TVA Calculation Package

Page: 01 of 220

Title Ash Pond Breaching Project Work Plan 1

Location Description: *(Optional)*	Ash Pond at Watts Bar Fossil Plant, Spring City, TN	**Total Pages:** *(including appendices & attachments)*

Calculation ID *(All parts required to form a unique ID)*:

Org Code	Location/ Plant Code	Branch Code	**Alphanumeric Part** = Discipline Code (1) + Type Code (1) + "X" + Unit Field (3) + Sys Code (3) + Year (4) + Sequence No. (4)
GEN	WBF	FES	CDX0000002012001005

NOTE: When referencing the calculation ID, include all parts without spaces or dashes between them.

Unit(s), Spill gate(s), or Voltages (PSO): 000	**Key Nouns (For CTS/CCRIS):**

Applicable Design Document(s):	**Rev**	**RIMS/EDMS Accession Number** *(Optional)*
WBF-10W253-WP-1	**R0**	
	R	
UNID System(s):	**R**	
000	**R**	

	R0	R	R	R
DCN, PCN, NA				
Prepared: Sign→ Print Name	Robert Hopper Jintao Wen Donna Friis			
Checked: Sign→ Print Name	Ben Pernezny Steve Whiteside, PE Tim Verwey, PE	Stephen L. Whiteside		

These calculations contain unverified assumption(s) that must be verified later? ☐ Yes ☒ No

These calculations contain special requirements and/or limiting conditions? ☒ Yes ☐ No

Approved: Sign→ Print Name	David Mason, PE			
Approval Date	8/17/12			

These calculations contain a design output attachment? ☒ Yes ☐ No

Revision Applicability	☒ Entire calc	☐ Entire calc ☐ Selected pgs	☐ Entire calc ☐ Selected pgs	☐ Entire calc ☐ Selected pgs

Computer output Microfiche generated? ☐ Yes ☒ No Number: ____________

Purpose of the Calculation: Support development of design drawings for Ash Pond Breaching Project Work Plan 1.

TVA Calculation Coversheet
CTS Input Form

Page: 02 of 219

Preparer	**Preparer Login ID**	**Date**
Checker	**Checker Login ID**	**Date**

Update Code: ☒ Add ☐ Change ☐ Delete
☐ Rename ☐ Supersede ☐ Duplicate ☐ Verify

The following section applies if a calculation is being renamed, superseded, or has a duplicate.

	Org Code	Plant	Branch	Number	Cur Rev	New Rev
Current Calc ID:						

The following section applies to all calculations.

Calc ID:	FPG	WBF	FES	CDX0000002012001005	0	0

Firm: *(TVA or Contractor)* CDM Smith

Cross-References

A/C/D	Xref Code	Type	Org Code	Plant	Branch	Number	Rev

TVA Calculation Record of Revision

Calculation Identifier: CDX0000002012001005

Title

Revision No.	**Description of Revision**

TVA Computer File Storage Information Sheet

Page: 04 of 219

Calculation Identifier: CDX0000002012001005 **Rev.** ______ **Plant:** WBF

Subject: These software model calculations support the Ash Pond Breaching Project Work Plan 1.

Software Name: 1.) HEC-HMS 3.5 2.) U.S.EPA SWMM 5.0 **Revision Level:** ______

Vendor Name: 1.) U.S. Army Corps of Engineers 2.) U.S. EPA

Address: 1.) http://www.hec.usace.army.mil/software/hec-hms/download.html
2.) http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/

Executable Files

☒ No TVA developed **executable files** were used in this calculation.
Comments:

☐ TVA developed **executable files** used in this calculation have been stored electronically and sufficient identifying information is provided below for each executable file. *(Any retrieved file requires re-verification of its contents before use.)*

Input Files

☒ 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.)*

TVA Calculation Table of Contents

Calculation Identifier: CDX0000002012001005 **Revision:** ______

Table of Contents

CLIENT TVA
PROJECT Watts Bar Ash Pond
DETAIL Ash Pond Inflow Hydrograph
PROJECT NO. 92016.2202
TVA Calculation Package GENWBFFESCDX0000002012001005

COMPUTED BY / DATE R.H. 07/27/12
CHECKED BY / DATE B.P. 08/14/12
REVISION NO. / DATE - -
REVIEWED BY / DATE - - -

Ash Pond Inflow Hydrograph

1.0 Objective

Develop Ash Pond inflow hydrographs for range of design rainfall events.

2.0 Procedure

1.) Develop watershed hydrologic modeling parameters using SCS peak flow methods.
2.) Build hydrologic model in HEC-HMS using SCS peak flow methods.
3.) Simulate suite of design storms.
4.) Verify model by comparison of resulting hydrographs and peak flows with available information.

3.0 References / Data Sources

1.) Volume 2 of 3: Facilities Design and Construction Requirements TVA Coal Combustion Products Management Program Master Programmatic Document (Revision 1.0) 2009, by URS.

2.) NRCS WinTR-55 Manual (ftp://ftp.wcc.nrcs.usda.gov/wntsc/H&H/WinTR55/WinTR55UserGuide.pdf)

3.) HEC-HMS Version 3.5 Software and Users Manual
http://www.hec.usace.army.mil/software/hec-hms/download.html http://www.hec.usace.army.mil/software/hec-hms/documentation/HEC-HMS_Users_Manual_3.5.pdf

4.) Survey conducted Nov 2011, CAD file: B000EXBS.dwg
Survey conducted May 2012 CAD file: wf06_wbn12397_20120505(ver2007).dwg

5.) The culverts (6 RCP barrels) along the security roadway are reported to overtop approximately once per year by TVA security staff.

4.0 Assumptions / Limitations

1.) Watershed hydrologic parameters developed based on desktop information available in GIS, survey data, and limited field observation.

5.0 Calculations

5.1 Develop hydrologic parameters

1.) Subbasin Area - delineation performed in GIS using USGS topographic map and aerials (Refer to Table 1 and Figure 1 Drainage Area).

Table 1. Watts Bar Ash Pond Subbasin Hydrologic Parameters

Subbasin	Area (acres)	Area (sq mi)	Composite CN	Lag (hr)	Lag (min)
1	20.5	0.032	88	0.25	14.71
2	11.9	0.019	84	0.25	15.18
3	19.2	0.03	86	0.28	16.85
4	16.8	0.026	84	0.30	18.19
5	44.4	0.069	84	0.33	20.06
6	68.5	0.107	66	0.48	28.84
7	8.4	0.013	73	0.25	14.90
Total	189.7	0.296			

2.) Table 2 - Composite Curve Number - input land use conditions (Fig 1) and hydrologic soils group (Fig 2) into WinTR-55

The SCS Curve Number Method was utilized to calculate losses occurring prior to runoff. SCS Curve Numbers were developed for each subbasin based on existing land cover as observed on 2011 Aerial photography with consideration for recent removal of coal combustion facility and landfill closure area conditions. Table 2 lists the watershed subbasin curve numbers and the land surface conditions and hydrologic soils group used to assign the curve number using Win TR-55. Figure 2 shows the hydrologic soil group distribution across the drainage area.

Additionally, the water surface area of the Ash Pond itself is accounted for as directly connected impervious area with 5.8 acres entered in the model.

Table 2. Ash Pond Drainage Area Hydrologic Modeling SCS Curve Numbers

Subbasin	Acres	Land Use Description	Hydrologic Soils Group	CN	Composite CN (from TR-55)	Tc (hr)	Tc (min)
1	20.5	5.8 open water impervious	5.8 acres urban D HSG	98	88	0.25	14.71
		14.7 acres fair cond grass	6.6 acres B HSG	84			
			8.1 acres urban D HSG				
2	11.9	managed pervious - fair cond grass	all urban D HSG	84	84	0.25	15.18
3	19.2	7 acres grass	all urban D HSG	79	86	0.28	16.85
		10 acres gravel		89			
		2.2 acres buildings		98			
4	16.8	managed pervious - fair cond grass	all urban D HSG	84	84	0.30	18.19
5	44.4	6 acres of gravel	all urban D HSG	91	84	0.33	20.06
		31.9 acres of fair cond grass		84			
		8.5 acres of woods - fair cond					
6	68.5	forested - fair cond	39.9 acres of B HSG	60	66	0.48	28.84
			28.6 acres of C HSG	73			
7	8.4	forested - fair cond	all C HSG	73	73	0.25	14.90

3.) Table 3 - Lag Time - developed utilizing longest flow path for each subbasin as shown on Figure 1
(Summary in Table 1, Calculations in Table 3)

Runoff from each subbasin is transformed to a discharge hydrograph using the SCS Unit Hydrograph Method. This method utilizes a Lag Time in minutes derived as 0.6 times the time of concentration along the longest flow path in each subbasin. The time of concentration was calculated as the total of the sheet flow, shallow concentrated flow, and channel flow segments. Figure 2 shows the longest flow paths for each subbasin and Table 4 lists the calculated lag times.

4.) Table 4 - Area Elevation - curve for Ash Pond derived from survey in CAD (existing conditions curve utilized in model)

Table 4. Ash Pond Area- Elevation Curve from CAD

Elev	Area (sq ft)	Elev	Area (Acres)
710	353,001	710	8.10
709	346,630	709	7.96
708	339,126	708	7.79
707	332,287	707	7.63
706	325,514	706	7.47
705	318,807	705	7.32
704	312,166	704	7.17

703	305,590	703	7.02
702	299,083	702	6.87
701	292,644	701	6.72
700	286,273	700	6.57
699	279,970	699	6.43
698	273,735	698	6.28
697	267,569	697	6.14
696	261,470	696	6.00
695	255,441	695	5.86
694	249,480	694	5.73

5). Table 5 - Reach dimensions and conditions derived from GIS aerials and limited available survey in CAD

Routing of runoff from each subbasin was through a network of four reaches representing the drainage pathways on the site. Routing was performed using the Muskingum Cunge method using a typical cross section of estimated dimensions for each reach in the low gradient conditions. Typical reach characteristics, as listed in Table 5, are based the CAD file (388911.dwg) and GIS aerials. The culverts (6 barrels) conveying flows beneath the roadway just upstream of the Ash Pond are included in the model since they provide some storage, although limited information was available to model the dimensions of these culverts or of any upstream culverts.

Table 5. Reach Characteristics (ft)

Reach	High Elev (ft)	Low Elev (ft)	Length (ft)	Slope	Bottom Width	Side Slope	Channel Condition	Manning's n
1	705	703	670	0.0030	5	3H:1V	Constructed grassed	0.4
2	709	705	560	0.0071	4	3H:1V	Constructed grassed	0.4
3	724	709	1670	0.0090	3	3H:1V	Forested	0.5
4	720	709	2200	0.0050	2	3H:1V	Forested	0.5

A storage area was modeled behind the roadway culverts upstream of the Ash Pond to account for limited attenuation and verify the frequency of overtopping flows at the roadway. The small estimated storage area is based on very limited CAD survey information in the area behind the culverts. The roadway is anecdotally known to flood on a yearly basis. Therefore, model results for the 1-year rainfall indicating that the culverts overtop provides some verification that the modeled flows are reasonable for the site conditions.

6.) Table 6 - Rainfall for the drainage area is from the NOAA Atlas 14 website for the Watts Bar Dam Station. An SCS Type II rainfall distribution with 24 hour duration is used for each recurrence interval. NOAA precipitation data provided as Table 7.

NOAA Atlas 14 Point Precipitation Frequency Estimates. Accessed May 19, 2012.
http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nc

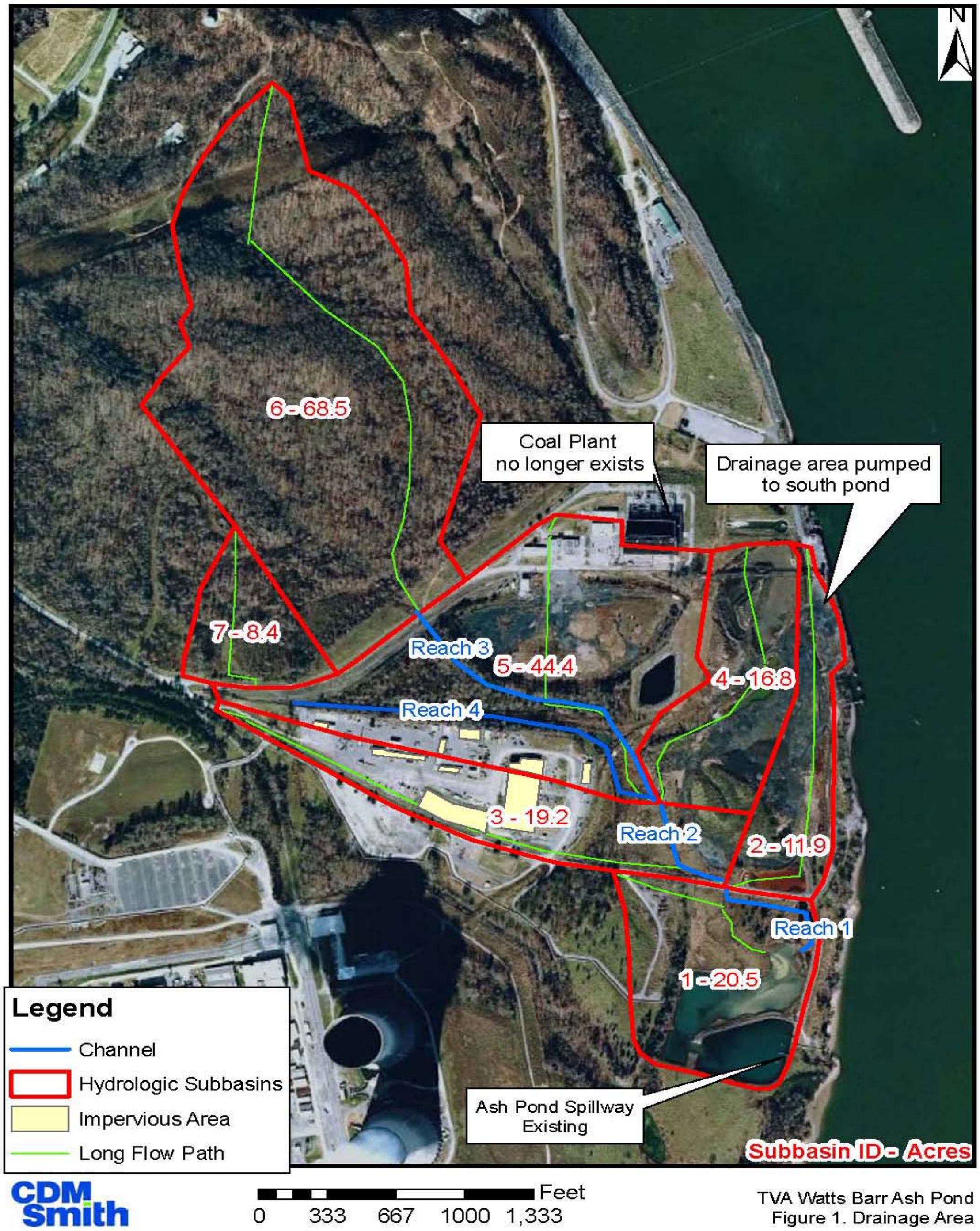
Table 6. NOAA Rainfall at Watts Bar Dam Station

Recurrence Interval (yr)	Rainfall (in)
1	2.95
2	3.53
10	4.9
25	5.73
50	6.39
100	7.06

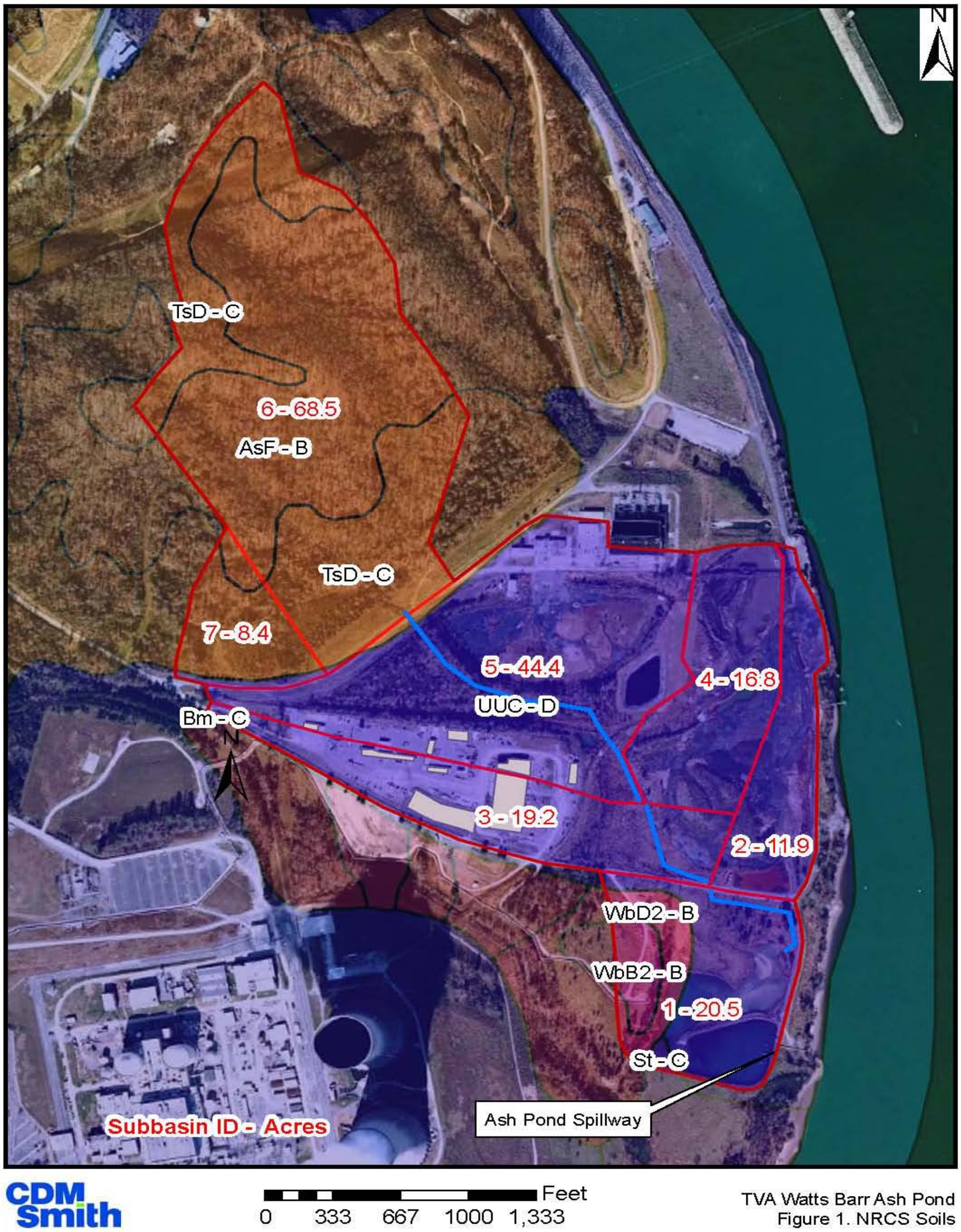
Figure 3 provides a schematic view of the HMS model. The model file folder is named: WattsBarAshPondHMS

6.0 Conclusions

The result is a detailed hydrologic model using the SCS peak flow method of the Watts Bar Ash Pond verified based on available information. The resulting inflow hydrographs shall be used as inputs for hydraulic modeling associated with design of Ash Pond discharge spillway improvements.



TVA Watts Barr Ash Pond
Figure 1. Drainage Area



CDM Smith

TVA Watts Barr Ash Pond
Figure 1. NRCS Soils

Watts Bar Ash Pond Lag Time Calculations

Watershed Id: 1 Ash Pond

Segment for Travel Time Method

Total Time of Concentration (hr)	0.41
Lag Time (hr)	0.25

SHEET FLOW

1. Surface Description		Grass
2. Flow Length, L	ft	150
3. Manning's "n"		0.15
4. 2-Yr, 24-Hr Rainfall, P_2	in	3.59
5. High point el		654
6. Low point el		651
7. Land slope, s	ft/ft	0.0200

Kinematic Tt = $\frac{0.007\,(n\,L)^{0.8}}{(P_2)^{0.5}\,s^{0.4}}$

8. Travel Time	hr	0.21

SHALLOW CONCENTRATED FLOW

9. Surface Description (Paved or Unpaved)		Unpaved
10. Flow Length, L	ft	440
11. High point el		651
12. Low point el		645
13. Watercourse slope, s	ft/ft	0.014
14. Hydraulic Radius, r (A/P)		0.25

Manning's Eq. V =1.49 $r^{0.67}\,s^{0.5}$ / n

15. Manning's n		0.1
16. Average Velocity, V	ft/s	0.69
17. Travel Time	hr	0.18

CHANNEL FLOW 1

18. Channel length, L	ft	350
19. High point channel el		645
20. Low point channel el		636
21. Manning's "n"		0.03
22. Channel bottom width,	ft	1
23. Channel top width,	ft	4
24. Channel depth,	ft	1
25. Cross sectional flow area, a	ft^2	2.5
26. Wetted perimeter, p_w	ft	4.6
27. Hydraulic radius, $r=a/p_w$	ft	0.54
28. Channel slope, s	ft/ft	0.0257
29. Average Velocity, V	ft/s	5.29
30. Travel Time	hr	0.02

POND FLOW

18. Channel length, L	ft	0
29. Average Velocity, V	ft/s	1.00
30. Travel Time	hr	0.00

Watershed Id: 2

Segment for Travel Time Method

Total Time of Concentration (hr)	0.42
Lag Time (hr)	0.25

SHEET FLOW

1. Surface Description		Grass
2. Flow Length, L	ft	150
3. Manning's "n"		0.15
4. 2-Yr, 24-Hr Rainfall, P_2	in	3.59
5. High point el		654
6. Low point el		645
7. Land slope, s	ft/ft	0.0600

Kinematic Tt = $\frac{0.007\,(n\,L)^{0.8}}{(P_2)^{0.5}\,s^{0.4}}$

8. Travel Time	hr	0.14

SHALLOW CONCENTRATED FLOW

9. Surface Description (Paved or Unpaved)		Unpaved
10. Flow Length, L	ft	1122
11. High point el		645
12. Low point el		580
13. Watercourse slope, s	ft/ft	0.058
14. Hydraulic Radius, r (A/P)		0.25

Manning's Eq. V =1.49 $r^{0.67}\,s^{0.5}$ / n

15. Manning's n		0.1
16. Average Velocity, V	ft/s	1.42
17. Travel Time	hr	0.22

CHANNEL FLOW 1

18. Channel length, L	ft	912
19. High point channel el		580
20. Low point channel el		529
21. Manning's "n"		0.06
22. Channel bottom width,	ft	1
23. Channel top width,	ft	4
24. Channel depth,	ft	1
25. Cross sectional flow area, a	ft^2	2.5
26. Wetted perimeter, p_w	ft	4.6
27. Hydraulic radius, $r=a/p_w$	ft	0.54
28. Channel slope, s	ft/ft	0.0559
29. Average Velocity, V	ft/s	3.90
30. Travel Time	hr	0.07

Watershed Id: 3

Segment for Travel Time Method

Total Time of Concentration (hr)	0.47
Lag Time (hr)	0.28

SHEET FLOW

1. Surface Description		Grass
2. Flow Length, L	ft	150
3. Manning's "n"		0.15
4. 2-Yr, 24-Hr Rainfall, P_2	in	3.59
5. High point el		672
6. Low point el		669
7. Land slope, s	ft/ft	0.0200

Kinematic Tt = $\frac{0.007\,(n\,L)^{0.8}}{(P_2)^{0.5}\,s^{0.4}}$

8. Travel Time	hr	0.21

CHANNEL FLOW 1

18. Channel length, L	ft	2550
19. High point channel el		669
20. Low point channel el		651
21. Manning's "n"		0.03
22. Channel bottom width,	ft	1
23. Channel top width,	ft	4
24. Channel depth,	ft	1
25. Cross sectional flow area, a	ft^2	2.5
26. Wetted perimeter, p_w	ft	4.6
27. Hydraulic radius, $r=a/p_w$	ft	0.54
28. Channel slope, s	ft/ft	0.0071
29. Average Velocity, V	ft/s	2.77
30. Travel Time	hr	0.26

Watershed Id: 4

Segment for Travel Time Method

Total Time of Concentration (hr)	0.51
Lag Time (hr)	0.30

SHEET FLOW

1. Surface Description		Grass
2. Flow Length, L	ft	150
3. Manning's "n"		0.15
4. 2-Yr, 24-Hr Rainfall, P_2	in	3.59
5. High point el		664
6. Low point el		658
7. Land slope, s	ft/ft	0.0400

Kinematic Tt = $\frac{0.007\,(n\,L)^{0.8}}{(P_2)^{0.5}\,s^{0.4}}$

8. Travel Time	hr	0.16

SHALLOW CONCENTRATED FLOW

9. Surface Description (Paved or Unpaved)		Unpaved
10. Flow Length, L	ft	287
11. High point el		658
12. Low point el		656
13. Watercourse slope, s	ft/ft	0.007
14. Hydraulic Radius, r (A/P)		0.25

Manning's Eq. V =1.49 $r^{0.67}\,s^{0.5}$ / n

15. Manning's n		0.1
16. Average Velocity, V	ft/s	0.49
17. Travel Time	hr	0.16

CHANNEL FLOW 1

18. Channel length, L	ft	1385
19. High point channel el		656
20. Low point channel el		652
21. Manning's "n"		0.04
22. Channel bottom width,	ft	2
23. Channel top width,	ft	8
24. Channel depth,	ft	2
25. Cross sectional flow area, a	ft^2	10.0
26. Wetted perimeter, p_w	ft	9.2
27. Hydraulic radius, $r=a/p_w$	ft	1.09
28. Channel slope, s	ft/ft	0.0029
29. Average Velocity, V	ft/s	2.11
30. Travel Time	hr	0.18

Watts Bar Ash Pond Lag Time Calculations

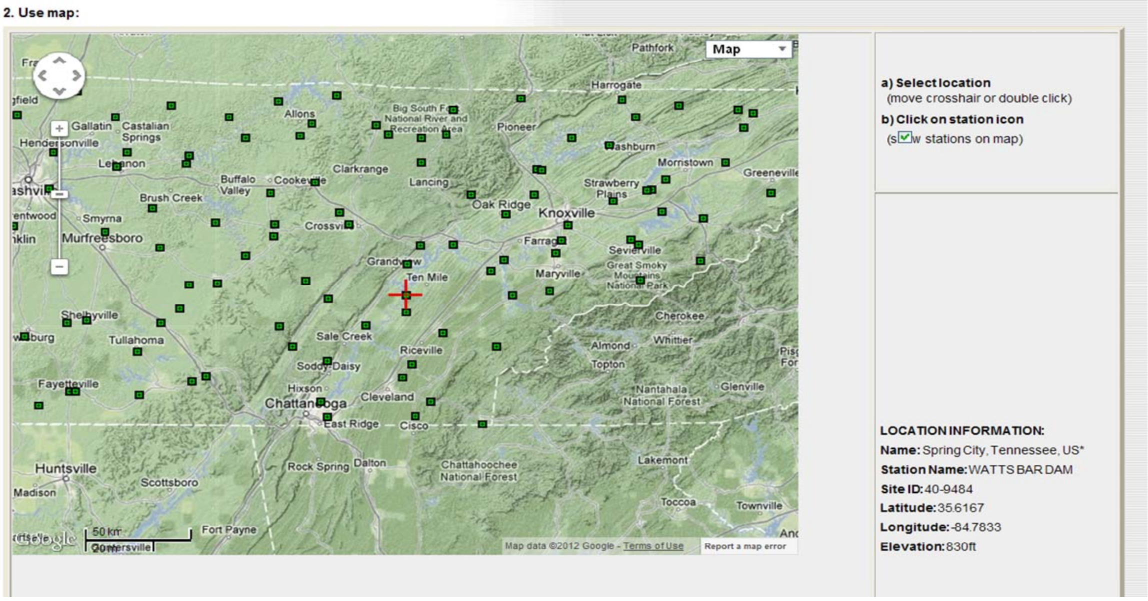
		Watershed Id: 5	Watershed Id: 6	Watershed Id: 7
Segment for Travel Time Method				
Total Time of Concentration (hr)		0.56	0.80	0.41
Lag Time (hr)		0.33	0.48	0.25
SHEET FLOW				
1. Surface Description		Grass	Woods	Woods
2. Flow Length, L	ft	150	200	200
3. Manning's "n"		0.15	0.4	0.4
4. 2-Yr, 24-Hr Rainfall, P_2	in	3.59	3.59	3.59
5. High point el		674	828	768
6. Low point el		672	786	750
7. Land slope, s	ft/ft	0.0133	0.2100	0.0900
Kinematic Tt = $\frac{0.007\ (n\ L)^{0.8}}{(P_2)^{0.5}\ s^{0.4}}$				
8. Travel Time	hr	0.25	0.23	0.32
SHALLOW CONCENTRATED FLOW				
9. Surface Description (Paved or Unpaved)		Unpaved	Unpaved	Unpaved
10. Flow Length, L	ft	555	884	475
11. High point el		672	786	750
12. Low point el		657	738	696
13. Watercourse slope, s	ft/ft	0.027	0.054	0.114
14. Hydraulic Radius, r (A/P)		0.25	0.25	0.25
Manning's Eq. $V = 1.49\ r^{0.67}\ s^{0.5} / n$				
15. Manning's n		0.1	0.1	0.1
16. Average Velocity, V	ft/s	0.97	1.37	1.98
17. Travel Time	hr	0.16	0.18	0.07
CHANNEL FLOW 1		main	main	main
18. Channel length, L	ft	975	2382	384
19. High point channel el		657	738	696
20. Low point channel el		654	727	672
21. Manning's "n"		0.03	0.04	0.06
22. Channel bottom width,	ft	1	1	1
23. Channel top width,	ft	4	4	4
24. Channel depth,	ft	1	1	1
25. Cross sectional flow area, a	ft^2	2.5	2.5	2.5
26. Wetted perimeter, p_w	ft	4.6	4.6	4.6
27. Hydraulic radius, $r=a/p_w$	ft	0.54	0.54	0.54
28. Channel slope, s	ft/ft	0.0031	0.0046	0.0625
29. Average Velocity, V	ft/s	1.83	1.68	4.12
30. Travel Time	hr	0.15	0.39	0.03

Table 7. NOAA Rainfall at Watts Bar Dam Station

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.36** (0.333-0.393)	**0.425** (0.393-0.464)	**0.504** (0.464-0.549)	**0.571** (0.525-0.622)	**0.662** (0.604-0.720)	**0.736** (0.667-0.798)	**0.814** (0.732-0.881)	**0.894** (0.795-0.969)	**1.01** (0.882-1.09)	**1.1** (0.952-1.19)
10-min	**0.575** (0.531-0.628)	**0.68** (0.628-0.743)	**0.806** (0.744-0.878)	**0.913** (0.839-0.995)	**1.06** (0.963-1.15)	**1.17** (1.06-1.27)	**1.29** (1.16-1.40)	**1.42** (1.26-1.54)	**1.59** (1.39-1.72)	**1.73** (1.50-1.88)
15-min	**0.718** (0.664-0.785)	**0.855** (0.789-0.934)	**1.02** (0.941-1.11)	**1.16** (1.06-1.26)	**1.34** (1.22-1.45)	**1.49** (1.35-1.61)	**1.63** (1.47-1.77)	**1.79** (1.59-1.94)	**2** (1.76-2.17)	**2.17** (1.88-2.35)
30-min	**0.985** (0.910-1.08)	**1.18** (1.09-1.29)	**1.45** (1.34-1.58)	**1.67** (1.54-1.82)	**1.98** (1.81-2.15)	**2.24** (2.03-2.42)	**2.5** (2.25-2.71)	**2.78** (2.48-3.02)	**3.19** (2.79-3.45)	**3.51** (3.05-3.81)
60-min	**1.23** (1.14-1.34)	**1.48** (1.37-1.62)	**1.86** (1.71-2.02)	**2.18** (2.00-2.38)	**2.64** (2.41-2.87)	**3.03** (2.75-3.29)	**3.45** (3.10-3.73)	**3.9** (3.47-4.23)	**4.57** (4.01-4.95)	**5.13** (4.45-5.56)
2-hr	**1.46** (1.35-1.59)	**1.75** (1.62-1.91)	**2.2** (2.02-2.39)	**2.57** (2.36-2.79)	**3.12** (2.84-3.38)	**3.58** (3.25-3.88)	**4.09** (3.67-4.42)	**4.63** (4.12-5.00)	**5.43** (4.75-5.88)	**6.1** (5.26-6.62)
3-hr	**1.58** (1.47-1.72)	**1.9** (1.76-2.06)	**2.36** (2.18-2.56)	**2.76** (2.54-2.98)	**3.33** (3.05-3.59)	**3.81** (3.46-4.11)	**4.33** (3.90-4.67)	**4.89** (4.36-5.27)	**5.72** (5.01-6.18)	**6.41** (5.55-6.94)
6-hr	**1.96** (1.83-2.12)	**2.34** (2.18-2.53)	**2.86** (2.66-3.09)	**3.32** (3.07-3.57)	**3.96** (3.65-4.26)	**4.52** (4.13-4.85)	**5.1** (4.63-5.48)	**5.73** (5.16-6.16)	**6.63** (5.87-7.14)	**7.38** (6.45-7.96)
12-hr	**2.44** (2.27-2.62)	**2.9** (2.70-3.13)	**3.53** (3.29-3.81)	**4.07** (3.78-4.38)	**4.82** (4.45-5.18)	**5.45** (5.00-5.85)	**6.1** (5.57-6.55)	**6.79** (6.15-7.30)	**7.76** (6.95-8.35)	**8.55** (7.57-9.23)
24-hr	**2.95** (2.77-3.15)	**3.53** (3.31-3.78)	**4.3** (4.03-4.60)	**4.9** (4.59-5.24)	**5.73** (5.35-6.11)	**6.39** (5.95-6.81)	**7.06** (6.55-7.51)	**7.74** (7.16-8.22)	**8.66** (7.98-9.20)	**9.38** (8.60-9.96)
2-day	**3.57** (3.34-3.82)	**4.26** (3.99-4.57)	**5.2** (4.86-5.56)	**5.93** (5.54-6.33)	**6.92** (6.45-7.38)	**7.7** (7.17-8.21)	**8.5** (7.88-9.06)	**9.3** (8.60-9.91)	**10.4** (9.56-11.1)	**11.2** (10.3-12.0)
3-day	**3.83** (3.58-4.09)	**4.57** (4.28-4.89)	**5.55** (5.19-5.93)	**6.31** (5.88-6.73)	**7.31** (6.81-7.79)	**8.1** (7.53-8.63)	**8.88** (8.24-9.47)	**9.67** (8.94-10.3)	**10.7** (9.87-11.4)	**11.5** (10.6-12.3)
4-day	**4.09** (3.81-4.36)	**4.88** (4.56-5.22)	**5.91** (5.52-6.31)	**6.69** (6.23-7.13)	**7.71** (7.17-8.21)	**8.49** (7.89-9.05)	**9.27** (8.59-9.87)	**10** (9.29-10.7)	**11** (10.2-11.8)	**11.8** (10.8-12.6)
7-day	**4.98** (4.65-5.32)	**5.93** (5.54-6.34)	**7.11** (6.64-7.60)	**7.99** (7.45-8.53)	**9.13** (8.49-9.74)	**9.99** (9.28-10.6)	**10.8** (10.0-11.5)	**11.6** (10.8-12.4)	**12.7** (11.7-13.5)	**13.5** (12.4-14.4)
10-day	**5.68** (5.32-6.07)	**6.74** (6.31-7.21)	**8.01** (7.50-8.56)	**8.98** (8.40-9.58)	**10.2** (9.56-10.9)	**11.2** (10.4-11.9)	**12.1** (11.3-12.9)	**13** (12.1-13.9)	**14.2** (13.1-15.2)	**15.1** (13.9-16.1)
20-day	**7.82** (7.36-8.26)	**9.23** (8.70-9.77)	**10.7** (10.1-11.3)	**11.8** (11.1-12.5)	**13.1** (12.4-13.9)	**14.1** (13.2-14.9)	**15** (14.1-15.8)	**15.8** (14.8-16.7)	**16.8** (15.8-17.8)	**17.6** (16.4-18.6)
30-day	**9.59** (9.13-10.1)	**11.3** (10.7-11.8)	**12.9** (12.3-13.5)	**14.1** (13.4-14.8)	**15.5** (14.7-16.2)	**16.5** (15.6-17.3)	**17.4** (16.5-18.2)	**18.2** (17.2-19.1)	**19.2** (18.1-20.2)	**19.9** (18.7-20.9)
45-day	**12.1** (11.6-12.7)	**14.2** (13.5-14.9)	**16.1** (15.3-16.8)	**17.4** (16.6-18.3)	**19.1** (18.2-20.0)	**20.2** (19.3-21.2)	**21.3** (20.2-22.3)	**22.2** (21.1-23.3)	**23.4** (22.2-24.5)	**24.1** (22.9-25.4)

60-day	**14.5** (13.8-15.2)	**17** (16.2-17.8)	**19.2** (18.3-20.1)	**20.8** (19.8-21.8)	**22.7** (21.5-23.7)	**24** (22.8-25.1)	**25.2** (23.9-26.3)	**26.2** (24.9-27.5)	**27.4** (26.0-28.8)	**28.2** (26.7-29.7)

Pasted from <http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nc>



2. Use map:

a) Select location
(move crosshair or double click)

b) Click on station icon
(s☑w stations on map)

LOCATION INFORMATION:
Name: Spring City, Tennessee, US*
Station Name: WATTS BAR DAM
Site ID: 40-9484
Latitude: 35.6167
Longitude: -84.7833
Elevation: 830ft

Map
Knoxville
Oak Ridge
Chattanooga
Murfreesboro
Huntsville
Cleveland
Ten Mile
Maryville
Sevierville
Morristown
Great Smoky Mountains National Park
Nantahala National Forest
Chattahoochee National Forest
50 km
Map data ©2012 Google - Terms of Use
Report a map error

Fig. B-2. Approximate geographic boundaries for SCS rainfall distributions (SCS, 1986):

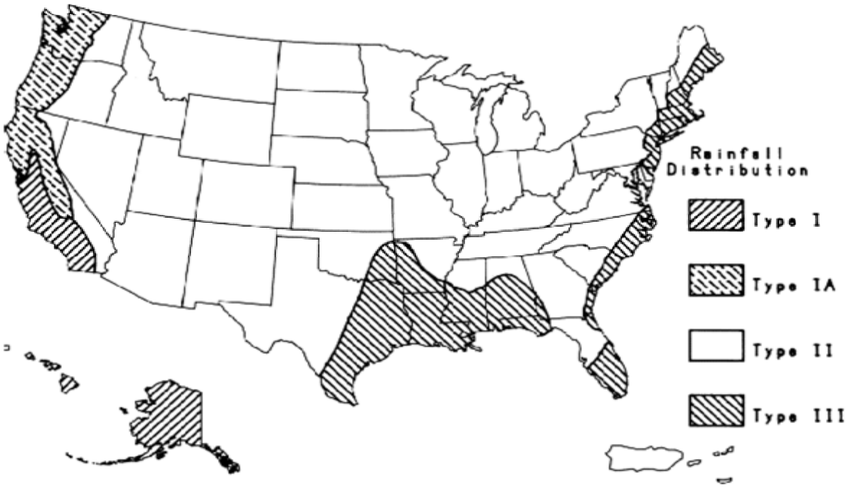
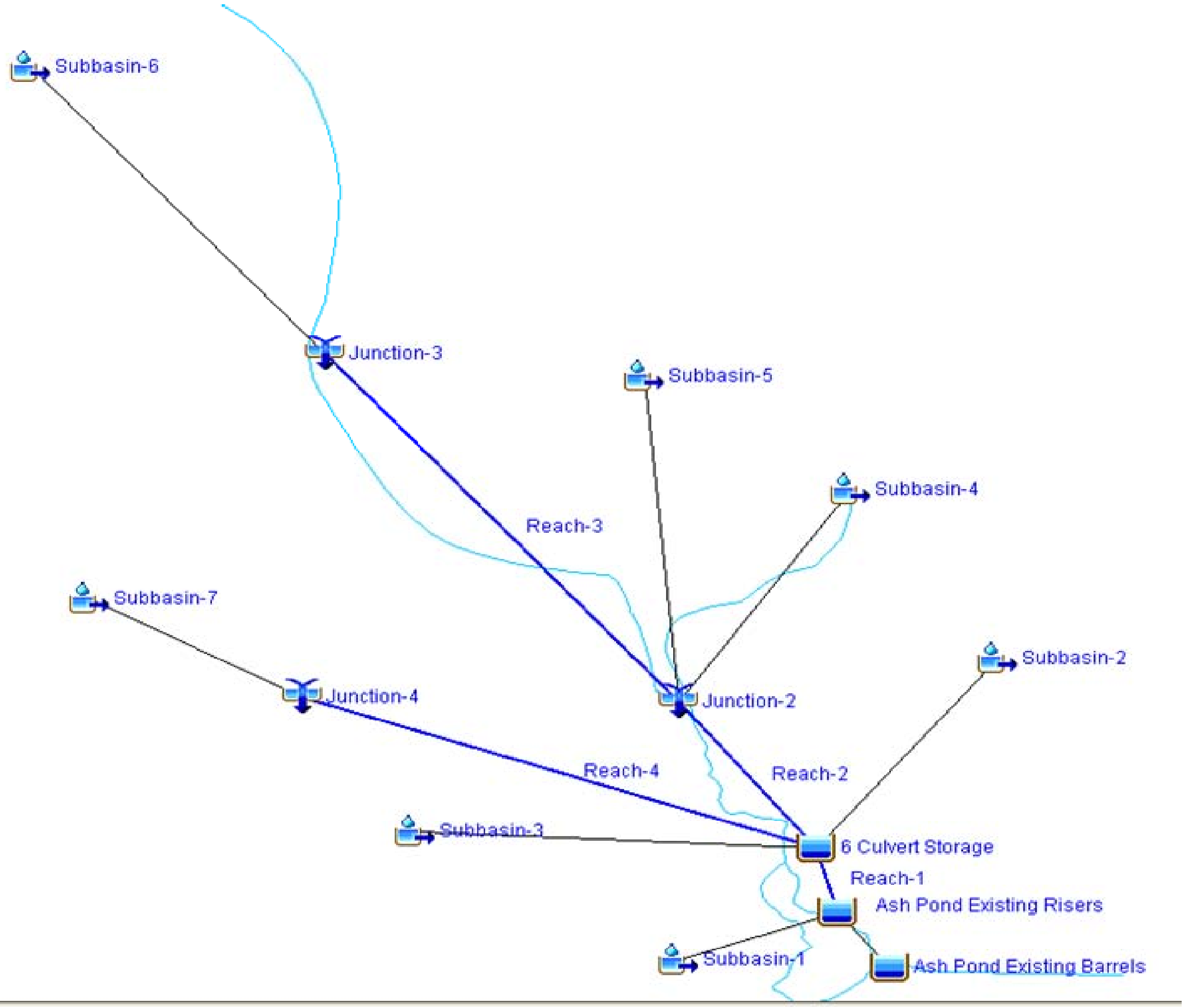


Figure B-2.—Approximate geographic boundaries for SCS rainfall distributions.

Figure 3 HEC -HMS Schematic



CLIENT	TVA	COMPUTED BY / DATE	R.H.	07/27/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	B.P.	08/14/12
DETAIL	Ash Pond Spillway Modeling	REVISION NO. / DATE	-	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	- -	-
TVA CALCULATION PACKAGE	GENWBFFESCDX0000002012001005			

Ash Pond Spillway Modeling

1.0 Objective

1. Create hydraulic model of the Watts Bar Ash Pond spillway structures on which to base proposed conditions modeling.
2. Simulate conditions in the Watts Bar Ash Pond to determine the rainfall return interval which can be detained by a temporary cofferdam constructed to protect the spillway during construction of spillway improvements.
3. Simulate hydraulic conditions in the Watts Bar Ash Pond and spillway to iteratively determine the spillway improvement configuration required to convey the peak flow with 1 foot of freeboard, associated with the 100 year design frequency rainfall at a dam crest elevation of 701 ft.

2.0 Procedure

1.) Develop pond and spillway model in EPA SWMM based on surveyed existing conditions.
2.) Input hydrographs from HEC-HMS model for suite of design storms into SWMM model entering Ash Pond node.
3.) Simulate temporary spillway conditions with cofferdam.
4.) Simulate and iteratively determine suitable configuration and dimensions for proposed Ash Pond spillway.

3.0 References / Data Sources

1.) Volume 2 of 3: Facilities Design and Construction Requirements TVA Coal Combustion Products Management Program Master Programmatic Document (Revision 1.0) 2009, by URS.

2.) EPA, Stormwater Management Model (SWMM) 5.0 Software and Users Manual http://www.epa.gov/nrmrl/wswrd/wq/models/swmm/

3.) Survey conducted Nov 2011, CAD file: B000EXBS.dwg
Survey conducted May 2012 CAD file: wf06_wbn12397_20120505(ver2007).dwg

4.0 Assumptions / Limitations

1.) Downstream stages in Lake Chickamauga are not modeled in this calculation since they are not expected to peak at the same time as the Watts Bar Ash Pond and will therefore not affect the design configuration.

2.) Stage storage conditions in the Ash Pond are subject to future modification due to removal of ash and the splitter dyke. Projected future conditions based on pond survey B000EXBS.dwg were used to develop the area/elevation data for this calculation.

5.0 Calculations

The three SWMM model files:
TVA_AshPond_Existing.inp
TVA_AshPond_Cofferdam.inp
TVA_AshPond_Proposed.inp

5.1 Existing Conditions

Purpose: Create a hydraulic model of the existing conditions of the Watts Bar Ash Pond spillway structures on which to base proposed conditions modeling.

Methodology: Model the Ash Pond as a storage reservoir with the inflow hydrograph as output from the HMS model. Model the existing riser barrel structures as combined weir and culverts in series which are in parallel to the dam crest. Utilize dynamic wave simulation to account for back water effects between structures.

The following elements are interconnected in the model to represent the existing conditions as in the Figure 1 SWMM Model Schematic:

Storage Unit - Ash Pond, see Table 1 for elevation area information
Weirs 2, 5, 6 - Transverse type weir representing the riser crest at varying heights near 4.4 ft, length of 14.14' each.
Storage Unit 4 - This storage accounts for the volume between the riser weir and the barrels entrance
Culvert 1 - 3 - 3 ft diameter RCP barrels
Channel 3 - channel downstream of barrels modeled to contribute no tailwater
Weir 4 - emergency spillway over breach berm at 710 ft, 180 feet in length
Channel 10 - represents area/channel downstream of emergency spillway

Table 1. Ash Pond Stage Storage Curve

Table 1. Ash Pond Stage Storage Curve

Elevation (ft)	Area (Acres)
694	5.73
695	5.86
696	6
697	6.14
698	6.28
699	6.43
700	6.57
701	6.72
702	6.87
703	7.02
704	7.17
705	7.32
706	7.47
707	7.63
708	7.79
709	7.96
710	8.1

Result: The existing conditions model shows that the Ash Pond and existing riser barrel structure together are capable of storing/passing flows from the 100 year return interval rainfall without overtopping the dam at an elevation of 710 ft. This behavior is consistent with expectations for the existing structures.

5.2 Temporary Cofferdam

Purpose: Simulate conditions in the Watts Bar Ash Pond to determine the rainfall return interval which can be detained by a temporary cofferdam constructed to protect the spillway during construction of spillway improvements.

Methodology: Conduct a model run with conditions modified from the existing conditions SWMM model. The breach spillway is at elevation 701 ft for a length of 180 ft and set the initial water surface depth at zero to reflected pumped conditions. The existing riser/barrels are assumed to continue to discharge at their current configuration.

The following elements are adjusted in the cofferdam model to represent the proposed temporary conditions with an earthen cofferdam:

Storage Unit 4 - This storage accounts for the volume between the weir and the culvert entrance.
Culvert 1 - 4 - 4 x 6 box culverts
Channel 3 - channel downstream of culverts modeled to contribute no tailwater
Weir 4 - emergency spillway over breach berm, 180 feet in length
Channel 10 - represents area/channel downstream of emergency spillway

Results: The storage in the Ash Pond and conveyance of the existing riser/barrel structures handle flows from the 10-year event without overtopping the breach. Flows occurring in the 25-year event overtop the breach. Therefore a cofferdam would be capable of protecting the spillway construction for a storm exceeding the 10-year event but less than the 25-year.

Refer to separate Cofferdam calculation sheet for further detailed description and results.

5.3 Proposed Conditions

Purpose: Model the Watts Bar Ash Pond and spillway to determine the spillway improvement dimensions required to convey the peak flow with 1 foot of freeboard, associated with the 100 year design frequency rainfall at a dam crest elevation of 701 ft.

Methodology: Beginning with the existing conditions base model, adjust spillway dimensions and run iterative simulations with the proposed conditions to determine the proposed dimensions for the spillway structures:

The following elements are interconnected in the model to represent the proposed conditions as modified from the existing conditions by:

Weir 2 - Transverse type weir, height of 4 ft, length of 60'.
Storage Unit 4 - This storage accounts for the volume between the weir and the culvert entrance.
Culvert 1 - 4 - 4 x 6 box culverts
Channel 3 - channel downstream of culverts modeled to contribute no tailwater from Lake Chickamauga
Weir 4 - emergency spillway over breach berm, 180 feet in length
Channel 10 - represents area/channel downstream of emergency spillway with no tailwater from Lake Chickamauga

Figure 2 shows the model schematic for the proposed conditions.

Results: Four 4 x 6 foot box culverts are recommended to ensure adequate conveyance for the design storm with sufficient additional capacity to account for losses due to design configuration of the entrance.

Tables 2 and 3 summarize the modeled conditions and results of the proposed conditions modeling, respectively.

Table 2. SWMM Scenarios Parameter Summary

Scenario	Riser Elevation (ft)	Riser Length (ft)	Configuration	Dam Crest Elevation (ft)	Dam Crest Length (ft)
Existing	700.4	42.42	RCP	708	250
Temporary Cofferdam	700.4	42.42	3 – 36” RCP	701	180
Proposed	698	65	Boxes	701	180

Table 3. Ash Pond Proposed Conditions Modeling Results

Design Storm	Peak Inflow (cfs)	Peak Discharge (cfs)	Peak Stage (ft)	Peak Storage (ac-ft)
100yr	555	418	699.77	35.34
1/3 PMP	1,239	229 (Breach only)	701.56	47.54

6.0 Conclusions

1.) The result is a hydraulic model in EPA's SWMM software suitable for evaluation of proposed spillway and cofferdam conditions.

2. The rainfall return interval which can be detained by a temporary cofferdam constructed to protect the spillway during construction is the 10 year storm.

3. Based on the modeling, the proposed spillway configuration includes a 60 foot weir at elevation 698 with 4 - 4 x 6 ft box culverts at an elevation of 695.

Figure 1. Watts Bar Ash Pond an Ash Pond Spillway Modeling

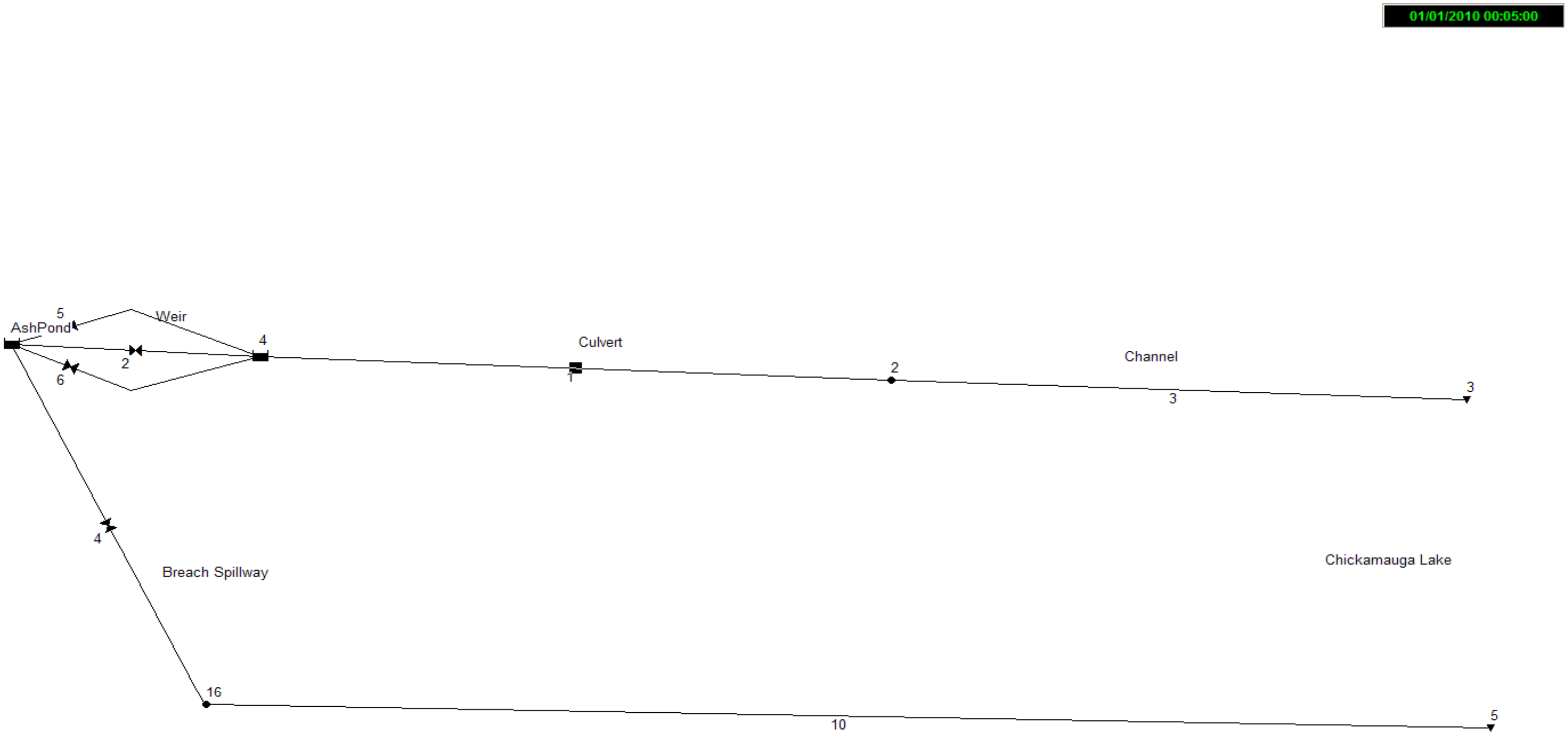
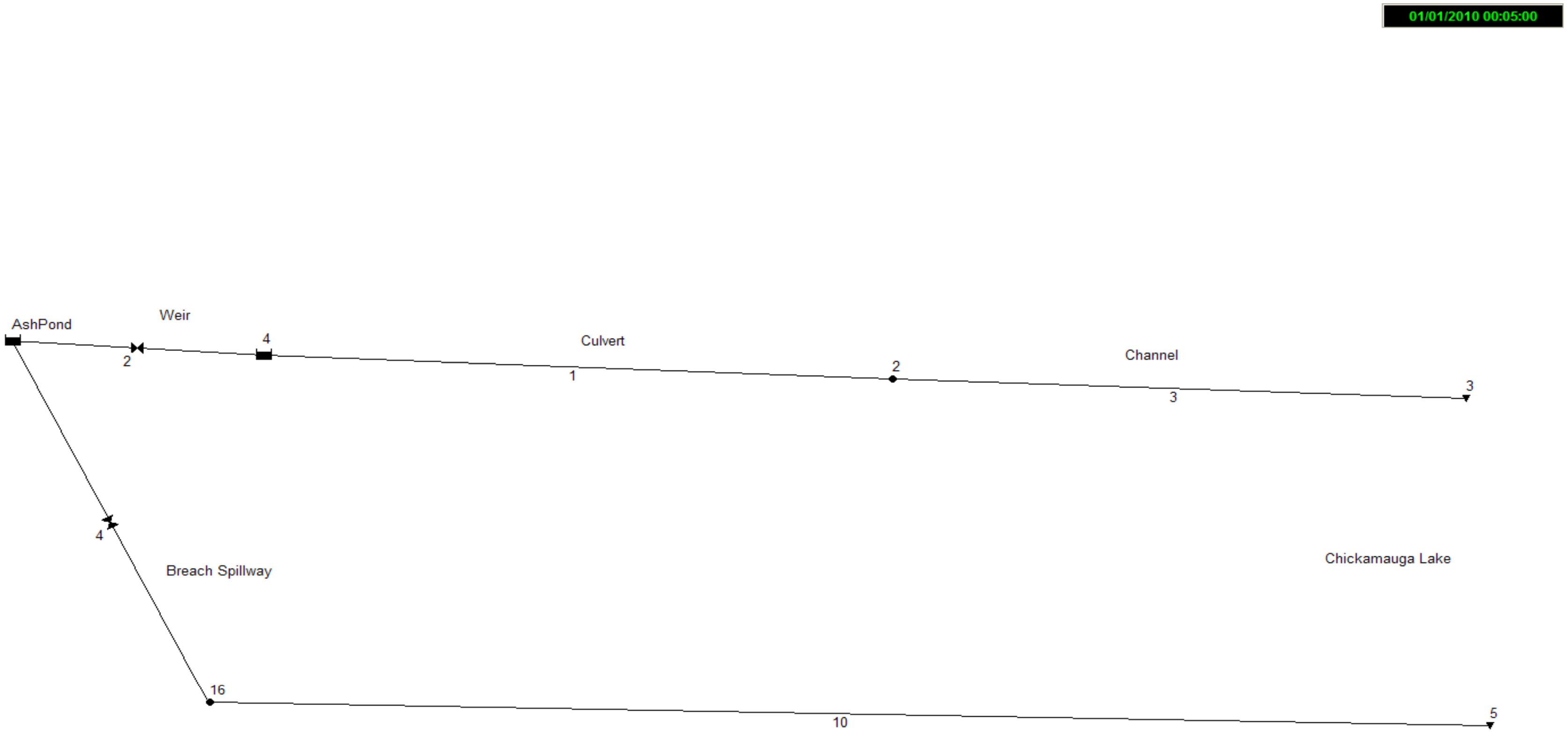


Figure 2. Watts Bar Ash Pond and Spillway EPA SWMM5.0 Schematic - Proposed Conditions



CLIENT	TVA	COMPUTED BY / DATE	R.H.	07/27/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	B.P.	08/14/12
DETAIL	Cofferdam	REVISION NO. / DATE	-	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	-	-
TVA CALCULATION PACKAGE	GENWBFFESCDX0000002012001005			

Calculation Description: Cofferdam Design Frequency Storm

1.0 Objective

Determine design frequency (return interval) storm event which can be detained behind temporary cofferdam with various configurations of the existing riser structures.

2.0 Procedure

Using the SWMM model based on existing conditions, simulate various conditions with temporary cofferdam to estimate maximum stage during various design storms.

3.0 References / Data Sources

SWMM model of existing conditions described in modeling narrative.

4.0 Assumptions / Limitations

1.) Pond will be completely dewatered to elevation 694 ft.
2.) Cofferdam elevation will correspond to final berm elevation of 701 ft.
3.) The three existing risers' crest elevations are at 704.4 ft +/- 0.1 ft with a length of 14.14 ft each.

5.0 Calculations

5.1 Determine the Channel Dimensions and Lining

Refer to table below for Watts Bar Ash Pond maximum stage for various configurations of the existing riser structures for each of the 5, 10, 25, and 100-year return interval rainfall events. Values in bold indicate overtopping expected under the associated conditions.

6.0 Conclusions

1.) Temporary conditions with the temporary earthen cofferdam at elevation 701' and the breach at 701' will detain the runoff associated with the 10-yr return interval storm within the Ash Pond without any risers in service. Lowering the crest of one or all of the three existing risers by about 4' would allow them to pass a storm exceeding the 25-year rainfall and lowering one or all by about 6' would allow them to pass a storm exceeding the 100-year rainfall event while the temporary cofferdam is in place.

Table 1. Watts Bar Ash Pond Temporary Cofferdam Maximum Stages

	Ash Pond Stage (ft)			
Temporary Configuration Alternative	**5-yr**	**10-yr**	**25-yr**	**100-yr**
Existing Risers with Dam at 710'	**705.04**	**705.17**	**705.43**	**706.1**
Existing Risers (or no risers) with Berm at 701'	699.51	700.66	**701.1**	**701.28**
3 Lowered Risers (to 700.4') with Berm at 701'	699.51	700.54	700.68	**701.09**
2 Lowered Risers (to 700.4') with Berm at 701'	699.51	700.57	700.75	**701.15**
1 Lowered Riser (to 700.4') with Berm at 701'	699.51	700.6	700.91	**701.21**
3 Lowered Risers (to 698.4) with Berm at 701'	698.59	698.74	699.07	699.88
2 Lowered Risers (to 698.4') with Berm at 701'	698.64	698.81	699.19	700

Exhibit 2
Hydraulics Calculations

SPILLWAY DESIGN

RATING CURVE

DEWATERING

INFLOW CHANNEL

CLIENT	TVA	COMPUTED BY / DATE	M.E.A. 08/15/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	R.H. 08/16/12
DETAIL	Proposed Ash Pond Spillway	REVISION NO. / DATE	- -
PROJECT NO.	92016.2202	REVIEWED BY / DATE	- -
TVA CALCULATION PACKAGE	GENWBFFESCDX0000002012001005		

Calculation Description: **Hydraulic Design Confirmation of Ash Pond Spillway**

1.0 Introduction and Purpose

The purpose of this calculation package is to confirm the final hydrauilc design of the spillway structures with respect to capacity, air supply and venting, energy dissipation and erosion protection. The calculations are organized according to the following areas of concern: (1) the overflow spillway; (2) the culvert entrance structure; (3) the culvert conveyance structures; and (4) the riprap channel protection. Additional calculations are used to determine the rating curve of the structure at various river water surface elevations.

2.0 References & Assumptions

1 USBR Water Measurement Manual
2 H&H Calculation Package for this project
3 King and Brater "Handbook of Hydraulics"
4 TVA HEC-2 model for the Tennessee River, Chickamauga Reservoir
5 National Engineering Handbook - Section 11 - Drop Spillways
6 FHA culvert curves
7 HDR Engineering Inc. (2001) “Handbook of Public Water Systems”
8 HEC 14, Section 11
9 Henderson (1966) "Open Channel Flow"
10 HEC 23, Design Guideline 5

Assumptions as noted in each calculation section.

3.0 Area 1 - Overflow Spillway

The overflow spillway is a three-sided structure with individual weir lengths on each side. Sections of concrete wall extended upward between the weir sections to (a) provide an avenue for air supply to the lower weir nappes; and (b) help divide the flow evenly among the four culverts. Failure to provide sufficient air supply to the lower weir nappes can result in excessive negative pressures under the nappes, which may lead to loading fluctuations and subsequent structure vibration. Evenly distributed flow among the four culverts is required as part of their hydraulic design assumptions.

3.1 Free Discharge Capacity

Flow over a free discharging rectangular weir is governed by the Francis equation (Ref. 1):

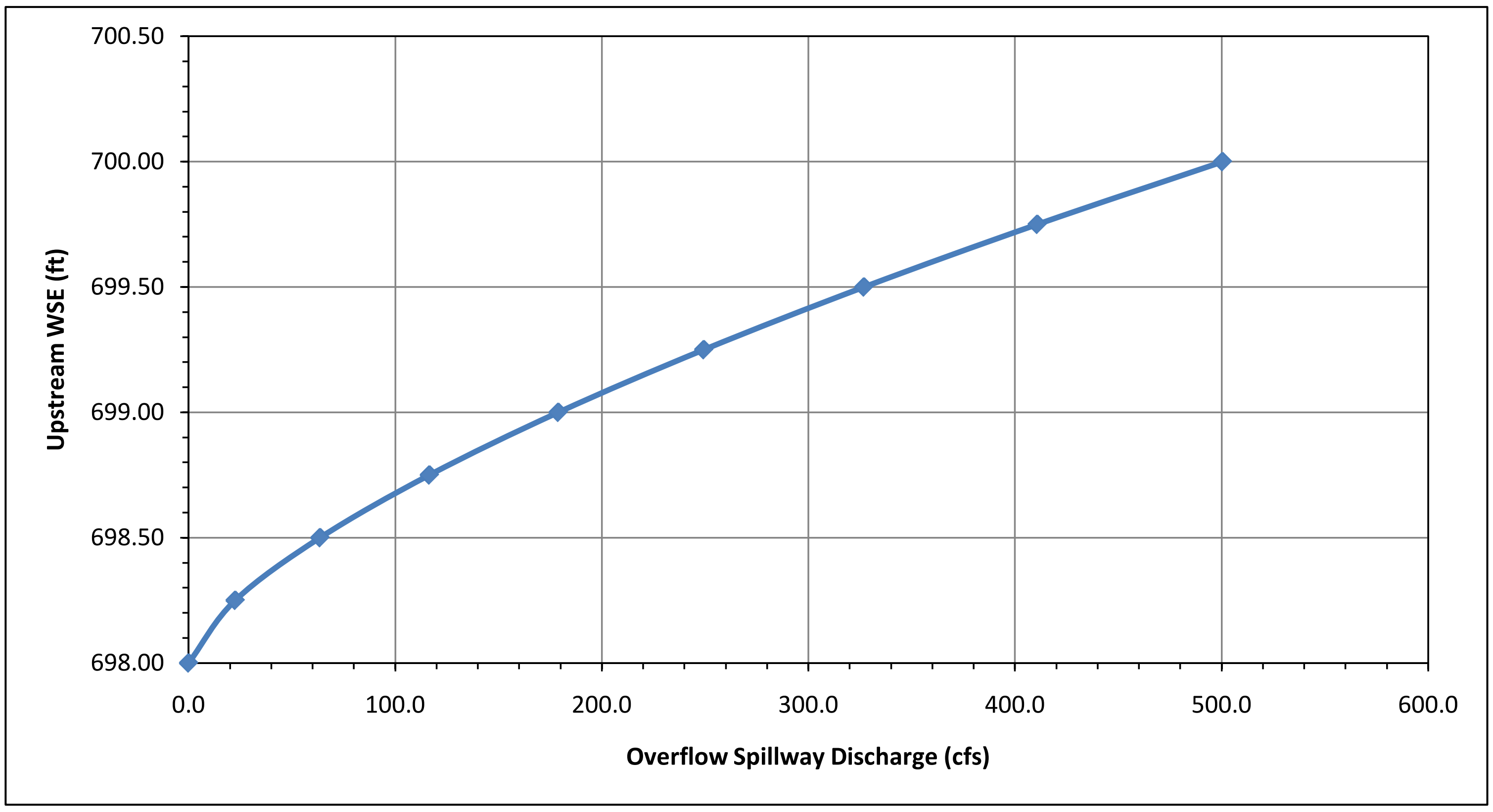
$$\boxed{Q = 3.33\left(L - 0.2H\right)H^{3/2}}$$

where: Q = discharge (cfs); L = weir length (ft); and H = weir head (ft). The quantity "L-0.2H" is the effective weir length which takes into account the side contractions of the weir nappe. The invert elevation of the weir crest is elevation 698.00 ft and the maximum allowable water surface elevation (WSE) in the pond is 700.00 ft. Therefore, the maximum allowable weir head is 2.00 ft.

3.1.1 Calculate Free Discharge Rating Curve

		South Weir		Middle Weir		North Weir					
H (ft)	Upstream WSE (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	South Weir Q (cfs)	Middle Weir Q (cfs)	North Weir Q (cfs)	Total Weir Q (cfs)
0.00	698.00	12.75	12.75	28.83	28.83	12.75	12.75	0.0	0.0	0.0	0.0
0.25	698.25	12.75	12.70	28.83	28.78	12.75	12.70	5.3	12.0	5.3	22.6
0.50	698.50	12.75	12.65	28.83	28.73	12.75	12.65	14.9	33.8	14.9	63.6
0.75	698.75	12.75	12.60	28.83	28.68	12.75	12.60	27.3	62.0	27.3	116.5
1.00	699.00	12.75	12.55	28.83	28.63	12.75	12.55	41.8	95.3	41.8	178.9
1.25	699.25	12.75	12.50	28.83	28.58	12.75	12.50	58.2	133.0	58.2	249.4
1.50	699.50	12.75	12.45	28.83	28.53	12.75	12.45	76.2	174.6	76.2	326.9
1.75	699.75	12.75	12.40	28.83	28.48	12.75	12.40	95.6	219.6	95.6	410.8
2.00	700.00	12.75	12.35	28.83	28.43	12.75	12.35	116.3	267.8	116.3	500.4

699.65



3.1.2 Evaluate Free Discharge Capacity

Design capacity of the spillway is 420 cfs (Ref. 2). The spillway is capable of passing that discharge at an upstream WSE of approximately 699.6 ft, which is below the maximum allowable upstream WSE of 700.00 ft. **The free discharge capacity is acceptable.**

3.2 Submerged Discharge Capacity

Flow over a submerged weir is governed by the following equation (Ref. 3):

$$Q = Q_1\left[1-\left(\frac{H_2}{H_1}\right)^n\right]^{0.385}$$

where: Q = submerged discharge (cfs); Q_1 = free weir discharge at weir head of H_1 (ft); H_2 = height of downstream WSE above weir invert (ft); H_1 = upstream weir head; and n = free weir discharge equation exponent (1.5 for a rectangular weir).

3.2.1 Calculate Maximum Allowable Downstream WSE at Design Flow

Maximum allowable H_1 = 700 ft - 698 ft =	2.00	ft
Q_1 (per section 3.1.1) =	500.4	cfs
Required Q =	420.0	cfs
Q/Q_1 =	0.84	
(Q/Q_1)^(1/0.385) =	0.63	
(H_2/H_1)^1.5 =	0.37	
H_2/H_1 =	0.51	
H_2 =	1.02	ft
Maximum Allowable Downstream WSE =	699.02	ft

3.2.2 Calculate Maximum Allowable River WSE at Design Flow

A downstream WSE of 699.02 ft requires that the culvert conveyance structures are flowing full. Therefore, the difference in WSE from the downstream side of the weir to the river can be determined by the standard headloss equation for the form losses and the Manning's equation for friction losses.

Standard Headloss Eqn:

$$\Delta H = K\frac{V^2}{2g}$$

Manning's Eqn: $$\boxed{Q = \frac{1.49}{n} A R^{2/3} S^{1/2}}$$

where: ΔH = energy loss due to a form loss (ft); K = form loss coefficient for specific form geometry (available from standard hydraulic texts); V = average conduit velocity (fps); g = acceleration due to gravity (ft^2/s); Q = discharge (cfs); n = Manning's coefficient; A = flow area (ft^2); R = hydraulic radius (ft); and S = friction slope (headloss per unit length) (ft/ft).

3.2.2.1 Calculate Form and Friction Losses

Form Loss	K (---)	Q (cfs)	Q per Culvert (cfs)	Culvert Width (ft)	Culvert Height (ft)	Ave. Velocity (fps)	ΔH (ft)
Culvert Entrance	0.5	420	105	6	4	4.4	0.15
Culvert S-Bend	4.0	420	105	6	4	4.4	1.19
Dissipator Contr.	0.1	420	105	6	3.5	5.0	0.04
Culvert Exit	1.0	420	105	6	3.5	5.0	0.39
						Total	1.76

Friction Loss	n (---)	Q (cfs)	Q per Culvert (cfs)	Culvert Width (ft)	Culvert Height (ft)	Ave. Velocity (fps)	S (ft/ft)	Length (ft)	ΔH (ft)
6' x 4' Culvert	0.012	420	105	6	4	4.4	0.0010	85.0	0.08
8' x 18' Drop Box	0.012	420	210	8	18	1.5	0.0000	12.5	0.00
6' x 5' Culvert	0.012	420	105	6	5	3.5	0.0005	60.0	0.03
								Total	0.11

Total Energy Losses (ft) = 1.88 (Assumes WSE variations across lateral weir are negligible at these flow depths.)

