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Summary Report

CWCB POGG1,PDAA,202000002982

Bruce Canyon Reservoir 50% Design

The history of the Cucharas Basin is one of perpetual drought punctuated by a few normal years. – Lewis "Beaver" Edmundson, HCWCD Board

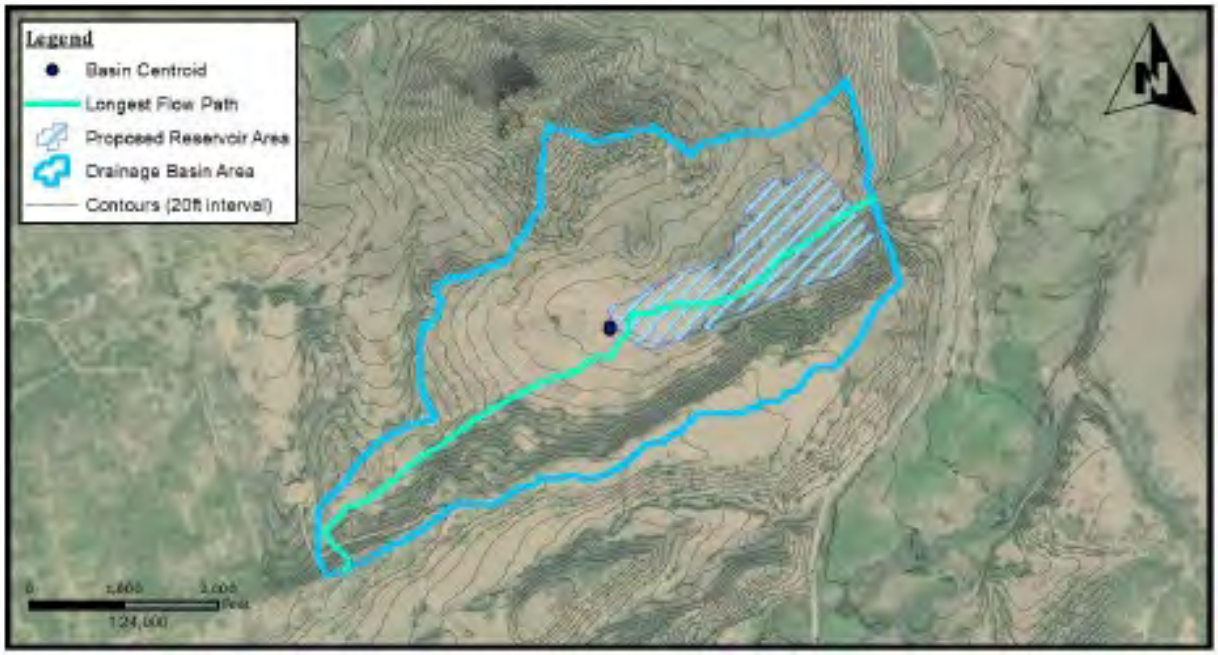
The Cucharas River basin is short of water, and that is exacerbated by a profound lack of storage – 70% less than existed in the 1940s. The Cucharas Basin Storage Collaborative was formed in 2015 to assess the storage needs of the basin and narrow down over a dozen options for collective storage development to meet the basin's storage needs. These options included opportunities for collaborative repair, construction and operation of new or enlarged storage structures within the basin. Five preferred options were selected by the Collaborative, and one of those was construction of Bruce Canyon Reservoir, about 2.5 miles southwest of La Veta, Colorado.

Description

Bruce Canyon dam will be a new off-channel reservoir impounded by a 1,160-foot long and 78-foot tall homogenous earthen embankment constructed in a natural valley.

It would be owned by Huerfano County Water Conservancy District on behalf of the Cucharas Basin Storage Collaborative. The design shows the dam located in the northwest ¼ of Section 5, Township 30 South, Range 68 West, of the Sixth PM, at a ground surface elevation of approximately 7350 feet. The reservoir would be filled with diversions from the Cucharas River via the Butte Ditch. A conditional storage right of 1,406 acre-feet (af) was decreed for Bruce Canyon Reservoir in Case No. 17CW3075, which also includes conditional exchanges to the Butte Ditch of up to 31.1 cubic feet per second (cfs) to fill Bruce Canyon Reservoir and conditional exchanges of up to 8 cfs for releases from Bruce Canyon Reservoir to the Cucharas River. The reservoir will likely be filled in the first part of the irrigation season when there is exchange potential from downstream sources, and releases may be made throughout the year for augmentation purposes.

As shown in the following graphic, the drainage basin for Bruce Canyon dam was determined to be relatively small at only 346 acres or 0.54 square miles.



The spillway design for Bruce Canyon dam was revised from the 30% design phase based on updated hydrologic analysis. Following are revisions made to the spillway design during the 50% Design Phase:

- The spillway alignment was altered from the previous design phase to discharge flows just past the natural saddle located approximately 900 feet north of the north dam abutment. This would avoid costly blasting and excavation through the volcanic dike associated with the previous alignment and would carry flows away from the groin of the dam and into a different drainage, reducing impacts at Highway 12 and in the Town of La Veta.
- The spillway invert elevation was raised from 7404.9 ft to 7409 ft, which results in a normal storage of approximately 1,200 ac-ft.
- The spillway will provide a total of 5 feet of freeboard between the spillway invert and dam crest, increasing spillway freeboard and capacity. Increasing the freeboard allows for the proposed spillway width to be reduced from 80 feet proposed during the 30% Design Phase to 40 feet currently shown in the 50% Design Drawings.
- The spillway profile will drop 6 feet from the spillway crest at a -3.6% grade and then transition to a shallower grade of -0.50% until the spillway discharges into the natural draw.
- Proposed spillway riprap lining has been reduced in size and extent during the 50% Design Phase. The riprap will only line the portion of the spillway where supercritical flows or turbulent flows resulting from a hydraulic jump are expected.

The dam crest was raised 6.1 ft to an elevation of 7414 feet. This targets a storage capacity of 1,200 ac-ft to get as close as possible to the 1,406 ac-ft conditional storage right decreed in Case No. 17CW3075, while maintaining 5 feet of freeboard between the dam crest and spillway invert.

The inlet structure includes a 12-inch slide gate mounted to a 12-inch diameter orifice plate to restrict flows through the 24-inch diameter conduit. This was included to prevent a pressure flow condition within the conduit, which poses a dam safety concern. Calculations were updated which verified that the proposed design is still capable of meeting the 5-day drawdown rule.

An outlet channel/pipe approximately 1,850 feet long will be constructed downstream from the USBR Type 5 baffled outlet structure, east to discharge to the Cucharas River. The outlet channel will have a design capacity of 8 cfs to accommodate the largest conditional exchange rate from Bruce Canyon Reservoir decreed in Case No. 17CW3075.

The proposed design of Bruce Canyon Reservoir was furthered into the 50% Design phase with major revisions to the embankment configuration, foundation treatment and spillway design. The 50% Design Drawings also show additional detail for the proposed outlet works. A 24-inch diameter plastic pipe bypass inverted siphon approximately has been proposed for the Butte Ditch, which is impacted by the current design of Bruce Canyon Reservoir.

A Hydrology Report conservatively assuming an Extreme Hydrologic Hazard designation was completed during this design phase and submitted to Colorado Division of Water Resources, Dam Safety Branch for approval. The Hydrology Report establishes key characteristics of the IDF (inflow design flood) for Bruce Canyon Reservoir, which informs the spillway design going forward. Further study of the Hydrologic Hazard designation is recommended to explore if Bruce Canyon Reservoir could be reduced to a High Hydrologic Hazard designation. A smaller, less expensive spillway could be pursued in the next design phase if the structure qualifies for a High Hydrologic Hazard designation.

Cost

The engineer's opinion of probable cost for actual construction is $17,045,000. That equates to approximately $13,830 per acre-foot based on the current dam configuration, which can store approximately 1,233 ac-ft.

Final design, survey and permitting are expected to add approximately $750,000, plus $470,000 for construction observation/testing. This brings the estimated total project to $18,265,000, based on quantities shown in the 50% Design Drawings.

The cost estimate does not include land or easement acquisition (not yet discussed with landowners).



Bruce Canyon Reservoir
50% Design Report

December, 2021

AG File # 18-117

HUERFANO COUNTY WATER CONSERVANCY DISTRICT

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INTRODUCTION

The Huerfano County Water Conservancy District (HCWCD) retained Applegate Group, Inc. (Applegate Group) to further their work on the Bruce Canyon Reservoir project from 30% design to 50% design phase. The Colorado Water Conservation Board (CWCB) continues to fund this project through the 50% design phase with a Water Supply Reserve Fund (WSRF) Grant. The Grant was approved in March 2020 for the following general scope of work:

1. Complete geotechnical analyses typical of 50 percent design.
2. Complete a hydrologic analysis.
3. Complete 50% design drawings for Bruce Canyon Reservoir
4. Prepare a Construction Specification Table of Contents
5. Complete an Engineer's Opinion of Probable Cost at the 50% design level
6. Present and discuss 50% Design with the Dam Safety Branch of Colorado Division of Water Resources (CDWR)
7. Identify required information and scope of work for upcoming 90% Design Phase

Previous studies completed specific to Bruce Canyon Reservoir are summarized below:

1. Applegate Group and Parsons Water completed a Cucharas Basin Collaborative Storage Study in June 2017 with the objectives of 1) determining storage needs in the Cucharas Basin and 2) completing a reconnaissance level study and screening of potential storage sites to meet the storage needs. This reconnaissance level study was based on limited geotechnical data found in a literature search and did not include a field geotechnical investigation. The final deliverable included a concept-level design and associated cost estimate for five recommended storage sites including Bruce Canyon Reservoir.
2. Cesare, Inc. (Cesare) completed a November 2018 reconnaissance level geotechnical investigation for five sites identified in the June 2017 report. This study included field investigations, site-specific geotechnical drilling, and laboratory analyses.
3. Applegate Group completed 30% Design Phase for Bruce Canyon Dam in January 2020. This phase of design included preliminary Drawings, Opinion of Probable Cost, and Report for the structure at a 30% design level which are included as Appendices in this report.

In general, the 50% Design Phase scope of work summarized in this report included updating and revising the 30% design level with additional detail utilizing information and recommendations found in the aforementioned studies as well as input from the HCWCD and Dam Safety Branch of the CDWR. Deliverables for the Bruce Canyon Reservoir 50% Design Phase include revised Design Drawings, updated Opinion of Probable Cost, a Table of Contents for Construction Specifications, and this 50% Design Phase Report.

The remainder of this report will summarize engineering design efforts completed under the 50% Design Phase scope as well as describe any revisions and modifications from the 30% Design Phase deliverables.

GEOTECHNICAL EVALUATION SUMMARY

Cesare continued their geotechnical evaluation of the Bruce Canyon reservoir site during the 50% Design Phase. Cesare's scope of work encompassed additional laboratory testing of samples collected during the preliminary geotechnical evaluation, geotechnical engineering analysis of proposed dam features, and further refining technical constraints and design recommendations to a 50% design level. Please note that samples and boreholes were completed during the preliminary geotechnical investigation assuming the dam crest centerline would align with the volcanic dike. The dam crest center alignment has since been shifted approximately 400 feet upstream due to concerns stemming from the highly fractured nature of the formation.

The remainder of this section will briefly summarize Cesare's efforts and findings during the 50% design phase. Cesare completed a 50% design geotechnical evaluation for Bruce Canyon Reservoir that built upon their findings and recommendations from the previous November 2018 Preliminary Geotechnical Evaluation. Cesare's *Geotechnical Evaluation Report* (September 2020) is included in Appendix A and summarizes their efforts, which included laboratory testing of samples collected during the previous study and engineering analysis of the proposed design.

LABORATORY TESTING

The following laboratory testing was completed on samples collected during the preliminary geotechnical investigation by Cesare during the 50% design phase.

DIRECT SHEAR TESTS

Direct shear tests were performed according to ASTM D3080 standards on an in-situ claystone sample and a remolded silty sand sample to assess strength properties of the bedrock and embankment material respectively. Results of the direct shear tests are shown in the following table.

TABLE 1. DIRECT SHEAR TEST DATA

Boring/ Exploratory Pit No.	Sample Depth (ft)	Material	Peak Strength		Ultimate strength (~20% Strain)	
			ϕ	C (psf)	ϕ	C (psf)
BC-1	15	Claystone	29.8	0	21.2	0
BCP-6	7 to 9	Silty Sand	29.3	380	28.7	217

PERMEABILITY

Permeability tests were performed according to ASTM D5084 standards on 3 potential embankment samples remolded to 96% compaction and wetted to 1% to 2% over optimum moisture content to represent their placed condition within the embankment. Results of the permeability tests are shown in the following table.

TABLE 2. PERMEABILITY PARAMETERS

Boring/Exploratory Pit No.	Sample Depth (ft)	Material	Hydraulic Conductivity (cm/s)
BCP-1 BCP-5	1 to 8 2 to 8	Sandy Clay	1.65E-07
BCP-2 BCP-4	2 to 10 2 to 8	Silty Clayey Sand	2.21E-06
BCP-6	7 to 9	Silty Sand	3.18E-05

TRIAXIAL COMPRESSION TESTS

Triaxial compression tests were performed according to ASTM D4767 standards on 2 potential embankment samples remolded as described above for the permeability tests to represent their placed condition within the embankment. Results of the triaxial compression tests are shown in the following table.

TABLE 3. REMOLDED TRIAXIAL STRENGTH DATA

Exploratory Pit No.	Depth (ft)	Material	Total		Effective	
			ϕ	C (psf)	ϕ	C (psf)
BC-1 BC-5	1 to 8 2 to 8	Sandy Clay	16.5	342	35.2	0
BC-2 BC-4	2 to 10 20 to 8	Silty Clayey Sand	12.7	1270	28.4	282

PINHOLE DISPERSION

Pinhole dispersion tests were performed according to ASTM 4647 on 3 potential embankment materials samples, remolded as described above, and one in-situ sample to test for the presence of dispersive materials on-site. Results of the pinhole dispersion tests are shown in the following table.

TABLE 4. DISPERSIVITY CLASSIFICATION

Boring/ Exploratory Pit No.	Sample Depth (ft)	Material	Classification	Dispersivity
B-2	15	Clay with Sand	ND1	Nondispersive
BCP-1 BCP-5	1 to 8 2 to 8	Sandy Clay	D2	Dispersive
BCP-2 BCP-4	2 to 10 2 to 8	Silty Clayey Sand	ND2	Nondispersive
BCP-6	7 to 9	Silty Sand	ND3	Slightly to Moderately Dispersive

GEOTECHNICAL ENGINEERING ANALYSIS

Cesare furthered their engineering analysis based on additional laboratory testing completed during the 50% design phase as well as their engineering judgement. The following geotechnical engineering analysis were performed by Cesare during the 50% design phase.

STABILITY AND SEEPAGE ANALYSIS

The embankment proposed during the 30% design phase was shifted approximately 400 feet upstream away from the volcanic dike, and the stability of this configuration was assessed during steady state, pseudo-seismic, and transient rapid drawdown loading scenarios. The stability and seepage analysis considered the max dam section assuming a crest width of 25 feet, dam height of 69 feet, upstream dam face slope of 2.5H:1V, and downstream dam face slope of 3H:1V. A seepage analysis was also performed on the abutment section.

Seepage parameters furthered in the analysis were based upon laboratory testing, on-site Packer tests, as well as Cesare's experience on similar projects which are summarized in the following table.

TABLE 5. DESIGN HYDRAULIC CONDUCTIVITIES

Material	Saturated Hydraulic Conductivity	
	(cm/s)	(ft/s)
Homogeneous Embankment	2.3E-6	7.48E-8
Native Soil	3.0E-5	1.05E-6
Weathered Claystone	1.0E-7	3.3E-9
Unweathered Claystone*	4.9E-5	1.62E-6

*Horizontal conductivity. Vertical is one order of magnitude less.

Direct shear and triaxial compression test results as well as Cesare's judgement informed strength parameters utilized for the stability and seepage analysis. Strength parameters furthered in the analysis are summarized in the following table.

TABLE 6. STABILITY ANALYSIS STRENGTH PARAMETERS

Material	Friction Angle (deg)	Cohesion (psf)	Remarks
Embankment	25	75	Ranged from sandy clay to silty sand
Weathered Claystone	25	50	Predominant condition
Weathered Claystone	15	0	Residual, occurring during use
Unweathered Claystone	0	3,000	Fresh (unconfined strength)
Native Soil	15	25	Ranged from sandy clay to silty sand
Internal Drain	30	10	Minus 3/8 inch well graded sand

Factors of Safety of the max dam section resulting Cesare's analysis are shown in the following table.

TABLE 7. STABILITY ANALYSES RESULTS

Analysis	Factor of Safety		Required Factor of Safety
	Block	Circular	
Full, steady state, upstream	2.06	1.95	1.5
Full, steady state, upstream, pseudo-seismic	1.13	1.05	1.0
Transient, upstream	1.14	1.21	1.2*
Full, steady state, downstream	1.75	1.68	1.5
Full, steady state, downstream, pseudo-seismic	1.22	1.10	1.0
Full, steady state, downstream, residual bedrock strength	1.28	1.44	1.1**

* Lowest factor of safety **Case-by-case determination

SETTLEMENT

The maximum dam section was analyzed to assess the settlement potential based on timed consolidation tests performed during the preliminary geotechnical investigation. Cesare estimated 4 feet of consolidation would occur rapidly within the embankment mostly during the construction period. An additional 4 inches of consolidation could also occur within the bedrock from inundation with seepage from the reservoir pool.

GEOTECHNICAL RECOMMENDATIONS

Cesare provided the following key recommendations for Bruce Canyon Dam going forward based on their findings during the 50% design phase:

- Dispersive clays exist within proposed borrow areas for embankment fill which pose a serious dam safety concern. Embankment material constructed from dispersive clays can migrate through fractured bedrock eventually leading to a piping induced failure of the dam. Failure modes from dispersive clays must be mitigated by either a filter zones or treatment with lime.
- The dam embankment should be designed to include at least 1 foot of camber at the maximum dam section that tapers off at the abutments to address settlement concerns.
- The upstream dam face slope of the proposed embankment should be flattened relative to the 2.5H:1V slope used in the 30% design to have adequate factor of safety against sliding during a transient rapid drawdown scenario.
- The keyway trench should extend at least 15 feet into bedrock contact to penetrate at least 5 feet into sound bedrock. The keyway trench should be excavated with side slopes no steeper than 1H:1V.
- Existing soil below the foundation footprint should be excavated to bedrock contact to its compressible nature. This material may be utilized as compacted fill if their properties meet the design intent.
- A bedrock grouting program should be developed to address weathering, fractures, as well as air slaking when its exposed. A grouting plinth is recommended to address fractures within the exposed bedrock face.
- The outlet works should bear directly on unweathered bedrock.
- The borrow area should be further investigated, studied, and characteristic to verify the quantity of viable embankment material with the realigned dam crest centerline.
- A new drilling program and updated geotechnical evaluation must be performed along the realigned dam crest centerline.

