APPENDIX B

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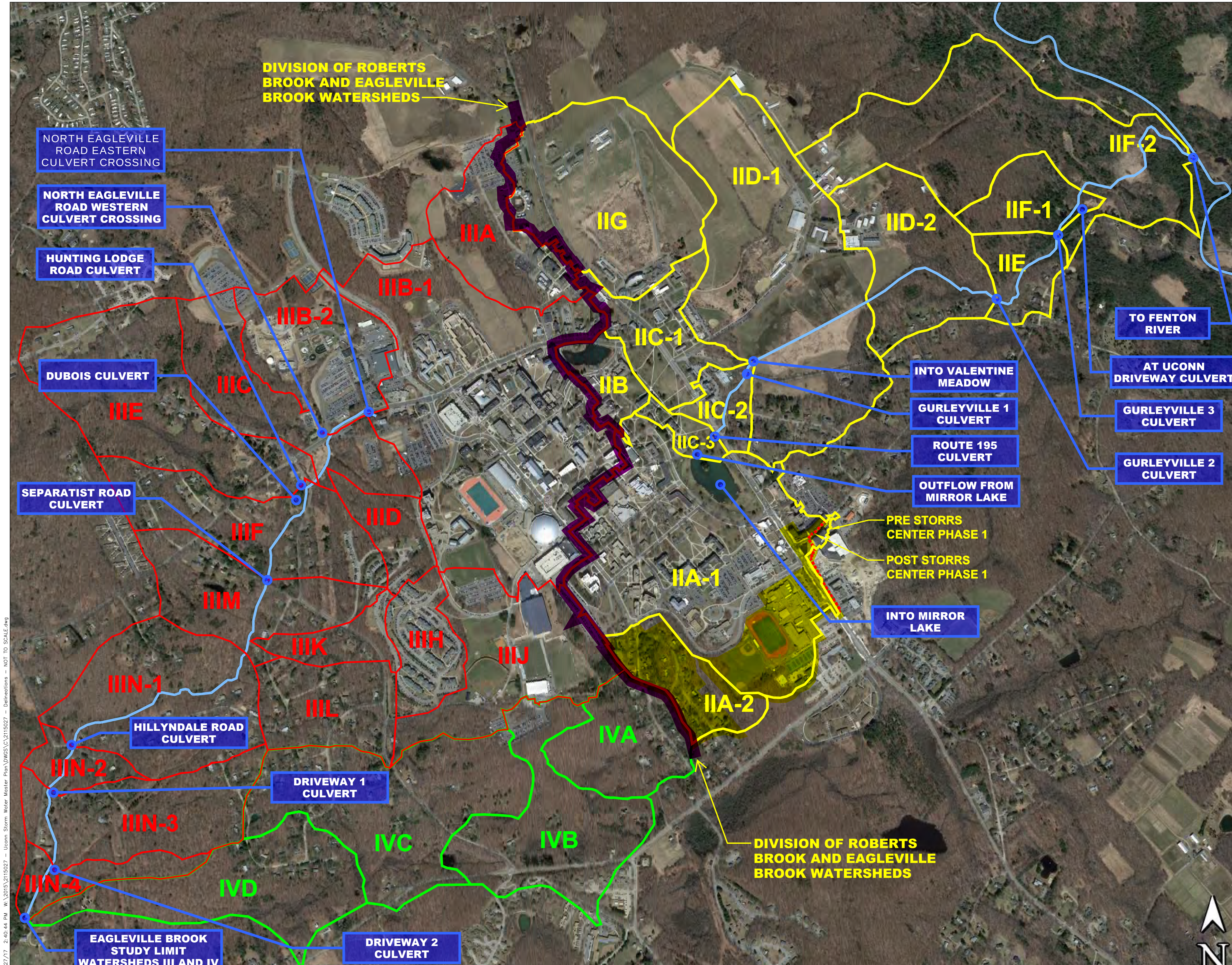
CIVIL, STRUCTURAL, MECHANICAL, ELECTRICAL, TECHNOLOGY AND COMMISSIONING

JOB TITLE: MIRROR LAKE FEASIBILITY STUDY					DRAWING NUMBER
SHEET TITLE: PIPE OUTLET RELOCATIONS				REVISION INFO N/A	STRM-1
JOB NUMBER 2115027	SCALE NTS	DATE 03/04/2021	DRAWN BY JJB	REFERENCE DRAWING	

5/12/21 9:58:00 AM W:\2015\2115027 - Uconn Storm Water Master Plan\CIVIL\Mirror Lake Feasibility Study\2115027 - TG Forebays - Pipe Relocation.dwg



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APPENDIX C

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Mirror Lake Dam Improvements- Conceptual Design Report

MIRROR LAKE DAM IMPROVEMENTS PROJECT CT DAM ID #7806

Storrs, Connecticut

April 20, 2021
GZA File No. 05.0046161.07

PREPARED FOR:
BVH Integrated Services, P.C.
206 West New Berry Road
Bloomfield, CT 06002

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April 20, 2021
File No. 05.0046161.07

Mr. Scott Waitkus, P.E.
Vice President
BVH Integrated Services, P.C.
206 West Newberry Road
Bloomfield, CT 06002

Re: Mirror Lake Dam Improvements- Conceptual Design Report
Mirror Lake Dam (CT DAM ID #7806)
University of Connecticut Storrs Campus

Dear Mr. Waitkus,

GZA GeoEnvironmental, Inc. (GZA) is pleased to present this report detailing our subsurface investigations and engineering analyses in support of the Mirror Lake Dam Improvements Project to BVH Integrated Services (BVH). This report was prepared in accordance with our proposal dated November 10, 2020 and executed on December 8, 2020. This report is subject to the Limitations attached as **Appendix A**.

GZA's scope of services was to provide feasibility-level dam safety engineering and dredge services to support the proposed Mirror Lake Dam and Lake improvements. GZA completed a field exploration program, hydrologic and hydraulic (H&H) analysis, and geotechnical engineering analyses in support of the proposed improvements. This report provides a summary of the following:

- Project background;
- Geotechnical explorations;
- Geotechnical laboratory testing;
- H&H analysis results;
- Embankment seepage and slope stability analyses results;
- Spillway stability analysis results;
- Anticipated required permits; and
- Conceptual-level repair plans and brief technical specifications.

The results of the dredge feasibility study and limnological study were provided under separate covers.

We appreciate the opportunity to work with you on this project and look forward to our continued collaboration. Please contact James Davis, P.E. (860-462-3016) or David M. Barstow (860-250-2131) if you have any questions or require additional information.

Very truly yours,

GZA GEOENVIRONMENTAL, INC.

James F. Davis, P.E.
Sr. Project Manager

David M. Leone, PE
Consultant/Reviewer

David M. Barstow, P.E.
Principal-In-Charge

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1.0 INTRODUCTION

1.1 SITE DESCRIPTION

Mirror Lake Dam is located on the University of Connecticut (UCONN) Storrs Campus in Storrs, Connecticut. The dam impounds Mirror Lake to the south and is bordered by Storrs Road to the east and north and by academic buildings to the west. The dam can be accessed via a sidewalk that extends between Mansfield Road and Storrs Road. The approximate Dam location is presented on **Figure 1 – Locus Plan**.

Based on available information[1], Mirror Lake Dam originally consisted of a "wooden dam" that was replaced with an earthen embankment in 1922. The dam was reportedly "reinforced" in 1935 after heavy spring rains caused a leak and the dam was repaired/replaced again in 1946. Drawings and/or engineering calculations of the current dam are not known to exist.

Mirror Lake Dam currently consists of an earthen embankment with a concrete, ogee-shaped spillway. The earthen embankment is about 390-feet long with a top of dam width of about 5 to 8 feet. The embankment has a maximum height of about 11.7 feet. The downstream slope is vegetated and 3 horizontal to 1 vertical (3H:1V) or flatter. The upstream slope is vegetated and ranges from about 1.6H:1V to 2H:1V between the top of dam and the normal water line.

The ogee-shaped spillway has a crest elevation of 584.88 feet and is 12-feet long (i.e., weir length). In 2021, a riprap apron was constructed downstream of the spillway, which replaced a former concrete apron. A concrete pedestrian bridge spans over the spillway at about El. 588 feet. The spillway discharges to Roberts Brook that eventually flows into the Fenton River. A 12-inch diameter, steel sleeved low-level outlet pipe is located to the right of the spillway with an invert of El. 579 feet.

Mirror Lake Dam is currently classified by the Connecticut Department of Energy and Environmental Protection (CTDEEP) as a Hazard Class BB (Moderate Hazard) dam. GZA prepared a "Revised Hydrological Analysis, Dam Break Modeling, and Hazard Classification Analysis" Report, dated December 3, 2019. GZA's 2019 Report included a hypothetical dam breach analysis. Based on the estimated flood limits, Route 195 (Storrs Road) would be overtopped and Mirror Lake Dam has the potential to be classified as a Class C dam in accordance with CT DEEP Dam Safety regulations. The CT DEEP hazard classes with corresponding impacts are summarized below.

Hazard Class	Potential Impact of Dam Failure
AA (Negligible Hazard)	No measurable damage to roadways, land and structures and negligible economic loss
A (Low Hazard)	Damage to agricultural land, unpaved local roadways, or minimal economic loss
BB (Moderate Hazard)	Damage to normally unoccupied storage structures, paved local roadways, or moderate economic loss

[1] https://today.uconn.edu/2016/10/reflections-mirror-lake/, dated October 14, 2016

B (Significate Hazard)	Possible loss of life, minor damage to habitable structures, residences, damage to local utility facilities, collector roadways and railroads, or significant economic loss
C (High Hazard)	Probably loss of life, major damage to habitable structures, residences, damage to major utility facilities, arterial roadways, or great economic loss.

Pertinent dimensions and elevations of the existing dam are summarized below. Elevations in this report reference the North American Vertical Datum of 1988 (NAVD88).

Top of Dam Elevation: Varies from El. 588.0 to 588.6 ft
Embankment Length: 378 feet
Spillway Crest Elevation: El. 584.88 ft
Low-Level Outlet Invert: El. 579 ft
Spillway Length: 12 feet

1.2 PROJECT BACKGROUND

GZA has previously completed a regulatory dam inspection and hydrologic and hydraulic analysis of Mirror Lake Dam. The results of GZA's previous assignments were presented in the following:

- "Mirror Lake Dam Visual Inspection Report", October 21, 20216 (GZA 2016);
- "Hydrologic Analysis, Dam Break Modeling, and Hazard Classification Analysis for Mirror Lake Dam", December 3, 2019 (GZA 2019); and
- "Culvert Below Route 195 Analysis, Mirror Lake Dam Breach Analysis", April 28, 2020 (GZA 2020).

The previous assignments identified the following deficiencies at Mirror Lake Dam:

- Inadequate factors of safety against slope stability (Lenard 2010[2]);
- Inadequate factors of safety against sliding for the spillway (Lenard 2010); and
- Inability to pass the 100-year flood with 1-foot of freeboard.

In addition, Mirror Lake has aquatic and aesthetic deficiencies that are likely associated with the relatively shallow water levels and relatively large amount of sediment in the lake.

1.3 PROJECT APPROACH

UCONN has requested a feasibility-level study to evaluate improvements to Mirror Lake and Mirror Lake Dam from a stormwater, dam-safety, and aesthetic standpoint. This Report is specific to the dam-safety evaluation and proposed improvements for the dam. GZA's scope of work included the following:

- Subsurface explorations;
- Geotechnical laboratory testing program;

[2] "Revised Dam Safety Calculations Mirror Lake Dam, Storrs, Connecticut", Lenard Engineering, Inc., dated February 20, 2010.

- Spillway design flood and spillway capacity analyses; and
- Seepage and stability analyses.

Details and results of the above-mentioned tasks are described in further detail in subsequent sections below.

2.0 SUBSURFACE EXPLORATION PROGRAM

2.1 HISTORIC TEST BORINGS

Four test boring (B-3, B-4, B-6 and B-7) were drilled by Glacier Drilling under the direction of Lenard Engineering, Inc. between May and October 2004. Each of the test borings were completed as a monitoring well. The test borings were drilled with 4-1/4-inch diameter, hollow-stem augers to refusal at depths of 15.8 to 20.0 feet. Coring was performed at B-3 to a final depth of 24 feet. The four test boring locations are presented on the attached **Figure 2- Exploration Location Plan** and the test boring logs are included in **Appendix B**.

2.2 GZA TEST BORINGS

Four test borings (GZ-1, GZ-2, GZ-3, GZ-4) were drilled by Seaboard Drilling of Chicopee, Massachusetts between January 8 and January 14, 2021. Test borings GZ-1 and GZ-3 were performed at the crest of the embankment and test boring GZ-2 and GZ-4 were performed at the embankment toe. As required by CTDEEP Dam Safety, a General Permit was acquired prior to the start of the drilling program. The test borings were advanced to depths of about 25 feet to 33.5 feet with an ATV-mounted drill rig using cased, rotary wash drilling methods. Split-spoon samples were obtained continuously in general accordance with ASTM D1586, the Standard Penetration Test (SPT). The SPT consists of advancing a 1-3/8-inch I.D. split-spoon sampler driven (normally) 24 inches into the ground with a 140 lb. hammer falling 30 inches. The SPT value, referred to as the "N" value, is the number of blows per foot (bpf) of penetration required to drive the sampler from 6 to 18 inches of penetration, and is a commonly used indicator of soil density and consistency. Bedrock was cored in three of the explorations using an NX-sized, double-tube core barrel. Each of the test borings were completed as a groundwater observation well.

The recovered rock cores were described using a modified International Society for Rock Mechanics (ISRM) system. The rock description, rock core recovery value, and Rock Quality Designation (RQD) value were recorded for each rock core run, providing a qualitative understanding of the physical and engineering properties of the rock. The RQD reflects the fracture frequency and spacing within the core run and is calculated by summing the lengths of intact core pieces 4 inches or greater in length and dividing that value by the total length of the core run

The subsurface explorations were monitored and logged by GZA personnel. The soils were classified according to the modified Burmister classification system. The exploration locations were determined in the field using a Geoexplorer 6000 Series GPS. The exploration logs are attached as **Appendix C**. The approximate exploration locations are presented on the attached **Figure 2-Exploration Location Plan**.

2.3 LABORATORY TESTING

Six (6) grain size analysis tests with hydrometers (ASTM D6913) were performed on soil samples to confirm the visual-manual classifications made in the field and assess engineering properties of the encountered soil. The laboratory test results are attached in **Appendix D** and summarized below.

Test Boring	Sample Depth	Stratum	% Passing No. 200 Sieve
GZ-1	2' – 4'	Embankment Fill	39.8
GZ-1	12' – 14'	Glacial Till	25.7
GZ-2	4' – 6'	Fill	37.3
GZ-3	6' – 8'	Embankment Fill	44.6
GZ-3	14' – 16'	Glacial Till	17.9
GZ-4	6' – 8'	Glacial Till	24.8

3.0 SUBSURFACE CONDITIONS

A generalized description of the subsurface strata encountered in the explorations is presented below, in order of increasing depth. A summary of subsurface conditions is provided in **Table 1**.

Asphalt and Topsoil– A surficial, approximate 0.3-foot thick layer of asphalt was encountered at the ground surface at GZ-1 and GZ-3 and a surficial, approximate 0.3-foot thick layer of Topsoil was encountered at the ground surface at GZ-2 and GZ-4.

Embankment Fill – Embankment Fill was encountered below the asphalt at GZ-1 and GZ-3. The Embankment Fill ranged from about 4.7- to 10.7-feet thick. Embankment Fill generally consisted of fine to coarse sand with up to 50% silt and up to 20% gravel. SPT N-values in the Embankment Fill ranged from 4 to 15 which indicates a relative density that ranged from loose to medium dense.

Core Wall – A Core Wall was encountered below the Embankment Fill at crest boring GZ-1 and was approximately 4.5 feet thick. Based on an 18-inch long core performed through the core wall and observation of the drilling wash cuttings, the Core Wall does not appear to be grouted or made of concrete and consists of a field stone, dry-stacked wall. The Core Wall was not encountered at crest boring GZ-3.

Fill –Fill was encountered below Topsoil at the two test borings (GZ-2 and GZ-4) at the embankment toe. The Fill ranged from about 5- to 7.5-feet thick. The Fill generally consisted of fine to coarse sand with up to 50% silt and up to 50% gravel. SPT N-values in the Fill ranged from 3 to 18 which indicates a relative density that ranged from loose to medium dense.

Glacial Till –Glacial Till was encountered in each test borings at depths ranging between 5 to 11 feet below ground surface, corresponding between El. 574.9 feet and El. 578.5 feet. The Glacial Till generally consisted of sand with up to 50% gravel and up to 30% silt. SPT N-values in the Glacial Till ranged from 21 to 84 which indicates a relative density that ranged from medium dense to very dense.

Bedrock – The depth to bedrock ranged from 19 to 28.5 feet below grade, corresponding to El. 555.8 to 563.4 feet. Bedrock was confirmed in test borings GZ-2, GZ-3 and GZ-4 by collecting rock cores. Bedrock was inferred in GZ-1 based on drilling and split spoon refusal. The bedrock generally consisted of hard, slightly weathered, slightly fractured, fine to medium grained, gray GNEISS. The rock core recovery values ranged from 72 to 100 percent and the RQD values ranged from 68 percent to 97 percent. Photographs of the rock cores are presented in **Appendix E**.

Groundwater – Groundwater depths were measured within each of the explorations and installed observation wells at the times and conditions noted on the logs. GZA also measured groundwater within the existing observation wells installed as part of the Lenard exploration program. Groundwater below the crest of the dam ranged from about 4.9 to 7.1 feet, corresponding to about El. 581.0 feet and 583.3 feet. Groundwater at the embankment toe ranged from 0.9 to 3.4 feet, corresponding to El. 578.0 feet to 580.1 feet. Fluctuations in groundwater levels will vary due to the water surface elevation in Mirror Lake, seasonal variations in rainfall, temperature, and other factors different than those prevailing at the time the readings were taken. The measured groundwater levels are included on the exploration logs in **Appendix B** and are summarized on **Table 2- Summary of Groundwater Measurements**.

4.0 HYDROLOGIC AND HYDRAULIC ANALYSIS

The objective of GZA's analysis was to perform an Incremental Damage Assessment (IDA) of the proposed dam configuration to support recommendation of an appropriate Spillway Design Flood (SDF). The methodologies of establishing the SDF with use of an IDA is consistent with methods described in FEMA[3] and FERC[4] guidance. IDA is an iterative process where the downstream flooding impacts with and without dam failure are compared. The SDF was then selected as "the flood flow above which the incremental increase in water surface elevation due to failure of the dam is no longer considered to present an unacceptable threat to downstream life and property," per FERC guidance. The dam failure analyses were performed in accordance with guidance provided by CT DEEP[5].

The proposed dam configuration that was modeled during the IDA consisted of raising the earthen embankment to El. 589.08 feet (up to approximately 1 foot) and replacing the existing spillway with a notched spillway. The notched spillway was 8-feet long (weir length) at El. 583.5 feet and steps up to El. 587 feet where the spillway is 16-feet long (weir length). The new normal pool would be El. 583.5 feet, down from the current normal pool of El. 584.88 feet

[3] Federal Emergency Management Agency. FEMA P-94 "Selecting and Accommodating Inflow Design Floods for Dams". 2013.
[4] Federal Energy Regulatory Commission. Chapter II "Selecting and Accommodating Inflow Design Floods for Dams". Revised 2015.
[5] "Guidance Document for EAPs", CT DEEP, Dam Safety Program, published May 2016.

4.1 HYDROLOGIC ANALYSIS

GZA utilized the previously developed HEC-HMS version 4.3 hydrologic model prepared as part of the previous Hazard Classification Analysis (GZA 2019) for Mirror Lake Dam. As discussed in the Hazard Classification Analysis Report, part of the campus drains to Mirror Lake. The rainfall-runoff routing inputs are summarized in **Tables 3, 4** and **5** below. GZA used the watershed parameters published by BVH Integrated Services (BVH). BVH divided the contributing watershed into 2 subwatersheds, called IIA-1 and IIA-2. A map of the subwatersheds, extracted from BVH's report, is presented in **Appendix F**.

Table 3: HEC-HMS Subwatershed Inputs

Parameter	Inputs*	
Subwatershed	**IIA-1**	**IIA-2**
Drainage Area (sq. mi.)	0.23	0.04
Loss Method	SCS Curve Number	SCS Curve Number
Curve Number	75.7	63.9
Transform Method	SCS Unit Hydrograph	SCS Unit Hydrograph
Lag Time** (minutes)	9	30.6

* Parameters were obtained from "CAMPUS DRAINAGE MASTERPLAN", Vol I & IV of VI, BVH Integrated Services, Draft February 13, 2018. The lag time was obtained by multiplied the time of concentration (presented in BVH's report) by 0.6.

Table 4: HEC-HMS Dam and Reservoir Inputs

Parameter	Inputs
Reservoir	Elevation-Storage Curve (see **Appendix C**)
Dam	Proposed Dam Top and Spillway crest length and elevation from Section 2.0 Dam Top weir coefficient = 2.6* Spillway crest weir coefficient = 2.74*

* Parameters were obtained from "CAMPUS DRAINAGE MASTERPLAN", Vol I & IV of VI, BVH Integrated Services, Draft February 13, 2018.

Table 5: HEC-HMS Precipitation Inputs

Recurrence Interval	24-hour Precipitation Depth*
50-Year	6.9
100-Year	7.8
200-Year	8.8
500-Year	10.3

* Depths provided by NOAA Atlas 14. Storms were temporally distributed using WinTR-20.

The computed peak inflow, outflow, and water surface elevation at Mirror Lake Dam are presented in **Table 6**.

Table 6: HEC-HMS Outputs for Mirror Lake Dam

Recurrence Interval	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Water Surface Elevation (feet, NAVD88)
50-Year	540	170	587.3
100-Year	630	210	587.8
200-Year	750	270	588.3
500-Year	900	340	588.9

4.2 HYDRAULIC ANALYSIS

To evaluate the extent of flooding due to potential failure of Mirror Lake Dam, GZA performed hydraulic simulations of hypothetical dam break floods. GZA conducted dam break analyses using the two-dimensional, unsteady, mixed flow regimes within HEC-RAS for the following scenarios:

1. 100-year flood.
2. 200-year flood.
3. 500-year flood.

The previously developed HEC-RAS model prepared as part of the previous Hazard Classification Analysis (GZA 2019) for Mirror Lake Dam was used for the dam breach analyses. Refer to the 2019 report for parameter inputs and methodology. For the various flood conditions modeled, GZA set the lake elevation to the peak water surface elevation calculated from HEC-HMS (see Table 6) for each flood. GZA added the outflow hydrograph for each storm from HEC-HMS as an inflow hydrograph at the upstream limit of the HEC-RAS 2D Flow Area.

Dam breach parameters, based on recommended range of values published in the FERC guidelines[6] and based on engineering judgment, are summarized in **Table 7** below. GZA performed the simulations using the Full Saint Venant Equations, which is the recommended method in the HEC-RAS 2D Modeling User's Manual (published February 2016). GZA performed the simulations with a 5-second timestep.

Table 7: Summary of Dam Breach Parameters for Mirror Lake Dam

Flood Condition	Trigger Failure at Set Time (Hr:Min)	Breach Formation Shape	Breach Bottom Width (ft)	Breach Bottom Elevation (feet, NAVD88)	Final Breach Slide Slope H:V	Time to Maximum Breach (hrs)	Reservoir Elevation (feet, NAVD88)
100-Year Flood	12:36*	Trapezoidal	27.5	580	1:2	0.5	587.8
200-Year Flood	12:36*	Trapezoidal	27.5	580	1:2	0.5	588.3
500-Year Flood	12:36*	Trapezoidal	27.5	580	1:2	0.5	588.9

[6] Chapter II, Appendix II-A of the "Engineer Guidelines for the Evaluation of Hydropower Projects, FERC, July 2015.

*Time of maximum water surface elevation in Mirror Lake (from HEC-HMS model).

4.3 DAM BREACH RESULTS

The peak dam breach flows through the dam for the various breach scenarios are summarized in **Table 8**. Maximum water surface elevations at the downstream culverts are shown in **Tables 9** through **11** below. An inundation map presenting the downstream culverts/roadways, the estimated 500-year flood and 500-year breach inundation is presented in **Appendix K**.

Table 8: Peak Flows Including Dam Breach through Proposed Mirror Lake Dam

Flood Condition	Peak Flow (CFS)
100-Year	330
200-Year	670
500-Year	825

Table 9: Water Surface Elevation Results at Modeled Structures, 100-Year Flood

Structure	Headwater (HW) or Tailwater (TW)*	Breach Scenario			Overtopping	
		100-yr Flood No Breach (El., ft)	100-yr Flood + Breach (El., ft)	100-yr Flood Incremental Rise (ft)	Overtopping Depth, No Breach (ft)	Overtopping Depth, Breach (ft)
Mirror Lake Dam	HW Stage (ft)	587.8	587.8	0.0	0.0	0.0
	TW Stage (ft)	580.6	583.4	3.4		
30 Inch DS	HW Stage (ft)	576.3	577.9	1.6	0.7	2.3
(.03 miles downstream)	TW Stage (ft)	575.1	577.8	2.7		
Route 195	HW Stage (ft)	574.4	577.6	3.2	-1.6	1.7
(.06 miles downstream)	TW Stage (ft)	571.4	573.7	2.3		
Willowbrook Foot Bridge	HW Stage (ft)	569.8	571.4	1.6	0.8	2.4
(.09 miles downstream)	TW Stage (ft)	566.4	568.5	2.1		
Gurleyville, Culvert 1	HW Stage (ft)	529.0	530.4	1.4	0.9	2.3
(0.2 miles downstream)	TW Stage (ft)	522.1	523.3	1.2		

Gurleyville, Culvert 2 (0.9 miles downstream)	HW Stage (ft)	473.4	475.0	1.6	-3.5	-1.9
	TW Stage (ft)	472.9	473.9	1.0		
Gurleyville, Culvert 3 (1.1 miles downstream)	HW Stage (ft)	385.9	388.1	2.3	-1.7	0.6
	TW Stage (ft)	380.7	381.2	0.5		
DS Driveway (1.2 miles downstream)	HW Stage (ft)	314.1	316.6	2.6	-3.0	-0.4
	TW Stage (ft)	311.6	312.6	0.9		

Table 10: Water Surface Elevation Results at Modeled Structures, 200-year Flood

Structure	Headwater (HW) or Tailwater (TW)*	Breach Scenario			Overtopping	
		200-yr Flood No Breach (El., ft)	200-yr Flood + Breach (El., ft)	200-yr Flood Incremental Rise (ft)	Overtopping Depth, No Breach (ft)	Overtopping Depth, Breach (ft)
Mirror Lake Dam	HW Stage (ft)	588.3	588.3	0.0	0	0
	TW Stage (ft)	580.9	583.8	3.8		
30 Inch DS (.03 miles downstream)	HW Stage (ft)	576.5	578.2	1.6	0.9	2.5
	TW Stage (ft)	576.1	578.1	2.0		
Route 195 (.06 miles downstream)	HW Stage (ft)	575.9	577.8	1.9	-0.1	1.8
	TW Stage (ft)	571.8	574.0	2.2		
Willowbrook Foot Bridge (.09 miles downstream)	HW Stage (ft)	570.0	571.6	1.7	1.0	2.6
	TW Stage (ft)	566.6	568.7	2.1		
Gurleyville, Culvert 1 (0.2 miles downstream)	HW Stage (ft)	529.2	530.5	1.4	1.0	2.4
	TW Stage (ft)	522.2	523.4	1.2		
Gurleyville, Culvert 2	HW Stage (ft)	473.7	475.5	1.8	-3.2	-1.4

(0.9 miles downstream)	TW Stage (ft)	473.1	474.1	1.0		
Gurleyville, Culvert 3	HW Stage (ft)	386.1	388.6	2.6	-1.5	1.1
(1.1 miles downstream)	TW Stage (ft)	380.6	381.5	0.9		
DS Driveway	HW Stage (ft)	314.7	317.1	2.4	-2.3	0.1
(1.2 miles downstream)	TW Stage (ft)	311.8	312.7	0.9		

Table 11: Water Surface Elevation Results at Modeled Structures, 500-year Flood

Structure	Headwater (HW) or Tailwater (TW)*	Breach Scenario			Overtopping	
		500-yr Flood No Breach (El., ft)	500-yr Flood + Breach (El., ft)	500-yr Flood Incremental Rise (ft)	Overtopping Depth, No Breach (ft)	Overtopping Depth, Breach (ft)
Mirror Lake Dam	HW Stage (ft)	588.9	588.9	0.0	0	0
	TW Stage (ft)	581.2	583.8	3.8		
30 Inch DS	HW Stage (ft)	576.8	578.3	1.5	1.3	2.8
(.03 miles downstream)	TW Stage (ft)	576.7	578.2	1.6		
Route 195	HW Stage (ft)	576.5	577.9	1.5	0.5	2.0
(.06 miles downstream)	TW Stage (ft)	572.2	574.1	1.9		
Willowbrook Foot Bridge	HW Stage (ft)	570.2	571.8	1.6	1.2	2.8
(.09 miles downstream)	TW Stage (ft)	566.9	569.0	2.1		
Gurleyville, Culvert 1	HW Stage (ft)	529.3	530.8	1.4	1.2	2.7
(0.2 miles downstream)	TW Stage (ft)	522.4	523.5	1.1		
Gurleyville, Culvert 2	HW Stage (ft)	474.0	476.3	2.3	-2.9	-0.6
(0.9 miles downstream)	TW Stage (ft)	473.3	474.4	1.1		

Gurleyville, Culvert 3	HW Stage (ft)	386.8	389.2	2.4	-0.7	1.7
(1.1 miles downstream)	TW Stage (ft)	380.8	381.8	0.9		
DS Driveway	HW Stage (ft)	315.2	317.3	2.2	-1.8	0.3
(1.2 miles downstream)	TW Stage (ft)	312.1	312.8	0.7		

* Headwater (HW) Stage is the maximum water surface elevation at the structure's upstream side. Tailwater (TW) Stage is the maximum water surface elevation at the structure's downstream side. Negative overtopping values indicate that the structure is not overtopped.

4.4 RECOMMENDED SPILLWAY DESIGN FLOOD

CT DEEP Dam Safety Regulations do not provide guidance on minimum Spillway Design Floods. However, the U.S. Army Corps of Engineers (ACOE) provides guidance regarding design storms for various dam size classifications and hazard classifications. Mirror Lake Dam fits the classification of existing Small size dams and the suggested ACOE design storm criteria are summarized in **Table 12** below.

Table 12: ACOE Recommended Design Floods for Small Size, Existing Dams

Hazard Classification	Design Flood
Class A or Class BB	100-year
Class B	100-year to 500-year
Class C	1,000-year to ½ Probable Maximum Flood (PMF)

Mirror Lake Dam appears to meet the CT DEEP Dam Safety requirements for a hazard classification C (high hazard) dam based on overtopping of State Route 195, an arterial road (Based on Connecticut Department of Transportation classification map), during a hypothetical dam breach. Based on GZA's previous dam failure analyses and judgment, the Route 195 crossing is the only sensitive location with respect to the dam's potential for a Class C hazard rating. The dam breach flood does not appear to inundate occupied structures. Gurleyville Road Culvert 3 passes the 500-year flood, but fails to pass the 500-year flood with a dam breach, subjecting Gurleyville Road to damage. However, Gurleyville Road is a collector road and damage to collector roads would be consistent with a Hazard Class B rating. For Class C dams, the ACOE recommended design storm is the 1,000-year flood to ½ Probable Maximum Flood. However, GZA's IDA indicates that Route 195 is subject to damage and/or destruction during the natural 500-year flood with or without dam failure. The roadway is expected to overtop by approximately 0.5 foot during the natural flood, without dam failure. Additionally, incremental depths due to dam failure downstream of the dam during the 500-year flood are generally on the order of approximately 2 feet or less. Therefore, the incremental consequence of dam failure during the 500-year design flood is judged to be insignificant and GZA recommends the 500-year flood as the SDF.

The peak water surface during the 500-year flood is El. 588.9 feet and the minimum embankment elevation should be EL. 589.9 feet as CT DEEP Dam Safety requires a minimum 1-foot of freeboard during the SDF.

5.0 GEOTECHNICAL ANALYSIS

GZA performed geotechnical analyses for Mirror Lake Dam including seepage, slope stability, gravity structure stability and liquefaction assessments. The objective of the geotechnical analysis was to evaluate the stability of the earthen embankment and concrete spillway based on proposed improvements, mainly from raising the embankment to provide a minimum 1-foot freeboard during the Spillway Design Flood (SDF). The analyses were performed to design the proposed improvements such that they will meet the minimum required factors of safety for stability based on the state of practice guidance.

5.1 ENGINEERING PROPERTIES

Table 13 below presents the engineering properties used in the proposed conditions geotechnical analyses. The soil properties used in the analyses were estimated based on the results of the subsurface explorations, laboratory testing program, empirical formulas and published data for similar materials.

Table 13: Material Properties used in GZA's Seepage and Stability Analyses for Mirror Lake Dam

Strata	Total Unit Weight, γ_t (pcf)	Effective Strength		Total Strength		Saturated Horizontal Permeability, k_{sat}	
		Cohesion, c' (psf)	Friction Angle, ϕ'(°)	Cohesion, c' (psf)	Friction Angle, ϕ'(°)	ft/day	cm/s
Structural Fill	125	0	34	Same as effective strength		3.00	1E-03
Embankment Fill	120	0	29	300	10	0.02	7E-06
Improved Embankment Fill	120	0	32	300	10	0.02	7E-06
Toe Drain	120	0	33	Same as effective strength		25.00	9E-03
Glacial Till	130	0	38	Same as effective strength		0.70	2E-04
Core Wall	130	0	35	Same as effective strength		0.020	7E-06
Bedrock	Impenetrable					2E-04	7E-08

Notes:
1) Unit weights based on typical values for similar materials
2) Effective friction angles are based on correlations from SPT-N testing
3) Permeability values are based on typical values for similar materials and empirical correlation from grain size distributions.

Refer to **Appendix G** for backup calculations supporting the material properties.

5.2 SEISMIC SITE PARAMETERS

In order to estimate the potential for amplification of bedrock accelerations due to the overlying soil conditions, GZA performed a site class calculation in accordance with ASCE 7-10 Standard. SPT N-Values of samples located within the upper 100-feet of the soil column were utilized in the analysis. Conditions encountered in the test borings indicate a Site Class D is currently present at the site. The site class calculation is attached in **Appendix H**.

GZA obtained ground motion parameters for the site latitude and longitude using the ASCE 7 Online Hazard Tool. The website allows the user to input the site's latitude and longitude, risk category, and site class in order to obtain site-specific seismic parameters in accordance with the 2010 ASCE 7 Standard "Minimum Design Loads for Buildings and Other Structures". The acceleration parameter outputs from the ASCE 7 Online Hazard Tool are provided in **Appendix H.**

The maximum average ground accelerations acting on the embankment were calculated from the peak ground acceleration and adjusted for site class and embankment height in accordance with NCRHP Report 611 "Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments". The calculations resulted in a pseudostatic acceleration to be used in the stability analyses described herein. The calculations and a summary of the resulting values are provided in **Appendix H.**

5.3 LIQUEFACTION ANALYSIS

Using the SPT N-Values obtained from GZA borings GZ-1 through GZ-4, the peak ground acceleration obtained from ASCE 7 Online Hazard Tool, and an assumed design earthquake magnitude (M = 6.0), GZA performed a liquefaction analysis of the site soils based on the procedures outlined in Idriss and Boulanger (2014).

Based on our assessment, the Embankment Fill and underlying Glacial Till are not considered susceptible to liquefaction during the design earthquake acceleration and magnitude. In addition, estimated seismically induced settlements are on the order of less than 1-inch and would not have a significant effect on available freeboard, or the overall slope stability. The liquefaction analyses results are included in **Appendix H**.

5.4 SEEPAGE ANALYSIS

GZA performed steady-state seepage analyses for Mirror Lake Dam under normal operating conditions (Normal Pool) and under the SDF conditions (Flood Pool). GZA used SEEP/W® by Geo-Slope International, Ltd. GeoStudio 2021), an industry standard, two-dimensional, finite element-based seepage analysis software package, for the seepage analyses. The software was used to estimate the location of the phreatic surface through the dam, to estimate the pore pressures at specific finite element nodes, and to estimate exit gradients at specific element nodes, e.g., near the toe of the dam.

The Normal Pool reservoir elevation (EL. 583.5 ft) and the SDF (i.e. 500-year flood = EL. 588.9 ft) used in the seepage analyses were based on the hydrologic and hydraulic (H&H) analyses performed by GZA. See Section 4.4 of this report.

The resulting flow and exit gradients the model estimates are then compared to the limiting gradient criteria of 1. The results of the seepage analyses are typically imported into GeoStudio's SLOPE/W software as a set of input data to support the slope stability analysis. The process typically starts with the assignment of permeability values to the soil strata based on field, laboratory or correlated data. The seepage model is then run and evaluated against piezometer/observation well data for a given lake/tailwater condition. Using the results of the seepage analysis, the permeability values of the various strata are adjusted to "calibrate" the seepage model. Once the seepage model generates results that generally match existing instrument readings, the model can be used to extrapolate seepage conditions for storm events with higher lake levels beyond those associated with existing instrumentation readings. The effect of proposed drainage features such as internal drains and toe drains can also be simulated in the seepage model.

5.4.1 SEEPAGE ANALYSIS RESULTS

GZA developed a typical cross section, Cross Section A-A', of the existing conditions at the dam in GeoStudio 2021 software package using existing topographic survey and subsurface information obtained during the exploration program. Hydraulic conductivity values were assigned to various soil layers in the SEEP/W module and the model was run and evaluated against groundwater data collected during the subsurface investigations. The model produced similar groundwater conditions to what was observed at the site. Cross Section A-A' is attached in **Appendix H** and the location of the cross section is presented on **Figure 2**.

Using the same seepage parameters from the existing conditions, Cross Section A-A' was updated for the proposed dam conditions and a seepage evaluation was performed. The maximum exit gradient of seepage at the toe of the dam was calculated to be 0.2 for normal Pool and SDF conditions. The *critical gradient* is the gradient level at which soil transport is assumed to begin. Taking the critical gradient as 1.0, as is typically done for sands[7], the safety factor against potential piping failure for proposed conditions is 5. Due to the significant uncertainties inherent in such seepage calculations, the recommend factor of safety against seepage failure (i.e. piping) ranges from 2.5 to 3[8]. The proposed conditions factor of safety against piping exceeds the minimum requirements, as shown in **Table 14**, below. Graphic results of steady state analyses for Mirror Lake Dam under normal pool and SDF conditions are presented in **Appendix H**.

Table 14: Seepage Analysis Results

Pool Elevation	Computed Exit Gradient, i_e	Critical Gradient, i_{cr}	FS, i_{cr}/i_e	Required FS
Normal (El. 583.5ft)	0.2	1.0	5.0	2.5 - 3.0
500-Year Flood (El. 590ft)	0.2	1.0	5.0	2.5 - 3.0

5.5 SLOPE STABILITY ANALYSIS

The stability of the slopes of an embankment dam is an important factor in the overall safety of the structure. Earthen slopes of a dam must have sufficient capacity to resist sliding or rotational failure under a variety of loading conditions. CTDEEP Dam Safety Regulations do not provide prescriptive minimum factors of safety for slope stability; Therefore, the guidelines established in the U.S. Army Corps of Engineers document entitled "Slope Stability - EM-1110-2-1902", dated October 31, 2003 will be used as the minimum requirements. The safety factors are a function of several different parameters, including soil type, soil strength, slope angle, phreatic surface and pore pressure distribution, and loading conditions.

[7] USACE EM1110-2-1901, "Seepage Analysis and Control for Dams"

[8] Cedergren, H.R.; Seepage, Drainage and Flow Nets. 1977

GZA performed slope stability analyses for the proposed conditions at Mirror Lake Dam, which calculated a factor of safety against slope instability under various loading conditions. The slope stability models were created using SLOPE/W® (2021), a two-dimensional limit equilibrium-based software program created by Geo-Slope International, Ltd. The SLOPE/W® program searches for the critical failure surface between failure surface initiation and termination points set by the user. The method of analysis selected by GZA was Spencer's Method since it is a "complete" equilibrium method where all static equilibrium conditions (both sliding and rotation) are satisfied. The method of analysis divides the dam embankment into a series of vertical slices along the circular failure surface. The stability of each slice was then determined to calculate the overall factor of safety for the entire failure surface and the output will be presented in graphical form.

The slope stability analysis was performed on the same cross section, Cross Section A-A', of the dam as analyzed in the previously described seepage analyses. This allowed the pore pressures calculated within and below the dam from the SEEP/W® runs to be imported directly into the SLOPE/W® slope stability model. Iterative changes were made to the cross section until the minimum factors of safety were met.

Proposed Cross Section A-A' is provided in **Appendix H** and the location of the cross section is presented on **Figure 2**.

5.5.1 SLOPE STABILITY ANALYSIS RESULTS

The proposed conditions were modeled and the results for the given loading conditions and required minimum factors of safety against slope failure are presented in **Table 15** below. The proposed conditions meet or exceed the minimum guidelines from the ACOE. Refer to the calculations in **Appendix H** for additional information.

Table 15: Proposed Conditions - Slope Stability Analysis Results

Load Case	Loading Condition	Dam Face	Slope Stability Factor of Safety	
			Required FS (USACE)*	Calculated
1	Rapid Drawdown from Flood Level	Upstream	1.1	1.9
2	Rapid Drawdown from Normal Pool	Upstream	1.3	1.9
3	Steady-state seepage at Normal Pool	Upstream	1.5	1.8
		Downstream		1.7
4	Steady-state seepage at Flood Pool	Upstream	1.4	2.3
		Downstream		1.4
5	Earthquake at Normal Pool	Upstream	1.0*	1.2
		Downstream		1.1

*Required factors of safety are based on USACE guidelines except for seismic case, where a minimum factor of safety greater than 1.0 is typically used in dam engineering practice.

5.6 SPILLWAY GRAVITY ANALYSIS

GZA performed a gravity analysis for the proposed spillway cross section, which was analyzed using the guidelines established in the U.S. Army Corp of Engineers document entitled "Gravity Dam Design - EM 1110-2-2200", dated June 30, 1995 and EM 1110-2-2100, "Stability Analysis of Concrete Structures."

The USACE's guidance for establishing the required factors of safety/acceptance criteria for a given structure requires two initial steps: 1) evaluating the likelihood of each load case, and 2) establishing the quality of the site information. The USACE's minimum required factors of safety/acceptance criteria for a critical (i.e., high hazard) structure are defined by one of two categories of site information, "well-defined site information" and "ordinary site information." Both categories require that the foundation strengths and loading conditions be established with a high level of confidence. However, for a site to qualify as "well-defined," the Corps states that measured uplift pressure data is required. For the purposes of GZA's analyses, Mirror Lake Dam was considered to be an "ordinary" site in that the available information is relatively limited, and also since there are no uplift pressure measurements.

A gravity analysis was performed assuming the proposed spillway is bearing on naturally-deposited glacial till. The proposed spillway cross section was analyzed for sliding, overturning and flotation. Bearing pressures developed at the toe of the concrete was evaluated against the capacity of the glacial till bearing layer and compressive strength of the concrete itself. Bearing pressures and uplift pressures were used to evaluate the stress conditions at the base of the spillway. If tensile stresses were found to exist along the plane of analysis, then a cracked base analysis was performed in accordance with the guidelines outlined in USACE EM 1110-2-2200. GZA evaluated the potential for a crack between the spillway and foundation to develop under each loading condition. If cracking was predicted, the crack length was iterated, and the resultant location was recomputed until force equilibrium is reached. Overturning stability was then re-evaluated based on the revised resultant location and sliding resistance was re-evaluated based on the "uncracked" portion of the base of the spillway.

5.6.1 GRAVITY ANALYSIS RESULTS

Table 16 below presents the calculated factors of safety for sliding and overturning of the proposed spillway cross section under the prescribed loading conditions. The location of the proposed cross section is presented in **Appendix J**. All prescribed loading conditions for the proposed cross section were calculated to meet or exceed the Corps' requirements for sliding, overturning, flotation, and bearing capacity. Refer to the calculations in **Appendix I** for additional information regarding the computed factors of safety for each requirement.

Table 16: Proposed Conditions - Spillway Gravity Analysis Results

Loading Condition	Failure Mode	Stability Criterion	Spillway Section
Normal Pool (El. 583.5)	Sliding	FS ≥ 2.0	5.2
	Overturning	Resultant within middle 1/3 of base	✓
Flood Pool	Sliding	FS ≥ 1.7	2.2

(El. 589)	Overturning	Resultant within base	✓
Ice Loading at Normal Pool	Sliding	FS ≥ 2.0	2.0
	Overturning	Resultant within middle 1/3 of base	✓
Pseudostatic at Normal Pool	Sliding	FS ≥ 1.3	1.9
	Overturning	Resultant within base	✓

Notes: Stability criterion based on requirements for "ordinary" site information per EM 1110-2-2100

× represents proposed condition not meeting requirement for location of resultant
✓ represents proposed condition meeting requirement for location of resultant

6.0 PROPOSED CONDITIONS

The proposed improvements to Mirror Lake Dam are required to address inadequate spillway capacity, downstream slope stability, and aesthetics. The proposed dam improvements consist of replacing the existing spillway with a concrete stepped spillway in the same general footprint, raising the earthen embankment, adding upstream erosion protection, and regrading the upstream and downstream slopes.

The lowest level of the stepped spillway will be 8-feet long (weir length) at El. 583.5 feet and then increase to 16-feet long at El. 587 feet. The spillway design flood will be the 500-year storm with a peak water surface of El. 588.9 feet. CT DEEP requires 1-foot of freeboard during the design flood. Therefore, the existing embankment will be raised to at least El. 589.9 feet. The proposed embankment top width will be 8 feet wide. Prior to adding new fill, the existing topsoil will need to be removed and the existing Embankment Fill will need to be proof compacted. Proof compaction consists of at least 4 passes of a large vibratory drum roller with a minimum static weight of 3,000 pounds per foot of drum width. Any localized weak or unstable areas identified during proof compaction should be excavated and replaced with engineered fill. The upstream and downstream slopes of the proposed embankment will be constructed as 3 horizontal to 1 vertical. On the upstream slope, riprap will be added from the upstream toe of the embankment to 1 foot below the top of dam to provide erosion protection, as well as to improve the stability.

A conventional toe drain with a perforated PVC pipe surrounded by free draining soils will be constructed at the downstream embankment toe. The toe drain will help lower the shallow groundwater at the toe of the dam, lower the groundwater table through the dam, and improve stability. The toe drain will discharge to the downstream channel.

The downstream channel will consist of a concrete apron that transitions to Roberts Brook. The Roberts Brook side channels will be lined with riprap for erosion/scour protection.

Concept sketches of the proposed embankment and spillway improvements are presented in **Appendix J**.