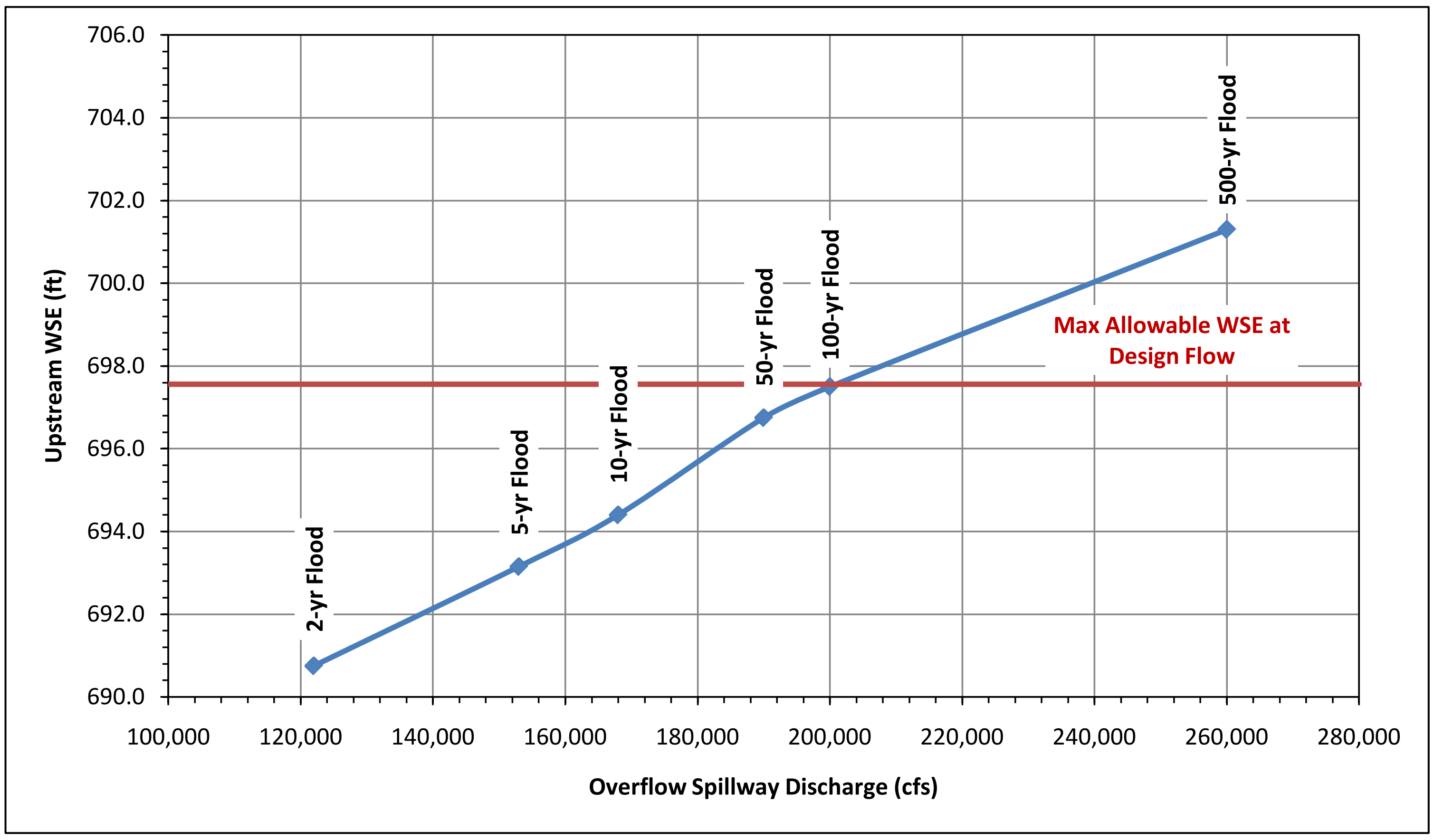
3.2.3 Evaluate Submerged Discharge Capacity

Subtracting the culvert conveyance losses from the maximum allowable downstream WSE yields a maximum allowable river WSE of 699.02 ft - 1.88 ft = 697.14 ft.

Tennessee River flow data is available at river miles 527.8 and 529.9 (Ref. 4), as shown below. The overflow spillway enters the river approximately halfway between these two locations. Assuming the river WSE at the spillway location can be estimated as a straight average of the upstream and downstream values, the following tailwater rating curve is established.

Flood Event	Flow (cfs)	WSE at River Mile 527.8 (ft)	WSE at River Mile 529.9 (ft)	Average (ft)
2-Year	122,000	690.3	691.2	690.8
5-Year	153,000	692.7	693.6	693.2
10-Year	168,000	693.9	694.9	694.4
50-Year	190,000	696.3	697.2	696.8
100-Year	200,000	697.0	698.0	697.5
500-Year	260,000	700.8	701.8	701.3

Flow (cfs)	Max. Allowable WSE (ft)	Est. 25-yr Flood Flow (cfs)	WSE (ft)	Est. 40-yr Flood Flow (cfs)	WSE (ft)
100,000	697.56	176,250	706.0	184,500	706.0
280,000	697.56	176,250	690.0	184,500	690.0



As shown on the tailwater rating curve, the overflow spillway design is able to pass the design flow against river WSEs equivalent to the 100-yr flood elevation. **The submerged discharge capacity is acceptable.**

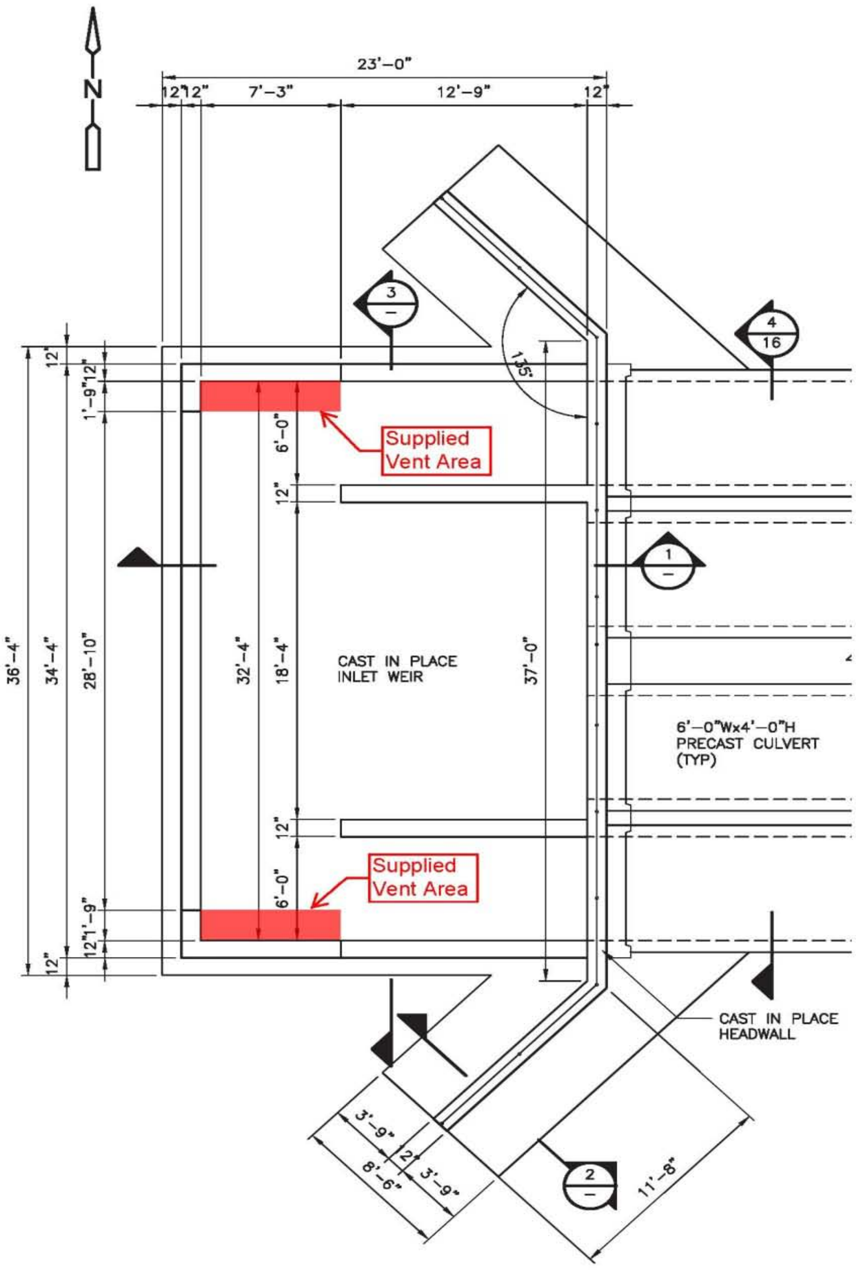
3.3 Lower Weir Nappe Air Supply

Lower weir nappe vent area supply requirements are provided in Ref. 5 and shown below. Pressure differentials of 0.3 ft of water are permissible, but calculations have been based on providing a pressure differential of 0.1 feet of water for conservatism. Weir head is 699.8 ft - 698.00 ft = 1.8 ft per section 3.1.2.

Allowable pressure differential, p (ft of water) = 0.1

Weir	Length (ft)	Height (ft)	Required Vent Area (in^2)	Required Vent Area (ft^2)
North	12.75	1.8	2.51	0.017
Middle	28.83	1.8	5.67	0.039
South	12.75	1.8	2.51	0.017
		Total	10.68	0.07

Supplied vent area is shown below and equals 2 x 7'3" x 1'9" = 25.375 ft^2. **Vent area supply is acceptable.**


N
23'-0"
12"
12"
7'-3"
12'-9"
12"
3
4
16
135°
12"
12"
1'-9"
6'-0"
Supplied Vent Area
12"
1
36'-4"
34'-4"
28'-10"
32'-4"
18'-4"
CAST IN PLACE INLET WEIR
37'-0"
6'-0"Wx4'-0"H PRECAST CULVERT (TYP)
12"
Supplied Vent Area
6'-0"
1'-9"
12"
12"
CAST IN PLACE HEADWALL
3'-9"
2"
8'-6"
3'-9"
2
11'-8"

DROP SPILLWAYS — AERATION OF WEIRS

EQUATION

$$\frac{A}{L} = 5.3 \times 10^{-4} \frac{H_e^{3.64}}{p^{1.64}}$$

where:

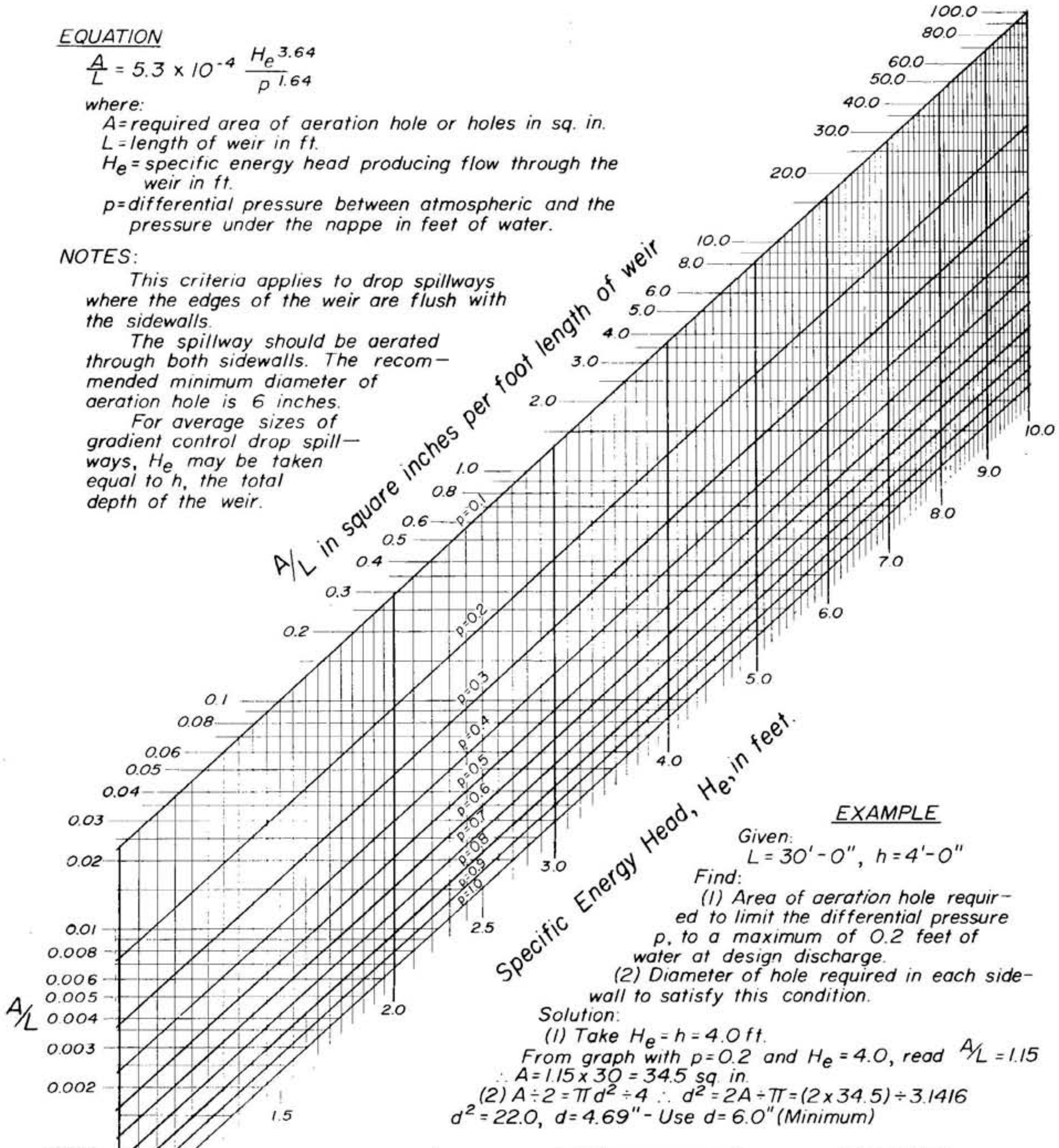
A = required area of aeration hole or holes in sq. in.
L = length of weir in ft.
H_e = specific energy head producing flow through the weir in ft.
p = differential pressure between atmospheric and the pressure under the nappe in feet of water.

NOTES:

This criteria applies to drop spillways where the edges of the weir are flush with the sidewalls.

The spillway should be aerated through both sidewalls. The recommended minimum diameter of aeration hole is 6 inches.

For average sizes of gradient control drop spillways, H_e may be taken equal to h, the total depth of the weir.

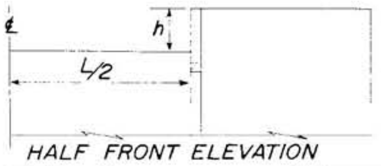


EXAMPLE

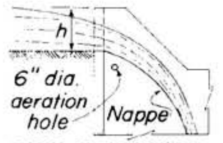
Given:
$L = 30'-0"$, $h = 4'-0"$

Find:
(1) Area of aeration hole required to limit the differential pressure p, to a maximum of 0.2 feet of water at design discharge.
(2) Diameter of hole required in each sidewall to satisfy this condition.

Solution:
(1) Take $H_e = h = 4.0$ ft.
From graph with $p = 0.2$ and $H_e = 4.0$, read $A/L = 1.15$
$\therefore A = 1.15 \times 30 = 34.5$ sq. in.
(2) $A \div 2 = \pi d^2 \div 4 \therefore d^2 = 2A \div \pi = (2 \times 34.5) \div 3.1416$
$d^2 = 22.0$, $d = 4.69"$ - Use $d = 6.0"$ (Minimum)



HALF FRONT ELEVATION



SIDE ELEVATION

REFERENCE:
Aeration of Spillways by G. H. Hickox. — Trans. ASCE 1944, page 537, paper No. 2215

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-81
SHEET 1 OF 1 SHEETS
DATE 7-10-53

4.0 Area 2 - Culvert Entrance Structure

The culvert entrance structure must deliver flow into the culverts without submerging the overflow spillway which would reduce its capacity. For normal river WSEs, the maximum entrance structure WSE is produced when the culverts are operating under inlet control. Conditions where the river WSE is controlling was evaluated in section 3.2.

4.1 Free Discharge WSE

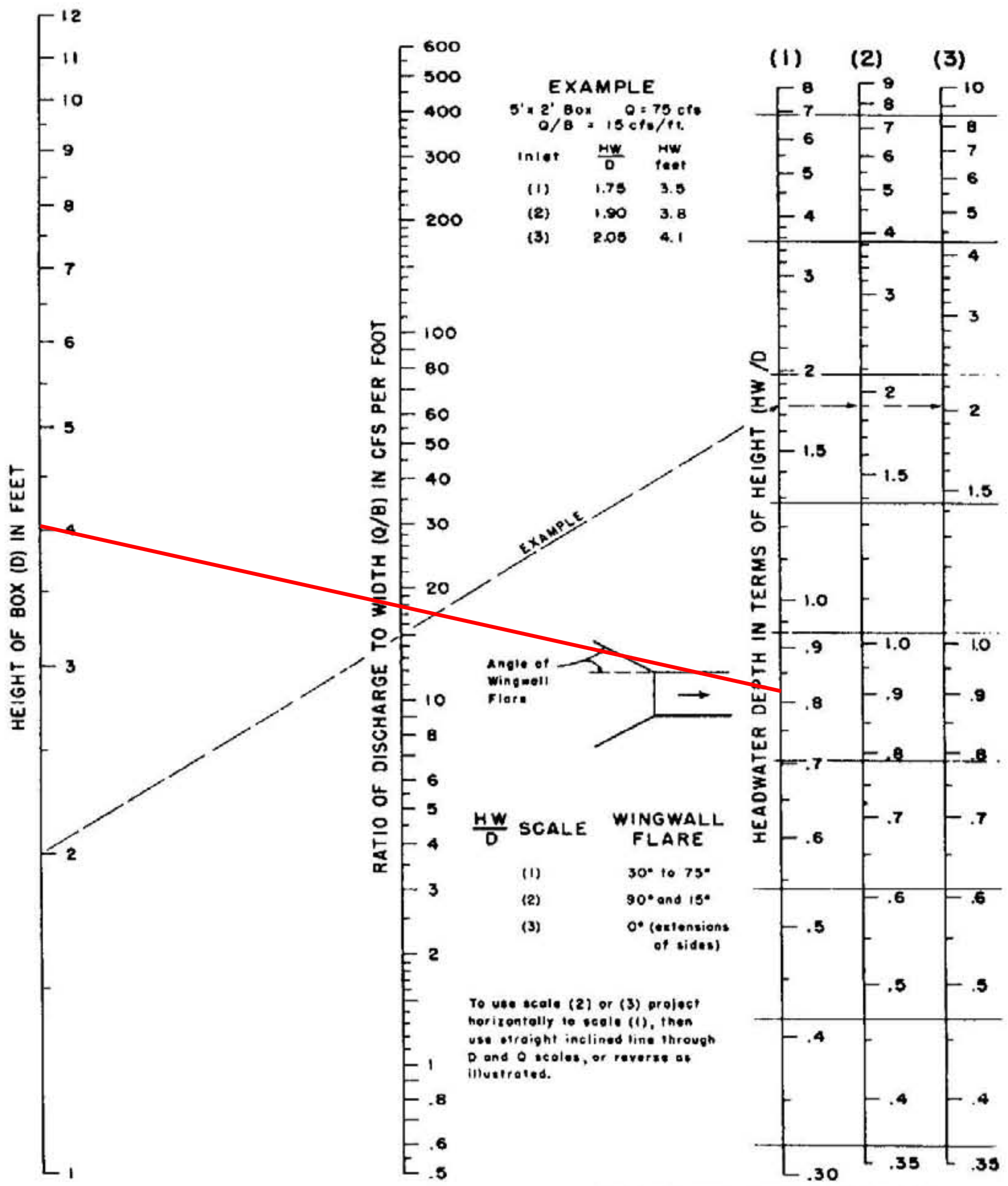
4.1.1 Calculate WSE Immediately Upstream of Culvert Entrance

The WSE required to deliver flow into a culvert under inlet control is determined using Chart 8B from Ref. 6 as shown below.

Design Discharge (cfs) = 420
No. of Culverts = 4
Culvert Discharge, Q (cfs) = 105
Culvert Width, B (ft) = 6
Q/B (cfs/ft) = 17.5
Culvert Height, D (ft) = 4
Hw/D (per chart) = 0.85 {conservative}
Upstream Depth, Hw (ft) = 3.4

Inv. Elev. of Culvert Entrance (ft) = 692.75
WSE at Culverts Entrance (ft) = 696.15

CHART 8B



EXAMPLE

5'x 2' Box Q = 75 cfs
Q/B = 15 cfs/ft.

Inlet	$\frac{HW}{D}$	HW feet
(1)	1.75	3.5
(2)	1.90	3.8
(3)	2.05	4.1

$\frac{HW}{D}$ SCALE	WINGWALL FLARE
(1)	30° to 75°
(2)	90° and 15°
(3)	0° (extensions of sides)

To use scale (2) or (3) project horizontally to scale (1), then use straight inclined line through D and Q scales, or reverse as illustrated.

HEADWATER DEPTH
FOR BOX CULVERTS
WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

4.1.2 Calculate WSE Change Across Lateral Weir

The north and south weir segments are oriented perpendicular to the overall flow direction of the spillway so these weir segments will behave as lateral weirs, which at treament plants are known as launders. The downstream WSE difference across a zero slope launder can be calculated using the standard equation as presented in Ref. 7.

$$\boxed{H_L = \sqrt{2\frac{h_c^3}{h_o} + h_o^2}}$$

where H_L = water depth at upstream end of launder (ft); H_c = critical depth (ft); and h_o = depth at downsteam end of launder (ft).

Total Flow Rate (cfs) = 420.00
North Weir Length (ft) = 12.75
Middle Weir Length (ft) = 28.83
South Weir Length (ft) = 12.75
Total Weir Length (ft) = 54.33
Side Weir Flow Rate (cfs) = 98.56

Channel Width (ft) = 6.00
Unit Discharge (cfs/ft) = 16.43
h_c (ft) = 2.03
h_o (ft) = 3.40 (per section 4.1.1)
H_L (ft) = 4.06
WSE at Upstream End (ft) = 696.81

4.1.3 Evaluate Weir Freeboard

The above calculations show that the WSE at the upstream end of the north and south weirs will be 696.81 ft. The result is 698.00 ft - 696.81 ft = 1.19 ft of freeboard on the weir crest. **<u>The design of the culvert entrance channel is acceptable.</u>**

5.0 Area 3 - Culvert Conveyance Structures

The culvert conveyance structures must pass flow to the downstream riprap channel while dissipating the energy gained from the drop in elevation. Failure to do so would result in supercritical flow at the exit of the culvert which would exceed the velocity limitations of the riprap. Energy dissipation will be achieved using an outlet weir that will force a hydraulic jump within the downstream section of culvert at the drop exit.

5.1 Determine Flow Conditions Exiting Drop

At the design discharge, the trajectory of flow exiting the upstream section of culvert will impact the vertical wall of the drop structure and some energy will be dissipated. A conservative approach is to assume that no energy dissipation occurs and that the drop height is equal to the distance from the culvert entrance structure invert to the drop structure invert (The conservatism is necessary since the flow approaching the drop is supercritical, as shown below using Manning's eqn, per section 3.2.2, and the available design formulas assume subcritical flow approaching the drop). The flow conditions approaching the outlet weir can be determined using the "Simple Straight Drop" formulas presented in Ref. 8.

Culvert Width (ft)	No. of Culverts	Q (cfs)	Q per Culvert (cfs)	Q per Unit Width (cfs/ft)	Normal Depth (ft)	Slope (ft/ft)	n	R (ft)	V (fps)	Q (cfs)	Froude Number
6	4	420	105	17.50	1.83	0.005	0.012	1.14	9.6	420.0	1.25

5.1.1 Calculate the Drop Number

$$\boxed{N_d = \frac{q^2}{g h_o^3}}$$

where: N_d = drop number; q = unit discharge (cfs/ft); g = acceleration due to gravity (ft/s^2); and h_o = drop height (ft).

Design Dicharge (cfs) = 420.0
No. of Culverts = 4
Discharge per Culvert (cfs) = 105.0
Culvert Width (ft) = 6.0
Unit Discharge, q (cfs/ft) = 17.5

Culvert Entrance Inv. Elev. (ft) = 692.75
Drop Structure Inv. Elev. (ft) = 685.37
Drop Height, h_o (ft) = 7.38

N_d = 0.024

5.1.2 Calculate the Flow Depth and Velocity Exiting Drop

Flow depth exiting the drop is calculated by:

$$\boxed{y_3 = 1.66 h_o N_d^{0.27}}$$

where y_3 = flow depth exiting the drop (ft).

y_3 (ft) = 4.46
Discharge per Culvert (cfs) = 105.00
Drop Exit Velocity (fps) = 3.93
Froude No. = 0.33
Drop Exit Inv. Elev. (ft) = 685.37

Drop Exit WSE (ft) = 689.83

5.2 Determine Flow Conditions in Downstream Culvert

The outlet weir at the end of the downstream culvert will force subcritical flow to occur for the entire length of conduit. Use backwater calcs to determine flow profile from the weir upstream to the drop exit.

5.2.1 Calculate WSE at Outlet Weir

Flow over the outlet weir is governed by the Francis equation (Ref. 1) without the weir length modification for the side contractions of the weir nappe (Ref.1):

$$\boxed{Q = 3.33LH^{3/2}}$$

where: Q = discharge (cfs); L = weir length (ft); and H = weir head (ft).

Design Dicharge (cfs) = 420.0
No. of Culverts = 4
Discharge per Culvert (cfs) = 105.0
Weir Length (ft) = 6.0
H (ft) = 3.02
Culvert Outlet Inv. Elev. (ft) = 685.21
Weir Height (ft) = 1.50
Weir Inv. Elev. (ft) = 686.71
WSE (ft) = 689.73

5.2.2 Calculate WSE at Drop Exit

The standard step method can be used to calculate the WSE at the drop exit and can be found in standard hydraulic texts. The basic formula is:

$$\boxed{S_f - S_o = \frac{y_1 - y_2 + {}^{V_1}\!/_{2g} - {}^{V_2}\!/_{2g}}{L}}$$

where S_f = friction slope; S_o = channel slope; y_1 = upstream depth; y_2 = downstream depth; V_1 = upstream velocity; V_2 = downstream velocity; g = acceleration due to gravity; and L = channel length. The calculations below follow the suggested solution method found in Ref. 9.

y (ft)	A (ft^2)	P (ft)	R (ft)	C^2	V (fps)	V^2/2g (ft)	E (ft)	V^2/C^{2}R	So-(V^2/C^{2}R)m	ΔE (ft)	L (ft)
4.52	27.14	15.05	1.80	18767	3.87	0.23	4.76	0.000442			
									0.00458	0.15	32.00
4.68	28.11	15.37	1.83	18854	3.74	0.22	4.90	0.00040			

Depth at Drop Exit (ft) = 4.68
Culvert Inv. Elev. at Drop Exit (ft) = 685.37
WSE at Drop Exit (ft) = 690.05

5.3 Check Overall Culvert Conveyance Design

Since the outlet weir backwaters the drop exit, i.e. the drop exit WSE generated by the outlet weir is greater than that generated by the drop, the flow will remain subcritical throughout the downstream culvert length and the energy gained from the drop will be dissipated at the drop itself. **The design is acceptable.**

5.4 Check Vent Supply Area

The flow within the drop structure will entrain a significant amount of air and needs a constant air supply to remain in a stable flow regime and not generate fluctuating loads. While air will be supplied through the upstream culvert the dedicated vents at the top of each drop have been provided to ensure sufficient air supply. The same procedure used in section 3.3 can be used.

Allowable pressure differential, p (ft of water) = 0.1

Design Dicharge (cfs) = 420.0
No. of Culverts = 4
Discharge per Culvert (cfs) = 105.0
Weir Length (ft) = 6.0
H_e (ft) = 3.02
Required Vent Area (in^2) = 7.78
Minimum Vent Diameter (in) = 3.15

Vent diameter provided is 4 inches. **Vent design is acceptable.**

6.0 Area 4 - Riprap Channel Protection

The steep slopes of the embankment downstream of the culvert conveyance structures will produce high velocities which will erode the embankment if it is not protected by riprap. The design of riprap channels for embankment flows is performed according to Ref. 10.

6.1 Check Adequacy of Riprap Design

Perform calculations for maximum slope of 14.6% and apply uniform across entire channel.

6.1.1 Compute interstitial velocity and average velocity

$$\boxed{V_i = 2.48\sqrt{g d_{50}}\,\frac{S^{0.58}}{C_u^{2.22}}}$$

where: V_i = interstitial velocity (fps); g = accelearation due to gravity (ft/s^2); d_{50} = median rock size; S = embankment slope; and C_u = coefficient of uniformity of the riprap, d_{60}/d_{10}.

g (ft/s^2) = 32.2
d_{50} (in) = 15
d_{50} (ft) = 1.25
S (ft/ft) = 0.146
C_u = 2.1
V_i (fps) = 0.99

$$\boxed{V_{ave} = \eta V_i}$$

porosity of the rock, η = 0.45
V_{ave} (fps) = 0.45

6.1.2 Compute the average flow depth (y) as if all the flow is contained within the thickness of the riprap layer (t) (i.e., t = y)

$$\boxed{y = q_f / V_{ave}}$$

where q_f = unit discharge (cfs/ft)

Minimum Embankment Flow Width (ft) = 37.17
Design Discharge (cfs) = 420.00
q_f (cfs/ft) = 11.30
y (ft) = 25.30

Check if y is greater than the riprap thickness, t:

riprap thickness (in) = 30.00
riprap thickness (ft) = 2.50

y is greater than t. Go to next step.

6.1.3 Find allowable flow depth over the riprap.

$$\boxed{h = \frac{0.06\left(S_g - 1\right)d_{50}\tan\phi}{0.97S}}$$

where h = allowable flow depth (ft); S_g = specific gravity of the riprap; and ϕ = angle of repose of the riprap (deg).

S_g = 2.65

d_{50} (ft) = 1.25

ϕ (deg) = 42

S = 0.146

h (ft) = 0.79

6.1.4 Calculate the Manning roughness coefficient, n

$$\boxed{n = 0.034\left(d_{50}\right)^{1/6}}$$

n = 0.035

6.1.5 Calculate unit discharge, q_1, that can flow over the riprap using Manning's equation.

$$\boxed{q_1 = \frac{1.486}{n} h^{5/3} S^{1/2}}$$

q_1 (cfs/ft) = 10.789

6.1.6 Calculate the required interstitial flow, q_2, through the riprap and the flow provided by the riprap thickness, q.

$$\boxed{q_2 = q_f - q_1} \qquad \boxed{q = tV_{ave}}$$

q_2 (cfs/ft) = 0.511

q (cfs/ft) = 1.117

6.1.7 Determine Adequacy of Design

Since q_2 is less than q, <u>**the riprap design is acceptable**</u>.

7.0 Spillway Rating Curve

In order to provide a means for TWA to approximate the flow discharging through the spillway a rating curve is required. The rating curve provides the correlation between WSE upstream of the weir and the spillway discharge. Since river WSEs are capable of backwatering the spillway, at certain river WSEs different curves are required.

7.1 Calculate Spillway Rating Curve

7.1.1 Determine Maximum Free Discharge River WSE

Per section 3.2.2.1, the headloss through the culvert conveyance structures when fully submerged is 1.88 ft. Subtract this value from spillway weir invert elevation to determine maximum free discharge river WSE.

Culvert Conveyance Strucutre Headloss (ft) = 1.88
Spillway Weir Inv. Elev. (ft) = 698.00
Maximum Free Discharge River WSE (ft) = 696.12

7.1.2 Calculate Free Discharge Rating Curve

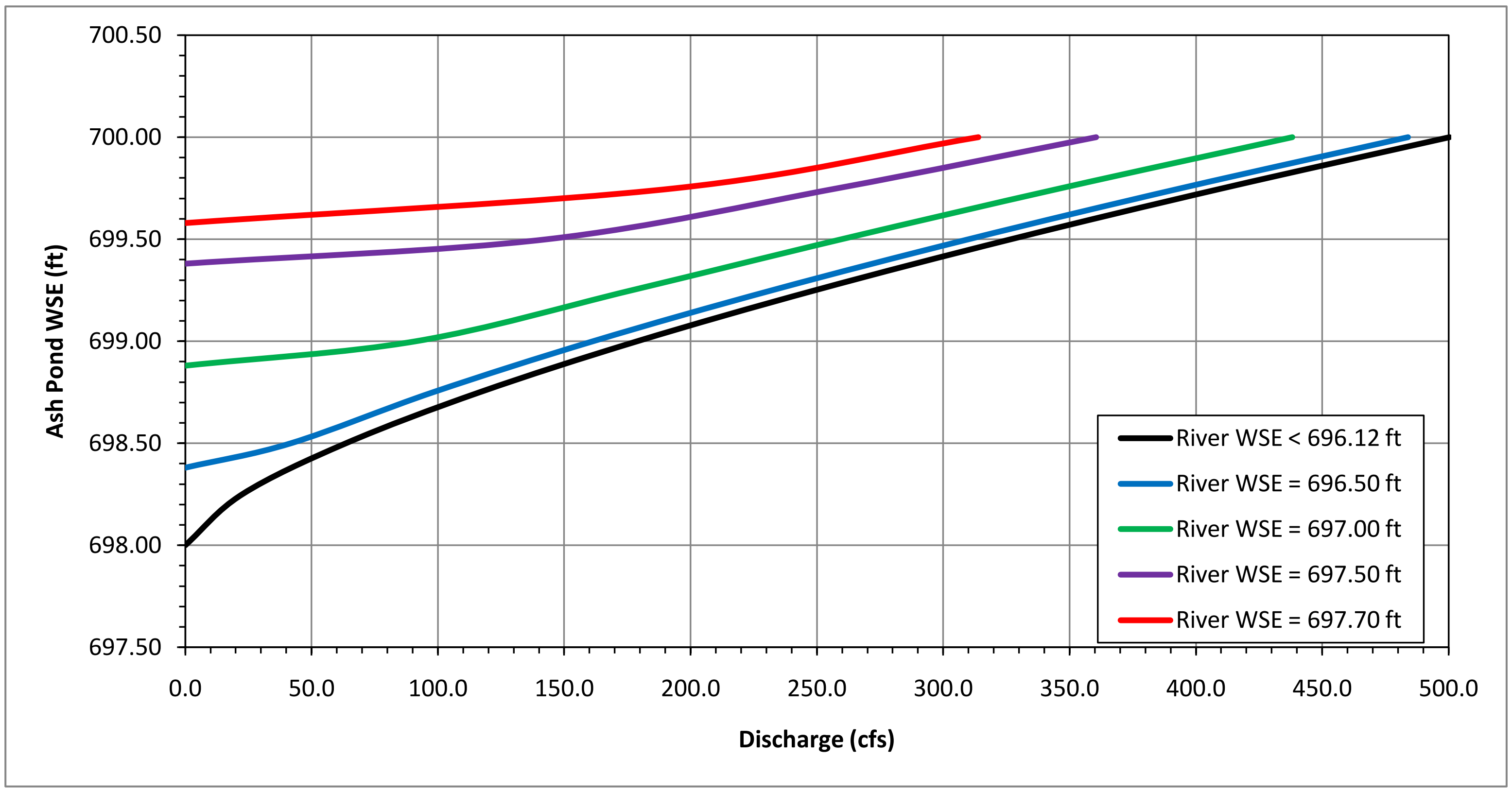
Calculations are per section 3.1.1.

7.1.3 Calculate Submerged Discharge Rating Curves

Calculations are per section 3.2. Formulas are valid up to a WSE upstream of the spillway weir of 700 ft, which is the top of the spillway structure walls. (D/S = downstream; U/S = upstream)

River WSE (ft)	Culvert Losses (ft)	WSE D/S of Weir (ft)	H_2 (ft)	WSE U/S of Weir (ft)	H_1 (ft)	H_2/H_1	Q/Q_1	Q_1 (cfs)	Q (cfs)
696.5	1.88	698.38	0.38	698.38	0.38	1.00	0.00	42.20	0.00
696.5	1.88	698.38	0.38	698.50	0.50	0.76	0.66	63.61	41.87
696.5	1.88	698.38	0.38	698.75	0.75	0.51	0.84	116.54	98.10
696.5	1.88	698.38	0.38	699.00	1.00	0.38	0.90	178.92	161.45
696.5	1.88	698.38	0.38	699.25	1.25	0.30	0.93	249.35	232.35
696.5	1.88	698.38	0.38	699.50	1.50	0.25	0.95	326.86	310.14
696.5	1.88	698.38	0.38	699.75	1.75	0.22	0.96	410.74	394.21
696.5	1.88	698.38	0.38	700.00	2.00	0.19	0.97	500.41	484.03
697.0	1.88	698.88	0.88	698.88	0.88	1.00	0.00	147.90	0.00
697.0	1.88	698.88	0.88	699.00	1.00	0.88	0.51	178.92	91.36
697.0	1.88	698.88	0.88	699.25	1.25	0.70	0.71	249.35	176.79
697.0	1.88	698.88	0.88	699.50	1.50	0.59	0.79	326.86	259.78
697.0	1.88	698.88	0.88	699.75	1.75	0.50	0.84	410.74	346.60
697.0	1.88	698.88	0.88	700.00	2.00	0.44	0.88	500.41	438.15
697.5	1.88	699.38	1.38	699.38	1.38	1.00	0.00	288.82	0.00
697.5	1.88	699.38	1.38	699.50	1.50	0.92	0.44	326.86	143.36
697.5	1.88	699.38	1.38	699.75	1.75	0.79	0.63	410.74	258.29
697.5	1.88	699.38	1.38	700.00	2.00	0.69	0.72	500.41	360.56
697.7	1.88	699.58	1.58	699.58	1.58	1.00	0.00	353.04	0.00
697.7	1.88	699.58	1.58	699.75	1.75	0.90	0.47	410.74	193.79
697.7	1.88	699.58	1.58	700.00	2.00	0.79	0.63	500.41	313.91

7.1.4 Plot Rating Curves



CLIENT	TVA	COMPUTED BY / DATE	R.H. 08/16/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	M.E.A. 08/16/12
DETAIL	Proposed Ash Pond Spillway	REVISION NO. / DATE	- -
PROJECT NO.	92016.2202	REVIEWED BY / DATE	- -
TVA CALCULATION PACKAGE	GENWBFFESCDX0000002012001005		

Calculation Description: **Watts Bar Ash Pond Spillway Rating Curve**

8.0 Spillway Rating Curve

Purpose: Develop Ash Pond Spillway Rating Curve for use in measuring discharge flowrate with staff gage reading.

Method: Increase height above weir increments to 0.01 ft from table developed for spillway design in Section 3.1.1.

Assumptions: Chickamauga Lake water surface elevation is less than 696.12 ft (refer to Section 3.2.3 for lake flood stages).
Rating curve includes all discharge flowrates not exceeding the primary spillway capacity up to WSE 700.00 ft.

Results: The Watt Bar Ash Pond post-construction rating curve in tabular and graphical formats are below in Table 1 and Figure 1.

Table 8-1. Watts Bar Ash Pond Primary Spillway Stage-Discharge Rating Table

		South Weir		Middle Weir		North Weir					
H (ft)	Upstream WSE (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	South Weir Q (cfs)	Middle Weir Q (cfs)	North Weir Q (cfs)	Total Weir Q (cfs)
0.00	698.00	12.75	12.75	28.83	28.83	12.75	12.75	0.0	0.0	0.0	0
0.01	698.01	12.75	12.75	28.83	28.83	12.75	12.75	0.0	0.1	0.0	0
0.02	698.02	12.75	12.75	28.83	28.83	12.75	12.75	0.1	0.3	0.1	1
0.03	698.03	12.75	12.74	28.83	28.83	12.75	12.74	0.2	0.5	0.2	1
0.04	698.04	12.75	12.74	28.83	28.83	12.75	12.74	0.3	0.8	0.3	1
0.05	698.05	12.75	12.74	28.83	28.82	12.75	12.74	0.5	1.1	0.5	2
0.06	698.06	12.75	12.74	28.83	28.82	12.75	12.74	0.6	1.4	0.6	3
0.07	698.07	12.75	12.74	28.83	28.82	12.75	12.74	0.8	1.8	0.8	3
0.08	698.08	12.75	12.73	28.83	28.82	12.75	12.73	1.0	2.2	1.0	4
0.09	698.09	12.75	12.73	28.83	28.82	12.75	12.73	1.1	2.6	1.1	5
0.10	698.10	12.75	12.73	28.83	28.81	12.75	12.73	1.3	3.0	1.3	6
0.11	698.11	12.75	12.73	28.83	28.81	12.75	12.73	1.5	3.5	1.5	7
0.12	698.12	12.75	12.73	28.83	28.81	12.75	12.73	1.8	4.0	1.8	8
0.13	698.13	12.75	12.72	28.83	28.81	12.75	12.72	2.0	4.5	2.0	8
0.14	698.14	12.75	12.72	28.83	28.81	12.75	12.72	2.2	5.0	2.2	9
0.15	698.15	12.75	12.72	28.83	28.80	12.75	12.72	2.5	5.6	2.5	10
0.16	698.16	12.75	12.72	28.83	28.80	12.75	12.72	2.7	6.1	2.7	12
0.17	698.17	12.75	12.72	28.83	28.80	12.75	12.72	3.0	6.7	3.0	13
0.18	698.18	12.75	12.71	28.83	28.80	12.75	12.71	3.2	7.3	3.2	14
0.19	698.19	12.75	12.71	28.83	28.80	12.75	12.71	3.5	7.9	3.5	15
0.20	698.20	12.75	12.71	28.83	28.79	12.75	12.71	3.8	8.6	3.8	16
0.21	698.21	12.75	12.71	28.83	28.79	12.75	12.71	4.1	9.2	4.1	17
0.22	698.22	12.75	12.71	28.83	28.79	12.75	12.71	4.4	9.9	4.4	19
0.23	698.23	12.75	12.70	28.83	28.79	12.75	12.70	4.7	10.6	4.7	20
0.24	698.24	12.75	12.70	28.83	28.79	12.75	12.70	5.0	11.3	5.0	21
0.25	698.25	12.75	12.70	28.83	28.78	12.75	12.70	5.3	12.0	5.3	23
0.26	698.26	12.75	12.70	28.83	28.78	12.75	12.70	5.6	12.7	5.6	24
0.27	698.27	12.75	12.70	28.83	28.78	12.75	12.70	5.9	13.4	5.9	25
0.28	698.28	12.75	12.69	28.83	28.78	12.75	12.69	6.3	14.2	6.3	27
0.29	698.29	12.75	12.69	28.83	28.78	12.75	12.69	6.6	15.0	6.6	28
0.30	698.30	12.75	12.69	28.83	28.77	12.75	12.69	6.9	15.7	6.9	30
0.31	698.31	12.75	12.69	28.83	28.77	12.75	12.69	7.3	16.5	7.3	31
0.32	698.32	12.75	12.69	28.83	28.77	12.75	12.69	7.6	17.3	7.6	33
0.33	698.33	12.75	12.68	28.83	28.77	12.75	12.68	8.0	18.2	8.0	34
0.34	698.34	12.75	12.68	28.83	28.77	12.75	12.68	8.4	19.0	8.4	36
0.35	698.35	12.75	12.68	28.83	28.76	12.75	12.68	8.7	19.8	8.7	37
0.36	698.36	12.75	12.68	28.83	28.76	12.75	12.68	9.1	20.7	9.1	39
0.37	698.37	12.75	12.68	28.83	28.76	12.75	12.68	9.5	21.6	9.5	41
0.38	698.38	12.75	12.67	28.83	28.76	12.75	12.67	9.9	22.4	9.9	42
0.39	698.39	12.75	12.67	28.83	28.76	12.75	12.67	10.3	23.3	10.3	44
0.40	698.40	12.75	12.67	28.83	28.75	12.75	12.67	10.7	24.2	10.7	46

Table 8-1. Watts Bar Ash Pond Primary Spillway Stage-Discharge Rating Table

		South Weir		Middle Weir		North Weir		South Weir Q	Middle Weir Q	North Weir Q	Total Weir Q
H (ft)	Upstream WSE (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	(cfs)	(cfs)	(cfs)	(cfs)
0.41	698.41	12.75	12.67	28.83	28.75	12.75	12.67	11.1	25.1	11.1	47
0.42	698.42	12.75	12.67	28.83	28.75	12.75	12.67	11.5	26.1	11.5	49
0.43	698.43	12.75	12.66	28.83	28.75	12.75	12.66	11.9	27.0	11.9	51
0.44	698.44	12.75	12.66	28.83	28.75	12.75	12.66	12.3	27.9	12.3	53
0.45	698.45	12.75	12.66	28.83	28.74	12.75	12.66	12.7	28.9	12.7	54
0.46	698.46	12.75	12.66	28.83	28.74	12.75	12.66	13.2	29.9	13.2	56
0.47	698.47	12.75	12.66	28.83	28.74	12.75	12.66	13.6	30.8	13.6	58
0.48	698.48	12.75	12.65	28.83	28.74	12.75	12.65	14.0	31.8	14.0	60
0.49	698.49	12.75	12.65	28.83	28.74	12.75	12.65	14.5	32.8	14.5	62
0.50	698.50	12.75	12.65	28.83	28.73	12.75	12.65	14.9	33.8	14.9	64
0.51	698.51	12.75	12.65	28.83	28.73	12.75	12.65	15.3	34.8	15.3	66
0.52	698.52	12.75	12.65	28.83	28.73	12.75	12.65	15.8	35.9	15.8	67
0.53	698.53	12.75	12.64	28.83	28.73	12.75	12.64	16.2	36.9	16.2	69
0.54	698.54	12.75	12.64	28.83	28.73	12.75	12.64	16.7	38.0	16.7	71
0.55	698.55	12.75	12.64	28.83	28.72	12.75	12.64	17.2	39.0	17.2	73
0.56	698.56	12.75	12.64	28.83	28.72	12.75	12.64	17.6	40.1	17.6	75
0.57	698.57	12.75	12.64	28.83	28.72	12.75	12.64	18.1	41.2	18.1	77
0.58	698.58	12.75	12.63	28.83	28.72	12.75	12.63	18.6	42.2	18.6	79
0.59	698.59	12.75	12.63	28.83	28.72	12.75	12.63	19.1	43.3	19.1	81
0.60	698.60	12.75	12.63	28.83	28.71	12.75	12.63	19.5	44.4	19.5	84
0.61	698.61	12.75	12.63	28.83	28.71	12.75	12.63	20.0	45.6	20.0	86
0.62	698.62	12.75	12.63	28.83	28.71	12.75	12.63	20.5	46.7	20.5	88
0.63	698.63	12.75	12.62	28.83	28.71	12.75	12.62	21.0	47.8	21.0	90
0.64	698.64	12.75	12.62	28.83	28.71	12.75	12.62	21.5	48.9	21.5	92
0.65	698.65	12.75	12.62	28.83	28.70	12.75	12.62	22.0	50.1	22.0	94
0.66	698.66	12.75	12.62	28.83	28.70	12.75	12.62	22.5	51.2	22.5	96
0.67	698.67	12.75	12.62	28.83	28.70	12.75	12.62	23.0	52.4	23.0	98
0.68	698.68	12.75	12.61	28.83	28.70	12.75	12.61	23.6	53.6	23.6	101
0.69	698.69	12.75	12.61	28.83	28.70	12.75	12.61	24.1	54.8	24.1	103
0.70	698.70	12.75	12.61	28.83	28.69	12.75	12.61	24.6	56.0	24.6	105
0.71	698.71	12.75	12.61	28.83	28.69	12.75	12.61	25.1	57.2	25.1	107
0.72	698.72	12.75	12.61	28.83	28.69	12.75	12.61	25.6	58.4	25.6	110
0.73	698.73	12.75	12.60	28.83	28.69	12.75	12.60	26.2	59.6	26.2	112
0.74	698.74	12.75	12.60	28.83	28.69	12.75	12.60	26.7	60.8	26.7	114
0.75	698.75	12.75	12.60	28.83	28.68	12.75	12.60	27.3	62.0	27.3	117
0.76	698.76	12.75	12.60	28.83	28.68	12.75	12.60	27.8	63.3	27.8	119
0.77	698.77	12.75	12.60	28.83	28.68	12.75	12.60	28.3	64.5	28.3	121
0.78	698.78	12.75	12.59	28.83	28.68	12.75	12.59	28.9	65.8	28.9	124
0.79	698.79	12.75	12.59	28.83	28.68	12.75	12.59	29.4	67.0	29.4	126
0.80	698.80	12.75	12.59	28.83	28.67	12.75	12.59	30.0	68.3	30.0	128
0.81	698.81	12.75	12.59	28.83	28.67	12.75	12.59	30.6	69.6	30.6	131
0.82	698.82	12.75	12.59	28.83	28.67	12.75	12.59	31.1	70.9	31.1	133
0.83	698.83	12.75	12.58	28.83	28.67	12.75	12.58	31.7	72.2	31.7	136
0.84	698.84	12.75	12.58	28.83	28.67	12.75	12.58	32.3	73.5	32.3	138
0.85	698.85	12.75	12.58	28.83	28.66	12.75	12.58	32.8	74.8	32.8	140
0.86	698.86	12.75	12.58	28.83	28.66	12.75	12.58	33.4	76.1	33.4	143
0.87	698.87	12.75	12.58	28.83	28.66	12.75	12.58	34.0	77.4	34.0	145
0.88	698.88	12.75	12.57	28.83	28.66	12.75	12.57	34.6	78.8	34.6	148
0.89	698.89	12.75	12.57	28.83	28.66	12.75	12.57	35.2	80.1	35.2	150
0.90	698.90	12.75	12.57	28.83	28.65	12.75	12.57	35.7	81.5	35.7	153
0.91	698.91	12.75	12.57	28.83	28.65	12.75	12.57	36.3	82.8	36.3	155
0.92	698.92	12.75	12.57	28.83	28.65	12.75	12.57	36.9	84.2	36.9	158
0.93	698.93	12.75	12.56	28.83	28.65	12.75	12.56	37.5	85.6	37.5	161
0.94	698.94	12.75	12.56	28.83	28.65	12.75	12.56	38.1	86.9	38.1	163
0.95	698.95	12.75	12.56	28.83	28.64	12.75	12.56	38.7	88.3	38.7	166
0.96	698.96	12.75	12.56	28.83	28.64	12.75	12.56	39.3	89.7	39.3	168
0.97	698.97	12.75	12.56	28.83	28.64	12.75	12.56	39.9	91.1	39.9	171
0.98	698.98	12.75	12.55	28.83	28.64	12.75	12.55	40.6	92.5	40.6	174
0.99	698.99	12.75	12.55	28.83	28.64	12.75	12.55	41.2	93.9	41.2	176
1.00	699.00	12.75	12.55	28.83	28.63	12.75	12.55	41.8	95.3	41.8	179
1.01	699.01	12.75	12.55	28.83	28.63	12.75	12.55	42.4	96.8	42.4	182
1.02	699.02	12.75	12.55	28.83	28.63	12.75	12.55	43.0	98.2	43.0	184
1.03	699.03	12.75	12.54	28.83	28.63	12.75	12.54	43.7	99.7	43.7	187
1.04	699.04	12.75	12.54	28.83	28.63	12.75	12.54	44.3	101.1	44.3	190
1.05	699.05	12.75	12.54	28.83	28.62	12.75	12.54	44.9	102.6	44.9	192
1.06	699.06	12.75	12.54	28.83	28.62	12.75	12.54	45.6	104.0	45.6	195

Table 8-1. Watts Bar Ash Pond Primary Spillway Stage-Discharge Rating Table

		South Weir		Middle Weir		North Weir					
H (ft)	Upstream WSE (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	South Weir Q (cfs)	Middle Weir Q (cfs)	North Weir Q (cfs)	Total Weir Q (cfs)
1.07	699.07	12.75	12.54	28.83	28.62	12.75	12.54	46.2	105.5	46.2	198
1.08	699.08	12.75	12.53	28.83	28.62	12.75	12.53	46.8	107.0	46.8	201
1.09	699.09	12.75	12.53	28.83	28.62	12.75	12.53	47.5	108.4	47.5	203
1.10	699.10	12.75	12.53	28.83	28.61	12.75	12.53	48.1	109.9	48.1	206
1.11	699.11	12.75	12.53	28.83	28.61	12.75	12.53	48.8	111.4	48.8	209
1.12	699.12	12.75	12.53	28.83	28.61	12.75	12.53	49.4	112.9	49.4	212
1.13	699.13	12.75	12.52	28.83	28.61	12.75	12.52	50.1	114.4	50.1	215
1.14	699.14	12.75	12.52	28.83	28.61	12.75	12.52	50.8	115.9	50.8	217
1.15	699.15	12.75	12.52	28.83	28.60	12.75	12.52	51.4	117.5	51.4	220
1.16	699.16	12.75	12.52	28.83	28.60	12.75	12.52	52.1	119.0	52.1	223
1.17	699.17	12.75	12.52	28.83	28.60	12.75	12.52	52.7	120.5	52.7	226
1.18	699.18	12.75	12.51	28.83	28.60	12.75	12.51	53.4	122.1	53.4	229
1.19	699.19	12.75	12.51	28.83	28.60	12.75	12.51	54.1	123.6	54.1	232
1.20	699.20	12.75	12.51	28.83	28.59	12.75	12.51	54.8	125.2	54.8	235
1.21	699.21	12.75	12.51	28.83	28.59	12.75	12.51	55.4	126.7	55.4	238
1.22	699.22	12.75	12.51	28.83	28.59	12.75	12.51	56.1	128.3	56.1	241
1.23	699.23	12.75	12.50	28.83	28.59	12.75	12.50	56.8	129.9	56.8	243
1.24	699.24	12.75	12.50	28.83	28.59	12.75	12.50	57.5	131.4	57.5	246
1.25	699.25	12.75	12.50	28.83	28.58	12.75	12.50	58.2	133.0	58.2	249
1.26	699.26	12.75	12.50	28.83	28.58	12.75	12.50	58.9	134.6	58.9	252
1.27	699.27	12.75	12.50	28.83	28.58	12.75	12.50	59.6	136.2	59.6	255
1.28	699.28	12.75	12.49	28.83	28.58	12.75	12.49	60.3	137.8	60.3	258
1.29	699.29	12.75	12.49	28.83	28.58	12.75	12.49	60.9	139.4	60.9	261
1.30	699.30	12.75	12.49	28.83	28.57	12.75	12.49	61.6	141.0	61.6	264
1.31	699.31	12.75	12.49	28.83	28.57	12.75	12.49	62.4	142.7	62.4	267
1.32	699.32	12.75	12.49	28.83	28.57	12.75	12.49	63.1	144.3	63.1	270
1.33	699.33	12.75	12.48	28.83	28.57	12.75	12.48	63.8	145.9	63.8	273
1.34	699.34	12.75	12.48	28.83	28.57	12.75	12.48	64.5	147.6	64.5	276
1.35	699.35	12.75	12.48	28.83	28.56	12.75	12.48	65.2	149.2	65.2	280
1.36	699.36	12.75	12.48	28.83	28.56	12.75	12.48	65.9	150.8	65.9	283
1.37	699.37	12.75	12.48	28.83	28.56	12.75	12.48	66.6	152.5	66.6	286
1.38	699.38	12.75	12.47	28.83	28.56	12.75	12.47	67.3	154.2	67.3	289
1.39	699.39	12.75	12.47	28.83	28.56	12.75	12.47	68.1	155.8	68.1	292
1.40	699.40	12.75	12.47	28.83	28.55	12.75	12.47	68.8	157.5	68.8	295
1.41	699.41	12.75	12.47	28.83	28.55	12.75	12.47	69.5	159.2	69.5	298
1.42	699.42	12.75	12.47	28.83	28.55	12.75	12.47	70.2	160.9	70.2	301
1.43	699.43	12.75	12.46	28.83	28.55	12.75	12.46	71.0	162.6	71.0	305
1.44	699.44	12.75	12.46	28.83	28.55	12.75	12.46	71.7	164.3	71.7	308
1.45	699.45	12.75	12.46	28.83	28.54	12.75	12.46	72.4	166.0	72.4	311
1.46	699.46	12.75	12.46	28.83	28.54	12.75	12.46	73.2	167.7	73.2	314
1.47	699.47	12.75	12.46	28.83	28.54	12.75	12.46	73.9	169.4	73.9	317
1.48	699.48	12.75	12.45	28.83	28.54	12.75	12.45	74.7	171.1	74.7	320
1.49	699.49	12.75	12.45	28.83	28.54	12.75	12.45	75.4	172.8	75.4	324
1.50	699.50	12.75	12.45	28.83	28.53	12.75	12.45	76.2	174.6	76.2	327
1.51	699.51	12.75	12.45	28.83	28.53	12.75	12.45	76.9	176.3	76.9	330
1.52	699.52	12.75	12.45	28.83	28.53	12.75	12.45	77.7	178.0	77.7	333
1.53	699.53	12.75	12.44	28.83	28.53	12.75	12.44	78.4	179.8	78.4	337
1.54	699.54	12.75	12.44	28.83	28.53	12.75	12.44	79.2	181.5	79.2	340
1.55	699.55	12.75	12.44	28.83	28.52	12.75	12.44	79.9	183.3	79.9	343
1.56	699.56	12.75	12.44	28.83	28.52	12.75	12.44	80.7	185.1	80.7	346
1.57	699.57	12.75	12.44	28.83	28.52	12.75	12.44	81.5	186.8	81.5	350
1.58	699.58	12.75	12.43	28.83	28.52	12.75	12.43	82.2	188.6	82.2	353
1.59	699.59	12.75	12.43	28.83	28.52	12.75	12.43	83.0	190.4	83.0	356
1.60	699.60	12.75	12.43	28.83	28.51	12.75	12.43	83.8	192.2	83.8	360
1.61	699.61	12.75	12.43	28.83	28.51	12.75	12.43	84.5	194.0	84.5	363
1.62	699.62	12.75	12.43	28.83	28.51	12.75	12.43	85.3	195.8	85.3	366
1.63	699.63	12.75	12.42	28.83	28.51	12.75	12.42	86.1	197.6	86.1	370
1.64	699.64	12.75	12.42	28.83	28.51	12.75	12.42	86.9	199.4	86.9	373
1.65	699.65	12.75	12.42	28.83	28.50	12.75	12.42	87.7	201.2	87.7	376
1.66	699.66	12.75	12.42	28.83	28.50	12.75	12.42	88.4	203.0	88.4	380
1.67	699.67	12.75	12.42	28.83	28.50	12.75	12.42	89.2	204.8	89.2	383
1.68	699.68	12.75	12.41	28.83	28.50	12.75	12.41	90.0	206.6	90.0	387
1.69	699.69	12.75	12.41	28.83	28.50	12.75	12.41	90.8	208.5	90.8	390
1.70	699.70	12.75	12.41	28.83	28.49	12.75	12.41	91.6	210.3	91.6	394
1.71	699.71	12.75	12.41	28.83	28.49	12.75	12.41	92.4	212.2	92.4	397

Table 8-1. Watts Bar Ash Pond Primary Spillway Stage-Discharge Rating Table

H (ft)	Upstream WSE (ft)	South Weir		Middle Weir		North Weir		South Weir Q (cfs)	Middle Weir Q (cfs)	North Weir Q (cfs)	Total Weir Q (cfs)
		Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)	Actual Length (ft)	Effect. Length (ft)				
1.72	699.72	12.75	12.41	28.83	28.49	12.75	12.41	93.2	214.0	93.2	400
1.73	699.73	12.75	12.40	28.83	28.49	12.75	12.40	94.0	215.9	94.0	404
1.74	699.74	12.75	12.40	28.83	28.49	12.75	12.40	94.8	217.7	94.8	407
1.75	699.75	12.75	12.40	28.83	28.48	12.75	12.40	95.6	219.6	95.6	411
1.76	699.76	12.75	12.40	28.83	28.48	12.75	12.40	96.4	221.4	96.4	414
1.77	699.77	12.75	12.40	28.83	28.48	12.75	12.40	97.2	223.3	97.2	418
1.78	699.78	12.75	12.39	28.83	28.48	12.75	12.39	98.0	225.2	98.0	421
1.79	699.79	12.75	12.39	28.83	28.48	12.75	12.39	98.8	227.1	98.8	425
1.80	699.80	12.75	12.39	28.83	28.47	12.75	12.39	99.6	229.0	99.6	428
1.81	699.81	12.75	12.39	28.83	28.47	12.75	12.39	100.5	230.9	100.5	432
1.82	699.82	12.75	12.39	28.83	28.47	12.75	12.39	101.3	232.8	101.3	435
1.83	699.83	12.75	12.38	28.83	28.47	12.75	12.38	102.1	234.7	102.1	439
1.84	699.84	12.75	12.38	28.83	28.47	12.75	12.38	102.9	236.6	102.9	442
1.85	699.85	12.75	12.38	28.83	28.46	12.75	12.38	103.7	238.5	103.7	446
1.86	699.86	12.75	12.38	28.83	28.46	12.75	12.38	104.6	240.4	104.6	450
1.87	699.87	12.75	12.38	28.83	28.46	12.75	12.38	105.4	242.3	105.4	453
1.88	699.88	12.75	12.37	28.83	28.46	12.75	12.37	106.2	244.3	106.2	457
1.89	699.89	12.75	12.37	28.83	28.46	12.75	12.37	107.0	246.2	107.0	460
1.90	699.90	12.75	12.37	28.83	28.45	12.75	12.37	107.9	248.1	107.9	464
1.91	699.91	12.75	12.37	28.83	28.45	12.75	12.37	108.7	250.1	108.7	468
1.92	699.92	12.75	12.37	28.83	28.45	12.75	12.37	109.6	252.0	109.6	471
1.93	699.93	12.75	12.36	28.83	28.45	12.75	12.36	110.4	254.0	110.4	475
1.94	699.94	12.75	12.36	28.83	28.45	12.75	12.36	111.2	256.0	111.2	478
1.95	699.95	12.75	12.36	28.83	28.44	12.75	12.36	112.1	257.9	112.1	482
1.96	699.96	12.75	12.36	28.83	28.44	12.75	12.36	112.9	259.9	112.9	486
1.97	699.97	12.75	12.36	28.83	28.44	12.75	12.36	113.8	261.9	113.8	489
1.98	699.98	12.75	12.35	28.83	28.44	12.75	12.35	114.6	263.8	114.6	493
1.99	699.99	12.75	12.35	28.83	28.44	12.75	12.35	115.5	265.8	115.5	497
2.00	700.00	12.75	12.35	28.83	28.43	12.75	12.35	116.3	267.8	116.3	500

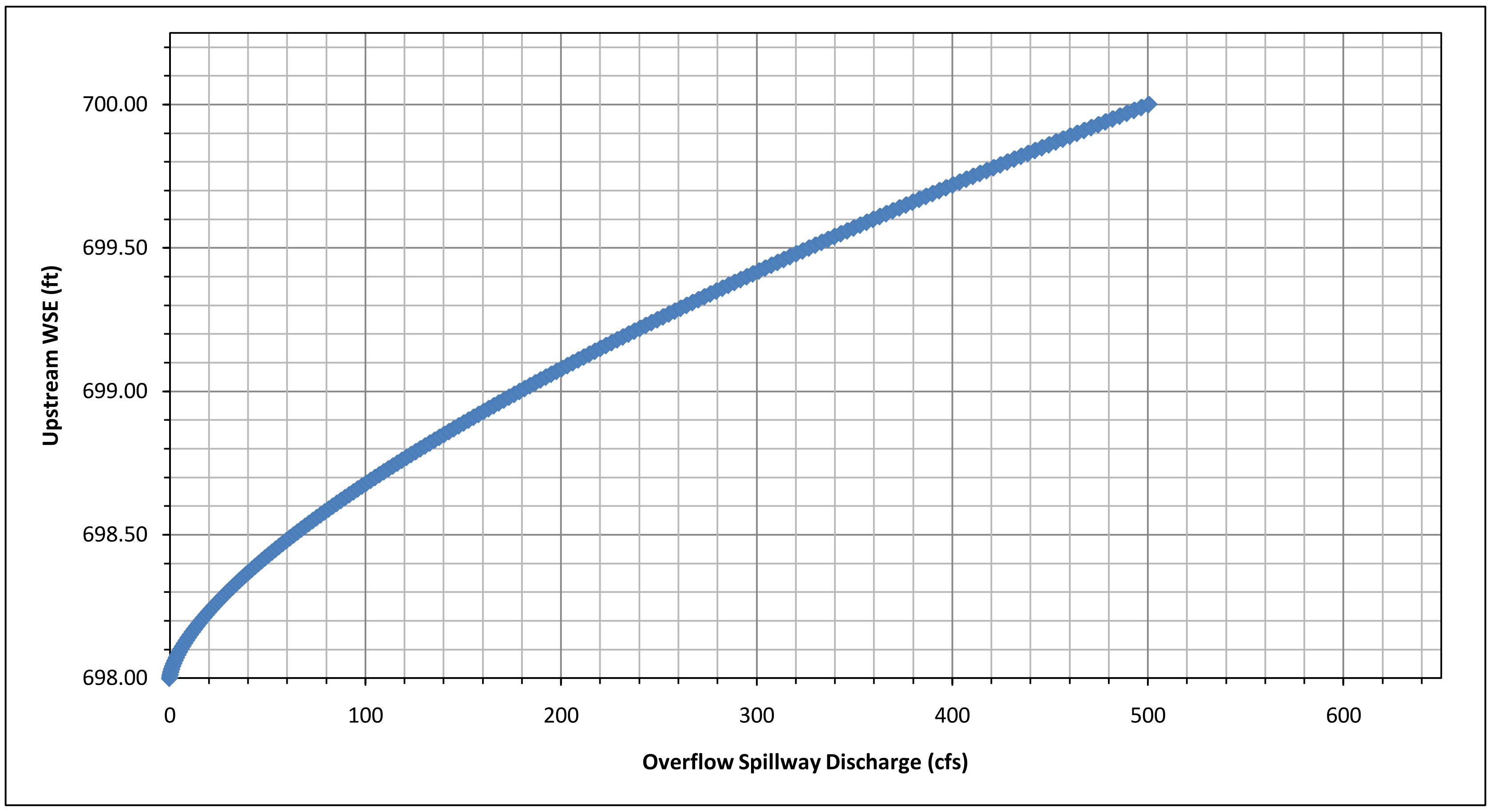


Figure 8-1. Watts Bar Ash Pond Primary Spillway Weir Stage-Discharge Rating Curve

CLIENT	TVA	COMPUTED BY / DATE	R.H.	07/27/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	M.S.	08/16/12
DETAIL	Dewatering	REVISION NO. / DATE	-	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	-	-
TVA CALCULATION PACKAGE	GENWBFFESCDX0000002012001005			

Calculation Description: Dewatering Pumping Rates

1.0 Objective

Determine pumping volume and rates required to dewater Watts Bar Ash Pond prior to construction.

2.0 Procedure

1.) From Elevation-Area incremental data, determine volume to be pumped each day then convert units to determine maximum pumping rate.
2.) Account for separation of two areas of pond by splitter dike.

3.0 References / Data Sources

1.) Proposed plan sheet Ash Pond Breaching Project Excavation and Cofferdam Plan Work Plan 1 (10W253-07).

4.0 Assumptions / Limitations

1.) Maximum drawdown rate is 1ft/day to limit stresses on embankments.
2.) Initial water surface elevation is approximately 704.5 ft, corresponding to crest of existing riser/barrel structures.
3.) Water surface elevation following rainfall event which fills pond is 701 ft, corresponding to breach elevation.
4.) Bottom of pond is between 693 ft and 694 ft, but 694 is the lowest elevation considered in this calculation.
5.) Pumping rate corresponding to 1 ft per day withdrawal rate varies depending on stage in pond with the highest pumping rate experienced when the water surface elevation is at its highest (704.5 ft).
6.) The two sides of the pond (split by splitter dike) will be hydraulically separate and pumped separately beginning between elevation 703 and 704 ft. Therefore the maximum pumping rate required is determined by the higher of the total pumping rate divided by two pumps or the maximum pumping rate for the larger of the two ponds once they are hydraulically separated.
7.) Water from the Ash Pond will be pumped through a silt bag prior to discharge to remove solids in the water. A Dirtbag 55 measuring 10′ by 15′ has an average capacity of 1,500 gpm or 3.3 cfs.

5.0 Calculations

5.1 Determine the Channel Dimensions and Lining

- The attached spreadsheet named TVA_Ashpond_Dewatering.xls includes tables showing the compiled volume and pumping calculations. Table 1 lists the elevation/area and cumulative volumes for the pond. Refer to Table 2 for dewatering pumping rates varied by water surface elevation and Table 3 for pumping durations varied by pumping capacity.

6.0 Conclusions

1.) Initial dewatering of the Watts Bar Ash Pond will require removal of an estimated 16.2 million gallons using some combination of pumps and/or siphons to reduce the water surface elevation from 704.5 ft to 694 ft. The estimated pumping duration at a maximum drawdown rate of 1 ft/day is 11.5 days. The estimated duration for dewatering following a rainfall event which fills the pond to the elevation of the breach (701 ft) is 7 days at a maximum drawdown rate of 1 ft/day. Table 1 lists various pumping capacities which could be utilized to dewater the pond under a variety of schedules.

2.) The estimated maximum required pumping capacity to dewater the Watts Bar Ash Pond from the normal pool elevation of 704.5 ft is estimated at 3,853 gpm for the entire pond at a rate of 1/ft per day during a 10 hour work day. Between the elevation of 703 ft and 704 ft, the pond will split into two ponds. Once the ponds are hydraulically split, a maximum pumping capacity of 2,200 gpm will be required for the larger (north) of the two areas of the pond, and a maximum of 1,200 gpm for the smaller (south) pond based on a 1 ft/day drawdown rate with 10 hour workdays.

Table 1. Watts Bar Ash Pond Dewatering Pumping Rates

	North Pond[1]					South Pond[1]					Combined						
Elev Range	**Avg Area**	**Incremental Volume**		**Pumping Rate (1 ft/day - 10 hrs)[2, 3]**		**Avg Area**	**Incremental Volume**		**Pumping Rate (1 ft/day - 10 hrs)[2, 3]**		**Avg Area**	**Incremental Volume**		**Cumulative Volume**		**Pumping Rate (1 ft/day - 10 hrs)[1, 2, 3]**	
(ft)	**(acre ft)**	**(cf)**	**(gal)**	**(cfs)**	**(gpm)**	**(acre ft)**	**(cf)**	**(gal)**	**(cfs)**	**(gpm)**	**(acre ft)**	**(cf)**	**(gal)**	**(cf)**	**(gal)**	**(cfs)**	**(gpm)**
694-695	0.25	10,856	81,209	0.30	135	0.25	10,687	79,941	0.30	133	0.49	21,543	161,149	21,543	161,149	*0.60*	*269*
695-696	0.97	42,165	315,418	1.17	526	0.55	24,083	180,150	0.67	300	1.52	66,248	495,568	87,790	656,717	*1.84*	*826*
696-697	2.15	93,458	699,112	2.60	1,165	0.88	38,344	286,829	1.07	478	3.03	131,801	985,942	219,591	1,642,658	*4.58*	*1,643*
697-698	2.99	130,144	973,545	3.62	1,623	1.19	51,729	386,956	1.44	645	4.18	181,873	1,360,501	401,464	3,003,159	*6.32*	*2,268*
698-699	3.34	145,493	1,088,363	4.04	1,814	1.47	63,837	477,534	1.77	796	4.81	209,330	1,565,897	610,794	4,569,056	*7.27*	*2,610*
700-701	3.54	154,133	1,152,991	4.28	1,922	1.68	73,148	547,185	2.03	912	5.22	227,281	1,700,176	838,074	6,269,233	*7.89*	*2,834*
701-702	3.68	160,214	1,198,480	4.45	1,997	1.84	80,330	600,910	2.23	1,002	5.52	240,544	1,799,390	1,078,618	8,068,623	*8.35*	*2,999*
702-703	3.80	165,355	1,236,937	4.59	2,062	2.00	87,132	651,789	2.42	1,086	5.80	252,486	1,888,726	1,331,104	9,957,349	*8.77*	*3,148*
702-703	3.89	169,520	1,268,098	4.71	2,113	2.14	93,214	697,285	2.59	1,162	6.03	262,734	1,965,383	1,593,837	11,922,732	*9.12*	*3,276*
703-704	*See Notes 1 and 4*					*See Notes 1 and 4*					6.39	278,215	2,081,193	1,872,052	14,003,925	9.66	3,469
704-704.5											6.78	295,508	2,210,552	2,167,560	**16,214,477**	**10.26**	**3,684**
704.5-705											7.09	309,003	2,311,505	2,476,563	18,525,982	10.73	3,853

Notes:

[1] *The Ash Pond becomes hydraulically seperated by the splitter dike into north and south sides at approximately elevation 703.5.*

[2] *The Ash Pond shall be dewatered at a constant rate over a 10-hour duration such that the elevation drops by a maximum of 1 foot per day. The pumping rate over the 10-hour duration may be subject to change based on field observation of bank instability. Dewatering of the entire pond depth from elevation 704.5 ft to 694 ft will take a minimum of 11 days at 1 ft/day.*

[3] *A 10 hour work day is assumed for the daily pumping duration, per direction from TVA staff.*

[4] *The normal pool at the time the survey was performed was at elevation 704.5 feet.*

[5] *All pumped water shall be filtered through a sediment bag prior to discharge.*

[6] *Drawdown rates specified herein and use of sediment bags shall be adhered to for initial dewatering efforts as well as additional dewatering efforts that may be required during construction, which is expected to occur due to ground water and stormwater runoff contributions.*

CLIENT TVA
PROJECT Watts Bar Ash Pond
DETAIL Proposed Ash Pond Inflow Channel
PROJECT NO. 92016.2202
TVA CALCULATION PACKAGE GENWBFFESCDX0000002012001005

COMPUTED BY / DATE R.H. 07/27/12
CHECKED BY / DATE B.N. 08/14/12
REVISION NO. / DATE - -
REVIEWED BY / DATE - -

Calculation Description: Proposed Ash Pond Inflow Channel

1.0 Objective

Develop channel dimensions and liner required for modified channel entrance into lowered Ash Pond.