Please review Cesare's *Geotechnical Evaluation Report*, included in Appendix A, for more details on their findings and recommendations.

DESIGN COMPONENTS

Bruce Canyon Reservoir 50% Design Drawings builds upon previous efforts while incorporating new information gathered during the 50% Design Phase. Key components of the proposed Bruce Canyon Reservoir are summarized in the following table.

TABLE 8. PROPOSED BRUCE CANYON CHARACTERISTICS

Dam Element	Value
Jurisdictional Height	74 Feet
Structural Height	78 Feet
Spillway Invert Elevation	7409 Feet
Normal Storage Capacity	1,233 Acre-feet
Max Storage Capacity	1,552 Acre-feet
Dam Crest Elevation	7414 Feet
Dam Crest Width	25 Feet
Normal Freeboard	5 Feet
Upstream Dam Face Slope	3H:1V
Downstream Dam Face Slope	2.5H:1V

The remainder of this section will discuss components of the Bruce Canyon Reservoir 50% Design in more detail along with revisions from the previous design phase.

HYDROLOGIC ANALYSIS

The preliminary hydrologic analyses completed during the previous design phase, as described in the 30% Design Phase Report, were further studied to solidify the Inflow Design Flood (IDF) and thus design requirements for the spillway of Bruce Canyon Reservoir. The preliminary Hydrologic Hazard analysis was furthered based on recommendations provided in the Colorado Dam Safety Branch's *Guidelines for Hydrologic Hazard Analysis*[1] and United State Bureau of Reclamation's *Reclamation Consequence Estimating Methodology (RCEM)*[2] along with overtopping dam breach flood inundation modeling results produced by DSS-WISE Lite Web Application. Please note that the *30% Design Report* indicated a High Hydrologic Hazard Classification for Bruce Canyon Dam but more refined analysis during the 50% Design Phase determined the structure could be upgraded to an Extreme Hydrologic Hazard Classification when accounting for impacts further downstream in the town of Walsenburg, Colorado which was not originally considered during the 30% Design Phase. The results of the consequence analysis were marginal, especially when a sensitivity analysis was applied to the Fatality Rate, making a High Hydrologic Hazard designation a possibility with further study. A High Hydrologic Hazard designation would also be possible if an early warning detection system was implemented for the Bruce Canyon Reservoir which would justify a lower Fatality Rate for the analysis. An Extreme Hydrologic Hazard designation was assumed at this phase of design to conservatively determine the design storm for the Hydrologic Analysis.

A Hydrology Study of Bruce Canyon Reservoir was performed in accordance with *Rules and Regulations for Dam Safety and Construction (Rules and Regs)*[3] as well as recommendation found in *Hydrologic Basin Response Parameter Estimation Guidelines (Hydrology Guidelines)*[4] both published by the Colorado Dam Safety Branch. The IDF for Bruce Canyon dam was determined according to the Prescriptive Method described in Rule 7.2 of the *Rules and Regs* assuming an Extreme Hydrologic

[1] Guidelines for Hydrologic Hazard Analysis. Colorado Division of Water Resources. January 7, 2020.
[2] Reclamation Consequence Estimating Methodology (RCEM). United States Bureau of Reclamation. July 2015.
[3] Rules and Regulations for Dam Safety and Dam Construction. Colorado Division of Water Resources, Office of the State Engineer, Dam Safety. Effective January 1, 2020.
[4] Hydrologic Basin Response Parameter Estimation Guidelines, Office of the State Engineer, Dam Safety Branch. Revised May 2008.

Hazard designation for the structure resulting in a Probable Maximum Precipitation (PMP) design storm. Probable Maximum Precipitation design storm hyetographs were obtained utilizing the *Colorado-New Mexico Reginal Extreme Precipitation (CO-NM REPS) PMP Tool* made publicly available by the Colorado Dam Safety Branch. The Critical Rainfall was the "Local 24-Hour Synthetic Hybrid PMP Storm" which results in a total rainfall amount of **21.54 in** which is significantly higher than the design rainfall of 5.26 in assumed during the previous phase. A HEC-HMS hydrologic model was developed for Bruce Canyon Reservoir's drainage which generated an IDF hydrograph shown on Figure 2 in the following section of this report.

A *Hydrology Report* for Bruce Canyon Reservoir meeting the requirements of Rule 6.8.5 of the *Rules and Regs* was prepared and submitted to the Colorado Dam Safety Branch for their review. Please reference the *Hydrology Report*, included in Appendix B of this report, for more detailed information on the hydrologic analysis efforts performed by Applegate Group as part of 50% Design Phase for Bruce Canyon Reservoir.

SPILLWAY DESIGN

The spillway design for Bruce Canyon dam was revised from the 30% design phase based on the updated hydrologic analysis described above. The following summarizes revisions made to the spillway design during the 50% Design Phase:

- The spillway alignment was altered from the previous design phase to discharge flows just past the natural saddle located approximately 900 feet north of the north dam abutment. This alignment was determined to be preferable as it avoids costly blasting and excavation through the volcanic dike associated with the previous alignment. The revised alignment carries flows away from the groin of the dam and into a different drainage which is preferable to the previous design from a Dam Safety perspective because of the lengthened flow path and attenuation for the new alignment that reduces impacts at Highway 12 and in La Veta relative to the spillway alignment for 30% design.
- The spillway invert elevation was raised from 7404.9 ft to 7409 ft which results in a normal storage of approximately 1,200 ac-ft.
- The spillway will provide a total of 5 feet of freeboard between the spillway invert and dam crest as opposed to 3 feet of freeboard during the 30% design phase. Increasing spillway freeboard allows an increased hydraulic head in the spillway and thus increases capacity without having to increase spillway width. Increasing the freeboard allows for the proposed spillway width to be reduced from 80 feet proposed during the 30% Design Phase to 40 feet currently shown in the *50% Design Drawings*.
- The spillway profile has been adjusted to accommodate the new alignment as shown on Sheet 10 of the *50% Design Drawings*. Generally, the spillway profile will drop 6 feet from the spillway crest at a -3.6% grade and then transition to a shallower grade of -0.50% until the spillway discharges into the natural draw.
- Proposed spillway riprap lining has been reduced in size and extent during the 50% Design Phase. Required riprap size has been reduced from a D_{50} of 18 inches for the 30% design to 12 inches for 50% design due to lower spillway grades. The extent of the riprap lining will be reduced only encompass 380 linear feet of the upstream portion of the alignment instead of the entire alignment. The riprap will only line the portion of the spillway were supercritical flows or turbulent flows resulting from a hydraulic jump are expected.

A 1-dimensional hydraulic model was developed utilizing HEC-RAS 6.1 software to determine the rating curve and hydraulics of the proposed spillway design. Figure 1 shows the rating curve of the proposed spillway.

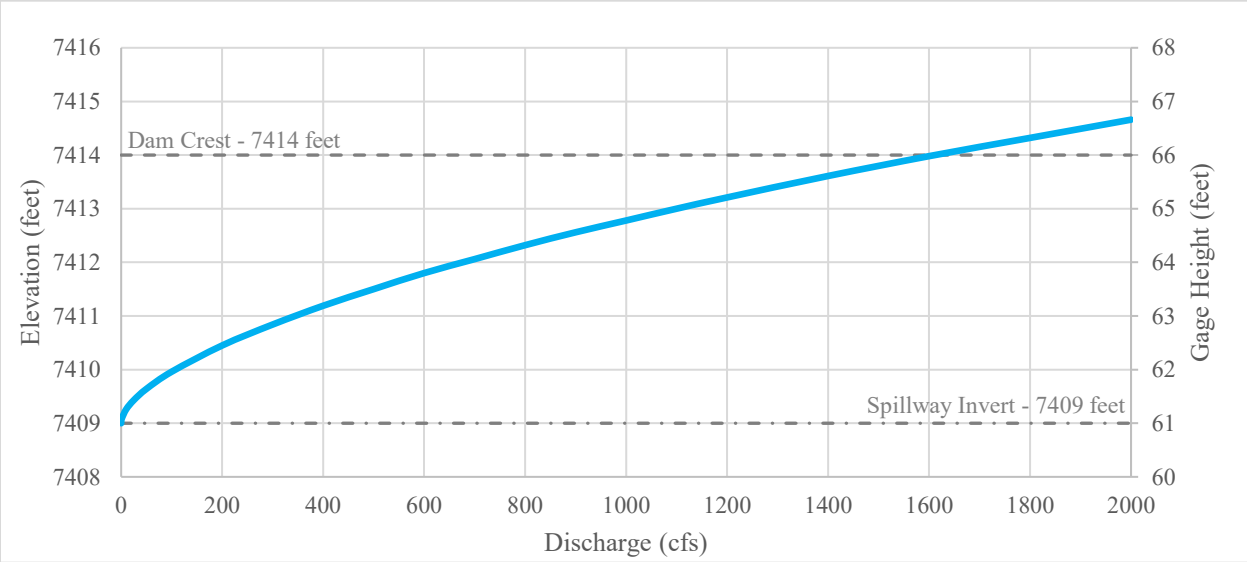


FIGURE 1. SPILLWAY RATING CURVE

The rating curve was integrated into the HEC-HMS hydrologic model mentioned above to verify that the proposed spillway design could route the IDF through the reservoir with at least 1 foot of residual freeboard. The HEC-HMS model simulation results confirmed that the proposed spillway design can route the IDF with 1.1 of freeboard resulting in a maximum discharge of 1,046 cfs. The IDF hydrograph along with the spillway discharge hydrograph generated from the HEC-HMS model are shown in the following figure.

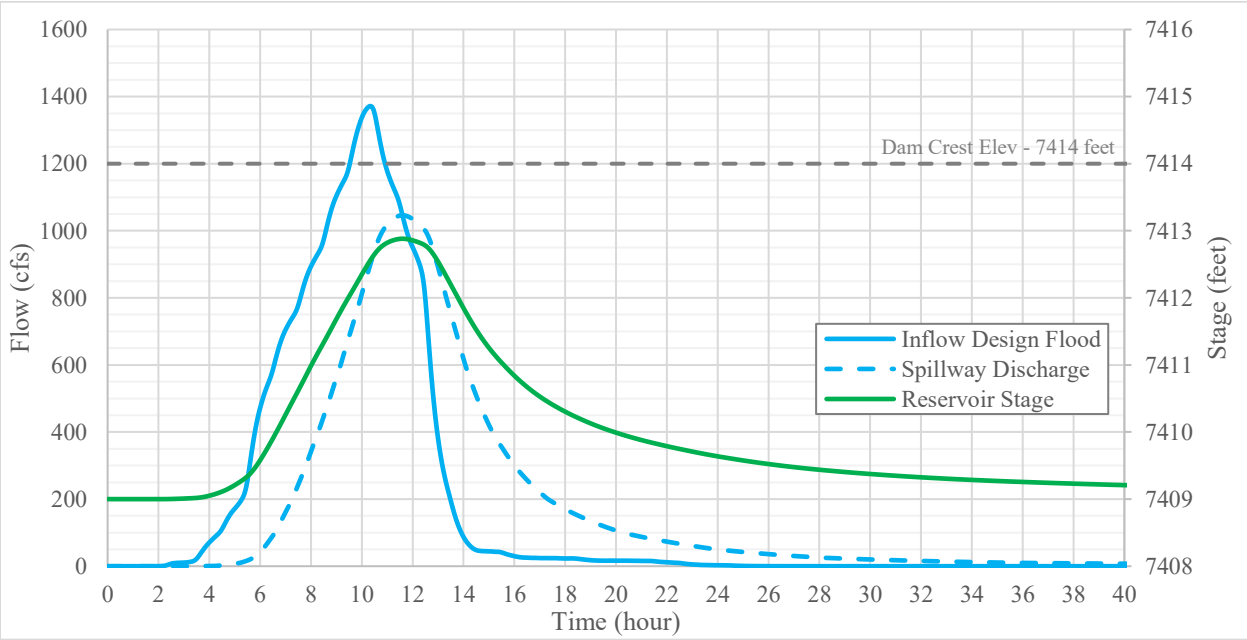


FIGURE 2. IDF ROUTING RESULTS

Geotechnical investigation of the spillway is recommended going forward to identify the depth and extents of bedrock along the alignment. The spillway should be founded on bedrock if possible, which would reduce the amount of riprap currently proposed for the spillway. Additional geotechnical exploration at subsequent design phases will also confirm whether excavation of the spillway channel will require rock blasting, which could affect cost of spillway construction.

FOUNDATION TREATMENT

The keyway trench was adjusted from the previous design phase per Cesare's recommendations. The keyway trench is aligned with the dam crest centerline alignment with a 10-foot bottom width, but excavation side slopes have been revised to 1H:1V per Cesare's recommendation to reduce required excavation into bedrock material. The keyway trench will extend 5 feet into sound bedrock which Cesare estimate to be about 15 feet below the bedrock contact layer. The total keyway trench depth will be 33 feet below existing grades at the max dam section assuming subgrade conditions encountered in borehole "BC-1" drilled by Cesare during the preliminary site investigation. Weathered bedrock contact and sound bedrock shown in the 50% Design Drawings were based on borehole "BC-1" and Cesare's recommendations for the max dam section, while those elements for the abutment sections were based on geometries utilized in Cesare's slope stability analysis. This information was gathered assuming the initial dam crest alignment which has since shifted 400 feet upstream from the volcanic dike. Additional testing and site characterization will be required at subsequent design phases to properly evaluate bedrock depths and conditions.

A foundation filter zone has also been added to the downstream slope of the keyway trench to address concerns of dispersive embankment material migrating through fractured bedrock that could eventually initiate a piping failure of the dam. The foundation filter zone tie into the chimney filter and blanket drain already in the design.

EMBANKMENT AND DRAINS

The embankment section shown in the 50% Design Drawings reflects recommendations from Cesare per their engineering analysis as well as changes requested by HCWCD. The following summarizes these revisions from the previous design phase:

- The dam crest was raised 6.1 ft to an elevation of 7414 feet to target a storage capacity of 1,200 ac-ft to get as close as possible to the 1,406 ac-ft conditional storage right decreed in Case No. 17CW3075 while maintaining 5 feet of freeboard between the dam crest and spillway invert. The proposed rating curve that incorporates the new grading is shown in the following figure.

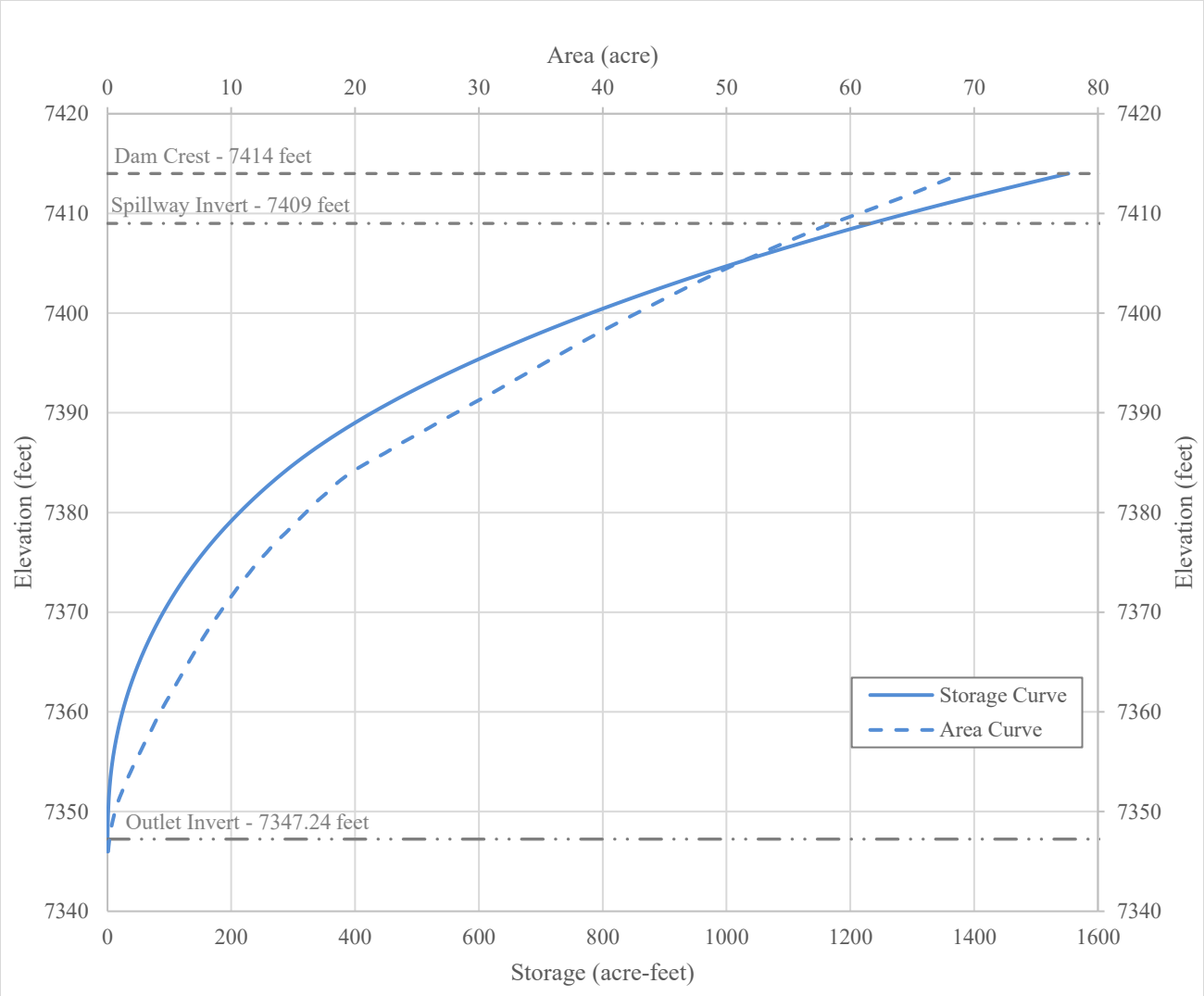


FIGURE 3. STAGE-STORAGE-AREA CURVE

- The slope of the upstream dam face will be 3H:1V and the slope of downstream dam face will be 2.5H:1V per Cesare's recommendation following their slope stability analysis.
- A camber of 1 foot was incorporated into embankment design at the maximum dam section recommended by Cesare per their settlement analysis.
- The dam crest center alignment has been straightened to simplify constructability of the embankment.
- A new embankment zone of non-dispersive clay was added in between the blanket drain, foundation filter zone, and bedrock contact to address Cesare's concern regarding dispersive material and fractured bedrock conditions. This zone could either be nondispersive material sorted from the borrow area or dispersive material that is treated with lime. Additional study and characterization of the borrow will need to be completed to assess feasibility of either method. Material availability within the borrow area should also be furthered studied to explore if the nondispersive zone can be expanded to other portions of the embankment section.

