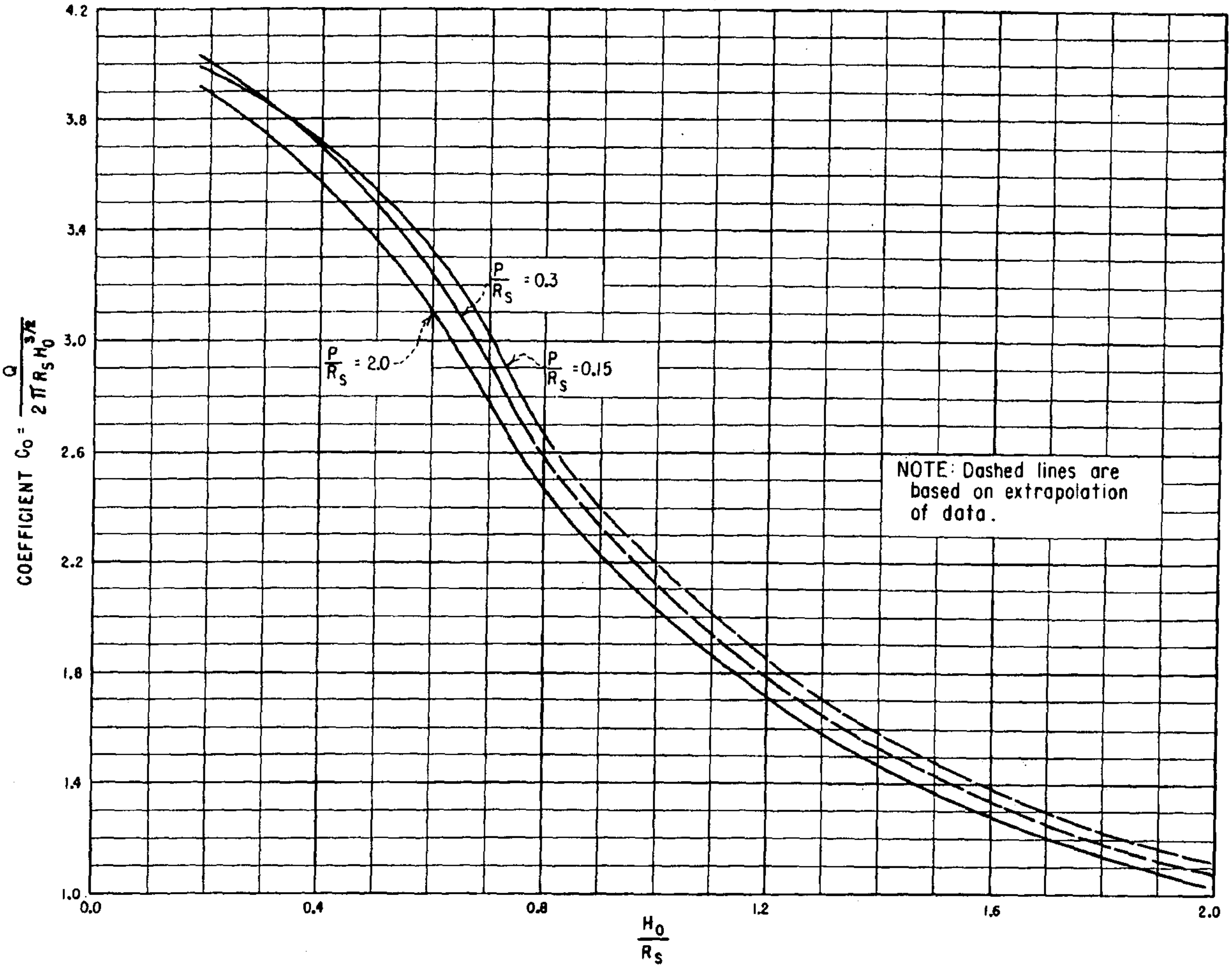


Figure 9-57.—Relationship of circular crest coefficient C_o to H_o/R_s for different approach depths (aerated nappe). 288-D-2441.

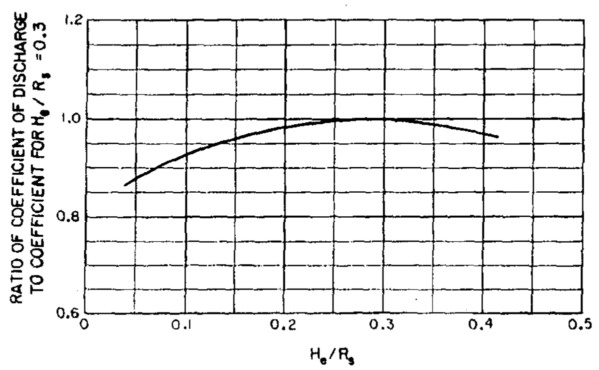


Figure 9-58.—Circular crest discharge coefficient for other than design head. 288-D-2442.

$R = Q_a^{1/2}/5H_a^{1/4}$; where H_a is equal to the distance between the water surface and the elevation under consideration. The diameter of the jet thus decreases with the distance of the free vertical fall for normal design applications.

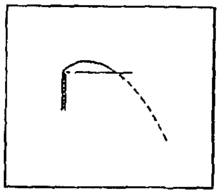
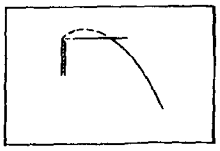
If an assumed total loss (including jet contraction losses, friction losses, velocity losses from direction changes, etc.) is taken as 0.1 H_a, the equation for determining the approximate required shaft radius may be written:

$$R = 0.204 \frac{Q_a^{1/2}}{H_a^{1/4}} \qquad (29)$$

Because this equation is for the shape of the jet,

Table 9-5.—Coordinates of lower nappe surface for different values of H_s/R_s when $P/R_s = 2.0$.

[Negligible approach velocity and aerated nappe]

H_s/R_s	0.00	0.10*	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.80	1.00	1.20	1.50	2.00
X/H_s	Y/H_s for portion of profile above weir crest														
0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
.010	.0150	.0145	.0133	.0130	.0128	.0125	.0122	.0119	.0116	.0112	.0104	.0095	.0086	.0077	.0070
.020	.0280	.0265	.0250	.0243	.0236	.0231	.0225	.0220	.0213	.0202	.0180	.0159	.0140	.0115	.0090
.030	.0395	.0365	.0350	.0337	.0327	.0317	.0308	.0299	.0289	.0270	.0231	.0198	.0168	.0126	.0085
.040	.0490	.0460	.0435	.0417	.0403	.0389	.0377	.0363	.0351	.0324	.0268	.0220	.0176	.0117	.0050
.050	.0575	.0535	.0506	.0487	.0471	.0454	.0436	.0420	.0402	.0368	.0292	.0226	.0168	.0092	
.060	.0650	.0605	.0570	.0550	.0531	.0510	.0489	.0470	.0448	.0404	.0305	.0220	.0147	.0053	
.070	.0710	.0665	.0627	.0605	.0584	.0560	.0537	.0514	.0487	.0432	.0308	.0201	.0114	.0001	
.080	.0765	.0710	.0677	.0655	.0630	.0603	.0578	.0550	.0521	.0455	.0301	.0172	.0070		
.090	.0820	.0765	.0722	.0696	.0670	.0640	.0613	.0581	.0549	.0471	.0287	.0135	.0018		
.100	.0860	.0810	.0762	.0734	.0705	.0672	.0642	.0606	.0570	.0482	.0264	.0089			
.120	.0940	.0880	.0826	.0790	.0758	.0720	.0683	.0640	.0596	.0483	.0195				
.140	.1000	.0935	.0872	.0829	.0792	.0750	.0 05	.0654	.0599	.0460	.0101				
.160	.1045	.0980	.0905	.0855	.0812	.076[illegible]	.0710	.0651	.0585	.0418					
.180	.1080	.1010	.0927	.0872	.0820	.0766	.0705	.0637	.0559	.0361					
.200	.1105	.1025	.0938	.0877	.0819	.0756	.0688	.0611	.0521	.0292					
.250	.1120	.1035	.0926	.0850	.0773	.0683	.0596	.0495	.0380	.0068					
.300	.1105	.1000	.0850	.0764	.0668	.0559	.0446	.0327	.0174						
.350	.1060	.0930	.0750	.0650	.0540	.0410	.0280	.0125							
.400	.0970	.0830	.0620	.0500	.0365	.0220	.0060								
.450	.0845	.0700	.0450	.0310	.0170	.000									
.500	.0700	.0520	.0250	.0100											
.550	.0520	.0320	.0020												
.600	.0320	.0080													
.650	.0090														
Y/H_s	X/H_s for portion of profile below weir crest														
0.000	0.668	0.615	0.554	0.520	0.487	0.450	0.413	0.376	0.334	0.262	0.158	0.116	0.093	0.070	0.048
-.020	.705	.652	.592	.560	.526	.488	.452	.414	.369	.293	.185	.145	.120	.096	.074
-.040	.742	.688	.627	.596	.563	.524	.487	.448	.400	.320	.212	.165	.140	.115	.088
-.060	.777	.720	.660	.630	.596	.557	.519	.478	.428	.342	.232	.182	.155	.129	.100
-.080	.808	.752	.692	.662	.628	.589	.549	.506	.454	.363	.250	.197	.169	.140	.110
-.100	.838	.784	.722	.692	.657	.618	.577	.532	.478	.381	.266	.210	.180	.150	.118
-.150	.913	.857	.793	.762	.725	.686	.641	.589	.531	.423	.299	.238	.204	.170	.132
-.200	.978	.925	.860	.826	.790	.745	.698	.640	.575	.459	.326	.260	.224	.184	.144
-.250	1.040	.985	.919	.883	.847	.801	.750	.683	.613	.490	.348	.280	.239	.196	.153
-.300	1.100	1.043	.976	.941	.900	.852	.797	.722	.648	.518	.368	.296	.251	.206	.160
-.400	1.207	1.150	1.079	1.041	1.000	.944	.880	.791	.706	.562	.400	.322	.271	.220	.168
-.500	1.308	1.246	1.172	1.131	1.087	1.027	.951	.849	.753	.598	.427	.342	.287	.232	.173
-.600	1.397	1.335	1.260	1.215	1.167	1.102	1.012	.898	.793	.627	.449	.359	.300	.240	.179
-.800	1.563	1.500	1.422	1.369	1.312	1.231	1.112	.974	.854	.673	.482	.384	.320	.253	.184
-1.000	1.713	1.646	1.564	1.508	1.440	1.337	1.189	1.030	.899	.710	.508	.402	.332	.260	.188
-1.200	1.846	1.780	1.691	1.635	1.553	1.422	1.248	1.074	.933	.739	.528	.417	.340	.266	
-1.400	1.970	1.903	1.808	1.748	1.653	1.492	1.293	1.108	.963	.760	.542	.423	.344		
-1.600	2.085	2.020	1.918	1.855	1.742	1.548	1.330	1.133	.988	.780	.553	.430			
-1.800	2.196	2.130	2.024	1.957	1.821	1.591	1.358	1.158	1.008	.797	.563	.433			
-2.000	2.302	2.234	2.126	2.053	1.891	1.630	1.381	1.180	1.025	.810	.572				
-2.500	2.557	2.475	2.354	2.266	2.027	1.701	1.430	1.221	1.059	.838	.588				
-3.000	2.778	2.700	2.559	2.428	2.119	1.748	1.468	1.252	1.086	.853					
-3.500	....	2.916	2.749	2.541	2.171	1.777	1.489	1.267	1.102						
-4.000	....	3.114	2.914	2.620	2.201	1.796	1.500	1.280							
-4.500	....	3.306	3.053	2.682	2.220	1.806	1.509								
-5.000	....	3.488	3.178	2.734	2.227	1.811									
-5.500	....	3.653	3.294	2.779	2.229										
-6.000	....	3.820	3.405	2.812	2.232										
H_s/R_s	0.00	0.10	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.80	1.00	1.20	1.50	2.00

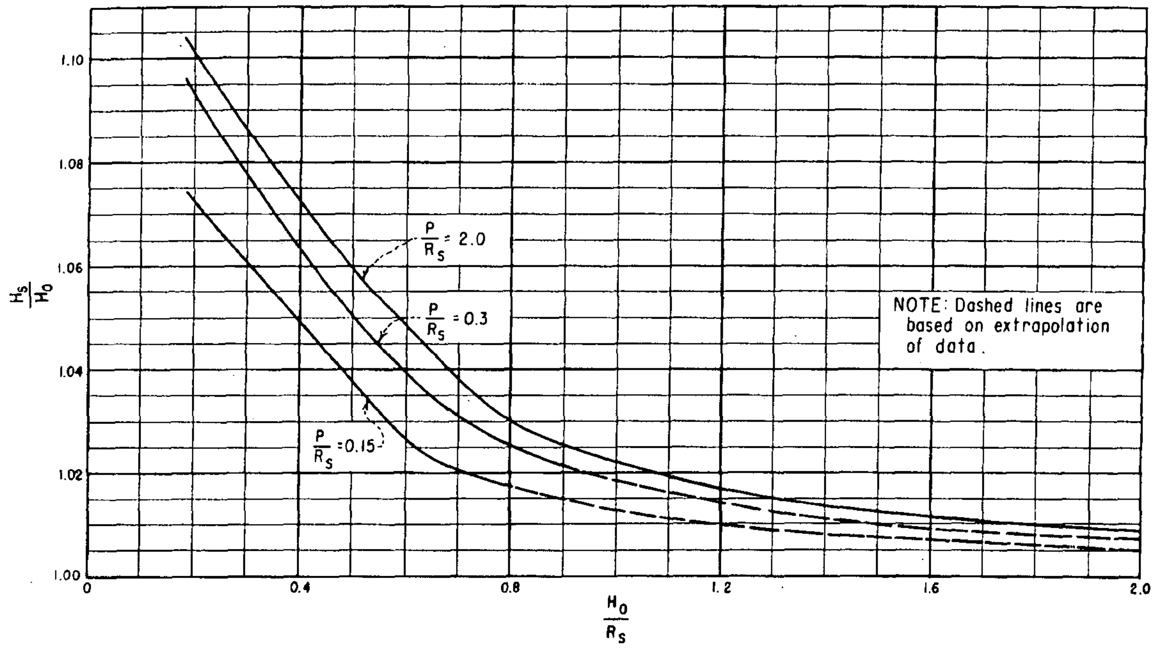
*The tabulation for H_s/R_s = 0.10 was obtained by interpolation between H_s/R_s = 0 and 0.20.

Table 9-6.—Coordinates of lower nappe surface for different values of H_s/R_s when P/R_s = 0.30.

H_s/R_s	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.80
X/H_s	Y/H_s for portion of profile above weir crest								
0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
.010	.0130	.0130	.0130	.0125	.0120	.0120	.0115	.0110	.0100
.020	.0245	.0242	.0240	.0235	.0225	.0210	.0195	.0180	.0170
.030	.0340	.0335	.0330	.0320	.0300	.0290	.0270	.0240	.0210
.040	.0415	.0411	.0390	.0380	.0365	.0350	.0320	.0285	.0240
.050	.0495	.0470	.0455	.0440	.0420	.0395	.0370	.0325	.0245
.060	.0560	.0530	.0505	.0490	.0460	.0440	.0405	.0350	.0250
.070	.0610	.0575	.0550	.0530	.0500	.0470	.0440	.0370	.0245
.080	.0660	.0620	.0590	.0565	.0530	.0500	.0460	.0385	.0235
.090	.0705	.0660	.0625	.0595	.0550	.0520	.0480	.0390	.0215
.100	.0740	.0690	.0660	.0620	.0575	.0540	.0500	.0395	.0190
.120	.0800	.0750	.0705	.0650	.0600	.0560	.0510	.0380	.0120
.140	.0840	.0790	.0735	.0670	.0615	.0560	.0515	.0355	.0020
.160	.0870	.0810	.0750	.0675	.0610	.0550	.0500	.0310	
.180	.0885	.0820	.0755	.0675	.0600	.0535	.0475	.0250	
.200	.0885	.0820	.0745	.0660	.0575	.0505	.0435	.0180	
.250	.0855	.0765	.0685	.0590	.0480	.0390	.0270		
.300	.0780	.0670	.0580	.0460	.0340	.0220	.0050		
.350	.0660	.0540	.0425	.0295	.0150				
.400	.0495	.0370	.0240	.0100					
.450	.0300	.0170	.0025						
.500	.0090	−.0060							
.550									
Y/H_s	X/H_s for portion of profile below weir crest								
−0.000	0.519	0.488	0.455	0.422	0.384	0.349	0.310	0.238	0.144
−.020	.560	.528	.495	.462	.423	.387	.345	.272	.174
−.040	.598	.566	.532	.498	.458	.420	.376	.300	.198
−.060	.632	.601	.567	.532	.491	.451	.406	.324	.220
−.080	.664	.634	.600	.564	.522	.480	.432	.348	.238
−.100	.693	.664	.631	.594	.552	.508	.456	.368	.254
−.150	.760	.734	.701	.661	.618	.569	.510	.412	.290
−.200	.831	.799	.763	.723	.677	.622	.558	.451	.317
−.250	.893	.860	.826	.781	.729	.667	.599	.483	.341
−.300	.953	.918	.880	.832	.779	.708	.634	.510	.362
−.400	1.060	1.024	.981	.932	.867	.780	.692	.556	.396
−.500	1.156	1.119	1.072	1.020	.938	.841	.745	.595	.424
−.600	1.242	1.203	1.153	1.098	1.000	.891	.780	.627	.446
−.800	1.403	1.359	1.301	1.227	1.101	.970	.845	.672	.478
−1.000	1.549	1.498	1.430	1.333	1.180	1.028	.892	.707	.504
−1.200	1.680	1.622	1.543	1.419	1.240	1.070	.930	.733	.524
−1.400	1.800	1.739	1.647	1.489	1.287	1.106	.959	.757	.540
−1.600	1.912	1.849	1.740	1.546	1.323	1.131	.983	.778	.551
−1.800	2.018	1.951	1.821	1.590	1.353	1.155	1.005	.797	.560
−2.000	2.120	2.049	1.892	1.627	1.380	1.175	1.022	.810	.569
−2.500	2.351	2.261	2.027	1.697	1.428	1.218	1.059	.837	
−3.000	2.557	2.423	2.113	1.747	1.464	1.247	1.081	.852	
−3.500	2.748	2.536	2.167	1.778	1.489	1.263	1.099		
−4.000	2.911	2.617	2.200	1.796	1.499	1.274			
−4.500	3.052	2.677	2.217	1.805	1.507				
−5.000	3.173	2.731	2.223	1.810					
−5.500	3.290	2.773	2.228						
−6.000	3.400	2.808							
H_s/R_s	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.80

Table 9-7.—Coordinates of lower nappe surface for different values of H_s/R_s when $P/R_s = 0.15$.

H_s/R_s	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.80
X/H_s	Y/H_s for portion of profile above weir crest								
0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
.010	.0120	.0120	.0115	.0115	.0110	.0110	.0105	.0100	.0090
.020	.0210	.0200	.0195	.0190	.0185	.0180	.0170	.0160	.0140
.030	.0285	.0270	.0265	.0260	.0250	.0235	.0225	.0200	.0165
.040	.0345	.0335	.0325	.0310	.0300	.0285	.0265	.0230	.0170
.050	.0405	.0385	.0375	.0360	.0345	.0320	.0300	.0250	.0170
.060	.0450	.0430	.0420	.0400	.0380	.0355	.0330	.0265	.0165
.070	.0495	.0470	.0455	.0430	.0410	.0380	.0350	.0270	.0150
.080	.0525	.0500	.0485	.0460	.0435	.0400	.0365	.0270	.0130
.090	.0560	.0530	.0510	.0480	.0455	.0420	.0370	.0265	.0100
.100	.0590	.0560	.0535	.0500	.0465	.0425	.0375	.0255	.0065
.120	.0630	.0600	.0570	.0520	.0480	.0435	.0365	.0220	
.140	.0660	.0620	.0585	.0525	.0475	.0425	.0345	.0175	
.160	.0670	.0635	.0590	.0520	.0460	.0400	.0305	.0110	
.180	.0675	.0635	.0580	.0500	.0435	.0365	.0260	.0040	
.200	.0670	.0625	.0560	.0465	.0395	.0320	.0200		
.250	.0615	.0560	.0470	.0360	.0265	.0160	.0015		
.300	.0520	.0440	.0330	.0210	.0100				
.350	.0380	.0285	.0165	.0030					
.400	.0210	.0090							
.450	.0015								
.500									
.550									
Y/H_s	X/H_s for portion of profile below weir crest								
−0.000	0.454	0.422	0.392	0.358	0.325	0.288	0.253	0.189	0.116
−.020	.499	.467	.437	.404	.369	.330	.292	.228	.149
−.040	.540	.509	.478	.444	.407	.368	.328	.259	.174
−.060	.579	.547	.516	.482	.443	.402	.358	.286	.195
−.080	.615	.583	.550	.516	.476	.434	.386	.310	.213
−.100	.650	.616	.584	.547	.506	.462	.412	.331	.228
−.150	.726	.691	.660	.620	.577	.526	.468	.376	.263
−.200	.795	.760	.729	.685	.639	.580	.516	.413	.293
−.250	.862	.827	.790	.743	.692	.627	.557	.445	.319
−.300	.922	.883	.843	.797	.741	.671	.594	.474	.342
−.400	1.029	.988	.947	.893	.828	.749	.656	.523	.381
−.500	1.128	1.086	1.040	.980	.902	.816	.710	.567	.413
−.600	1.220	1.177	1.129	1.061	.967	.869	.753	.601	.439
−.800	1.380	1.337	1.285	1.202	1.080	.953	.827	.655	.473
−1.000	1.525	1.481	1.420	1.317	1.164	1.014	.878	.696	.498
−1.200	1.659	1.610	1.537	1.411	1.228	1.059	.917	.725	.517
−1.400	1.780	1.731	1.639	1.480	1.276	1.096	.949	.750	.531
−1.600	1.897	1.843	1.729	1.533	1.316	1.123	.973	.770	.544
−1.800	2.003	1.947	1.809	1.580	1.347	1.147	.997	.787	.553
−2.000	2.104	2.042	1.879	1.619	1.372	1.167	1.013	.801	.560
−2.500	2.340	2.251	2.017	1.690	1.423	1.210	1.049	.827	
−3.000	2.550	2.414	2.105	1.738	1.457	1.240	1.073	.840	
−3.500	2.740	2.530	2.153	1.768	1.475	1.252	1.088		
−4.000	2.904	2.609	2.180	1.780	1.487	1.263			
−4.500	3.048	2.671	2.198	1.790	1.491				
−5.000	3.169	2.727	2.207	1.793					
−5.500	3.286	2.769	2.210						
−6.000	3.396	2.800							
H_s/R_s	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.80



NOTE: Dashed lines are based on extrapolation of data.

Figure 9-59.—Relationship of H_s/H_o to H_o/R_s for circular sharp-crested weirs. 288–D–2443.

its use for determining the shape of the shaft will result in the minimum size that will accommodate the flow without restrictions and without developing pressures along the side of the shaft.

A typical shaft profile obtained by equation (29) is shown by the lines designated *abc* on figure 9-63. If the shaft profile, *abc*, is enlarged above selected points *b*, as shown by the dashed lines *db*, the flow at section A-A will be under pressure; below section A-A the free jet profile should follow lines *bc*.

Aeration is required at the control either through the introduction of air into a sudden enlargement of the shaft or the installation of a deflector to ensure free flow below the control section A-A. Elbows and passageway sizes and slopes must be such that free flow is maintained below the point of control. Failure to provide adquate aeration at the point of control could introduce cavitation and make-and-break siphonic action that could cause severe vibration. For a profile (e.g., *abe*) established for a specific head, the control must remain at section A-A for any higher head so that above the section pressure flow will prevail. The flow below section A-A must be kept free flow. If the profile *dbe* is adopted, once a head is reached to make the shaft flow full at point *b*, section A-A will be the point of control, and pressure flow above the control will prevail for that and all greater heads.

For submerged crest flow, the corresponding nappe shape, as determined from section 9.26(c), for design head H_o will be such that along its lower levels it will closely follow the profile determined from equation (29) if H_e approximates H_o. It must be remembered that on the basis of the losses assumed in equation (29), profile *abc* will be the minimum shaft size that will accommodate the required flow and that no part of the crest shape should be permitted to project inside this profile. As noted in section 9.14, small subatmospheric crest pressures can be tolerated if proper precautions are taken to obtain a smooth surface and if the negative pressure forces are recognized in the structural design. The choice of the minimum crest and transition shapes rather than wider shapes, then becomes a matter of economics, structural arrangement, and layout adaptability.

Where the transition profile corresponds to the continuation of the crest shape as determined by tables 9-5, 9-6, and 9-7, the discharge can be computed from equation (28) using a coefficient from figure 9-57. Where the transition profile differs

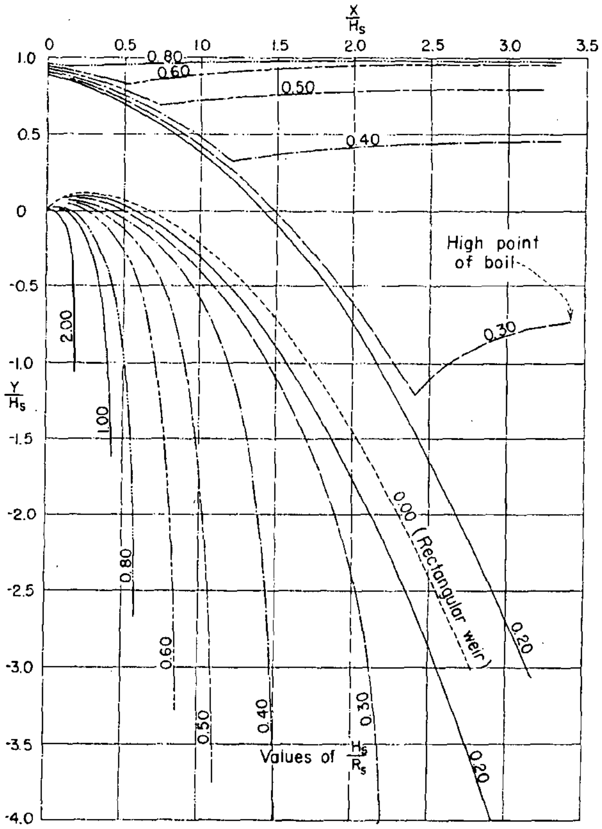


Figure 9-60.—Upper and lower nappe profiles for circular weir (aerated nappe and negligible approach velocity). 288-D-2444.

from the crest shape profile so that a constricted control section is established, the discharge must be determined from equation (29). On figure 9-55, the discharge-head relationship curve *ag* can then be computed from the coefficients determined from figure 9-58, while the discharge-head relationship curve *gh* will be based on equation (29).

(e) *Conduit Design.*—If, for a designated discharge, the conduit of a drop inlet spillway were to flow full below the transition without being under pressure, the required size of the shaft and outlet leg would vary according to the available net head along its length. So long as the slope of the hydraulic gradient that is dictated by the hydraulic losses is flatter than the slope of the conduit, the flow will accelerate and the required size of conduit will decrease. When the conduit slope is flatter than the slope of the hydraulic gradient, the flow will decelerate and the required size of conduit will increase. All points along the conduit will act simultaneously to control the rate of flow. For heads greater than that used to size it, the conduit will flow under pressure with the control at the downstream end; for heads less than that used to size it, the conduit will flow partly full for its entire length, and the control will remain in the transition upstream. On figure 9-55, the head at which the conduit just flows full is represented by point *h*. At heads above point *h*, the conduit flows full under pressure; at heads less than *h* the conduit flows partly full with controlling conditions dictated by the transition design.

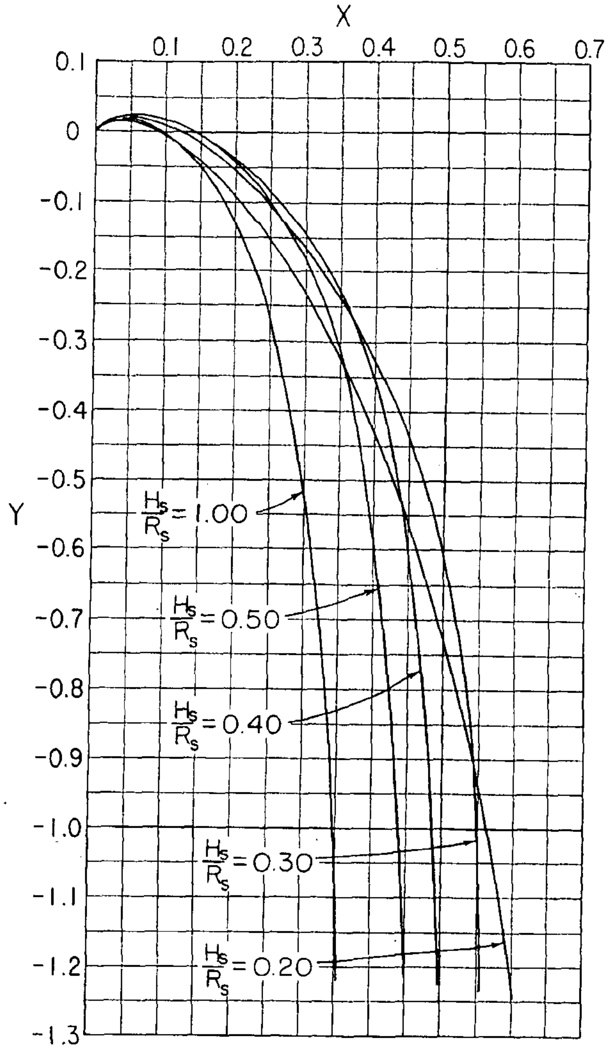


Figure 9-61.—Comparison of lower nappe shapes for circular weir for different heads. 288-D-2445.

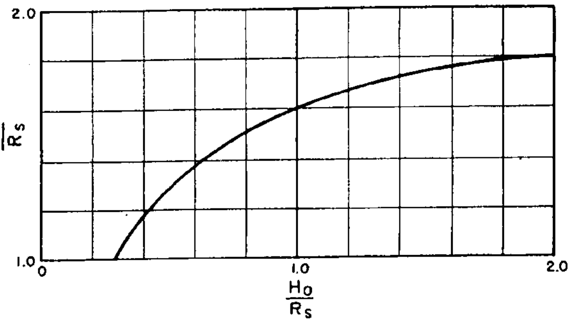


Figure 9-62.—Increased circular crest radius needed to minimize subatmospheric pressure along crest. 288-D-2446.

Because it is impractical to build a conduit with a varying diameter, it's size is ordinarily constant beyond the inlet transition. Thus, the conduit from the control point in the transition to the downstream end will have an excess of area. If atmospheric pressure can be maintained along the portion of the conduit flowing partly full, it will continue to flow at that stage even though the downstream end fills. Progressively greater discharges will not alter the partly full flow in the upper lengths of the conduit, but full-flow conditions under pressure will occupy increasing lengths of the downstream end of the conduit. At the discharge represented by point *h* on figure 9-55, the full flow condition has moved back to the transition control section and the conduit will flow full for its entire length.

If the conduit flows at such a stage that the downstream end flows full, both the inlet and outlet will be sealed. To forestall siphon action by the withdrawal of air from the conduit would require an adequate venting system. Unless venting is effected over the entire length of conduit, it may prove inadequate to prevent subatmospheric pressures along some portion of the length because of the possibility of sealing at any point by surging, wave action, or eddy turbulences. Thus, if no venting is provided or if the venting is inadequate, a make-and-break siphon action will attend the flow in the range of discharges approaching full-flow conditions. This action is accompanied by erratic discharges, by thumping and vibration, and by surges at the entrance and outlet of the spillway.

To avoid siphonic flow conditions, the size of the downstream conduit for ordinary designs (especially for those handling higher heads) should be chosen so that it will never flow full beyond the inlet transition. To allow for air bulking, surging, etc., the conduit size should ordinarily be selected so that it will not flow more than 75 percent full (in area) at the downstream end at maximum discharge. Under this limitation, air will be able to pass up the conduit from the downstream portal and thus prevent the formation of subatmospheric pressure along the conduit length. Care must be taken, however, in selecting the vertical and horizontal curvatures of the conduit profile and alignment to prevent sealing along some portion by surging or wave action.

(f) *Design Example.*—The following example problem illustrates the procedure for designing a morning glory drop inlet spillway: Design an ungated drop inlet spillway that will operate under a maximum surcharge head of 10 feet, but will limit the outflow to 2,000 ft^3/s. Determine alternative overflow crest shapes and discharge head relationships, considering that (1) the overflow crest radius must be minimized because the intake is formed as a tower away from the abutment, and subatmospheric pressures along the crest can be tolerated; and (2) the crest radius may be any size because it is located on a knoll at the abutment, and subatmospheric pressures along the crest should be minimized. In both cases the conduit must not flow more than 75 percent full at the downstream end. The controlling dimensions are shown on figure 9-64.

(1) *Case 1.*—The radius of the overflow crest must be minimized, and subatmospheric pressures may be tolerated:

Assume $P/R_s \geq 2$ (see fig. 9-57). R_s is determined by a trial-and-error procedure of assuming values of R_s and computing the discharge.

Assume R_s = 7.0 feet; then H_0/R_s = 10/7 = 1.43. For H_0/R_s = 1.43 and $P/R_s \geq 2$, from figure 9-57, C_0 = 1.44. Then, $Q = C_0(2\pi R_s)H_0^{3/2}$ = $1.44(2\pi)(7.0)10^{3/2}$ = 2,010 ft^3/s, which is approximately the required discharge. From figure 9-59, for H_0/R_s = 1.43 and $P/R_s \geq 2$, H_s/H_0 = 1.014, H_s = 1.014 H_0, and H_s = 1.014(10) = 10.14 feet. Then, H_s/R_s = 10.14/7.0 = 1.45.

Using table 9-5, points on the profile of the crest shape that conforms to the lower nappe surface for H_s/R_s = 1.45 are computed by interpolation. These points are then plotted as shown on figure 9-65.

The next step is to determine the transition shape required to pass 2,000 ft^3/s with an H_0 of 10 feet above the crest (water surface elevation 110.0).

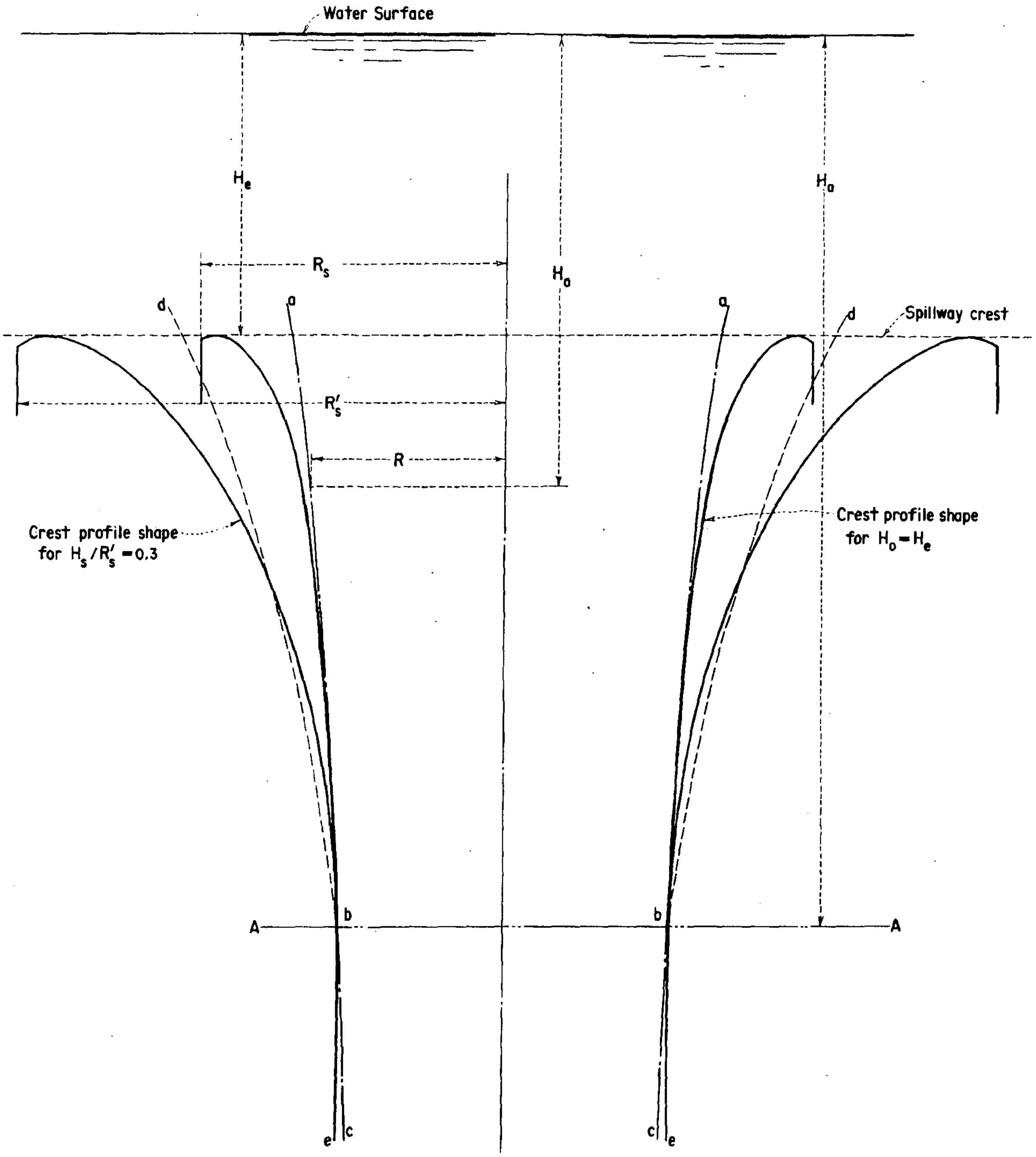


Figure 9-63.—Comparison of drop inlet profiles for various flow conditions. 288–D–2447.

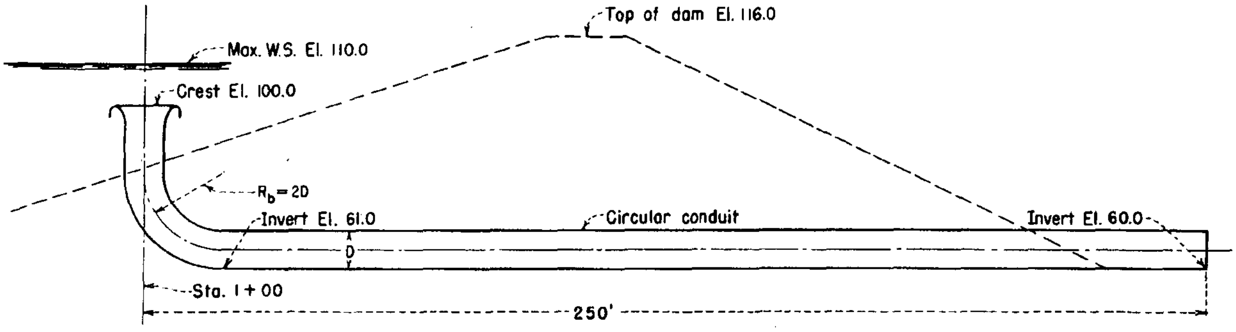


Figure 9-64.—Drop inlet spillway profile. For design example in section 9.26(f). 228–D–2448.

This shape is determined by the use of equation (29):

$$R = 0.204\frac{Q_a^{1/2}}{H_a^{1/4}} = 0.204\frac{(2{,}000)^{1/2}}{H_a^{1/4}} = \frac{9.12}{H_a}$$

Points on the transition are computed as shown in the following table and are plotted on the same graph on which points for the crest shape have already been plotted (fig. 9-65).

Elevation of section	H_a	$H_a^{1/4}$	$R=\frac{9.12}{H_a^{1/4}}$
100	10	1.78	5.13
98	12	1.86	4.90
96	14	1.93	4.72
94	16	2.00	4.56
92	18	2.06	4.43
88	22	2.17	4.20

A smooth curve should be drawn through the controlling points on the crest and transition shapes to determine the final shape of the crest and transition.

The final step is to determine the minimum uniform conduit diameter that will pass the flow from the transition section to the conduit portal without the conduit flowing more than 75 percent full. The procedure is as follows: (1) Select a trial conduit and throat diameter and find the corresponding throat location, (2) compute the length from transition throat to outlet portal, (3) approximate the friction losses in the conduit by assuming the conduit flows three-fourths full for its entire length, and (4) check the elevation of the invert at the outlet portal required to pass the design discharge through the selected size conduit. After an approximate conduit size has been determined in this manner, it should be checked by computing the water surface profile through the conduit by open channel flow computations.

For this problem assume a conduit diameter of 9.0 feet. From figure 9-65, a radius of 4.5 feet is found to be at 6.9 feet below the crest; therefore, the elevation of the 9.0-foot-diameter throat is 93.1. The tunnel length may be scaled or calculated by approximate methods. In this example the approximate tunnel length is 270 feet.

Assuming that the conduit flows 75 percent full, area = $0.75\pi(4.5^2)$ = 47.7 ft², velocity = 2,000/47.7 = 41.9 ft/s, and $h_v = 41.9^2/64.4 = 27.3$ feet.

From table B-3, for 75 percent full flow, d/D = 0.702, and the hydraulic radius $r = 0.2964(9.0) = 2.67$.

Using a value of $n = 0.014$ to maximize the losses, by Manning's equation (equation (30), app. B):

$$s = \left(\frac{vn}{1.486r^{2/3}}\right)^2 = \left[\frac{(41.9)\ (.014)}{(1.486)\ (2.67)^{2/3}}\right]^2 = 0.04$$

and $h_f = 0.04(270) = 10.8$ feet.