6.1 ANTICIPATED CONSTRUCTION SEQUENCE

We understand the improvements to the dam will be constructed at the same time as the dredging of Mirror Lake. At this time, hydraulic dredging is anticipated to be the preferred dredging method, which will require water to be present in the Lake for the dredging equipment to maneuver. We anticipate a sheetpile cofferdam around the existing spillway will be required to demolish the existing spillway and construct the new spillway. While there is a cofferdam around the existing spillway, a temporary spillway will be needed through the embankment to pass normal flows during construction. The temporary spillway is anticipated to consist of a grouted or concrete-lined channel that extends from the impoundment, through the embankment, and to the downstream channel. The temporary spillway invert will be at the same elevation as the existing spillway. Riprap or other scour protection may be required where the temporary spillway discharges into the downstream channel. Due to the relatively limited access to the dam, consideration should be given to the temporary spillway location and sequencing so as not to cut off access from one side of the dam without properly planning ahead.

Once the new spillway has been constructed and backfilled, the cofferdam can be removed, and the temporary spillway can be removed and backfilled. The new spillway will have a crest elevation that is about 1.5 feet lower than existing spillway, so the normal lake level will be lower once the new spillway is constructed. If the hydraulic dredging is not completed and the equipment requires the additional freeboard, the cofferdam may need to remain in place to keep the lake levels higher. Once the cofferdam and temporary spillway are removed, the embankment improvements, including proof compacting the existing soil, adding new downstream and crest fill, adding upstream riprap and installing a toe drain, can be completed. The upstream riprap will be placed in the wet as there will not be a planned drawdown during construction.

6.2 ANTICIPATED PERMIT REQUIREMENTS

Based on our experience with dam improvement projects and discussion with regulators (CT DEEP Dam Safety & Water Quality and ACOE), the anticipated permits, including approval duration, for the dam improvements are anticipated to consist of:

Regulator	Permit ID	Estimated Approval Duration
CT DEEP Dam Safety	Individual Permit	5 - 7 months
CT DEEP Water Quality	Section 401 Water Quality Certificate	5 – 7 months
CT DEEP Fisheries	Determination of Need for Fishway	1 – 2 months
Army Corps of Engineers	Pre-Construction Notification	5 – 7 months
CT DEEP NDDB	Rare Species Review	2 months

GZA would coordinate with CT DEEP to confirm that a diversion permit is not required.

TABLES

TABLE 1
SUMMARY OF TEST EXPLORATION DATA

University of Connecticut
Mirror Lake Dam
Storrs, Connecticut

	GZA TEST BORINGS[1]			
	GZ-1	GZ-2	GZ-3	GZ-4
Depth (ft) to:				
Asphalt	0	NE	0	NE
Embankment Fill	0.3	NE	0.3	NE
Core Wall	5.0	NE	NE	NE
Fill	NE	0	NE	0.0
Glacial Till	9.5	7.5	11.0	5.0
Bedrock	25.5	19.5	28.5	24.1
Groundwater[2]	7.0	3.3	7.1	1.9
Bottom of Exploration	25.5	24.9	33.5	29.1
Thickness (ft) of:				
Asphalt	0.3	NE	0.3	NE
Embankment Fill	4.7	NE	10.7	NE
Core Wall	4.5	NE	NE	NE
Fill	NE	7.5	NE	5.0
Glacial Till	16.0	12.0	17.5	19.1
Approximate Elevations (ft):				
Ground Surface[3]	588.0	582.9	588.1	579.9
Top of Asphalt	588.0	NE	588.1	NE
Top of Embankment Fill	587.7	NE	587.8	NE
Top of Core Wall	583.0	NE	NE	NE
Top of Fill	NE	582.9	NE	579.9
Top of Glacial Till	578.5	575.4	577.1	574.9
Top of Bedrock	562.5	563.4	559.6	555.8
Groundwater[2]	581.0	579.6	581.0	578.0
Bottom of Exploration	562.5	558.0	554.6	550.8

NE - Not encountered

Notes:
1. GZA test borings performed by Seaboard Drilling between January 8 to January 14, 2021 and observed by GZA.
2. Groundwater was encountered at the times and dates noted on the exploration logs and Table 2.
3. Ground surface elevations at test borings based on survey performed by GZA. Spillway (El. 584.88 feet) used as a benchmark and references NAVD88.

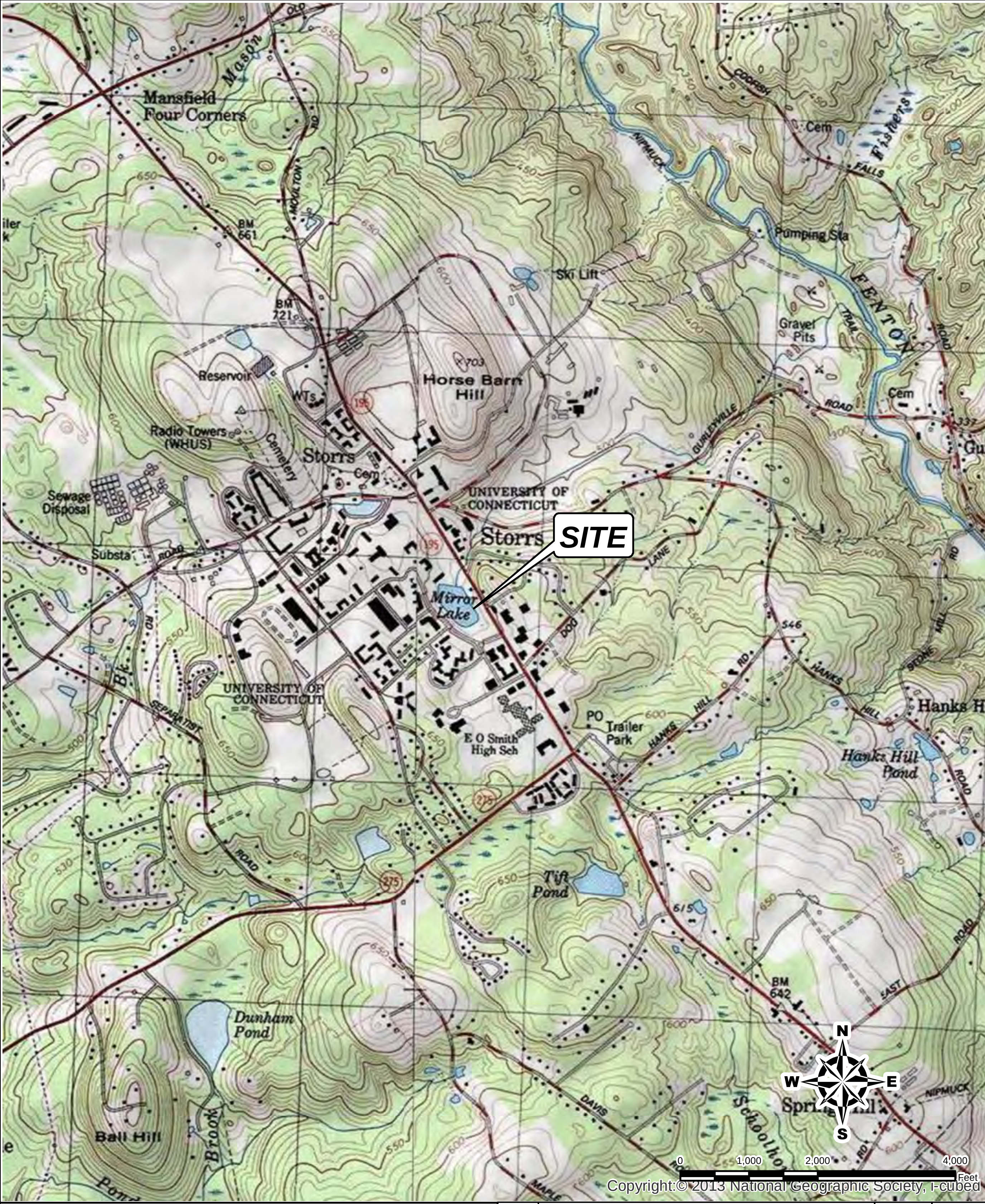
TABLE 2
Summary of Groundwater Measurements

University of Connecticut
Mirror Lake Dam
Storrs, Connecticut

Observation Well No.	Date Installed	Ground Surface Elevation (ft)[1]	Measured Groundwater (feet) Depth and Elevation											
			1/8/21		1/11/21		1/12/21		1/13/21		1/14/21		1/26/21	
			Depth	El.	Depth	El.	Depth	El.	Depth	El.	Depth	El.	Depth	El.
GZ-1	1/12/21	588.0					5.9	582.2			7.0	581.1	7.0	581.0
GZ-2	1/8/21	582.9			3.6	579.3	3.2	579.7			3.4	579.6	3.3	579.7
GZ-3	1/14/21	588.1									6.7	581.4	7.1	581.0
GZ-4	1/13/21	579.9									1.9	578.1	1.9	578.0
MW-B3	5/3/04	588.2	4.9	583.3	5.0	583.2	5.2	583.0	5.4	582.8	5.5	582.7	5.5	582.7
MW-B4	5/3/04	587.4	5.0	582.4	5.8	581.6	5.9	581.5	6.1	581.3	6.2	581.2	6.2	581.2
MW-B6	5/7/04	587.2	5.7	581.5	5.7	581.6	5.8	581.4	5.9	581.4	5.9	581.3	5.9	581.3
MW-B7	10/8/04	581.0	1.1	579.9	1.0	580.0	0.9	580.1	0.8	580.2	1.0	580.1	1.0	580.0

Notes:
1. Ground surface elevations at test borings based on survey performed by GZA. Spillway (El. 584.88 feet) used as benchmark and references NAVD88.

FIGURES



NO.	ISSUE / DESCRIPTION	BY	DATE

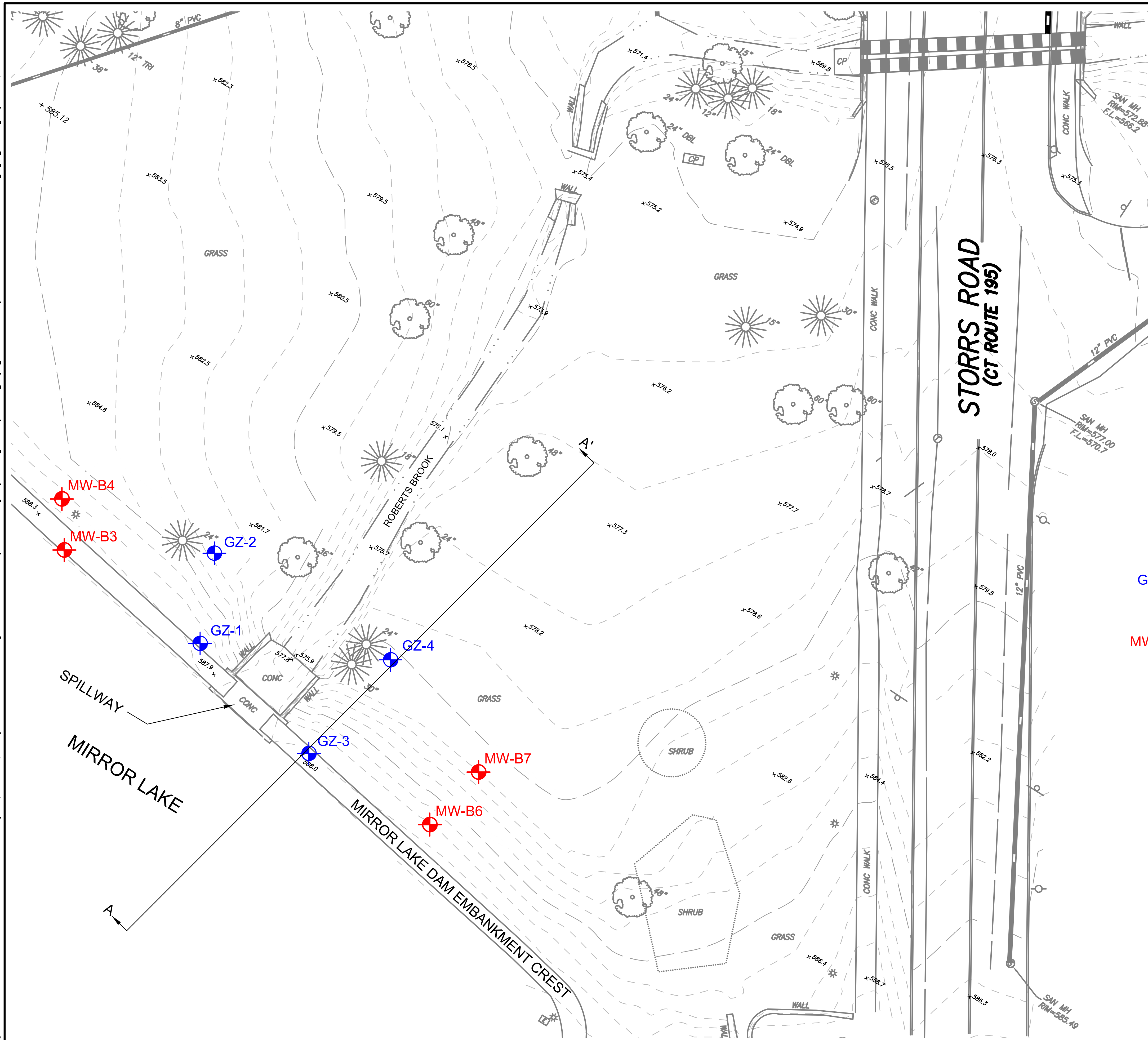
MIRROR LAKE DAM
STORRS, CONNECTICUT

PREPARED BY:
GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com

PREPARED FOR:
UNIVERSITY OF CONNECTICUT
STORRS, CONNECTICUT

LOCUS PLAN

PROJ MGR: JFD	REVIEWED BY: DMB	CHECKED BY: JFD	FIGURE
DESIGNED BY: MR	DRAWN BY: MR	SCALE: 1 in = 2,000 ft	
DATE: MARCH 2021	PROJECT NO. 05.0046161.07	REVISION NO.	1



GENERAL NOTES

1. BASE MAP DEVELOPED FROM ELECTRONIC DRAWING FILE 2115027–UCONN STORM WATER MASTER PLAN PREPARED BY LENARD ENGINEERING, INC. TRANSMITTED TO GZA ON 12/31/2020.
2. GZA TEST BORINGS WERE LOCATED USING A GEOEXPLORER 6000 SERIES GPS. TEST BORING LOCATIONS SHOULD BE CONSIDERED ACCURATE TO THE DEGREE IMPLIED BY THE METHODS USED.
3. GLACIER DRILLING TEST BORING LOCATIONS WERE INCLUDED ON THE BASE MAP PROVIDED BY OTHERS.

LEGEND

GZ-1 — TEST BORINGS COMPLETED BY SEABOARD DRILLING BETWEEN JANUARY 8 AND JANUARY 14, 2021 AND OBSERVED BY GZA PERSONNEL.

MW-B3 — TEST BORINGS COMPLETED BY GLACIER DRILLING BETWEEN MAY AND OCTOBER 2004 AND OBSERVED BY LENARD, INC.

A' / A — SECTION A–A' WHERE SEEPAGE AND STABILITY ANLAYSES PERFORMED

0 15 30 60

SCALE IN FEET

MIRROR LAKE DAM
STORRS. CONNECTICUT

EXPLORATION LOCATION PLAN

PREPARED BY:		PREPARED FOR:	
GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		BVH INTEGRATED SERVICES	
PROJ MGR: JFD	REVIEWED BY: DMB	CHECKED BY: JFD	FIGURE
DESIGNED BY: JFD	DRAWN BY: MR	SCALE: AS NOTED	2
DATE: MARCH,2021	PROJECT NO. 05.0046161.07	REVISION NO. 0	SHEET NO.

APPENDIX A – LIMITATIONS

USE OF REPORT

1. GeoEnvironmental, Inc. (GZA) prepared this report on behalf of, and for the exclusive use of BVH Integrated Services (Client) for the stated purpose(s) and location(s) identified in the Report. Use of this report, in whole or in part, at other locations, or for other purposes, may lead to inappropriate conclusions; and we do not accept any responsibility for the consequences of such use(s). Further, reliance by any party not identified in the agreement, for any use, without our prior written permission, shall be at that party's sole risk, and without any liability to GZA.

STANDARD OF CARE

2. Our findings and conclusions are based on the work conducted as part of the Scope of Services set forth in the Report and/or proposal, and reflect our professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as our professional opinions concerning the limited data gathered during the course of our work. Conditions other than described in this report may be found at the subject location(s).

3. Our services were performed using the degree of skill and care ordinarily exercised by qualified professionals performing the same type of services at the same time, under similar conditions, at the same or a similar property. No warranty, expressed or implied, is made.

SUBSURFACE CONDITIONS

4. If presented, the generalized soil profile(s) and description, along with the conclusions and recommendations provided in our Report, are based in part on widely-spaced subsurface explorations by GZA and/or others, with a limited number of soil and/or rock samples and groundwater /piezometers data and are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location refer to the exploration logs. The nature and extent of variations between these explorations may not become evident until further exploration or construction. If variations or other latent conditions then appear evident, it will be necessary to reevaluate the conclusions and recommendations of this report.

5. Water level readings have been made in test holes (as described in the Report), monitoring wells and piezometers, at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Report. Fluctuations in the groundwater and piezometer levels, however, occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, reservoir and tailwater levels, the presence of subsurface utilities, and/or natural or artificially induced perturbations.

GENERAL

6. The observations described in this report were made under the conditions stated therein. The conclusions presented were based solely upon the services described therein, and not on scientific tasks or procedures beyond the scope of described services or the time and budgetary constraints imposed by the Client.

7. In preparing this report, GZA relied on certain information provided by the Client, state and local officials, and other parties referenced therein available to GZA at the time of the evaluation. GZA did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this evaluation.

8. Any GZA hydrologic analysis presented herein is for the rainfall volumes and distributions stated herein. For storm conditions other than those analyzed, the response of the site's spillway, impoundment, and drainage network has not been evaluated.

9. Observations were made of the site and of structures on the site as indicated within the report. Where access to portions of the structure or site, or to structures on the site was unavailable or limited, GZA renders no opinion as to the condition of that portion of the site or structure. In particular, it is noted that water levels in the impoundment and elsewhere and/or flow over the spillway may have limited GZA's ability to make observations of underwater portions of the structure. Excessive vegetation, when present, also inhibits observations.

10. In reviewing this Report, it should be realized that the reported condition of the dam is based on observations of field conditions during the course of this study along with data made available to GZA. It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued inspection and care can there be any chance that unsafe conditions be detected.

COMPLIANCE WITH CODES AND REGULATIONS

11. We used reasonable care in identifying and interpreting applicable codes and regulations. These codes and regulations are subject to various, and possibly contradictory, interpretations. Compliance with codes and regulations by other parties is beyond our control.

12. This scope of work does not include an assessment of the need for fences, gates, no-trespassing signs, repairs to existing fences and railings and other items which may be needed to minimize trespass and provide greater security for the facility and safety to the public. An evaluation of the project for compliance with OSHA rules and regulations is also excluded.

COST ESTIMATES

13. Unless otherwise stated, our cost estimates are for comparative, or general planning purposes. These estimates may involve approximate quantity evaluations and may not be sufficiently accurate to develop construction bids, or to predict the actual cost of work addressed in this Report. Further, since we have no control over the labor and material costs required to plan and execute the anticipated work, our estimates were made using our experience and readily available information. Actual costs may vary over time and could be significantly more, or less, than stated in the Report.

ADDITIONAL SERVICES

14. It is recommended that GZA be retained to provide services during any future: site observations, explorations, evaluations, design, implementation activities, construction and/or implementation of remedial measures recommended in this Report. This will allow us the opportunity to: i) observe conditions and compliance with our design concepts and opinions; ii) allow for changes in the event that conditions are other than anticipated; iii) provide modifications to our design; and iv) assess the consequences of changes in technologies and/or regulations.

APPENDIX B – 2004 TEST BOING LOGS

Soil Sampling Log

Date Started 5-3-04

Date Finish 5-3-04

Weight Of Hammer [X] 140 [ ] 300

Hammer Fall [X] 30' [ ] 24"

Ground Water Observations

Date	Time	Depth

Sampler O.D. 2" I.D. 1 3/8"

Type Of Rig Truck Mounted Rig - CME-75

GLACIER DRILLING

78 Golden St.
Meriden, CT 06450
Phone/Fax 860-645-1304

LENARD ENGINEERING, INC.
P.O. Box 580
Storrs, CT 06268

Sheet 1 Of 1

Proj. No.

Location Mansfield Rd.-Mirror Lk Dam
Storrs, CT

Offset

Ground Elevation

Hole No. B-3

	Casing	Sampler	Core Barrel
Type	HSA	SS	
Size I.D.	4 1/4"	1 3/8"	

Dept Below Surface	Sample No. Depths Elev. Ft.	Type Of Sample	Blows Per 6" On Sample From 0-6	To 6-12	12-18	Density Or Consist Moisture	Profile Change Depth Elev.	Field Identification Of Soils / Remarks	Sample No.	Pen	Rec	PID
								3" Asphalt.				
								Auger to refusal at 4.0'				
	4.0-4' 11"	SS	35	100/ 4"				Fractured rock.	1	11"	8"	
								Auger to 5.0' through boulder. Rock in tip.				
	5-	SS	100/ 0"					Auger through boulder to 10.0'	2	--	--	
	10-12	SS	8	9	13			Green brown very fine to fine sand, trace medium-coarse sand,	3	24"	16"	
					15			occasional fractured cobble, little silt. Bottom 2" - brown silty fine sand.				
								Auger to refusal at 18.5'	C1	5.0'	52"	
								Roller bit hole to 19.0'				
								Core from 19-24'.				
								Gray white rock.				
							Depth:	Time required:				
							19-20'	6 minutes				
							20-21'	6 minutes				
							21-22'	7 minutes				
							22-23'	7 minutes				
							23-24'	6 minutes				
							24.0'	B.O.B., set a 2" Monitoring Well using:				
								Threaded Plug				
								10' Screen, .010 slot				
								9' Riser				
								300 lbs. Sand				
								50 lbs. Bentonite Chips				
								Expandable Gripper				
								Lock				
								8" Road Box				
								160 lbs. Cement Mix				

...ler: Time Sabo
...stant: Lavelle Tatum
Engineer: Bryan Tucker

Proportions used trace = 0-10%, little = 10-20%, some = 20-35%, and = 35-50%

Sample Type:
C = Cored W = Washed
SS = Split Spoon
UP = Undisturbed Piston

Cohesionless Density
0-10 Loose
10-30 Med Comp.
30-50 Dense

Total Footage:
Earth Boring 24.0 Ft.
Rock Coring Ft.

Soil Sampling Log

Date Started 5-3-04

Date Finish 5-3-04

Weight Of Hammer ☒ 140 ☐ 300

Hammer Fall ☒ 30' ☐ 24"

Ground Water Observations

Date	Time	Depth

Sampler O.D. 2" I.D. 1 3/8"

Type Of Rig Truck Mounted Rig - CME-75

GLACIER DRILLING
78 Golden St.
Meriden, CT 06450
Phone/Fax 860-645-1304

LENARD ENGINEERING, INC.
P.O. Box 580
Storrs, CT 06268

Sheet 1 Of 1

Proj. No.

Location Mansfield Rd.-Mirror Lk Dam
Storrs, CT

Offset

Ground Elevation

Hole No. Mw-4 / B-4

Type	Casing	Sampler	Core Barrel
Type	HSA	SS	
Size I.D.	4 1/4"	1 3/8"	

Dept. Below Surface	Sample No. Depths Elev. Ft.	Type Of Sample	Blows Per 6" On Sample From 0-6	To 6-12	12-18	Density Or Consist Moisture	Profile Change Depth Elev.	Field Identification Of Soils Remarks	Sample No.	Pen	Rec	PID
								Auger to refusal at 4.0'				
	5-7	SS	3	5	8	Med. Comp.	Top 6"	Tan brown very fine sand and silt.	1	24"	14"	
					5	--	Bottom 8"	Dark brown fine sand, some silt, trace fractured cobble.				
	10-12	SS	9	16	18	Med. Comp.	Top 6"	Brown fine sand and silt, trace organics, trace coarse gravel.	2	24"	18"	
					22	Moist	Bottom 12"	Dark grayish medium-coarse sand, trace silt, trace fractured cobble.				
								Drill cuttings from 12-15' - Dark brown to black very fine silty sand, saturated.				
	15-17	SS	3	3	4	Loose		Gray brown fine-medium sand, trace coarse sand, little silt.	3	24"	6"	
					4	Wet						
								Auger to refusal at 17.0'.				
							17.0'	B.O.B., set a 2" Monitoring Well to 16'3" using:				
								Threaded Plug 10' Screen, .010 slot 6' 3" Riser 300 lbs. Sand 50 lbs. Bentonite Chips Expandable Gripper Lock 8" Road Box 80 lbs. Cement Mix				

Driller: Time Sabo
Assistant: Lavelle Tatum
Engineer: Bryan Tucker

Proportions used trace= 0-10%, little = 10-20%, some = 20-35%, and = 35-50%

Sample Type:
C = Cored W = Washed
SS = Split Spoon
UP = Undisturbed Piston

Cohesionless Density
0-10 Loose
10-30 Med. Comp.
30-50 Dense

Total Footage:
Earth Boring 17.0 Ft.
Rock Coring Ft.

Soil Sampling Log

GLACIER DRILLING
78 Golden St.
Meriden, CT 06450
Phone/Fax 860-645-1304

Date Started 5-7-03
Date Finish 5-7-03
Weight Of Hammer [X] 140 [ ] 300
Hammer Fall [X] 30' [ ] 24"

Ground Water Observations

Date	Time	Depth

Sampler O.D. 2" I.D. 1 3/8"

Type Of Rig Truck Mounted Rig - CME-75

LENARD ENGINEERING, INC.
P.O. Box 580
Storrs, CT 06268

Sheet 1 Of 1
Proj. No.
Location Mansfield Rd.-Mirror Lk Dam
Storrs, CT
Offset
Ground Elevation
Hole No. MW - 6 / B - 6

Type	Casing HSA	Sampler SS	Core Barrel
Size I.D.	4 1/4"	1 3/8"	

Dept. Below Surface	Sample No. Depths Elev. Ft.	Type Of Sample	Blows Per 6" On Sample From 0-6	To 6-12	12-18	Density Or Consist Moisture	Profile Change Depth Elev.	Field Identification Of Soils Remarks	Sample No.	Pen	Rec	PID
	5-7	SS	4	6	8	Med. Comp.	Top 6"	Brown fine sand and silt.	1	24"	20"	
					8	--	Next 4"	Brown fine dense sand, little fine-medium gravel, trace silt.				
							Bottom 10"	Green brown fine sand, little medium-coarse sand, trace fine-medium gravel, fractured cobble throughout.				
	10-12	SS	3	3	3	Loose	Top 3"	Brown fine sand and silt.	2	24"	8"	
					5		Bottom 5"	Black loose fine-medium and fine-medium gravel.				
	15-17	SS	11	21	29	Med. Comp.		Gray brown fine sand, trace medium sand, trace fine-medium gravel.	3	24"	5"	
					24	Wet						
								Auger to refusal at 20.0.				
							20.0'	B.O.B., set a 2" Monitoring Well to 20.0' using:				
								Threaded Plug 10' Screen, .010 slot 6' 3" Riser 300 lbs. Sand 50 lbs. Bentonite Chips Expandable Gripper Lock 8" Road Box 80 lbs. Cement Mix				

Driller: Time Sabo
Helper/Assistant: Lavelle Tatum
Engineer: Bryan Tucker

Proportions used trace= 0-10%, little = 10-20%, some = 20-35%, and = 35-50%

Sample Type:
C = Cored W = Washed
SS = Split Spoon
UP = Undisturbed Piston

Cohesionless Density
0-10 Loose
10-30 Med. Comp.
30-50 Dense

Total Footage:
Earth Boring 20.0 Ft.
Rock Coring Ft.

Soil Sampling Log

GLACIER DRILLING
75 Commerce Circle
Durham, CT 06422
Phone/Fax 860-645-1304

Started 10-8-04
Date Finish 10-8-04
Weight Of Hammer ☒ 140 ☐ 300
Hammer Fall ☒ 30' ☐ 24"

Ground Water Observations

Date	Time	Depth

Sampler O.D. 2" I.D. 1 3/8"
Type Of Rig Track Mounted Rig: CME-850

~~LENARD ENGINEERING, INC.~~
P.O. Box 580
~~Storrs, CT 06268~~

Sheet 1 Of 1
Proj. No.
Location Mansfield Rd. (Mirror Lake)
Storrs, CT
Offset
Ground Elevation
Hole No. B-7

	Casing	Sampler	Core Barrel
Type	HSA	SS	
Size I.D.	4 1/4"	1 3/8"	

Dept. Below Surface	Sample No. Depths Elev. Ft.	Type Of Sample	Blows Per 6" On Sample 0-6	6-12	12-18	Density Or Consist Moisture	Profile Change Depth Elev.	Field Identification Of Soils Remarks	Sample No.	Pen	Rec	PID
	0 - 2	SS	2	2	2 / 5	Loose		Dark brown topsoil (organics).	1	24"	6"	
	5-7	SS	3	8	14 / 8	Med. Comp. Moist	Top 3" / Bottom 21"	Dark brown fine sand and silt. / Tan fine sand, trace medium sand, trace silt, trace fine gravel.	2	24"	24"	
	10-12	SS	7	7	14 / 13	Med. Comp. Wet		Grey tan fine sand and silt, trace medium sand, piece dark grey to black weathered rock (cobble).	3	24"	16"	
	15-15.8	SS	7	100/ 3"		Dense Wet		Tan fine sand, trace coarse sand to fine gravel, rock in tip.	4	9"	9"	
							15.8'	B.O.B., refusal: set a 2" PVC Monitoring Well using:				
								Threaded Plug				
								10' Screen, .010 slot				
								5' Riser				
								300 lbs Sand				
								50 lbs Bentonite Chips				
								Expandable Gripper				
								Lock				
								8" Road Box				
								2 bags Concrete Mix				

Driller: Tim Sabo
Assistant: Rick Behrend / Barry Rummell
Soils Engineer: Bryan

Proportions used trace= 0.10%, little = 10.20%, some = 20,35%, and = 35.50%

Sample Type:
C = Cored W = Washed
SS = Split Spoon
UP = Undisturbed Piston

Cohesionless Density
0-10 Loose
10-30 Med. Comp.
30-50 Dense

Total Footage: 15.8
Earth Boring Ft.
Rock Coring Ft.

APPENDIX C – GZA TEST BORING LOGS

TEST BORING LOG

GZA GeoEnvironmental, Inc.
Engineers and Scientists

University of Connecticut
Mirror Lake Dam
Storrs, Connecticut

EXPLORATION NO.: GZ-1
SHEET: 1 of 2
PROJECT NO: 05.0046161.07
REVIEWED BY: J. Davis

Logged By: S. DeAngelis
Drilling Co.: Seaboard Drilling
Foreman: M. Glynn

Type of Rig: ATV
Rig Model: D-50T
Drilling Method: Rotary Wash

Boring Location: See Plan
Ground Surface Elev. (ft.): 588
Final Boring Depth (ft.): 25.5
Date Start - Finish: 1/11/2021 - 1/11/2021

H. Datum: NAD83
V. Datum: NAVD88

Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size: NX

Groundwater Depth (ft.)

Date	Time	Water Depth	Stab. Time
1/12/2021	0800	5.85	17 hrs
1/14/2021	0800	6.95	3 days
1/26/2021	0800	7.0	15 days

Casing Blows/Core Rate

Depth (ft)	Casing Blows/Core Rate
	15
	12
	13
	12
	18
5	20
	50+
	1:37
	2:30
	54
10	39
	46
	63
	65
	40
15	32
	36
	35
	33
	17
20	35
	47
	61
	53
25	
30	

Sample

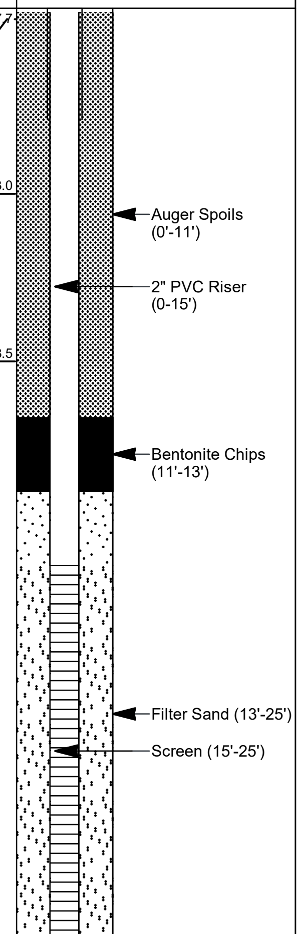
No.	Depth (ft.)	Pen. (in)	Rec. (in)	Blows per 6"	SPT Value	Remark
SS-1	0-2	24	9	12 3 2 10	5	1
SS-2	2-4	24	12	12 5 3 2	8	
SS-3	4-6	24	11	5 3 12 14	15	
SS-4	6-7.1	13	0	10 23 50/1"		
C-1	7-8.5	18	15			2
SS-5	10-12	24	0	3 16 13 15	29	
SS-6	12-14	24	18	17 20 20 21	40	
SS-7	14-16	24	11	16 21 19 15	40	
SS-8	16-18	24	24	14 13 11 19	24	
SS-9	18-20	24	10	48 37 24 19	61	
SS-10	20-22	24	13	21 13 13 16	26	
SS-11	22-24	24	8	16 14 24 26	38	
SS-12	24-25.5	17	10	16 68 50/5"		3, 4

Sample Description Modified Burmister

SS-1 : Top 4": Asphalt
Bottom 5": Brown, fine to coarse SAND, little Silt, trace fine Gravel
SS-2 : Loose, brown, fine to coarse SAND and SILT, little fine Gravel
SS-3 : Top 7": Dark brown, fine to coarse SAND and SILT, little fine Gravel, trace Organics
Bottom 4": Grey, fine to coarse SAND and GRAVEL, trace Silt
SS-4 : No Recovery
C-1 : Top 6": Hard, slight weathering, moderately fractured, fine to medium grained, grey GNEISS boulder
Bottom 9": Hard, slight weathering, moderately fractured, fine to coarse grained, grey GRANITE boulder
SS-5 : No Recovery
SS-6 : Dense, grey, fine to coarse SAND, some fine Gravel, some Silt
SS-7 : Dense, grey, fine to coarse SAND and fine GRAVEL, some Silt
SS-8 : Medium dense, grey, fine to medium SAND, little fine Gravel, trace Silt
SS-9 : Very dense, grey, fine to coarse SAND, little Silt, little Gravel
SS-10 : Medium dense, grey, fine to coarse SAND, little Silt, little Gravel
SS-11 : Dense, grey, fine to coarse SAND, little Silt, little Gravel
SS-12 : Grey, fine to coarse

Stratum Description

Depth (ft.)	Stratum Description	Elev. (ft.)
0.3	ASPHALT	587.7
	EMBANKMENT FILL	
5		583.0
	CORE WALL	
9.5		578.5
	GLACIAL TILL	
25.5		562.5



REMARKS

1 - Test boring advanced with 4-inch diameter casing and rotary wash drilling methods. Casing blows per foot provided in Casing Blows column. Ground surface elevation estimated by surveying using existing spillway crest as benchmark (El. 584.88 ft) and references NAVD88.
2 - NX-sized, double-tube core barrel used to core between about 7 and 8.5 feet. Core times in units of min/foot.
3 - Rollerbit refusal encountered at about 25.5 feet.
4 - Monitoring well installed at 25 feet. 10 feet of 2" slotted pipe set between 15 and 25 feet. Well finished to ground surface with solid PVC pipe. Filter sand place in annulus around well from 13 feet to 25 feet. Bentonite seal from 11 feet to 13 feet below grade. Auger spoils (or filter sand) from 0 feet to 11 feet below grade. Well capped at ground surface. Roadbox installed at ground surface.

Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: GZ-1

TEST BORING LOG

GZA GeoEnvironmental, Inc. *Engineers and Scientists*	**University of Connecticut** **Mirror Lake Dam** **Storrs, Connecticut**	**EXPLORATION NO.:** GZ-1 **SHEET:** 2 of 2 **PROJECT NO:** 05.0046161.07 **REVIEWED BY:** J. Davis

Logged By: S. DeAngelis **Drilling Co.:** Seaboard Drilling **Foreman:** M. Glynn	**Type of Rig:** ATV **Rig Model:** D-50T **Drilling Method:** Rotary Wash	**Boring Location:** See Plan **Ground Surface Elev. (ft.):** 588 **Final Boring Depth (ft.):** 25.5 **Date Start - Finish:** 1/11/2021 - 1/11/2021	**H. Datum:** NAD83 **V. Datum:** NAVD88

Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size: NX

Groundwater Depth (ft.)

Date	Time	Water Depth	Stab. Time
1/12/2021	0800	5.85	17 hrs
1/14/2021	0800	6.95	3 days
1/26/2021	0800	7.0	15 days

Depth (ft)	Casing Blows/ Core Rate	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows per 6"	SPT Value	Sample Description Modified Burmister	Remark	Field Test Data	Depth (ft.)	Stratum Description	Elev. (ft.)
								SAND and GRAVEL, little Silt					
								End of exploration at 25.5 feet.					
35													
40													
45													
50													
55													
60													

REMARKS

Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: GZ-1

TEST BORING LOG

GZA GeoEnvironmental, Inc.
Engineers and Scientists

University of Connecticut
Mirror Lake Dam
Storrs, Connecticut

EXPLORATION NO.: GZ-2
SHEET: 1 of 1
PROJECT NO: 05.0046161.07
REVIEWED BY: J. Davis

Logged By: S. DeAngelis
Drilling Co.: Seaboard Drilling
Foreman: M. Glynn

Type of Rig: ATV
Rig Model: D-50T
Drilling Method: Rotary Wash

Boring Location: See Plan
Ground Surface Elev. (ft.): 582.9
Final Boring Depth (ft.): 24.9
Date Start - Finish: 1/8/2021 - 1/8/2021

H. Datum: NAD83
V. Datum: NAVD88

Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size: NX

Groundwater Depth (ft.)

Date	Time	Water Depth	Stab. Time
1/11/2021	0800	3.6	3 days
1/12/2021	0800	3.2	4 days
1/14/2021	0800	3.35	6 days
1/26/2021	0800	3.25	18 days

Depth (ft)	Casing Blows/ Core Rate	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows per 6"	SPT Value	Remark
	16, 12	SS-1	0-2	24	14	1 6 10 7	16	1
	18, 26	SS-2	2-4	24	14	3 2 1 9	3	
5	21, 34	SS-3	4-6	24	9	5 2 3 2	5	
	35, 51	SS-4	6-8	24	19	6 18 25 20	43	
	9, 32	SS-5	8-10	24	12	16 21 19 21	40	
10	33, 53	SS-6	10-12	24	11	11 10 11 9	21	
	48, 149	SS-7	12-14	24	24	9 18 27 24	45	
15	39, 37	SS-8	14-16	24	18	8 18 35 49	53	
		SS-9	16-16.9	9	9	74 50/3"		
		SS-10	18-19.6	18	12	30 44 40	84	
20	2:30, 4:00, 4:30, 4:00, 5:15	C-1	19.8-24.8	60	43			2, 3
25								
30								4

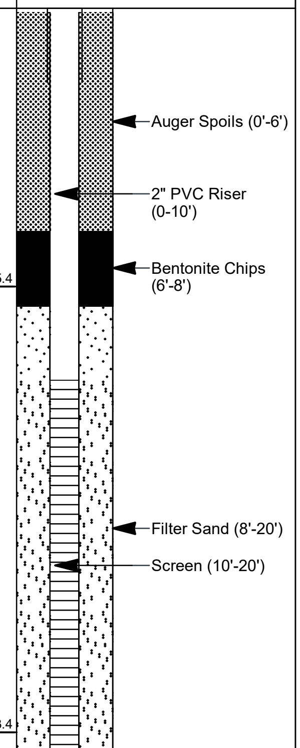
Sample Description — Modified Burmister

SS-1 : Top 6" TOPSOIL
Bottom 8": Brown, grey, fine to coarse SAND and SILT, some fine Gravel
SS-2 : Very loose, brown, fine to coarse SAND and SILT, little fine Gravel
SS-3 : Loose, brown, fine to coarse SAND and SILT, trace fine Gravel
SS-4 : Dense, brown, fine to coarse SAND, some Silt, little fine Gravel
SS-5 : Dense, brown, fine to coarse SAND, little Silt, trace fine Gravel
SS-6 : Medium dense, grey, fine to coarse SAND, little fine Gravel, little Silt
SS-7 : Dense, grey, fine to medium SAND, little Silt, trace fine Gravel
SS-8 : Grey, fine to medium SAND, little fine Gravel, trace Silt
SS-9 : Very dense, grey, fine to medium SAND, little fine Gravel, little Silt
SS-10 : Very dense, grey, fine to coarse SAND, some fine Gravel, little Silt
C-1 : Hard, very slight weathering, sound to slightly fractured, fine to medium grained, grey GNEISS
REC = 72% RQD = 68%

End of exploration at 24.9 feet.

Stratum Description

Depth (ft.)	Stratum Description	Elev. (ft.)
0-7.5	FILL	
7.5		575.4
7.5-19.5	GLACIAL TILL	
19.5		563.4
19.5-24.9	BEDROCK	
24.9		558.0



REMARKS

1 - Test boring advanced with 4-inch diameter casing and rotary wash drilling methods. Casing blows per foot provided in Casing Blows column. Ground surface elevation estimated by surveying using existing spillway crest as benchmark (El. 584.88 ft) and references NAVD88.
2 - Rollerbit refusal encountered at about 19.8 feet.
3 - NX-sized, double-tube core barrel used to core bedrock. Core times in units of min/foot. RQD = Rock Quality Designation
4 - Monitoring well installed at 20 feet. 10 feet of 2" slotted PVC pipe set between 10 and 20 feet. Well finished to ground surface with solid PVC pipe. Filter sand place in annulus around well from 8 feet to 20 feet. Bentonite seal from 6 feet to 8 feet below grade. Auger spoils (or filter sand) from 0 feet to 6 feet below grade. Roadbox installed at ground surface.

Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: GZ-2

TEST BORING LOG

GZA GeoEnvironmental, Inc. *Engineers and Scientists*	University of Connecticut Mirror Lake Dam Storrs, Connecticut	**EXPLORATION NO.:** GZ-3 **SHEET:** 1 of 2 **PROJECT NO:** 05.0046161.07 **REVIEWED BY:** J. Davis

Logged By: S. DeAngelis **Drilling Co.:** Seaboard Drilling **Foreman:** M. Glynn	**Type of Rig:** ATV **Rig Model:** D-50T **Drilling Method:** Roatary Wash	**Boring Location:** See Plan **Ground Surface Elev. (ft.):** 588.1 **Final Boring Depth (ft.):** 33.5 **Date Start - Finish:** 1/13/2021 - 1/14/2021	**H. Datum:** NAD83 **V. Datum:** NAVD88

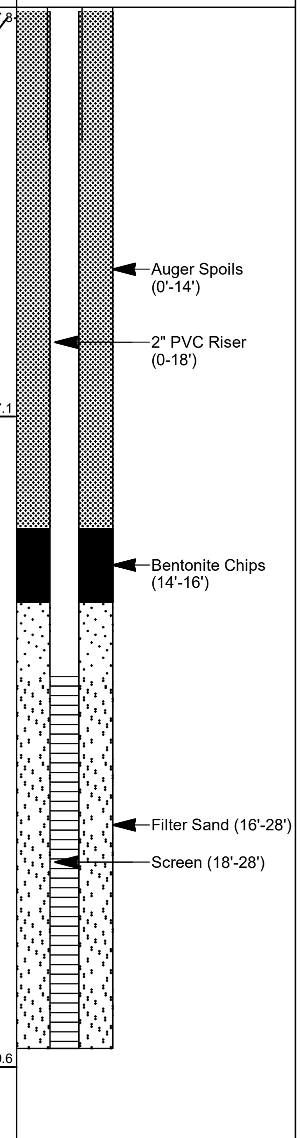
Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size: NX

Groundwater Depth (ft.)

Date	Time	Water Depth	Stab. Time
1/14/2021	1500	6.7	5 min.
1/26/2021	0800	7.1	12 days

Depth (ft)	Casing Blows/ Core Rate	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows per 6"	SPT Value	Sample Description Modified Burmister	Remark	Field Test Data	Stratum Depth (ft.)	Stratum Description	Elev. (ft.)
	12 19	SS-1	0-2	24	0	6 2 2 1	4	SS-1 : No Recovery	1		0.3	ASPHALT	587.8
	18 10	SS-2	2-4	24	13	3 2 3 3	5	SS-2 : Loose, brown, fine to coarse SAND and SILT, little fine Gravel					
5	17 34	SS-3	4-6	24	14	2 3 3 4	6	SS-3 : Loose, brown, SILT and fine to coarse SAND, trace fine Gravel				EMBANKMENT FILL	
	44 31	SS-4	6-8	24	20	4 3 5 6	8	SS-4 : Loose, brown, fine to coarse SAND and SILT, trace fine Gravel					
	7	SS-5	8-10	24	17	5 2 2 2	4	SS-5 : Loose, brown, fine to coarse SAND and SILT, little fine Gravel					
10	10 12	SS-6	10-12	24	0	5 26 24 30	50	SS-6 : No Recovery			11		577.1
	13 48	SS-7	12-14	24	12	10 29 30 27	59	SS-7 : Very dense, grey, fine to coarse SAND, some Gravel, little Silt					
15	47 61	SS-8	14-16	24	14	17 27 27 22	54	SS-8 : Very dense, grey, fine to coarse SAND, some Gravel, little Silt					
	67 59	SS-9	16-18	24	13	29 28 18 15	46	SS-9 : Dense, grey, fine to coarse SAND, some Gravel, little Silt					
	60 28	SS-10	18-20	24	5	19 18 14 19	32	SS-10 : Dense, grey, fine SAND, little fine Gravel, little Silt					
20	30 35	SS-11	20-21.4	16	8	12 22 50/4"		SS-11 : Grey, fine to coarse SAND, some Gravel, some Silt				GLACIAL TILL	
	46 49								2				
25	25 29	SS-12	24-25.7	21	13	22 26 26 50/3"	52	SS-12 : Very dense, grey, fine to coarse SAND, some Silt, little Gravel					
	21 24 49	SS-13	26-27.7	21	10	14 16 36 50/3"	52	SS-13 : Very dense, grey, brown, fine to coarse SAND, some Silt, little Gravel			28.5		559.6
30	4:30 5:00 5:00	C-1	28.5-33.5	60	60			C-1 : Hard, very slight weathering, slightly fractured, fine to medium grained, grey GNEISS	3 4			BEDROCK	



REMARKS

1 - Test boring advanced with 4-inch diameter casing and rotary wash drilling methods. Casing blows per foot provided in Casing Blows column. Ground surface elevation estimated by surveying using existing spillway crest as benchmark (El. 584.88 ft) and references NAVD88.
2 - Difficult rollerbit resistance encountered at about 22 feet.
3 - Rollerbit and casing refusal at 28.5 feet.
4 - NX-sized, double-tube core barrel used to core bedrock. Core times in units of min/foot. RQD = Rock Quality Designation

Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: GZ-3

TEST BORING LOG

GZA GeoEnvironmental, Inc.
Engineers and Scientists

University of Connecticut
Mirror Lake Dam
Storrs, Connecticut

EXPLORATION NO.: GZ-3
SHEET: 2 of 2
PROJECT NO: 05.0046161.07
REVIEWED BY: J. Davis

Logged By: S. DeAngelis
Drilling Co.: Seaboard Drilling
Foreman: M. Glynn

Type of Rig: ATV
Rig Model: D-50T
Drilling Method: Roatary Wash

Boring Location: See Plan
Ground Surface Elev. (ft.): 588.1
Final Boring Depth (ft.): 33.5
Date Start - Finish: 1/13/2021 - 1/14/2021

H. Datum: NAD83
V. Datum: NAVD88

Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size: NX

Groundwater Depth (ft.)