In addition to the previously stated revisions, survey monuments along the dam crest have also been incorporated into the 50% design drawings which are required for High or Significant Hazard dams per

Rule 7.7.2.3.1 of the *Rules and Regs*. The purpose of the survey monuments is to monitor settlement of the embankment throughout the life of the dam.

The current design maintains the chimney drain and blanket drain proposed during the previous design phase along with the foundation filter zone added to the design during the 50% design phase. Filter zones have been adjusted to fit the new dam embankment design. Additional detail and dam sections were added to the 50% Design Drawings which show filter zones at the max dam section, north abutment, and south abutment. A filter compatibility analysis was completed during 50% design phase based on viable embankment materials encountered in the borrow area during Cesare's preliminary geotechnical investigation. Filter compatibility calculations determined C33 sand and ASTM No.8, No.78, and No.68 coarse aggregates as suitable materials for the two-stage toe drain filter which is demonstrated in the following figure. Filter compatibility calculations are provided in Appendix F.

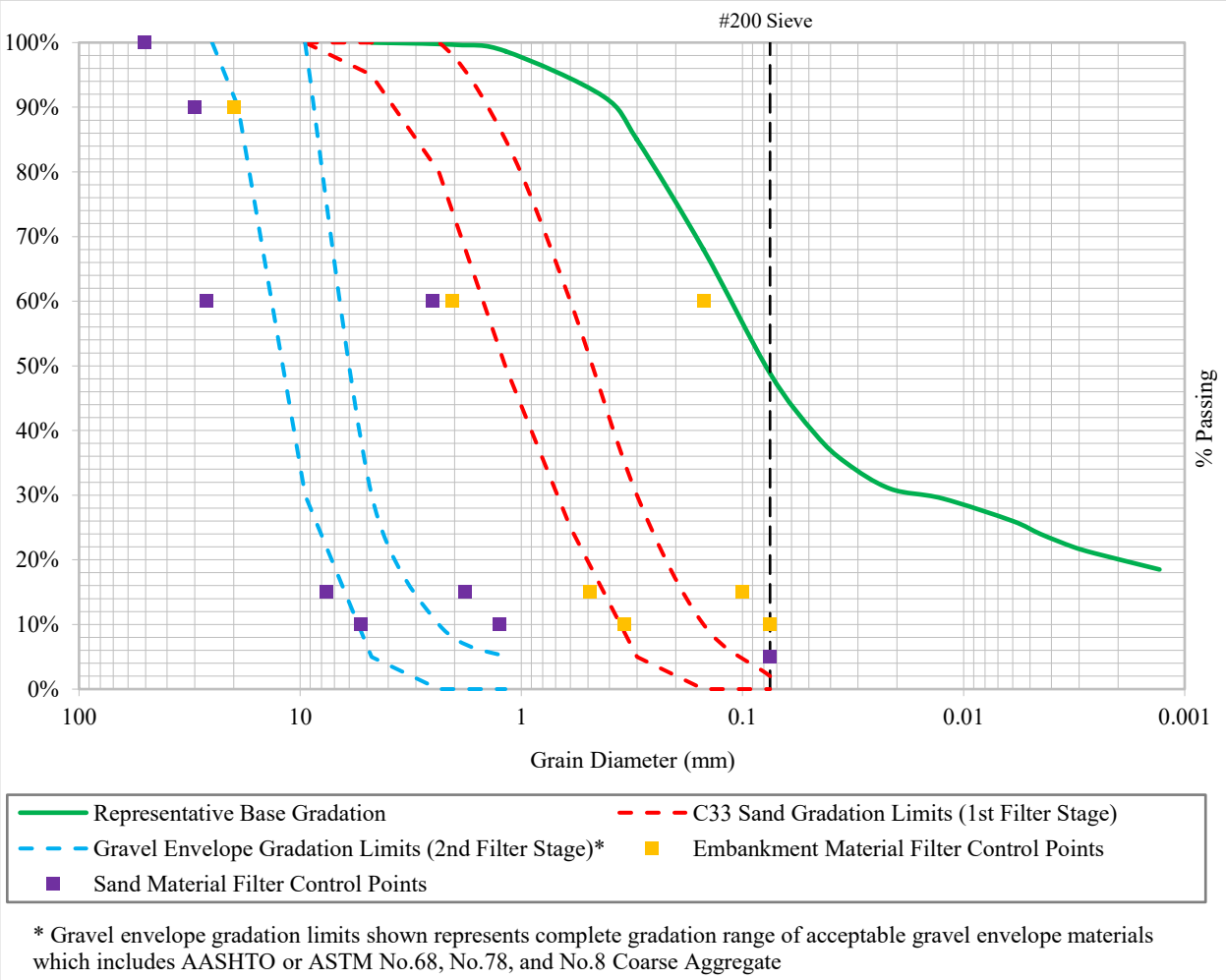


FIGURE 4. FILTER COMPATIBILITY CONTROL POINTS

OUTLET WORKS

The outlet works design was furthered during the 50% design phase with additional detail and revisions show in the current drawings. The rating curve and drawdown curve of the current outlet works design are shown in the following figures.

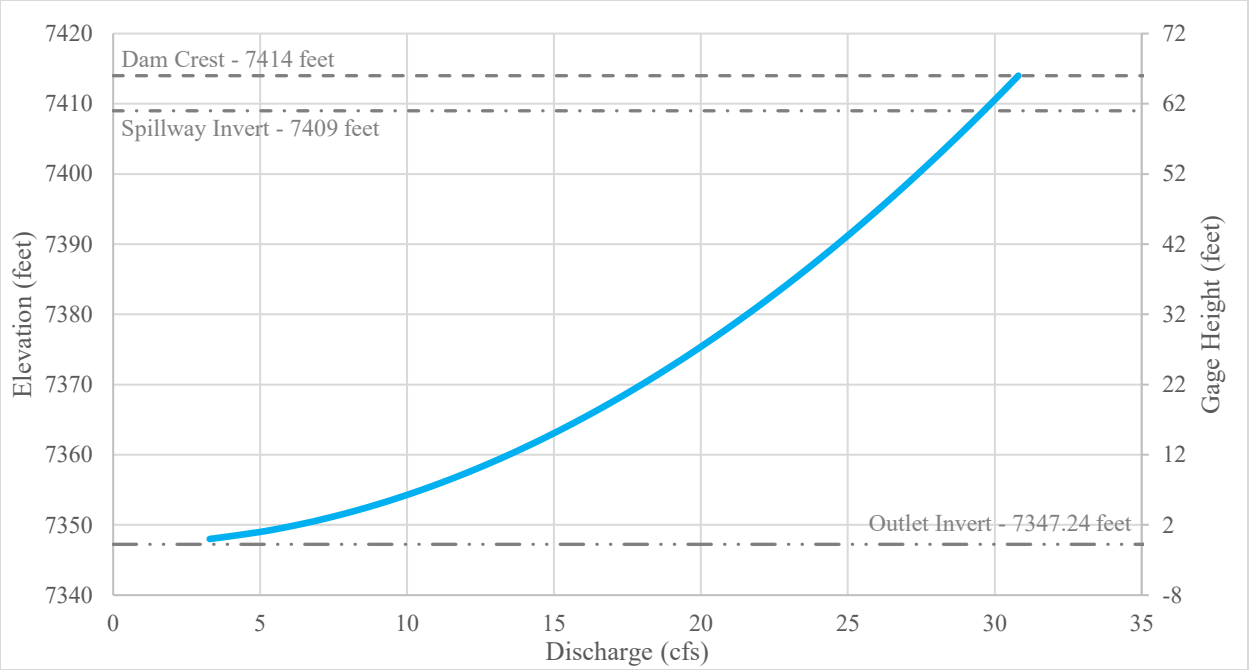


FIGURE 5. OUTLET WORKS DISCHARGE RATING CURVE

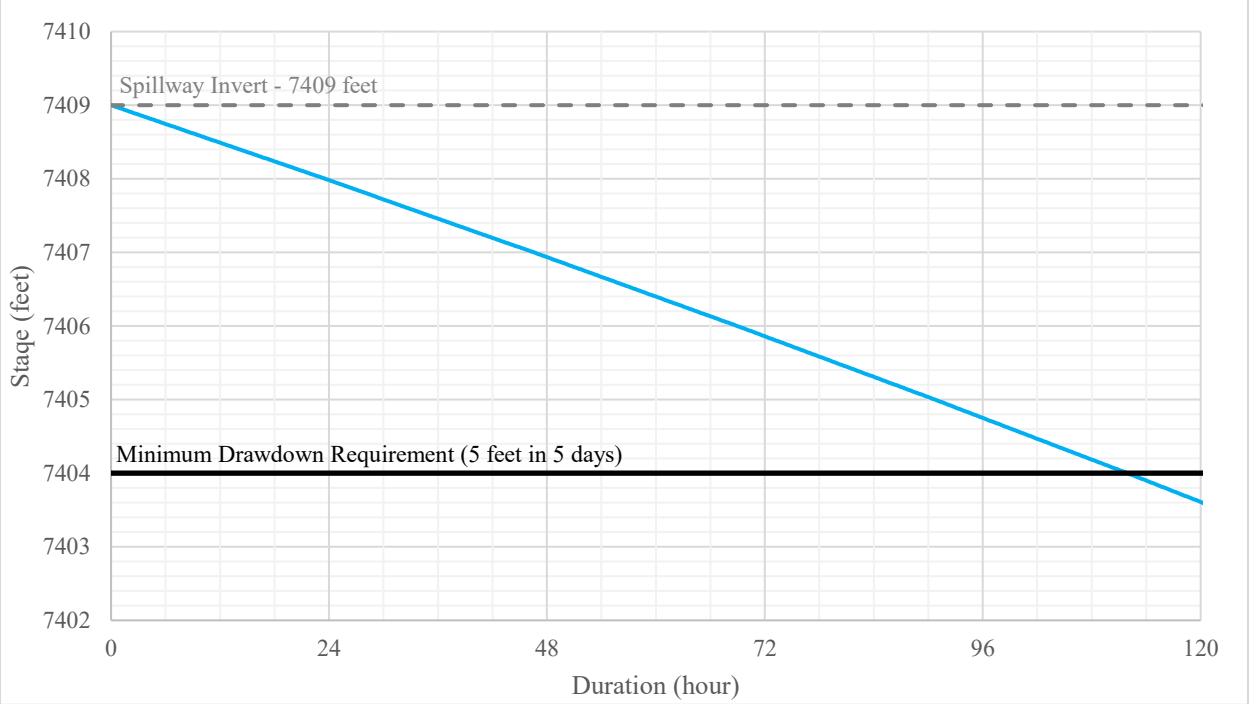


FIGURE 6. DRAWDOWN CURVE

Individual components of the outlet works are discussed in greater detail in the following sub sections.

CONDUIT

The outlet conduit will consist of 24-inch diameter ¼ inch thick, welded steel pipe encased in reinforced concrete instead of ductile iron pipe proposed during the 30% design phase. Welded steel pipe was selected for its improved joint performance and structural characteristics. A structural analysis

determined that the conduit design provided adequate factor of safety against applicable loading conditions; structural calculations are provided in Appendix F. Lining options such as epoxy or grout coatings should be explored further during the next design phase. The 50% Design Drawings show the proposed conduit section complete with a rebar layout.

INLET STRUCTURE

The inlet structure includes a 12-inch slide gate mounted to a 12-inch diameter orifice plate to restrict flows through the 24-inch diameter conduit. This was included to prevent a pressure flow condition within the conduit which poses a dam safety concern. Calculations were updated which verified that the proposed design is still capable of meeting the 5-day drawdown rule as shown in Figure 6 above.

AIR VENT

The 50% Design Drawings depict a 6-inch diameter air vent immediately downstream of the orifice plate. The air vent was incorporated to prevent damage from cavitation and pressure developing within the conduit.

GRADE BEAM

The air vent and gate stem of the 12-inch slide gate will be carried up the embankment face via a reinforced concrete grade beam that will terminate at a pedestal on the dam crest. The pedestal will contain a gate operator and oil filler to maintain and operate the slide gate. The concrete grade beam will encase the air vent, gate stem, as well as an additional 2-inch conduit that can accommodate a pressure transducer. Reservoir gage markings every 0.5 vertical feet will be embedded on the surface of the grade beam. Concrete piers spaced every 20 feet along the grade beam that extend beyond frost depth to protect the grade beam from frost heave or damage from ice loading. The 50% Design Drawings show the proposed grade beam alignment and section with rebar reinforcement.

TRASH RACK

A trash rack that bolts to the face of the inlet structure is shown in the 50% Design Drawings. Trash rack openings were sized to limit velocity to no more than 2 ft/s through the trash rack assuming 50% blockage. The trash rack will be painted with a protective coating to protect the trash rack from degradation from rust and erosion.

OUTLET STRUCTURE

Construction details for a USBR Type 5 Standard Baffled Outlet Structure was sized for the outlet works design and is depicted in the 50% Design Drawings; sizing calculations are provided in Appendix E. This structure was selected following design procedures found in *Hydraulic Design of Stilling Basin for Pipe or Channel Outlets*[5] conservatively assuming maximum discharge conditions through the outlet works. The impact basin depicted in the drawings deviates from the standard design with a steel impact plate in leu of a floating concrete wall section. The steel impact plate will be removable to facilitate camera inspections of the outlet that are required for High Hazard structures every 10 years per the *Rules and Regs*.

OUTLET CHANNEL

An outlet channel/pipe approximately 1,850 feet long will be constructed downstream from the USBR Type 5 baffled outlet structure, east to discharge to the Cucharas River. The outlet channel will have a design capacity of 8 cfs to accommodate the largest conditional exchange rate from Bruce Canyon Reservoir decreed in Case No. 17CW3075. The outlet channel alignment is shown in Sheet 5 of the 50%

[5] Belchley, G.L. *Hydraulic Design of Stilling Basin for Pipe or Channel Outlets.* Research Report No. 24U.S. Dept. of the Interior, Bureau of Reclamation. Retrieved from https://www.usbr.gov/tsc/techreferences/hydraulics_lab/pubs/PAP/PAP-0269.pdf

Design Drawings, and will include an approximately 750-foot piped section with the remaining 1,100 feet being open-channel ditch. The outlet may also need to include a bore under Highway 12 for discharge to the Cucharas River, unless the outlet can be routed through an existing culvert. Details of the outlet channel design will be completed at the 90% design stage, and will be based on survey data also to be completed at 90% design.

STANDPIPE

The standpipe proposed during the 30% design phase has been removed from the 50% design as the benefit it provided did not justify the construction cost associated with it. The element was originally incorporated into the design to provide freeboard between the normal operating pool and spillway invert to prevent wind induced waves from activating and damaging the spillway. The current spillway design currently addresses wave runup concerns by inducing waves to break on the approach section of the spillway prior to reaching the invert. To a minor extent the standpipe would also prevent minor inflows from activating the spillway but this was deemed not to be a concern considering the small drainage basin (0.54 square mile) and that the dam will be off-channel.

BUTTE DITCH SIPHON

The existing Butte Ditch alignment is impacted by the proposed spillway alignment as well as the raised normal operating pool. The ditch will have to be realigned to bypass around the reservoir and maintain normal operations for shareholders. An inverted siphon traveling approximately 2,540 linear feet along the downstream side of the dam is proposed with a preliminary alignment is shown in the 50% Drawings. Preliminary sizing calculations indicated that 24-inch diameter HDPE or PVC siphon pipe with a pressure rating able to withstand 50 psi internal pressure would be required assuming a design flow of 13 cfs; calculations are provided in Appendix F. The 13 cfs design capacity for the siphon is based on input from the Water Commissioner that the existing physical capacity of Butte Ditch is 13 cfs, although the Butte Ditch decreed diversion rate totals 8 cfs. The owners of the Butte Ditch should be included in the design process as the design is furthered to the 90% Design Phase. Siphon design during the next design phase should also include infrastructure to fill the Bruce Canyon Reservoir with ditch water. It is assumed that the channel to fill Bruce Canyon Reservoir would divert off the Butte Ditch upstream of the proposed inverted siphon, and as a result the inverted siphon will not need to be sized to accommodate the maximum conditional exchange to the Butte Ditch of 31.1 cfs as decreed in Case No. 17CW3075.

OPINION OF PROBABLE COST

The Opinion of Probable Cost was updated to reflect the proposed 50% design. A summary of the updated Opinion of Probable Cost is included below, and the full cost estimate is included in Appendix E. The primary components driving project costs are earthwork and construction of the drain system. Costs for earthwork assume suitable borrow material (of sufficient quality and quantity) exists in the reservoir for construction of the embankment, and that material excavated to exposed bedrock contact can be processed for use as a fill material either in the cut off trench or embankment. As discussed, additional geotechnical investigation is necessary to confirm the suitability and quantity of native materials in the reservoir area. Note that quantities for excavation, backfill and other filter materials were approximated based on geometries shown in the 50% Design Plans. Project costs are summarized in the following table.

TABLE 9. OPINION OF PROBABLE COST SUMMARY

Description	Estimated Cost
Site Preparation	$ 300,000
Sitework, Grading and Foundation Preparation	$ 9,614,000
Filter Drain System	$ 3,003,000
Emergency Spillway	$ 571,000
Infrastructure	$ 681,000
Survey	$ 35,000
Contingency (20%)	$ 2,841,000
Total Estimated Construction Cost	**$ 17,045,000**
Final Design (Engineering, Geotech, Survey, Permitting)	$ 750,000
Construction Observation, QA/QC Testing	$ 470,000
Project Total	**$ 18,265,000**

SUMMARY

The proposed design of Bruce Canyon Reservoir was furthered into the 50% design phase with major revisions to the embankment configuration, foundation treatment, and spillway design. The 50% Design Drawings also show additional detail for the proposed outlet works. A 24-inch diameter plastic pipe bypass inverted siphon approximately has been proposed for the Butte Ditch which is impacted by the current design of Bruce Canyon Reservoir. **The total cost to complete the project is estimated to be $18,265,000** based on quantities shown in the 50% Design Drawings, including $750,000 for final design, survey, and permitting, and $470,000 for construction observation/testing. Total estimated construction cost of $17,045,000 equates to approximately **$13,830 per acre-feet** based on the current dam configuration which can store approximately 1,233 ac-ft.

A *Hydrology Report* conservatively assuming an Extreme Hydrologic Hazard designation was completed during this design phase and submitted to Colorado Dam Safety for approval. The *Hydrology Report* establishes key characteristics of the IDF for Bruce Canyon Reservoir which informs the spillway design going forward. Further study of the Hydrologic Hazard designation is recommended to explore if Bruce Canyon Reservoir could be reduced to a High Hydrologic Hazard designation. A smaller, less expensive spillway could be pursued in the next design phase if the structure qualifies for a High Hydrologic Hazard designation.

