



**Final Supplemental Watershed Plan No. 1 - Environmental
Assessment**

United States
Department of
Agriculture

Central Sonoma Watershed - Matanzas Creek Dam Rehabilitation Project
Sonoma County, California

Natural
Resources
Conservation
Service

Sponsoring Local Organization: Sonoma County Water Agency
Lead Agency: Natural Resources Conservation Service (NRCS)

October 2026

Appendix D - TM006 - Spillway Stability and Integrity Analysis



TM006 – Spillway Stability and Integrity Analysis

Table of Contents

1.0 Introduction	2
1.1 Purpose and Scope	2
2.0 Site Description	2
3.0 Hydrologic and Hydraulic Evaluation	3
4.0 SITES Stability and Integrity Analysis	3
4.1 NRCS Criteria	3
4.2 Auxiliary Spillway Characteristics	3
4.2.1 Auxiliary Spillway Surface Conditions	5
4.2.2 Material Characterization	5
4.3 Stability Results	6
4.4 Integrity Results	6
4.5 Limitations	6
5.0 Summary	8
6.0 References	9
Appendix A. Auxiliary Spillway Parameters	A-1
Appendix B. Stability Analysis Calculations	B-2
Appendix C. Integrity Analysis Calculations	C-3

Figures

Figure 3-1. Upper section of auxiliary spillway (view is looking north towards downstream channel)	4
Figure 3-2. Middle section of auxiliary spillway (view is looking south towards upstream channel)	4
Figure 4-3. Lower section of auxiliary spillway (view is looking east towards upstream channel; photo is taken from top of constructed dike)	5
Figure 3-4. SITES integrity evaluation of 24-hr FBH (unfavorable conditions): Breached	7
Figure 3-5. SITES integrity evaluation of 24-hr FBH (favorable conditions): Not Breached – 283 feet remaining.....	7

Tables

Table 3-1. Summary of hydrologic results for Matanzas Creek Dam	3
Table 3-2. Auxiliary Spillway Surface Parameters.....	5

1.0 Introduction

Matanzas Creek Dam (CA00794) is an earthen embankment dam located in Sonoma County, California. Construction of the dam was proposed as a result of the original Central Sonoma Watershed Plan developed in 1958 under the National Resources Conservation Service (NRCS) PL-566 program. The dam was designed with technical assistance from the NRCS and constructed in 1964 as a flood control structure. Sonoma County Water Agency (Sonoma Water) currently owns, operates, and maintains the dam.

In 2016, HDR and Kleinfelder completed a dam assessment for the NRCS, which evaluated the dam based on Technical Release 210-60 (TR-60) (NRCS, 2019) design criteria. It was determined that Matanzas Creek Dam is out of compliance with TR-60 criteria due to its inability to route the principal spillway hydrograph without activating the earthen auxiliary spillway (HDR; Kleinfelder, 2016). The 2016 study did not include a stability and integrity analysis of the dam.

1.1 Purpose and Scope

Jones & DeMille Engineering (JDE) and AECOM have contracted with the NRCS to develop a supplemental watershed plan and environmental document that focuses on bringing Matanzas Creek Dam into compliance with NRCS and California Division of Safety of Dams (CA DSOD) standards. This report focuses on the auxiliary spillway stability and integrity analysis per TR-60 guidelines for the existing conditions of the dam. A hydrologic analysis of the watershed and hydraulic performance of the existing dam is provided in *TM005 – Existing Hydrology Analysis* (JDE, 2023).

2.0 Site Description

Matanzas Creek Dam is an earthen embankment dam that was constructed in 1964 for flood protection for downstream infrastructure, which includes the City of Santa Rosa. The dam is located approximately five river miles upstream from the confluence of Santa Rosa Creek and Matanzas Creek. The contributing watershed to the dam is 11.45 square miles. The NRCS and CA DSOD hazard classifications for the dam are High Hazard and Extremely High Hazard, respectively.

The dam has a crest elevation of 427.63 feet (NAVD 88), a crest length of approximately 685 feet, a crest top width of 24 feet, and a total height of approximately 95 feet. The embankment has a 3:1 upstream slope with one wave berm that is 10 feet in width. The downstream face of the dam has a 2.5:1 slope and two stability berms that are also both 10 feet wide. The dam features a principal spillway and auxiliary spillway with crest elevations of 377.63 feet and 412.63 feet (NAVD 88), respectively. The auxiliary spillway of the dam is a vegetated earthen spillway that wraps around the right abutment of the embankment. The auxiliary spillway operates as a broad-crested weir with a weir length of 200 feet and 2:1 side slopes. The crest of the spillway includes a concrete cut-off wall that extends 10 feet below the ground surface.

For additional information and photographs of the existing dam, refer to *TM001 – Existing Condition Assessment* (JDE & AECOM, 2023) and *TM005 – Existing Hydrology Analysis* (JDE, 2023).

3.0 Hydrologic and Hydraulic Evaluation

Hydrologic and hydraulic analyses were completed for Matanzas Creek Dam and are described in detail in *TM005 – Existing Hydrology Analysis* (JDE, 2023). Probable Maximum Precipitation (PMP) depths and distributions were determined using HMR 58/59 guidelines. Rainfall losses were based on the SCS Curve Number method, and time of concentration for the watershed was determined using the Velocity Method. A calibration of the CN (71.4), lag time (1.8 hours), and rating curves of the spillways was completed based on local rain gage, stream gage, and reservoir pool data available for the dam. A summary of hydrologic results is provided in Table 3-1. Based on the hydrologic modeling, the auxiliary spillway has sufficient capacity to route the NRCS 6- and 24-hour SDH and FBH storm events.

Table 3-1. Summary of hydrologic results for Matanzas Creek Dam

Storm Event	Precipitation Depth (in)	Peak Water Surface Elevation (ft)	Peak Auxiliary Spillway Discharge (cfs)
6-hr SDH	5.24	404.59	0
6-hr FBH	6.57	413.52	347
24-hr SDH	14.11	417.94	5,705
24-hr FBH	24.45	421.73	13,983

4.0 SITES Stability and Integrity Analysis

4.1 NRCS Criteria

Per TR-60, an earthen and vegetated auxiliary spillway requires routing the 6-hour Stability Design Hydrograph (SDH), also known as the Auxiliary Spillway Hydrograph (ASH), to check to stability of the spillway. The integrity analysis of the spillway evaluates the headcut development of the spillway while routing the 6-hour and 24-hour Freeboard Hydrographs (FBH). For high hazard potential dams (including Matanzas Creek Dam), special consideration of the layout of the spillway and selected spillway parameters should be taken to ensure the spillway will not breach during the FBH storm event.

The spillway analysis was completed using SITES (Version 2005.1.11) software (USDA, 2020). Required material parameters (vegetation retardance curve index, headcut erodibility index, etc.) for the stability and integrity analysis were determined using guidelines found in the Agricultural Handbook Number 667 (AH667) (Temple et al., 1987) and the National Engineering Handbook (NEH) Part 628 Chapter 52 (NRCS, 1997).

4.2 Auxiliary Spillway Characteristics

The auxiliary spillway consists of an earthen, vegetated channel with varying widths. The auxiliary spillway channel can be described in three sections. The upper section consists of the constructed portion of spillway that includes of a uniform width of 200 feet, 2H:1V side slopes, and an average slope of 1%. The middle section of the auxiliary spillway bends significantly, increases significantly in slope, and decreases in channel width. Lastly, the lower section returns to a milder slope, increases in width (wider than the constructed 200 feet width), and consists of tall grasses and mature trees before it returns to Matanzas Creek. See Figures 4-1 through 4-3 for photos of the auxiliary spillway that were taken during a site visit in January 2021.

A ground surface profile of the auxiliary spillway centerline was developed using the topographic survey that was performed in January 2021 by Cinquini & Passarino, Inc. With the limited data available, the

profiles of subsurface materials were approximated (further discussed in Section 4.2.2). The plan and profile views of the auxiliary spillway are provided in Appendix A.

The auxiliary spillway crest is approximately located at station 2+30 with an elevation of 412.63 feet. The auxiliary spillway continues until it reaches the “valley elevation” of the Matanzas Creek flowline at an approximate station of 22+50. An average width of 195 feet and 2H:1V side slopes were used for the spillway analysis.



Figure 4-1. Upper section of auxiliary spillway (view is looking north towards downstream channel)



Figure 4-2. Middle section of auxiliary spillway (view is looking south towards upstream channel)



Figure 4-3. Lower section of auxiliary spillway (view is looking east towards upstream channel; photo is taken from top of constructed dike)

4.2.1 Auxiliary Spillway Surface Conditions

Based on site observations and AH667 guidelines, the auxiliary spillway surface parameters shown in Table 4-1 were used for the SITES analysis. Note that there are several mature trees within stations 18+00 to 22+00. Surface parameters for this section of the spillway were adjusted accordingly to account for the trees, and a sensitivity analysis confirmed that the adjusted parameters did not change the outcome of the spillway integrity results.