Date	Time	Water Depth	Stab. Time
1/14/2021	1500	6.7	5 min.
1/26/2021	0800	7.1	12 days

Depth (ft)	Casing Blows/ Core Rate	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows per 6"	SPT Value	Sample Description Modified Burmister	Remark	Field Test Data	Depth (ft.)	Stratum Description	Elev. (ft.)
	3:45							REC=100% RQD=97%					
	3:00								5			BEDROCK	
											33.5		554.6
								End of exploration at 33.5 feet.					
35													
40													
45													
50													
55													
60													

REMARKS

5 - Monitoring well installed at 28 feet. 10 feet of 2"slotted PVC pipe set between 18 and 28 feet. Well finished to ground surface with solid PVC pipe. Filter sand placed in annulus around well from 16 feet to 28 feet. Bentonite seal from 14 feet to 16 feet below grade. Auger spoils (or filter sand) from 0 feet to 14 feet below grade. Roadbox installed at ground surface.

Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: GZ-3

TEST BORING LOG

GZA GeoEnvironmental, Inc.
Engineers and Scientists

University of Connecticut
Mirror Lake Dam
Storrs, Connecticut

EXPLORATION NO.: GZ-4
SHEET: 1 of 1
PROJECT NO: 05.0046161.07
REVIEWED BY: J. Davis

Logged By: S. DeAngelis
Drilling Co.: Seaboard Drilling
Foreman: M. Glynn

Type of Rig: ATV
Rig Model: D-50T
Drilling Method: Rotary Wash

Boring Location: See Plan
Ground Surface Elev. (ft.): 579.9
Final Boring Depth (ft.): 29.1
Date Start - Finish: 1/12/2021 - 1/13/2021

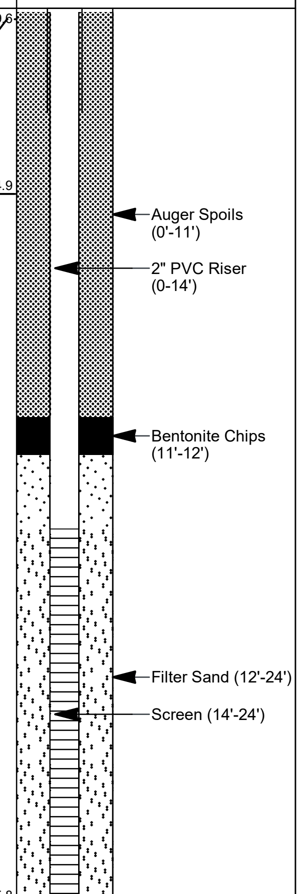
H. Datum: NAD83
V. Datum: NAVD88

Hammer Type: Automatic Hammer
Hammer Weight (lb.): 140
Hammer Fall (in.): 30
Auger or Casing O.D./I.D Dia (in.): 4

Sampler Type: SS
Sampler O.D. (in.): 2.0
Sampler Length (in.): 24
Rock Core Size: NX

Groundwater Depth (ft.)			
Date	**Time**	**Water Depth**	**Stab. Time**
1/14/2021	0800	1.85	1 day
1/26/2021	0800	1.9	13 days

Depth (ft)	Casing Blows/ Core Rate	Sample No.	Sample Depth (ft.)	Pen. (in)	Rec. (in)	Blows per 6"	SPT Value	Sample Description Modified Burmister	Remark	Field Test Data	Depth (ft.)	Stratum Description	Elev. (ft.)
	9 18	SS-1	0-2	24	4	1 2 3 3	5	SS-1 : Top 4": Topsoil	1		0.3	TOPSOIL	579.6
	31 48	SS-2	2-4	24	8	3 11 7 11	18	SS-2 : Medium dense, grey, fine to coarse GRAVEL, little fine to coarse Sand, trace Silt				FILL	
5	51 70	SS-3	4-6	24	17	9 8 17 18	25	SS-3 : Medium dense, grey, fine to coarse SAND, some fine Gravel, some Silt			5		574.9
	88 79	SS-4	6-8	24	11	8 13 17 17	30	SS-4 : Dense, grey, fine to coarse SAND, some Silt, some Gravel					
	49 103	SS-5	8-10	24	10	20 18 13 11	31	SS-5 : Dense, grey, fine to coarse SAND and GRAVEL, little Silt					
10	85 76	SS-6	10-12	24	13	9 11 11 33	22	SS-6 : Medium dense, grey, fine to coarse SAND and GRAVEL, little Silt					
	31	SS-7	12-14	24	15	12 13 15 18	28	SS-7 : Medium dense, grey, fine to medium SAND, some Silt, little fine Gravel					
15		SS-8	14-16	24	15	14 16 12 14	28	SS-8 : Medium dense, grey, fine to coarse SAND, little fine Gravel, little Silt				GLACIAL TILL	
		SS-9	16-18	24	14	19 23 22 30	45	SS-9 : Dense, grey, brown, fine SAND, little fine Gravel, little Silt					
	7 12	SS-10	18-19.8	22	11	30 33 51 50/4"	84	SS-10 : Very dense, brown, fine to medium SAND, trace Silt					
20	8 9	SS-11	20-20.9	11	7	29 50/5"		SS-11 : Brown, fine to medium SAND, trace Silt					
	15	SS-12	22-22.9	11	7	30 50/5"		SS-12 : Brown, fine to medium SAND, trace Silt					
25	5:30	SS-13	24-24.1	1	0	50/1"		SS-13 : No Recovery	2		24.1		555.8
	3:45 4:60 4:45 6:00	C-1	24.1-29.1	60	49			C-1 : Hard, very slight weathering, slightly fractured, fine to medium grained, grey GNEISS REC=82% RQD=77%	3 4		29.1	BEDROCK	550.8
30								End of exploration at 29.1 feet.					



REMARKS

1 - Test boring advanced with 4-inch diameter casing and rotary wash drilling methods. Casing blows per foot provided in Casing Blows column. Ground surface elevation estimated by surveying using existing spillway crest as benchmark (El. 584.88 ft) and references NAVD88.
2 - Rollerbit refusal encountered at about 24 feet.
3 - NX-sized, double-tube core barrel used to core bedrock. Core times in units of min/foot. RQD = Rock Quality Designation.
4 - Monitoring well installed at 24 feet. 10 feet of 2" slotted PVC pipe set between 14 and 24 feet. Well finished to gound surface with solid PVC pipe. Filter sand placed in annulus around well from 12 feet to 24 feet. Bentonite seal from 11 feet to 12 feet below grade. Auger spoils (or filter sand) from 0 feet to 11 feet below grade. Roadbox installed at ground surface.

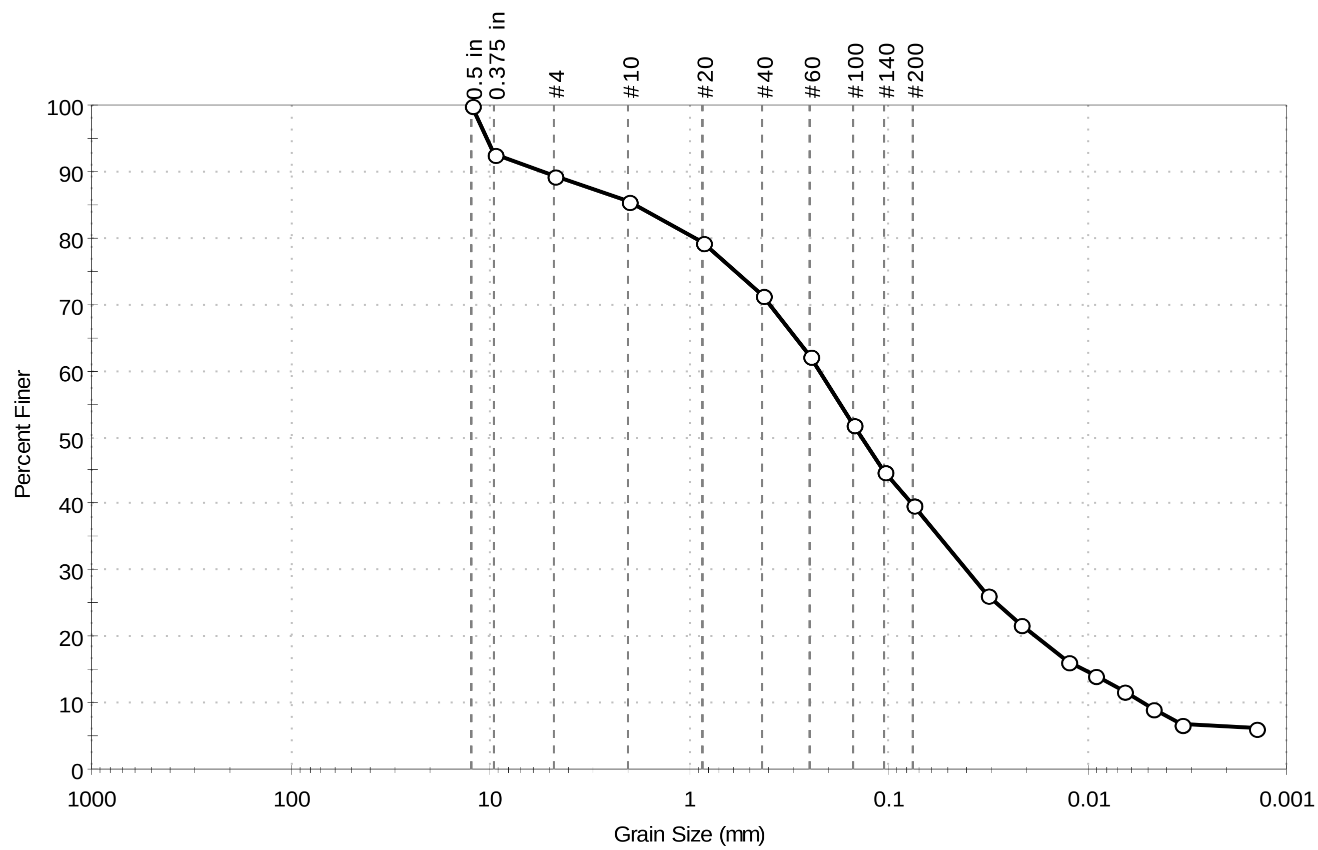
Stratification lines represent approximate boundaries between soil and bedrock types. Actual transitions may be gradual. Water level readings have been made at the times and under the conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the times the measurements were made.

Exploration No.: GZ-4

APPENDIX D – LABORATORY TEST RESULTS

Client:	GZA GeoEnvironmental, Inc.		
Project:	Mirror Lake Dam		
Location:	Storrs, CT	Project No:	GTX-313166
Boring ID: GZ-1	Sample Type: bag	Tested By:	ckg
Sample ID: SS-2	Test Date: 02/10/21	Checked By:	bfs
Depth : 2-4	Test Id: 609963		
Test Comment:	---		
Visual Description:	Moist, dark yellowish brown silty sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D6913/D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	10.6	49.6	39.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.5 in	12.50	100		
0.375 in	9.50	93		
#4	4.75	89		
#10	2.00	85		
#20	0.85	79		
#40	0.42	71		
#60	0.25	62		
#100	0.15	52		
#140	0.11	45		
#200	0.075	40		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0322	26		
---	0.0215	22		
---	0.0126	16		
---	0.0092	14		
---	0.0066	12		
---	0.0047	9		
---	0.0034	7		
---	0.0014	6		

Coefficients

D_{85} = 1.8840 mm | D_{30} = 0.0407 mm

D_{60} = 0.2233 mm | D_{15} = 0.0106 mm

D_{50} = 0.1375 mm | D_{10} = 0.0052 mm

C_u = 42.942 | C_c = 1.427

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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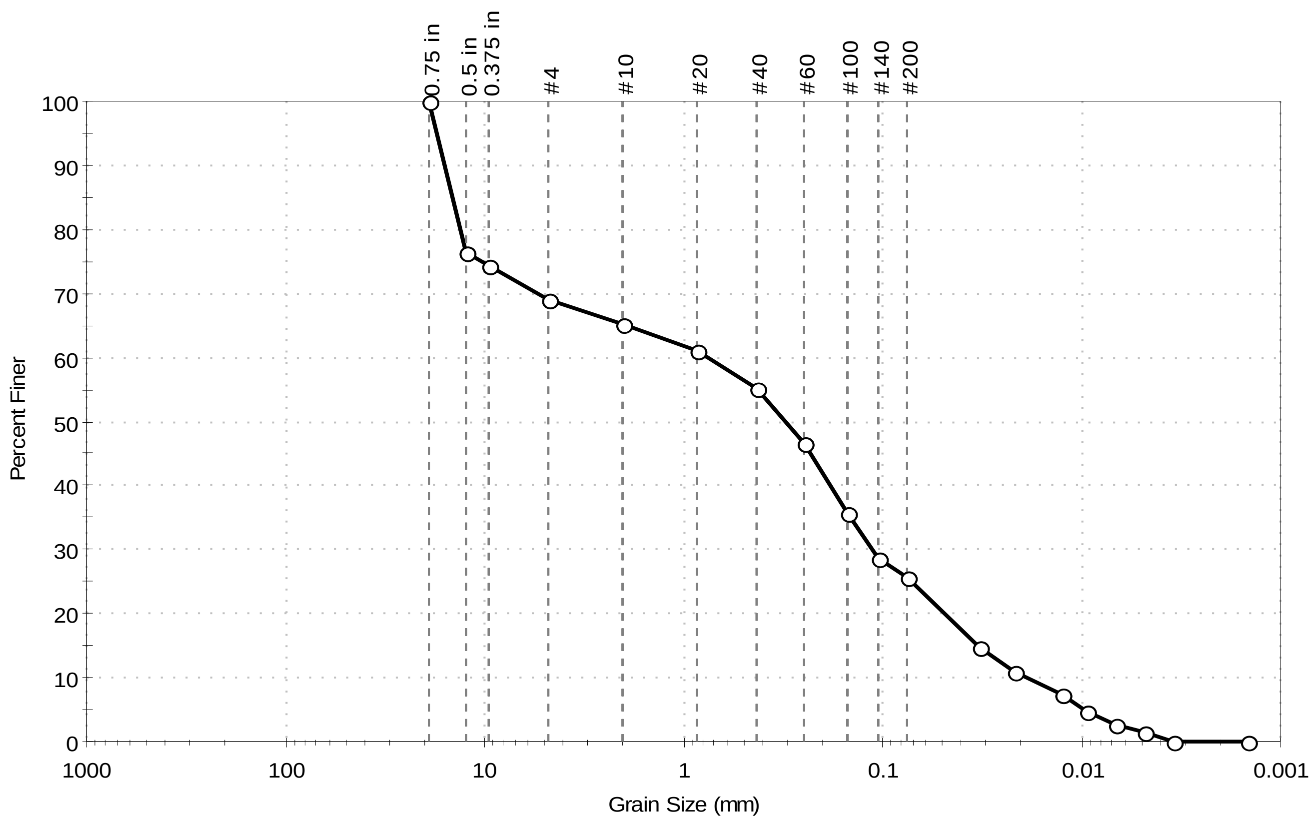
Client:	GZA GeoEnvironmental, Inc.
Project:	Mirror Lake Dam
Location:	Storrs, CT
Project No:	GTX-313166
Boring ID:	GZ-1
Sample ID:	SS-6
Depth :	12-14
Sample Type:	bag
Test Date:	02/11/21
Test Id:	609964
Tested By:	ckg
Checked By:	bfs
Test Comment:	---
Visual Description:	Moist, olive gray silty sand with gravel
Sample Comment:	---

Particle Size Analysis - ASTM D6913/D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	31.1	43.2	25.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	76		
0.375 in	9.50	74		
#4	4.75	69		
#10	2.00	65		
#20	0.85	61		
#40	0.42	55		
#60	0.25	47		
#100	0.15	36		
#140	0.11	29		
#200	0.075	26		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0326	15		
---	0.0216	11		
---	0.0126	7		
---	0.0095	5		
---	0.0068	3		
---	0.0048	1		
---	0.0035	0		
---	0.0015	0		

Coefficients

D_{85} = 14.5674 mm	D_{30} = 0.1137 mm
D_{60} = 0.7558 mm	D_{15} = 0.0330 mm
D_{50} = 0.3074 mm	D_{10} = 0.0189 mm
C_u = 39.989	C_c = 0.905

Classification

ASTM N/A

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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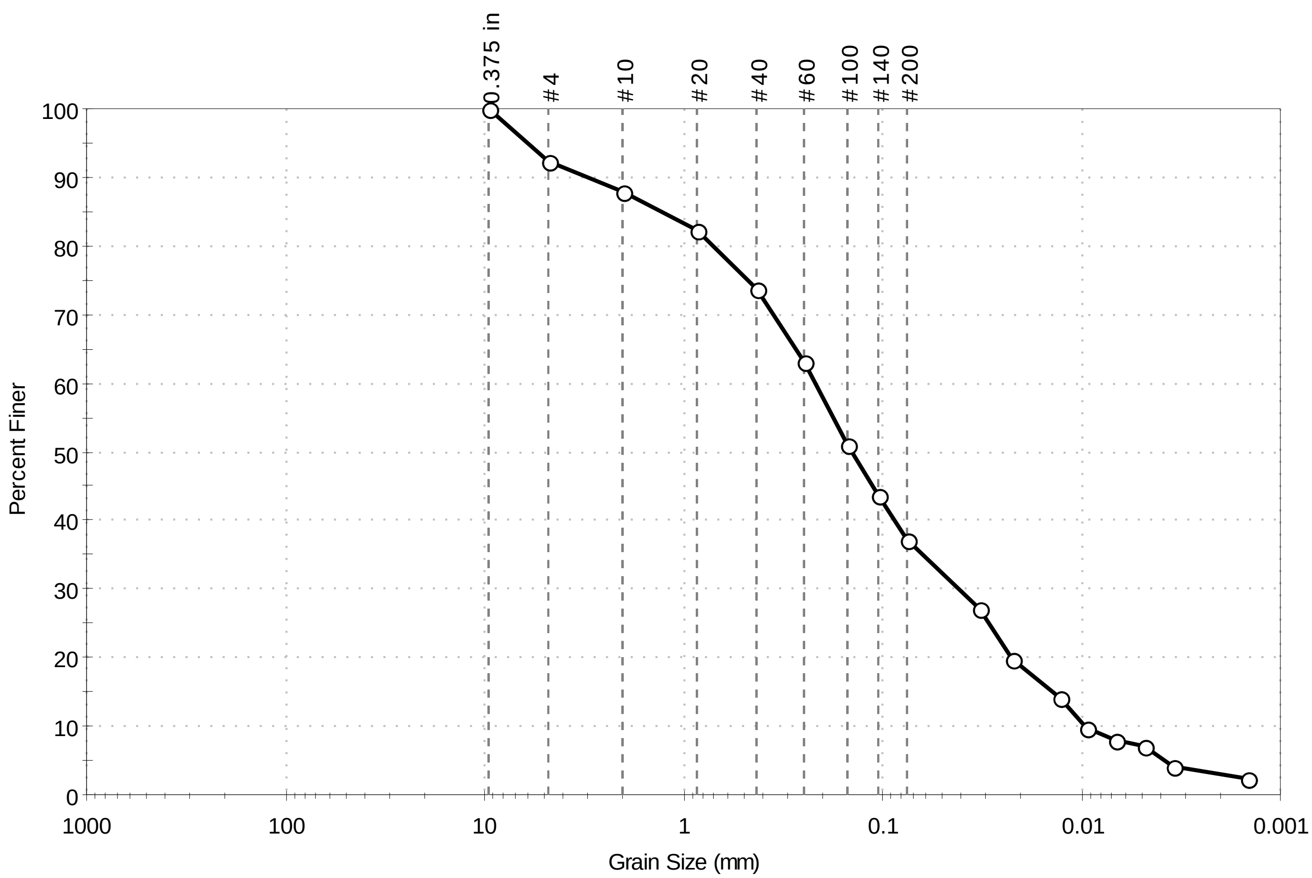
Client:	GZA GeoEnvironmental, Inc.		
Project:	Mirror Lake Dam		
Location:	Storrs, CT	Project No:	GTX-313166
Boring ID: GZ-2	Sample Type: bag	Tested By:	ckg
Sample ID: SS-3	Test Date: 02/10/21	Checked By:	bfs
Depth : 4-6	Test Id: 609965		
Test Comment:	---		
Visual Description:	Moist, dark olive gray clayey sand		
Sample Comment:	---		

Particle Size Analysis - ASTM D6913/D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	7.7	55.0	37.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	92		
#10	2.00	88		
#20	0.85	82		
#40	0.42	74		
#60	0.25	63		
#100	0.15	51		
#140	0.11	44		
#200	0.075	37		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0324	27		
---	0.0222	20		
---	0.0129	14		
---	0.0095	10		
---	0.0068	8		
---	0.0048	7		
---	0.0034	4		
---	0.0015	2		

Coefficients

D_{85} =1.2928 mm D_{30} =0.0413 mm

D_{60} =0.2195 mm D_{15} =0.0139 mm

D_{50} =0.1434 mm D_{10} =0.0097 mm

C_u =22.629 C_c =0.801

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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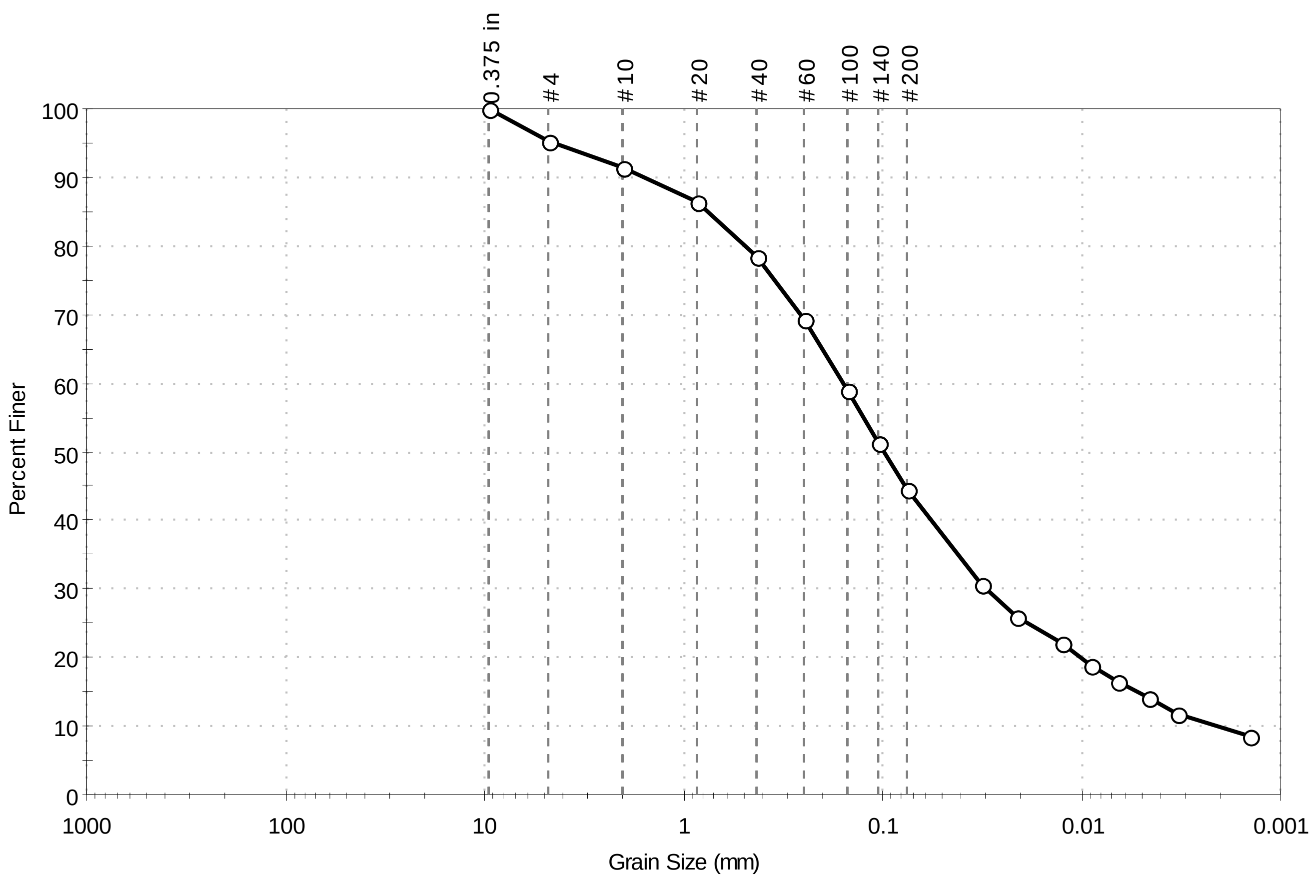
GeoTesting EXPRESS

Client: GZA GeoEnvironmental, Inc.			
Project: Mirror Lake Dam			
Location: Storrs, CT		Project No:	GTX-313166
Boring ID: GZ-3	Sample Type: bag	Tested By:	ckg
Sample ID: SS-4	Test Date: 02/11/21	Checked By:	bfs
Depth : 6-8	Test Id: 609966		
Test Comment: ---			
Visual Description: Moist, olive brown silty sand			
Sample Comment: ---			

Particle Size Analysis - ASTM D6913/D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	4.7	50.7	44.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.375 in	9.50	100		
#4	4.75	95		
#10	2.00	91		
#20	0.85	86		
#40	0.42	78		
#60	0.25	69		
#100	0.15	59		
#140	0.11	51		
#200	0.075	45		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0315	31		
---	0.0214	26		
---	0.0126	22		
---	0.0091	19		
---	0.0065	17		
---	0.0046	14		
---	0.0033	12		
---	0.0014	9		

Coefficients

D_{85} = 0.7550 mm D_{30} = 0.0298 mm
D_{60} = 0.1582 mm D_{15} = 0.0052 mm
D_{50} = 0.0989 mm D_{10} = 0.0021 mm
C_u = 75.333 C_c = 2.673

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD
Dispersion Device : Apparatus A - Mech Mixer
Dispersion Period : 1 minute
Est. Specific Gravity : 2.65
Separation of Sample: #200 Sieve

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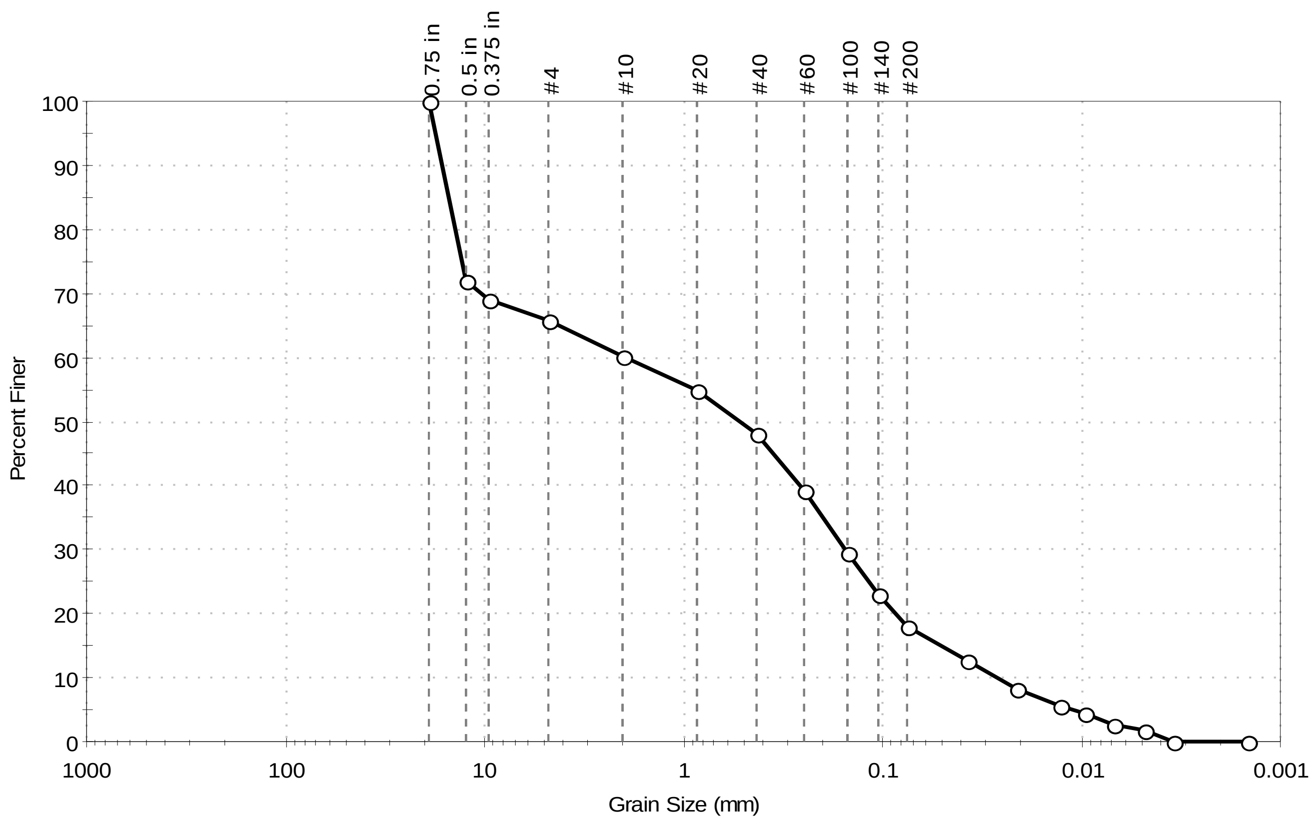
Client:	GZA GeoEnvironmental, Inc.		
Project:	Mirror Lake Dam		
Location:	Storrs, CT	Project No:	GTX-313166

Boring ID:	GZ-3	Sample Type:	bag	Tested By:	ckg
Sample ID:	SS-8	Test Date:	02/11/21	Checked By:	bfs
Depth :	14-16	Test Id:	609967		

Test Comment: ---
Visual Description: Moist, olive gray silty sand with gravel
Sample Comment: ---

Particle Size Analysis - ASTM D6913/D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	34.1	48.0	17.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	72		
0.375 in	9.50	69		
#4	4.75	66		
#10	2.00	60		
#20	0.85	55		
#40	0.42	48		
#60	0.25	39		
#100	0.15	29		
#140	0.11	23		
#200	0.075	18		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0374	13		
---	0.0214	8		
---	0.0130	6		
---	0.0097	4		
---	0.0069	3		
---	0.0049	2		
---	0.0035	0		
---	0.0015	0		

Coefficients

D_{85} = 15.1949 mm
D_{30} = 0.1551 mm
D_{60} = 1.9309 mm
D_{15} = 0.0509 mm
D_{50} = 0.5135 mm
D_{10} = 0.0267 mm
C_u = 72.318
C_c = 0.467

Classification

ASTM N/A

AASHTO Stone Fragments, Gravel and Sand (A-1-b (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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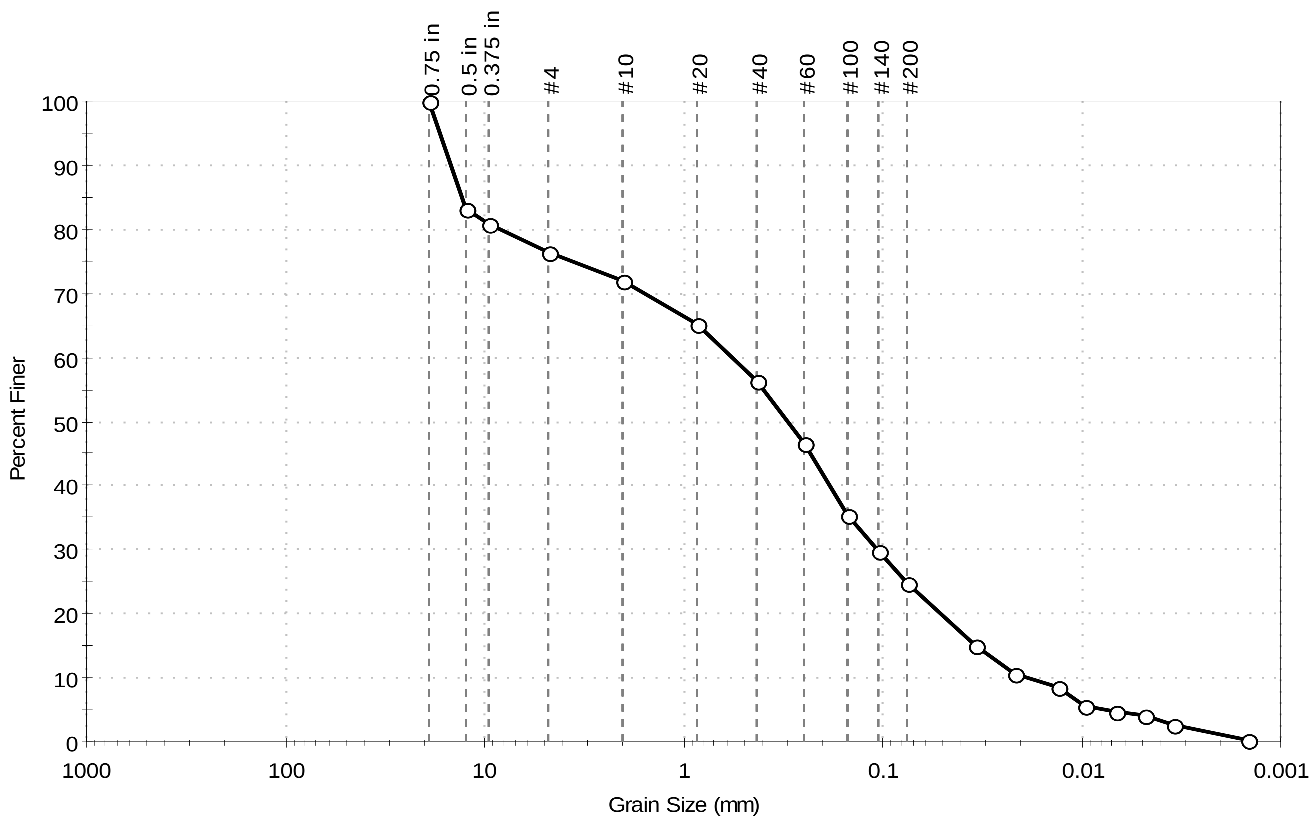
Client:	GZA GeoEnvironmental, Inc.
Project:	Mirror Lake Dam
Location:	Storrs, CT
Project No:	GTX-313166
Boring ID:	GZ-4
Sample ID:	SS-4
Depth :	6-8
Sample Type:	bag
Test Date:	02/10/21
Test Id:	609968
Tested By:	ckg
Checked By:	bfs
Test Comment:	---
Visual Description:	Moist, olive gray clayey sand with gravel
Sample Comment:	---

Particle Size Analysis - ASTM D6913/D7928



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	23.7	51.5	24.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
0.75 in	19.00	100		
0.5 in	12.50	83		
0.375 in	9.50	81		
#4	4.75	76		
#10	2.00	72		
#20	0.85	65		
#40	0.42	56		
#60	0.25	47		
#100	0.15	35		
#140	0.11	30		
#200	0.075	25		
Hydrometer	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0344	15		
---	0.0216	11		
---	0.0132	9		
---	0.0096	6		
---	0.0068	5		
---	0.0048	4		
---	0.0035	3		
---	0.0015	0		

Coefficients

D_{85} = 13.0725 mm
D_{30} = 0.1075 mm
D_{60} = 0.5695 mm
D_{15} = 0.0339 mm
D_{50} = 0.3005 mm
D_{10} = 0.0183 mm
C_u = 31.120
C_c = 1.109

Classification

ASTM N/A

AASHTO Silty Gravel and Sand (A-2-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

Dispersion Device : Apparatus A - Mech Mixer

Dispersion Period : 1 minute

Est. Specific Gravity : 2.65

Separation of Sample: #200 Sieve

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APPENDIX E – BEDROCK CORE PHOTOGRAPHS

Mirror Lake Dam
Storrs, Connecticut
Rock Core Photographs

Boring No.	Run	Depth (ft)	Recovery (in)	Recovery (%)	RQD (in)	RQD (%)	Rock Type	Core Box Row Number
GZ-2	C-1	19.8 - 24.8	43	72	41	68	Gneiss	1
GZ-1	C-1	7 - 8.5	15	83	15	83	Boulder	2
GZ-4	C-1	24.1 - 29.1	49	82	46	77	Gneiss	3
GZ-3	C-1	28.5 - 33.5	60	100	58	97	Gneiss	4

Notes:

1. Table row corresponds to the core box section in which the rock core sample is contained; Table Row 1=Top of Core Box, Table Row 4=Bottom of Core Box.
2. Top of rock core is to the left, bottom is to the right.
3. Top photo is dry, bottom photo is wetted.

APPENDIX F – SUBWATERSHED MAP

CAMPUS DRAINAGE MASTERPLAN

Volume I of VI

Eagleville Brook and Roberts Brook Watersheds
University of Connecticut
Storrs, Connecticut
Project #901950

UCONN
UNIVERSITY OF CONNECTICUT

DRAFT

February 13, 2018

BVH INTEGRATED SERVICES, P.C.

50 Griffin Road South, Bloomfield, CT 06002
ph. (860) 286-9171

One Gateway Center, Suite 701, Newton, MA 02458
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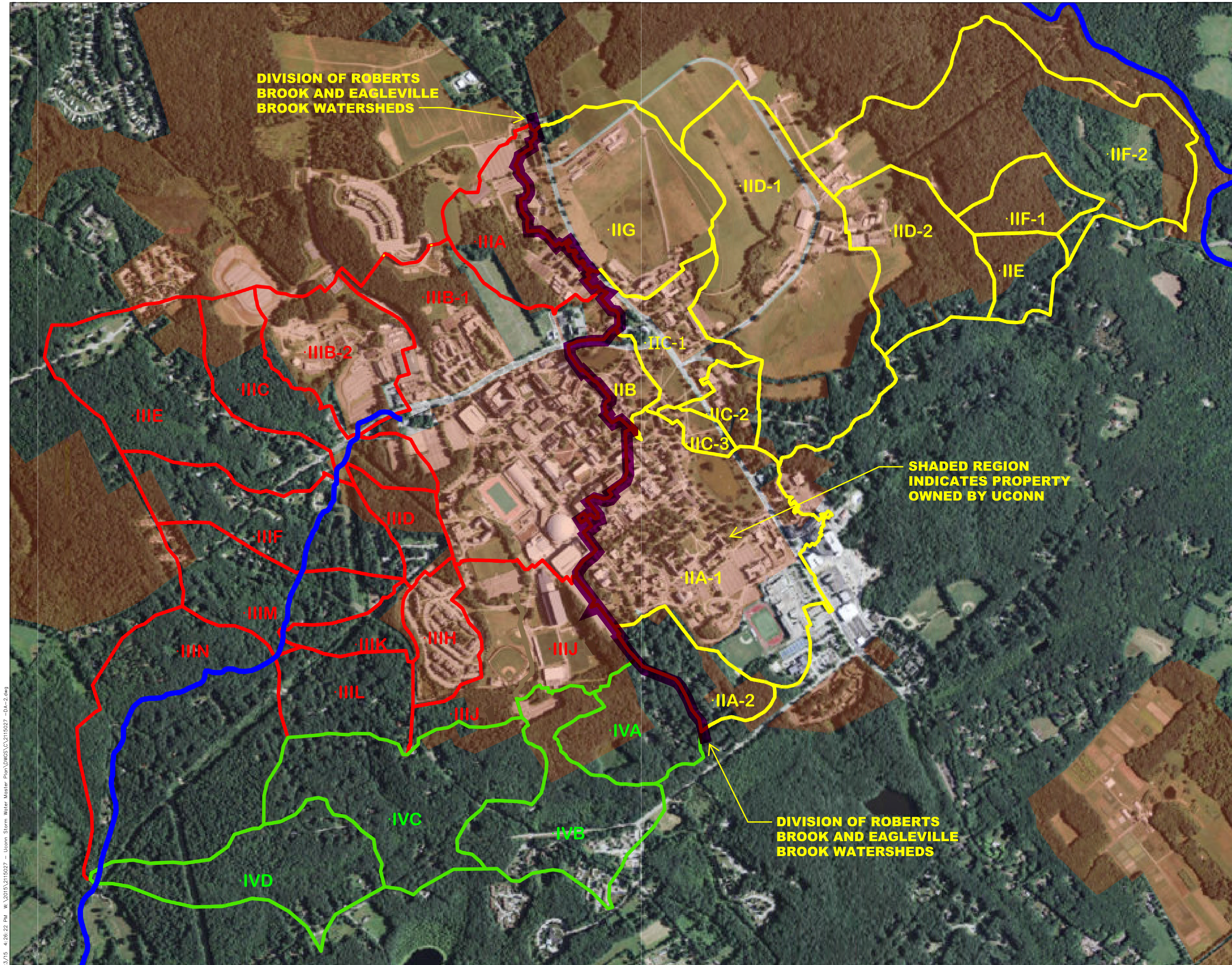


DIVISION OF ROBERTS BROOK AND EAGLEVILLE BROOK WATERSHEDS
IIIA
IIG
IID-1
IIF-2
IID-2
IIF-1
IIE
IIIB-1
IIIB-2
IIC-1
IIIC
IIB
IIIE
IIC-2
IIC-3
SHADED REGION INDICATES PROPERTY OWNED BY UCONN
IIID
IIIF
IIA-1
IIIM
IIIH
IIIK
IIIN
IIIJ
IIIL
IIIJ
IIA-2
IVA
IVC
IVB
IVD
DIVISION OF ROBERTS BROOK AND EAGLEVILLE BROOK WATERSHEDS

DA-1A

APPENDIX G – MATERIAL PROPERTIES CALCULATIONS

Correlation of SPT-N Values to ϕ Worksheet

Project:	05.0046161.07 - Mirror Lake Dam		
Location:	Storrs, Connecticut		
Calculated By:	EK	**Date:**	2/11/2021
Checked By:	JD	**Date:**	2/28/2021

Purpose: To estimate ϕ value for granular soils encountered in test borings, using three correlations (attached). Correlations are made using N_{field} and $(N1)_{60}$

References:
1) Peck, Hanson, and Thornburn; "Foundation Engineering" 2nd ed., Wiley, New York, 1974
2) M.Carter and S.P.Bentley (1991), Correlations of soil properties, Pentech Press Publishers, London, UK
3) Hatanaka, M., Uchida, A. (1996). Empirical correlation between penetration resistance and effective friction of sandy soil. Soils & Foundations, Vol. 36 (4), 1-9, Japanese Geotechnical Society.