The following efforts are recommended if HCWCD wishes to advance this project to the 90% Design Phase:

- Full topographic survey of proposed work areas and inundation area.
- Additional geotechnical investigation and evaluation of the new dam crest centerline, spillway alignment, and borrow area.
- Completion of a Hazard Classification Analysis including a Hazard Classification Report submitted to the Dam Safety Branch for Approval.
- Completion of a Hydrologic Hazard Analysis including a *Hydrologic Hazard Report* submitted to the Dam Safety Branch for approval.
- Design to the level of detail required for a Dam Safety Branch Submittal Package.

- Completion of Construction Specifications for inclusion to the Dam Safety Branch Submittal Package.
- Acquiring easements for the spillway inundation area and outlet works discharge channel.
- Generation of a submittal package to the Colorado Dam Safety Branch including *Design Drawings, Geotechnical Report,* and *Design Report*.
- Complete design of the proposed Butte Ditch siphon to be included in the Bruce Canyon Reservoir *Design Drawings* as part of the Dam Safety Branch submittal.
- Design of the outlet channel from the downstream toe of the dam back to the Cucharas River, including a means to cross Highway 12.

APPENDIX A

GEOTECHNICAL EVALUATION REPORT

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

GEOTECHNICAL EVALUATION

Cucharas Basin Collaborative Storage Project
Bruce Canyon Site 50% Design
Huerfano County, Colorado



Report Prepared for:

Steve Smith, P.E.
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Project No. 18.117
September 30, 2020

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September 30, 2020

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EXECUTIVE SUMMARY

Cesare, Inc. (Cesare) submitted an updated preliminary geotechnical study report for this project in November 2019 consisting of baseline evaluation of seven sites along the Cucharas River drainage. Of those sites, the Cucharas Basin Collaborative Storage stakeholders and Applegate Group, Inc. selected the Bruce Canyon location for further evaluation and up to 50% design. Cesare was provided notice to proceed for the further evaluation in July 2020. Upon beginning the engineering analysis, Cesare was provided the dam's most recent plan configuration. The location and configuration provided was different than what Cesare's preliminary evaluation was based on. The proposed dam location was moved upstream an estimated 200 to 400 feet.

Due to fiscal constraints, the designers opted to continue the present analyses based on the new location and configuration, but using existing data. Appropriate field exploration and associated field and laboratory testing must be performed prior to construction to verify the design parameters used and meet the State Engineer's Office requirements for dam design. Additional engineering analysis must be performed to validate the data.

Cesare completed laboratory and engineering analyses for the new Bruce Canyon site of the Cucharas Basin Collaborative Storage project. The laboratory analysis included classification and soil mechanics, primarily testing soil samples from borrow area exploratory test pits. Engineering analysis included steady state and transient seepage analysis and associated stability analysis, considering the assumed embankment and assumed abutment subsurface conditions.

The present embankment cross section consists of an upstream slope of 2.5:1, horizontal to vertical, a 25 foot wide crest, and a 3:1 downstream slope. An internal graded granular filter and drain is planned to discharge to a pipe along the downstream toe. Cesare's analysis indicates the present cross section meets the SEO requirements for slope stability, excepting one time step in the transient analysis considering rapid drawdown when using block failure analysis. Cesare's laboratory analysis indicates dispersive soils among the available borrow material, which will require treatment or mediation.

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COMMON ABBREVIATIONS

AASHTO ..... **American Association of State Highway and Transportation Officials**
ABC ..... **aggregate base course**
ACI ..... **American Concrete Institute**
ADA ..... **Americans with Disabilities Act**
ADSC ..... **Association of Drilled Contractors**
AI ..... **Asphalt Institute**
APM ..... **asphalt paving material**
ASCE ..... **American Society of Civil Engineers**
ASTM ..... **American Society for Testing and Materials**
AWWA ..... **American Water Works Association**
bgs ..... **below ground surface**
CDOT ..... **Colorado Department of Transportation**
CBR ..... **California Bearing Ratio**
CFR ..... **Code of Federal Regulations**
CGS ..... **Colorado Geological Survey**
CKD ..... **cement of kiln dust stabilized subgrade**
CMU ..... **concrete masonry unit**
CTB ..... **cement treated base course**
deg ..... **degree**
EDLA ..... **equivalent daily load application**
e_m ..... **edge moisture variation distance**
EPS ..... **expanded polystyrene**
ESAL ..... **equivalent single axle loads**
f'c ..... **specified compressive strength of concrete at the age of 28 days**
F_a ..... **seismic site coefficient**
FHWA ..... **Federal Highway Administration**
FS ..... **factor of safety**
F_V ..... **seismic site coefficient**
GSA ..... **global stability analysis**
GVW ..... **gross vehicle weight**
IBC ..... **International Building Code**
ICC-ES ..... **International Code Council Evaluation Services, Inc.**
IRC ..... **International Residential Code**
kip ..... **1,000 pounds-force**
km ..... **kilometer**
LTS ..... **lime treated subgrade**
MDD ..... **maximum dry density**
mg/L ..... **milligrams per liter**
MGPEC ..... **Metropolitan Government Pavement Engineers Council**
mm ..... **millimeter**
Mr ..... **resilient modulus**
MSE ..... **mechanically stabilized earth**
mV ..... **millivolts**
NAPA ..... **National Asphalt Pavement Association**
N_{DESIGN} ..... **design gyrations**
OSHA ..... **Occupational Safety and Health Administration**

OMC..... optimum moisture content
OWTS ..... onsite wastewater treatment system
PCA..... Portland Cement Association
PCC..... portland cement concrete
pcf ..... pounds per cubic foot
pci..... pounds per cubic inch
pH..... potential of hydrogen
psf ..... pounds per square foot
psi..... pounds per square inch
PT ..... post-tension
RAP..... recycled asphalt pavement
S_s ..... mapped spectral accelerations for short periods
SEO..... Colorado State Engineer's Office
SPT ..... standard penetration test
UBC ..... Uniform Building Code
USGS ..... United States Geological Survey

1. INTRODUCTION

Cesare, Inc. (Cesare) completed a preliminary geotechnical evaluation of the proposed Bruce Canyon site in November 2019. The preliminary study was part of a site selection project for one or two permanent water storage reservoirs for the Cucharas Basin Collaborative Storage (CBCS). CBCS is a group of stakeholders requiring additional long term water storage for municipal and agricultural needs.

The dam location considered during the site selection process was based on using an existing volcanic dike crossing the Bruce Canyon drainage as the foundation for the impoundment embankment. During cursory field observations of the dam sites prior to the preliminary evaluation for site selection, Cesare mentioned that using the dike for any part of the embankment foundation was not advisable due to its highly fractured nature and potential alteration of the bedrock surrounding the dike. Seepage was likely and would be difficult to mitigate. The proposed dam centerline was moved slightly upstream to the abutting bedrock and the overall dike structure location was maintained.

The preliminary report for the selection study was submitted to the SEO, who rejected a location using any part of the overall dike structure as a foundation for the embankment. The dam location was then moved upstream about 400 feet. Cesare was not notified of this change until preparation of this document commenced some 6 months later. Due to fiscal constraints, the designers opted to continue the present analyses based on the new location and configuration, but using existing data. The following document is based on the new location, configuration, and the existing information.

For the Bruce Canyon site 50% design, Cesare's scope of services included performing additional laboratory analysis on potential borrow material and dam foundation material, engineering analysis of the proposed dam configuration, and present geotechnical related design and construction recommendations.

2. PROJECT DESCRIPTION

The presently defined project consists of constructing a dam about 1,170 feet long and about 67 feet in maximum height above existing grade. The planned crest elevation is 7,408 feet and the normal storage elevation will be about 7,403 feet. The dam will retain a reservoir of about 898 acre-feet in volume at normal storage elevation and about 47 acres in surface area. Discharge will be through a 24 inch ductile iron pipe (DIP) pipe encased in concrete. The discharge pipe will extend from the upstream embankment toe below the dam and discharge into a stilling basin at the downstream embankment toe.

Cesare understands normal operations will entail providing water for the various stakeholders. Planned normal discharge is about 5 cubic feet per second (cfs) and maximum discharge of about 12.6 cfs. These values are equivalent to about 2/3 feet per day drawdown during normal operations and about 1-1/2 feet per day at maximum capacity.

At the maximum 12.6 cfs discharge, the reservoir can be emptied in about 36-1/2 days. This is equivalent to an average drawdown of about 1-1/2 feet per day. This is a drawdown rate higher than usual, as most reservoirs are designed for about 1/2 to 1 foot per day drawdown.

3. SITE LOCATION AND EXISTING CONDITIONS

The site location was described in the preliminary report presented in Appendix A; however, the embankment relocation necessitates modifying the existing conditions description. The embankment site is located in the northwest quarter of Section 5, Township 30 South, and Range 68 West in Huerfano County. More specifically, it is less than 1/4 mile west of State Highway 12 (SH12), about 1/2 mile north of Three Bridges, and about 2-1/2 miles south of La Veta, Colorado.

The new location is within a broader portion of Bruce Canyon with flatter side slopes rising from the flowline. The slope along the flowline remains relatively flat. Vegetation over of the new dam location consists of native grass, weeds, and small bushes. As the side slopes steepen and the overburden thins, vegetation becomes a heavier growth of coniferous trees. The reservoir will extend about 1/2 mile to the southwest, upstream from the embankment.

4. GEOLOGIC CONDITIONS

The geologic conditions, both regional and site specific, were described in Cesare's preliminary study presented in Appendix A.

5. SUBSURFACE EXPLORATION

Cesare explored subsurface conditions for design by having 4 borings drilled to depths of about 30 to 50 feet below existing ground surface along the original dam alignment. Exploratory backhoe pits were excavated to provide preliminary evaluation of potential borrow materials. Cesare's field exploration was described in Cesare's preliminary report, including boring and exploratory pit location plan and logs, are presented in Appendix A.

6. LABORATORY TESTING

Cesare performed laboratory testing during the preliminary evaluation on representative samples recovered during the subsurface exploration for classification of materials for evaluating preliminary engineering properties, correlating subsurface material, and developing preliminary design criteria. The laboratory test results from the preliminary evaluation are presented in Appendix A in the preliminary report and in tabular format in Appendix B for clarity.

Cesare performed additional laboratory testing to evaluate specific design criteria for the 50% design. Results are presented in both tabular and graphical formats in Appendix B. Total testing, including both preliminary and recent, is described in following sections.

6.1 CLASSIFICATION TESTING

California samples collected from borings and bulk samples collected from exploratory pits were used for classification testing. Tests were performed on both overburden soil and bedrock material. Engineering properties determined by classification testing were coupled with the geologic origin of the material to aid in the selection of foundation and embankment material for more detailed testing and analysis. The types of tests performed with the number of tests conducted included:

- Natural moisture content (ASTM D2216)
  - 6 bulk samples and 10 California samples
- In situ density (ASTM D2166)

1 bulk sample and 1 California sample

- Atterberg limits (ASTM D4318)
  10 California samples and 9 bulk samples
- Grain size distribution (ASTM D422)
  10 California samples and 6 bulk samples
- Grain size and hydrometer (ASTM D230)
  3 bulk samples
- Moisture/density relationship (ASTM D698)
  3 bulk samples

6.2 ENGINEERING TESTING

Testing of materials recovered from the foundation area of the dam and borrow areas were performed to evaluate strength, permeability, compressibility, and swelling characteristics of representative material. The test types performed are described in the following sections.

6.2.1 Time Consolidation Tests (ASTM D2435)

Cesare conducted timed consolidation tests on three remolded bulk samples of overburden soil to evaluate the potential consolidation of native soil and embankment material. The remolded samples were tested at about 96% relative compaction at a moisture content between 1% and 2% above OMC as determined by ASTM D698. Samples were inundated with water at an applied load of 0.25 kips per square foot (ksf). The applied load was progressively doubled to a maximum pressure of approximately 16 ksf. No rebound cycle or unloading was performed.

6.2.2 Swell/Consolidation Tests (ASTM D4546)

Cesare performed one swell/consolidation test on a sample from a backhoe pit to evaluate the collapse potential of the native soil. The sample was from BCP-5, in what was originally the borrow area and now within the presently planned embankment area. The sample was loaded to 500 psf surcharge pressure and then inundated. The sample collapsed 9.9% when inundated, indicating very high collapse potential. Cesare estimates the collapse would be greater under the anticipated embankment loading. No rebound cycle or unloading was performed.

Cesare performed three swell/consolidation tests on remolded overburden samples from combined Exploratory Pits BCP-1 and 5, combined BCP-2 and 4, and BCP-6. The samples exhibited 0.2% to -0.4% swell potential, indicating low to nil swell potential in the clay overburden.

6.2.3 Direct Shear Tests (ASTM D3080)

Cesare conducted one direct shear test on an in situ claystone sample to evaluate the in situ bedrock strength and one on a remolded silty sand sample to evaluate one of the potential embankment materials' strength. The samples were tested in saturated conditions at normal loads of 2, 4, and 8 ksf. The samples were sheared at a rate of 0.04% strain per minute to a strain of over 20% total shear.

6.2.4 Permeability Tests (ASTM D5084)

Cesare had flexible wall constant head permeability tests conducted on 3 remolded embankment soil

samples. The samples were remolded to about 96% of maximum density at moisture contents of about 1% to 2% over optimum as determined by ASTM D698 and tested under a confining pressure of 30 psi.

6.2.5 Triaxial Compression Tests - Consolidated Undrained (CU) (ASTM D4767)

Cesare had triaxial compression tests on two remolded samples performed; one on clay overburden soil and one on silty clayey sand soil material to evaluate other potential embankment material strengths. The samples were remolded to about 96% of maximum density at moisture contents of about 1% to 2% over optimum as determined by ASTM D698. Three tests were performed on each sample at confining pressures of 25, 50, and 100 psi. The samples were tested at a strain rate of 0.01% per minute, while measuring pore water pressures.

6.2.6 Pinhole Dispersion (ASTM 4647)

Cesare had pinhole dispersion tests conducted on three remolded samples of potential embankment materials and one in situ sample. The remolded samples were tested at about 96% compaction at a moisture content of about 1% to 2% over optimum, as determined by ASTM D698.

7. SUBSURFACE CONDITIONS

The subsurface conditions encountered at the original dam alignment and the ponding were described in Cesare's preliminary report presented in Appendix A. These conditions were relied upon for the seepage and stability analyses.

The geotechnical conditions underlying the maximum section at creek flowline of the original dam location were considered adequate to evaluate the new location from a broad perspective. The abutment characterization at the original site is considered inappropriate for the new location. The limitations of this evaluation are understood. The obvious risks must be reduced by properly evaluating the new location, particularly the abutments, prior to finalizing design.

One element of the subsurface conditions not described in Cesare's preliminary report was various soil exhibiting moderately dispersive to dispersive behavior. The soil dispersivity varied within soil types, such that some clays were dispersive and some were not, while some silty to silty clayey sand were moderately dispersive and others were not.

Dispersive soil can be treated and/or mitigated by various methods. Alternatives for treating the soils include adding lime to them. Mitigating the soil is accomplished by constructing an appropriate filter and drain system. Treating and/or mitigating dispersive soil is considered critical in dam design.

8. EMBANKMENT ANALYSIS

The preliminary evaluation was based on an embankment bearing on bedrock immediately abutting the volcanic dike on its upstream side. The original location would require detailed evaluation of the dike material and intervening bedrock to verify its seepage characteristics and competence. The SEO rejected using the overall dike structure to provide any structural support for the embankment. Due to this, the dam location was revised to a location about 400 feet upstream at which the downstream embankment would not bear on the overall dike structure's slope.

8.1 CONFIGURATION

The new embankment configuration provided to Cesare has a crest width of 25 feet at an elevation of 7,408 feet. The upstream slope is planned for 2.5:1 and the downstream slope is planned for 3:1. The embankment will vary in height from 0 at the abutments to about 69 feet at approximate station (Sta) 7+70. The reason for the steeper slope upstream and flatter slope downstream is unknown.

The material encountered in the ponding area/borrow source exhibited variations, but not sufficiently to justify a zoned embankment. Based on Cesare's testing the material included silty, silty clayey, and clayey sands; and clays with sand to sandy. Their deposition appear lenticular, likely making segregation inefficient. Unless more detailed evaluation of the borrow area reveals more continuous deposition, Cesare recommends a homogeneous embankment with an internal filter/drain system. The internal filter/drain would discharge into a pipe at the downstream toe to collect the drain discharge and direct it to a single location. The filter/drain system was modeled as shown in the designer's drawing; however, it should like directly on the bedrock surface and the downstream excavation slope.

The upstream slope will require riprap slope protection, nominally estimated at 12 to 18 inch particles, with underlying bedding. The bedding would require design as a graded filter zone, likely consisting of two or more graded layers to cover the embankment soil and prevent piping through the riprap. The upper native soils are loose and compressible and/or collapsible in their present condition. Considering some of the soils are dispersive, stabilization should consist of excavating the native soil to bedrock contact below all embankment aspects and replacing them as structural fill. The excavation should stop at the embankment toe then continue to the ground surface on a 1:1 slope from the excavation surface.

Due to the fractured and weathered bedrock below its contact, a seepage cutoff trench should extend into the bedrock a depth sufficient to penetrate sound, relatively fresh bedrock. Cesare estimates this depth to be about 15 feet. Volcanic dikes typically alter the bedrock to a significant distance around them, including inducing greater fracturing and tilting the bedding planes in sedimentary rock. A grouting program should be implemented once the trench is excavated as described in Section **9.4 FOUNDATION GROUTING**.

An outlet pipe will extend below the embankment, near the existing creek flowline. The outlet pipe will discharge to a stilling basin at the downstream embankment toe. The outlet pipe should be encased in reinforced concrete bearing on sound bedrock below the weathered and fractured bedrock zone.

8.1.1 Soil Dispersivity

The pinhole dispersion tests indicate the soil available for use in the embankment range from ND1 to D2, indicated nondispersive to dispersive. The soil dispersivity test results relative to classifications are presented in Table 8.1.

TABLE 8.1. Dispersivity Classification

Boring/Test Pit	Sample Depth (feet)	Classification	Dispersivity
B-2	15	ND1	Nondispersive
BCP-1 BCP-5	1 to 8 2 to 8	D2	Dispersive
BCP-2 BCP-4	2 to 10 2 to 8	ND2	Nondispersive
BCP-6	7 to 9	ND3	Slightly to moderately dispersive

The dispersive soil nature makes the internal filter and its gradation critical to successful dam performance. Additional seepage analysis should be performed to evaluate abutments, in particular, to address potential piping through the abutment and around the embankment. Additional dispersivity testing should be performed to verify these conditions and attempt to relate them to specific material types and source locations.

8.2 MATERIAL PARAMETERS

Cesare based the stability analysis and seepage parameters on its field and laboratory test results, and experience with similar projects.