2.0 Procedure

1.) Determine existing channel dimensions for reference.
2.) Lay out proposed alignment to determine site constraints and channel slope.
3.) Calculate channel dimensions using Mannings equation in spreadsheet.
4.) Determine channel lining required based on permissible shear stress.

3.0 References / Data Sources

1.) Existing conditions survey of Ash Pond berm conducted May 2012 (file - wf06_wbn12397_20120505.dwg).
2.) Plan sheet: Ash Pond Breaching Project Excavation and Cofferdam Plan Work Plan 1, 10W253-07.

4.0 Assumptions / Limitations

1.) The channel will connect the existing 8' wide channel (Elev 705') to the newly lowered Ash Pond (Elev 698') over a distance of approximately 90' with a slope of 0.10.

2.) Materials for lining shall be the same as those being used on the discharge spillway (riprap d50 = 15") for ease of procurement and construction.

3.) The design storm shall be the 1-yr since this is expected to be a temporary channel which may be removed after one year of service. Also, flows exceeding the 1-yr design storm are expected to take the alternate flow route through or to the west of the dry ash area.

5.0 Calculations

5.1 Determine the Channel Dimensions and Lining

- Refer to channel calculations spreadsheet.

6.0 Conclusions

- A channel lined with TDOT Class B riprap is recommended at a bottom width of 15' with 3:1 side slopes to realign the existing channel to enter the lowered ash pond at the increased slope.

CDM Smith

CLIENT TVA
PROJECT Watts Bar Ash Pond
DETAIL Channel Realignment
JOB NO. 92016.2202
DATE CHECKED
CHECKED BY
COMPUTED BY R. Hopper
DATE 7/26/2012
PAGE NO. 1 of 2
TVA CALCULATION PACKAGE GENWBFFESCDX0000002012001005

OBJECTIVE

- Design channel realignment for channel entering lowered Ash Pond near proposed spillway.

Design Parameters:

-Drainage Area =	190 acres
-Design storm frequency =	10 year

Approach:

1- Calculate the design flow rate
2- Calculate normal depth and select channel size
3- Determine channel lining

Development

1- Calculate the design flow rate

The maximum design flow rate from the HEC-HMS Analysis.

$Q_{10\text{-}YR}$ = 58.0 cfs 1-yr (50% of flow directed to other channel)

2- Calculate normal depth and select channel size

B - Channel width, feet
H,V - Channel sideslope
Y - Depth of flow, feet
A - Channel area, square feet
A - Channel area, square feet
P - Wetted perimeter, feet
R - Hydraulic radius, feet
Q - Design discharge, cfs
s - Channel longitudinal slope
n - Mannings Roughness coeffiecient

Channel Characteristics

B =	15	H,V =	3
n =	0.086	$Q_{10\text{-}YR}$ =	58.0

Riprap Mannings n'!A1

The value for n is obtained from Attachment 1

s = 0.1 *(Average channel slope based on proposed grades)*

Y	A	P	R	Z_{REQ}	Z_{AV}
0.75	12.94	19.74	0.66	10.59	9.76
0.80	13.92	20.06	0.69	10.59	10.91
1.00	18.00	21.32	0.84	10.59	16.08

.
Normal depth =

Freeboard =	0.50	feet
Velocity at Normal Depth, feet/sec:	4.2	feet/sec
Design depth =	0.50	feet
Use =	1.5	feet

CLIENT	TVA	JOB NO.	92016.2202	COMPUTED BY	R. Hopper
PROJECT	Watts Bar Ash Pond	DATE CHECKED		DATE	7/26/2012
DETAIL	Existing Channel Realign	CHECKED BY		PAGE NO.	2 of 2

3- Determine channel lining

-- Calculate the shear stress and determine the appropriate channel lining using the 10 year 24-hr event

- Calculate shear stress

T = ydS

T = 4.99 lb/sf

T = shear stress in lb/sf

y = U.W. of H_2O (62.4 lb/cf)

- Determine appropriate channel lining (Permissible shear stress TDOT Manual Table 5A-7)

Permissible Shear'!A1

Recommended Lining = Riprap with 15" d50 (TDOT Class B)

http://www.tdot.state.tn.us/chief_engineer/assistant_engineer_design/design/drainmanpdf/chapter%205.pdf

RESULTS

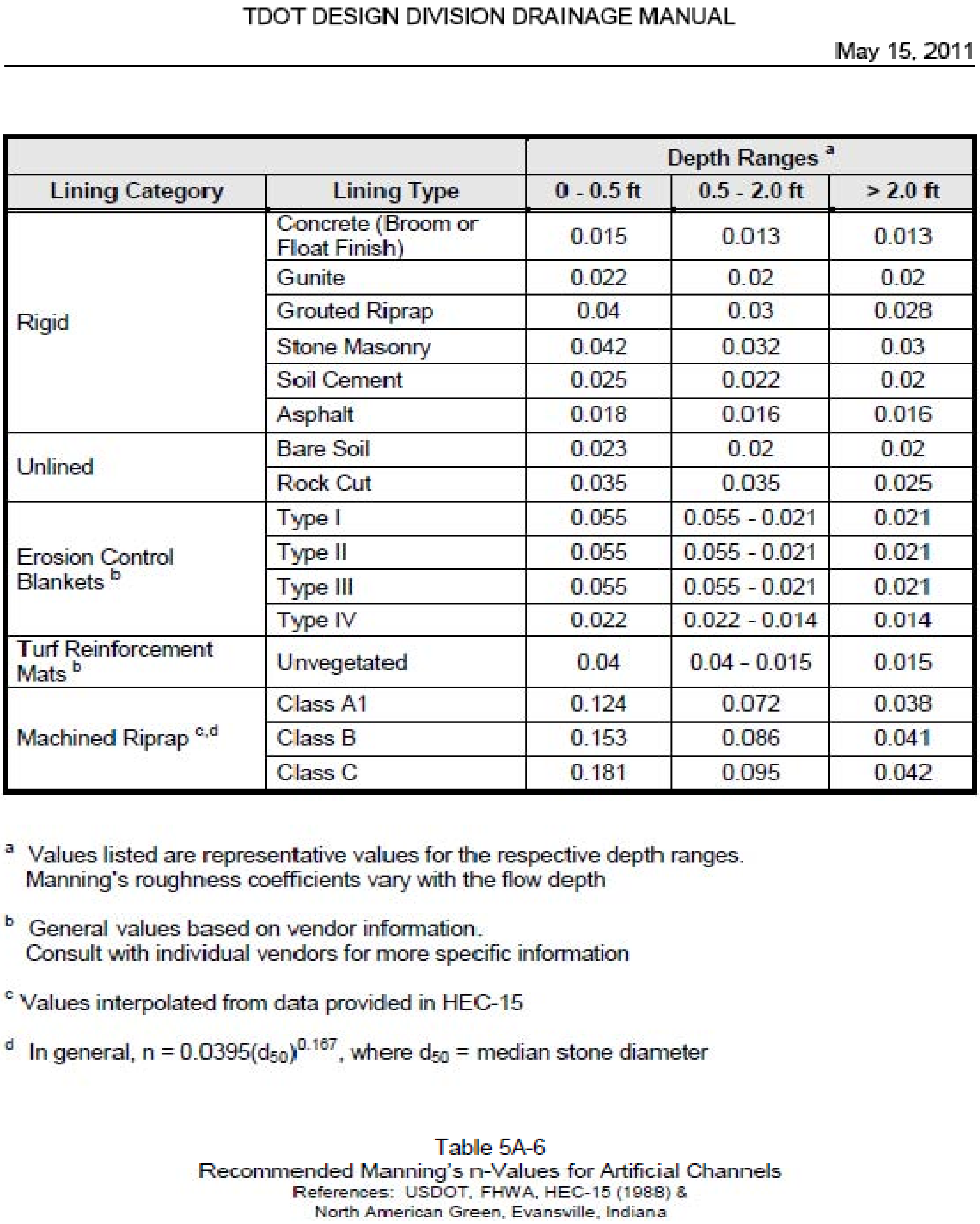
Below are the recommended channel dimensions and characteristics.

1.5 = Channel Depth (feet)
4.2 = Channel Velocity (feet/sec) for the 10-year 24-hr
4.99 = Shear Stress for the 10-year 24-hr event
Riprap with 15" d50 (TDOT Class B)

CONCLUSION

Due to the increased slope and the the in-situ dry ash material a riprap lining with d50 = 15" is recommended to line the channel realignment at a minimim slope of 0.10 and width of 15'.

http://www.tdot.state.tn.us/chief_engineer/assistant_engineer_design/design/drainmanpdf/chapter%205.pdf page 5A-17 (PDF pg 76)



TDOT DESIGN DIVISION DRAINAGE MANUAL

May 15, 2011

		Depth Ranges [a]		
Lining Category	**Lining Type**	**0 - 0.5 ft**	**0.5 - 2.0 ft**	**> 2.0 ft**
Rigid	Concrete (Broom or Float Finish)	0.015	0.013	0.013
	Gunite	0.022	0.02	0.02
	Grouted Riprap	0.04	0.03	0.028
	Stone Masonry	0.042	0.032	0.03
	Soil Cement	0.025	0.022	0.02
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.023	0.02	0.02
	Rock Cut	0.035	0.035	0.025
Erosion Control Blankets [b]	Type I	0.055	0.055 - 0.021	0.021
	Type II	0.055	0.055 - 0.021	0.021
	Type III	0.055	0.055 - 0.021	0.021
	Type IV	0.022	0.022 - 0.014	0.014
Turf Reinforcement Mats [b]	Unvegetated	0.04	0.04 – 0.015	0.015
Machined Riprap [c,d]	Class A1	0.124	0.072	0.038
	Class B	0.153	0.086	0.041
	Class C	0.181	0.095	0.042

[a] Values listed are representative values for the respective depth ranges. Manning's roughness coefficients vary with the flow depth

[b] General values based on vendor information. Consult with individual vendors for more specific information

[c] Values interpolated from data provided in HEC-15

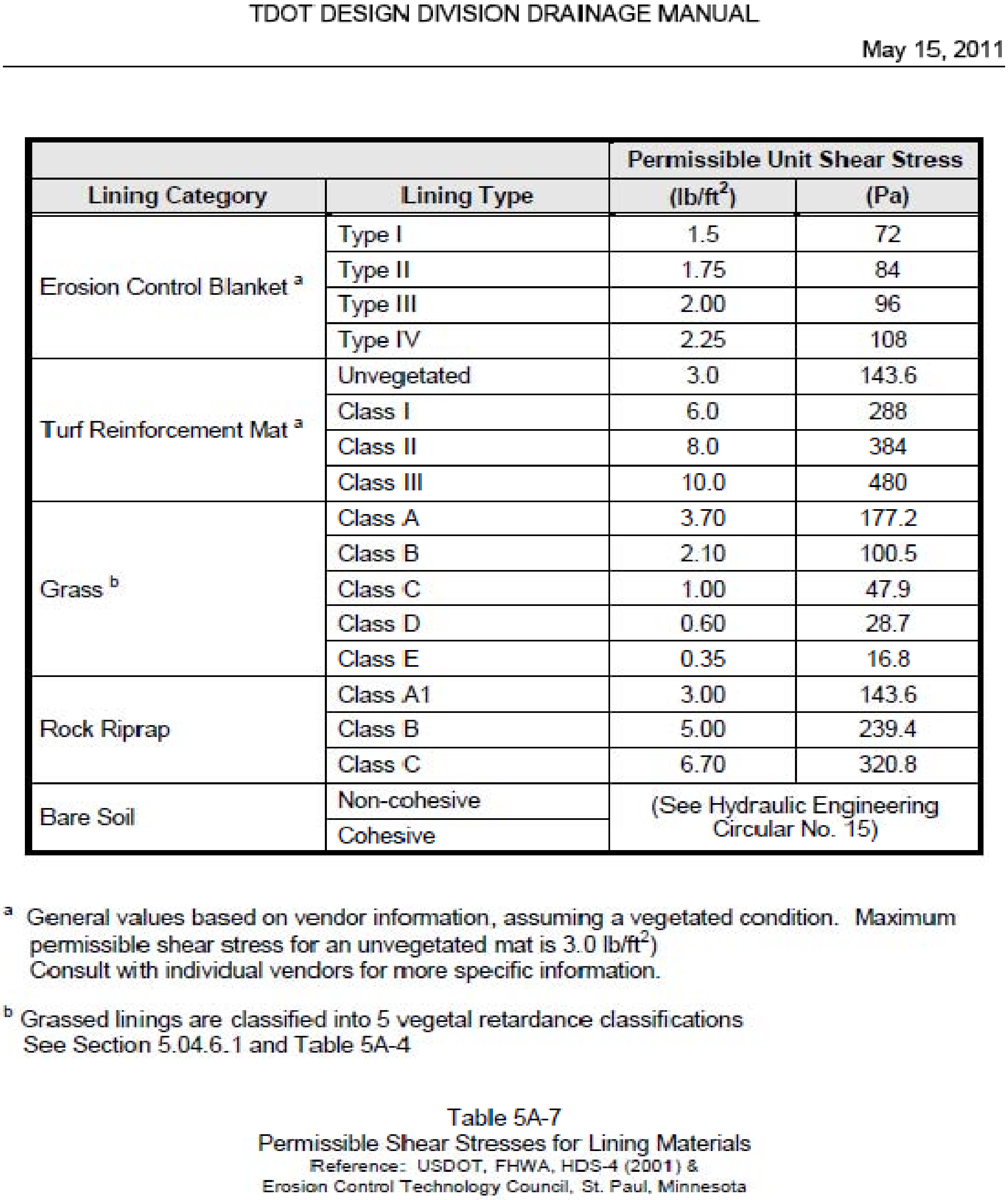
[d] In general, $n = 0.0395(d_{50})^{0.167}$, where d_{50} = median stone diameter

Table 5A-6

Recommended Manning's n-Values for Artificial Channels

References: USDOT, FHWA, HEC-15 (1988) &
North American Green, Evansville, Indiana

http://www.tdot.state.tn.us/chief_engineer/assistant_engineer_design/design/drainmanpdf/chapter%205.pdf page 5A-18 (PDF pg 77)



		Permissible Unit Shear Stress	
Lining Category	**Lining Type**	**(lb/ft^2)**	**(Pa)**
Erosion Control Blanket [a]	Type I	1.5	72
	Type II	1.75	84
	Type III	2.00	96
	Type IV	2.25	108
Turf Reinforcement Mat [a]	Unvegetated	3.0	143.6
	Class I	6.0	288
	Class II	8.0	384
	Class III	10.0	480
Grass [b]	Class A	3.70	177.2
	Class B	2.10	100.5
	Class C	1.00	47.9
	Class D	0.60	28.7
	Class E	0.35	16.8
Rock Riprap	Class A1	3.00	143.6
	Class B	5.00	239.4
	Class C	6.70	320.8
Bare Soil	Non-cohesive	(See Hydraulic Engineering Circular No. 15)	
	Cohesive		

[a] General values based on vendor information, assuming a vegetated condition. Maximum permissible shear stress for an unvegetated mat is 3.0 lb/ft^2)
Consult with individual vendors for more specific information.

[b] Grassed linings are classified into 5 vegetal retardance classifications
See Section 5.04.6.1 and Table 5A-4

Table 5A-7
Permissible Shear Stresses for Lining Materials
Reference: USDOT, FHWA, HDS-4 (2001) &
Erosion Control Technology Council, St. Paul, Minnesota

Exhibit 3
Calculation Reference – Draft Geotechnical Boring Logs

CDM Smith

B O R E H O L E L O G
B-103

Client: TVA
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Location: Spring City, Tennessee
Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling
Surface Elevation (ft.): 711
Drilling Method/Rig: 3.25" HSA// CME-55
Total Depth (ft.): 58.5
Drillers: Tim Hall
Depth to Initial Water Level (ft-bgs): 27.2
Drilling Date: Start: 6-11-12 **End:** 6-11-12
Abandonment Method: Converted to observation well
Borehole Coordinates:
Field Screening Instrument:
N 464,486.5 E 2,331,360.8
Logged By: J. Wen

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-1	24/20	711.0 0	PP>4.5 TV=0.5	13 9 10 10	▨	FILL	3-inches of Gravel **-FILL-** Moist, very stiff, reddish brown, CLAY, trace sand and gravel.
SS	S-2	24/17		PP>4.5 TV=1.2	4 7 10 12	▨		Moist, very stiff, reddish brown, CLAY, trace sand.
SS	S-3	24/18	706.0 5	PP=3.5 TV=0.7	3 6 7 9	▨		Moist, stiff, reddish brown, CLAY, trace sand.
SS	S-4	24/21		PP=4.5 TV=1.7	4 7 10 12	▨		Moist, very stiff, reddish brown, CLAY, trace sand.
SS	S-5	24/21		PP=4.5 TV=0.9	2 4 8 12	▨		Moist, stiff, reddish brown CLAY, trace sand.
SS	S-6	24/18	701.0 10	PP=2.3 TV=0.8	3 4 8 9	▨		Moist, stiff, reddish brown CLAY, trace sand.
SS	S-7	24/20		PP=3.5 TV=0.9	4 5 9 11	▨		Moist, stiff, reddish brown CLAY, trace sand.
			696.0		4 6	▨		Moist, very stiff, dark gray, CLAY and SILT, trace sand. **-ALLUVIAL SOIL-**

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: **Date:**

CDM Smith

BOREHOLE LOG
B-103

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-8	24/18	696.0 15	PP=4.5 TV=1.2	11 16		FILL	
SS	S-9	24/24		PP=3.0 TV=1.3	6 6 8 11		CL	Moist, stiff, dark brown, CLAY and SILT, some sand.
SS	S-10	24/24	691.0 20	PP=2.5 TV=1.1	2 4 6 8			Moist, stiff, dark brown, CLAY and SILT, little sand.
ST	U-1	24/24						Moist, dark brown, CLAY and SILT, little sand.
SS	S-11	24/24	686.0 25		2 4 7 6			Wet, stiff, dark brown, SILT, some clay, fine sand.
							SC	Wet, loose, light brown, fine SAND, some clay.
SS	S-12	24/24	681.0 30		2 2 4 5			
SS	S-13	24/24	676.0 35		1 WOH 1 4			Wet, very loose, light brown, fine SAND, some clay.
					1 1			Wet, very loose, dark gray, fine to medium SAND, some clay.

CDM Smith

BOREHOLE LOG
B-103

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-14	24/24	671.0 40		2 4		SC	
SS	S-15	24/24	666.0 45		2 3 6 10		GC	Wet, loose, dark gray, fine GRAVEL and fine to coarse SAND, some silt, clay (round shape river rocks). Difficult drilling starting from 46 feet, sand heave before shale.
SS	S-16	2/0			50/2"		LS	NO SAMPLE RECOVERY. Auger refusal at 48.2 feet-bgs.
NQ	C-1	21.6/2	661.0 50		3:00 3:00			**RUN 1: 48.2 to 50 feet-bgs** REC = 10%, RQD = 0% Hard, slightly to completely weathered, gray, fine-grained, LIMESTONE, jointing horizontal, very close to close, rough, planar, fresh to decomposed, open.
NQ	C-2	24/7			2:15 2:15			**RUN 2: 50 to 52 feet-bgs** REC = 33.3%, RQD = 0% Hard, slightly to completely weathered, gray, fine-grained, LIMESTONE, jointing horizontal to moderately dipping, very close, rough, stepped, fresh to decomposed, open.
NQ	C-3	12/0			6:00			**RUN 3: 52 to 53 feet-bgs** REC = 0%, RQD = 0% No Recovery.
NQ	C-4	24/18	656.0 55		6:00 7:00			**RUN 4: 53 to 55 feet-bgs** REC = 75%, RQD = 66.7% Hard, slightly to moderately weathered, gray with white, fine grained, LIMESTONE, jointing horizontal to low angle, very close to moderate spacing, rough, undulating, fresh to decomposed, open.
NQ	C-5	24/12			5:00 5:00		SHALE / LS	**RUN 5: 55 to 57 feet-bgs** REC = 50%, RQD = 0% Hard, slightly to moderately weathered, gray with white, fine grained, LIMESTONE and SHALE, jointing moderately dipping, very close, rough, planar, fresh to decomposed, open.
NQ	C-6	18/0			6:00 3:00			**RUN 6: 57 to 58.5 feet-bgs** REC = 0%, RQD = 0% No Recovery.
			651.0 60					Boring terminated at 58.5 feet-bgs.

CDM Smith

B O R E H O L E   L O G
B-104

Client: TVA

Project Location: Spring City, Tennessee

Project Name: TVA Watts Bar Fossil Plant Phase II

Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling

Drilling Method/Rig: 3.25" HSA// CME-55

Drillers: Tim Hall

Drilling Date: Start: 6-12-12 **End:** 6-12-12

Borehole Coordinates:

N 464,634.1 E 2,331,336.6

Surface Elevation (ft.): 710

Total Depth (ft.): 30

Depth to Initial Water Level (ft-bgs): Not Measured

Abandonment Method: Grouted to ground surface

Field Screening Instrument:

Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-1	24/20	710.0 0		9 14 18 17		BOT-TOM ASH	Dry, dense, black, fine to coarse BOTTOM ASH, trace clay and gravel.
SS	S-2	24/19			8 19 38 41			Moist, very dense, black, fine to coarse BOTTOM ASH, trace clay.
SS	S-3	12/11	705.0		32 50			Moist, very dense, black, fine to coarse BOTTOM ASH, trace clay.
			5					
SS	S-4	24/15			11 10 9 6			Wet, medium dense, black, fine to coarse BOTTOM ASH, trace clay.
SS	S-5	24/14	700.0		3 3 4 4			Wet, loose, black, fine to coarse BOTTOM ASH.
SS	S-6	24/0	10		2 4 6 4			NO SAMPLE RECOVERY.
SS	S-7	24/14			7 3 3 2			Wet, loose, black, fine to coarse BOTTOM ASH.
			695.0		8 3			Wet, loose, black, medium coarse to coarse BOTTOM ASH.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: **Date:**

BOREHOLE-PP READINGS/NO ROCK TVA PHASE II_RHL.GPJ CDM_CORP.GDT 8/8/12

CDM Smith

BOREHOLE LOG
B-104

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-8	24/24	695.0 15		3 2		BOTTOM ASH	Wet, loose, black, medium coarse to coarse BOTTOM ASH.
SS	S-9	24/24		PP=2.2 TV=0.5	5 1 1 6		BOTTOM ASH / CL	Wet, medium stiff, dark gray CLAY and black, medium coarse BOTTOM ASH trace sand.
SS	S-10	24/24	690.0 20		8 6 5 5			Wet, stiff, dark gray, CLAY and black, medium to coarse BOTTOM ASH, trace sand.
ST	U-1	24/24						Wet, dark gray, CLAY and black, medium to coarse BOTTOM ASH, trace sand.
SS	S-11	24/24	685.0 25	PP=0.5 TV=0.2	4 4 7 6		CH	Wet, stiff, dark gray, CLAY, trace sand. **-ALLUVIAL SOIL-**
SS	S-12	24/24		PP=1.0 TV=0.5	5 5 5 6			Wet, stiff, dark gray, CLAY, trace sand.
SS	S-13	24/24	680.0 30	PP=0.5 TV=0.2	6 7 7 9			Wet, stiff, dark gray, CLAY, little clay, trace sand.
			675.0 35					Boring terminated at 30 feet-bgs.

BOREHOLE-PP READINGS/NO ROCK TVA PHASE II_RHL.GPJ CDM_CORP.GDT 8/8/12

Sheet 1 of 2

CDM Smith

B O R E H O L E L O G
B-104A

Client: TVA	**Project Name:** TVA Watts Bar Fossil Plant Phase II
Project Location: Spring City, Tennessee	**Project Number:** 95618-92016
Drilling Contractor: Total Depth Drilling	**Surface Elevation (ft.):** 711.04
Drilling Method/Rig: 3.25" HSA// CME-55	**Total Depth (ft.):** 28
Drillers: Tim Hall	**Depth to Initial Water Level (ft-bgs):** 25.9
Drilling Date: Start: 6-12-12 **End:** 6-12-12	**Abandonment Method:** Grouted to ground surface
Borehole Coordinates:	**Field Screening Instrument:**
N 464,614.4 E 2,331,123.6	**Logged By:** R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-1	24/22	711.0 0		6 19 18 16		BOT-TOM ASH	Dry, dense, black, fine to coarse BOTTOM ASH.
SS	S-2	24/19			6 17 18 22			Dry, dense, black, fine to coarse BOTTOM ASH, trace clay.
SS	S-3	24/20	706.0 5		12 17 23 23			Moist, dense, black, fine to coarse BOTTOM ASH, little clay.
SS	S-4	24/16			15 20 18 19			Wet, dense, black, fine to coarse BOTTOM ASH.
SS	S-5	24/19			4 8 4 12			Wet, medium dense, black, medium coarse to coarse BOTTOM ASH.
ST	U-1	15/15	701.0 10					Wet, black, medium coarse to coarse BOTTOM ASH.
SS	S-6	24/22			20 21 17 17			Wet, dense, black, medium coarse to coarse BOTTOM ASH.
			696.0		4 4			Wet, loose, black, coarse BOTTOM ASH.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Groundwater level was measured during drilling and may not represent stabilized levels.

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey

Reviewed by: **Date:**

CDM Smith

BOREHOLE LOG
B-104A

Client: TVA

Project Location: Spring City, Tennessee

Project Name: TVA Watts Bar Fossil Plant Phase II

Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-7	24/16	696.0 15		4 4		BOT-TOM ASH	
SS	S-8	24/8			13 8 4 3			Wet, medium dense, black, coarse BOTTOM ASH.
SS	S-9	24/22	691.0 20		7 7 6 6			Wet, medium dense, black, coarse BOTTOM ASH.
SS	S-10	24/24		PP=2.5 TV=0.5	4 8 5 10		CL	Wet, medium dense, black, coarse BOTTOM ASH. Wet, stiff, reddish brown, CLAY. **-ALLUVIAL SOIL-**
SS	S-11	24/24	686.0 25	PP=1.0 TV=0.5	4 3 4 5			Wet, medium stiff, reddish brown, CLAY.
SS	S-12	24/24		PP=1.2 TV=0.7	3 4 6 7			Wet, stiff, reddish brown, CLAY, trace sand.
			681.0 30 676.0 35					Boring termintated at 28 feet-bgs.

Sheet 1 of 3

CDM Smith

BOREHOLE LOG
B-105

Client: TVA

Project Location: Spring City, Tennessee

Project Name: TVA Watts Bar Fossil Plant Phase II

Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling

Drilling Method/Rig: 3.25" HSA// CME-55

Drillers: Tim Hall

Drilling Date: Start: 6-12-12 **End:** 6-13-12

Borehole Coordinates:

N 464,726.4 E 2,331,408.3

Surface Elevation (ft.): 711

Total Depth (ft.): 58

Depth to Initial Water Level (ft-bgs): 29.2

Abandonment Method: Grouted to ground surface

Field Screening Instrument:

Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			711.0 0					
SS	S-1	24/22		PP>4.5 TV=1.2	5 11 10 10		FILL	6-inches GRAVEL/FLY ASH **-FILL-** Moist, very stiff, reddish brown, CLAY, trace sand.
SS	S-2	24/20		PP>4.5 TV=1.2	7 7 10 11			Moist, very stiff, reddish brown, CLAY, trace sand.
SS	S-3	24/24	706.0 5	PP>4.5 TV=1.5	5 5 10 14			Moist, stiff to very stiff, reddish brown, CLAY, little sand.
SS	S-4	24/24		PP=4.5 TV=2.0	5 8 8 11			Moist, very stiff, dark gray, SILT and reddish brown, CLAY, trace sand.
SS	S-5	24/24		PP>4.5 TV=1.5	5 7 7 11			Moist, stiff, dark gray, SILT and reddish brown, CLAY, trace sand.
			701.0 10					
SS	S-6	24/20		PP=3.5 TV=1.0	5 6 8 6			Moist, stiff, dark gray, SILT and reddish brown, CLAY, trace sand.
SS	S-7	24/24		PP>4.5 TV=1.2	3 7 8 9			Moist, very stiff, reddish brown, CLAY, trace sand.
			696.0		1 4			Moist, stiff, reddish brown to gray, CLAY, some sand.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:

HSA	- Hollow Stem Auger
SSA	- Solid Stem Auger
HA	- Hand Auger
AR	- Air Rotary
DTR	- Dual Tube Rotary
FR	- Foam Rotary
MR	- Mud Rotary
RC	- Reverse Circulation
CT	- Cable Tool
JET	- Jetting
D	- Driving
DTC	- Drill Through Casing

SAMPLING TYPES:

AS	- Auger/Grab Sample
CS	- California Sampler
BX	- 1.5" Rock Core
NX	- 2.1" Rock Core
GP	- Geoprobe
HP	- Hydro Punch
SS	- Split Spoon
ST	- Shelby Tube
WS	- Wash Sample

OTHER:

AGS	- Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Groundwater level was measured during drilling and may not represent stabilized levels.

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey

Reviewed by: **Date:**

CDM Smith

BOREHOLE LOG
B-105

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-8	24/24	696.0 15	PP=2.0 TV=0.7	6 8	▨	FILL	Moist, reddish brown to gray, CLAY, some sand.
ST	U-1	24/21						
SS	S-9	24/24		PP=1.2 TV=0.2	3 5 3 4	▨	CL	Wet, medium stiff to stiff, dark gray CLAY, trace sand. **-ALLUVIAL SOIL-**
SS	S-10	24/4	691.0 20	PP=1.5 TV=0.2	3 3 5 5			Wet, medium stiff to stiff, dark gray CLAY, trace sand.
SS	S-11	24/18		PP=1.0 TV=0.1	1 2 4 3			Wet, medium stiff, dark gray CLAY, trace sand.
			686.0 25					
SS	S-12	24/6			WOH WOH 2 2	▨	SC	Wet, very loose, gray, fine to medium SAND, little silt.
			681.0 30					
SS	S-13	24/24			1 1 2 2			Wet, very loose, brown, fine SAND, some silt, little clay.
			676.0 35					
					2 1			Wet, very loose, gray, fine to medium SAND, some clay, silt.

CDM Smith

BOREHOLE LOG
B-105

Sheet 3 of 3

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-14	24/24	671.0 40		2 1		SC	
SS	S-15	24/24	666.0 45		4 4 31 43		SW-SM	Wet, dense to very dense, gray, fine to coarse SAND, some gravel, trace silt, roots. Auger refusal at 48.0 feet-bgs.
NQ	C-1	60/15	661.0 50		5:00 . 5:00 . 6:00 . 8:00 . 8:00		GW / SHALE / LS	**RUN 1: 48 to 53 feet-bgs** REC = 25%, RQD = 7% Hard, moderately weathered, gray, aphanitic, INTERBEDDED SHALE, LIMESTONE, and RIVER ROCK, very thin to thin bedding, low angle jointing, very close to close spacing, rough, discolored, open.
NQ	C-2	60/15	656.0 55		8:00 . 8:00 . 11:00 . 9:00 . 10:00		SHALE / LS	**RUN 2: 53 to 58 feet-bgs** REC = 25%, RQD = 0% Hard, highly weathered, gray, aphanitic, INTERBEDDED SHALE and LIMESTONE, very thin bedding, low angle to moderately dipping jointing, very close spacing, rough, discolored, open.
			651.0 60					Boring terminated at 58.0 feet-bgs.

Sheet 1 of 3

CDM Smith

B O R E H O L E L O G
B-106

Client: TVA

Project Location: Spring City, Tennessee

Project Name: TVA Watts Bar Fossil Plant Phase II

Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling

Drilling Method/Rig: 3.25" HSA// CME-55

Drillers: Tim Hall / Alan

Drilling Date: Start: 6-13-12 **End:** 6-14-12

Borehole Coordinates:

N 464,751.2 E 2,331,512.0

Surface Elevation (ft.): 693.9

Total Depth (ft.): 45.5

Depth to Initial Water Level (ft-bgs): 12.2

Abandonment Method: Grouted to ground surface

Field Screening Instrument:

Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.) 693.9	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-1	24/18	0	PP=2.5	6 12 8 12	▩	FILL	Dry, very stiff, brown, SILT, little sand. **-FILL-**
SS	S-2	24/16		PP=2.5	6 5 4 4	▩		Moist, stiff, brown, SILT, trace sand.
SS	S-3	24/20	688.9 5	PP=1.0 TV=0.2	1 2 2 3	▨	CL	Moist, soft to medium stiff, brown, CLAY, trace roots. **-ALLUVIAL SOIL-**
SS	S-4	24/12			2 2 2 3	▨	CL	Moist, very loose to loose, brown, fine SAND, some silt, clay, trace roots.
SS	S-5	24/15	683.9	PP=2.0 TV =0.4	2 2 3 5	▨		Moist, medium stiff, brown, CLAY, some sand.
SS	S-6	24/24	10		2 2 2 3	▨		Wet, very loose to loose, brown, fine SAND, some silt, clay.
						▨		
ST	U-1	24/24				░	SM	Wet, brown, fine to medium SAND, little silt, clay.
			678.9			░		

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Groundwater level was measured during drilling and may not represent stabilized levels.

Survey coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey

Reviewed by: **Date:**

CDM Smith

B O R E H O L E L O G
B-106

Client: TVA
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Location: Spring City, Tennessee
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			678.9 15				SM	
SS	S-7	24/0			2 2 2 2			NO SAMPLE RECOVERY.
SS	S-8	24/24	673.9		1 2 2 3		SC	Wet, loose, brown, fine to medium SAND, little clay.
SS	S-9	24/24	20		4 4 4 4			Wet, loose to medium, brown, fine to medium SAND, little clay, silt.
SS	S-10	24/24	668.9		WOH 1 2 2			Wet, very loose, brown, fine to medium SAND, some silt, clay.
			25					
SS	S-11	24/24	663.9		7 12 20 52/5"		GW / SHALE	Wet, dense, dark gray, fine to coarse gravel size RIVER ROCK and weathered SHALE. Auger refusal at 31.5 feet-bgs.
			30					
NQ	C-1	60/20	658.9		0:30 . 0:30 . 4:30 . 4:30 . 4:30		GW / SHALE / LS	**RUN 1: 30.5 to 35.5 feet-bgs** REC = 33%, RQD = 0% Hard, highly weathered, gray, aphanitic, INTERBEDDED SHALE, LIMESTONE, and RIVER ROCK, very thin bedding, low angle to moderately dipping jointing, very close to close spacing, rough, discolored, open.
NQ	C-2	60/36	35		4:30 . 4:00 . 5:30 . 7:30		SHALE / LS	**RUN 2: 35.5 to 40.5 feet-bgs** REC = 60%, RQD = 10% Hard, moderately to highly weathered, gray, aphanitic, INTERBEDDED SHALE and LIMESTONE, very thin to thin bedding, low angle to moderately dipping jointing, very close to close spacing, rough, discolored, open.

CDM Smith

B O R E H O L E   L O G
B-106

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			653.9 40		. 3:30		SHALE / LS	
NQ	C-3	60/17	648.9 45		3:30 . 4:30 . 3:30 . 3:00 . 3:30			**RUN 3: 40.5 to 45.5 feet-bgs** REC = 28%, RQD = 0% Medium hard to hard, highly weathered, gray, aphanitic, INTERBEDDED SHALE and LIMESTONE, very thin bedding, horizontal to moderately dipping jointing, very close spacing, rough, discolored, open.
			643.9 50 638.9 55 633.9 60					Boring terminated at 45.5 feet-bgs.

CDM Smith

B O R E H O L E L O G
B-107

Client: TVA
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Location: Spring City, Tennessee
Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling
Surface Elevation (ft.): 710.04
Drilling Method/Rig: 3.25" HSA// CME-55
Total Depth (ft.): 44.3
Drillers: Tim Hall
Depth to Initial Water Level (ft-bgs): 27.8
Drilling Date: Start: 6-13-12 **End:** 6-13-12
Abandonment Method: Converted to observation well
Borehole Coordinates:
Field Screening Instrument:
N 464,931.0 E 2,331,455.9
Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			710.0 0			■	ASPHALT	5-inches ASPHALT.
						▨	FILL	7-inches GRAVEL BASE. **-FILL-** Moist, reddish brown, CLAY, trace sand.
SS	S-1	24/12		PP=2.5 TV=0.8	8 8 7 8	▨		Moist, stiff to very stiff, reddish brown, CLAY, trace sand.
SS	S-2	24/20	705.0 5	PP>4.5 TV=2.0	5 6 7 12	▨		Moist, stiff, gray, CLAY, trace sand.
SS	S-3	24/24		PP>4.5 TV=1.8	3 6 9 10	▨		Moist, stiff to very stiff, reddish brown, CLAY, trace sand.
SS	S-4	24/24		PP>4.5 TV=2.0	6 7 10 12	▨		Moist, very stiff, gray to reddish brown, CLAY, trace sand.
ST	U-1	24/18	700.0 10			▨		Moist, gray to reddish brown, CLAY, trace sand.
SS	S-5	24/20		PP=2.5 TV=1.3	4 8 10 13	▨		Moist, very stiff, gray to reddish brown, CLAY, trace sand.
			695.0		4 9	▨		Moist, very stiff, gray to reddish brown, CLAY, trace sand.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: **Date:**

BOREHOLE LOG
B-107

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-6	24/24	695.0 15	PP=4.0 TV=1.2	13 13		FILL	
SS	S-7	24/20		PP=2.5 TV=1.0	WOH 7 8 10		CL	Wet, stiff to very stiff, brown, CLAY, trace silt. **-ALLUVIAL SOIL-**
SS	S-8	24/24		PP=1.0 TV=0.6	5 5 8 6			Wet, stiff, brown, CLAY, trace silt.
SS	S-9	24/12	690.0 20	PP=1.0 TV=0.6	4 4 6 4			Wet, stiff, brown, CLAY, trace silt.
SS	S-10	24/24		PP=2.0 TV=0.4	1 3 3 3			Wet, medium stiff, reddish brown, CLAY, some sand, trace silt.
			685.0 25					
SS	S-11	24/0			1 1 1 2			NO SAMPLE RECOVERY.
			680.0 30					
SS	S-12	24/24			WOH WOH 1 3		SC	Wet, very loose, brown, fine to medium SAND, little clay.
			675.0 35					
					1 2			Wet, very loose, brown to gray, fine SAND, some silt, little clay.

CDM Smith

BOREHOLE LOG
B-107

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-13	24/20	670.0 40		3 3		SC	
SS	S-14	15/15			12 29 58/3"		GP	Wet, very dense, dark gray, fine GRAVEL, some sand.
			665.0 45					Boring terminated at 44.3 feet-bgs upon auger refusal.
			660.0 50					
			655.0 55					
			650.0 60					

Sheet 1 of 3

CDM Smith

BOREHOLE LOG
B-108

Client: TVA
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Location: Spring City, Tennessee
Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling
Surface Elevation (ft.): 710.48
Drilling Method/Rig: 3.25" HSA// CME-55
Total Depth (ft.): 57
Drillers: Alan
Depth to Initial Water Level (ft-bgs): 22.7
Drilling Date: Start: 6-14-12 **End:** 6-14-12
Abandonment Method: Grouted to ground surface
Borehole Coordinates:
Field Screening Instrument:
N 465,254.7 E 2,331,425.3
Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-1	24/16	710.5 0	PP=2.0	7 18 12 6		FILL	Dry, medium to dense, gray, fine to medium GRAVEL, trace clay. Dry, medium stiff, reddish brown, CLAY, trace gravel and sand.
SS	S-2	24/18		PP=2.5 TV=1.2	5 3 4 6			Moist, medium stiff, reddish brown, CLAY, trace sand.
SS	S-3	24/20	705.5 5	PP=3.0 TV=1.5	2 5 7 9			Moist, stiff, reddish brown, CLAY, trace sand.
SS	S-4	24/20		PP=3.5 TV=1.2	2 6 7 9			Moist, stiff, reddish brown, CLAY, trace sand.
SS	S-5	24/20	700.5	PP=4.2 TV=1.2	2 5 7 9			Moist, stiff, reddish brown, CLAY, trace sand, roots.
SS	S-6	24/24	10	PP>4.5 TV=2.1	3 4 10 14			Moist, stiff, reddish brown, CLAY, trace sand, roots. Moist, stiff, dark gray SILT, trace sand and clay.
SS	S-7	24/22		PP=3.5 TV=0.9	3 6 7 8			Moist, stiff, dark gray SILT, trace sand.
			695.5		3 4			Moist, stiff, dark gray SILT, trace sand.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Groundwater level was measured during drilling and may not represent stabilized levels.

Survey coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: **Date:**

CDM Smith

B O R E H O L E L O G
B-108

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-8	24/24	695.5 15	PP=3.0 TV=1.0	6 7		FILL	
ST	U-1	24/18						Moist, reddish brown, CLAY, little silt, trace sand.
SS	S-9	24/3			3 4 5 7			Moist, stiff, reddish brown, CLAY, trace sand.
SS	S-10	24/24	690.5 20	PP=2.5 TV=1.0	3 4 4 5			Moist, medium stiff to stiff, reddish brown, CLAY, some sand.
SS	S-11	24/24			1 2 2 2		CL	Wet, very loose to loose, brown, CLAY and fine SAND. **-ALLUVIAL SOIL-**
			685.5 25					
SS	S-12	24/8			1 2 2 3			Wet, very loose to loose, brown, fine to medium coarse SAND, some silt, clay, trace gravel, roots.
			680.5 30					
SS	S-13	24/24			WOH WOH 1 2		SC	Wet, very loose, gray, fine SAND, some clay.
			675.5 35					
					WOH 1			Wet, very loose, gray, fine SAND, some clay.

CDM Smith

B O R E H O L E L O G
B-108

Client: TVA

Project Name: TVA Watts Bar Fossil Plant Phase II

Project Location: Spring City, Tennessee

Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-14	24/24	670.5 40		2 3	▨	SC	
SS	S-15	24/22	665.5 45		3 9 9 27	●	GW	Wet, medium dense, gray, fine to coarse gravel size RIVER ROCK and fine to coarse SAND. Auger refusal at 47.1 feet-bgs.
NQ	C-1	60/23	660.5 50		1:00 . 1:30 . 5:00 . 4:00 . 6:00	▦	GW / SHALE / LS	**RUN 1: 47 to 52 feet-bgs** REC = 38%, RQD = 0% Hard, highly weathered, gray, aphanitic, INTERBEDDED SHALE, LIMESTONE, and RIVER ROCK, extremely thin to thin bedding, horizontal to moderately dipping jointing, very close spacing, rough, discolored, open.
NQ	C-2	60/27	655.5 55		3:30 . 6:00 . 5:00 . 4:30 . 5:00	▦	SHALE / LS	**RUN 2: 52 to 57 feet-bgs** REC = 45%, RQD = 7% Hard, highly weathered, gray, aphanitic, INTERBEDDED SHALE and LIMESTONE, extremely thin to thin bedding, horizontal to low angular jointing, very close spacing, rough, discolored, open.
			650.5 60					Boring terminated at 57.0 feet-bgs.

CDM Smith

BOREHOLE LOG
B-109

Client: TVA
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Location: Spring City, Tennessee
Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling
Surface Elevation (ft.): 706.53
Drilling Method/Rig: 3.25" HSA// CME-55
Total Depth (ft.): 30
Drillers: Tim Hall
Depth to Initial Water Level (ft-bgs): Not Encountered
Drilling Date: Start: 6-15-12 **End:** 6-15-12
Abandonment Method: Grouted to ground surface
Borehole Coordinates:
Field Screening Instrument:
N 464,949.2 E 2,331,015.2
Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			706.5					
SS	S-1	24/4	0		1 1 WOH 1		FLY ASH	Dry, very loose, black, fine FLY ASH, little roots.
SS	S-2	24/24			WOH WOH WOH WOH			Wet, very loose, black, FLY ASH, trace roots.
SS	S-3	24/2	701.5 5		WOH WOH WOH WOH			Wet, very loose, black, FLY ASH, little gravel.
SS	S-4	24/6			WOH WOH WOH WOH			Wet, very loose, black, FLY ASH.
SS	S-5	24/20	696.5		WOH WOH WOH WOH			Wet, very loose, black, FLY ASH.
SS	S-6	24/12	10		WOH WOH WOH WOH		ML / FLY ASH	Wet, loose, black to gray, SILT and FLY ASH, trace roots and gravel.
ST	U-1	24/24						Wet, black to gray, SILT and FLY ASH, trace roots and gravel.
			691.5		4			Wet, stiff, gray, SILT, trace clay. **-ALLUVIAL SOIL-**

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Groundwater level was measured during drilling and may not represent stabilized levels.

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the

Reviewed by: **Date:**

CDM Smith

BOREHOLE LOG
B-109

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-7	24/24	691.5 15	PP=1.2 TV=0.6	5 7 11	▨	CL	Wet, stiff, reddish brown, CLAY, trace sand and roots.
SS	S-8	24/12		PP=1.7 TV=0.7	2 4 5 6	▨		Wet, stiff, reddish brown, CLAY, trace silt and sand.
SS	S-9	24/24	686.5 20	PP=1.0 TV=0.2	1 4 5 6	▨		Wet, stiff, reddish brown, CLAY, trace silt and sand.
SS	S-10	24/24	681.5 25	PP=1.0 TV=0.5	1 3 4 5	▨		Wet, medium stiff, reddish brown, CLAY, little silt, tace sand.
SS	S-11	24/24	676.5 30	PP=0.5 TV=0.2	WOH 1 2 3	▥	ML	Wet, soft, light brown, SILT, little sand, trace gravel.
			671.5 35					Boring terminated at 30 feet-bgs.

CDM Smith

BOREHOLE LOG
B-110

Client: TVA
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Location: Spring City, Tennessee
Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling
Surface Elevation (ft.): 707.29
Drilling Method/Rig: 3.25" HSA// CME-55
Total Depth (ft.): 33.1
Drillers: Tim Hall
Depth to Initial Water Level (ft-bgs): 7.2
Drilling Date: Start: 6-15-12 **End:** 6-15-12
Abandonment Method: Converted to observation well
Borehole Coordinates:
Field Screening Instrument:
N 464,996.7 E 2,330,939.0
Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			707.3					
SS	S-1	24/12	0		2 1 2 2		FLY ASH	Moist, soft, gray to black, TOP SOIL and FLY ASH, trace roots.
SS	S-2	24/3			1 WOH 1 WOH			Moist, soft, gray to black, TOP SOIL and FLY ASH.
SS	S-3	24/8	702.3 5		WOH WOH WOH WOH			Wet, very loose, black, fine FLY ASH.
SS	S-4	24/18			WOH WOH WOH WOH			Wet, very loose, black, fine FLY ASH.
SS	S-5	24/2	697.3		WOH WOH WOH WOH			Wet, very loose, black, fine FLY ASH.
ST	U-1	24/20	10					Wet, black, fine FLY ASH.
SS	S-6	24/24			WOH WOH 1			Wet, very loose, black, fine FLY ASH.
			692.3		2		ML	Wet, very soft, dark gray, SILT, some fly ash, trace roots.

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:

HSA	Hollow Stem Auger
SSA	Solid Stem Auger
HA	Hand Auger
AR	Air Rotary
DTR	Dual Tube Rotary
FR	Foam Rotary
MR	Mud Rotary
RC	Reverse Circulation
CT	Cable Tool
JET	Jetting
D	Driving
DTC	Drill Through Casing

SAMPLING TYPES:

AS	Auger/Grab Sample
CS	California Sampler
BX	1.5" Rock Core
NX	2.1" Rock Core
GP	Geoprobe
HP	Hydro Punch
SS	Split Spoon
ST	Shelby Tube
WS	Wash Sample

OTHER:

AGS	Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: **Date:**

CDM Smith

BOREHOLE LOG
B-110

Client: TVA
Project Location: Spring City, Tennessee

Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-7	24/18	692.3 15		WOH WOH WOH 1		ML	Wet, very soft, dark gray SILT, little fly ash, roots.
SS	S-8	24/18		PP=0.7 TV=0.2	1 2 3 4		CL	Wet, stiff, reddish brown, CLAY, trace sand and fly ash. **-ALLUVIAL SOIL-**
SS	S-9	24/9	687.3 20	PP=0.7 TV=0.1	WOH 1 2 2			Wet, soft, brown, CLAY, little gray silt, trace sand.
SS	S-10	24/6			1 WOH 1 2			Wet, soft, brown, CLAY, little gray silt, trace sand.
			682.3 25					
SS	S-11	24/24			1 1 2 4		SM	Wet, very loose, brown, fine to medium SAND, little silt, trace clay and gravel.
			677.3 30					
SS	S-12	1/1			50/1"		GW	Wet, very dense, brown, fine to coarse GRAVEL, little sand. Boring terminated at 33.1 feet-bgs upon auger refusal.
			672.3 35					

BOREHOLE-PP READINGS/NO ROCK TVA PHASE II_RHL.GPJ CDM_CORP.GDT 8/8/12

CDM Smith

BOREHOLE LOG
B-111

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling
Drilling Method/Rig: 3.25" HSA// CME-55
Drillers: Alan / Tim Hall
Drilling Date: Start: 6-14-12 **End:** 6-14-12
Borehole Coordinates:
N 465,122.0 E 2,330,987.2

Surface Elevation (ft.): 706.54
Total Depth (ft.): 30
Depth to Initial Water Level (ft-bgs): 7.4
Abandonment Method: Grouted to ground surface
Field Screening Instrument:
Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-1	24/9	706.5 0		1 1 1 1		FLY ASH	Moist, very loose, black, fine FLY ASH, trace clay, roots.
SS	S-2	24/0			1 WOH 1 WOH			NO SAMPLE RECOVERY.
SS	S-3	24/16	701.5 5		WOH WOH WOH WOH			Wet, very loose, black, fine, FLY ASH.
SS	S-4	24/22			WOH WOH 1 WOH			Wet, very loose, black, fine, FLY ASH.
SS	S-5	24/20	696.5		WOH 1 WOH WOH			Wet, very loose, black, fine, FLY ASH.
SS	S-6	24/24	10		WOH WOH 1 5			Wet, very loose, black, fine, FLY ASH.
SS	S-7	24/2			WOH WOH WOH WOH			Wet, very loose, black, fine, FLY ASH.
			691.5		WOH 1	▨	CL	Wet, soft, gray to brown, CLAY, trace fly ash and roots. **-ALLUVIAL SOIL-**

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Hammer weight = 140 pounds, drop height = 30 inches
Split spoon = 2 inches OD, 24 inches long
PP = Pocket Penetrometer
TV = Torvane
WOH = Weight of Hammer

Groundwater level was measured during drilling and may not represent stabilized levels.

Reviewed by: **Date:**

Boring coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the

CDM Smith

BOREHOLE LOG
B-111

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
SS	S-8	24/24	691.5 15		1 2	▨	CL	
SS	S-9	24/24		PP=0.5 TV=0.7	WOH WOH 1 1	▨		Wet, soft, gray to brown, CLAY, trace fly ash and roots.
SS	S-10	24/6			WOH WOH WOH 3	▨		Wet, soft, gray to brown, CLAY, trace sand.
SS	S-11	24/24	686.5 20		1 2 2 5	▨		Wet, soft to medium stiff, reddish brown, CLAY, some silt.
						▨		
ST	U-1	24/19				▨		Wet, reddish brown, CLAY, some silt.
SS	S-12	24/24	681.5 25	PP=0.5	1 1 1 1	▨		Wet, very soft to soft, gray, CLAY, trace sand.
						▨		
SS	S-13	24/24			1 2 2 3	▨		Wet, soft to medium stiff, gray, CLAY, trace sand.
			676.5 30					Boring terminated at 30 feet-bgs.
			671.5 35					

CDM Smith

BOREHOLE LOG
HA-1

Client: TVA
Project Location: Spring City, Tennessee
Project Name: TVA Watts Bar Fossil Plant Phase II
Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling
Drilling Method/Rig: HA/
Drillers:
Drilling Date: **Start:** 6-11-12 **End:** 6-12-12
Borehole Coordinates:
N 464,949.0 E 2,331,410.5

Surface Elevation (ft.): 707
Total Depth (ft.): 13
Depth to Initial Water Level (ft-bgs): 2
Abandonment Method: Backfilled with Cuttings
Field Screening Instrument:
Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
AS	S-1	12/12	707.0 0				FLY ASH	Moist, black FLY ASH, trace grass roots.
AS	S-2	12/12						Moist, black FLY ASH.
AS	S-3	12/12						Wet, black FLY ASH.
AS	S-4	12/12						
AS	S-5	12/12	702.0 5					
AS	S-6	12/12						
AS	S-8	12/12						
AS	S-9	12/12						
AS	S-10	12/12						
			697.0 10					
							ML	Wet, dark gray SILT. **-ALLUVIAL SOILS-**
								Hand auger terminated at 13 feet-bgs.
			692.0					

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:

HSA	Hollow Stem Auger
SSA	Solid Stem Auger
HA	Hand Auger
AR	Air Rotary
DTR	Dual Tube Rotary
FR	Foam Rotary
MR	Mud Rotary
RC	Reverse Circulation
CT	Cable Tool
JET	Jetting
D	Driving
DTC	Drill Through Casing

SAMPLING TYPES:

AS	Auger/Grab Sample
CS	California Sampler
BX	1.5" Rock Core
NX	2.1" Rock Core
GP	Geoprobe
HP	Hydro Punch
SS	Split Spoon
ST	Shelby Tube
WS	Wash Sample

OTHER:

AGS	Above Ground Surface

REMARKS

Groundwater level was measured during drilling and may not represent stabilized levels.

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: **Date:**

CDM Smith

BOREHOLE LOG
HA-2

Client: TVA

Project Location: Spring City, Tennessee

Project Name: TVA Watts Bar Fossil Plant Phase II

Project Number: 95618-92016

Drilling Contractor: Total Depth Drilling

Drilling Method/Rig: HA/

Drillers:

Drilling Date: Start: 6-11-12 **End:** 6-12-12

Borehole Coordinates:

N 465,117.8 E 2,331,402.3

Surface Elevation (ft.): 707

Total Depth (ft.): 13

Depth to Initial Water Level (ft-bgs): 3

Abandonment Method: Backfilled with Cuttings

Field Screening Instrument:

Logged By: R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			707.0 0			■	FLY ASH	Moist, black FLY ASH, trace grass roots.
AS	S-1	24/12				■		
AS	S-2	24/12				■		Moist, black FLY ASH.
AS	S-3	24/12	702.0 5			■		Wet, black FLY ASH.
			697.0 10			■		
						▨	CL / ML	Wet, reddish brown CLAY and gray SILT -ALLUVIAL SOIL-.
								Hand auger terminated at 13 feet-bgs.
			692.0					

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:

HSA	-	Hollow Stem Auger
SSA	-	Solid Stem Auger
HA	-	Hand Auger
AR	-	Air Rotary
DTR	-	Dual Tube Rotary
FR	-	Foam Rotary
MR	-	Mud Rotary
RC	-	Reverse Circulation
CT	-	Cable Tool
JET	-	Jetting
D	-	Driving
DTC	-	Drill Through Casing

SAMPLING TYPES:

AS	-	Auger/Grab Sample
CS	-	California Sampler
BX	-	1.5" Rock Core
NX	-	2.1" Rock Core
GP	-	Geoprobe
HP	-	Hydro Punch
SS	-	Split Spoon
ST	-	Shelby Tube
WS	-	Wash Sample

OTHER:

AGS	-	Above Ground Surface

REMARKS

Groundwater level was measured during drilling and may not represent stabilized levels.

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: **Date:**

CDM Smith

B O R E H O L E L O G
HA-3

Client: TVA	**Project Name:** TVA Watts Bar Fossil Plant Phase II
Project Location: Spring City, Tennessee	**Project Number:** 95618-92016
Drilling Contractor: Total Depth Drilling	**Surface Elevation (ft.):** 707.1
Drilling Method/Rig: HA/	**Total Depth (ft.):** 16
Drillers:	**Depth to Initial Water Level (ft-bgs):** 3
Drilling Date: Start: 6-11-12 **End:** 6-12-12	**Abandonment Method:** Backfilled with Cuttings
Borehole Coordinates:	**Field Screening Instrument:**
N 465,212.4 E 2,331,136.2	**Logged By:** R. Lawrence

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			707.1 0				FLY ASH	Moist, black FLY ASH, trace grass roots.
								Moist, black FLY ASH.
								Wet, black FLY ASH.
			702.1 5					
			697.1 10					
			692.1					

EXPLANATION OF ABBREVIATIONS

DRILLING METHODS:
HSA - Hollow Stem Auger
SSA - Solid Stem Auger
HA - Hand Auger
AR - Air Rotary
DTR - Dual Tube Rotary
FR - Foam Rotary
MR - Mud Rotary
RC - Reverse Circulation
CT - Cable Tool
JET - Jetting
D - Driving
DTC - Drill Through Casing

SAMPLING TYPES:
AS - Auger/Grab Sample
CS - California Sampler
BX - 1.5" Rock Core
NX - 2.1" Rock Core
GP - Geoprobe
HP - Hydro Punch
SS - Split Spoon
ST - Shelby Tube
WS - Wash Sample
OTHER:
AGS - Above Ground Surface

REMARKS

Groundwater level was measured during drilling and may not represent stabilized levels.

Borehole coordinates are approximate based upon handheld GPS and elevations are estimated by overlaying coordinates with the survey.

Reviewed by: **Date:**

CDM Smith

BOREHOLE LOG
HA-3

Client: TVA

Project Location: Spring City, Tennessee

Project Name: TVA Watts Bar Fossil Plant Phase II

Project Number: 95618-92016

Sample Type	Sample Number	Sample Adv/Rec (inches)	Elev. Depth (ft.)	Pocket Penetrometer Reading (tsf)	Blows per 6-in	Graphic Log	USCS Designation	Material Description
			692.1 15			▨	FLY ASH	
								Hand auger terminated at 16 feet-bgs.
			687.1 20					
			682.1 25					
			677.1 30					
			672.1 35					

Exhibit 4

Geotechnical Calculations

Foundation Analyses

Liquefaction Potential Evaluation

Slope Stability Analyses

CDM Smith Calculation Form

pg. 1 of 2

Client:	TVA	**Job No.** 92016	**Calculations By:** JW
Project:	WBF Ash Pond Breaching	**Checked By/Date** D.K.Neamtu/8-17-12	**Date:** 08-15-2012
Detail:	Settlement&Bearing	**Reviewed By/Date** S.L.Whiteside/8-17-12	**Calc #:** 1
			Revision No./Date: _____

Calculation Brief Title: WBF Ash Pond Breaching - Foundation Analyses

1.0 Purpose/Objective:

This calculation package contains bearing capacity and settlement analyses for the proposed spillway structure for the Ash Pond Breaching Project at the existing Watts Bar Fossil (WBF) plant near Spring Lake, Tennessee. The analyses were performed in support of design for the new spillway structure. The objective was to confirm that the foundation soils are suitable for support of the proposed spillway.

2.0 Procedure:

In general the calculations contained herein were performed in accordance with the requirements outlined in Reference A and B (listed below in Section 3.0). Subsurface soil properties were estimated based upon geotechnical borings completed for this project (see Section 3.0 C).

A. For inlet structures (including inlet weir, wingwalls and headwall), subsurface conditions based upon B-105. A cohesion of 1000 psf is assumed for clay layer based on the in-situ and laboratory tests performed at this layer. Calculations were performed for the 23 ft by 34 ft mat foundation (weir) and the 12-inch-wide wall footings (head wall and wingwalls).

B. For outlet structures (including headwall and wingwalls), subsurface soil conditions based upon B-106. Calculations were performed for 14-inch-wide wall footing.

C. Allowable bearing capacities were calculated using equation 4-1 of Reference B. Meyerhof Bearing Capacity factors were used as listed in Table 4-4 of Reference B.

D. Elastic Settlement of sandy soils was calculated using Schmertmann Method described in section 3-3-d of Reference A. Calculations was based upon SPT N-values from borings B-105 and B-106.

E. Consolidation Settlement of clayey soil was calculated using procedures listed in Table 3-5 of Reference A. Consolidation parameters were based on laboratory tests performed on Sample U-1 collected from the clay layer at boring B-105.

3.0 References/Data Sources:

A. *Settlement Analysis*, Engineer Manual EM 1110-1-1902, by USACE, September 1990

B. *Bearing Capacity of Soils*, Engineer Manual EM 1110-1-1905, by USACE, October 1992

C. Boring Logs of B-2, B-3, B-103, B-104, B-105, B-106 performed by CDM Smith.

4.0 Assumptions and Limitations:

A. The concrete culverts and drop box vaults of the spillway structure will be completely buried below existing grade with a depth of cover of less than 13 ft. The culverts and drop boxes are hollow concrete boxes (6 ft by 4 ft concrete culverts and 8ft by 18 ft concrete vaults) that will be filled with water during storm events. The net loading at bearing elevation for these structures is assumed to be minimal due to the reduction in in-situ stresses due to soil, including:

- Removal of soil from the crest of the dike to reduce the crest from EL.711 to EL.701;

pg. 2 of 2

- Removal of soil from downstream slope to flatten to 3H(min):1V;

B. Allowable bearing capacities are based upon subsurface conditions and proposed foundation characteristics (minimum of 2000 psf required). Long-term foundation settlements were calculated based upon service loading of 1000 psf. This structure will maintain normal pool and remain empty to low pool except during storm events when peak water surface EL.700 is reached.

C. Liquefaction potential of subsurface soil was checked (under a separate calculation package) based upon soil borings B-105 and B-106, the calculation shows all subsurface soil layers have enough factor of safety against liquefaction under 2500-year design earthquake event. Thus only static settlement was considered for this project.

5.0 Calculations: Calculation sheets are attached and results are summarized in Table 1.

6.0 Conclusions/Results:

A. Calculated bearing capacities for inlet and outlet structures are at least 2 ksf.

B. Calculated settlements for all inlet and outlet wall footings are less than 1 inch under 2 ksf foundation loads.

C. Calculated settlement for inlet weir structure is less than 1.5 inches under foundation load of 1000 psf.

TVA WBF Ash Pond Breaching
Spring City, TN

Table 1: Summary of Settlement and Bearing Capacity Calculations

Structure	Foundation Dimensions	Subsurface Soil Type[1]	Soil Parameters Used in Calculation[1,2]	Bearing Capacity, ksf	Estimated Settlement (Total/Differential), inch	
					under design load of 2000 psf	under design load of 1000 psf
Inlet Head Wall and Wing Walls	12-inch-wide strip	Clay	Cohesion=1000 psf	2.0	<1.0/<0.5	N/A
Inlet Weir	23 ft by 34 ft mat	Clay	Cohesion=1000 psf; friction angle = 28 degrees	2.0	N/A	<1.5/<0.75
Outlet Head Wall and Wing Walls	14-inch-wide strip	Silty and Clayey Sand	Friciton angle = 28 degrees	2.7	<1.0/<0.5	N/A

Notes:

1. Based on boring B-105 and B-106 performed by CDM Smith.
2. Friction angle based on SPT N-values, cohesion based on In-situ and laborotary tests.

N/A : Not Applicable

CLIENT	TVA	COMPUTED BY / DATE	JW	08/10/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	DKN	08/17/12
DETAIL	Proposed Spillway at Ash/Stilling Pond	REVISION NO. / DATE	-	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	-	-

Calculation Description: **Bearing capacity calculation for inlet weir of the proposed new Spillway-assuming foundation soil is clay**

1.0 Procedure

For bearing capacity calculations, assume that loose/soft soils, if any, at bearing depth will be overexcavated and backfilled/compacted with select material. The compacted select material will have strength properties equal or greater than those of the native underlying soils. Therefore, use the native soil strength properties for calculations.

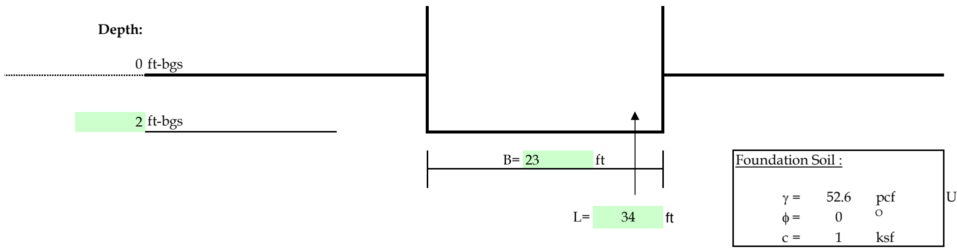
Soil Properties:

use unit weight of	γ =	115	pcf	
use friction angle of	Φ =	0	°	
use unit soil cohesion	c =	1000	ksf	Assumed from in-situ and laborotary tests

Note:

γ = unit weight (pcf) Φ = friction angle(degree) c = unit cohesion(ksf)

Depth:



Foundation Soil :

γ = 52.6 pcf USE BOUYANT UNIT WEIGHT

ϕ = 0 °

c = 1 ksf

2.0 Calculations

Ultimate Bearing Capacity Equation

$$\boxed{q_u = c\,Nc\,\zeta c + 0.5\,B'\,\gamma'_H\,N\gamma\,\zeta\gamma + \sigma'_D\,Nq\,\zeta q}$$

For friction angle 0°; See Table 4-4 of EM 1110-2-1905

Nq = 1

Nγ = 0

Nc = 5.14

Nϕ = 1.00

Using Meyerhof:

$\zeta_\gamma = \zeta\gamma s * \zeta\gamma i * \zeta\gamma d$ = (1+0.1*Nϕ*B/W)*(1.0)*(1+.1*Nϕ^0.5*D/B)

$\zeta_q = \zeta qs * \zeta qi * \zeta qd$ = (1+0.1*Nϕ*B/W)*(1.0)*(1+.1*Nϕ^0.5*D/B)

$\zeta_c = \zeta cs * \zeta ci * \zeta cd$ = (1+0.2*Nϕ*B/W)*(1.0)*(1+.2*Nϕ^0.5*D/B)

ζ_γ = 1.07

ζ_q = 1.07

ζ_c = 1.15

σ'_D = γD = 0.105 ksf

γ'_H = 0.053 ksf

$$\boxed{q_u = c\,Nc\,\zeta c + 0.5\,B'\,\gamma'_H\,N\gamma\,\zeta\gamma + \sigma'_D\,Nq\,\zeta q}$$

q_u = 5.904 + 0.000 + 0.113

= 6.02 ksf

3.0 Results

Ultimate bearing capacity = 6.02 ksf

Use Factor of Safety = 3.00

Allowable Bearing Capacity = 2.0 ksf

CDM Smith

CLIENT	TVA	COMPUTED BY / DATE	JW	08/10/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	DKN	08/17/12
DETAIL	Proposed Spillway at Ash/Stilling Pond	REVISION NO. / DATE	-	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	-	-

Calculation Description: **Bearing capacity calculation for outlet walls of the proposed new Spillway**

1.0 Procedure

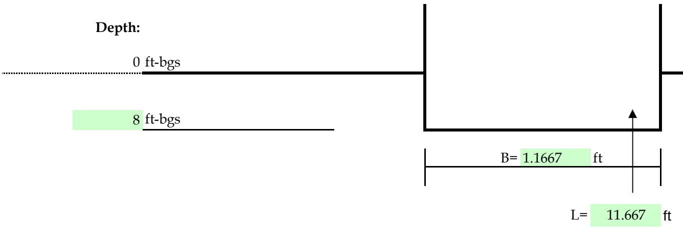
For bearing capacity calculations, assume that loose/soft soils, if any, at bearing depth will be overexcavated and backfilled/compacted with select material. The compacted select material will have strength properties equal or greater than those of the native underlying soils. Therefore, use the native soil strength properties for calculations.

Soil Properties:

use unit weight of	γ =	120	pcf	
use friction angle of	Φ =	28	o	Assumed from SPT N-values from B-106
use unit soil cohesion	c =	0	ksf	

Note:

γ = unit weight (pcf) Φ = friction angle(degree) c = unit cohesion(ksf)



Foundation Soil :

γ =	57.6	pcf
ϕ =	28	o
c =	0	ksf

USE BOUYANT UNIT WEIGHT

2.0 Calculations

Ultimate Bearing Capacity Equation

$$\boxed{q_u = c\,Nc\,\zeta c + 0.5\,B'\,\gamma'_H\,N\gamma\,\zeta\gamma + \sigma'_D\,Nq\,\zeta q}$$

For friction angle 28°; See Table 4-4 of EM 1110-2-1905

Nq = 14.72
Nγ = 11.19
Nc = 25.8
Nϕ = 2.77

Using Meyerhof:

$\zeta_\gamma = \zeta\gamma s^* \zeta\gamma i^* \zeta\gamma d$ = (1+0.1*Nϕ*B/W)*(1.0)*(1+.1*Nϕ^0.5*D/B)
$\zeta_q = \zeta qs^* \zeta qi^* \zeta qd$ = (1+0.1*Nϕ*B/W)*(1.0)*(1+.1*Nϕ^0.5*D/B)
$\zeta_c = \zeta cs^* \zeta ci^* \zeta cd$ = (1+0.2*Nϕ*B/W)*(1.0)*(1+.2*Nϕ^0.5*D/B)

ζ_γ = 1.14
ζ_q = 1.14
ζ_c = 1.30

σ'_D = γD = 0.461 ksf
γ'_H = 0.058 ksf

$$\boxed{q_u = c\,Nc\,\zeta c + 0.5\,B'\,\gamma'_H\,N\gamma\,\zeta\gamma + \sigma'_D\,Nq\,\zeta q}$$

q_u = 0.000 + 0.431 + 7.766
= 8.20 ksf

3.0 Results

Ultimate bearing capacity = 8.20 ksf

Use Factor of Safety = 3.00

Allowable Bearing Capacity = 2.7 ksf

CDM Smith

CLIENT	TVA	COMPUTED BY / DATE	JW	08/10/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	DKN	08/17/12
DETAIL	Proposed Spillway at Ash/Stilling Pond	REVISION NO. / DATE	-	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	-	-

Calculation Description: **Bearing capacity calculation for inlet walls of the proposed new Spillway**

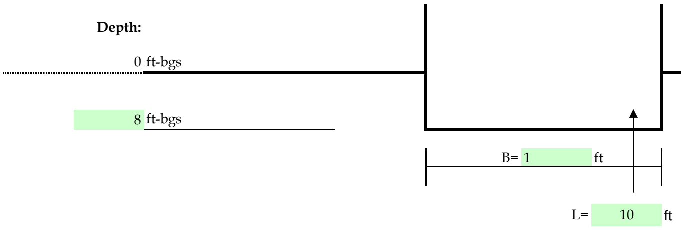
1.0 Procedure

For bearing capacity calculations, assume that loose/soft soils, if any, at bearing depth will be overexcavated and backfilled/compacted with select material. The compacted select material will have strength properties equal or greater than those of the native underlying soils. Therefore, use the native soil strength properties for calculations.