The invert elevation at the downstream portal of the conduit will then be equal to (1) the elevation of the throat, plus (2) the velocity head at the throat, minus (3) the velocity head in the conduit flowing 75 percent full, minus (4) the friction losses in the conduit, minus (5) the depth of flow at the downstream portal. The required portal invert elevation for this trial conduit diameter is approximately $93.1 + (1/1.1)(110.0 - 93.1) - 27.3 - 10.8 - 0.702(9.0) = 64.1$.

Although this elevation is somewhat higher than the established portal invert elevation, 60.0, actual losses through the conduit will be larger than those

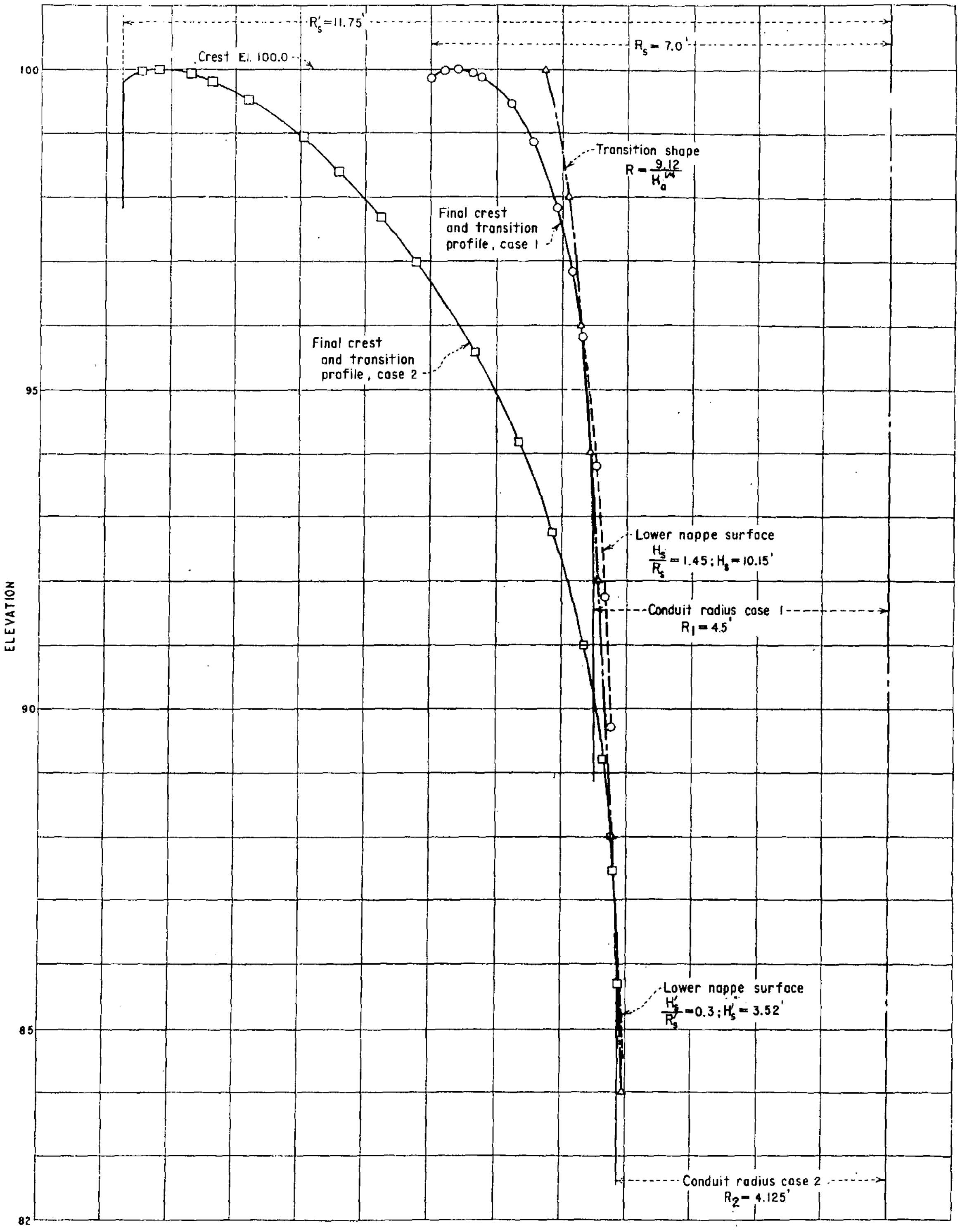


Figure 9-65.—Drop inlet crest, transition, and conduit plottings. For design example in section 9.26(f). 288–D–2515.

estimated because the conduit will flow 75 percent full throughout its length.

Therefore, the 9.0-foot-diameter conduit appears to be, for all practical purposes, the minimum uniform diameter conduit that will meet the requirements of the problem. Computations of the water surface profile through the 9.0-foot-diameter conduit, shown in table 9-8, are then performed to verify the approximate solution given above. These computations are based on Bernoulli's theorem (eq. (32), app. B).

Discharge-head computations for this design are shown in table 9-9. For the lower range of heads, the coefficient relationships of various H_e/R_s values are obtained from figure 9-58, assuming a coefficient of 3.75 for $H_e/R_s = 0.3$. For the higher ranges of head, the discharges can be obtained from equation (29) using a throat radius of 4.50 at elevation 93.1. Smooth curves are then plotted for both head range computations. The intersection of the curves is replaced by an approximate transition curve to more nearly represent actual conditions. The discharge curve is plotted on figure 9-66. The computations show that the conduit will be only 76 percent full at the downstream end; therefore, the design is satisfactory.

(2) *Case 2.*—The radius of the overflow crest may be any size, and subatmospheric pressures along crest must be minimized:

First, determine the minimum crest radius for the given: $H_o = 10$ feet, and $Q = 2{,}000$ ft³/s for case 1. Assume $P/R_s = 0.15$ and, as in case 1, determine R_s by trial and error.

Assuming $R_s = 7.0$ feet, $H_o/R_s = 10/7 = 1.43$. For $H_o/R_s = 1.43$ and $P/R_s = 0.15$ from figure 9-57, $C_o = 1.55$. Then, $Q = C_o(2\pi R_s)H_o^{3/2} = 1.55(2\pi)7.0(10)^{3/2} = 2{,}155$ ft³/s. Since a 2,000-ft³/s discharge is required, the assumed value of R_s is too large.

Assuming $R_s = 6.7$ feet, $H_o/R_s = 10/6.7 = 1.49$. From figure 9-57, $C_o = 1.49$ and $Q = 1{,}985$ ft³/s, which is approximately the required discharge.

Using $H_o/R_s = 1.49$, enter figure 9-62 and find the approximate increased crest radius required to minimize subatmospheric pressures. For $H_o/R_s = 1.49$, $R_s'/R_s = 1.74$ and $R_s' = 1.74(6.7) = 11.7$ feet; use 11.75 feet. Points on the profile of the crest shape that conform to the lower nappe surface for $H_s'/R_s' = 0.30$ and $R_s' = 11.75$ are computed using values from table 9-7 and are plotted as shown on figure 9-65.

Computations for the required transition shape to pass 2,000 ft³/s with a head of 10 feet on the crest are identical to those given in case 1. Figure 9-65 shows the plotted points and the crest and transition curves.

From an inspection of the transition and crest shape plots for case 2, it can be seen that the conduit diameter for case 1 is too large for case 2. If the 9.0-foot-diameter conduit used in case 1 were used in case 2, a smooth transition connecting the crest and conduit would be considerably outside the transition shape determined by equation (29). This means that for a head of 10 feet on the crest, the discharge would not longer be limited to 2,000 ft³/s by the transition, but would increase because of the larger size transition. This discharge would require a larger uniform diameter conduit to pass the discharge and not flow more than 75 percent full. A still larger uniform diameter conduit with a still larger maximum discharge would finally be required for a satisfactory hydraulic design. However, a smaller uniform diameter conduit would flow more

Table 9-8.—Water surface profile computations for case 1. Conduit diameter = 9.0 feet; $Q = 2000$ ft³/s, $n = 0.014$.

Station	ΔL	Trial d/D	d	a	v	h_v	r	$r^{2/3}$	s	$\frac{s_1+s_2}{2}$	Δh_L	$\Sigma\Delta h_L$	$d_2+h_{v_2}$ $+\Sigma\Delta h_L$	Invert elevation	Datum gradient	Remarks
1+00	-	1.00	-	63.6	31.4	15.3	2.25	1.72	0.030	-	-	-	-	93.1	108.4	-
1+19	39	0.56	5.04	36.66	54.6	46.2	2.41	1.80	.081	0.056	2.2	2.2	53.4	61.0	114.4	Too high
		.59	5.37	39.06	51.2	40.7	2.48	1.83	.069	.049	1.9	1.9	47.9	-	108.9	OK
2+30	111	.63	5.67	42.2	47.4	34.8	2.54	1.86	.057	.063	7.0	8.9	49.4	60.5	109.9	Too high
		.64	5.76	42.99	46.5	33.6	2.58	1.88	.054	.062	6.8	8.7	48.0	-	108.5	OK
3+50	120	.72	6.48	49.04	40.8	25.8	2.69	1.93	.039	.047	5.6	14.3	45.7	60.0	105.7	Too low
		.70	6.30	47.56	42.0	27.5	2.67	1.92	.042	.048	5.8	14.5	48.3	-	108.3	OK

Table 9-9.—Computations for discharge curve for case 1, R_s=7.0 feet.

Head on crest, feet	Crest control			Throat control	
	$\frac{H_e}{R_s}$	[1]C	$Q = C(2\pi R_s)H_e^{3/2}$	H_a	$Q_a = \left(\frac{R}{0.204}\right)^2 H_a^{1/2}$
1	0.14	3.56	157	-	-
2	.29	3.75	467	-	-
3	.43	3.58	820	-	-
4	-	-	-	10.9	1,600
6	-	-	-	12.9	1,750
8	-	-	-	14.9	1,880
10	-	-	-	16.9	2,000

[1] Coefficient of 3.75 assumed for H_e/R_s=0.3 (from fig. 9.57). Coefficients for H_e/R_s values other than 0.3 based on ratios shown on figure 9-58.

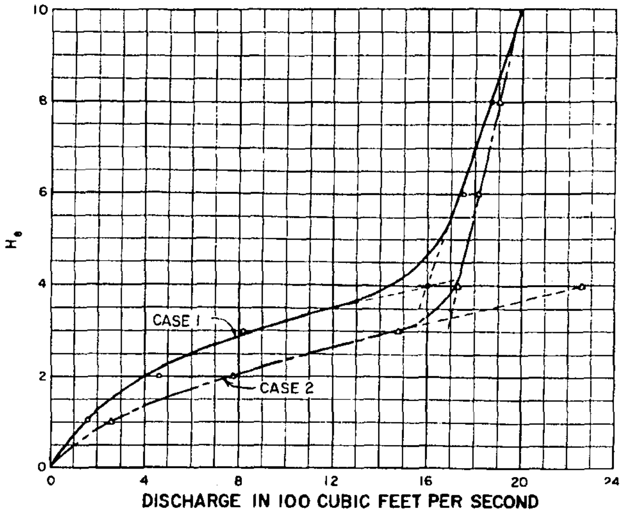


Figure 9-66.—Drop inlet spillway discharge curves. For design example in section 9.26(f). 288-D-2516.

than 75 percent full at the downstream end.

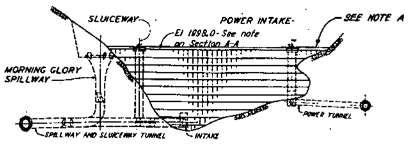
The simplest solution to this problem is to vary the diameter of the conduit. An upstream diameter should be chosen based on the crest profile and transition where they converge. This procedure establishes the throat size necessary to limit the maximum discharge to 2,000 ft³/s. At some suitable location downstream from the throat, the conduit should be enlarged to prevent it from flowing more than 75 percent full. The location of this enlargement should be determined by economic or construction considerations to meet hydraulic requirements.

For this problem, an 8.25-foot-diameter conduit with its throat at elevation 86.0 is selected. It will be assumed that the most economical design is obtained by extending this conduit to the point where it flows 75 percent full. At this point the conduit is enlarged to the diameter needed to make it flow 75 percent full at the downstream portal. To determine the point at which the tunnel must be enlarged, water surface profiles are run downstream by the step method, as shown in table 9-10. A bend radius of 16.5 feet (2*D*) is used. The table shows that the conduit must increase in size starting at the P.T. (point of tangency) of the vertical bend, station 1+16.5. The size of the downstream conduit may be approximated by assuming a given size conduit flowing 75 percent full at the downstream portal and using the distance from the point of enlargement to the portal as one reach in the water surface profile computations. Although this method results in losses slightly larger than would be obtained by using shorter reaches, it is accurate enough to determine conduit size if the length of the conduit downstream from the expansion is not excessively long. Use of shorter steps and an assumed minimum value of *n* would be required to determine the depth and velocity at the downstream portal for use in designing an energy dissipator. The transition from the smaller to the larger diameter conduit should be proportioned as explained in section 9.19(b).

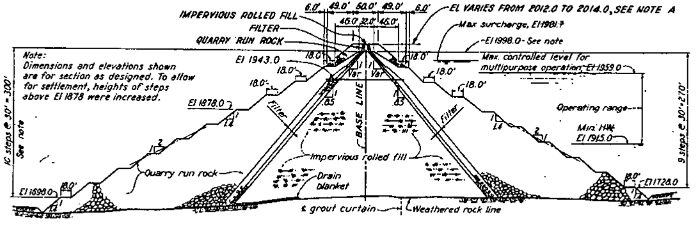
Discharge-head relationships for this case are computed similarly to those for case 1. The throat radius in this instance is 4.13 feet at elevation 86.0. Computations are shown in table 9-11, and the discharge curve is plotted on figure 9-66.

9.27. Culvert Spillways.—(a) *General.*—As described in section 9.8(j), a culvert spillway ordinarily consists of a simple culvert conduit placed through a dam or along an abutment, generally on a uniform grade, with its entrance placed vertically or inclined. The culvert cross section can be round if it is constructed of fabricated or precast pipe, or it may be square, rectangular, or of some other shape if cast in place. The culvert can freely discharge, or it can empty into an open channel so that the outflowing jet is supported along the channel floor.

The factors that combine to determine the nature of flow in a culvert spillway include such variables as the slope, size, shape, length, and roughness of the conduit barrel, and the inlet and outlet geometry. The combined effect of these factors determines the location of the control which, 22 C 4 10N200

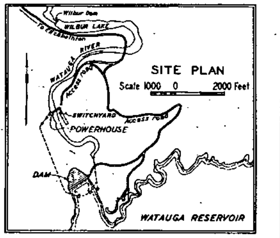


DOWNSTREAM ELEVATION

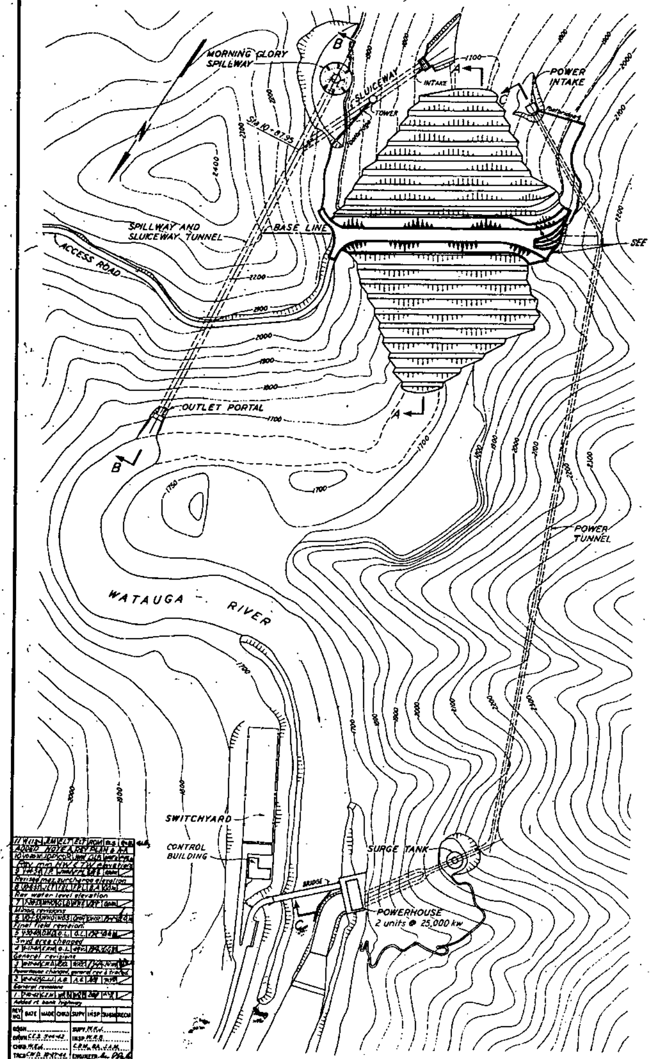


Note:
Dimensions and elevations shown are for section as designed. To allow for settlement, heights of steps above El 1878 were increased.

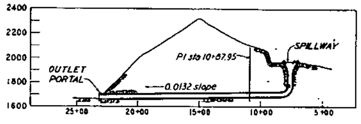
SECTION A-A



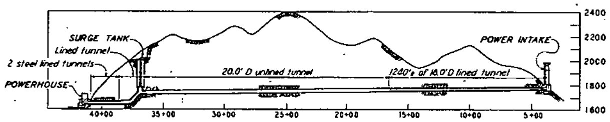
SITE PLAN



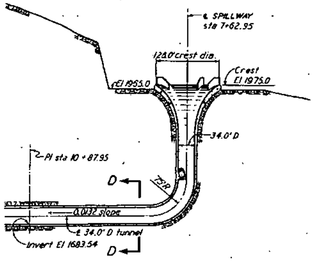
PLAN



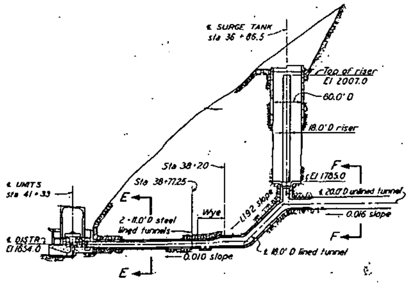
SECTION B-B



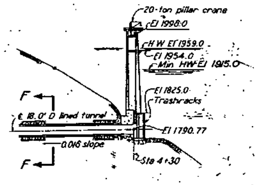
SECTION C-C



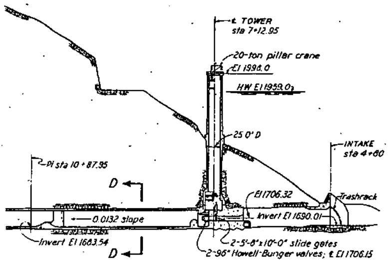
SECTION THRU SPILLWAY



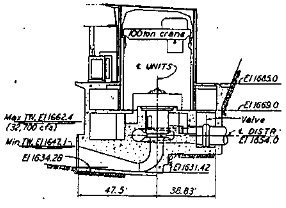
SECTION THRU POWERHOUSE & SURGE TANK



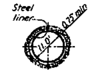
SECTION THRU POWER INTAKE



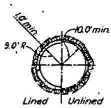
SECTION THRU SLUICEWAY



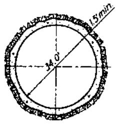
SECTION THRU UNIT



SECTION E-E



SECTION F-F



SECTION D-D

NOTE A:
FOR MODIFICATIONS TO DAM, SEE RAISING TOP OF DAM, PLAN, SECTIONS & DETAILS, DWG 21E210.

Scale 200 0 200 400 Feet
PLAN & DOWNSTREAM ELEVATION

Scale 30 0 30 60 Feet
SECTION THRU UNIT

Scale 20 0 20 40 Feet
SECTIONS D-D, E-E, & F-F

Scale 400 0 400 800 Feet
SECTIONS B-B & C-C

Scale 100 0 100 200 Feet
SECT. A-A, SECTS THRU: SPLWY, POWER INTAKE, PH & SURGE TANK, & SLUICEWAY

REV NO	DATE	MADE	CHKD	SUPV	INSP	SUBM	RECM
11	[illegible]	JM	ELT	ELT	RDM	[illegible]	[illegible]
ADDED NOTE A, REV PLAN & A-A							
10	[illegible]	JDD	COR	[illegible]	GLB	[illegible]	[illegible]
Rev. min. HW & TW elevations							
9	[illegible]	I.P.	[illegible]	[illegible]	[illegible]		
Revised max. surcharge elevation							
8	[illegible]	JLT	TRL	TRL	R.A.	[illegible]	
Rev. water level elevation							
7	[illegible]	WHO	GLB	WRE	WEP	[illegible]	
Minor revisions							
6	[illegible]	WHO	WDS	OHR	OHR	[illegible]	
Final field revision							
5	[illegible]	DMO	O.L.	O.L.	[illegible]	[illegible]	
Swyd area changed							
4	9-17-47	E.M.	O.L.	[illegible]	[illegible]	[illegible]	
General revisions							
3	[illegible]	C.R.D.	[illegible]	[illegible]	[illegible]	[illegible]	
Powerhouse changed, general rev & traced							
2	[illegible]	C.J.J.	A.B.	A.B.	[illegible]	[illegible]	
General revisions							
1	7-10-42	C.E.M.	[illegible]	[illegible]	[illegible]	[illegible]	
Added rt. bank highway							

DSGN.
DRWN C.E.B. 5-4-42
CHKD W.E.J.
TRCD C.W.D. [illegible]
COMP.
SUPV W.E.J.
INSP W.R.B.
C.R.M., R.A., J.A.M.
ENGINEER [illegible]
G. O. May [illegible]

HSM

① J.A.M.
② J.A.M., W.R.B.

PROJECT MANAGER James B. [illegible]

DAM, CONDUIT & POWERHOUSE

GENERAL PLAN, ELEVATION & SECTIONS

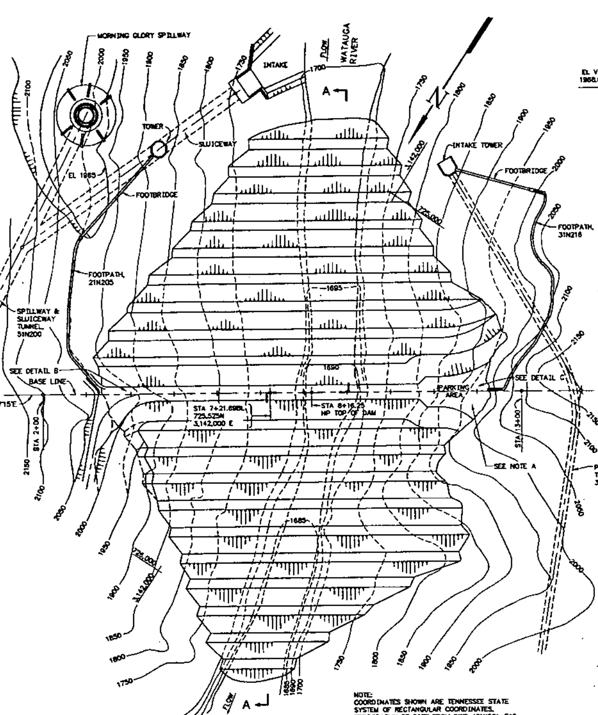
WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
M. L. Dickinson KSH	George K. Reid	T. B. Parker

KNOXVILLE	6-5-42	22	C	4	10N200 R11

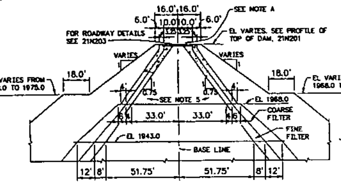
RECORD DRAWING AS CONSTRUCTED
W. V. [illegible]

Box 407



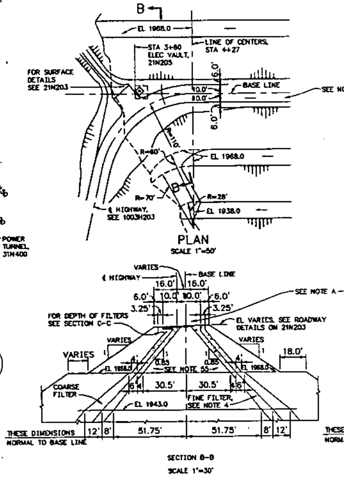
PLAN

NOTE:
COORDINATES SHOWN ARE TENNESSEE STATE SYSTEM OF RECTANGULAR COORDINATES.
TOPOGRAPHY OF SITE FROM DWG 461K501-E10

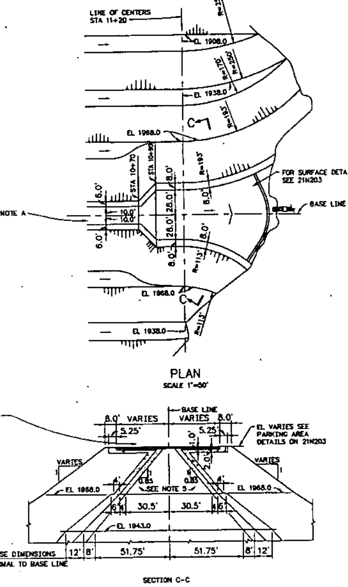


DETAIL A

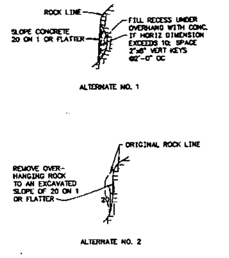
SCALE 1"=30'



DETAIL B



DETAIL C

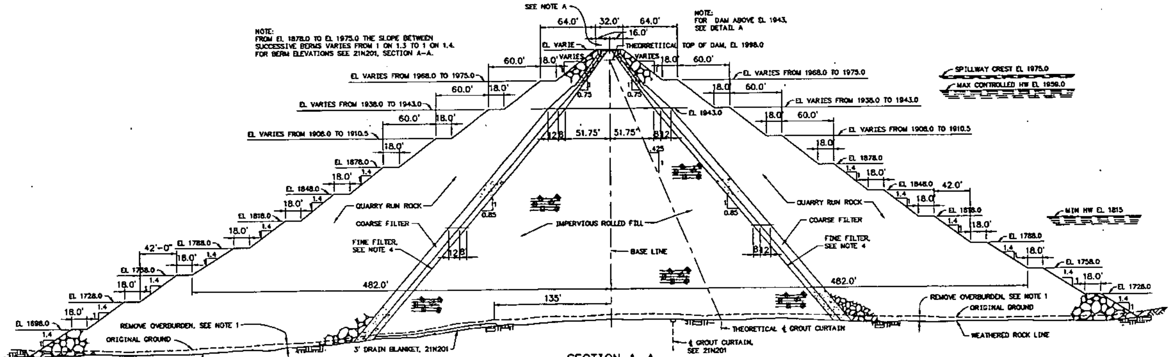


DETAIL D

SEE NOTE 2

NOT TO SCALE

NOTE:
FROM EL 1878.0 TO EL 1975.0 THE SLOPE BETWEEN SUCCESSIVE BERMS VARIES FROM 1 ON 1.3 TO 1 ON 1.4.
FOR BERM ELEVATIONS SEE 21N201, SECTION A-A.



SECTION A-A

SCALE 1"=50'

COMPANION DRAWING: 21N201

NOTE A:
FOR MODIFICATIONS TO DAM, SEE RAISING TOP OF DAM, PLAN, SECTIONS & DETAILS, DWG 21E210.

DESIGN DATA:

EARTH FILL:
SATURATED WEIGHT-125 POUNDS PER CUBIC FOOT.
ANGLE OF INTERNAL FRICTION-30 DEGREES.
COHESION-NONE.

ROCK FILL:
WEIGHT IN PLACE-120 POUNDS PER CUBIC FOOT.
ANGLE OF INTERNAL FRICTION-45 DEGREES.

SAFETY FACTOR OBTAINED:
1.7 FOR MAXIMUM SECTION.

NOTES:

1. OVERBURDEN SHALL BE REMOVED OVER THE ENTIRE BASE AREA TO PROVIDE FOUNDATION ON WEATHERED ROCK. EXCEPTIONS MAY BE MADE IN THE DOWNSTREAM HALF OF THE ROLLED FILL AREA, WHERE TALUS ACCUMULATIONS MAY BE LEFT IN PLACE.
2. WHERE OVERHANGING ROCK IS ENCOUNTERED WITHIN THE IMPERVIOUS ROLLED FILL CORE UPSTREAM FROM THE BASE LINE, CONSTRUCTION SHALL BE AS SHOWN IN DETAIL D, ALTERNATE NO. 1 OR ALTERNATE NO. 2
3. SANDY CLAY MAY BE PLACED IN THE DOWNSTREAM QUARTER OF THE IMPERVIOUS ROLLED FILL CORE, BUT EACH SUCH LAYER SHALL EXTEND TO THE DOWNSTREAM FILTER.
4. FILTER MATERIAL SHALL CONFORM TO THE FOLLOWING REQUIREMENTS: THE "15 PERCENT SIZE" OF FILTER SHALL BE LARGER THAN 5 TIMES THE "15 PERCENT SIZE" AND SMALLER THAN 5 TIMES THE "85 PERCENT SIZE" OF THE ADJACENT FINER ZONE.
5. THE CONTROL SLOPE ON THE CORE ABOVE EL 1943 SHALL BE AS FOLLOWS:
RIGHT ABUTMENT TO STA 4+27, CONSTANT AT 1 ON 0.85;
STA 4+27 TO STA 7+20, VARYING FROM 1 ON 0.85 TO 1 ON 0.75;
STA 7+20 TO STA 9+20, CONSTANT AT 1 ON 0.75;
STA 9+20 TO STA 11+70, VARYING FROM 1 ON 0.75 TO 1 ON 0.85;
STA 11+70 TO LEFT ABUTMENT, CONSTANT AT 1 ON 0.85;

THICKNESS OF FILTERS ABOVE EL 1968 SHALL BE UNIFORM. TOP SHALL BE ADJUSTED AS INDICATED TO MEET ROADWAY DETAILS.

R
R12 9/27/01 GBK JHP GBK VAN VAN OTN OTN
ELECTRONICALLY RESTORED

SCALE: 1"=100' EXCEPT AS NOTED

MAIN EMBANKMENT

PLAN & SECTIONS
SHEET 1

	T.J.S.	F.D.J.	R.R.L.			

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R00 | 4-29-42 | 22 | C | 21W200 | R 12

22 C 21W200

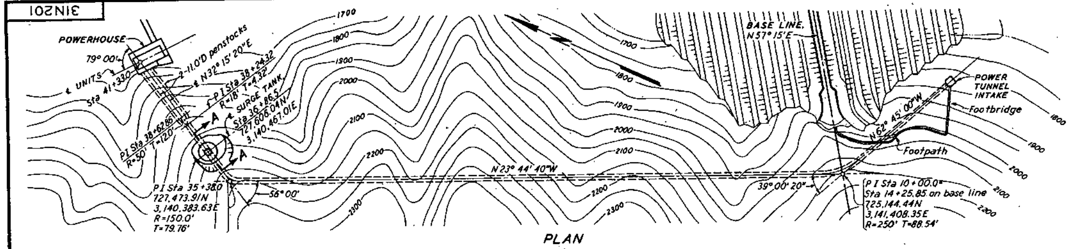
TASK COMPLETED BY: | REV NO.

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES :(21N200 R11)

PLOT FACTOR:1200
W_TVA

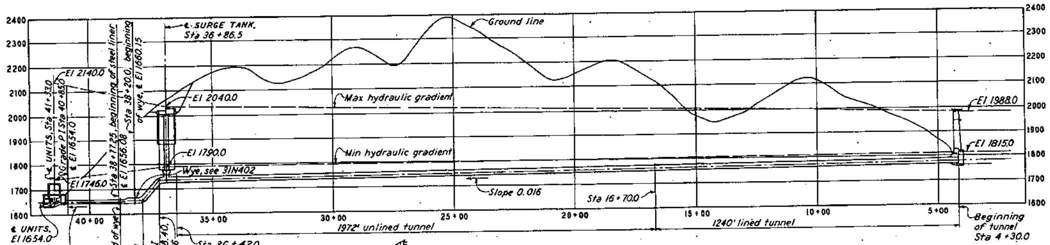
C.A.D. DRAWING
DO NOT ALTER MANUALLY

31N201



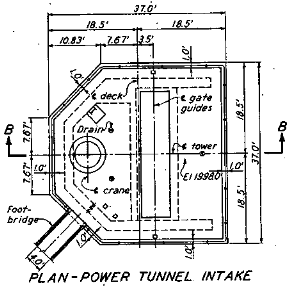
PLAN

Scale 1"=200'

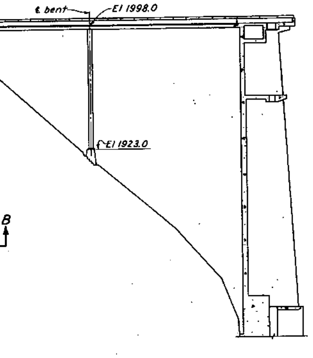


PROFILE

Scale 1"=200'

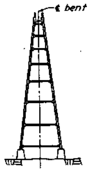


PLAN-POWER TUNNEL INTAKE



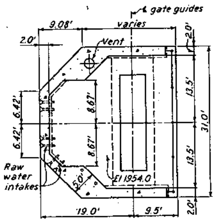
SECTION ON ℄ FOOTBRIDGE

Scale 1"=30'

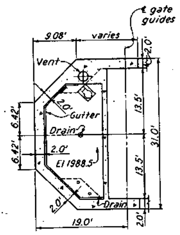


ELEVATION-BENT

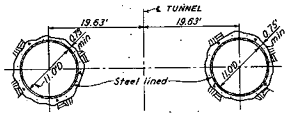
Scale 1"=30'



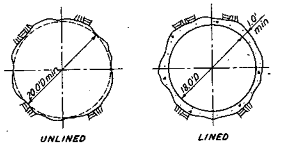
SECTION F-F



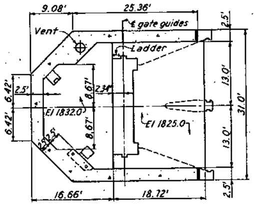
SECTION E-E



PENSTOCK SECTIONS

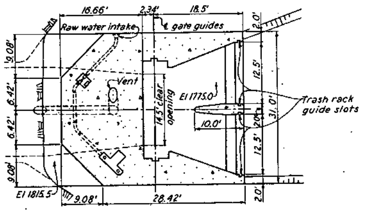


TYPICAL TUNNEL SECTIONS



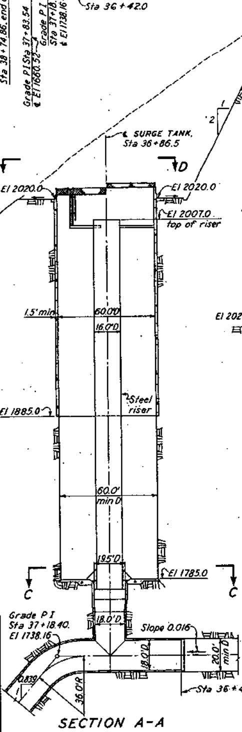
SECTION G-G

NOTES:
1. Design loading for intake tower:
  I. Construction
    a. No side loads.
    b. 30 lb per sq ft wind load. Hoist and crane loads.
  II. H W El 1988.0
    Wind load and wave action plus hoist and crane loads.
  III. H W El 1815.0
    Wind load and wave action plus hoist and crane loads.
  IV. Intake trashrack structure designed for
    10' differential head.



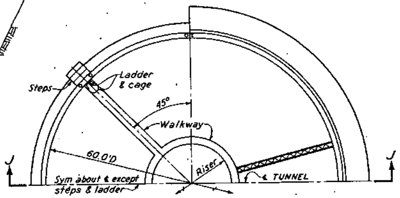
SECTION H-H

Scale 1"=10'
Except as noted

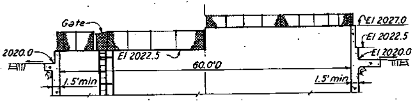


SECTION A-A

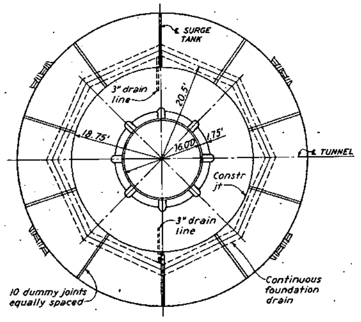
Scale 1"=30'



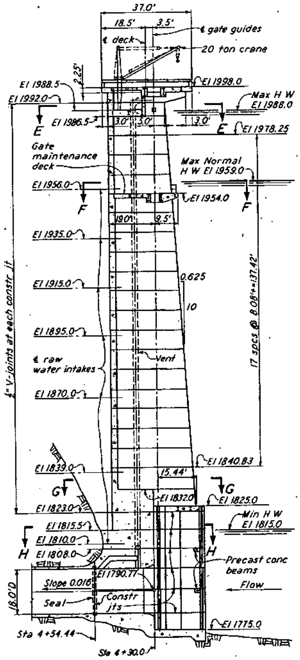
SECTION D-D



SECTION J-J



SECTION C-C



SECTION B-B

Scale 1"=20'

THIS DRAWING SUPERSEDES 31N200

REV NO.	DATE	MADE	CHKD	SUPV	INSP	SUBM	RECM
4	1-25-50	W.E.B.	R.E.M.	T.J.A.	O.H.R.	O.L.	[illegible]
Final field revision and traced							
3	7-30-45	E.F.M.	E.E.C.	O.L.	W.E.L.	A.A.M.	
Moved intake tower 10' dnstr							
2	5-23-45	R.H.H.	O.H.R.	O.L.	W.E.L.	A.A.M.	
Surge tank top changed							
1	9-25-44	R.H.H.	O.H.R.	A.G.	W.E.L.	G.P.A.	
Minor revisions							

DSGN.
DRWN. E.F.M. 1-19-45
CHKD. W.W.E. 3-15-45
TRCD. W.E.B. 1-25-50
COMP. R.E.M. 9-28-51
SUPV. A.G.
INSP. F.E.B.
ENGINEER C. R. Meador

F.E.B. | A.A.M. E.C.R. | S.K. | H.J.P. | H.B.T.