8.2.1 Seepage Analysis

8.2.1.1 Soil and Bedrock

Cesare used the geometric mean of permeability values from three tests performed, as presented previously.

The Packer test results presented in Table 2 of Cesare's preliminary report indicate a range that is relatively high for what is anticipated in unweathered claystone; therefore, likely relates to fracture flow, at least in the unweathered claystone. The sandstones encountered appeared well indurated to poorly nonindurated and likely to exhibit fracture flow in the well indurated zones.

Fracture flow in the fresher claystone is unlikely to be uniform below the embankment, such that the claystone would be consistently relatively permeable. Work by Zhang (2013) and others indicate claystone fractures tend to close under increased loading, and when wetted. Cesare believes a conservative approach considering fracture flow during the reservoir life is appropriate.

The weighted geometric mean of in situ permeability testing is about 2.7 by 10^{-6} cm/s. Packer testing measures the horizontal flow component of in situ permeability. Cesare estimates the vertical flow will likely be one order of magnitude lower, thus, the ratio of vertical to horizontal permeabilities would be 0.1.

The material requiring seepage parameters for analysis includes the homogeneous fill, native soil, and the unweathered and weathered bedrock. The values used are presented in Table 8.2. The values presented for embankment materials and weathered bedrock are based on laboratory test results described previously. The unweathered bedrock considers the Packer test results for this

project and other similar projects and research into published rates for the local claystone bedrock.

TABLE 8.2. Design Hydraulic Conductivities

Material	Saturated Hydraulic Conductivity (cm/sec)	Saturated Hydraulic Conductivity (ft/sec)
Homogeneous embankment	2.3e-6	7.48e-8
Native soil	3.0e-5	1.05e-6
Weathered claystone	1.0e-7	3.3e-9
Unweathered claystone	4.9e-5*	1.62e-6*

* Horizontal conductivity. Vertical is one order of magnitude less.

Considering the relatively high permeabilities in the unweathered claystone based on the insitu packer tests, Cesare recommends a grouting program be implemented as described in Section **9.4 FOUNDATION GROUTING**.

8.2.2 Triaxial and Direct Shear Tests

Cesare had triaxial compression tests conducted on remolded samples of sandy clay and clayey silty sand, both of which were potential borrow material. The remolded strengths represent fully softened strength of the soil. The clay sample was intended to represent the fully softened upper bedrock surface below the embankment. Although the bedrock classification testing indicated a much higher percentage of material passing the #200 screen, the shear angle from testing is similar to remolded claystone materials found elsewhere along the Colorado Front Range. The remolding results in a material that is less dense than in situ material, and hence weaker. This provides a reasonable estimate of the bedrock strength that would underlie the embankment after weathering occurs, which is less than peak but stronger than residual. Remolded triaxial strength test results are presented in Table 8.3.

TABLE 8.3. Remolded Triaxial Strength Data

Exploratory Pit No.	Material	Depth (feet)	Passing #200 (%)	Total		Effective	
				Φ	C (psf)	Φ	C (psf)
BC-1 BC-5	Sandy clay	1 to 8 2 to 8	53.5	16.5	342	35.2	0
BC-2 BC-4	Silty clayey sand	2 to 10 20 to 8	38.2	12.7	1270	28.4	282

Cesare conducted direct shear testing on samples of in situ claystone bedrock and remolded silty sand soil. Total strain was on the order of 20%, or approximately 0.4 inches. A summary of the direct shear test results is presented in Table 8.4.

TABLE 8.4. Direct Shear Test Data

Boring/ Exploratory Pit No.	Depth (feet)	Material	Passing #200 (%)	Peak Strength		Ultimate Strength (~20% Strain)	
				Φ	C	Φ	C
BC-1	15	Claystone	79.6	29.8	0	21.2	0
BCP-6	7 to 9	Silty Sand	21.0	29.3	380	28.7	217

8.2.3 Strength Parameters

Based on our testing and judgement, the strength parameters assigned to the embankment materials are presented in Table 8.5. Due to the nature of this analysis, including a site that specific geotechnical characteristics for which are unknown and limited information on the borrow material, Cesare opted using conservative values. These parameters must be refined during the field exploration and laboratory analysis to be performed for the new location.

TABLE 8.5. Stability Analysis Strength Parameters

Material	Friction Angle (degrees)	Cohesion (psf)	Remarks
Embankment	25	75	Ranged from sandy clay to silty sand
Weathered claystone	25	50	Predominant condition
Weathered claystone	15	0	Residual, occurring during use
Unweathered claystone	0	3,000	Fresh (unconfined strength)
Native soil	15	25	Ranged from sandy clay to silty sand
Internal drain	30	10	Minus 3/8 inch well graded sand

8.3 SEISMIC DESIGN

The *Rules and Regulations for Dam Safety and Dam Construction* (2007) indicate a pseudo static analysis for embankment dams is acceptable, for the following cases:

> *"5.9.2.3.1 The embankment is to be mechanically compacted to at least 95% of the maximum standard Proctor density, ASTM D698, or at least 90% of the maximum modified Proctor density, ASTM D1557 or at least 70% relative density per ASTM D4253 and ASTM D4254, if Proctor testing is not appropriate; no materials prone to liquefaction are present in the foundation and the design peak bedrock acceleration is 0.20g or less; or*
>
> *5.9.2.3.2 The embankment is to be mechanically compacted to at least 95% of the maximum standard Proctor density, ASTM D698, or at least 90% of the maximum modified Proctor density, ASTM D1557; potentially submerged portions of the embankment except for internal drain elements are constructed of clayey material; the dam is constructed on clayey soil or bedrock foundation and peak bedrock acceleration is 0.35g or less; and*
>
> *5.9.2.3.3 All static stability safety factor requirements of these Rules are met; minimum freeboard requirements of these Rules are met; and the pseudostatic coefficient selected for analysis must be at least 50% of the design peak bedrock*

acceleration, but not less than 0.05g and the factor of safety under pseudostatic analysis shall be 1.0 or greater. In determining the factor of safety for pseudostatic analysis, a search for the critical failure surface shall be made."

The peak bedrock acceleration for 10% exceedance in 50 years is 0.0475g and for 2% exceedance is 0.143g[1]. The analysis requirement includes using at least 50% of the peak acceleration, but not less than 0.05g. Cesare used 0.1g in that this value is customarily used and is suitably conservative.

8.4 STABILITY AND SEEPAGE RESULTS

Cesare analyzed the maximum embankment section at Sta 7+70 for seepage and stability and the abutments for seepage. The embankment section analysis included steady state seepage at full pool surface elevation for both upstream and downstream slopes, and transient (rapid drawdown) on the upstream face. The transient discharge rate used was 12.6 cfs, the maximum anticipated rate. Cesare analyzed both upstream and downstream slopes at full pool considering a pseudo-seismic force and the downstream slope considering residual bedrock. These scenarios meet the CSO, Dam Safety Branch requirements (2007) for slope stability, with the exception of the transient upstream analysis at a single time step using block failure analysis.

When evaluating the single time step failure, Cesare considered the following:

- The conservative strength parameters used. Refining the parameters with more strength testing during a complete characterization of the new site should be performed.
- The one time step is the next to last of the transient model time steps. Cesare's experience with transient analysis is the critical time step is typically earlier in the drawdown, often between 50% and 70% drawdown. The very high discharge/drawdown rate is a possible reason in that the phreatic surface is shown to be very close to the exposed slope at that time step indicating high pore pressures. This supposed failure may also be simply related to a mathematical anomaly in the software's analysis.

The shallow depth of the failure surface. The failure surface does not exhibit the characteristics of a catastrophic failure surface. A shallow failure such as this is unlikely to compromise the dam on a short term basis. If it were to occur; however, it would require immediate repair.

8.4.1 Seepage

Cesare analyzed the maximum height embankment section considering both steady state through the embankment and rapid drawdown within the reservoir for transient. The abutments were also analyzed considering steady state seepage.

8.4.2 Stability

The results of Cesare's stability analyses are presented in graphical format in Appendix C and in tabular format in Table 8.6, including the SEO's requirements.

[1] United States Geological Survey; Earthquake Hazards Program, Unified Hazard Tool, earthquake.usgs.gov/hazards/interactive/

TABLE 8.6. Stability Analyses Results

Section Station	Analysis	Factor of Safety		Required Factor of Safety
		Block	Circular	
7+70	Full, steady state, upstream	2.06	1.95	1.5
	Full, steady state, upstream, pseudo-seismic	1.13	1.05	1.0
	Transient, upstream	1.14	1.21	1.2*
	Full, steady state, downstream	1.75	1.68	1.5
	Full, steady state, downstream, pseudo-seismic	1.22	1.10	1.0
	Full, steady state, downstream, residual bedrock strength	1.28	1.44	1.1**

* Lowest factor of safety. **Case-by-case determination.

8.5 SETTLEMENT

Cesare performed a settlement analysis on the embankment at the deepest section using the change in void ratio method. The maximum embankment section at Sta 7+70 is planned for a total average embankment thickness, including replacing the native soil, of about 88 feet. Considering this and the timed consolidation results, we estimated about 4 feet of embankment consolidation during construction. We estimate the lesser embankment thicknesses will consolidate proportionally less. This consolidation occurs rapidly in the soil, as demonstrated by the timed consolidation results, and likely be complete by the end of embankment construction. However, Cesare recommends a minimum of 1 foot of camber at maximum section to account for unforeseen conditions. This can taper to 0 at embankment heights of less than 10 feet.

Cesare estimated the bedrock below the embankment/densified subgrade could consolidate an additional 4 inches. Cesare conservatively based this on the upper weathered bedrock being lower density than the sound bedrock and becoming wetted from seepage.

8.6 GEOTECHNICAL EVALUATION RECOMMENDATIONS

The new dam location must be evaluated according to the current SEO requirements. These requirements include drilling to depths of 1.5 times the maximum dam height and 10 feet into bedrock. Considering a dam height of 70 feet, borings would be about 105 feet deep with appropriate in situ permeability testing performed. The bedrock dip should be determined for consideration in the analysis to evaluate the groundwater gradient to or away from the volcanic dike.

The proposed borrow quantities must be verified in the ponding area by more detailed exploration with borings and exploratory backhoe pits. Laboratory evaluation should include detailed evaluation of dispersive behavior and its relationship to material and more strength testing to further evaluate strength parameters used in analysis. Cesare recommends more triaxial shear testing of potential embankment material and more undrained shear testing of bedrock material.

The dam section should be revised to provide a flatter slope upstream than downstream. This would likely result in exhibiting greater stability in transient analysis. Making the downstream slope steeper, if desired and if found to meet SEO stability requirements, would allow moving the dam centerline to

the east and potentially provide greater storage. Considering the downstream pseudo-seismic analysis results shown previously, justifying a steeper downstream slope would require refining the strength parameters used in analysis to higher values, which will require additional strength testing.

The filter/drain to cut off seepage should be relocated to the bedrock surface at the downstream excavation slope of the cutoff trench, the downstream bedrock surface, and the downstream overburden excavation slope to protect the dispersive soil from migrating into bedrock fractures and beginning piping issues.

9. CONSTRUCTION CONSIDERATIONS

9.1 GROUNDWATER CONTROL

Groundwater was measured within the overburden soil in Borings BC-1 and BC-2 during drilling. The groundwater depth in BC-1 lowered to within the underlying the bedrock when measured the day after drilling, potentially near the seepage cutoff depth. The variable nature of the subsurface material may result in variable rates of inflow into open excavations. The contractor should implement groundwater control that should minimize foundation material disturbance and borrow excavations. Directing seeps to a seepage collection system may be an effective control. The groundwater could possibly be within the seepage cutoff that will receive fill such that seepage should be managed so fill placement should occur in the dry. Saturated borrow material may require wasting. The contractor should be responsible for designing and maintaining dewatering systems. Localized sumps may be adequate.

Surface drainage should be prevented from entering or flooding excavations and from causing uncontrolled erosion on excavated slopes. The contractor should be responsible for controlling surface drainage and meeting applicable local, state, and federal regulations.

9.2 EXCAVATIONS

9.2.1 General Considerations

The relative ease or difficultly of the excavation of soil and bedrock material onsite will vary greatly, both horizontally and with depth. Materials ranged from unconsolidated deposits that should be readily excavated to bedrock that may require ripping or more rigorous excavation methods, such as hoe-ram. Cesare recommends no blasting and blasting for excavations will not be allowed.

If ripping is used, a program should be initiated to evaluate the effects of the ripping on underlying bedrock. Once ripped bedrock is cleared, the remaining surface should be inspected to evaluate whether the ripping is opening bedrock fractures and increasing the potential for seepage. If underlying fractures are affected, the ripping depth should be reduced or eliminated. The bedrock should not be ripped more than 1 foot at a time.

9.2.2 Embankment Foundation

The entire foundation area should be stripped of vegetation and topsoil. The soil should be excavated to bedrock contact. The excavated soil may be used as fill for these areas, provided they are free of organics or other deleterious materials. The exposed surface of the bedrock should be protected from

drying and cracking. Use of a mud mat to cover the surface is advised and is described in Section **9.3 FOUNDATION PREPARATION**.

A seepage cutoff should be constructed to extend through the more fractured and weathered bedrock and penetrate at least 5 feet into the underlying sound bedrock. Sound bedrock is considered bedrock having a SPT blow count of 50/6 or higher. The cutoff base shall be protected from drying and desiccation, similar to the embankment bedrock contact described previously. The cutoff side slopes should be no steeper than 1:1.

9.2.3 Borrow and Reservoir

Material for embankment construction will be excavated from within the reservoir ponding area. Cesare recommends additional exploration in the reservoir area to prove sufficient available quantities for embankment construction. Any borrow area within the reservoir ponding area should be maintained a minimum distance of 500 feet from its closest edge to the upstream embankment toe.

Soil is preferred for the embankment, as opposed to conditioned bedrock. Cesare's borings at the original embankment indicated about 14 to 18 feet of soil above bedrock contact. The exploratory pits extended to depths of about 8 to 11 feet before excavator bucket refusal on harder material. As presented previously, groundwater control may be necessary in the borrow pits.

9.2.4 Moisture Conditioning

The embankment material should be conditioned in the borrow area and/or required excavation area to within 2% of the OMC according to ASTM D698. This can be accomplished through prewetting or drying in the excavation or mixing or drying on grade. Variable moisture contents exist naturally and the contractor should design a program to moisten or dry borrow material to produce uniform moisture contents in the borrow pit, prior to its placement as embankment fill. The application of water should be carefully controlled to avoid over watering or over drying the borrow material.

9.2.5 Temporary Cuts

Temporary cuts in the soil and weathered bedrock material should not exceed slopes of 2:1. Temporary cuts in competent bedrock material should not exceed slopes of 1:1. Steeper slopes may require bracing or other stabilization methods to provide for safe working conditions. The contractor should be responsible for designing and maintaining construction slopes. All slopes should be protected from runoff due to precipitation events. Methods of slope stabilization should comply with applicable state, local, and federal regulations.

9.3 FOUNDATION PREPARATION

9.3.1 Downstream Shell

The claystone foundation bedrock tends to air slake upon exposure and drying. The foundation surface within the cutoff trench should be protected from losing moisture, freezing, and effects of weathering. With a grouting program, a plinth block should be cast in the bottom of the cutoff trench. This should be cast within 24 hours after the bedrock at the bottom of the cutoff trench is exposed to protect the bedrock surface.

Dispersive soil could be in contact with the bedrock contact, which is likely highly fractured, providing avenues for the dispersive soil to migrate into the fractures and begin a process leading to piping of the embankment soil. The filter/drain zones are critical to this. The downstream slope of the cutoff trench, the bedrock surface below the downstream shell, and the downstream slope of the native soil excavation surface should all be protected with a graded filter/drain zone.

Immediately upon completion of excavation; appropriate geologic mapping, surveying, inspection, foundation preparation, and embankment fill or filter/drain zone should be placed, depending on upstream or downstream, should take place. These should occur within 24 hours of exposing the final foundation surface. Experience gained during construction may allow for variations in this.

Cesare's experience has shown that metal tracked equipment should be kept off the final excavated bedrock surface. Rubber tired equipment should be used for the final excavation to foundation grade. The subgrade surface should provide an unyielding foundation for the embankment fill. Should the bedrock exposed at finished subgrade elevation exhibit a very blocky surface with voids in the matrix, the voids should be filled with flowable grout. In addition, should relatively highly weathered areas be exposed that are considered soft compared to the surrounding bedrock, they should be excavated to sound bedrock and backfilled with embankment material or flowable grout.

9.3.2 Foundation Grouting

A grouting plinth sufficient to resist grouting pressures near the bedrock surface should be installed in the bottom of the seepage cutoff trench. The grouting should begin with a basic program of grouting the centerline at the bottom of the cutoff trench at locations nominally 20 feet apart. If the initial grouting program indicates grout takes, a secondary program of similar nature, but staggering the grout inject location to be between the initial row. If grout take is still evident, a tertiary program should be implemented.

9.4 OUTLET PIPE

The outlet pipe should bear on unweathered bedrock encased in reinforced concrete. The depth to bedrock in the planned outlet pipe location will require on the order of 15 to 20 feet of excavation below bedrock contact to reach sound unweathered bedrock. The bedrock will likely be exposed for sufficient time to allow desiccation and cracking. Thus, a mud mat should be placed on it and below the encasement. The encasement's longitudinal sides should have slopes of 1 to 10, horizontal to vertical, from the bearing surface. A collar should surround the encasement on all four sides by at least 12 inches of filter material meeting the project requirements. The filter material should extend along the encasement at least 5 feet.

9.5 SLOPE STABILIZATION

The embankment material is susceptible to erosion. Thus, downstream slopes will require stabilization. Cesare recommends seeding and cultivating native vegetation for slope stabilization. The topsoil removed during clearing and grubbing can be placed to help initiate vegetating the slopes.

The upstream slope should be protected from wave action with riprap or other method. Although no calculations were performed, Cesare estimates the riprap will be 12 to 18 inch particles based on its

experience. The bedding below the riprap will likely require at least two layers of successively graded filters to protect the underlying material from piping or washout.

10. LIMITATIONS

This report has been prepared for the exclusive use of CBCS and Applegate Group, Inc. for specific application to the project discussed. This report has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are intended or made. Since changes in the location and design of the project as outlined in this report are likely, the conclusions and recommendations contained in this report shall not be considered valid for final design.

The information and recommendations presented in this report are based on relevant literature and data obtained from limited number of subsurface exploration borings and exploratory backhoe pits and laboratory tests. Some geologic information presented is interpretive and reflects only the opinion of the geologist as to the character and extent of geologic material. The data has been compiled and report prepared solely to aid in the design of Bruce Canyon Reservoir.