Soil Properties:

use unit weight of	γ =	115	pcf	
use friction angle of	Φ =	0	$^{\circ}$	
use unit soil cohesion	c =	1000	ksf	Assumed from in-situ and laborotary tests

Note:
γ = unit weight (pcf) Φ = friction angle(degree) c = unit cohesion(ksf)



Foundation Soil :

γ = 52.6 pcf
ϕ = 0 $^{\circ}$
c = 1 ksf

USE BOUYANT UNIT WEIGHT

2.0 Calculations

Ultimate Bearing Capacity Equation

$$\boxed{q_u = c\,Nc\,\zeta c + 0.5\,B'\,\gamma'_H\,N\gamma\,\zeta\gamma + \sigma'_D\,Nq\,\zeta q}$$

For friction angle 0°; See Table 4-4 of EM 1110-2-1905

Nq = 1
Nγ = 0
Nc = 5.14
Nϕ = 1.00

Using Meyerhof:

$\zeta_\gamma = \zeta\gamma s * \zeta\gamma i * \zeta\gamma d$ = (1+0.1*Nϕ*B/W)*(1.0)*(1+.1*Nϕ^0.5*D/B)
$\zeta_q = \zeta qs * \zeta qi * \zeta qd$ = (1+0.1*Nϕ*B/W)*(1.0)*(1+.1*Nϕ^0.5*D/B)
$\zeta_c = \zeta cs * \zeta ci * \zeta cd$ = (1+0.2*Nϕ*B/W)*(1.0)*(1+.2*Nϕ^0.5*D/B)

ζ_γ = 1.09
ζ_q = 1.09
ζ_c = 1.18

σ'_D = γD = 0.421 ksf
γ'_H = 0.053 ksf

$$\boxed{q_u = c\,Nc\,\zeta c + 0.5\,B'\,\gamma'_H\,N\gamma\,\zeta\gamma + \sigma'_D\,Nq\,\zeta q}$$

q_u = 6.082 + 0.000 + 0.459
= 6.54 ksf

3.0 Results

Ultimate bearing capacity = 6.54 ksf

Use Factor of Safety = 3.00

Allowable Bearing Capacity = 2.2 ksf

CLIENT	TVA	COMPUTED BY / DATE	JW	08/10/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	DKN	08/17/12
DETAIL	Proposed Spillway at Ash/Stilling Pond	REVISION NO. / DATE	-	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	-	-

Calculation Description: **Bearing capacity calculation for inlet weir of the proposed new Spillway-assuming foundation soil is sand**

1.0 Procedure

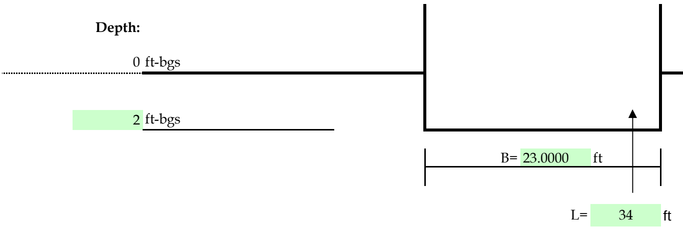
For bearing capacity calculations, assume that loose/soft soils, if any, at bearing depth will be overexcavated and backfilled/compacted with select material. The compacted select material will have strength properties equal or greater than those of the native underlying soils. Therefore, use the native soil strength properties for calculations.

Soil Properties:

use unit weight of	γ =	120	pcf	
use friction angle of	Φ =	28	o	Assumed from SPT N-values from B-106
use unit soil cohesion	c =	0	ksf	

Note:

γ = unit weight (pcf) Φ = friction angle(degree)   c = unit cohesion(ksf)



Foundation Soil :

γ = 57.6 pcf
ϕ = 28 o
c = 0 ksf

USE BOUYANT UNIT WEIGHT

2.0 Calculations

Ultimate Bearing Capacity Equation

$$q_u = c\ Nc\ \zeta c + 0.5\ B'\ \gamma'_H\, N\gamma\ \zeta\gamma + \sigma'_D\ Nq\ \zeta q$$

For friction angle 28°;   See Table 4-4 of EM 1110-2-1905

Nq = 14.72
Nγ = 11.19
Nc = 25.8
Nϕ = 2.77

For large footing where B > 6 ft apply reduction factor r_γ (page 4-14 EM 1110-1-1905, October 30, 1992).

$r_\gamma = 1 - 0.25 \times \log_{10}(B/6)$
$= 1 - 0.25\ X \log_{10}(23/6)$
$= 0.85$

Using Meyerhof:

ζ_γ = ζγs* ζγi* ζγd   = (1+0.1*Nϕ*B/W)*(1.0)*(1+.1*Nϕ^0.5*D/B)
ζ_q = ζqs* ζqi* ζqd   = (1+0.1*Nϕ*B/W)*(1.0)*(1+.1*Nϕ^0.5*D/B)
ζ_c = ζcs* ζci* ζcd   = (1+0.2*Nϕ*B/W)*(1.0)*(1+.2*Nϕ^0.5*D/B)

$\zeta_\gamma = 1.20$
$\zeta_q = 1.20$
$\zeta_c = 1.40$

σ'_D = γD = 0.115 ksf
γ'_H = 0.058 ksf

$$q_u = c\ Nc\ \zeta c + 0.5\ B'\ \gamma'_H\, N\gamma\ \zeta\gamma + \sigma'_D\ Nq\ \zeta q$$

q_u = 0.000 + 7.554 + 2.033
= 9.59 ksf

3.0 Results

Ultimate bearing capacity =	**9.59**	**ksf**
Use Factor of Safety =	**3.00**	
Allowable Bearing Capacity =	**3.2**	**ksf**

CDM Smith

CLIENT	TVA	JOB NO.	92016.2202	COMPUTED BY	JW
PROJECT	Watts Bar Ash Pond	DATE CHECKED	DKN	DATE	8/10/2012
DETAIL	Settlement Calculation	CHECKED BY	8/17/2012	PAGE NO.	1 of 8

Purpose: To estimate the total settlement of the wall footing at the inlet area.

Objective: Calculate the settlement caused by foundation load.

Reference: 1. Schmertmann, John, "Static Cone To Compare Static Settlement Over Sands", Journal of the Soil Mechanics and Foundations Division, ASCE, May 1970.

2. Schmertmann, John; Hartman, John Paul; Brown, Philip, "Improved Strain Influence Factor Diagrams", Journal of the Soil Mechanics and Foundations Division, ASCE, August 1978.

3. USACE, "Engineering Design - Settlement Analysis", EM 1110-1-1904, September 30, 1990.

4. NAVFAC, "Soil Mechanics", Design Manual 7.1 .

Soil Information: B-105 and B-106 performed by CDM Smith.

Assumptions:
1. Triangular strain factor distribution within subsurface soils, i.e. strain = 0 at incompressible boundary.
2. All split spoon sampling was carried out in accordance with ASTM D1556.
3. Loading occurs instantaneously.
4. Clay is over consolidated; assuming same overconsolidation margin for same clay layers.
5. Only one-dimensional consolidation is considered.
6. Assuming same initial void ratio for same clay layers.
7. The foundation is rigid.

1.0: Boring Information

Depth	B-105	
	Layer Description	SPT N-Value
0		
1	CL	
2	CL	
3	CL	
4	CL	
13	SC	3
18	SC	3
23	SC	3
28	SW	35

Layer Thickness, ft	Design N Values	
	Mid Layer Depth	N Value
1	0.5	CLAY
1	1.5	CLAY
1	2.5	CLAY
1	3.5	CLAY
9	8.5	3
5	15.5	3
5	20.5	3
5	25.5	35

Note:
All depths are in feet below foundation subgrade.

2.0: Foundation Information and Elastic Settlement Strain Influence Depth

Soil Type:	Silty Sand	
Depth of Water Table (d) ft.	0	Assumed GW
Depth of Foundation (D) ft.	8	
Length of Foundation (L) ft.	10	
Width of Foundation (B) ft.	1.0	
L/B	10.00	
Z/B	4.00	
Iz	0.20	
Compressible Layer Thickness (H) ft.	28	
Depth of Influence based on Strain Condition ft.	4	
Depth of Influence Used for Calculations ft.	4	
σ'_{Izp}	53	psf
Max Izp depth:	1.00	H/4
Existing overburden pressure (tsf)	0.23	(At Foundation Level)
Additional Loading (tsf)	0.77	(Based on Additional Load @ Foundation Level)
Effective overburden pressure at Izp(tsf)	0.03	tsf
Izp =	1.04	
Foundation Load	2,000	psf

3.1: Strain Influence Factors used in Elastic Settlement Calculation

Strain	
slope =	0.8409
slope =	0.3470

Increments	Depth (ft.)	Strain Influence
1	0.50	
2	1.50	
3	2.50	
4	3.50	
5	0.00	
6	0.00	
7	0.00	
8	0.00	

Sandy soil outside of Schmertmann influence depth, not elastic settlement

3.2: Strain Influence Factors used in Elastic Settlement Calculation - Continue

Soil Type:

Soil	*q_c/N*	*Descrpition*
Silt	2	Combination of silts, sandy silts, slightly cohesive sand-silts.
Silty Sand	2.75	Silty sands
Sand	3.5	Clean to slightly silty sands.

Where:
q_c = Average Dutch Cone Resistance
N = SPT N value

Strain Condition:

Strain	*Es/qc*	*Descrpition*
Axisymmetric	2.5	L/B = 1
Plane	3.5	L/B > 10

CLIENT TVA	JOB NO. 92016.2202	COMPUTED BY JW
PROJECT Watts Bar Ash Pond	DATE CHECKED DKN	DATE 8/10/2012
DETAIL Settlement Calculation	CHECKED BY 8/17/2012	PAGE NO. 6 of 8

4.1: Boussinesq Stresses used in Consolidation Settlement Calculation

Load Dimensions:

Length(ft)	10
Width(ft)	1

b (ft)	5
a (ft)	1

Net Pressure Increase: **1539.2** psf

Center Stress Calculation

EM 1110-1-1904, table C-1; Superposition

Layer center depth	A^2	B^2	C	Influence factor I	Boussinesq Stress $\Delta\sigma'0$	Initial soil stress σ'_0	Final Stress	$\Delta\sigma'_0/\sigma'_0$
1	1.25	26	5.12	0.55	845.73	489.6	1335.3	1.7
3	9.25	34	5.85	0.20	311.29	547.2	858.5	0.6
5	25.25	50	7.09	0.11	171.99	604.8	776.8	0.3
7	49.25	74	8.62	0.07	107.89	662.4	770.3	0.2
9	81.25	106	10.31	0.05	72.90	748.8	821.7	0.1
11	121.25	146	12.09	0.03	52.05	864	916.1	0.1
13	169.25	194	13.94	0.03	38.80	979.2	1018.0	0.0
15	225.25	250	15.82	0.02	29.93	1094.4	1124.3	0.0
17	289.25	314	17.73	0.02	23.73	1209.6	1233.3	0.0
19	361.25	386	19.65	0.01	19.25	1324.8	1344.1	0.0
21	441.25	466	21.59	0.01	15.91	1440	1455.9	0.0
23	529.25	554	23.54	0.01	13.37	1555.2	1568.6	0.0
25	625.25	650	25.50	0.01	11.38	1670.4	1681.8	0.0
27	729.25	754	27.46	0.01	9.80	1785.6	1795.4	0.0
29	841.25	866	29.43	0.01	8.53	1900.8	1909.3	0.0
31	961.25	986	31.40	0.00	7.48	2016	2023.5	0.0

4.2: Consolidation Settlment Calculation

Foundation depth(ft) 8
Soil Stress at Foundation Depth(psf): 460.8
Soil unit weight below depth of foundation(psf): 120
Foundation contact pressure(psf) 2,000
Overconsolidation margin(psf) 1960
Initial Void Ratio eo: 0.65

Compression Index Cc : 0.1386
ReCompression Index Cr : 0.01485
Stress Increase at Foundation Depth(psf): 1539.2
G.W. Depth from Foundation(ft) 0

depth from foundation bottom(ft)	Layer center depth, from Foundation Bottom, ft	Initial σ'_0	Preconsolidation Stress σ'_p	Final σ'_f	Strain ε	Settlement in Sublayer(ft)
0						
1	0.5	489.6	2449.6	1335	0.006	0.00392
2	1.5	547.2	2507.2	858	0.003	0.00176
3	2.5	604.8	2564.8	777	0.002	0.00098
4	3.5	662.4	2622.4	770	0.001	0.00059
6	5	748.8	2708.8	822	0.001	Sandy soil, no consolidation settlement
8	7	864	2824	916	0.000	
10	9	979.2	2939.2	1018	0.000	
12	11	1094.4	3054.4	1124	0.000	
14	13	1209.6	3169.6	1233	0.000	
16	15	1324.8	3284.8	1344	0.000	
18	17	1440	3400	1456	0.000	
20	19	1555.2	3515.2	1569	0.000	
22	21	1670.4	3630.4	1682	0.000	
24	23	1785.6	3745.6	1795	0.000	
26	25	1900.8	3860.8	1909	0.000	
28	27	2016	3976	2023	0.000	

Consolidation Settlement: 0.0073 *ft*

5: Elastic and Total Settlment Calculation

Layer	Delta Z	Avg. SPT (1)	Corrected qc (tsf) (2)	Es (tsf) (3)	Depth to Mid Layer	Iz (4)	(Iz/Es)*Delta Z) (5)
1	1	CLAY			0.50		
2	1	CLAY			1.50		
3	1	CLAY			2.50		
4	1	CLAY			3.50		
5	9	3	Sandy soil outside of Schmertmann influence depth, no elastic settlement				
6	5	3					
7	5	3					
8	5	35					
	28				Total Elastic Settlement/tsf		0.0000 ft/tsf

Settlements:

Elastic Settlement

t = 1 years e = **0.00** Inches (C2=1.2)

Elastic Settlement: = 0.00 Inches

Consolidation Settlement: = 0.09 Inches

Total Settlement: = **0.09** Inches

Notes:

1. Refer to SPT vs. Depth for average N values (not corrected).
2. Refer to reference page for values.
3. Schmertmann SPT-correlations modified by Ladd, E_s = average equivalent modulus over depth z for foundation type.
4. Iz obtained from strain influence spreadsheet.
5. Represents the settlement attributed to each layer assuming C_1 equals to 1.

Purpose: To estimate the total settlement of the wall footing at outlet area.

Objective: Calculate the settlement caused by foundation load.

Reference:

1. Schmertmann, John, "Static Cone To Compare Static Settlement Over Sands", Journal of the Soil Mechanics and Foundations Division, ASCE, May 1970.

2. Schmertmann, John; Hartman, John Paul; Brown, Philip, "Improved Strain Influence Factor Diagrams", Journal of the Soil Mechanics and Foundations Division, ASCE, August 1978.

3. USACE, "Engineering Design - Settlement Analysis", EM 1110-1-1904, September 30, 1990.

4. NAVFAC, "Soil Mechanics", Design Manual 7.1 .

Soil Information: B-105 and B-106 performed by CDM Smith.

Assumptions:
1. Triangular strain factor distribution within subsurface soils, i.e. strain = 0 at incompressible boundary.
2. All split spoon sampling was carried out in accordance with ASTM D1556.
3. Loading occurs instantaneously.

1.0: Boring Information

To estimate the total settlement of the wall footing at outlet area.

Depth	B-105	
	Layer Description	SPT N-Value
0		
2	SM	4
4	SC	4
5	SC	4

Layer Thickness, ft	Design N Values	
	Mid Layer Depth	N Value
2	1.0	4
2	3.0	4
1	4.5	4

Note:
All depths are in feet below foundation subgrade.

2.0: Foundation Information and Elastic Settlement Strain Influence Depth

To estimate the total settlement of the

Soil Type:	Silty Sand	
Depth of Water Table (d) ft.	0	Assumed GW
Depth of Foundation (D) ft.	8	
Length of Foundation (L) ft.	11.670	
Width of Foundation (B) ft.	1.167	
L/B	10.00	
Z/B	4.00	
Iz	0.20	
Compressible Layer Thickness (H) ft.	14.5	
Depth of Influence based on Strain Condition ft.	5	
Depth of Influence Used for Calculations ft.	5	
σ'_{Izp}	61	psf
Max Izp depth:	1.17	H/4
Existing overburden pressure (tsf)	0.23	(At Foundation Level)
Additional Loading (tsf)	0.77	(Based on Additional Load @ Foundation Level)
Effective overburden pressure at Izp(tsf)	0.03	tsf
Izp =	1.00	
Foundation Load	2,000	psf

3.1: Strain Influence Factors used in Elastic Settlement Calculation

To estimate the total settlement of the wall footing at outlet area.

Strain	
slope =	0.6862
slope =	0.2858

Increments	Depth (ft.)	Strain Influence
1	1.00	0.89
2	3.00	0.48
3	4.50	0.05

3.2: Strain Influence Factors used in Elastic Settlement Calculation - Continue

To estimate the total settlement of the wall footing at outlet area.

Soil Type:

Soil	*q_c/N*	*Descrpition*
Silt	2	Combination of silts, sandy silts, slightly cohesive sand-silts.
Silty Sand	2.75	Silty sands
Sand	3.5	Clean to slightly silty sands.

Where: q_c = Average Dutch Cone Resistance

N = SPT N value

Strain Condition:

Strain	*Es/qc*	*Descrpition*
Axisymmetric	2.5	L/B = 1
Plane	3.5	L/B > 10

5: Elastic and Total Settlment Calculation

To estimate the total settlement of the wall footing at outlet area.

Layer	Delta Z	Avg. SPT (1)	Corrected qc (tsf) (2)	Es (tsf) (3)	Depth to Mid Layer	Iz (4)	(Iz/Es)*Delta Z) (5)	
1	2	4	11.00	38.5	1.00	0.89	0.0460	
2	2	4	11.00	38.5	3.00	0.48	0.0248	
3	1	4	11.00	38.5	4.50	0.05	0.0012	
	5				Total Elastic Settlement/tsf		0.0720	ft/tsf

Settlements:

Elastic Settlement

t = 1 years e = **0.80** Inches (C2=1.2)

Elastic Settlement: = 0.80 Inches

Consolidation Settlement: = 0.00 Inches

Total Settlement: = **0.80** Inches

Notes:

1. Refer to SPT vs. Depth for average N values (not corrected).
2. Refer to reference page for values.
3. Schmertmann SPT-correlations modified by Ladd, E_s = average equivalent modulus over depth z for foundation type.
4. Iz obtained from strain influence spreadsheet.
5. Represents the settlement attributed to each layer assuming C_1 equals to 1.

CLIENT TVA	JOB NO. 92016.2202	COMPUTED BY JW
PROJECT Watts Bar Ash Pond	DATE CHECKED DKN	DATE 8/10/2012
DETAIL Settlement Calculation	CHECKED BY 8/17/2012	PAGE NO. 1 of 8

Purpose: To estimate the total settlement of the inlet weir structure under foundation load of 1000 psf.

Objective: Calculate the settlement caused by foundation load.

Reference: 1. Schmertmann, John, "Static Cone To Compare Static Settlement Over Sands", Journal of the Soil Mechanics and Foundations Division, ASCE, May 1970.

2. Schmertmann, John; Hartman, John Paul; Brown, Philip, "Improved Strain Influence Factor Diagrams", Journal of the Soil Mechanics and Foundations Division, ASCE, August 1978.

3. USACE, "Engineering Design - Settlement Analysis", EM 1110-1-1904, September 30, 1990.

4. NAVFAC, "Soil Mechanics", Design Manual 7.1 .

Soil Information: B-105 and B-106 performed by CDM Smith.

Assumptions:
1. Triangular strain factor distribution within subsurface soils, i.e. strain = 0 at incompressible boundary.
2. All split spoon sampling was carried out in accordance with ASTM D1556.
3. Loading occurs instantaneously.
4. Clay is over consolidated; assuming same overconsolidation margin for same clay layers.
5. Only one-dimensional consolidation is considered.
6. Assuming same initial void ratio for same clay layers.
7. The foundation is rigid.

1.0: Boring Information

Depth	B-105	
	Layer Description	SPT N-Value
0		
2	CL	
4	CL	
6	CL	
8	CL	
13	SC	3
18	SC	3
23	SC	3
28	SW	35

Layer Thickness, ft	Design N Values	
	Mid Layer Depth	N Value
2	1.0	CLAY
2	3.0	CLAY
2	5.0	CLAY
2	7.0	CLAY
5	10.5	3
5	15.5	3
5	20.5	3
5	25.5	35

Note:
All depths are in feet below foundation subgrade.

2.0: Foundation Information and Elastic Settlement Strain Influence Depth

Soil Type:	Silty Sand	
Depth of Water Table (d) ft.	15.5	based on boring B-105
Depth of Foundation (D) ft.	6.5	
Length of Foundation (L) ft.	34	
Width of Foundation (B) ft.	23.0	
L/B	1.48	
Z/B	2.11	
Iz	0.11	
Compressible Layer Thickness (H) ft.	30	
Depth of Influence based on Strain Condition ft.	48	
Depth of Influence Used for Calculations ft.	30	
σ'_{Izp}	900	psf
Max Izp depth:	7.50	H/4
Existing overburden pressure (tsf)	0.39	(At Foundation Level)
Additional Loading (tsf)	0.11	(Based on Additional Load @ Foundation Level)
Effective overburden pressure at Izp(tsf)	0.45	tsf
Izp =	0.55	
Foundation Load	1,000	psf

3.1: Strain Influence Factors used in Elastic Settlement Calculation

Strain	
slope =	0.0592
slope =	0.0244

Increments	Depth (ft.)	Strain Influence
1	1.00	0.16
2	3.00	0.28
3	5.00	0.40
4	7.00	0.52
5	10.50	0.48
6	15.50	0.35
7	20.50	0.23
8	25.50	0.11

3.2: Strain Influence Factors used in Elastic Settlement Calculation - Continue

Soil Type:

Soil	*q_c/N*	*Descrpition*
Silt	2	Combination of silts, sandy silts, slightly cohesive sand-silts.
Silty Sand	2.75	Silty sands
Sand	3.5	Clean to slightly silty sands.

Where: q_c = Average Dutch Cone Resistance
N = SPT N value

Strain Condition:

Strain	*Es/qc*	*Descrpition*
Axisymmetric	2.5	L/B = 1
Plane	3.5	L/B > 10

4.1: Boussinesq Stresses used in Consolidation Settlement Calculation

Load Dimensions:

Length(ft)	34
Width(ft)	23

b (ft)	17
a (ft)	12

Net Pressure Increase: **220** psf

Center Stress Calculation

EM 1110-1-1904, table C-1; Superposition

Layer center depth	A^2	B^2	C	Influence factor I	Boussinesq Stress $\Delta\sigma'0$	Initial soil stress σ'_0	Final Stress	$\Delta\sigma'_0/\sigma'_0$
1	133.25	290	20.55	1.00	219.93	900	1119.9	0.2
3	141.25	298	20.74	0.99	218.17	1140	1358.2	0.2
5	157.25	314	21.12	0.97	212.48	1380	1592.5	0.2
7	181.25	338	21.69	0.92	202.45	1620	1822.4	0.1
9	213.25	370	22.41	0.86	189.10	1860	2049.1	0.1
11	253.25	410	23.29	0.79	173.92	1975.2	2149.1	0.1
13	301.25	458	24.30	0.72	158.25	2090.4	2248.7	0.1
15	357.25	514	25.42	0.65	143.01	2205.6	2348.6	0.1
17	421.25	578	26.65	0.59	128.74	2320.8	2449.5	0.1
19	493.25	650	27.97	0.53	115.70	2436	2551.7	0.0
21	573.25	730	29.36	0.47	103.98	2551.2	2655.2	0.0
23	661.25	818	30.83	0.43	93.55	2666.4	2760.0	0.0
25	757.25	914	32.35	0.38	84.32	2781.6	2865.9	0.0
27	861.25	1018	33.92	0.35	76.18	2896.8	2973.0	0.0
29	973.25	1130	35.53	0.31	69.01	3012	3081.0	0.0
31	1093.25	1250	37.18	0.28	62.68	3127.2	3189.9	0.0

4.2: Consolidation Settlment Calculation

Foundation depth(ft) 6.5
Soil Stress at Foundation Depth(psf): 780
Soil unit weight below depth of foundation(psf): 120
Foundation contact pressure(psf) 1,000
Overconsolidation margin(psf) 1960
Initial Void Ratio eo: 0.65

Compression Index Cc : 0.1386
ReCompression Index Cr : 0.01485
Stress Increase at Foundation Depth(psf): 220
G.W. Depth from Foundation(ft) 9

depth from foundation bottom(ft)	Layer center depth, from Foundation Bottom, ft	Initial σ'_0	Preconsolidation Stress σ'_p	Final σ'_f	Strain ε	Settlement in Sublayer(ft)
0						
2	1	900	2860	1120	0.001	0.00171
4	3	1140	3100	1358	0.001	0.00137
6	5	1380	3340	1592	0.001	0.00112
8	7	1620	3580	1822	0.001	0.00092
10	9	1860	3820	2049	0.001	
12	11	1975.2	3935.2	2149	0.001	
14	13	2090.4	4050.4	2249	0.000	
16	15	2205.6	4165.6	2349	0.000	
18	17	2320.8	4280.8	2450	0.000	
20	19	2436	4396	2552	0.000	
22	21	2551.2	4511.2	2655	0.000	
24	23	2666.4	4626.4	2760	0.000	
26	25	2781.6	4741.6	2866	0.000	
28	27	2896.8	4856.8	2973	0.000	
30	29	3012	4972	3081	0.000	
32	31	3127.2	5087.2	3190	0.000	

Consolidation Settlement: 0.0051 *ft*

5: Elastic and Total Settlment Calculation

Layer	Delta Z	Avg. SPT (1)	Corrected qc (tsf) (2)	Es (tsf) (3)	Depth to Mid Layer	Iz (4)	(Iz/Es)*Delta Z) (5)
1	2	CLAY			1.00		
2	2	CLAY			3.00		
3	2	CLAY			5.00		
4	2	CLAY			7.00		
5	5	3	8.25	21.1	10.50	0.48	0.1130
6	5	3	8.25	21.1	15.50	0.35	0.0841
7	5	3	8.25	21.1	20.50	0.23	0.0551
8	5	35	122.50	312.8	25.50	0.11	0.0018
	28				Total Elastic Settlement/tsf		0.2539 ft/tsf

Settlements:

Elastic Settlement

t = 1 years e = **0.40** Inches (C2=1.2)

Elastic Settlement: = 0.40 Inches

Consolidation Settlement: = 0.06 Inches

Total Settlement: = **0.46** Inches

Notes:

1 Refer to SPT vs. Depth for average N values (not corrected).
2 Refer to reference page for values.
3 Schmertmann SPT-correlations modified by Ladd, E_s = average equivalent modulus over depth z for foundation type.

4 Iz obtained from strain influence spreadsheet.

5 Represents the settlement attributed to each layer assuming C_1 equals to 1.

CDM Smith Calculation Form

pg. 1 of 1

Client:	TVA	**Job No.** 92016	**Calculations By:** J W
Project:	WBF Ash Pond Breaching	**Checked By/Date** D.K.Neamtu/8-15-12	**Date:** 08/15/2012
Detail:	Liquefaction Analyses	**Reviewed By/Date** S.L.Whiteside/8-16-12	**Calc #:** 1
			Revision No./Date: _____

Calculation Brief Title: TVA WBF Ash Pond Breaching Project - Liquefaction Potential Evaluation

1.0 Purpose/Objective:

The purpose of this calculation is to estimate the Factor of Safety against soil liquefaction or softening under the design earthquake event. This evaluation is based upon the SPT N-values from two geotechnical borings performed by CDM Smith along the proposed new spillway. The objective is to determine post-earthquake strength of soils layers to be used for seismic slope stability analyses (under a separate calculation package).

2.0 Procedure:

This calculation was performed in general accordance with the methods given in Reference D (listed below). Section 1.4.2.2 outlines the methodologies for determining factors of safety against classic liquefaction (Youd et al., 2001) and cyclic softening (Idriss and Boulanger, 2008). This reference defines Category 1 soils as those susceptible to classical liquefaction, classified sands or gravels or silts/clays with PI less than 7. Category 2 soils are those susceptible to cyclic softening, classified as silts and clays with PI greater than 7. The subsurface profile contains at least two layers (fill and native clay/silt) that are considered Category 2 soils. However, all layers were evaluated based upon classical liquefaction because this approach tends to produce more-conservative results for Category 2 soils when SPT N-values are less than 10. All the Fill and Silt soil encountered in B-105 and B-106 with N-values above 10 are located within the excavated zone and will be replaced with compacted engineered fill during construction.

3.0 References/Data Sources:

A. Youd et al. (2001). "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshop on Evaluation of Liquefaction Resistance of Soils", Journal of Geotechnical and Geoenvironmental Engineering, October 2001, page 817-833.
B. Design Earthquake magnitude from USGS deaggregation data. (Attached as page 3 of the calculation)
C. Design peak ground acceleration from "Report - Existing Conditions Stability Analyses, Ash Pond Area at Watts Bar Fossil Pant", by CDM Smith, January 31, 2012.
D. " TVA Coal Combustion Products Management Program Master Programmatic Document (revision 1.0)", by URS, December 7, 2009
E. "Department of Defense Handbook: Soil Dynamic and Special Design Aspects", November 15, 1997.

4.0 Assumptions and Limitations:

A. All soils evaluated are susceptible only to classical liquefaction and can be classified as Category 1 material defined in Reference D.

5.0 Calculations: Attached on next 4 pages.

6.0 Conclusions/Results:

A. All soils evaluated have a factor of safety against liquefaction above 1.4. Therefore, based on the Reference D, the seismic slope stability analyses can consider the full static drained strength for granular soils and full undrained strength for clayey soils.

TVA WBF Ash Pond Breaching Project
Spring City, TN

Liquefaction Potential Evaluation at B-105

Design Earthquake Magnitude (M_{design}) = 5.83 (from USGS deaggregation data, see page 4)

Magnitude Scaling Factor (MSF) = 1.9 ($MSF = 10^{2.24}/M_w^{2.56}$)

Boring	Depth, ft	Depth, meters	Sample #	Soil Type	N value	A_{max}, g	Depth to GWT	P_a	C_r	C_N	r_d	Total Stress, psf	Effective Stress, psf	CSR	Fines content	$(N_1)_{60}$	$(N_1)_{60cs}$	$CRR_{7.5}$	Factor of Safety for $M_{7.5}$	Factor of Safety for M_{design}
B-105	1	0.30	1	**FILL**	21	0.13	29.2	2089	0.75	1.70	1.00	115	115	0.08	80	26.8	37.1	non-liquefiable	**Non-Liquefiable**	**Non-Liquefiable**
B-105	3	0.91	2	**FILL**	17	0.13	29.2	2089	0.75	1.70	0.99	345	345	0.08	80	21.7	31.0	non-liquefiable	**Non-Liquefiable**	**Non-Liquefiable**
B-105	5	1.52	3	**FILL**	15	0.13	29.2	2089	0.75	1.70	0.99	575	575	0.08	82	19.1	28.0	0.37	**4.40**	**8.39**
B-105	7	2.13	4	**FILL**	16	0.13	29.2	2089	0.75	1.61	0.98	805	805	0.08	80	19.3	28.2	0.38	**4.53**	**8.63**
B-105	9	2.74	5	**FILL**	14	0.13	29.2	2089	0.75	1.42	0.98	1035	1035	0.08	80	14.9	22.9	0.26	**3.09**	**5.88**
B-105	11	3.35	6	**FILL**	14	0.13	29.2	2089	0.80	1.29	0.97	1265	1265	0.08	80	14.4	22.3	0.25	**2.99**	**5.69**
B-105	13	3.96	7	**FILL**	15	0.13	29.2	2089	0.80	1.18	0.97	1495	1495	0.08	80	14.2	22.0	0.24	**2.96**	**5.63**
B-105	15	4.57	8	**CL**	10	0.13	29.2	2089	0.85	1.10	0.97	1725	1725	0.08	80	9.4	16.2	0.17	**2.12**	**4.03**
B-105	19	5.79	9	**CL**	8	0.13	29.2	2090	0.85	0.98	0.96	2185	2185	0.08	80	6.7	13.0	0.14	**1.74**	**3.31**
B-105	21	6.40	10	**CL**	8	0.13	29.2	2091	0.95	0.93	0.95	2415	2415	0.08	80	7.1	13.5	0.15	**1.81**	**3.44**
B-105	24	7.32	11	**CL**	6	0.13	29.2	2092	0.95	0.87	0.94	2760	2760	0.08	80	5.0	11.0	0.12	**1.52**	**2.90**
B-105	29	8.84	12	**SC**	2	0.13	29.2	2093	0.95	0.79	0.93	3335	3335	0.08	40	1.5	6.8	0.09	**1.09**	**2.08**
B-105	34	10.37	13	**SC**	3	0.13	29.2	2094	1.00	0.76	0.90	3910	3610	0.08	39.8	2.3	7.7	0.09	**1.14**	**2.18**
B-105	39	11.89	14	**SC**	3	0.13	29.2	2095	1.00	0.74	0.86	4485	3873	0.08	40	2.2	7.6	0.09	**1.11**	**2.11**
B-105	41	12.50	15	**SW**	35	0.13	29.2	2096	1.00	0.73	0.84	4715	3979	0.08	8.3	25.4	26.1	0.32	**3.76**	**7.16**

References: Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils", by T.L. Youd et al., J. Geotech. and Geoenvir. Engrg., ASCE, 127(10), 817-833, 2001.

Assumptions/Input:

1. Calculations assume unit weight of 115 pcf.
2. Amax is the PGA for a 2500-yr return period. PGArock = 0.116g; PGAdesign = 0.13g based upon amplification factor from page 5
3. Fines content is based upon visual-manual classification of soil samples
4. Formulas for chart values are as follows:

r_d = 1-.00765*.3048*D (for D<30 feet)
D = depth, in feet

$N_1 60$ = N*Ce*Cb*Cr*Cs*Cn
$C_e = C_b = C_s = 1.0$
C_r = 0.75 to 0.95
$C_n = (P_a/\sigma_{vo}')$^0.5

$(N_1)_{60cs}$ is Equivalent Clean Sand Value under influence of fines content.
$CRR_{7.5}$ estimated based upon corrected blowcount and fines content for M = 7.5
$CSR = 0.65*(A_{max}/g)*(\sigma_{vo}/\sigma_{vo}')*r_d$
Factor of Safety $M_{7.5} = CRR_{7.5}/CSR$
Factor of Safety $M_{design} = (CRR_{7.5}/CSR)$ * MSF

TVA WBF Ash Pond Breaching Project
Spring City, TN

Liquefaction Potential Evaluation at B-106

Design Earthquake Magnitude (M_{design}) = 5.83 (from USGS deaggregation data, see page 4)

Magnitude Scaling Factor (MSF) = 1.9 ($MSF = 10^{2.24}/M_w^{2.56}$)

Boring	Depth, ft	Depth, meters	Sample #	Soil Type	N value	A_{max}, g	Depth to GWT	P_a	C_r	C_N	r_d	Total Stress, psf	Effective Stress, psf	CSR	Fines content	$(N_1)_{60}$	$(N_1)_{60cs}$	$CRR_{7.5}$	Factor of Safety for $M_{7.5}$	Factor of Safety for M_{design}
B-106	1	0.30	1	**ML**	20	0.13	12.2	2089	0.75	1.70	1.00	115	115	0.08	60	25.5	35.6	non-liquefiable	**Non-Liquefiable**	**Non-Liquefiable**
B-106	3	0.91	2	**ML**	9	0.13	12.2	2089	0.75	1.70	0.99	345	345	0.08	60	11.5	18.8	0.20	**2.39**	**4.55**
B-106	5	1.52	3	**ML**	4	0.13	12.2	2089	0.75	1.70	0.99	575	575	0.08	60	5.1	11.1	0.12	**1.47**	**2.81**
B-106	7	2.13	4	**CL**	4	0.13	12.2	2089	0.75	1.61	0.98	805	805	0.08	59.9	4.8	10.8	0.12	**1.45**	**2.76**
B-106	9	2.74	5	**CL**	5	0.13	12.2	2089	0.75	1.42	0.98	1035	1035	0.08	60	5.3	11.4	0.13	**1.52**	**2.89**
B-106	11	3.35	6	**CL**	4	0.13	12.2	2089	0.80	1.29	0.97	1265	1265	0.08	58.9	4.1	9.9	0.11	**1.37**	**2.60**
B-106	17	5.18	7	**SM**	4	0.13	12.2	2089	0.85	1.12	0.96	1955	1655.48	0.10	45	3.8	9.6	0.11	**1.14**	**2.18**
B-106	19	5.79	8	**SC**	4	0.13	12.2	2089	0.85	1.09	0.96	2185	1760.68	0.10	45	3.7	9.4	0.11	**1.08**	**2.06**
B-106	21	6.40	9	**SC**	8	0.13	12.2	2089	0.95	1.06	0.95	2415	1866	0.10	45	8.0	14.6	0.16	**1.51**	**2.87**
B-106	24	7.32	10	**SC**	3	0.13	12.2	2089	0.95	1.02	0.94	2760	2024	0.11	45.5	2.9	8.5	0.10	**0.92**	**1.75**
B-106	29	8.84	11	**GW**	32	0.13	12.2	2089	0.95	0.96	0.93	3335	2287	0.11	10	29.1	30.6	non-liquefiable	**Non-Liquefiable**	**Non-Liquefiable**

References: Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils", by T.L. Youd et al., J. Geotech. and

Assumptions/Input:

1. Calculations assume unit weight of 115 pcf.
2. Amax is the PGA for a 2500-yr return period. PGArock = 0.116g; PGAdesign = 0.13g based upon amplification factor from page 5
3. Fines content is based upon visual-manual classification of soil samples.
4. Formulas for chart values are as follows:

$r_d = 1-.00765*.3048*D$ (for D<30 feet)

D = depth, in feet

$N_160 = N*Ce*Cb*Cr*Cs*Cn$

$C_e = C_b = C_s = 1.0$

$C_r = 0.75$ to 0.95

$C_n = (P_a/\sigma_{vo}')\text{^}0.5$

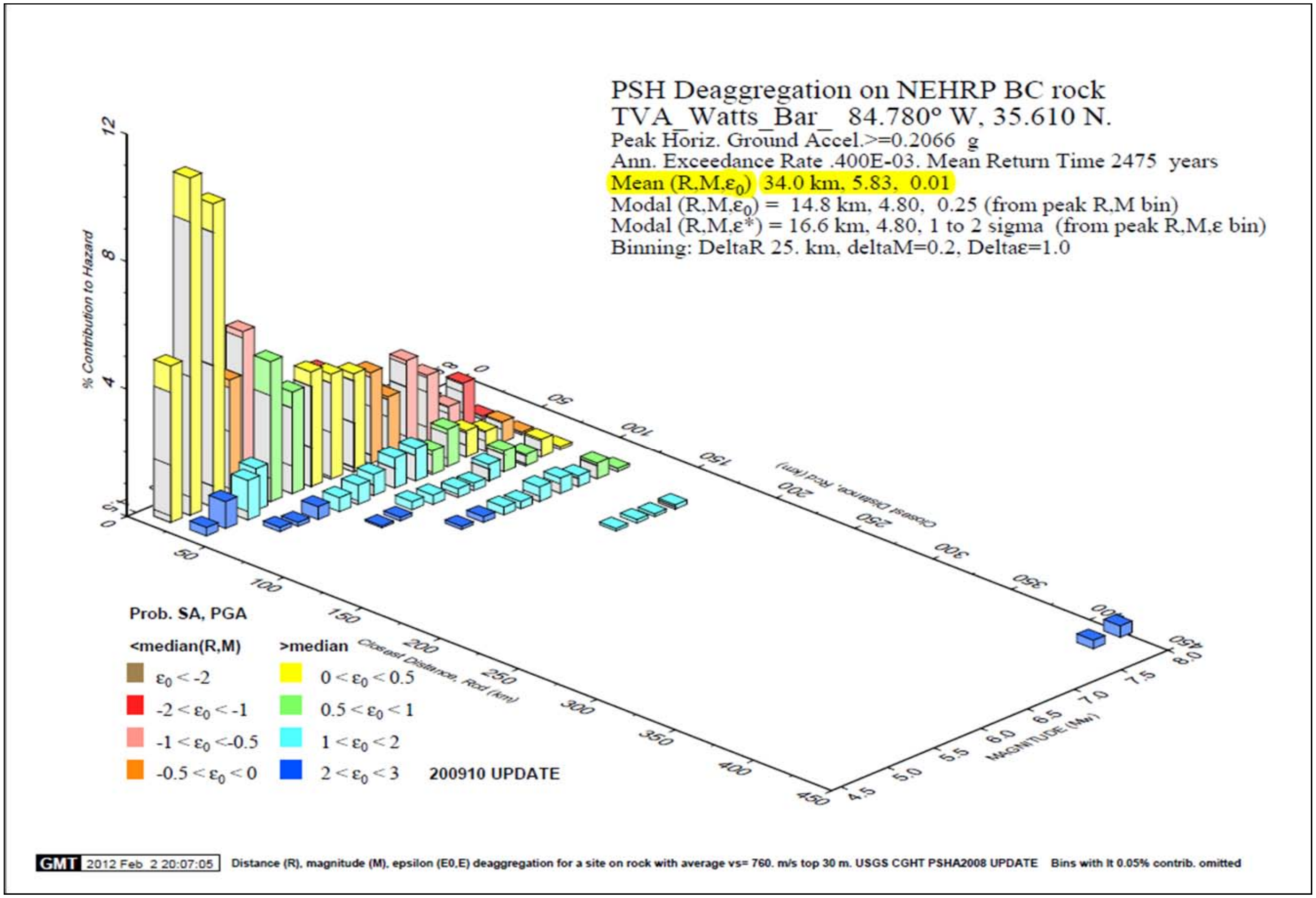
$(N_1)_{60cs}$ is Equivalent Clean Sand Value under influence of fines content.

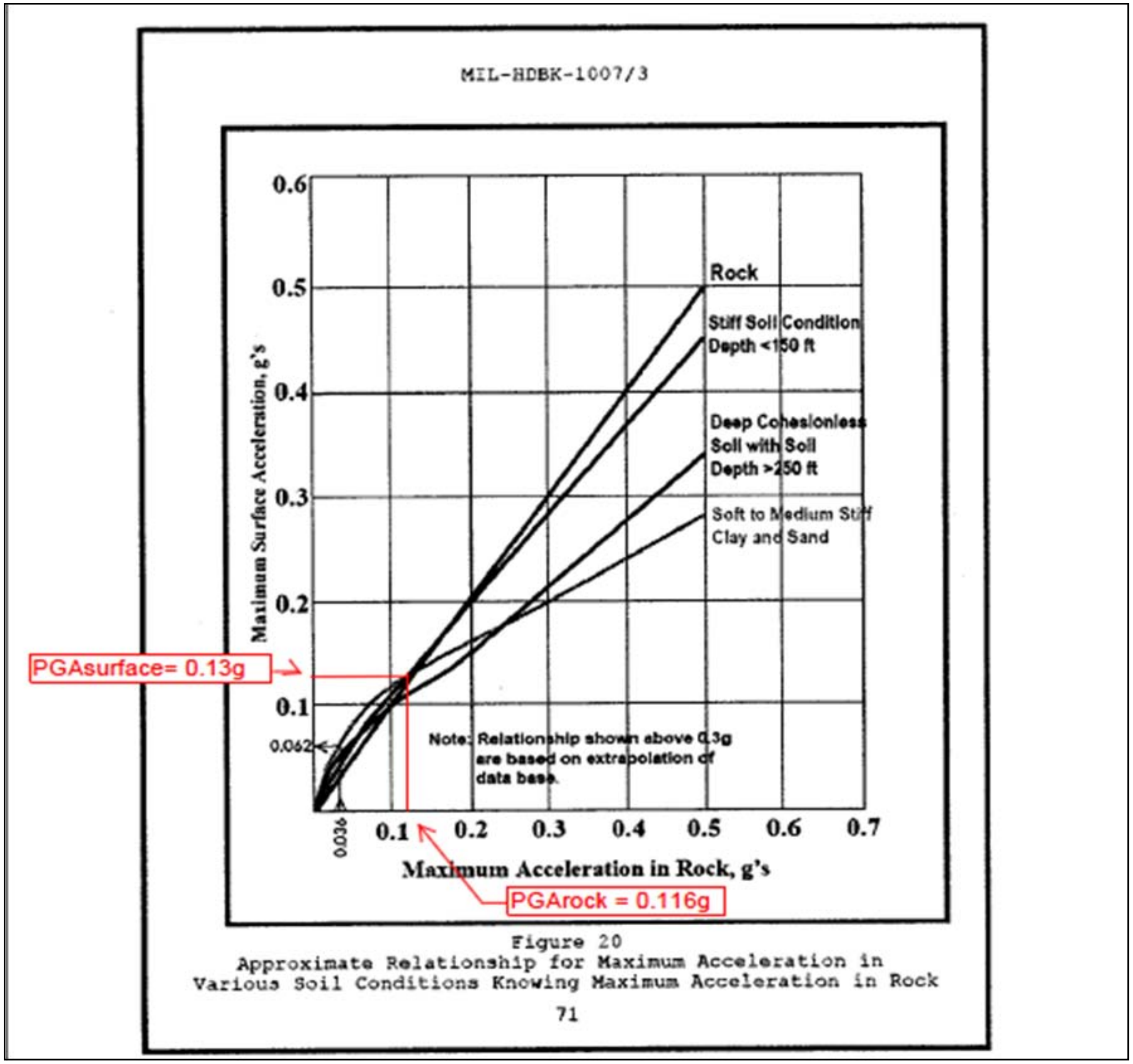
$CRR_{7.5}$ estimated based upon corrected blowcount and fines content for M = 7.5

$CSR = 0.65*(A_{max}/g)*(\sigma_{vo}/\sigma_{vo}')*r_d$

Factor of Safety $M_{7.5} = CRR_{7.5}/CSR$

Factor of Safety $M_{design} = (CRR_{7.5}/CSR) * MSF$


PSH Deaggregation on NEHRP BC rock
TVA_Watts_Bar_ 84.780° W, 35.610 N.
Peak Horiz. Ground Accel.>=0.2066 g
Ann. Exceedance Rate .400E-03. Mean Return Time 2475 years
Mean (R,M,ε0) 34.0 km, 5.83, 0.01
Modal (R,M,ε0) = 14.8 km, 4.80, 0.25 (from peak R,M bin)
Modal (R,M,ε*) = 16.6 km, 4.80, 1 to 2 sigma (from peak R,M,ε bin)
Binning: DeltaR 25. km, deltaM=0.2, Deltaε=1.0
% Contribution to Hazard
0
4
8
12
Closest Distance, Rcd (km)
50
100
150
200
250
300
350
400
450
MAGNITUDE (Mw)
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
Prob. SA, PGA
<median(R,M)
>median
ε0 < -2
-2 < ε0 < -1
-1 < ε0 <-0.5
-0.5 < ε0 < 0
0 < ε0 < 0.5
0.5 < ε0 < 1
1 < ε0 < 2
2 < ε0 < 3
200910 UPDATE
GMT 2012 Feb 2 20:07:05
Distance (R), magnitude (M), epsilon (E0,E) deaggregation for a site on rock with average vs= 760. m/s top 30 m. USGS CGHT PSHA2008 UPDATE Bins with lt 0.05% contrib. omitted



MIL-HDBK-1007/3

Note: Relationship shown above 0.3g are based on extrapolation of data base.

PGAsurface= 0.13g

PGArock = 0.116g

Figure 20
Approximate Relationship for Maximum Acceleration in Various Soil Conditions Knowing Maximum Acceleration in Rock

71

Source: Department of Defence Handbook - Soil Dynamics and Special Design Aspects, November 15, 1997.

CDM Smith Calculation Form

Client: TVA	**Job No.** 92016	**Calculations By:** J. Wen
Project: WBF Ash Pond Breaching	**Checked By/Date** D.K.Neamtu/8-13-12	**Date:** 08/10/2012
Detail: Slope Stability	**Reviewed By/Date** S.L.Whiteside/8-13-12	**Calc #:** 1
		Revision No./Date: ______

Calculation Brief Title: WBF Ash Pond Breaching Project - Slope Stability Analyses

1.0 Purpose/Objective:

This calculation package contains slope stability analyses under static and seismic conditions for the Ash Pond Breaching Project at the existing Watts Bar Fossil (WBF) plant near Spring Lake, Tennessee. These analyses were performed in support of design of the new spillway structure at Ash/Stilling Pond Area. The objective is to confirm that the calculated factors of safety are equal to or greater than the minimum required for each design case in accordance with Reference B (listed below in Section 3.0).

2.0 Procedure:

The calculations contained herein were performed in general accordance with the requirements outlined in Reference B (listed below in Section 3.0).

A. The attached Figure 1 shows the location of the critical cross-sections selected for the proposed new spillway structure. Subsurface soil profile and soil strength parameters at this cross section were assumed based on the soil borings(CDM -105 and CDM-106) performed by CDM Smith in this area recently. The subsurface conditions observed in these borings, topographic information collected by the survey, available design drawings, and project Contract Drawings for the site were used as the basis for the stability analyses cross-sections.

B. Prior to beginning the stability analyses, steady-state seepage analyses were performed using the SEEP/W model developed by GEO-SLOPE International. For the seepage analyses, hydraulic conductivity values of the various subsurface layers were assumed based upon experience in similar geologic units. The seepage model was run under steady-state seepage conditions for each of the design cases to provide input for SLOPE/W.

C. The slope stability modeling was performed using the SLOPE/W model developed by GEO-SLOPE International, and Spencer Method was selected. The stability criteria for the cross-sections considered the requirements for impoundments and landfills, as listed in Reference B.

D. This calculation package only includes the proposed condition at the new spillway structure location. The Existing conditions stability analyses were performed previously by CDM Smith and can be found in Reference A (listed below in Section 3.0).

E. The static stability criteria for impoundments as listed in Section 1.7.2 of Reference B were utilized. The seismic stability criteria for impoundments are the same as those considered for landfills in Section 1.4.2 of Reference B.

F. Rapid drawdown analyses were performed by using 3-stage computation in accordance with the procedure described in Table 2-1 of Reference D.

pg. 2 of 2

3.0 References/Data Sources:

A. "Report-Existing Conditions Stability Analyses, Ash Pond Area at Watts Bar Fossil Pant", by CDM Smith, January 31, 2012.
B. "TVA Coal Combustion Products Management Program, Master Programmatic Document", by URS, December 7, 2009
C. Borings B-105 and B-106 performed by CDM Smith.
D. "Slope Stability", USACE EM 1110-2-1902.

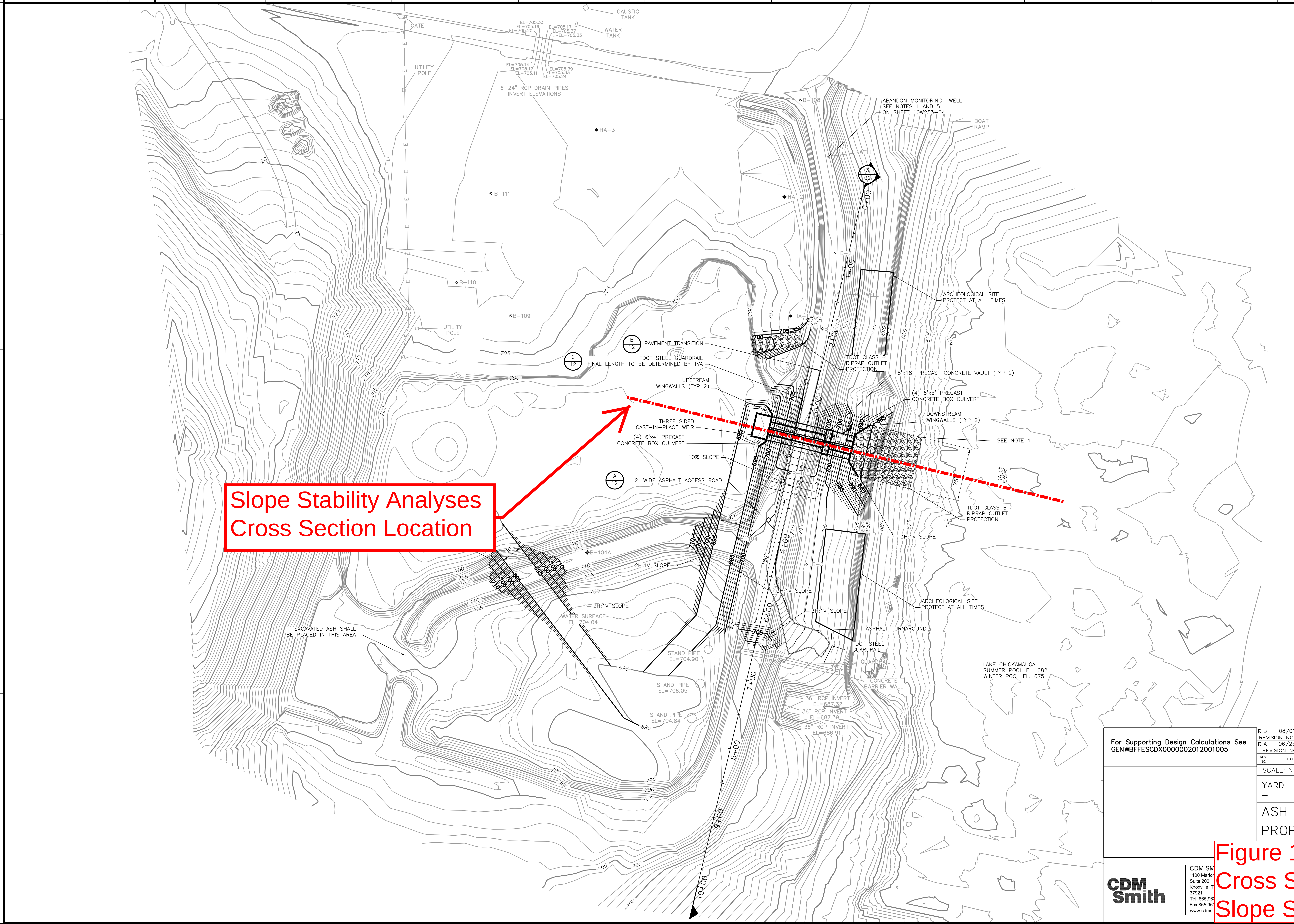
4.0 Assumptions and Limitations:

A. Slope stability cross-sections assume a subsurface profile similar to conditions encountered in the borings in this area. Refer to modeling results for subsurface layers.
B. Design soil parameters and the basis for selection are summarized in Tables 1a and 1b.
C. Model boundary conditions used in the seepage models are summarized in Table 2.
D. Culverts and drop box structures through the cross-section are excluded for clarity. Design cross-section depicts 3H:1V downstream slopes. Headwall stability assessed by structural calculations.

5.0 Calculations: Modeling results for each case are attached and Factors of Safety are summarized in Table 3.

6.0 Conclusions/Results:

A. Calculated Factors of Safety for Deep-Seated Slope Failures under static and seismic conditions are listed in Tables 3. Deep-seated slope failures are considered to have a minimum depth greater than 10 feet.
B. All cases produce an acceptable factor of safety for slope stability at the proposed spillway location.


CAUSTIC TANK
WATER TANK
GATE
EL=705.33
EL=705.19
EL=705.20
EL=705.17
EL=705.37
EL=705.33
EL=705.14
EL=705.17
EL=705.11
EL=705.39
EL=705.33
EL=705.24
UTILITY POLE
6-24" RCP DRAIN PIPES INVERT ELEVATIONS
B-108
HA-3
HA-2
HA-1
B-111
B-110
B-109
B-2
B-107
B-105
B-104A
WELL
ABANDON MONITORING WELL SEE NOTES 1 AND 5 ON SHEET 10W253-04
BOAT RAMP
3/09
0+00
1+00
2+00
3+00
4+10
5+00
6+00
7+00
8+00
9+00
10+00
ARCHEOLOGICAL SITE PROTECT AT ALL TIMES
B/12 PAVEMENT TRANSITION
C/12 TDOT STEEL GUARDRAIL FINAL LENGTH TO BE DETERMINED BY TVA
TDOT CLASS B RIPRAP OUTLET PROTECTION
8'x18' PRECAST CONCRETE VAULT (TYP 2)
UPSTREAM WINGWALLS (TYP 2)
(4) 6'x5' PRECAST CONCRETE BOX CULVERT
DOWNSTREAM WINGWALLS (TYP 2)
THREE SIDED CAST-IN-PLACE WEIR
(4) 6'x4' PRECAST CONCRETE BOX CULVERT
SEE NOTE 1
10% SLOPE
A/12 12' WIDE ASPHALT ACCESS ROAD
75'
TDOT CLASS B RIPRAP OUTLET PROTECTION
3H:1V SLOPE
2H:1V SLOPE
WATER SURFACE EL=704.04
EXCAVATED ASH SHALL BE PLACED IN THIS AREA
ASPHALT TURNAROUND
TDOT STEEL GUARDRAIL
GUARDRAIL
CONCRETE BARRIER WALL
STAND PIPE EL=704.90
STAND PIPE EL=706.05
STAND PIPE EL=704.84
36" RCP INVERT EL=687.32
36" RCP INVERT EL=687.39
36" RCP INVERT EL=686.91
LAKE CHICKAMAUGA SUMMER POOL EL. 682 WINTER POOL EL. 675
N
1" = 50'
25 0 50

Slope Stability Analyses
Cross Section Location

NOTES:

1. CONSTRUCTION OF RIPRAP OUTLET PROTECTION MAY BE CONSTRUCTED IN PHASES BASED ON LAKE ELEVATION. PROTECTION TO EXTEND TO ELEVATION 675.
2. SECURITY BARRIER SHALL BE EXTENDED AS DIRECTED BY TVA NUCLEAR SECURITY.

COORDINATION OF CONSTRUCTION SEQUENCE:

SECURITY MUST BE MAINTAINED AT ALL TIMES FOR THE WATTS BAR NUCLEAR SITE. ALL CONSTRUCTION ACTIVITIES SHALL BE COORDINATED WITH WATTS BAR SECURITY PERSONNEL. THE FOLLOWING IS ONE LOGICAL SEQUENCE OF CONSTRUCTION AND WAS DEVELOPED TO MEET THE TVA'S SITE REQUIREMENTS AS WELL AS THE PERFORMANCE REQUIREMENTS OF THE PROPOSED IMPROVEMENTS.

1. DEWATER THE EXISTING POND AT A PUMPING RATE THAT LOWERS THE POND LEVEL NO MORE THAN ONE FOOT PER DAY. BASED UPON THE EXISTING AVAILABLE INFORMATION, THE FOLLOWING STAGE-STORAGE RELATIONSHIP CAN BE ASSUMED FOR THE EXISTING PONDS. (SEE 10W253-10 FOR TABLE)
2. THE DEWATERING PUMP(S) MAY BE DISCHARGED TO ONE OF THE THREE EXISTING SPILLWAY RISER PIPES OR MAY BE CONVEYED WITH A DISCHARGE HOSE(S) OVER THE DIKE TO THE RIPRAP CHANNEL AT THE EXISTING OUTFALL 002 DISCHARGE LOCATION. GROUT UNUSED SPILLWAY PIPES AND REMOVE RISERS AS SPECIFIED.
3. WHEN POND DEWATERING SLOWS DUE TO THE HIGHER GROUND SURFACE ELEVATIONS BETWEEN THE NORTH AND SOUTH PORTIONS OF THE POND, BREACH THE WEST SPLITTER DIKE AS SHOWN ON SHEET 10W253-05 TO ALLOW WATER TO FLOW BETWEEN THE NORTH/SOUTH PORTIONS OF THE POND AND COMPLETE DEWATERING.
4. PROVIDE STRUCTURAL SUPPORT FOR THE EXISTING SPILLWAY RISER PIPES, AS NECESSARY, DURING AND AFTER DRAWDOWN.
5. EXCAVATE WET ASH AT THE COFFERDAM LOCATION AND PLACE IT WITHIN THE POND FOOTPRINT AREA ADJACENT TO THE SPLITTER DIKE.
6. CONSTRUCT THE COFFERDAM AS SHOWN ON SHEET 10W253-07 TO EXTEND THE EXISTING ACCESS ROAD TO THE SPLITTER DIKE AND PROVIDE NEW ACCESS FOR WATTS BAR SECURITY PERSONNEL.
7. EXCAVATE THE BREACH IN THE EAST DIKE TO EL. 701.
8. USE THE PUMPS AS NECESSARY TO MAINTAIN WATER LEVEL IN POND AS LOW AS POSSIBLE, BUT AT LEAST ONE FOOT BELOW THE TOP OF THE COFFERDAM AT ALL TIMES.
9. EXCAVATE FOR THE NEW SPILLWAY STRUCTURE, CULVERTS, AND DROP STRUCTURES.
10. CONSTRUCT THE SPILLWAY WEIR, BOX CULVERTS, DROP STRUCTURES, WING WALLS, ETC AS SHOWN ON DRAWINGS.
11. BACKFILL SPILLWAY EXCAVATION TO FINISHED GRADE WITH SELECT FILL MATERIALS AND CONSTRUCT RIPRAP SLOPE PROTECTION DOWNSTREAM OF SPILLWAY OUTLET
12. REDIRECT SECURITY TRAFFIC TO THE CREST OF THE EAST DIKE.
13. BREACH EAST END SPLITTER DIKE BETWEEN COFFERDAM TIE-IN AND EAST DIKE, AS SHOWN ON SHEET 10W253-05. INSTALL TURBIDITY BARRIERS TO REDUCE POTENTIAL FOR SEDIMENT TRANSPORT AT THIS LOCATION.
14. GROUT REMAINING SPILLWAY PIPE UTILIZED FOR BYPASS DURING CONSTRUCTION AND REMOVE THE RISER.
15. COMPLETE REMOVAL OF TEMPORARY CONSTRUCTION MEASURES (SUCH AS DEWATERING ELEMENTS) AND PERFORM SITE STABILIZATION CLEAN-UP ACTIVITIES. UPON FINAL INSPECTION AND APPROVAL BY THE ENGINEER AND OWNER, DEMOBILIZE FROM SITE.

PLOT DATE: 08/01/2012 USER: NAGEL, ROBERT
C:\CDMXM\NAGELRG\D0908982\WBF-10W253-05-SHT -REV 1.DWG

DRAFT
ISSUED FOR 90% REVIEW
NOT FOR CONSTRUCTION

For Supporting Design Calculations See
GENWBFFESCDX0000002012001005

REV. NO.	DATE	DSGN	DRWN	CHKD	SUPV	RVWD	APPD	ISSD	PROJECT ID	AS CONST	REV CD
R B	08/01/12	RN	JM	DN	SW	JM	MT	JK	–	–	–
REVISION NO. B											
R A	06/25/12	RN	JM	DN	SW	JM	MT	JK	–	–	–
REVISION NO. A											

DISCIPLINE INTERFACE
1
2
3
4

SCALE: NONE EXCEPT AS NOTED

YARD
–

ASH POND BREACHING PROJECT
PROPOSED CONDITIONS

CDM Smith

CDM SM
1100 Marion
Suite 200
Knoxville, T
37921
Tel. 865.963
Fax 865.963
www.cdmsm

Figure 1
Cross Section Location of
Slope Stability Analyses

CDM SMITH	B
TASK COMPLETED BY:	REV NO.

PLOT FACTOR:XX
W_TVA

C.A.D. DRAWING
DO NOT ALTER MANUALLY

TVA WBF Ash Pond Breaching Project
Spring City, TN

Table 1a: Seepage Parameters used in SEEP/W Model

Layer	Material	K_h		k_h / k_v	Basis of Parameter Selection
		ft/day	cm/sec		
1	Fill	0.0028	1.0E-06	10	From Peck(1); typical value for mixture of sand, clay, and silt.
2	Clay	0.0014	5.0E-07	4	From Peck; typical value for low-permeability soil.
3	Sand	2.83	1.0E-03	4	From Peck; typical value for sand.
4	Weathered Rock and Gravel	28.35	1.0E-02	4	From Peck; typical value for sand and gravel mixtures.
5	Bedrock	0.0006	2.0E-07	1	From Domenico(2); page 39; high-end value for Shale bedrock.

Reference:

1. Ralph B. Peck, 'Foundation Engineering', 2nd edition; page 43.

2. Patrick A. Domenico, 'Physical and Chemical Hydrogeology', 2nd edition.

TVA WBF Ash Pond Breaching Project
Spring City, TN

Table 1b: Strength Parameters used in SLOPE/W Model

Layer	Material	Unit Weight, pcf	Effective Friction Angle, degrees	Undrained Shear Strength, psf	Basis of Parameter Selection [1]
1	Fill	120/115[2]	32	-	Selected based on engineering experiences
2	Clay	110/105[2]	29	1000[5]	Selected based on lower 1/3 N-values[3] and pocket penetrometer readings[4] from B-105 and B-106
3	Sand	120	28	-	Selected based on Lower 1/3 N-values[3] from B-105 and B-106
4	Weathered Rock and Gravel	125	36	-	Based upon experience in similar geologic conditions
5	Bedrock	Impenetrable			Assumed

Note:

1. Correlation of N-value and friction angle from Ralph B. Peck, 'Foundation Engineering', 2nd edition, 1974; page 310.
2. Values listed are saturated/moist unit weights.
3. Lower 1/3 value is defined as the value where at least 2/3 of all the readings are greater or equal. N-value is defined as the sum of the blows to drive the 2nd and 3rd 6-inch-increments of each split spoon sample.
4. Pocket penetrometer readings were performed on split spoon samples and Shelby tube sample during drilling.
5. Undrained shear strength used for end of construction, rapid drawdown and seismic conditions.

TVA WBF Ash Pond Breaching Project
Spring City, TN

Table 2 - Boundary Conditions used in Seepage Model

Run #	Modeling Scenario	West Side Boundary	East Side Boundary
1	End of Construction	Groundwater Level of EL 693	Max Normal Pool of EL 682.5 in Chickamauga Lake
2	Long Term-Maximum Surcharge Pool	100-year Storm Water Level of EL 700	
3	Rapid Drawdown	Rapid drawdown from EL 700 to EL 695	
4	Seismic Condition	Normal Pool of EL 698	

TVA WBF Ash Pond Breaching Project

Spring City, TN

Table 3 - Results of Slope Stability Analyses

Run #	Modeling Scenario[2]	Required Factor of Safety	Calculated Factor of Safety[1]	
			inboard	outboard
1	End of Construction	1.3	2.5	1.7
2	Long Term with Maximum Pool Level	1.5	2.5	1.7
3	Rapid Drawdown Condition	1.3	2.0	N/A
4	Seismic Condition[3]	1.0	1.8	1.1

Notes:

1. Factor of Safety was calculated by using Spencer Method. Failure surfaces less than 10-foot-deep were not considered deep-seated, and results are not listed here.

2. For run 1 and 4, undrained strength was used for clay layer. For run 3, both drained and undrained strength were considered in the clay layer.

3. For seismic condition, a 2500-year return period PHA=0.116g was used as peak ground acceleration.

N/A: Not Applicable.