INTAKE

PLAN & SECTIONS PRINCIPAL FEATURES OF DESIGN

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED O. A. Meyer
RECOMMENDED Ross M. Riegel
APPROVED George Rich

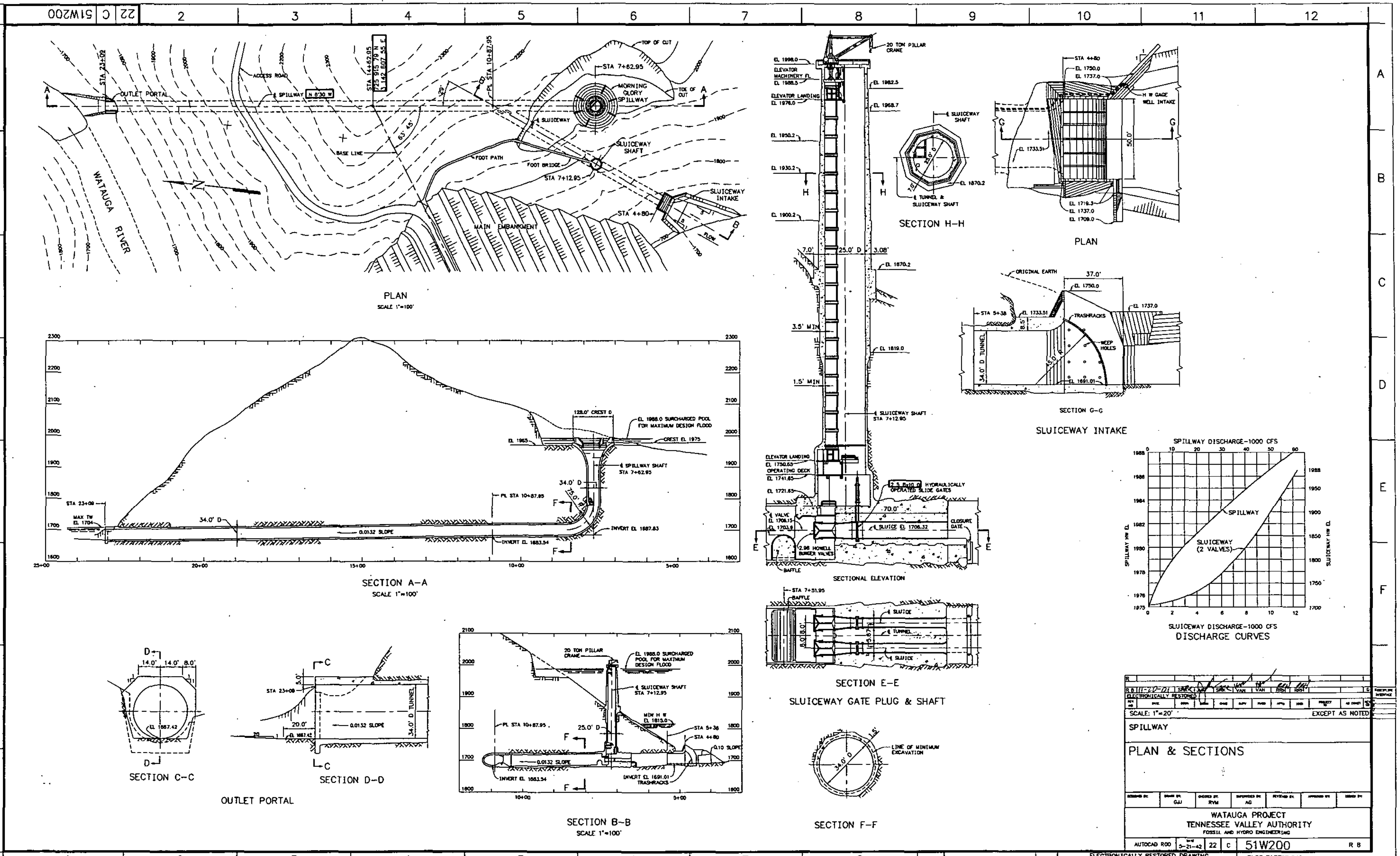
KNOXVILLE | 3-20-45 | 22 | C | 4 | 31N201R4

RECORD DRAWING AS CONSTRUCTED
Geo K. Leonard 1-18-60

W.R.M. E.M.T. R.R.L. B.A.
C.W.S. N.E.W. R.B.B. R.H.Q.
E.S.H. M.A.B. C.E.
W.W. C.V.P. F.J.O'B. R.M.G.
① S.K. E.M.T. K.C.R. H.J.P.
M.M.W. J.W.R. P.J.R. F.J.O'B. E.S.H. C.W.B.
② S.K. H.B.T. F.E.B. E.M.T. H.J.P.
W.R. R.H.Q. E.S.H. W.W.
③ S.K. H.B.T. W.R.M. F.E.B. H.J.P. E.M.T.
R.H.Q. W.W. H.H.Q. P.J.R. W.R. F.D.J.
④
⑤
⑥

Box 403

Box 403



PLAN
SCALE 1"=100'

SECTION A–A
SCALE 1"=100'

SECTIONAL ELEVATION

SECTION H–H

PLAN

SECTION G–G

SLUICEWAY INTAKE

DISCHARGE CURVES

SECTION E–E

SLUICEWAY GATE PLUG & SHAFT

SECTION C–C

SECTION D–D

OUTLET PORTAL

SECTION B–B
SCALE 1"=100'

SECTION F–F

R B 11-20-01 SAR JAF SAR VAN VAN RRH RRH
ELECTRONICALLY RESTORED
SCALE: 1"=20' EXCEPT AS NOTED

SPILLWAY

PLAN & SECTIONS

DRAWN BY GJJ
CHECKED BY RVM
SUPERVISED BY AG

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

AUTOCAD R00 | 3-21-42 | 22 | C | 51W200 | R B

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES : (51N200 R7)

PLOT FACTOR: 240
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

51N201

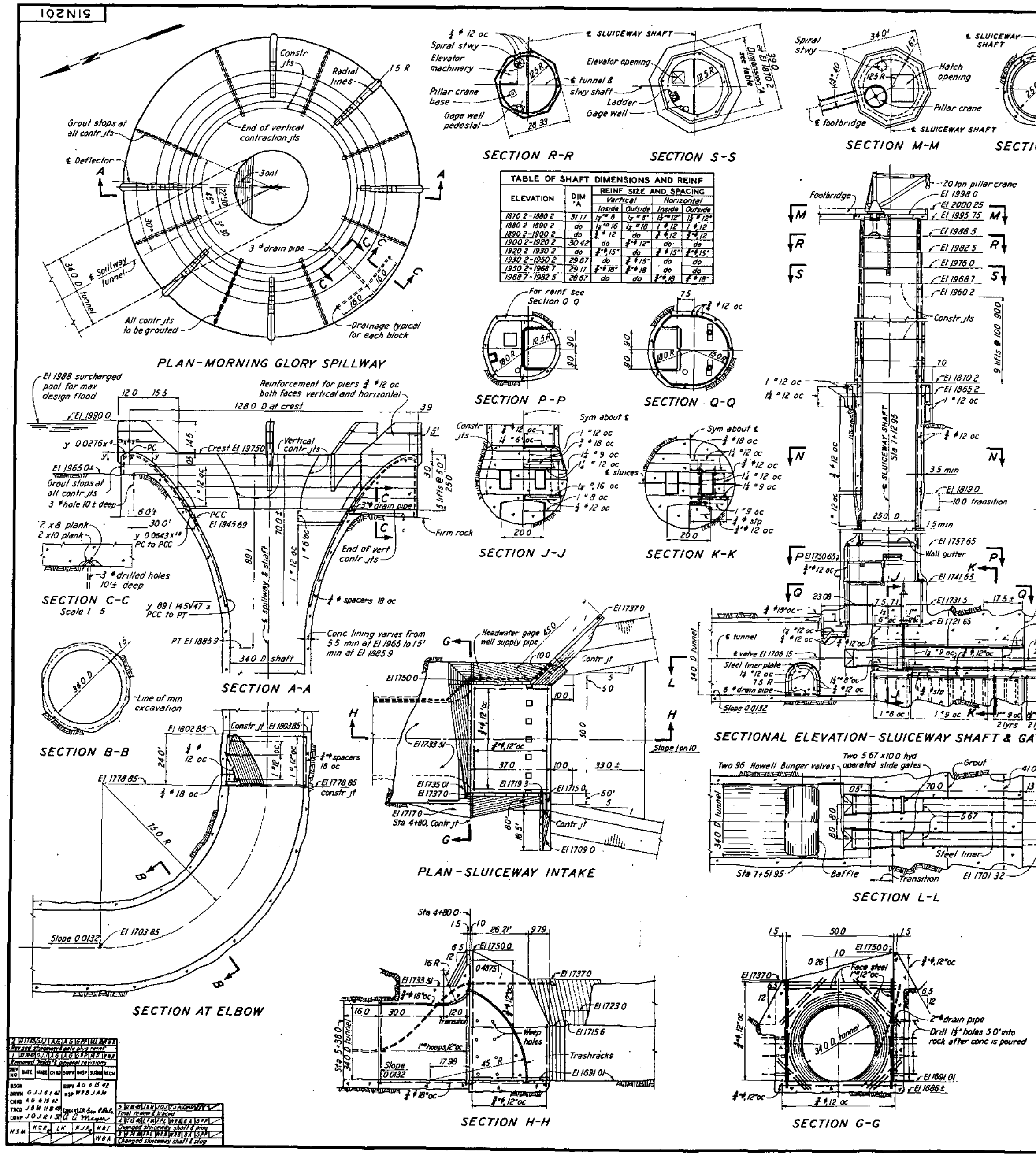
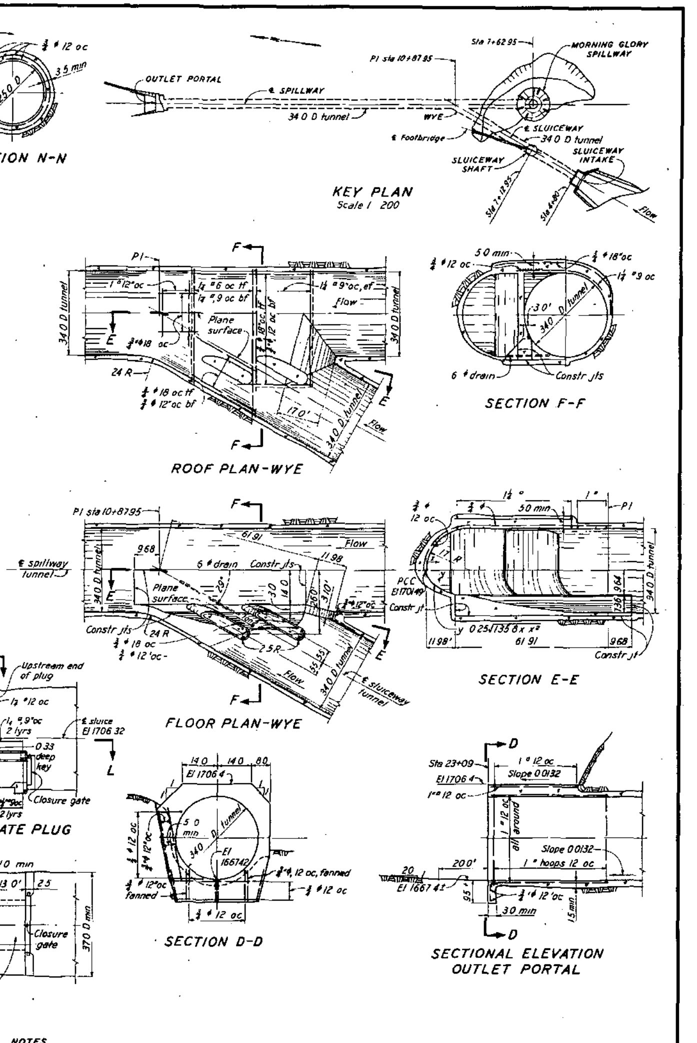


TABLE OF SHAFT DIMENSIONS AND REINF

ELEVATION	DIM "A"	REINF SIZE AND SPACING			
		Vertical		Horizontal	
		Inside	Outside	Inside	Outside
1870 2 - 1880 2	31 17	1¼"# 8	1¼ # 8"	1¼"# 12"	1¼ # 12"
1880 2 1890 2	do	1¼"# 16	1¼ # 16	1 ⌀ 12	1 ⌀ 12
1890 2 - 1900 2	do	¾ ⌀ 12	do	¾ ⌀ 12	¾"⌀ 12
1900 2 - 1920 2	30 42	do	¾"⌀ 12"	do	do
1920 2 1930 2	do	¾"⌀ 15"	do	¾ ⌀ 15"	¾"⌀ 15"
1930 2 - 1950 2	29 67	do	¾ ⌀ 15"	do	do
1950 2 - 1968 7	29 17	¾"⌀ 18"	¾"⌀ 18	do	do
1968 7 - 1982 5	28 67	do	do	¾"⌀ 18	¾ ⌀ 18"



NOTES

1 Dimensions and details are for design purposes only and are not to be used for construction

2 Design loading conditions
- Sluiceway shaft
  - General assumptions
    - Dead load including all equipment and loaded crane in overhanging position
    - Wind load 30 lb per sq ft
    - Wave action 1200 lb per lin ft acting at HW Elevation
    - Uplift full HW outside, zero inside over ⅔ of area
  - Design cases
    - I HW below base of shaft
      - a Wind load and 50°F temp drop
      - b Wind load and 35°F temp rise
    - II HW El 1988 water load uplift wind and wave action with 20°F temp drop
- Sluiceway plug slab
  - Closure gate closed, 125 ft water pressure normal stresses increased by 25%

Scale 1 20'
Except as noted

SPILLWAY

PRINCIPAL FEATURES
OF DESIGN

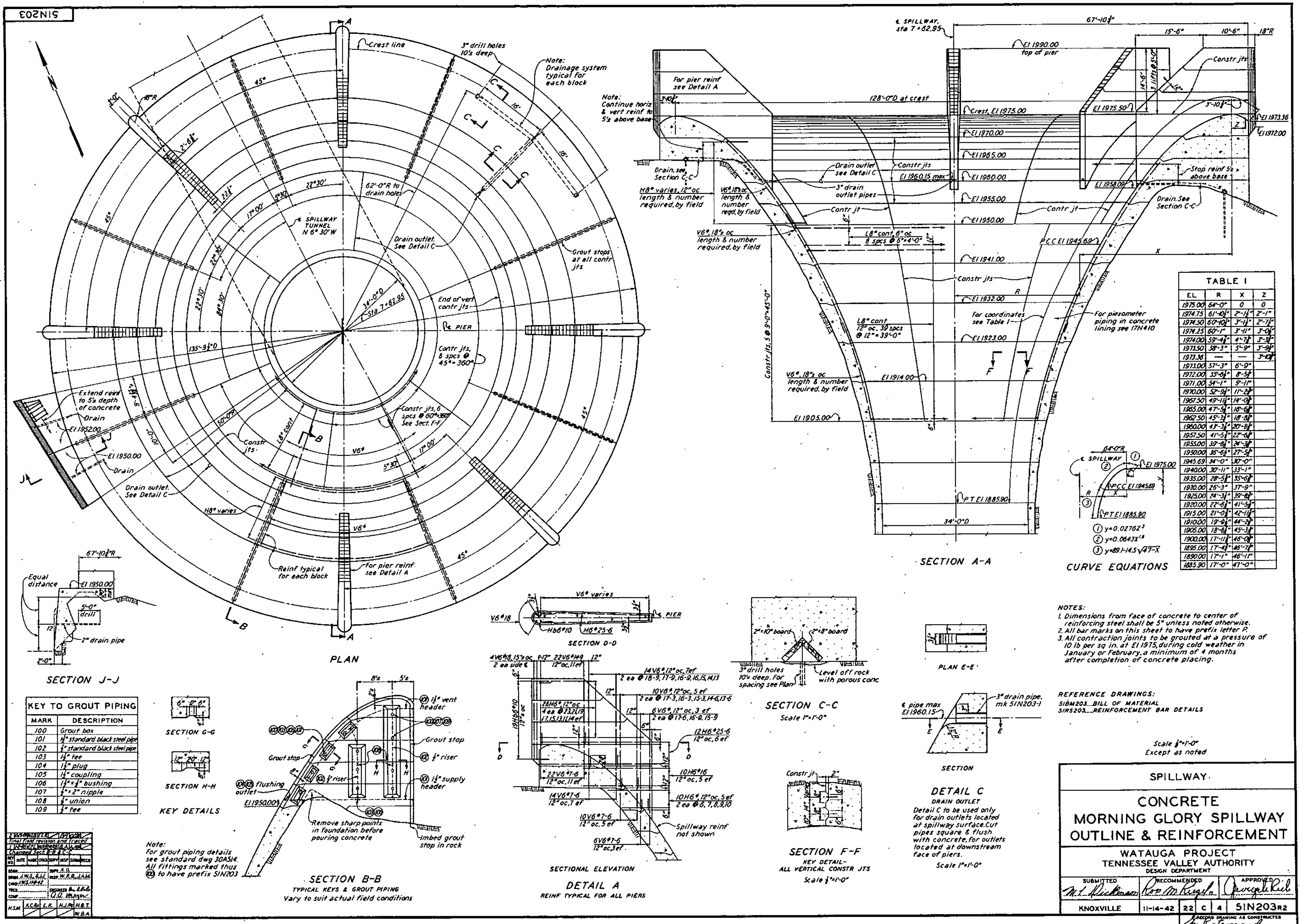
WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
M L Dickinson	Ross M Riegel	George K Rich

KNOXVILLE	6-24-42	22	C	4	51N201 R5

RECORD DRAWING AS CONSTRUCTED

MF R5



Note: For grout piping details see standard dwg 30A514. All fittings marked thus ⑩ to have prefix 5IN203

Detail C to be used only for drain outlets located at spillway surface. Cut pipes square & flush with concrete, for outlets located at downstream face of piers.

Scale 1"=1'-0"

① $y=0.0276Z^3$

② $y=0.0643X^{1.8}$

③ $y=89.1-14.5\sqrt{47-X}$

CURVE EQUATIONS

TABLE I

EL	R	X	Z
1975.00	64'-0"	0	0
1974.75	61'-10⅝"	2'-1½"	2'-1"
1974.50	60'-10⅛"	3'-1⅛"	2'-7⅜"
1974.25	60'-1"	3'-11"	3'-0⅛"
1974.00	59'-4⅛"	4'-7⅝"	3'-3⅞"
1973.50	58'-3"	5'-9"	3'-9⅝"
1973.36	—	—	3'-10⅞"
1973.00	57'-3"	6'-9"	
1972.00	55'-6⅝"	8'-5⅜"	
1971.00	54'-1"	9'-11"	
1970.00	52'-9⅛"	11'-2⅞"	
1967.50	49'-11⅛"	14'-0⅞"	
1965.00	47'-5⅛"	16'-6⅞"	
1962.50	45'-3⅛"	18'-8⅞"	
1960.00	43'-3⅛"	20'-8⅞"	
1957.50	41'-5⅜"	22'-6⅝"	
1955.00	39'-8⅝"	24'-3⅜"	
1950.00	36'-6⅜"	27'-5⅝"	
1945.69	34'-0"	30'-0"	
1940.00	30'-11"	33'-1"	
1935.00	28'-5⅜"	35'-6⅝"	
1930.00	26'-3"	37'-9"	
1925.00	24'-3⅛"	39'-8⅞"	
1920.00	22'-6⅝"	41'-5⅜"	
1915.00	21'-0⅛"	42-11⅞"	
1910.00	19'-9⅛"	44'-2⅞"	
1905.00	18'-8⅛"	45'-3⅞"	
1900.00	17'-11⅛"	46'-0⅞"	
1895.00	17'-4⅜"	46'-7⅝"	
1890.00	17'-1"	46'-11"	
1885.90	17'-0"	47'-0"	

KEY TO GROUT PIPING

MARK	DESCRIPTION
100	Grout box
101	1½" standard black steel pipe
102	½" standard black steel pipe
103	1½" tee
104	1½" plug
105	1½" coupling
106	1½" × ½" bushing
107	½" × 2" nipple
108	½" union
109	½" tee

NOTES:

1. Dimensions from face of concrete to center of reinforcing steel shall be 5" unless noted otherwise.
2. All bar marks on this sheet to have prefix letter P.
3. All contraction joints to be grouted at a pressure of 10 lb per sq in. at El 1975, during cold weather in January or February, a minimum of 4 months after completion of concrete placing.

REFERENCE DRAWINGS:

5IBM203...BILL OF MATERIAL
5IRS203...REINFORCEMENT BAR DETAILS

Scale ⅛"=1'-0"
Except as noted

SPILLWAY

CONCRETE
MORNING GLORY SPILLWAY
OUTLINE & REINFORCEMENT

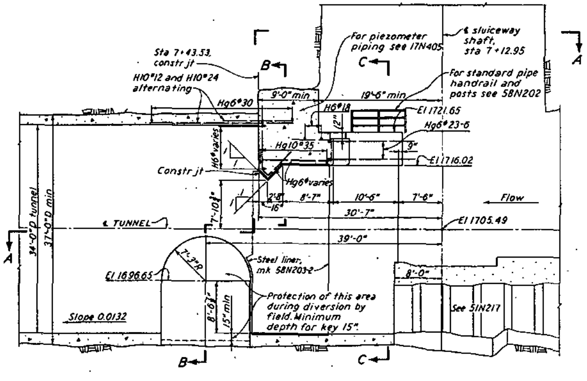
WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
M. L. Dickinson	Ross M. Riegel	George R. Rich

KNOXVILLE | 11-14-42 | 22 | C | 4 | 5IN203R2

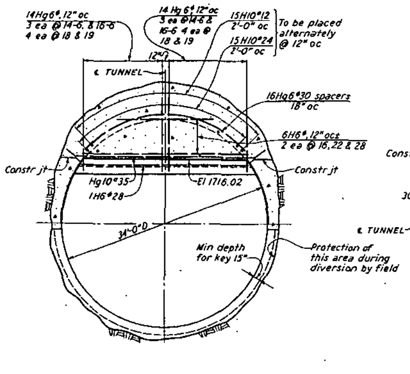
RECORD DRAWING AS CONSTRUCTED
Geo. R. Leonard

5IN206

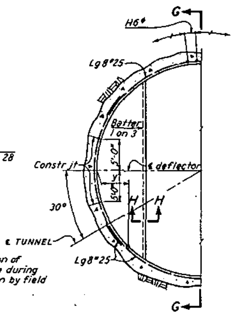


SECTIONAL ELEVATION–TUNNEL AT SLUICEWAY SHAFT

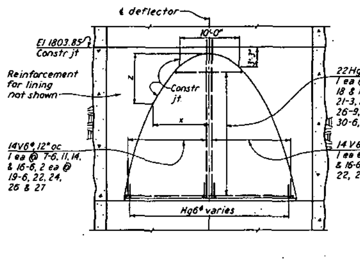
FIRST STAGE CONSTRUCTION



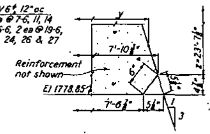
SECTION B-B



SECTION E-E



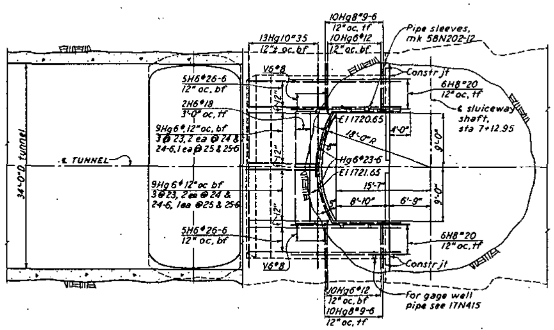
SECTION G-G



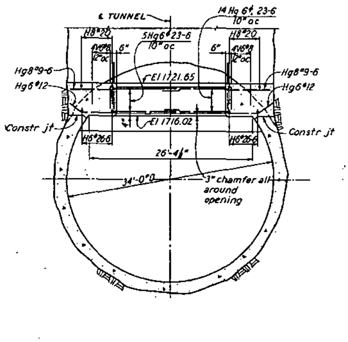
SECTION H-H

Scale 1"=1'-0"

TABLE		
Z	Y	X
0	0	0
6"	2"	2'-4[illegible]"
1'-0"	4"	3'-4[illegible]"
2'-0"	8"	4'-8[illegible]"
4'-0"	16"	6'-7[illegible]"
6'-0"	2'-0"	8'-0"
8'-0"	2'-8"	9'-1[illegible]"
10'-0"	3'-4"	10'-1[illegible]"
14'-0"	4'-8"	11'-8[illegible]"
19'-0"	6'-4"	13'-2[illegible]"
23'-7[illegible]"	7'-10[illegible]"	14'-4"
24'-0	7'-6[illegible]"	14'-1[illegible]"

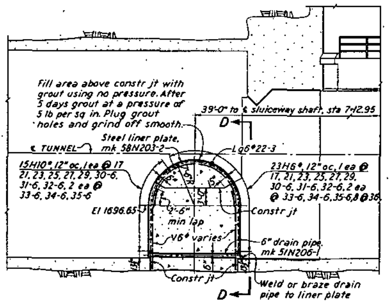


SECTIONAL PLAN A-A



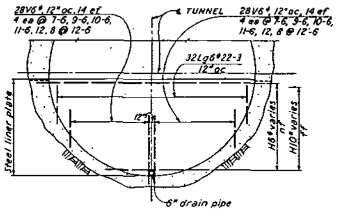
SECTION C-C

SECTION F-F

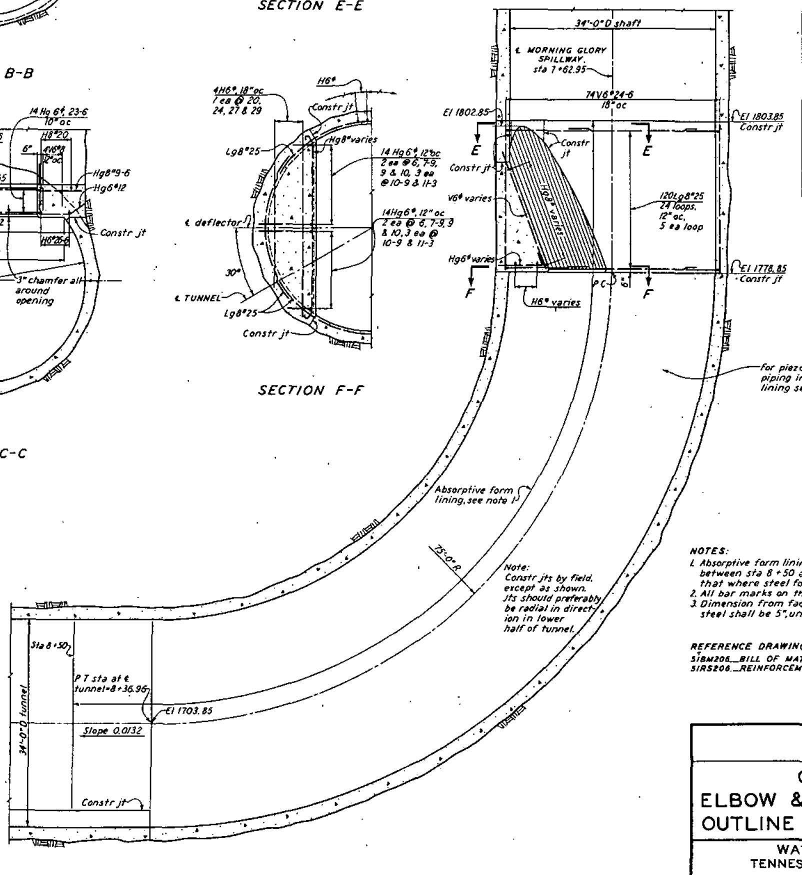


SECTIONAL ELEVATION

SECOND STAGE CONSTRUCTION



SECTION D-D



SECTION ON ¢ ELBOW

NOTES:
1. Absorptive form lining shall be used on all surfaces between sta 8+50 and El 1803.85 at elbow except that where steel forms are used it may be omitted.
2. All bar marks on this sheet to have prefix letter P.
3. Dimension from face of concrete to ¢ reinforcing steel shall be 5", unless otherwise noted.

REFERENCE DRAWINGS:
5IBM206__BILL OF MATERIAL
5IRS206__REINFORCEMENT BAR DETAILS

Scale ⅛"=1'-0"
Except as noted

SPILLWAY

CONCRETE
ELBOW & TUNNEL DETAILS
OUTLINE & REINFORCEMENT

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DESIGN DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
M. L. Dickinson	Ross M Riegel	George Rich

KNOXVILLE	10-31-42	22	C	4	5IN206R4

RECORD DRAWING AS CONSTRUCTED
Geo K. [illegible] 12-22-52

8-18-49 JGB 12-31-52

4 [illegible] Signed as constructed & traced.
3 [illegible] Removed flap valve on weir drain
2 [illegible] Elbow details changed
1 [illegible] Tunnel details changed

REV NO	DATE	MADE	CHKD	SUPV	INSP	SUBM	RECM

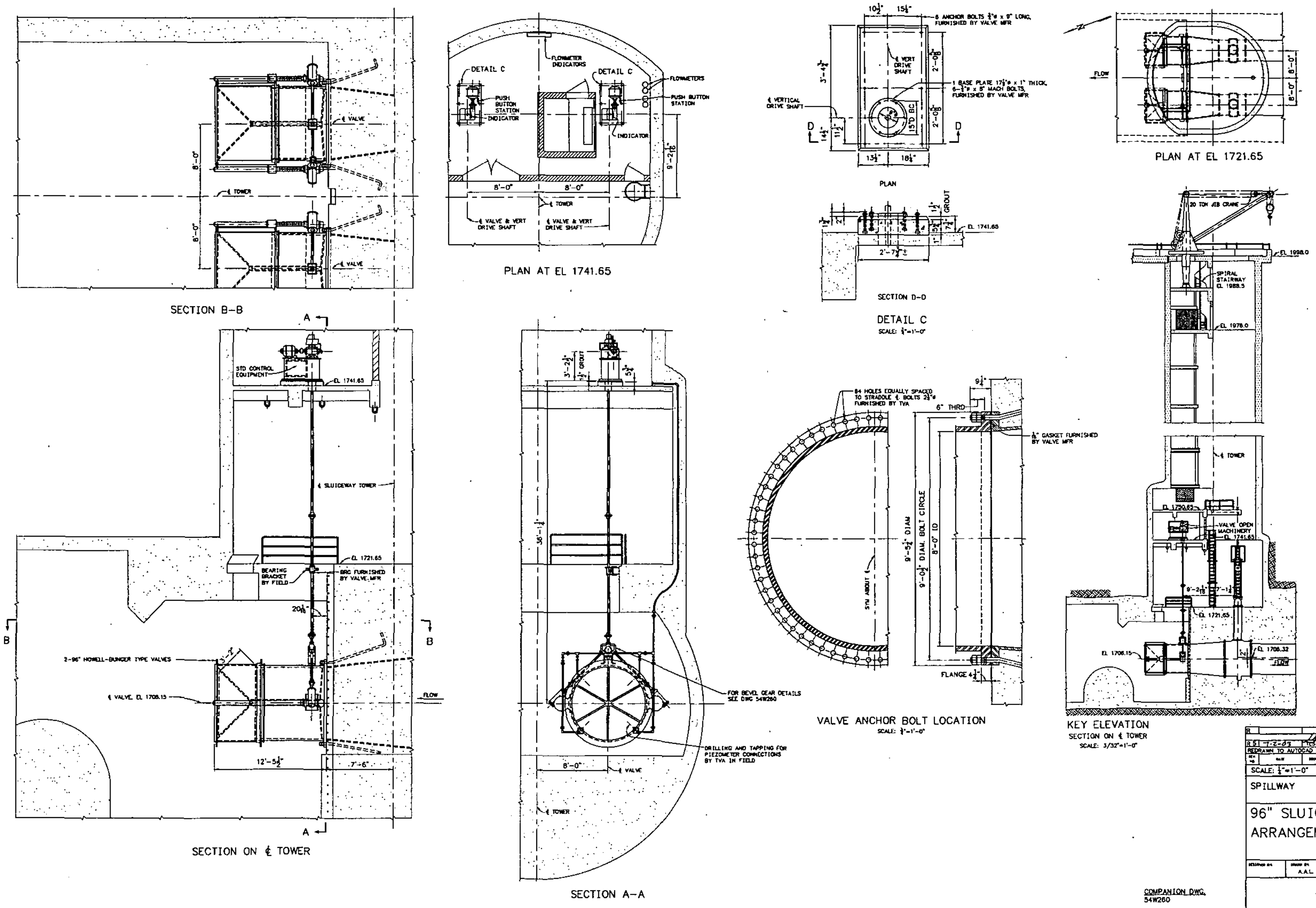
DSGN ....
DRWN G.L.L. 10-15-42
CHKD R.E.M., A.G.
TRCD W.C.B. [illegible]
COMP [illegible] 12-2-52
SUPV A.G. 10-29-42
INSP W.B.B., J.A.M.
ENGINEER [illegible]
C.C. Mayer

R.C.Rk H.J.Pe W.B.A.

R.B.R., W.R.M.
E.M.T., L.B.B.
C.W.S., C.M.H.
M.M.W.

① L.K., K.C.R., W.R.M. F.E.Bu, R.G., E.M.T. ② ③ F.E.Bu ④ ⑤ ⑥

MF
RAx



NOTE:
FOR MANUFACTURER'S DETAILS OF REGULATING VALVES REFER TO S. MORGAN SMITH CO FILE. TVA CONTRACT NO. TV 94738.

COMPANION DWG.
54W260

R 5 7-2-03 TCS JAO REB
REDRAWN TO AUTOCAD FORMAT AND

SCALE: ¼"=1'-0" EXCEPT AS NOTED

SPILLWAY

96" SLUICEWAY REGULATING VALVES ARRANGEMENT

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
	A.A.L.	N.M.D.	N.M.D.			

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

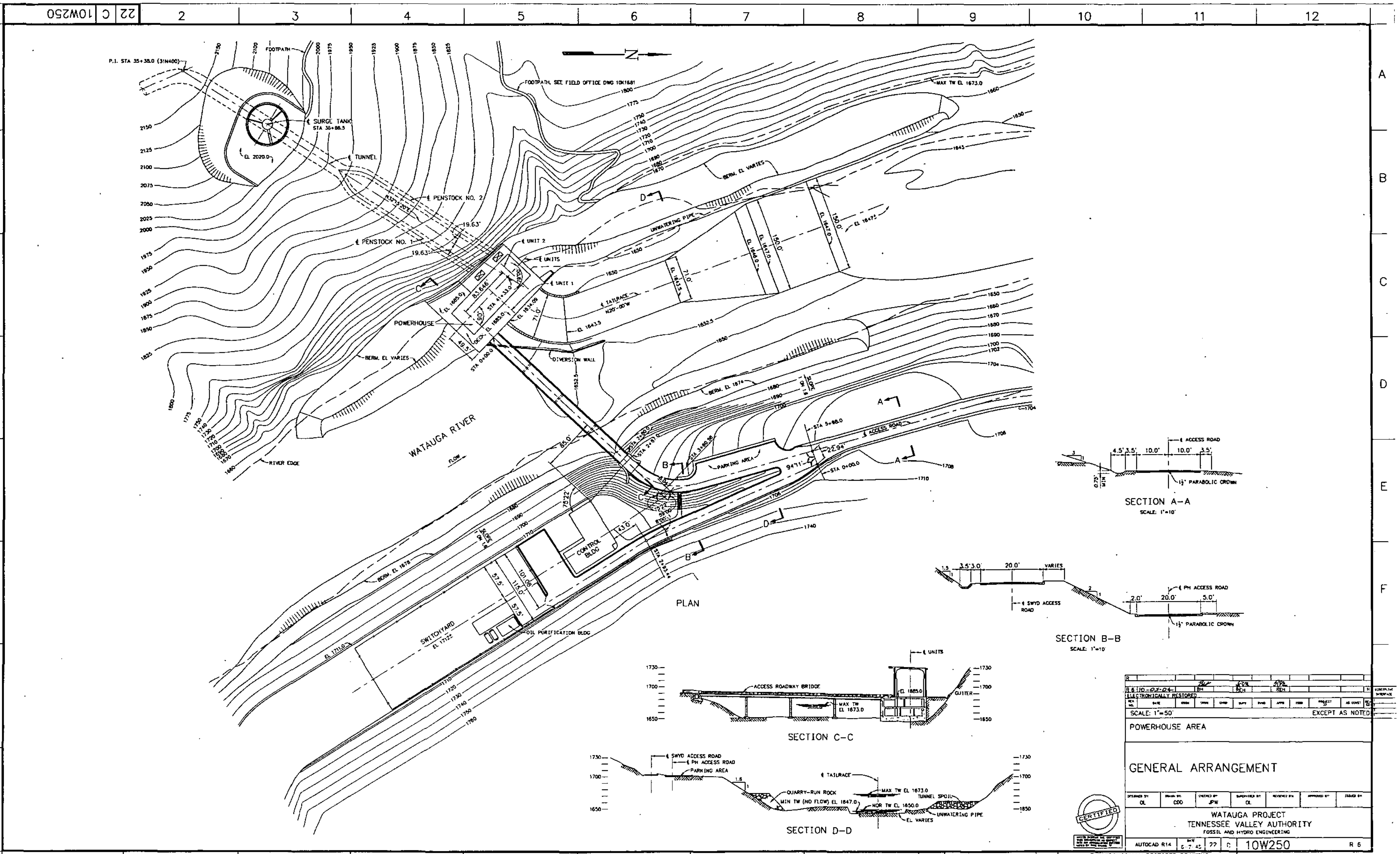
AUTOCAD R14 | 9-10-42 | 22 | M | 54W220 | R 5

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES :(54N220 R4)

PLOT FACTOR:48
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TASK COMPLETED BY: REV NO.



R										
R 6	10-03-04		BH		REH		REH			
ELECTRONICALLY RESTORED										

SCALE: 1"=50' EXCEPT AS NOTED

POWERHOUSE AREA

GENERAL ARRANGEMENT

DESIGNED BY	DRAWN BY	CHECKED BY	SUPERVISED BY	REVIEWED BY	APPROVED BY	ISSUED BY
OL	CDD	JPW	OL			

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
FOSSIL AND HYDRO ENGINEERING

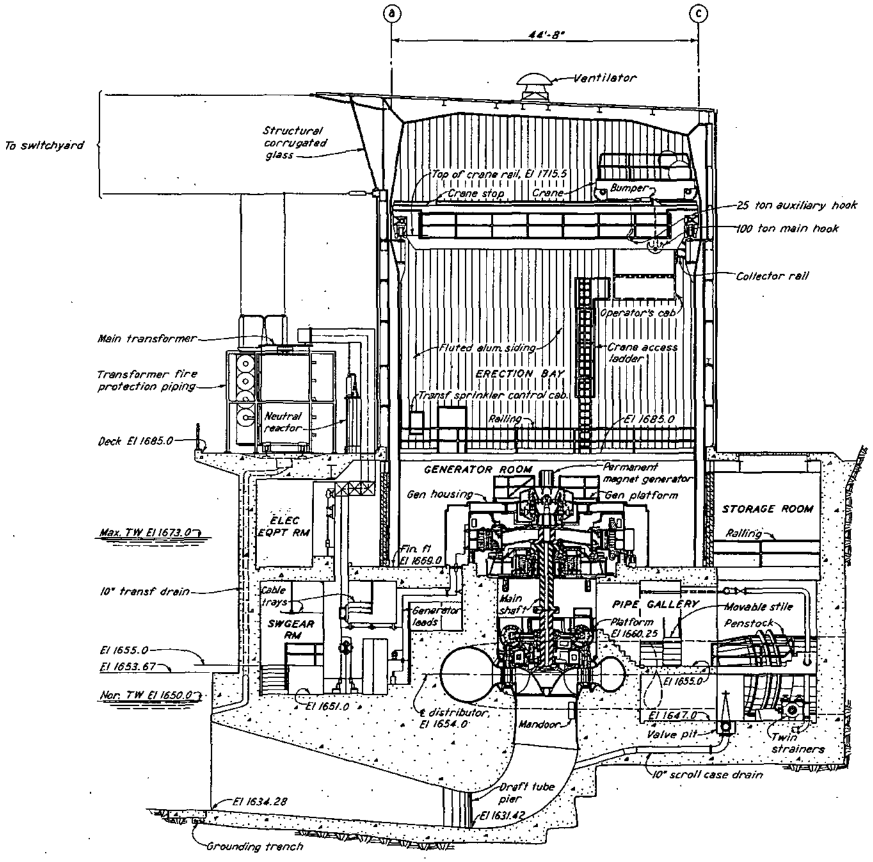
AUTOCAD R14 | DATE 5-7-45 | 22 | C | 10W250 | R 6

ELECTRONICALLY RESTORED DRAWING
THIS DRAWING HAS BEEN COMPLETELY REDRAWN
AND SUPERSEDES : (10N250 R5)

PLOT FACTOR:600
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

46K205



Scale ⅛" = 1'-0"

1	5-24-50	M.K.M.	S.A.D.	R.H.G.	H.N.G.		
Traced							
REV NO.	DATE	MADE	CHKD	SUPV	INSP	SUBM	RECM

DSGN.
DRWN. T.R.E.
CHKD. R.T.C.
TRCD. M.K.M. 5-24-50
COMP.
SUPV. R.H.G.
INSP. H.C.B.
ENGINEER

S.R.	A.A.M.	G.P.P.		H.J.P.

POWERHOUSE

EQUIPMENT
TRANSVERSE SECTION
THRU UNIT 2

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

RECOMMENDED	REVIEWED	APPROVED
Harry B. Tour	W. H. Allen	R. A. Monroe

KNOXVILLE | 12-6-48 | 22 | A | 4 | 46K205R1

MF
R1+

E.C., P.I.R., W.R.M., E.M.T., H.W.S.,r, O.W.,
O.C., W.R.B., E.E.M., C.V.P., L.W.S., W.W.,
C.L.M., B.S.M., R.F., C.W.B., F.J.O'B., Holm

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE TABLES

JULY 1974

INSTRUCTIONS FOR USE OF TABLES

1. Purpose of Tables

The purpose of these tables is to provide a means of determining the discharge of the Howell-Bunger valves in the sluice tunnel at South Holston Dam. The tables are based on field discharge measurements and pressure measurements taken at several discharges in the sluice upstream from the Howell-Bunger valves. The tables give the discharge in cubic feet per second for one valve when the reservoir elevation and valve opening are known throughout the complete range of normal operating conditions. These tables supersede the tables dated April 1959.

2. Arrangement and Use of Tables

The tables give the discharge in cubic feet per second per valve for each 5-foot interval of headwater between reservoir elevations 1600 and 1755, and for each 1 percent of valve opening between 5 percent and 89 percent valve positions. Discharges are tabulated only to the nearest 10 cubic feet per second because the accuracy of the field measurements does not warrant greater refinement. It is possible to set any discharge within 40 cubic feet per second by using the tabular values. This tolerance has been accepted by the Division of Water Control Planning, and therefore, *it will not be necessary to interpolate* between tabular entries in these tables.

The reservoir elevation values used in the tables are those given by the recorder in the control room. The valve opening used in the tables is that indicated by the pointer on the valve control mechanism.

The arrangement of tables is such that the discharge over the entire range of valve openings for a 100-foot range of reservoir elevation is on two consecutive pages. For example, discharges are given on pages 2 and 3 for reservoir elevations 1600 through 1700. Discharges should be taken from the table for the tabulated values nearest to those observed. For example, if the reservoir is at elevation 1658.76 and the valve number 1 opening is 76.4 percent, the discharge is found on page 3, in the column headed 1660 opposite a valve opening of 76 percent, as 3370 cubic feet per second. If valve number 2 were set at 56.6 percent at the same time when valve number 1 was operating as given above, the discharge for valve number 2 would be found on page 3, in the column headed 1660 opposite a valve opening of 57 percent, as 2720 cubic feet per second. The total discharge would be the sum of the discharges of the two valves or 6090 cubic feet per second.

3. Valve Opening for Maximum and Minimum Discharge

Maximum discharge for the Howell-Bunger valves at South Holston Dam occurs at 89 percent valve opening. At valve openings greater than 89 percent the discharge becomes less. Therefore, the valves should not be operated beyond 89 percent. No tabular data are presented for such operation.

Minimum valve openings should not be less than 5 percent because of cavitation effects. No tabular values are given for such operation.

4. Adjustment of Valve Opening Indicator

At the time the field measurements were made, the valve opening indicator showed an opening of 0 percent when the valve was closed. In case of repairs to or adjustment of the valve and its control mechanism, the pointer should be reset to this position so that the tables will still be applicable.