Field logs of the borings and exploratory pits are representative of the subsurface conditions at the specific locations at the time of the evaluation. Variations will likely occur at the revised dam location and additional exploratory backhoe pits. The professional judgments expressed in this report meet the standard care or our profession.

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

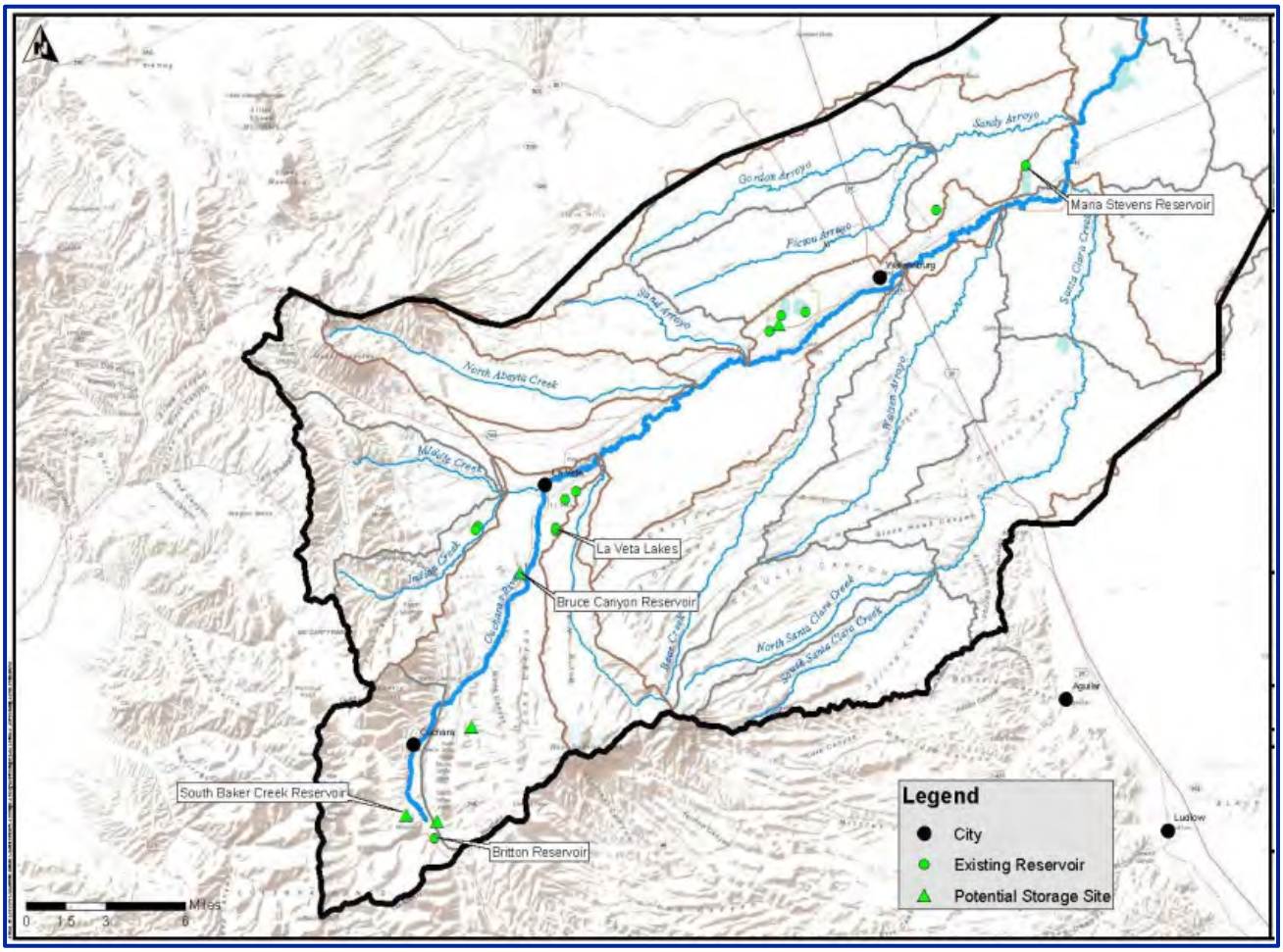
APPENDIX A

Preliminary Report

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PRELIMINARY GEOTECHNICAL EVALUATION

Cucharas Basin Collaborative Storage
Huerfano County, Colorado



Report Prepared for:

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November 7, 2019

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1. INTRODUCTION

Cesare, Inc. (Cesare) completed a preliminary geotechnical evaluation of five proposed sites under consideration for constructing one or more permanent water storage reservoirs for the Cucharas Collaborative Storage (CCS). CCS is a group of stakeholders requiring additional long term water storage for municipal and agricultural needs. The five preferred alternative sites were selected from an initial 50 potential sites. Cesare's scope of work was to provide geotechnical and geological information, technical constraints, and preliminary design recommendations, as necessary, to allow site selection for new and/or enlarged water storage.

2. PROJECT DESCRIPTION

The overall project consists of developing increased permanent water storage capacity. The reservoirs are intended to provide municipal water for Cucharas Sanitation and Water District, Town of La Veta, and the City of Walsenburg in drought years. In addition, various farmers managing about 11,000 irrigable acres require water during most years. The total present and future demands were estimated at about 12,980 acre feet per year (AFY) and 33,673 AFY, respectively. Requirements for a 3 year drought were estimated at about 3,630 TO 3,670 AFY for municipal and about 15,000 AFY for irrigation.

Applegate Group, Inc. (Applegate) performed initial screening of almost 50 sites during the first phase of the overall project resulting in recommending the five sites considered for this work. Applegate developed conceptual plans for each site to prepare initial construction requirements and costs. Cesare performed a preliminary evaluation of each of the five sites, including limited geology, field exploration, laboratory analysis, and engineering analysis. The results are to assess the technical constraints as they apply to the economic constraints. Cesare also prepared recommendations for additional exploration and analysis that may be necessary for site selection, given that final design will require detailed evaluation in field, laboratory, and engineering phases.

2.1 BRITTON

The Britton site is just downstream from two existing ponds, about 3 miles south of Cuchara, Colorado. The preliminary plans call for a new zoned earth fill embankment of about 48 feet in average height at its maximum section. The reservoir ponding area is the planned borrow area. The two existing ponds would be inundated by the new reservoir.

2.2 BRUCE CANYON

The Bruce Canyon site is about 2-1/2 miles southwest of La Veta, Colorado. It is a relatively broad valley cut perpendicularly by a volcanic dike that was incised by a perennial drainage creating a relatively narrow draw. Preliminary plans call for a new zoned earth fill embankment within the draw, about 77 feet in average height at its maximum section. The planned borrow source is the reservoir ponding area.

2.3 LA VETA LAKES

La Veta Lakes is the site of two small existing reservoirs about 1/2 mile south of La Veta, Colorado. Preliminary plans call for two homogeneous earth fill embankments, a north and a south, to combine the two lakes into one and increase the total reservoir capacity. The new embankment and raises

will be about 5 feet at their maximum sections. The planned borrow is the small embankment between the two ponds.

2.4 MARIA STEVENS

Maria Stevens is an existing reservoir about 6-1/2 miles northeast of Walsenburg, Colorado. The preliminary plans call for two zoned earth fill embankments, a new western and a raised southern, to increase the reservoir's capacity. The new western embankment extends along the majority of the existing reservoir's west side and continues around its north side, just past its northeast corner. The south embankment parallels State Highway 10 (SH10) to its south. The raises will be about 5 feet average height at their maximum sections. The planned borrow is from an area east of the reservoir.

2.5 SOUTH BAKER

The South Baker site is about 2 miles southwest of Cuchara, Colorado. Preliminary plans call for a zoned earth fill embankment, about 66 feet average height at its maximum section. The planned borrow source is the reservoir ponding area.

3. SITE CONDITIONS

3.1 BRITTON

The Britton site is located about 3 miles south of Cuchara, Colorado. It is a steep walled valley, generally trending downward in slope from southeast to northwest. The valley is heavily forested on both sides with the trees thinning near the valley's flowline at the proposed dam centerline. State Highway 12 (SH12) is located about 200 feet west of the proposed southernmost dam abutment.

The valley does not appear to carry either perennial or intermittent stream runoff, other than specific storm runoff. Two existing ponds about 500 feet upstream of the proposed dam centerline were holding water at the time of our field exploration. No other free water was visible. Cesaree noted no bedrock outcrops at the site at the time of our field exploration.

3.2 BRUCE CANYON

The Bruce Canyon site is located about 2-1/4 miles south of La Veta, Colorado. It is at the confluence of two relatively broad valleys; one at higher elevation to the north and the other at lower elevation to the south. The southern, lower, valley will provide the reservoir water storage. It generally trends downward in a gentle slope from southwest to northeast.

The confluence tapers to pass through a relative narrow draw formed by an ephemeral drainage through a ridgeline made prominent by the volcanic dike protruding from it. The proposed dam location is within this draw. The ridgeline flanks comprising the draw, slope moderately on both sides. The northern slope is moderately to sparsely vegetated with small conifer trees and low brush. The southern slope is moderately to heavily forested, primarily with conifer and some deciduous trees. SH12 is located about 1/4 mile to the southeast of the proposed dam location.

The valley carries an ephemeral stream. The existing Marker Lake is about 1/4 mile northeast, Hayes Reservoir is about 1 mile north, and Butte Reservoir is about 1 mile northwest of the dam location. No other free water was visible at the time of our field exploration. Butte Ditch forms the perimeter

of the proposed storage area with its alignment near the terminus of the proposed south abutment embankment. The ditch was dry at the time of this evaluation.

Sandstone was exposed in the ridge forming the proposed dam location. Bedrock outcrops also include the dike in the ridge forming the dam location, Goemmer Butte, and a lesser peak that are all of volcanic origin. Goemmer Butte and the lesser peak are about 3/4 mile and 1/2 mile northwest of the proposed dam location, respectively.

3.3 LA VETA LAKES

The La Veta Lakes site is located about 1/2 mile south of La Veta, Colorado. The two lakes covering this site are west and below the crest of a low hill. The hill slopes downward gently to moderately away from the crest in all directions. The ground surface around the lakes generally slopes downward to the west and southwest.

The northern lake appears to have been created through excavation. The southern lake appears the same but also has low embankments on its west, south, and partial southern east sides. The hill is sparsely vegetated with small trees and bushes. A sparse to heavy growth of native grasses surrounds the lakes. The lakes were holding water at the time of our field exploration.

The Cucharas River is less than 1/2 mile west of the lakes. Wahatoya Creek is a separate drainage about 3/4 of a mile east of the lakes. Wahatoya and Daigre Reservoirs are about 1 to 1-1/2 miles northeast of the lakes. A small unnamed reservoir is about 1/2 mile northeast of the lakes. Cesaree noted bedrock outcrops on the hill's peak and numerous other locations around the hill and its edges at the time of our field exploration.

3.4 MARIA STEVENS

The Maria Stevens site is an existing lake located about 4-1/2 miles northeast of Walsenburg, Colorado along SH10. County Road 120 (CR120) extends north from SH10 about 800 feet west of the lake's edge. General topography ranges from relatively flat to rolling and incised by various streams and drainages. The existing reservoir is within a shallow draw that drains to the north. The ground surface slopes gently upward to the east and west from the lake. Low embankments are on both the lake's northern and southern ends creating the reservoir. SH10 trends easterly, parallel to and about 50 feet from the south embankment. Several residences, buildings, roads, and parking exist along the lake's west side along with three boat launch ramps. Vegetative cover consists of a heavy growth of native grasses and weeds with some small trees and bushes.

Cucharas River is about 900 feet south of the lake, with no structural connection between the two. Duran Ditch parallels the lake's western edge about 200 feet to the west. Cucharas Reservoir begins about 3 miles northeast of the lake, with the Cucharas Dam about 6-1/4 miles to the northeast. Cesaree noted no bedrock outcrops on or near the site at the time of our field exploration.

3.5 SOUTH BAKER

The South Baker site is located about 2 miles south of Cuchara, Colorado. It is within a secondary valley of a relatively broad east and west trending valley. An isolated east-west trending ridge divides

the secondary valley from the large valley and at its eastern end near the mountain forming the large valley's southern side. The proposed dam location is in the secondary valley, an estimated 500 feet upstream of the crotch of the large/secondary valleys.

At the dam location, the secondary valley is steep walled, heavily forested on both sides, with the trees thinning to a narrow open meadow in the valley's bottom that widens to the west. The valley slopes downward from west to east at moderate slope. SH12 is located about a 1/4 mile northeast of the proposed dam centerline.

The valley appears to carry an intermittent stream that was flowing at the time of our field explorations. No other free water was visible nor were rock outcrops visible at the time of our field exploration.

4. GEOLOGIC CONDITIONS

The Spanish Peaks/Cucharas region is geologically part of the Raton Basin in southern Colorado. The La Veta syncline is one of the large landscape features in this area. The syncline is a fold that includes a sequence of sedimentary units representing rocks of Paleozoic, Mesozoic, and Tertiary ages. The fold has steeply dipping beds on its west limb bounded on the west by the Sangre de Cristo Mountains and a gently dipping limb on the eastern side where the sedimentary units flatten toward the plains. The Spanish Peaks are prominent features of intrusive igneous rock found along the axis of the syncline fold. These tertiary intrusions are stocks, plugs, laccoliths, sills, and radiating dikes that cut through the sedimentary units as Johnson (1969)[1] indicates.

Sedimentary Rock

Paleozoic sedimentary rocks outcrop on the western side of the La Veta syncline. The units are from the Pennsylvanian/Permian Sangre de Cristo group; red and gray conglomerate, arkose, sandstone, siltstone, shale, and gray limestone. These units are north-south striking and create higher elevation ridges and steep valleys because of their resistance to erosion.

Mesozoic sedimentary units' outcrop on the western (steeply dipping to near vertical) and eastern side (gently dipping to flat lying) of the syncline axis. This sequence includes the Jurassic Morrison Formation, Dakota Sandstone, Carlile Shale, Niobrara Formation, Pierre Shale, Trinidad Sandstone, and the Raton Formation. These units have sandstone, siltstone, shale, limestone, as well as coal, chalk, and gypsum beds. Because of their variable resistance to weathering and erosion, the steeply dipping beds create ridges and hogbacks that strike generally north-south on the western side of the La Veta syncline.

The axial units of the La Veta syncline include the Tertiary Poison Canyon Formation, the Cuchara Formation, and the Huerfano Formation. These are arkosic conglomerate and sandstone, siltstone, and shale. The Cuchara Formation is sandstone and claystone. The Huerfano Formation is shale and sandstone. Each of these units is unconformable with the unit below. These units are elevated due

[1] Johnson, R.B., 1969. Geologic map of the Trinidad quadrangle, south-central Colorado. US Geological Survey, Miscellaneous Geologic Investigations Map I-558. Map Scale 1:250,000.

to the intrusion of the West and East Spanish Peaks and essentially drape over the flanks of the stocks.

Johnson observed that throughout the Spanish Peaks region, the competent sedimentary rocks, such as conglomerate, sandstone, and limestone are highly jointed, but noted the effect of contact metamorphism on the sedimentary rocks is generally not significant. Locally bleached sandstone and baked shale adhere to the walls of some of the smaller intrusive bodies, and the shale has been altered to slate or phyllite. Near the intrusive mass of West Spanish Peak, conglomerates, sandstone, and shale beds have been altered to conglomeratic quartzite, hornfels, and slate which are more resistant rock units.

Igneous Rock

The intrusive igneous bodies of the Spanish Peaks cut through and across the sedimentary sequence and fold structure of the La Veta syncline. The softer sedimentary rocks were subsequently weathered and eroded away to reveal the more resistant radiating dikes, sills, laccoliths, and plugs of silicic, intermediate, and basic composition. There are several references for the types of igneous intrusions and the mineralogy of the different intrusive events in Penn 1992[2] and 1994[3]. The most common rock compositions are monzonite and syenite porphyries. More mafic rocks are prevalent farther from the two peaks. The East Spanish Peak stock and some radial dikes are granite and granodiorite. Basaltic rocks most commonly form sills, dikes, and plugs distal to the two peaks. The dikes vary from 3 to 100 feet in thickness and are exposed for distances of up to 12 miles.

A portion of the Trinidad geologic quadrangle map[1] in Figure 1 shows the locations of the five project sites. Four of the five study sites are located in the central and western portions of the La Veta syncline fold and Spanish Peaks intrusions. Maria Stevens is the only site located on the gently dipping eastern side of the fold on the plains.

[2] Penn, B. S., Snee, L. W., and Wendlandt, R. F., 1992, 40Ar/39Ar geochronologic constraints on the intrusive history of the Spanish Peaks area in south-central Colorado (abs.): American Geophysical Union Fall Meeting, EOS, v. 73, no. 43, p. 657.

[3] Penn, B. S., 1994, An investigation of the temporal and geochemical characteristics, and the petrogenetic origins of the Spanish Peaks intrusive rocks of south-central Colorado: Ph. D. thesis T-4323, Colorado School of Mines, Golden, Colorado, 198p.