Instructions:
- Create separate tab for each boring, add/delete rows to accommodate boring depth
- Edit "Strata" column on right side of sheet to correspond with boring log, denote granular strata with S1, S2….SN
- Input CE value in cell B6 from table on right side of sheet, CB and CS values correspond to borehole diameters and sampler configurations, and are not likely to change
- Input groundwater level in cell B9. Use bottom of borehole if none encountered.
- User input required in columns A, C, J, and P. Also, ground surface elevation (if known) in cell C11
- Copy cells K12:O12 and paste at each sample depth.
- Update/edit formulas at bottom of sheet to average f values for each strata, transfer value(s) to "Summary" sheet

Assumptions:

Results: See attached sheets

Strata	*SPT-Based* Selected ϕ Value
Embankment Fill	29 °
Fill	30 °
Glacial Till	38 °

Empirical Correlations of SPT N-Value and Internal Frictional Angle
05.0046161.07 - Mirror Lake Dam - Storrs, Connecticut

Boring ID: **GZ-1**
CE 1.20 (Automatic)
CB 1.0 (borehole diameter 60-115mm)
CS 1.0 (sampler without liner)
gw level (ft): 7 (below ground surface)

Depth (feet)	Elev in ft (NAVD 88)	Unit Weight (pcf)	Stress Increment (psf)	Total Stress (psf)	Pore Water Pressure (psf)	Effective Stress σv' (tsf)	Cn	Cr	N_{field} (blows/ft)	N_{60} (blows/ft)	$(N_1)_{60}$ (blows/ft)	Carter & Bentley (1991) Φ' based on $N_{field} < 70$	PH&T 1974 Φ' based on Min. Value of $N_{60} < 73$	Estimated Fines Content (%)	Strata	Depth for C_R (meters)
0.0	588	120	0	0	0	0.0000	-	0.75							ASPHALT	0.00
1.0	587.0	120	120	120	0	0.0600	1.70	0.75	5	5	8	28.5	28.5		EMBANKMENT FILL	0.30
2.0	586.0	120	120	240	0	0.1200	1.70	0.75								0.61
3.0	585.0	120	120	360	0	0.1800	1.70	0.75	8	7	12	29.5	29.3			0.91
4.0	584.0	120	120	480	0	0.2400	1.70	0.75								1.22
5.0	583.0	120	120	600	0	0.3000	1.70	0.75	15	14	23	31.5	31.3			1.52
6.0	582.0	120	120	720	0	0.3600	1.67	0.75							CORE WALL	1.83
7.0	581.0	120	120	840	0	0.4200	1.54	0.75								2.13
8.0	580.0	120	120	960	62.4	0.4488	1.49	0.75								2.44
9.0	579.0	120	120	1080	124.8	0.4776	1.45	0.75								2.74
10.0	578.0	120	120	1200	187.2	0.5064	1.41	0.80							GLACIAL TILL	3.05
11.0	577.0	120	120	1320	249.6	0.5352	1.37	0.80	29	28	38	35.8	35.5			3.35
12.0	576.0	120	120	1440	312	0.5640	1.33	0.80								3.66
13.0	575.0	120	120	1560	374.4	0.5928	1.30	0.80	40	38	50	38.8	38.3			3.96
14.0	574.0	120	120	1680	436.8	0.6216	1.27	0.85								4.27
15.0	573.0	120	120	1800	499.2	0.6504	1.24	0.85	40	41	51	38.8	39.0			4.57
16.0	572.0	120	120	1920	561.6	0.6792	1.21	0.85								4.88
17.0	571.0	120	120	2040	624	0.7080	1.19	0.85	24	24	29	34.3	34.3			5.18
18.0	570.0	120	120	2160	686.4	0.7368	1.16	0.85								5.49
19.0	569.0	120	120	2280	748.8	0.7656	1.14	0.85	61	62	71	42.8	43.0			5.79
20.0	568.0	120	120	2400	811.2	0.7944	1.12	0.95								6.10
21.0	567.0	120	120	2520	873.6	0.8232	1.10	0.95	26	30	33	34.8	36.0			6.40
22.0	566.0	120	120	2640	936	0.8520	1.08	0.95								6.71
23.0	565.0	120	120	2760	998.4	0.8808	1.07	0.95	38	43	46	38.3	39.5			7.01
24.0	564.0	120	120	2880	1060.8	0.9096	1.05	0.95								7.32
25.0	563.0	120	120	3000	1123.2	0.9384	1.03	0.95								7.62
25.5	562.5	120	60	3060	1154.4	0.9528	1.02	0.95								7.77
		Bottom of Boring @ 25.5														
											S1 Average ϕ' =	29.8	29.7			
											S2 Average ϕ' =	37.6	33.9			

Notes:
100 number requires manual input
25 groundwater table (if not measured, use bottom of boring depth instead)

Empirical Correlations of SPT N-Value and Internal Frictional Angle
05.0046161.07 - Mirror Lake Dam - Storrs, Connecticut

Boring ID: **GZ-2**
CE 1.20 (Automatic)
CB 1.0 (borehole diameter 60-115mm)
CS 1.0 (sampler without liner)
gw level (ft): **3.25** (below ground surface)

Depth (feet)	Elev in ft (NAVD 88)	Unit Weight (pcf)	Stress Increment (psf)	Total Stress (psf)	Pore Water Pressure (psf)	Effective Stress σv' (tsf)	Cn	Cr	N_{field} (blows/ft)	N_{60} (blows/ft)	$(N_1)_{60}$ (blows/ft)	Carter & Bentley (1991) Φ' based on $N_{field} < 70$	PH&T 1974 Φ' based on Min. Value of $N_{60} < 73$	Estimated Fines Content (%)	Strata	Depth for C_R (meters)
0.0	582.9	120	0	0	0	0.0000	-	0.75							TOPSOIL	0.00
1.0	581.9	120	120	120	0	0.0600	1.70	0.75	16	14	24	31.8	31.3			0.30
2.0	580.9	120	120	240	0	0.1200	1.70	0.75								0.61
3.0	579.9	120	120	360	0	0.1800	1.70	0.75	3	3	5	28.0	28.0		FILL	0.91
4.0	578.9	120	120	480	46.8	0.2166	1.70	0.75								1.22
5.0	577.9	120	120	600	109.2	0.2454	1.70	0.75	5	5	8	28.5	28.5			1.52
6.0	576.9	120	120	720	171.6	0.2742	1.70	0.75								1.83
7.0	575.9	120	120	840	234	0.3030	1.70	0.75	43	39	66	39.5	38.5			2.13
8.0	574.9	120	120	960	296.4	0.3318	1.70	0.75								2.44
9.0	573.9	120	120	1080	358.8	0.3606	1.67	0.75	40	36	60	38.8	37.5			2.74
10.0	572.9	120	120	1200	421.2	0.3894	1.60	0.80								3.05
11.0	571.9	120	120	1320	483.6	0.4182	1.55	0.80	21	20	31	33.5	33.3			3.35
12.0	570.9	120	120	1440	546	0.4470	1.50	0.80							GLACIAL TILL	3.66
13.0	569.9	120	120	1560	608.4	0.4758	1.45	0.80	45	43	63	39.8	39.5			3.96
14.0	568.9	120	120	1680	670.8	0.5046	1.41	0.85								4.27
15.0	567.9	120	120	1800	733.2	0.5334	1.37	0.85	53	54	74	41.3	41.8			4.57
16.0	566.9	120	120	1920	795.6	0.5622	1.33	0.85								4.88
17.0	565.9	120	120	2040	858	0.5910	1.30	0.85	84	86	111	N/A	N/A			5.18
18.5	564.4	120	180	2220	951.6	0.6342	1.26	0.85								5.64
			Rock core													
19.5	563.4	150	150	2370	1014	0.6780										
20.5	562.4	150	150	2520	1076.4	0.7218										
21.5	561.4	150	150	2670	1138.8	0.7656									BEDROCK	
22.5	560.4	150	150	2820	1201.2	0.8094										
23.5	559.4	150	150	2970	1263.6	0.8532										
		Bottom of Boring @ 23.5														

	Carter & Bentley (1991)	PH&T 1974
S1 Average ϕ' =	29.4	29.3
S2 Average ϕ' =	38.6	38.1

Notes:

100 number requires manual input

25 groundwater table (if not measured, use bottom of boring depth instead)

Empirical Correlations of SPT N-Value and Internal Frictional Angle
05.0046161.07 - Mirror Lake Dam - Storrs, Connecticut

Boring ID: **GZ-3**
CE 1.20 (Automatic)
CB 1.0 (borehole diameter 60-115mm)
CS 1.0 (sampler without liner)
gw level (ft): 7.1 (below ground surface)

Depth (feet)	Elev in ft (NAVD 88)	Unit Weight (pcf)	Stress Increment (psf)	Total Stress (psf)	Pore Water Pressure (psf)	Effective Stress σv' (tsf)	Cn	Cr	N_{field} (blows/ft)	N_{60} (blows/ft)	$(N_1)_{60}$ (blows/ft)	Carter & Bentley (1991) Φ' based on $N_{field} < 70$	PH&T 1974 Φ' based on Min. Value of $N_{60} < 73$	Estimated Fines Content (%)	Strata	Depth for C_R (meters)
0.0	588.1	120	0	0	0	0.0000	-	0.75							ASPHALT	0.00
1.0	587.1	120	120	120	0	0.0600	1.70	0.75	4	4	6	28.0	28.0		EMBANKMENT FILL	0.30
2.0	586.1	120	120	240	0	0.1200	1.70	0.75								0.61
3.0	585.1	120	120	360	0	0.1800	1.70	0.75	5	5	8	28.5	28.5			0.91
4.0	584.1	120	120	480	0	0.2400	1.70	0.75								1.22
5.0	583.1	120	120	600	0	0.3000	1.70	0.75	6	5	9	28.8	28.5			1.52
6.0	582.1	120	120	720	0	0.3600	1.67	0.75								1.83
7.0	581.1	120	120	840	0	0.4200	1.54	0.75	8	7	11	29.5	29.3			2.13
8.0	580.1	120	120	960	56.16	0.4519	1.49	0.75								2.44
9.0	579.1	120	120	1080	118.56	0.4807	1.44	0.75	4	4	5	28.0	28.0			2.74
10.0	578.1	120	120	1200	180.96	0.5095	1.40	0.80								3.05
11.0	577.1	120	120	1320	243.36	0.5383	1.36	0.80	50	48	65	40.8	40.8		GLACIAL TILL	3.35
12.0	576.1	120	120	1440	305.76	0.5671	1.33	0.80								3.66
13.0	575.1	120	120	1560	368.16	0.5959	1.30	0.80	59	57	73	42.3	42.3			3.96
14.0	574.1	120	120	1680	430.56	0.6247	1.27	0.85								4.27
15.0	573.1	120	120	1800	492.96	0.6535	1.24	0.85	54	55	68	41.5	42.0			4.57
16.0	572.1	120	120	1920	555.36	0.6823	1.21	0.85								4.88
17.0	571.1	120	120	2040	617.76	0.7111	1.19	0.85	46	47	56	40.0	40.5			5.18
18.0	570.1	120	120	2160	680.16	0.7399	1.16	0.85								5.49
19.0	569.1	120	120	2280	742.56	0.7687	1.14	0.85	32	33	37	36.8	36.8			5.79
20.0	568.1	120	120	2400	804.96	0.7975	1.12	0.95								6.10
21.0	567.1	120	120	2520	867.36	0.8263	1.10	0.95	97	111	122	N/A	N/A			6.40
22.0	566.1	120	120	2640	929.76	0.8551	1.08	0.95								6.71
23.0	565.1	120	120	2760	992.16	0.8839	1.06	0.95								7.01
24.0	564.1	120	120	2880	1054.56	0.9127	1.05	0.95								7.32
25.0	563.1	120	120	3000	1116.96	0.9415	1.03	0.95	52	59	61	41.3	42.8			7.62
26.0	562.1	120	120	3120	1179.36	0.9703	1.02	0.95								7.92
27.0	561.1	120	120	3240	1241.76	0.9991	1.00	0.95	52	59	59	41.3	42.8			8.23
28.5	559.6	120	180	3420	1335.36	1.0423	0.98	0.95								8.69
			Rock core												BEDROCK	
29.5	558.6	150	150	3570	1397.76	1.0861										
30.5	557.6	150	150	3720	1460.16	1.1299										
31.5	556.6	150	150	3870	1522.56	1.1737										
32.5	555.6	150	150	4020	1584.96	1.2175										
33.5	554.6	150	150	4170	1647.36	1.2613										
		Bottom of Boring @ 33.5														
											S1 Average ϕ' =	28.6	28.0			
											S2 Average ϕ' =	40.5	38.5			

Notes:
100 number requires manual input
25 groundwater table (if not measured, use bottom of boring depth instead)

Empirical Correlations of SPT N-Value and Internal Frictional Angle
05.0046161.07 - Mirror Lake Dam - Storrs, Connecticut

Boring ID: **GZ-4**
CE 1.20 (auto hammer)
CB 1.0 (borehole diameter 60-115mm)
CS 1.0 (sampler without liner)
gw level (ft): **1.9** (below ground surface)

Depth (feet)	Elev in ft (NAVD 88)	Unit Weight (pcf)	Stress Increment (psf)	Total Stress (psf)	Pore Water Pressure (psf)	Effective Stress σv' (tsf)	Cn	Cr	N_{field} (blows/ft)	N_{60} (blows/ft)	$(N_1)_{60}$ (blows/ft)	Carter & Bentley (1991) Φ' based on N_{field} < 70	PH&T 1974 Φ' based on Min. Value of N_{60} < 73	Estimated Fines Content (%)	Strata	Depth for C_R (meters)
0.0	579.9	120	0	0	0	0.0000	-	0.75							TOP SOIL	0.00
1.0	578.9	120	120	120	0	0.0600	1.70	0.75	5	5	8	28.5	28.5		FILL	0.30
2.0	577.9	120	120	240	6.24	0.1169	1.70	0.75								0.61
3.0	576.9	120	120	360	68.64	0.1457	1.70	0.75	18	16	28	32.5	32.0			0.91
4.0	575.9	120	120	480	131.04	0.1745	1.70	0.75								1.22
5.0	574.9	120	120	600	193.44	0.2033	1.70	0.75	25	23	38	34.5	34.0		GLACIAL TILL	1.52
6.0	573.9	120	120	720	255.84	0.2321	1.70	0.75								1.83
7.0	572.9	120	120	840	318.24	0.2609	1.70	0.75	30	27	46	36.0	35.3			2.13
8.0	571.9	120	120	960	380.64	0.2897	1.70	0.75								2.44
9.0	570.9	120	120	1080	443.04	0.3185	1.70	0.75	31	28	47	36.5	35.5			2.74
10.0	569.9	120	120	1200	505.44	0.3473	1.70	0.80								3.05
11.0	568.9	120	120	1320	567.84	0.3761	1.63	0.80	22	21	34	33.8	33.5			3.35
12.0	567.9	120	120	1440	630.24	0.4049	1.57	0.80								3.66
13.0	566.9	120	120	1560	692.64	0.4337	1.52	0.80	28	27	41	35.5	35.3			3.96
14.0	565.9	120	120	1680	755.04	0.4625	1.47	0.85								4.27
15.0	564.9	120	120	1800	817.44	0.4913	1.43	0.85	28	29	41	35.5	35.8			4.57
16.0	563.9	120	120	1920	879.84	0.5201	1.39	0.85								4.88
17.0	562.9	120	120	2040	942.24	0.5489	1.35	0.85	45	46	62	39.8	40.3			5.18
18.0	561.9	120	120	2160	1004.64	0.5777	1.32	0.85								5.49
19.0	560.9	120	120	2280	1067.04	0.6065	1.28	0.85	84	86	110	N/A	N/A			5.79
20.0	559.9	120	120	2400	1129.44	0.6353	1.25	0.95								6.10
21.0	558.9	120	120	2520	1191.84	0.6641	1.23	0.95	100	114	140	N/A	N/A			6.40
22.0	557.9	120	120	2640	1254.24	0.6929	1.20	0.95	100	114	137	N/A	N/A			6.71
23.0	556.9	120	120	2760	1316.64	0.7217	1.18	0.95								7.01
24.0	555.9	120	120	2880	1379.04	0.7505	1.15	0.95								7.32
			Rock core													
25.0	554.9	150	1350	3270	1441.44	0.9143									BEDROCK	
26.0	553.9	150	150	3420	1503.84	0.9581										
27.0	552.9	150	150	3570	1566.24	1.0019										
28.0	551.9	150	150	3720	1628.64	1.0457										
29.0	550.9	150	150	3870	1691.04	1.0895										
		Bottom of Boring @ 16														
											S1 Average ϕ' =	30.5	30.3			
											S2 Average ϕ' =	35.9	35.6			

Notes:
100 number requires manual input
25 groundwater table (if not measured, use bottom of boring depth instead)

Empirical Correlations of SPT N-Value and Internal Frictional Angle
05.0046161.07 - Mirror Lake Dam - Storrs, Connecticut

TABLE 1 - SUMMARY OF CALCULATED FRICTION ANGLES

			Average ϕ Values at Each Boring	
Test Boring	Strata	Strata Name or Description	Carter & Bentley	PH&T
GZ-1	S1	Embankment Fill	29.8	29.7
	S2	Glacial Till	37.6	33.9
GZ-2	S1	Fill	29.4	29.3
	S2	Glacial Till	38.6	38.1
GZ-3	S1	Embankment Fill	28.6	28.0
	S2	Glacial Till	40.5	38.5
GZ-4	S1	Fill	30.5	30.3
	S2	Glacial Till	35.9	35.6

TABLE 2 - SUMMARY OF CALCULATED FRICTION ANGLES

Strata	Median Value (1)	Lower Bound (2)
Embankment Fill	29 °	28 °
Fill	30 °	28 °
Glacial Till	38 °	35 °

1) Median value using all applicable correlation methods
2) Lower Bound value is estimated as the median value x (1 - Coefficient of Variation)

TABLE 3 - SELECTED FRICTION ANGLES BY STRATUM

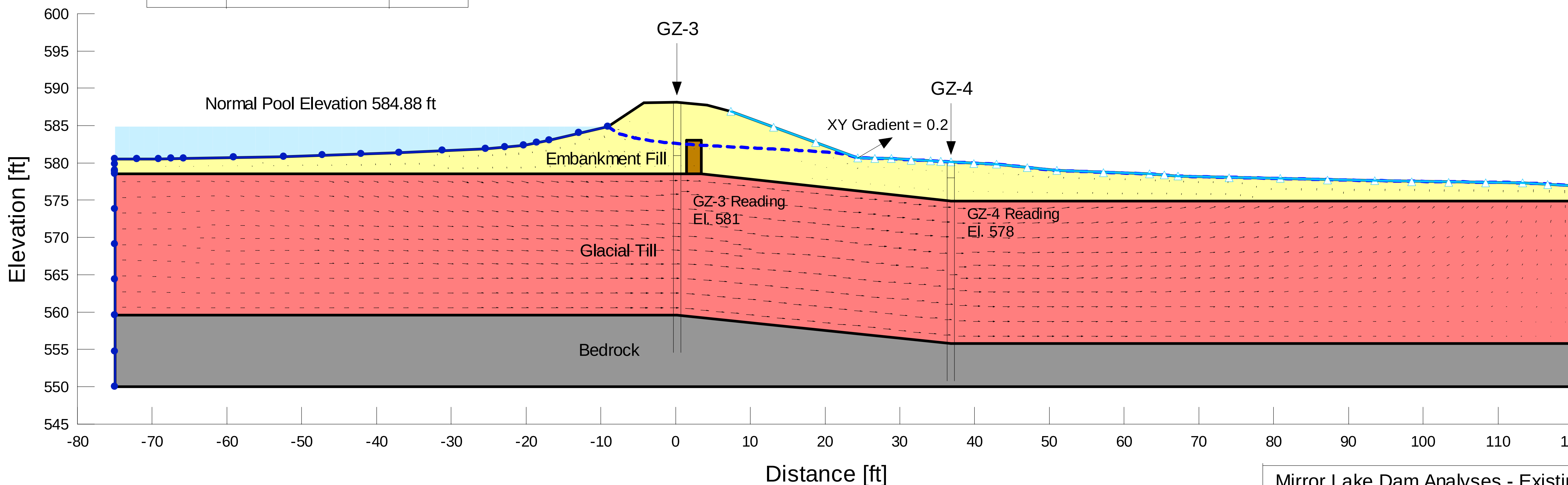
Strata	Selected ϕ Value
Embankment Fill	29 °
Fill	30 °
Glacial Till	38 °

APPENDIX H – EMBANKMENT SEEPAGE AND STABILITY CALCULATIONS

Seepage - Normal Pool Condition

Color	Name	Sat Kx (ft/d)
	Bedrock	0.0002
	Boulder Wall	0.02
	Embankment Fill	0.02
	Glacial Till	0.7

Color	Name	Category	Kind	Parameters
	Drainage	Hydraulic	Water Rate	0 ft³/d
	Upstream - Normal Pool	Hydraulic	Water Total Head	584.88 ft



\\gzaglast\jobs_46,000-46,499\46161.h61 University of Connecticut\46161-07.jfd\Calculations\Seep & Slope Model\

Mirror Lake Dam Analyses - Existing

Seepage Analyses
Normal Pool Level

PREPARED BY:
GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com

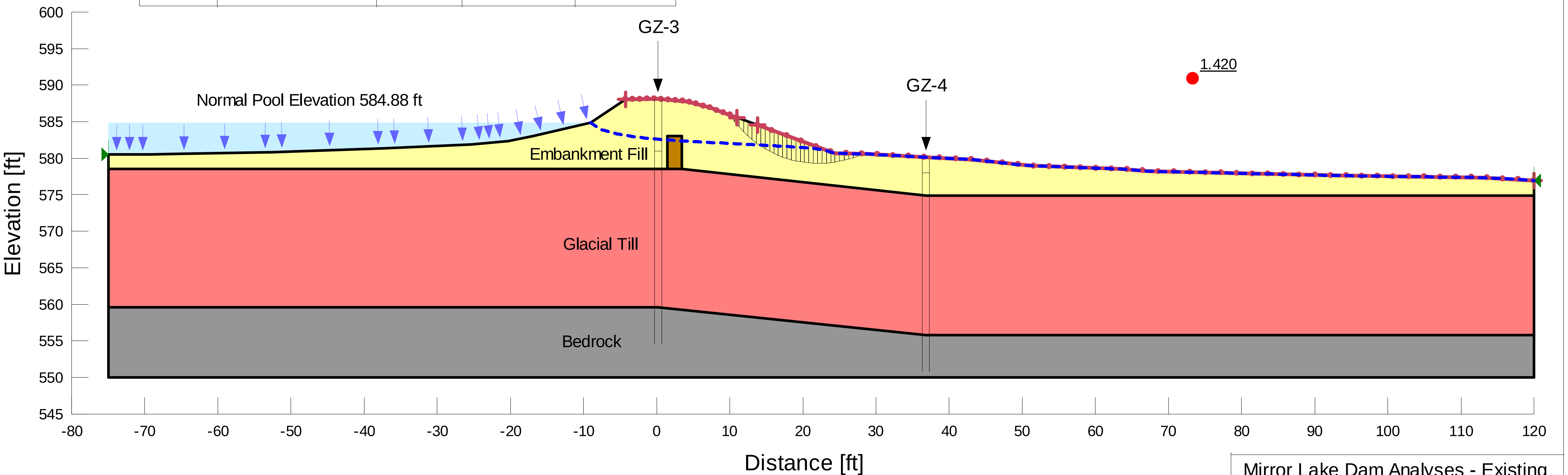
PREPARED FOR:
University of Connecticut
Storrs, Connecticut

PROJ MGR: JD | REVIEWED BY: JD
DESIGNED BY: EK | DRAWN BY: EK
DATE: 03/02/2021 | PROJECT NO.: 05.0046161.07

FIGURE
1

Slope Stability (D/S) - Normal Pool Condition

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Impenetrable material		
	Boulder Wall	130	0	35
	Embankment Fill	120	0	29
	Glacial Till	130	0	38



Mirror Lake Dam Analyses - Existing

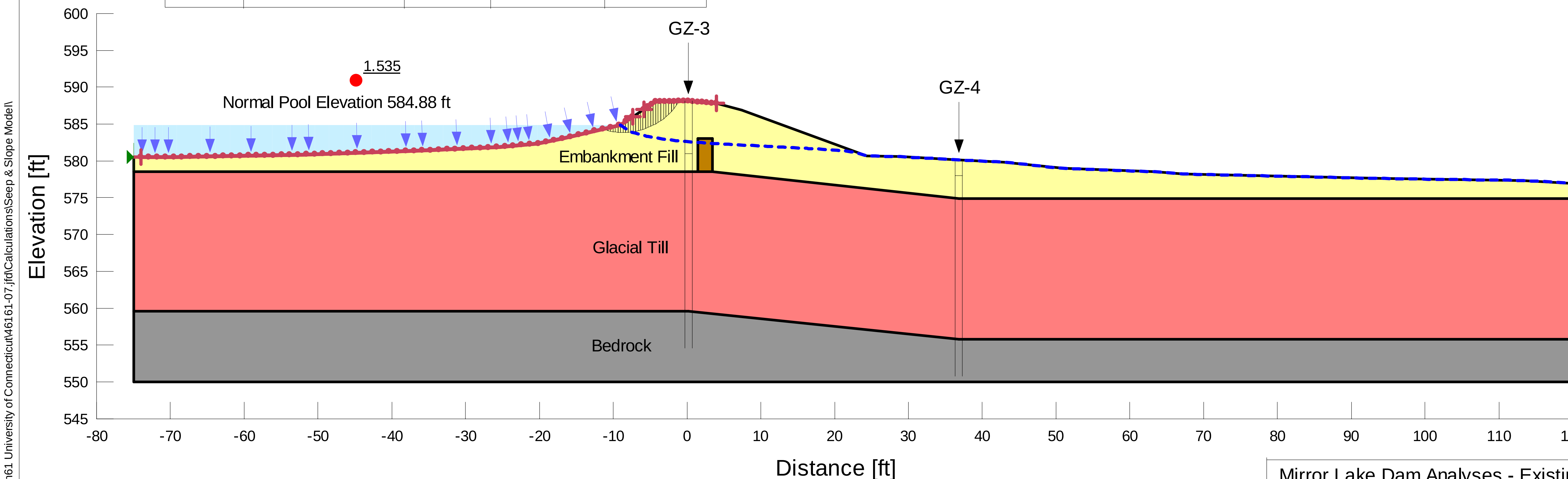
Downstream Slope Stability
Normal Pool Level

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com		PREPARED FOR: University of Connecticut Storrs, Connecticut
PROJ MGR: JD	REVIEWED BY: JD	FIGURE 2
DESIGNED BY: EK	DRAWN BY: EK	
DATE: 03/02/2021	PROJECT NO.: 05.0046161.07	

\\gzaglast\jobs_46,000-46,499\46161.h61 University of Connecticut\46161-07.jfd\Calculations\Seep & Slope Model\

Slope Stability (U/S) - Normal Pool Condition

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Impenetrable material		
	Boulder Wall	130	0	35
	Embankment Fill	120	0	29
	Glacial Till	130	0	38



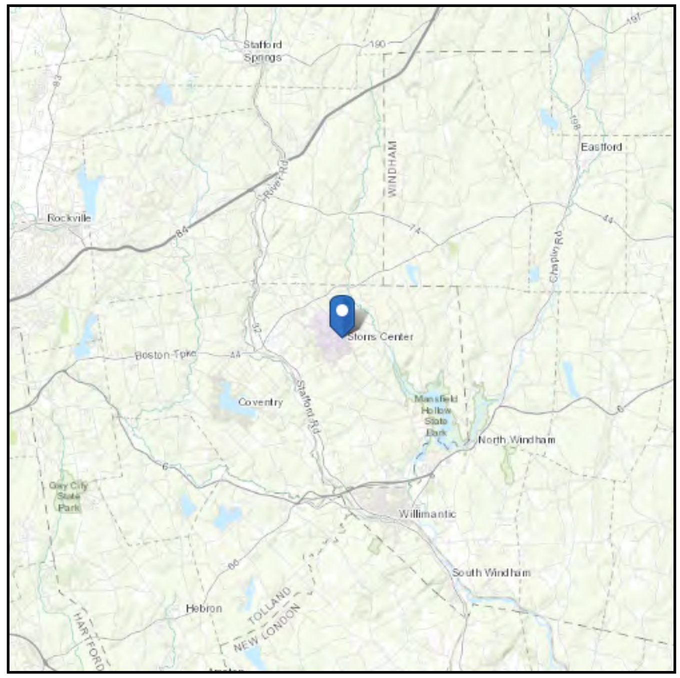
Mirror Lake Dam Analyses - Existing		
Upstream Slope Stability Normal Pool Level		
PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: University of Connecticut Storrs, Connecticut	
PROJ MGR: JD	REVIEWED BY: JD	FIGURE
DESIGNED BY: EK	DRAWN BY: EK	3
DATE: 03/02/2021	PROJECT NO.: 05.0046161.07	

ASCE 7 Hazards Report

Address:
No Address at This Location

Standard: ASCE/SEI 7-16
Risk Category: IV
Soil Class: D - Stiff Soil

Elevation: 583.7 ft (NAVD 88)
Latitude: 41.806997
Longitude: -72.247247



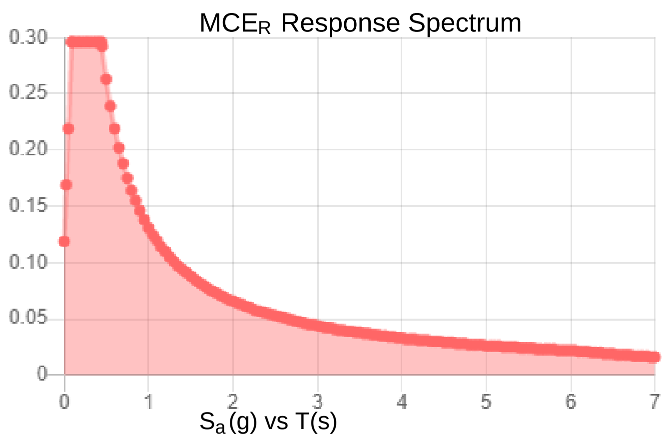
Seismic

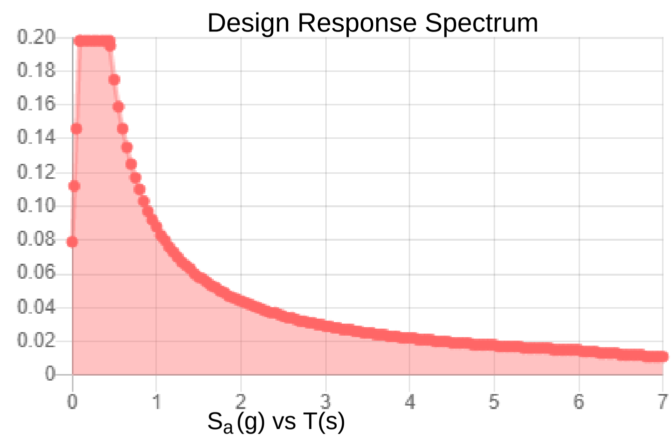
Site Soil Class: D - Stiff Soil

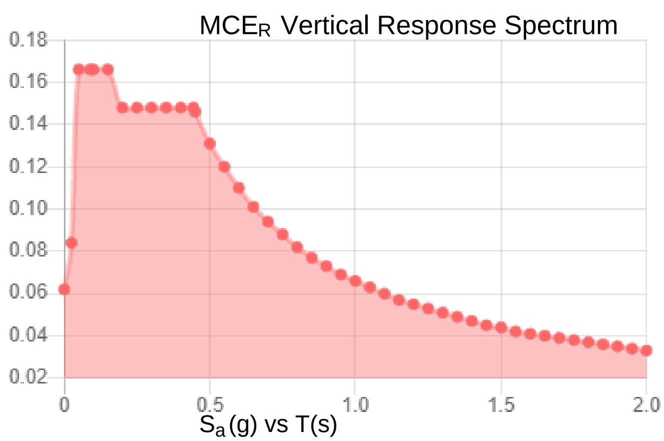
Results:

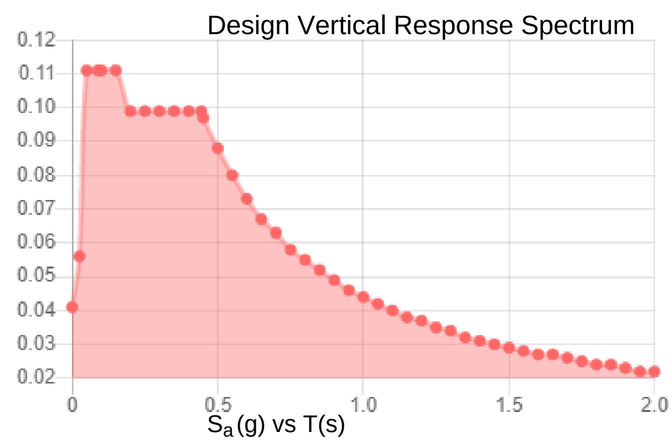
S_S :	0.185	S_{D1} :	0.088
S_1 :	0.055	T_L :	6
F_a :	1.6	PGA :	0.1
F_v :	2.4	PGA_M :	0.159
S_{MS} :	0.296	F_{PGA} :	1.6
S_{M1} :	0.131	I_e :	1.5
S_{DS} :	0.198	C_v :	0.7

Seismic Design Category C









Data Accessed: Thu Apr 01 2021

Date Source: USGS Seismic Design Maps based on ASCE/SEI 7-16 and ASCE/SEI 7-16 Table 1.5-2. Additional data for site-specific ground motion procedures in accordance with ASCE/SEI 7-16 Ch. 21 are available from USGS.

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Seismic Site Class Calculation Summary

Project:	Mirror Lake Dam	**Project No.:**	05.0046461.07
Location:	Storrs, Connecticut		
Calculated By:	EK	**Date:**	3/1/2021
Checked By:	JD	**Date:**	3/15/2021

OBJECTIVES: 1) Determine seismic site class in accordance with ASCE-7 2016 Standard
2) Using USGS "DesignMaps" application, determine seismic parameters for use in analysis including:
- Design peak ground acceleration (PGA_M) for use in pseudostatic slope stability analysis
- Accelerations and other seismic data for liquefaction analyses (if required)

3) Using the USGS interactive deaggregations, determine the appropriate earthquake magnitude for use in liquefaction analysis (if required).

INPUT: - Boring logs for test borings GZ-1, GZ-2, GZ-3, GZ-4 by GZA (2021).

PROCEDURES:

Table 20.3-1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard rock	>5,000 ft/s	NA	NA
B. Rock	2,500 to 5,000 ft/s	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50 blows/ft	>2,000 lb/ft^2
D. Stiff soil	600 to 1,200 ft/s	15 to 50 blows/ft	1,000 to 2,000 lb/ft^2
E. Soft clay soil	<600 ft/s	<15 blows/ft	<1,000 lb/ft^2
	Any profile with more than 10 ft of soil that has the following characteristics: — Plasticity index $PI > 20$, — Moisture content $w \geq 40\%$, — Undrained shear strength $\bar{s}_u < 500$ lb/ft^2		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

Note: For SI: 1 ft = 0.3048 m; 1 ft/s = 0.3048 m/s; 1 lb/ft^2 = 0.0479 kN/m^2.

Step 1 Develop the conceptual subsurface profile.

Step 2 Determine whether conditions are present that indicate Site Class F:
1. Soils vulnerable to potential failure (liquefiable soils, sensitive clays, weakly cemented soils)
2. Peats or highly organic clays greater than 10 feet in thickness
3. Thick layers (greater than 25 feet) of highly plastic clay (PI > 75)
4. Very thick soft/medium stiff clays (greater than 125 feet)

Step 3 Check for existence of greater than 10 feet of soft clay (where s_u < 500 psf, w > 40%, and PI > 20).
If these conditions are met, classify as Site Class E.

Step 4 Categorize the site using the following three methods:
- $\bar{v}_s$ method - $\bar{N}$ method - $\bar{s}_u$ method

If shear wave velocity data are available, they should be used to classify the site. The N and s_u methods should only be used if shear wave velocity data is not available, as the correlation between site amplification and these geotechnical parameters is more uncertain (and therefore more conservative) that the correlation with $\bar{v}_s$.

ASSUMPTIONS: The bottom SPT N-values for borings at depths less than 100 feet were assumed to carry through to full analysis depth.

RESULTS: Based on SPT data, site should be considered Site Class D (See attached calc sheets)

SPT-Based Seismic Site Class Calculation

Mirror Lake Dam - 05. 0046161.07
Storrs, Connecticut

Calculated By: EK   Date: 3/1/2021
Checked By: JD   Date: 3/15/2021

INPUT

Exploration ID: **GZ-1**   Ground Surface Elevation: 588   Depth of Boring: 26 ft

Depth to Bedrock: 26 ft

EQUATIONS

$$\bar{N} = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{m} \frac{d_i}{N_i}}$$

where: m = number of layers
d_i = the thickness of any soil or rock layer between 0 and 100 feet.
N_i = the Standard Penetration Resistance (ASTM D 1586) not to exceed 100 blows/ft as directly measured in the field without corrections.
Note: d_i calculated assuming breaks between sub-layers occur at the midpoint between SPT sample intervals (unless noted otherwise).

CALCULATION

Are peats or highly organic clays greater than 10 feet in thickness present? No
Are thick layers (greater than 25 feet) of highly plastic clay (PI > 75) present? No
Are very thick soft/medium stiff clays (greater than 125 feet) present? No
Is greater than 10 feet of soft clay (where s_u < 500 psf, $w \geq$ 40%, and PI > 20) present? No

$\bar{N}$ = 49.2   (Site Class D)

Soil Strata	SPT Interval Depth Top, ft	SPT Interval Depth Bottom, ft	SPT Elevation (mid-interval)	SPT N-value	d_i	d_i / N_i	Comments
Sand, Silt, Gravel	0.0	2.0	587.0	5	2.0	0.4	
	2.0	4.0	585.0	8	2.0	0.3	
	4.0	6.0	583.0	15	2.0	0.1	
	6.0	7.1	581.5	100	2.6	0.0	
	10.0	12.0	577.0	29	3.5	0.1	
	12.0	14.0	575.0	40	2.0	0.1	
	14.0	16.0	573.0	40	2.0	0.1	
	16.0	18.0	571.0	24	2.0	0.1	
	18.0	20.0	569.0	61	2.0	0.0	
	20.0	22.0	567.0	26	2.0	0.1	
	22.0	24.0	565.0	38	2.0	0.1	
	24.0	25.5	563.3	100	76.0	0.8	

DATA VALIDATION

Σd_i = 100.0

SPT-Based Seismic Site Class Calculation

Mirror Lake Dam - 05. 0046161.07
Storrs, Connecticut

Calculated By: EK Date: 3/1/2021
Checked By: JD Date: 3/15/2021

INPUT

Exploration ID: **GZ-2** Ground Surface Elevation: 582.9 Depth of Boring: 25 ft

Depth to Bedrock: 20 ft

EQUATIONS

$$\bar{N} = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{m} \frac{d_i}{N_i}}$$

where: m = number of layers
d_i = the thickness of any soil or rock layer between 0 and 100 feet.
N_i = the Standard Penetration Resistance (ASTM D 1586) not to exceed 100 blows/ft as directly measured in the field without corrections.
Note: d_i calculated assuming breaks between sub-layers occur at the midpoint between SPT sample intervals (unless noted otherwise).

CALCULATION

Are peats or highly organic clays greater than 10 feet in thickness present? No
Are thick layers (greater than 25 feet) of highly plastic clay (PI > 75) present? No
Are very thick soft/medium stiff clays (greater than 125 feet) present? No
Is greater than 10 feet of soft clay (where s_u < 500 psf, $w \geq$ 40%, and PI > 20) present? No

$\bar{N}$ = 40.6 (Site Class D)

Soil Strata	SPT Interval Depth Top, ft	SPT Interval Depth Bottom, ft	SPT Elevation (mid-interval)	SPT N-value	d_i	d_i / N_i	Comments
Sand, Silt, Gravel	0.0	2.0	581.9	16.0	2.0	0.1	
	2.0	4.0	579.9	3.0	2.0	0.7	
	4.0	6.0	577.9	5.0	2.0	0.4	
	6.0	8.0	575.9	43.0	2.0	0.0	
	8.0	10.0	573.9	40.0	2.0	0.1	
	10.0	12.0	571.9	21.0	2.0	0.1	
	12.0	14.0	569.9	45.0	2.0	0.0	
	14.0	16.0	567.9	53.0	2.0	0.0	
	16.0	16.9	566.5	100.0	1.5	0.0	
	18.0	19.5	564.2	84.0	82.6	1.0	

DATA VALIDATION

Σd_i = 100.0

SPT-Based Seismic Site Class Calculation

Mirror Lake Dam - 05. 0046161.07
Storrs, Connecticut

Calculated By: EK Date: 3/1/2021
Checked By: JD Date: 3/15/2021

INPUT

Exploration ID: **GZ-3** Ground Surface Elevation: 588.1 Depth of Boring: 34 ft

Depth to Bedrock: 29 ft

EQUATIONS

$$\bar{N} = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{m} \frac{d_i}{N_i}}$$

where: m = number of layers
d_i = the thickness of any soil or rock layer between 0 and 100 feet.
N_i = the Standard Penetration Resistance (ASTM D 1586) not to exceed 100 blows/ft as directly measured in the field without corrections.
Note: d_i calculated assuming breaks between sub-layers occur at the midpoint between SPT sample intervals (unless noted otherwise).

CALCULATION

Are peats or highly organic clays greater than 10 feet in thickness present? No
Are thick layers (greater than 25 feet) of highly plastic clay (PI > 75) present? No
Are very thick soft/medium stiff clays (greater than 125 feet) present? No
Is greater than 10 feet of soft clay (where s_u < 500 psf, $w \geq$ 40%, and PI > 20) present? No

$\bar{N}$ = 26.9 (Site Class D)

Soil Strata	SPT Interval Depth		SPT Elevation	SPT N-value	d_i	d_i / N_i	Comments
	Top, ft	Bottom, ft	(mid-interval)				
Sand, Silt, Gravel	0.0	2.0	587.1	4	2.0	0.5	
	2.0	4.0	585.1	5	2.0	0.4	
	4.0	6.0	583.1	6	2.0	0.3	
	6.0	8.0	581.1	8	2.0	0.3	
	8.0	10.0	579.1	4	2.0	0.5	
	10.0	12.0	577.1	50	2.0	0.0	
	12.0	14.0	575.1	59	2.0	0.0	
	14.0	16.0	573.1	54	2.0	0.0	
	16.0	18.0	571.1	46	2.0	0.0	
	18.0	20.0	569.1	32	2.0	0.1	
	20.0	22.0	567.1	100	3.0	0.0	
	24.0	25.7	563.3	52	3.2	0.1	
	26.7	27.7	560.9	52	73.8	1.4	

DATA VALIDATION

Σd_i = 100.0

SPT-Based Seismic Site Class Calculation

Mirror Lake Dam - 05. 0046161.07
Storrs, Connecticut

Calculated By: EK Date: 3/1/2021
Checked By: JD Date: 3/15/2021

INPUT

Exploration ID: **GZ-4** Ground Surface Elevation: 579.9 Depth of Boring: 29 ft

Depth to Bedrock: 24 ft

EQUATIONS

$$\bar{N} = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{m} \frac{d_i}{N_i}}$$

where: m = number of layers
d_i = the thickness of any soil or rock layer between 0 and 100 feet.
N_i = the Standard Penetration Resistance (ASTM D 1586) not to exceed 100 blows/ft as directly measured in the field without corrections.
Note: d_i calculated assuming breaks between sub-layers occur at the midpoint between SPT sample intervals (unless noted otherwise).

CALCULATION

Are peats or highly organic clays greater than 10 feet in thickness present? No
Are thick layers (greater than 25 feet) of highly plastic clay (PI > 75) present? No
Are very thick soft/medium stiff clays (greater than 125 feet) present? No
Is greater than 10 feet of soft clay (where s_u < 500 psf, $w \geq$ 40%, and PI > 20) present? No

$\bar{N}$ = 54.8 (Site Class C)

Soil Strata	SPT Interval Depth Top, ft	Bottom, ft	SPT Elevation (mid-interval)	SPT N-value	d_i	d_i / N_i	Comments
Sand, Silt, Gravel	0.0	2.0	578.9	5	2.0	0.4	
	2.0	4.0	576.9	18	2.0	0.1	
	4.0	6.0	574.9	25	2.0	0.1	
	6.0	8.0	572.9	30	2.0	0.1	
	8.0	10.0	570.9	31	2.0	0.1	
	10.0	12.0	568.9	22	2.0	0.1	
	12.0	14.0	566.9	28	2.0	0.1	
	14.0	16.0	564.9	28	2.0	0.1	
	16.0	18.0	562.9	45	2.0	0.0	
	18.0	19.8	561.0	84	1.9	0.0	
	20.0	20.9	559.5	100	1.6	0.0	
	22.0	22.9	557.5	100	2.0	0.0	
	24.0	24.1	555.9	100	76.6	0.8	

DATA VALIDATION

Σd_i = 100.0

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SPT-Based Liquefaction Susceptibility Calculation

Project:	Mirror Lake Dam	**Project No:**	05.0046161.07
Location:	Storrs, Connecticut		
Calculated By:	EK	**Date:**	3/30/2021
Checked By:	JD	**Date:**	3/30/2021

PURPOSE: Estimate exploration-specific factor of safety against liquefaction.

REFERENCES:

1. Idriss, I.M. and Boulanger, R.W. (2014). *CPT and SPT Based Liquefaction Triggering Procedures.* Center for Geotechnical Modeling, University of California at Davis. Report No. UCD/CGM-14/01.

2. Idriss, I.M. and Boulanger, R.W. (2004). Semi-Empirical Procedures for Evaluating Liquefaction Potential During Earthquakes. Proceedings of the Joint International Conference on Soil Dynamics & Earthquake Engineering and International Conference on Earthquake Geotechnical Engineering. Berkeley, California. January, 2004. pp.32-56.

INSTRUCTIONS:

1. Create and modify calculation worksheet tabs to accommodate number of borings and depths.
2. Enter input parameters for each boring in shaded fields.
3. Input data from boring (depths, N, estimated fines content, and interpreted soil strata).
4. Add summary of results below.