July 1974

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1600	1605	1610	1615	1620	1625	1630	1635	1640	1645	1650	1655	1660	1665	1670	1675	1680	1685	1690	1695	1700	
1																						1
2																						2
3																						3
4																						4
* 5	140	140	140	150	150	150	160	160	160	170	170	170	170	180	180	180	180	190	190	190	190	5
6	180	180	190	190	200	200	200	210	210	220	220	220	230	230	230	240	240	240	250	250	250	6
7	230	240	240	250	250	260	260	270	270	280	280	290	290	300	300	310	310	310	320	320	330	7
8	270	280	290	290	300	300	310	320	320	330	330	340	340	350	360	360	370	370	380	380	390	8
9	310	320	330	340	340	350	360	360	370	380	380	390	400	400	410	420	420	430	430	440	440	9
10	350	360	370	380	390	400	400	410	420	430	430	440	450	450	460	470	480	480	490	490	500	10
11	400	410	420	430	440	440	450	460	470	480	490	500	500	510	520	530	530	540	550	560	560	11
12	440	450	460	470	490	500	510	510	520	530	540	550	560	570	580	590	600	600	610	620	630	12
13	490	500	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	13
14	540	550	560	580	590	600	610	630	640	650	660	670	680	690	700	710	720	730	740	750	760	14
15	590	600	620	630	640	660	670	680	700	710	720	730	750	760	770	780	790	800	810	820	840	15
16	640	650	670	680	700	710	730	740	750	770	780	790	810	820	830	850	860	870	880	890	900	16
17	680	700	710	730	750	760	780	790	810	820	840	850	860	880	890	900	920	930	940	950	970	17
18	720	740	760	780	790	810	830	840	860	870	890	900	920	930	950	960	970	990	1000	1010	1030	18
19	770	790	800	820	840	860	880	890	910	930	940	960	970	990	1000	1020	1030	1050	1060	1070	1090	19
20	810	830	850	870	890	900	920	940	960	980	990	1010	1030	1040	1060	1070	1090	1100	1120	1130	1150	20
21	840	870	890	910	930	950	970	980	1000	1020	1040	1050	1070	1090	1110	1120	1140	1150	1170	1180	1200	21
22	880	900	930	950	970	990	1010	1030	1050	1070	1080	1100	1120	1140	1150	1170	1190	1200	1220	1240	1250	22
23	920	940	970	990	1010	1030	1050	1070	1090	1110	1130	1150	1170	1190	1210	1220	1240	1260	1270	1290	1310	23
24	960	980	1000	1030	1050	1070	1090	1110	1130	1160	1180	1190	1210	1230	1250	1270	1290	1310	1320	1340	1360	24
25	990	1020	1040	1060	1090	1110	1130	1150	1180	1200	1220	1240	1260	1280	1300	1320	1340	1350	1370	1390	1410	25
26	1030	1060	1080	1110	1130	1150	1180	1200	1220	1240	1270	1290	1310	1330	1350	1370	1390	1410	1430	1450	1460	26
27	1070	1100	1120	1150	1170	1200	1220	1250	1270	1290	1320	1340	1360	1380	1400	1420	1440	1460	1480	1500	1520	27
28	1120	1140	1170	1200	1220	1250	1270	1300	1320	1350	1370	1390	1420	1440	1460	1480	1500	1520	1540	1560	1580	28
29	1160	1180	1210	1240	1270	1290	1320	1350	1370	1390	1420	1440	1470	1490	1510	1530	1560	1580	1600	1620	1640	29
30	1190	1220	1250	1280	1310	1330	1360	1390	1410	1440	1460	1490	1510	1530	1560	1580	1600	1620	1650	1670	1690	30
31	1230	1260	1290	1320	1350	1380	1400	1430	1460	1480	1510	1540	1560	1580	1610	1630	1660	1680	1700	1720	1750	31
32	1270	1300	1330	1360	1390	1420	1450	1480	1510	1530	1560	1580	1610	1640	1660	1690	1710	1730	1760	1780	1800	32
33	1310	1340	1370	1410	1440	1470	1500	1520	1550	1580	1610	1630	1660	1690	1710	1740	1760	1790	1810	1840	1860	33
34	1350	1380	1420	1450	1480	1510	1540	1570	1600	1630	1660	1680	1710	1740	1760	1790	1820	1840	1870	1890	1920	34
35	1390	1420	1460	1490	1520	1550	1590	1620	1650	1680	1700	1730	1760	1790	1820	1840	1870	1900	1920	1950	1970	35
36	1430	1460	1500	1530	1570	1600	1630	1660	1690	1720	1750	1780	1810	1840	1870	1900	1920	1950	1980	2000	2030	36
37	1470	1500	1540	1580	1610	1640	1680	1710	1740	1770	1800	1830	1860	1890	1920	1950	1980	2000	2030	2060	2080	37
38	1510	1540	1580	1620	1650	1690	1720	1750	1790	1820	1850	1880	1910	1940	1970	2000	2030	2060	2090	2110	2140	38
39	1540	1580	1610	1650	1690	1720	1760	1790	1820	1860	1890	1920	1950	1980	2010	2040	2070	2100	2130	2160	2180	39
40	1570	1610	1650	1690	1720	1760	1800	1830	1860	1900	1930	1960	1990	2030	2060	2090	2120	2150	2170	2200	2230	40
41	1610	1650	1690	1730	1770	1800	1840	1880	1910	1950	1980	2010	2040	2080	2110	2140	2170	2200	2230	2260	2290	41
42	1650	1690	1730	1770	1810	1840	1880	1920	1950	1990	2020	2060	2090	2120	2150	2190	2220	2250	2280	2310	2340	42
43	1680	1720	1760	1800	1840	1880	1920	1960	1990	2030	2060	2100	2130	2170	2200	2230	2260	2290	2330	2360	2390	43
44	1720	1760	1800	1840	1880	1920	1960	2000	2030	2070	2110	2140	2180	2210	2240	2280	2310	2340	2370	2410	2440	44
45	1740	1790	1830	1870	1910	1950	1990	2030	2070	2110	2140	2180	2210	2250	2280	2320	2350	2380	2420	2450	2480	45
46	1780	1820	1870	1910	1950	1990	2030	2070	2110	2150	2190	2220	2260	2290	2330	2360	2400	2430	2460	2500	2530	46
47	1810	1860	1900	1950	1990	2030	2070	2110	2150	2190	2230	2270	2300	2340	2370	2410	2440	2480	2510	2540	2580	47
48	1840	1890	1940	1980	2020	2070	2110	2150	2190	2230	2270	2300	2340	2380	2410	2450	2480	2520	2550	2590	2620	48
49	1870	1920	1970	2010	2060	2100	2140	2180	2220	2260	2300	2340	2380	2420	2450	2490	2520	2560	2590	2630	2660	49
50	1910	1960	2010	2050	2100	2140	2190	2230	2270	2310	2350	2390	2430	2470	2500	2540	2580	2610	2650	2680	2720	50

JULY 1974

* THE MINIMUM ALLOWABLE
VALVE OPENING IS 5 PERCENT

RESERVOIR ELEVATION 1600 TO 1700
VALVE OPENING, PERCENT 5 TO 50

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1600	1605	1610	1615	1620	1625	1630	1635	1640	1645	1650	1655	1660	1665	1670	1675	1680	1685	1690	1695	1700	
51	1940	1990	2040	2090	2130	2180	2220	2260	2300	2350	2390	2430	2470	2500	2540	2580	2620	2650	2690	2730	2760	51
52	1970	2020	2070	2120	2160	2210	2250	2300	2340	2380	2420	2460	2500	2540	2580	2620	2660	2690	2730	2770	2800	52
53	2010	2060	2110	2160	2210	2250	2300	2340	2390	2430	2470	2510	2550	2590	2630	2670	2710	2750	2790	2820	2860	53
54	2040	2090	2140	2190	2240	2290	2330	2380	2420	2470	2510	2550	2590	2630	2670	2710	2750	2790	2830	2860	2900	54
55	2070	2120	2180	2220	2270	2320	2370	2410	2460	2500	2550	2590	2630	2670	2710	2750	2790	2830	2870	2910	2940	55
56	2100	2150	2210	2260	2310	2350	2400	2450	2490	2540	2580	2620	2670	2710	2750	2790	2830	2870	2910	2950	2990	56
57	2140	2200	2250	2300	2350	2400	2450	2490	2540	2590	2630	2670	2720	2760	2800	2840	2880	2920	2960	3000	3040	57
58	2170	2230	2280	2330	2380	2430	2480	2530	2580	2620	2670	2710	2760	2800	2840	2880	2920	2970	3010	3040	3080	58
59	2200	2260	2310	2360	2410	2470	2510	2560	2610	2660	2700	2750	2790	2840	2880	2920	2960	3010	3050	3090	3130	59
60	2230	2290	2340	2390	2450	2500	2550	2600	2650	2690	2740	2790	2830	2880	2920	2960	3000	3050	3090	3130	3170	60
61	2260	2320	2370	2430	2480	2530	2580	2630	2680	2730	2780	2820	2870	2910	2960	3000	3040	3090	3130	3170	3210	61
62	2280	2340	2390	2450	2500	2550	2610	2660	2700	2750	2800	2850	2890	2940	2980	3030	3070	3110	3160	3200	3240	62
63	2310	2370	2420	2480	2530	2590	2640	2690	2740	2790	2840	2880	2930	2980	3020	3070	3110	3150	3200	3240	3280	63
64	2340	2400	2460	2510	2570	2620	2670	2720	2780	2830	2870	2920	2970	3020	3060	3110	3150	3200	3240	3280	3320	64
65	2370	2430	2490	2540	2600	2650	2710	2760	2810	2860	2910	2960	3010	3050	3100	3150	3190	3240	3280	3320	3370	65
66	2400	2460	2520	2580	2630	2690	2740	2790	2850	2900	2950	3000	3040	3090	3140	3190	3230	3280	3320	3360	3410	66
67	2420	2480	2540	2600	2650	2710	2760	2820	2870	2920	2970	3020	3070	3120	3170	3210	3260	3300	3350	3390	3440	67
68	2440	2500	2560	2620	2680	2730	2790	2840	2890	2940	3000	3050	3100	3140	3190	3240	3280	3330	3380	3420	3460	68
69	2470	2530	2590	2650	2710	2760	2820	2870	2930	2980	3030	3080	3130	3180	3230	3280	3320	3370	3420	3460	3510	69
70	2500	2560	2620	2680	2740	2800	2850	2910	2960	3020	3070	3120	3170	3220	3270	3320	3360	3410	3460	3500	3550	70
71	2530	2590	2650	2710	2770	2830	2890	2940	3000	3050	3110	3160	3210	3260	3310	3360	3400	3450	3500	3550	3590	71
72	2550	2610	2670	2740	2800	2850	2910	2970	3020	3080	3130	3180	3230	3280	3330	3380	3430	3480	3530	3570	3620	72
73	2580	2640	2710	2770	2830	2890	2950	3000	3060	3110	3170	3220	3270	3320	3370	3420	3470	3520	3570	3610	3660	73
74	2610	2670	2740	2800	2860	2920	2980	3040	3090	3150	3200	3260	3310	3360	3410	3460	3510	3560	3610	3660	3700	74
75	2630	2690	2760	2820	2880	2940	3000	3060	3120	3170	3230	3280	3330	3390	3440	3490	3540	3590	3640	3680	3730	75
76	2660	2720	2790	2850	2910	2980	3040	3090	3150	3210	3260	3320	3370	3420	3480	3530	3580	3630	3680	3730	3770	76
77	2680	2740	2810	2870	2940	3000	3060	3120	3180	3230	3290	3340	3400	3450	3500	3550	3610	3660	3710	3750	3800	77
78	2700	2760	2830	2900	2960	3020	3080	3140	3200	3260	3310	3370	3420	3480	3530	3580	3630	3680	3730	3780	3830	78
79	2720	2790	2860	2920	2990	3050	3110	3170	3230	3290	3340	3400	3450	3510	3560	3610	3670	3720	3770	3820	3870	79
80	2750	2820	2880	2950	3010	3080	3140	3200	3260	3320	3370	3430	3490	3540	3590	3650	3700	3750	3800	3850	3900	80
81	2770	2840	2900	2970	3030	3100	3160	3220	3280	3340	3400	3450	3510	3570	3620	3670	3730	3780	3830	3880	3930	81
82	2790	2860	2920	2990	3060	3120	3180	3240	3300	3360	3420	3480	3540	3590	3650	3700	3750	3800	3860	3910	3960	82
83	2820	2890	2960	3020	3090	3150	3220	3280	3340	3400	3460	3520	3570	3630	3680	3740	3790	3850	3900	3950	4000	83
84	2840	2910	2980	3040	3110	3180	3240	3300	3360	3420	3480	3540	3600	3650	3710	3770	3820	3870	3920	3980	4030	84
85	2860	2930	3000	3070	3130	3200	3260	3330	3390	3450	3510	3570	3620	3680	3740	3790	3850	3900	3950	4000	4060	85
86	2880	2950	3020	3090	3150	3220	3280	3350	3410	3470	3530	3590	3650	3710	3760	3820	3870	3930	3980	4030	4080	86
87	2900	2970	3040	3110	3180	3240	3310	3370	3430	3500	3560	3620	3670	3730	3790	3840	3900	3950	4010	4060	4110	87
88	2900	2980	3050	3120	3190	3250	3320	3380	3450	3510	3570	3630	3690	3740	3800	3860	3910	3970	4020	4070	4130	88
*89	2910	2990	3060	3130	3200	3260	3330	3390	3460	3520	3580	3640	3700	3760	3810	3870	3930	3980	4030	4090	4140	89

JULY 1974

* THE MAXIMUM VALVE OPENING
SHOULD NOT EXCEED 89 PERCENT

RESERVOIR ELEVATION 1600 TO 1700
VALVE OPENING, PERCENT 51 TO 89

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY **ENGINEERING LABORATORY**

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1700	1705	1710	1715	1720	1725	1730	1735	1740	1745	1750	1755										
1																						1
2																						2
3																						3
4																						4
*5	190	200	200	200	200	210	210	210	210	220	220	220										5
6	250	260	260	260	270	270	270	270	280	280	280	290										6
7	330	330	330	340	340	350	350	350	360	360	370	370										7
8	390	390	400	400	400	410	410	420	420	430	430	440										8
9	440	450	460	460	470	470	480	480	490	490	500	500										9
10	500	510	510	520	530	530	540	540	550	560	560	570										10
11	560	570	580	580	590	600	600	610	620	620	630	640										11
12	630	640	640	650	660	670	670	680	690	700	700	710										12
13	700	710	710	720	730	740	750	760	760	770	780	790										13
14	760	770	780	790	800	810	820	830	840	850	850	860										14
15	840	850	860	870	880	890	900	910	920	920	930	940										15
16	900	920	930	940	950	960	970	980	990	1000	1010	1020										16
17	970	980	990	1000	1010	1030	1040	1050	1060	1070	1080	1090										17
18	1030	1040	1050	1060	1080	1090	1100	1110	1130	1140	1150	1160										18
19	1090	1100	1120	1130	1140	1160	1170	1180	1190	1210	1220	1230										19
20	1150	1160	1180	1190	1200	1220	1230	1240	1260	1270	1280	1300										20
21	1200	1210	1230	1240	1260	1270	1290	1300	1320	1330	1340	1360										21
22	1250	1270	1280	1300	1310	1330	1340	1360	1370	1390	1400	1420										22
23	1310	1320	1340	1360	1370	1390	1400	1420	1430	1450	1460	1480										23
24	1360	1380	1390	1410	1430	1440	1460	1470	1490	1510	1520	1540										24
25	1410	1430	1440	1460	1480	1490	1510	1530	1540	1560	1580	1590										25
26	1460	1480	1500	1520	1540	1550	1570	1590	1610	1620	1640	1660										26
27	1520	1540	1560	1580	1600	1610	1630	1650	1670	1680	1700	1720										27
28	1580	1600	1620	1640	1660	1680	1700	1720	1740	1750	1770	1790										28
29	1640	1660	1680	1700	1720	1740	1760	1780	1800	1820	1840	1850										29
30	1690	1710	1730	1750	1770	1790	1810	1830	1850	1870	1890	1910										30
31	1750	1770	1790	1810	1830	1850	1870	1890	1910	1930	1950	1570										31
32	1800	1830	1850	1870	1890	1910	1930	1960	1980	2000	2020	2040										32
33	1860	1880	1910	1930	1950	1970	1990	2020	2040	2060	2080	2100										33
34	1920	1940	1960	1990	2010	2030	2050	2080	2100	2120	2140	2160										34
35	1970	2000	2020	2040	2070	2090	2120	2140	2160	2180	2210	2230										35
36	2030	2050	2080	2100	2130	2150	2180	2200	2220	2250	2270	2290										36
37	2080	2110	2140	2160	2190	2210	2240	2260	2280	2310	2330	2360										37
38	2140	2170	2190	2220	2250	2270	2300	2320	2350	2370	2400	2420										38
39	2180	2210	2240	2260	2290	2320	2340	2370	2390	2420	2440	2470										39
40	2230	2260	2290	2310	2340	2370	2390	2420	2450	2470	2500	2520										40
41	2290	2320	2350	2370	2400	2430	2460	2480	2510	2530	2560	2590										41
42	2340	2370	2400	2420	2450	2480	2510	2540	2560	2590	2620	2640										42
43	2390	2420	2450	2480	2500	2530	2560	2590	2620	2640	2670	2700										43
44	2440	2470	2500	2530	2560	2590	2610	2640	2670	2700	2730	2750										44
45	2480	2510	2540	2570	2600	2630	2660	2690	2720	2750	2770	2800										45
46	2530	2560	2590	2620	2650	2680	2710	2740	2770	2800	2830	2860										46
47	2580	2610	2640	2670	2700	2730	2770	2800	2820	2850	2880	2910										47
48	2620	2650	2680	2720	2750	2780	2810	2840	2870	2900	2930	2960										48
49	2660	2690	2730	2760	2790	2820	2860	2890	2920	2950	2980	3010										49
50	2720	2750	2790	2820	2850	2880	2920	2950	2980	3010	3040	3070										50

JULY 1974

* THE MINIMUM ALLOWABLE
VALVE OPENING IS 5 PERCENT

RESERVOIR ELEVATION 1700 TO 1755
VALVE OPENING, PERCENT 5 TO 50

SOUTH HOLSTON DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY **ENGINEERING LABORATORY**

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1700	1705	1710	1715	1720	1725	1730	1735	1740	1745	1750	1755										
51	2760	2790	2830	2860	2900	2930	2960	2990	3030	3060	3090	3120										51
52	2800	2840	2870	2910	2940	2970	3010	3040	3070	3100	3140	3170										52
53	2860	2890	2930	2960	3000	3030	3070	3100	3130	3170	3200	3230										53
54	2900	2940	2970	3010	3040	3080	3110	3150	3180	3210	3250	3280										54
55	2940	2980	3020	3050	3090	3120	3160	3190	3230	3260	3290	3330										55
56	2990	3020	3060	3100	3130	3170	3200	3240	3270	3310	3340	3370										56
57	3040	3080	3120	3150	3190	3230	3260	3300	3330	3370	3400	3440										57
58	3080	3120	3160	3200	3240	3270	3310	3350	3380	3420	3450	3490										58
59	3130	3170	3200	3240	3280	3320	3350	3390	3430	3460	3500	3530										59
60	3170	3210	3250	3290	3320	3360	3400	3440	3470	3510	3550	3580										60
61	3210	3250	3290	3330	3370	3410	3440	3480	3520	3560	3590	3630										61
62	3240	3280	3320	3360	3400	3440	3480	3510	3550	3590	3620	3660										62
63	3280	3320	3360	3400	3440	3480	3520	3560	3600	3630	3670	3710										63
64	3320	3360	3410	3450	3490	3530	3570	3600	3640	3680	3720	3760										64
65	3370	3410	3450	3490	3530	3570	3610	3650	3690	3730	3770	3800										65
66	3410	3450	3490	3530	3580	3620	3660	3700	3740	3770	3810	3850										66
67	3440	3480	3520	3560	3610	3650	3690	3730	3770	3810	3840	3880										67
68	3460	3510	3550	3590	3630	3680	3720	3760	3800	3840	3880	3920										68
69	3510	3550	3590	3640	3680	3720	3760	3800	3840	3880	3920	3960										69
70	3550	3590	3640	3680	3720	3770	3810	3850	3890	3930	3970	4010										70
71	3590	3640	3680	3720	3770	3810	3850	3890	3940	3980	4020	4060										71
72	3620	3660	3710	3750	3800	3840	3880	3930	3970	4010	4050	4090										72
73	3660	3710	3750	3800	3840	3890	3930	3970	4010	4060	4100	4140										73
74	3700	3750	3800	3840	3890	3930	3970	4020	4060	4100	4140	4190										74
75	3730	3780	3820	3870	3920	3960	4000	4050	4090	4130	4180	4220										75
76	3770	3820	3870	3910	3960	4000	4050	4090	4140	4180	4220	4270										76
77	3800	3850	3900	3940	3990	4030	4080	4120	4170	4210	4250	4300										77
78	3830	3880	3930	3970	4020	4060	4110	4150	4200	4240	4290	4330										78
79	3870	3910	3960	4010	4060	4100	4150	4190	4240	4280	4330	4370										79
80	3900	3950	4000	4050	4090	4140	4190	4230	4280	4320	4360	4410										80
81	3930	3980	4030	4070	4120	4170	4220	4260	4310	4350	4400	4440										81
82	3960	4010	4060	4100	4150	4200	4250	4290	4340	4380	4430	4470										82
83	4000	4050	4100	4150	4200	4240	4290	4340	4380	4430	4480	4520										83
84	4030	4080	4130	4180	4230	4270	4320	4370	4410	4460	4510	4550										84
85	4060	4110	4160	4210	4260	4300	4350	4400	4450	4490	4540	4580										85
86	4080	4130	4190	4240	4280	4330	4380	4430	4480	4520	4570	4620										86
87	4110	4160	4210	4260	4310	4360	4410	4460	4510	4550	4600	4650										87
88	4130	4180	4230	4280	4330	4380	4430	4480	4520	4570	4620	4660										88
*89	4140	4190	4240	4290	4340	4390	4440	4490	4540	4590	4630	4680										89

JULY 1974

* THE MAXIMUM VALVE OPENING SHOULD NOT EXCEED 89 PERCENT

RESERVOIR ELEVATION 1700 TO 1755
VALVE OPENING, PERCENT 51 TO 89

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
ENGINEERING LABORATORY

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE TABLES

JULY 1974

INSTRUCTIONS FOR USE OF TABLES

1. Purpose of Tables

The purpose of these tables is to provide a means of determining the discharge of the Howell-Bunger valves in the sluice tunnel at Watauga Dam. The tables are based on field discharge measurements and pressure measurements taken at several discharges in the sluice upstream from the Howell-Bunger valves. The tables give the discharge in cubic feet per second for one valve when the reservoir elevation and valve opening are known throughout the complete range of normal operating conditions. These tables supersede the tables dated August 1971.

2. Arrangement and Use of Tables

The tables give the discharge in cubic feet per second per valve for each 5-foot interval of headwater between reservoir elevations 1800 and 1985, and for each 1 percent of valve opening between 7 percent and 92 percent valve positions. Discharges are tabulated only to the nearest 10 cubic feet per second because the accuracy of the field measurements does not warrant greater refinement. It is possible to set any discharge within 40 cubic feet per second by using the tabular values. This tolerance has been accepted by the Division of Water Control Planning and, therefore, *it will not be necessary to interpolate* between tabular entries in these tables.

The reservoir elevation values used in the tables are those given by the recorder in the control room. The valve opening used in the tables is that indicated by the pointer on the valve control mechanism.

The arrangement of tables is such that the discharge over the entire range of valve openings for a 100-foot range of reservoir elevation is on two consecutive pages. For example, discharges are given on pages 2 and 3 for reservoir elevations 1800 through 1900. Discharges should be taken from the table for the tabulated values nearest to those observed. For example, if the reservoir is at elevation 1858.76 and the valve number 1 opening is 76.4 percent, the discharge is found on page 3, in the column headed 1860 opposite a valve opening of 76 percent, as 3220 cubic feet per second. If valve number 2 were set at 56.6 percent at the same time when valve number 1 was operating as given above, the discharge for valve number 2 would be found on page 3, in the column headed 1860 opposite a valve opening of 57 percent, as 2560 cubic feet per second. The total discharge would be the sum of the discharges of the two valves or 5780 cubic feet per second.

3. Valve Opening for Maximum and Minimum Discharge

Maximum discharge for the Howell-Bunger valves at Watauga Dam occurs at 92 percent valve opening. At valve openings greater than 92 percent the discharge becomes less. Therefore, the valves should not be operated beyond 92 percent. No tabular data are presented for such operation.

Minimum valve openings should not be less than 7 percent because of cavitation effects. No tabular values are given for such operation.

4. Adjustment of Valve Opening Indicator

At the time the field measurements were made, the valve opening indicator showed an opening of 3 percent when the valve was closed. In case of repairs to or adjustment of the valve and its control mechanism, the pointer should be reset to zero position so that the tables will still be applicable.

July 1974

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1800	1805	1810	1815	1820	1825	1830	1835	1840	1845	1850	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	
6																						6
* 7	130	130	130	140	140	140	150	150	150	150	160	160	160	170	170	170	170	180	180	180	180	7
8	150	160	160	170	170	170	180	180	190	190	190	200	200	200	200	210	210	210	220	220	220	8
9	190	200	200	210	210	220	220	230	230	240	240	240	250	250	260	260	260	270	270	270	280	9
10	220	230	240	240	250	250	260	260	270	270	280	280	290	290	300	300	310	310	310	320	320	10
11	270	270	280	290	290	300	300	310	320	320	330	330	340	350	350	360	360	370	370	380	380	11
12	310	310	320	330	340	340	350	360	370	370	380	390	390	400	400	410	420	420	430	430	440	12
13	340	350	360	370	380	390	400	400	410	420	430	430	440	450	460	460	470	480	480	490	500	13
14	390	400	410	420	430	440	450	450	460	470	480	490	500	500	510	520	530	530	540	550	560	14
15	430	440	450	470	480	490	500	510	520	530	530	540	550	560	570	580	590	600	600	610	620	15
16	480	490	500	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	16
17	530	540	550	570	580	590	600	620	630	640	650	660	670	680	690	700	710	720	730	740	750	17
18	570	590	600	620	630	650	660	670	690	700	710	720	740	750	760	770	780	790	800	810	830	18
19	620	640	650	670	680	700	710	730	740	760	770	780	800	810	820	830	850	860	870	880	890	19
20	660	680	700	720	730	750	760	780	790	810	820	840	850	860	880	890	900	920	930	940	960	20
21	710	720	740	760	780	790	810	830	840	860	870	890	900	920	930	950	960	970	990	1000	1010	21
22	750	770	790	810	820	840	860	880	890	910	930	940	960	970	990	1000	1020	1030	1050	1060	1080	22
23	790	810	830	850	870	890	910	930	940	960	980	990	1010	1030	1040	1060	1070	1090	1110	1120	1130	23
24	830	850	870	890	910	930	950	970	990	1000	1020	1040	1060	1070	1090	1110	1120	1140	1160	1170	1190	24
25	860	880	910	930	950	970	990	1010	1030	1050	1070	1090	1100	1120	1140	1160	1170	1190	1210	1220	1240	25
26	900	920	950	970	990	1010	1030	1050	1070	1090	1110	1130	1150	1170	1190	1210	1220	1240	1260	1280	1290	26
27	930	960	980	1010	1030	1050	1070	1100	1120	1140	1160	1180	1200	1220	1240	1250	1270	1290	1310	1330	1340	27
28	970	990	1020	1040	1070	1090	1110	1140	1160	1180	1200	1220	1240	1260	1280	1300	1320	1340	1360	1370	1390	28
29	1010	1030	1060	1080	1110	1130	1160	1180	1200	1230	1250	1270	1290	1310	1330	1350	1370	1390	1410	1430	1450	29
30	1050	1070	1100	1130	1150	1180	1200	1230	1250	1270	1300	1320	1340	1360	1380	1400	1420	1440	1460	1480	1500	30
31	1090	1120	1150	1170	1200	1230	1250	1280	1300	1330	1350	1370	1400	1420	1440	1460	1480	1500	1530	1550	1570	31
32	1130	1160	1190	1220	1240	1270	1300	1320	1350	1370	1400	1420	1440	1470	1490	1510	1540	1560	1580	1600	1620	32
33	1160	1190	1220	1250	1280	1310	1340	1360	1390	1410	1440	1460	1490	1510	1540	1560	1580	1600	1630	1650	1670	33
34	1200	1230	1260	1290	1320	1350	1380	1410	1430	1460	1490	1510	1540	1560	1590	1610	1630	1660	1680	1700	1730	34
35	1240	1270	1300	1340	1370	1400	1420	1450	1480	1510	1540	1560	1590	1610	1640	1660	1690	1710	1740	1760	1780	35
36	1280	1310	1350	1380	1410	1440	1470	1500	1530	1560	1580	1610	1640	1660	1690	1720	1740	1770	1790	1810	1840	36
37	1320	1350	1390	1420	1450	1480	1510	1540	1570	1600	1630	1660	1690	1710	1740	1770	1790	1820	1840	1870	1890	37
38	1360	1390	1430	1460	1490	1530	1560	1590	1620	1650	1680	1710	1740	1760	1790	1820	1850	1870	1900	1920	1950	38
39	1390	1430	1470	1500	1540	1570	1600	1630	1670	1700	1730	1760	1790	1810	1840	1870	1900	1930	1950	1980	2000	39
40	1430	1470	1510	1540	1580	1610	1650	1680	1710	1740	1780	1810	1840	1870	1890	1920	1950	1980	2010	2030	2060	40
41	1470	1510	1550	1590	1620	1660	1690	1730	1760	1790	1820	1850	1890	1920	1950	1980	2000	2030	2060	2090	2120	41
42	1500	1540	1580	1620	1650	1690	1720	1760	1790	1830	1860	1890	1920	1950	1980	2010	2040	2070	2100	2130	2160	42
43	1540	1580	1620	1650	1690	1730	1760	1800	1830	1870	1900	1930	1970	2000	2030	2060	2090	2120	2150	2180	2210	43
44	1570	1620	1660	1700	1730	1770	1810	1840	1880	1910	1950	1980	2020	2050	2080	2110	2140	2170	2200	2230	2260	44
45	1610	1650	1690	1730	1770	1810	1850	1880	1920	1960	1990	2030	2060	2090	2120	2160	2190	2220	2250	2280	2310	45
46	1640	1690	1730	1770	1810	1850	1890	1920	1960	2000	2030	2070	2100	2140	2170	2200	2230	2270	2300	2330	2360	46
47	1680	1720	1760	1800	1850	1890	1930	1960	2000	2040	2070	2110	2150	2180	2210	2250	2280	2310	2350	2380	2410	47
48	1700	1750	1790	1840	1880	1920	1960	2000	2040	2070	2110	2150	2180	2220	2250	2290	2320	2350	2390	2420	2450	48
49	1740	1780	1830	1870	1920	1960	2000	2040	2080	2120	2150	2190	2230	2260	2300	2330	2370	2400	2430	2470	2500	49
50	1770	1820	1860	1910	1950	1990	2040	2080	2120	2160	2190	2230	2270	2310	2340	2380	2410	2450	2480	2510	2550	50
51	1800	1850	1900	1940	1980	2030	2070	2110	2150	2190	2230	2270	2310	2340	2380	2420	2450	2490	2520	2560	2590	51
52	1830	1880	1930	1970	2020	2060	2100	2150	2190	2230	2270	2310	2340	2380	2420	2460	2490	2530	2560	2600	2630	52
53	1870	1920	1970	2010	2060	2100	2150	2190	2230	2270	2310	2350	2390	2430	2470	2510	2540	2580	2620	2650	2690	53
54	1900	1950	2000	2040	2090	2140	2180	2220	2270	2310	2350	2390	2430	2470	2510	2550	2580	2620	2660	2690	2730	54
55	1930	1980	2030	2080	2120	2170	2210	2260	2300	2340	2390	2430	2470	2510	2550	2590	2620	2660	2700	2730	2770	55

JULY 1974

* THE MINIMUM ALLOWABLE VALVE OPENING IS 7 PERCENT

RESERVOIR ELEVATION 1800 TO 1900
VALVE OPENING, PERCENT 7 TO 55

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1800	1805	1810	1815	1820	1825	1830	1835	1840	1845	1850	1855	1860	1865	1870	1875	1880	1885	1890	1895	1900	
56	1970	2020	2070	2120	2170	2210	2260	2300	2350	2390	2430	2480	2520	2560	2600	2640	2680	2710	2750	2790	2830	56
57	2000	2050	2100	2150	2200	2250	2290	2340	2380	2430	2470	2510	2560	2600	2640	2680	2720	2750	2790	2830	2870	57
58	2020	2080	2130	2180	2230	2280	2330	2370	2420	2460	2510	2550	2590	2630	2680	2720	2760	2790	2830	2870	2910	58
59	2050	2110	2160	2210	2260	2310	2360	2410	2450	2500	2540	2590	2630	2670	2710	2750	2800	2840	2870	2910	2950	59
60	2090	2150	2200	2250	2300	2350	2400	2450	2500	2550	2590	2640	2680	2720	2760	2810	2850	2890	2930	2970	3010	60
61	2120	2180	2230	2280	2340	2390	2440	2490	2530	2580	2630	2670	2720	2760	2800	2850	2890	2930	2970	3010	3050	61
62	2150	2210	2260	2320	2370	2420	2470	2520	2570	2620	2660	2710	2750	2800	2840	2880	2930	2970	3010	3050	3090	62
63	2180	2240	2290	2350	2400	2450	2500	2550	2600	2650	2700	2750	2790	2840	2880	2920	2970	3010	3050	3090	3130	63
64	2210	2270	2320	2380	2430	2490	2540	2590	2640	2690	2730	2780	2830	2870	2920	2960	3010	3050	3090	3130	3170	64
65	2230	2290	2340	2400	2450	2510	2560	2610	2660	2710	2760	2810	2850	2900	2940	2990	3030	3080	3120	3160	3200	65
66	2260	2320	2370	2430	2490	2540	2590	2640	2700	2750	2790	2840	2890	2940	2980	3030	3070	3120	3160	3200	3240	66
67	2290	2350	2400	2460	2520	2570	2630	2680	2730	2780	2830	2880	2930	2970	3020	3070	3110	3160	3200	3240	3290	67
68	2320	2380	2440	2490	2550	2610	2660	2710	2760	2820	2870	2920	2960	3010	3060	3110	3150	3200	3240	3280	3330	68
69	2340	2410	2470	2520	2580	2640	2690	2750	2800	2850	2900	2950	3000	3050	3100	3140	3190	3240	3280	3330	3370	69
70	2360	2430	2490	2550	2600	2660	2720	2770	2820	2880	2930	2980	3030	3080	3120	3170	3220	3260	3310	3350	3400	70
71	2380	2450	2510	2570	2620	2680	2740	2790	2850	2900	2950	3000	3050	3100	3150	3200	3240	3290	3340	3380	3420	71
72	2410	2480	2540	2600	2660	2710	2770	2830	2880	2930	2990	3040	3090	3140	3190	3240	3280	3330	3380	3420	3470	72
73	2440	2510	2570	2630	2690	2750	2800	2860	2920	2970	3020	3070	3130	3180	3230	3270	3320	3370	3420	3460	3510	73
74	2470	2540	2600	2660	2720	2780	2840	2890	2950	3000	3060	3110	3160	3210	3260	3310	3360	3410	3460	3500	3550	74
75	2490	2560	2620	2680	2740	2800	2860	2920	2970	3030	3080	3140	3190	3240	3290	3340	3390	3440	3480	3530	3580	75
76	2520	2580	2650	2710	2770	2830	2890	2950	3010	3060	3120	3170	3220	3280	3330	3380	3430	3480	3530	3570	3620	76
77	2550	2610	2680	2740	2810	2870	2930	2990	3040	3100	3150	3210	3260	3310	3370	3420	3470	3520	3570	3610	3660	77
78	2570	2630	2700	2760	2830	2890	2950	3010	3070	3120	3180	3230	3290	3340	3390	3440	3490	3540	3590	3640	3690	78
79	2600	2660	2730	2800	2860	2920	2980	3040	3100	3160	3210	3270	3320	3380	3430	3480	3530	3580	3630	3680	3730	79
80	2620	2680	2750	2820	2880	2940	3000	3060	3120	3180	3240	3290	3350	3400	3460	3510	3560	3610	3660	3710	3760	80
81	2630	2700	2770	2840	2900	2970	3030	3090	3150	3200	3260	3320	3370	3430	3480	3530	3590	3640	3690	3740	3790	81
82	2660	2730	2800	2860	2930	2990	3050	3120	3180	3230	3290	3350	3400	3460	3510	3570	3620	3670	3720	3770	3820	82
83	2680	2750	2820	2890	2960	3020	3080	3140	3200	3260	3320	3380	3440	3490	3550	3600	3650	3700	3760	3810	3860	83
84	2700	2770	2840	2910	2980	3040	3100	3170	3230	3290	3350	3400	3460	3520	3570	3630	3680	3730	3780	3830	3880	84
85	2720	2790	2860	2930	3000	3060	3130	3190	3250	3310	3370	3430	3490	3540	3600	3650	3700	3760	3810	3860	3910	85
86	2750	2820	2890	2960	3030	3100	3160	3220	3290	3350	3410	3460	3520	3580	3640	3690	3740	3800	3850	3900	3950	86
87	2770	2840	2910	2980	3050	3120	3180	3250	3310	3370	3430	3490	3550	3600	3660	3720	3770	3820	3880	3930	3980	87
88	2790	2860	2930	3000	3070	3140	3200	3270	3330	3390	3450	3510	3570	3630	3690	3740	3800	3850	3900	3960	4010	88
89	2810	2880	2960	3030	3090	3160	3230	3290	3350	3420	3480	3540	3600	3650	3710	3770	3820	3880	3930	3990	4040	89
90	2830	2900	2980	3050	3120	3180	3250	3310	3380	3440	3500	3560	3620	3680	3740	3790	3850	3900	3960	4010	4070	90
91	2840	2910	2990	3060	3130	3190	3260	3330	3390	3450	3510	3570	3630	3690	3750	3810	3860	3920	3970	4030	4080	91
*92	2850	2920	3000	3070	3140	3210	3270	3340	3400	3460	3530	3590	3650	3710	3760	3820	3880	3930	3990	4040	4090	92

JULY 1974

* THE MAXIMUM VALVE OPENING SHOULD NOT EXCEED 92 PERCENT

RESERVOIR ELEVATION 1800 TO 1900
VALVE OPENING, PERCENT 56 TO 92

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985				
6																						6
* 7	180	180	190	190	190	190	200	200	200	200	200	210	210	210	210	210	220	220				7
8	220	230	230	230	230	240	240	240	240	250	250	250	250	260	260	260	260	270				8
9	280	280	290	290	290	300	300	300	310	310	310	320	320	320	320	330	330	330				9
10	320	330	330	340	340	340	350	350	350	360	360	370	370	370	380	380	380	390				10
11	380	390	390	400	400	410	410	410	420	420	430	430	440	440	450	450	450	460				11
12	440	450	450	460	460	470	470	480	480	490	490	500	500	510	510	520	520	530				12
13	500	500	510	510	520	530	530	540	540	550	560	560	570	570	580	580	590	590				13
14	560	560	570	580	580	590	600	610	610	620	620	630	640	640	650	660	660	670				14
15	620	630	640	640	650	660	670	670	680	690	700	700	710	720	720	730	740	740				15
16	690	700	710	720	720	730	740	750	760	760	770	780	790	800	800	810	820	830				16
17	750	760	770	780	790	800	810	820	830	840	850	850	860	870	880	890	900	910				17
18	830	840	850	860	870	880	890	900	910	920	930	940	940	950	960	970	980	990				18
19	890	910	920	930	940	950	960	970	980	990	1000	1010	1020	1030	1040	1050	1060	1070				19
20	960	970	980	990	1000	1010	1030	1040	1050	1060	1070	1080	1090	1100	1110	1120	1140	1150				20
21	1010	1030	1040	1050	1070	1080	1090	1100	1110	1130	1140	1150	1160	1170	1180	1200	1210	1220				21
22	1080	1090	1100	1120	1130	1140	1160	1170	1180	1190	1210	1220	1230	1240	1260	1270	1280	1290				22
23	1130	1150	1160	1180	1190	1210	1220	1230	1250	1260	1270	1290	1300	1310	1320	1340	1350	1360				23
24	1190	1200	1220	1230	1250	1260	1270	1290	1300	1320	1330	1340	1360	1370	1380	1400	1410	1420				24
25	1240	1250	1270	1290	1300	1320	1330	1350	1360	1380	1390	1400	1420	1430	1450	1460	1470	1490				25
26	1290	1310	1330	1340	1360	1370	1390	1410	1420	1440	1450	1470	1480	1490	1510	1520	1540	1550				26
27	1340	1360	1380	1390	1410	1430	1440	1460	1480	1490	1510	1520	1540	1550	1570	1580	1600	1610				27
28	1390	1410	1430	1450	1460	1480	1500	1510	1530	1550	1560	1580	1590	1610	1620	1640	1650	1670				28
29	1450	1470	1480	1500	1520	1540	1560	1570	1590	1610	1620	1640	1660	1670	1690	1710	1720	1740				29
30	1500	1520	1540	1560	1580	1600	1620	1630	1650	1670	1690	1700	1720	1740	1750	1770	1790	1800				30
31	1570	1590	1610	1630	1650	1660	1680	1700	1720	1740	1760	1770	1790	1810	1830	1840	1860	1880				31
32	1620	1640	1660	1680	1700	1720	1740	1760	1780	1800	1820	1840	1860	1870	1890	1910	1930	1950				32
33	1670	1690	1710	1730	1750	1780	1800	1820	1840	1850	1870	1890	1910	1930	1950	1970	1990	2000				33
34	1730	1750	1770	1790	1810	1830	1860	1880	1900	1920	1940	1960	1980	1990	2010	2030	2050	2070				34
35	1780	1800	1830	1850	1870	1890	1920	1940	1960	1980	2000	2020	2040	2060	2080	2100	2120	2140				35
36	1840	1860	1880	1910	1930	1950	1970	2000	2020	2040	2060	2080	2100	2120	2140	2160	2180	2200				36
37	1890	1920	1940	1970	1990	2010	2030	2060	2080	2100	2120	2150	2170	2190	2210	2230	2250	2270				37
38	1950	1970	2000	2020	2050	2070	2090	2120	2140	2160	2190	2210	2230	2250	2270	2300	2320	2340				38
39	2000	2030	2060	2080	2110	2130	2150	2180	2200	2230	2250	2270	2290	2320	2340	2360	2380	2400				39
40	2060	2090	2110	2140	2160	2190	2210	2240	2260	2290	2310	2330	2360	2380	2400	2430	2450	2470				40
41	2120	2140	2170	2200	2220	2250	2270	2300	2320	2350	2370	2400	2420	2450	2470	2490	2520	2540				41
42	2160	2190	2210	2240	2270	2290	2320	2340	2370	2400	2420	2450	2470	2490	2520	2540	2560	2590				42
43	2210	2240	2260	2290	2320	2340	2370	2400	2420	2450	2480	2500	2530	2550	2570	2600	2620	2650				43
44	2260	2290	2320	2350	2380	2400	2430	2460	2480	2510	2540	2560	2590	2610	2640	2660	2690	2710				44
45	2310	2340	2370	2400	2430	2460	2480	2510	2540	2570	2590	2620	2640	2670	2700	2720	2750	2770				45
46	2360	2390	2420	2450	2480	2510	2540	2560	2590	2620	2650	2670	2700	2730	2750	2780	2800	2830				46
47	2410	2440	2470	2500	2530	2560	2590	2620	2650	2670	2700	2730	2760	2780	2810	2840	2860	2890				47
48	2450	2480	2510	2540	2570	2600	2630	2660	2690	2720	2750	2780	2800	2830	2860	2890	2910	2940				48
49	2500	2530	2560	2590	2620	2660	2690	2720	2740	2770	2800	2830	2860	2890	2920	2940	2970	3000				49
50	2550	2580	2610	2640	2680	2710	2740	2770	2800	2830	2860	2890	2920	2940	2970	3000	3030	3060				50
51	2590	2620	2660	2690	2720	2750	2780	2810	2840	2870	2900	2930	2960	2990	3020	3050	3080	3110				51
52	2630	2670	2700	2730	2760	2800	2830	2860	2890	2920	2950	2980	3010	3040	3070	3100	3130	3160				52
53	2690	2720	2760	2790	2820	2860	2890	2920	2950	2980	3010	3040	3070	3110	3130	3160	3190	3220				53
54	2730	2760	2800	2830	2870	2900	2930	2960	3000	3030	3060	3090	3120	3150	3180	3210	3240	3270				54
55	2770	2810	2840	2880	2910	2940	2980	3010	3040	3080	3110	3140	3170	3200	3230	3260	3290	3320				55