Client: TVA
Project: WBF Ash Pond Breaching

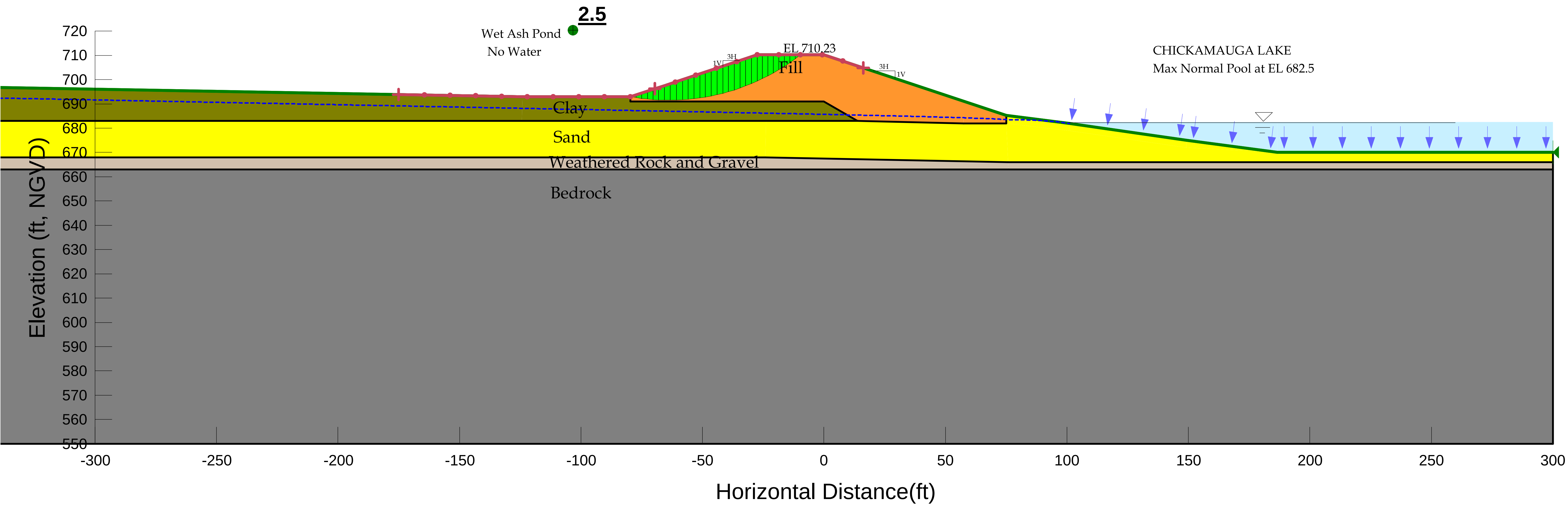
Computed By: Wen, Jintao
Date & Time: 8/9/2012 2:35:45 PM

TVA Watts Bar Fossil Plant, Spring City, TN
Slope Stability Analyses
New Spillway Location at Wet Ash Pond Area

Run #1
Location: New Spillway at Ash Pond

Model Scenario:
Proposed Conditon at New Spillway
Static Analysis - End of Construction

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2: Clay 110 pcf 105 pcf 1000 psf 0 °
Layer 3: Sand 120 pcf 0 psf 28 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 36 °
Layer 5: Bedrock



Client: **TVA**
Project: **WBF Ash Pond Breaching**

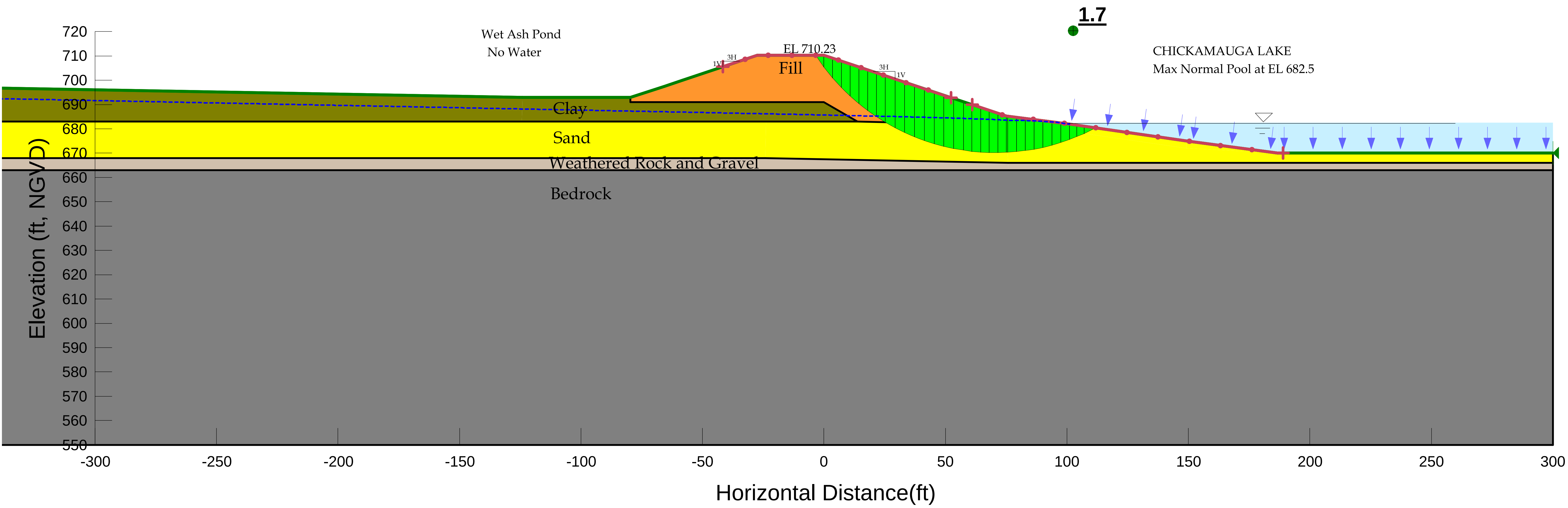
Computed By: **Wen, Jintao**
Date & Time: **8/9/2012 2:35:45 PM**

TVA Watts Bar Fossil Plant, Spring City, TN
Slope Stability Analyses
New Spillway Location at Wet Ash Pond Area

Run #1
Location: New Spillway at Ash Pond

Model Scenario:
Proposed Conditon at New Spillway
Static Analysis - End of Construction

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2: Clay 110 pcf 105 pcf 1000 psf 0 °
Layer 3: Sand 120 pcf 0 psf 28 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 36 °
Layer 5: Bedrock



Client: **TVA**
Project: **WBF Ash Pond Breaching**

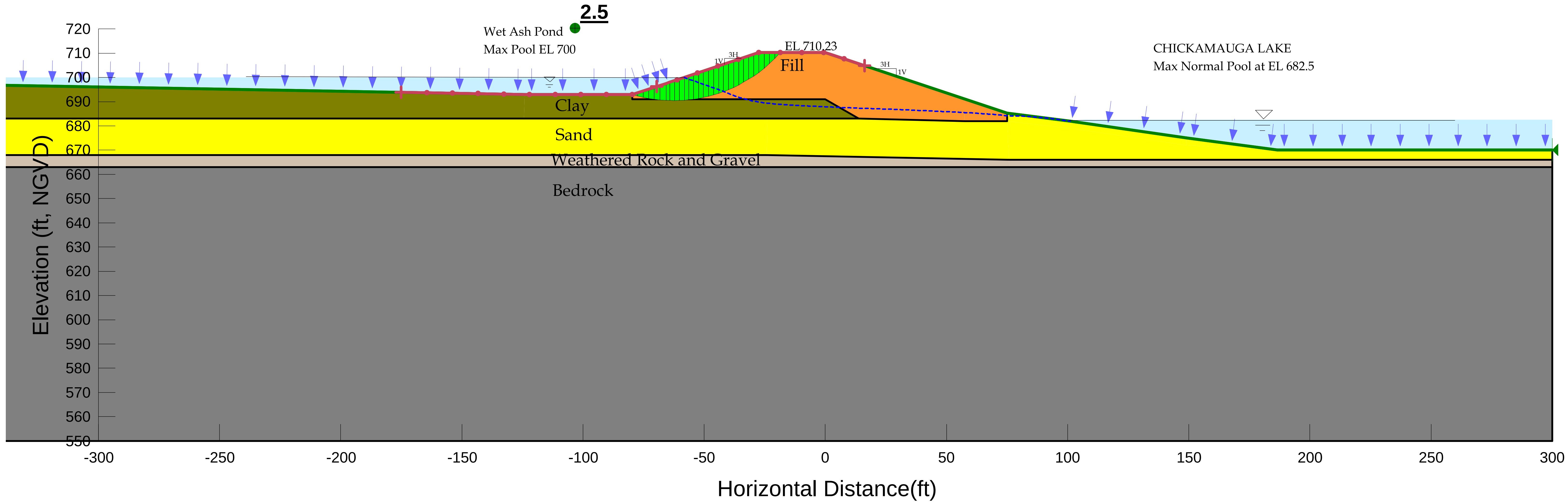
Computed By: **Wen, Jintao**
Date & Time: **8/9/2012 2:47:58 PM**

TVA Watts Bar Fossil Plant, Spring City, TN
Slope Stability Analyses
New Spillway Location at Wet Ash Pond Area

Run #2
Location: New Spillway at Ash Pond

Model Scenario:
Proposed Conditon at New Spillway
Long Term Max Pool Condition

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2: Clay 110 pcf 105 pcf 0 psf 29 °
Layer 3: Sand 120 pcf 0 psf 28 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 36 °
Layer 5: Bedrock



Client: **TVA**
Project: **WBF Ash Pond Breaching**

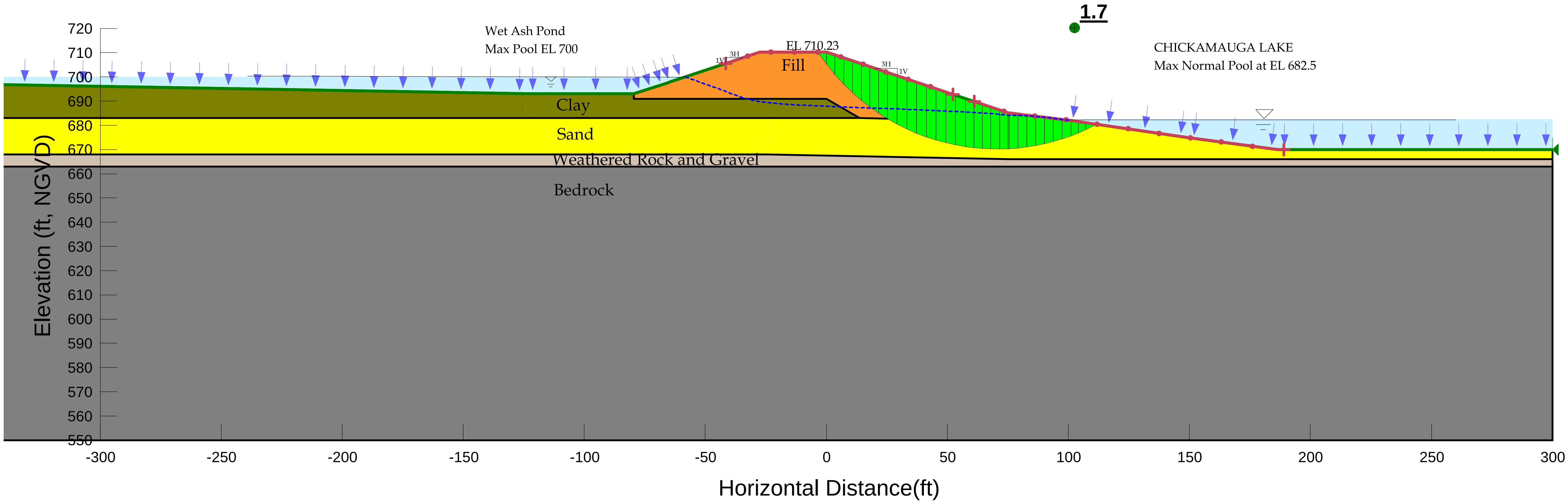
Computed By: **Wen, Jintao**
Date & Time: **8/9/2012 2:47:58 PM**

TVA Watts Bar Fossil Plant, Spring City, TN
Slope Stability Analyses
New Spillway Location at Wet Ash Pond Area

Run #2
Location: New Spillway at Ash Pond

Model Scenario:
Proposed Conditon at New Spillway
Long Term Max Pool Condition

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2: Clay 110 pcf 105 pcf 0 psf 29 °
Layer 3: Sand 120 pcf 0 psf 28 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 36 °
Layer 5: Bedrock



Client: TVA
Project: WBF Ash Pond Breaching

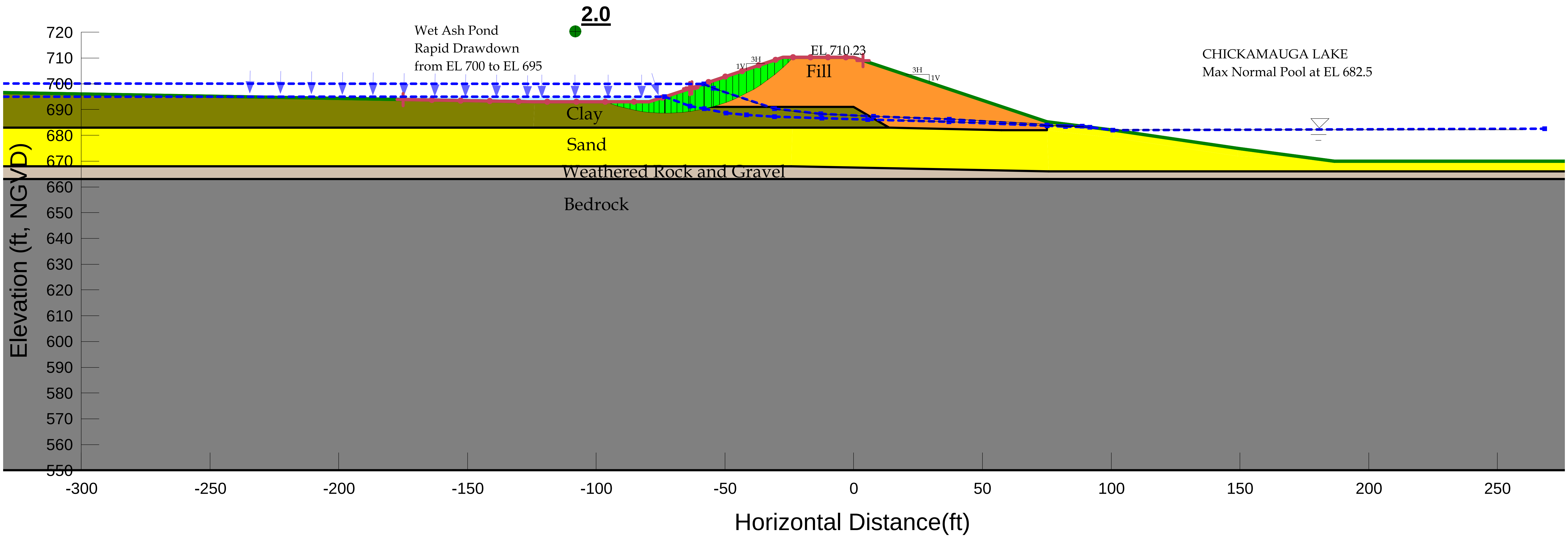
Computed By: Wen, Jintao
Date & Time: 8/15/2012 5:31:50 PM

TVA Watts Bar Fossil Plant, Spring City, TN
Slope Stability Analyses
New Spillway Location at Wet Ash Pond Area

Run #3
Location: New Spillway at Ash Pond

Model Scenario:
Proposed Conditon at New Spillway
Rapid Drawdown Condition

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 ° 0 psf 0 ° 1 2
Layer 2: Clay 110 pcf 105 pcf 0 psf 29 ° 1000 psf 0 ° 1 2
Layer 3: Sand 120 pcf 0 psf 28 ° 0 psf 0 ° 1 2
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 36 ° 0 psf 0 ° 1 2
Layer 5: Bedrock 1 2



Client: TVA
Project: WBF Ash Pond Breaching

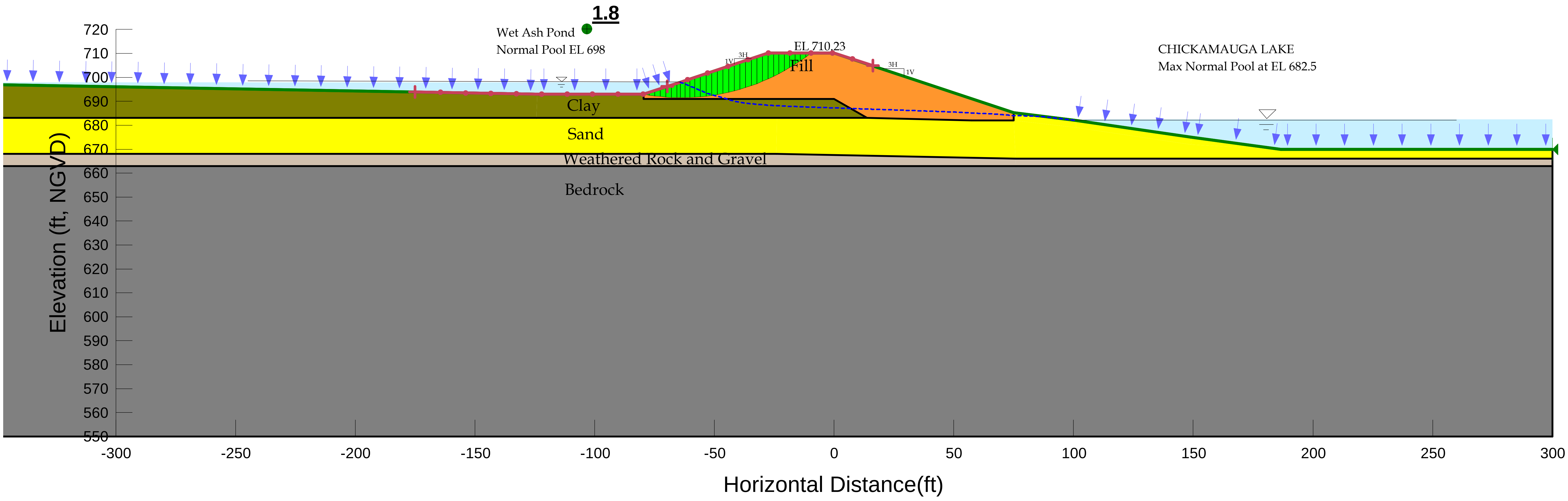
Computed By: Wen, Jintao
Date & Time: 8/9/2012 2:41:47 PM

TVA Watts Bar Fossil Plant, Spring City, TN
Slope Stability Analyses
New Spillway Location at Wet Ash Pond Area

Run #4
Location: New Spillway at Ash Pond

Model Scenario:
Proposed Conditon at New Spillway
Seismic Analysis - PHA=0.116g

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2: Clay 110 pcf 105 pcf 1000 psf 0 °
Layer 3: Sand 120 pcf 0 psf 28 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 36 °
Layer 5: Bedrock



Client: TVA
Project: WBF Ash Pond Breaching

Computed By: Wen, Jintao
Date & Time: 8/9/2012 2:41:47 PM

TVA Watts Bar Fossil Plant, Spring City, TN
Slope Stability Analyses
New Spillway Location at Wet Ash Pond Area

Run #4
Location: New Spillway at Ash Pond

Model Scenario:
Proposed Conditon at New Spillway
Seismic Analysis - PHA=0.116g

Layer 1: Fill 120 pcf 115 pcf 0 psf 32 °
Layer 2: Clay 110 pcf 105 pcf 1000 psf 0 °
Layer 3: Sand 120 pcf 0 psf 28 °
Layer 4: Weathered Rock and Gravel 125 pcf 0 psf 36 °
Layer 5: Bedrock

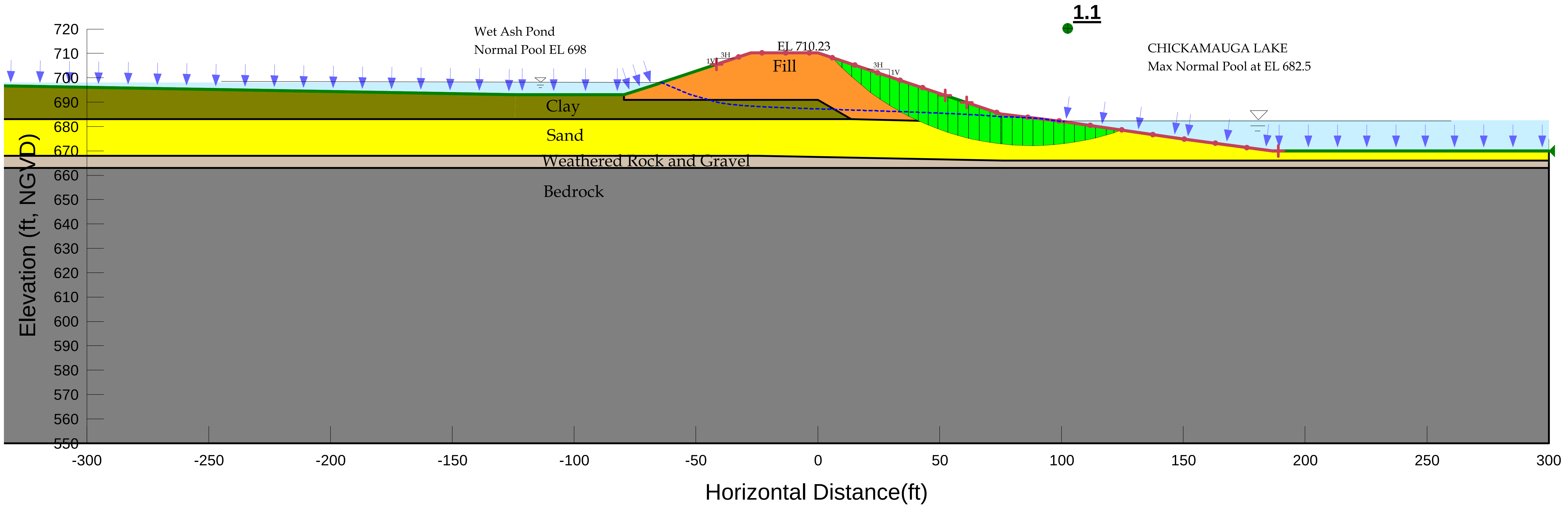


Exhibit 5
Structural Calculations

DESIGN SEISMIC BASE SHEAR

CAST IN PLACE CONCRETE DESIGN – INLET

CAST IN PLACE CONCRETE DESIGN – OUTLET

PRECAST CULVERT DESIGN FOR INLET AND OUTLET

CDM Smith

CLIENT	TVA	COMPUTED BY / DATE	PHS / 08/16/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	df / 8/17/12
DETAIL	Design Seismic Base Shear	REVISION NO. / DATE	- / -
PROJECT NO.	92016.2202	REVIEWED BY / DATE	- / -

Calculation Description: Design Seismic Base Shear

1.0 Objective

Determine seismic base shear applied to the inlet and outlet concrete structure.

2.0 Procedure

1.) Determine soil site class per Geotechnical Design Memorandum.
2.) Find latitude/longitude of plant to determine spectral accelerations and seismic site coefficients from USGS.
3.) Determine Seismic Design Category from IBC Table 1613.5.1 and equations 16-37 thru 16-40.
4.) Determine response modification coefficients, importance factor for occupancy category, and seismic response coefficients.
5.) Calculate weight and volume of inlet weir wall, wingwall, and outlet end, respectively.
6.) Calculate Seismic Design Base Shear on structure.

3.0 References / Data Sources

1.) Geotechnical Design Memorandum
2.) USGS Seismic Data
3.) ASCE 7
4.) IBC 2006

4.0 Assumptions / Limitations

1.) Design Base Shear is taken throughout the structure.

5.0 Calculations

5.1 Determine soil site class per Geotechnical Design Memorandum.

- Refer to Geotechnical Design Memorandum

5.2 Find latitude/longitude of plant to determine spectral accelerations and seismic site coefficients from USGS.

- Refer to sheet printed with address and lat/long and USGS output data.

5.3 Determine Seismic Design Category from IBC Table 1613.5.1 and equations 16-37 thru 16-40.

- Refer to Mathcad Spreadsheet "Design Base Shear"

5.4 Determine response modification coefficients, importance factor for occupancy category, and seismic response coefficients.

- Refer to EXCEL spreadsheet "Hydrodynamic Loads with Earthquake in Transverse Direction"

5.5 Calculate weight and volume of inlet weir wall, wingwall, and outlet end, respectively.

5.6 Calculate Seismic Design Base Shear on structure.

- For 5.5 and 6.6, refer back to the Mathcad Spreadsheet "Design Base Shear"

6.0 Conclusions

- The Seismic Design Category for this project is "C" and the design base shear for the inlet structure is approximately 52 kips and for the outlet structure is approximately 43 kips.

Checked by: dlf
8/17/12

USGS Design Maps Summary Report

User–Specified Input

Report Title TVA Watts Bar
Fri August 17, 2012 15:45:44 UTC

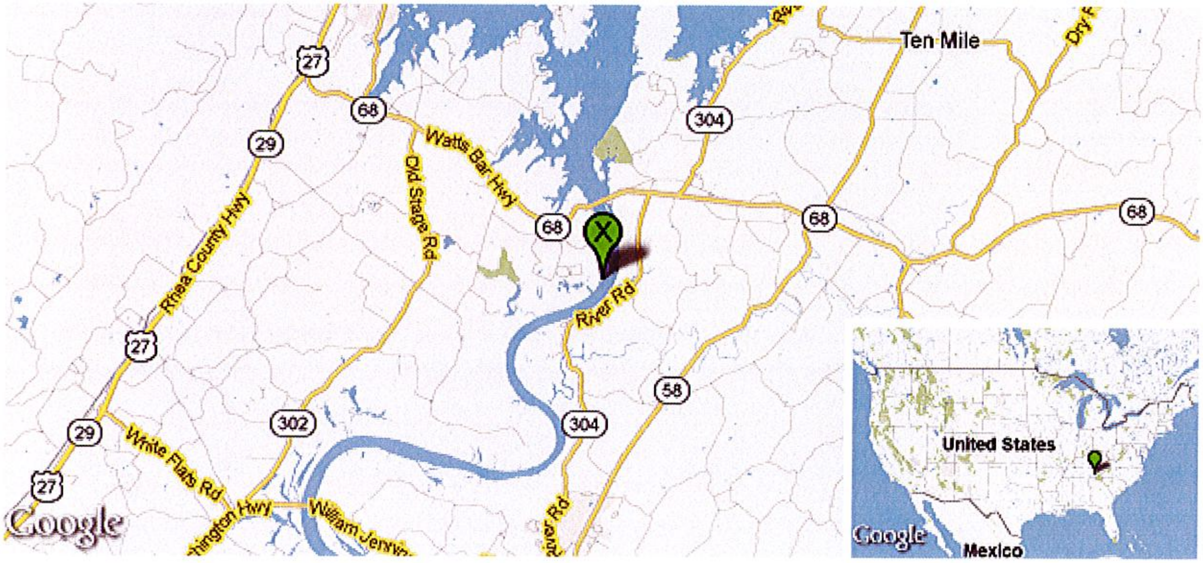
Building Code Reference Document 2006/2009 International Building Code
(which makes use of 2002 USGS hazard data)

Site Coordinates 35.6°N, 84.78°W

Site Soil Classification Site Class D – "Stiff Soil"

Occupancy Category Occupancy Category III

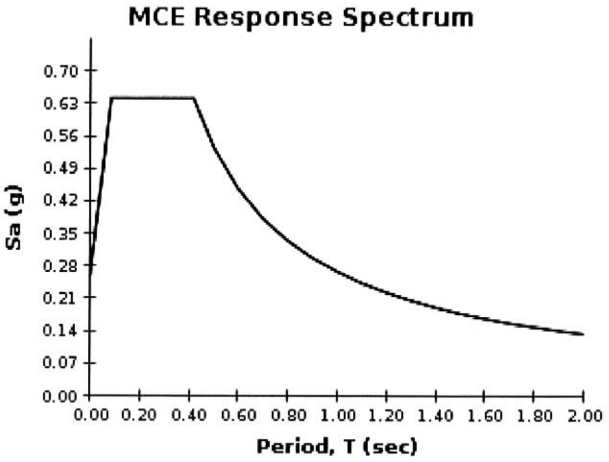
ok

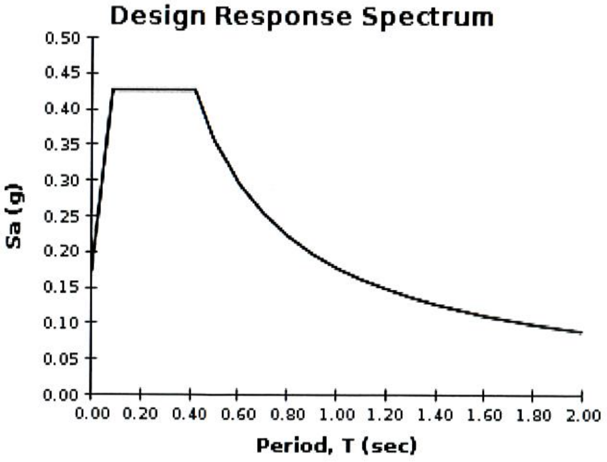


USGS–Provided Output

$S_S =$ 0.443 g
$S_{MS} =$ 0.641 g
$S_{DS} =$ 0.427 g

$S_1 =$ 0.114 g
$S_{M1} =$ 0.268 g
$S_{D1} =$ 0.178 g





Checked by dlf
8/17/12

USGS Design Maps Detailed Report

2006/2009 International Building Code (35.6°N, 84.78°W)

Section 1613.5.1 — Mapped acceleration parameters

Note: Maps in the 2006 and 2009 International Building Code are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 1613.5.3.

From Figure 1613.5(1)[1]	$S_S = 0.443$ g
From Figure 1613.5(2)[2]	$S_1 = 0.114$ g

Section 1613.5.2 — Site class definitions

SITE CLASS	SOIL PROFILE NAME	Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_S > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_S \le 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_S \le 2{,}500$	$\bar{N} > 50$	>2,000 psf
D	Stiff soil profile	$600 \le \bar{v}_S < 1{,}200$	$15 \le \bar{N} \le 50$	1,000 to 2,000 psf
E	Stiff soil profile	$\bar{v}_S < 600$	$\bar{N} < 15$	<1,000 psf
E	—	Any profile with more than 10 ft of soil having the characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \ge 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet)		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 1613.5.3 — Site coefficients and adjusted maximum considered earthquake spectral response acceleration parameters

TABLE 1613.5.3(1)
VALUES OF SITE COEFFICIENT F_a

Site Class	Mapped Spectral Response Acceleration at Short Period				
	$S_s \le 0.25$	$S_s = 0.5$	$S_s = 0.75$	$S_s = 1$	$S_s \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_s

For Site Class = D and S_s = 0.443 g, F_a = 1.445

TABLE 1613.5.3(2)
VALUES OF SITE COEFFICIENT F_v

Site Class	Mapped Spectral Response Acceleration at 1-s Period				
	$S_1 \le 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \ge 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight-line interpolation for intermediate values of S_1

For Site Class = D and S_1 = 0.114 g, F_v = 2.343

In the equations below, the equation number corresponding to the 2006 edition is listed first, and that corresponding to the 2009 edition is listed second.

Equation (16-37; 16-36): $S_{MS} = F_aS_S = 1.445 \times 0.443 = 0.641$ g

Equation (16-38; 16-37): $S_{M1} = F_vS_1 = 2.343 \times 0.114 = 0.268$ g

Section 1613.5.4 — Design spectral response acceleration parameters

Equation (16-39; 16-38): $S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3} \times 0.641 = 0.427$ g

Equation (16-40; 16-39): $S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3} \times 0.268 = 0.178$ g

Section 1613.5.6 — Determination of seismic design category

TABLE 1613.5.6(1)
SEISMIC DESIGN CATEGORY BASED ON SHORT-PERIOD RESPONSE ACCELERATION

VALUE OF S_{DS}	**OCCUPANCY CATEGORY**		
	I or II	**III**	**IV**
$S_{DS} < 0.167g$	A	A	A
$0.167g \leq S_{DS} < 0.33g$	B	B	C
$0.33g \leq S_{DS} < 0.50g$	C	C	D
$0.50g \leq S_{DS}$	D	D	D

For Occupancy Category = I and S_{DS} = 0.427 g, Seismic Design Category = C

TABLE 1613.5.6(2)
SEISMIC DESIGN CATEGORY BASED ON 1-SECOND PERIOD RESPONSE ACCELERATION

VALUE OF S_{D1}	**OCCUPANCY CATEGORY**		
	I or II	**III**	**IV**
$S_{D1} < 0.067g$	A	A	A
$0.067g \leq S_{D1} < 0.133g$	B	B	C
$0.133g \leq S_{D1} < 0.20g$	C	C	D
$0.20g \leq S_{D1}$	D	D	D

For Occupancy Category = I and S_{D1} = 0.178 g, Seismic Design Category = C

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is **E** for buildings in Occupancy Categories I, II, and III, and **F** for those in Occupancy Category IV, irrespective of the above.

Seismic Design Category ≡ "the more severe design category in accordance with Table 1613.5.6(1) or 1613.5.6(2)" = C

Note: See Section 1613.5.6.1 for alternative approaches to calculating Seismic Design Category.

References

1. *Figure 1613.5(1)*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/IBC-2006-Figure1613_5(01).pdf
2. *Figure 1613.5(2)*: http://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/IBC-2006-Figure1613_5(02).pdf

CDM Smith

CLIENT TVA
PROJECT Ash Pond Breaching Project
DETAIL Design Base Shear

JOB NO. 95618-92016
DATE CHECKED 8/17/12
CHECKED BY

COMPUTED BY PHS
DATE
PAGE NO. 1/

Determine Seismic Design Category per IBC 2006

Per IBC 2006 and Table 1613.5.2, the project site must be considered as class site "D".

Per USGS Seismic lookup for lat/long 35.611,-84.782:

ok

$S_s := 0.441$ $\quad$ $S_1 := .114$

Per Table 1613.5.3(1): $F_a := 1.448$ (linearly interpolated)

Per Table 1613.5.3(2): $F_v := 2.344$

$S_{ms} := F_a \cdot S_s$ $\quad$ $S_{ms} = 0.639$ $\quad$ (Eq16 − 37)

$S_{m1} := F_v \cdot S_1$ $\quad$ $S_{m1} = 0.267$ $\quad$ (Eq16 − 38)

$S_{DS} := \frac{2}{3} \cdot S_{ms}$ $\quad$ $S_{DS} = 0.426$ $\quad$ (Eq16 − 39)

$S_{D1} := \frac{2}{3} \cdot S_{m1}$ $\quad$ $S_{D1} = 0.178$ $\quad$ (Eq16 − 40)

Per Table 1613.5.1(1) for occupancy category III, The seismic design category based on Sds is "C".

Per Table 1613.5.1(2) for occupancy category III, the seismic design category based on Sd1 is "C".

Therefore, the structure must be designed per seismic design category "C".

$R_c := 1$	Response Modification Coefficient
$R_i := 2$	Response Modification Coefficient
$I := 1.25$	Importance Factor for Occupancy Category III
$C_i := S_{DS} = 0.426$	Seismic Response Coefficient, ACI
$T_L := 12s$	ASCE 7
$C_c := .053 = 0.053$	From calculation "Hydrodynamic Loads with Earthquake in Transverse Direction"
$\gamma_{conc} := 150pcf$	Weight of Concrete

Inlet Weir with Wingwall

$h_{wall} := 7.25ft$ Height of Weir Wall

$t_{wall} := 12in$ Thickness of weir wall

$toe := 12in$ Toe on wall

$l_{slab} := 34ft + 4in$ Length of slab

$w_{slab} := 22ft$ Width of slab

$t_{slab} := 14in$ Thickness of Slab

$h_{wingwall} := 13ft$ Total maximum height of Wingwall

$l_{wingwall} := 11.67ft$ Length of Wingwall

$$wall_{volume} := 2 \cdot l_{slab} \cdot h_{wall} \cdot t_{wall} + 2 \cdot w_{slab} \cdot h_{wall} \cdot t_{wall} + 2 \cdot 12.75ft \cdot t_{wall} \cdot 5.25ft = 950.708\ ft^3$$

$$wingwall_{volume} := 2 \cdot l_{wingwall} \cdot \left(h_{wingwall} \cdot t_{wall}\right) = 303.42\ ft^3$$

$$weight_{inletweir} := \gamma_{conc} \cdot \left(wall_{volume} + wingwall_{volume}\right) = 188.119 \cdot kip$$

$$P_i := C_i \cdot I \cdot \frac{weight_{inletweir}}{R_i} = 50.053 \cdot kip$$

$$P_c := C_c \cdot I \cdot \frac{weight_{inletweir}}{R_c} = 12.463 \cdot kip$$

$$V := \sqrt{P_i^2 + P_c^2} = 51.581 \cdot kip$$

Design Base Shear

Outlet End

$h_{wall} := 15.33ft$ Maximum Height of Wall

$l_{wingwall} := 21.5ft$ Length of Wingwall

$l_{wall} := 37.17ft$ Length of weir wall

$$wingwall_{volume} := \left(2 \cdot l_{wingwall} + l_{wall}\right) \cdot \left(h_{wingwall} \cdot t_{wall}\right) = 1.042 \times 10^3\ ft^3$$

$$weight_{outlet} := \gamma_{conc} \cdot wingwall_{volume} = 156.332 \cdot kip$$

$$P_i := C_i \cdot I \cdot \frac{weight_{outlet}}{R_i} = 41.595 \cdot kip$$

$$P_c := C_c \cdot I \cdot \frac{weight_{outlet}}{R_c} = 10.357 \cdot kip$$

$$V := \sqrt{P_i^2 + P_c^2} = 42.865 \cdot kip$$

Design Base Shear

HYDRODYNAMIC LOADS WITH EARTHQUAKE IN TRANSVERSE DIRECTION

GEOMETRIC PROPERTIES

H_L=	7.25	[ft]	Operating Height of Water
L=	36.17	[ft]	Tank Wall Length in Seismic Direction
B=	1	[ft]	Analyzed Width of Tank Wall
H_L/L=	0.20	[ft]	
L/2=	18.085	[ft]	Half of wall length
t_w=	1	[ft]	Wall thickness

MATERIAL PROPERTIES

γ_c=	150	[pcf]	Concrete unit weight
f'_c=	4500	[psi]	Compressive Strength
$E_c=57000*(f'_c)^{0.5}$=	3824	[ksi]	Elastic Modulus
γ_L=	62.4	[pcf]	Water unit weight

GEOMETRIC CALCULATIONS

$W_L=B*L*H_L*\gamma_L$=	16.4	[k]	Fluid Weight

EQUIVALENT WEIGHTS OF ACCEL. LIQUID

$$\frac{W_i}{W_L}=\frac{\tanh[\,0.866(\frac{L}{H_L})]}{0.866(\frac{L}{H_L})}= \quad 0.231$$

ACI 350.3-06 Eq 9-1

$$\frac{W_c}{W_L}=0.264(\frac{L}{H_L})\tanh[\,3.16(\frac{H_L}{L})]= \quad 0.738$$

ACI 350.3-06 Eq 9-2

HEIGHTS TO COG EBP

$$\frac{h_i}{H_L}=\left\{\begin{matrix}\frac{L}{H_L}<1.333\rightarrow\frac{h_i}{H_L}=0.5-0.09375\left(\frac{L}{H_L}\right)\\ \frac{L}{H_L}\geq 1.333\rightarrow\frac{h_i}{H_L}=0.375\end{matrix}\right\}= \quad 0.3750$$

ACI 350.3-06 Eq 9-3 and 9-4

$$\frac{h_c}{H_L}=1-\frac{\cosh\left[3.16\left(\frac{H_L}{L}\right)\right]-1}{3.16\left(\frac{H_L}{L}\right)\sinh\left[3.16\left(\frac{H_L}{L}\right)\right]}= \quad 0.52$$

ACI 350.3-06 Eq 9.5

HEIGHTS TO COG IBP

$$\frac{h_i'}{H_L}=\begin{cases}\frac{L}{H_L}<0.75\rightarrow\frac{h_i'}{H_L}=0.45\\ \frac{L}{H_L}\geq 0.75\rightarrow\frac{h_i'}{H_L}=\dfrac{0.866\left(\frac{L}{H_L}\right)}{2\tanh\left[0.866\left(\frac{L}{H_L}\right)\right]}-\frac{1}{8}\end{cases}= \quad 2.04$$

ACI 350.3-06 Eq 9-6 and 9-7

$$\frac{h_c'}{H_L}=1-\frac{\cosh\left[3.16\left(\frac{H_L}{L}\right)\right]-2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left[3.16\left(\frac{H_L}{L}\right)\right]}= \quad 2.87$$

ACI 350.3-06 Eq 9-8

DYNAMIC PROPERTIES

$$\lambda=\sqrt{3.16g\tanh\left[3.16\left(\frac{H_L}{L}\right)\right]}= \quad 7.55\ (\mathrm{ft/s^2})^{1/2}$$

ACI 350.3-06 Eq 9-13

$$\omega_c=\frac{\lambda}{\sqrt{L}}= \quad 1.256\ [\mathrm{Hz}]$$

ACI 350.3-06 Eq 9-12

$$Tc=\frac{2\pi}{\omega_c}= \quad 5.004\ [\mathrm{sec}]$$

ACI 350.3-06 Eq 9-14

SEISMIC DESIGN INFORMATION

$S_{DS}=$	0.43	Short period code spectra acceleration
$S_{D1}=$	0.18	1-sec period code spectra acceleration
$T_s = S_{D1}/S_{DS} =$	0.42	ACI 350.3-06 Eq 9-34
$R_i=$	2.00	ACI 350.3-06 Table 4.1.1(b)
$R_c=$	1.00	ACI 350.3-06 Table 4.1.1(b)
I=	1.25	ACI 350.3-06 Table 4.1.1(a)
$T_L=$	12.00 sec	ASCE 7-10 Fig 22-12

SEISMIC RESPONSE COEFFICIENTS

$C_i=S_{DS}=$	0.43	ACI 350.3-06 Eq 9-32 (conservative)
$C_c=$	0.053	ACI 350.3-06 Eq. 9-37
$C_t=0.4S_{DS}=$	0.1704	ACI 350.3-06 Sec 9.4.3

EFFECTIVE MASS COEFFICIENT ε

$$\varepsilon=\left[0.0151*\left(\frac{L}{H_L}\right)^2-0.1908*\left(\frac{L}{H_L}\right)+1.021\right]\leq 1.0= \quad 0.44$$

ACI 350.3-06 Eq 9-44

VERTICAL ACCELERATION

$$\ddot{u}_V = Sav \cdot \left[\frac{I}{R_i} \right] \geq 0.2 S_{DS} =$$ 0.085 ACI 350.3-06 Eq 4-15

$$q_{hy} = \gamma_{fluid} H_L =$$ 0.452 [ksf] Lateral static pressure of fluid

$$p_{vy} = \ddot{u}_V q_{hy} =$$ 0.039 [ksf] ACI 350.3-06 Eq 4-14

DYNAMIC LATERAL FORCES

$$P_i = C_i I \left[\frac{W_i}{R_i} \right] =$$ 1.008 [k] ACI 350.3-06 Eq 4-3

$$P_C = C_C I \left[\frac{W_C}{R_C} \right] =$$ 0.81 [k] ACI 350.3-06 Eq 4-4

IMPULSIVE

$$q_{i\_top} = \frac{\frac{P_i}{2}\left[4 * H_L - 6 * h_i - (6 * H_L - 12 * h_i) * 1\right]}{H_L^2} =$$ 0.017 ksf

$$q_{i\_bot} = \frac{\frac{P_i}{2}\left[4 * H_L - 6 * h_i - (6 * H_L - 12 * h_i) * 0\right]}{H_L^2} =$$ 0.122 ksf

CONVECTIVE

$$q_{c\_top} = \frac{\frac{P_C}{2}\left[4 * H_L - 6 * h_C - (6 * H_L - 12 * h_C) * 1\right]}{H_L^2} =$$ 0.061 ksf

$$q_{C\_bot} = \frac{\frac{P_C}{2}\left[4 * H_L - 6 * h_C - (6 * H_L - 12 * h_C) * 0\right]}{H_L^2} =$$ 0.050 ksf

FREE BOARD PER ACI350.3

Cc = 0.04083 ACI 9-37, 9-38

$$d_{\max} = \frac{L}{2} C_c I =$$ 0.92 ft

Minimum 12 Inches Freeboard Required

Wall Weight	0.15 ksf
Wall Impulsive	0.018 ksf

CDM Smith

CLIENT	TVA	COMPUTED BY / DATE	PHS	08/16/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	dlg	8/17/12
DETAIL	Cast In Place Concrete Design-Inlet	REVISION NO. / DATE	-0	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	-	-

Calculation Description: Cast In Place Concrete Design - Inlet Structure

---

1.0 Objective

Design all cast in place concrete inlet structure to be able to handle applied loads.

2.0 Procedure

1.) Determine loads applied to all walls (wingwall and weir), beams, columns. Including seismic, fluid/earth lateral load, pedestrian live load (on rail), HS-20 Vehicle Live Load surcharge, Soil Vertical Pressure, and Self-weight of concrete.
2.) Calculate applied moments and shears using AASHTO load combinations.
3.) Calculate flexural (moment) and shear capacities of walls (wingwall and weir), beams, and columns.
4.) Check overturning, sliding, and bearing for the wingwalls.
4.) Check torsion requirements for beams.
5.) Check all capacity/applied ratios are less than 1.
6.) Check Buoyancy for Inlet Structure

3.0 References / Data Sources

1.) ASCE 7
2.) IBC 2006
3.) ACI 318

4.0 Assumptions / Limitations

1.) Wingwalls are designed as cantilevered retaining walls at maximum height.
2.) Inlet weir structure designed as cantilevered wall, does not meet requirements to design as panel.

5.0 Calculations

5.1 Weir Wall

- Refer to Mathcad spreadsheet "Inlet Weir-Wall" for full design calculations.

5.2 Wingwall

- Refer to RetainPro Output Titled "Inlet Stem Wall" for full design calculations (including stability requirements) and wall diagrams.

5.3 Column Between Box Culverts

- Refer to Enercalc output "Concrete Column at inlet weir between box culverts" for full design calculations and wall diagrams.

5.4 Beam Above Box Culverts

- Refer to Enercalc output "Beam between culverts - vertical load on beam" and "Beam between culverts - horizontal load on beam" and Mathcad spreadsheet "Beam between inlet culverts" for full design calculations and diagrams.

5.5 Buoyancy Calculations

- Refer To excel spreadsheet "Buoyancy Check for Rectangular Tanks"

6.0 Conclusions

- The weir wall and wingwall are 12" thick, with max heights of 7'-3" and reinforcing of #6 @ 6inches on center, each way, each face. The wingwall requires a 4'-6" heel and toe, and a 4'-6" key to meet stability requirements.

- The columns between culverts are also 12" thick, and 26" wide, with #6 @ 6inches on center, each way, each face.

- The beams above the culverts are 12" wide, with reinforcing #6 @ 6inches on center, each way, each face.

CDM Smith

Project Name : TVA
Project Number: 95618-92016
Subject : Inlet Weir-Wall

Calculations By: PHS
Checked By :
Date : 8-17-12

LIMITATIONS : This program should only be used with a full knowledge of the analysis procedure used in the program. Result of the program is subject to structural engineering evaluation and judgment. This program is for the use of CDM Structural Engineering Staff Only.

CANTILEVER WALL DESIGN - SINGLE DOWEL

This program analyzes the main reinforcement of a cantilever retaining wall which utilizes a standard reinforcement layout. The standard layout is comprised of vertical bars at 6" oc and dowels at 6" oc. The program also checks the shear capacity of the stem. This reinforcement layout is considered to be economical for wall heights less than 12' for water loading and less than 10' for earth loading.

User Input

>> Wall Height - Range: $h := 0..7.25$ ft
>> Wall Height - Max : $hmax := 7.25$ ft

>> Wall Thickness $hw := 12$ inches

>> Fluid Density (*) $\gamma := 90$ psf
>> Lateral Load Factor $LF := 1.69$
>> Durability Factor (dowel) $S_{D\_d} := 1.0$

>> Durability Factor (vert): $S_{D\_v} := 1.0$

(*)- 63 pcf for water, 90 to 120 pcf for earth fill

>> Concrete Strength $fc := 4500$ psi
>> Steel Strength $fy := 60000$ psi
>> Concrete Cover $c := 2.0$ inches
>> Vehicle Lateral Live Loa $VL := 120$ psf
Earth Surcharge Factor $ES := 2.17$

>> Seismic Lateral Load $SL := 40$ psf
$EQ := 1.0$ Vehicle Surcharge governs, Seismic not used

Flexural Analysis

Procedure

Revise Dowel and Vertical Bar Sizes such that Moment Capacity (ϕMn) > Factored Moment (Mu). Note: Std Dowel Spacing is 6" and Vertical Spacing is 6".

Select Reinforcement Sizes

>>Dowel Size / Area $\phi d := 6$ $Ad := (\phi d \cdot 0.125)^2 \cdot \frac{\pi}{4} \cdot 2$ $Ad = 0.884$ sq.in/ft

>>Vert. Size $\phi v := 6$ $Av := (\phi v \cdot 0.125)^2 \cdot \frac{\pi}{4} \cdot 2$ $Av = 0.884$ sq.in/ft

Effective Depth Dowels : $dd := (hw - c) - (0.5 \cdot \phi d \cdot .125)$

$dd = 9.625$ inches

Effective Depth Verticals : $dv := (hw - c) - (0.5 \cdot \phi v \cdot .125)$

$dv = 9.625$ inches

Check Min. Steel Ratio

Steel Ratio Dowels : $\rho d := \frac{Ad}{(12 \cdot dd)}$ $\rho d = 0.00765$ $Cd := \text{if}\left(\rho d \ge 0.003, 1, \frac{1}{1.33}\right)$

Steel Ratio Verticals: $\rho v := \frac{Av}{(12 \cdot dv)}$ $\rho v = 0.00765$ $Cv := \text{if}\left(\rho v \ge 0.003, 1, \frac{1}{1.33}\right)$

$Cd = 1$ $Cv = 1$

Moment Capacity

Moment Capacity -Dowels $\phi Md(h) := \frac{0.9 \cdot Ad \cdot fy}{12000} \cdot \left[dv - \frac{Ad \cdot fy}{2 \cdot 12 \cdot (0.85 \cdot fc)}\right] \cdot Cd$ kip-ft (Eqn 3)

$\phi Md(1) = 35.974$ kip-ft

Moment Capacity - Verticals $\phi Mv(h) := \frac{0.9 \cdot Av \cdot fy}{12000} \cdot \left[dv - \frac{Av \cdot fy}{2 \cdot 12 \cdot (0.85 \cdot fc)}\right] \cdot Cv$ kip-ft (Eqn 4)

$\phi Mv(1) = 35.974$ kip-ft

Redefine Moment Capacity of Verticals as a scalar value (ϕMv1)

Moment Capacity - Verticals $\phi Mv1 := \phi Mv(1)$ kip-ft (Eqn 5)

Substitute Eqn 5 into Eqn 1 to calculate h (h1) the point at which moment capacity of verticals equal to applied Factored Moment

$$h1 := \left[\frac{\phi Mv1 \cdot 1000}{\frac{1}{6} \cdot \left(LF \cdot S_{D\_v} \cdot \gamma\right) + \frac{1}{2}\left(VL \cdot ES \cdot S_{D\_v}\right)}\right]^{0.33333} \qquad h1 = 6.138 \text{ ft}$$

Projection Length of Loaded Face Dowels : $pl := hmax - h1 + \frac{dv}{12}$ $pl = 1.914$ ft

Dowel Development Length
(Per ACI-318 12.2.2)

$$Ld := if\left[\phi d > 6, 0.05\cdot\phi d\cdot 0.125\cdot\frac{fy}{\sqrt{fc}}\cdot\left(\frac{1}{12}\right), 0.04\cdot\phi d\cdot 0.125\cdot\frac{fy}{\sqrt{fc}}\cdot\left(\frac{1}{12}\right)\right]$$ $Ld = 2.236$ ft

Check if pl>Ld $pl := (if(Ld > pl, Ld, pl))$ $pl = 2.236$

Moments and Shears

Factored Moment (dowel) : $Mu_d(h) := \frac{1}{6\cdot 1000}\cdot\left(LF\cdot S_{D\_d}\cdot\gamma\cdot h^3\right) + \frac{1}{2\cdot 1000}\left(VL\cdot ES\cdot h^2\right)$ kip-ft (Eqn 1)

Max. Factored Moment (dowel): $Mu_d(hmax) = 16.504$

Factored Moment (vert) : $Mu_v(h) := \frac{1}{6\cdot 1000}\cdot\left(LF\cdot S_{D\_v}\cdot\gamma\cdot h^3\right) + \frac{1}{2\cdot 1000}\left(VL\cdot ES\cdot h^2\right)$ kip-ft (Eqn 1)

Max. Factored Moment (vert): $Mu_v\left(h1 - \frac{dv}{12}\right) = 7.558$

Factored Shear : $Vu(h) := \frac{1}{2\cdot 1000}\cdot\left(LF\cdot\gamma\cdot h^2\right) + \frac{1}{1000}(VL\cdot ES\cdot h)$ kips (Eqn 2)

Max. Factored Shear : $Vu(hmax) = 5.885$ kips

Check Moment Capacities

Moment Capacity - Dowels $\phi Md(hmax) = 35.974$ kip-ft

Moment Capacity - Verticals at Dowel Cutoff Poin $\phi Mv\left(h1 - \frac{dv}{12}\right) = 35.974$ kip-ft

Moment Capacity Ratio - Dowels $\frac{Mu_d(hmax)}{\phi Md(hmax)} = 0.459$ OK if <1
Increase As if>1

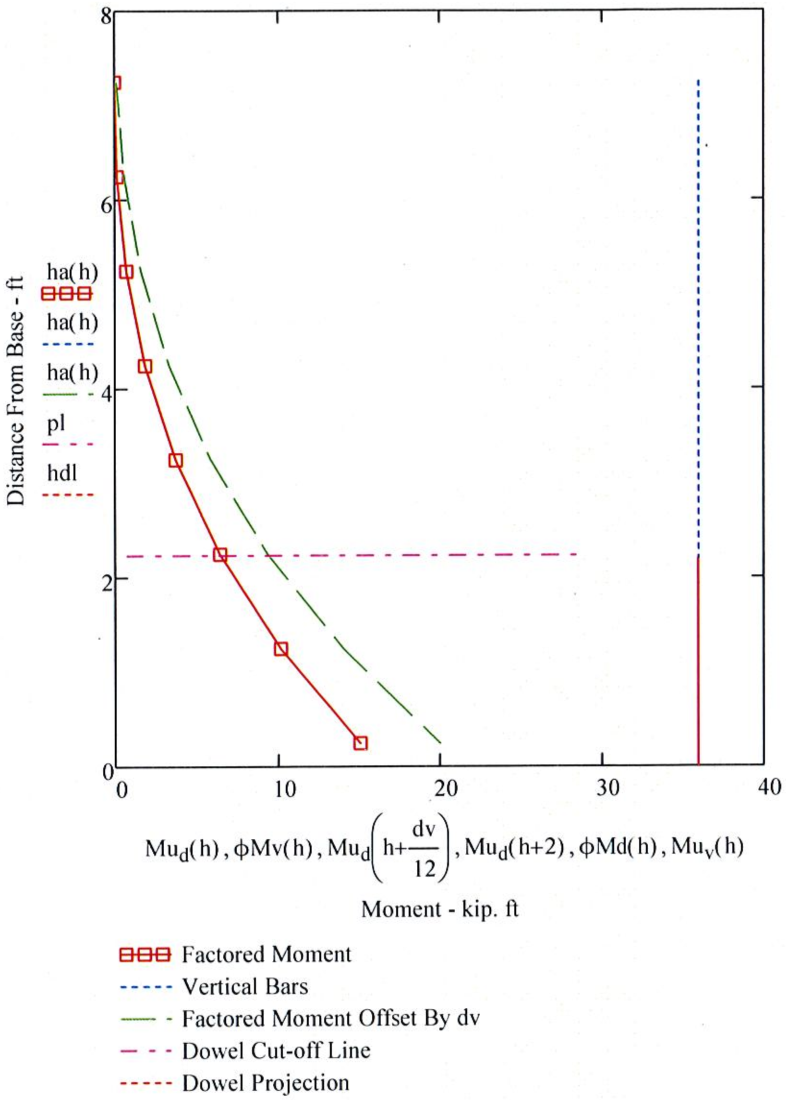
Moment Capacity Ratio - Verticals $\frac{Mu_v\left(h1 - \frac{dv}{12}\right)}{\phi Mv1} = 0.21$ OK if <1
Increase As if>1

Shear Capacity $\phi Vn := \frac{0.85\cdot 12\cdot dd\cdot 2\cdot\sqrt{fc}}{1000}$ $\phi Vn = 13.172$ kips

Shear Capacity Ratio $\frac{Vu(hmax)}{\phi Vn} = 0.447$

Following variables are defined to facilitate graphing

- Variable change $ha(h) := hmax - h$
- Dowel Proj. Range Variable $hdl := 0, 0.1 .. pl$ $pl = 2.236$



Design Summary

- Wall Thickness $hw = 12$ inches - Dowel Size $\phi d = 6$
- Verticals Size $\phi v = 6$ - Dwl Proj. $pl = 2.236$ ft

CDM Smith
2301 Maitland Center Parkway
Maitland, FL 32751

Title : **Inlet Stem wall**
Job # : **TVA Watts** Dsgnr: **PHS**
Description....

dlf 8/17/2012

Page: ______
Date: **JUL 31,2012**

This Wall in File: T:\STRU\PHS\tva\TVA INLET WING WALL.

Retain Pro 9 © 1989 - 2011 Ver: 9.19 8152
Registration #: RP-1190655 RP9.19
Licensed to: CDM - TRACIE VANN

Cantilevered Retaining Wall Design

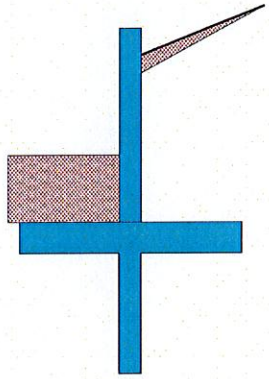
Code: AASHTO LRFD

Criteria

Retained Height = 6.25 ft
Wall height above soil = 1.00 ft
Slope Behind Wall = 3.00 : 1
Height of Soil over Toe = 30.00 in
Water height over heel = 0.0 ft

Soil Data

Allow Soil Bearing = 2,000.0 psf
Equivalent Fluid Pressure Method
Heel Active Pressure = 90.0 psf/ft
Toe Active Pressure = 30.0 psf/ft
Passive Pressure = 300.0 psf/ft
Soil Density, Heel = 120.00 pcf
Soil Density, Toe = 120.00 pcf
Footing||Soil Friction = 0.400
Soil height to ignore for passive pressure = 12.00 in



Thumbnail

Surcharge Loads

Surcharge Over Heel = 240.0 psf
NOT Used To Resist Sliding & Overturning
Surcharge Over Toe = 0.0 psf
NOT Used for Sliding & Overturning

Axial Load Applied to Stem

Axial Dead Load = 0.0 lbs
Axial Live Load = 0.0 lbs
Axial Load Eccentricity = 0.0 in

Lateral Load Applied to Stem

Lateral Load = 0.0 #/ft
...Height to Top = 0.00 ft
...Height to Bottom = 0.00 ft
The above lateral load has been increased by a factor of 1.60

Wind on Exposed Stem = 50.0 psf

Adjacent Footing Load

Adjacent Footing Load = 0.0 lbs
Footing Width = 0.00 ft
Eccentricity = 0.00 in
Wall to Ftg CL Dist = 0.00 ft
Footing Type Line Load
Base Above/Below Soil at Back of Wall = 0.0 ft
Poisson's Ratio = 0.300

Design Summary

Wall Stability Ratios
Overturning = 2.76 OK
Sliding = 2.54 OK

Total Bearing Load = 8,643 lbs
...resultant ecc. = 15.55 in

Soil Pressure @ Toe = 1,536 psf OK
Soil Pressure @ Heel = 192 psf OK
Allowable = 2,000 psf
Soil Pressure Less Than Allowable
ACI Factored @ Toe = 2,151 psf
ACI Factored @ Heel = 269 psf

Footing Shear @ Toe = 30.4 psi OK
Footing Shear @ Heel = 37.0 psi OK
Allowable = 100.6 psi

Sliding Calcs (Vertical Component NOT Used)
Lateral Sliding Force = 5,232.8 lbs
less 100% Passive Force = - 9,854.2 lbs
less 100% Friction Force = - 3,457.0 lbs

Added Force Req'd = 0.0 lbs OK
....for 1.5 : 1 Stability = 0.0 lbs OK

Stem Construction

			Top Stem	**2nd**
			Stem OK	Stem OK
Design Height Above Ftg	ft	=	3.33	0.00
Wall Material Above "Ht"		=	Concrete	Concrete
Thickness		=	12.00	12.00
Rebar Size		=	# 6	# 6
Rebar Spacing		=	6.00	6.00
Rebar Placed at		=	Edge	Edge
Design Data				
fb/FB + fa/Fa		=	**0.060**	**0.347**
Total Force @ Section	lbs	=	1,601.7	4,778.5
Moment....Actual	ft-#	=	2,150.3	12,437.1
Moment.....Allowable	ft-#	=	35,830.5	35,830.5
Shear.....Actual	psi	=	14.2	41.7
Shear.....Allowable	psi	=	100.6	100.6
Wall Weight	psf	=	150.0	150.0
Rebar Depth 'd'	in	=	9.63	9.63
LAP SPLICE IF ABOVE	in	=	12.00	12.00
LAP SPLICE IF BELOW	in	=	12.00	
HOOK EMBED INTO FTG	in	=		9.39
Lap splice above base reduced by stress ratio				
Masonry Data				
f'm	psi	=		
Fs	psi	=		
Solid Grouting		=		
Modular Ratio 'n'		=		
Short Term Factor		=		
Equiv. Solid Thick.		=		
Masonry Block Type		=	Medium Weight	
Masonry Design Method		=	ASD	
Concrete Data				
f'c	psi	=	4,500.0	4,500.0
Fy	psi	=	60,000.0	60,000.0

Load Factors

Building Code	AASHTO LRFD
Dead Load	1.300
Live Load	2.170
Earth, H	1.690
Wind, W	1.300
Seismic, E	1.000

Cantilevered Retaining Wall Design

Code: AASHTO LRFD

Footing Dimensions & Strengths

Toe Width	=	4.50 ft
Heel Width	=	5.50
Total Footing Width	=	10.00
Footing Thickness	=	14.00 in
Key Width	=	12.00 in
Key Depth	=	54.00 in
Key Distance from Toe	=	4.50 ft

f'c = 4,500 psi Fy = 60,000 psi
Footing Concrete Density = 150.00 pcf
Min. As % = 0.0018
Cover @ Top 2.00 @ Btm.= 3.00 in

Footing Design Results

		Toe	Heel
Factored Pressure	=	2,151	269 psf
Mu' : Upward	=	18,918	5,583 ft-#
Mu' : Downward	=	6,733	18,920 ft-#
Mu: Design	=	12,185	13,336 ft-#
Actual 1-Way Shear	=	30.43	36.98 psi
Allow 1-Way Shear	=	100.62	100.62 psi

Toe Reinforcing = # 6 @ 15.25 in
Heel Reinforcing = # 6 @ 6.00 in
Key Reinforcing = # 6 @ 0.00 in

Other Acceptable Sizes & Spacings

Toe: #4@ 7.00 in, #5@ 10.75 in, #6@ 15.25 in, #7@ 20.75 in, #8@ 27.25 in, #9@ 34
Heel: #4@ 7.00 in, #5@ 10.75 in, #6@ 15.25 in, #7@ 20.75 in, #8@ 27.25 in, #9@ 34
Key: #4@ 12.50 in, #5@ 19.25 in, #6@ 27.25 in, #7@ 37.25 in,

Summary of Overturning & Resisting Forces & Moments

.....OVERTURNING.....

Item		Force lbs	Distance ft	Moment ft-#
Heel Active Pressure	=	3,577.8	2.97	10,634.1
Surcharge over Heel	=	1,605.0	4.46	7,155.6
Toe Active Pressure	=			
Surcharge Over Toe	=			
Adjacent Footing Load	=			
Added Lateral Load	=			
Load @ Stem Above Soil	=	50.0	7.92	395.8
Total	=	5,232.8	**O.T.M.** =	18,185.5

Resisting/Overturning Ratio = **2.76**
Vertical Loads used for Soil Pressure = 8,642.5 lbs

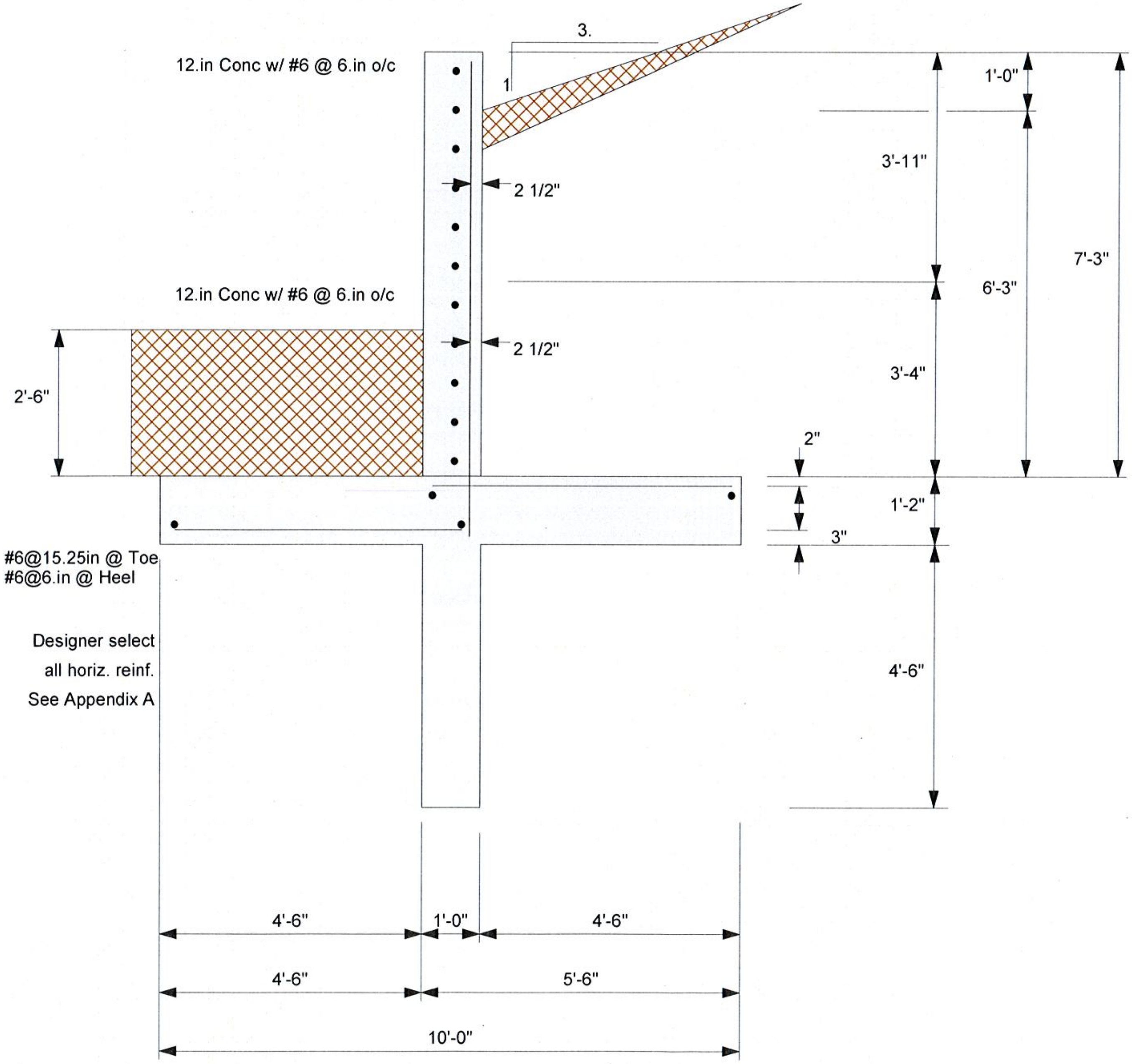
Vertical component of active pressure NOT used for soil pressure

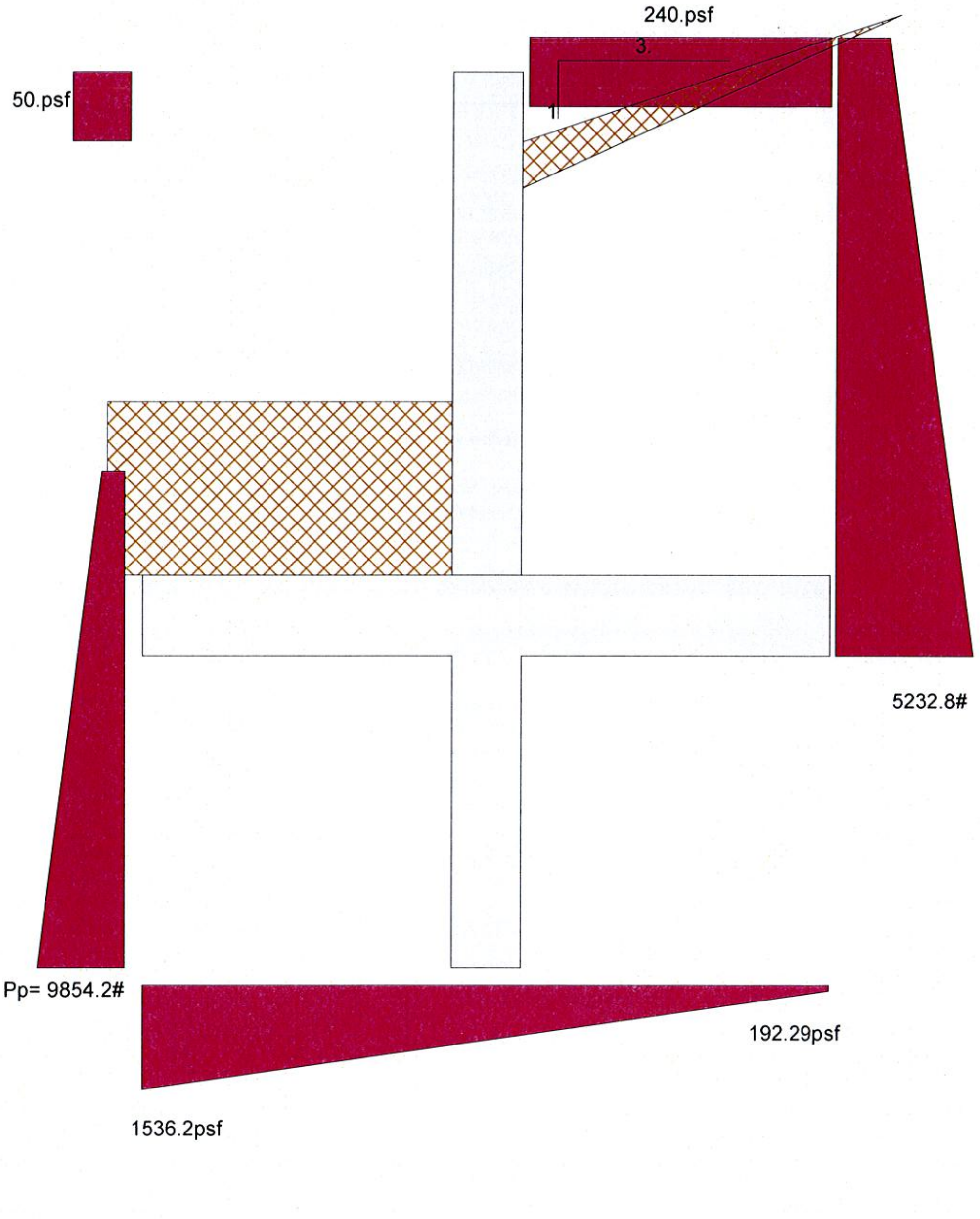
.....RESISTING.....

		Force lbs	Distance ft	Moment ft-#
Soil Over Heel	=	3,375.0	7.75	26,156.3
Sloped Soil Over Heel	=	405.0	8.50	3,442.5
Surcharge Over Heel	=			
Adjacent Footing Load	=			
Axial Dead Load on Stem	=			
* Axial Live Load on Stem	=			
Soil Over Toe	=	1,350.0	2.25	3,037.5
Surcharge Over Toe	=			
Stem Weight(s)	=	1,087.5	5.00	5,437.5
Earth @ Stem Transitions	=			
Footing Weight	=	1,750.0	5.00	8,750.0
Key Weight	=	675.0	5.00	3,375.0
Vert. Component	=			
Total =		8,642.5 lbs	**R.M.=**	50,198.8

* Axial live load NOT included in total displayed, or used for overturning resistance, but is included for soil pressure calculation.

DESIGNER NOTES:


3.
1
12.in Conc w/ #6 @ 6.in o/c
1'-0"
3'-11"
7'-3"
2 1/2"
12.in Conc w/ #6 @ 6.in o/c
6'-3"
2 1/2"
2'-6"
3'-4"
2"
1'-2"
3"
#6@15.25in @ Toe
#6@6.in @ Heel
Designer select
all horiz. reinf.
See Appendix A
4'-6"
4'-6"
1'-0"
4'-6"
4'-6"
5'-6"
10'-0"


240.psf
3.
1
50.psf
5232.8#
Pp= 9854.2#
192.29psf
1536.2psf

Concrete Column

File: T:\STRU\PHS\tva\Inlet Weir Wall Col and Beams.ec6
ENERCALC, INC. 1983-2011, Build:6.12.6.7, Ver:6.2.00.0

Lic. # : KW-06007264 **Licensee : cdm**

Description : Concrete Column at inlet weir between box culverts

df 8/17/2012

Code References

Calculations per ACI 318-05, IBC 2006, CBC 2007, ASCE 7-05
Load Combinations Used : 2006 IBC & ASCE 7-05

General Information

f'c : Concrete 28 day strength = 4.50 ksi
E = = 3,122.0 ksi
Density = 145.0 pcf
β = 0.8250
fy - Main Rebar = 60.0 ksi
E - Main Rebar = 29,000.0 ksi
Allow. Reinforcing Limits *ASTM A615 Bars Used*
Min. Reinf. = 1.0 %
Max. Reinf. = 8.0 %
Load Combination :2006 IBC & ASCE 7-05

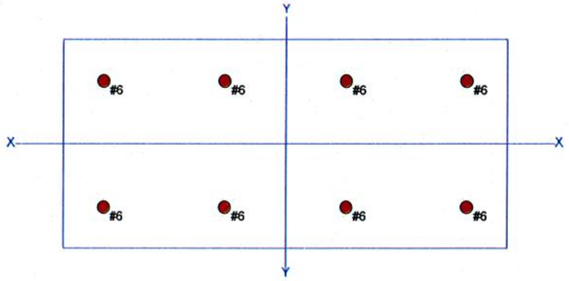
Overall Column Height = 4.0 ft
End Fixity Top Pinned, Bottom Fixed

Brace condition for deflection (buckling) along columns :
X-X (width) axis : Fully braced against buckling along X-X Axis
Y-Y (depth) axis :Fully braced against buckling along Y-Y Axis

Column Cross Section

Column Dimensions :12.0in high x 26.0in Wide, Column Edge to Rebar Edge Cover = 2.0in

Column Reinforcing : 4 - #6 bars @ corners,, 2 - #6 bars top & bottom between corner bars



Applied Loads

Entered loads are factored per load combinations specified by user.

Column self weight included : 1,256.67 lbs * Dead Load Factor
AXIAL LOADS . . .
Axial Load at 4.0 ft above base, D = 2.20, L = 1.20 k
BENDING LOADS . . .
from beams: Lat. Point Load at 4.0 ft creating My-y, L = 1.20 k

DESIGN SUMMARY

Load Combination +1.30D+2.170L
Location of max.above base 3.973 ft

Maximum Stress Ratio **0.009807 : 1**

Ratio = (Pu^2+Mu^2)^.5 / (PhiPn^2+PhiMn^2)^.5

Pu =	7.098 k	φ * Pn =	723.39 k
Mu-x =	0.0 k-ft	φ * Mn-x =	0.0 k-ft
Mu-y =	0.0 k-ft	φ * Mn-y =	0.0 k-ft
Mu Angle =	270.0 deg		
Mu at Angle =	0.0 k-ft	φMn at Angle =	1.814 k-ft

Pn & Mn values located at Pu-Mu vector intersection with capacity curve

Column Capacities . . .

Pnmax : Nominal Max. Compressive Axial Capacity	1,391.14 k
Pnmin : Nominal Min. Tension Axial Capacity	-211.20 k
φ Pn, max : Usable Compressive Axial Capacity	723.39 k
φ Pn, min : Usable Tension Axial Capacity	-137.280 k

Maximum SERVICE Load Reactions . .

Top along Y-Y	0.0 k	Bottom along Y-Y	0.0 k
Top along X-X	0.0 k	Bottom along X-X	0.0 k

Maximum SERVICE Load Deflections . . .