INPUT PARAMETERS:

1. Use boring logs GZ-1 through GZ-4 for subsurface and drilling data.
2. Use site-adjusted PGA_M based on 2014 seismic data from USGS, adjusted for Site Class D.
3. Use assumed M = 6.0 (USGS deaggregation of seismic data for magnitude versus distance from site indicates that this value is slightly conservative, as mean value for ±2500 year return period is M = 5.49)

SUMMARY OF RESULTS:

1. Analyses indicate that the downstream embankment fill soils encountered are not susceptible to liquefaction.

SPT-Based Liquefaction Factor of Safety Calculation

Calculated By: EK Date: 3/30/2021
Checked By: JD Date: 3/30/2021

Project Name: Mirror Lake Dam
Project Location: Storrs, Connecticut
Project Number: 05.0046161.07
Calculations Reference: Idriss & Boulanger (2014)

Exploration ID: **GZ-1**

Elevation Data (at time of drilling):
Ground Surface Elevation: 588.0
Groundwater Elevation: 581.0
Groundwater Depth (ft): 7.0
Unit Weight of Water (pcf): 62.4

Drilling Data:
Typical rod stickup during SPT: 4 ft
Typical rod stickup during SPT: 1.219 m
Borehole Diameter: 4 in

Material Properties:
Assumed Soil Weight Above Water Table, γ = 120 pcf
Assumed Soil Weight Below Water Table, γ_{sat} = 125 pcf
Atmospheric Pressure, P_a = 2089 psf

Seismic Assumptions (API Preliminary):
Max Accel at Surface, a_{max} (g)= 0.159
Design Earthquake Magnitude, M = 6.00
Is void redistribution significant? No
Earthquake Return Period (yrs) >2500

Design Ground Surface Elevation: 589.1
Design Groundwater Elevation: 581.0
Design Groundwater Depth (ft): 8.1
Thickness of New Fill (ft): 1.1
Thickness of New Fill (m): 0.3
Assumed Soil Weight New Fill, γ = 125 pcf

SPT Correction Factors:
Split Spoon Type: I.D.=1-3/8 in - Standard Sampler
Hammer Type: Auto Hammer

Subsurface Data and Parameter Calculations

Depth (mid-SPT interval)	Elev.	Depth	Total Stress, σ_v	Effective Stress, σ'_v	N_{field}	Flags	Hammer Energy Ratio, ER	C_E	C_R	C_B	C_s	N_{60}	C_N	$(N_1)_{60}$	Fines Content	K_0	ΔN	$(N_1)_{60CS}$	$(N_1)_{60-sr}$
ft	ft	m	psf	psf	blows/ft		%					blows/ft		blows/ft	%		blows/ft	blows/ft	blows/ft
1	587.0	0.30	120	120	5	Unsaturated	60	1.00	0.75	1.00	1.00	4	1.70	6	40	0.50	6	12	10
3	585.0	0.91	360	360	8	Unsaturated	60	1.00	0.75	1.00	1.00	6	1.70	10	40	0.50	6	16	13
5	583.0	1.52	600	600	15	Unsaturated	60	1.00	0.75	1.00	1.00	11	1.70	19	40	0.50	6	25	22
6.55	581.5	2.00	786	786	100	Unsaturated	60	1.00	0.80	1.00	1.00	80	1.07	86	25	0.50	5	91	88
11	577.0	3.35	1340	1090	29		60	1.00	0.85	1.00	1.00	25	1.26	31	25	0.50	5	36	33
13	575.0	3.96	1590	1216	40		60	1.00	0.85	1.00	1.00	34	1.18	40	25	0.50	5	45	42
15	573.0	4.57	1840	1341	40		60	1.00	0.85	1.00	1.00	34	1.14	39	25	0.50	5	44	41
17	571.0	5.18	2090	1466	24		60	1.00	0.95	1.00	1.00	23	1.15	26	25	0.50	5	31	28
19	569.0	5.79	2340	1591	61		60	1.00	0.95	1.00	1.00	58	1.05	61	25	0.50	5	66	63
21	567.0	6.40	2590	1716	26		60	1.00	0.95	1.00	1.00	25	1.08	27	25	0.50	5	32	29
23	565.0	7.01	2840	1842	38		60	1.00	0.95	1.00	1.00	36	1.04	38	25	0.50	5	43	40
24.75	563.3	7.54	3059	1951	100		60	1.00	0.95	1.00	1.00	95	1.00	95	25	0.50	5	100	97

Capacity/Demand Ratio (Factor of Safety) Calculations / **Vertical Settlement**

Depth (mid-SPT interval)	CRR (M=7.5, σ = 1 atm)	MSF_{max}	MSF	C_σ	K_σ	Q	α	a	b	c	ξ_R	K_α	CRR (M, σ, α)	r_d	Design Total Stress, σ_v	Design Effective Stress, σ'_v	CSR	F_s	Post-Liquef. Shear Strength	Layer Thickness	F_α	γ_{lim}	γ_{max}	Vertical reconsol Strain, ε_v	ΔSi
ft						[for Kα]	[for Kα]	[for Kα]	[for Kα]	[for Kα]	[for Kα]				psf	psf			psf	ft				ft	in
1	0.13	1.13	1.08	0.08	1.10	10	0.25	0.48	0.12	0.21	-0.52	1.89	0.30	1.00	258	258	0.10	**5.0**		2.0	0.86	0.38	0.000	0.000	0.00
3	0.16	1.19	1.12	0.09	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	0.50	0.99	498	498	0.10	**5.0**		2.0	0.72	0.25	0.000	0.000	0.00
5	0.28	1.46	1.28	0.13	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	1.00	0.98	738	738	0.10	**5.0**		1.8	0.25	0.09	0.000	0.000	0.00
6.55	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.97	924	924	0.10	**5.0**		3.0	-5.21	0.00	0.000	0.000	0.00
11	1.42	2.06	1.64	0.21	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	6.47	0.95	1478	1228	0.12	**5.0**		3.2	-0.52	0.02	0.000	0.000	0.00
13	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.93	1728	1353	0.12	**5.0**		2.0	-1.19	0.00	0.000	0.000	0.00
15	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.92	1978	1478	0.13	**5.0**		2.0	-1.11	0.00	0.000	0.000	0.00
17	0.58	1.78	1.47	0.17	1.06	10	0.25	0.48	0.12	0.21	-0.60	2.52	2.27	0.91	2228	1604	0.13	**5.0**		2.0	-0.17	0.04	0.000	0.000	0.00
19	4.13	2.20	1.72	0.30	1.08	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.42	0.89	2478	1729	0.13	**5.0**		2.0	-2.94	0.00	0.000	0.000	0.00
21	0.62	1.81	1.49	0.17	1.03	10	0.25	0.48	0.12	0.21	-0.60	2.52	2.39	0.88	2728	1854	0.13	**5.0**		2.0	-0.21	0.04	0.000	0.000	0.00
23	4.13	2.20	1.72	0.30	1.04	10	0.25	0.48	0.12	0.21	-0.60	2.52	18.63	0.86	2978	1979	0.13	**5.0**		1.9	-1.00	0.00	0.000	0.000	0.00
24.75	4.13	2.20	1.72	0.30	1.02	10	0.25	0.48	0.12	0.21	-0.60	2.52	18.32	0.85	3196	2089	0.13	**5.0**		0.9	-6.10	0.00	0.000	0.000	0.00

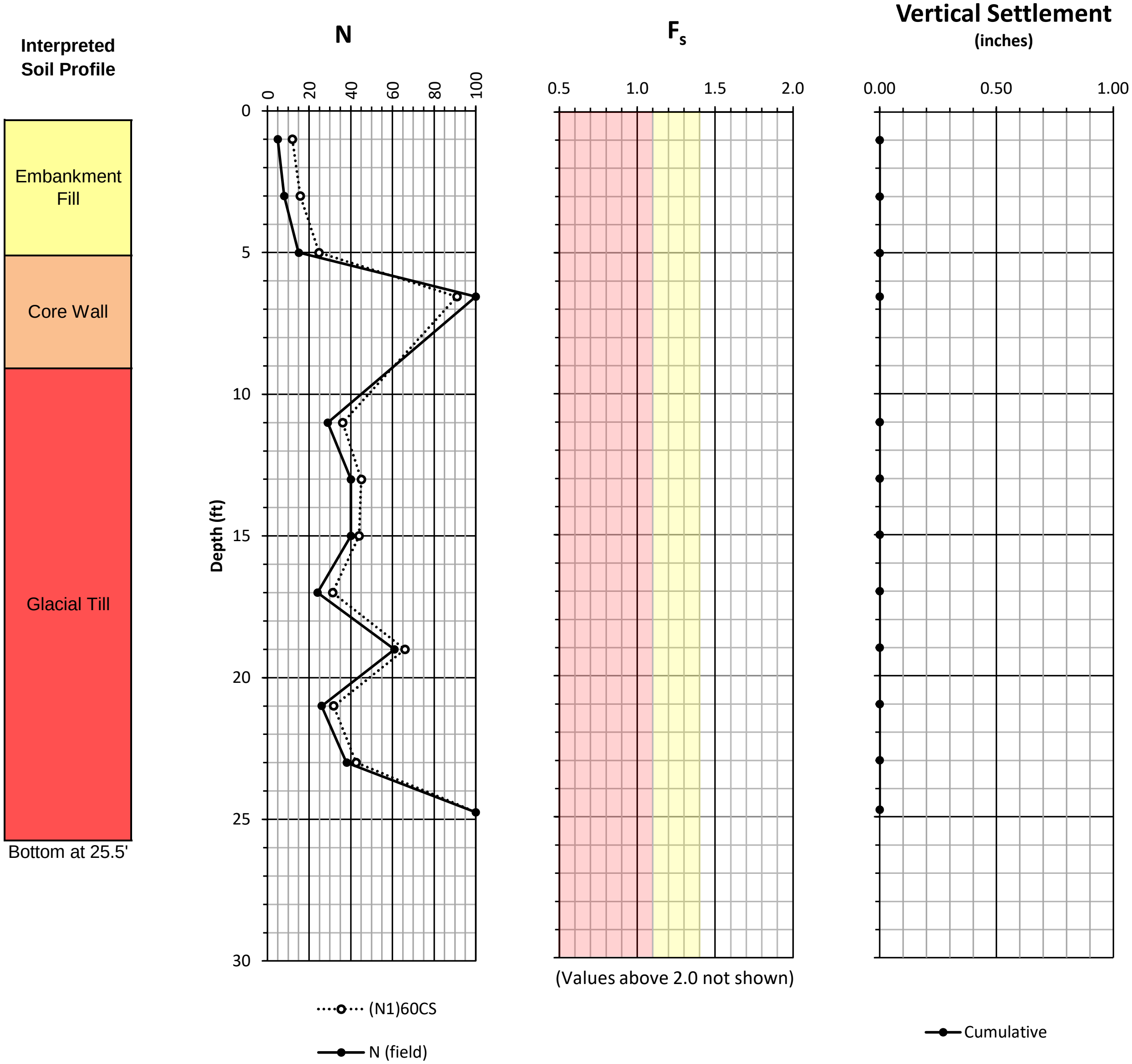
Notes:
1. Factor of safety calculations limited to 5.0. Actual FS may be greater but shown as 5.0.
2. Factor of safety presented as 5.0 for Unsaturated and Silt/Clay soils; not calculated.
3. Ground surface elevation obtained from boring logs
4. Fines content was conservatively estimated based on low end of range for soil description provided on log where laboratory test results were not available.

Indicates factors of safety < 1.1, where liquefaction is likely
Indicates factors of safety ≥ 1.1 but < 1.4, where settlement due to cyclic strain softening is possible

Liquefaction Depth Profiles

GZ-1

Interpreted Soil Profile



Notes/Comments

1) FS > 1.4 indicate liquefaction not likely

SPT-Based Liquefaction Factor of Safety Calculation

Calculated By: EK   Date: 3/30/2021
Checked By: JD   Date: 3/30/2021

Project Name: Mirror Lake Dam
Project Location: Storrs, Connecticut
Project Number: 05.0046161.07
Calculations Reference: Idriss & Boulanger (2014)

Exploration ID: GZ-2

Elevation Data (at time of drilling):
Ground Surface Elevation: 582.9
Groundwater Elevation: 579.7
Groundwater Depth (ft): 3.3
Unit Weight of Water (pcf): 62.4

Drilling Data:
Typical rod stickup during SPT: 4 ft
Typical rod stickup during SPT: 1.2192 m
Borehole Diameter: 4 in

Material Properties:
Assumed Soil Weight Above Water Table, γ = 120 pcf
Assumed Soil Weight Below Water Table, γ_{sat} = 125 pcf
Atmospheric Pressure, P_a = 2089 psf

Seismic Assumptions (API Preliminary):
Max Accel at Surface, a_{max} (g)= 0.159
Design Earthquake Magnitude, M = 6.00
Is void redistribution significant? No
Earthquake Return Period (yrs) >2500

Design Ground Surface Elevation: 582.9
Design Groundwater Elevation: 579.7
Design Groundwater Depth (ft): 3.3
Thickness of New Fill (ft): 0.0
Thickness of New Fill (m): 0.0
Assumed Soil Weight New Fill, γ = 125 pcf

SPT Correction Factors:
Split Spoon Type: I.D.=1-3/8 in - Standard Sampler
Hammer Type: Auto Hammer

Subsurface Data and Parameter Calculations

Depth (mid-SPT interval)	Elev.	Depth	Total Stress, σ_v	Effective Stress, σ'_v	N_{field}	Flags	Hammer Energy Ratio, ER	C_E	C_R	C_B	C_s	N_{60}	C_N	$(N_1)_{60}$	Fines Content	K_0	ΔN	$(N_1)_{60CS}$	$(N_1)_{60-sr}$
ft	ft	m	psf	psf	blows/ft		%					blows/ft		blows/ft	%		blows/ft	blows/ft	blows/ft
1	581.9	0.30	120	120	16	Unsaturated	60	1.00	0.75	1.00	1.00	12	1.70	20	40	0.50	6	26	24
3	579.9	0.91	360	360	3	Unsaturated	60	1.00	0.75	1.00	1.00	2	1.70	4	40	0.50	6	9	7
5	577.9	1.52	609	500	5		60	1.00	0.75	1.00	1.00	4	1.70	6	40	0.50	6	12	10
7	575.9	2.13	859	625	43		60	1.00	0.80	1.00	1.00	34	1.36	47	25	0.50	5	52	49
9	573.9	2.74	1109	750	40		60	1.00	0.80	1.00	1.00	32	1.33	43	25	0.50	5	48	45
11	571.9	3.35	1359	875	21		60	1.00	0.85	1.00	1.00	18	1.41	25	25	0.50	5	30	27
13	569.9	3.96	1609	1000	45		60	1.00	0.85	1.00	1.00	38	1.21	46	25	0.50	5	51	48
15	567.9	4.57	1859	1126	53		60	1.00	0.85	1.00	1.00	45	1.15	52	25	0.50	5	57	54
16.45	566.5	5.01	2040	1216	100		60	1.00	0.95	1.00	1.00	95	1.02	97	25	0.50	5	102	99
18.8	564.1	5.73	2334	1363	84		60	1.00	0.95	1.00	1.00	80	1.04	83	25	0.50	5	88	85

Capacity/Demand Ratio (Factor of Safety) Calculations / **Post-Liquef. Shear Strength** / **Vertical Settlement**

Depth (mid-SPT interval)	CRR (M=7.5, σ = 1 atm)	MSF_{max}	MSF	C_σ	K_σ	Q	α	a	b	c	ξ_R	K_α	CRR (M, σ, α)	r_d	Design Total Stress, σ_v	Design Effective Stress, σ'_v	CSR	F_s	Post-Liquef. Shear Strength	Layer Thickness	F_α	γ_{lim}	γ_{max}	Vertical reconsol Strain, ε_v	ΔSi
ft						[for Kα]	[for Kα]	[for Kα]	[for Kα]	[for Kα]	[for Kα]				psf	psf			psf	ft				ft	in
1	0.32	1.51	1.31	0.14	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	1.14	1.00	120	120	0.10	**5.0**		2.0	0.17	0.08	0.000	0.000	0.00
3	0.11	1.10	1.06	0.07	1.10	10	0.25	0.48	0.12	0.21	-0.42	1.33	0.18	1.00	360	360	0.10	**5.0**		2.0	0.93	0.51	0.000	0.000	0.00
5	0.13	1.13	1.08	0.08	1.10	10	0.25	0.48	0.12	0.21	-0.50	1.72	0.27	0.99	609	500	0.12	**2.2**		2.0	0.86	0.38	0.000	0.000	0.00
7	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.98	859	625	0.14	**5.0**		2.0	-1.75	0.00	0.000	0.000	0.00
9	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.96	1109	750	0.15	**5.0**		2.0	-1.41	0.00	0.000	0.000	0.00
11	0.51	1.73	1.44	0.16	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	2.02	0.95	1359	875	0.15	**5.0**		2.0	-0.11	0.04	0.000	0.000	0.00
13	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.94	1609	1000	0.16	**5.0**		2.0	-1.71	0.00	0.000	0.000	0.00
15	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.93	1859	1126	0.16	**5.0**		1.0	-2.17	0.00	0.000	0.000	0.00
16.45	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.92	2040	1216	0.16	**5.0**		1.5	-6.22	0.00	0.000	0.000	0.00
18.8	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.90	2334	1363	0.16	**5.0**		2.4	-4.92	0.00	0.000	0.000	0.00

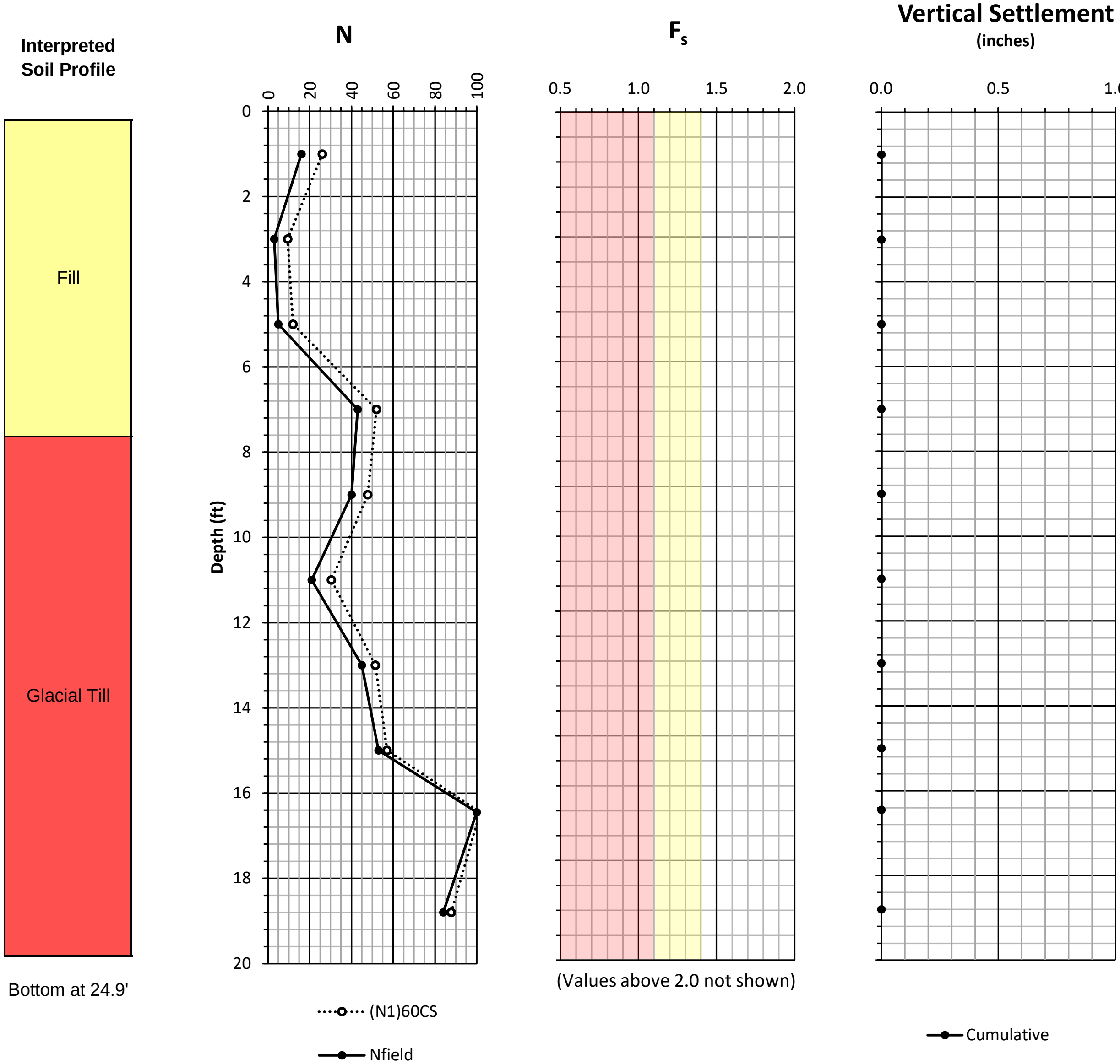
Notes:
1. Factor of safety calculations limited to 5.0. Actual FS may be greater but shown as 5.0.
2. Factor of safety presented as 5.0 for Unsaturated and Silt/Clay soils; not calculated.
3. Ground surface elevation obtained from boring logs
4. Fines content was conservatively estimated based on low end of range for soil description provided on log where laboratory test results were not available.

Indicates factors of safety < 1.1, where liquefaction is likely
Indicates factors of safety $\geq$ 1.1 but < 1.4, where settlement due to cyclic strain softening is possible

Liquefaction Depth Profiles

GZ-2

Interpreted Soil Profile



Bottom at 24.9'

(Values above 2.0 not shown)

Notes/Comments

1) FS > 1.4 indicate liquefaction not likely

SPT-Based Liquefaction Factor of Safety Calculation

Calculated By: EK   Date: 3/30/2021
Checked By: JD   Date: 3/30/2021

Project Name: Mirror Lake Dam
Project Location: Storrs, Connecticut
Project Number: 05.0046161.07
Calculations Reference: Idriss & Boulanger (2014)

Exploration ID: GZ-3

Elevation Data (at time of drilling):
Ground Surface Elevation: 588.1
Groundwater Elevation: 581.0
Groundwater Depth (ft): 7.1
Unit Weight of Water (pcf): 62.4

Drilling Data:
Typical rod stickup during SPT: 4 ft
Typical rod stickup during SPT: 1.2192 m
Borehole Diameter: 4 in

Material Properties:
Assumed Soil Weight Above Water Table, γ = 120 pcf
Assumed Soil Weight Below Water Table, γ_{sat} = 125 pcf
Atmospheric Pressure, P_a = 2089 psf

Seismic Assumptions (API Preliminary):
Max Accel at Surface, a_{max} (g)= 0.159
Design Earthquake Magnitude, M = 6.00
Is void redistribution significant? No
Earthquake Return Period (yrs) >2500

Design Ground Surface Elevation: 589.1
Design Groundwater Elevation: 581.0
Design Groundwater Depth (ft): 8.1
Thickness of New Fill (ft): 1.0
Thickness of New Fill (m): 0.3
Assumed Soil Weight New Fill, γ = 125 pcf

SPT Correction Factors:
Split Spoon Type: I.D.=1-3/8 in - Standard Sampler
Hammer Type: Auto Hammer

Subsurface Data and Parameter Calculations

Depth (mid-SPT interval) (ft)	Elev. (ft)	Depth (m)	Total Stress, σ_v (psf)	Effective Stress, σ'_v (psf)	N_{field} (blows/ft)	Flags	Hammer Energy Ratio, ER (%)	C_E	C_R	C_B	C_s	N_{60} (blows/ft)	C_N	$(N_1)_{60}$ (blows/ft)	Fines Content (%)	K_0	ΔN (blows/ft)	$(N_1)_{60CS}$ (blows/ft)	$(N_1)_{60-sr}$ (blows/ft)
1	587.1	0.30	120	120	4	Unsaturated	60	1.00	0.75	1.00	1.00	3	1.70	5	45	0.50	6	11	9
3	585.1	0.91	360	360	5	Unsaturated	60	1.00	0.75	1.00	1.00	4	1.70	6	45	0.50	6	12	10
5	583.1	1.52	600	600	6	Unsaturated	60	1.00	0.75	1.00	1.00	5	1.70	8	45	0.50	6	13	11
7	581.1	2.13	840	840	8		60	1.00	0.80	1.00	1.00	6	1.63	10	45	0.50	6	16	14
9	579.1	2.74	1090	971	4		60	1.00	0.80	1.00	1.00	3	1.60	5	45	0.50	6	11	9
11	577.1	3.35	1340	1096	50		60	1.00	0.85	1.00	1.00	43	1.17	50	20	0.50	4	54	51
13	575.1	3.96	1590	1221	59		60	1.00	0.85	1.00	1.00	50	1.12	56	20	0.50	4	61	58
15	573.1	4.57	1840	1347	54		60	1.00	0.85	1.00	1.00	46	1.11	51	20	0.50	4	55	53
17	571.1	5.18	2090	1472	46		60	1.00	0.95	1.00	1.00	44	1.09	48	20	0.50	4	52	49
19	569.1	5.79	2340	1597	32		60	1.00	0.95	1.00	1.00	30	1.10	33	20	0.50	4	38	35
20.7	567.4	6.31	2552	1703	100		60	1.00	0.95	1.00	1.00	95	1.01	96	20	0.50	4	100	97
24.85	563.3	7.57	3071	1963	52		60	1.00	0.95	1.00	1.00	49	1.02	50	20	0.50	4	55	52
26.85	561.3	8.18	3321	2088	52		60	1.00	0.95	1.00	1.00	49	1.00	49	20	0.50	4	54	51

Capacity/Demand Ratio (Factor of Safety) Calculations

Depth (ft)	CRR (M=7.5, σ = 1 atm)	MSF_{max}	MSF	C_σ	K_σ	Q [for Kα]	α [for Kα]	a [for Kα]	b [for Kα]	c [for Kα]	ξ_R [for Kα]	K_α	CRR (M, σ, α)	r_d	Design Total Stress, σ_v (psf)	Design Effective Stress, σ'_v (psf)	CSR	**F_s**	**Post-Liquef. Shear Strength (psf)**
1	0.12	1.12	1.07	0.08	1.10	10	0.25	0.48	0.12	0.21	-0.48	1.65	0.24	1.00	245	245	0.10	**5.0**	
3	0.13	1.13	1.08	0.08	1.10	10	0.25	0.48	0.12	0.21	-0.50	1.75	0.28	0.99	485	485	0.10	**5.0**	
5	0.14	1.15	1.09	0.08	1.10	10	0.25	0.48	0.12	0.21	-0.53	1.93	0.33	0.98	725	725	0.10	**5.0**	
7	0.17	1.20	1.12	0.09	1.09	10	0.25	0.48	0.12	0.21	-0.59	2.45	0.49	0.97	965	965	0.10	**4.9**	
9	0.12	1.12	1.07	0.08	1.06	10	0.25	0.48	0.12	0.21	-0.45	1.46	0.20	0.96	1215	1096	0.11	**1.9**	
11	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.95	1465	1221	0.12	**5.0**	
13	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.93	1715	1346	0.12	**5.0**	
15	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.92	1965	1472	0.13	**5.0**	
17	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.91	2215	1597	0.13	**5.0**	
19	2.15	2.20	1.72	0.24	1.06	10	0.25	0.48	0.12	0.21	-0.60	2.52	9.93	0.89	2465	1722	0.13	**5.0**	
20.7	4.13	2.20	1.72	0.30	1.06	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.05	0.88	2677	1828	0.13	**5.0**	
24.85	4.13	2.20	1.72	0.30	1.02	10	0.25	0.48	0.12	0.21	-0.60	2.52	18.29	0.85	3196	2088	0.13	**5.0**	
26.85	4.13	2.20	1.72	0.30	1.00	10	0.25	0.48	0.12	0.21	-0.60	2.52	17.96	0.84	3446	2213	0.13	**5.0**	

Vertical Settlement

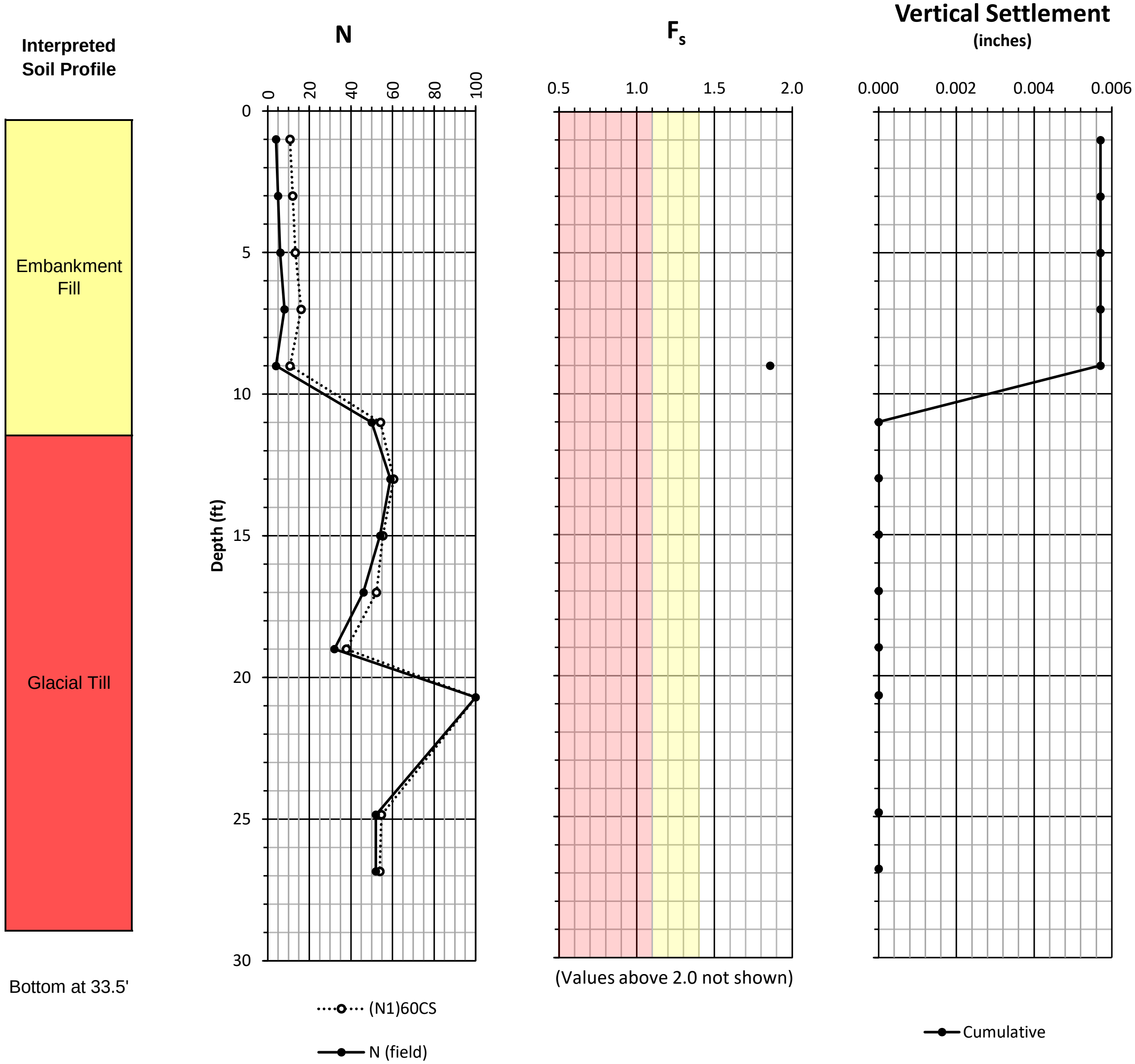
Depth (ft)	Layer Thickness (ft)	F_α	γ_{lim}	γ_{max}	Vertical reconsol Strain, ε_v (ft)	ΔSi (in)
1	2.0	0.90	0.44	0.000	0.000	0.01
3	2.0	0.86	0.38	0.000	0.000	0.01
5	2.0	0.82	0.33	0.000	0.000	0.01
7	2.0	0.71	0.25	0.000	0.000	0.01
9	2.0	0.90	0.44	0.001	0.000	0.01
11	2.0	-1.93	0.00	0.000	0.000	0.00
13	2.0	-2.47	0.00	0.000	0.000	0.00
15	2.0	-2.03	0.00	0.000	0.000	0.00
17	2.0	-1.77	0.00	0.000	0.000	0.00
19	1.9	-0.64	0.01	0.000	0.000	0.00
20.7	2.9	-6.08	0.00	0.000	0.000	0.00
24.85	3.1	-1.97	0.00	0.000	0.000	0.00
26.85	1.0	-1.91	0.00	0.000	0.000	0.00

Notes:
1. Factor of safety calculations limited to 5.0. Actual FS may be greater but shown as 5.0.
2. Factor of safety presented as 5.0 for Unsaturated and Silt/Clay soils; not calculated.
3. Ground surface elevation obtained from boring logs
4. Fines content was conservatively estimated based on low end of range for soil description provided on log where laboratory test results were not available.

Indicates factors of safety < 1.1, where liquefaction is likely
Indicates factors of safety $\geq$ 1.1 but < 1.4, where settlement due to cyclic strain softening is possible

Liquefaction Depth Profiles

GZ-3



Notes/Comments

1) FS > 1.4 indicate liquefaction not likely

SPT-Based Liquefaction Factor of Safety Calculation

Project Name: Mirror Lake Dam
Project Location: Storrs, Connecticut
Project Number: 05.0046161.07
Calculations Reference: Idriss & Boulanger (2014)

Calculated By: EK Date: 3/30/2021
Checked By: JD Date: 3/30/2021

Exploration ID: **GZ-4**

Elevation Data (at time of drilling):
Ground Surface Elevation: 579.9
Groundwater Elevation: 578.0
Groundwater Depth (ft): 1.9
Unit Weight of Water (pcf): 62.4

Drilling Data:
Typical rod stickup during SPT: 4 ft
Typical rod stickup during SPT: 1.2192 m
Borehole Diameter: 4 in

Material Properties:
Assumed Soil Weight Above Water Table, γ = 120 pcf
Assumed Soil Weight Below Water Table, γ_{sat} = 125 pcf
Atmospheric Pressure, P_a = 2089 psf

Seismic Assumptions (API Preliminary):
Max Accel at Surface, a_{max} (g)= 0.159
Design Earthquake Magnitude, M = 6.00
Is void redistribution significant? No
Earthquake Return Period (yrs) >2500

Design Ground Surface Elevation: 579.9
Design Groundwater Elevation: 578.0
Design Groundwater Depth (ft): 1.9
Thickness of New Fill (ft): 0.0
Thickness of New Fill (m): 0.0
Assumed Soil Weight New Fill, γ = 125 pcf

SPT Correction Factors:
Split Spoon Type: I.D.=1-3/8 in - Standard Sampler
Hammer Type: Auto Hammer

Subsurface Data and Parameter Calculations

Depth (mid-SPT interval)	Elev.	Depth	Total Stress, σ_v	Effective Stress, σ'_v	N_{field}	Flags	Hammer Energy Ratio, ER	C_E	C_R	C_B	C_s	N_{60}	C_N	$(N_1)_{60}$	Fines Content	K_0	ΔN	$(N_1)_{60CS}$	$(N_1)_{60\text{-}sr}$
ft	ft	m	psf	psf	blows/ft		%					blows/ft		blows/ft	%		blows/ft	blows/ft	blows/ft
1	578.9	0.30	120	120	5	Unsaturated	60	1.00	0.75	1.00	1.00	4	1.70	6	40	0.50	6	12	10
3	576.9	0.91	366	297	18		60	1.00	0.75	1.00	1.00	14	1.70	23	40	0.50	6	29	26
5	574.9	1.52	616	422	25		60	1.00	0.75	1.00	1.00	19	1.70	32	25	0.50	5	37	34
7	572.9	2.13	866	547	30		60	1.00	0.80	1.00	1.00	24	1.53	37	25	0.50	5	42	39
9	570.9	2.74	1116	672	31		60	1.00	0.80	1.00	1.00	25	1.44	36	25	0.50	5	41	38
11	568.9	3.35	1366	798	22		60	1.00	0.85	1.00	1.00	19	1.45	27	25	0.50	5	32	29
13	566.9	3.96	1616	923	28		60	1.00	0.85	1.00	1.00	24	1.33	32	25	0.50	5	37	34
15	564.9	4.57	1866	1048	28		60	1.00	0.85	1.00	1.00	24	1.28	31	25	0.50	5	36	33
17	562.9	5.18	2116	1173	45		60	1.00	0.95	1.00	1.00	43	1.15	49	25	0.50	5	54	51
18.9	561.0	5.76	2353	1292	84		60	1.00	0.95	1.00	1.00	80	1.04	83	25	0.50	5	88	85
20.45	559.5	6.23	2547	1389	100		60	1.00	0.95	1.00	1.00	95	1.01	96	25	0.50	5	101	98
22.45	557.5	6.84	2797	1514	100		60	1.00	0.95	1.00	1.00	95	1.01	96	25	0.50	5	101	98
24.05	555.9	7.33	2997	1615	100		60	1.00	0.95	1.00	1.00	95	1.01	96	25	0.50	5	101	98

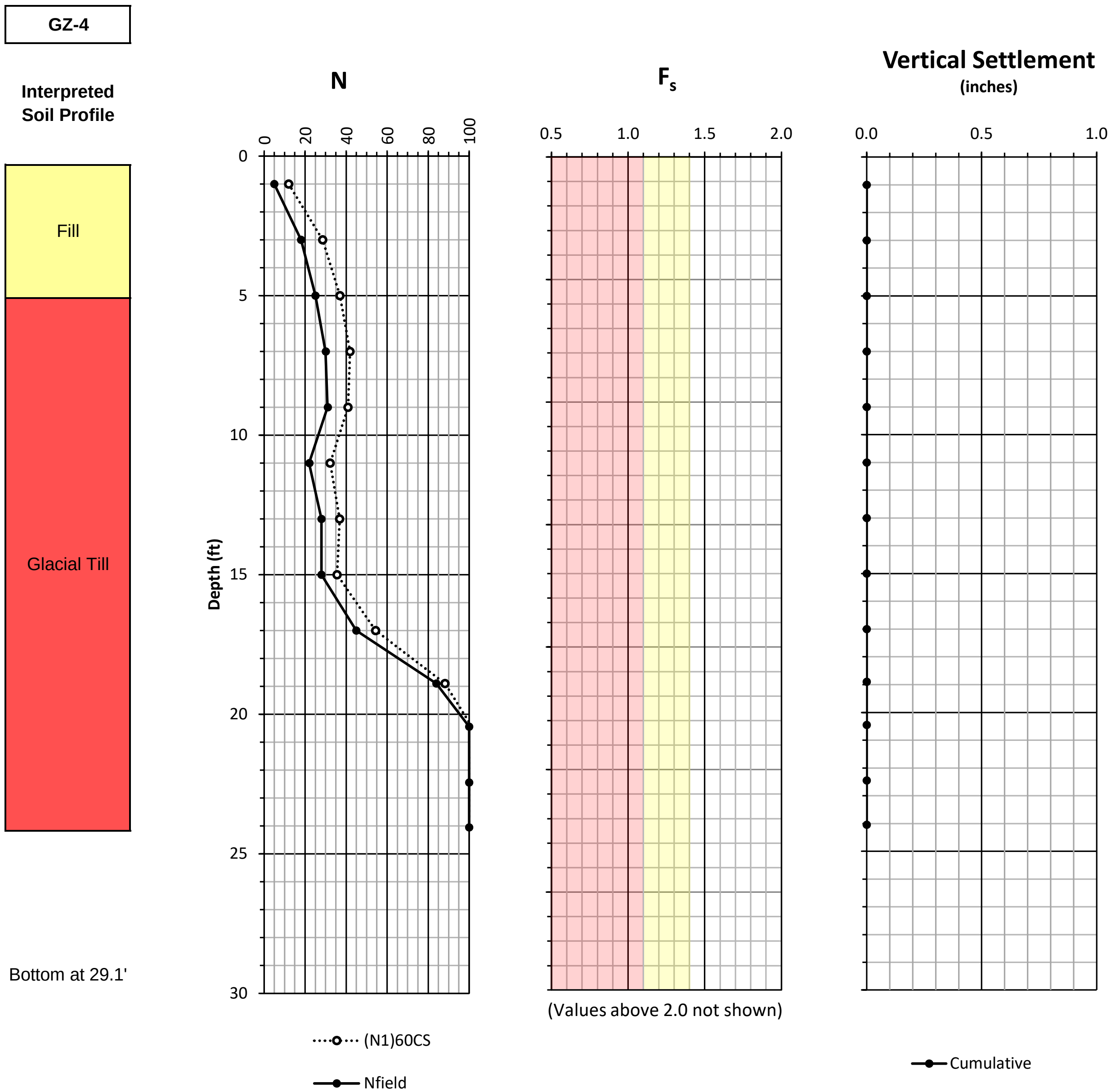
Capacity/Demand Ratio (Factor of Safety) Calculations / **Post-Liquef. Shear Strength** / **Vertical Settlement**

Depth (mid-SPT interval)	CRR (M=7.5, σ = 1 atm)	MSF_{max}	MSF	C_σ	K_σ	Q	α	a	b	c	ξ_R	K_α	CRR (M, σ, α)	r_d	Design Total Stress, σ_v	Design Effective Stress, σ'_v	CSR	F_s	Post-Liquef. Shear Strength	Layer Thickness	F_α	γ_{lim}	γ_{max}	Vertical reconsol Strain, ε_v	ΔSi
ft						[for Kα]	[for Kα]	[for Kα]	[for Kα]	[for Kα]	[for Kα]				psf	psf			psf	ft				ft	in
1	0.13	1.13	1.08	0.08	1.10	10	0.25	0.48	0.12	0.21	-0.52	1.89	0.30	1.00	120	120	0.10	**5.0**		2.0	0.86	0.38	0.000	0.000	0.00
3	0.41	1.62	1.37	0.15	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	1.55	1.00	366	297	0.13	**5.0**		2.0	0.01	0.06	0.000	0.000	0.00
5	1.73	2.11	1.67	0.22	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	8.00	0.99	616	422	0.15	**5.0**		2.0	-0.58	0.02	0.000	0.000	0.00
7	4.13	2.20	1.72	0.29	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.98	866	547	0.16	**5.0**		2.0	-0.94	0.01	0.000	0.000	0.00
9	4.13	2.20	1.72	0.27	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.96	1116	672	0.17	**5.0**		2.0	-0.87	0.01	0.000	0.000	0.00
11	0.66	1.83	1.50	0.18	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	2.74	0.95	1366	798	0.17	**5.0**		2.0	-0.23	0.03	0.000	0.000	0.00
13	1.66	2.10	1.67	0.22	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	7.67	0.94	1616	923	0.17	**5.0**		2.0	-0.57	0.02	0.000	0.000	0.00
15	1.25	2.03	1.62	0.21	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	5.63	0.93	1866	1048	0.17	**5.0**		1.0	-0.48	0.02	0.000	0.000	0.00
17	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.91	2116	1173	0.17	**5.0**		2.0	-1.94	0.00	0.000	0.000	0.00
18.9	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.90	2353	1292	0.17	**5.0**		1.9	-4.95	0.00	0.000	0.000	0.00
20.45	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.75	0.89	2547	1389	0.17	**5.0**		1.6	-6.19	0.00	0.000	0.000	0.00
22.45	4.13	2.20	1.72	0.30	1.10	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.69	0.88	2797	1514	0.17	**5.0**		2.0	-6.17	0.00	0.000	0.000	0.00
24.05	4.13	2.20	1.72	0.30	1.08	10	0.25	0.48	0.12	0.21	-0.60	2.52	19.34	0.86	2997	1615	0.17	**5.0**		1.6	-6.15	0.00	0.000	0.000	0.00

Notes:
1. Factor of safety calculations limited to 5.0. Actual FS may be greater but shown as 5.0.
2. Factor of safety presented as 5.0 for Unsaturated and Silt/Clay soils; not calculated.
3. Ground surface elevation obtained from boring logs
4. Fines content was conservatively estimated based on low end of range for soil description provided on log where laboratory test results were not available.

Indicates factors of safety < 1.1, where liquefaction is likely
Indicates factors of safety ≥ 1.1 but < 1.4, where settlement due to cyclic strain softening is possible

Liquefaction Depth Profiles



Notes/Comments

1) FS > 1.4 indicate liquefaction not likely

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Engineers and Scientists

JOB	05.0046161.07		
SHEET NO.	1	OF	2
CALCULATED BY	EK	DATE	4/2/2021
CHECKED BY	JD	DATE	4/2/2021
SCALE			

PURPOSE / SCOPE:

1. Estimate the acceleration to be used in the pseudostatic SLOPE/w analyses to estimate the resistance to global instability under seismic loading conditions.

REFERENCES:

The following technical references were used in preparing this calculation:

1. Transportation Research Board (2008). "Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments". NCRHP Report 611.
2. FHWA (2011). "LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations - Reference Manual". Publication No. FHWA NHI-11-032.
3. ASCE 7 Hazard Tool. Accessed 4/1/2021, from https://asce7hazardtool.online/
4. ASCE (2016). "Minimum Design Loads for Buildings and Other Structures". ASCE Standard 7-16.

ASSUMPTIONS:

1. "Site Class D - Stiff Soil", and "Risk Category IV - Essential Facilities" has been assumed in the development of of ground motion parameters.

METHODOLOGY:

Step 1: Obtain bedrock ground motion parameters for site.

Based on ASCE 7 Hazard Tool, the bedrock ground motion parameters for the site coordinates are as follows:

PGA	S_s	S_1
0.1	0.185	0.055

See attached output from ASCE website.

Step 2: Adjust bedrock ground motions for site conditions.

The ground motion parameters above were adjusted to reflect the assumption of Site Class D profile, using the following equations:

$$S_{M1} = F_v \cdot S_1$$
$$PGA_M = F_{PGA} \cdot PGA$$

In accordance with Sections 11.4.3 and 11.8.3 of the ASCE 7-16 Standard:

$F_v =$ 2.4
$F_{PGA} =$ 1.6

The resulting site-adjusted ground motion parameters are as follows:

$S_{M1} =$ 0.132 g
$PGA_M =$ 0.160 g

Step 3: Adjust the peak ground acceleration for slope height and ground motion characteristics to obtain the maximum average acceleration acting on the slope.

Equation 7-1 of Reference 1 was used to adjust the peak ground acceleration determined in Step 2, based on the slope height and the spectral acceleration for the site.

$$k_{av} = \alpha \cdot PGA_M$$

where α is the slope height reduction factor, determined by Equation 7-2 of Reference 1, below.

$$\alpha = 1 + 0.01 \cdot H \cdot (0.5 \cdot \beta - 1)$$

Step 3 - Continued

The H term in the above equation represents the vertical slope height, in feet. β is a function of the shape of the acceleration response spectrum, and provided in Reference 1 as:

$$\beta = \frac{S_{M1}}{PGA_M}$$

Based on the parameters from Step 2, and a slope height , H = 11.5 feet

$\beta =$ 0.825
$\alpha =$ 0.932

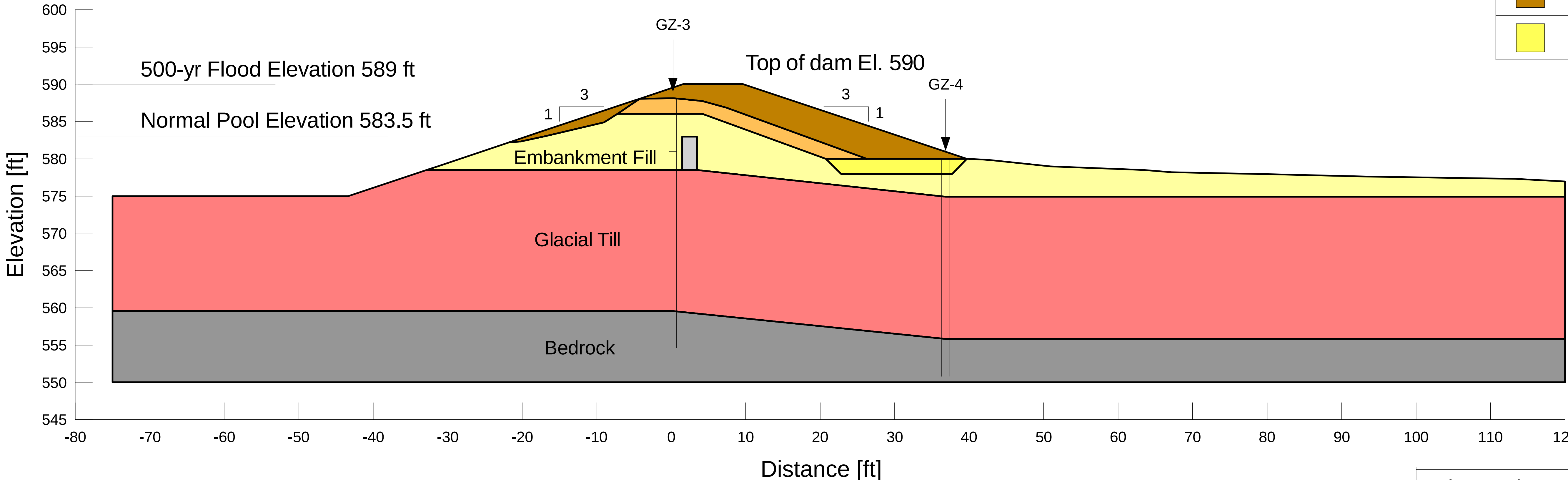
Peak average seismic coefficient, $k_{av} =$ 0.149 g

Step 4: Establish k_s and FS based on allowable displacement.

According to References 1 and 2, if the peak average seismic coefficient is used in a pseudostatic analysis, then a factor of safety of 1.0 or more implies no slope movement. If the peak average coefficient is reduced by 50% (as is typically done) then a factor of safety greater than 1.1 to 1.3 implies minimal deformation, assuming the slope can accommodate 1 to 2 inches of permanent seismic displacement.