JULY 1974

* THE MINIMUM ALLOWABLE
GATE OPENING IS 7 PERCENT

RESERVOIR ELEVATION 1900 TO 1985
VALVE OPENING, PERCENT 7 TO 55

WATAUGA DAM

HOWELL-BUNGER VALVE DISCHARGE

IN CUBIC FEET PER SECOND

TENNESSEE VALLEY AUTHORITY

ENGINEERING LABORATORY

VALVE OPENING PERCENT	RESERVOIR ELEVATION																					VALVE OPENING PERCENT
	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945	1950	1955	1960	1965	1970	1975	1980	1985				
56	2830	2860	2900	2930	2970	3000	3040	3070	3100	3140	3170	3200	3230	3270	3300	3330	3360	3390				56
57	2870	2900	2940	2980	3010	3050	3080	3120	3150	3180	3220	3250	3280	3310	3350	3380	3410	3440				57
58	2910	2950	2980	3020	3060	3090	3130	3160	3200	3230	3260	3300	3330	3360	3390	3430	3460	3490				58
59	2950	2990	3030	3060	3100	3140	3170	3210	3240	3280	3310	3340	3380	3410	3440	3480	3510	3540				59
60	3010	3050	3080	3120	3160	3200	3230	3270	3300	3340	3370	3410	3440	3480	3510	3540	3570	3610				60
61	3050	3090	3130	3160	3200	3240	3280	3310	3350	3380	3420	3450	3490	3520	3560	3590	3620	3660				61
62	3090	3130	3170	3210	3250	3280	3320	3360	3390	3430	3470	3500	3540	3570	3610	3640	3670	3710				62
63	3130	3170	3210	3250	3290	3330	3370	3400	3440	3480	3510	3550	3580	3620	3650	3690	3720	3760				63
64	3170	3220	3260	3290	3330	3370	3410	3450	3490	3520	3560	3600	3630	3670	3700	3740	3770	3810				64
65	3200	3240	3280	3320	3360	3400	3440	3480	3520	3550	3590	3630	3660	3700	3740	3770	3810	3840				65
66	3240	3290	3330	3370	3410	3450	3490	3520	3560	3600	3640	3680	3710	3750	3780	3820	3860	3890				66
67	3290	3330	3370	3410	3450	3490	3530	3570	3610	3650	3690	3720	3760	3800	3830	3870	3910	3940				67
68	3330	3370	3410	3450	3490	3540	3580	3620	3650	3690	3730	3770	3810	3850	3880	3920	3950	3990				68
69	3370	3410	3460	3500	3540	3580	3620	3660	3700	3740	3780	3820	3860	3890	3930	3970	4000	4040				69
70	3400	3440	3480	3530	3570	3610	3650	3690	3730	3770	3810	3850	3890	3930	3960	4000	4040	4070				70
71	3420	3470	3510	3560	3600	3640	3680	3720	3760	3800	3840	3880	3920	3960	4000	4030	4070	4110				71
72	3470	3510	3560	3600	3640	3680	3730	3770	3810	3850	3890	3930	3970	4010	4040	4080	4120	4160				72
73	3510	3550	3600	3640	3690	3730	3770	3810	3850	3890	3940	3980	4010	4050	4090	4130	4170	4210				73
74	3550	3600	3640	3690	3730	3770	3820	3860	3900	3940	3980	4020	4060	4100	4140	4180	4220	4260				74
75	3580	3620	3670	3710	3760	3800	3850	3890	3930	3970	4010	4050	4090	4130	4170	4210	4250	4290				75
76	3620	3670	3710	3760	3800	3850	3890	3930	3980	4020	4060	4100	4140	4180	4220	4260	4300	4340				76
77	3660	3710	3750	3800	3850	3890	3930	3980	4020	4060	4110	4150	4190	4230	4270	4310	4350	4390				77
78	3690	3740	3780	3830	3880	3920	3960	4010	4050	4100	4140	4180	4220	4260	4300	4350	4390	4430				78
79	3730	3780	3830	3870	3920	3960	4010	4050	4100	4140	4180	4230	4270	4310	4350	4390	4430	4480				79
80	3760	3810	3850	3900	3950	3990	4040	4080	4130	4170	4220	4260	4300	4340	4390	4430	4470	4510				80
81	3790	3840	3880	3930	3980	4020	4070	4110	4160	4200	4250	4290	4330	4380	4420	4460	4500	4540				81
82	3820	3870	3920	3970	4010	4060	4110	4150	4200	4240	4290	4330	4370	4420	4460	4500	4540	4580				82
83	3860	3910	3950	4000	4050	4100	4140	4190	4240	4280	4330	4370	4410	4460	4500	4540	4580	4630				83
84	3880	3930	3980	4030	4080	4130	4170	4220	4270	4310	4360	4400	4450	4490	4530	4570	4620	4660				84
85	3910	3960	4010	4060	4110	4160	4200	4250	4300	4340	4390	4430	4480	4520	4560	4610	4650	4690				85
86	3950	4000	4050	4100	4150	4200	4250	4300	4340	4390	4430	4480	4520	4570	4610	4660	4700	4740				86
87	3980	4030	4080	4130	4180	4230	4280	4330	4370	4420	4470	4510	4560	4600	4650	4690	4730	4780				87
88	4010	4060	4110	4160	4210	4260	4310	4360	4400	4450	4500	4540	4590	4630	4680	4720	4770	4810				88
89	4040	4090	4140	4190	4240	4290	4340	4390	4430	4480	4530	4570	4620	4670	4710	4750	4800	4840				89
90	4070	4120	4170	4220	4270	4320	4370	4420	4470	4510	4560	4610	4650	4700	4740	4790	4830	4880				90
91	4080	4130	4180	4230	4280	4330	4380	4430	4480	4530	4580	4620	4670	4710	4760	4800	4850	4890				91
*92	4090	4150	4200	4250	4300	4350	4400	4450	4500	4540	4590	4640	4680	4730	4780	4820	4870	4910				92

JULY 1974

* THE MAXIMUM VALVE OPENING SHOULD NOT EXCEED 92 PERCENT

RESERVOIR ELEVATION 1900 TO 1985
VALVE OPENING, PERCENT 56 TO 92

Tennessee Valley Authority
Division of Water Control Planning
Hydraulic Data Branch

Report No. 19-10-1

Advance Report No. 1

WATAUGA MODEL STUDIES

Knoxville, Tennessee
June 1944

ADVANCE REPORT NO. 1

WATAUGA MODEL STUDIES

SUMMARY

This report presents the results of tests made on models of the spillway for the Watauga project. The spillway and Howell-Bunger outlet valves for the Watauga and South Holston projects have many features in common. Advance Report No. 1, South Holston Model Studies, describes tests made on the South Holston project. The results of these tests are all applicable to the Watauga project with the exception of the discharge rating curve, the deflector at the foot of the vertical shaft, and the stilling basin. Additional studies peculiar to the Watauga project are summarized as follows:

An 8-foot deflector at the foot of the vertical shaft, placed at an angle of 30 degrees with the tunnel, gives satisfactory flow conditions in the tunnel. Plate 1 shows the location of this deflector.

No negative pressures of any consequence occurred on the spillway face. There were no excessive pressures on the deflector.

The portal design as shown on Plate 1 appeared to be satisfactory. It appeared that no additional structures were necessary to prevent dangerous erosion.

SPILLWAY OPERATION

The development of the spillway for the Watauga project was, in general, the same as for the South Holston project. Reference is made to Advance Report No. 1, South Holston Model Studies, for details. The deflector at the base of the vertical shaft of the Watauga spillway differed from that for the South Holston spillway. The same deflectors were tested as for the South Holston spillway with the same result for the 10-foot one, namely, filling of the shaft for the higher discharges. The 5-foot and 6-1/2-foot deflectors were too small to be effective. The 8-foot deflector at the bottom of the vertical shaft, located 30 degrees to the right of the tunnel, gave satisfactory performance. Moving the deflector to either side of this position caused uneven flow and standing waves in the tunnel. Figure 1 shows flow in the tunnel without the deflector, and Figure 2 shows the same flow with the deflector in its recommended position. Figure 3 shows the flow with the deflector 20 degrees to the left of the tunnel. The improvement caused by proper location of the deflector is clearly shown by these photographs.

Piezometers were located on the 1:100 scale model of the Watauga model, as shown on Plate 2. A summary of the pressures observed for various discharges is given in Table 1.

Calibration of Spillway

The spillway discharges measured on the South Holston model are also applicable to the Watauga model. Plate 3 is a curve showing the relationship between reservoir elevation and spillway discharge.

HOWELL-BUNGER VALVE OPERATION

Reference is made to Advance Report No. 1, South Holston Model Studies, for details of the structures required below the Howell-Bunger valves, both immediately below the valves, and at the Y.

EROSION STUDIES AT TUNNEL PORTAL

Tests were made on a 1:51 scale model of the Watauga tunnel outlet, as shown on Plate 1, to determine whether special treatment or structures would be necessary to prevent serious erosion at the tunnel portal. Performance without a stilling basin appeared to be satisfactory. There was no eddy action to cause serious erosion at the portal structure although deep erosion occurred in the river bed downstream. Plate 1 shows a cross section immediately below the portal as it existed after ten minutes of model operation with a spillway discharge of 60,000 cubic feet per second. The maximum erosion at the structure for this discharge was 8 feet. It seems likely that a 10-foot cut-off wall at the portal would prevent damage for a considerable period of time.

ACKNOWLEDGMENTS

This investigation was conducted by the Hydraulic Data Branch under the direction of Albert S. Fry, Chief of Branch. The tests were made and the report prepared in the Hydraulic Laboratory at Norris under the supervision of G. H. Hickox, Head, Hydraulic Laboratory Section. A. J. Peterka and B. R. Blackwell were in charge of the testing. They were assisted by the entire laboratory staff. The report was prepared by B. R. Blackwell.

TABLE 1

PRESSURE IN SPILLWAY

Piezometer pressures are expressed in feet of water.

Piezometer Number	Discharge in Cubic Feet Per Second							
	60,000	50,000	45,000	40,000	35,000	30,000	20,000	10,000
1	6	5	5	5	4	4	4	3
2	3	2	2	2	1	2	0	0
3	3	1	0	-1	-1	-1	0	0
4	9	6	6	6	4	2	1	1
5	10	3	2	3	2	2	0	0
6	3	4	4	4	4	4	4	3
7	2	2	2	2	2	2	1	1
8	-1	0	0	0	0	0	0	1
9	18	20	12	3	0	0	0	0
10	9	4	6	5	4	4	9	0
11a	47	31	32	7	1	2	1	1
11b	38	23	22	19	4	3	2	2
11c	28	17	27	23	20	2	1	1
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	68	70	64	56	35	14	1	-5
15	83	69	60	55	48	42	30	18
16	69	55	47	41	34	29	17	1
17	18	17	16	15	13	12	9	4

Note: Piezometer locations are shown on Plate 2.

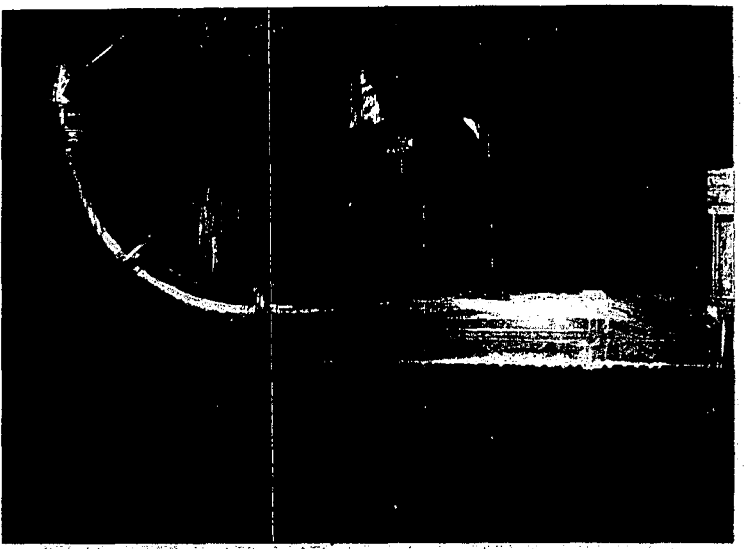


Figure 1.--Spiral flow in elbow and tunnel with no deflector in the spillway shaft. Discharge, 40,000 cubic feet per second.

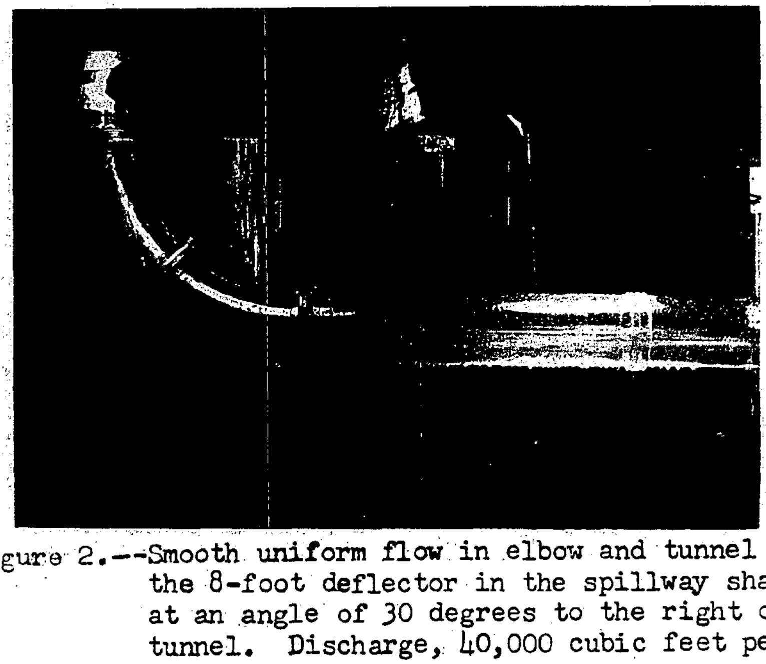


Figure 2.--Smooth uniform flow in elbow and tunnel with the 8-foot deflector in the spillway shaft at an angle of 30 degrees to the right of the tunnel. Discharge, 40,000 cubic feet per second.

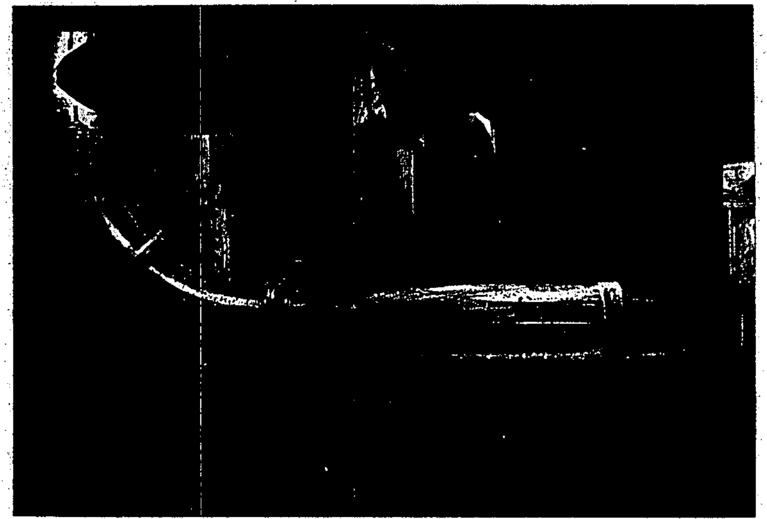
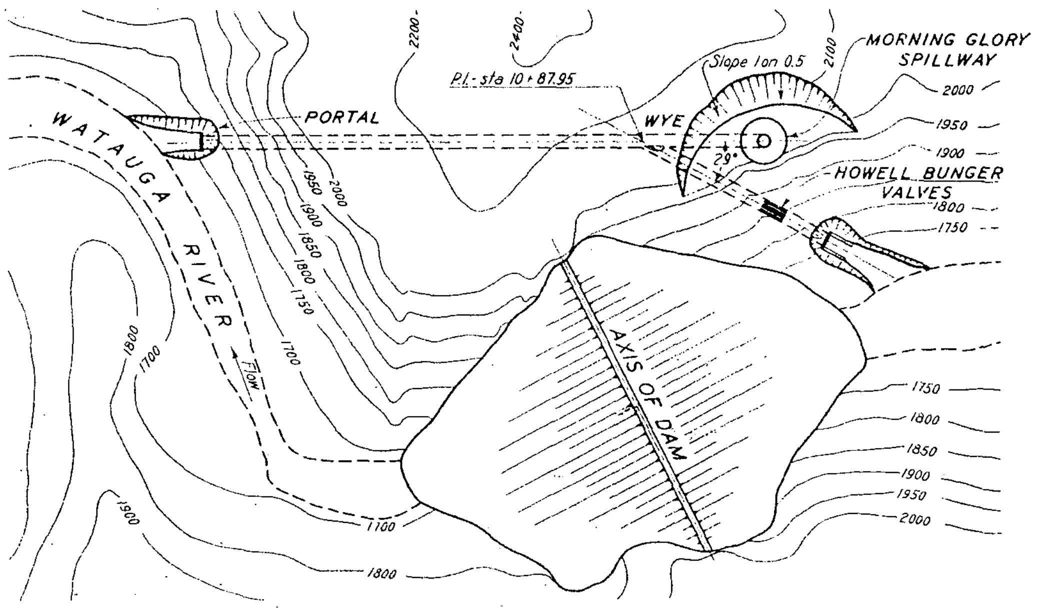
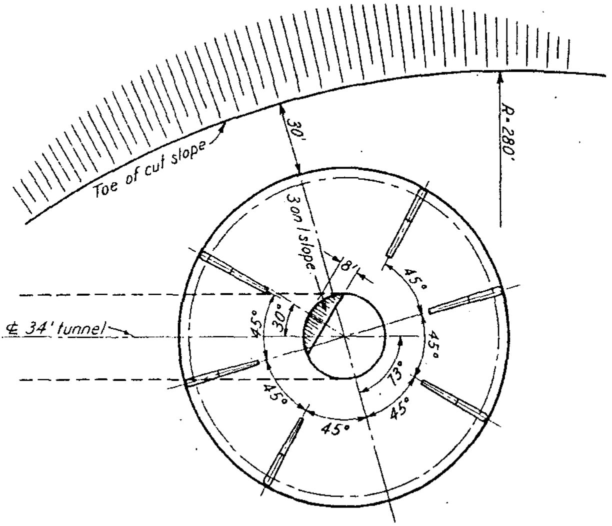


Figure 3.--Spiral flow in elbow and tunnel with the 8-foot deflector 20 degrees to the left of the tunnel. Discharge, 40,000 cubic feet per second.



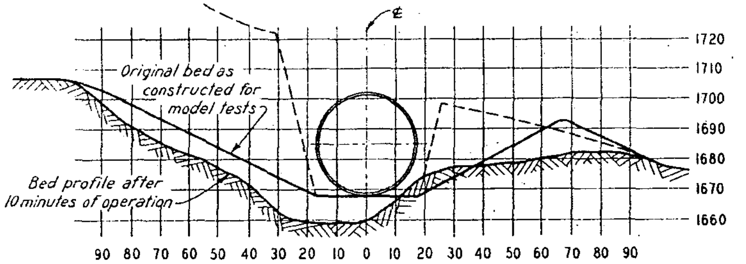
GENERAL LAYOUT

Scale 0 200 400 600 Feet



PLAN

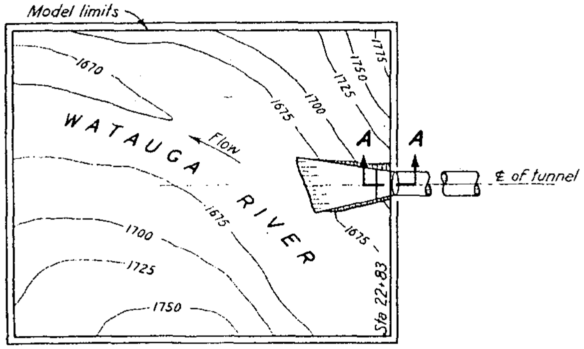
SCHEME AL



BED PROFILES AT STA 22 + 83

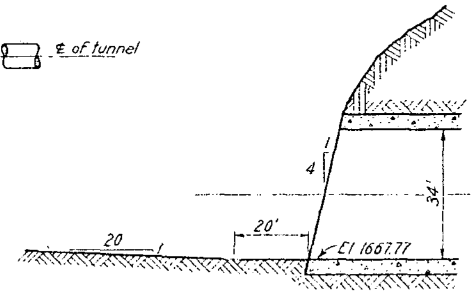
DISCHARGE = 60 000 CFS

TEST NO. 216



MODEL LAYOUT

Scale 0 100 200 300 Feet



SECTION A-A

TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

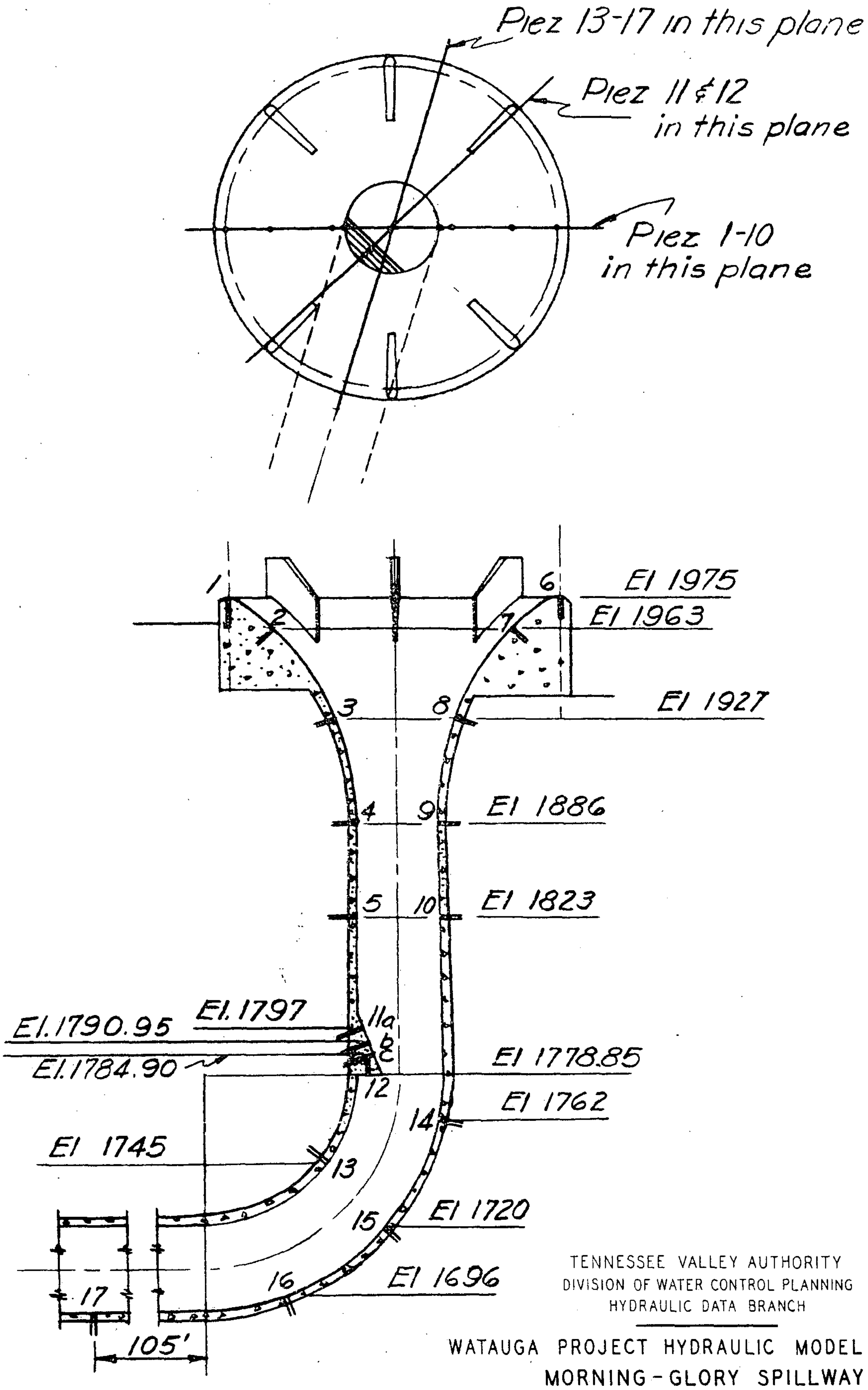
WATAUGA PROJECT HYDRAULIC MODEL STUDIES

SPILLWAY AND TUNNEL

MODEL DETAILS AND TEST RESULTS

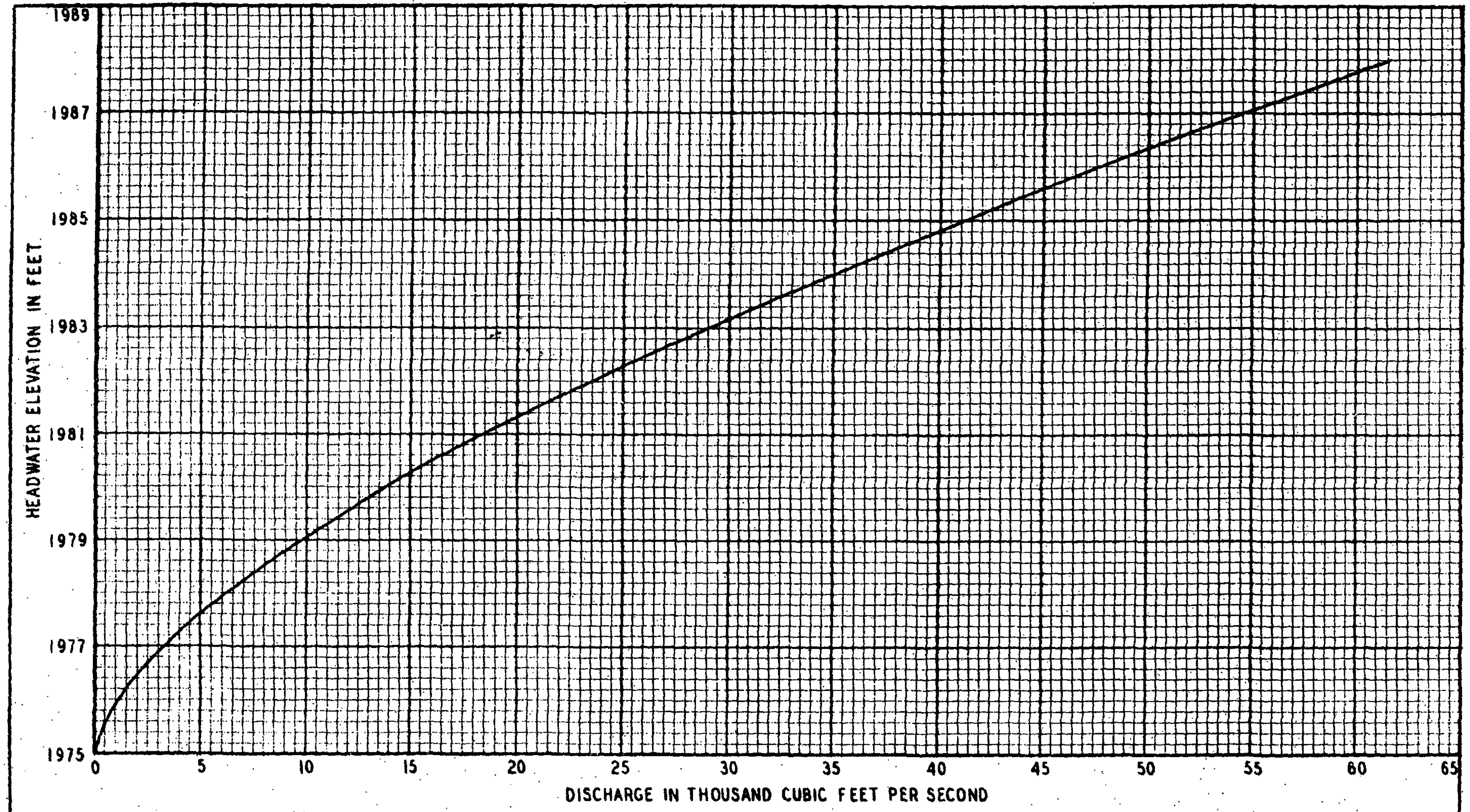
MODEL SCALES 1:34, 1:51, AND 1:100

PLATE 1



TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

WATAUGA PROJECT HYDRAULIC MODEL STUDIES
MORNING-GLORY SPILLWAY
PIEZOMETER LOCATIONS
MODEL SCALE 1:100

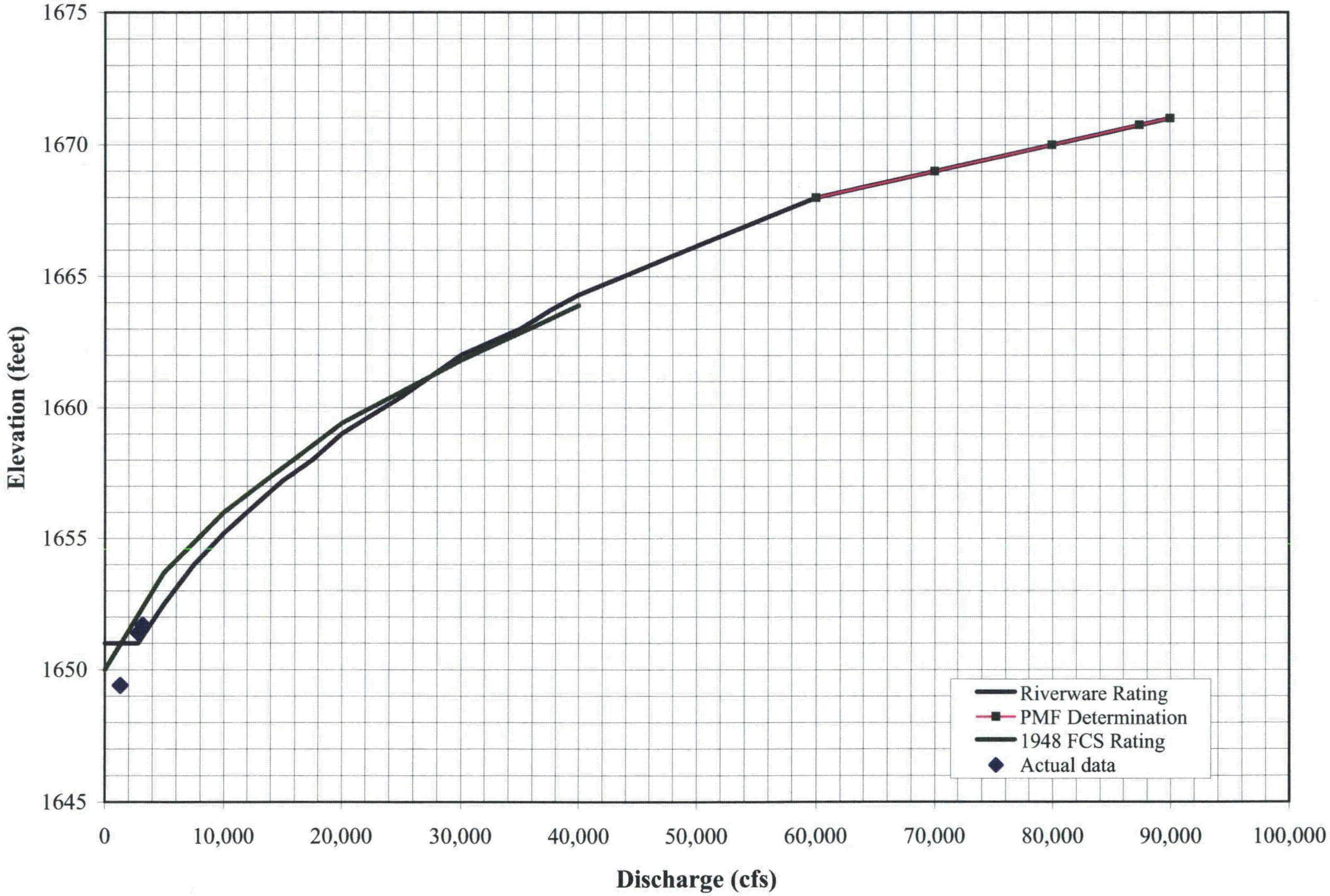


TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING
HYDRAULIC DATA BRANCH

WATAUGA PROJECT HYDRAULIC MODEL STUDIES
MORNING-GLORY SPILLWAY
SPILLWAY RATING CURVE

PLATE 3

Watauga Tailwater Rating



Watauga Tailwater Rating

Actual da
1300
2820
3200

Riverware Rating

Q*1000	Q	Elevation
0	0	1651
2.8	2,800	1651
5	5,000	1652.5
7.5	7,500	1654
10	10,000	1655.2
12.5	12,500	1656.2
15	15,000	1657.2
17.5	17,500	1658
20	20,000	1659
22.5	22,500	1659.7
25	25,000	1660.4
27.5	27,500	1661.2
30	30,000	1662
32.5	32,500	1662.5
35	35,000	1663
37.5	37,500	1663.7
40	40,000	1664.3
60	60,000	1668
70	70,000	1669
80	80,000	1670
90	90,000	1671

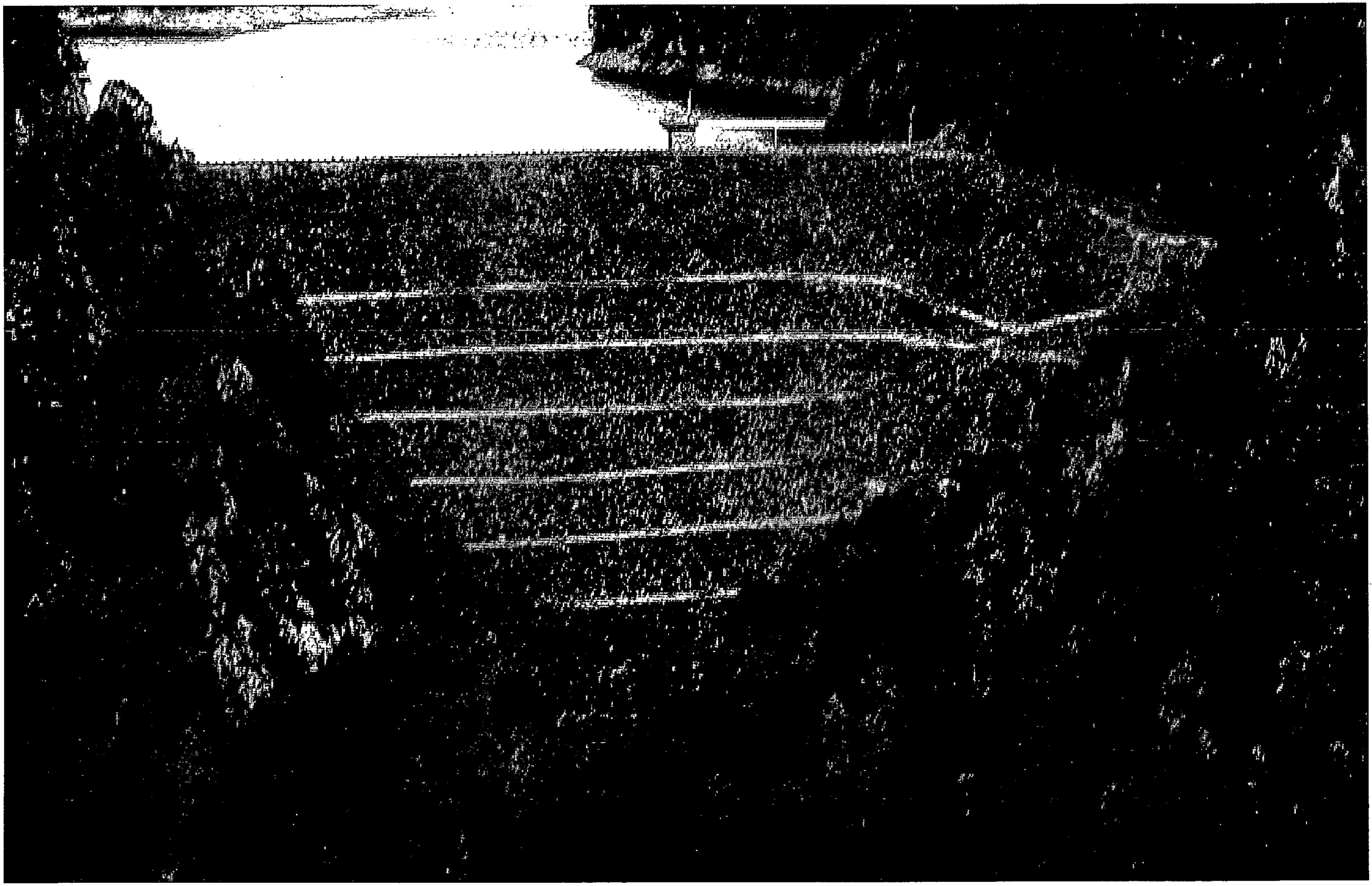
Flood Control Section 1948

Q	Elevation	
0	1650	
5,000	1653.7	
10,000	1656	
20,000	1659.4	
30,000	1661.8	
40,000	1663.9	
60,000	1668	
70,000	1669	
80,000	1670	
87,400	1670.75	**PMF**
90,000	1671	

ıta

1649.4
1651.4
1651.7

WATAUGA DAM



January 2000

RESERVOIR OPERATION OVERVIEW

Watauga is a multipurpose tributary project located on the Watauga River in northeastern Tennessee. Watauga is operated for many purposes, including flood control, augmentation of flows for navigation and water supply, hydropower production, water quality, recreation, and aquatic ecology. It is an earth and rockfill dam with two hydroelectric units installed. Construction originally began in early 1942, but was curtailed later that year in favor of other wartime construction efforts. Construction resumed in 1946, the dam was closed in 1948, and the hydroelectric units began operation in 1949.

Watauga Reservoir has an annual pool variation of about 26 feet during normal years. This fluctuation is necessary to provide for seasonal flood storage and for economical augmentation of flows during the drier seasons of the year. The pool elevation (feet above mean sea level) at Watauga is the highest of any TVA reservoir.

Table of Contents

Table of Contents (Cont.)