Along Y-Y 0.0 in at 0.0 ft above base
for load combination :
Along X-X 0.0 in at 0.0 ft above base
for load combination :

General Section Information . φ = 0.650 β = 0.8250 θ = 0.80

ρ : % Reinforcing	1.128 %	Rebar % Ok
Reinforcing Area	3.520 in^2	
Concrete Area	312.0 in^2	

Description : Concrete Column at inlet weir between box culverts

Governing Load Combination Results

Governing Factored Load Combination	Dist. from base ft	Axial Load k Pu	φ * Pn	Bending Analysis k-ft δ x	δ x * Mux	δ y	δy * Muy	Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.30D+2.170L	3.97	7.10	723.39	1.000		1.000	-0.00	270.000	0.00	1.81	**0.010**

Maximum Reactions - Unfactored

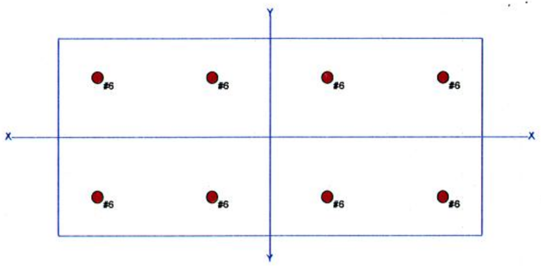
Note: Only non-zero reactions are listed.

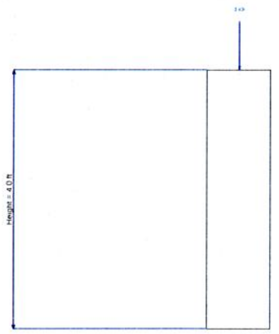
Load Combination	Reaction along X-X Axis @ Base	@ Top	Reaction along Y-Y Axis @ Base	@ Top	Axial Reaction @ Base
D Only		k		k	3.457 k
L Only		k	0.000	0.000 k	1.200 k
D+L		k	0.000	0.000 k	4.657 k

Maximum Deflections for Load Combinations - Unfactored Loads

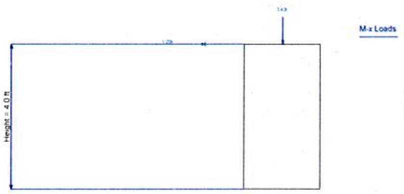
Load Combination	Max. X-X Deflection		Distance		Max. Y-Y Deflection		Distance	
D Only	0.0000	in	0.000	ft	0.000	in	0.000	ft
L Only	0.0000	in	0.000	ft	0.000	in	0.000	ft
D+L	0.0000	in	0.000	ft	0.000	in	0.000	ft

Sketches



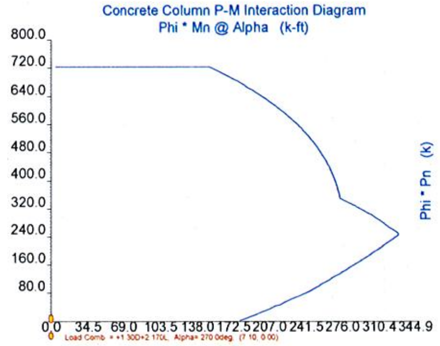


Looking along X-X Axis



Looking along Y-Y Axis

Interaction Diagrams



Concrete Beam

Description : Beam between culverts- vertical load on beam

df 8/17/2012

CODE REFERENCES

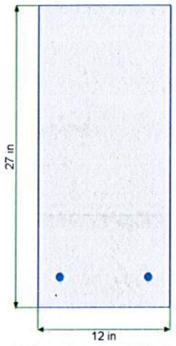
Calculations per ACI 318-05, IBC 2006, CBC 2007, ASCE 7-05
Load Combination Set : 2006 IBC & ASCE 7-05

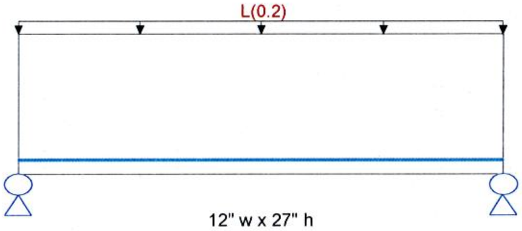
Material Properties

f'c = 4.50 ksi
fr = $f'c^{1/2}$ * 7.50 = 503.12 psi
ψ Density = 150.0 pcf
λ LtWt Factor = 1.0
Elastic Modulus = 3,823.68 ksi
fy - Main Rebar = 60.0 ksi
E - Main Rebar = 29,000.0 ksi

ϕ Phi Values Flexure : 0.90
Shear : 0.750
β_1 = 0.8250
Fy - Stirrups 60.0 ksi
E - Stirrups = 29,000.0 ksi
Stirrup Bar Size # = # 3
Number of Resisting Legs Per Stirrup = 2

Load Combination 2006 IBC & ASCE 7-05





Cross Section & Reinforcing Details

Rectangular Section, Width = 12.0 in, Height = 27.0 in
Span #1 Reinforcing....
2-#6 at 2.750 in from Bottom, from 0.0 to 6.0 ft in this span

Applied Loads

Service loads entered. Load Factors will be applied for calculations.

Beam self weight calculated and added to loads
Load for Span Number 1
Uniform Load : L = 0.20 k/ft, Tributary Width = 1.0 ft, (Live)

DESIGN SUMMARY

Design OK

Maximum Bending Stress Ratio =	**0.042** : 1	
Section used for this span	**Typical Section**	
Mu : Applied	3.927	k-ft
Mn * Phi : Allowable	93.752	k-ft
Load Combination	+1.30D+2.170L+1.60H	
Location of maximum on span	3.000	ft
Span # where maximum occurs	Span # 1	

Maximum Deflection			
Max Downward L+Lr+S Deflection	0.000 in	Ratio =	0 <360
Max Upward L+Lr+S Deflection	0.000 in	Ratio =	0 <360
Max Downward Total Deflection	0.000 in	Ratio =	999 <180
Max Upward Total Deflection	0.000 in	Ratio =	999 <180

Vertical Reactions - Unfactored

Support notation : Far left is #1

Load Combination	Support 1	Support 2
Overall MAXimum	1.612	1.613
D Only	1.012	1.013
L Only	0.600	0.600
D+L	1.612	1.613

Shear Stirrup Requirements

Entire Beam Span Length : Vu < PhiVc/2, Req'd Vs = Not Reqd, use stirrups spaced at 0.000 in

Maximum Forces & Stresses for Load Combinations

Load Combination Segment Length	Span #	Location (ft) in Span	Bending Stress Results (k-ft) Mu : Max	Phi*Mnx	Stress Ratio
MAXimum BENDING Envelope					
Span # 1	1	3.000	3.93	93.75	0.04
+1.30D+2.170L+1.60H					
Span # 1	1	3.000	3.93	93.75	0.04

Description : Beam between culverts- vertical load on beam

Overall Maximum Deflections - Unfactored Loads

Load Combination	Span	Max. "-" Defl	Location in Span	Load Combination	Max. "+" Defl	Location in Span
D+L	1	0.0002	3.060		0.0000	0.000

Concrete Beam

File: T:\STRU\PHS\tva\Inlet Weir Wall Col and Beams.ec6
ENERCALC, INC. 1983-2011, Build:6.12.6.7, Ver:6.2.00.0

Lic. # : KW-06007264 **Licensee : cdm**

Description : Beam between culverts- horizontal load on beam

df 8/17/2012

CODE REFERENCES

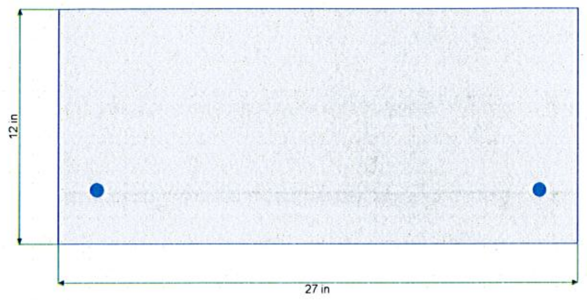
Calculations per ACI 318-05, IBC 2006, CBC 2007, ASCE 7-05
Load Combination Set : 2006 IBC & ASCE 7-05

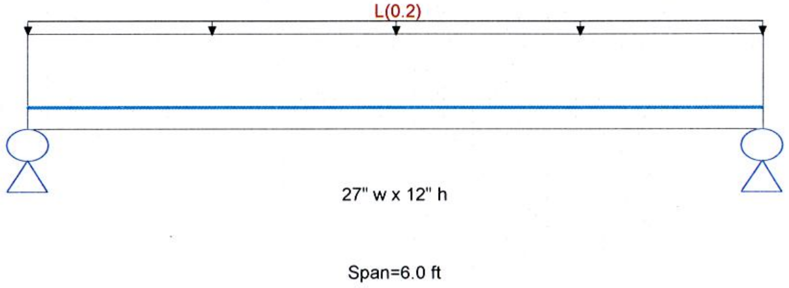
Material Properties

f'c = 4.50 ksi
fr = $f'c^{1/2}$ * 7.50 = 503.12 psi
ψ Density = 150.0 pcf
λ LtWt Factor = 1.0
Elastic Modulus = 3,823.68 ksi
fy - Main Rebar = 60.0 ksi
E - Main Rebar = 29,000.0 ksi

φ Phi Values Flexure : 0.90
Shear : 0.750
β_1 = 0.8250
Fy - Stirrups 60.0 ksi
E - Stirrups = 29,000.0 ksi
Stirrup Bar Size # = # 3
Number of Resisting Legs Per Stirrup = 2

Load Combination 2006 IBC & ASCE 7-05





Cross Section & Reinforcing Details

Rectangular Section, Width = 27.0 in, Height = 12.0 in
Span #1 Reinforcing....
2-#6 at 2.750 in from Bottom, from 0.0 to 6.0 ft in this span

Applied Loads

Service loads entered. Load Factors will be applied for calculations.

Load for Span Number 1
Uniform Load : L = 0.20 k/ft, Tributary Width = 1.0 ft, (Live)

DESIGN SUMMARY

Design OK

Maximum Bending Stress Ratio = **0.055** : 1
Section used for this span **Typical Section**
Mu : Applied 1.953 k-ft
Mn * Phi : Allowable 35.618 k-ft
Load Combination +1.30D+2.170L+1.60H
Location of maximum on span 3.000 ft
Span # where maximum occurs Span # 1

Maximum Deflection			
Max Downward L+Lr+S Deflection	0.000 in	Ratio =	0 <360
Max Upward L+Lr+S Deflection	0.000 in	Ratio =	0 <360
Max Downward Total Deflection	0.000 in	Ratio =	999 <180
Max Upward Total Deflection	0.000 in	Ratio =	999 <180

Vertical Reactions - Unfactored

Support notation : Far left is #1

Load Combination	Support 1	Support 2
Overall MAXimum	0.600	0.600
L Only	0.600	0.600
D+L	0.600	0.600

Shear Stirrup Requirements

Entire Beam Span Length : Vu < PhiVc/2, Req'd Vs = Not Reqd, use stirrups spaced at 0.000 in

Maximum Forces & Stresses for Load Combinations

Load Combination Segment Length	Span #	Location (ft) in Span	Bending Stress Results (k-ft) Mu : Max	Phi*Mnx	Stress Ratio
MAXimum BENDING Envelope					
Span # 1	1	3.000	1.95	35.62	0.05
+1.30D+2.170L+1.60H					
Span # 1	1	3.000	1.95	35.62	0.05

Description : Beam between culverts- horizontal load on beam

Overall Maximum Deflections - Unfactored Loads

Load Combination	Span	Max. "-" Defl	Location in Span	Load Combination	Max. "+" Defl	Location in Span
D+L	1	0.0004	3.060		0.0000	0.000

CDM Smith

CLIENT TVA
PROJECT Ash Pond Breaching Project
DETAIL Beam between inlet culverts
Check for torsion

JOB NO. 95618-92016
DATE CHECKED 8/17/12
CHECKED BY

COMPUTED BY PHS
DATE 7/31/12
PAGE NO. 1/

Beam Properties:

$\gamma_{conc} := 150\text{pcf}$ — Self weight of concrete

$l := 6\text{ft}$ — Length of Beam

$f_y := 60\text{ksi}$ — Yield stress of steel

$f_c := 4.5\text{ksi}$ — Compressive strength of concrete

$b := 14\text{in}$ — Width of Beam

$h := 2.25\text{ft}$ — Height of Beam

Torsional Check:

$A_{cp} := b \cdot h = 2.625\,\text{ft}^2$ — Area of outside perimeter of concrete

$P_{cp} := 2 \cdot b + 2 \cdot h = 6.833\,\text{ft}$ — Outside perimeter of concrete

$$T_n := .75 \cdot \sqrt{f_c \cdot \text{psi}} \cdot \frac{A_{cp}{}^2}{P_{cp}} = 7.306\,\text{ft} \cdot \text{kip}$$

Factored Threshold Torsion (if Tu is less, can neglect torsion effects)

Applied Loads (using AASHTO Load Combinations):

$L := 2.17$ — Live Load factor

$H := 1.69$ — Lateral Earth Pressure Factor

Load on guardrail (usually 200lbf point load, 50plf used conservatively)

$\text{guardrail} := 50\text{plf}$

$h_{gr} := 42\text{in}$ — Height of guardrail

$\text{surcharge} := 120\text{psf}$ — Load from vehicle surcharge

$\text{earth} := 90\text{pcf}$ — Lateral Earch Pressure

$$M_{guardrail} := L \cdot \text{guardrail} \cdot 1\,\text{ft} \cdot \left(h_{gr} + \frac{h}{2}\right) = 0.502 \cdot \text{kip} \cdot \text{ft}$$

Torsional Moment due to guardrail

$$M_{surcharge} := L \cdot \text{surcharge} \cdot (h - 1\,\text{ft}) \cdot 1\,\text{ft} \cdot \left[\frac{h}{2} - \frac{(h - 1\,\text{ft})}{2}\right] = 0.163 \cdot \text{kip} \cdot \text{ft}$$

Torsional moment due to vehicle surcharge

$$M_{earth} := H \cdot \text{earth} \cdot (h - 1\,\text{ft}) \cdot 1\,\text{ft} \cdot \frac{(h - 1\,\text{ft})}{2} \cdot \left[\frac{h}{2} - \frac{(h - 1\,\text{ft})}{3}\right] = 0.084 \cdot \text{kip} \cdot \text{ft}$$

Torsional moment due to lateral earth pressure

$$T_u := M_{guardrail} + M_{surcharge} + M_{earth} = 0.749 \cdot \text{kip} \cdot \text{ft}$$

Total Factored Applied Torsional Moment

$$\frac{T_u}{T_n} = 0.102$$

OK if <1, and therefore can neglect torsional effects

CDM 5400 Glenwood Avenue Suite 300 Raleigh, NC 27612	Client TVA Project Watts Bar Ash Pond Detail Buoyancy Calc	Job No. 95618-92016 Date Checked 8-17-2012 Checked By SLJ	Computed By PHS Date 8/17/2012 Page No. 1

Buoyancy Check For Rectangular Tanks

Author:	Justin Boggs	Date:	20-Mar-07	Checked By:		File Name:	buoy-rec.xls

Limitations

This program should only be used with a full knowledge of the analysis procedure used in the program. Result of the program is subject to structural engineering evaluation and judgement. This program is for the use of CDM Structural Engineering Staff Only.

Parameters

Concrete Density (γ_c)	0.150	kip/ft^3	*Backfill Soil Density (γ_{sat})* *(Typ. Range 100 to 125 pcf)*	0.110	kip/ft^3
Water Density (γ_w)	0.0624	kip/ft^3	*Soil Friction Angle (ϕ)* *(Typ. Range 15 to 20 deg)*	20	°

Structure Dimensions

Inside Length (l)	32.33	ft	*Top Slab Thickness (t_{ts})*	0	in	*Height of Walls above Base Slab (h_t)*	5.25	ft
Inside Width (w)	20	ft	*Base Slab Thickness (t_{bs})*	14	in	*Height to Grade above Base Slab (h_e)*	0	ft
Wall Thickness (t_w)	12	in	*Base Slab Toe Width (l_{toe})*	12	in	*Height to GWL above Base Slab (h_w)*	4.25	ft
Cut-off/Interior Wall Thickne	12	in	*Cut-off/Interior Walls*	93.17	ft	*Interior Wall Height*	5	ft

Uplift Forces

Volume of Displaced Water - Above Base Slab Level ([32.33 ft + 2(1)]*[20 ft + 2(1)])* 4.25 ft = 3209.86	$\left(l+2\frac{t_w}{12}\right)\left(w+2\frac{t_w}{12}\right)h_w =$	3209.9	ft^3
Volume of Displaced Water - Volume of Base Slab	$\left(l+2\frac{t_w+l_{toe}}{12}\right)\left(w+2\frac{t_w+l_{toe}}{12}\right)h_w =$	1017.2	ft^3
Volume of Displaced Water - Total		4227.1	ft^3
Uplift Force (U)	$V\cdot\gamma_w =$	263.90	kip

Resisting Loads

Weight of Top Slab (wts)	$l\cdot w\frac{t_{ts}}{12}\gamma_c =$	0.00	kip
Weight of Base Slab (wbs)	$\left(l+2\frac{t_w+l_{toe}}{12}\right)\left(w+2\frac{t_w+l_{toe}}{12}\right)\frac{t_{bs}}{12}\gamma_c =$	152.59	kip
Weight of Exterior Walls (ww)	$\left[\left(l+2\frac{t_w+l_{toe}}{12}\right)\left(w+2\frac{t_w+l_{toe}}{12}\right)-(w\cdot l)\right]h_t\cdot\gamma_c =$	85.57	kip
Weight of Interior Walls (wwi)	$=$	69.88	kip
Weight of Soil Above Toe of Base Slab (ws1)	$\left[\left(l+2\frac{t_w+l_{toe}}{12}\right)\left(w+2\frac{t_w+l_{toe}}{12}\right)-\left(l+2\frac{t_w}{12}\right)\left(w+2\frac{t_w}{12}\right)\right]\left[(h_e-h_w)\gamma_{sat}+\left[h_w(\gamma_{sat}-\gamma_w)\right]\right]=$	0.00	kip
Weight of Soil in "Pullout Wedges" (ws2)	$\left(\frac{1}{2}h_e^2TAN(\phi)\gamma_{sat}-\frac{1}{2}h_w^2TAN(\phi)\gamma_w\right)\cdot 2\cdot\left(l+2\frac{t_w}{12}+w+2\frac{t_w}{12}\right)=$	0.00	kip
Weight of Water In structure		61	kip
Weight of Structure		308.03	kip
Weight of Structure + Soil Area 1		368.58	kip
Weight of Structure + Soil Area 1 + Soil Area 2		368.58	kip

Factor of Safety Against Uplift

Weight of Structure / Uplift	1.17	≥	1.1	OK
Weight of Structure + Soil Area 1 / Uplift	1.40	≥	1.3	OK
Weight of Structure + Soil Area 1 + Soil Area 2 / Uplift	1.40	≥	1.3	OK

Average Bearing Pressure

Weight of concrete		308.03	kip
Bearing Area	(32.33 ft + 2(12 /12)) * (20 ft + 2(12 /12)) = 755.26 sf	755.26	sf
Concrete per square foot weight:	(308.03 * 1000 lb/kip)/(755.26 sf) = 407.85 psf	407.851	psf
Pressure from water inside structure:	5.25 ft * (62.43 pcf) = 327.7575 psf	327.758	psf
	TOTAL	735.608	psf
Weight of soil displaced by structure	(5.25 + (14/12))*(110 pcf) = 705.833333333333 psf	705.833	psf
Net soil bearing pressure = total structure bearing pressure - existing soil weight	(735.61 psf - 705.83 psf)= 29.77 psf	30	psf

CDM Smith

CLIENT TVA
PROJECT Watts Bar Ash Pond
DETAIL Cast In Place Concrete Design-Outlet
PROJECT NO. 92016.2202

COMPUTED BY / DATE PHS 08/16/12
CHECKED BY / DATE dlg 8/17/12
REVISION NO. / DATE - -
REVIEWED BY / DATE - -

Calculation Description: Cast In Place Concrete Design - Outlet Structure

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1.0 Objective

Design all cast in place concrete outlet structure to be able to handle applied loads.

2.0 Procedure

1.) Determine loads applied to all walls (wingwall and weir), beams, columns. Including seismic, fluid/earth lateral load, pedestrian live load (on rail), HS-20 Vehicle Live Load surcharge, Soil Vertical Pressure, and Self-weight of concrete.
2.) Calculate applied moments and shears using AASHTO load combinations.
3.) Calculate flexural (moment) and shear capacities of walls (wingwall and weir), beams, and columns.
4.) Check overturning, sliding, and bearing for the wingwalls.
4.) Check torsion requirements for beams.
5.) Check all capacity/applied ratios are less than 1.

3.0 References / Data Sources

1.) ASCE 7
2.) IBC 2006
3.) ACI 318

4.0 Assumptions / Limitations

1.) Wingwalls are designed as cantilevered retaining walls at maximum height.
2.) Outlet weir structure designed as cantilevered wall, does not meet requirements to design as panel.

5.0 Calculations

5.1 Weir Wall

- Refer to Mathcad spreadsheet "Outlet Weir-Wall" for full design calculations.

5.2 Wingwall

- Refer to RetainPro Output Titled "Outlet Stem Wall" for full design calculations (including stability requirements) and wall diagrams.

5.3 Column Between Box Culverts

- Refer to Enercalc output "Concrete Column at outlet weir between box culverts" for full design calculations and wall diagrams.

5.4 Beam Above Box Culverts

- Refer to Enercalc output "Beam between culverts - vertical load on beam" and "Beam between culverts - horizontal load on beam" and Mathcad spreadsheet "Beam between outlet culverts" for full design calculations and diagrams.

6.0 Conclusions

- The weir wall and wingwall are 14" thick, with max heights of 10'-2" and reinforcing of #6 @ 6inches on center, each way, each face. The wingwall requires a 5'-8" heel and toe, and a 4'-0" key to meet stability requirements.

- The columns between culverts are also 14" thick, and 26" wide, with #6 @ 6inches on center, each way, each face.

- The beams above the culverts are 14" wide, with reinforcing #6 @ 6inches on center, each way, each face.

Project Name : TVA
Project Number: 95618-92016
Subject : Outlet Weir-Wall

Calculations By: PHS
Checked By : dl
Date : 8/17/2012

LIMITATIONS : This program should only be used with a full knowledge of the analysis procedure used in the program. Result of the program is subject to structural engineering evaluation and judgment. This program is for the use of CDM Structural Engineering Staff Only.

CANTILEVER WALL DESIGN - SINGLE DOWEL

This program analyzes the main reinforcement of a cantilever retaining wall which utilizes a standard reinforcement layout. The standard layout is comprised of vertical bars at 6" oc and dowels at 6" oc. The program also checks the shear capacity of the stem. This reinforcement layout is considered to be economical for wall heights less than 12' for water loading and less than 10' for earth loading.

User Input

>> Wall Height - Range: $h := 0..10.17$ ft
>> Wall Height - Max : $hmax := 10.17$ ft
>> Wall Thickness $hw := 14$ inches

>> Fluid Density (*) $\gamma := 90$ psf
>> Lateral Load Factor $LF := 1.69$
>> Durability Factor (dowel) $S_{D\_d} := 1.0$
>> Durability Factor (vert): $S_{D\_v} := 1.0$

(*)- 63 pcf for water, 90 to 120 pcf for earth fill

>> Concrete Strength $fc := 4500$ psi
>> Steel Strength $fy := 60000$ psi
>> Concrete Cover $c := 2.0$ inches
>> Vehicle Lateral Live Load $VL := 120$ psf
Earth Surcharge Factor $ES := 2.17$

>> Seismic Lateral Load $SL := 40$ psf
$EQ := 1.0$ Vehicle Surcharge governs, Seismic not used

Flexural Analysis

Procedure

Revise Dowel and Vertical Bar Sizes such that Moment Capacity (ϕ**Mn**) > Factored Moment (Mu). Note: Std Dowel Spacing is 6" and Vertical Spacing is 6".

Select Reinforcement Sizes

>>Dowel Size / Area $\phi d := 6 \quad Ad := (\phi d \cdot 0.125)^2 \cdot \frac{\pi}{4} \cdot 2$ $\quad Ad = 0.884$ sq.in/ft

>>Vert. Size $\phi v := 6 \quad Av := (\phi v \cdot 0.125)^2 \cdot \frac{\pi}{4} \cdot 2$ $\quad Av = 0.884$ sq.in/ft

Effective Depth Dowels : $dd := (hw - c) - (0.5 \cdot \phi d \cdot .125)$

$dd = 11.625$ inches

Effective Depth Verticals : $dv := (hw - c) - (0.5 \cdot \phi v \cdot .125)$

$dv = 11.625$ inches

Check Min. Steel Ratio

Steel Ratio Dowels : $\rho d := \frac{Ad}{(12 \cdot dd)} \qquad \rho d = 0.00633 \qquad Cd := \mathrm{if}\left(\rho d \ge 0.003, 1, \frac{1}{1.33}\right)$

Steel Ratio Verticals: $\rho v := \frac{Av}{(12 \cdot dv)} \qquad \rho v = 0.00633 \qquad Cv := \mathrm{if}\left(\rho v \ge 0.003, 1, \frac{1}{1.33}\right)$

$Cd = 1 \qquad Cv = 1$

Moment Capacity

Moment Capacity -Dowels $\phi Md(h) := \frac{0.9 \cdot Ad \cdot fy}{12000} \cdot \left[dv - \frac{Ad \cdot fy}{2 \cdot 12 \cdot (0.85 \cdot fc)}\right] \cdot Cd$ kip-ft (Eqn 3)

$\phi Md(1) = 43.926$ kip-ft

Moment Capacity - Verticals $\phi Mv(h) := \frac{0.9 \cdot Av \cdot fy}{12000} \cdot \left[dv - \frac{Av \cdot fy}{2 \cdot 12 \cdot (0.85 \cdot fc)}\right] \cdot Cv$ kip-ft (Eqn 4)

$\phi Mv(1) = 43.926$ kip-ft

Redefine Moment Capacity of Verticals as a scalar value (ϕMv1)

Moment Capacity - Verticals $\phi Mv1 := \phi Mv(1)$ kip-ft (Eqn 5)

Substitute Eqn 5 into Eqn 1 to calculate h (h1) the point at which moment capacity of verticals equal to applied Factored Moment

$$h1 := \left[\frac{\phi Mv1 \cdot 1000}{\frac{1}{6} \cdot \left(LF \cdot S_{D\_v} \cdot \gamma\right) + \frac{1}{2}\left(VL \cdot ES \cdot S_{D\_v}\right)}\right]^{0.33333}$$

$h1 = 6.561$ ft

Projection Length of Loaded Face Dowels : $pl := hmax - h1 + \frac{dv}{12}$ $pl = 4.578$ ft

Dowel Development Length
(Per ACI-318 12.2.2)

$$Ld := if\left[\phi d > 6, 0.05\cdot\phi d\cdot 0.125\cdot\frac{fy}{\sqrt{fc}}\cdot\left(\frac{1}{12}\right), 0.04\cdot\phi d\cdot 0.125\cdot\frac{fy}{\sqrt{fc}}\cdot\left(\frac{1}{12}\right)\right] \qquad Ld = 2.236 \text{ ft}$$

Check if pl>Ld $pl := (if(Ld > pl, Ld, pl))$ $pl = 4.578$

Moments and Shears

Factored Moment (dowel) : $Mu_d(h) := \frac{1}{6\cdot 1000}\cdot\left(LF\cdot S_{D\_d}\cdot\gamma\cdot h^3\right) + \frac{1}{2\cdot 1000}\left(VL\cdot ES\cdot h^2\right)$ kip-ft (Eqn 1)

Max. Factored Moment (dowel): $Mu_d(hmax) = 40.131$

Factored Moment (vert) : $Mu_v(h) := \frac{1}{6\cdot 1000}\cdot\left(LF\cdot S_{D\_v}\cdot\gamma\cdot h^3\right) + \frac{1}{2\cdot 1000}\left(VL\cdot ES\cdot h^2\right)$ kip-ft (Eqn 1)

Max. Factored Moment (vert): $Mu_v\left(h1 - \frac{dv}{12}\right) = 8.504$

Factored Shear : $Vu(h) := \frac{1}{2\cdot 1000}\cdot\left(LF\cdot\gamma\cdot h^2\right) + \frac{1}{1000}(VL\cdot ES\cdot h)$ kips (Eqn 2)

Max. Factored Shear : $Vu(hmax) = 10.514$ kips

Check Moment Capacities

Moment Capacity - Dowels $\phi Md(hmax) = 43.926$ kip-ft

Moment Capacity - Verticals at Dowel Cutoff Poin $\phi Mv\left(h1 - \frac{dv}{12}\right) = 43.926$ kip-ft

Moment Capacity Ratio - Dowels $\frac{Mu_d(hmax)}{\phi Md(hmax)} = 0.914$ OK if <1
Increase As if>1

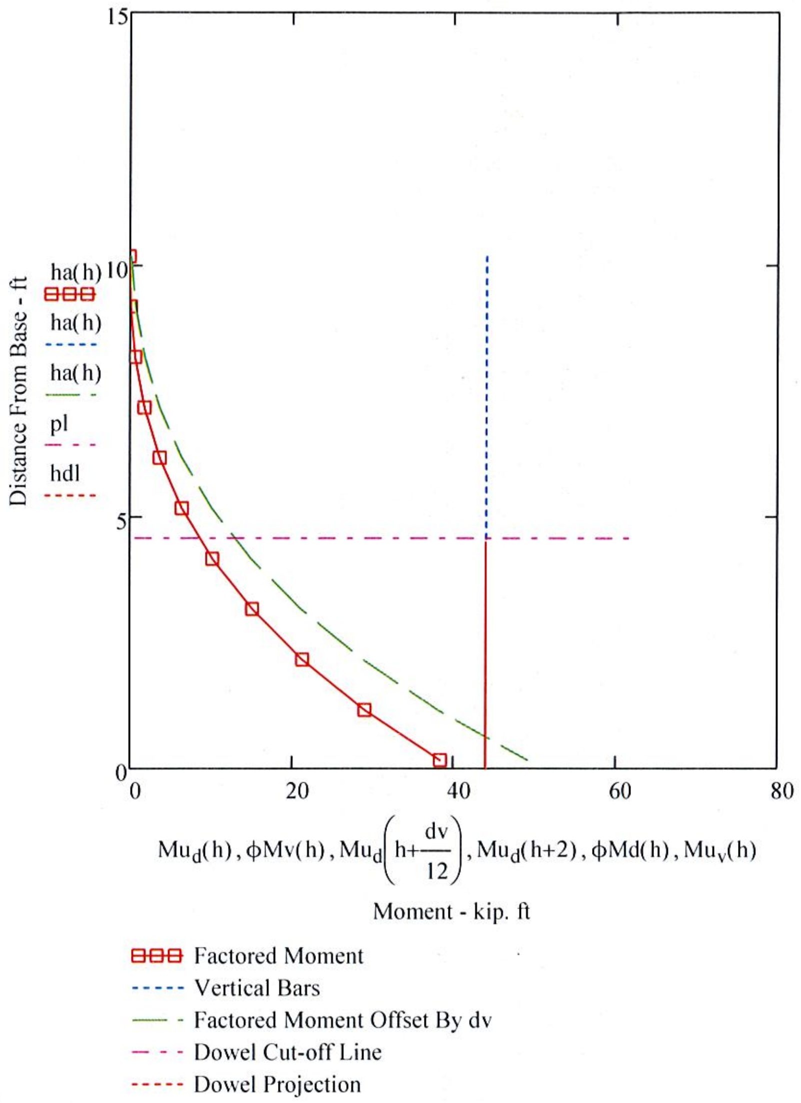
Moment Capacity Ratio - Verticals $\frac{Mu_v\left(h1 - \frac{dv}{12}\right)}{\phi Mv1} = 0.194$ OK if <1
Increase As if>1

Shear Capacity $\phi Vn := \frac{0.85\cdot 12\cdot dd\cdot 2\cdot\sqrt{fc}}{1000}$ $\phi Vn = 15.909$ kips

Shear Capacity Ratio $\frac{Vu(hmax)}{\phi Vn} = 0.661$

Following variables are defined to facilitate graphing

- Variable change $ha(h) := hmax - h$
- Dowel Proj. Range Variable $hdl := 0, 0.1 .. pl$ $pl = 4.578$



Design Summary

- Wall Thickness $hw = 14$ inches
- Verticals Size $\phi v = 6$
- Dowel Size $\phi d = 6$
- Dwl Proj. $pl = 4.578$ ft

Title : **Outlet Stem wall**
Job # : **TVA Watts** Dsgnr: **PHS**
Description....
Page: ______
Date: **JUL 31,2012**

dlf 8/17/2012

This Wall in File: T:\STRU\PHS\tva\tva outlet wing wall.rp5

Retain Pro 9 © 1989 - 2011 Ver: 9.19 8152
Registration #: RP-1190655 RP9.19
Licensed to: CDM - TRACIE VANN

Cantilevered Retaining Wall Design

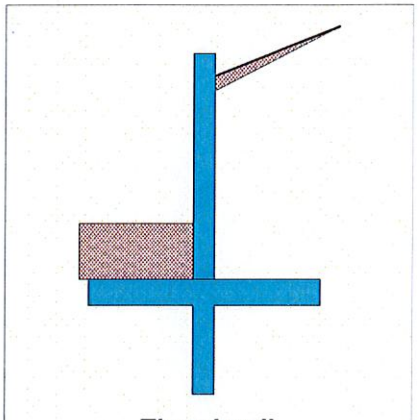
Code: AASHTO LRFD

Criteria

Retained Height	=	9.17 ft
Wall height above soil	=	1.00 ft
Slope Behind Wall	=	3.00 : 1
Height of Soil over Toe	=	30.00 in
Water height over heel	=	0.0 ft

Soil Data

Allow Soil Bearing	=	2,000.0 psf
Equivalent Fluid Pressure Method		
Heel Active Pressure	=	90.0 psf/ft
Toe Active Pressure	=	30.0 psf/ft
Passive Pressure	=	300.0 psf/ft
Soil Density, Heel	=	120.00 pcf
Soil Density, Toe	=	120.00 pcf
Footing||Soil Friction	=	0.400
Soil height to ignore for passive pressure	=	12.00 in



Thumbnail

Surcharge Loads

Surcharge Over Heel = 240.0 psf
NOT Used To Resist Sliding & Overturning
Surcharge Over Toe = 0.0 psf
NOT Used for Sliding & Overturning

Axial Load Applied to Stem

Axial Dead Load	=	0.0 lbs
Axial Live Load	=	0.0 lbs
Axial Load Eccentricity	=	0.0 in

Lateral Load Applied to Stem

Lateral Load	=	0.0 #/ft
...Height to Top	=	0.00 ft
...Height to Bottom	=	0.00 ft
The above lateral load has been increased by a factor of		1.60
Wind on Exposed Stem	=	50.0 psf

Adjacent Footing Load

Adjacent Footing Load	=	0.0 lbs
Footing Width	=	0.00 ft
Eccentricity	=	0.00 in
Wall to Ftg CL Dist	=	0.00 ft
Footing Type		
Base Above/Below Soil at Back of Wall	=	0.0 ft
Poisson's Ratio	=	0.300

Design Summary

Wall Stability Ratios

Overturning	=	2.44	OK
Sliding	=	1.56	OK
Total Bearing Load	=	13,247 lbs	
...resultant ecc.	=	20.92 in	
Soil Pressure @ Toe	=	1,946 psf	OK
Soil Pressure @ Heel	=	173 psf	OK
Allowable	=	2,000 psf	

Soil Pressure Less Than Allowable

ACI Factored @ Toe	=	2,724 psf	
ACI Factored @ Heel	=	242 psf	
Footing Shear @ Toe	=	56.9 psi	OK
Footing Shear @ Heel	=	63.4 psi	OK
Allowable	=	100.6 psi	

Sliding Calcs (Vertical Component NOT Used)

Lateral Sliding Force	=	8,976.5 lbs	
less 100% Passive Force	= -	8,666.7 lbs	
less 100% Friction Force	= -	5,298.7 lbs	
Added Force Req'd	=	0.0 lbs	OK
....for 1.5 : 1 Stability	=	0.0 lbs	OK

Load Factors

Building Code	AASHTO LRFD
Dead Load	1.300
Live Load	2.170
Earth, H	1.690
Wind, W	1.300
Seismic, E	1.000

Stem Construction

		Top Stem	2nd
		Stem OK	Stem OK
Design Height Above Ftg	ft =	3.33	0.00
Wall Material Above "Ht"	=	Concrete	Concrete
Thickness	=	14.00	14.00
Rebar Size	=	# 6	# 6
Rebar Spacing	=	6.00	6.00
Rebar Placed at	=	Edge	Edge
Design Data			
fb/FB + fa/Fa	=	**0.243**	**0.750**
Total Force @ Section	lbs =	4,435.3	9,091.0
Moment....Actual	ft-# =	10,648.7	32,833.7
Moment.....Allowable	ft-# =	43,750.5	43,750.5
Shear.....Actual	psi =	32.1	65.5
Shear.....Allowable	psi =	100.6	100.6
Wall Weight	psf =	175.0	175.0
Rebar Depth 'd'	in =	11.63	11.63
LAP SPLICE IF ABOVE	in =	12.00	15.71
LAP SPLICE IF BELOW	in =	12.00	
HOOK EMBED INTO FTG	in =		9.39

Lap splice above base reduced by stress ratio

Masonry Data			
f'm	psi =		
Fs	psi =		
Solid Grouting	=		
Modular Ratio 'n'	=		
Short Term Factor	=		
Equiv. Solid Thick.	=		
Masonry Block Type	=	Medium Weight	
Masonry Design Method	=	ASD	
Concrete Data			
f'c	psi =	4,500.0	4,500.0
Fy	psi =	60,000.0	60,000.0

This Wall in File: T:\STRU\PHS\tva\tva outlet wing wall.rp5

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Registration #: RP-1190655 RP9.19
Licensed to: CDM - TRACIE VANN

Cantilevered Retaining Wall Design

Code: AASHTO LRFD

Footing Dimensions & Strengths

Toe Width = 5.67 ft
Heel Width = 6.83
Total Footing Width = 12.50
Footing Thickness = 14.00 in
Key Width = 14.00 in
Key Depth = 48.00 in
Key Distance from Toe = 5.67 ft
f'c = 4,500 psi Fy = 60,000 psi
Footing Concrete Density = 150.00 pcf
Min. As % = 0.0018
Cover @ Top 2.00 @ Btm.= 3.00 in

Footing Design Results

		Toe	Heel
Factored Pressure	=	2,724	242 psf
Mu' : Upward	=	37,758	9,911 ft-#
Mu' : Downward	=	10,690	38,577 ft-#
Mu: Design	=	27,068	28,666 ft-#
Actual 1-Way Shear	=	56.94	63.44 psi
Allow 1-Way Shear	=	100.62	100.62 psi

Toe Reinforcing = # 6 @ 9.00 in
Heel Reinforcing = # 6 @ 6.00 in
Key Reinforcing = # 6 @ 0.00 in

Other Acceptable Sizes & Spacings
Toe: #4@ 4.25 in, #5@ 6.50 in, #6@ 9.00 in, #7@ 12.25 in, #8@ 16.00 in, #9@ 20.2
Heel: #4@ 4.25 in, #5@ 6.50 in, #6@ 9.25 in, #7@ 12.75 in, #8@ 16.75 in, #9@ 21.0
Key:

Summary of Overturning & Resisting Forces & Moments

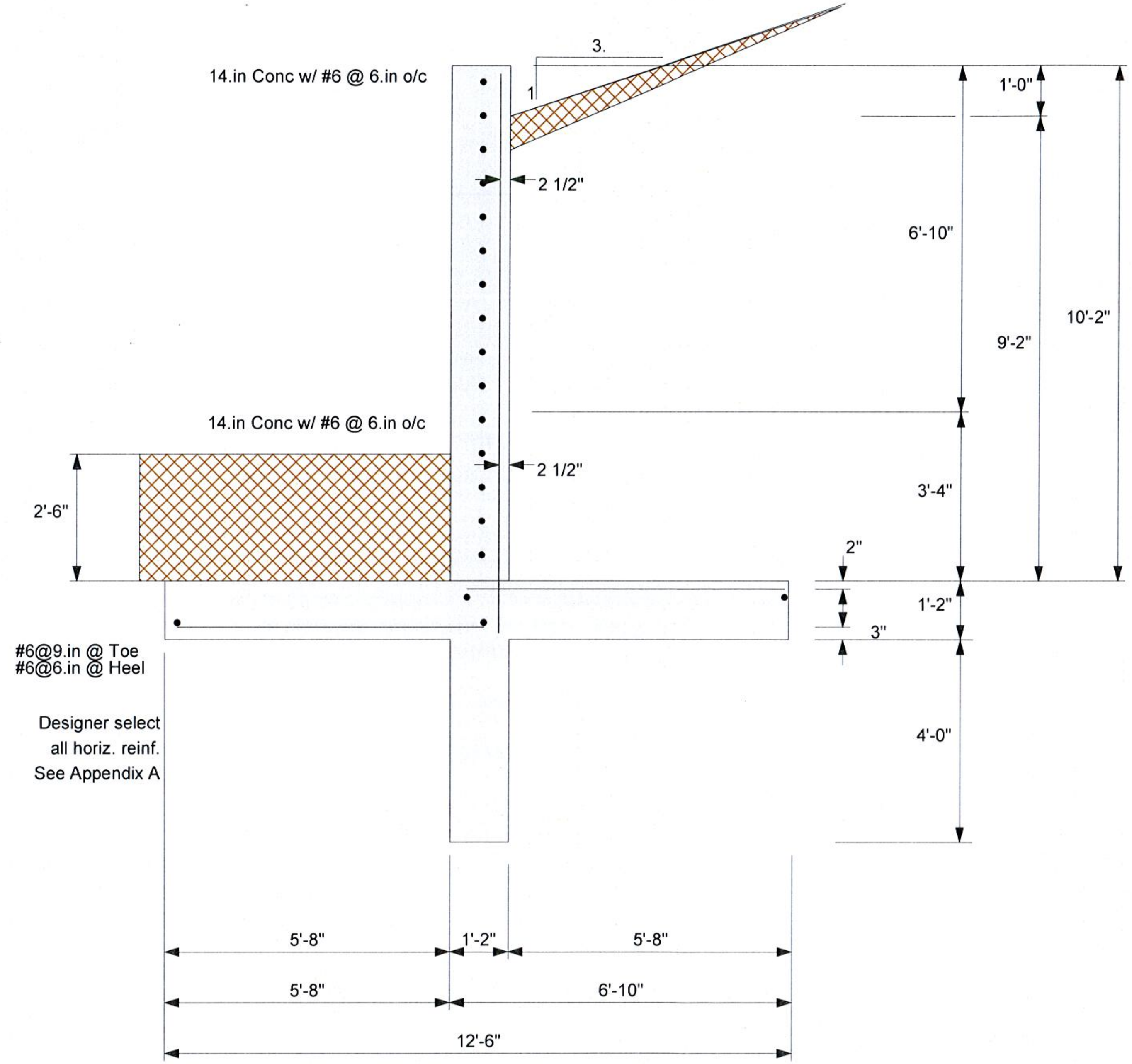
		.....OVERTURNING.....		
Item		**Force** lbs	**Distance** ft	**Moment** ft-#
Heel Active Pressure	=	6,725.9	4.08	27,409.2
Surcharge over Heel	=	2,200.6	6.11	13,451.8
Toe Active Pressure	=			
Surcharge Over Toe	=			
Adjacent Footing Load	=			
Added Lateral Load	=			
Load @ Stem Above Soil	=	50.0	10.84	541.8
Total	=	8,976.5	**O.T.M.** =	41,402.9

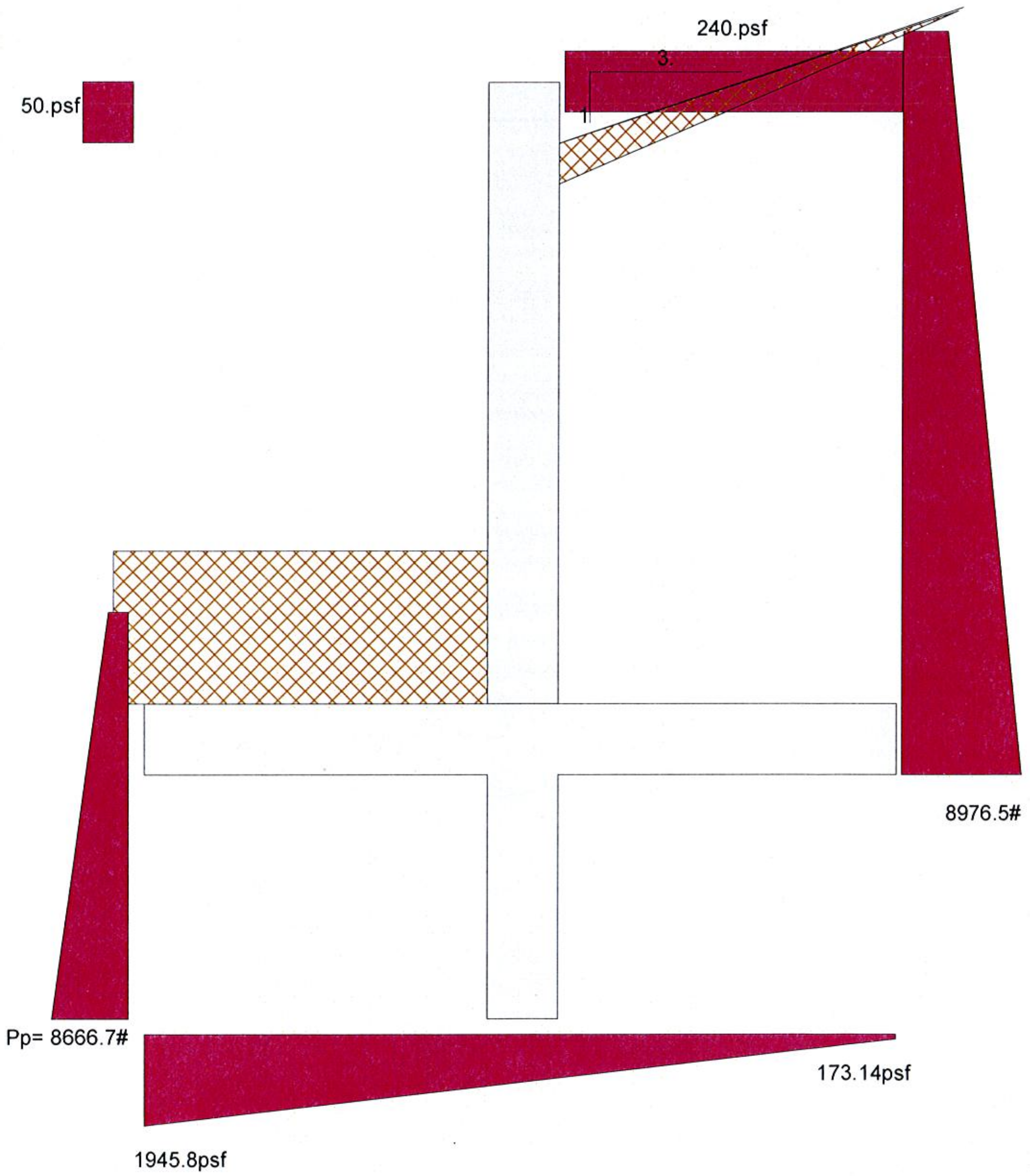
Resisting/Overturning Ratio = **2.44**
Vertical Loads used for Soil Pressure = 13,246.7 lbs
Vertical component of active pressure NOT used for soil pressure

		.....RESISTING.....		
		Force lbs	**Distance** ft	**Moment** ft-#
Soil Over Heel	=	6,235.6	9.67	60,298.3
Sloped Soil Over Heel	=	642.2	10.61	6,816.8
Surcharge Over Heel	=			
Adjacent Footing Load	=			
Axial Dead Load on Stem	=			
* Axial Live Load on Stem	=			
Soil Over Toe	=	1,701.0	2.84	4,822.3
Surcharge Over Toe	=			
Stem Weight(s)	=	1,779.8	6.25	11,129.4
Earth @ Stem Transitions	=			
Footing Weight	=	2,188.1	6.25	13,679.2
Key Weight	=	700.0	6.25	4,377.3
Vert. Component	=			
Total =		13,246.7 lbs	**R.M.=**	101,123.3

* Axial live load NOT included in total displayed, or used for overturning resistance, but is included for soil pressure calculation.

DESIGNER NOTES:


3.
1
14.in Conc w/ #6 @ 6.in o/c
2 1/2"
14.in Conc w/ #6 @ 6.in o/c
2 1/2"
2'-6"
1'-0"
6'-10"
9'-2"
10'-2"
3'-4"
2"
1'-2"
3"
4'-0"
#6@9.in @ Toe
#6@6.in @ Heel
Designer select
all horiz. reinf.
See Appendix A
5'-8"
1'-2"
5'-8"
5'-8"
6'-10"
12'-6"


240.psf
3
1
50.psf
8976.5#
Pp= 8666.7#
173.14psf
1945.8psf

Concrete Column

File: T:\STRU\PHS\tva\Outlet Weir Wall Col and Beams.ec6
ENERCALC, INC. 1983-2011, Build:6.12.6.7, Ver:6.2.00.0

Lic. # : KW-06007264 **Licensee : cdm**

Description : Concrete Column at outlet weir between box culverts

df 8/17/12

Code References

Calculations per ACI 318-05, IBC 2006, CBC 2007, ASCE 7-05
Load Combinations Used : 2006 IBC & ASCE 7-05

General Information

f'c : Concrete 28 day strength = 4.50 ksi
E = = 3,122.0 ksi
Density = 145.0 pcf
β = 0.8250
fy - Main Rebar = 60.0 ksi
E - Main Rebar = 29,000.0 ksi
Allow. Reinforcing Limits *ASTM A615 Bars Used*
Min. Reinf. = 1.0 %
Max. Reinf. = 8.0 %
Load Combination :2006 IBC & ASCE 7-05

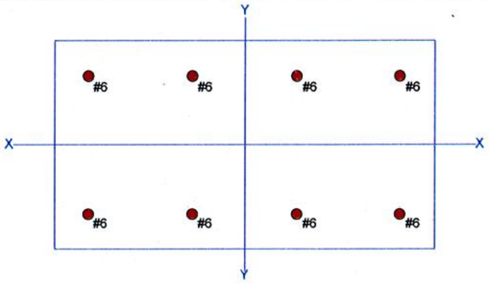
Overall Column Height = 5.0 ft
End Fixity Top Pinned, Bottom Fixed

Brace condition for deflection (buckling) along columns :
X-X (width) axis : Fully braced against buckling along X-X Axis
Y-Y (depth) axis :Fully braced against buckling along Y-Y Axis

Column Cross Section

Column Dimensions :14.0in high x 26.0in Wide, Column Edge to Rebar Edge Cover = 2.0in

Column Reinforcing :4 - #6 bars @ corners,, 2.0 - #6 bars top & bottom between corner bars



Applied Loads

Entered loads are factored per load combinations specified by user.

Column self weight included : 1,832.64 lbs * Dead Load Factor
AXIAL LOADS . . .
Axial Load at 5.0 ft above base, D = 2.20, L = 1.20 k
BENDING LOADS . . .
from beams: Lat. Point Load at 4.0 ft creating My-y, L = 1.20 k

DESIGN SUMMARY

Load Combination +1.30D+2.170L
Location of max.above base 4.966 ft

Maximum Stress Ratio **0.009832 : 1**
Ratio = (Pu^2+Mu^2)^.5 / (PhiPn^2+PhiMn^2)^.5

Pu =	7.846 k	φ * Pn =	805.49 k
Mu-x =	0.0 k-ft	φ * Mn-x =	0.0 k-ft
Mu-y =	1.828 k-ft	φ * Mn-y =	0.0 k-ft
Mu Angle =	90.0 deg		
Mu at Angle =	1.828 k-ft	φMn at Angle =	185.709 k-ft

Pn & Mn values located at Pu-Mu vector intersection with capacity curve

Column Capacities . . .

Pnmax : Nominal Max. Compressive Axial Capacity	1,590.04 k
Pnmin : Nominal Min. Tension Axial Capacity	-211.20 k
φ Pn, max : Usable Compressive Axial Capacity	826.82 k
φ Pn, min : Usable Tension Axial Capacity	-137.280 k

Maximum SERVICE Load Reactions . .

Top along Y-Y	0.8448 k	Bottom along Y-Y	0.3552 k
Top along X-X	0.0 k	Bottom along X-X	0.0 k

Maximum SERVICE Load Deflections . . .

Along Y-Y 0.0 in at 0.0 ft above base
for load combination :
Along X-X .0000270 in at 3.255 ft above base
for load combination : L Only

General Section Information . φ = 0.650 β = 0.8250 θ = 0.80
ρ : % Reinforcing 0.9670 % Rebar < Min of 1.0 %
Reinforcing Area 3.520 in^2
Concrete Area 364.0 in^2

Concrete Column

File: T:\STRU\PHS\tva\Outlet Weir Wall Col and Beams.ec6
ENERCALC, INC. 1983-2011, Build:6.12.6.7, Ver:6.2.00.0

Lic. # : KW-06007264 **Licensee : cdm**

Description : Concrete Column at outlet weir between box culverts

Governing Load Combination Results

Governing Factored Load Combination	Dist. from base ft	Axial Load k Pu	φ * Pn	δ x	δ x * Mux	δ y	δy * Muy	Bending Analysis k-ft Alpha (deg)	δ Mu	φ Mn	Utilization Ratio
+1.30D+2.170L	4.97	7.85	805.49	1.000		1.000	1.83	90.000	1.83	185.71	**0.010**

Maximum Reactions - Unfactored

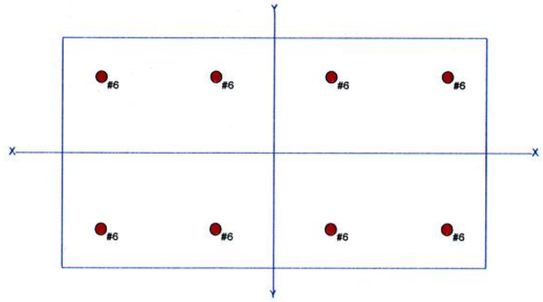
Note: Only non-zero reactions are listed.

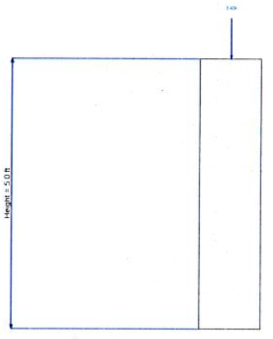
Load Combination	Reaction along X-X Axis @ Base	@ Top	Reaction along Y-Y Axis @ Base	@ Top	Axial Reaction @ Base
D Only		k		k	4.033 k
L Only		k	0.355	0.845 k	1.200 k
D+L		k	0.355	0.845 k	5.233 k

Maximum Deflections for Load Combinations - Unfactored Loads

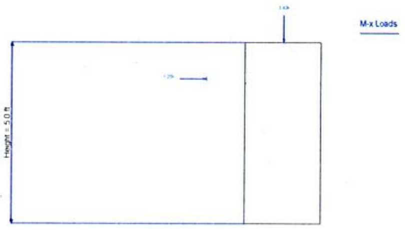
Load Combination	Max. X-X Deflection		Distance		Max. Y-Y Deflection		Distance	
D Only	0.0000	in	0.000	ft	0.000	in	0.000	ft
L Only	0.0000	in	3.255	ft	0.000	in	0.000	ft
D+L	0.0000	in	3.255	ft	0.000	in	0.000	ft

Sketches



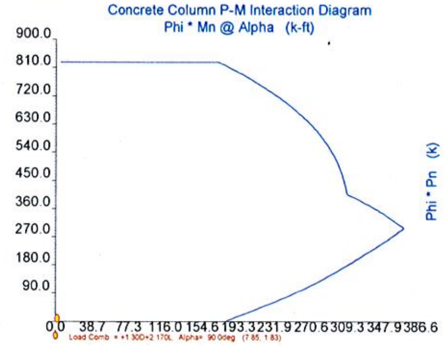


Looking along X-X Axis



Looking along Y-Y Axis

Interaction Diagrams



Concrete Beam

File: T:\STRU\PHS\tva\Outlet Weir Wall Col and Beams.ec6
ENERCALC, INC. 1983-2011, Build:6.12.6.7, Ver:6.2.00.0

Lic. # : KW-06007264 **Licensee : cdm**

Description : Beam between culverts- vertical load on beam

CODE REFERENCES

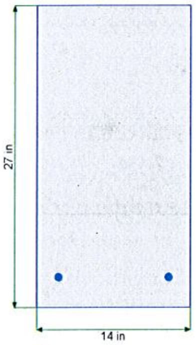
Calculations per ACI 318-05, IBC 2006, CBC 2007, ASCE 7-05
Load Combination Set : 2006 IBC & ASCE 7-05

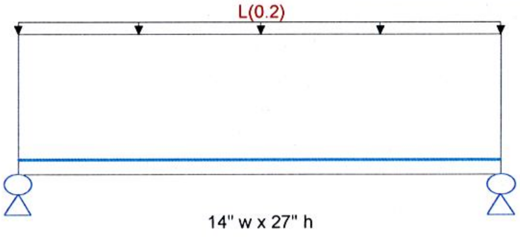
Material Properties

f'c = 4.50 ksi
fr = $f'c^{1/2}$ * 7.50 = 503.12 psi
ψ Density = 150.0 pcf
λ LtWt Factor = 1.0
Elastic Modulus = 3,823.68 ksi
fy - Main Rebar = 60.0 ksi
E - Main Rebar = 29,000.0 ksi

φ Phi Values Flexure : 0.90
Shear : 0.750
β_1 = 0.8250
Fy - Stirrups 60.0 ksi
E - Stirrups = 29,000.0 ksi
Stirrup Bar Size # = # 3
Number of Resisting Legs Per Stirrup = 2

Load Combination 2006 IBC & ASCE 7-05





14" w x 27" h

Span=6.0 ft

Cross Section & Reinforcing Details

Rectangular Section, Width = 14.0 in, Height = 27.0 in
Span #1 Reinforcing....
2-#6 at 2.750 in from Bottom, from 0.0 to 6.0 ft in this span

Applied Loads

Service loads entered. Load Factors will be applied for calculations.

Beam self weight calculated and added to loads
Load for Span Number 1
Uniform Load : L = 0.20 k/ft, Tributary Width = 1.0 ft, (Live)

DESIGN SUMMARY

Design OK

Maximum Bending Stress Ratio = **0.045** : 1
Section used for this span **Typical Section**
Mu : Applied 4.256 k-ft
Mn * Phi : Allowable 94.078 k-ft
Load Combination +1.30D+2.170L+1.60H
Location of maximum on span 3.000 ft
Span # where maximum occurs Span # 1

Maximum Deflection

Max Downward L+Lr+S Deflection	0.000 in	Ratio =	0 <360
Max Upward L+Lr+S Deflection	0.000 in	Ratio =	0 <360
Max Downward Total Deflection	0.000 in	Ratio =	999 <180
Max Upward Total Deflection	0.000 in	Ratio =	999 <180

Vertical Reactions - Unfactored

Support notation : Far left is #1

Load Combination	Support 1	Support 2
Overall MAXimum	1.781	1.781
D Only	1.181	1.181
L Only	0.600	0.600
D+L	1.781	1.781

Shear Stirrup Requirements

Entire Beam Span Length : Vu < PhiVc/2, Req'd Vs = Not Reqd, use stirrups spaced at 0.000 in

Maximum Forces & Stresses for Load Combinations

Load Combination Segment Length	Span #	Location (ft) in Span	Bending Stress Results (k-ft) Mu : Max	 Phi*Mnx	 Stress Ratio
MAXimum BENDING Envelope					
Span # 1	1	3.000	4.26	94.08	0.05
+1.30D+2.170L+1.60H					
Span # 1	1	3.000	4.26	94.08	0.05

Description : Beam between culverts- vertical load on beam

Overall Maximum Deflections - Unfactored Loads

Load Combination	Span	Max. "-" Defl	Location in Span	Load Combination	Max. "+" Defl	Location in Span
D+L	1	0.0002	2.940		0.0000	0.000

File: T:\STRU\PHS\tva\Outlet Weir Wall Col and Beams.ec6
ENERCALC, INC. 1983-2011, Build:6.12.6.7, Ver:6.2.00.0

Concrete Beam

Lic. # : KW-06007264 **Licensee : cdm**

Description : Beam between culverts- horizontal load on beam

df 8/17/2012

CODE REFERENCES

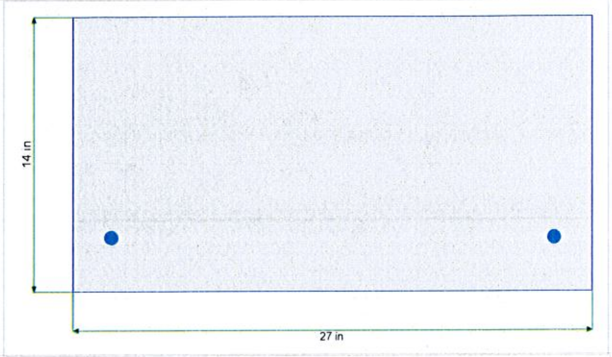
Calculations per ACI 318-05, IBC 2006, CBC 2007, ASCE 7-05
Load Combination Set : 2006 IBC & ASCE 7-05

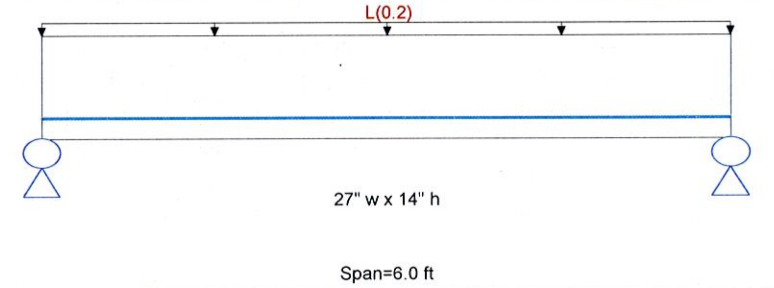
Material Properties

f'c = 4.50 ksi
$fr = f'c^{1/2} * 7.50$ = 503.12 psi
ψ Density = 150.0 pcf
λ LtWt Factor = 1.0
Elastic Modulus = 3,823.68 ksi
fy - Main Rebar = 60.0 ksi
E - Main Rebar = 29,000.0 ksi

ϕ Phi Values Flexure : 0.90
Shear : 0.750
β_1 = 0.8250
Fy - Stirrups 60.0 ksi
E - Stirrups = 29,000.0 ksi
Stirrup Bar Size # = # 3
Number of Resisting Legs Per Stirrup = 2

Load Combination 2006 IBC & ASCE 7-05





Cross Section & Reinforcing Details

Rectangular Section, Width = 27.0 in, Height = 14.0 in
Span #1 Reinforcing....
2-#6 at 2.750 in from Bottom, from 0.0 to 6.0 ft in this span

Applied Loads

Service loads entered. Load Factors will be applied for calculations.

Load for Span Number 1
Uniform Load : L = 0.20 k/ft, Tributary Width = 1.0 ft, (Live)

DESIGN SUMMARY

Design OK

Maximum Bending Stress Ratio =	**0.045** : 1
Section used for this span	**Typical Section**
Mu : Applied	1.953 k-ft
Mn * Phi : Allowable	43.538 k-ft
Load Combination	+1.30D+2.170L+1.60H
Location of maximum on span	3.000 ft
Span # where maximum occurs	Span # 1

Maximum Deflection			
Max Downward L+Lr+S Deflection	0.000 in	Ratio =	0 <360
Max Upward L+Lr+S Deflection	0.000 in	Ratio =	0 <360
Max Downward Total Deflection	0.000 in	Ratio =	999 <180
Max Upward Total Deflection	0.000 in	Ratio =	999 <180

Vertical Reactions - Unfactored

Support notation : Far left is #1

Load Combination	Support 1	Support 2
Overall MAXimum	0.600	0.600
L Only	0.600	0.600
D+L	0.600	0.600

Shear Stirrup Requirements

Entire Beam Span Length : Vu < PhiVc/2, Req'd Vs = Not Reqd, use stirrups spaced at 0.000 in

Maximum Forces & Stresses for Load Combinations

Load Combination Segment Length	Span #	Location (ft) in Span	Bending Stress Results (k-ft) Mu : Max	Phi*Mnx	Stress Ratio
MAXimum BENDING Envelope					
Span # 1	1	3.000	1.95	43.54	0.04
+1.30D+2.170L+1.60H					
Span # 1	1	3.000	1.95	43.54	0.04

Description : Beam between culverts- horizontal load on beam

Overall Maximum Deflections - Unfactored Loads

Load Combination	Span	Max. "-" Defl	Location in Span	Load Combination	Max. "+" Defl	Location in Span
D+L	1	0.0002	3.060		0.0000	0.000

CDM Smith

CLIENT TVA
PROJECT Ash Pond Breaching Project
DETAIL Beam between outlet culverts
Torsion Check

JOB NO. 95618-92016
DATE CHECKED 8/17/2012
CHECKED BY df

COMPUTED BY PHS
DATE 7/31/12
PAGE NO. 1/

Beam Properties:

$\gamma_{conc} := 150\text{pcf}$	Self weight of concrete
$l := 6\text{ft}$	Length of Beam
$f_y := 60\text{ksi}$	Yield stress of steel
$f_c := 4.5\text{ksi}$	Compressive strength of concrete
$b := 14\text{in}$	Width of Beam
$h := 2.25\text{ft}$	Height of Beam

Torsional Check:

$A_{cp} := b \cdot h = 2.625\,\text{ft}^2$	Area of outside perimeter of concrete
$P_{cp} := 2 \cdot b + 2 \cdot h = 6.833\,\text{ft}$	Outside perimeter of concrete
$T_n := .75 \cdot \sqrt{f_c \cdot \text{psi}} \cdot \frac{{A_{cp}}^2}{P_{cp}} = 7.306\,\text{ft} \cdot \text{kip}$	Factored Threshold Torsion (if Tu is less, can neglect torsion effects)

Applied Loads (using AASHTO Load Combinations):

$L := 2.17$	Live Load factor
$H := 1.69$	Lateral Earth Pressure Factor
$\text{guardrail} := 50\text{plf}$	Load on guardrail (usually 200lbf point load, 50plf used conservatively)
$h_{gr} := 42\text{in}$	Height of guardrail
$\text{surcharge} := 120\text{psf}$	Load from vehicle surcharge
$\text{earth} := 90\text{pcf}$	Lateral Earch Pressure
$M_{guardrail} := L \cdot \text{guardrail} \cdot 1\,\text{ft} \cdot \left(h_{gr} + \frac{h}{2}\right) = 0.502 \cdot \text{kip} \cdot \text{ft}$	Torsional Moment due to guardrail
$M_{surcharge} := L \cdot \text{surcharge} \cdot (h - 1\,\text{ft}) \cdot 1\,\text{ft} \cdot \left[\frac{h}{2} - \frac{(h - 1\,\text{ft})}{2}\right] = 0.163 \cdot \text{kip} \cdot \text{ft}$	Torsional moment due to vehicle surcharge
$M_{earth} := H \cdot \text{earth} \cdot (h - 1\,\text{ft}) \cdot 1\,\text{ft} \cdot \frac{(h - 1\,\text{ft})}{2} \cdot \left[\frac{h}{2} - \frac{(h - 1\,\text{ft})}{3}\right] = 0.084 \cdot \text{kip} \cdot \text{ft}$	Torsional moment due to lateral earth pressure
$T_u := M_{guardrail} + M_{surcharge} + M_{earth} = 0.749 \cdot \text{kip} \cdot \text{ft}$	Total Factored Applied Torsional Moment
$\frac{T_u}{T_n} = 0.102$	OK if <1, and therefore can neglect torsional effects

CDM Smith

CLIENT	TVA	COMPUTED BY / DATE	KMF	08/16/12
PROJECT	Watts Bar Ash Pond	CHECKED BY / DATE	dg	8/17/12
DETAIL	Precast Box Culverts	REVISION NO. / DATE	-	-
PROJECT NO.	92016.2202	REVIEWED BY / DATE	-	-

Calculation Description: Precast Box Culvert Design for Inlet and Outlet

1.0 Objective

Design inlet and outlet precast box culverts for use by the precaster.

2.0 Procedure

1.) Determine loads applied to all walls and slabs. Including fluid/earth lateral load, pedestrian live load (on rail), HS-20 Vehicle Live Load surcharge, Soil Vertical Pressure, and Self-weight of concrete.

2.) Calculate applied moments and shears using AASHTO load combinations.
3.) Calculate flexural (moment) and shear capacities of walls (wingwall and weir), beams, and columns.
4.) Check all capacity/applied ratios are less than 1.

3.0 References / Data Sources

1.) ASCE 7
2.) IBC 2006
3.) ACI 318

4.0 Assumptions / Limitations

1.) Concrete strength increased in design for precast concrete.

5.0 Calculations

5.1 Inlet Side Box Culverts

- Refer to FDOT Box Culvert Analysis Program design for the "6x4 under 13.5' fill" Culverts: Dimensions and Material Properties, Box and Headwall Load Cases, Box Reinforcement Design, and Bouyancy Check for Rectangular Tanks

5.2 Outlet Side Box Culverts

- Refer to FDOT Box Culvert Analysis Program design for the "6x5 under 13.5' fill" Culverts: Dimensions and Material Properties, Box and Headwall Load Cases, Box Reinforcement Design, and Bouyancy Check for Rectangular Tanks

6.0 Conclusions

- The culverts have 8inch walls and slabs with reinforcing of #5 @ 6inches on center, each way, each face, top and bottom.