Therefore, the accelerations that could be used in the pseudostatic slope stability analyses are as follows:

FS > 1.0 and no permanent deformation,	$k_{av} =$	0.149	g
FS > 1.1 to 1.3 and 1-2 inches of permanent deformation,	$k_s =$	0.075	g



Color	Name	Sat Kx (ft/d)
	Bedrock	0.0002
	Boulder Wall	0.02
	Embankment Fill	0.02
	Glacial Till	0.7
	Improved Embankment Fill	0.02
	Structural Fill	3
	Toe Drain	30

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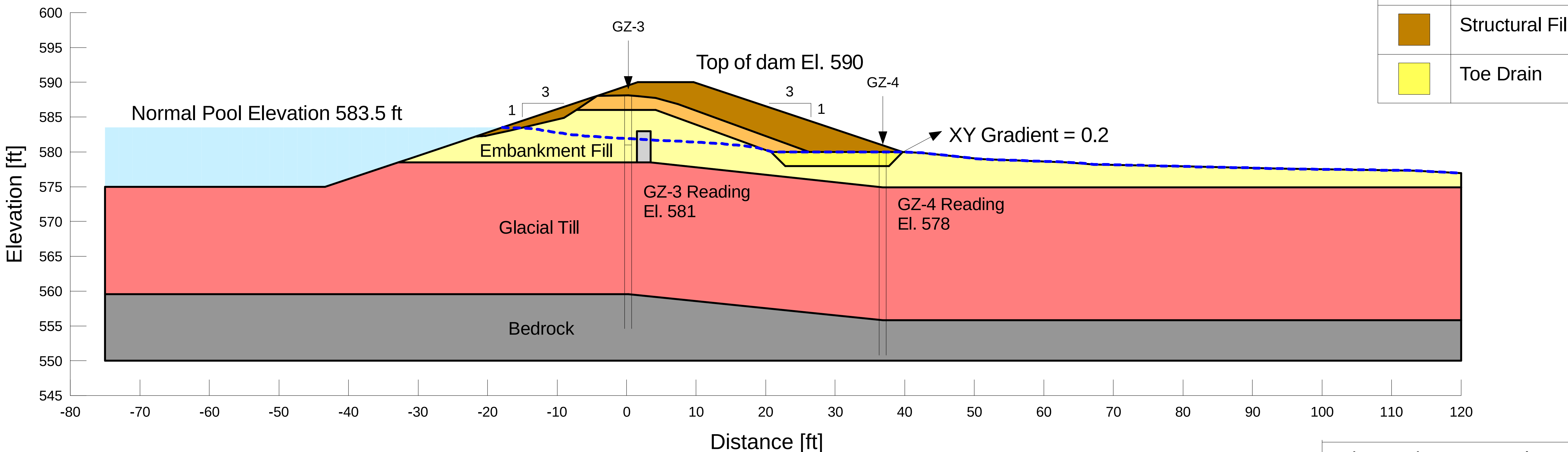
Mirror Lake Dam Analyses - Proposed		
Cross-section		
PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: University of Connecticut Storrs, Connecticut	
PROJ MGR: JD	REVIEWED BY: JD	FIGURE 1
DESIGNED BY: EK	DRAWN BY: EK	
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07	



Color	Name	Sat Kx (ft/d)
	Bedrock	0.0002
	Boulder Wall	0.02
	Embankment Fill	0.02
	Glacial Till	0.7
	Improved Embankment Fill	0.02
	Structural Fill	3
	Toe Drain	30

Mirror Lake Dam Analyses - Proposed

Seepage Analyses
Normal Pool Level

PREPARED BY:	PREPARED FOR:
GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	University of Connecticut Storrs, Connecticut

PROJ MGR: JD	REVIEWED BY: JD	FIGURE 2
DESIGNED BY: EK	DRAWN BY: EK	
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07	

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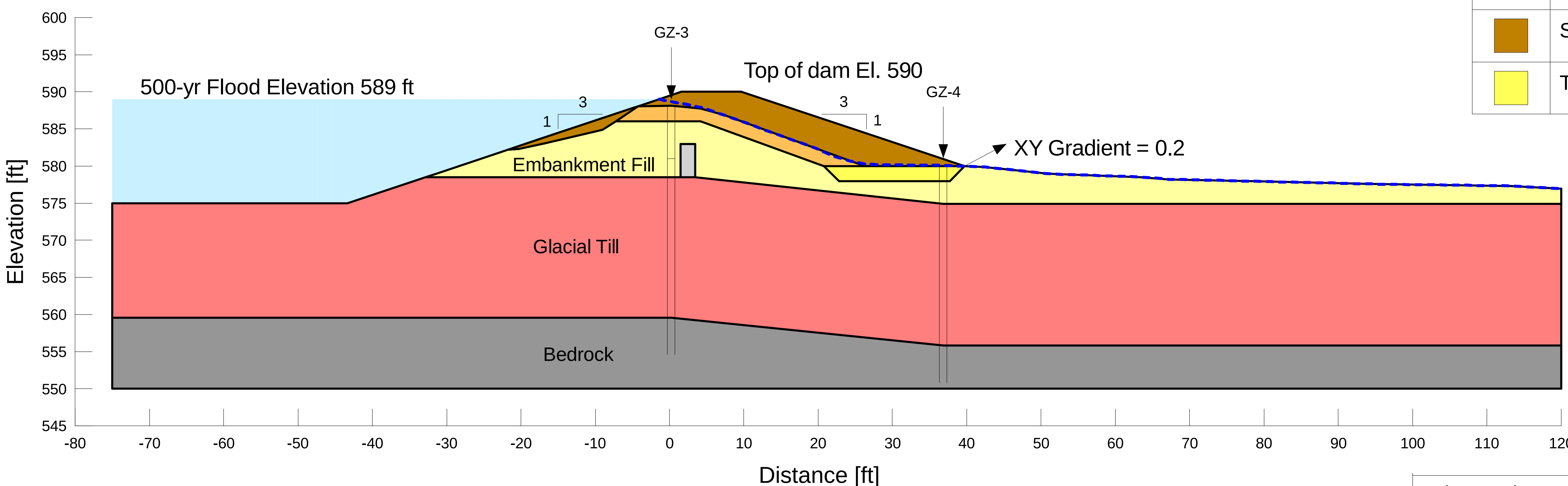
Color	Name	Sat Kx (ft/d)
	Bedrock	0.0002
	Boulder Wall	0.02
	Embankment Fill	0.02
	Glacial Till	0.7
	Improved Embankment Fill	0.02
	Structural Fill	3
	Toe Drain	30



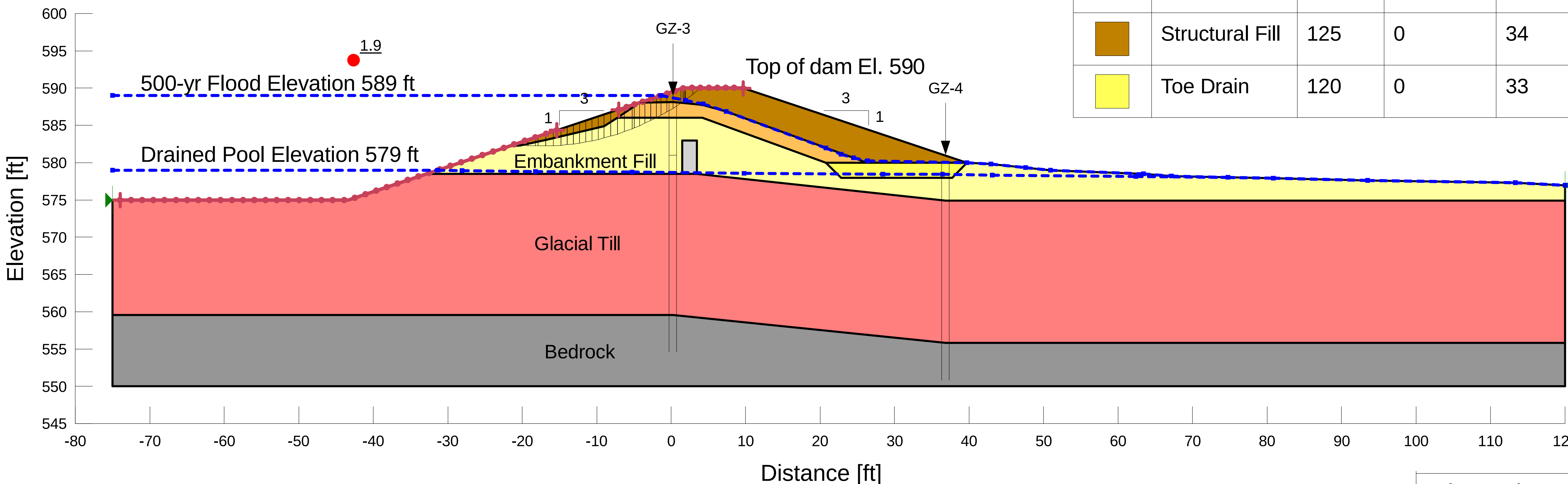
Mirror Lake Dam Analyses - Proposed

Seepage Analyses
500 yr Flood Level

PREPARED BY:	PREPARED FOR:
GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	University of Connecticut Storrs, Connecticut

PROJ MGR: JD	REVIEWED BY: JD	FIGURE 3
DESIGNED BY: EK	DRAWN BY: EK	
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07	

\\gzaglastjobs_46,000-46,499\46161.h61 University of Connecticut\46161-07.jfd\Calculations\Seep & Slope Model\



Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Cohesion R (psf)	Phi R (°)
	Bedrock		Impenetrable material			
	Boulder Wall	130	0	35	1	34
	Embankment Fill	120	0	29	300	10
	Glacial Till	130	0	38	1	37
	Improved Embankment Fill	120	0	32	300	10
	Structural Fill	125	0	34	1	33
	Toe Drain	120	0	33	1	32

Mirror Lake Dam Analyses - Proposed

Upstream Slope Stability
Rapid Drawdown - 500 yr Flood

PREPARED BY:
GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com

PREPARED FOR:
University of Connecticut
Storrs, Connecticut

PROJ MGR: JD
REVIEWED BY: JD
DESIGNED BY: EK
DRAWN BY: EK
DATE: 04/02/2021
PROJECT NO.: 05.0046161.07

FIGURE 4

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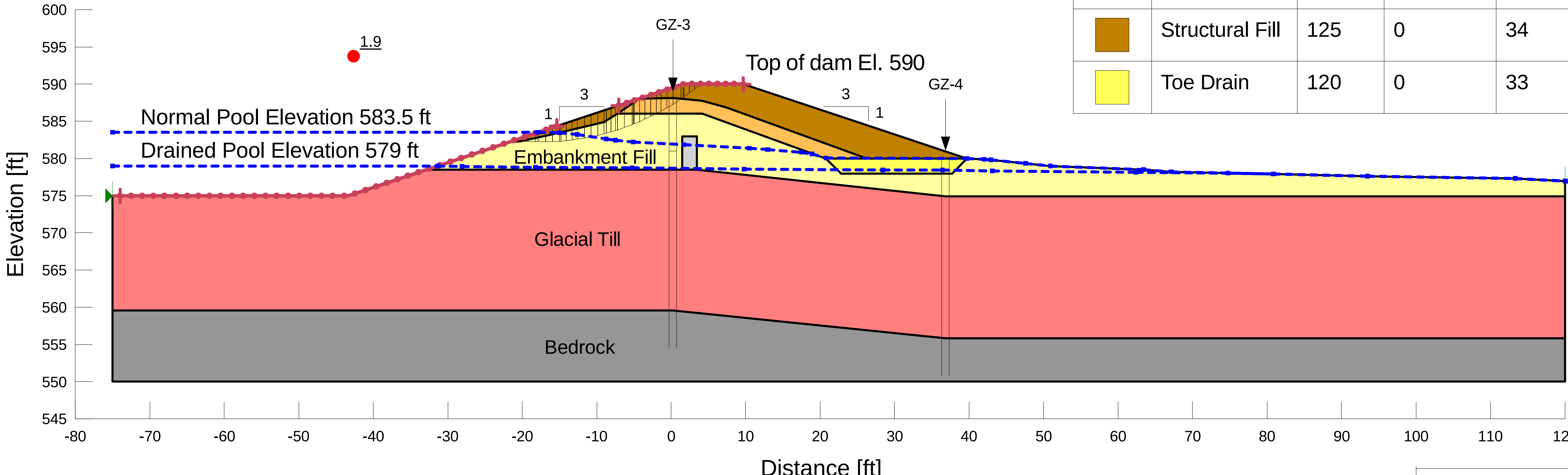
Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)	Cohesion R (psf)	Phi R (°)
	Bedrock		Impenetrable material			
	Boulder Wall	130	0	35	1	34
	Embankment Fill	120	0	29	300	10
	Glacial Till	130	0	38	1	37
	Improved Embankment Fill	120	0	32	300	10
	Structural Fill	125	0	34	1	33
	Toe Drain	120	0	33	1	32



Mirror Lake Dam Analyses - Proposed

Upstream Slope Stability
Rapid Drawdown - Normal Pool

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: University of Connecticut Storrs, Connecticut	
PROJ MGR: JD	REVIEWED BY: JD	FIGURE 5
DESIGNED BY: EK	DRAWN BY: EK	
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07	

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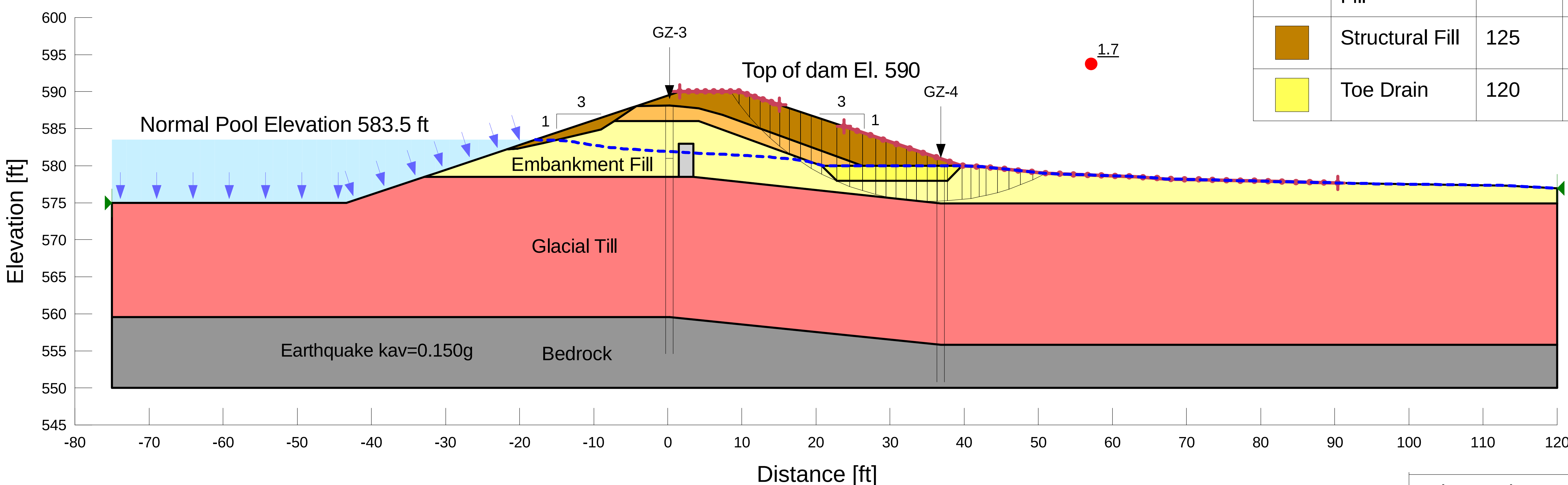

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Impenetrable material		
	Boulder Wall	130	0	35
	Embankment Fill	120	0	29
	Glacial Till	130	0	38
	Improved Embankment Fill	120	0	32
	Structural Fill	125	0	34
	Toe Drain	120	0	33

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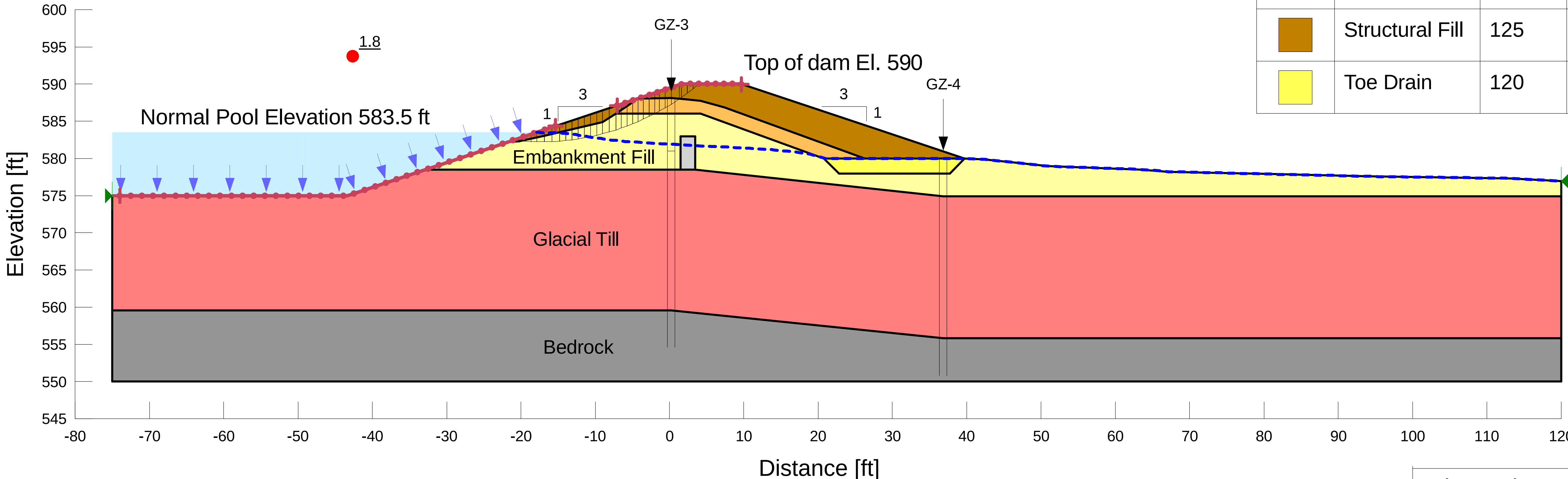
Mirror Lake Dam Analyses - Proposed	
Downstream Slope Stability Normal Pool Level	
PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: University of Connecticut Storrs, Connecticut
PROJ MGR: JD	REVIEWED BY: JD
DESIGNED BY: EK	DRAWN BY: EK
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07
FIGURE 6	

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Impenetrable material		
	Boulder Wall	130	0	35
	Embankment Fill	120	0	29
	Glacial Till	130	0	38
	Improved Embankment Fill	120	0	32
	Structural Fill	125	0	34
	Toe Drain	120	0	33



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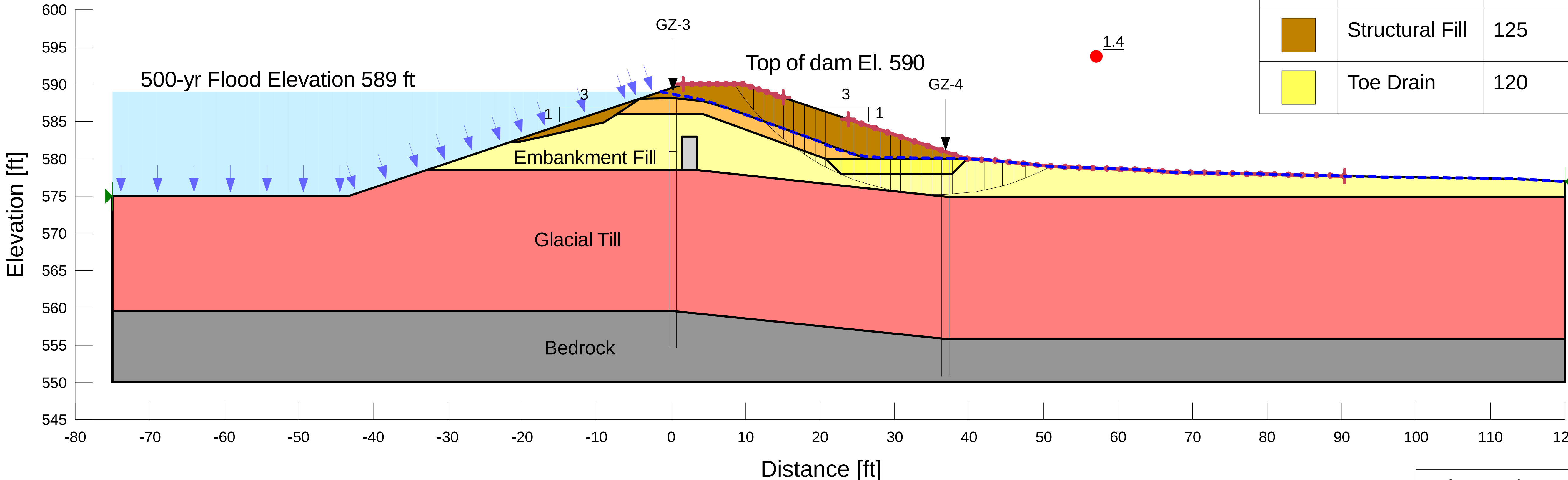
Mirror Lake Dam Analyses - Proposed

Upstream Slope Stability
Normal Pool Level

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: University of Connecticut Storrs, Connecticut	
PROJ MGR: JD	REVIEWED BY: JD	FIGURE 7
DESIGNED BY: EK	DRAWN BY: EK	
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07	



Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Impenetrable material		
	Boulder Wall	130	0	35
	Embankment Fill	120	0	29
	Glacial Till	130	0	38
	Improved Embankment Fill	120	0	32
	Structural Fill	125	0	34
	Toe Drain	120	0	33

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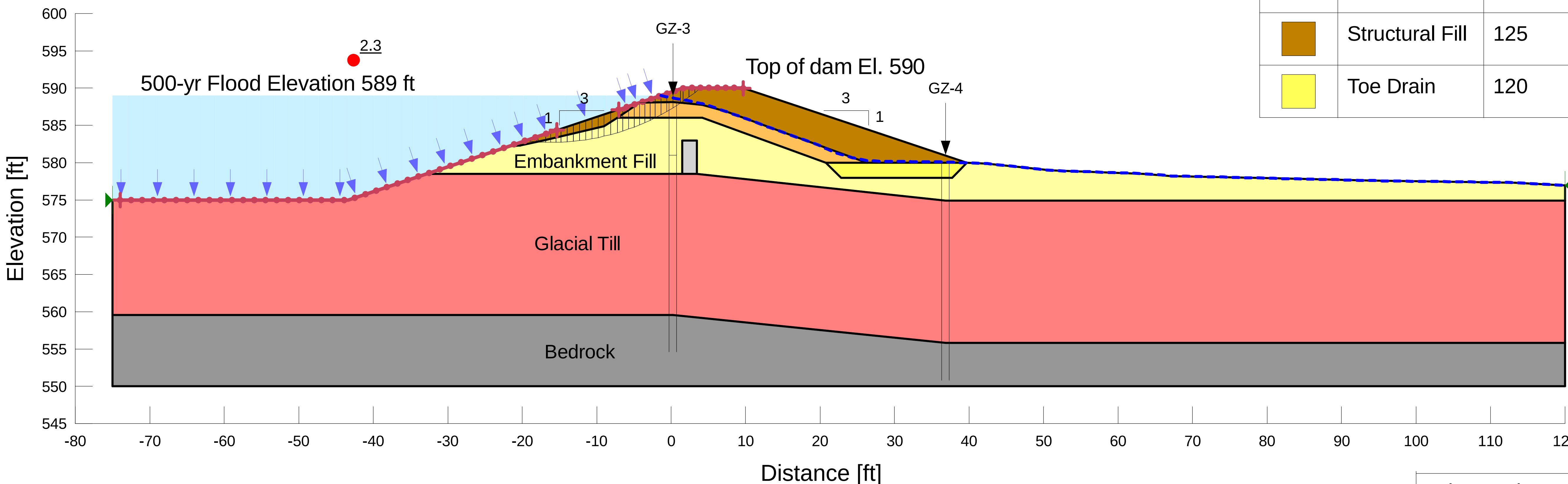
Mirror Lake Dam Analyses - Proposed

Downstream Slope Stability
500 yr Flood Level

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: University of Connecticut Storrs, Connecticut
PROJ MGR: JD	REVIEWED BY: JD
DESIGNED BY: EK	DRAWN BY: EK
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07

FIGURE
8



Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Impenetrable material		
	Boulder Wall	130	0	35
	Embankment Fill	120	0	29
	Glacial Till	130	0	38
	Improved Embankment Fill	120	0	32
	Structural Fill	125	0	34
	Toe Drain	120	0	33

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Mirror Lake Dam Analyses - Proposed

Upstream Slope Stability
500 yr Flood Level

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: University of Connecticut Storrs, Connecticut
PROJ MGR: JD	REVIEWED BY: JD
DESIGNED BY: EK	DRAWN BY: EK
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07

FIGURE 9

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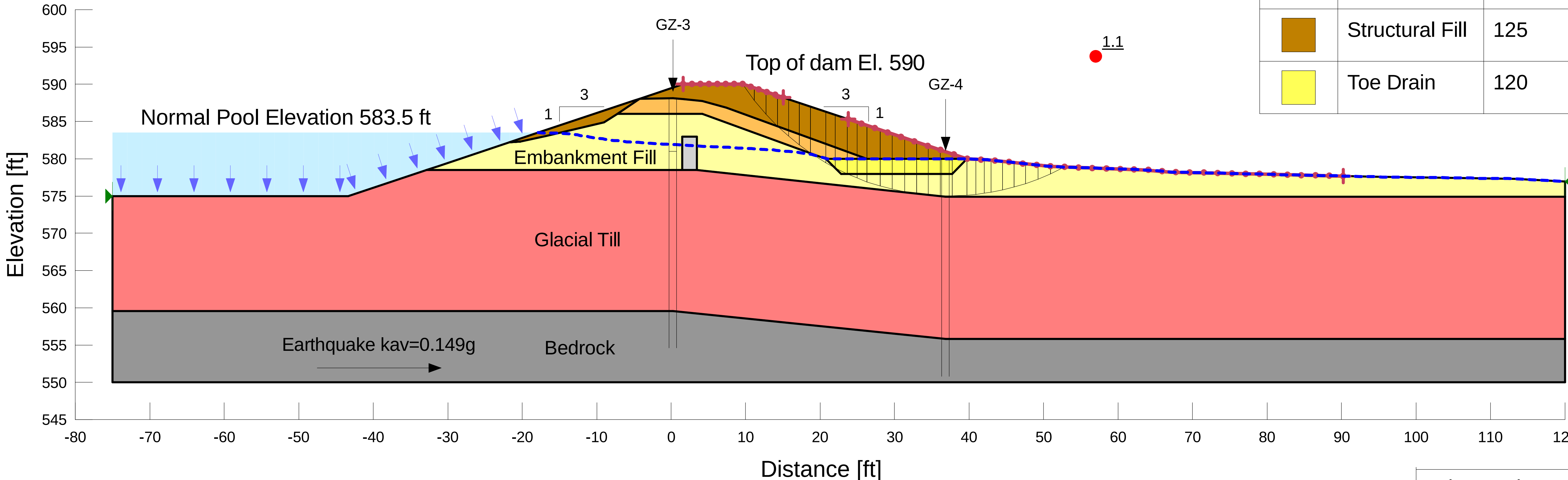
Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Impenetrable material		
	Boulder Wall	130	0	35
	Embankment Fill	120	0	29
	Glacial Till	130	0	38
	Improved Embankment Fill	120	0	32
	Structural Fill	125	0	34
	Toe Drain	120	0	33



Mirror Lake Dam Analyses - Proposed

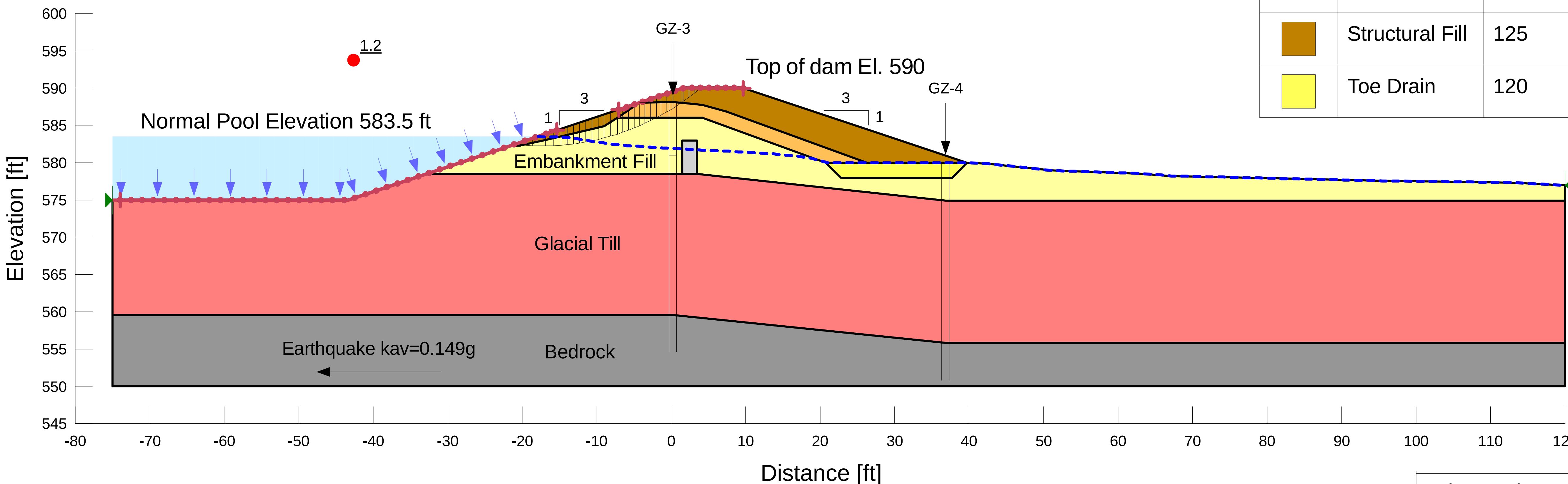
Downstream Slope Stability
Normal Pool + Earthquake

PREPARED BY:
GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com

PREPARED FOR:
University of Connecticut
Storrs, Connecticut

PROJ MGR: JD	REVIEWED BY: JD	FIGURE
DESIGNED BY: EK	DRAWN BY: EK	10
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07	

Color	Name	Unit Weight (pcf)	Effective Cohesion (psf)	Effective Friction Angle (°)
	Bedrock	Impenetrable material		
	Boulder Wall	130	0	35
	Embankment Fill	120	0	29
	Glacial Till	130	0	38
	Improved Embankment Fill	120	0	32
	Structural Fill	125	0	34
	Toe Drain	120	0	33



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Mirror Lake Dam Analyses - Proposed

Upstream Slope Stability
Normal Pool + Earthquake

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists www.gza.com	PREPARED FOR: University of Connecticut Storrs, Connecticut	
PROJ MGR: JD	REVIEWED BY: JD	FIGURE 11
DESIGNED BY: EK	DRAWN BY: EK	
DATE: 04/02/2021	PROJECT NO.: 05.0046161.07	

APPENDIX I – GRAVITY ANALYSIS CALCULATIONS

(Unit Definition - Click Arrow to Expand)

Objective:

To perform stability analysis of **Mirror Lake Dam**, **proposed spillway cross section** using assumption of cracked base where applicable, and calculate factors of safety against sliding and to evaluate overturning stability under proposed conditions.

Design Methodology:

- Evaluate stability using conventional equilibrium analyses and limit state theory
- Calculate base pressures with and without considering uplift effects
- Determine non-compression zone, where a cracked section is assumed to have developed cracked area and is assumed to be subjected to full headwater pressure.
- Uplift pressure profile is revised and a cracked length is obtained using an iterative solution per USACE methodology

References:

- "Evaluation of Concrete Dam Safety" by ASDSO. Northeast Regional Technical Seminar
- "Gravity Dam Design" by USACE EM1110-2-2200, Jun 1995
- "Stability Analysis of Concrete Structures" by USACE EM1110-2-2100, Dec 2005
- "Design of Small Dams" by US Bureau of Reclamation, 1977
- "Evaluation and comparison of stability analysis and uplift criteria for concrete gravity dams by three federal agencies" by USACE ERDC/ITL TR-00-1, Jun 2000

Case Descriptions - Loading Conditions:

(Per US Army Corps of Engineers)

Case #1: Normal water levels
Case #2: Flood (500 yr) water levels
Case #3: Normal water levels + ice
Case #4: Normal water levels + earthquake

Assumptions:

- Full upstream hydraulic head applied to cracked length and is linearly interpolated to downstream hydraulic head over uncracked length (depending on efficiency and location of relief wells)
- Pseudostatic method for seismic analysis (apply horizontal acceleration as a % of g)
- Summation of moments about the centerline of the base
- Plane of analysis at dam/foundation interface (El. 573)
- Bedrock-Dam interface friction angle = 29 deg

Notes for MathCAD User (No Calculations)

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Engineers and Scientists

Input Parameters

1) Dam Geometry:

Total Base width $B := 18ft$

Toe base width $B_1 := 2ft$

heel width $B_3 := 0ft$

Crest width $B_2 := B - B_1 - B_3 = 16\,ft$

Height of toe slope $H_1 := 10.5ft$

Height of heel slope $H_3 := 14ft$

Analysis length $LF := 1ft$

Dam base elevation $EL_b := 573ft$

Dam crest elevation $EL_c := EL_b + H_3 = 587\,ft$

Top elevation of heel slope $EL_{B3} := EL_b + H_3 = 587\,ft$

Dam height $H_{dam} := EL_c - EL_b = 14\,ft$

Dam heel slope height $H_{slp\_B3} := EL_{B3} - EL_b = 14\,ft$

Downstream batter angle (from vertical) $\theta_d := 0\,°$

Upstream batter angle (from vertical) $\theta_u := \operatorname{atan}\left(\frac{B_3}{H_3}\right) = 0 \cdot °$

Inclination angle of base $\beta := 0deg$

Sliding direction (upslope / downslope to DS) $f_\beta := 1$ (+1 sloping down to DS; and -1 sloping up to DS)

Drainage Gallery base elevation $EL_{dg} := EL_b = 573\,ft$ *(No drainage gallery in this section)*

Drain Effectiveness $E_{dr} := 0\%$ (fully effective = 100%; ineffective = 0%)
EM 1110-2-2200 limits effectiveness to between 25% and 50% without site-specific measurements.

Distance of drain to heel $d_{dr} := 0ft$ *(set to zero if no drain installed)*

Shear Key Area $A_{shear} := 0ft^2$ *(set to zero if no shear keys present)*

Shear Key Cohesion $c_{shear} := 0psf$ *(set to zero if no shear keys present)*

1) Dam Geometry (continued): *Refer to Figure #1*

Assume coordinates of heel (0,0)

Geometry based on CAD

W1: Concrete Spillway cross-section

$X_{Centroid.W1} := 8ft$ $\quad Y_{Centroid.W1} := 7ft$

$Area_{W1} := 224ft^2$ $\quad Volume_{W1} := Area_{W1} \cdot LF = 224\ ft^3$

W2: Concrete Spillway cross-section

$X_{Centroid.W2} := 17ft$ $\quad Y_{Centroid.W2} := 5.25ft$

$Area_{W2} := 21ft^2$ $\quad Volume_{W2} := Area_{W2} \cdot LF = 21\ ft^3$

N/A Fields

2) General Design Elevations

Flood pool elevation $\quad EL_{fw} := 589ft$

Normal pool elevation $\quad EL_{nw} := 583.5ft$

3) Case Specific Loads, Dimensions and Elevations

Tailwater Elevation

$$EL_{dw} := \begin{pmatrix} 575.9ft \\ 581.2ft \\ 575.9ft \\ 575.9ft \end{pmatrix} \begin{matrix} \text{Case \#1} \\ \text{Case \#2} \\ \text{Case \#3} \\ \text{Case \#4} \end{matrix}$$

Tailwater Height

$$H_{dw} := EL_{dw} - EL_b \quad \boxed{H_{dw} = \begin{pmatrix} 2.9 \\ 8.2 \\ 2.9 \\ 2.9 \end{pmatrix} ft} \begin{matrix} \text{Case \#1} \\ \text{Case \#2} \\ \text{Case \#3} \\ \text{Case \#4} \end{matrix}$$

Headwater Elevation

$$EL_{uw} := \begin{pmatrix} EL_{nw} \\ EL_{fw} \\ EL_{nw} \\ EL_{nw} \end{pmatrix} \begin{matrix} \text{Case \#1} \\ \text{Case \#2} \\ \text{Case \#3} \\ \text{Case \#4} \end{matrix}$$

Headwater Height

$$H_{uw} := EL_{uw} - EL_b \quad \boxed{H_{uw} = \begin{pmatrix} 10.5 \\ 16 \\ 10.5 \\ 10.5 \end{pmatrix} ft} \begin{matrix} \text{Case \#1} \\ \text{Case \#2} \\ \text{Case \#3} \\ \text{Case \#4} \end{matrix}$$

Ice thickness $\quad \boxed{H_{ice} := 1ft}$ *(initial assumption)*

Ice pressure $\quad \boxed{f_{ice} := 5ksf}$ *(per USACE)*

Horizontal Seismic Coefficient $\quad \boxed{\lambda := 0.129}$ % acceleration *(Class C PGA per 2014 USGS data)*

4) Basic Material Properties

Cohesion between dam/foundation $c_0 := 0\,psi$ *(Initial assumption)*

Cohesion between dam/foundation $c_{dam} := c_0$ *(Based on lab test data and field observations)*

Interface friction angle $\phi_{dam} := 29°$ *(Based on lab test data)*

Allowable foundation bearing capacity $BC := 13.4\,ksf$

Maximum compressive strength of dam: $Cu_{dam} := 3000\,psi$ *(per USACE 1110-2-2006)*

Unit weight of dam material $\gamma_{dam} := 150\,pcf$ *(based on slope stability analysis assumed parameters)*

$\gamma_c := 150\,pcf$

Unit weight of Fill material $\gamma_{fillus} := 130\,pcf$ *(based on slope stability analysis assumed parameters)*

$\gamma_{fillds} := 130\,pcf$

Fill internal frictional angle $\phi_{fill} := 38°$

5) Design Factor of Safety (FS) against sliding

US Army Corps of Engineers				
Case		Loading Conditions	Required Factor of Safety	
			Ordinary Site Info	Well Defined Site Info
1	Normal Pool	Usual	2	1.7
2	100-year Flood	Unusual	1.7	1.1
3	Normal Pool + Ice	Usual	2	1.7
4	Normal Pool + Seismic	Extreme	1.3	1.1

Factors of Safety Used in Analysis (Ordinary)

$$FS\_SLIDING_{min} := \begin{pmatrix} 2.0 \\ 1.7 \\ 2.0 \\ 1.3 \end{pmatrix}$$

Case #1
Case #2 - See Notes
Case #3
Case #4 - See Notes

Factor of Safety Notes
- 100-year storm is considered "Unusual" due to return period of greater than 10 years but less than or equal to 300 yr, in accorcance with EM 1110-2-2100.

Misc, Input Parameter Notes (No Calculations)

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LOAD CASE #1 - Normal Pool

I. INITIAL VERTICAL LOADS AND MOMENTS:

A. Dam self-weights - (Refer to FBD for dam geometry, variable notation, and sign convention)

Weight of individual Dam Sections

$$W_1 := -Area_{W1} \cdot \gamma_{dam} \cdot LF = -33.6 \cdot kip$$

$$W_2 := -Area_{W2} \cdot \gamma_{dam} \cdot LF = -3.15 \cdot kip$$

$$W_3 := -Area_{W3} \cdot \gamma_{dam} \cdot LF = 0 \cdot kip$$

$$W_4 := -Area_{W4} \cdot \gamma_{dam} \cdot LF = 0 \cdot kip$$

Σ Weights of Dam

$$W_{dam} := W_1 + W_2 + W_3 + W_4 = -36.75 \cdot kip$$

Moment arms about Center of Base:

$$D_1 := X_{Centroid.W1} - \frac{B}{2} = -1\ ft$$

$$D_2 := X_{Centroid.W2} - \frac{B}{2} = 8\ ft$$

$$D_3 := 0ft$$

$$D_4 := 0ft$$

Moments due to vertical forces about centerline:

$$M_1 := W_1 \cdot D_1 = 33.6 \cdot kip \cdot ft$$

$$M_2 := W_2 \cdot D_2 = -25.2 \cdot kip \cdot ft$$

$$M_3 := W_3 \cdot D_3 = 0 \cdot kip \cdot ft$$

$$M_4 := W_4 \cdot D_4 = 0 \cdot kip \cdot ft$$

Σ Dam Weight Moments about centerline of Dam

$$M_{dam} := M_1 + M_2 + M_3 + M_4 = 8.4 \cdot kip \cdot ft$$

▶ Headwater (Vertical)

▶ Field: Tailwater

▶ Vertical Soil Load

▶ N/A Field: Upstream Silt

E. Uplift Pressure:

Height of drainage gallery to plane of analysis $H_{dg} := EL_{dg} - EL_b = 0\ \text{ft}$

Effective Hydraulic Head at Drainage Gallery, H_{dr}

$$H_{dr} := \begin{cases} (1 - E_{dr}) \cdot \left[\left(H_{uw_1} - H_{dw_1} \right) \dfrac{B - d_{dr}}{B} + H_{dw_1} - H_{dg} \right] + H_{dg} & \text{if } H_{dg} \ge H_{dw_1} \\ (1 - E_{dr}) \cdot \left(H_{uw_1} - H_{dw_1} \right) \cdot \dfrac{B - d_{dr}}{B} + H_{dw_1} & \text{otherwise} \end{cases} = 10.5 \cdot \text{ft}$$

based on drain effectiveness $E_{dr} = 0 \cdot \%$

Head at heel $H_{heel} := H_{uw_1} = 10.5\ \text{ft}$

Head at toe $H_{toe} := H_{dw_1} = 2.9\ \text{ft}$

Uplift Pressure at Heel $u_{up\_us} := H_{uw_1} \cdot \gamma_w = 0.655 \cdot \text{ksf}$

Uplift Pressure at Toe $u_{up\_ds} := H_{toe} \cdot \gamma_w = 0.181 \cdot \text{ksf}$

Uplift Pressure below Drainage Gallery $u_{up\_dg} := H_{dr} \cdot \gamma_w = 0.655 \cdot \text{ksf}$

Uplift forces below dam base:
Refer to FBD for notation:

$$U_1 := u_{up\_ds} \cdot (B - d_{dr}) \cdot LF = 3.257 \cdot \text{kip}$$

$$U_2 := \frac{1}{2} \left(u_{up\_dg} - u_{up\_ds} \right) \cdot (B - d_{dr}) \cdot LF = 4.268 \cdot \text{kip}$$

$$U_3 := u_{up\_dg} \cdot d_{dr} \cdot LF = 0 \cdot \text{kip}$$

$$U_4 := \frac{1}{2} \left(u_{up\_us} - u_{up\_dg} \right) \cdot d_{dr} \cdot LF = 0 \cdot \text{kip}$$

Σ Uplift Forces = $U := U_1 + U_2 + U_3 + U_4 = 7.525 \cdot \text{kip}$

Moment arms of Uplift Forces

$$d_{up1} := \frac{1}{2} \cdot (B - d_{dr}) - \frac{1}{2} \cdot B = 0\ \text{ft}$$

$$d_{up2} := \frac{2}{3} \cdot (B - d_{dr}) - \frac{1}{2} B = 3\ \text{ft}$$

$$d_{up3} := (B - d_{dr}) + \frac{1}{2} d_{dr} - \frac{1}{2} B = 9\ \text{ft}$$

$$d_{up4} := (B - d_{dr}) + \frac{2}{3} \cdot d_{dr} - \frac{1}{2} B = 9\ \text{ft}$$

Moments due to Uplift Components

$$M_{up1} := U_1 \cdot d_{up1} = 0 \cdot kip \cdot ft$$

$$M_{up2} := U_2 \cdot d_{up2} = 12.804 \cdot kip \cdot ft$$

$$M_{up3} := U_3 \cdot d_{up3} = 0$$

$$M_{up4} := U_4 \cdot d_{up4} = 0$$

Σ Uplift Moments = $M_{up} := M_{up1} + M_{up2} + M_{up3} + M_{up4} = 12.804 \cdot kip \cdot ft$

II. INITIAL HORIZONTAL FORCES AND MOMENTS:

A. Headwater: (Horizontal Component)

Horizontal Component of Headwater on Dam

$$F_{uwa.x} := \begin{vmatrix} \gamma_w \cdot \left(H_{uw_1} - H_{dam}\right) \cdot H_{dam} \cdot LF \ \text{ if } \ H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ 0 \ \text{ otherwise} \end{vmatrix} = 0 \cdot kip$$

$$F_{uwb.x} := \begin{vmatrix} \frac{1}{2} \gamma_w \cdot H_{dam}{}^2 \cdot LF \ \text{ if } \ H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ \frac{1}{2} \gamma_w \cdot \left(H_{uw_1}\right)^2 \cdot LF \ \text{ otherwise} \end{vmatrix} = 3.44 \cdot kip$$

Σ Horizontal Forces by Headwater $F_{uw.x} := F_{uwa.x} + F_{uwb.x} = 3.44\, kip$

Moment arms of Headwater on Dam

$$arm_{uwa.y} := \begin{vmatrix} \frac{H_{dam}}{2} \ \text{ if } \ H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ 0 \ \text{ otherwise} \end{vmatrix} = 0 \cdot ft$$

$$arm_{uwb.y} := \begin{vmatrix} \frac{1}{3} H_{dam} \ \text{ if } \ H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ \frac{H_{uw_1}}{3} \ \text{ otherwise} \end{vmatrix} = 3.5 \cdot ft$$

Moment due to Headwater on Dam

$$M_{uwa.x} := F_{uwa.x} \cdot arm_{uwa.y} = 0 \cdot kip \cdot ft$$

$$M_{uwb.x} := F_{uwb.x} \cdot arm_{uwb.y} = 12.039 \cdot kip \cdot ft$$

Σ Moments due to Headwater $M_{uw.x} := M_{uwa.x} + M_{uwb.x} = 12.039 \cdot kip \cdot ft$

Field: Tailwater

B. Tailwater: (Horizontal Component)

Horizontal Force due to Tailwater

$$F_{dw.x} := \frac{-1}{2}\gamma_w \cdot \left(H_{dw_1}\right)^2 \cdot LF = -0.262\,kip$$

Moment arm of Tailwater

$$arm_{dw.y} := \frac{1}{3} H_{dw_1} = 0.967\,ft$$

Moment due to Tailwater

$$M_{dw.x} := F_{dw.x} \cdot arm_{dw.y} = -0.254\,ft \cdot kip$$

Field: Tailwater

C. Silt and Soil horizontal loading on upstream side of dam:

Earth Pressure Coefficients, At Rest Condition

$$K_{0fill} := 1 - \sin\left(\phi_{fill}\right) = 0.38$$

$$K_{0silt} := 1 - \sin\left(\phi_s\right) = 0.50$$

Loads due to upstream fill (polygon area)

$$EL_{F2} = 575\,ft$$

Horizontal Force

$$F_{fill.x} := \frac{1}{2}\left[K_{0fill} \cdot \left(\gamma_{fillus} - \gamma_w\right)\right] \cdot \left(EL_{F2} - EL_b\right)^2 \cdot LF = 0.052\,kip$$

$$F_{fill.x2a} := 0$$

Moment arm of fill

$$arm_{fill.y} := \frac{1}{3}\left(EL_{F2} - EL_b\right) = 0.667\,ft$$

$$arm_{fill.y2a} := 0$$

Moment due to fill

$$M_{fill.x} := F_{fill.x} \cdot arm_{fill.y} = 0.035\,ft \cdot kip$$

$$M_{fill.x2a} := F_{fill.x2a} \cdot arm_{fill.y2a} = 0$$

D. Soil horizontal loading on downstream side of dam:

$$EL_{F1} = 575.9\,ft$$

Loads due to lower downstream fill (triangular area)

Horizontal Force

$$F_{ds\_fill.x3} := \frac{-1}{2} K_{0fill} \cdot \left(\gamma_{fillds} - \gamma_w\right) \cdot \left(EL_{F1} - EL_b\right)^2 \cdot LF = -0.109\,kip$$

Moment arm of fill

$$arm_{ds\_fill.y3} := \frac{1}{3}\left(EL_{F1} - EL_b\right) = 0.967\,ft$$

Moment due to fill

$$M_{ds\_fill.x3} := F_{ds\_fill.x3} \cdot arm_{ds\_fill.y3} = -0.106\,ft \cdot kip$$