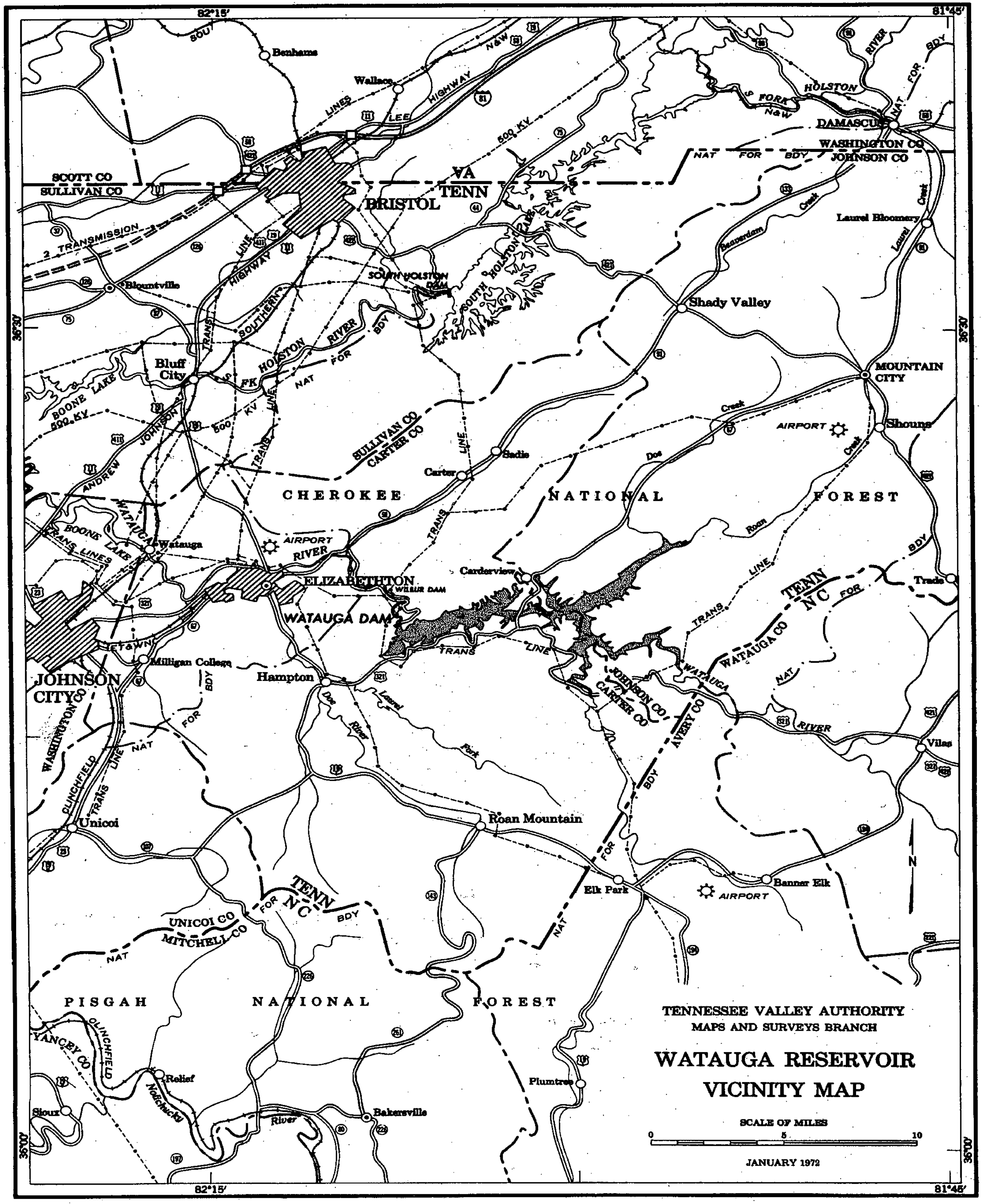
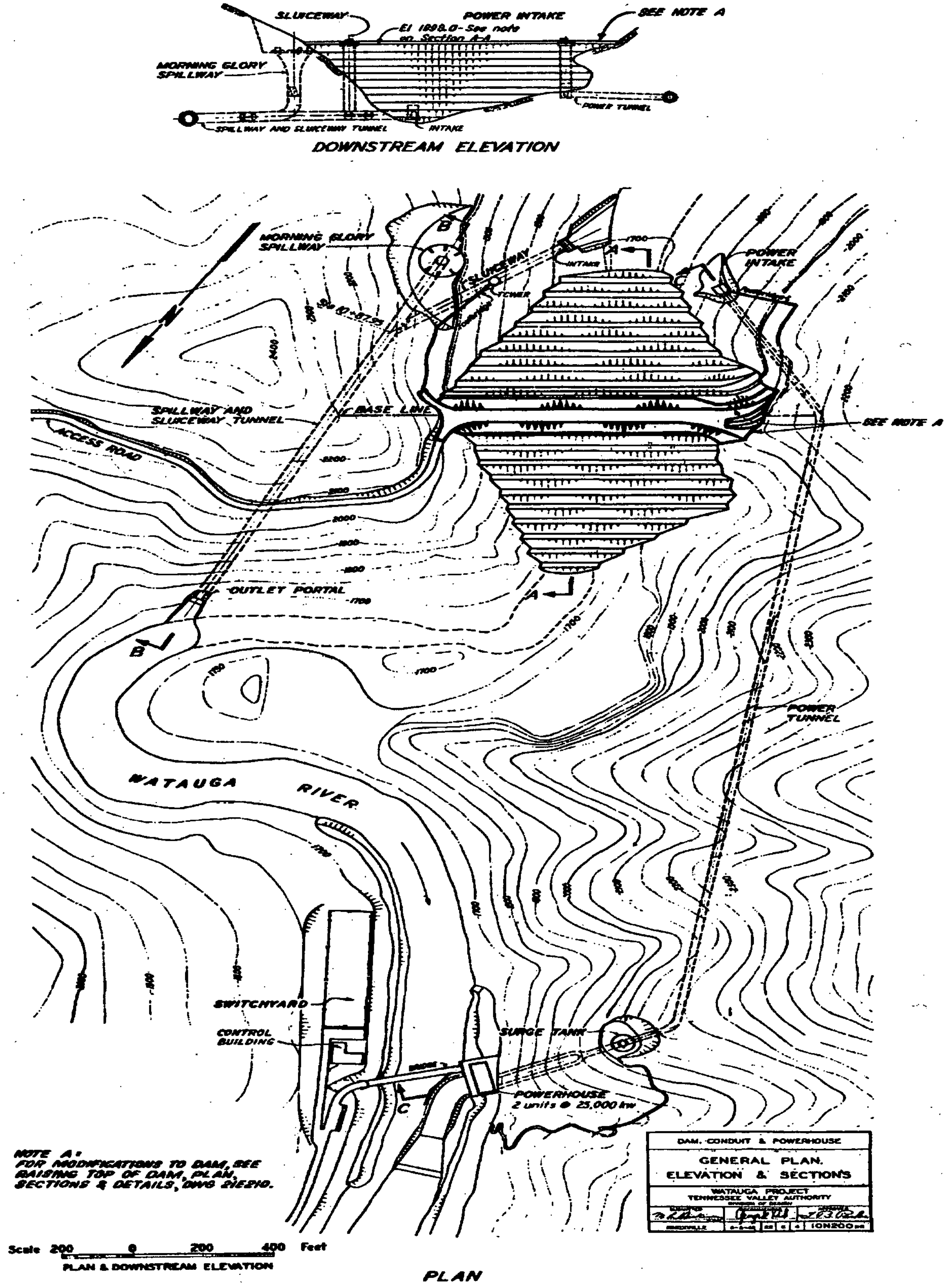
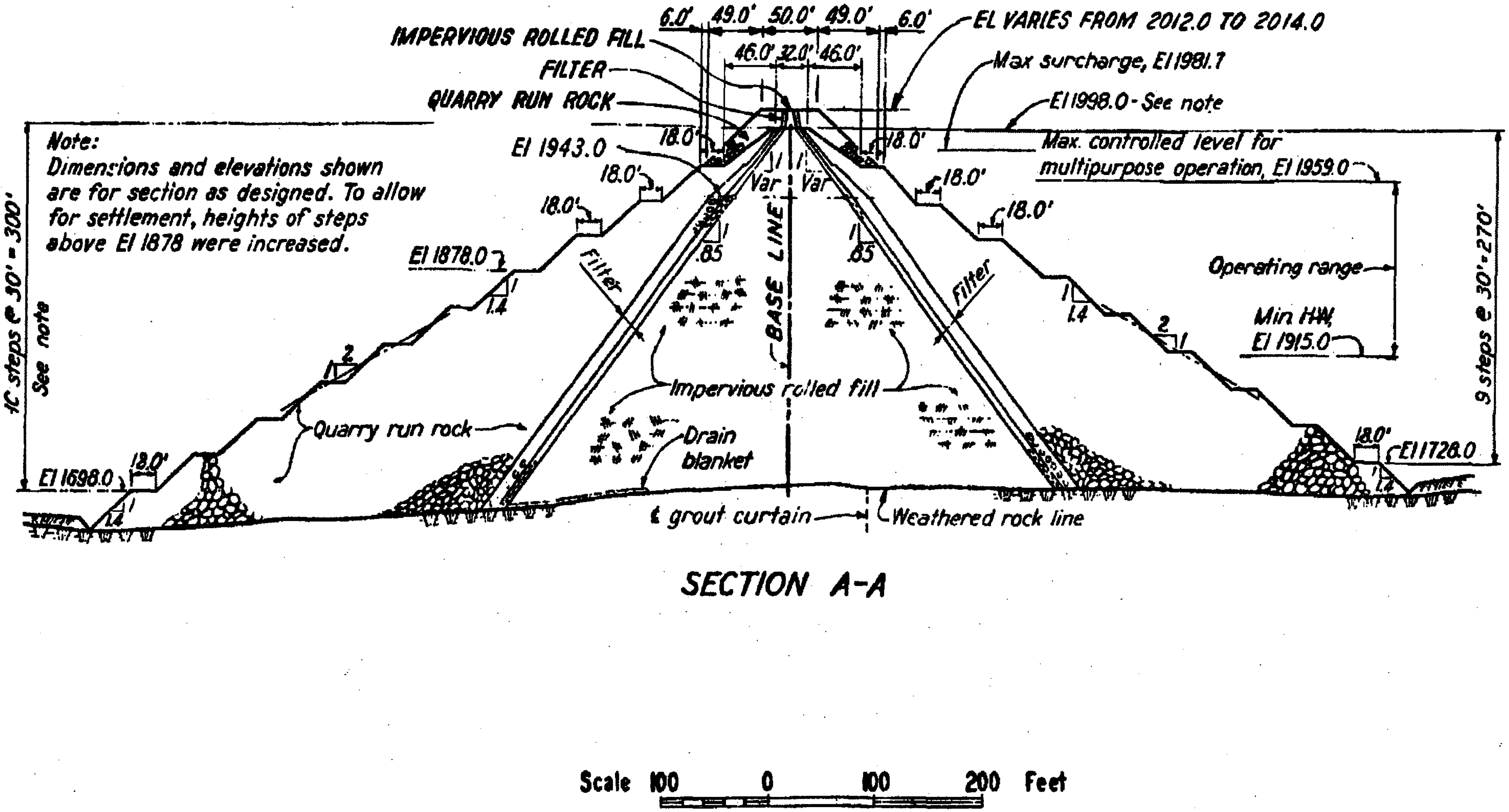

TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH
WATAUGA RESERVOIR
VICINITY MAP
SCALE OF MILES
0
5
10
JANUARY 1972
82°15′
81°45′
36°30′
36°00′
BRISTOL
VA
TENN
SCOTT CO
SULLIVAN CO
WASHINGTON CO
JOHNSON CO
DAMASCUS
Benhams
Wallace
Blountville
Bluff City
Laurel Bloomery
Shady Valley
MOUNTAIN CITY
Shouns
Sadie
Carter
Watauga
ELIZABETHTON
WILBUR DAM
WATAUGA DAM
Carderview
Trade
Milligan College
JOHNSON CITY
Hampton
Unicoi
Roan Mountain
Elk Park
Banner Elk
Vilas
Relief
Sioux
Bakersville
Plumtree
SOUTH HOLSTON DAM
SOUTH HOLSTON LAKE
BOONE LAKE
HOLSTON RIVER
S FK HOLSTON RIVER
WATAUGA RIVER
Doe River
Laurel Fork
Roan Creek
Doe Creek
Beaverdam Creek
Laurel Creek
Nolichucky River
CHEROKEE NATIONAL FOREST
PISGAH NATIONAL FOREST
SULLIVAN CO
CARTER CO
JOHNSON CO
CARTER CO
WATAUGA CO
AVERY CO
UNICOI CO
MITCHELL CO
YANCEY CO
WASHINGTON CO
TENN
NC
NAT FOR BDY
AIRPORT
500 KV
2 TRANSMISSION LINES
TRANS LINE
SOUTHERN
N&W
CLINCHFIELD
LEE HIGHWAY
ANDREW JOHNSON HIGHWAY
N

FIGURE 1 - General Plan and Downstream Elevation



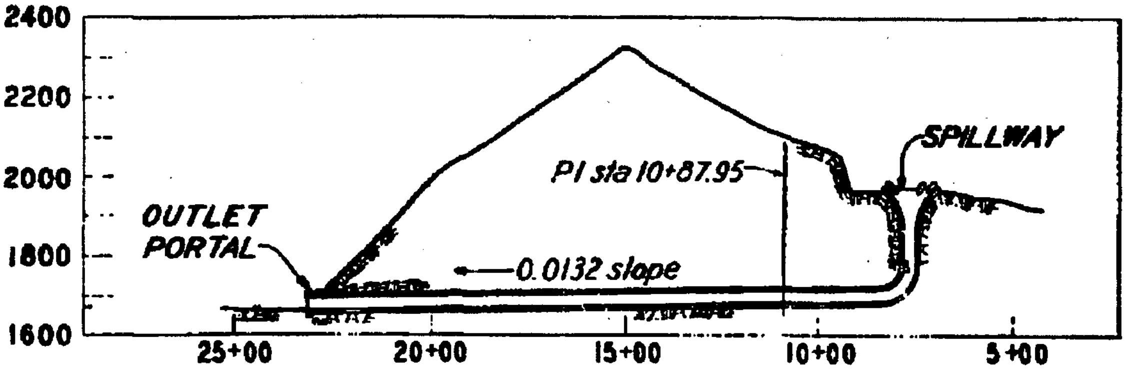
NOTE A:
FOR MODIFICATIONS TO DAM, SEE RAISING TOP OF DAM, PLAN, SECTIONS & DETAILS, DWG 21E210.

FIGURE 2 - Section A-A



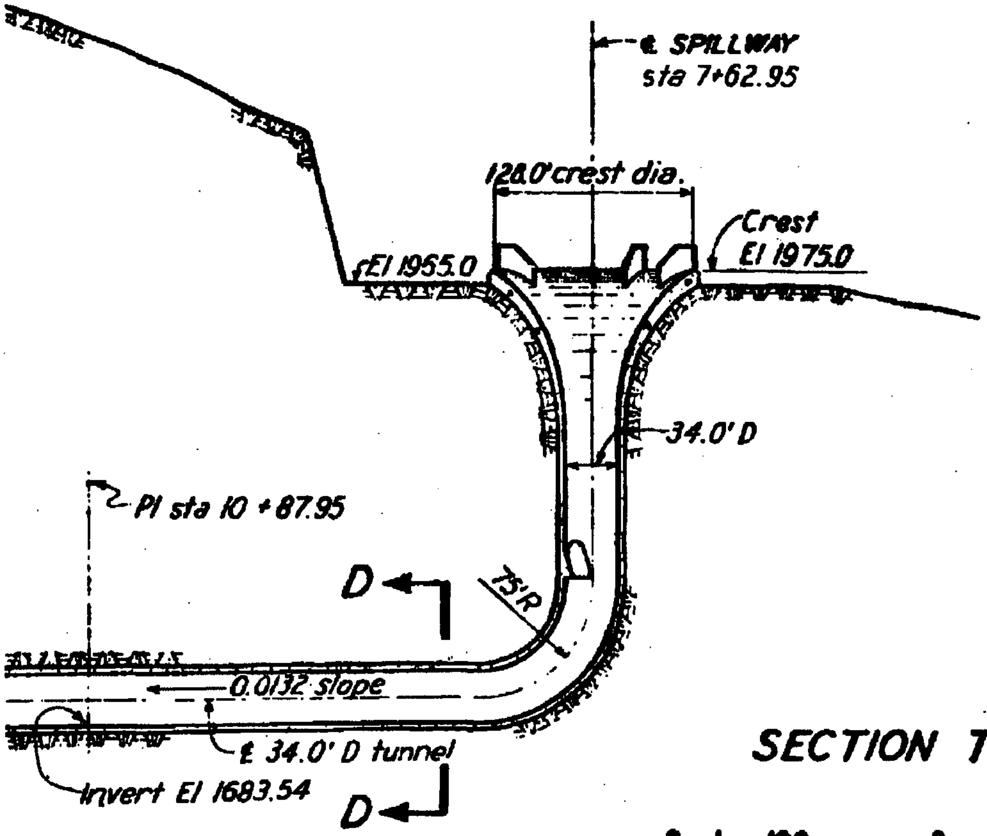
Note:
Dimensions and elevations shown are for section as designed. To allow for settlement, heights of steps above El 1878 were increased.

FIGURE 3 - Section B-B and thru Spillway



SECTION B-B

Scale 400 0 400 800 Feet



SECTION THRU SPILLWAY

Scale 100 0 100 200 Feet

FIGURE 4 - Sections C-C, Power Intake, Powerhouse, and Surge Tank

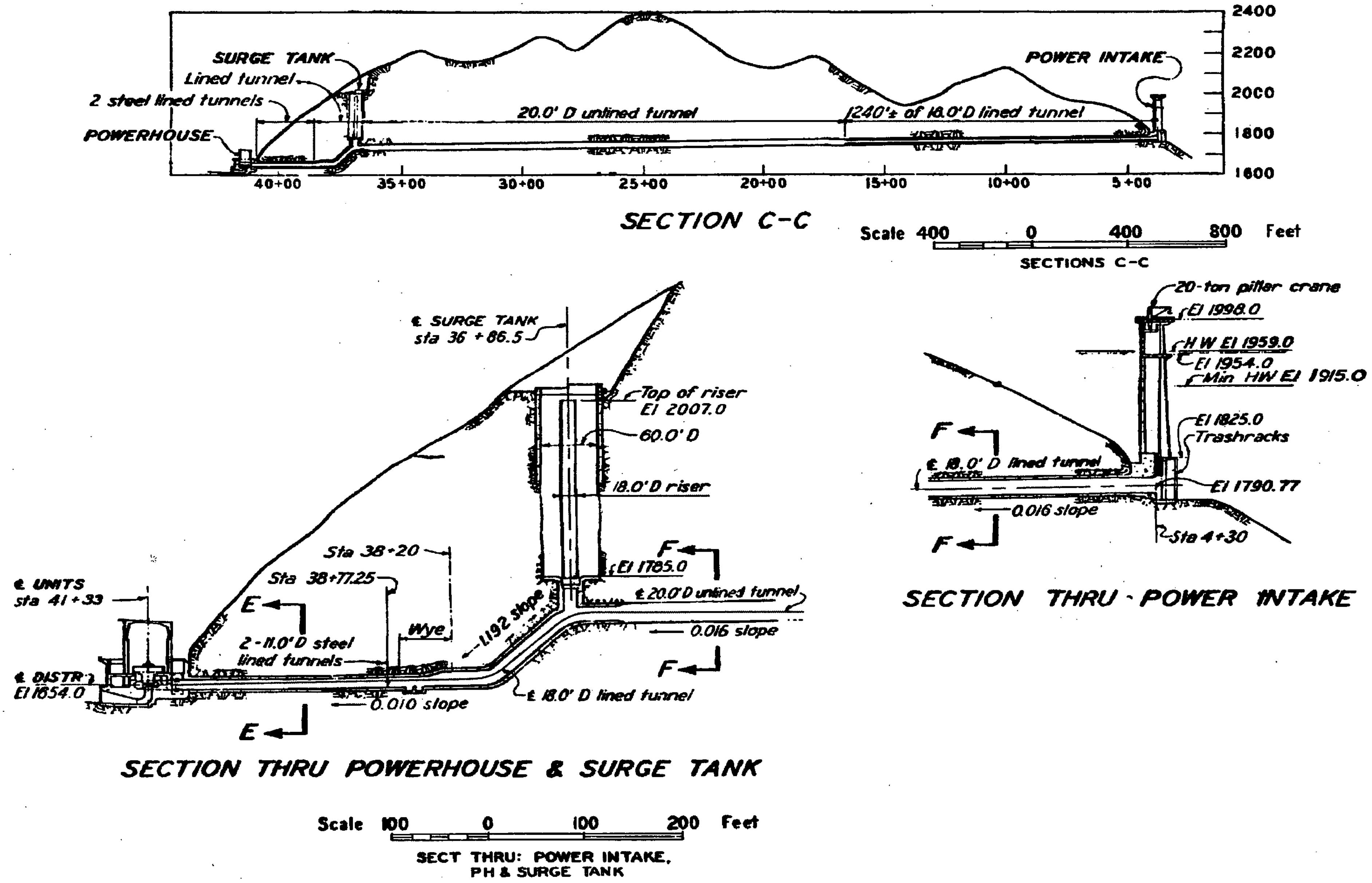
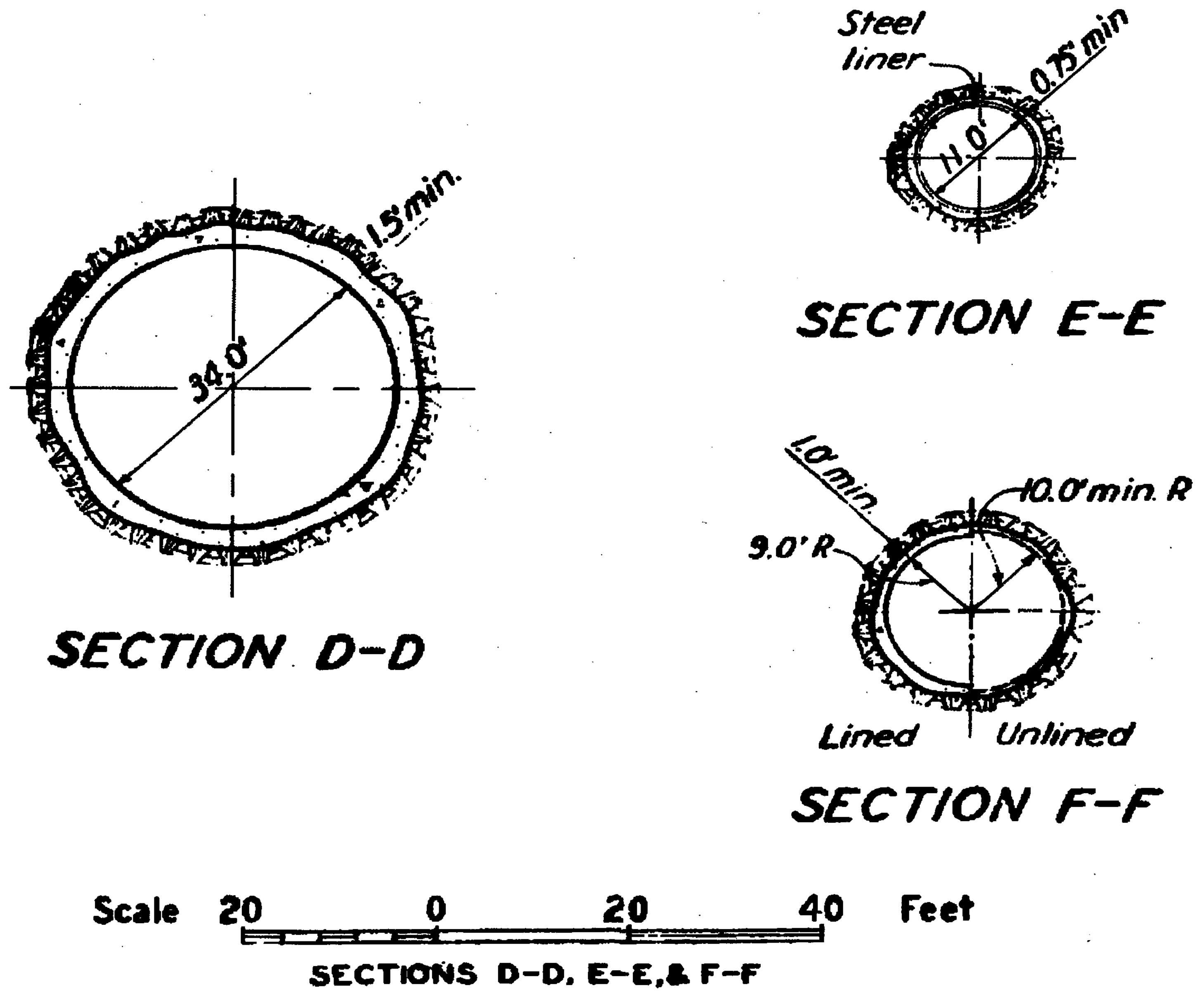


FIGURE 5 - Sections D-D, E-E, and F-F



WATAUGA PROJECT

WATAUGA RIVER

SUMMARY OF PRINCIPAL FEATURES

Note:
Elevations are based on the U.S.C. & G.S. 1936 Supplementary Adjustment.

LOCATION

Dam-on Watauga River at river mile 36.7; in Carter County, Tennessee; 5 miles east of Elizabethton, Tennessee; 19 air miles south of the Tennessee-Virginia State line at Bristol; 104 air miles northeast of Knoxville, Tennessee. Powerhouse-on Watauga River at river mile 35.8; 1.8 miles above Wilbur Dam.

CHRONOLOGY

Initial appropriation by Congress	December 17, 1941
Authorized by TVA Board of Directors	January 15, 1942
Construction started	February 16, 1942
Construction deferred	December 21, 1942
Construction resumed	July 22, 1946
Dam closure	December 1, 1948
Unit 2 in commercial operation	August 30, 1949
Unit 1 in commercial operation	September 29, 1949
Safety Modifications for Probable Maximum Flood Construction completed	October 23, 1983

PROJECT COST

Initial project, including 2 units and switchyard	$32,368,782
Safety Modifications for Probable Maximum Flood	1,086,000
Total , including switchyard	$33,454,782

STREAMFLOW

Drainage area at dam	468 sq. miles
Gaging station discharge records:	
At Butler, Tennessee, August 1900 to December 1901; 1 November 1920 to October 1948; drainage area	427 sq. miles
Below Wilbur Dam, Tennessee, January 1948 to date; drainage area	471 sq. miles

STREAMFLOW (CONT.)

Near Elizabethton, Tennessee, October 1902 to December 1908; drainage area	474 sq. miles
At Siam, Tennessee, March 1946 to May 1946; drainage area	480 sq. miles
At Elizabethton, Tennessee, October 1925 to July 1949; July 1953 to date; drainage area	692 sq. miles
Maximum natural flood at dam site (estimated ,August 1940)	71,500 cfs
Maximum regulated flood since closure of dam (February ,1957)	8945 cfs
Average unregulated flow at dam site: (estimated ,1903-1999)	716 cfs
Minimum daily natural flow at dam site (estimated , 1954)	39 cfs

RESERVOIR

Counties affected:	
State of Tennessee	Carter, Johnson
Reservoir land at May 1996:	
Fee simple	5,496 ac.
Easements	2,419 ac.
Total	7,915 ac.
Transferred	3,688 ac.
Operating levels at dam:	
Probable maximum flood elevation	el. 2009.2
500 year flood elevation	el. 1974.5
100 year flood elevation	el. 1967.0
Maximum used for design (130,000 cfs)	el. 1988.0
Spillway crest (area 7,00 ac.)	el. 1975.0
Summer pool (area 6,430 c.)	el. 1959.0
Winter pool (area 4,690 c.)	el. 1915.0
Backwater, length at normal maximum pool level	16.3 miles
Shoreline, length at normal maximum pool level:	
Main shore	104 miles
Islands	2 miles
Total	106 miles
Original river area (to el. 1975 crossing)	313 ac.
Storage (flat pool assumption):	
Total volume:	
At spillway crest (el. 1975)	677,000 ac.-ft
At normal maximum pool (el. 1959)	568,700 ac.-ft
At normal minimum pool (el. 1915)	323,000 ac.-ft
January 1 to January 25 (el. 1975-1940)	223,000 ac.-ft
April 15 (el. 1975-1959)	108,300 ac.-ft
Useful controlled storage (el. 1975-1915)	354,000 ac.-ft

TAILWATER (At Powerhouse)

Maximum used.for design	el. 1664.0
Full plant operation (1 unit)	el. 1651.3
One unit operating at best efficiency	el. 1649.8
Minimum level	el. 1647.1

HEAD (Gross)

Maximum static (el. 1975-1647.1)	327.9 ft
Normal maximum operating (el. 1959-1650)	309.0 ft
Average operating	286.0 ft
Minimum operating (el. 1815-1652)	163.0 ft

RESERVOIR ADJUSTMENTS

Clearing (estimated)	1,663 ac.
Highways:	
Access	5.7 miles
State	10.1 miles
County and tertiary	39.1 miles
Total	54.9 miles
Bridges, highway	3
Families affected	761
Graves	1,281
Utilities adjusted or constructed	66.4 miles

DAM

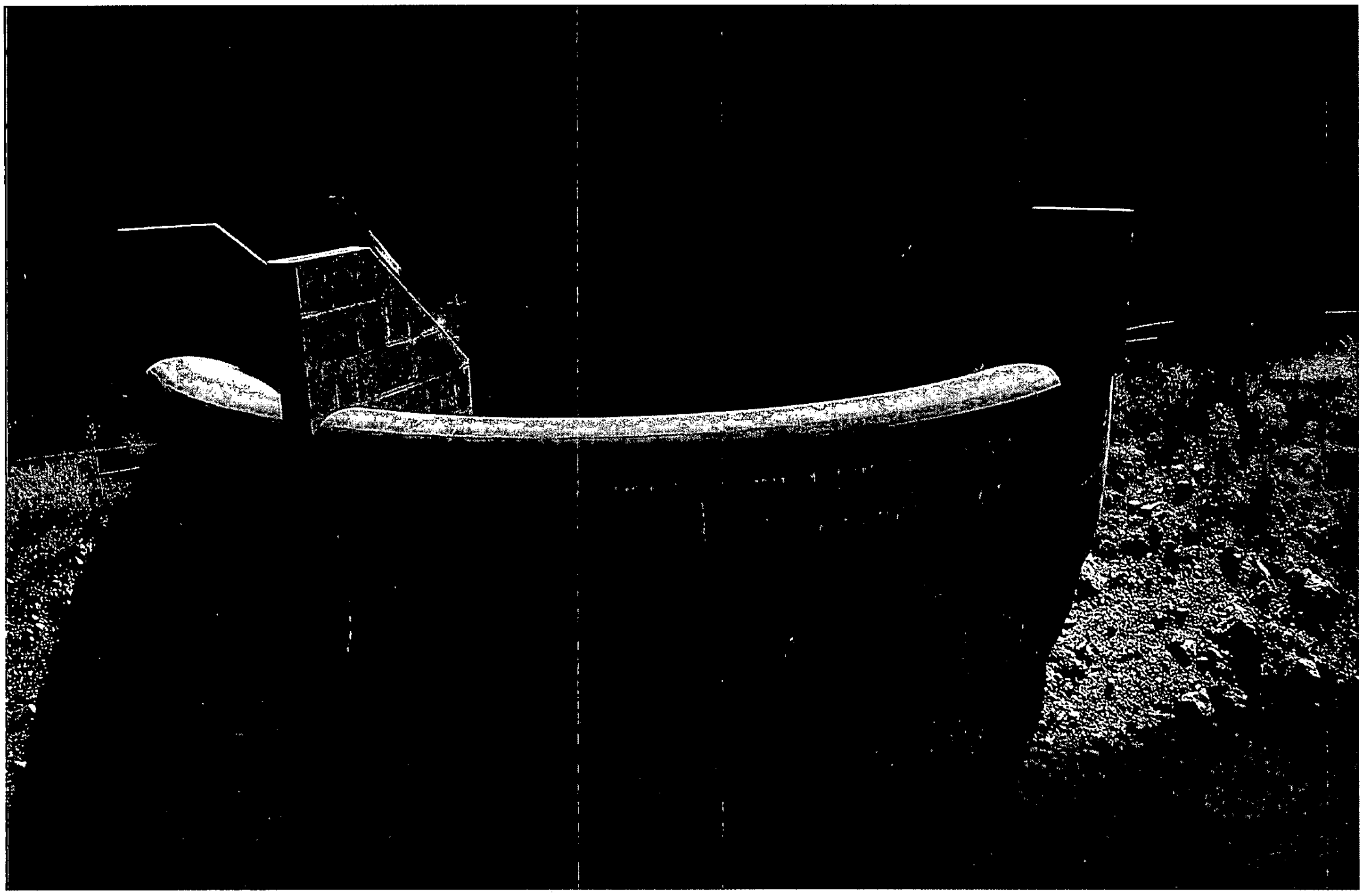
Material and type	Rockfill and impervious rolled earthfill embankment
Length	900 ft
Maximum height	318 ft
Maximum width at base	1260 ft
Top of embankment (original)	el. 1998.0
Top of embankment (modified for PMF)	varies from el. 2012.0 to 2014.0
Top width	32 ft
Foundation	Unicoi quartzite and Shady dolomite

OUTLETWORKS

SPILLWAY

Location	Right abutment
Material and type	Concrete, uncontrolled morning-glory spillway with concrete-lined shaft and discharge tunnel
Crest diameter	128 ft
Crest length, clear	385 ft
Crest level	el. 1975.0
Shaft and tunnel diameter	34 ft
Length:	
Shaft and elbow	313 ft
Tunnel	1,472 ft
Invert of tunnel outlet	el. 1667.4
Discharge capacity, HW el. 1988 (design level)	62,000 cfs

FIGURE 6 - Morning-glory Spillway Intake - Right Bank, September 1999

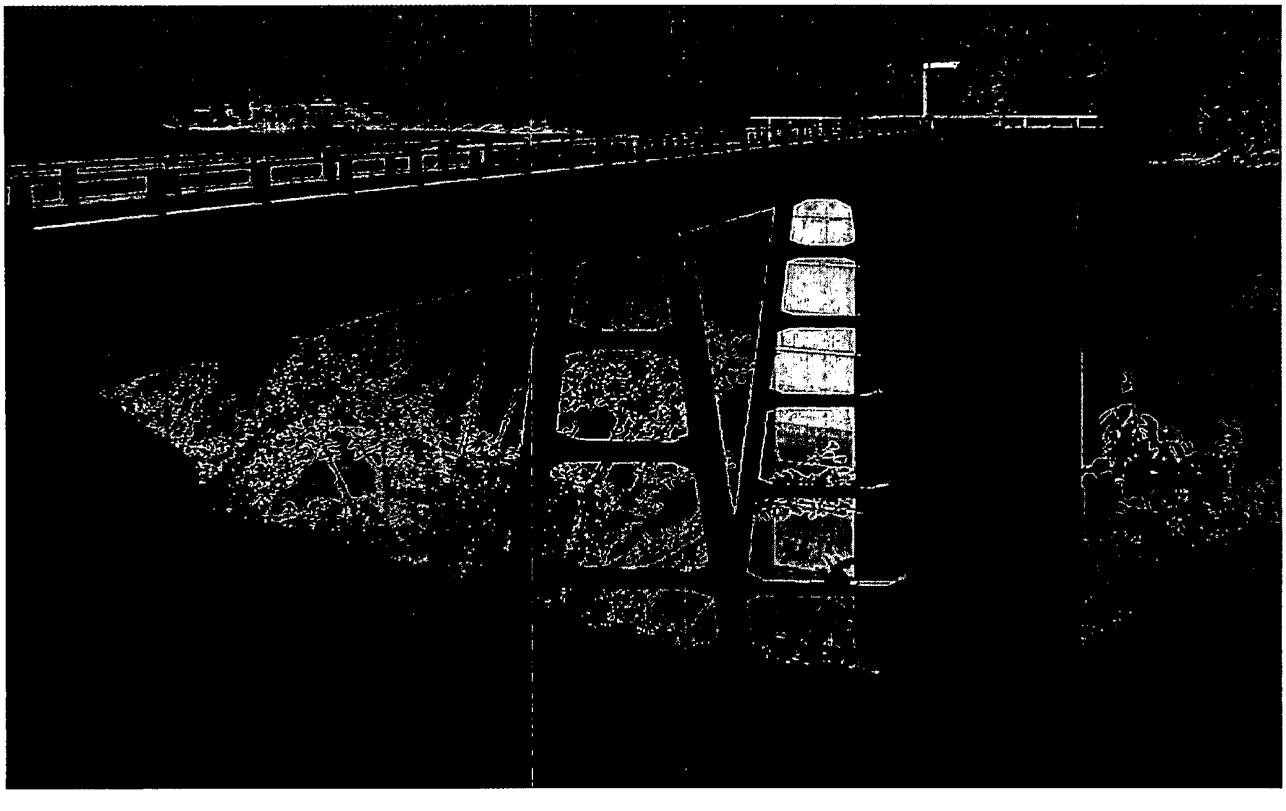


OUTLETWORKS (CONT.)

SLUICEWAY

Location	Right abutment
Material and type	Concrete-lined tunnel with concrete access tower to regulating valves in tunnel plug; discharges into spillway tunnel
Tunnel:	
Diameter	34 ft
Length	608 ft
Tower:	
Inside diameter	25 ft
Height	276 ft
Regulating valves	Two 96-in. Howell-Bunger valves
Emergency gates	Two 5-ft-8-in by 10-ft hydraulically operated slide gates
Centerline of valves	el. 1706.2
Service crane on tower	One 20-ton pillar crane
Discharge capacity:	
HW el. 1981.5 (maximum design level)	11,500 cfs
HW el. 1975 (spillway crest)	11,300 cfs
HW el. 1959 (normal maximum HW)	11,000 cfs

FIGURE 7 - Sluiceway Access Tower near Right Bank, September 1999

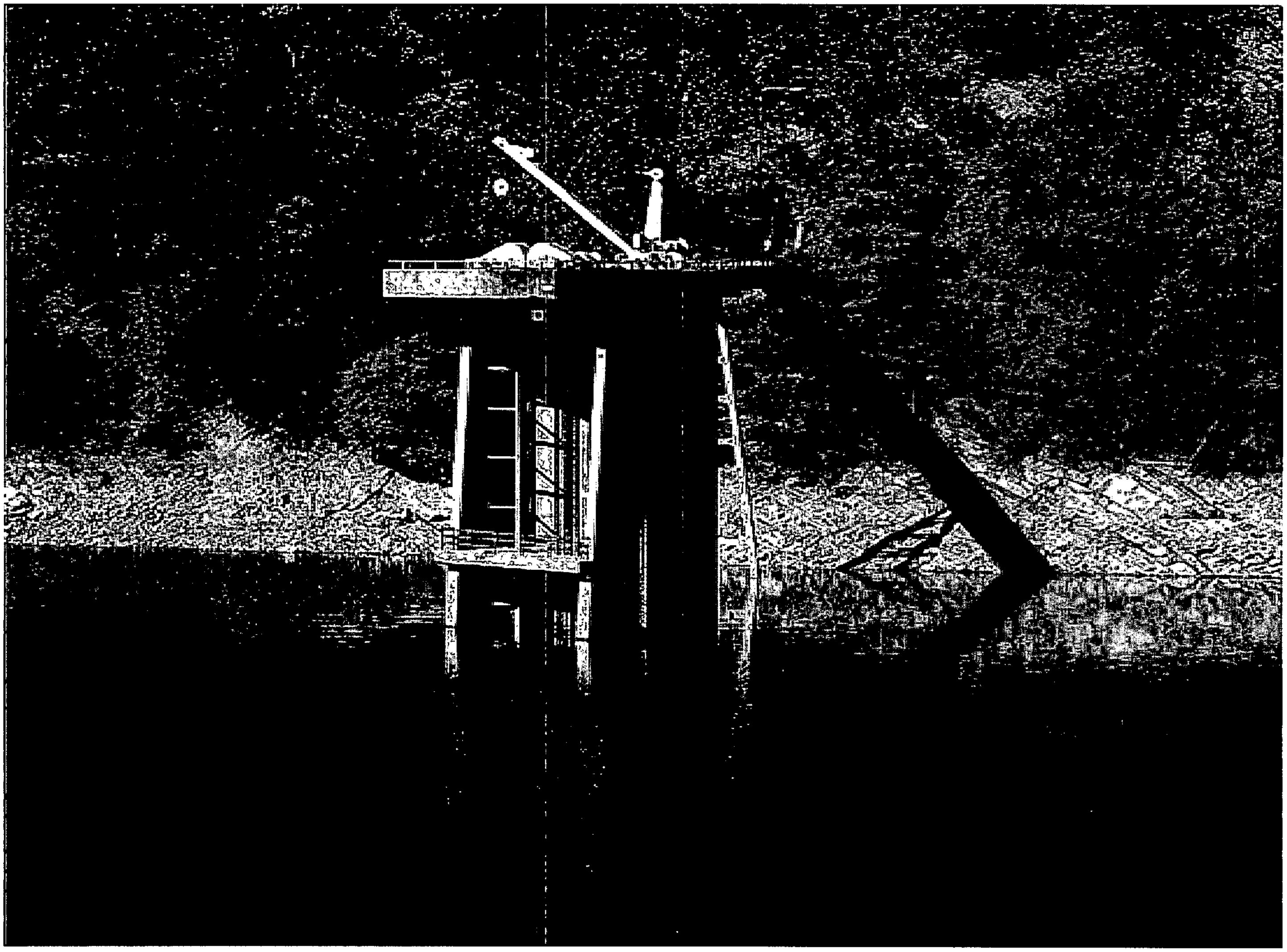


POWER FACILITIES

INTAKE

Type	U-shaped reinforced concrete tower
Size:	
Overall maximum at bottom	37 ft 6 in. by 31 ft
Height	225 ft
Trashracks	8 racks, 13 ft wide by 12 ft 3-1/2 in. high
Gross area at racks	1,175 sq. ft
Gate	1 structural steel, 18.83-ft wide by 24.9-ft-high gate with roller trains
Service crane	One 20-ton-capacity pillar crane

FIGURE 8 - Power Intake Structure near Left Bank, September 1999



POWER FACILITIES (CONT.)