Table 4-1. Auxiliary Spillway Surface Parameters

Parameter Description	Values for Sta. 00+00 to 18+00	Values for Sta. 18+00 to 22+00
Vegetal Retardance Curve Index	5.60	7.64
Vegetal Cover Factor	0.75	0.75
Maintenance Code	1 (uniform cover)	2 (minor discontinuities)
Potential Root Depth (ft)	1	3

4.2.2 Material Characterization

Characterizing the material parameters and stratum were limited to available as-built drawings, construction specifications, design reports, and previous geotechnical reports for Matanzas Creek Dam. The available data, however, was not sufficient to provide adequate certainty in the material characteristics. Therefore, a range of geotechnical parameters (listed as “unfavorable” and “favorable”) were provided for each material layer to account for this uncertainty (AECOM, 2022b).

In general, there are four material layers located within the auxiliary spillway: topsoil, bedrock (weak volcanic tuff and basalt), alluvium/colluvium, and claystone. The topsoil and bedrock layers are located in the upper portion of the auxiliary spillway, and the alluvium and claystone layers are located in the lower

portion of the spillway. See Appendix A for a summary of material parameters used for the spillway analysis.

4.3 Stability Results

TR-60 requires the use of the 6-hour SDH auxiliary spillway discharge for the stability analysis. However, as shown in Table 3-1, the 6-hour SDH does not engage Matanzas Creek Dam's auxiliary spillway. Therefore, Matanzas Creek Dam passes the TR-60 stability criterion.

To be thorough, however, the spillway stability was also analyzed using the 6-hour FBH, which is not a TR-60 requirement. As shown in Table 3-1, this storm produces approximately 0.9 feet of head through the spillway, which is equivalent of a peak discharge of approximately 350 cfs. Allowable shear stresses for soil and vegetation were estimated based on methods presented in Agricultural Handbook Number 667 (AH667) (Temple et al., 1987).

The SITES results show that the auxiliary spillway does not pass the AH667 stability analysis for the 6-hour FBH for both favorable and unfavorable soil parameters. However, it is noted that the point of failure in the spillway is in result of a steep grade (approximately 40%) in the auxiliary spillway located near station 11+80. If this small section were graded to the surrounding average grade of 13%, the auxiliary spillway would pass the stability analysis, assuming favorable soil parameters. If unfavorable soil parameters were assumed in the spillway, the auxiliary spillway may pass or fail the stability analysis depending on the soil classification that is assumed. A summary of results is provided in Appendix B.

4.4 Integrity Results

The SITES evaluation indicated that the spillway has minimal erosion, if any, during the 6-hour FBH storm event for both the unfavorable and favorable material parameters. For the 24-hour FBH storm event, however, the SITES evaluation indicated that the auxiliary spillway would breach when considering the unfavorable material parameters (see Figure 4-4) and not breach with the favorable parameters (see Figure 4-5). Assuming the favorable parameters, the SITES model reports a distance of 283 feet from auxiliary spillway crest and the end of the developed headcut.

Due to the results of the integrity analysis being dependent on the assumed material parameters, a sensitivity analysis was completed. The spillway was evaluated assuming one material layer had favorable parameters while the remaining layers had unfavorable parameters. It was determined that the topsoil parameters had the most influence (followed by the bedrock parameters) on whether the spillway would meet integrity criteria or not. Another parameter included in the sensitivity analysis was the spillway width (this spillway has a varying width although SITES assumes a uniform width). However, this analysis confirmed that the spillway width has a much less of an impact on the integrity results than the topsoil parameters. The procedures and results of the sensitivity analysis is provided in Appendix C.

4.5 Limitations

SITES assumes a uniform spillway cross-section, and it does not account for hydraulics associated with bends in the spillway. Matanzas Creek Dam does not have a uniform cross-section and it has one major bend in the spillway alignment.

The SITES integrity analysis evaluates the erosion process in a spillway over the course of a 6-hour or 24-hour FBH storm event. This typically results in stepped, incremental eroded spillway material in the analyses. As observed in the Figures 3-4 and 3-5 however, this is not the case for the SITES evaluation of Matanzas Creek Dam. Given the spillway profile, materials parameters, and hydrologic storms, SITES resulted in a several headcuts that merge together which resulted in an abrupt drop in the spillway (70+

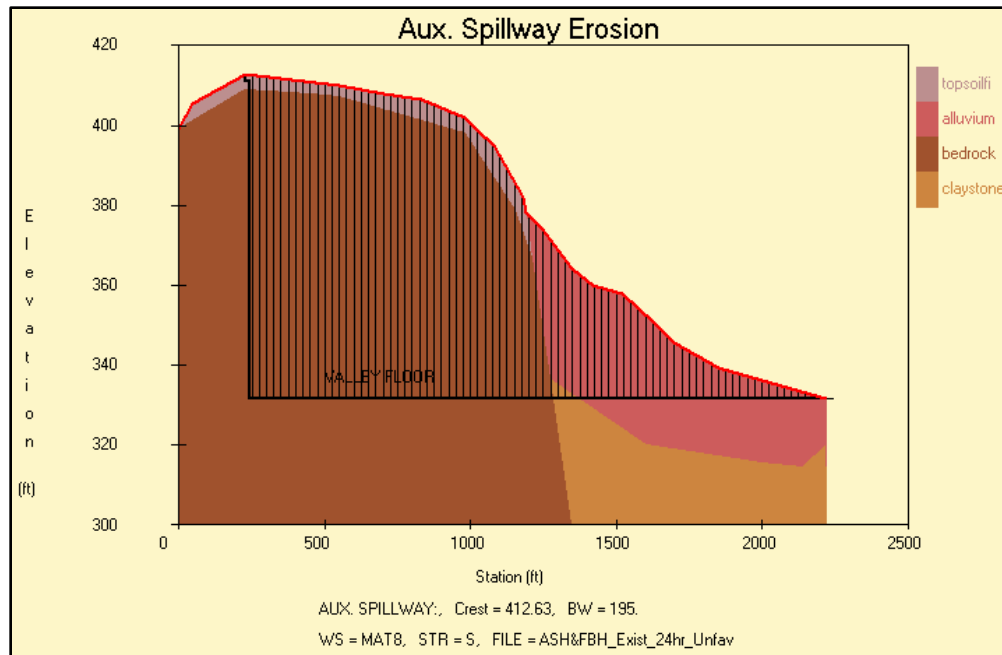


Figure 4-4. SITES integrity evaluation of 24-hr FBH (unfavorable conditions): Breached

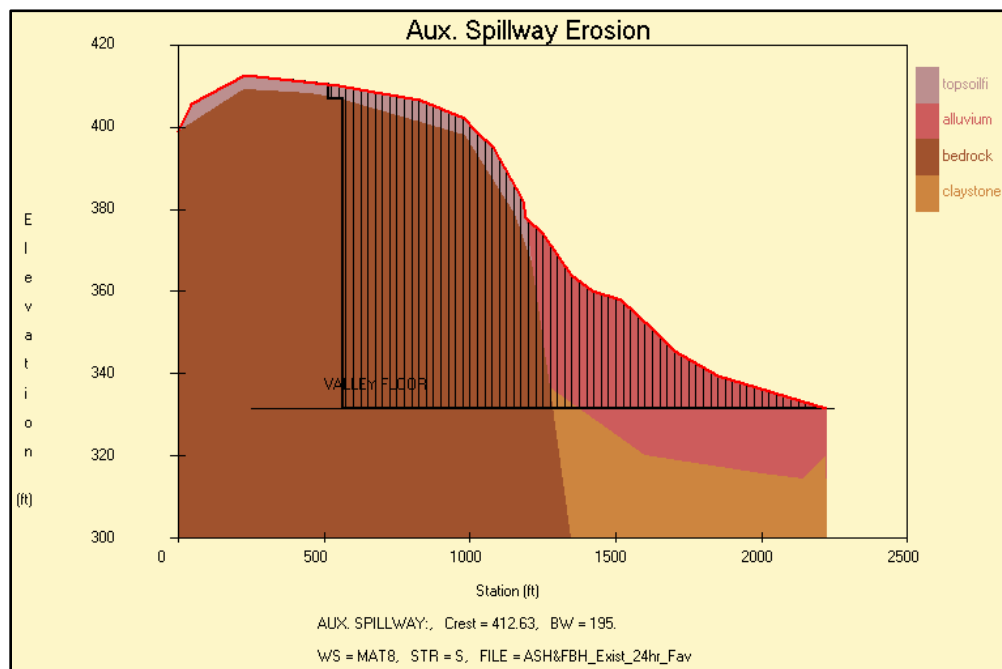


Figure 4-5. SITES integrity evaluation of 24-hr FBH (favorable conditions): Not Breached – 283 feet remaining

feet). This type of headcut is unlikely as such a large drop may likely cause other geotechnical and geological failures. Modeling the erodibility and the integrity of the spillway during the 24-hour FBH with additional software (i.e. 1D modeling, 2D modeling, or computational fluid mechanics) is recommended to further analyze the results produced by SITES.

The results of the SITES stability and integrity analyses for Matanzas Creek Dam vary depending on the assumed subsurface material characteristics. A range of geotechnical parameters were developed based on the limited subsurface data for the spillway. Additional geotechnical investigation would be needed to determine more accurate material characteristics, which would bring clarity to the stability and integrity analyses. Without additional geotechnical investigation, it is recommended to assume the unfavorable parameters in the spillway, which would result in the dam breaching during the 24-hour FBH.