N/A Field: Silt

N/A Fields DownstreamSoil

N/A Fields Upstream Soil

(Summary of Vertical Forces Raw Data - Click to expand)

III. SUMMARY OF INITIAL LOADS AND MOMENTS - CASE #1

SUMMARY OF VERTICAL FORCES/MOMENTS

Component	Acting			Resisting		
	Force (kip)	Arm (ft)	Moment (kip-ft)	Force (kip)	Arm (ft)	Moment (kip-ft)
Weight of Dam, Area #1	-	-	-	-33.6	-1.0	33.6
Weight of Dam, Area #2	-	-	-	-3.2	8.0	-25.2
Weight of Dam, Area #3	-	-	-	0.0	0.0	0.0
Weight of Dam, Area #4	-	-	-	0.0	0.0	0.0
Headwater over Dam, Fuwa.y	-	-	-	0.0	-9.0	0.0
Headwater over Dam, Fuwb.y	-	-	-	0.0	0.0	0.0
Headwater over Dam, Fuwc.y	-	-	-	0.0	0.0	0.0
Tailwater over Dam, Fdw.y	-	-	-	0.0	-9.0	0.0
Fill weight on heel, Ffill.y	-	-	-	0.0	-9.0	0.0
Silt weight on heel, Fsilt.y	-	-	-	0.0	-9.0	0.0
Fill weight on toe, Area 1A	-	-	-	0.0	9.0	0.0
Fill weight on heel, Area 2a	-	-	-	0.0	9.0	0.0
Uplift Pressure, Area #1	3.3	0.0	0.0	-	-	-
Uplift Pressure, Area #2	4.3	3.0	12.8	-	-	-
Uplift Pressure, Area #3	0.0	9.0	0.0	-	-	-
Uplift Pressure, Area #4	0.0	9.0	0.0	-	-	-
Totals	**7.5**	**-**	**12.8**	**-36.8**	**-**	**8.4**

Σ **Vertical Forces w/ uplift** $FV_{tot} := \left(F_{vr} + F_{va}\right) \cdot kips$ $\boxed{FV_{tot} = -29.225 \cdot kips}$

Σ **Vertical Moments w/ uplift** $MV_{tot} := \left(M_{vr} + M_{va}\right) \cdot kips \cdot ft$ $\boxed{MV_{tot} = 21.2 \cdot kips \cdot ft}$

(Summary of Horizontal Forces Raw Data - Click to expand)

SUMMARY OF HORIZONTAL FORCES/MOMENTS

Component	Acting			Resisting		
	Force (kip)	Arm (ft)	Moment (kip-ft)	Force (kip)	Arm (ft)	Moment (kip-ft)
Headwater on Dam, Fuwa.x	0.0	0.0	0.0	-	-	-
Headwater on Dam, Fuwb.x	3.4	3.5	12.0	-	-	-
Saturated Silt, Fsilt.x	0.0	0.0	0.0	-	-	-
Unsaturated Fill, Ffill.x2a	0.0	0.0	0.0	-	-	-
Saturated Fill, Ffill.x	0.1	0.7	0.0	-	-	-
Tailwater on Dam, Fdw.x	-	-	-	-0.3	1.0	-0.3
Upper Downstream Fill, Fds_fill.x1	-	-	-	0.0	0.0	0.0
Upper Downstream Fill, Fds_fill.x2	-	-	-	0.0	0.0	0.0
Lower Downstream Fill, Fds_fill.x3	-	-	-	-0.1	1.0	-0.1
Totals	**3.5**	**-**	**12.1**	**-0.4**	**-**	**-0.4**

Σ **Horizontal Forces** $FH_{tot} := \left(F_{hr} + F_{ha}\right) \cdot kips$ $\boxed{FH_{tot} = 3.12 \cdot kips}$

Σ **Horizontal Moments** $MH_{tot} := \left(M_{hr} + M_{ha}\right) \cdot kips \cdot ft$ $\boxed{MH_{tot} = 11.7 \cdot kips \cdot ft}$

Σ **Moments (w/ uplift)** $M_{tot} := \left(M_{ha} + M_{hr} + M_{va} + M_{vr}\right) \cdot kips \cdot ft = 32.919\, ft \cdot kip$

IV. EVALUATE OVERTURNING AND BASE PRESSURES

- Check Resultant Location - COE EM1110-2-2200 Overturning Stability Criteria

- **Usual Conditions = Within middle third of the base**
- Unusual Conditions = Within middle half of the base
- Extreme Conditions = Within base

A. Calculate Eccentricity and Base Pressures

- Resultant and Eccentricity

- Eccentricity (from centroid of Base Area)

$$e_o := \frac{M_{tot}}{-FV_{tot}} = 1.126\,ft$$

(+) = D/S of Centroid
(-) = U/S of Centroid

- Resultant Location (from toe)

$$R_o := \frac{1}{2}B - e_o = 7.874\,ft$$

- Evaluate Overturning using Resultant Location

$$\mathbf{Location}_{\mathbf{Ro}_1} := \begin{cases} \text{"WITHIN MIDDLE 1/3"} & \text{if } \left(R_o \geq \frac{B}{3}\right) \wedge \left(R_o \leq \frac{2B}{3}\right) \\ \text{"OUTSIDE MIDDLE 1/3"} & \text{otherwise} \end{cases}$$

$$\mathbf{Location}_{\mathbf{Ro}_1} = \text{"WITHIN MIDDLE 1/3"}$$

- Base Pressures (includes Uplift)

Base Pressure at Heel:

$$P_{us\_o} := \frac{-FV_{tot}}{B \cdot LF} \cdot \left(1 - \frac{6 \cdot e_o}{B}\right) = 1.014\,ksf$$

(-) = tension
(+) = compression

Base Pressure at Toe:

$$P_{ds\_o} := \frac{-FV_{tot}}{B \cdot LF} \cdot \left(1 + \frac{6 \cdot e_o}{B}\right) = 2.233\,ksf$$

(-) = tension
(+) = compression

C. Check if Cracked Base Analysis (CBA) is Required

(CBA is required when base pressure with uplift are negative, i.e. base in tension)

$$\mathbf{CBA}_1 := \begin{cases} \text{"REQUIRED"} & \text{if } \left(P_{us\_o} < 0\right) \vee \left(P_{ds\_o} < 0\right) \\ \text{"NOT REQUIRED"} & \text{otherwise} \end{cases}$$

$$\mathbf{CBA}_1 = \text{"NOT REQUIRED"}$$

(Note: if CBA not needed, do not edit Cracked Base Analysis Region

Cracked Base Analysis - Case #1 (Click to Expand, if Required)
Revised Parameters (Click to Expand)

Evaluate Sliding Stability (shear friction factor):

Base Inclination Angle $\beta = 0$

Base Area for Analysis $A_0 := B_{unc} \cdot LF = 18\,ft^2$

With no cohesion

$$FS\_SLIDING_1 := \frac{\left(-F_V\cdot\cos(\beta) - F_U + F_H\cdot\sin(\beta)\cdot f_\beta\right)\cdot\tan\left(\phi_{dam}\right) + \left(A_0 - A_{shear}\right)\cdot c_0 + A_{shear}\cdot c_{shear}}{F_H\cdot\cos(\beta) - F_V\cdot\sin(\beta)\cdot f_\beta} = 5.192$$

Calculated $FS_{sliding}$ $FS\_SLIDING_1 = 5.2$

Required Factor of Safety (from Page 5): $\boxed{FS\_SLIDING_{min_1} = 2.0}$

$$\textbf{Sliding\_Stability} := \begin{cases} \text{"SLIDING OK"} & \text{if } FS\_SLIDING_1 \ge FS\_SLIDING_{min_1} \\ \text{"NOT ADEQUATE"} & \text{otherwise} \end{cases}$$

Sliding_Stability = "SLIDING OK"

- Base Pressure at Toe (includes Uplift)

$$\mathbf{p_{toe_1}} := \begin{cases} P_{ds\_o} & \text{if } \mathbf{CBA_1 =} \text{"NOT REQUIRED"} \\ \dfrac{-\left(F_V + F_U\right)}{B_{unc}\cdot LF}\cdot\left[1 + 6\cdot\left(\dfrac{e_{rev}}{B_{unc}}\right)\right] & \text{otherwise} \end{cases}$$

$\mathbf{p_{toe_1}} = 2.2\cdot ksf$

Check to see if pressure exceeds foundation bearing capacity:

$$\mathbf{BC_1} := \begin{cases} \text{"OK"} & \text{if } \mathbf{p_{toe_1}} < BC \\ \text{"EXCEEDED"} & \text{otherwise} \end{cases}$$

$\mathbf{BC_1}$ = "OK"

Check to see if pressure exceeds dam compressive strength:

$$\mathbf{Cu\_dam_1} := \begin{cases} \text{"OK"} & \text{if } \mathbf{p_{toe_1}} < 0.3\cdot Cu_{dam} \\ \text{"EXCEEDED"} & \text{otherwise} \end{cases}$$

$\mathbf{Cu\_dam_1}$ = "OK"

Check flotation:

$$FS\_FLOT_1 := \frac{-F_V}{F_U} = 4.883$$

Required Factor of Safety against Flotation (from USACE EM 1110-2-2100, Table 3-4): $\boxed{FS\_FLOT_{min_1} := 1.3}$

$$\mathbf{Flotation_1} := \begin{cases} \text{"OK"} & \text{if } FS\_FLOT_1 \ge FS\_FLOT_{min_1} \\ \text{"NOT ADEQUATE"} & \text{otherwise} \end{cases}$$

$\mathbf{Flotation_1}$ = "OK"

END OF LOAD CASE #1 ANALYSIS

LOAD CASE #2 - Flood Pool

I. INITIAL VERTICAL LOADS AND MOMENTS:

A. Dam self-weights - (Same as Load Case #1)

Σ **Weights of Dam** $W_{dam} = -36.75 \cdot kips$

Σ **Dam Weight Moments about centerline of Dam** $M_{dam} = 8.4 \cdot kips \cdot ft$

B. Headwater: (Vertical Component)

Conditional statement using variable H_water_over_crest
(*determines whether headwater higher than dam crest*)

$$H_{water\_over\_crest} := H_{uw_2} - H_{dam} = 2\ ft$$

Height of water above crest

$$H_{ov}(H_{water\_over\_crest}) := \begin{vmatrix} H_{water\_over\_crest} & \text{if } H_{water\_over\_crest} > 0 \cdot ft \\ 0 & \text{otherwise} \end{vmatrix}$$

$$\boxed{H_{ov}(H_{water\_over\_crest}) = 2\ ft}$$

Headwater weight on dam (if crest not overtopped, areas of a, b, and c = 0)
a, b, c correspond to various areas of water over the dam, refer to FBD

Headwater Area A $F_{uwa.y} := 0$ Above heel

Headwater Area B $F_{uwb.y} := 0 kip$

Headwater Area C $F_{uwc.y} := (B_2 + B_3) \cdot [H_{ov}(H_{water\_over\_crest}) \cdot (\gamma_w \cdot -LF)] = -1.997\, kip$ Above crest

Σ **Vertical components of Headwater over the Upstream face of the Dam**

$$F_{uw.y} := F_{uwa.y} + F_{uwb.y} + F_{uwc.y} = -1.997\, kip$$

Moment arms of a, b & c about the Center of Base

Headwater Area A $arm_{uwa.x} := X_{Centroid.hw} - \frac{1}{2} B = -9\ ft$ Above heel

Headwater Area B $arm_{uwb.x} := \left(\frac{-1}{2}\right) \cdot B + \left(\frac{1}{2}\right) \cdot B_3 = -9\ ft$

Headwater Area C $arm_{uwc.x} := \frac{B}{2} - \frac{(B_2 + B_3)}{2} = 1\ ft$ Above crest

Moments of vertical headwater forces a, b & c forces about centerline:

Headwater Area A $M_{uwa.y} := F_{uwa.y} \cdot arm_{uwa.x} = 0 \cdot kip \cdot ft$

Headwater Area B $M_{uwb.y} := F_{uwb.y} \cdot arm_{uwb.x} = 0 \cdot kip \cdot ft$

Headwater Area C $M_{uwc.y} := F_{uwc.y} \cdot arm_{uwc.x} = -1.997 \cdot kip \cdot ft$

Σ Moments from the vertical component of Headwater on U/S face of the Dam

$$M_{uw.y} := M_{uwa.y} + M_{uwb.y} + M_{uwc.y} = -1.997 \cdot kip \cdot ft$$

Field: Tailwater

D. Soil and Silt Loads: (Vertical Components) - Same as Load Case #1

E. Uplift Pressure:

Height of drainage gallery to plane of analysis $H_{dg} := EL_{dg} - EL_b = 0\,ft$

Effective Hydraulic Head at Drainage Gallery, H_{dr}

$$H_{dr} := \begin{cases} (1 - E_{dr}) \cdot \left[\left(H_{uw_2} - H_{dw_2}\right) \dfrac{B - d_{dr}}{B} + H_{dw_2} - H_{dg} \right] + H_{dg} & \text{if } H_{dg} \ge H_{dw_2} \\ (1 - E_{dr}) \cdot \left(H_{uw_2} - H_{dw_2}\right) \cdot \dfrac{B - d_{dr}}{B} + H_{dw_2} & \text{otherwise} \end{cases} = 16 \cdot ft$$

based on drain effectiveness $E_{dr} = 0 \cdot \%$

Head at heel $H_{heel} := H_{uw_2} = 16\,ft$

Head at toe $H_{toe} := H_{dw_2} = 8.2\,ft$

Uplift Pressure at Heel $u_{up\_us} := H_{uw_2} \cdot \gamma_w = 0.998 \cdot ksf$

Uplift Pressure at Toe $u_{up\_ds} := H_{toe} \cdot \gamma_w = 0.512 \cdot ksf$

Uplift Pressure below Drainage Gallery $u_{up\_dg} := H_{dr} \cdot \gamma_w = 0.998 \cdot ksf$

Uplift forces below dam base:
Refer to FBD for notation:

$$U_1 := u_{up\_ds} \cdot \left(B - d_{dr}\right) \cdot LF = 9.21 \cdot kip$$

$$U_2 := \frac{1}{2} \left(u_{up\_dg} - u_{up\_ds}\right) \cdot \left(B - d_{dr}\right) \cdot LF = 4.38 \cdot kip$$

$$U_3 := u_{up\_dg} \cdot d_{dr} \cdot LF = 0 \cdot kip$$

$$U_4 := \frac{1}{2} \left(u_{up\_us} - u_{up\_dg}\right) \cdot d_{dr} \cdot LF = 0 \cdot kip$$

Σ Uplift Forces = $U := U_1 + U_2 + U_3 + U_4 = 13.591 \cdot kip$

Moment arms of Uplift Forces - Same as Load Case #1

Moments due to Uplift Components

$$M_{up1} := U_1 \cdot d_{up1} = 0 \cdot kip \cdot ft$$

$$M_{up2} := U_2 \cdot d_{up2} = 13.141 \cdot kip \cdot ft$$

$$M_{up3} := U_3 \cdot d_{up3} = 0$$

$$M_{up4} := U_4 \cdot d_{up4} = 0$$

Σ Uplift Moments =

$$M_{up} := M_{up1} + M_{up2} + M_{up3} + M_{up4} = 13.141 \cdot kip \cdot ft$$

II. INITIAL HORIZONTAL FORCES AND MOMENTS:

A. Headwater: (Horizontal Component)

Horizontal Component of Headwater on Dam

$$F_{uwa.x} := \begin{cases} \frac{1}{2}\gamma_w \cdot H_{dam}{}^2 \cdot LF & \text{if } H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ \frac{1}{2}\gamma_w \cdot \left(H_{uw_2}\right)^2 \cdot LF & \text{otherwise} \end{cases} = 6.115 \cdot kips$$

$$F_{uwb.x} := \begin{cases} \gamma_w \cdot \left(H_{uw_2} - H_{dam}\right) \cdot \left(H_{dam}\right) \cdot LF & \text{if } H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ 0 & \text{otherwise} \end{cases} = 1.747 \cdot kips$$

Σ Horizontal Forces by Headwater

$$F_{uw.x} := F_{uwa.x} + F_{uwb.x} = 7.862\,kip$$

Moment arms of Headwater on Dam

$$arm_{uwa.y} := \begin{cases} \frac{1}{3}H_{dam} & \text{if } H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ \frac{1}{3}H_{uw_2} & \text{otherwise} \end{cases} = 4.667 \cdot ft$$

$$arm_{uwb.y} := \begin{cases} \frac{H_{dam}}{2} & \text{if } H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ 0 & \text{otherwise} \end{cases} = 7 \cdot ft$$

Moment of Headwater on Dam

$$M_{uwa.x} := F_{uwa.x} \cdot arm_{uwa.y} = 28.538 \cdot kip \cdot ft$$

$$M_{uwb.x} := F_{uwb.x} \cdot arm_{uwb.y} = 12.23 \cdot kip \cdot ft$$

Σ Moments due to Headwater

$$M_{uw.x} := M_{uwa.x} + M_{uwb.x} = 40.768 \cdot kip \cdot ft$$

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Field: Tailwater

B. Tailwater: (Horizontal Component)

Horizontal Force due to Tailwater $F_{dw.x} := \frac{-1}{2} \frac{2}{3} \cdot \gamma_w \cdot \left(H_{dw_2}\right)^2 \cdot LF = -1.399\,\text{kip}$

Moment arm of Tailwater $arm_{dw.y} := \frac{1}{3} H_{dw_2} = 2.733\,\text{ft}$

Moment due to Tailwater $M_{dw.x} := F_{dw.x} \cdot arm_{dw.y} = -3.823\,\text{ft} \cdot \text{kip}$

Field: Tailwater

C. Soil horizontal loading on upstream side of dam: Same as Load Case #1

D. Soil horizontal loading on downstream side of dam: - Same as Load Case #1

(Summary of Vertical Forces Raw Data - Click to expand)

III. SUMMARY OF INITIAL LOADS AND MOMENTS - CASE #2

SUMMARY OF VERTICAL FORCES/MOMENTS

Component	Acting			Resisting		
	Force (kip)	Arm (ft)	Moment (kip-ft)	Force (kip)	Arm (ft)	Moment (kip-ft)
Weight of Dam, Area #1	-	-	-	-33.6	-1.0	33.6
Weight of Dam, Area #2	-	-	-	-3.2	8.0	-25.2
Weight of Dam, Area #3	-	-	-	0.0	0.0	0.0
Weight of Dam, Area #4	-	-	-	0.0	0.0	0.0
Headwater over Dam, Fuwa.y	-	-	-	0.0	-9.0	0.0
Headwater over Dam, Fuwb.y	-	-	-	0.0	-9.0	0.0
Headwater over Dam, Fuwc.y	-	-	-	-2.0	1.0	-2.0
Tailwater over Dam, Fdw.y	-	-	-	0.0	-9.0	0.0
Fill weight on heel, Ffill.y	-	-	-	0.0	-9.0	0.0
Silt weight on heel, Fsilt.y	-	-	-	0.0	-9.0	0.0
Fill weight on toe, Area 1A	-	-	-	0.0	9.0	0.0
Fill weight on heel, Area 2a	-	-	-	0.0	9.0	0.0
Uplift Pressure, Area #1	9.2	0.0	0.0	-	-	-
Uplift Pressure, Area #2	4.4	3.0	13.1	-	-	-
Uplift Pressure, Area #3	0.0	9.0	0.0	-	-	-
Uplift Pressure, Area #4	0.0	9.0	0.0	-	-	-
Totals	**13.6**	**-**	**13.1**	**-38.7**	**-**	**6.4**

Σ **Vertical Forces w/ uplift** $FV_{tot} := (F_{vr} + F_{va}) \cdot kips$ $\boxed{FV_{tot} = -25.156 \cdot kips}$

Σ **Vertical Moments w/ uplift** $MV_{tot} := (M_{vr} + M_{va}) \cdot kips \cdot ft$ $\boxed{MV_{tot} = 19.5 \cdot kips \cdot ft}$

(Summary of Horizontal Forces Raw Data - Click to expand)

SUMMARY OF HORIZONTAL FORCES/MOMENTS

Component	Acting			Resisting		
	Force (kip)	Arm (ft)	Moment (kip-ft)	Force (kip)	Arm (ft)	Moment (kip-ft)
Headwater on Dam, Fuwa.x	6.1	4.7	28.5	-	-	-
Headwater on Dam, Fuwb.x	1.7	7.0	12.2	-	-	-
Saturated Silt, Fsilt.x	0.0	0.0	0.0	-	-	-
Saturated Fill, Ffill.x2a	0.0	0.0	0.0	-	-	-
Saturated Fill, Ffill.x	0.1	0.7	0.0	-	-	-
Tailwater on Dam, Fdw.x	-	-	-	-1.4	2.7	-3.8
Upper Downstream Fill, Fds_fill.x1	-	-	-	0.0	0.0	0.0
Upper Downstream Fill, Fds_fill.x2	-	-	-	0.0	0.0	0.0
Lower Downstream Fill, Fds_fill.x3	-	-	-	-0.1	1.0	-0.1
Totals	**7.9**	**-**	**40.8**	**-1.5**	**-**	**-3.9**

Σ **Horizontal Forces** $FH_{tot} := (F_{hr} + F_{ha}) \cdot kips$ $\boxed{FH_{tot} = 6.407 \cdot kips}$

Σ **Horizontal Moments** $MH_{tot} := (M_{hr} + M_{ha}) \cdot kips \cdot ft$ $\boxed{MH_{tot} = 36.9 \cdot kips \cdot ft}$

Σ **Moments (w/ uplift)** $M_{tot} := (M_{ha} + M_{hr} + M_{va} + M_{vr}) \cdot kips \cdot ft$ $\boxed{M_{tot} = 56.4 \cdot kips \cdot ft}$

IV. EVALUATE OVERTURNING AND BASE PRESSURES

- Check Resultant Location - COE EM1110-2-2200 Overturning Stability Criteria

- Usual Conditions = Within middle third of the base
- **Unusual Conditions = Within middle half of the base**
- Extreme Conditions = Within base

A. Calculate Eccentricity and Base Pressures

- Resultant and Eccentricity

- Eccentricity (from centroid of Base Area)

$$e_o := \frac{M_{tot}}{-FV_{tot}} = 2.243\,\text{ft}$$

(+) = D/S of Centroid
(-) = U/S of Centroid

- Resultant Location (from toe)

$$R_o := \frac{1}{2}B - e_o = 6.757\,\text{ft}$$

- Evaluate Overturning using Resultant Location

$$\textbf{Location}_{\textbf{Ro}_2} := \begin{cases} \text{"WITHIN MIDDLE HALF"} & \text{if } \left(R_o \geq \frac{B}{4}\right) \wedge \left(R_o \leq \frac{3B}{4}\right) \\ \text{"OUTSIDE MIDDLE HALF"} & \text{otherwise} \end{cases}$$

$$\boxed{\textbf{Location}_{\textbf{Ro}_2} = \text{"WITHIN MIDDLE HALF"}}$$

- Base Pressures (includes Uplift)

Base Pressure at Heel:

$$P_{us\_o} := \frac{-FV_{tot}}{B \cdot LF} \cdot \left(1 - \frac{6 \cdot e_o}{B}\right) = 0.353\,\text{ksf}$$

(-) = tension
(+) = compression

Base Pressure at Toe:

$$P_{ds\_o} := \frac{-FV_{tot}}{B \cdot LF} \cdot \left(1 + \frac{6 \cdot e_o}{B}\right) = 2.442\,\text{ksf}$$

(-) = tension
(+) = compression

C. Check if Cracked Base Analysis (CBA) is Required

(CBA is required when base pressure with uplift are negative, i.e. base in tension)

$$\textbf{CBA}_2 := \begin{cases} \text{"REQUIRED"} & \text{if } \left(P_{us\_o} < 0\right) \vee \left(P_{ds\_o} < 0\right) \\ \text{"NOT REQUIRED"} & \text{otherwise} \end{cases}$$

$$\boxed{\textbf{CBA}_2 = \text{"NOT REQUIRED"}}$$

(Note: if CBA not needed, skip cracked base analysis section and move on to Factor of Safety calculation)

Cracked Base Analysis - Case #2 (Click to Expand, if Required)

Revised Parameters (Click to Expand)

Evaluate Sliding Stability (shear friction factor):

Base Inclination Angle $\beta = 0$

Base Area for Analysis $A_0 := B_{unc} \cdot LF = 18\,\text{ft}^2$

With no cohesion

$$FS\_SLIDING_2 := \frac{\left(-F_V \cdot \cos(\beta) - F_U + F_H \cdot \sin(\beta) \cdot f_\beta\right) \cdot \tan\left(\phi_{dam}\right) + \left(A_0 - A_{shear}\right) \cdot c_0 + A_{shear} \cdot c_{shear}}{F_H \cdot \cos(\beta) - F_V \cdot \sin(\beta) \cdot f_\beta} = 2.177$$

Calculated $FS_{sliding}$ $FS\_SLIDING_2 = 2.2$ Required Factor of Safety (from Page 5): $\boxed{FS\_SLIDING_{min_2} = 1.7}$

$$\textbf{Sliding\_Stability} := \begin{cases} \text{"SLIDING OK"} & \text{if } FS\_SLIDING_2 \geq FS\_SLIDING_{min_2} \\ \text{"NOT ADEQUATE"} & \text{otherwise} \end{cases}$$

$\boxed{\textbf{Sliding\_Stability} = \text{"SLIDING OK"}}$

Re-Evaluate Overturning and Base Pressures

Final Resultant Location:

$$R_{rev} := \frac{1}{2} \cdot B_{unc} - e_{rev} = 6.757\,\text{ft}$$

(+) = U/S of toe
(-) = D/S of toe

$$\textbf{Location}_{\textbf{Rrev}_2} := \begin{cases} \text{"OK"} & \text{if } \left(R_{rev} \geq \frac{B_{unc}}{4}\right) \wedge \left(R_{rev} \leq \frac{3B_{unc}}{4}\right) \\ \text{"NG"} & \text{otherwise} \end{cases}$$

$\boxed{\textbf{Location}_{\textbf{Rrev}_2} = \text{"OK"}}$

- Base Pressure at Toe (includes Uplift)

$$\textbf{p}_{\textbf{toe}_2} := \begin{cases} P_{ds\_o} & \text{if } \textbf{CBA}_2 = \text{"NOT REQUIRED"} \\ \frac{-(F_V + F_U)}{B_{unc} \cdot LF} \cdot \left[1 + 6 \cdot \left(\frac{e_{rev}}{B_{unc}}\right)\right] & \text{otherwise} \end{cases}$$

$\boxed{\textbf{p}_{\textbf{toe}_2} = 2.4 \cdot \text{ksf}}$

Check to see if pressure exceeds foundation bearing capacity:

$$\textbf{BC}_2 := \begin{cases} \text{"OK"} & \text{if } \textbf{p}_{\textbf{toe}_2} < 1.33BC \\ \text{"EXCEEDED"} & \text{otherwise} \end{cases}$$

$\boxed{\textbf{BC}_2 = \text{"OK"}}$

Check to see if pressure exceeds dam compressive strength:

$$\textbf{Cu\_dam}_2 := \begin{cases} \text{"OK"} & \text{if } \textbf{p}_{\textbf{toe}_2} < 0.9 \cdot Cu_{dam} \\ \text{"EXCEEDED"} & \text{otherwise} \end{cases}$$

$\boxed{\textbf{Cu\_dam}_2 = \text{"OK"}}$

Check flotation:

$$FS\_FLOT_2 := \frac{-F_V}{F_U} = 2.851$$

Required Factor of Safety against Flotation (from USACE EM 1110-2-2100, Table 3-4): $\boxed{FS\_FLOT_{min_2} := 1.1}$

$$\textbf{Flotation}_2 := \begin{cases} \text{"OK"} & \text{if } FS\_FLOT_2 \geq FS\_FLOT_{min_2} \\ \text{"NOT ADEQUATE"} & \text{otherwise} \end{cases}$$

$\boxed{\textbf{Flotation}_2 = \text{"OK"}}$

END OF LOAD CASE #2 ANALYSIS

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LOAD CASE #3 - Normal Pool + Ice

I. INITIAL VERTICAL LOADS AND MOMENTS:

A. Dam self-weights - (Same as Load Case #1)

Σ Weights of Dam $W_{dam} = -36.75 \cdot kips$

Σ Dam Weight Moments about centerline of Dam $M_{dam} = 8.4 \cdot kips \cdot ft$

B. Headwater: (Vertical Component)

Conditional statement using variable H_water_over_crest
(*determines whether headwater higher than dam crest)*

$$H_{water\_over\_crest} := H_{uw_3} - H_{dam} = -3.5\,ft$$

Height of water above crest

$$H_{ov}(H_{water\_over\_crest}) := \begin{vmatrix} H_{water\_over\_crest} & \text{if } H_{water\_over\_crest} > 0 \cdot ft \\ 0 & \text{otherwise} \end{vmatrix}$$

$$\boxed{H_{ov}(H_{water\_over\_crest}) = 0\,ft}$$

Headwater weight on dam (if crest not overtopped, areas of a, b, and c = 0)
a, b, c correspond to various areas of water over the dam, refer to FBD

Headwater Area A $F_{uwa.y} := -\gamma_w \cdot Area_{uwa.y} \cdot LF = 0$

Headwater Area B $F_{uwb.y} := 0kip$

Headwater Area C $F_{uwc.y} := 0kip$

Σ Vertical components of Headwater over the Upstream face of the Dam

$$F_{uw.y} := F_{uwa.y} + F_{uwb.y} + F_{uwc.y} = 0$$

Moment arms of a, b & c about the Center of Base (same as Load Case #1)

Moments of vertical headwater forces a, b & c forces about centerline:

Headwater Area A $M_{uwa.y} := F_{uwa.y} \cdot arm_{uwa.x} = 0 \cdot kip \cdot ft$

Headwater Area B $M_{uwb.y} := F_{uwb.y} \cdot arm_{uwb.x} = 0 \cdot kip \cdot ft$

Headwater Area C $M_{uwc.y} := F_{uwc.y} \cdot arm_{uwc.x} = 0 \cdot kip \cdot ft$

Σ Moments from the vertical component of Headwater on U/S face of the Dam

$$M_{uw.y} := M_{uwa.y} + M_{uwb.y} + M_{uwc.y} = 0 \cdot kip \cdot ft$$

Field: Tailwater

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D. Soil and Silt Loads: (Vertical Components) - Same as Load Case #1

E. Uplift Pressure:

Height of drainage gallery to plane of analysis $H_{dg} := EL_{dg} - EL_b = 0\,ft$

Effective Hydraulic Head at Drainage Gallery, H_{dr}

$$H_{dr} := \begin{cases} (1-E_{dr})\cdot\left[\left(H_{uw_3} - H_{dw_3}\right)\dfrac{B-d_{dr}}{B} + H_{dw_3} - H_{dg}\right] + H_{dg} & \text{if } H_{dg} \geq H_{dw_3} \\ (1-E_{dr})\cdot\left(H_{uw_3} - H_{dw_3}\right)\cdot\dfrac{B-d_{dr}}{B} + H_{dw_3} & \text{otherwise} \end{cases} = 10.5\cdot ft$$

based on drain effectiveness $E_{dr} = 0\cdot\%$

Head at heel $H_{heel} := H_{uw_3} = 10.5\,ft$

Head at toe $H_{toe} := H_{dw_3} = 2.9\,ft$

Uplift Pressure at Heel $u_{up\_us} := H_{uw_3}\cdot\gamma_w = 0.655\cdot ksf$

Uplift Pressure at Toe $u_{up\_ds} := H_{toe}\cdot\gamma_w = 0.181\cdot ksf$

Uplift Pressure below Drainage Gallery $u_{up\_dg} := H_{dr}\cdot\gamma_w = 0.655\cdot ksf$

Uplift forces below dam base:
Refer to FBD for notation:

$$U_1 := u_{up\_ds}\cdot\left(B - d_{dr}\right)\cdot LF = 3.257\cdot kip$$

$$U_2 := \frac{1}{2}\left(u_{up\_dg} - u_{up\_ds}\right)\cdot\left(B - d_{dr}\right)\cdot LF = 4.268\cdot kip$$

$$U_3 := u_{up\_dg}\cdot d_{dr}\cdot LF = 0\cdot kip$$

$$U_4 := \frac{1}{2}\left(u_{up\_us} - u_{up\_dg}\right)\cdot d_{dr}\cdot LF = 0\cdot kip$$

Σ Uplift Forces = $U := U_1 + U_2 + U_3 + U_4 = 7.525\cdot kip$

Moment arms of Uplift Forces - Same as Load Case #1

Moments due to Uplift Components

$$M_{up1} := U_1\cdot d_{up1} = 0\cdot kip\cdot ft$$

$$M_{up2} := U_2\cdot d_{up2} = 12.804\cdot kip\cdot ft$$

$$M_{up3} := U_3\cdot d_{up3} = 0$$

$$M_{up4} := U_4\cdot d_{up4} = 0$$

Σ Uplift Moments = $M_{up} := M_{up1} + M_{up2} + M_{up3} + M_{up4} = 12.804\cdot kip\cdot ft$

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II. INITIAL HORIZONTAL FORCES AND MOMENTS:

A. Headwater: (Horizontal Component)

Horizontal Component of Headwater on Dam

$$F_{uwa.x} := \begin{cases} \gamma_w \cdot \left(H_{uw_3} - H_{dam}\right) \cdot H_{dam} \cdot LF & \text{if } H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ 0 & \text{otherwise} \end{cases} = 0 \cdot kips$$

$$F_{uwb.x} := \begin{cases} \frac{1}{2} \gamma_w \cdot H_{dam}^{\ 2} \cdot LF & \text{if } H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ \frac{1}{2} \gamma_w \cdot \left(H_{uw_3}\right)^2 \cdot LF & \text{otherwise} \end{cases} = 3.44 \cdot kips$$

Σ Horizontal Forces by Headwater

$$F_{uw.x} := F_{uwa.x} + F_{uwb.x} = 3.44\,kip$$

Moment arms of Headwater on Dam

$$arm_{uwa.y} := \begin{cases} \frac{H_{dam}}{2} & \text{if } H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ 0 & \text{otherwise} \end{cases} = 0 \cdot ft$$

$$arm_{uwb.y} := \begin{cases} \frac{1}{3} H_{dam} & \text{if } H_{ov}\left(H_{water\_over\_crest}\right) > 0 \\ \frac{1}{3} H_{uw_3} & \text{otherwise} \end{cases} = 3.5 \cdot ft$$

Moment of Headwater on Dam

$$M_{uwa.x} := F_{uwa.x} \cdot arm_{uwa.y} = 0 \cdot kip \cdot ft$$

$$M_{uwb.x} := F_{uwb.x} \cdot arm_{uwb.y} = 12.039 \cdot kip \cdot ft$$

Σ Moments due to Headwater

$$M_{uw.x} := M_{uwa.x} + M_{uwb.x} = 12.039 \cdot kip \cdot ft$$

Field: Tailwater

B. Tailwater: (Horizontal Component)

Horizontal Force due to Tailwater

$$F_{dw.x} := \frac{-1}{2} \gamma_w \cdot \left(H_{dw_3}\right)^2 \cdot LF = -0.262\,kip$$

Moment arm of Tailwater

$$arm_{dw.y} := \frac{1}{3} H_{dw_3} = 0.967\,ft$$

Moment due to Tailwater

$$M_{dw.x} := F_{dw.x} \cdot arm_{dw.y} = -0.254\,ft \cdot kip$$

Field: Tailwater

C. Silt and Soil horizontal loading on upstream side of dam: - Same as Load Case #1

D. Soil horizontal loading on downstream side of dam: - Same as Load Case #1

E. Ice Loading

Horizontal Ice Force

$$F_{ice.x} := H_{ice} \cdot \left(f_{ice}\right) \cdot LF = 5\,kip$$

Moment Arm of Ice Force

$$arm_{ice.y} := \left(H_{uw_3} - 0.5 \cdot H_{ice}\right) = 10\,ft$$

Moment due to Ice Force

$$M_{ice.x} := F_{ice.x} \cdot arm_{ice.y} = 50\,ft \cdot kip$$

(Summary of Vertical Forces Raw Data - Click to expand)

III. SUMMARY OF INITIAL LOADS AND MOMENTS - CASE #3

SUMMARY OF VERTICAL FORCES/MOMENTS

Component	Acting			Resisting		
	Force (kip)	Arm (ft)	Moment (kip-ft)	Force (kip)	Arm (ft)	Moment (kip-ft)
Weight of Dam, Area #1	-	-	-	-33.6	-1.0	33.6
Weight of Dam, Area #2	-	-	-	-3.2	8.0	-25.2
Weight of Dam, Area #3	-	-	-	0.0	0.0	0.0
Weight of Dam, Area #4	-	-	-	0.0	0.0	0.0
Headwater over Dam, Fuwa.y	-	-	-	0.0	-9.0	0.0
Headwater over Dam, Fuwb.y	-	-	-	0.0	-9.0	0.0
Headwater over Dam, Fuwc.y	-	-	-	0.0	1.0	0.0
Tailwater over Dam, Fdw.y	-	-	-	0.0	-9.0	0.0
Fill weight on heel, Ffill.y	-	-	-	0.0	-9.0	0.0
Silt weight on heel, Fsilt.y	-	-	-	0.0	-9.0	0.0
Fill weight on toe, Area 1A	-	-	-	0.0	9.0	0.0
Fill weight on toe, Area 1B	-	-	-	0.0	9.0	0.0
Uplift Pressure, Area #1	3.3	0.0	0.0	-	-	-
Uplift Pressure, Area #2	4.3	3.0	12.8	-	-	-
Uplift Pressure, Area #3	0.0	9.0	0.0	-	-	-
Uplift Pressure, Area #4	0.0	9.0	0.0	-	-	-
Totals	**7.5**	**-**	**12.8**	**-36.8**	**-**	**8.4**

Σ **Vertical Forces w/ uplift** $FV_{tot} := \left(F_{vr} + F_{va}\right) \cdot kips = -29.225\,kip$

Σ **Vertical Moments w/ uplift** $MV_{tot} := \left(M_{vr} + M_{va}\right) \cdot kips \cdot ft = 21.204\,ft \cdot kip$

(Summary of Horizontal Forces Raw Data - Click to expand)

SUMMARY OF HORIZONTAL FORCES/MOMENTS

Component	Acting			Resisting		
	Force (kip)	Arm (ft)	Moment (kip-ft)	Force (kip)	Arm (ft)	Moment (kip-ft)
Headwater on Dam, Fuwa.x	0.0	0.0	0.0	-	-	-
Headwater on Dam, Fuwb.x	3.4	3.5	12.0	-	-	-
Saturated Silt, Fsilt.x	0.0	0.0	0.0	-	-	-
Unsaturated Fill, Ffill.x2a	0.0	0.0	0.0	-	-	-
Saturated Fill, Ffill.x	0.1	0.7	0.0	-	-	-
Ice on Dam, Fice.x	5.0	10.0	50.0	-	-	-
Tailwater on Dam, Fdw.x	-	-	-	-0.3	1.0	-0.3
Upper Downstream Fill, Fds_fill.x1	-	-	-	0.0	0.0	0.0
Upper Downstream Fill, Fds_fill.x2	-	-	-	0.0	0.0	0.0
Lower Downstream Fill, Fds_fill.x3	-	-	-	-0.1	1.0	-0.1
Totals	**8.5**	**-**	**62.1**	**-0.4**	**-**	**-0.4**

Σ **Horizontal Forces** $FH_{tot} := \left(F_{hr} + F_{ha}\right) \cdot kips = 8.12\,kip$

Σ **Horizontal Moments** $MH_{tot} := \left(M_{hr} + M_{ha}\right) \cdot kips \cdot ft = 61.715\,ft \cdot kip$

Σ **Moments (w/ uplift)** $M_{tot} := \left(M_{ha} + M_{hr} + M_{va} + M_{vr}\right) \cdot kips \cdot ft = 82.919\,ft \cdot kip$

IV. EVALUATE OVERTURNING AND BASE PRESSURES

- Check Resultant Location - COE EM1110-2-2200 Overturning Stability Criteria

- **Usual Conditions = Within middle third of the base**
- Unusual Conditions = Within middle half of the base
- Extreme Conditions = Within base

A. Calculate Eccentricity and Base Pressures

- Resultant and Eccentricity

- Eccentricity (from centroid of Base Area)

$$e_o := \frac{M_{tot}}{-FV_{tot}} = 2.837\,\text{ft}$$

(+) = D/S of Centroid
(-) = U/S of Centroid

- Resultant Location (from toe)

$$R_o := \frac{1}{2}B - e_o = 6.163\,\text{ft}$$

- Evaluate Overturning using Resultant Location

$$\text{Location}_{Ro_3} := \begin{cases} \text{"WITHIN MIDDLE 1/3"} & \text{if } \left(R_o \ge \frac{B}{3}\right) \wedge \left(R_o \le \frac{2B}{3}\right) \\ \text{"OUTSIDE MIDDLE 1/3"} & \text{otherwise} \end{cases}$$

$$\text{Location}_{Ro_3} = \text{"WITHIN MIDDLE 1/3"}$$

- Base Pressures (includes Uplift)

Base Pressure at Heel:

$$P_{us\_o} := \frac{-FV_{tot}}{B \cdot LF} \cdot \left(1 - \frac{6 \cdot e_o}{B}\right) = 0.088\,\text{ksf}$$

(-) = tension
(+) = compression

Base Pressure at Toe:

$$P_{ds\_o} := \frac{-FV_{tot}}{B \cdot LF} \cdot \left(1 + \frac{6 \cdot e_o}{B}\right) = 3.159\,\text{ksf}$$

(-) = tension
(+) = compression

C. Check if Cracked Base Analysis (CBA) is Required

(CBA is required when base pressure with uplift are negative, i.e. base in tension)

$$\text{CBA}_3 := \begin{cases} \text{"REQUIRED"} & \text{if } \left(P_{us\_o} < 0\right) \vee \left(P_{ds\_o} < 0\right) \\ \text{"NOT REQUIRED"} & \text{otherwise} \end{cases}$$

$$\text{CBA}_3 = \text{"NOT REQUIRED"}$$

(Note: if CBA not needed, do not edit Cracked Base Analysis Region

Cracked Base Analysis - Case #3 (Click to Expand, if Required)

Revised Parameters (Click to Expand)

Evaluate Sliding Stability (shear friction factor):

Base Inclination Angle $\beta = 0$

Base Area for Analysis $A_0 := B_{unc} \cdot LF = 18\,\text{ft}^2$

$$FS\_SLIDING_3 := \frac{\left(-F_V\cdot\cos(\beta) - F_U + F_H\cdot\sin(\beta)\cdot f_\beta\right)\cdot\tan\left(\phi_{dam}\right) + \left(A_0 - A_{shear}\right)\cdot c_0 + A_{shear}\cdot c_{shear}}{F_H\cdot\cos(\beta) - F_V\cdot\sin(\beta)\cdot f_\beta} = 2.0$$

Calculated $FS_{sliding}$ $FS\_SLIDING_3 = 2.0$

Required Factor of Safety (from Page 5): $\boxed{FS\_SLIDING_{min_3} = 2.0}$

$$\textbf{Sliding\_Stability} := \begin{cases} \text{"SLIDING OK"} & \text{if } FS\_SLIDING_3 \geq FS\_SLIDING_{min_3} \\ \text{"NOT ADEQUATE"} & \text{otherwise} \end{cases}$$

$\boxed{\textbf{Sliding\_Stability} = \text{"SLIDING OK"}}$

- Base Pressure at Toe (includes Uplift)

$$\mathbf{p_{toe_3}} := \begin{cases} P_{ds\_o} & \text{if } \mathbf{CBA_3} = \text{"NOT REQUIRED"} \\ \dfrac{-\left(F_V + F_U\right)}{B_{unc}\cdot LF}\cdot\left[1 + 6\cdot\left(\dfrac{e_{rev}}{B_{unc}}\right)\right] & \text{otherwise} \end{cases}$$

$\boxed{\mathbf{p_{toe_3}} = 3.2\cdot ksf}$

Check to see if pressure exceeds foundation bearing capacity:

$$\mathbf{BC_3} := \begin{cases} \text{"OK"} & \text{if } \mathbf{p_{toe_3}} < BC \\ \text{"EXCEEDED"} & \text{otherwise} \end{cases}$$

$\boxed{\mathbf{BC_3} = \text{"OK"}}$

Check to see if pressure exceeds dam compressive strength:

$$\mathbf{Cu\_dam_3} := \begin{cases} \text{"OK"} & \text{if } \mathbf{p_{toe_3}} < 0.3\cdot Cu_{dam} \\ \text{"EXCEEDED"} & \text{otherwise} \end{cases}$$

$\boxed{\mathbf{Cu\_dam_3} = \text{"OK"}}$

Check flotation:

$$FS\_FLOT_3 := \frac{-F_V}{F_U} = 4.883$$

Required Factor of Safety against Flotation (from USACE EM 1110-2-2100, Table 3-4): $\boxed{FS\_FLOT_{min_3} := 1.3}$

$$\mathbf{Flotation_3} := \begin{cases} \text{"OK"} & \text{if } FS\_FLOT_3 \geq FS\_FLOT_{min_3} \\ \text{"NOT ADEQUATE"} & \text{otherwise} \end{cases}$$

$\boxed{\mathbf{Flotation_3} = \text{"OK"}}$

END OF LOAD CASE #3 ANALYSIS

LOAD CASE #4 - Normal Pool + Earthquake

I. INITIAL VERTICAL LOADS AND MOMENTS:

A. Dam self-weights - (Same as Load Case #1)

Σ **Weights of Dam** $W_{dam} = -36.75 \cdot kips$

Σ **Dam Weight Moments about centerline of Dam** $M_{dam} = 8.4 \cdot kips \cdot ft$

B. Headwater: (Vertical Component), Same as Load Case #1

C. Tailwater: (Vertical Component) Same as Load Case #1

D. Soil and Silt Loads: (Vertical Components) - Same as Load Case #1

E. Uplift Pressure: Same as Load Case #1

II. INITIAL HORIZONTAL FORCES AND MOMENTS:

A. Headwater: (Horizontal Component) - Same as Load Case #1

Field: Tailwater

B. Tailwater: (Horizontal Component)

(Typically neglect stabilizing force from tailwater during seismic event, unless additional capacity is needed)

$TW := 0$

Horizontal Force due to Tailwater

$$F_{dw.x} := \begin{cases} -\frac{1}{2}\gamma_w \cdot \left(H_{dw_1}\right)^2 \cdot LF & \text{if } TW = 1 \\ 0 & \text{otherwise} \end{cases} = 0 \cdot kips$$

Moment arm of Tailwater $arm_{dw.y} := \frac{1}{3} H_{dw_3} = 0.967\,ft$

Moment due to Tailwater $M_{dw.x} := F_{dw.x} \cdot arm_{dw.y} = 0\,ft \cdot kip$

Field: Tailwater

C. Silt and Soil horizontal loading on upstream side of dam: - Same as Load Case #1

D. Earthquake Loading

1. Add'l Horizontal Forces and Moments for Concrete due to Earthquake:

Additional horizontal forces:

$F_{W1q.x} := -\lambda \cdot W_1 = 4.334\,kip$

$F_{W2q.x} := -\lambda \cdot W_2 = 0.406\,kip$

$F_{W3q.x} := -\lambda \cdot W_3 = 0$

$$F_{W4q.x} := -\lambda \cdot W_4 = 0$$

Σ Additional Concrete Forces Due to Earthquake

$$F_{damq.x} := F_{W1q.x} + F_{W2q.x} + F_{W3q.x} + F_{W4q.x} = 4.741\,\text{kip}$$

Moment arms about Toe:

$$arm_{W1q.y} := Y_{Centroid.W1} = 7\,\text{ft}$$

$$arm_{W2q.y} := Y_{Centroid.W2} = 5.25\,\text{ft}$$

$$arm_{W3q.y} := 0\text{ft}$$

$$arm_{W4q.y} := 0\text{ft}$$

Additional moments:

$$M_{W1q.x} := F_{W1q.x} \cdot arm_{W1q.y} = 30.341\,\text{ft}\cdot\text{kip}$$

$$M_{W2q.x} := F_{W2q.x} \cdot arm_{W2q.y} = 2.133\,\text{ft}\cdot\text{kip}$$

$$M_{W3q.x} := F_{W3q.x} \cdot arm_{W3q.y} = 0$$

$$M_{W4q.x} := F_{W4q.x} \cdot arm_{W4q.y} = 0$$

Σ Additional Concrete Moments Due to Earthquake

$$M_{damq.x} := M_{W1q.x} + M_{W2q.x} + M_{W3q.x} + M_{W4q.x} = 32.474\,\text{ft}\cdot\text{kip}$$

2. Additional Horizontal Forces and Moments from Soil due to Earthquake:

Earthquake Forces from Upstream and Downstream Soil (See Appendix G of EM 1110-2-2100)

Peak Ground Acceleration: $PGA := \lambda = 0.129$ g

- Assume $k_v := 0$ and neglect effect of soil friction on dam. Vertical face, therefore use EQ G-5 and G-6

Upstream (active) Embankment Angle: $\beta_{us} := 0$ $\beta_{us} = 0 \cdot °$

Passive Side Embankment Angle: $\beta_{ds} := 0$ $\beta_{ds} = 0 \cdot °$

Seismic Inertia Angle:

$$\psi := \operatorname{atan}\left(\frac{\frac{2}{3}PGA}{1 - k_v}\right) = 0.086 \qquad \psi = 4.915 \cdot °$$

Active seismic soil pressure coefficient (fill):

$$K_{AE\_fill} := \frac{\cos(\phi_{fill} - \psi)^2}{\cos(\psi)^2 \cdot \left(1 + \sqrt{\frac{\sin(\phi_{fill})\sin(\phi_{fill} - \psi - \beta_{us})}{\cos(\beta_{us}) \cdot \cos(\psi)}}\right)^2} = 0.283$$

Active seismic soil pressure coefficient (silt):

$$K_{AE\_silt} := \frac{\cos(\phi_s - \psi)^2}{\cos(\psi)^2 \cdot \left(1 + \sqrt{\frac{\sin(\phi_s)\sin(\phi_s - \psi - \beta_{us})}{\cos(\beta_{us})\cdot\cos(\psi)}}\right)^2} = 0.387$$

Passive seismic soil pressure coefficient (fill):

Analyses of previous load cases conservatively used K_0 rather than K_P. Since $K_{PE} >> K_0$, assume seismic force will negate any stabilizing force of the downstream soil.