CONDUIT (Intake to Powerhouse)

Type	Single concrete-lined and unlined tunnel sections branching into 2 concrete-lined and steel-lined sections
Size:	
Single-tunnel section:	
Concrete lined, inside diameter	18 ft
Unlined, inside diameter	20 ft
Two-tunnel section, inside diameter	11 ft
Lengths:	
Single-tunnel section:	
Concrete lined	1,450 ft
Unlined	1,972 ft
Wye transition	55 ft
Two-tunnel section:	
Steel lined	227 ft
Total length	3,704 ft

SURGE TANK

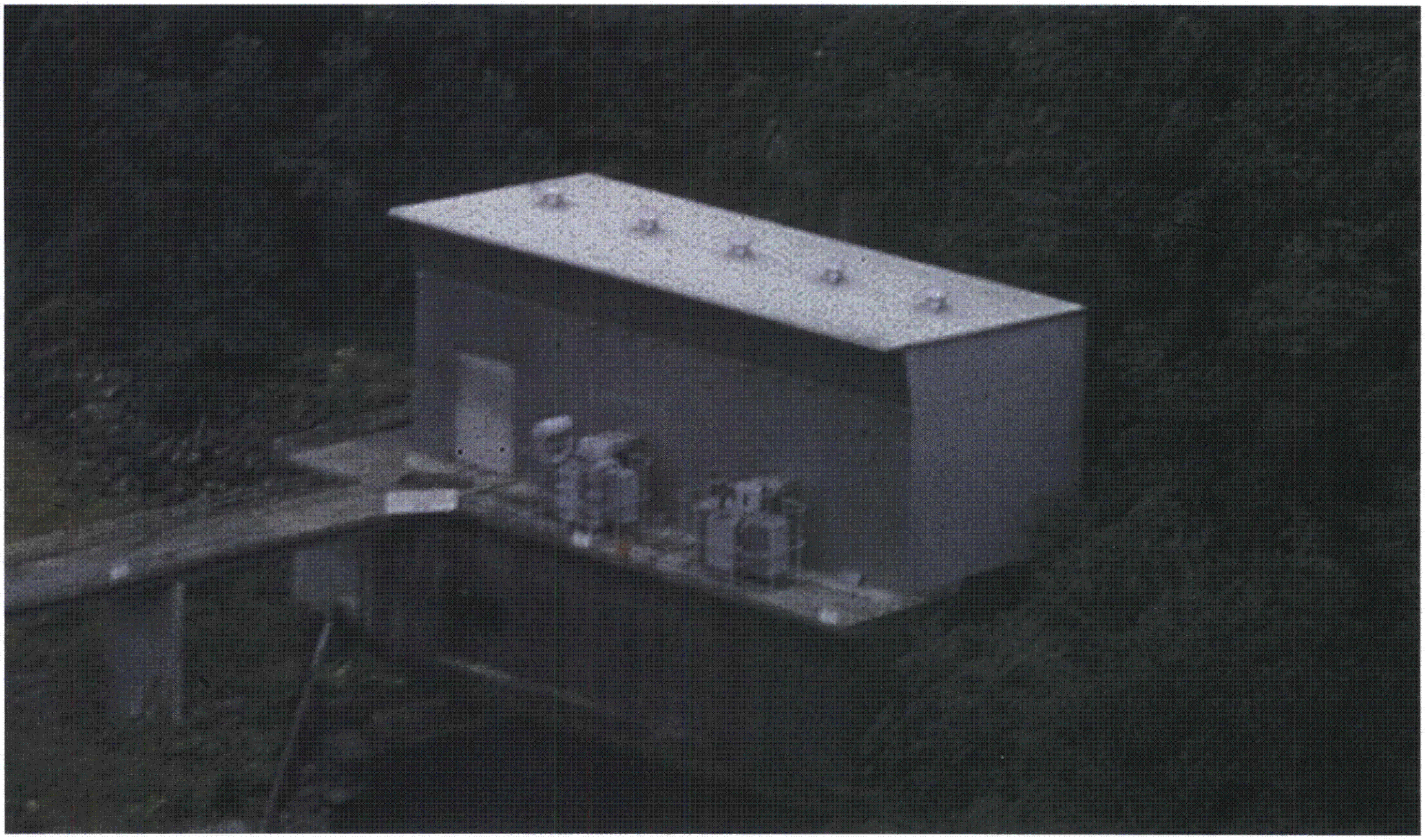
Type	Differential, partially concrete-lined chamber excavated in rock with steel internal riser
Tank height	237.5 ft
Riser height	226.5 ft
Tank (inside diameter)	60 ft
Riser (outside diameter)	16 ft

POWER FACILITIES (CONT.)

POWERHOUSE

Generating capacity, 2-unit total	57,600 kW
Type of construction	Enclosed, reinforced concrete, structural steel frame with insulated aluminum panels
Principal outside dimensions, including service bay	150 ft long by 90 ft wide by 107 ft high
Service bay	60 ft-6 in. by 68 ft-6 in.
Draft tubes:	
Type	Elbow, 2 openings
Horizontal length (centerline of turbine to downstream face)	47 ft-6 in.
Vertical distance from distributor centerline to draft tube floor	22 ft-7 in.
Net area at outlet openings, per.unit	301 sq. ft
Erecting crane	One 100-ton overhead traveling crane with one, 25-ton auxiliary hook

FIGURE 9 - Powerhouse, nearly one mile downstream from dam
January 2000

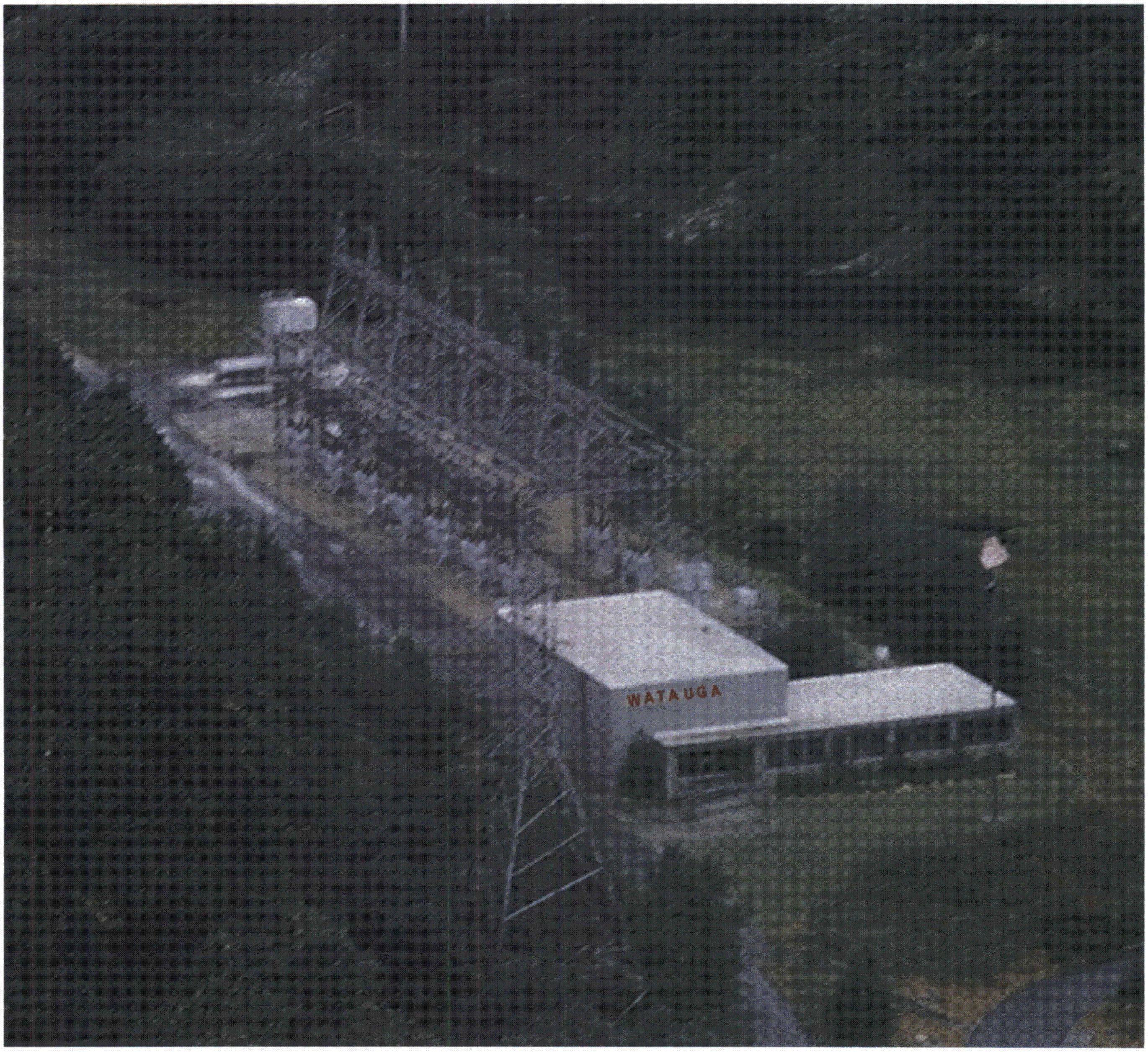


POWER FACILITIES (CONT.)

CONTROL BUILDING

Location	On right bank adjacent to switchyard
Type of construction	L-shaped, reinforced concrete, structural steel, brick, and aluminum siding
Floor area	9,200 sq. ft
Volume	130,000 cu. ft

FIGURE 10 - Control Building and switchyard, across the river from powerhouse, January 2000



POWER FACILITIES (CONT.)

EXCAVATED TAILRACE CHANNEL

Length	400 ft
Width	Varies 71 to 150 ft
Depth (maximum)	8 ft

HYDRAULIC TURBINES

Number	2
Manufacturer	Newport News Shipbuilding and Dry Dock Co.
Type	Vertical Francis
Rated capacity (each)	34,500 hp at 216-ft net head
Rated speed	200 rpm
Maximum runaway speed	395 rpm
Specific speed at rating	45
Value of sigma at rating	0.135
Diameter of runner, intake	108 in.
Diameter of runner, discharge	105.5 in.
Centerline to bottom of runner	32 in.
Centerline to top of runner	16.25 in.
Diameter of guide vane circle	134 in.
Diameter of lower pit	14.0 ft
Spacing of turbines, center to center of units	40 ft
Draft tubes (see Powerhouse)	Elbow type
Governors	Woodward, cabinet actuator type
Heaviest assembly lifted by crane	41,500 lb

GENERATORS

Number	2
Manufacturer	Westinghouse Electric Corp.
Type	Enclosed, water-cooled, vertical-shaft
Rating	27,777 kVA, 25,000 kW, 1162 A, 60 degrees C rise,0.9 pf, 13.8 kV, 3 ph, 60 Hz
Capacity	31,944 kVA, 28,750 kW, 1336 A, 80 degrees C rise

Note:
    Units 1-2 rewound and rerated:
        Unit 1 - November 1978
        Unit 2 - July 1980
Rating Units 1-2:
    32,000 kVA, 28,800 kW, 1339A, 60 degrees C rise, 0.9 pf, 13.8 kV, 3 phase, 60 hz
Efficiency (guaranteed): 97.70 percent

At rated kVA, 1.0 pf	97.70 percent
At 75% kVA, 0.9 pf	97.20 percent
Flywheel effect	10,000,000 lb.-ft 2

POWER FACILITIES (CONT.)

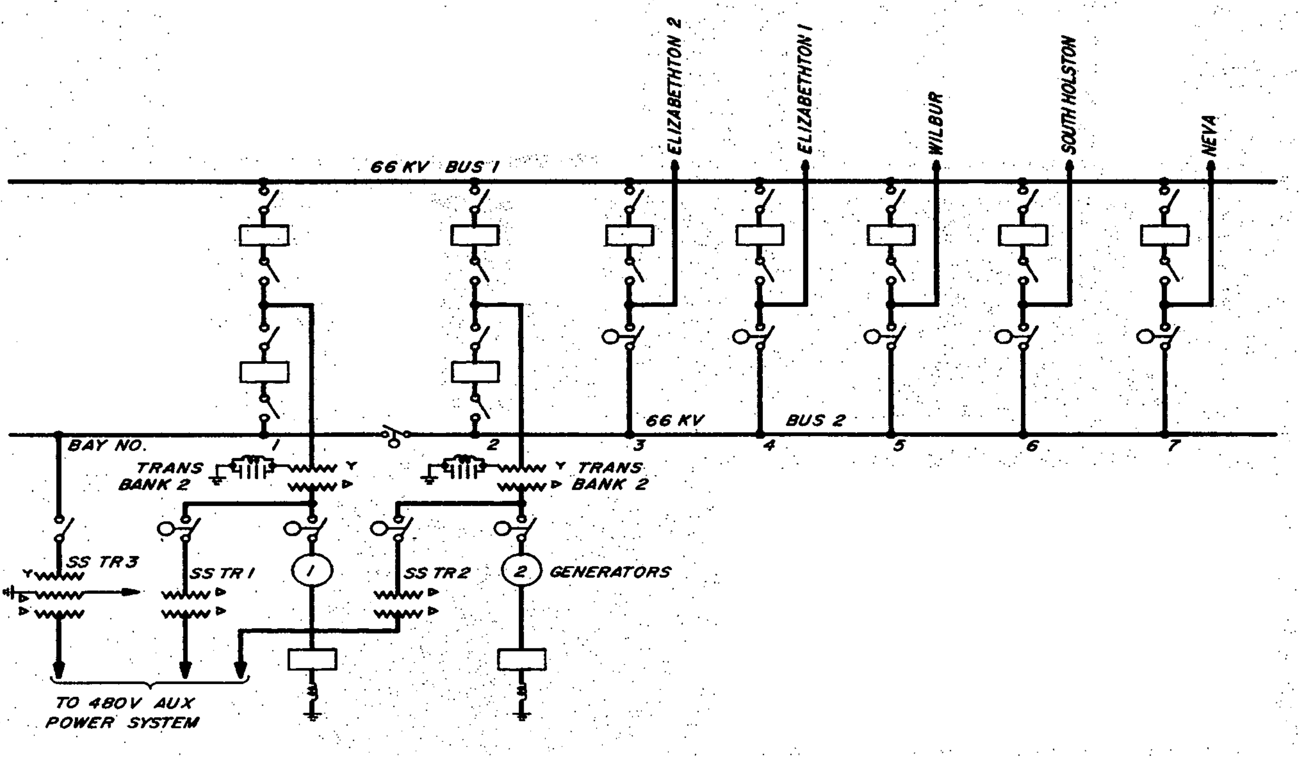
GENERATORS (CONT.)

Thrust bearing	Kingsbury type, dia. 56 in. max. load 294 tons
Neutral reactor	0.75 ohm, 5000 A, 1 min
Exciters:	
Main	175 kW, 250 V
Pilot	6.25 kW, 250 V
Weight of heaviest crane lift, rotor	96.5 tons
Diameter over air housing, less trim	348 in.
Top of pilot exciter:	
Above stator soleplates	106 in.
Above generator floor	130 in.

GENERATOR AND TURBINE MODERNIZATION

Watauga Unit 1 is scheduled to be modernized starting in August 2009 and completing in April 2010. Unit 2 is scheduled to be modernized starting in September 2010 and completing in May 2011. The project scope of the modernizations, including components to be replaced and rehabilitated, is yet to be determined.

SINGLE LINE DIAGRAM OF MAIN CONNECTIONS



(See Figure 10 for view of Switchyard)

POWER FACILITIES (CONT.)

ELECTRIC CONTROLS

From control room in control building:
Watauga generators, transformers, switchyard, sources of auxiliary power, and station auxiliaries, by direct control.

TRANSMISSION PLANT

Step-up transformers:
    2 3-phase, 2-winding transformers, banks 1 and 2; rating each transformer 13.2-69 kV, 24,000 kVA self-cooled, 32,000 kVA forced-air-cooled; Westinghouse
69-kV circuit breakers:
    9 600-A, 1,000,000-kVA, 5/20-Hz, pneu, Allis-Chalmers
Structures:
    7 69-kV switchyard bays, 26 ft wide
    2 transformer structures

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	Manuf	Yr of Manuf
				55 deg	65 deg							H-X	H-Y	X-Y			
Watauga	Bank 1	3	MNL934301	N/A	35/46.5	161/13.8	OA/FA	DETC	Conservator	4740	Wye/Delta	7.95	N/A	N/A	96PA2-142275	ABB	1997
Watauga	Bank 2	3	40088730	24/32	N/A	69/13.2	OA/FA	DETC	Gas-Blanketed	2900	Wye/Delta	8.53	N/A	N/A	TV-96201	Westing-house	1948

Note: H=High voltage winding
Y=Tertiary winding
X=Low voltage winding

RESERVOIR AND POWER DATA

Watauga				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1975	7.20	677.0	324.3	61.3	2,610	23.50	68.0	2,950	23.04
1974	7.10	669.8	323.3	61.3	2,610	23.50	68.0	2,950	23.04
1973	7.02	662.8	322.3	61.3	2,610	23.50	68.0	2,950	23.04
1972	6.95	655.8	321.3	61.3	2,610	23.50	68.0	2,950	23.04
1971	6.90	648.9	320.3	61.3	2,610	23.50	68.0	2,950	23.04
1970	6.86	642.0	319.3	60.9	2,590	23.45	68.0	2,950	23.01
1969	6.83	635.1	318.3	60.3	2,580	23.38	68.0	2,960	22.98
1968	6.80	628.3	317.3	59.7	2,560	23.32	68.0	2,960	22.94
1967	6.77	621.5	316.3	59.1	2,540	23.25	68.0	2,970	22.90
1966	6.74	614.8	315.3	58.6	2,520	23.18	68.0	2,970	22.86
1965	6.70	608.1	314.3	58.0	2,510	23.12	68.0	2,980	22.83
1964	6.67	601.4	313.3	57.4	2,490	23.05	68.0	2,980	22.79
1963	6.63	594.7	312.2	56.8	2,470	22.98	68.0	2,990	22.75
1962	6.60	588.1	311.2	56.2	2,450	22.92	68.0	2,990	22.71
1961	6.56	581.5	310.2	55.6	2,430	22.85	68.0	3,000	22.68
1960	6.53	575.0	309.2	55.5	2,430	22.78	67.8	3,010	22.57
1959	6.49	568.5	308.2	55.4	2,440	22.72	67.6	3,010	22.45
1958	6.45	562.0	307.2	55.4	2,450	22.65	67.4	3,020	22.33
1957	6.40	555.6	306.2	55.4	2,450	22.58	67.2	3,030	22.21
1956	6.36	549.2	305.2	55.4	2,460	22.51	67.0	3,040	22.09
1955	6.31	542.9	304.2	55.3	2,460	22.45	66.8	3,040	21.97
1954	6.26	536.6	303.2	55.3	2,470	22.38	66.6	3,050	21.85
1953	6.21	530.4	302.2	55.3	2,480	22.31	66.4	3,060	21.72
1952	6.15	524.2	301.2	55.2	2,480	22.25	66.2	3,070	21.60
1951	6.09	518.1	300.2	55.2	2,490	22.18	66.0	3,070	21.48
1950	6.03	512.0	299.2	55.2	2,500	22.11	65.8	3,080	21.37
1949	5.98	506.0	298.2	55.3	2,510	22.03	65.7	3,090	21.25
1948	5.92	500.0	297.2	55.3	2,520	21.95	65.5	3,100	21.14
1947	5.87	494.1	296.2	55.4	2,530	21.88	65.3	3,100	21.03
1946	5.82	488.3	295.2	55.4	2,540	21.80	65.1	3,110	20.91
1945	5.78	482.5	294.2	55.5	2,550	21.73	64.9	3,120	20.80
1944	5.74	476.7	293.1	55.5	2,570	21.65	64.7	3,130	20.69
1943	5.71	471.0	292.1	55.6	2,580	21.58	64.5	3,130	20.57

NOTE: Energy in storage values not included in this data

RESERVOIR AND POWER DATA

Watauga				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1942	5.68	465.3	291.1	55.6	2,590	21.50	64.3	3,140	20.46
1941	5.66	459.6	290.1	55.7	2,600	21.43	64.1	3,150	20.35
1940	5.64	454.0	289.1	55.7	2,610	21.36	63.9	3,160	20.24
1939	5.62	448.4	288.1	55.8	2,620	21.30	63.7	3,160	20.12
1938	5.59	442.8	287.1	55.8	2,630	21.24	63.5	3,170	20.01
1937	5.57	437.2	286.1	55.9	2,640	21.17	63.2	3,180	19.90
1936	5.54	431.6	285.1	55.9	2,650	21.11	63.0	3,190	19.78
1935	5.51	426.1	284.1	56.0	2,660	21.05	62.8	3,190	19.67
1934	5.48	420.6	283.1	56.0	2,670	20.99	62.6	3,200	19.56
1933	5.44	415.1	282.1	56.1	2,680	20.92	62.4	3,210	19.44
1932	5.40	409.7	281.1	56.1	2,690	20.86	62.1	3,220	19.33
1931	5.36	404.3	280.1	56.2	2,700	20.80	61.9	3,220	19.22
1930	5.32	399.0	279.1	56.2	2,710	20.73	61.7	3,230	19.11
1929	5.27	393.7	278.1	56.2	2,720	20.67	61.5	3,240	19.01
1928	5.23	388.4	277.1	56.3	2,730	20.61	61.3	3,250	18.90
1927	5.18	383.2	276.1	56.3	2,740	20.55	61.2	3,250	18.80
1926	5.14	378.1	275.0	56.3	2,750	20.48	61.0	3,260	18.69
1925	5.10	373.0	274.0	56.3	2,760	20.42	60.8	3,270	18.59
1924	5.06	367.9	273.0	56.3	2,770	20.36	60.6	3,280	18.48
1923	5.01	362.8	272.0	56.4	2,780	20.29	60.4	3,280	18.38
1922	4.97	357.9	271.0	56.4	2,790	20.23	60.2	3,290	18.27
1921	4.93	352.9	270.0	56.4	2,800	20.17	60.0	3,300	18.17
1920	4.89	348.0	269.0	56.2	2,800	20.10	59.8	3,300	18.11
1919	4.85	343.1	268.0	56.0	2,800	20.02	59.6	3,300	18.05
1918	4.81	338.3	267.0	55.9	2,810	19.95	59.4	3,300	17.99
1917	4.77	333.5	266.0	55.7	2,810	19.88	59.2	3,300	17.93
1916	4.73	328.7	265.0	55.5	2,810	19.81	59.0	3,300	17.86
1915	4.70	324.0	264.0	55.3	2,810	19.74	58.8	3,300	17.80
1914	4.66	319.4	263.0	55.1	2,820	19.67	58.6	3,300	17.74
1913	4.62	314.7	262.0	55.0	2,820	19.59	58.4	3,300	17.68
1912	4.59	310.1	261.0	54.8	2,820	19.52	58.2	3,300	17.62
1911	4.55	305.5	260.0	54.6	2,820	19.45	58.0	3,300	17.56
1910	4.52	301.0	259.0	54.4	2,830	19.38	57.8	3,300	17.50

NOTE: Energy in storage values not included in this data

RESERVOIR AND POWER DATA

Watauga				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1909	4.48	296.5	258.0	54.2	2,830	19.31	57.6	3,300	17.44
1908	4.45	292.0	257.0	54.1	2,830	19.24	57.4	3,300	17.38
1907	4.40	287.6	256.0	53.9	2,840	19.16	57.2	3,300	17.32
1906	4.36	283.2	255.0	53.7	2,840	19.09	57.0	3,300	17.26
1905	4.31	278.9	254.0	53.5	2,840	19.02	56.8	3,300	17.20
1904	4.26	274.6	253.0	53.3	2,840	18.95	56.6	3,300	17.14
1903	4.21	270.4	252.0	53.2	2,850	18.88	56.4	3,300	17.08
1902	4.15	266.2	251.0	53.0	2,850	18.80	56.2	3,300	17.02
1901	4.09	262.1	250.0	52.8	2,850	18.73	56.0	3,300	16.96
1900	4.03	258.0	249.0	52.6	2,860	18.66	55.8	3,300	16.89
1899	3.97	254.0	248.0	52.4	2,860	18.59	55.6	3,300	16.83
1898	3.91	250.1	247.0	52.3	2,860	18.52	55.4	3,300	16.77
1897	3.86	246.2	246.0	52.1	2,860	18.45	55.2	3,300	16.71
1896	3.82	242.3	245.0	51.9	2,870	18.37	55.0	3,300	16.65
1895	3.78	238.5	244.0	51.7	2,870	18.30	54.8	3,300	16.59
1894	3.74	234.8	243.0	51.5	2,870	18.23	54.6	3,300	16.53
1893	3.71	231.0	242.0	51.3	2,880	18.16	54.4	3,300	16.47
1892	3.69	227.3	241.0	51.2	2,880	18.09	54.2	3,300	16.41
1891	3.67	223.7	240.0	51.0	2,880	18.02	54.0	3,300	16.35
1890	3.66	220.0	239.0	50.8	2,880	17.94	53.8	3,300	16.29
1889	3.65	216.3	238.0	50.6	2,890	17.87	53.6	3,300	16.23
1888	3.63	212.7	237.0	50.4	2,890	17.80	53.4	3,300	16.17
1887	3.62	209.1	236.0	50.3	2,890	17.73	53.2	3,300	16.11
1886	3.59	205.5	235.0	50.1	2,890	17.66	53.0	3,300	16.05
1885	3.57	201.9	234.0	49.9	2,900	17.58	52.8	3,300	15.98
1884	3.54	198.3	233.0	49.7	2,900	17.51	52.6	3,300	15.92
1883	3.51	194.8	232.0	49.5	2,900	17.44	52.4	3,300	15.86
1882	3.48	191.3	231.0	49.4	2,910	17.37	52.2	3,300	15.80
1881	3.44	187.8	230.0	49.2	2,910	17.30	52.0	3,300	15.74
1880	3.40	184.4	229.0	49.0	2,910	17.23	51.8	3,300	15.68
1879	3.36	181.0	228.0	48.8	2,910	17.15	51.6	3,300	15.62
1878	3.31	177.7	227.0	48.6	2,920	17.08	51.4	3,300	15.56
1877	3.26	174.4	226.0	48.5	2,920	17.01	51.2	3,300	15.50

NOTE: Energy in storage values not included in this data

RESERVOIR AND POWER DATA

Watauga

				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1876	3.21	171.2	225.0	48.3	2,920	16.94	51.0	3,300	15.44
1875	3.15	168.0	224.0	48.1	2,930	16.87	50.8	3,300	15.38
1874	3.10	164.9	223.0	47.9	2,930	16.80	50.6	3,300	15.32
1873	3.04	161.8	222.0	47.7	2,930	16.72	50.4	3,300	15.26
1872	2.99	158.8	221.0	47.6	2,930	16.65	50.2	3,300	15.20
1871	2.94	155.8	220.0	47.4	2,940	16.58	50.0	3,300	15.14
1870	2.89	152.9	219.0	47.2	2,940	16.51	49.8	3,300	15.07
1869	2.85	150.0	218.0	47.0	2,940	16.44	49.6	3,300	15.01
1868	2.80	147.2	217.0	46.8	2,950	16.37	49.4	3,300	14.95
1867	2.76	144.4	216.0	46.7	2,950	16.29	49.2	3,300	14.89
1866	2.72	141.7	215.0	46.5	2,950	16.22	49.0	3,300	14.83
1865	2.68	139.0	214.0	46.3	2,950	16.15	48.8	3,300	14.77
1864	2.65	136.3	213.0	46.1	2,960	16.08	48.6	3,300	14.71
1863	2.61	133.7	212.0	45.9	2,960	16.01	48.4	3,300	14.65
1862	2.58	131.1	211.0	45.8	2,960	15.93	48.2	3,300	14.59
1861	2.55	128.5	210.0	45.6	2,960	15.86	48.0	3,300	14.53
1860	2.52	126.0	209.0	45.4	2,970	15.79	47.8	3,300	14.47
1859	2.49	123.5	208.0	45.2	2,970	15.72	47.6	3,300	14.41
1858	2.46	121.0	207.0	45.0	2,970	15.65	47.4	3,300	14.35
1857	2.42	118.6	206.0	44.8	2,980	15.58	47.2	3,300	14.29
1856	2.37	116.2	205.0	44.7	2,980	15.50	47.0	3,300	14.23
1855	2.32	113.8	204.0	44.5	2,980	15.43	46.8	3,300	14.17
1854	2.27	111.5	203.0	44.3	2,980	15.36	46.6	3,300	14.10
1853	2.21	109.3	202.0	44.1	2,990	15.29	46.4	3,300	14.04
1852	2.14	107.1	201.0	43.9	2,990	15.22	46.2	3,300	13.98
1851	2.07	105.0	200.0	43.8	2,990	15.15	46.0	3,300	13.92
1850	1.99	103.0	199.0	43.6	3,000	15.07	45.8	3,300	13.86
1849	1.92	101.0	198.0	43.4	3,000	15.00	45.6	3,300	13.80
1848	1.85	99.2	197.0	43.2	3,000	14.93	45.4	3,300	13.74
1847	1.79	97.3	196.0	43.0	3,000	14.86	45.2	3,300	13.68
1846	1.73	95.6	195.0	42.9	3,010	14.79	45.0	3,300	13.62
1845	1.68	93.9	194.0	42.7	3,010	14.71	44.8	3,300	13.56
1844	1.64	92.2	193.0	42.5	3,010	14.64	44.6	3,300	13.50

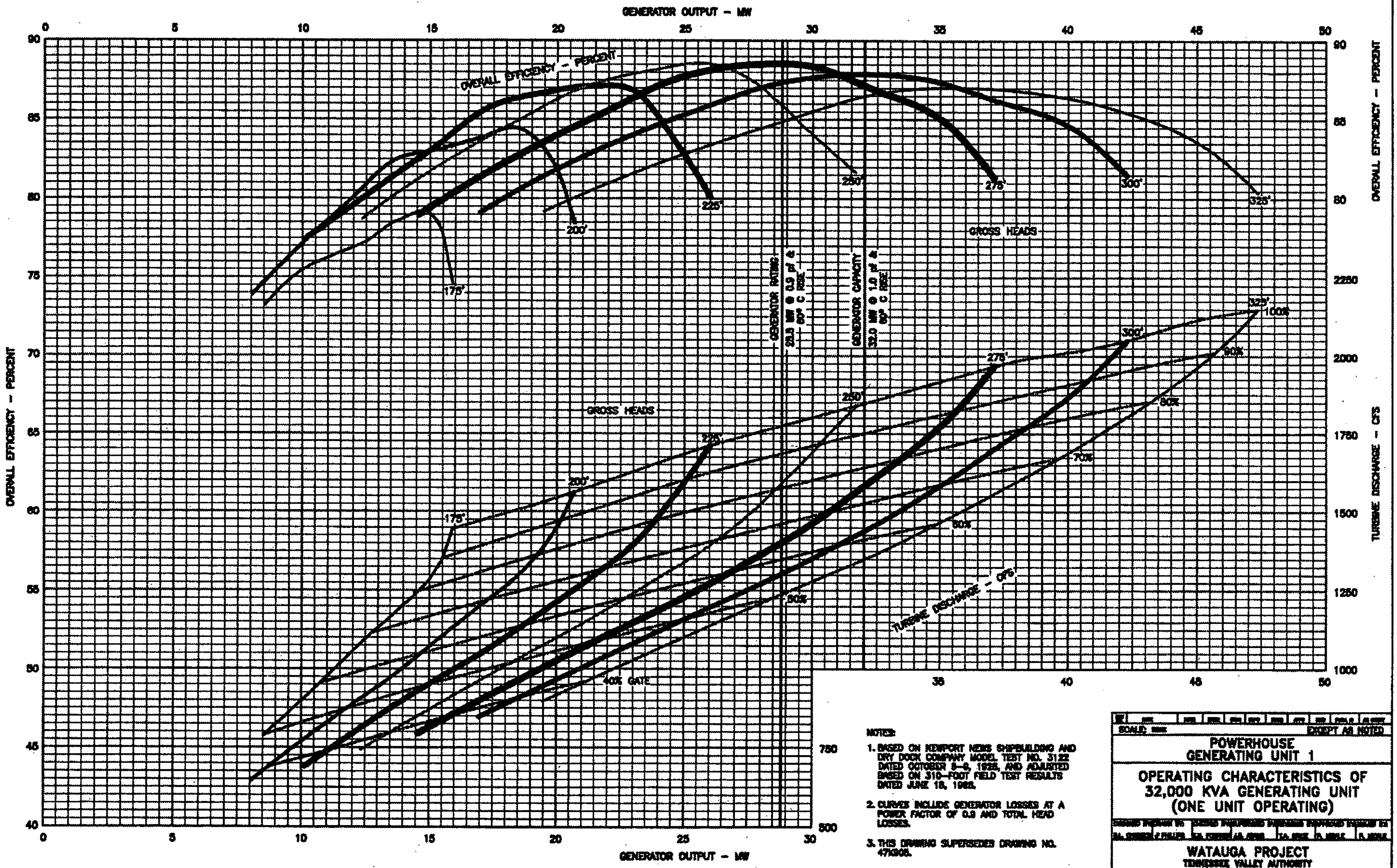
NOTE: Energy in storage values not included in this data

RESERVOIR AND POWER DATA

Watauga

				Best Efficiency			Maximum Sustainable		
Elevation (feet)	Area (acre*1000)	Volume (ac-ft*1000)	Gross Head (feet)	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS	Plant Output (mW)	Turbine Discharge (cfs)	kW/CFS
1843	1.60	90.6	192.0	42.3	3,010	14.57	44.4	3,300	13.44
1842	1.57	89.0	191.0	42.1	3,020	14.50	44.2	3,300	13.38
1841	1.55	87.4	190.0	42.0	3,020	14.43	44.0	3,300	13.32
1840	1.53	85.9	189.0	41.8	3,020	14.36	43.8	3,300	13.26
1839	1.52	84.4	188.0	41.6	3,030	14.28	43.6	3,300	13.19
1838	1.51	82.9	187.0	41.4	3,030	14.21	43.4	3,300	13.13
1837	1.49	81.4	186.0	41.2	3,030	14.14	43.2	3,300	13.07
1836	1.48	79.9	185.0	41.1	3,030	14.07	43.0	3,300	13.01
1835	1.46	78.4	184.0	40.9	3,040	14.00	42.8	3,300	12.95
1834	1.45	77.0	183.0	40.7	3,040	13.93	42.6	3,300	12.89
1833	1.43	75.5	182.0	40.5	3,040	13.85	42.4	3,300	12.83
1832	1.41	74.1	181.0	40.3	3,050	13.78	42.2	3,300	12.77
1831	1.40	72.7	180.0	40.2	3,050	13.71	42.0	3,300	12.71
1830	1.38	71.3	179.0	40.0	3,050	13.64	41.8	3,300	12.65
1829	1.37	69.9	178.0	39.8	3,050	13.57	41.6	3,300	12.59
1828	1.35	68.6	177.0	39.6	3,060	13.49	41.4	3,300	12.53
1827	1.34	67.2	176.0	39.4	3,060	13.42	41.2	3,300	12.47
1826	1.32	65.9	175.0	39.3	3,060	13.35	41.0	3,300	12.41
1825	1.31	64.6	174.0	39.1	3,070	13.28	40.8	3,300	12.35
1824	1.29	63.3	173.0	38.9	3,070	13.21	40.6	3,300	12.29
1823	1.28	62.0	172.0	38.7	3,070	13.14	40.4	3,300	12.22
1822	1.27	60.7	171.0	38.5	3,070	13.06	40.1	3,300	12.16
1821	1.26	59.5	170.0	38.3	3,080	12.99	39.9	3,300	12.10
1820	1.25	58.2	169.0	38.2	3,080	12.92	39.7	3,300	12.04
1819	1.24	57.0	168.0	38.0	3,080	12.85	39.5	3,300	11.98
1818	1.23	55.7	167.0	37.8	3,080	12.78	39.3	3,300	11.92
1817	1.22	54.5	166.0	37.6	3,090	12.71	39.1	3,300	11.86
1816	1.20	53.3	165.0	37.4	3,090	12.63	38.9	3,300	11.80
1815	1.19	52.1	164.0	37.3	3,090	12.56	38.7	3,300	11.74

NOTE: Energy in storage values not included in this data



NOTES:

1. BASED ON NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY MODEL TEST NO. 3122 DATED OCTOBER 5–6, 1928, AND ADJUSTED BASED ON 310–FOOT FIELD TEST RESULTS DATED JUNE 18, 1965.

2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 0.9 AND TOTAL HEAD LOSSES.

3. THIS DRAWING SUPERSEDES DRAWING NO. 47K908.

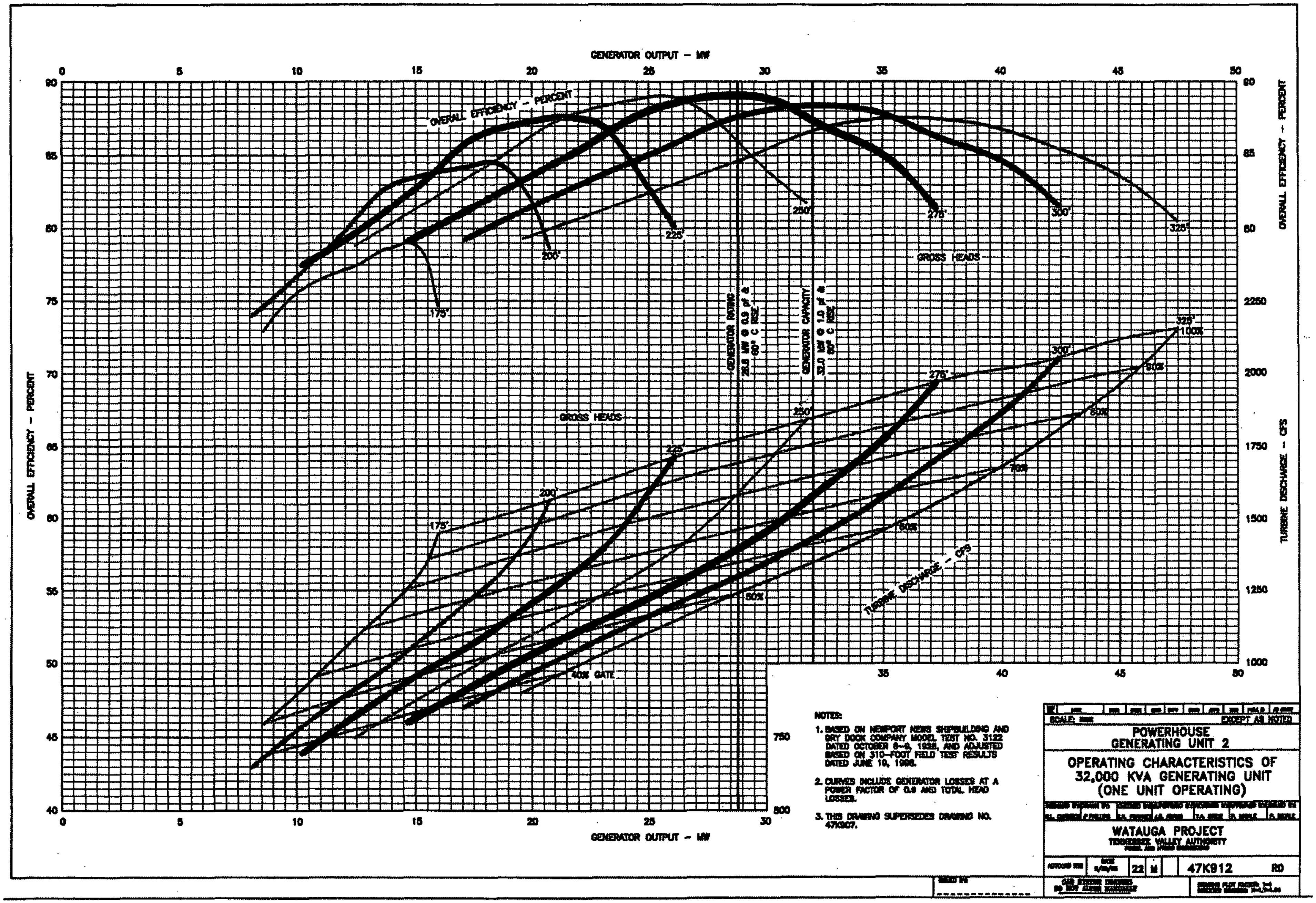
EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 1

OPERATING CHARACTERISTICS OF
32,000 KVA GENERATING UNIT
(ONE UNIT OPERATING)

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY

22 M 47K911 R0



NOTES:

1. BASED ON NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY MODEL TEST NO. 3122 DATED OCTOBER 8–9, 1938, AND ADJUSTED BASED ON 310–FOOT FIELD TEST RESULTS DATED JUNE 19, 1996.
2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 0.9 AND TOTAL HEAD LOSSES.
3. THIS DRAWING SUPERSEDES DRAWING NO. 47K907.