5.0 Summary

The auxiliary spillway for Matanzas Creek Dam has been evaluated for stability and integrity per TR-210-60 and AH667 guidelines using SITES. There is limited geotechnical data available for the spillway. Unless further geotechnical investigation is performed to better define the spillway soil characteristics, it is recommended to use the unfavorable material parameters presented in this report.

The stability of the spillway is analyzed using the 6-hour SDH storm event. The SDH storm event does not engage the spillway for this dam; therefore, the spillway is in compliance with stability requirements. However, the spillway stability was also evaluated using the 6-hour FBH. Based on these results, it is recommended to regrade small, steep sections of the spillway or install channel liners with higher acceptable shear stress to provide additional stability of the spillway.

Based on the unfavorable material parameters used in the integrity analysis of the spillway, the existing spillway would breach during the 24-hour FBH storm event. Proposed alternatives presented in the Plan-EA should mitigate the potential for significant headcutting leading to dam failure. This may include channel erosion protection, channel concrete lining, roller-compacted concrete lining, a cutoff wall, etc. Due to the uncertainty in the subsurface materials in the spillway, it is recommended to conduct additional geotechnical investigation and spillway integrity analyses. This additional data may conclude that there are no integrity issues in the spillway, and there is no need for spillway reinforcement, as mentioned previously.

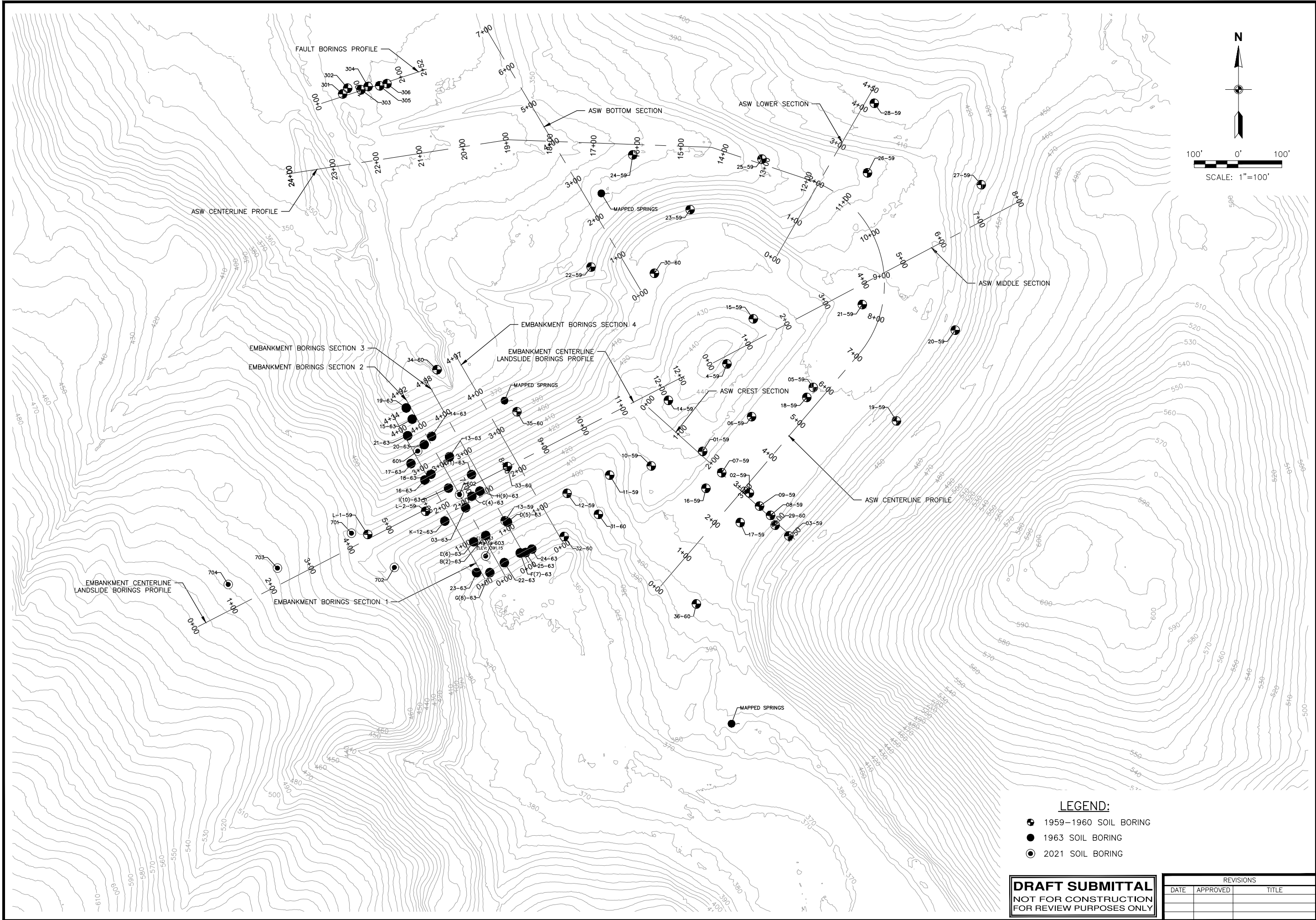
6.0 References

- AECOM. (2022a). Technical Memorandum No. 002: *Geologic Investigation Report*.
- AECOM. (2022b). Technical Memorandum: *Recommended Geological Input Parameters for SITES*
- HDR; Kleinfelder. (2016). *California Dam Assessment for Matanzas Creek Dam Sonoma Water, CA*. Natural Resources Conservation Service. California State Office. April 2016.
- Jones and DeMille Engineering (JDE), AECOM. (2023). Technical Memorandum No. 001: *Existing Conditions Assessment*.
- JDE. (2023). Technical Memorandum No. 005: *Existing Hydrology Analysis*.
- National Resources Conservation Service (NRCS). (1997). *National Engineering Handbook, Part 628 Dams, Chapter 52: Field Procedures Guide for the Headcut Erodibility Index*. August 1997.
- NRCS. (2019). Technical Release 210-60. *Earth Dams and Reservoirs*. U.S. Department of Agriculture. March 2019.
- Temple, D.M., Robinson K.M., Ahring R.M., and Davis A.G. (2020). Agricultural Handbook Number 667 – Stability Design of Grass-Lined Open Channels. U.S. Department of Agricultural. September 1987.
- U.S. Department of Agricultural (USDA). (2020). SITES Version 2005.1.11.

Appendix A. Auxiliary Spillway Parameters

The exhibits and table provided in this appendix are included in a technical memorandum found in *TM002 – Geologic Investigation Report* (AECOM, 2022a)

\\na.aecom.com\lifs\AMER\Oakland-USOAK01\DCS\Projects_WTR\60647670_MatanzasDam\400_Technical\420_CADD\BORING AUXILIARY SPILLWAY SECTION SHEETS.dwg



- LEGEND:**
- 1959-1960 SOIL BORING
 - 1963 SOIL BORING
 - 2021 SOIL BORING

DRAFT SUBMITTAL
NOT FOR CONSTRUCTION
FOR REVIEW PURPOSES ONLY

REVISIONS		
DATE	APPROVED	TITLE



United States
Department of
Agriculture



AECOM Technical Services, Inc.
300 Lakeside Drive, Suite 400
Oakland, California 94612
www.aecom.com

GEOLOGIC INVESTIGATIONS PLAN SHEET 1 OF 10

MATANZAS CREEK DAM SUPPLEMENTAL WATERSHED PLAN AND ENVIRONMENTAL DOCUMENT

IN

SANTA ROSA CREEK WATERSHED

SONOMA COUNTY, CALIFORNIA

DESIGNED BY: LTF

DRAWN BY: SLS

CHECKED BY: LTF

FILE NAME:

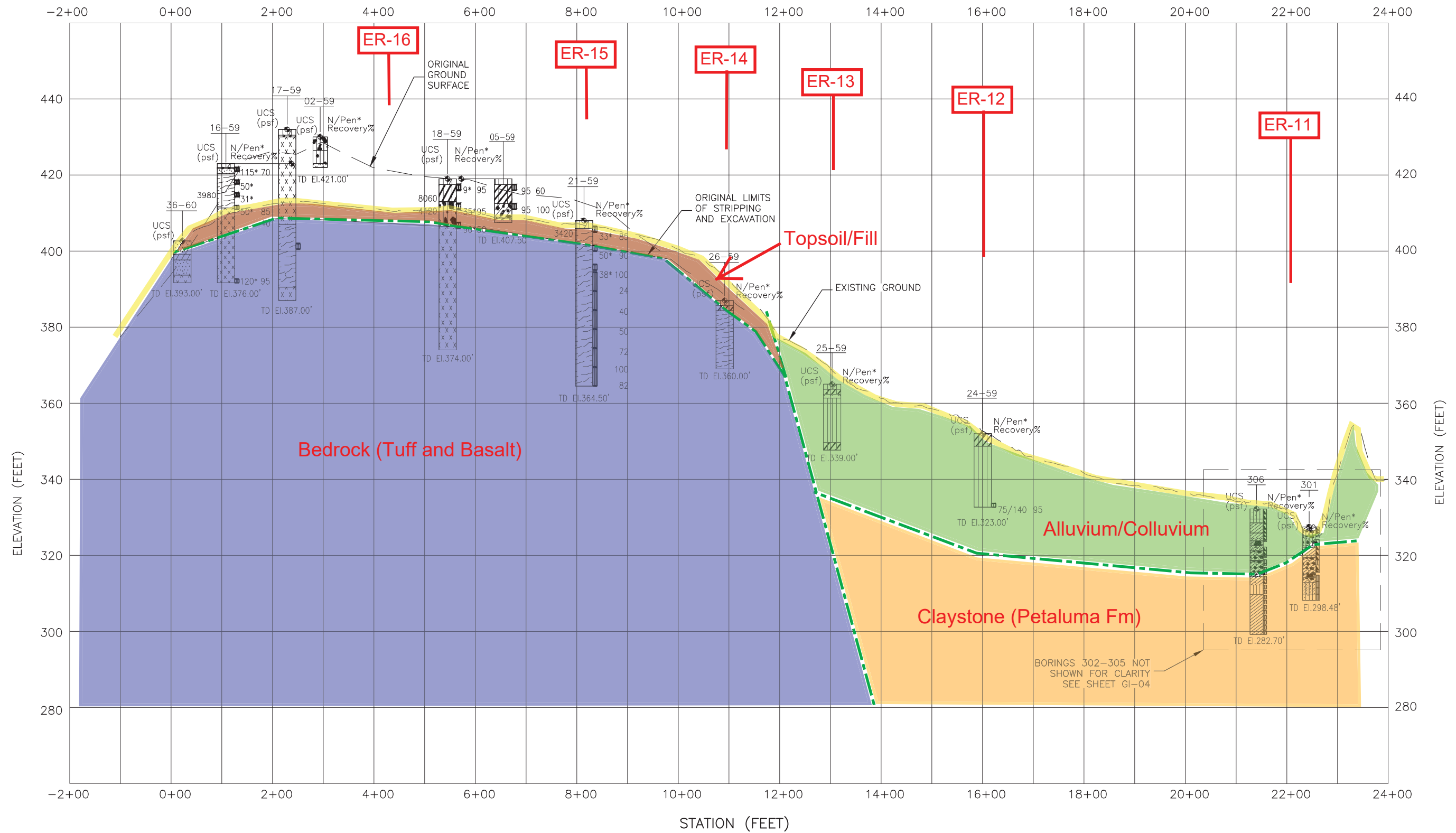
DATE CHECKED: 1/4/2022

SHEET NO. GI-01

OF XX

JAN. 7, 2022

\\na.aecomnet.com\lisa\AMER\Oakland-USOAK01\DCS\Projects_WTR\60647670_MatanzasDam\400_Technical\420_CADD\BORING AUXILIARY SPILLWAY SECTION SHEETS.dwg



AUXILIARY SPILLWAY CENTERLINE LANDSIDE BORINGS PROFILE

Figure 5. Subsurface Profile for ASW

NOTES:
1. CROSS-SECTIONS LOOKING DOWNSTREAM.

DRAFT SUBMITTAL
NOT FOR CONSTRUCTION
FOR REVIEW PURPOSES ONLY



REVISIONS		
DATE	APPROVED	TITLE

DESIGNED BY: LTF
DRAWN BY: SLS
CHECKED BY: LTF
FILE NAME: 1/4/2022
DATE CHECKED: 1/4/2022

GEOLOGIC INVESTIGATIONS PROFILE SHEET 3 OF 10
MATANZAS CREEK DAM SUPPLEMENTAL WATERSHED PLAN AND ENVIRONMENTAL DOCUMENT
IN
SANTA ROSA CREEK WATERSHED
SONOMA COUNTY, CALIFORNIA

United States
Department of
Agriculture
USDA
AECOM Technical Services, Inc.
300 Lakeside Drive, Suite 400
Oakland, California 94612
www.aecom.com
AECOM

DRAWING NO.
SHEET NO.
GI-03
OF
XX

JAN. 7, 2022

Table 4. Recommended Material Parameters for SITES Analysis

Stratum Description	USCS	Bounding Case	Material Type & Strength Assumption for Kh Estimate	Dry Unit Weight (pcf)	PI	Clay Fraction (%)	D ₇₅ (mm)	D ₅₀ (mm)	Derived Headcut Erodibility Index Parameters				
									Ms	Kb	Kd	Js	Kh
Topsoil/Fill	GM, ML, CL, CH, GC, SC ⁽¹⁾	Unfavorable Values	Clay, UCS=2 ksf / Sand, N ₆₀ =5 bpf	85	15	15	0.020	---	0.04	1.0	1.0	1.0	0.04
		Favorable Values	Clay, UCS=3 ksf / Sand, N ₆₀ =10 bpf	90	30	25	0.500	---	0.07	1.0	1.0	1.0	0.07
Alluvium / Colluvium	GM, GC, SC, SM, CH, CL, MH	Unfavorable Values	Sand, N ₆₀ =10 bpf	95	20	10	0.500	---	0.05	1.0	1.0	1.0	0.05
		Favorable Values	Sand, N ₆₀ =20 bpf	105	30	20	10.000	---	0.08	1.0	1.0	1.0	0.08
Claystone (Petaluma Fm)	CL, ML	Unfavorable Values	Clay, N ₆₀ =20 bpf (est. UCS=4 ksf)	110	20	20	0.010	---	0.20	1.0	1.0	1.0	0.20
		Favorable Values	Clay, N ₆₀ =30 bpf (est. UCS=8 ksf)	120	30	30	0.050	---	0.45	1.0	1.0	1.0	0.45
Bedrock (Sonoma Volcanics Tuff & Basalt)	n/a	Unfavorable Values	Rock, UCS=6 ksf	80	---	---	---	76.2	0.30	1.0	1.0	1.0	0.30
		Favorable Values	Rock, UCS=8 ksf	100	---	---	---	101.6	0.45	1.0	1.0	1.0	0.45
Proposed Fill	CL, CH, CL-ML	Unfavorable Values	Clay, UCS=2 ksf	90	15	20	0.005	---	0.06	1.0	1.0	1.0	0.06
		Favorable Values	Clay, UCS=3 ksf	100	25	30	0.010	---	0.09	1.0	1.0	1.0	0.09
Notes: (1) Values assumed based on range of soil index properties in borrow area and pre-construction spillway channel area.													

Appendix B. Stability Analysis Calculations



CALCULATION COVER SHEET



Project Name:	Matanzas Creek Dam – Supplemental Watershed Plan-ED	
Project Number:	2006-048	
Title of Calculations:	Spillway Stability Analysis – SITES and AH667	
Calculations By:	Hayden C.	Date: 2/3/2022
Reviewed By:	K. Curtis	Date: 2/22/2022
Number of pages (Including cover sheet): 6		
DESCRIPTION & PURPOSE		
TR-60 requires the evaluation of earthen spillway stability 6-hr SDH storm event. As shown in Table 3-1, the 6-hr SDH does not engage the dam's auxiliary spillway. Therefore, the dam meets the TR-60 stability criterion. To be thorough, however, the spillway stability was also analyzed using the 6-hour FBH. As shown in Table 3-1, this storm produces approximately 0.9 feet of head through the spillway, which is equivalent of a peak discharge of approximately 350 cfs. Allowable shear stresses for soil and vegetation were estimated based on methods presented in AH667. A critical component to this analysis is accurate geotechnical characteristics of the spillway channel materials. Geotechnical investigation for Matanzas Creek Dam's auxiliary spillway was not included, so "unfavorable" and "favorable" parameters were estimated based on available as-builts, construction specifications, design reports, and previous geotechnical investigations. It is also noted that there is a small section of steep slope (40%) in the existing spillway profile, but the average slope in this general area is 10-14%. Therefore, this analysis includes calculations assuming that this small section was graded to 13%.		
REFERENCES / DATA		
References: • NRCS, Technical Release 210-60 – Earth Dams and Reservoirs, March 2019. • NRCS, National Engineering Handbook (NEH) Part 628 Chapter 52 (including Appendix 52D) • USDA, Agricultural Handbook Number 667 • AECOM, Technical Memorandum – <i>Recommended Geologic Input Parameters for SITES Analysis</i>. January 29, 2022		
DESIGN CRITERIA / ANALYSIS / METHODS / ASSUMPTIONS		
See Appendix A for summary of auxiliary spillway profile and unfavorable/favorable material parameters. High hazard dams typically have an auxiliary spillway flow frequency for the 100-year storm event. However, the existing auxiliary spillway for Matanzas Creek Dam is activated for the 50-year storm event. Therefore, you will note that this stability analysis was completed with a 2% flow frequency. Note that the possible USCS soil classifications are based on a range of soil index properties in borrow area and pre-construction spillway channel area. The assumed possible classifications for the topsoil and alluvium layers are as follows (see next page):		

- Topsoil: GM, ML, CL, CH, GC, SC
- Alluvium/Colluvium: FM, FC, SC, SM, CH, CL, MH

6-hr FBH SITES Stability Results – Existing profile

EROSIONALLY EFFECTIVE STRESS FOR STABILITY ANALYSIS OF AUX. EXIT CHANNEL
(Refer to Ag. Handbook 667, Chapt. 3, for allowable stresses.)