<u>Earthquake Horizontal Forces from Soil upstream (refer to FBD for dam geometry)</u>

- Seismic loading due to fill (triangular area)

Horizontal Force

$$F_{fillq.x} := \frac{1}{2} K_{AE\_fill} \cdot (\gamma_{fillus} - \gamma_w) \cdot (EL_{F2} - EL_b)^2 \cdot LF = 0.038\,kip$$

Moment arm

$$arm_{fillq.y} := \frac{1}{3} \cdot (EL_{F2} - EL_b) = 0.667\,ft$$

Moment due to fill

$$M_{fillq.x} := F_{fillq.x} \cdot arm_{fillq.y} = 0.026\,ft \cdot kip$$

N/A Field; Seismic Loading due to Silt

3. Additional Horizontal Forces and Moments from Reservoir and Tailwater due to Earthquake:

<u>Hydrodynamic Force - Upstream Side:</u>

From Figure #10 of USBR Engineering Monograph #11

$C_e := 0.73$ for dam with vertical upstream face/slope

The increase in water pressure due to horizontal earthquake acceleration becomes:

$$P_e := C_e \cdot PGA \cdot \gamma_w \cdot \left(EL_{uw_4} - EL_b\right) = 61.7 \cdot psf$$

The total horizontal force due to P_e is expressed analytically as:

$$F_{uwq.x} := 0.726 \cdot P_e \cdot \left(EL_{uw_4} - EL_b\right) \cdot LF = 0.47 \cdot kip$$

The total horizontal moment due to P_e is expressed analytically as:

$$M_{uwq.x} := 0.299 \cdot P_e \cdot \left(EL_{uw_4} - EL_b\right)^2 \cdot LF = 2.034\,ft \cdot kip$$

N/A Field: Hydrodynamic Downstream Force
(Summary of Vertical Forces Raw Data - Click to expand)

III. SUMMARY OF INITIAL LOADS AND MOMENTS - CASE #4

SUMMARY OF VERTICAL FORCES/MOMENTS

Component	Acting			Resisting		
	Force (kip)	Arm (ft)	Moment (kip-ft)	Force (kip)	Arm (ft)	Moment (kip-ft)
Weight of Dam, Area #1	-	-	-	-33.6	-1.0	33.6
Weight of Dam, Area #2	-	-	-	-3.2	8.0	-25.2
Weight of Dam, Area #3	-	-	-	0.0	0.0	0.0
Weight of Dam, Area #4	-	-	-	0.0	0.0	0.0
Headwater over Dam, Fuwa.y	-	-	-	0.0	-9.0	0.0
Headwater over Dam, Fuwb.y	-	-	-	0.0	-9.0	0.0
Headwater over Dam, Fuwc.y	-	-	-	0.0	1.0	0.0
Tailwater over Dam, Fdw.y	-	-	-	0.0	-9.0	0.0
Fill weight on heel, Ffill.y	-	-	-	0.0	-9.0	0.0
Silt weight on heel, Fsilt.y	-	-	-	0.0	-9.0	0.0
Fill weight on toe, Area 1A	-	-	-	0.0	9.0	0.0
Fill weight on heel, Area 2a	-	-	-	0.0	9.0	0.0
Uplift Pressure, Area #1	3.3	0.0	0.0	-	-	-
Uplift Pressure, Area #2	4.3	3.0	12.8	-	-	-
Uplift Pressure, Area #3	0.0	9.0	0.0	-	-	-
Uplift Pressure, Area #4	0.0	9.0	0.0	-	-	-
Totals	**7.5**	**-**	**12.8**	**-36.8**	**-**	**8.4**

Σ **Vertical Forces w/ uplift** $FV_{tot} := (F_{vr} + F_{va}) \cdot kips$ $\boxed{FV_{tot} = -29.225 \cdot kips}$

Σ **Vertical Moments w/ uplift** $MV_{tot} := (M_{vr} + M_{va}) \cdot kips \cdot ft$ $\boxed{MV_{tot} = 21.2 \cdot kips \cdot ft}$

(Summary of Horizontal Forces Raw Data - Click to expand)

SUMMARY OF HORIZONTAL FORCES/MOMENTS

Component	Acting			Resisting		
	Force (kip)	Arm (ft)	Moment (kip-ft)	Force (kip)	Arm (ft)	Moment (kip-ft)
Headwater over Dam, Fuwa.x	0.0	0.0	0.0	-	-	-
Headwater over Dam, Fuwb.x	3.4	3.5	12.0	-	-	-
Saturated Silt, Fsilt.x	0.0	0.0	0.0	-	-	-
Unsaturated Fill, Ffill.x2a	0.0	0.0	0.0	-	-	-
Saturated Fill, Ffill.x	0.1	0.7	0.0	-	-	-
Seismic Force, Dam (Total)	4.7	7.0	32.5	-	-	-
Seismic Force, Silt, Fsiltq.x	0.0	0.0	0.0	-	-	-
Seismic Force, Silt, Fsilt1q.x	0.0	0.0	0.0	-	-	-
Seismic Force, Fill, Ffillq.x	0.0	0.7	0.0	-	-	-
Seismic Force, Headwater, Fuwq.x	0.5		2.0	-	-	-
Tailwater over Dam, Fdw.x	-	-	-	0.0	14.0	0.0
Seismic Tailwater, Fdwq.x	-	-	-	0.0	1.0	0.0
Total Downstream Earth Loads	-	-	-	0.0	1.2	0.0
Totals	**8.7**	**-**	**46.6**	**0.0**	**0.0**	**0.0**

Σ **Horizontal Forces** $FH_{tot} := (F_{hr} + F_{ha}) \cdot kips$ $\boxed{FH_{tot} = 8.741 \cdot kips}$

Σ **Horizontal Moments** $MH_{tot} := (M_{hr} + M_{ha}) \cdot kips \cdot ft$ $\boxed{MH_{tot} = 46.6 \cdot kips \cdot ft}$

Σ **Moments (w/ uplift)** $M_{tot} := (M_{ha} + M_{hr} + M_{va} + M_{vr}) \cdot kips \cdot ft$ $\boxed{M_{tot} = 67.8 \cdot kips \cdot ft}$

IV. EVALUATE OVERTURNING AND BASE PRESSURES

- Check Resultant Location - COE EM1110-2-2200 Overturning Stability Criteria

- Usual Conditions = Within middle third of the base
- Unusual Conditions = Within middle half of the base
- **Extreme Conditions = Within base**

A. Calculate Eccentricity and Base Pressures

- Resultant and Eccentricity

- Eccentricity
(from centroid of Base Area)

$$e_o := \frac{M_{tot}}{-FV_{tot}} = 2.32\ \text{ft}$$

(+) = D/S of Centroid
(-) = U/S of Centroid

- Resultant Location (from toe)

$$R_o := \frac{1}{2}B - e_o = 6.68\ \text{ft}$$

- Evaluate Overturning using Resultant Location

$$\text{Location}_{Ro_4} := \begin{cases} \text{"WITHIN BASE"} & \text{if } (R_o \geq 0) \wedge (R_o \leq B) \\ \text{"OUTSIDE BASE"} & \text{otherwise} \end{cases}$$

$$\text{Location}_{Ro_4} = \text{"WITHIN BASE"}$$

- Base Pressures (includes Uplift)

Base Pressure at Heel:

$$P_{us\_o} := \frac{-FV_{tot}}{B \cdot LF} \cdot \left(1 - \frac{6 \cdot e_o}{B}\right) = 0.368\ \text{ksf}$$

(-) = tension
(+) = compression

Base Pressure at Toe:

$$P_{ds\_o} := \frac{-FV_{tot}}{B \cdot LF} \cdot \left(1 + \frac{6 \cdot e_o}{B}\right) = 2.879\ \text{ksf}$$

(-) = tension
(+) = compression

C. Check if Cracked Base Analysis (CBA) is Required

(CBA is required when base pressure with uplift are negative, i.e. base in tension)

(Note: CBA not required for seismic, unless a crack exists under normal conditions)

$$\mathbf{CBA}_4 := \mathbf{CBA}_1 = \text{"NOT REQUIRED"}$$

Cracked Base Analysis - Case #4 (Click to Expand, if Required)

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Engineers and Scientists

Revised Parameters (Click to Expand)

Evaluate Sliding Stability (shear friction factor):

Base Inclination Angle $\beta = 0$

Base Area for Analysis $A_0 := B_{unc} \cdot LF = 18\,ft^2$

$F_V = -36.75\,kip$

$F_U = 7.525\,kip$

$$FS\_SLIDING_4 := \frac{\left(-F_V \cdot \cos(\beta) - F_U + F_H \cdot \sin(\beta) \cdot f_\beta\right) \cdot \tan(\phi_{dam}) + \left(A_0 - A_{shear}\right) \cdot c_0 + A_{shear} \cdot c_{shear}}{F_H \cdot \cos(\beta) - F_V \cdot \sin(\beta) \cdot f_\beta} = 1.853$$

Calculated $FS_{sliding}$ $FS\_SLIDING_4 = 1.9$

Required Factor of Safety (from Page 5): $\boxed{FS\_SLIDING_{min_4} = 1.3}$

$$\textbf{Sliding\_Stability} := \begin{cases} \text{"SLIDING OK"} & \text{if } FS\_SLIDING_4 \geq FS\_SLIDING_{min_4} \\ \text{"NOT ADEQUATE"} & \text{otherwise} \end{cases}$$

$\boxed{\textbf{Sliding\_Stability} = \text{"SLIDING OK"}}$

- Base Pressure at Toe (includes Uplift)

$$\mathbf{p_{toe_4}} := \begin{cases} P_{ds\_o} & \text{if } \mathbf{CBA_4} = \text{"NOT REQUIRED"} \\ \dfrac{-(F_V + F_U)}{B_{unc} \cdot LF} \cdot \left[1 + 6 \cdot \left(\dfrac{e_{rev}}{B_{unc}}\right)\right] & \text{otherwise} \end{cases}$$

$\boxed{\mathbf{p_{toe_4}} = 2.9 \cdot ksf}$

Check to see if pressure exceeds foundation bearing capacity:

$$\mathbf{BC_4} := \begin{cases} \text{"OK"} & \text{if } \mathbf{p_{toe_4}} < 1.33BC \\ \text{"EXCEEDED"} & \text{otherwise} \end{cases}$$

$\boxed{\mathbf{BC_4} = \text{"OK"}}$

Check to see if pressure exceeds dam compressive strength:

$$\mathbf{Cu\_dam_4} := \begin{cases} \text{"OK"} & \text{if } \mathbf{p_{toe_4}} < 0.9 \cdot Cu_{dam} \\ \text{"EXCEEDED"} & \text{otherwise} \end{cases}$$

$\boxed{\mathbf{Cu\_dam_4} = \text{"OK"}}$

Check flotation:

$$FS\_FLOT_4 := \frac{-F_V}{F_U} = 4.883$$

Required Factor of Safety against Flotation (from USACE EM 1110-2-2100, Table 3-4): $\boxed{FS\_FLOT_{min_4} := 1.1}$

$$\mathbf{Flotation_4} := \begin{cases} \text{"OK"} & \text{if } FS\_FLOT_4 \geq FS\_FLOT_{min_4} \\ \text{"NOT ADEQUATE"} & \text{otherwise} \end{cases}$$

$\boxed{\mathbf{Flotation_4} = \text{"OK"}}$

END OF LOAD CASE #4 ANALYSIS

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Engineers and Scientists

SUMMARY OF STABILITY ANALYSIS RESULTS - SPILLWAY SECTION (PROPOSED)

Sliding

Case	Description	Cracked Base Analysis	Minimum Required FS	Calculated FS
1	Normal water levels	*NOT REQUIRED*	2.0	5.2
2	Flood water levels	*NOT REQUIRED*	1.7	2.2
3	Normal water levels + Ice	*NOT REQUIRED*	2.0	2.0
4	Normal water levels + Earthquake	*NOT REQUIRED*	1.3	1.9

Overturning

Case	Description	Required Resultant Location	Calculated Resultant Location	Calculated Base Pressure at Toe (ksf)	Bearing Capacity OK?	Dam Compressive Strength OK?
1	Normal water levels	WITHIN MIDDLE 1/3	OK	2.2	OK	OK
2	Flood water levels	WITHIN BASE	OK	2.4	OK	OK
3	Normal water levels + Ice	WITHIN MIDDLE 1/3	OK	3.2	OK	OK
4	Normal water levels + Earthquake	WITHIN BASE	OK	2.9	OK	OK

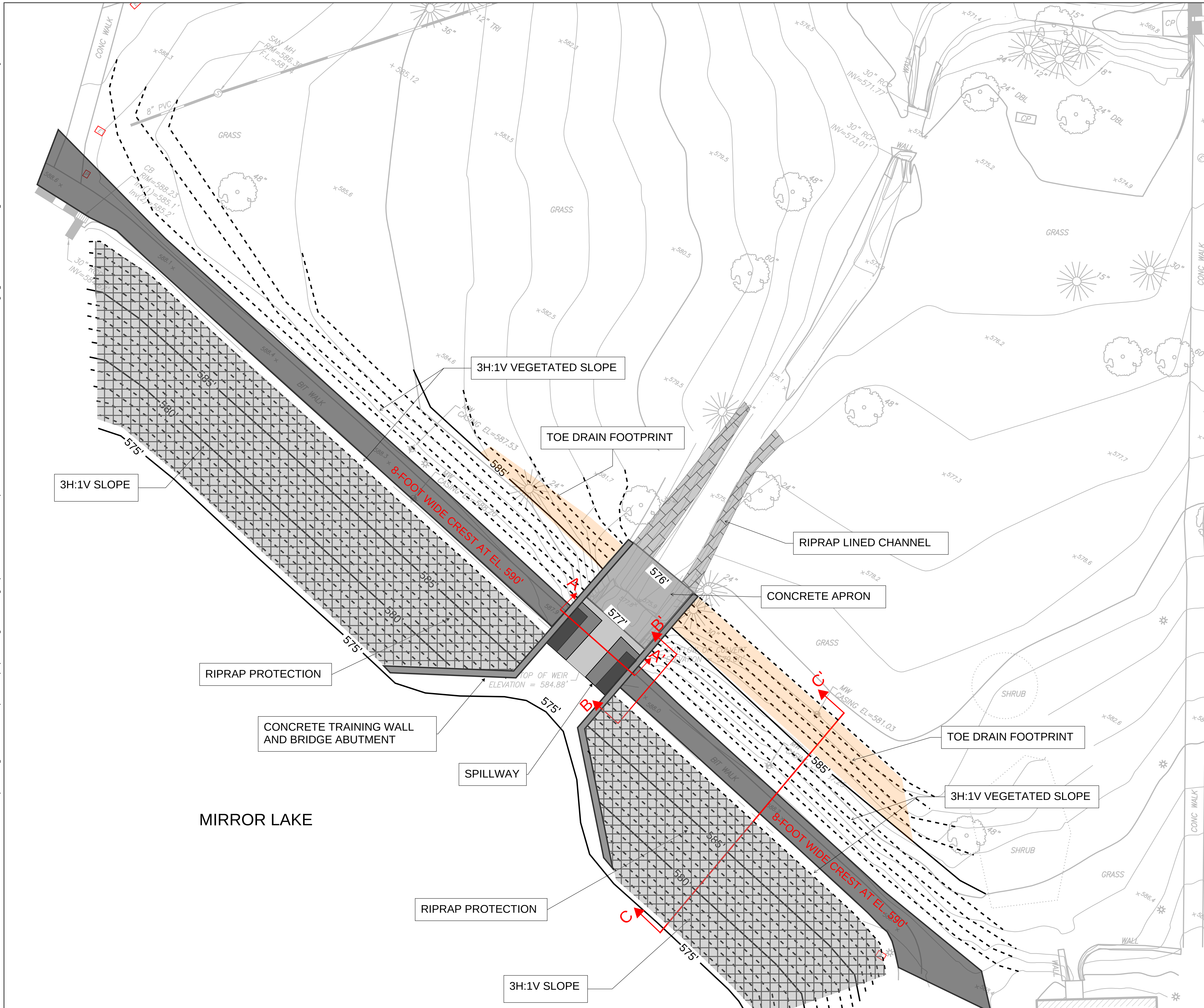
Flotation

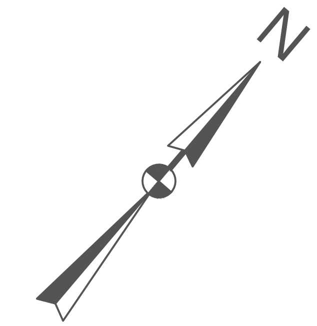
Case	Description	Minimum Required FS	Calculated FS	FS Flotation OK?
1	Normal water levels	1.3	4.9	OK
2	Flood water levels	1.1	2.9	OK
3	Normal water levels + Ice	1.3	4.9	OK
4	Normal water levels + Earthquake	1.1	4.9	OK

$q_{ult} = \gamma_{sub} D N_q + 0.5 \gamma_{sub} B N_\gamma$ = (130-62.4)(2)(61.55) +0.5(130-62.4)(12)(78.61) = 40,206 psf
$q_{all} = q_{ult}/FS$ = 40,206/3 = 13,402 psf = 13.4 ksf

$$FS\_SLIDING_3 := \mathrm{round}\left(FS\_SLIDING_3, 1\right)$$

APPENDIX J – PROPOSED CONDITIONS PLANS





GENERAL NOTES

1. BASE MAP BASED ON ELECTRONIC FILE ENTITLED "140069201-V-EX101-MIRROR LAKE.DWG", PROVIDED BY BVH.
2. VERTICAL ELEVATIONS ARE IN REFERENCE TO NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).

LEGEND

- SECTION LINE (SEE DRAWING 2)
- FOOTPRINT OF UPSTREAM SLOPE RIPRAP
- FOOTPRINT OF DOWNSTREAM SLOPE TOE DRAIN
- FOOTPRINT OF DOWNSTREAM CHANNEL RIPRAP

0 15 30 60
SCALE IN FEET

NO.	ISSUE/DESCRIPTION	BY	DATE

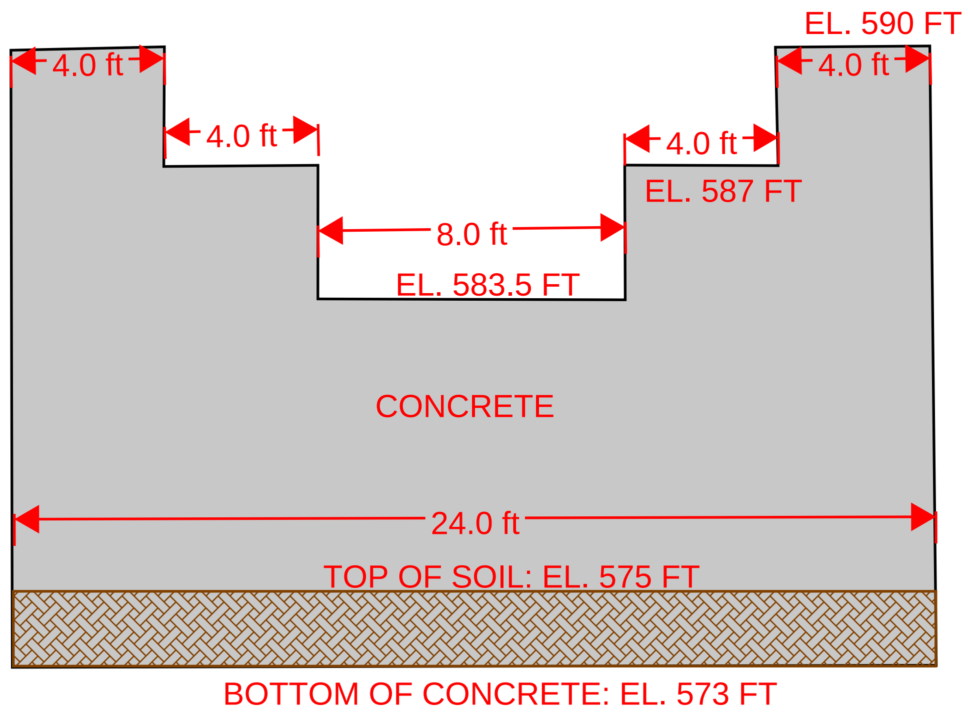
MIRROR LAKE DAM
STORRS, CONNECTICUT

PROPOSED CONCEPTUAL CONDITIONS PLAN

PREPARED BY:
GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com

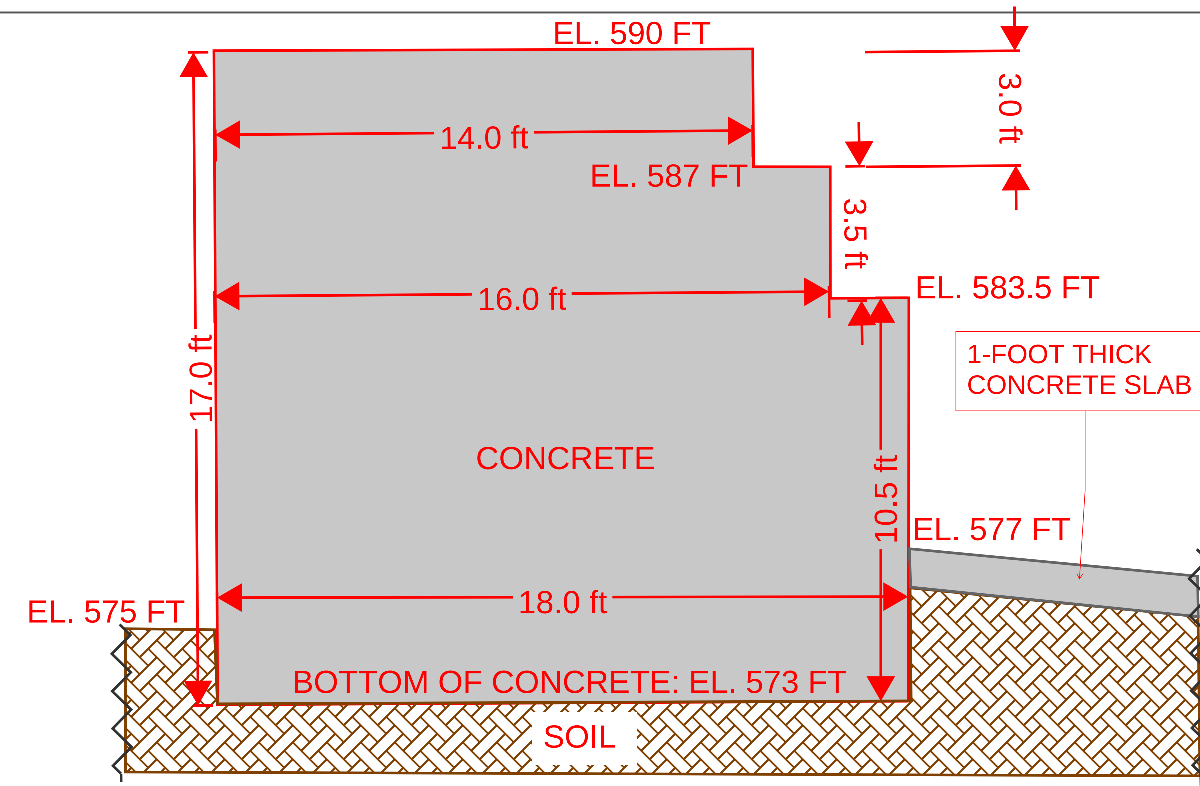
PREPARED FOR:
BVH INTEGRATED SERVICES
206 WEST NEWBERRY ROAD
BLOOMFIELD, CONNECTICUT

PROJ MGR: JFD	REVIEWED BY: DMB	CHECKED BY: DML	DWG 1
DESIGNED BY: JFD	DRAWN BY: JFD	SCALE: AS NOTED	
DATE: MARCH, 2021	PROJECT NO. 05.0046161.07	REVISION NO.	SHEET NO. 1 OF 3



SECTION A-A'

0 5' 10'
SCALE IN FEET



SECTION B-B'

0 5' 10'
SCALE IN FEET

GENERAL NOTES

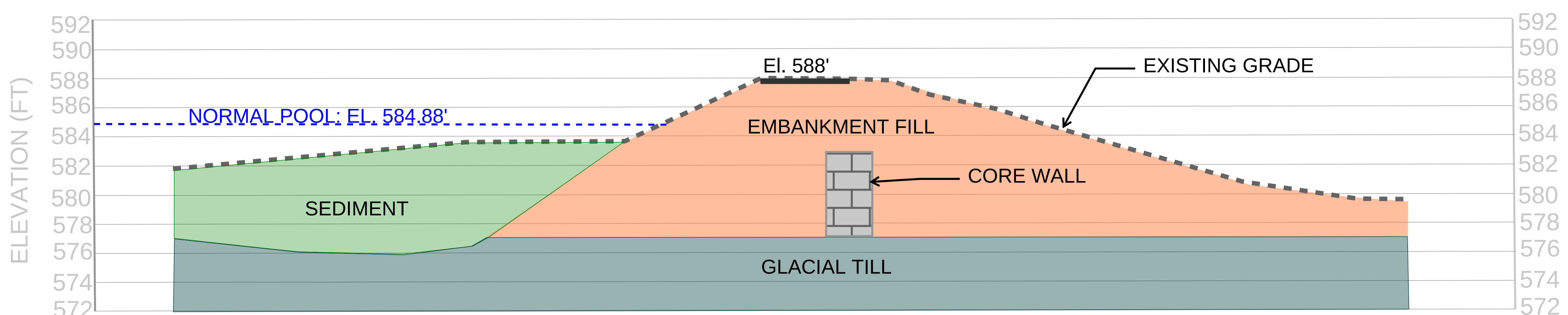
1. VERTICAL ELEVATIONS ARE IN REFERENCE TO NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).

TOE DRAIN CONSISTS OF:
- 6-INCH DIAMETER PERFORATED PVC PIPE DISCHARGE TO DOWNSTREAM CHANNEL.
- CLEANOUT AT EACH END OF DRAIN
- BACKFILL CONSIST OF 3/8-INCH CRUSHED STONE
- WRAP STONE IN MIRAFI 1100N GEOTEXTILE FABRIC

STANDARD RIPRAP CONSISTS OF:
CONNDOT FORM 818, M.12.02.1

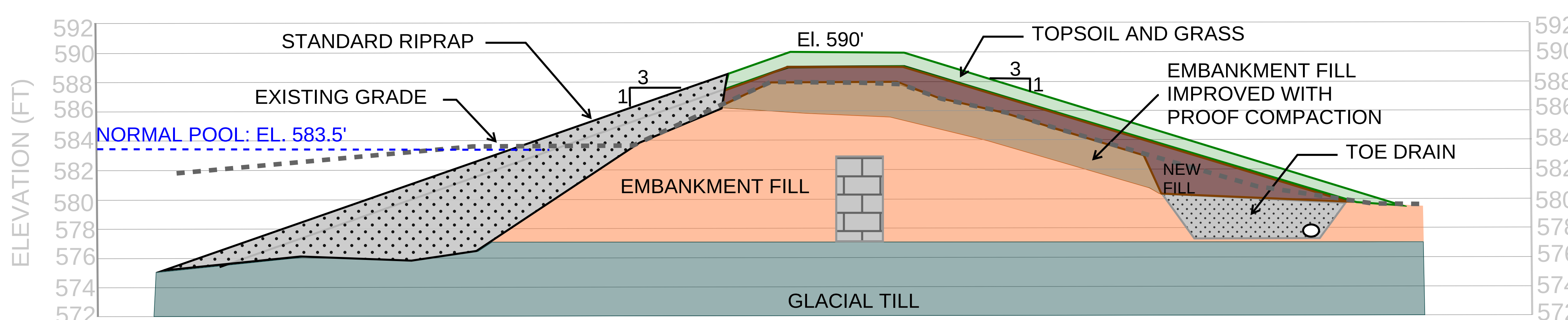
NEW FILL:
CONNDOT FORM 818, M.02.01 GRANULAR FILL WITH MODIFIED NO. 100 BETWEEN 0 AND 15 PERCENT AND MODIFIED NO. 200 BETWEEN 0 AND 12 PERCENT

PROOF COMPACTED EMBANKMENT FILL
MINIMUM OF 6 PASSES OF A VIBRATORY DRUM ROLLER WITH A MINIMUM DYNAMIC FORCE OF 5,000 LBS PER FOOT OF DRUM WIDTH



0 10' 20'
SCALE IN FEET

SECTION C-C' - EXISTING CONDITIONS



0 10' 20'
SCALE IN FEET

SECTION C-C' - PROPOSED CONDITIONS

NO.	ISSUE/DESCRIPTION	BY	DATE

MIRROR LAKE DAM
STORRS, CONNECTICUT

PROPOSED SECTIONS
SPILLWAY AND EMBANKMENT

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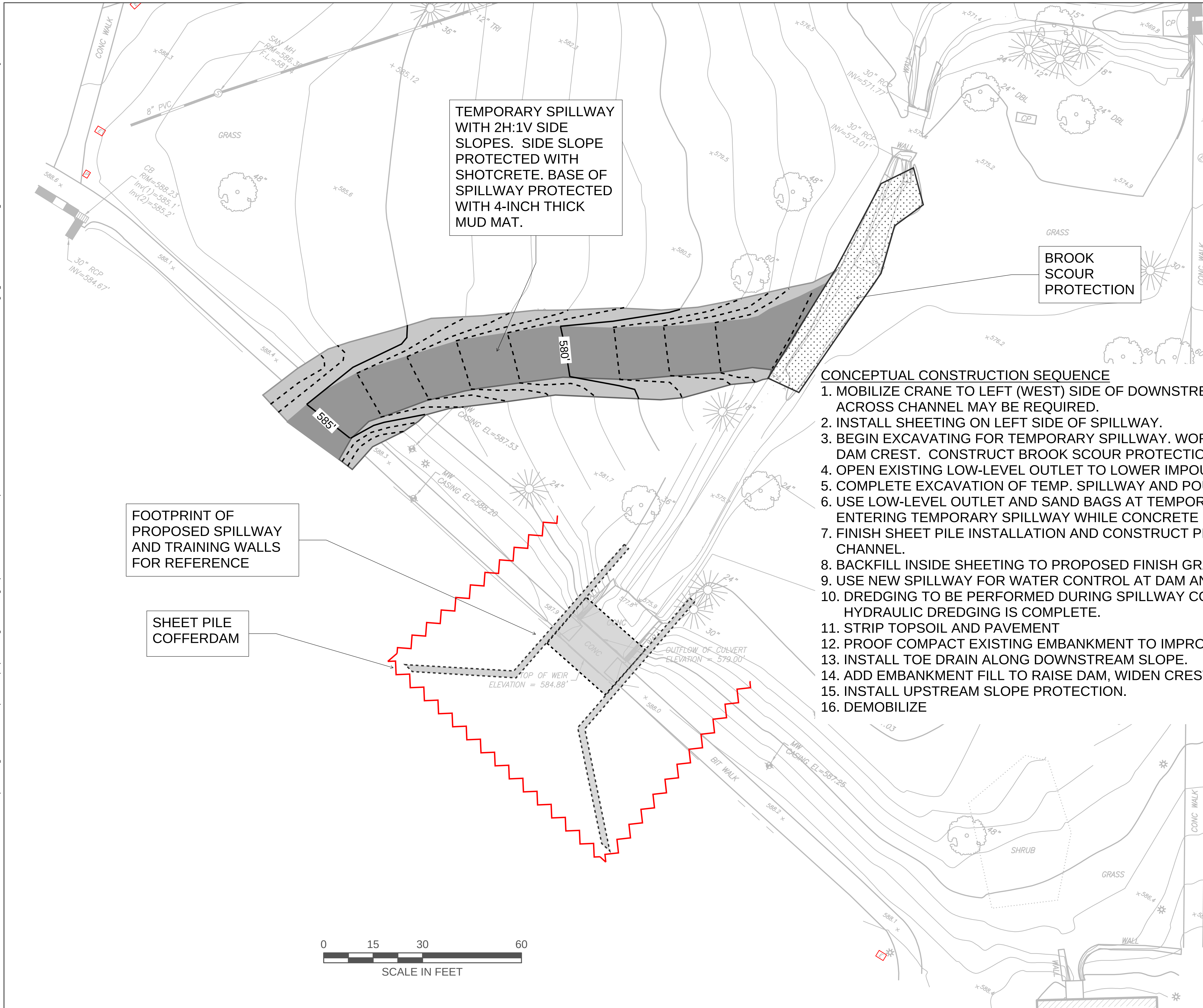
GZA GeoEnvironmental, Inc.
Engineers and Scientists
www.gza.com

PREPARED FOR:
BVH INTEGRATED SERVICES
206 WEST NEWBERRY ROAD
BLOOMFIELD, CONNECTICUT

PROJ MGR: JFD	REVIEWED BY: DMB	CHECKED BY: DML	DWG 2
DESIGNED BY: JFD	DRAWN BY: JFD	SCALE: AS NOTED	
DATE: MARCH, 2021	PROJECT NO. 05.0046161.07	REVISION NO.	SHEET NO. 2 OF 3



GENERAL NOTES

1. BASE MAP BASED ON ELECTRONIC FILE ENTITLED "140069201-V-EX101-MIRROR LAKE.DWG", PROVIDED BY BVH.
2. VERTICAL ELEVATIONS ARE IN REFERENCE TO NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).

CONCEPTUAL CONSTRUCTION SEQUENCE

1. MOBILIZE CRANE TO LEFT (WEST) SIDE OF DOWNSTREAM CHANNEL. A TEMPORARY RIPRAP ACCESS ACROSS CHANNEL MAY BE REQUIRED.
2. INSTALL SHEETING ON LEFT SIDE OF SPILLWAY.
3. BEGIN EXCAVATING FOR TEMPORARY SPILLWAY. WORK FROM DOWNSTREAM CHANNEL TOWARDS DAM CREST. CONSTRUCT BROOK SCOUR PROTECTION (I.E., RIPRAP, ARTICULATED CONCRETE BLOCKS)
4. OPEN EXISTING LOW-LEVEL OUTLET TO LOWER IMPOUNDMENT TO EL. 583 FT (1' BELOW SPILLWAY).
5. COMPLETE EXCAVATION OF TEMP. SPILLWAY AND POUR SIDE-CHANNEL AND BOTTOM PROTECTION.
6. USE LOW-LEVEL OUTLET AND SAND BAGS AT TEMPORARY SPILLWAY DURING TO PREVENT WATER FROM ENTERING TEMPORARY SPILLWAY WHILE CONCRETE CURES.
7. FINISH SHEET PILE INSTALLATION AND CONSTRUCT PERMANENT SPILLWAY, TRAINING WALLS AND D/S CHANNEL.
8. BACKFILL INSIDE SHEETING TO PROPOSED FINISH GRADES AND REMOVE SHEET PILES.
9. USE NEW SPILLWAY FOR WATER CONTROL AT DAM AND BACKFILL TEMPORARY SPILLWAY.
10. DREDGING TO BE PERFORMED DURING SPILLWAY CONSTRUCTION. KEEP SHEETING IN PLACE UNTIL HYDRAULIC DREDGING IS COMPLETE.
11. STRIP TOPSOIL AND PAVEMENT
12. PROOF COMPACT EXISTING EMBANKMENT TO IMPROVE UPPER SOILS.
13. INSTALL TOE DRAIN ALONG DOWNSTREAM SLOPE.
14. ADD EMBANKMENT FILL TO RAISE DAM, WIDEN CREST, AND CREATE 3H:1V SLOPE.
15. INSTALL UPSTREAM SLOPE PROTECTION.
16. DEMOBILIZE

NO.	ISSUE/DESCRIPTION	BY	DATE

MIRROR LAKE DAM
STORRS, CONNECTICUT

CONCEPTUAL COFFERDAM AND WATER CONTROL PLAN

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PREPARED FOR:
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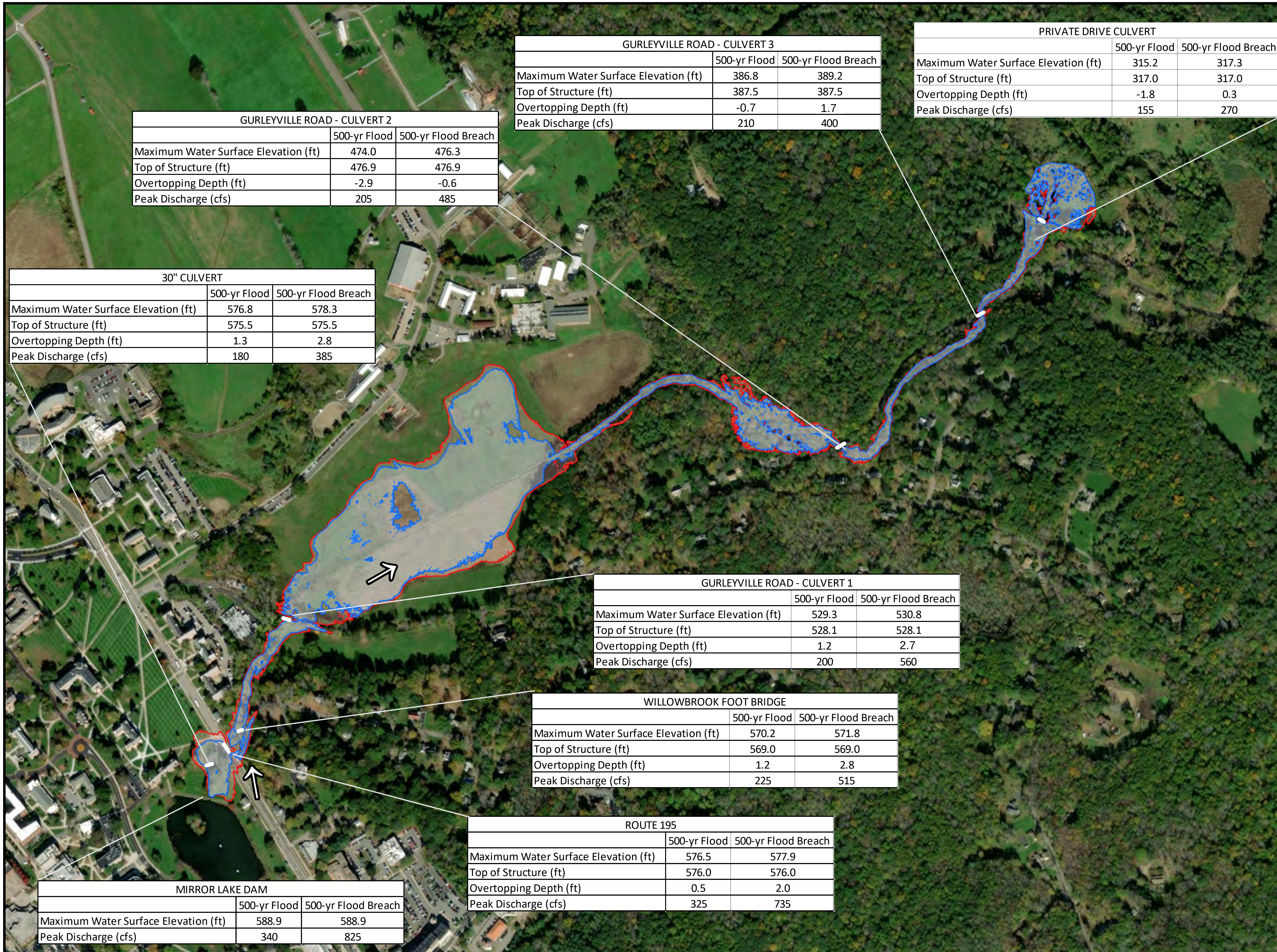
BLOOMFIELD, CONNECTICUT

PROJ MGR: JFD	REVIEWED BY: DMB	CHECKED BY: DML	DWG 3
DESIGNED BY: JFD	DRAWN BY: JFD	SCALE: AS NOTED	
DATE: MARCH, 2021	PROJECT NO. 05.0046161.07	REVISION NO.	SHEET NO. 3 OF 3

APPENDIX K – INUNDATION MAP- MIRROR LAKE DAM



MIRROR LAKE DAM		
	500-yr Flood	500-yr Flood Breach
Maximum Water Surface Elevation (ft)	588.9	588.9
Peak Discharge (cfs)	340	825

30" CULVERT		
	500-yr Flood	500-yr Flood Breach
Maximum Water Surface Elevation (ft)	576.8	578.3
Top of Structure (ft)	575.5	575.5
Overtopping Depth (ft)	1.3	2.8
Peak Discharge (cfs)	180	385

ROUTE 195		
	500-yr Flood	500-yr Flood Breach
Maximum Water Surface Elevation (ft)	576.5	577.9
Top of Structure (ft)	576.0	576.0
Overtopping Depth (ft)	0.5	2.0
Peak Discharge (cfs)	325	735

WILLOWBROOK FOOT BRIDGE		
	500-yr Flood	500-yr Flood Breach
Maximum Water Surface Elevation (ft)	570.2	571.8
Top of Structure (ft)	569.0	569.0
Overtopping Depth (ft)	1.2	2.8
Peak Discharge (cfs)	225	515

GURLEYVILLE ROAD - CULVERT 1		
	500-yr Flood	500-yr Flood Breach
Maximum Water Surface Elevation (ft)	529.3	530.8
Top of Structure (ft)	528.1	528.1
Overtopping Depth (ft)	1.2	2.7
Peak Discharge (cfs)	200	560

GURLEYVILLE ROAD - CULVERT 2		
	500-yr Flood	500-yr Flood Breach
Maximum Water Surface Elevation (ft)	474.0	476.3
Top of Structure (ft)	476.9	476.9
Overtopping Depth (ft)	-2.9	-0.6
Peak Discharge (cfs)	205	485

GURLEYVILLE ROAD - CULVERT 3		
	500-yr Flood	500-yr Flood Breach
Maximum Water Surface Elevation (ft)	386.8	389.2
Top of Structure (ft)	387.5	387.5
Overtopping Depth (ft)	-0.7	1.7
Peak Discharge (cfs)	210	400

PRIVATE DRIVE CULVERT		
	500-yr Flood	500-yr Flood Breach
Maximum Water Surface Elevation (ft)	315.2	317.3
Top of Structure (ft)	317.0	317.0
Overtopping Depth (ft)	-1.8	0.3
Peak Discharge (cfs)	155	270

Legend

500-Year Flood (no Breach)

500-Year Flood with Dam Breach

Modeled Structures

Flow Direction

NOTES:
1. AERIAL PHOTO WAS SUPPLIED BY ESRI

2. THE INUNDATION AREAS SHOWN ON THIS MAP REFLECT EVENTS OF AN EXTREMELY REMOTE NATURE. THESE RESULTS ARE NOT IN ANY WAY INTENDED TO REFLECT UPON THE INTEGRITY OF MIRROR LAKE DAM

3. THE INUNDATION AREA SHOWN IS APPROXIMATE AND SHOULD BE USED AS A GUIDELINE FOR ESTABLISHING EVACUATION ZONES.

4. ACTUAL INUNDATION AREA WILL DEPEND ON ACTUAL FAILURE CONDITIONS AND MAY DIFFER FROM THIS MAP.

4. INUNDATION AREA WAS CALCULATED BY SIMULATING DAM FAILURE WITH THE HEC-RAS 5.0.7 COMPUTER SOFTWARE.

5. WET WEATHER DAM FAILURE WAS SIMULATED WITH MAXIMUM WATER SURFACE ELEVATION RESULTING FROM 500-YEAR FLOOD AND 500-YEAR FLOOD (340 CFS PEAK FLOW) IN DOWNSTREAM RIVER

6. ELEVATION DATUM IS NAVD88.

INUNDATION MAP
MIRROR LAKE DAM

STORRS, CONNECTICUT

Prepared For:

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Job No.: 01.0019244.24

GZA GeoEnvironmental, Inc.