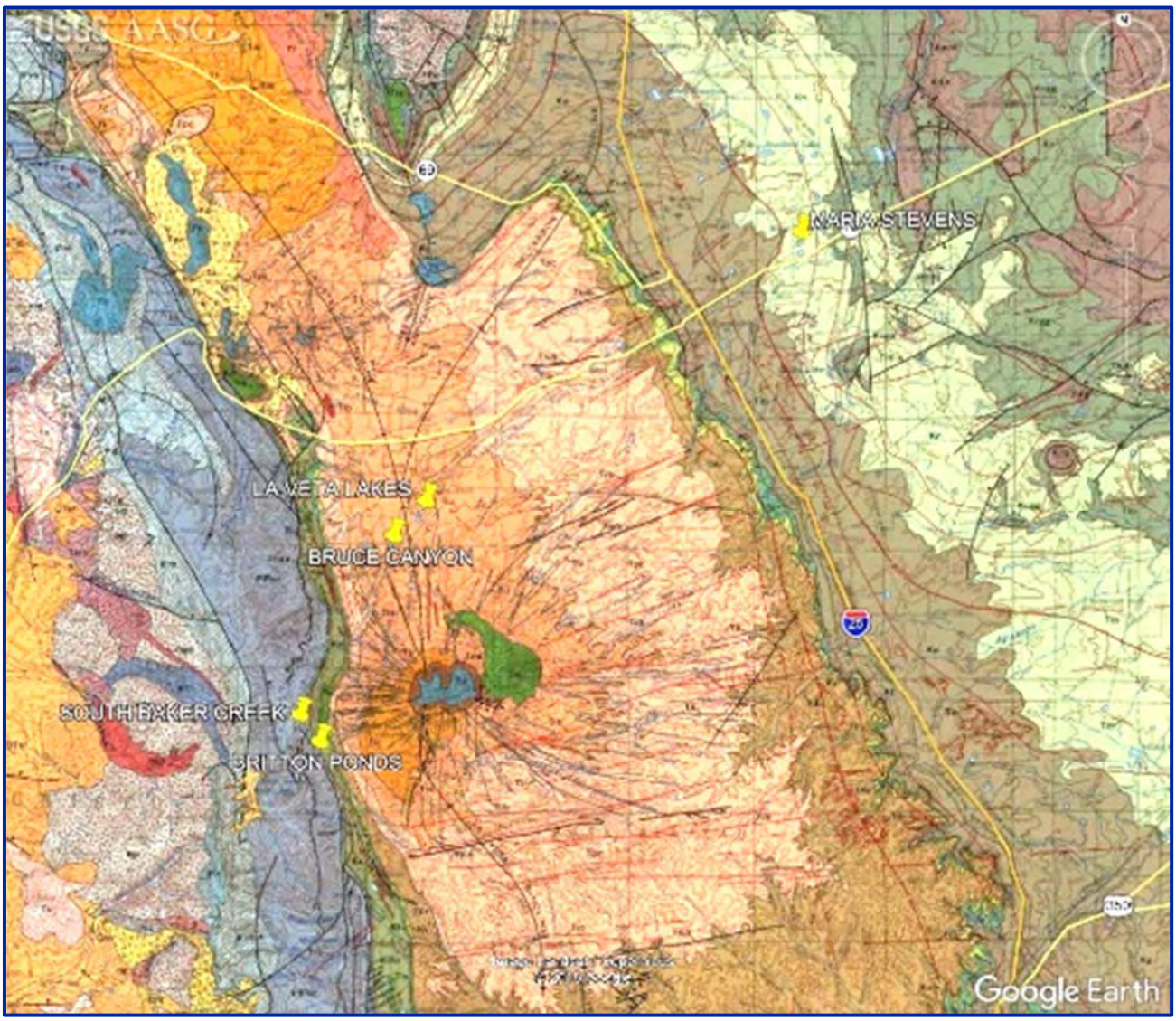


FIGURE 1. Geologic map showing the five study site locations. The La Veta syncline axis trends southeast to northwest and along the fold axis are the East and West Spanish peak intrusions and radiating dikes. The Maria Stevens site is north and east of the Cucharas area on the gently dipping east limb of the fold.

Mapped Hazards

According to the Colorado Landslide Inventory Map[4], only three landslides have been identified and mapped in the area of the subject dam locations (Figure 2). These landslides were mapped from aerial imagery and due to the scale (1:250K), smaller landslides may not be included in the inventory. These landslides are located southwest of the Town of La Veta in the Mesozoic sedimentary rock section. None of the study sites are near these mapped landslides but they are in a similar geologic and topographic setting.

[4] Colorado Geologic Survey, Colorado Landslide Inventory, 2018. (http://coloradogeologicalsurvey.org/geologic-hazards/landslides/colorado-landslide-inventory/)

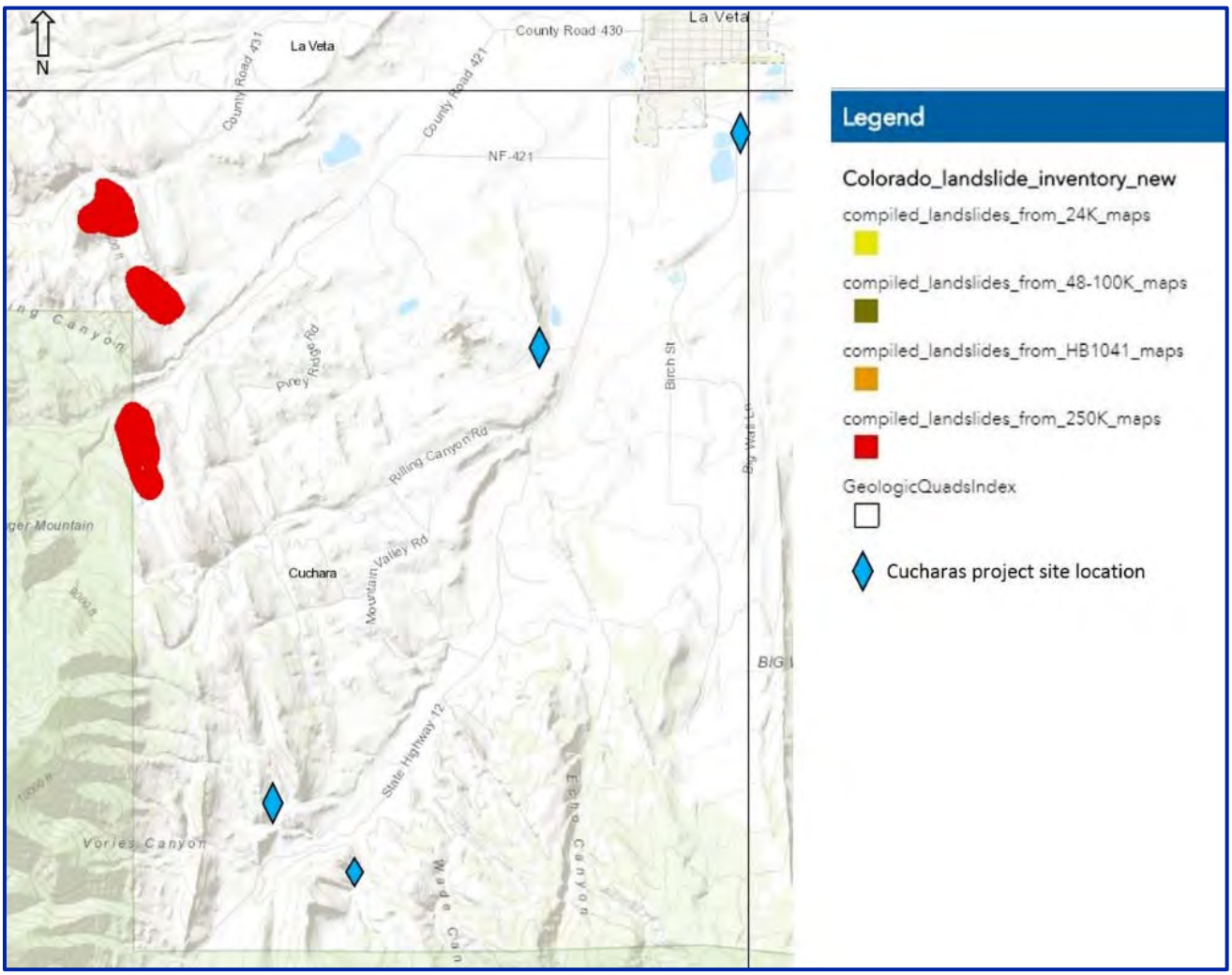


FIGURE 2. Mapped landslides in the Cucharas region from the Colorado landslides inventory. The red polygons are landslide areas digitized from 1:250,000 scale USGS mapping in the mid 1970's by Colton and others on 1 degree by 2 degree quadrangles. This map may not represent all landslides in the area.

Seismic hazards are low in the project area; however, earthquakes have occurred in the region, mainly south of the project area. Mapped earthquakes and percent chance of damage are shown on the USGS[5] (Figure 3). The project sites fall into the less than 1% chance of damage area mapped by the USGS. This indicates, should an earthquake occur, there is a very low risk of damage from an event that will affect any of the project sites.

[5] United States Geologic Survey; Colorado Area Seismicity (1973-8/14/2017). (https://earthquake.usgs.gov/earthquakes/byregion/colorado/CO_2017_damagemap.pdf)

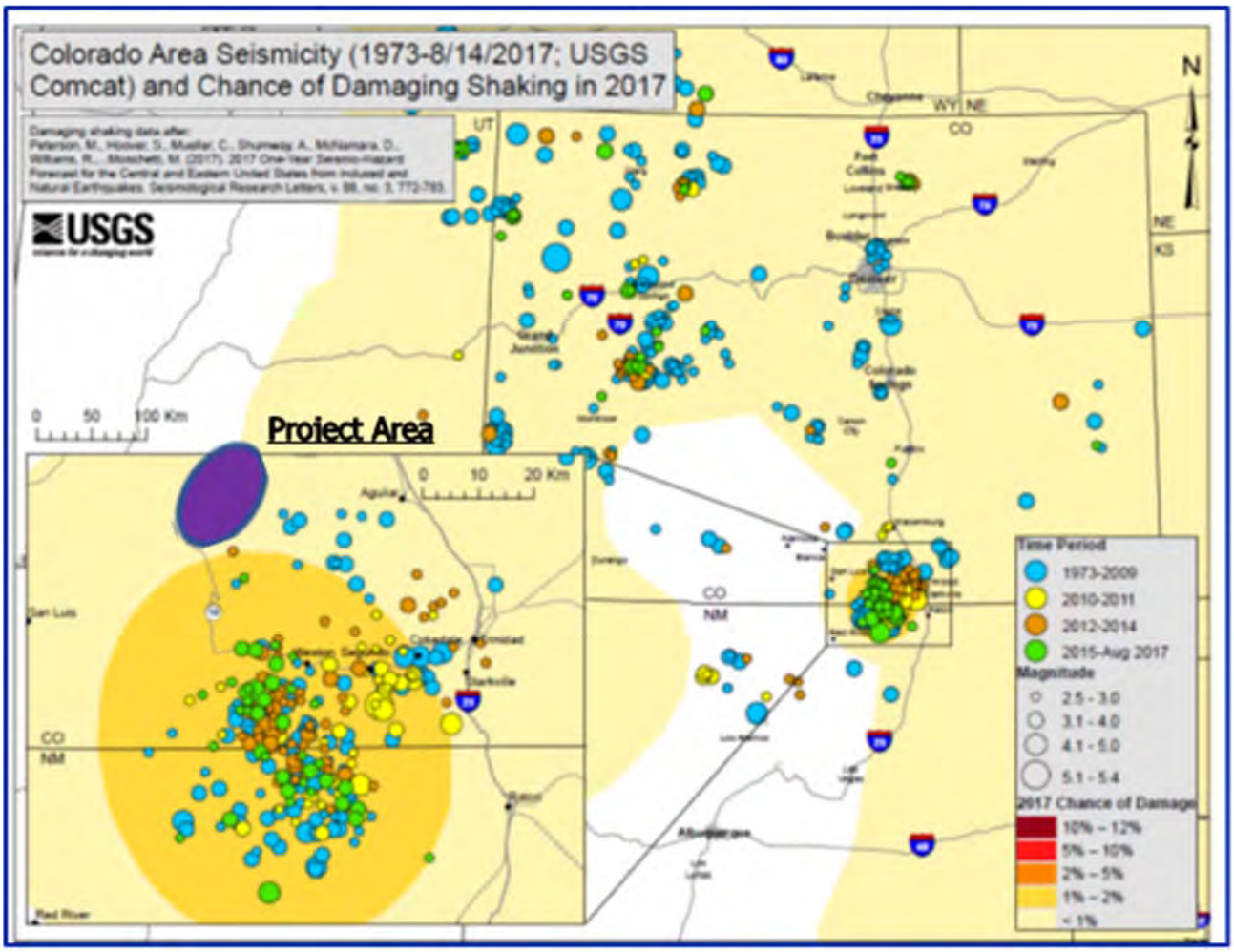


FIGURE 3. Colorado seismicity from the USGS earthquakes hazards program. There is very low seismic risk for the project area.

4.1 BRITTON

The Britton site is located south of Baker Creek on the east side of SH12 (Figure 4). The site is north of two existing ponds on the South Fork of the Cucharas River. The drainage is a northwest trending valley which is located on the contact between the Sangre de Cristo Formation and the steeply dipping Morrison/Ralston Creek Formation and is bounded on the east by a hogback ridge of Dakota Sandstone. The Morrison/Ralston Creek Formation in this area is described as a variegated maroon shale, gray limestone, red siltstone, gypsum, and gray sandstone. The Dakota is a buff sandstone, buff conglomeratic sandstone, and dark gray shale.



FIGURE 4. Britton Ponds project site (topographic and Google Earth images) is located southeast of the Baker Creek site, east of SH12 and north of Cucharas Pass. Britton Ponds is on the South Fork of the Cucharas River. The drainage occupies a northwest trending valley.

Geologic hazards at this site are minimal. The fracture nature of the sedimentary bedrock may lead to seepage and weathering along the fractures and bedding planes. This could result in a modification of drainage patterns.

4.2 BRUCE CANYON

The Bruce Canyon site is located southwest of the Town of La Veta off SH12. The potential dam site is upstream of an intrusive dike that strikes northwest to southeast, cutting through the Cuchara Formation that comprises the valley rock (Figure 5). The low valley drains an ephemeral creek through the dike and Butte Ditch runs around the periphery at an elevation of 7,420 feet. Goemmer Butte is west of the valley. Goemmer Butte is a volcanic plug intruded into the Cuchara Formation and exhibits the only evidence in the immediate vicinity of Spanish Peaks for magma venting to the surface. A crescent shaped body of eruptive breccia is well exposed on the south and west sides of the butte. The Eocene aged Cuchara Formation exposed here represents its lowermost part. Typically, the formation is arkosic, conglomeratic, and cross bedded, found in fining upward alluvial cycles. The mudstones are drab brown to red. There are prominent pebbles and cobbles in the sandstone and red mudstone helps distinguish the unit in this area (Penn, 1996[6]).

[6] Penn, B.S., Lindsey, D.A. and Thompson, R.A., 1996. Tertiary igneous rocks and Laramide structure and stratigraphy of the Spanish Peaks region, south-central Colorado: Road log and descriptions from Walsenberg to La Veta (first day) and La Veta to Aguilar (second day.



FIGURE 5. Bruce Canyon project site (topographic and Google Earth images) is located southwest of the Town of La Veta, west of CR12. Bruce Canyon is an east-west valley cut through by a north-south trending intrusive dike. There is an ephemeral spring and an irrigation ditch in the project area. Goemmer Butte is a prominent volcanic feature west of the project site.

Geologic hazards at Bruce Canyon are rockfall and landslides. The vertical face of the intrusive dike is a source area for rockfall into the project area (Figure 6). Even so, rockfall is not expected to affect the project adversely as there is little evidence of rockfall near the proposed abutment locations, the evidence indicates rocks that have fallen are not large, and rocks would likely fall into the reservoir, as opposed to on the embankment. The slopes on either side of the valley have the potential for downslope movement (Figure 7). Because of the interbedded and fractured nature of the sedimentary rock units in this area, the slope stability could be affected by infiltration and movement of water along fractures and bedding planes, increased weathering, and reduced strength along discontinuities.



FIGURE 6. Intrusive dike on the northeast side of the site. A potential source for rockfall into the project area.



FIGURE 7. Bruce Canyon project site. View looking north from the south side of the project area. Steep hill slopes on either side of the valley have the potential for downslope movement due to the fractured and interbedded nature of the sedimentary rock units.

4.3 LA VETA LAKES

The La Veta Lakes project site is located due south of the Town of La Veta. It is about 80 to 120 feet higher in elevation than the town center. The Cuchara Formation consists of red, pink, and white sandstone, and red, gray, and tan claystone and underlies the site. There are small intrusions of igneous material southwest of the site. La Veta Lakes are fed by a piped diversion from the Cucharas River. They occupy a relatively flat area slightly higher than the valley floor (Figure 8). Geologic hazards for this area are minimal. There is no significant geologic hazard.

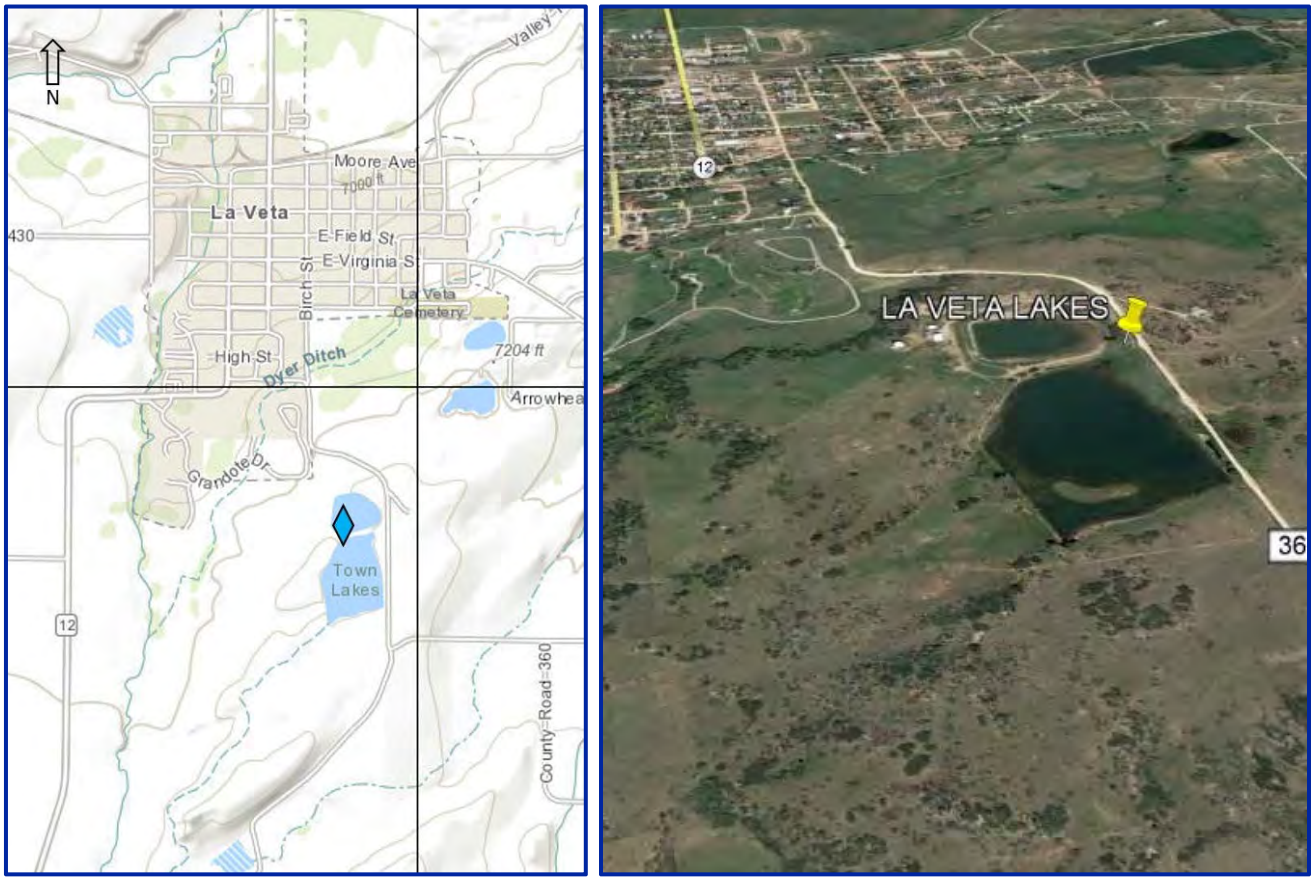


FIGURE 8. La Veta Lakes project site (topographic and Google Earth images) is located just south of the Town of La Veta and about 100 feet above the valley in elevation. La Veta Lakes is a water storage area that is fed by a piped diversion from the Cucharas River. The site is in the middle of the La Veta syncline and is underlain by the Tertiary Cuchara Formation.