Aux. Spillway Discharge = 347. cfs; Bottom Width = 195. ft

REACH NO.	FROM STA	TO STA	SLOPE %	MANNING'S n	VELOCITY ft/s	TOTAL STRESS lb/ft^2	EFFECTIVE STRESS lb/ft^2	
3	230.	550.	0.82	0.063	1.98	0.46	0.007	
4	550.	700.	1.33	0.063	2.29	0.64	0.010	
5	700.	830.	1.15	0.063	2.19	0.58	0.009	
6	830.	980.	3.00	0.062	2.93	1.13	0.018	
7	980.	1020.	7.50	0.062	3.87	2.14	0.034	
8	1020.	1080.	6.67	0.062	3.73	1.97	0.031	
9	1080.	1180.	13.00	0.062	4.56	3.15	0.049	
10	1180.	1190.	40.00	0.062	6.40	6.91	0.109	max.
11	1190.	1250.	6.67	0.062	3.73	1.97	0.031	
12	1250.	1350.	10.00	0.062	4.22	2.62	0.041	
13	1350.	1420.	5.71	0.062	3.56	1.77	0.028	
14	1420.	1520.	2.00	0.062	2.59	0.85	0.013	
15	1520.	1630.	6.82	0.062	3.76	2.01	0.031	
16	1630.	1700.	7.14	0.062	3.81	2.07	0.032	
17	1700.	1850.	4.00	0.062	3.20	1.38	0.022	
18	1850.	2220.	2.16	0.062	2.65	0.90	0.014	

6-hr FBH SITES Stability Results – Graded profile

EROSIONALLY EFFECTIVE STRESS FOR STABILITY ANALYSIS OF AUX. EXIT CHANNEL
(Refer to Ag. Handbook 667, Chapt. 3, for allowable stresses.)

Aux. Spillway Discharge = 347. cfs; Bottom Width = 195. ft

REACH NO.	FROM STA	TO STA	SLOPE %	MANNING'S n	VELOCITY ft/s	TOTAL STRESS lb/ft^2	EFFECTIVE STRESS lb/ft^2	
3	230.	550.	0.82	0.063	1.98	0.46	0.007	
4	550.	700.	1.33	0.063	2.29	0.64	0.010	
5	700.	830.	1.15	0.063	2.19	0.58	0.009	
6	830.	980.	3.00	0.062	2.93	1.13	0.018	
7	980.	1020.	7.50	0.062	3.87	2.14	0.034	
8	1020.	1080.	6.67	0.062	3.73	1.97	0.031	
9	1080.	1180.	13.00	0.062	4.56	3.15	0.049	max.
10	1180.	1250.	11.43	0.062	4.39	2.88	0.045	
11	1250.	1350.	10.00	0.062	4.22	2.62	0.041	
12	1350.	1420.	5.71	0.062	3.56	1.77	0.028	
13	1420.	1520.	2.00	0.062	2.59	0.85	0.013	
14	1520.	1630.	6.82	0.062	3.76	2.01	0.031	
15	1630.	1700.	7.14	0.062	3.81	2.07	0.032	
16	1700.	1850.	4.00	0.062	3.20	1.38	0.022	
17	1850.	2220.	2.16	0.062	2.65	0.90	0.014	

AH667/TR-60 Results

The NRCS's "AH667/TR-60 Auxiliary Spillway 6-hr FBH Stability Analysis From SITES" Version 2.6 spreadsheet was used to evaluate the spillway stability. Figures 1 and 2 represent the results assuming a GC soil classification for both existing profile and graded profile conditions. All possible soil classifications were evaluated, and the summary of results are shown in Table 1.

Summary

Stability analysis is evaluated using the 6-hr SDH. For Matanzas Creek Dam, the 6-hr SDH does not engage the auxiliary spillway; therefore, the dam meets the stability criterion.

To be thorough, the 6-hour FBH was used to evaluate stability (peak discharge of approximately 350 cfs through the spillway for this event). The results show that the spillway would not meet stability criterion for this storm event, assuming the existing auxiliary spillway profile. If the small, steep section of the spillway was regraded, the results show the spillway would meet stability requirements (depending on the soil classification of the topsoil layer).

AH667/TR-60 Auxiliary Spillway 6-hr FBH Stability Analysis from SITE S

Project Data	Date: Feb 22, 2022	Checked By: MW
	Designer: Hayden C.	
	Project: Matanzas Creek Dam - Sup. Watershed Plan-ED	Check Date: 3/6/2022
	County: Sonoma State: CA	
Topsoil Properties	GC 30	Dominant Textural Soil Class of Aux Spwy Topsoil Plasticity Index of Aux Spwy Topsoil (for CH, CL, GC, GM, MH, ML, OH, OL, SC, SM)
	90 pcf	Dry Density of Topsoil (lbs/ft ³)
	2.65	Specific Gravity of Topsoil, G _s
Vegetation	5.6	Aux Spwy Retardance Class (A-E) or Retardance Curve Index (2.88-10)
ASFlow Frequency	2.0%	Auxiliary spillway anticipated average use (see TR-60 2nd ed., pg 7-3)
SITE S 6-hr SDH values	see <i>Erosionally Effective Stress For Stability Analysis of Aux Exit Channel</i> table	
	6.91 psf	Total Stress, from SITE S 6-hr SDH (psf)
	0.109 psf	Soil Effective Stress, from SITE S 6-hr SDH (psf)

Soil Stress Analysis

Soil	Plasticity Index PI or D ₇₅	Allowable Effective Stress τ_{ab}	Void Ratio e	Void Ratio Correction C _e	$= \tau_{ab} * (C_e)^{1/2}$ τ_h	TR-60 AS Use Freq Multiplier	AH 667 Adjusted Allowable Stress τ_a	SITE S 6-hr SDH Soil Effective Stress
GC	PI=30	0.119 psf	0.84	0.909	0.098 psf	1.2	0.118 psf	0.109 psf

Soil is stable. SITE S 6-hr SDH actual effective stress less than adjusted AH 667 allowable effective soil stress.

Vegetal Stress Analysis

C _i - Retardance curve index AH 667 Table 3.2	AH 667 Allowable vegetal stress (AH 667 Eqn 1.17) $\tau_{va} = C_i * 0.75$	SITE S 6-hr SDH Vegetal Stress $\tau_{veg} = \tau_{tot} - \tau_{eff}$
5.6	4.20 psf	6.80 psf

Vegetation erodes--actual vegetal stress exceeds allowable!! Consider widening or raising auxiliary spillway crest, flatten exit slope, or use higher retardance vegetation.

Overall Stability

Unacceptable design. Soil and/or vegetation predicted to erode.

Version: 2.6 1/13/2010

Notes: This spreadsheet facilitates the USDA-NRCS TR-60 2nd edition stability analysis for earthen/vegetated auxiliary spillways with SITE S software output. Users enter project data, auxiliary spillway topsoil data, vegetation, auxiliary spillway flow frequency, and SITE S 6-hr SDH stress values. Depending on the soil, either PI or D₇₅ input is needed. The allowable vegetal and effective soil stresses are computed using USDA-ARS Ag Handbook 667 "Stability Design of Grass-Lined Open Channels". The design SITE S stresses are compared to the AH 667 stresses (as modified by TR-60). An appropriate design has equal or lower design stresses than allowable stresses.

Figure 1. Stability analysis – Existing spillway profile, favorable soil parameters, and GC soil classification (Fail)

AH667/TR-60 Auxiliary Spillway 6-hr FBH Stability Analysis from SITE S

Project Data	Date: Feb 22, 2022	Checked By: MW
	Designer: Hayden C.	
	Project: Matanzas Creek Dam - Sup. Watershed Plan-ED	
	County: Sonoma	Check Date: 3/8/2022
	State: CA	

Topsoil Properties	GC	Dominant Textural Soil Class of Aux Spwy Topsoil
	30	Plasticity Index of Aux Spwy Topsoil (for CH, CL, GC, GM, MH, ML, OH, OL, SC, SM)
	90 pcf	Dry Density of Topsoil (lbs/ft ³)
	2.65	Specific Gravity of Topsoil, G _s
Vegetation	5.6	Aux Spwy Retardance Class (A-E) or Retardance Curve Index (2.88-10)
ASFlow Frequency	2.0%	Auxiliary spillway anticipated average use (see TR-60 2nd ed., pg 7-3)
SITE S 6-hr SDH values	see <i>Erosionally Effective Stress For Stability Analysis of Aux Exit Channel</i> table	
	3.15 psf	Total Stress, from SITES 6-hr SDH (psf)
	0.049 psf	Soil Effective Stress, from SITES 6-hr SDH (psf)

Soil Stress Analysis

Soil	Plasticity Index PI or D ₇₅	Allowable Effective Stress τ_{ab}	Void Ratio e	Void Ratio Correction C _e	$= \tau_{ab} * (C_e)^2$ τ_h	TR-60 AS Use Freq Multiplier	AH 667 Adjusted Allowable Stress τ_a	SITE S 6-hr SDH Soil Effective Stress
GC	PI=30	0.119 psf	0.84	0.909	0.098 psf	1.2	0.118 psf	0.049 psf

Soil is stable. SITE S 6-hr SDH actual effective stress less than adjusted AH 667 allowable effective soil stress.