Inlet Side

Box Culvert Analysis Program
Dimensions and Material Properties

This program uses design values from the CurrentDataFile *in use. It is generally* ***not*** *necessary to save the modified Mathcad worksheet since all the design values are saved in the* CurrentDataFile.

df 8/17/2012

Reference:C:\FDOT Structures\Programs\LRFDBoxCulvertV3.2\ReadData.xmcd(R)

data file currently in use:
(verify your intended file)

CurrentDataFile = "\Data Files\6X4 w 13.5 soil.dat"

Only change new values. Calculate Worksheet (CTRL+F9) twice to save/view new values..
If current data values are correct, leave (XX) *in the* newData *field.*

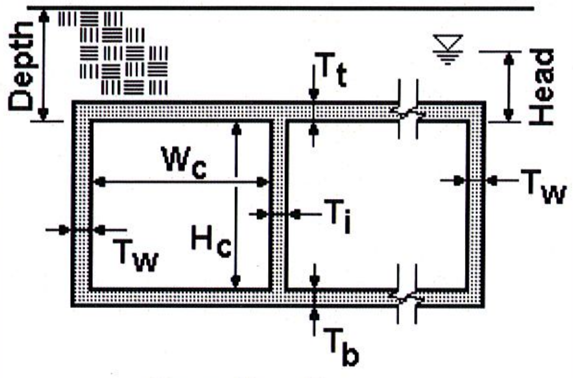
Project = "6' x 4' under 13.5' fill"   newProject := "6' x 4' under 13.5' fill"

DesignedBy = "KMF"   newDesignedBy := "XX"

CheckedBy = "DLF"   newCheckedBy := "XX"

Comment = "two cell, no box skew, wingwalls parallel to traffic"

newComment := "XX"



Box Section

Design Parameters

$b_w = 1\ ft$ *This program analyzes a one foot wide cross section*

Geometry and Box Dimensions

to enter and/or change data values, change **XX**·dimension *values to the desired values*

opening width of cell ✓ $W_c = 6\ ft$ $newW_c :=$ **XX**·ft

top slab thickness, (8 inch min.) ✓ $T_t = 8 \cdot in$ $newT_t :=$ **XX**·in

exterior wall thickness, (8 inch min.) ✓ $T_w = 8 \cdot in$ $newT_w :=$ **XX**·in

length of culvert along centerline $L_c = 100\ ft$ $newL_c :=$ **XX**·ft

distance from top of opening to surface   Depth = 14.17 ft   newDepth := **XX**·ft

opening height of cell $H_c = 4\ ft$ $newH_c := 4 \cdot ft$

bottom slab thickness, (8 inch min.) $T_b = 8 \cdot in$ $newT_b :=$ **XX**·in

interior wall thickness, (8 inch min.) $T_i = 8 \cdot in$ $newT_i :=$ **XX**·in

number of cells   NoOfCells = 1   newNoOfCells := **XX**

water head at top of box opening (typically = 0.0)   Head = 14.17 ft   newHead := **XX**·ft

extension type ✓
0 - *new box (no extension)*
1- *left extension*
2 - *right extension*

newExtension := XX

Extension = 0

extension notes:
1.Two feet is added automatically to the length of culvert and corresponding rebar lengths for splicing to existing culvert per Index No. 289
2. When switching extension types, extension-specific variables require new user inputs (e.g. H_{start}, H_{end}, & L_{ww})

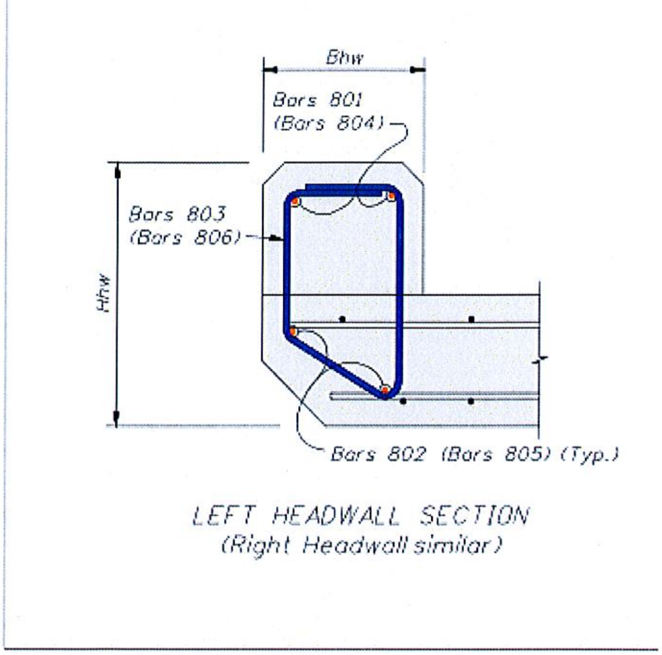
index for number of headwalls

$iwbeg := \text{if}(Extension \neq 2, 0, 1)$

$iwend := \text{if}(Extension \neq 1, 1, 0)$

$iw := iwbeg..iwend \qquad iw = \begin{array}{|r|}\hline 0 \\ \hline 1 \\ \hline \end{array}$

Change all Group values (color) and/or change individual values (white). (Use Math - Calculate Worksheet to update)



LEFT HEADWALL SECTION
(Right Headwall similar)

Left & right Headwall height *(headwall exceeding 2 feet above the top slab is beyond the intent of this program)*

$H_{hw} = \begin{pmatrix} 24 \\ 24 \end{pmatrix} \cdot in \qquad newH_{hw} := \textbf{XX} \cdot in \qquad newH_{hw.left} := \textbf{XX} \cdot in$

$newH_{hw.right} := \textbf{XX} \cdot in$

$B_{hw} = \begin{pmatrix} 12 \\ 12 \end{pmatrix} \cdot in \qquad newB_{hw} := \textbf{XX} \cdot in \qquad newB_{hw.left} := \textbf{XX} \cdot in$

$newB_{hw.right} := \textbf{XX} \cdot in$

CurrentDataFile = "\Data Files\6X4 w 13.5 soil.dat"

box end skew (enter zero if opposite end of extension)

$Skew_{box} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot deg \qquad newSkew_{box} := \begin{pmatrix} \textbf{XX} \cdot deg \\ \textbf{XX} \cdot deg \end{pmatrix}$ *left* *right*

depth of soil above top slab

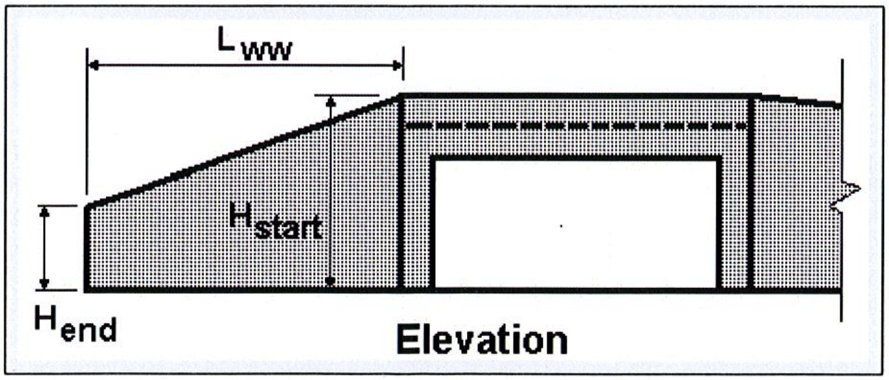
$SoilHeight := \text{if}(newDepth = \textbf{XX} \cdot ft, Depth, newDepth) - \text{if}(newT_t = \textbf{XX} \cdot in, T_t, newT_t) \qquad SoilHeight = 13.5\ ft$

Wingwall Geometry

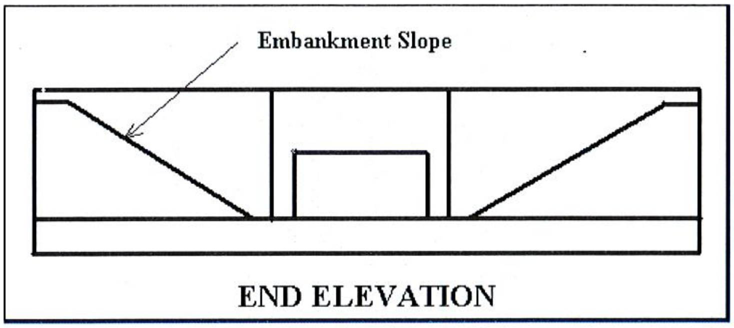
$ibeg := \text{if}(Extension \neq 2, 0, 2)$

$iend := \text{if}(Extension \neq 1, 3, 1)$

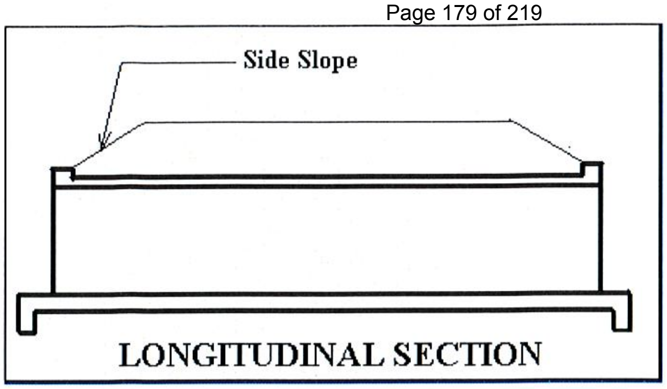
$i := ibeg..iend$



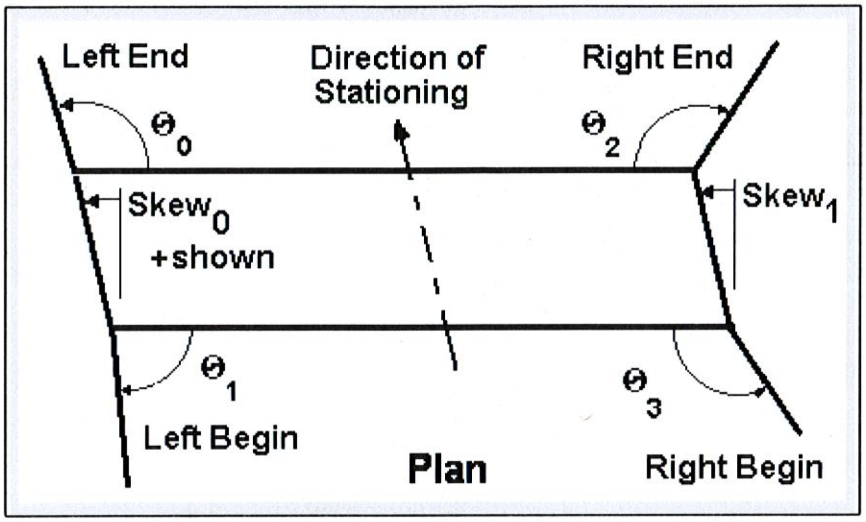
Elevation



END ELEVATION



LONGITUDINAL SECTION



Notes:

Box skew angles measured from square, counterclockwise positive. Wingwall angles θ *measured from box wall to wingwall. (allowable range for* θ *is 45 to 225 degrees).* EmbankmentSlope *is the slope of the soil below the top of the wingwall and used to calculate the wingwall length.* SideSlope *is the slope of the soil that goes downward perpendicular to the top of the headwall. If there are two headwalls and they are not parallel, default* $\beta_{sideslope}$ *has to be overridden using* β_{user}.

$$\text{EmbankmentSlope} := \frac{1}{2} \quad \frac{rise}{run}$$

$$\text{SideSlope} := \frac{1}{2} \quad \frac{rise}{run}$$

$$H_{start.default} := \max(H_{hw}) + \text{if}\left[\left(newH_c = \mathbf{XX}\cdot ft\right), H_c, newH_c\right] \qquad H_{start.default} = 6\,ft$$

Program current values

$i =$	$\frac{H_{start_i}}{ft} =$	$\frac{\theta_i}{deg} =$
0	8	90
1	8	90
2	8	90
3	8	90

0-left end

Change all values

$newH_{start_i} := \mathbf{XX}\cdot ft$

$new\theta_i := \mathbf{XX}\cdot deg$

Enable the following to use default values (right click - Enable Eval.)

$newH_{start_i} := H_{start.default}$

Change individual wingwall values

$newH_{start.ww_i} :=$	$new\theta_{ww_i} :=$
$\mathbf{XX}\cdot ft$	$\mathbf{XX}\cdot deg$
$\mathbf{XX}\cdot ft$	$\mathbf{XX}\cdot deg$
$\mathbf{XX}\cdot ft$	$\mathbf{XX}\cdot deg$
$\mathbf{XX}\cdot ft$	$\mathbf{XX}\cdot deg$

1-left begin
2-right end
3-right begin

*Default *Wingwall Length:*

$$i = \begin{array}{|r|}\hline 0\\\hline 1\\\hline 2\\\hline 3\\\hline\end{array}$$

$$L_{ww.default} = \begin{pmatrix}18\\18\\18\\18\end{pmatrix} ft$$

**assumes roadway CL is parallel to headwalls*

$$\beta_{sideslope} = \begin{pmatrix}26.57\\26.57\\26.57\\26.57\end{pmatrix} \cdot deg$$

0-left end
1-left begin
2-right end
3

$$H_{start} = \begin{pmatrix}8\\8\\8\\8\end{pmatrix} ft$$

*Default *Wingwall End Height:*

$$H_{end.default} = \begin{pmatrix}8\\8\\8\\8\end{pmatrix} ft$$

**assumes roadway CL is parallel to headwalls*

Program current values

$i =$	$\frac{L_{ww_i}}{ft} =$	$\frac{H_{end_i}}{ft} =$
0	17	8
1	17	8
2	17	8
3	17	8

0-left end
1-left begin
2-right end
3-right begin

Change all values

$newL_{ww_i} := \mathbf{XX} \cdot ft$

$newH_{end_i} := \mathbf{XX} \cdot ft$

*Enable the following to use *default values (right click - Enable Eval.):*

$newL_{ww_i} := L_{ww.default_i}$

$newH_{end_i} := H_{end.default_i}$

**Default value assumes roadway CL is parallel to headwalls*

Change individual wingwall values

$newL_{w.ww_i} :=$	$newH_{end.ww_i} :=$	$\beta_{user_i} :=$
XX·ft	**XX**·ft	**XX**·deg
XX·ft	**XX**·ft	**XX**·deg
XX·ft	**XX**·ft	**XX**·deg
XX·ft	**XX**·ft	**XX**·deg

Soil Properties

density of soil $\gamma_{soil} = 120 \cdot \frac{lbf}{ft^3}$ $new\gamma_{soil} := \mathbf{XX} \cdot \frac{lbf}{ft^3}$

soil friction angle $\phi = 30 \cdot deg$ $new\phi := \mathbf{XX} \cdot deg$

modulus of subgrade reaction $k_s = 100000 \cdot \frac{lbf}{ft^3}$ $newk_s := \mathbf{XX} \cdot \frac{lbf}{ft^3}$

nominal bearing capacity, this is allowable bearing pressure(typically from Geotech Engr) multiplied by factor of safety $q_{nom} = 2000 \cdot \frac{lbf}{ft^2}$ $newq_{nom} := \mathbf{XX} \cdot \frac{lbf}{ft^2}$

Material Properties

Environmental Class

1 - slightly aggressive
2 - moderately aggressive
3 - extremely aggressive

$Env = 2$ $newEnv := \mathbf{XX}$

modular ratio	$n_{mod} = 9$	$newn_{mod} := \mathbf{XX}$	*density of concrete*	$\gamma_{conc} = 150 \cdot \frac{lbf}{ft^3}$	$new\gamma_{conc} := \mathbf{XX} \cdot \frac{lbf}{ft^3}$
reinforcing strength	$F_y = 60 \cdot ksi$	$newF_y := \mathbf{XX} \cdot ksi$	*density of water*	$\gamma_w = 62.4 \cdot \frac{lbf}{ft^3}$	$new\gamma_w := \mathbf{XX} \cdot \frac{lbf}{ft^3}$

concrete strength preset for FDOT work

$f_{c.fdot} := if(Env \le 1, 3.4 \cdot ksi, 5.5 \cdot ksi)$ $f_{c.fdot} = 5.5 \cdot ksi$ $f_c = 5.5 \cdot ksi$ $newf_c := f_{c.fdot}$

Concrete Modulus of Elasticity (based on strength as given in the Structures Design Guidelines)

$E_{fdot} := if(AggFactor = 1, 0.9 \cdot 1820, 1820) \sqrt{\frac{f_{c.fdot}}{ksi}} \cdot ksi$

enter "0" for Standard Aggregate or "1" for Florida Aggregate

$AggFactor := 1$

$E_{fdot} = 3841.45 \cdot ksi$ $E = 3841 \cdot ksi$ $newE := E_{fdot}$

Construction Vehicle Load (optional)

Applies wheel load assuming no soil cover.

spacing between axles 1 and 2 & axles 2 and 3:

$ConAxleSpacing1 = 16\,ft$ $newConAxleSpacing1 := \mathbf{XX} \cdot ft$

$ConAxleSpacing2 = 16\,ft$ $newConAxleSpacing2 := \mathbf{XX} \cdot ft$

construction wheel loads 1, 2, and 3:

$ConWheel1 = 0 \cdot kip$ $newConWheel1 := \mathbf{XX} \cdot kip$

$ConWheel2 = 0 \cdot kip$ $newConWheel2 := \mathbf{XX} \cdot kip$

$ConWheel3 = 0 \cdot kip$ $newConWheel3 := \mathbf{XX} \cdot kip$

Headwall Loads

Additional dead load if a barrier is located on top of the headwall

$BarrierDL_{hw} = 0 \cdot \frac{kip}{ft}$ $newBarrierDL_{hw} := \mathbf{XX} \cdot \frac{kip}{ft}$

Set whether a line of truck wheels is considered as a loading. (1 = considered, 0 = not considered)

$ConsiderLL_{hw} = 1$ $newConsiderLL_{hw} := \mathbf{XX}$

enter "0" for not considered or "1" for considered

end of data entry

Write Box Design Data to NewDataFile

CurrentDataFile = "\Data Files\6X4 w 13.5 soil.dat"

assign the data read in to the data to be read out, then change only the new values using the fSwitchData *function:*

DataOut := DataIn

Reference:C:\FDOT Structures\Programs\LRFDBoxCulvertV3.2\ReadData.xmcd(R)

CurrentDataFile = "\Data Files\6X4 w 13.5 soil.dat"

Box Culvert Program:
Box & Headwall Load Cases

© 2002 Florida Department of Transportation

Project = "6' x 4' under 13.5' fill"

DesignedBy = "KMF"

CheckedBy = "DLF" df 8/17/12

Generate Loads- Instructions:

1. 'Calculate Worksheet (CTRL+F9)' to generate loads for the following worksheets (Repeat process if changes are made to Worksheet 1).
2. Close this worksheet without saving and proceed to the following worksheet.

Note: AASHTO section references are shown at right margin, where appropriate, in bold-italic font

Design Parameters

Geometry and box dimensions from CurrentDataFile

✓

$W_c = 6\ \text{ft}$ *opening width of cell*

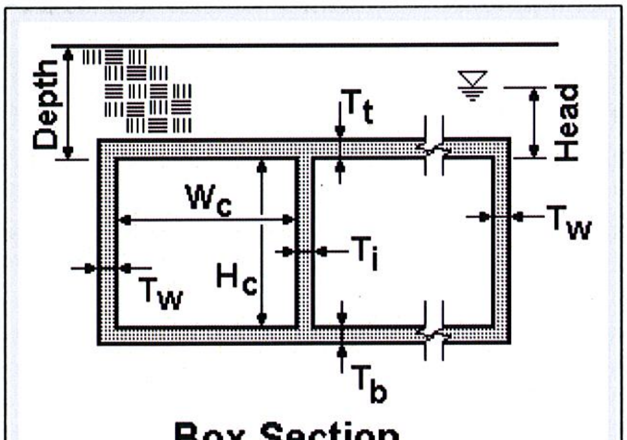
$H_c = 4\ \text{ft}$ *opening height of cell*

$T_t = 8\cdot\text{in}$ *top slab thickness, (8 inch min.)*

$T_b = 8\cdot\text{in}$ *bottom slab thickness, (8 inch min.)*

$T_i = 8\cdot\text{in}$ *interior wall thickness, (8 inch min.)*

$T_w = 8\cdot\text{in}$ *exterior wall thickness, (8 inch min.)*



Box Section

$L_c = 100\ \text{ft}$ *length of culvert along centerline*

$\text{NoOfCells} = 1$ *number of cells*

$\text{Extension} = 0$ *extension type*
0 new box no extension,
1 left extension,
2 right extension

$\text{Head} = 14.17\ \text{ft}$ *water head at top of box (typically = 0.0)*

$\text{Depth} = 14.17\ \text{ft}$ *distance from top of opening to surface*

$\text{HydraulicOpening} := W_c \cdot H_c \cdot \text{NoOfCells}$

$\text{HydraulicOpening} = 24\ \text{ft}^2$

$b_w = 1\ \text{ft}$ *This program analyses a one foot wide cross section*

Soil properties

$\gamma = 120\cdot\frac{\text{lbf}}{\text{ft}^3}$ *density of soil*

$\phi = 30\cdot\text{deg}$ *soil friction angle*

$k_s = 100000\cdot\frac{\text{lbf}}{\text{ft}^3}$ *modulus of subgrade reaction*

$q_{nom} = 2000\ \text{ft}\cdot\frac{\text{lbf}}{\text{ft}^3}$

Material properties

$\text{Env} = 2$ *Environmental Class 1-slightly aggresive 2-moderate 3-extreme*

$n_{mod} = 9$ *modular ratio*

$f_c = 5.5 \cdot ksi$ *concrete strength preset for FDOT work*

$E = 3841 \cdot ksi$ *concrete modulus of elasticity*

$\gamma_{conc} = 150 \cdot \frac{lbf}{ft^3}$ *density of concrete*

$F_y = 60 \cdot ksi$ *reinforcing strength*

Construction vehicle loads (optional)

$ConWheel1 = 0 \cdot kip$

$ConWheel2 = 0 \cdot kip$

$ConWheel3 = 0 \cdot kip$ *construction wheel loads*

$ConAxleSpacing1 = 16\,ft$ *axle spacing between Wheels 1 and 2*

$ConAxleSpacing2 = 16\,ft$ *axle spacing between Wheels 2 and 3*

Headwall Loads

$ConsiderLL_{hw} = 1$

$BarrierDL_{hw} = 0 \cdot \frac{kip}{ft}$

Box Culvert Design:

Section 1 - Box Loads, 75 pages

$Strength_{box}{}^T =$

	0	1	2	3	4	5	6	7	8	9
0	5.34	1.73	5.34	1.73	11.09	6.28	2.39	6.9	1.85	5.74
1	9.63	-2.53	9.63	-2.53	0	4.04	0	-4.16	0	0
2	0.01	0	0.01	0	0	9.63	-2.53	10.21	-1.95	...

$Service_{box}{}^T =$

	0	1	2	3	4	5	6	7	8	9
0	3.66	0	3.66	0	8.46	4.46	0	4.84	0	4.11
1	6.72	0.33	6.72	0.33	0	2.63	0	-2.75	0	0
2	0	0	0	0	0	6.72	0.33	7.19	0.8	...

Write box load data to DataOut variable

$DataOut_{85} := Strength_{box}$

$DataOut_{86} := Service_{box}$

Headwall Design

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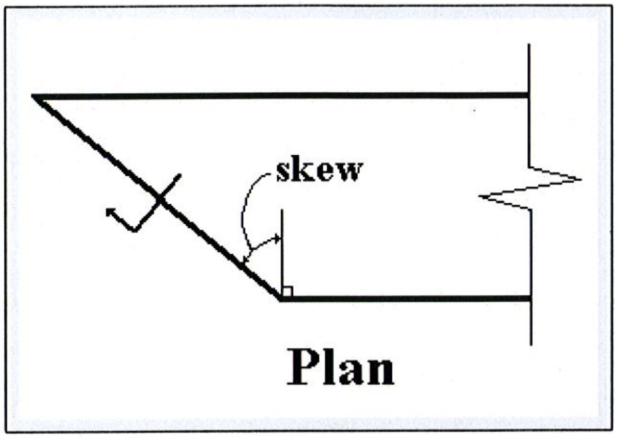
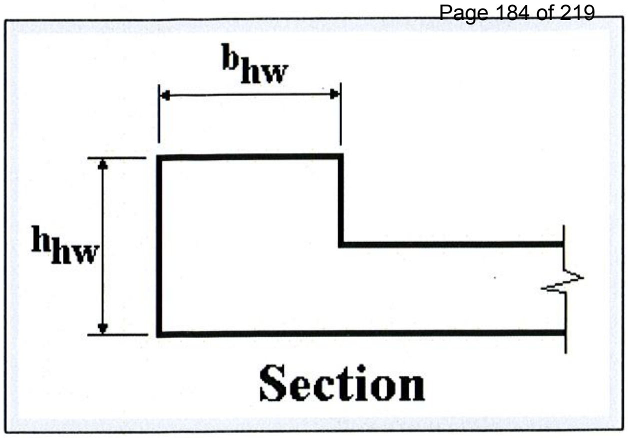
Design Headwall

Note: No lateral load analysis is performed on the headwall. If significant horizontal loads are anticipated, supplemental calculations are required.





Note: AASHTO section references are shown at right margin in bold-italic font.

SkewDiagram

Tributary Area for headwall design is defined in this file

nc := NoOfCells

iwbeg := if(Extension ≠ 2, 0, 1) iwend := if(Extension ≠ 1, 1, 0) iw := iwbeg.. iwend *index for walls*

Design parameters

$\text{iw} = \begin{array}{|r|}\hline 0 \\ \hline 1 \\ \hline\end{array}$ $B_{hw} = \begin{pmatrix} 12 \\ 12 \end{pmatrix} \cdot \text{in}$

$\text{iw} = \begin{array}{|r|}\hline 0 \\ \hline 1 \\ \hline\end{array}$ $H_{hw} = \begin{pmatrix} 24 \\ 24 \end{pmatrix} \cdot \text{in}$

$\text{Skew} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot \text{deg}$ *left* *right*

$\text{BarrierDL}_{hw} = 0 \cdot \dfrac{\text{kip}}{\text{ft}}$ *Additional dead load if a barrier is located on top of the headwall*

$\text{ConsiderLL}_{hw} = 1$ *This variable sets whether a line of truck wheels is considered as a loading. A 1 value means it is considered and a 0 means it is not*

ic := 0 .. (nc − 1) *index for cells*

NoOfCells = 1 *number of cells*

$f_c = 5.5 \cdot \text{ksi}$

$W_c = 6\ \text{ft}$ *opening width of cell*

$H_c = 4\ \text{ft}$ *opening height of cell*

$T_i = 8 \cdot \text{in}$ *interior wall thickness*

$T_t = 8 \cdot \text{in}$ *top slab thickness*

$T_w = 8 \cdot \text{in}$ *exterior wall thickness*

$\text{Env} = 2$ *Environmental Class*
1 is slightly aggressive
2 is moderate
3 is extreme

$E = 3841 \cdot \text{ksi}$ *concrete modulus of elasticity*

$\gamma = 120 \cdot \dfrac{\text{lbf}}{\text{ft}^3}$ *soil density*

$\text{SoilHeight} = 13.5\ \text{ft}$ *soil height above top slab*

$\gamma_w = 62.4 \cdot \dfrac{\text{lbf}}{\text{ft}^3}$ *weight of water*

$n_{mod} = 9$ *ratio of steel and concrete modulus of elasticity*

$\gamma_{conc} = 150 \cdot \dfrac{\text{lbf}}{\text{ft}^3}$ *concrete unit weight*

$F_y = 60 \cdot \text{ksi}$

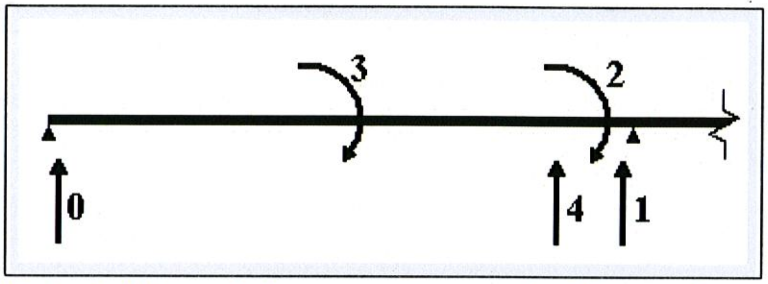
Calculate load combinations

Strength

$\text{Strength}_{hw} := 1.25 \cdot \text{Force}_{sw} + 1.35 \cdot \text{Force}_{ew} + 1.75 \cdot \text{Force}_{ll} \cdot \text{ConsiderLL}_{hw} + 1.75 \cdot \text{Force}_{lane} \cdot \text{ConsiderLL}_{hw}$

Service

$Service_{hw} := 1.0 \cdot Force_{sw} + 1.0 \cdot Force_{ew} + 1.0 \cdot Force_{ll} \cdot ConsiderLL_{hw} + 1.0 \cdot Force_{lane} \cdot ConsiderLL_{hw}$



*Due to the difference in the center-to-center span (model) versus clear span (actual) a reduction in the moment forces is allowed. For end moments, a reduction of 1/3*Vend*t is used and for midspan moments 1/6*Vend*t is used.*

$$Strength_{hw} = \begin{pmatrix} 29.05 & 16.79 & 1.6 \times 10^{-14} & 46.41 & 29.27 \\ 29.05 & 16.79 & 1.6 \times 10^{-14} & 46.41 & 29.27 \end{pmatrix} \qquad Service_{hw} = \begin{pmatrix} 16.97 & 9.96 & 9.22 \times 10^{-15} & 27.13 & 17.09 \\ 16.97 & 9.96 & 9.22 \times 10^{-15} & 27.13 & 17.09 \end{pmatrix}$$

$$Strength_{hw_{iw,2}} := Strength_{hw_{iw,2}} - \frac{1}{3} \cdot Strength_{hw_{iw,1}} \cdot \frac{T_w}{ft} \qquad Service_{hw_{iw,2}} := Service_{hw_{iw,2}} - \frac{1}{3} \cdot Service_{hw_{iw,1}} \cdot \frac{T_w}{ft}$$

$$Strength_{hw_{iw,3}} := Strength_{hw_{iw,3}} - \frac{1}{6} \cdot \left(\frac{4 \cdot Strength_{hw_{iw,3}}}{L_{hw_{iw,0}}} \right) \cdot \frac{T_w}{ft} \qquad Service_{hw_{iw,3}} := Service_{hw_{iw,3}} - \frac{1}{6} \cdot \left(\frac{4 \cdot Service_{hw_{iw,3}}}{L_{hw_{iw,0}}} \right) \cdot \frac{T_w}{ft}$$

$$Strength_{hw} = \begin{pmatrix} 29.05 & 16.79 & -3.73 & 43.31 & 29.27 \\ 29.05 & 16.79 & -3.73 & 43.31 & 29.27 \end{pmatrix} \qquad Service_{hw} = \begin{pmatrix} 16.97 & 9.96 & -2.21 & 25.32 & 17.09 \\ 16.97 & 9.96 & -2.21 & 25.32 & 17.09 \end{pmatrix}$$

Write box and headwall load CurrentDataFile

CurrentDataFile = "\Data Files\6X4 w 13.5 soil.d DataOut := DataIn

$DataOut_{31} := \frac{L_0}{ft}$

$DataOut_{85} := Strength_{box}$ $\quad DataOut_{86} := Service_{box}$ $\quad DataOut_{87} := Strength_{hw}$ $\quad DataOut_{88} := Service_{hw}$

$DataOut_{101} := BoxForce_{trk}$ $\quad DataOut_{102} := BoxForce_{ll}$ $\quad DataOut_{103} := BoxForce_{dc}$

$DataOut_{104} := BoxForce_{lane}$ $\quad DataOut_{105} := BoxForce_{es}$ $\quad DataOut_{106} := BoxForce_{ev}$

$DataOut_{107} := BoxForce_{eh}$ $\quad DataOut_{108} := BoxForce_{wa}$ $\quad DataOut_{109} := BoxForce_{ls}$

$DataOut_{112} := \frac{Haunch_{top}}{in}$ $\quad DataOut_{113} := \frac{Haunch_{bot}}{in}$

WRITEPRN(CurrentDataFile) := DataOut

WRITEPRN(NewDataFile) := DataOut

Reference:C:\FDOT Structures\Programs\LRFDBoxCulvertV3.2\ReadData.xmcd(R)

CurrentDataFile = "\Data Files\6X4 w 13.5 soil.dat"

Box Culvert Program:
Box Reinforcement Design

Project = "6' x 4' under 13.5' fill" —ck

DesignedBy = "KMF"

CheckedBy = "DLF" 8/17/2012

Note: AASHTO section references are shown at right margin, where appropriate, in bold-italic font

$b_w = 1\ \text{ft}$ *This program analyzes a one foot wide cross section*

1. Design Parameters

Geometry and Box Dimensions

$W_c = 6\ \text{ft}$ *opening width of cell*

$H_c = 4\ \text{ft}$ *opening height of cell*

$T_t = 8\cdot\text{in}$ *top slab thickness, (8 inch min.)*

$T_b = 8\cdot\text{in}$ *bottom slab thickness, (8 inch min.)*

$T_w = 8\cdot\text{in}$ *exterior wall thickness, (8 inch min.)*

$T_i = 8\cdot\text{in}$ *interior wall thickness, (8 inch min.) (Ti=Tw for one cell boxs)*

$L_c = 100\ \text{ft}$ *length of culvert along centerline*

$\text{Depth} = 14.17\ \text{ft}$ *distance from top of opening to surface*

$\text{Extension} = 0$ *extension type*
0 new box, no extension.
1 left extension
2 right extension

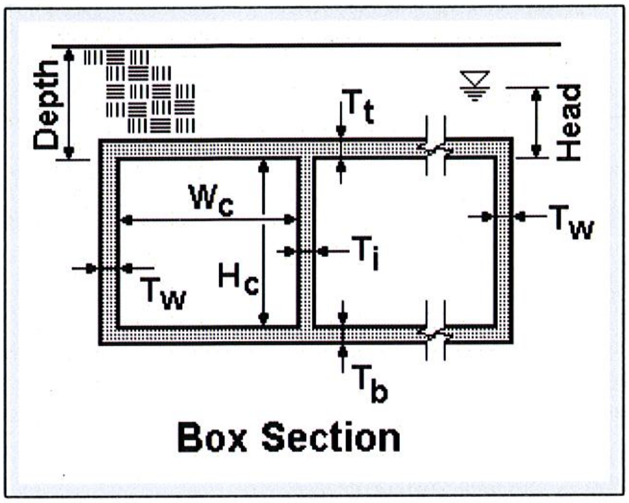
$\text{NoOfCells} = 1$ *number of cells*

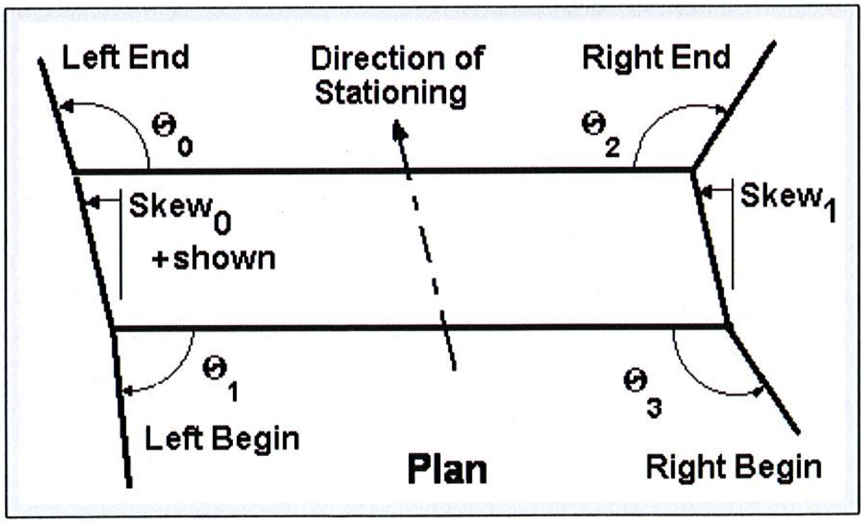
$\text{Head} = 14.17\ \text{ft}$ *water head at top of box (typically = 0.0)*

$$\text{Skew}_{box} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}\cdot\text{deg}$$

$$\text{HydraulicOpening} := W_c\cdot H_c\cdot\text{NoOfCells}$$

$$\text{HydraulicOpening} = 24\ \text{ft}^2$$





Soil Properties

$\gamma = 120\cdot\frac{\text{lbf}}{\text{ft}^3}$ *density of soil*

$k_s = 100000\cdot\frac{\text{lbf}}{\text{ft}^3}$ *modulus of subgrade reaction*

$\phi = 30\cdot\text{deg}$ *soil friction angle*

Material Properties

$Env = 2$ *Environmental Class*
1-slightly aggressive
2-moderate *3-extreme*

$n_{mod} = 9$ *modular ratio*

$f_c = 5.5 \cdot ksi$ *concrete strength*

$\gamma_{conc} = 150 \cdot \frac{lbf}{ft^3}$ *density of concrete*

$E = 3841 \cdot ksi$ *concrete modulus of elasticity*

$F_y = 60 \cdot ksi$ *reinforcing strength*

Construction Vehicle Loads (if required)

$ConWheel1 = 0 \cdot kip$ $ConWheel2 = 0 \cdot kip$ $ConWheel3 = 0 \cdot kip$ *construction wheel loads*

$ConAxleSpacing1 = 16\,ft$ *space between axles 1 and 2*

$ConAxleSpacing2 = 16\,ft$ *space between axles 2 and 3*

2. Design and Check Main Reinforcing

CurrentDataFile = "\Data Files\6X4 w 13.5 soil.dat"

$it := 0..20$ *index for transverse sections*

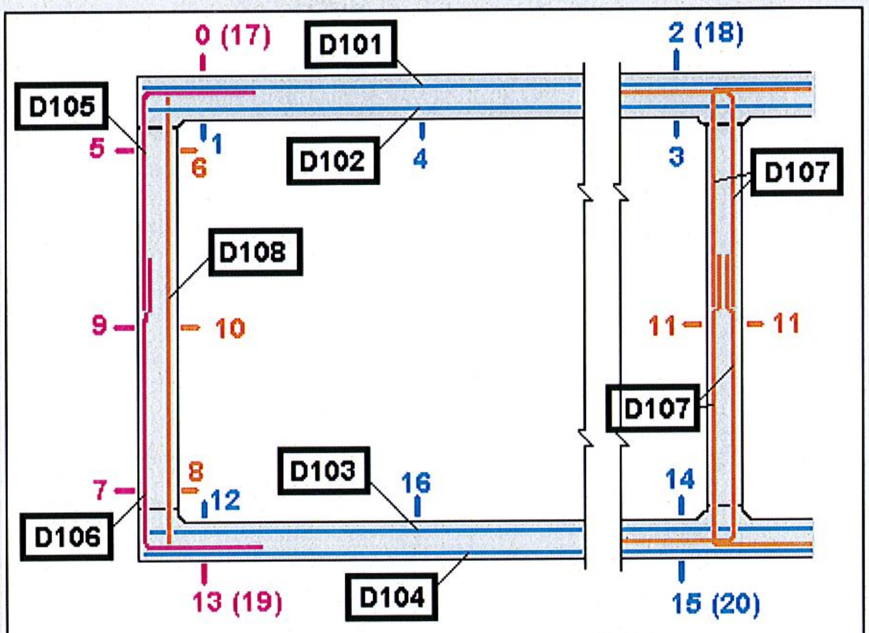
$BarSize_{box_{it}} := 0$ $S_{box_{it}} := 12 \cdot in$

Cross Section Notes:
1. Bars shown with the same color are combined as Bar Groups.
2. Colored numbers indicate moment analysis locations.
3. Colored numbers in parenthesis indicate shear analysis locations.
4. Black numbers refer to bar designations.

Enter box reinforcing size and spacing

Generally, reinforcement should be at least a #3 bar and spacing should not exceed 12 inches.

Note: Shear generally controls slab and wall thicknesses and cracking generally controls reinforcement areas



BOX CROSS SECTION
Reinforcement and Analysis Locations

Bar Designation (section number) *Bar Sizes & Spacings used in analysis* *Change Bar Group values (color) or change individual Bars (white)*

D101(2)
D102(1,3,4)
D103(12,14,16)
D104(15)

$BarSize_{slabs} = \begin{pmatrix} 5 \\ 5 \\ 5 \\ 5 \end{pmatrix}$ $S_{slabs} = \begin{pmatrix} 6 \\ 6 \\ 6 \\ 6 \end{pmatrix} \cdot in$

$newBarSize_{slabs} := \mathbf{XX}$

$newS_{slabs} := \mathbf{XX} \cdot in$

$BarSizeD1_{01} := \mathbf{XX}$ $SD1_{01} := \mathbf{XX} \cdot in$

$BarSizeD1_{02} := \mathbf{XX}$ $SD1_{02} := \mathbf{XX} \cdot in$

$BarSizeD1_{03} := \mathbf{XX}$ $SD1_{03} := \mathbf{XX} \cdot in$

$BarSizeD1_{04} := \mathbf{XX}$ $SD1_{04} := \mathbf{XX} \cdot in$

D105(9,0,5)
D106(9,7,13)

$BarSize_{corners} = \begin{pmatrix} 5 \\ 5 \end{pmatrix}$ $S_{corners} = \begin{pmatrix} 6 \\ 6 \end{pmatrix} \cdot in$

$newBarSize_{corners} := \mathbf{XX}$

$newS_{corners} := \mathbf{XX} \cdot in$

$BarSizeD1_{05} := \mathbf{XX}$ $SD1_{05} := \mathbf{XX} \cdot in$

$BarSizeD1_{06} := \mathbf{XX}$ $SD1_{06} := \mathbf{XX} \cdot in$

D107(11)
D108(6,8,10)

$\text{BarSize}_{\text{walls}} = \begin{pmatrix} 5 \\ 5 \end{pmatrix}$

$S_{\text{walls}} = \begin{pmatrix} 6 \\ 6 \end{pmatrix} \cdot \text{in}$

$\text{newBarSize}_{\text{walls}} := \mathbf{XX}$

$\text{newS}_{\text{walls}} := \mathbf{XX} \cdot \text{in}$

$\text{BarSizeD1}_{07} := \mathbf{XX} \quad \text{SD1}_{07} := \mathbf{XX} \cdot \text{in}$

$\text{BarSizeD1}_{08} := \mathbf{XX} \quad \text{SD1}_{08} := \mathbf{XX} \cdot \text{in}$

Section 2 - Box Main Reinforcement, 10 pages

$\text{CheckCracking}_{\text{box}}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	...

$\text{Summary}(\text{CheckCracking}_{\text{box}}) = \text{"OK"}$

$\text{CheckM}_{\text{box}}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	...

$\text{Summary}(\text{CheckM}_{\text{box}}) = \text{"OK"}$

$\text{CheckAs}_{\text{min.box}}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	...

$\text{Summary}(\text{CheckAs}_{\text{min.box}}) = \text{"OK"}$

$\text{CheckShear}_{\text{box}}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	...

$\text{Summary}(\text{CheckShear}_{\text{box}}) = \text{"OK"}$

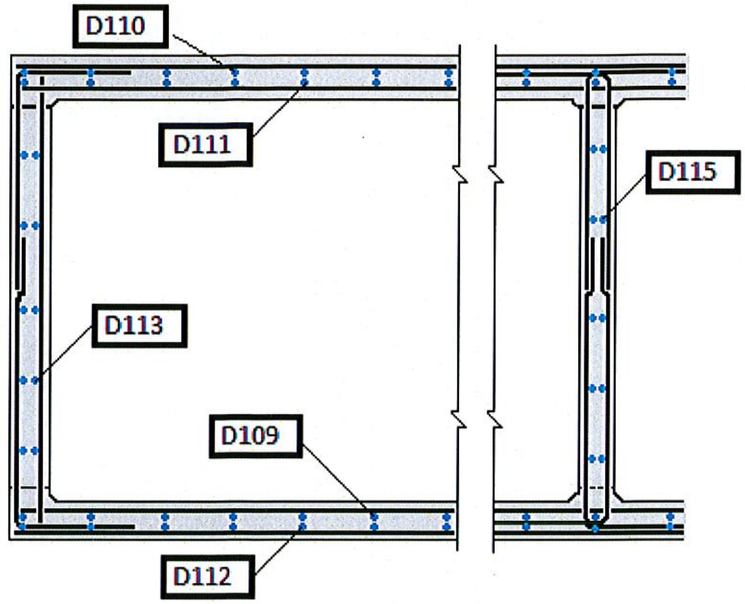
$\text{Summary}(\text{CheckAll}_{\text{box}}) = \text{"OK"}$

3. Design and Check Box Longitudinal Reinforcing

CurrentDataFile = "\Data Files\6X4 w 13.5 soil.dat"

To meet LRFD temperature and shrinkage requirements, reinforcement spacing should not exceed 12 inches.

$il := 0..4$ *index for longitudinal sections*



Box Cross Section
Longitudinal Reinf. and Analysis Locations

Enter Box Longitudinal Reinforcing

Bar Sizes & Spacings used in analysis

$$BarSize_{long} = \begin{pmatrix} 5 \\ 5 \\ 5 \\ 5 \\ 5 \end{pmatrix} \qquad S_{long} = \begin{pmatrix} 6 \\ 6 \\ 6 \\ 6 \\ 6 \end{pmatrix} \cdot in$$

Change Bar Group (color) values or change individual Bars (white)

$newBarSize_{long} := \mathbf{XX}$

$newS_{long} := \mathbf{XX} \cdot in$

$BarSizeD1_{09} := \mathbf{XX}$ $SD1_{09} := \mathbf{XX} \cdot in$

$BarSizeD1_{10} := \mathbf{XX}$ $SD1_{10} := \mathbf{XX} \cdot in$

$BarSizeD1_{11} := \mathbf{XX}$ $SD1_{11} := \mathbf{XX} \cdot in$

$BarSizeD1_{12} := \mathbf{XX}$ $SD1_{12} := \mathbf{XX} \cdot in$

$BarSizeD1_{13} := \mathbf{XX}$ $SD1_{13} := \mathbf{XX} \cdot in$

Section 3 - Box Longitudinal Reinforcement, 3 pages

$CheckAs_{temp.box}{}^{T} = (\text{"ok"} \quad \text{"ok"} \quad \text{"ok"} \quad \text{"ok"} \quad \text{"ok"})$

$Summary(CheckAs_{temp.box}) = \text{"OK"}$

$Summary(CheckAll_{box}) = \text{"OK"}$

Write Box Design Data to
CurrentDataFile = "\Data Files\6X4 w 13.5 soil.dat" **file**

Assign the data values read in to the ones to be read out, then change only the ones modified in this file

DataOut := DataIn

$DataOut_{32} := BarSize_{slabs}$ $DataOut_{33} := \frac{S_{slabs}}{in}$ $DataOut_{34} := BarSize_{walls}$ $DataOut_{35} := \frac{S_{walls}}{in}$

$DataOut_{36} := BarSize_{corners}$ $DataOut_{37} := \frac{S_{corners}}{in}$ $DataOut_{38} := BarSize_{long}$ $DataOut_{39} := \frac{S_{long}}{in}$

$DataOut_{55} := str2vec(Summary(CheckAll_{box}))$ $DataOut_{90} := ReinfBox$ $DataOut_{94} := \frac{As}{ft^2}$ $DataOut_{95} := \frac{S_{box}}{ft}$

$DataOut_{96} := BarSize_{loc}$

$DataOut_{110} := \frac{d}{ft}$ $DataOut_{111} := \frac{t_{section}}{ft}$

WRITEPRN(CurrentDataFile) := DataOut

WRITEPRN(NewDataFile) := DataOut

CDM 2301 Maitland Center Pkwy Suite 300 Maitland, FL 32751	Client TVA Project Ash Pond Detail 6'x4' Box Culvert Inlet Box Culvert	Job No. 95618-92016 Date Checked 8-17-2012 Checked By df	Computed By KMF Date 6/28/2012 Page No. 1

Buoyancy Check For Rectangular Tanks

Author:	Justin Boggs	Date:	20-Mar-07	Checked By:		File Name:	buoy-rec.xls

Limitations

This program should only be used with a full knowledge of the analysis procedure used in the program. Result of the program is subject to structural engineering evaluation and judgement. This program is for the use of CDM Structural Engineering Staff Only.

Parameters

Concrete Density (γ_c)	*0.150 kip/ft^3*	*Backfill Soil Density (γ_{sat})* *(Typ. Range 100 to 125 pcf)*	*0.115 kip/ft^3*
Water Density (γ_w)	*0.0624 kip/ft^3*	*Soil Friction Angle (ϕ)* *(Typ. Range 15 to 20 deg)*	*0 °* ✓

Structure Dimensions

Inside Length (l)	*1 ft*	*Top Slab Thickness (t_{ts})*	*8 in*	*Height of Walls above Base Slab (h_t)*	*4 ft*
Inside Width (w)	*6 ft*	*Base Slab Thickness (t_{bs})*	*8 in*	*Height to Grade above Base Slab (h_e)*	*6.67 ft*
Wall Thickness (t_w)	*8 in* ✓	*Base Slab Toe Width (l_{toe})*	*0 in*	*Height to GWL above Base Slab (h_w)*	*6.67 ft*
Interior Wall Thickness	*0 in*	*Interior Wall Length*	*0 ft*	*Interior Wall Height*	*0 ft*
		Height of Water in Box Culvert	*48 in*	*Height of Soil Above Top Slab (h_s)*	*24 in*

Uplift Forces

Volume of Displaced Water - Above Base Slab Level [6 ft + 2(0.67)]* 4.67 ft = 34.2		*34.2 ft^3*
Volume of Displaced Water - Volume of Base Slab		*4.9 ft^3*
Volume of Displaced Water - Total		*39.1 ft^3*
Uplift Force (U)	$V \cdot \gamma_w =$	2.44 *kip/ft*

Resisting Loads

Weight of Top Slab (wts)	$l \cdot w \frac{t_{ts}}{12} \gamma_c =$	*0.60 kip/ft*
Weight of Soil Above Top Slab		*0.77 kip/ft*
Weight of Water in Box Culvert (reduced by 40%)		*0.60 kip/ft*
Weight of Base Slab (wbs)		*0.733 kip/ft*
Weight of Exterior Walls (ww)		*0.93 kip/ft*
Weight of Interior Walls (wwi)	=	*0.00 kip/ft*
Weight of Soil Above Toe of Base Slab (ws1)	$\left[\left(1+2\frac{t_w+l_{toe}}{12}\right)\left(w+2\frac{t_w+l_{toe}}{12}\right)-\left(1+2\frac{t_w}{12}\right)\left(w+2\frac{t_w}{12}\right)\right]\left[(h_e-h_w)\gamma_{sat}+\left[h_w(\gamma_{sat}-\gamma_w)\right]\right]=$	*0.00 kip/ft*
Weight of Soil in "Pullout Wedges" (ws2)	$\left(\frac{1}{2}h_e^2 TAN(\phi)\gamma_{sat}-\frac{1}{2}h_w^2 TAN(\phi)\gamma_w\right)\cdot 2\cdot\left(1+2\frac{t_w}{12}+w+2\frac{t_w}{12}\right)=$	*0.00 kip/ft*
Weight of Structure		*2.27 kip/ft*
Weight of Structure + Soil Area 1		*2.27 kip/ft*
Weight of Structure + Soil Area 1 + Soil Area 2		*2.27 kip/ft*
Weight of Structure + Soil Above Top Slab		*3.64 kip/ft*

Factor of Safety Against Uplift

Weight of Structure + Soil Above Top Slab / Uplift	*1.49*	≥	*1.3*	*OK* ✓

Outlet Side

Box Culvert Analysis Program

Dimensions and Material Properties

This program uses design values from the CurrentDataFile *in use. It is generally* ***not*** *necessary to save the modified Mathcad worksheet since all the design values are saved in the* CurrentDataFile.

dlf 8/17/2012

Reference:C:\FDOT Structures\Programs\LRFDBoxCulvertV3.2\ReadData.xmcd(R)

data file currently in use:
(verify your intended file)

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.dat"

Only change new values. Calculate Worksheet (CTRL+F9) twice to save/view new values..
If current data values are correct, leave (XX) *in the* newData *field.*

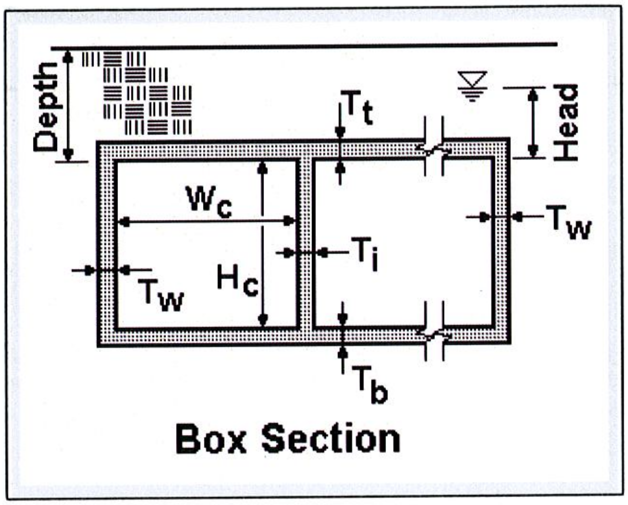
Project = "6' x 5' under 13.5' fill"   newProject := "XX"

DesignedBy = "KMF"   newDesignedBy := "XX"

CheckedBy = "DLF"   newCheckedBy := "XX"

Comment = "two cell, no box skew, wingwalls parallel to traffic"

newComment := "XX"



Box Section

Design Parameters

$b_w = 1$ ft   *This program analyzes a one foot wide cross section*

Geometry and Box Dimensions

to enter and/or change data values, change **XX**·dimension *values to the desired values*

opening width of cell	$W_c = 6$ ft	$newW_c :=$ **XX**·ft	*opening height of cell*	$H_c = 5$ ft	$newH_c :=$ **XX**·ft
top slab thickness, (8 inch min.)	$T_t = 8\cdot in$	$newT_t :=$ **XX**·in	*bottom slab thickness, (8 inch min.)*	$T_b = 8\cdot in$	$newT_b :=$ **XX**·in
exterior wall thickness, (8 inch min.)	$T_w = 8\cdot in$	$newT_w :=$ **XX**·in	*interior wall thickness, (8 inch min.)*	$T_i = 8\cdot in$	$newT_i :=$ **XX**·in
length of culvert along centerline	$L_c = 100$ ft	$newL_c :=$ **XX**·ft	*number of cells*	NoOfCells = 1	newNoOfCells := **XX**
distance from top of opening to surface	Depth = 14.17 ft	newDepth := **XX**·ft	*water head at top of box opening (typically = 0.0)*	Head = 14.17 ft	newHead := **XX**·ft

extension type
0 - *new box (no extension)*
1- *left extension*
2 - *right extension*

newExtension := XX ▾

Extension = 0

extension notes:
1.Two feet is added automatically to the length of culvert and corresponding rebar lengths for splicing to existing culvert per Index No. 289
2. When switching extension types, extension-specific variables require new user inputs (e.g. H_{start}, H_{end}, & L_{ww})

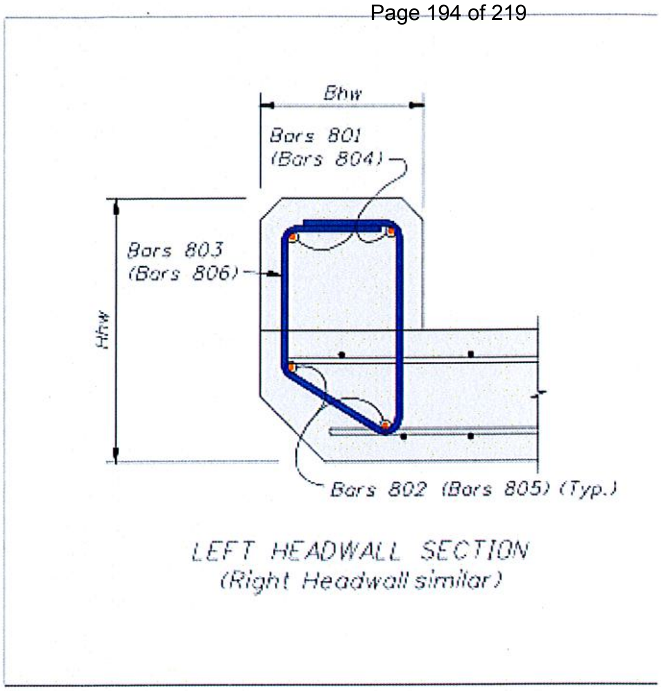
index for number of headwalls

$iwbeg := if(Extension \neq 2, 0, 1)$

$iwend := if(Extension \neq 1, 1, 0)$

$iw := iwbeg .. iwend \qquad iw = \begin{array}{|r|}\hline 0 \\ \hline 1 \\ \hline \end{array}$

Change all Group values (color) and/or change individual values (white). (Use Math - Calculate Worksheet to update)



Left & right Headwall height *(headwall exceeding 2 feet above the top slab is beyond the intent of this program)*

$H_{hw} = \begin{pmatrix} 24 \\ 24 \end{pmatrix} \cdot in \qquad newH_{hw} := \mathbf{XX} \cdot in$

$newH_{hw.left} := \mathbf{XX} \cdot in$

$newH_{hw.right} := \mathbf{XX} \cdot in$

$B_{hw} = \begin{pmatrix} 12 \\ 12 \end{pmatrix} \cdot in \qquad newB_{hw} := \mathbf{XX} \cdot in$

$newB_{hw.left} := \mathbf{XX} \cdot in$

$newB_{hw.right} := \mathbf{XX} \cdot in$

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.dat"

box end skew (enter zero if opposite end of extension)

$Skew_{box} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot deg \qquad newSkew_{box} := \begin{pmatrix} \mathbf{XX} \cdot deg \\ \mathbf{XX} \cdot deg \end{pmatrix}$ *left* *right*

depth of soil above top slab

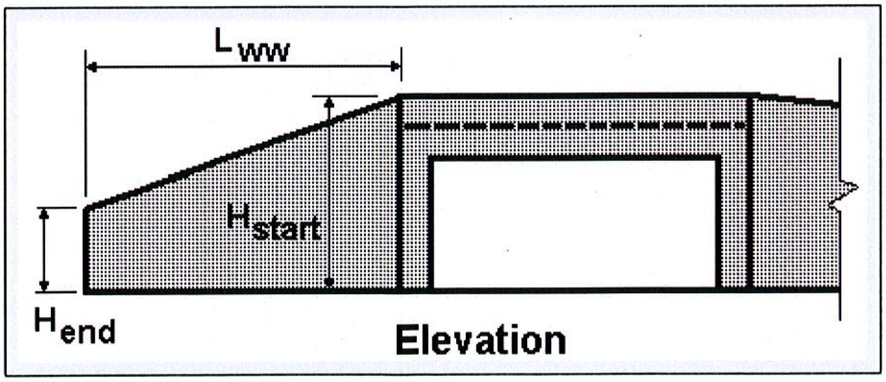
$SoilHeight := if(newDepth = \mathbf{XX} \cdot ft, Depth, newDepth) - if(newT_t = \mathbf{XX} \cdot in, T_t, newT_t) \qquad SoilHeight = 13.5\ ft$

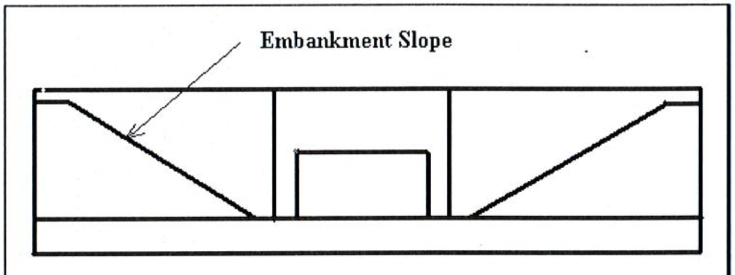
Wingwall Geometry

$ibeg := if(Extension \neq 2, 0, 2)$

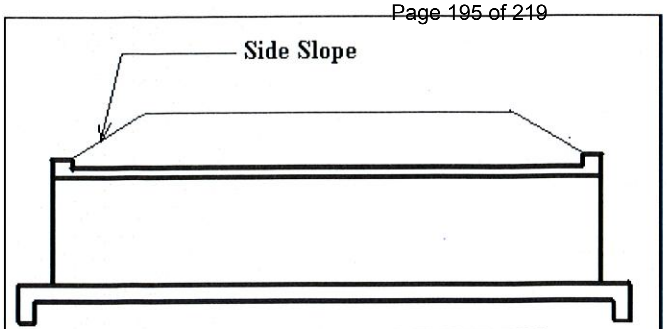
$iend := if(Extension \neq 1, 3, 1)$

$i := ibeg .. iend$

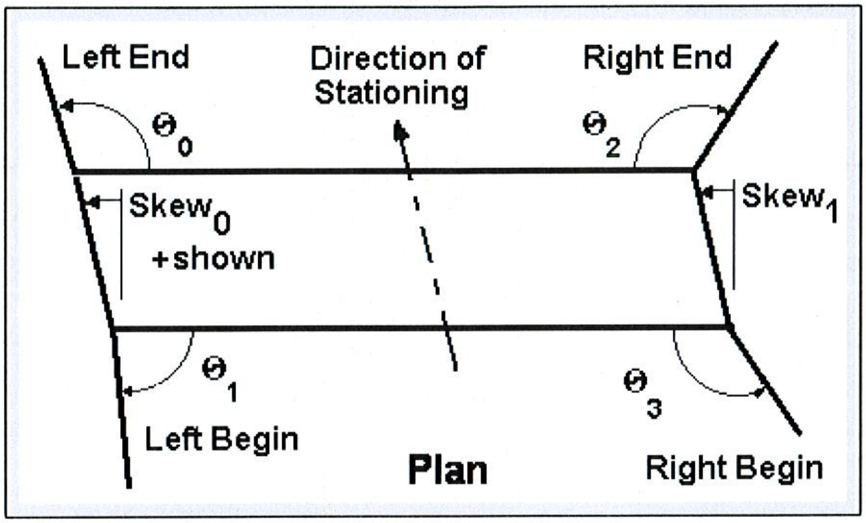




END ELEVATION



LONGITUDINAL SECTION



Notes:
Box skew angles measured from square, counterclockwise positive. Wingwall angles θ *measured from box wall to wingwall. (allowable range for* θ *is 45 to 225 degrees).* EmbankmentSlope *is the slope of the soil below the top of the wingwall and used to calculate the wingwall length.* SideSlope *is the slope of the soil that goes downward perpendicular to the top of the headwall. If there are two headwalls and they are not parallel, default* $\beta_{sideslope}$ *has to be overridden using* β_{user}.

$\text{EmbankmentSlope} := \frac{1}{2}$ *rise / run*

$\text{SideSlope} := \frac{1}{2}$ *rise / run*

$H_{start.default} := \max(H_{hw}) + \text{if}\left[\left(newH_c = \mathbf{XX}\cdot ft\right), H_c, newH_c\right]$

$H_{start.default} = 7\ ft$

Program current values

$i =$	$\frac{H_{start_i}}{ft} =$	$\frac{\theta_i}{deg} =$
0	8	90
1	8	90
2	8	90
3	8	90

0-left end

Change all values

$newH_{start_i} := \mathbf{XX}\cdot ft$

$new\theta_i := \mathbf{XX}\cdot deg$

Enable the following to use default values (right click - Enable Eval.)

$newH_{start_i} := H_{start.default}$

Change individual wingwall values

$newH_{start.ww_i} :=$	$new\theta_{ww_i} :=$
XX·ft	**XX**·deg
XX·ft	**XX**·deg
XX·ft	**XX**·deg
XX·ft	**XX**·deg

1-left begin
2-right end
3-right begin

$i = \begin{pmatrix} 0 \\ 1 \\ 2 \\ 3 \end{pmatrix}$

*Default *Wingwall Length:*

$L_{ww.default} = \begin{pmatrix} 18 \\ 18 \\ 18 \\ 18 \end{pmatrix} ft$

**assumes roadway CL is parallel to headwalls*

$\beta_{sideslope} = \begin{pmatrix} 26.57 \\ 26.57 \\ 26.57 \\ 26.57 \end{pmatrix} \cdot deg$

0-left end
1-left begin
2-right end
3

$H_{start} = \begin{pmatrix} 8 \\ 8 \\ 8 \\ 8 \end{pmatrix} ft$

*Default *Wingwall End Height:*

$H_{end.default} = \begin{pmatrix} 8 \\ 8 \\ 8 \\ 8 \end{pmatrix} ft$

**assumes roadway CL is parallel to headwalls*

Program current values

$i =$	$\frac{L_{ww_i}}{ft} =$	$\frac{H_{end_i}}{ft} =$
0	17	8
1	17	8
2	17	8
3	17	8

0-left end
1-left begin
2-right end
3-right begin

Change all values

$newL_{ww_i} := \mathbf{XX} \cdot ft$

$newH_{end_i} := \mathbf{XX} \cdot ft$

*Enable the following to use *default values (right click - Enable Eval.):*

$newL_{ww_i} := L_{ww.default_i}$

$newH_{end_i} := H_{end.default_i}$

**Default value assumes roadway CL is parallel to headwalls*

Change individual wingwall values

$newL_{w.ww_i} :=$	$newH_{end.ww_i} :=$	$\beta_{user_i} :=$
XX·ft	**XX**·ft	**XX**·deg
XX·ft	**XX**·ft	**XX**·deg
XX·ft	**XX**·ft	**XX**·deg
XX·ft	**XX**·ft	**XX**·deg

Soil Properties

density of soil $\gamma_{soil} = 120 \cdot \frac{lbf}{ft^3}$ $new\gamma_{soil} := \mathbf{XX} \cdot \frac{lbf}{ft^3}$

soil friction angle $\phi = 30 \cdot deg$ $new\phi := \mathbf{XX} \cdot deg$

modulus of subgrade reaction $k_s = 100000 \cdot \frac{lbf}{ft^3}$ $newk_s := \mathbf{XX} \cdot \frac{lbf}{ft^3}$

nominal bearing capacity, this is allowable bearing pressure(typically from Geotech Engr) multiplied by factor of safety $q_{nom} = 2000 \cdot \frac{lbf}{ft^2}$ $newq_{nom} := \mathbf{XX} \cdot \frac{lbf}{ft^2}$

Material Properties

Environmental Class

1 - slightly aggressive
2 - moderately aggressive
3 - extremely aggressive

$Env = 2$ $newEnv := \mathbf{XX}$

modular ratio $n_{mod} = 9$ $newn_{mod} := \mathbf{XX}$

density of concrete $\gamma_{conc} = 150 \cdot \frac{lbf}{ft^3}$ $new\gamma_{conc} := \mathbf{XX} \cdot \frac{lbf}{ft^3}$

reinforcing strength $F_y = 60 \cdot ksi$ $newF_y := \mathbf{XX} \cdot ksi$

density of water $\gamma_w = 62.4 \cdot \frac{lbf}{ft^3}$ $new\gamma_w := \mathbf{XX} \cdot \frac{lbf}{ft^3}$

concrete strength preset for FDOT work $f_{c.fdot} := if(Env \le 1, 3.4 \cdot ksi, 5.5 \cdot ksi)$ $f_{c.fdot} = 5.5 \cdot ksi$ $f_c = 5.5 \cdot ksi$ $newf_c := f_{c.fdot}$

Concrete Modulus of Elasticity (based on strength as given in the Structures Design Guidelines)

$E_{fdot} := if(AggFactor = 1, 0.9 \cdot 1820, 1820) \sqrt{\frac{f_{c.fdot}}{ksi}} \cdot ksi$

enter "0" for Standard Aggregate or "1" for Florida Aggregate $AggFactor := 1$

$E_{fdot} = 3841.45 \cdot ksi$ $E = 3841 \cdot ksi$ $newE := E_{fdot}$

Construction Vehicle Load (optional)

Applies wheel load assuming no soil cover.

spacing between axles 1 and 2 & axles 2 and 3:

$ConAxleSpacing1 = 16\,ft$ $newConAxleSpacing1 := \mathbf{XX} \cdot ft$

$ConAxleSpacing2 = 16\,ft$ $newConAxleSpacing2 := \mathbf{XX} \cdot ft$

construction wheel loads 1, 2, and 3:

$ConWheel1 = 0 \cdot kip$ $newConWheel1 := \mathbf{XX} \cdot kip$

$ConWheel2 = 0 \cdot kip$ $newConWheel2 := \mathbf{XX} \cdot kip$

$ConWheel3 = 0 \cdot kip$ $newConWheel3 := \mathbf{XX} \cdot kip$

Headwall Loads

Additional dead load if a barrier is located on top of the headwall $BarrierDL_{hw} = 0 \cdot \frac{kip}{ft}$ $newBarrierDL_{hw} := \mathbf{XX} \cdot \frac{kip}{ft}$

Set whether a line of truck wheels is considered as a loading. (1 = considered, 0 = not considered) $ConsiderLL_{hw} = 1$ $newConsiderLL_{hw} := \mathbf{XX}$

enter "0" for not considered or "1" for considered

end of data entry

Write Box Design Data to NewDataFile

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.dat"

assign the data read in to the data to be read out, then change only the new values using the fSwitchData *function:*

$DataOut := DataIn$

Reference:C:\FDOT Structures\Programs\LRFDBoxCulvertV3.2\ReadData.xmcd(R)

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.dat"

Box Culvert Program:

Box & Headwall Load Cases

Project = "6' x 5' under 13.5' fill"

DesignedBy = "KMF"

CheckedBy = "DLF" df 8/17/2012

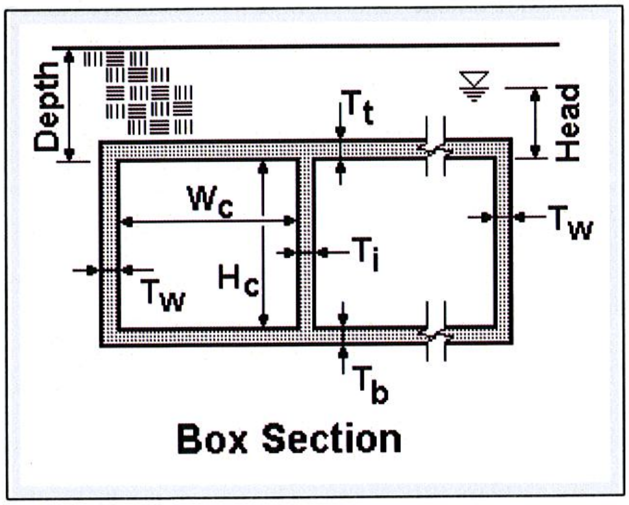
Generate Loads- Instructions:

1. 'Calculate Worksheet (CTRL+F9)' to generate loads for the following worksheets (Repeat process if changes are made to Worksheet 1).
2. Close this worksheet without saving and proceed to the following worksheet.

Note: AASHTO section references are shown at right margin, where appropriate, in bold-italic font

Design Parameters

Geometry and box dimensions from CurrentDataFile



Box Section

$W_c = 6\ \text{ft}$ *opening width of cell*

$H_c = 5\ \text{ft}$ *opening height of cell*

$T_t = 8\cdot\text{in}$ *top slab thickness, (8 inch min.)*

$T_b = 8\cdot\text{in}$ *bottom slab thickness, (8 inch min.)*

$T_i = 8\cdot\text{in}$ *interior wall thickness, (8 inch min.)*

$T_w = 8\cdot\text{in}$ *exterior wall thickness, (8 inch min.)*

$L_c = 100\ \text{ft}$ *length of culvert along centerline*

NoOfCells = 1 *number of cells*

Extension = 0 *extension type*
0 new box no extension,
1 left extension,
2 right extension

$\text{Head} = 14.17\ \text{ft}$ *water head at top of box (typically = 0.0)*

$\text{Depth} = 14.17\ \text{ft}$ *distance from top of opening to surface*

$\text{HydraulicOpening} := W_c \cdot H_c \cdot \text{NoOfCells}$

$\text{HydraulicOpening} = 30\ \text{ft}^2$

$b_w = 1\ \text{ft}$ *This program analyses a one foot wide cross section*

Soil properties

$\gamma = 120 \cdot \frac{\text{lbf}}{\text{ft}^3}$ *density of soil*

$\phi = 30 \cdot \text{deg}$ *soil friction angle*

$k_s = 100000 \cdot \frac{\text{lbf}}{\text{ft}^3}$ *modulus of subgrade reaction*

$q_{nom} = 2000\ \text{ft} \cdot \frac{\text{lbf}}{\text{ft}^3}$

Material properties

Env = 2 *Environmental Class* *1-slightly aggresive* *2-moderate* *3-extreme*

$n_{mod} = 9$ *modular ratio*

$f_c = 5.5 \cdot ksi$ *concrete strength preset for FDOT work*

$E = 3841 \cdot ksi$ *concrete modulus of elasticity*

$\gamma_{conc} = 150 \cdot \frac{lbf}{ft^3}$ *density of concrete*

$F_y = 60 \cdot ksi$ *reinforcing strength*

Construction vehicle loads (optional)

$ConWheel1 = 0 \cdot kip$

$ConWheel2 = 0 \cdot kip$

$ConWheel3 = 0 \cdot kip$ *construction wheel loads*

$ConAxleSpacing1 = 16\,ft$ *axle spacing between Wheels 1 and 2*

$ConAxleSpacing2 = 16\,ft$ *axle spacing between Wheels 2 and 3*

Headwall Loads

$ConsiderLL_{hw} = 1$

$BarrierDL_{hw} = 0 \cdot \frac{kip}{ft}$

Box Culvert Design:

Section 1 - Box Loads, 75 pages

$Strength_{box}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	5.64	2.05	5.64	2.05	11.98	6.34	2.71	7.09	2.08	5.95
1	9.63	-2.53	9.63	-2.53	0	5.07	0	-5.18	0	0
2	0.01	0	0.01	0	0	9.63	-2.53	10.34	-1.82	...

$Service_{box}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	3.84	0	3.84	0	9.19	4.48	0	4.95	0	4.6
1	6.72	0.33	6.72	0.33	0	3.32	0	-3.42	0	0
2	0	0	0	0	0	6.72	0.33	7.29	0.9	...