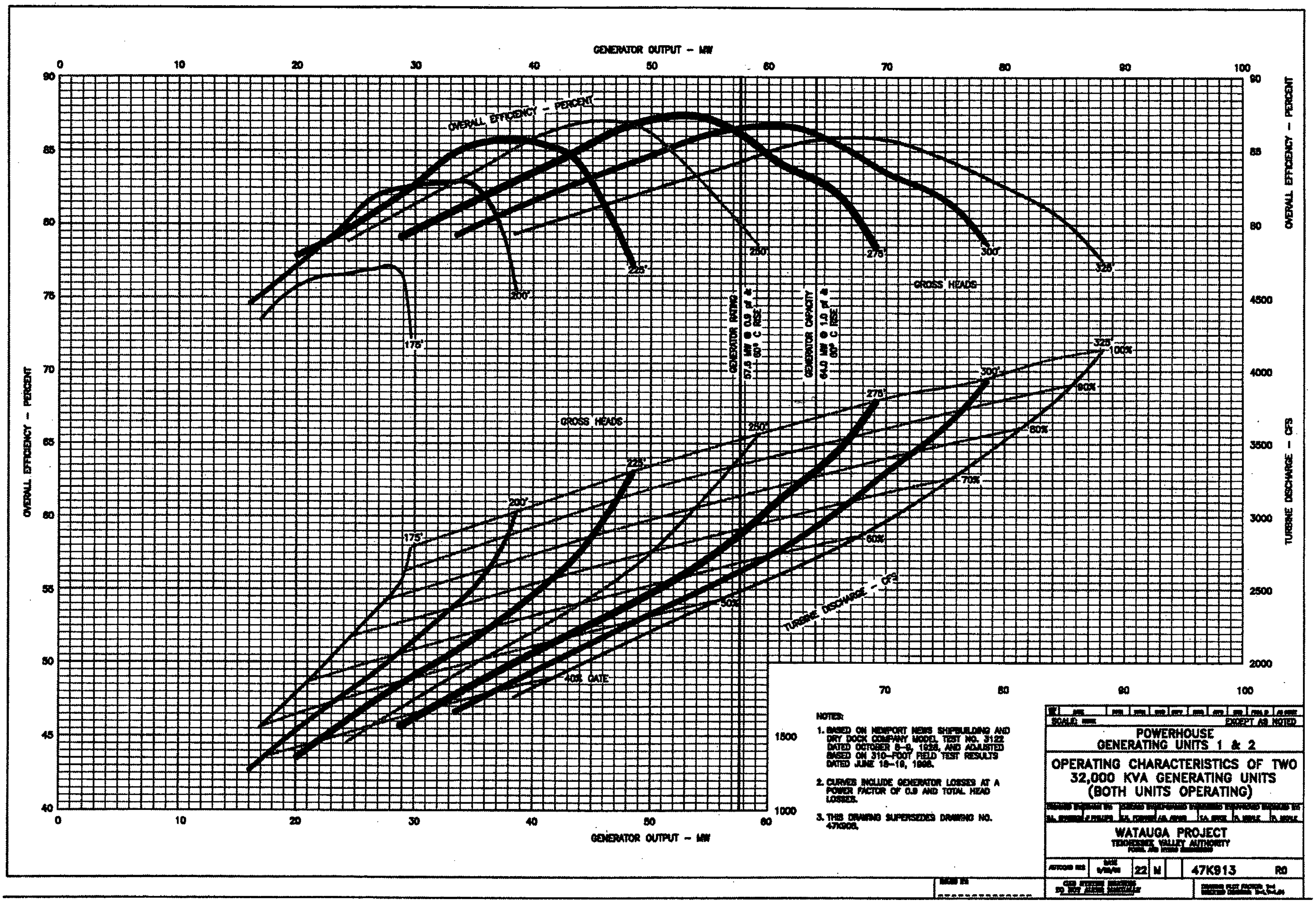
SCALE: NONE EXCEPT AS NOTED

POWERHOUSE
GENERATING UNIT 2

OPERATING CHARACTERISTICS OF
32,000 KVA GENERATING UNIT
(ONE UNIT OPERATING)

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY

22 M 47K912 R0



NOTES:

1. BASED ON NEWPORT NEWS SHIPBUILDING AND DRY DOCK COMPANY MODEL TEST NO. 3122 DATED OCTOBER 8–9, 1928, AND ADJUSTED BASED ON 310–FOOT FIELD TEST RESULTS DATED JUNE 18–19, 1996.

2. CURVES INCLUDE GENERATOR LOSSES AT A POWER FACTOR OF 0.9 AND TOTAL HEAD LOSSES.

3. THIS DRAWING SUPERSEDES DRAWING NO. 47K908.

POWERHOUSE
GENERATING UNITS 1 & 2

OPERATING CHARACTERISTICS OF TWO
32,000 KVA GENERATING UNITS
(BOTH UNITS OPERATING)

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY

47K913 R0

Watauga Spill Compilation

Tennessee Valley Authority
River System Operations

YEAR	MAXIMUM AVERAGE DAILY DISCHARGE (TURBINE + SPILL)	DATE	NUMBER OF PERIODS	TOTAL DAYS	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 year and does not always equal the sum of the days in periods because of extension of periods in to adjacent years. Water may be spilled through the spillway and/or Howell-Bunger valves. Maximum hourly average dishcarge to date was 3584 cfs at 9 a.m. on 4/18/87.
1948	0		0	0	Closure 12/1/48
1949	1339	9/30	0	0	
1950	1732	11/21	3	6	540---1/4---3; 192---2/8---2; 5---3/10---1 (all through Howell-Bunger valve for test)
1951	2061	11/5	0	0	
1952	2510	8/29	0	0	
1953	2024	8/31	0	0	
1954	2330	1/12	0	0	
1955	2768	11/8	0	0	
1956	2472	12/10	0	0	
1957	2804	4/11	0	0	
1958	2763	9/25	0	0	
1959	2831	9/9	0	0	
1960	2856	9/22	0	0	
1961	2580	6/20	0	0	
1962	2733	1/26	0	0	
1963	2282	2/15	1	19	83---9/27---19 (all through Howell-Bunger valve for downstream supply)
1964	2232	8/18	0	0	
1965	2697	3/20	0	0	
1966	2819	12/30	0	0	
1967	2779	12/23	0	0	
1968	2773	1/7	0	0	
1969	2819	11/15	1	15	90---9/19---15 (all through Howell-Bunger valve for downstream supply)
1970	2798	7/16	0	0	

Watauga Spill Compilation

Tennessee Valley Authority
River System Operations

YEAR	MAXIMUM AVERAGE DAILY DISCHARGE (TURBINE + SPILL)	DATE	NUMBER OF PERIODS	TOTAL DAYS	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 year and does not always equal the sum of the days in periods because of extension of periods in to adjacent years. Water may be spilled through the spillway and/or Howell-Bunger valves. Maximum hourly average dishcarge to date was 3584 cfs at 9 a.m. on 4/18/87.\
1971	1872	11/7	0	0	
1972	2864	2/28	0	0	
1973	2958	8/29	0	0	
1974	2942	5/21	0	0	
1975	2704	4/3	0	0	
1976	2722	10/19	0	0	
1977	2857	1/17	0	0	
1978	2783	1/28	0	0	
1979	2601	3/26	1	1	142---5/5---1
1980	2678	7/9	0	0	
1981	1918	8/14	0	0	
1982	2539	1/17	0	0	
1983	3005	10/24	0	0	
1984	2034	12/6	0	0	
1985	2666	1/21	0	0	
1986	2412	1/28	0	0	
1987	2886	4/18	0	0	
1988	849	6/22	0	0	
1989	2747	5/12	0	0	
1990	2704	3/19	0	0	
1991	3006	4/6	0	0	
1992	3069	6/12	0	0	
1993	2748	4/3	0	0	

Watauga Spill Compilation

YEAR	MAXIMUM AVERAGE DAILY DISCHARGE (TURBINE + SPILL)	DATE	NUMBER OF PERIODS	TOTAL DAYS	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 year and does not always equal the sume of the days in periods because of extension of periods into adjacent years. Water may be spilled through the spillway and/or Howell-Bunger valves. All unmarked spill was through valves. Maximum hourly average discharge to date was 8945 cfs at 11 p.m. on 2/11/57. *Spillway
1994	2905	1/20	0	0	
1995	3013	1/21& 22	0	0	
1996	2900	12/20	4	24	113---2/29---2; 13---3/4---1; 192---4/6---13; 200---4/20---8
1997	2890	5/29	0	0	
1998	2986	4/24	0	0	
1999	1500	1/5	0	0	

ANNUAL MAXIMUM AND MINIMUM ELEVATIONS, IN ORDER OF MAGNITUDE

RIVER SCHEDULING
TVA OPERATED RESERVOIR SYSTEM
FROM DATE OF RESERVOIR CLOSURE THROUGH 1999

WATAUGA

	MAXIMUM					MINIMUM			
ORDER	ELEVATION	YEAR	MONTH	DAY	ORDER	ELEVATION	YEAR	MONTH	DAY
1	1963.28	1987	APR.	19	1	1700.40 *	1948	DEC.	1
2	1962.99	1989	JULY	6	2	1813.47	1956	JAN.	13
3	1962.52 %	1992	JUNE	11	3	1814.68	1954	DEC.	22
4	1962.39	1991	MAR.	31	4	1815.66	1955	FEB.	5
5	1961.07	1974	APR.	6	5	1819.40	1956	JAN.	13
6	1961.05	1973	MAY	29	6	1823.07	1983	DEC.	6
7	1960.76	1997	MAY	28	7	1849.56	1984	JAN.	1
8	1960.69	1998	APR.	21	8	1881.49	1952	DEC.	31
9	1960.28	1996	JUNE	2	9	1881.72	1953	JAN.	1
10	1959.97	1979	JULY	24	10	1885.40	1959	JAN.	21
11	1959.90	1972	MAY	30	11	1888.69	1966	FEB.	9
12	1959.69	1990	MAY	7	12	1894.36	1958	DEC,	27
13	1959.56	1993	MAY	13	13	1895.50	1970	DEC.	18
14	1959.13	1994	JUNE	8	14	1898.61	1971	JAN.	1
15	1958.90	1995	JUNE	28	15	1903.05	1961	JAN.	10
16	1958.90	1957	APR.	10	16	1904.05	1960	DEC.	30
17	1958.67	1975	APR.	2	17	1909.28	1963	DEC.	31
18	1958.58	1950	JUNE	24	18	1909.30	1964	JAN.	1
19	1958.40	1980	APR.	20	19	1909.39	1957	JAN.	3
20	1957.88	1965	APR.	10	20	1911.74	1969	DEC.	7
21	1957.86	1968	JUNE	3	21	1914.20	1981	FEB.	10
22	1956.84	1960	APR.	7	22	1914.45	1965	DEC.	31
23	1956.21	1999	MAY	26	23	1914.46	1977	FEB.	21
24	1955.47	1958	MAY	23	24	1914.54	1962	NOV.	9
25	1955.22	1962	MAR.	31	25	1916.67	1951	DEC.	3
26	1955.06	1967	JUNE	6	26	1917.51	1968	DEC.	21
27	1955.04	1983	MAY	8	27	1919.43	1975	SEP.	17
28	1954.07	1982	MAY	10	28	1920.64	1980	NOV.	22
29	1953.19	1978	MAY	22	29	1921.45	1988	SEP.	16
30	1952.96	1952	APR.	14	30	1922.40	1976	JAN.	22
31	1952.12	1977	NOV.	10	31	1923.61	1985	JAN.	25
32	1952.00 %	1976	JUNE	27	32	1924.13	1987	DEC.	24
33	1950.53	1969	MAY	1	33	1924.45	1978	NOV.	22
34	1950.40	1963	APR.	4	34	1924.60	1982	JAN.	1
35	1950.08	1971	AUG.	30	35	1925.21	1974	DEC.	6
36	1948.55	1981	JUNE	9	36	1927.56	1989	JAN.	1
37	1947.30	1949	SEP.	1	37	1927.98	1986	JAN.	30
38	1945.66	1986	JUNE	16	38	1928.24	1979	JAN.	1
39	1944.82	1985	JUNE	3	39	1929.73	1997	DEC.	19
40	1944.59	1964	JUNE	5	40	1930.63	1998	JAN.	2
41	1944.32	1984	JULY	30	41	1931.61	1999	JAN.	6
42	1942.90	1961	JUNE	3	42	1931.78	1950	JAN.	13
43	1935.73	1966	DEC.	20	43	1933.14	1967	JAN.	3
44	1935.05	1988	MAY	30	44	1933.43	1996	JAN.	12
45	1934.98	1951	JAN.	1	45	1934.54	1995	JAN.	6
46	1934.39	1970	MAY	12	46	1934.71	1993	NOV.	27
47	1933.07	1953	MAY	11	47	1935.70	1994	DEC.	31
48	1929.58	1959	DEC.	31	48	1936.67	1990	JAN.	1
49	1925.25	1956	JULY	30	49	1937.73 %	1991	NOV.	20
50	1923.47	1954	JUNE	1	50	1939.95	1973	DEC.	19
51	1912.38	1955	JULY	25	51	1940.20	1992	JAN.	21
52	1819.40	1948	DEC.	31	52	1940.32	1972	NOV.	27

* CLOSURE
% MIDNIGHT ELEVATION
TOP-OF-GATES ELEVATION 1075

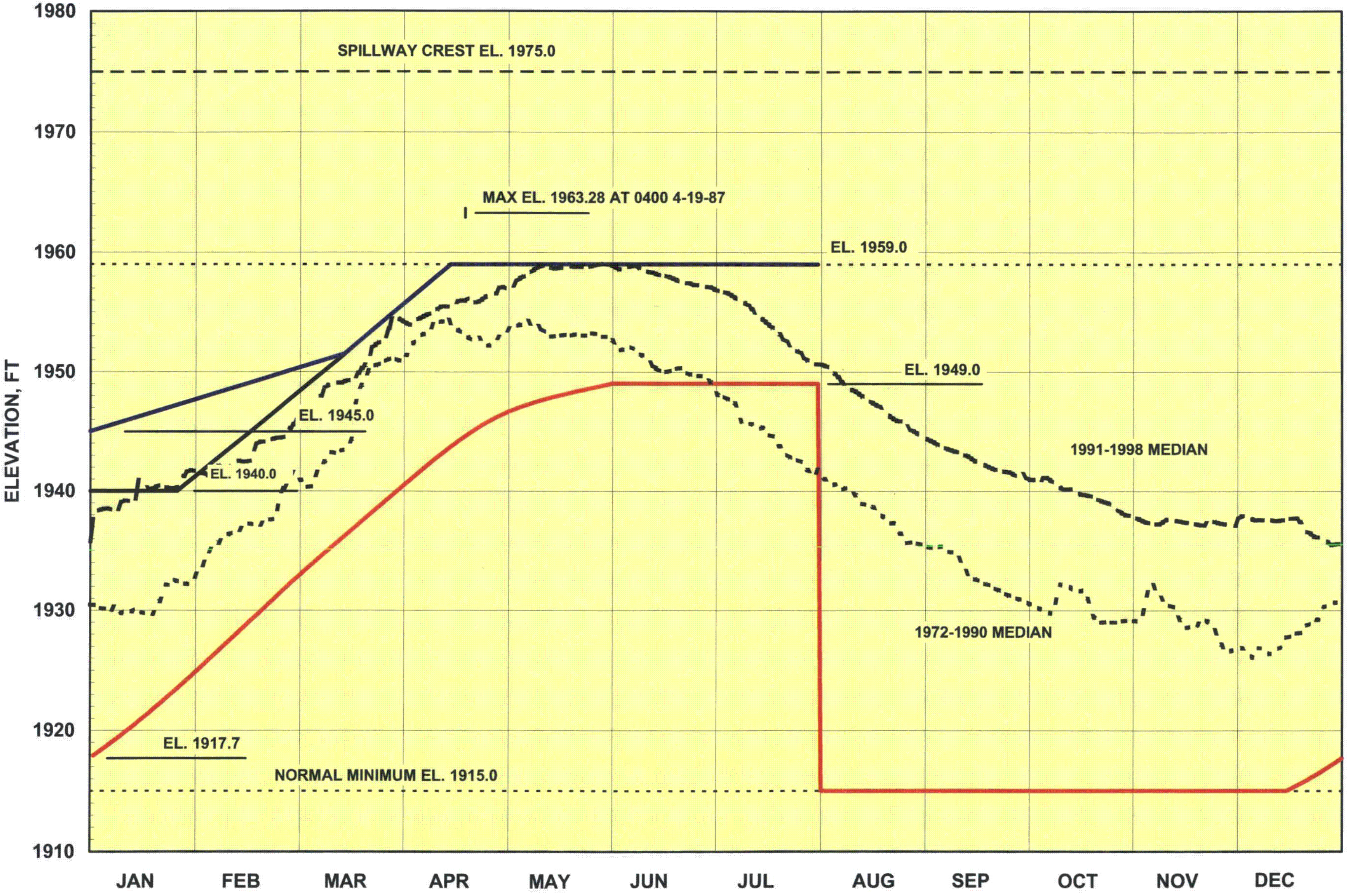
AVERAGE WEEKLY CFS

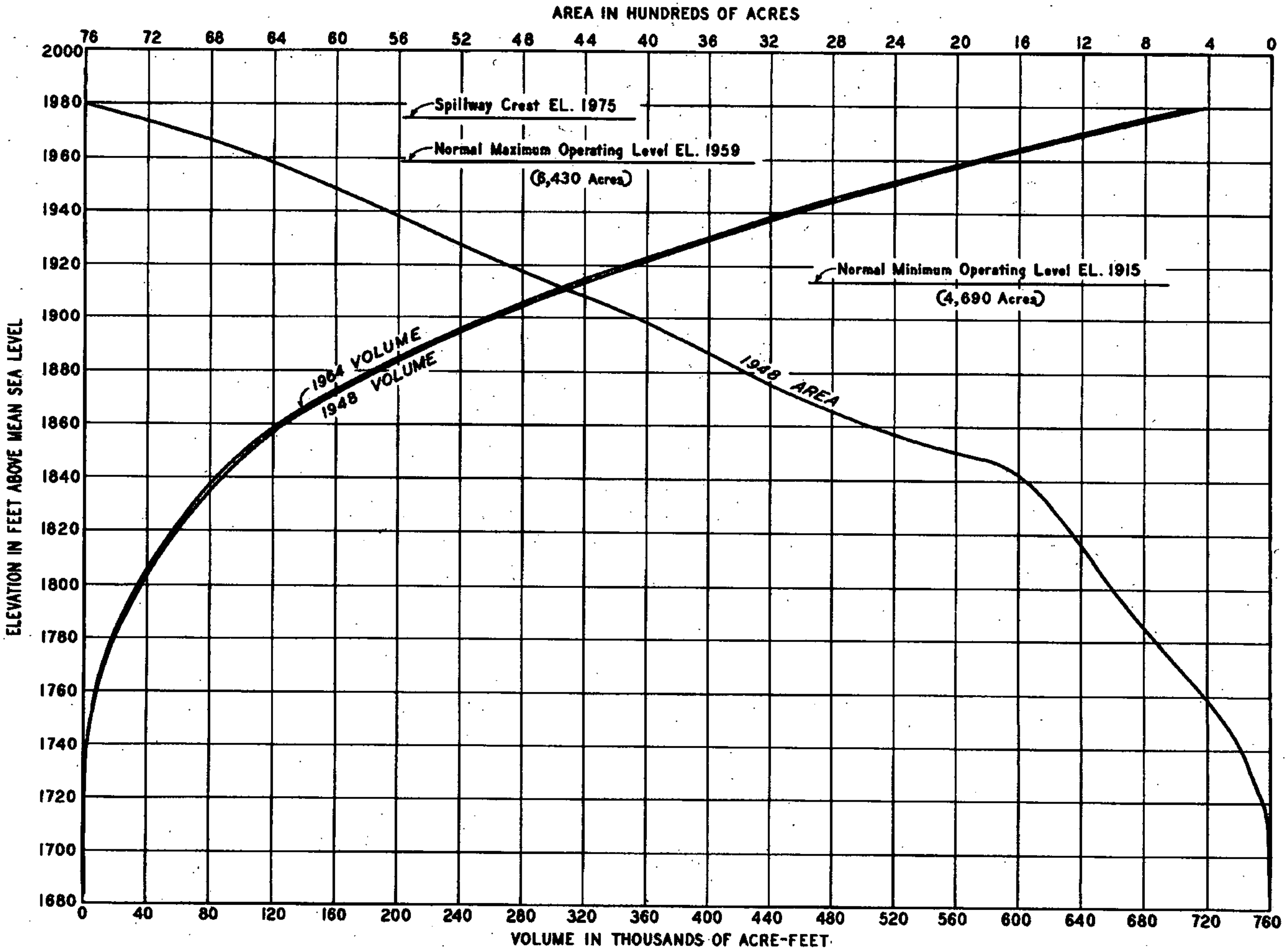
MAXIMUM, MINIMIUM, MEDIAN, AND MEAN
Adjusted Flow by Weeks
Watauga
Years = 1903-1999

WEEK ENDING	WEEK NO.	MAXIMUM	YR	MINIMUM	YR	MEDIAN	MEAN
JAN 7	1	2,740	1937	115	1954	745	906
JAN 14	2	4,100	1995	81	1954	721	917
JAN 21	3	4,630	1995	119	1981	721	914
JAN 28	4	3,890	1906	167	1966	906	1,050
FEB 4	5	6,190	1957	120	1966	887	1,100
FEB 11	6	4,140	1957	203	1934	873	1,100
FEB 18	7	4,530	1966	203	1934	979	1,200
FEB 25	8	3,720	1927	185	1934	1,010	1,120
MAR 4	9	3,360	1987	279	1988	979	1,090
MAR 11	10	2,920	1917	325	1988	1,090	1,200
MAR 18	11	5,610	1963	387	1985	946	1,320
MAR 25	12	3,730	1993	315	1988	1,010	1,250
APR 1	13	4,600	1960	305	1988	1,070	1,320
APR 8	14	4,790	1957	265	1966	943	1,190
APR 15	15	3,090	1987	299	1986	869	1,060
APR 22	16	4,770	1987	274	1942	841	1,010
APR 29	17	2,350	1973	239	1976	760	871
MAY 6	18	2,400	1989	236	1986	727	838
MAY 13	19	4,790	1984	268	1963	668	858
MAY 20	20	3,230	1905	250	1941	673	825
MAY 27	21	2,190	1942	209	1941	610	723
JUN 3	22	2,910	1973	182	1941	532	726
JUN 10	23	3,280	1992	174	1988	530	620
JUN 17	24	2,090	1992	171	1988	449	584
JUN 24	25	1,900	1972	181	1970	431	521
JUL 1	26	1,620	1929	33	1988	409	474
JUL 8	27	3,100	1989	105	1952	414	506
JUL 15	28	3,350	1905	112	1953	428	519
JUL 22	29	1,940	1949	151	1926	364	483
JUL 29	30	2,550	1935	97	1952	404	465
AUG 5	31	1,800	1940	67	1986	387	475
AUG 12	32	2,750	1905	42	1954	351	432
AUG 19	33	8,260	1940	100	1983	348	570
AUG 26	34	2,010	1961	89	1962	327	435
SEP 2	35	3,710	1906	44	1987	292	412
SEP 9	36	3,050	1928	65	1998	281	419
SEP 16	37	1,180	1906	39	1954	266	326
SEP 23	38	2,270	1945	40	1956	244	353
SEP 30	39	2,150	1924	48	1958	256	372
OCT 7	40	2,680	1995	75	1987	257	398
OCT 14	41	1,900	1976	48	1954	261	324
OCT 21	42	3,410	1964	50	1954	267	412
OCT 28	43	2,120	1937	64	1954	290	407
NOV 4	44	2,200	1949	63	1954	300	442
NOV 11	45	5,430	1977	77	1953	312	447
NOV 18	46	1,780	1927	129	1963	346	447
NOV 25	47	2,600	1906	92	1958	364	502
DEC 2	48	2,200	1934	149	1953	413	537
DEC 9	49	3,520	1950	148	1965	453	625
DEC 16	50	3,610	1961	89	1958	505	668
DEC 23	51	3,030	1915	107	1965	478	647
DEC 31	52	3,250	1932	130	1965	672	809

AVERAGE FLOW: 1903 - 1999 = 716 CFS

ANNUAL OPERATING CYCLE





ELEV FT	1948 AREA AC	VOLUME			
		1948 AC-FT	1953 AC-FT	1958 AC-FT	1964 AC-FT
1,980	7,600	718,000	717,000	716,000	714,000
1,975	7,300	681,000	680,000	679,000	677,000
1,970	6,930	646,000	645,000	643,000	642,000
1,960	6,480	579,000	578,000	576,000	575,000
1,950	6,070	516,000	515,000	514,000	512,000
1,940	5,680	457,000	456,000	455,000	454,000
1,930	5,310	402,000	401,000	400,000	399,000
1,920	4,900	351,000	350,000	349,000	348,000
1,910	4,500	304,000	303,000	302,000	301,000
1,900	4,070	262,000	261,000	260,000	258,000
1,890	3,710	223,000	222,000	221,000	220,000
1,875	3,200	171,000	170,000	169,000	168,000
1,860	2,560	128,000	127,000	127,000	126,000
1,850	2,000	105,000	104,000	104,000	103,000
1,840	1,550	87,200	86,800	86,600	85,900
1,830	1,390	72,500	72,100	72,000	71,300
1,820	1,250	59,300	59,000	58,900	58,200
1,810	1,130	47,400	47,100	47,000	46,300
1,795	929	32,100	31,800	31,700	31,000
1,780	715	19,800	19,500	19,500	18,800
1,770	572	13,300	13,200	13,200	12,700
1,760	411	8,440	8,370	8,380	7,980
1,750	285	4,950	4,940	4,920	4,580
1,740	183	2,610	2,610	2,600	2,390
1,730	113	1,140	1,120	1,120	990
1,720	38	379	374	378	300
1,710	11	134	129	134	76
1,685	0	0	0	0	0

NOTES:

Reservoir areas were measured on TVA land maps, scale 1:6,000, at elevations 1795, 1875, 1960, 1975 & 1980, and TVA topographic maps, scale 1:24,000, at elevations 1720, 1760, 1840 & 1920. Contours were made to conform to elevations on TVA sediment range cross sections which are located at one to three mile intervals within the reservoir.

The 1953 and subsequent volumes were determined by the constant factor method for computing sediment.

Elevations are referred to the 1936 Supplementary Adjustment of the U.S.C. & G.S.

Area of original river within the reservoir = 313 acres.

Drainage area above dam = 468 square miles.

Dam closure December 1, 1948.

WATAUGA RIVER - MILE 36.7

RESERVOIR AREAS
AND VOLUMES

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF WATER CONTROL PLANNING

SUBMITTED	RECOMMENDED	APPROVED
Edwin K. McCain	Paul C. Spath	

KNOXVILLE | 12-28-62 | 22 | DA | 1 | 321N800R2

THIS DRAWING SUPERSEDES 22-DA-1-321G334R1

SAFETY MODICATIONS FOR PROBABLE MAXIMUM FLOOD

Chronology

Safety analysis studies for Watauga Dam for the Probable Maximum Flood (PMF) were started on May 21, 1981, and completed on February 23, 1983. Final design was completed on October 13, 1982. Onsite construction began on April 11, 1983, and was completed on October 23, 1983.

Cost of Modifications

Design costs for the capital safety modifications to Watauga Dam were approximately $86,000. Construction costs were approximately $1,000,000. The total project cost was approximately $1,086,000. This total does not include costs for dam safety evaluation studies which resulted in the modifications.

Controlling Features

The embankments at Watauga were modified in order to safely pass the probable maximum flood. The embankments were raised ten feet by the addition of rockfill. These PMF modifications will prevent overtopping and erosion of the embankments and thus prevent breach and failure of the dam.

RESERVOIR RELEASE IMPROVEMENTS

A turbine venting system was installed at Watauga Hydro Plant to improve the dissolved oxygen content of the releases during the fall months. Turbine venting utilizes the vacuum breaker ports on the turbine casing to induce air into the water flowing through the turbine. Oxygen from this induced air is dissolved into the water. This technique consists of adding baffles over existing breaker ports and providing vacuum breaker system by-pass piping for aeration. This has resulted in a dissolved oxygen improvement in the tailwaters of approximately 2mg/L depending upon wicket gate opening, headwater elevation, and incoming dissolved oxygen concentration.

CONSTRUCTION DATA

PERSONNEL

	Dam and Reservoir Construction	Dam Construction Only
Peak employed	1,650	1,400*
Total man-hours	10,274,559	7,316,481
Number of injuries	48	41
Days lost	20,976	20,431
Fatalities	1	1
Accident frequency	4.7	5.6
Accident severity	2,042	2,792

* Estimated

HOUSING FACILITIES

Permanent houses built	None
Semipermanent houses built	55*
Dormitories built:	
Staff (52 total capacity)	2
Men (276 total capacity)	3
Demountable houses(4 duplex, 2 single)	6
Tents (55 total capacity)	11
Trailers	34

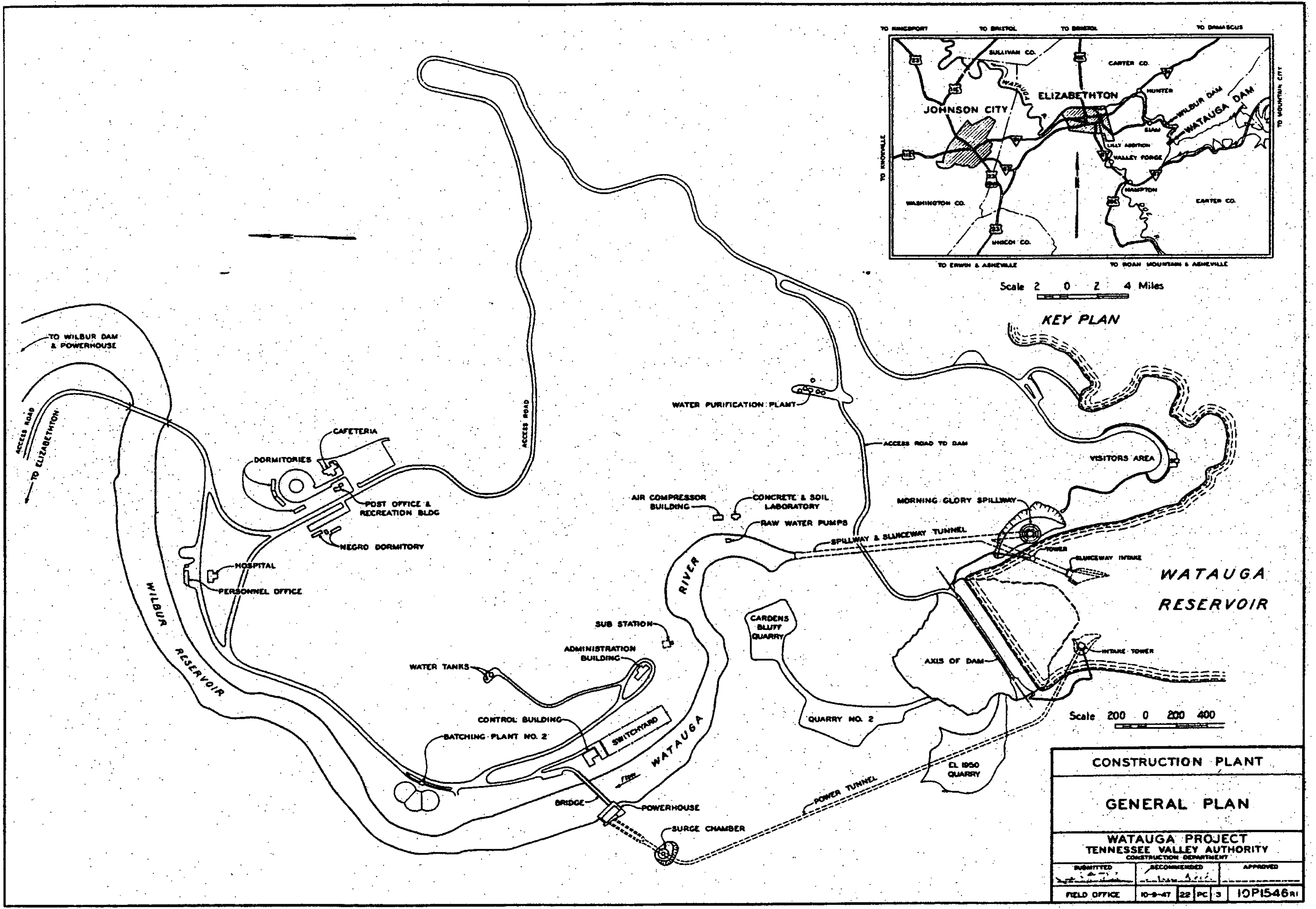
Public buildings constructed included a cafeteria (96 seats), hospital (8 beds), recreation building and post office, fire station, and an observation building.

*Used in place also for South Holston, renovation of Wilbur, Boone, and Fort Patrick Henry.

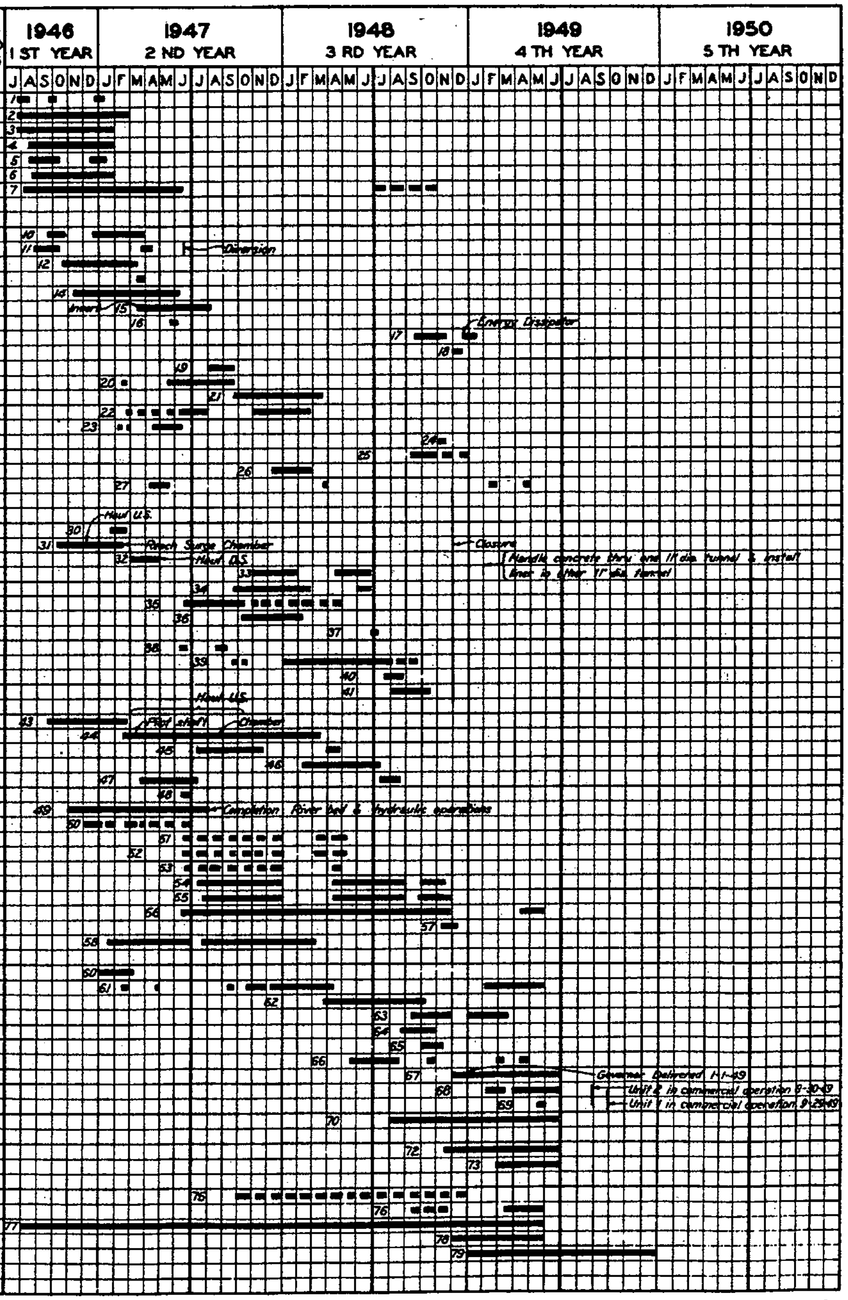
CONSTRUCTION DATA (CONT.)

QUANTITIES

	Dam and Power Plant
Dam and power facilities:	
Rock excavation	364,200 cu. yd
Unclassified excavation	254,900 cu. yd
Rolled earthfill	1,482,700 cu. yd
Rockfill-quarry run	1,771,900 cu. yd
Filter blanket-crushed rock	224,000 cu. yd
Riprap	19,200 cu. yd
Reinforcing steel	1,045 tons
Structural steel (includes trashracks, sluice liners, surge tank riser,and penstock)	1,290 tons
Formwork	584,000 sq. ft
Grouting	65,400 cu. ft
Concrete	80,400 cu. yd
Highway and railroad:	
Excavation	2,793,000 cu. yd


TO KINGSPORT
TO BRISTOL
TO BRISTOL
TO DAMASCUS
SULLIVAN CO.
CARTER CO.
WATAUGA
ELIZABETHTON
JOHNSON CITY
HUNTER
WILBUR DAM
WATAUGA DAM
SIAM
LILLY ADDITION
VALLEY FORGE
HAMPTON
WASHINGTON CO.
CARTER CO.
UNICOI CO.
TO KNOXVILLE
TO MOUNTAIN CITY
TO ERWIN & ASHEVILLE
TO ROAN MOUNTAIN & ASHEVILLE
Scale 2 0 2 4 Miles
KEY PLAN
TO WILBUR DAM & POWERHOUSE
ACCESS ROAD
TO ELIZABETHTON
CAFETERIA
DORMITORIES
POST OFFICE & RECREATION BLDG
NEGRO DORMITORY
ACCESS ROAD
HOSPITAL
PERSONNEL OFFICE
WILBUR RESERVOIR
WATER PURIFICATION PLANT
ACCESS ROAD TO DAM
VISITORS AREA
AIR COMPRESSOR BUILDING
CONCRETE & SOIL LABORATORY
RAW WATER PUMPS
MORNING GLORY SPILLWAY
SPILLWAY & SLUICEWAY TUNNEL
TOWER
SLUICEWAY INTAKE
WATAUGA RESERVOIR
RIVER
CARDENS BLUFF QUARRY
SUB STATION
ADMINISTRATION BUILDING
WATER TANKS
AXIS OF DAM
INTAKE TOWER
QUARRY NO. 2
CONTROL BUILDING
SWITCHYARD
BATCHING PLANT NO. 2
WATAUGA
FLOW
EL 1950 QUARRY
BRIDGE
POWERHOUSE
POWER TUNNEL
SURGE CHAMBER
Scale 200 0 200 400
CONSTRUCTION PLANT
GENERAL PLAN
WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT
SUBMITTED
RECOMMENDED
APPROVED
FIELD OFFICE
10-9-47
22
PC
3
10P1546R1

STAGES	NO.	ITEM OR EQUIPMENT	TOTAL QUANTITY CU YD	COMPLETE PRIOR TO JUL 1946 CU YD	TO BE COMPLETED JUL 1946 CU YD
CONSTR. SERVICES AND CONSTR. PLANT	1	Access Roads			
	2	Raw & Treated Water Supply			
	3	Air & Electric Systems			
	4	Job Buildings			
	5	Job Roads & Bridges			
	6	Aggregate Quarry & Aggregate Plant			
	7	Permanent Access Road			
	8				
	9				
DIVERSION TUNNEL AND SPILLWAY	10	Excavation - Tunnel Trim			
	11	- Open cut - Spillway Plaza & Portals			
	12	- Spillway shaft & Elbow			
	13	- Sluice shaft			
	14	Concrete - Tunnel lining & Wye			
	15	Elbow			
	16	- Diversion conduit (shelf)			
	17	- Gate plug & weirs			
	18	- Diversion conduit closure plug			
	19	- Spillway shaft			
	20	- Sluiceway shaft			
	21	- Bellmouth Spillway			
	22	- Control tower			
	23	- Tunnel portals including trash rack			
	24	Trash rack			
	25	Slide gates, control valves & sluice liners			
	26	Control tower bridge			
	27	Grouting tunnels & shafts			
	28				
	29				
POWER TUNNEL AND PENSTOCKS	30	Excavation - Open cut at portals			
	31	- Tunnel - U.S. portal to surge chamber			
	32	- Tunnel - P.H. to surge chamber			
	33	Clean invert - Entire tunnel			
	34	Concrete - 18' dia. - U.S. 1250'			
	35	- 11' dia. tunnels & incline section			
	36	Steel Penstocks - 320 tons			
	37	Grouting			
INTAKE	38	Excavation - Tower foundations			
	39	Concrete - Tower			
	40	Gate guides - (46 ton)			
	41	Gates & gate operating equipment			
	42				
SURGE CHAMBER	43	Excavation - Open cut for plaza			
	44	- Chamber			
	45	Concrete - Chamber & shaft (120' of lining at top)			
	46	Riser - 200 tons			
	47	Grouting			
DAM STRUCTURE	48	Cofferdam			
	49	Excavation - Unclassified			
	50	- Rock			
	51	- Cut-off wall			
	52	Foundation preparation & treatment			
	53	Concrete - Cut-off wall			
	54	Rolled earth fill			
	55	Filter blanket			
	56	Rock fill - Quarry run			
	57	Riprap			
	58	Rock Fill Quarry - Preparation			
	59				
POWERHOUSE	60	Cofferdam			
	61	Excavation - Rock (PH & Tailrace)			
	62	Concrete - Substructure			
	63	- Superstructure			
	64	Structural steel			
	65	Powerhouse crane			
	66	Butterfly valve			
	67	Turbine			
	68	Generator			
	69	Transformers			
CONTROL BLDG	70	Control building			
	71				
SWITCHYARD	72	Structures & improvements			
	73	Station equipment for switchyard			
	74				
GENERAL	75	Permanent powerhouse bridge			
	76	General yard improvements			
	77	Highway relocation			
	78	Reservoir filling			
	79	Clean-up & removal			
	80				
	81				



THIS DRAWING SUPERSEDES 21-CP-3 102-WW-3

GENERAL

PROJECT
CONSTRUCTION SCHEDULE

WATAUGA PROJECT
TENNESSEE VALLEY AUTHORITY
CONSTRUCTION DEPARTMENT

SUBMITTED	RECOMMENDED	APPROVED
	[illegible]	
FIELD OFFICE	1-16-47	77 [illegible] 3 10K39