Vegetal Stress Analysis

C _i - Retardance curve index AH 667 Table 3.2	AH 667 Allowable vegetal stress (AH 667 Eqn 1.17) $\tau_{va} = C_i * 0.75$	SITES 6-hr SDH Vegetal Stress $\tau_{veg} = \tau_{tot} - \tau_{eff}$
5.6	4.20 psf	3.10 psf

Vegetation is stable. SITES 6-hr SDH actual vegetal stress less than allowable AH 667 vegetal stress.

Overall Stability

Acceptable Design. Soil and vegetation predicted to be stable.

Version: **2.6** 1/13/2010

Notes: This spreadsheet facilitates the USDA-NRCS TR-60 2nd edition stability analysis for earthen/vegetated auxiliary spillways with SITES software output. Users enter project data, auxiliary spillway topsoil data, vegetation, auxiliary spillway flow frequency, and SITES 6-hr SDH stress values. Depending on the soil, either PI or D₇₅ input is needed. The allowable vegetal and effective soil stresses are computed using USDA-ARS Ag Handbook 667 "Stability Design of Grass-Lined Open Channels". The design SITES stresses are compared to the AH 667 stresses (as modified by TR-60). An appropriate design has equal or lower design stresses than allowable stresses.

Figure 2. Stability analysis – Graded spillway profile, favorable soil parameters, and GC soil classification (Pass)

Table 1. Summary of Spillway Stability Results for Matanzas Creek Dam

AH667/TR-60 Spillway Stability Results											Stability Results based on USCS Classification					
Profile Condition	Stratum Description	Bounding Case	Dry Unit (pcf)	PI	S.G.	Veg. Retrd Curve Index	AS Flow Freq.	Slope	SITES Total Stress (psf)	SITES Soil Effective Stress (psf)	GM	ML	CL	CH	GC	SC
Existing	Topsoil/Fill	Unfavorable Values	85	15	2.65	5.6	2%	40%	6.91	0.109	Fail (S&V)	Fail (S&V)	Fail (S&V)	NA ¹	Fail (S&V)	Fail (S&V)
		Favorable Values	90	30							Fail (S&V)	Fail (S&V)	Fail (S&V)	Fail (V)	Fail (V)	Fail (S&V)
Graded	Topsoil/Fill	Unfavorable Values	85	15	2.65	5.6	2%	13%	3.15	0.049	Fail (S)	Fail (S)	Pass	NA ¹	Pass	Fail (S)
		Favorable Values	90	30							Pass	Pass	Pass	Pass	Pass	Pass

NOTE: 6-hr SDH does NOT engage AS spillway; therefore it passes criteria. Results shown in table are representative of the 6-hr FBH

Fail (S) = Per AH667/TR-60, the spillway fails the soil stress analysis, but passes the vegetal stress analysis

Fail (V) = Per AH667/TR-60, the spillway fails the vegetal stress analysis, but passes the soil stress analysis

Fail (S&V) = Per AH667/TR-60, the spillway fails both the vegetal stress and the soil stress analyses

¹CH classification could not be evaluated due to PI<22

Appendix C. Integrity Analysis Calculations



CALCULATION COVER SHEET



Project Name:	Matanzas Creek Dam – Supplemental Watershed Plan-ED	
Project Number:	2006-048	
Title of Calculations:	Sensitivity Analysis of Material Characteristics for Spillway Integrity Evaluation	
Calculations By:	Hayden C.	Date: 2/3/2022
Reviewed By:	K. Curtis	Date: 2/22/2022
Number of pages (Including cover sheet): 6		
DESCRIPTION & PURPOSE		
TR-210-60 requires the evaluation of earthen spillway stability and integrity for the 6-hr and 24-hr FBH storm events. A critical component to this analysis is accurate geotechnical characteristics of the spillway channel materials. Geotechnical investigation for Matanzas Creek Dam's auxiliary spillway was not included, so "unfavorable" and "favorable" parameters were estimated based on available as-builts, construction specifications, design reports, and previous geotechnical investigations. The evaluation concluded that the spillway could breach if considering the unfavorable parameters during the 24-hr FBH, but it wouldn't breach if using the favorable parameters. Therefore, a sensitivity analysis was conducted to investigate which material layer, if any, was critical to the evaluation of the auxiliary spillway integrity analysis. This document summarizes the approach and results of the sensitivity analysis.		
REFERENCES / DATA		
References: • NRCS, Technical Release 210-60 – Earth Dams and Reservoirs, March 2019. • NRCS, National Engineering Handbook (NEH) Part 628 Chapter 52 (including Appendix 52D) • USDA, Agricultural Handbook Number 667 • AECOM, Technical Memorandum – <i>Recommended Geologic Input Parameters for SITES Analysis</i>. January 29, 2022		
DESIGN CRITERIA / ANALYSIS / METHODS / ASSUMPTIONS		
See Appendix A for summary of auxiliary spillway profile and unfavorable/favorable material parameters. The sensitivity analysis considers the 24-hour FBH only (existing spillway pass the 6-hour FBH integrity analysis for both sets of material parameters). The baseline results for the 24-hr FBH integrity analysis for unfavorable and favorable parameters are shown in Figures 1 and 2. The sensitivity analysis will evaluate the alluvium, bedrock, and topsoil layers (note the claystone layer has minimal involvement in the erosion process) by assuming the chosen layer has favorable parameters while the remaining layers have unfavorable parameters. Findings will lead to other adjustments, as necessary.		

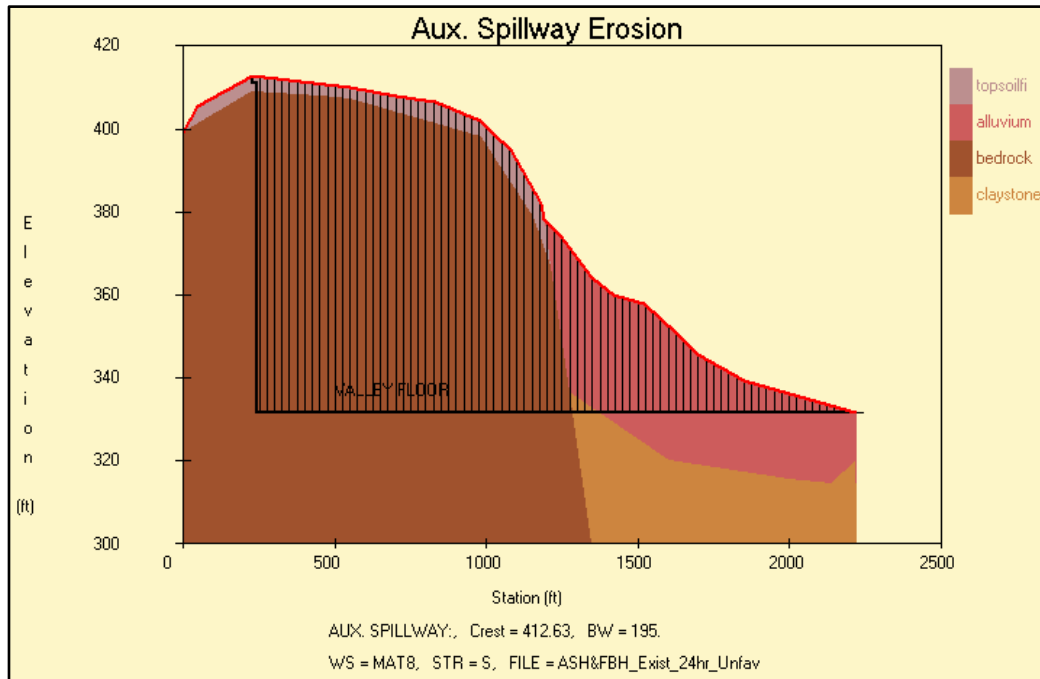


Figure 1. SITES integrity evaluation of 24-hr FBH (unfavorable conditions): Breached