Write box load data to DataOut variable

$DataOut_{85} := Strength_{box}$

$DataOut_{86} := Service_{box}$

Headwall Design

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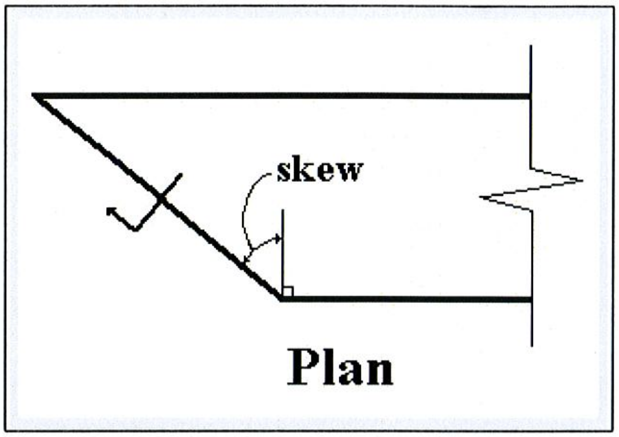
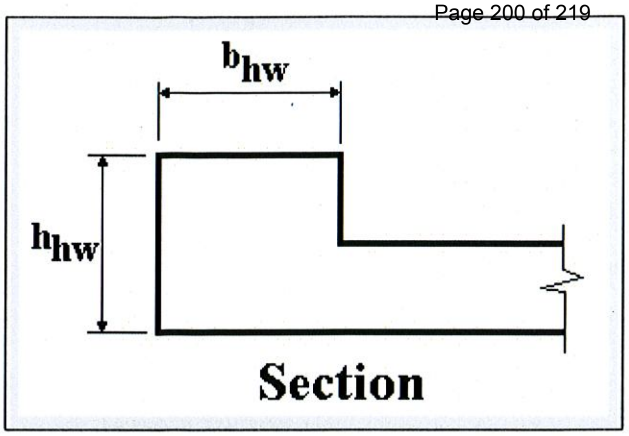
Design Headwall

Note: No lateral load analysis is performed on the headwall. If significant horizontal loads are anticipated, supplemental calculations are required.





Note: AASHTO section references are shown at right margin in bold-italic font.

SkewDiagram

Tributary Area for headwall design is defined in this file

$nc := NoOfCells$

$iwbeg := if(Extension \neq 2, 0, 1)$ $iwend := if(Extension \neq 1, 1, 0)$ $iw := iwbeg..iwend$ *index for walls*

Design parameters

$iw = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$ $B_{hw} = \begin{pmatrix} 12 \\ 12 \end{pmatrix} \cdot in$

$iw = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$ $H_{hw} = \begin{pmatrix} 24 \\ 24 \end{pmatrix} \cdot in$

$Skew = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot deg$ *left* *right*

$BarrierDL_{hw} = 0 \cdot \frac{kip}{ft}$ *Additional dead load if a barrier is located on top of the headwall*

$ConsiderLL_{hw} = 1$ *This variable sets whether a line of truck wheels is considered as a loading. A 1 value means it is considered and a 0 means it is not*

$ic := 0..(nc - 1)$ *index for cells*

$NoOfCells = 1$ *number of cells*

$f_c = 5.5 \cdot ksi$

$W_c = 6\ ft$ *opening width of cell*

$H_c = 5\ ft$ *opening height of cell*

$T_i = 8 \cdot in$ *interior wall thickness*

$T_t = 8 \cdot in$ *top slab thickness*

$T_w = 8 \cdot in$ *exterior wall thickness*

$Env = 2$ *Environmental Class*
1 is slightly aggressive
2 is moderate
3 is extreme

$E = 3841 \cdot ksi$ *concrete modulus of elasticity*

$\gamma = 120 \cdot \frac{lbf}{ft^3}$ *soil density*

$SoilHeight = 13.5\ ft$ *soil height above top slab*

$\gamma_w = 62.4 \cdot \frac{lbf}{ft^3}$ *weight of water*

$n_{mod} = 9$ *ratio of steel and concrete modulus of elasticity*

$\gamma_{conc} = 150 \cdot \frac{lbf}{ft^3}$ *concrete unit weight*

$F_y = 60 \cdot ksi$

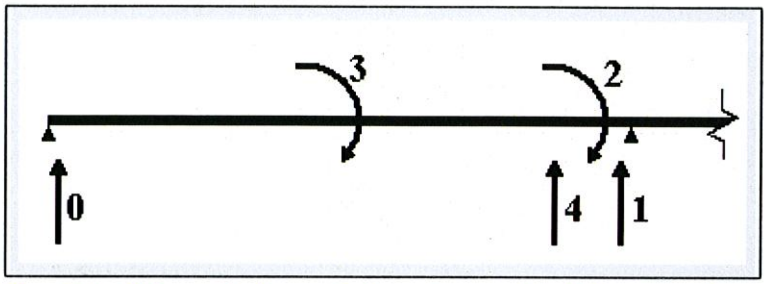
Calculate load combinations

Strength

$Strength_{hw} := 1.25 \cdot Force_{sw} + 1.35 \cdot Force_{ew} + 1.75 \cdot Force_{ll} \cdot ConsiderLL_{hw} + 1.75 \cdot Force_{lane} \cdot ConsiderLL_{hw}$

Service

$\text{Service}_{hw} := 1.0\cdot\text{Force}_{sw} + 1.0\cdot\text{Force}_{ew} + 1.0\cdot\text{Force}_{ll}\cdot\text{ConsiderLL}_{hw} + 1.0\cdot\text{Force}_{lane}\cdot\text{ConsiderLL}_{hw}$



*Due to the difference in the center-to-center span (model) versus clear span (actual) a reduction in the moment forces is allowed. For end moments, a reduction of 1/3*Vend*t is used and for midspan moments 1/6*Vend*t is used.*

$$\text{Strength}_{hw} = \begin{pmatrix} 29.05 & 16.79 & 1.6\times10^{-14} & 46.41 & 29.27 \\ 29.05 & 16.79 & 1.6\times10^{-14} & 46.41 & 29.27 \end{pmatrix}$$

$$\text{Service}_{hw} = \begin{pmatrix} 16.97 & 9.96 & 9.22\times10^{-15} & 27.13 & 17.09 \\ 16.97 & 9.96 & 9.22\times10^{-15} & 27.13 & 17.09 \end{pmatrix}$$

$$\text{Strength}_{hw_{iw,2}} := \text{Strength}_{hw_{iw,2}} - \frac{1}{3}\cdot\text{Strength}_{hw_{iw,1}}\cdot\frac{T_w}{ft}$$

$$\text{Service}_{hw_{iw,2}} := \text{Service}_{hw_{iw,2}} - \frac{1}{3}\cdot\text{Service}_{hw_{iw,1}}\cdot\frac{T_w}{ft}$$

$$\text{Strength}_{hw_{iw,3}} := \text{Strength}_{hw_{iw,3}} - \frac{1}{6}\cdot\left(\frac{4\cdot\text{Strength}_{hw_{iw,3}}}{L_{hw_{iw,0}}}\right)\cdot\frac{T_w}{ft}$$

$$\text{Service}_{hw_{iw,3}} := \text{Service}_{hw_{iw,3}} - \frac{1}{6}\cdot\left(\frac{4\cdot\text{Service}_{hw_{iw,3}}}{L_{hw_{iw,0}}}\right)\cdot\frac{T_w}{ft}$$

$$\text{Strength}_{hw} = \begin{pmatrix} 29.05 & 16.79 & -3.73 & 43.31 & 29.27 \\ 29.05 & 16.79 & -3.73 & 43.31 & 29.27 \end{pmatrix}$$

$$\text{Service}_{hw} = \begin{pmatrix} 16.97 & 9.96 & -2.21 & 25.32 & 17.09 \\ 16.97 & 9.96 & -2.21 & 25.32 & 17.09 \end{pmatrix}$$

Write box and headwall load CurrentDataFile

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.d

DataOut := DataIn

$\text{DataOut}_{31} := \frac{L_0}{ft}$

$\text{DataOut}_{85} := \text{Strength}_{box}$

$\text{DataOut}_{86} := \text{Service}_{box}$

$\text{DataOut}_{87} := \text{Strength}_{hw}$

$\text{DataOut}_{88} := \text{Service}_{hw}$

$\text{DataOut}_{101} := \text{BoxForce}_{trk}$

$\text{DataOut}_{102} := \text{BoxForce}_{ll}$

$\text{DataOut}_{103} := \text{BoxForce}_{dc}$

$\text{DataOut}_{104} := \text{BoxForce}_{lane}$

$\text{DataOut}_{105} := \text{BoxForce}_{es}$

$\text{DataOut}_{106} := \text{BoxForce}_{ev}$

$\text{DataOut}_{107} := \text{BoxForce}_{eh}$

$\text{DataOut}_{108} := \text{BoxForce}_{wa}$

$\text{DataOut}_{109} := \text{BoxForce}_{ls}$

$\text{DataOut}_{112} := \frac{\text{Haunch}_{top}}{in}$

$\text{DataOut}_{113} := \frac{\text{Haunch}_{bot}}{in}$

WRITEPRN(CurrentDataFile) := DataOut

WRITEPRN(NewDataFile) := DataOut

Reference:C:\FDOT Structures\Programs\LRFDBoxCulvertV3.2\ReadData.xmcd(R)

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.dat"

Box Culvert Program:
Box Reinforcement Design

Project = "6' x 5' under 13.5' fill"

DesignedBy = "KMF"

CheckedBy = "DLF" 8/17/2012 df

Note: AASHTO section references are shown at right margin, where appropriate, in bold-italic font

$b_w = 1\ \text{ft}$ *This program analyzes a one foot wide cross section*

1. Design Parameters

Geometry and Box Dimensions

$W_c = 6\ \text{ft}$ *opening width of cell*

$H_c = 5\ \text{ft}$ *opening height of cell*

$T_t = 8 \cdot \text{in}$ *top slab thickness, (8 inch min.)*

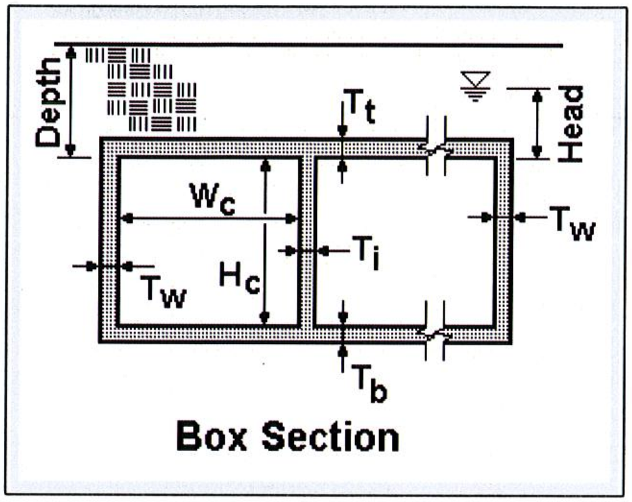
$T_b = 8 \cdot \text{in}$ *bottom slab thickness, (8 inch min.)*

$T_w = 8 \cdot \text{in}$ *exterior wall thickness, (8 inch min.)*

$T_i = 8 \cdot \text{in}$ *interior wall thickness, (8 inch min.) (Ti=Tw for one cell boxs)*

$L_c = 100\ \text{ft}$ *length of culvert along centerline*

$\text{Depth} = 14.17\ \text{ft}$ *distance from top of opening to surface*



Box Section

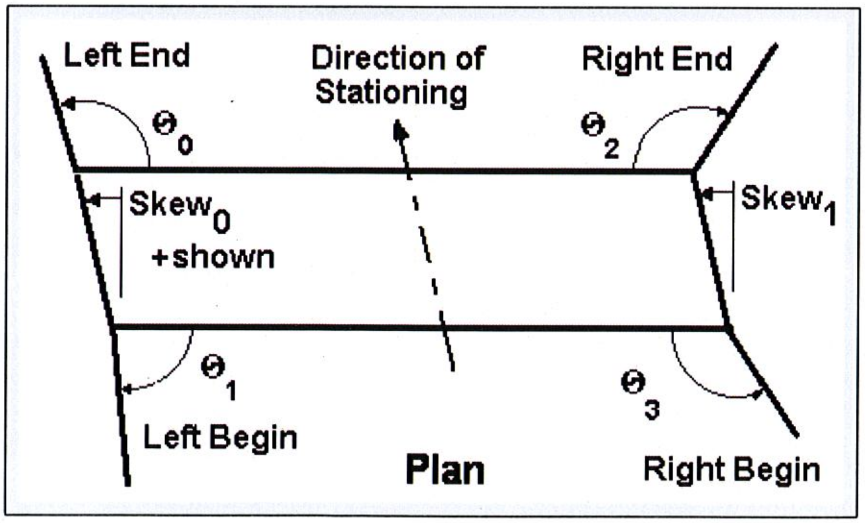
$\text{Extension} = 0$ *extension type*

0 new box, no extension.
1 left extension
2 right extension

$\text{NoOfCells} = 1$ *number of cells*

$\text{Head} = 14.17\ \text{ft}$ *water head at top of box (typically = 0.0)*

$$\text{Skew}_{\text{box}} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot \text{deg}$$



Plan

$$\text{HydraulicOpening} := W_c \cdot H_c \cdot \text{NoOfCells}$$

$$\text{HydraulicOpening} = 30\ \text{ft}^2$$

Soil Properties

$\gamma = 120 \cdot \frac{\text{lbf}}{\text{ft}^3}$ *density of soil*

$k_s = 100000 \cdot \frac{\text{lbf}}{\text{ft}^3}$ *modulus of subgrade reaction*

$\phi = 30 \cdot \text{deg}$ *soil friction angle*

Material Properties

$Env = 2$ *Environmental Class* *1-slightly aggressive* *2-moderate 3-extreme*

$n_{mod} = 9$ *modular ratio*

$f_c = 5.5 \cdot ksi$ *concrete strength*

$\gamma_{conc} = 150 \cdot \frac{lbf}{ft^3}$ *density of concrete*

$E = 3841 \cdot ksi$ *concrete modulus of elasticity*

$F_y = 60 \cdot ksi$ *reinforcing strength*

Construction Vehicle Loads (if required)

$ConWheel1 = 0 \cdot kip$ $ConWheel2 = 0 \cdot kip$ $ConWheel3 = 0 \cdot kip$ *construction wheel loads*

$ConAxleSpacing1 = 16\,ft$ *space between axles 1 and 2*

$ConAxleSpacing2 = 16\,ft$ *space between axles 2 and 3*

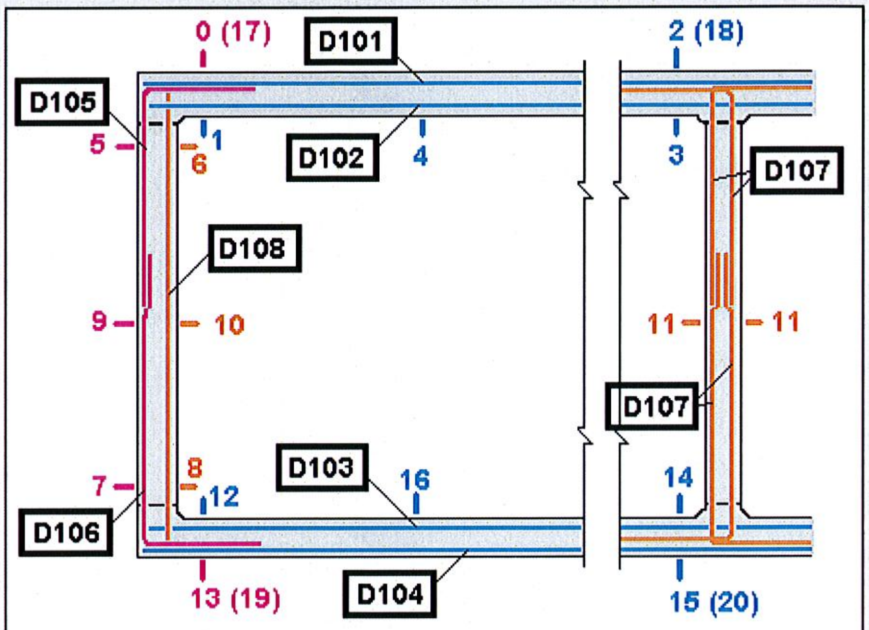
2. Design and Check Main Reinforcing

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.dat"

$it := 0..20$ *index for transverse sections*

$BarSize_{box_{it}} := 0$ $S_{box_{it}} := 12 \cdot in$

Cross Section Notes:
1. Bars shown with the same color are combined as Bar Groups.
2. Colored numbers indicate moment analysis locations.
3. Colored numbers in parenthesis indicate shear analysis locations.
4. Black numbers refer to bar designations.



BOX CROSS SECTION
Reinforcement and Analysis Locations

Enter box reinforcing size and spacing

Generally, reinforcement should be at least a #3 bar and spacing should not exceed 12 inches.

Note: Shear generally controls slab and wall thicknesses and cracking generally controls reinforcement areas

Bar Designation (section number) *Bar Sizes & Spacings used in analysis* *Change Bar Group values (color) or change individual Bars (white)*

D101(2)
D102(1,3,4)
D103(12,14,16)
D104(15)

$BarSize_{slabs} = \begin{pmatrix} 5 \\ 5 \\ 5 \\ 5 \end{pmatrix}$ $S_{slabs} = \begin{pmatrix} 6 \\ 6 \\ 6 \\ 6 \end{pmatrix} \cdot in$

$newBarSize_{slabs} := \mathbf{XX}$

$newS_{slabs} := \mathbf{XX} \cdot in$

$BarSizeD1_{01} := \mathbf{XX}$ $SD1_{01} := \mathbf{XX} \cdot in$

$BarSizeD1_{02} := \mathbf{XX}$ $SD1_{02} := \mathbf{XX} \cdot in$

$BarSizeD1_{03} := \mathbf{XX}$ $SD1_{03} := \mathbf{XX} \cdot in$

$BarSizeD1_{04} := \mathbf{XX}$ $SD1_{04} := \mathbf{XX} \cdot in$

D105(9,0,5)
D106(9,7,13)

$BarSize_{corners} = \begin{pmatrix} 5 \\ 5 \end{pmatrix}$ $S_{corners} = \begin{pmatrix} 6 \\ 6 \end{pmatrix} \cdot in$

$newBarSize_{corners} := \mathbf{XX}$

$newS_{corners} := \mathbf{XX} \cdot in$

$BarSizeD1_{05} := \mathbf{XX}$ $SD1_{05} := \mathbf{XX} \cdot in$

$BarSizeD1_{06} := \mathbf{XX}$ $SD1_{06} := \mathbf{XX} \cdot in$

D107(11)
D108(6,8,10)

$\text{BarSize}_{\text{walls}} = \begin{pmatrix} 5 \\ 5 \end{pmatrix}$ $S_{\text{walls}} = \begin{pmatrix} 6 \\ 6 \end{pmatrix} \cdot \text{in}$

$\text{newBarSize}_{\text{walls}} := \textbf{XX}$

$\text{newS}_{\text{walls}} := \textbf{XX} \cdot \text{in}$

$\text{BarSizeD1}_{07} := \textbf{XX}$ $\text{SD1}_{07} := \textbf{XX} \cdot \text{in}$

$\text{BarSizeD1}_{08} := \textbf{XX}$ $\text{SD1}_{08} := \textbf{XX} \cdot \text{in}$

Section 2 - Box Main Reinforcement, 10 pages

✓

$\text{CheckCracking}_{\text{box}}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	...

Summary(CheckCracking$_{\text{box}}$) = "OK"

$\text{CheckM}_{\text{box}}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	...

Summary(CheckM$_{\text{box}}$) = "OK"

$\text{CheckAs}_{\text{min.box}}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	...

Summary(CheckAs$_{\text{min.box}}$) = "OK"

$\text{CheckShear}_{\text{box}}^{T} =$

	0	1	2	3	4	5	6	7	8	9
0	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	"ok"	...

Summary(CheckShear$_{\text{box}}$) = "OK"

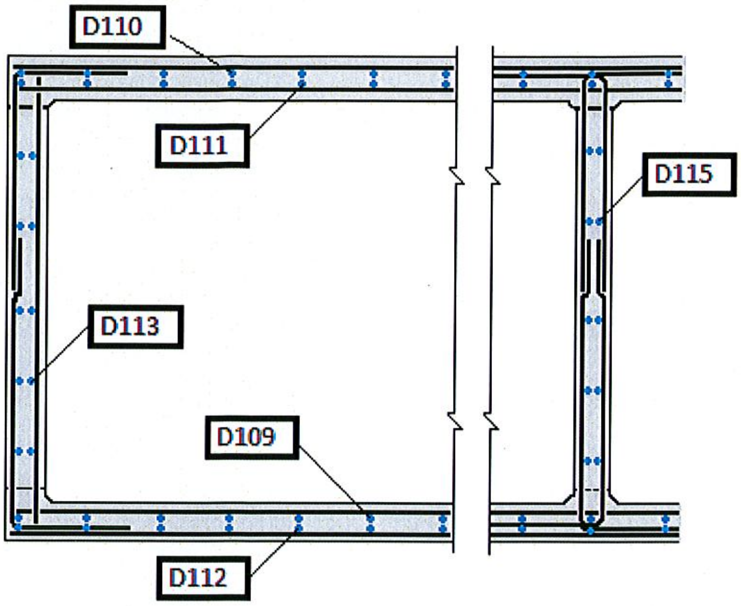
Summary(CheckAll$_{\text{box}}$) = "OK"

3. Design and Check Box Longitudinal Reinforcing

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.dat"

To meet LRFD temperature and shrinkage requirements, reinforcement spacing should not exceed 12 inches.

$il := 0..4$ *index for longitudinal sections*



Box Cross Section
Longitudinal Reinf. and Analysis Locations

Enter Box Longitudinal Reinforcing

Bar Sizes & Spacings used in analysis

$$BarSize_{long} = \begin{pmatrix} 5 \\ 5 \\ 5 \\ 5 \\ 5 \end{pmatrix} \qquad S_{long} = \begin{pmatrix} 6 \\ 6 \\ 6 \\ 6 \\ 6 \end{pmatrix} \cdot in$$

Change Bar Group (color) values or change individual Bars (white)

$newBarSize_{long} := 5$

$newS_{long} := 6 \cdot in$

$BarSizeD1_{09} :=$ **XX** $SD1_{09} :=$ **XX**·in

$BarSizeD1_{10} :=$ **XX** $SD1_{10} :=$ **XX**·in

$BarSizeD1_{11} :=$ **XX** $SD1_{11} :=$ **XX**·in

$BarSizeD1_{12} :=$ **XX** $SD1_{12} :=$ **XX**·in

$BarSizeD1_{13} :=$ **XX** $SD1_{13} :=$ **XX**·in

Section 3 - Box Longitudinal Reinforcement, 3 pages

$CheckAs_{temp.box}^{T} = (\text{"ok"} \quad \text{"ok"} \quad \text{"ok"} \quad \text{"ok"} \quad \text{"ok"})$

$Summary(CheckAs_{temp.box}) = \text{"OK"}$

$Summary(CheckAll_{box}) = \text{"OK"}$

Write Box Design Data to

CurrentDataFile = "\Data Files\6X5 w 13.5 soil.dat" **file**

Assign the data values read in to the ones to be read out, then change only the ones modified in this file

$DataOut := DataIn$

$DataOut_{32} := BarSize_{slabs}$ $DataOut_{33} := \frac{S_{slabs}}{in}$ $DataOut_{34} := BarSize_{walls}$ $DataOut_{35} := \frac{S_{walls}}{in}$

$DataOut_{36} := BarSize_{corners}$ $DataOut_{37} := \frac{S_{corners}}{in}$ $DataOut_{38} := BarSize_{long}$ $DataOut_{39} := \frac{S_{long}}{in}$

$DataOut_{55} := str2vec(Summary(CheckAll_{box}))$ $DataOut_{90} := ReinfBox$ $DataOut_{94} := \frac{As}{ft^2}$ $DataOut_{95} := \frac{S_{box}}{ft}$

$DataOut_{96} := BarSize_{loc}$

$DataOut_{110} := \frac{d}{ft}$ $DataOut_{111} := \frac{t_{section}}{ft}$

WRITEPRN(CurrentDataFile) := DataOut

WRITEPRN(NewDataFile) := DataOut

CDM
2301 Maitland Center Pkwy
Suite 300
Maitland, FL 32751

Client	TVA	Job No.	95618-92016
Project	Ash Pond	Date Checked	8-17-2012
Detail	6'x5' Box Culvert	Checked By	df
Computed By	KMF	Date	6/28/2012
Page No.	1		

Outlet Box Culvert

Buoyancy Check For Rectangular Tanks

Author:	Justin Boggs	Date:	20-Mar-07	Checked By:	df	File Name:	buoy-rec.xls

Limitations

This program should only be used with a full knowledge of the analysis procedure used in the program. Result of the program is subject to structural engineering evaluation and judgement. This program is for the use of CDM Structural Engineering Staff Only.

Parameters

Concrete Density (γ_c)	0.150 *kip/ft³*	*Backfill Soil Density (γ_{sat})* *(Typ. Range 100 to 125 pcf)*	0.115 *kip/ft³*
Water Density (γ_w)	0.0624 *kip/ft³*	*Soil Friction Angle (ϕ)* *(Typ. Range 15 to 20 deg)*	0 °

Structure Dimensions

Inside Length (l)	1 ft	*Top Slab Thickness (t_{ts})*	8 in	*Height of Walls above Base Slab (h_t)*	5 ft
Inside Width (w)	6 ft	*Base Slab Thickness (t_{bs})*	8 in	*Height to Grade above Base Slab (h_e)*	7.67 ft
Wall Thickness (t_w)	8 in	*Base Slab Toe Width (l_{toe})*	0 in	*Height to GWL above Base Slab (h_w)*	7.67 ft
Interior Wall Thickness	0 in	*Interior Wall Length*	0 ft	*Interior Wall Height*	0 ft
		Height of Water in Box Culvert	48 in	*Height of Soil Above Top Slab (h_s)*	24 in

Uplift Forces

Volume of Displaced Water - Above Base Slab Level [6 ft + 2(0.67)]* 5.67 ft = 41.6		41.6 ft³
Volume of Displaced Water - Volume of Base Slab		4.9 ft³
Volume of Displaced Water - Total		46.4 ft³
Uplift Force (U)	$V \cdot \gamma_w =$	2.90 kip/ft

Resisting Loads

Weight of Top Slab (wts)	$l \cdot w \dfrac{t_{ts}}{12} \gamma_c =$	0.60 kip/ft
Weight of Soil Above Top Slab		0.77 kip/ft
Weight of Water in Box Culvert (reduced by 40%)		0.60 kip/ft
Weight of Base Slab (wbs)		0.733 kip/ft
Weight of Exterior Walls (ww)		1.13 kip/ft
Weight of Interior Walls (wwi)	=	0.00 kip/ft
Weight of Soil Above Toe of Base Slab (ws1)	$\left[\left(1+2\frac{t_w+l_{toe}}{12}\right)\left(w+2\frac{t_w+l_{toe}}{12}\right)-\left(1+2\frac{t_w}{12}\right)\left(w+2\frac{t_w}{12}\right)\right]\left[(h_e-h_w)\gamma_{sat}+\left[h_w(\gamma_{sat}-\gamma_w)\right]\right]=$	0.00 kip/ft
Weight of Soil in "Pullout Wedges" (ws2)	$\left(\frac{1}{2}h_e^2 TAN(\phi)\gamma_{sat}-\frac{1}{2}h_w^2 TAN(\phi)\gamma_w\right)\cdot 2\cdot\left(1+2\frac{t_w}{12}+w+2\frac{t_w}{12}\right)=$	0.00 kip/ft
Weight of Structure		2.47 kip/ft
Weight of Structure + Soil Area 1		2.47 kip/ft
Weight of Structure + Soil Area 1 + Soil Area 2		2.47 kip/ft
Weight of Structure + Soil Above Top Slab		3.84 kip/ft

Factor of Safety Against Uplift

Weight of Structure + Soil Above Top Slab / Uplift	1.32	≥	1.3	OK

CDM Smith

CLIENT TVA
PROJECT Watts Bar Ash Pond
DETAIL Precast Drop Boxes
PROJECT NO. 92016.2202

COMPUTED BY / DATE KMF 08/16/12
CHECKED BY / DATE ag 8/17/12
REVISION NO. / DATE - -
REVIEWED BY / DATE - -

Calculation Description: Precast Drop Box Design

1.0 Objective

Design precast drop boxes for use by the precaster.

2.0 Procedure

1.) Determine loads applied to all walls and slabs. Including fluid/earth lateral load, pedestrian live load (on rail), HS-20 Vehicle Live Load surcharge, Soil Vertical Pressure, and Self-weight of concrete.

2.) Calculate applied moments and shears using AASHTO load combinations.
3.) Calculate flexural (moment) and shear capacities of walls (wingwall and weir), beams, and columns.
4.) Check all capacity/applied ratios are less than 1.
5.) Check Buoyancy for Drop Box.

3.0 References / Data Sources

1.) ASCE 7

2.) IBC 2006

3.) ACI 318

4.0 Assumptions / Limitations

1.) Concrete strength increased in design for precast concrete.

5.0 Calculations

5.1 Drop Box Buoyancy

- Refer to Excel spreadsheet "Buoyancy Checks for Rectangular Tanks" and attached diagram for check.

5.2 Drop Boxes

- Refer to excel spreadsheets "Longwall - Soil Load (90pcf), 2ft soil surcharge" and "Short wall - Soil Load (90pcf), 2ft soil surcharge" for design loads and reinforcing calculations.

6.0 Conclusions

- The drop boxes have 12inch walls and slabs with reinforcing of #5 @ 6inches on center, each way, each face, top and bottom.

CDM 2301 Maitland Center Pkwy Suite 300 Maitland, FL 32751	Client TVA Project Ash Pond Detail Drop Box	Job No. 95618-92016 Date Checked 8-17-2012 Checked By df	Computed By KMF Date 7/27/2012 Page No. 1

Buoyancy Check For Rectangular Tanks

Author:	Justin Boggs	Date:	20-Mar-07	Checked By:		File Name:	buoy-rec.xls

Limitations

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Parameters

Concrete Density (γ_c)	*0.150 kip/ft^3*	*Backfill Soil Density (γ_{sat})* *(Typ. Range 100 to 125 pcf)*	*0.115 kip/ft^3*
Water Density (γ_w)	*0.0624 kip/ft^3*	*Soil Friction Angle (ϕ)* *(Typ. Range 15 to 20 deg)*	*15 °*

Structure Dimensions

Inside Length (l)	*16 ft*	*Top Slab Thickness (t_{ts})*	*12 in*	*Height of Walls above Base Slab (h_t)*	*14.5 ft*
Inside Width (w)	*8 ft*	*Base Slab Thickness (t_{bs})*	*12 in*	*Height to Grade above Base Slab (h_e)*	*18.00 ft*
Wall Thickness (t_w)	*12 in*	*Base Slab Toe Width (l_{toe})*	*0 in*	*Height to GWL above Base Slab (h_w)*	*11.50 ft*
Interior Wall Thickness	*0 in*	*Interior Wall Length*	*0 ft*	*Interior Wall Height*	*0 ft*
		Height of Water in Box Culvert	*36 in*	*Height of Soil Above Top Slab (h_s)*	*42 in*

Uplift Forces

Volume of Displaced Water - Above Base Slab Level {[16 ft + 2(1)]*[8 ft + 2(1)]}* 11.5 ft = 2070		*2070.0 ft^3*
Volume of Displaced Water - Volume of Base Slab		*180.0 ft^3*
Volume of Displaced Water - Total		*2250.0 ft^3*
Uplift Force (U)	$V \cdot \gamma_w =$	140.40 *kip*

Resisting Loads

Weight of Top Slab (wts)	$l \cdot w \dfrac{t_{ts}}{12} \gamma_c =$	*19.20 kip*
Weight of Soil Above Top Slab		*33.14 kip*
Weight of Water in Drop Box		*23.96 kip*
Weight of Base Slab (wbs)		*27.00 kip*
Weight of Exterior Walls (ww) - 2 wall openings in 2 walls		*87.44 kip*
Weight of Interior Walls (wwi)		*0.00 kip*
Weight of Soil Above Toe of Base Slab (ws1)	$\left[\left(l+2\frac{t_w+l_{toe}}{12}\right)\left(w+2\frac{t_w+l_{toe}}{12}\right)-\left(l+2\frac{t_w}{12}\right)\left(w+2\frac{t_w}{12}\right)\right]\left[(h_e-h_w)\gamma_{sat}+\left[h_w(\gamma_{sat}-\gamma_w)\right]\right]=$	*0.00 kip*
Weight of Soil in "Pullout Wedges" (ws2)	$\left(\frac{1}{2}h_e^2 TAN(\phi)\gamma_{sat}-\frac{1}{2}h_w^2 TAN(\phi)\gamma_w\right)\cdot 2\cdot\left(l+2\frac{t_w}{12}+w+2\frac{t_w}{12}\right)=$	*217.63 kip*
Weight of Structure		*133.64 kip*
Weight of Structure + Soil Area 1		*133.64 kip*
Weight of Structure + Soil Area 1 + Soil Area 2		*351.27 kip*
Weight of Structure + 3FT water + Soil Above Top Slab		*190.74 kip*

Factor of Safety Against Uplift

Weight of Structure + Soil Area 1 + Soil Area 2 / Uplift	*2.50*	≥	*1.5*	*OK*
Weight of Structure + Soil Above Top Slab / Uplift	*1.36*	≥	*1.3*	*OK*

df 8/17/2012

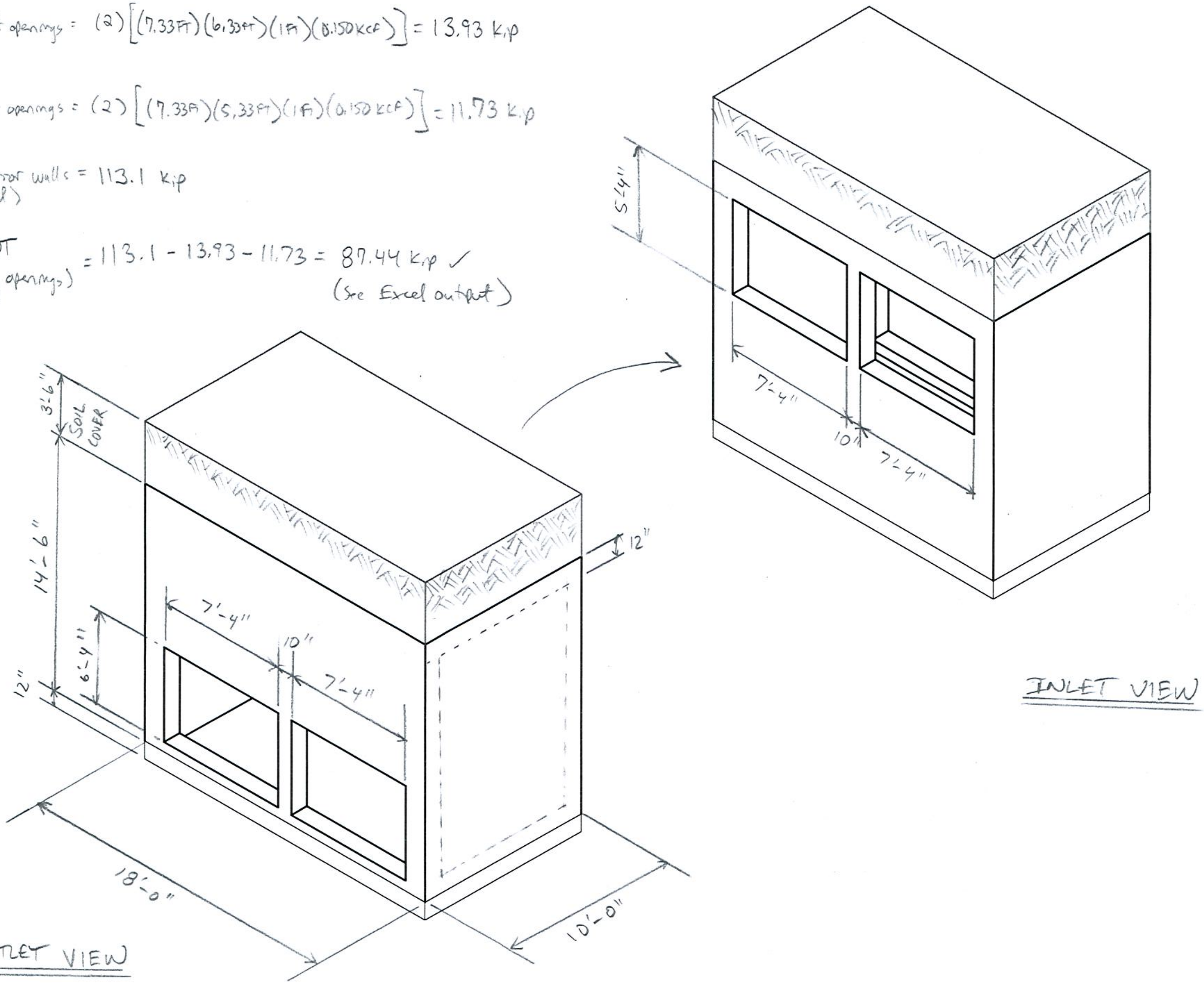
Precast Drop Box (Buoyancy)

$WT_{\text{outlet openings}} = (2)\left[(7.33\text{Ft})(6.33\text{Ft})(1\text{Ft})(0.150\text{ kcf})\right] = 13.93\text{ kip}$

$WT_{\text{INLET openings}} = (2)\left[(7.33\text{Ft})(5.33\text{Ft})(1\text{Ft})(0.150\text{ kcf})\right] = 11.73\text{ kip}$

$WT_{\text{Exterior walls (solid)}} = 113.1\text{ kip}$

Total WT (including openings) $= 113.1 - 13.93 - 11.73 = 87.44\text{ kip}$ ✓
(See Excel output)



CDM Smith 2301 Maitland Center Parkway Suite 300 Maitland, FL 32751	Client TVA Project Ash Pond Detail Drop Box	Job No. 95618-92016 Date Checked 8-17-2012 Checked By	Computed By KMF Date 8/17/2012 Page No.

REFERENCE: Rectangular Concrete Tanks, Fifth Edition

Author:	James Forehand	Checked By:	2009 R&D Team	File Name:	Rectangulartanks3.xls	Rev:	3

Wall Description: Longwall - Soil Load (90PCF), LF for lateral-at-rest earth pressure = 1.15*1.3=1.495

Input Parameters

Material Properties			**Panel Geometry**			**Load Factors**	
Concrete Strength, f'_c	5,000	psi	b	14.5	ft	Live Load Factor	1.5
Reinforcing Strength, f_y	60,000	psi	a	8.1	ft	Durability Coefficient	1.0

b/a	1.79	**Load**	**Bottom**	**Top**	**Sides**
Support Condition, Load 1	3	Triangular	Fixed	Free	Fixed
Support Condition, Load 2	8	Rectangular	Fixed	Free	Fixed
b/a upper limit	2.00	**b/a lower limit**	1.75		

Service Load Intensities

Load 1, Base Pressure, q	1305	**psf**
Load 2, Base Pressure, q	495	**psf**

Reinforcing Placement

Vertical Reinforcing	OF	
Clear Cover, cc	2	**inches**
Z_{max}	115	**kips/in**

!!! WARNING !!!

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Shear Analysis

Wall Thickness, t_w 12 **inches**

d_{base} = 9.69 inches

d_{side} = 9.06 inches

Outer Layer of Reinforcing

$$d = t_w - cc - \frac{\phi_{outer\ bar}}{2}$$

Inner Layer of Reinforcing

$$d = t_w - cc - \phi_{outer\ bar} - \frac{\phi_{inner\ bar}}{2}$$

$$V_u = C_s qa(lf)$$

Ultimate Shear Calculation, V_u

Shear	Coefficients, C_s		V_u, (kips/ft)		V_u, (kips/ft)	WARNINGS
LOCATION	Load 1	Load 2	Load 1	Load 2	Total Shear	
Bottom edge - midpoint	0.43	0.77	6.84	4.59	11.43	
Side edge - maximum	0.26	1.14	4.13	6.85	10.97	
Side edge - midpoint	0.26	0.54	4.10	3.22	7.32	
Top edge - midpoint	0.00	0.00	0.00	0.00	0.00	

$$\phi V_{c(base)} = \frac{.75*2\sqrt{f'_c}b_w d}{1000} = 12.33 \text{ kips/ft}$$

$$\phi V_{c(side)} = \frac{.75*2\sqrt{f'_c}b_w d}{1000} = 11.53 \text{ kips/ft}$$

Analysis Results Summary

DESIGN SUMMARY			**WARNINGS**
Wall Thickness	*12*	*inches*	

Vertical Reinforcing		
Dowels	*# 5 @ 6"*	
Dowel Projection	*LAP LENGTH, CLASS B*	
Vertical Bars	*# 5 @ 6"*	

Horizontal Reinforcing		
Corner Bars	*# 5 @ 6"*	
Horizontal Bars	*# 5 @ 6"*	

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VERTICAL MOMENT ANALYSIS

Support Condition, Load 1						Coeff.	Support Condition, Load 2					
	0.1b	0.2b	0.3b	0.4b				0.1b	0.2b	0.3b	0.4b	
END	0.9b	0.8b	0.7b	0.6b	0.5b		END	0.9b	0.8b	0.7b	0.6b	0.5b
-10	0	0	0	0	0	**TOP**	-48	0	0	0	0	0
-11	-3	0	2	4	4	**0.9a**	-46	-13	1	9	13	14
-11	-4	2	5	8	8	**0.8a**	-40	-15	3	15	21	23
-10	-3	4	9	12	13	**0.7a**	-35	-12	5	18	25	27
-10	-1	6	12	15	16	**0.6a**	-30	-9	7	18	24	26
-9	0	8	13	15	16	**0.5a**	-24	-7	6	13	17	19
-8	1	7	11	12	12	**0.4a**	-18	-5	1	4	4	4
-6	1	4	4	4	3	**0.3a**	-12	-7	-8	-13	-18	-19
-4	-1	-4	-8	-11	-12	**0.2a**	-6	-10	-23	-38	-50	-54
-1	-6	-18	-28	-36	-38	**0.1a**	-1	-17	-46	-76	-96	-104
0	-17	-41	-61	-72	-75	**BOT**	0	-24	-79	-128	-160	-171

$$M_{ux} = \frac{M_x q_i a^2 (lf)(df)}{1000}$$

Factored Moments (kip-feet), Load 1						Mx	Factored Moments (kip-feet), Load 2					
	0.1b	0.2b	0.3b	0.4b				0.1b	0.2b	0.3b	0.4b	
END	0.9b	0.8b	0.7b	0.6b	0.5b		END	0.9b	0.8b	0.7b	0.6b	0.5b
-1	0	0	0	0	0	**TOP**	-2	0	0	0	0	0
-1	0	0	0	1	1	**0.9a**	-2	-1	0	0	1	1
-1	-1	0	1	1	1	**0.8a**	-2	-1	0	1	1	1
-1	0	1	1	2	2	**0.7a**	-2	-1	0	1	1	1
-1	0	1	2	2	2	**0.6a**	-1	0	0	1	1	1
-1	0	1	2	2	2	**0.5a**	-1	0	0	1	1	1
-1	0	1	1	2	2	**0.4a**	-1	0	0	0	0	0
-1	0	0	1	1	0	**0.3a**	-1	0	0	-1	-1	-1
-1	0	0	-1	-1	-2	**0.2a**	0	0	-1	-2	-2	-3
0	-1	-2	-4	-5	-5	**0.1a**	0	-1	-2	-4	-5	-5
0	-2	-5	-8	-9	-10	**BOT**	0	-1	-4	-6	-8	-8

Factored Moments (kip-feet), Load 1 & Load 2 Superimposed						Mx	Reinforcing			
	0.1b	0.2b	0.3b	0.4b			Rebar	Rebar Spacing	d	A_s
END	0.9b	0.8b	0.7b	0.6b	0.5b		Size	inches	inches	in^2
-4	0	0	0	0	0	**TOP**	5	6	9.7	0.61
-4	-1	0	1	1	1	**0.9a**	5	6	9.7	0.61
-3	-1	0	1	2	2	**0.8a**	5	6	9.7	0.61
-3	-1	1	2	3	3	**0.7a**	5	6	9.7	0.61
-3	-1	1	2	3	3	**0.6a**	5	6	9.7	0.61
-2	0	1	2	3	3	**0.5a**	5	6	9.7	0.61
-2	0	1	2	2	2	**0.4a**	5	6	9.7	0.61
-1	0	0	0	0	-1	**0.3a**	5	6	9.7	0.61
-1	-1	-2	-3	-4	-4	**0.2a**	5	6	9.7	0.61
0	-2	-4	-7	-9	-10	**0.1a**	5	6	9.7	0.61
0	-3	-9	-14	-17	-18	**BOT**	5	6	9.7	0.61

$$\rho^*_{req} = \frac{1}{m}\left(1-\sqrt{1-\frac{2mR_n}{f_y}}\right); m=\frac{f_y}{0.85f'_c}; R_n=\frac{M_u}{\phi bd^2}; \phi=0.9; \rho^*_{req}=\rho*4/3, if\left(\rho_{req}\leq\frac{200}{f_y}\right) \qquad Z = f_s\sqrt[3]{d_c A}$$

Flexural Analysis Summary

Location	φM_n kip-feet	M_u kip-feet	ρ_{act}	ρ_{req}	f_s ksi	d_c in	A in^2	Z kips/in	WARNINGS
TOP	26	4	0.0053	0.0010	5.08	2.31	27.8	20.3	
0.9a	26	4	0.0053	0.0010	5.18	2.31	27.8	20.7	
0.8a	26	3	0.0053	0.0009	4.71	2.31	27.8	18.9	
0.7a	26	3	0.0053	0.0008	4.20	2.31	27.8	16.8	
0.6a	26	3	0.0053	0.0009	4.60	2.31	27.8	18.4	
0.5a	26	3	0.0053	0.0008	4.11	2.31	27.8	16.5	
0.4a	26	2	0.0053	0.0005	2.66	2.31	27.8	10.7	
0.3a	26	1	0.0053	0.0004	1.89	2.31	27.8	7.6	
0.2a	26	4	0.0053	0.0011	5.91	2.31	27.8	23.6	
0.1a	26	10	0.0053	0.0026	13.82	2.31	27.8	55.3	
BOT	26	18	0.0053	0.0036	25.08	2.31	27.8	100.4	

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HORIZONTAL MOMENT ANALYSIS

Support Condition, Load 1						Coeff.	Support Condition, Load 2					
	0.1b	0.2b	0.3b	0.4b				0.1b	0.2b	0.3b	0.4b	
END	0.9b	0.8b	0.7b	0.6b	0.5b		END	0.9b	0.8b	0.7b	0.6b	0.5b
-50	-25	-1	15	23	26	**TOP**	-236	-91	4	58	86	95
-57	-23	0	14	22	24	**0.9a**	-233	-83	4	54	80	88
-55	-21	1	14	21	23	**0.8a**	-200	-75	4	50	73	80
-53	-19	2	14	20	22	**0.7a**	-174	-66	5	45	65	71
-51	-16	3	13	18	20	**0.6a**	-148	-55	4	38	55	60
-48	-13	4	12	16	17	**0.5a**	-121	-43	4	30	43	47
-40	-10	4	10	12	13	**0.4a**	-91	-37	3	22	30	33
-31	-6	3	7	8	8	**0.3a**	-60	-21	1	11	15	16
-19	-3	1	2	1	1	**0.2a**	-30	-12	-3	-1	0	-1
-6	-2	-3	-4	-6	-6	**0.1a**	-7	-6	-9	-13	-16	-18
0	-3	-8	-12	-14	-15	**BOT**	0	-5	-16	-25	-32	-34

$$M_u = \frac{Coef * q_i a^2 (lf)(df)}{1000}$$

Factored Moments (kip-feet), Load 1						My	Factored Moments (kip-feet), Load 2					
	0.1b	0.2b	0.3b	0.4b				0.1b	0.2b	0.3b	0.4b	
END	0.9b	0.8b	0.7b	0.6b	0.5b		END	0.9b	0.8b	0.7b	0.6b	0.5b
-6	-3	0	2	3	3	**TOP**	-11	-4	0	3	4	5
-7	-3	0	2	3	3	**0.9a**	-11	-4	0	3	4	4
-7	-3	0	2	3	3	**0.8a**	-10	-4	0	2	4	4
-7	-2	0	2	3	3	**0.7a**	-8	-3	0	2	3	3
-6	-2	0	2	2	3	**0.6a**	-7	-3	0	2	3	3
-6	-2	1	2	2	2	**0.5a**	-6	-2	0	1	2	2
-5	-1	1	1	2	2	**0.4a**	-4	-2	0	1	1	2
-4	-1	0	1	1	1	**0.3a**	-3	-1	0	1	1	1
-2	0	0	0	0	0	**0.2a**	-1	-1	0	0	0	0
-1	0	0	-1	-1	-1	**0.1a**	0	0	0	-1	-1	-1
0	0	-1	-2	-2	-2	**BOT**	0	0	-1	-1	-2	-2

Factored Moments (kip-feet), Load 1 & Load 2 Superimposed						My	Corner Reinforcing				
	0.1b	0.2b	0.3b	0.4b			Rebar	Rebar Spacing	d	A_s	
END	0.9b	0.8b	0.7b	0.6b	0.5b		Size	inches	inches	in^2	
-18	-8	0	5	7	8	**TOP**	5	6	9.1	0.61	
-19	-7	0	4	7	7	**0.9a**	5	6	9.1	0.61	
-17	-6	0	4	6	7	**0.8a**	5	6	9.1	0.61	
-15	-6	0	4	6	6	**0.7a**	5	6	9.1	0.61	
-14	-5	1	4	5	5	**0.6a**	5	6	9.1	0.61	
-12	-4	1	3	4	4	**0.5a**	5	6	9.1	0.61	
-10	-3	1	2	3	3	**0.4a**	5	6	9.1	0.61	
-7	-2	0	1	2	2	**0.3a**	5	6	9.1	0.61	
-4	-1	0	0	0	0	**0.2a**	5	6	9.1	0.61	
-1	-1	-1	-1	-2	-2	**0.1a**	5	6	9.1	0.61	
0	-1	-2	-3	-3	-4	**BOT**	5	6	9.1	0.61	

$$\rho^*_{req} = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2mR_n}{f_y}}\right); m = \frac{f_y}{0.85f'_c}; R_n = \frac{M_u}{\phi b d^2}; \phi = 0.9; \rho^*_{req} = \rho * 4/3, if\left(\rho_{req} \le \frac{200}{f_y}\right) \qquad Z = f_s \sqrt[3]{d_c A}$$

Corner Bar Flexural Analysis Summary

Location	φM_n kip-feet	M_u kip-feet	ρ_{act}	ρ_{req}	f_s ksi	d_c in	A in^2	Z kips/in	WARNINGS
TOP	24	18	0.0056	0.0041	26.81	2.31	27.8	107.3	
0.9a	24	19	0.0056	0.0043	27.85	2.31	27.8	111.5	
0.8a	24	17	0.0056	0.0039	25.19	2.31	27.8	100.8	
0.7a	24	15	0.0056	0.0035	22.84	2.31	27.8	91.4	
0.6a	24	14	0.0056	0.0033	20.49	2.31	27.8	82.0	
0.5a	24	12	0.0056	0.0033	17.88	2.31	27.8	71.6	
0.4a	24	10	0.0056	0.0029	14.35	2.31	27.8	57.5	
0.3a	24	7	0.0056	0.0021	10.36	2.31	27.8	41.5	
0.2a	24	4	0.0056	0.0012	5.82	2.31	27.8	23.3	
0.1a	24	1	0.0056	0.0003	1.65	2.31	27.8	6.6	
BOT	24	0	0.0056	0.0000	0.00	2.31	27.8	0.0	

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HORIZONTAL MOMENT ANALYSIS (Continued)

Horizontal Bar Flexural Analysis Summary

Factored Moments (kip-feet), Load 1 & Load 2 Superimposed							Horizontal Reinforcing				
	0.1b	0.2b	0.3b	0.4b		Mx	Rebar	Rebar Spacing	d	A_s	
END	0.9b	0.8b	0.7b	0.6b	0.5b		Size	inches	inches	in^2	
-18	-8	0	5	7	8	**TOP**	5	6	9.1	0.61	
-19	-7	0	4	7	7	**0.9a**	5	6	9.1	0.61	
-17	-6	0	4	6	7	**0.8a**	5	6	9.1	0.61	
-15	-6	0	4	6	6	**0.7a**	5	6	9.1	0.61	
-14	-5	1	4	5	5	**0.6a**	5	6	9.1	0.61	
-12	-4	1	3	4	4	**0.5a**	5	6	9.1	0.61	
-10	-3	1	2	3	3	**0.4a**	5	6	9.1	0.61	
-7	-2	0	1	2	2	**0.3a**	5	6	9.1	0.61	
-4	-1	0	0	0	0	**0.2a**	5	6	9.1	0.61	
-1	-1	-1	-1	-2	-2	**0.1a**	5	6	9.1	0.61	
0	-1	-2	-3	-3	-4	**BOT**	5	6	9.1	0.61	

$$\rho^*_{req}=\frac{1}{m}\left(1-\sqrt{1-\frac{2mR_n}{f_y}}\right);m=\frac{f_y}{0.85f'_c};\ R_n=\frac{M_u}{\phi bd^2};\ \phi=0.9;\ \rho^*_{req}=\rho*4/3,\ if\left(\rho_{req}\le\frac{200}{f_y}\right)\qquad Z=f_s\sqrt[3]{d_cA}$$

Horizontal Bar Flexural Analysis Summary

Location	φM_n kip-feet	M_u kip-feet	ρ_{act}	ρ_{req}	f_s ksi	d_c in	A in^2	Z kips/in	**WARNINGS**
TOP	24	8	0.0056	0.0024	11.83	2.31	27.8	47.3	
0.9a	24	7	0.0056	0.0022	11.08	2.31	27.8	44.4	
0.8a	24	7	0.0056	0.0021	10.26	2.31	27.8	41.1	
0.7a	24	6	0.0056	0.0019	9.35	2.31	27.8	37.5	
0.6a	24	5	0.0056	0.0017	8.21	2.31	27.8	32.9	
0.5a	24	4	0.0056	0.0013	6.64	2.31	27.8	26.6	
0.4a	24	3	0.0056	0.0010	4.83	2.31	27.8	19.3	
0.3a	24	2	0.0056	0.0005	2.66	2.31	27.8	10.6	
0.2a	24	1	0.0056	0.0003	1.46	2.31	27.8	5.8	
0.1a	24	2	0.0056	0.0005	2.53	2.31	27.8	10.1	
BOT	24	4	0.0056	0.0011	5.44	2.31	27.8	21.8	

REINFORCING DETAILS

Vertical Reinforcing Cut-Off Details

Location	Rebar Size	Rebar Spacing	Termin Point	T_h (ft)	$12d_b$ inches	d inches	Dowel Termination Height (feet), h_d
TOP	5	6					
0.9a	5	6					
0.8a	5	6					
0.7a	5	6					
0.6a	5	6					
0.5a	5	6					
0.4a	5	6					
0.3a	5	6					
0.2a	5	6					
0.1a	5	6					
BOT	5	6					

NOTES:

1) *ACI 318 12.10.3 - Reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the effective depth of member or $12d_b$, whichever is greater, except at supports of simple spans and at free end of cantilevers.*

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Project	Ash Pod	Date Checked	8-17-2012	Date	8/17/2012
Detail	Drop Box	Checked By	df	Page No.	

REFERENCE: Rectangular Concrete Tanks, Fifth Edition

Author:	James Forehand	Checked By:	2009 R&D Team	File Name:	Rectangulartanks3.xls	Rev:	3

Wall Description: Short wall - Soil Load (90PCF), LF for lateral-at-rest earth pressure = 1.15*1.3=1.495

Input Parameters

Material Properties			Panel Geometry			Load Factors	
Concrete Strength, f'_c	5,000	psi	b	9.0	ft	Live Load Factor	1.5
Reinforcing Strength, f_y	60,000	psi	a	14.5	ft	Durability Coefficient	1.0

b/a	0.62	Load	Bottom	Top	Sides
Support Condition, Load 1	3	Triangular	Fixed	Free	Fixed
Support Condition, Load 2	8	Rectangular	Fixed	Free	Fixed

b/a upper limit	0.75	b/a lower limit	0.50

Service Load Intensities

Load 1, Base Pressure, q	1305	psf
Load 2, Base Pressure, q	495	psf

Reinforcing Placement

Vertical Reinforcing	OF	
Clear Cover, cc	2	inches
Z_{max}	115	kips/in

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Shear Analysis

Wall Thickness, t_w 12 *inches*

d_{base} = 9.69 inches
d_{side} = 9.06 inches

Outer Layer of Reinforcing

$$d = t_w - cc - \frac{\phi_{outer\ bar}}{2}$$

Inner Layer of Reinforcing

$$d = t_w - cc - \phi_{outer\ bar} - \frac{\phi_{inner\ bar}}{2}$$

$$V_u = C_s qa(lf)$$

Ultimate Shear Calculation, V_u

Shear	Coefficients, C_s		V_u, (kips/ft)		V_u, (kips/ft)	WARNINGS
LOCATION	Load 1	Load 2	Load 1	Load 2	Total Shear	
Bottom edge - midpoint	0.22	0.27	6.33	2.93	9.26	
Side edge - maximum	0.19	0.32	5.49	3.46	8.95	
Side edge - midpoint	0.16	0.31	4.50	3.30	7.80	
Top edge - midpoint	0.00	0.00	0.00	0.00	0.00	

$$\phi V_{c(base)} = \frac{.75*2\sqrt{f'_c}\,b_w d}{1000} = 12.33 \text{ kips/ft} \qquad \phi V_{c(side)} = \frac{.75*2\sqrt{f'_c}\,b_w d}{1000} = 11.53 \text{ kips/ft}$$

Analysis Results Summary

DESIGN SUMMARY			WARNINGS
Wall Thickness	12	inches	

Vertical Reinforcing

Dowels	# 5 @ 6"	
Dowel Projection	LAP LENGTH, CLASS B	
Vertical Bars	# 5 @ 6"	

Horizontal Reinforcing

Corner Bars	# 5 @ 6"	
Horizontal Bars	# 5 @ 6"	

CDM Smith
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Suite 300
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Client TVA	Job No. 95618-92016	Computed By KMF	
Project Ash Pod	Date Checked 8-17-2012	Date 8/17/2012	
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VERTICAL MOMENT ANALYSIS

Support Condition, Load 1						Coeff.	Support Condition, Load 2					
	0.1b	0.2b	0.3b	0.4b				0.1b	0.2b	0.3b	0.4b	
END	0.9b	0.8b	0.7b	0.6b	0.5b		END	0.9b	0.8b	0.7b	0.6b	0.5b
0	0	0	0	0	0	**TOP**	-6	0	0	0	0	0
-1	0	0	0	0	0	**0.9a**	-7	-3	0	1	1	2
-1	0	0	0	0	0	**0.8a**	-6	-3	0	1	3	3
-2	-1	0	0	1	1	**0.7a**	-6	-3	0	2	3	3
-3	-1	0	1	2	2	**0.6a**	-6	-3	0	2	4	4
-3	-1	0	2	2	3	**0.5a**	-6	-2	0	3	4	5
-3	-1	1	2	4	4	**0.4a**	-6	-2	1	3	5	5
-3	-1	1	3	4	5	**0.3a**	-5	-1	1	3	5	6
-2	0	1	2	3	4	**0.2a**	-3	-1	1	2	3	3
-1	0	0	-1	-1	-1	**0.1a**	-1	-1	-1	-2	-3	-3
0	-3	-8	-13	-16	-17	**BOT**	0	-3	-10	-17	-21	-23

$$M_{ux} = \frac{M_x q_i a^2 (lf)(df)}{1000}$$

Factored Moments (kip-feet), Load 1						Mx	Factored Moments (kip-feet), Load 2					
	0.1b	0.2b	0.3b	0.4b				0.1b	0.2b	0.3b	0.4b	
END	0.9b	0.8b	0.7b	0.6b	0.5b		END	0.9b	0.8b	0.7b	0.6b	0.5b
0	0	0	0	0	0	**TOP**	-1	0	0	0	0	0
-1	0	0	0	0	0	**0.9a**	-1	0	0	0	0	0
-1	0	0	0	0	0	**0.8a**	-1	0	0	0	0	0
-1	0	0	0	0	1	**0.7a**	-1	0	0	0	1	1
-1	0	0	0	1	1	**0.6a**	-1	0	0	0	1	1
-1	0	0	1	1	1	**0.5a**	-1	0	0	0	1	1
-1	0	0	1	2	2	**0.4a**	-1	0	0	1	1	1
-1	0	1	1	2	2	**0.3a**	-1	0	0	1	1	1
-1	0	1	1	1	2	**0.2a**	-1	0	0	0	1	1
0	0	0	0	-1	-1	**0.1a**	0	0	0	0	-1	-1
0	-1	-3	-5	-6	-7	**BOT**	0	0	-2	-3	-3	-4

Factored Moments (kip-feet), Load 1 & Load 2 Superimposed						Mx	Reinforcing			
	0.1b	0.2b	0.3b	0.4b			Rebar	Rebar Spacing	d	A_s
END	0.9b	0.8b	0.7b	0.6b	0.5b		Size	inches	inches	in^2
-1	0	0	0	0	0	**TOP**	5	6	9.7	0.61
-2	-1	0	0	0	0	**0.9a**	5	6	9.7	0.61
-2	-1	0	0	1	1	**0.8a**	5	6	9.7	0.61
-2	-1	0	1	1	1	**0.7a**	5	6	9.7	0.61
-2	-1	0	1	1	1	**0.6a**	5	6	9.7	0.61
-2	-1	0	1	2	2	**0.5a**	5	6	9.7	0.61
-2	-1	1	2	2	2	**0.4a**	5	6	9.7	0.61
-2	-1	1	2	3	3	**0.3a**	5	6	9.7	0.61
-2	0	1	1	2	2	**0.2a**	5	6	9.7	0.61
-1	0	0	-1	-1	-1	**0.1a**	5	6	9.7	0.61
0	-2	-5	-8	-10	-10	**BOT**	5	6	9.7	0.61

$$\rho^*_{req} = \frac{1}{m}\left(1-\sqrt{1-\frac{2mR_n}{f_y}}\right); m=\frac{f_y}{0.85f'_c}; R_n=\frac{M_u}{\phi bd^2}; \phi=0.9; \rho^*_{req}=\rho * 4/3, if\left(\rho_{req} \le \frac{200}{f_y}\right) \qquad Z = f_s \sqrt[3]{d_c A}$$

Flexural Analysis Summary

Location	φM_n kip-feet	M_u kip-feet	ρ_{act}	ρ_{req}	f_s ksi	d_c in	A in^2	Z kips/in	WARNINGS
TOP	26	1	0.0053	0.0003	1.68	2.31	27.8	6.7	
0.9a	26	2	0.0053	0.0004	2.36	2.31	27.8	9.4	
0.8a	26	2	0.0053	0.0004	2.25	2.31	27.8	9.0	
0.7a	26	2	0.0053	0.0005	2.53	2.31	27.8	10.1	
0.6a	26	2	0.0053	0.0006	3.11	2.31	27.8	12.4	
0.5a	26	2	0.0053	0.0006	3.11	2.31	27.8	12.4	
0.4a	26	2	0.0053	0.0006	3.44	2.31	27.8	13.8	
0.3a	26	3	0.0053	0.0008	4.13	2.31	27.8	16.5	
0.2a	26	2	0.0053	0.0006	3.04	2.31	27.8	12.2	
0.1a	26	1	0.0053	0.0003	1.57	2.31	27.8	6.3	
BOT	26	10	0.0053	0.0028	14.61	2.31	27.8	58.5	

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HORIZONTAL MOMENT ANALYSIS

Support Condition, Load 1							Support Condition, Load 2					
	0.1b	0.2b	0.3b	0.4b		Coeff.		0.1b	0.2b	0.3b	0.4b	
END	0.9b	0.8b	0.7b	0.6b	0.5b		END	0.9b	0.8b	0.7b	0.6b	0.5b
-2	-2	0	1	2	2	**TOP**	-31	-16	-1	9	16	18
-5	-2	0	1	2	3	**0.9a**	-35	-16	-1	8	15	17
-7	-4	0	2	3	4	**0.8a**	-34	-16	-1	8	14	16
-10	-5	0	3	5	5	**0.7a**	-33	-15	-1	8	14	16
-13	-6	0	3	6	6	**0.6a**	-33	-15	-1	8	14	16
-15	-6	0	4	7	7	**0.5a**	-32	-13	-1	8	13	15
-17	-6	0	4	7	8	**0.4a**	-29	-12	0	7	12	14
-16	-6	0	4	6	7	**0.3a**	-25	-10	0	7	10	11
-13	-4	0	3	4	5	**0.2a**	-17	-6	0	4	7	7
-5	-2	0	1	2	2	**0.1a**	-7	-2	0	1	2	2
0	0	-1	-2	-3	-3	**BOT**	0	0	-2	-3	-4	-4

$$M_u = \frac{Coef * q_i a^2 (lf)(df)}{1000}$$

Factored Moments (kip-feet), Load 1							Factored Moments (kip-feet), Load 2					
	0.1b	0.2b	0.3b	0.4b		My		0.1b	0.2b	0.3b	0.4b	
END	0.9b	0.8b	0.7b	0.6b	0.5b		END	0.9b	0.8b	0.7b	0.6b	0.5b
-1	-1	0	0	1	1	**TOP**	-5	-3	0	1	2	3
-2	-1	0	1	1	1	**0.9a**	-5	-2	0	1	2	3
-3	-2	0	1	1	2	**0.8a**	-5	-2	0	1	2	3
-4	-2	0	1	2	2	**0.7a**	-5	-2	0	1	2	3
-5	-2	0	1	2	3	**0.6a**	-5	-2	0	1	2	2
-6	-3	0	2	3	3	**0.5a**	-5	-2	0	1	2	2
-7	-3	0	2	3	3	**0.4a**	-5	-2	0	1	2	2
-7	-2	0	2	3	3	**0.3a**	-4	-2	0	1	2	2
-5	-2	0	1	2	2	**0.2a**	-3	-1	0	1	1	1
-2	-1	0	0	1	1	**0.1a**	-1	0	0	0	0	0
0	0	-1	-1	-1	-1	**BOT**	0	0	0	-1	-1	-1

Factored Moments (kip-feet), Load 1 & Load 2 Superimposed							Corner Reinforcing			
	0.1b	0.2b	0.3b	0.4b		My	Rebar	Rebar Spacing	d	A_s
END	0.9b	0.8b	0.7b	0.6b	0.5b		Size	inches	inches	in^2
-6	-4	0	2	3	4	**TOP**	5	6	9.1	0.61
-8	-3	0	2	3	4	**0.9a**	5	6	9.1	0.61
-8	-4	0	2	4	4	**0.8a**	5	6	9.1	0.61
-9	-4	0	3	4	5	**0.7a**	5	6	9.1	0.61
-10	-5	0	3	5	5	**0.6a**	5	6	9.1	0.61
-11	-5	0	3	5	5	**0.5a**	5	6	9.1	0.61
-11	-5	0	3	5	5	**0.4a**	5	6	9.1	0.61
-10	-4	0	3	4	5	**0.3a**	5	6	9.1	0.61
-8	-3	0	2	3	3	**0.2a**	5	6	9.1	0.61
-3	-1	0	1	1	1	**0.1a**	5	6	9.1	0.61
0	0	-1	-2	-2	-2	**BOT**	5	6	9.1	0.61

$$\rho^*_{req} = \frac{1}{m}\left(1-\sqrt{1-\frac{2mR_n}{f_y}}\right); m=\frac{f_y}{0.85f'_c}; R_n=\frac{M_u}{\phi bd^2}; \phi=0.9; \rho^*_{req}=\rho * 4/3, if\left(\rho_{req} \le \frac{200}{f_y}\right) \qquad Z = f_s \sqrt[3]{d_c A}$$

Corner Bar Flexural Analysis Summary

Location	φM_n kip-feet	M_u kip-feet	ρ_{act}	ρ_{req}	f_s ksi	d_c in	A in^2	Z kips/in	WARNINGS
TOP	24	6	0.0056	0.0017	8.66	2.31	27.8	34.7	
0.9a	24	8	0.0056	0.0023	11.41	2.31	27.8	45.7	
0.8a	24	8	0.0056	0.0025	12.40	2.31	27.8	49.6	
0.7a	24	9	0.0056	0.0029	14.11	2.31	27.8	56.5	
0.6a	24	10	0.0056	0.0032	15.53	2.31	27.8	62.2	
0.5a	24	11	0.0056	0.0033	16.84	2.31	27.8	67.4	
0.4a	24	11	0.0056	0.0033	17.20	2.31	27.8	68.9	
0.3a	24	10	0.0056	0.0032	15.57	2.31	27.8	62.3	
0.2a	24	8	0.0056	0.0024	12.04	2.31	27.8	48.2	
0.1a	24	3	0.0056	0.0010	5.01	2.31	27.8	20.1	
BOT	24	0	0.0056	0.0000	0.00	2.31	27.8	0.0	

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HORIZONTAL MOMENT ANALYSIS (Continued)

Horizontal Bar Flexural Analysis Summary

Factored Moments (kip-feet), Load 1 & Load 2 Superimposed							Horizontal Reinforcing			
	0.1b	0.2b	0.3b	0.4b		Mx	Rebar Size	Rebar Spacing inches	d inches	A_s in^2
END	0.9b	0.8b	0.7b	0.6b	0.5b					
-6	-4	0	2	3	4	**TOP**	5	6	9.1	0.61
-8	-3	0	2	3	4	**0.9a**	5	6	9.1	0.61
-8	-4	0	2	4	4	**0.8a**	5	6	9.1	0.61
-9	-4	0	3	4	5	**0.7a**	5	6	9.1	0.61
-10	-5	0	3	5	5	**0.6a**	5	6	9.1	0.61
-11	-5	0	3	5	5	**0.5a**	5	6	9.1	0.61
-11	-5	0	3	5	5	**0.4a**	5	6	9.1	0.61
-10	-4	0	3	4	5	**0.3a**	5	6	9.1	0.61
-8	-3	0	2	3	3	**0.2a**	5	6	9.1	0.61
-3	-1	0	1	1	1	**0.1a**	5	6	9.1	0.61
0	0	-1	-2	-2	-2	**BOT**	5	6	9.1	0.61

$$\rho^{*}_{req}=\frac{1}{m}\left(1-\sqrt{1-\frac{2mR_n}{f_y}}\right);m=\frac{f_y}{0.85f'_c};\ R_n=\frac{M_u}{\phi bd^2};\ \phi=0.9;\ \rho^{*}_{req}=\rho*4/3,\ if\left(\rho_{req}\leq\frac{200}{f_y}\right) \qquad Z=f_s\sqrt[3]{d_c A}$$

Horizontal Bar Flexural Analysis Summary

Location	φM_n kip-feet	M_u kip-feet	ρ_{act}	ρ_{req}	f_s ksi	d_c in	A in^2	Z kips/in	WARNINGS
TOP	24	4	0.0056	0.0011	5.66	2.31	27.8	22.7	
0.9a	24	4	0.0056	0.0012	6.05	2.31	27.8	24.2	
0.8a	24	4	0.0056	0.0013	6.23	2.31	27.8	24.9	
0.7a	24	5	0.0056	0.0014	6.85	2.31	27.8	27.4	
0.6a	24	5	0.0056	0.0015	7.65	2.31	27.8	30.6	
0.5a	24	5	0.0056	0.0016	8.15	2.31	27.8	32.6	
0.4a	24	5	0.0056	0.0016	8.13	2.31	27.8	32.6	
0.3a	24	5	0.0056	0.0015	7.26	2.31	27.8	29.1	
0.2a	24	3	0.0056	0.0010	5.12	2.31	27.8	20.5	
0.1a	24	1	0.0056	0.0004	1.81	2.31	27.8	7.3	
BOT	24	2	0.0056	0.0006	3.17	2.31	27.8	12.7	

REINFORCING DETAILS

Vertical Reinforcing Cut-Off Details

Location	Rebar Size	Rebar Spacing	Termin Point	T_h (ft)	$12d_b$ inches	d inches	Dowel Termination Height (feet), h_d
TOP	5	6					
0.9a	5	6					
0.8a	5	6					
0.7a	5	6					
0.6a	5	6					
0.5a	5	6					
0.4a	5	6					
0.3a	5	6					
0.2a	5	6					
0.1a	5	6					
BOT	5	6					

NOTES:

1) *ACI 318 12.10.3 - Reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the effective depth of member or $12d_b$, whichever is greater, except at supports of simple spans and at free end of cantilevers.*