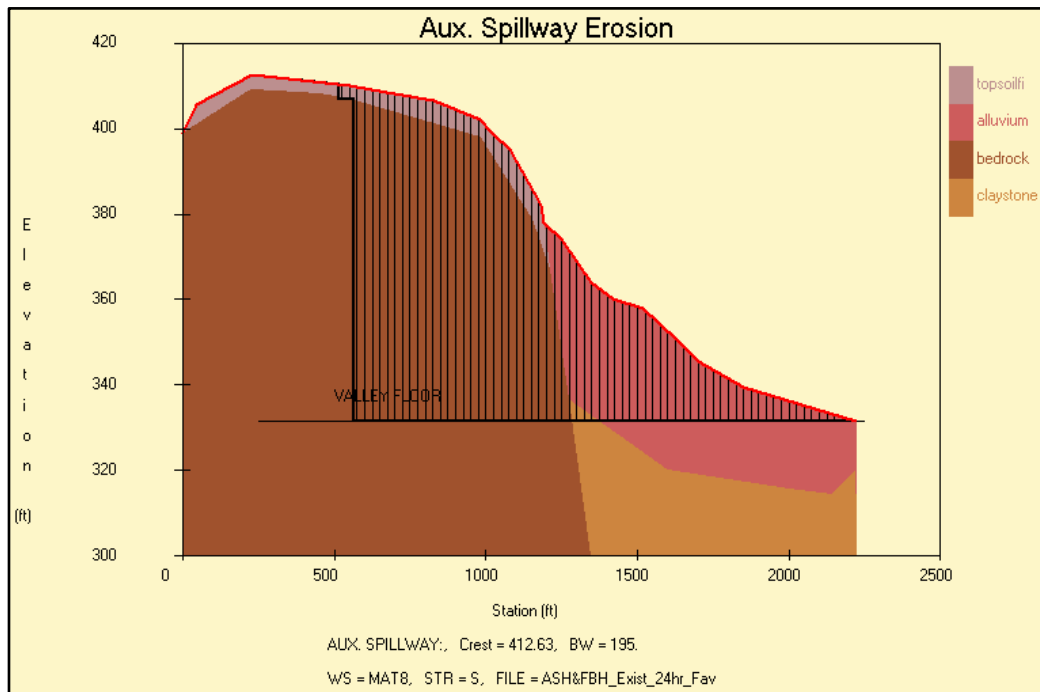


Figure 2. SITES integrity evaluation of 24-hr FBH (favorable conditions): Not breached – 283 feet remaining

Sensitivity evaluation: Alluvium

SITES evaluation with favorable material parameters for the alluvium layer and unfavorable parameters for all other layers produced a breach in the spillway, similar to Figure 1. This would suggest the alluvium layer alone is not critical enough to bring the evaluation to a non-breach scenario.

Sensitivity evaluation: Bedrock (Volcanic Tuff and Basalt)

Evaluating the spillway with favorable bedrock parameters and unfavorable parameters for all other layers also produced a breach similar to Figure 1. It can be noted Figures 1 and 2 that the SITES program is eroding away approximately 60+ feet in depth of bedrock material. The geotechnical data available for this layer, which suggested very weak volcanic tuff and basalt, was only available for depths ranging from 5-20+ feet. Therefore, the bedrock was further investigated to assumed greater head cut indexes up to 20 (representative of sandstone), which assumed that greater depths of bedrock were stronger than the material from which soil tests were available for. However, a reasonable increase for this volcanic layer would be limited to 2 (representative of a weak shale), which is approximately four times the value of the favorable condition. Even after raising the head cut index to 20, the SITES integrity evaluation continued to result in a spillway breach (see Figure 3), but it can be noted that the failure is due to the unfavorable topsoil layer, not the bedrock layer.

While these results suggest that the bedrock layer may affect the spillway integrity evaluation, it still results in spillway failure due to the unfavorable parameters in the topsoil layer. Also note that these results do not consider the concrete cutoff wall that is located at the auxiliary spillway crest. The concrete cutoff wall is 10 feet deep, which may prevent complete breach of the results shown in Figures 3 and 4. However, it is unknown if the concrete cutoff would fail should the downstream soil be eroded away (it may not have strength to bear soil pressure on upstream side of wall).

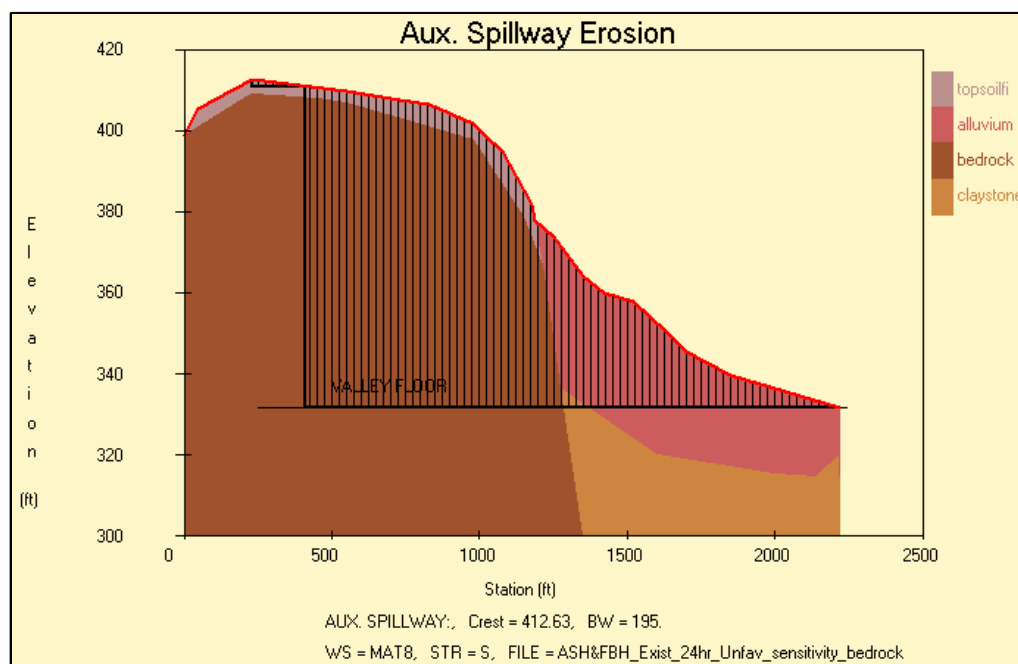


Figure 3. Bedrock sensitivity analysis - $K_h = 2$: Breached (unfavorable topsoil failure)

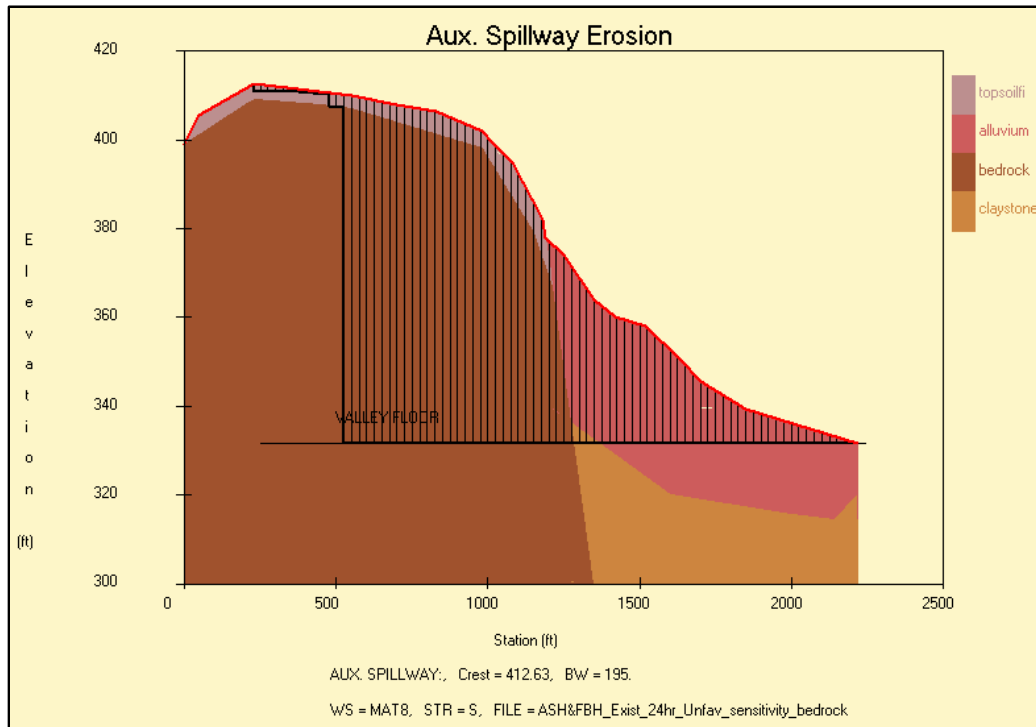


Figure 4. Bedrock sensitivity analysis – $K_b = 20$: Breached (unfavorable topsoil failure)

Sensitivity evaluation: Topsoil

The topsoil sensitivity was evaluated by assuming favorable parameters for the topsoil, and unfavorable parameters for the other soil layers. As shown in Figure 5, this resulted in passing TR-210-60 criteria (not breached) with 229 feet remaining between the developed headcut and the auxiliary spillway crest. These results suggest that the top soil material characteristics have the most sensitivity to the integrity analysis. The results of the analysis (breach vs not breach) largely depend on the topsoil characteristics.

Sensitivity evaluation: Spillway width

One other parameter included in the sensitivity analysis is the spillway width. SITES is limited to assuming a uniform, constant spillway width. As discussed in the report, Matanzas Creek Dam however has varying spillway width. It is a uniform 200 feet width downstream of the crest but then necks down to a width of 100 feet near the steepest grade. After the narrowing point, the spillway width opens back up to 200+ feet.

Assuming the same parameters described in the topsoil sensitivity analysis, it was found that the spillway width can be reduced to 125 feet and still pass the integrity analysis with approximately 47 feet remaining between the auxiliary spillway crest and the developed headcut (see Figure 6). This spillway width is significantly conservative considering the smallest width of the spillway is approximately 100 feet, and the average spillway width is 195 feet. A passing integrity analysis while assuming a width of 125 feet for the entire alignment of the spillway width suggests the outcome of the analysis is less sensitive to the width than it is to the topsoil characteristics.

Sensitivity analysis: Median parameters for the bedrock and topsoil layers

Thus far, the sensitivity analyses suggest that the topsoil layer is most influential on the SITES evaluation followed by the bedrock layer. Therefore, one last test was assuming the median or average unfavorable and favorable parameters for these two layers while assuming unfavorable parameters on the alluvium and claystone layers. As shown in Figure 7, the results show the spillway not breaching with 135 feet remaining.

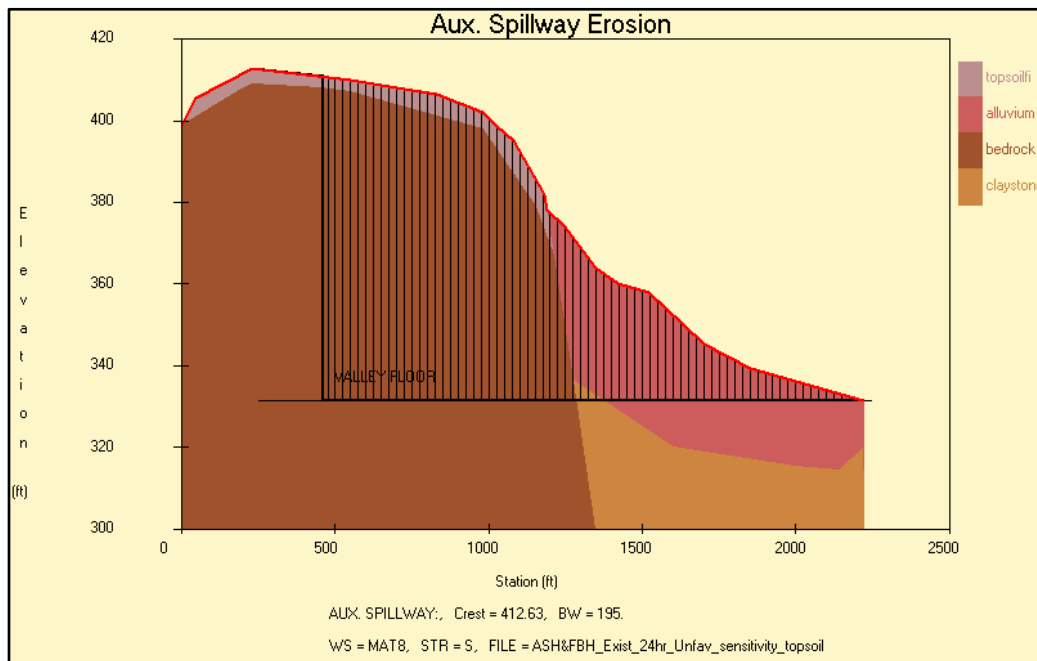


Figure 5. Topsoil sensitivity analysis: Not breached – 229 feet remaining

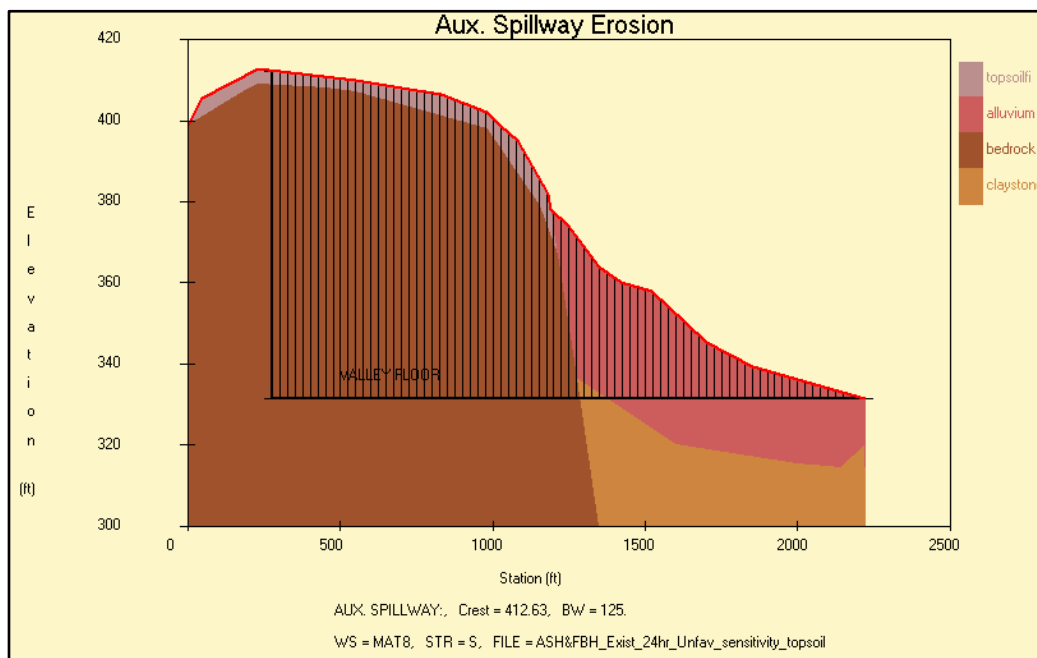


Figure 6. Spillway width sensitivity analysis (125 feet width) = Not breached - 47 feet remaining

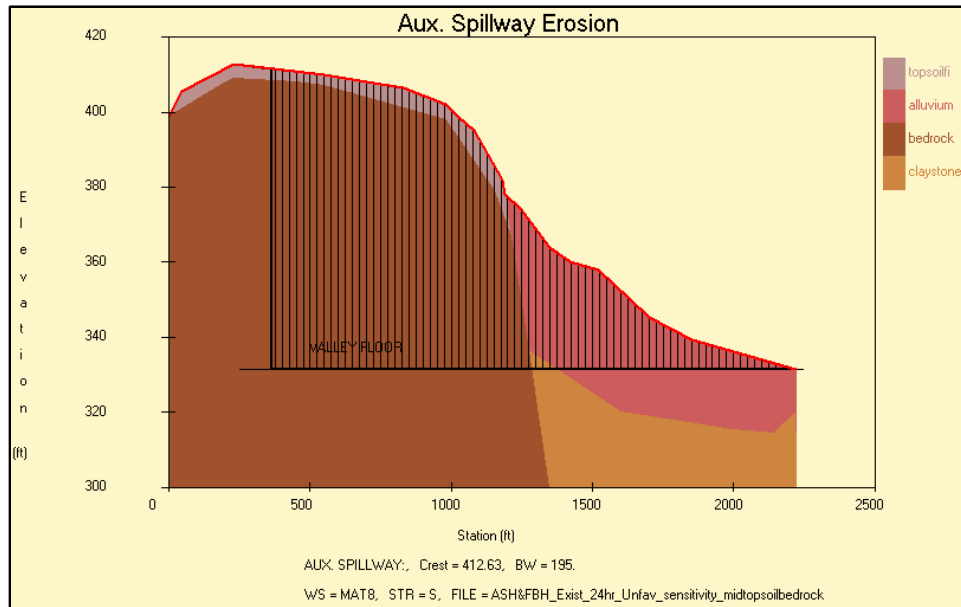


Figure 7. Median parameters for topsoil and bedrock: Not breached - 135 feet remaining

Limitations and Assumptions

SITES assumes a uniform spillway cross-section, and it does not account for hydraulics associated with bends in the spillway. Matanzas Creek Dam does not have a uniform spillway cross-section, and it has one major bend in the spillway alignment.

SITES integrity analyses evaluates the erosion process in a spillway over the course of a 6-hour or 24-hour FBH storm event. This typically results in stepped, incremental eroded spillway material in the analyses (see upper portion of spillway in Figure 4 as an example). As observed in Figures 1-7 however, this is not the case for the SITES evaluation of Matanzas Creek Dam. Given the spillway profile, materials parameters, and hydrologic storms, SITES resulted in a single headcut with an abrupt drop in the spillway (70+ feet). This type of headcut is unlikely as such a large drop may likely cause other geotechnical and geological failures. Modeling the erodibility and the integrity of the spillway during the 24-hour FBH with additional software is recommended to further analyze the results produced by SITES.

Summary

It has been determined that the spillway integrity fails assuming unfavorable material parameters but passes with favorable parameters. The sensitivity analyses suggest that the topsoil material characteristics (followed by the bedrock layer) have the most influence on the outcome the of SITES integrity analysis. Spillway width was also analyzed for sensitivity due to Matanzas Creek dam having a varying width; however, it was determined that this parameter does not have as big an impact on the results as the topsoil material does.

Additional geotechnical investigation would need to be completed to determine more accurate material characteristics in the auxiliary spillway. Doing so may bring clarification on the SITES spillway integrity analysis, which may largely affect the alternatives developed in the Plan-EA. Without additional geotechnical investigation, it is recommended to assume the unfavorable parameters in the spillway, which would result in Matanzas Creek Dam failing (breaching) during the 24-hour FBH integrity analysis.