4.4 MARIA STEVENS

Located east of Walsenburg on the north side of SH10, Maria Stevens Reservoir occupies a low point between two low ridges to the west and east (Figure 9). Geologically, the units in this area are the Niobrara Formation and the Pierre Shale. The Niobrara is Cretaceous age limestone with chalk layers. The Pierre Shale is Cretaceous age dark gray fissile siltstone and shale. Because of the location of Maria Stevens in the small topographic swale, it is interpreted that the Niobrara has been eroded in this area and the bedrock below the topsoil is the Pierre shale. Notably, on the ridge northwest of the site, there are several sand and gravel quarries indicating that fluvial erosion and deposition likely stripped the Niobrara from the surface as rivers crossed the area. A geologic hazard that may impact the project is possible sinkholes that may develop in buried limestone units.

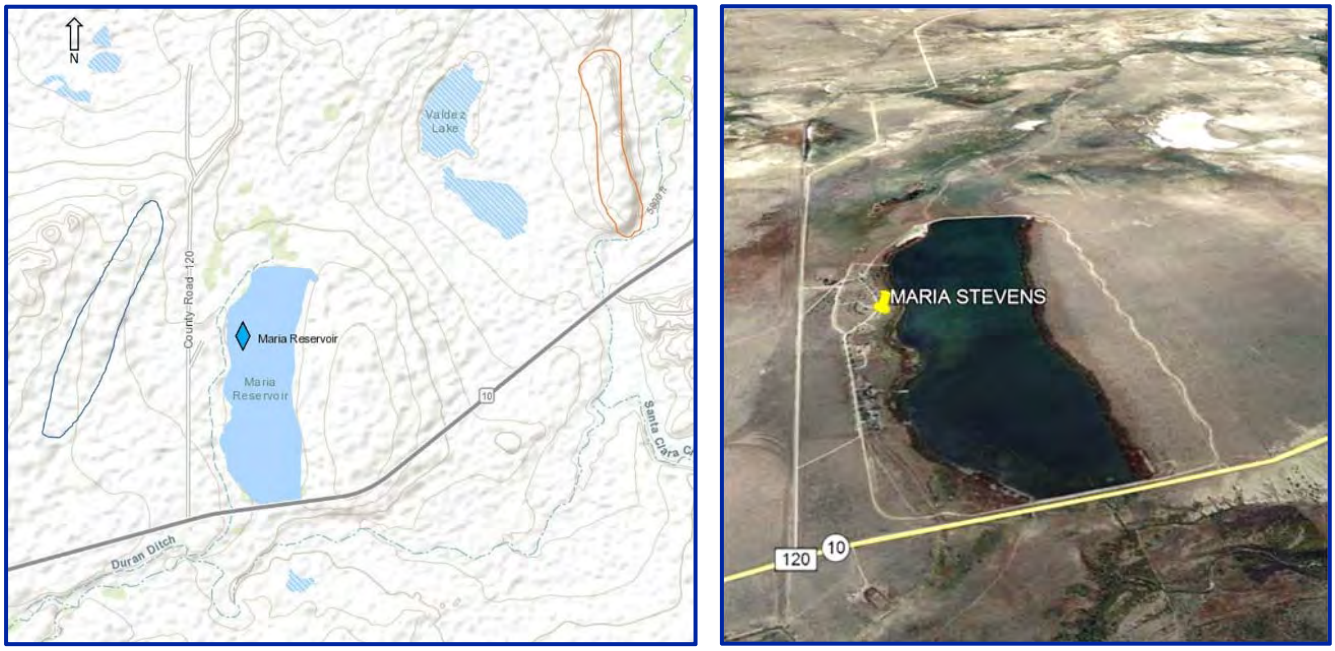


FIGURE 9. Location and topography of Maria Stevens Reservoir (topographic and Google Earth images). Walsenburg is west, via SH10. The circled area on the left of the topographic map is a gravel ridge. The circled area on the right of this map is a ridge of Cretaceous Carlile shale, Greenhorn limestone, and Graneros Shale consisting of dark gray shale, gray limestone, and gray shale. The reservoir sits in a low point underlain by Pierre shale.

4.5 SOUTH BAKER

The South Baker project site is located southwest of the Bruce Canyon site, west of CR12, north of Cucharas Pass (Figure 10). South Baker Creek is in a southwest–northeast trending valley with South Baker Creek and is a tributary of the South Fork of the Cucharas River. The South Baker Creek drainage is bounded on the north side by a small ridge and to the south by Boyd Mountain. The sedimentary units of this area are the Pennsylvanian Permian Sangre de Cristo Formation. Characterized by red and gray conglomerate, arkose, sandstone, siltstone, shale, and gray limestone. The variety of units in this formation suggests that there are variable weathering and erosion patterns in the steeply dipping unit. Boyd Mountain is well vegetated. Slope instability of the flank of Boyd Mountain is a potential hazard.

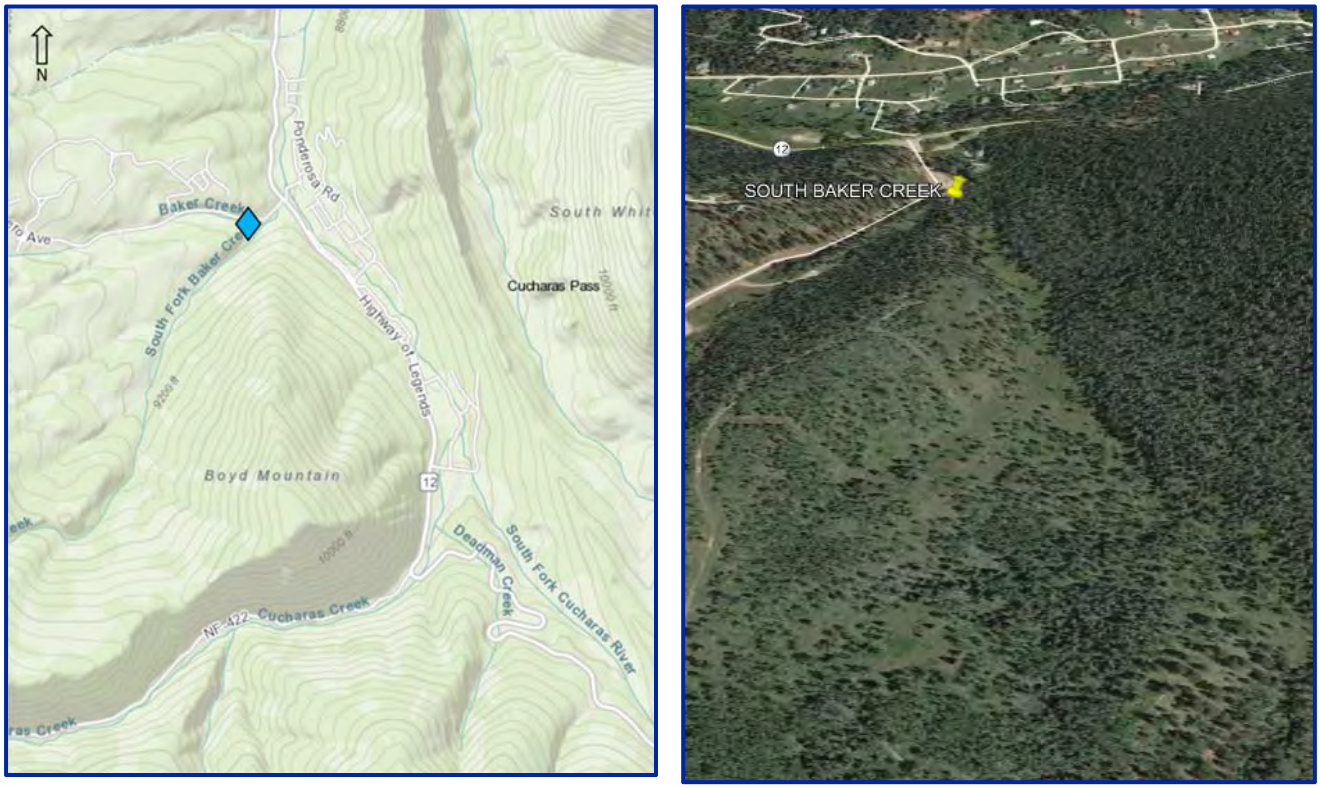


FIGURE 10. South Baker Creek project site (topographic and Google Earth images) is located southwest of the Bruce Canyon site, west of SH12, north of Cucharas Pass. South Baker Creek is a southwest–northeast trending valley with South Baker Creek becoming a tributary of the South Fork of the Cucharas River at the mouth of the valley. Google Earth image is an oblique image looking east down the creek drainage.

5. FIELD EXPLORATION

5.1 BORINGS

Cesare explored subsurface conditions at each site by drilling borings at the locations indicated in Figures 11, 14, 17, 19, and 22. Table 1 presents the number of borings drilled at each site.

TABLE 1. Borings Drilled

Site	Borings Drilled
Britton	2
Bruce Canyon	4
La Veta Lakes	7
Maria Stevens	6
South Baker	5

Abutment inaccessibility was an issue at the sites with relatively steep, heavily forested, slopes including the Britton, Bruce Canyon, and South Baker sites. Cesare drilled only two borings at the Britton site due to inaccessibility of the abutment locations; one in the general maximum dam section area and one close to the toe of the eastern abutment. Cesare drilled a boring at the maximum section location and near the toe of the north abutment at the Bruce Canyon site. A dirt road traversed the Bruce Canyon southern abutment allowing access to that boring location. We drilled the

approximate maximum section location and the toes of both northern and southern abutments at the South Baker site. In August 2019, Cesare returned to the Bruce Canyon and South Baker sites to perform additional drilling at abutment boring locations after access roads were constructed. Cesare drilled the north abutment at the Bruce Canyon 30 feet into bedrock. Cesare drilled both abutments at the South Baker site to bedrock contact at the north abutment and 20 feet into bedrock at the south abutment.

Borings were advanced using a CME 550 track mounted drill rig equipped with 6 inch diameter, continuous flight, hollow stem auger and HQ and NX wireline coring equipment. ODEX casing driving was used at one location. Soil and bedrock were sampled to practical auger refusal at designated intervals using a modified California sampler which is driven into the soil by dropping a 140 pound hammer through a free fall of 30 inches. The modified California sampler is a 2.5 inch outside diameter by 2 inch inside diameter device lined with thin brass tubes to recover relatively undisturbed samples. A penetration test is the procedure to drive the modified California sampler into the soil and to record the number of blows required to do so. The number of blows required for the sampler to penetrate 12 inches gives an indication of the consistency or relative density of the soil encountered. Results of the penetration tests and locations of sampling are presented on the Boring Logs profiles, Figures 12, 15, 18, 20, and 23. Individual logs are presented in Appendix A.

At a minimum of one boring per site, the bedrock was cored using HQ or NX wireline coring equipment. Wireline equipment includes drill steel and a core barrel comprised of an inner and outer barrel. The drill steel is thin walled pipe threaded at both ends that is connected, as necessary, to reach coring depths. The outer core barrel is larger diameter than the drill steel with a cutting edge on the bottom that cuts an annular space 3.78 inches in outside diameter and 2.5 inches inside diameter for HQ and cuts annular space of 2.375 inches in outside diameter and 1.75 inch inside diameter for NX. The inner barrel is a metal tube that is held stationary inside the outer barrel and holds the core sample as it is cut from the rock mass. The inner core barrel is retrieved from the outer core barrel by a thin cable attached to it, without removing the drill steel or outer barrel. During coring, the recovered core was continuously logged, wrapped in plastic sheeting or tubing, and stored in partitioned core boxes. Photographs of the cores are presented in Appendix B.

After coring completion, Cesare tested the bedrock in all cored intervals for in situ permeability using the Packer test. The Packer test consists of sealing the cored hole with a single inflatable rubber Packer at a specific depth and pumping water in a pipe through the Packer into the remaining open boring below. This procedure was started at selected heights above the cored bottom and then the Packer unit was raised to a second interval, with testing completed at each interval. During testing, Cesare recorded the flow into the interval in gallons, the time interval pumped in minutes, the pumping pressure, and the flow meter's height above ground. The pumping pressures were increased and decreased incrementally to provide a range of conditions to evaluate seepage. Based on these measurements, Cesare calculated the permeability for each pumping pressure increment. We performed Packer testing in Borings B-2, BC-2, BC-4, LVL-1, LVL-3, LVL-5, MS-1, MS-3, MS-5, and SB-2. Results of the Packer tests are summarized in Table 2.

TABLE 2. Averaged Packer Test Results

Boring	Interval Tested		Averaged Hydraulic Conductivity (cm/sec)
	Depth (feet)	Elevation* (feet)	
B-2	23.5 to 40.0	9210.5 to 9194.0	9.4E-4
	32.0 to 40.0	9202.0 to 9194.0	1.6E-3
BC-2	25.0 to 51.0	7339.0 to 7313.0	6.4E-6
	35.0 to 51.0	7329.0 to 7313.0	2.8E-5
BC-4	13.0 to 40.0	7395.0 to 7368.0	3.2E-6
	20.0 to 40.0	7388.0 to 7368.0	1.4E-5
	30.0 to 40.0	7378.0 to 7368.0	3.7E-5
LVL-1	19.0 to 40.0	7259.0 to 7238.0	3.3E-5
	29.0 to 40.0	7249.0 to 7238.0	2.7E-6
LVL-3	5.5 to 40.5	7279.0 to 7243.5	2.3E-4
	22.5 to 40.5	7261.5 to 7243.5	3.4E-4
LVL-5	19.0 to 41.0	7260.0 to 7238.0	2.5E-5
	29.0 to 41.0	7250.0 to 7238.0	8.9E-6
MS-1	29.0 to 41.0	5896.0 to 5884.0	2.6E-7
	35.0 to 41.0	5890.0 to 5884.0	8.1E-7
MS-3	33.5 to 50.0	5887.5 to 5971.0	2.0E-6
MS-5	29.0 to 41.0	5996.0 to 5984.0	2.7E-5
	35.0 to 41.0	5990.0 to 5984.0	1.9E-6
SB-2	19.0 to 51.0	8839.0 to 8807.0	5.0E-4
	35.0 to 51.0	8823.0 to 8807.0	8.9E-6

*Estimated

5.2 EXPLORATORY TEST PITS

To evaluate potential borrow material for construction, Cesare explored the ponding areas, or nearby areas, of each site with exploratory backhoe pits. A John Deere 225D excavator was used for most of the pits, excavating to depths of about 8 to 10 feet or penetration refusal on coarse material or bedrock. Our field personnel logged the material exposed in the pit excavations and recovered representative samples of the soil encountered. The pit locations are presented in Figures 11, 14, 17, 19, and 22. The pit log profiles are presented in Figures 13, 16, 21, and 24. We did not excavate exploratory pits at the La Veta Lakes site due to the very shallow bedrock that would refuse backhoe excavation.

6. LABORATORY ANALYSIS

Cesare performed laboratory testing on representative samples recovered during the subsurface investigation. The tests performed were for classification of material, evaluation of engineering properties, correlation of subsurface material, and development of analysis criteria. A summary table of laboratory test results and the individual tests are shown in Appendix C.

6.1 CLASSIFICATION TESTING

Bulk samples and California samples collected from borings and exploratory pits were used for classification testing. Tests were performed on both overburden soil and bedrock material. Classification testing results were coupled with the geologic origin of the material to aid in the selection of foundation and embankment analysis parameters. We performed 54 gradation and Atterberg limits tests for classification.

6.2 TIMED CONSOLIDATION TESTS (ASTM D2435)

Cesare conducted timed consolidation tests on existing fill soil and native overburden soil from the Maria Stevens site to evaluate the potential consolidation of the material under increased loading. Samples were inundated with water at 0.125 kips per square foot (ksf). The applied load was progressively doubled to a maximum pressure of approximately 4 ksf. We performed no rebound cycle or unloading after the maximum loading.

6.3 SWELL/CONSOLIDATION TESTS (ASTM D4546)

Cesare performed a swell/consolidation test on a sample from Exploratory Pit BCP-5 to evaluate the collapse potential of the native soil due to the presence of abundant voids or vugs in the larger pieces of material. The sample was trimmed from a small block in the bulk sample, loaded to 500 psf, and inundated with water. The sample collapsed 9.9% when wetted, indicating very high collapse potential. No rebound cycle or unloading was performed after the maximum loading.

7. SUBSURFACE CONDITIONS

Subsurface conditions of each site are described in the following sections. More complete descriptions of the subsoil and groundwater is shown in the boring and exploratory pit log profiles in Figures 12, 13, 15, 16, 18, 21, 21, 23, and 24 and the individual boring logs in Appendix A. These observations represent conditions at the time of field exploration and may not be indicative of other times or other locations. Groundwater can be expected to fluctuate with variations of seasons, irrigation, water level in the rivers and lakes, and weather.

7.1 BRITTON

The borings indicated the soil underlying the embankment consisted of about 15 to 20 feet of interbedded sandy clays, clayey sands, and poorly to well graded gravels with silt and sand, overlying weathered to fresh claystone bedrock. The claystone extended to depths of about 22 to 38 in Borings B-2 and B-1, respectively. We encountered sandstone below the claystone that extended to the remaining depths explored.

Cesare encountered groundwater during drilling at depths of 29-1/2 and 10-1/2 feet in Borings B-1 and B-2, respectively. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

The exploratory pits indicated about 5 to 8 feet of silty, clayey, and relatively clean sands, at which depths the backhoe refused. Exceptions were Pits BP-2 and BP-4 in which we encountered silty gravels at depths of about 6-1/2 and 4 feet, respectively, that extended to the remaining depths explored.

7.2 BRUCE CANYON

The soil underlying the Bruce Canyon site consisted of interbedded sandy clays and clayey sands to depths of about 14 feet in Boring BC-1 near the north abutment, 18 feet in BC-2 in the valley, about 5-1/2 feet in BC-3 on the south abutment, and less than 1 foot in BC-4 on the north abutment. The soil overlies claystone bedrock in the south abutment and sandstone in the valley and on the north abutment that extend to the remaining depths explored. We noted occasional relatively thin lenses of sandstone in the claystone in BC-3 and a thin lens of claystone in the sandstone in B-4.

Cesare encountered groundwater during drilling at depths of 10 and 8 feet in Borings BC-1 and BC-2, respectively. We did not encounter groundwater in BC-3 or BC-4 during drilling. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

The exploratory pits encountered interbedded silty, clayey, and silty/clayey sands and sandy clays to the depths explored. We encountered groundwater in BCP-1 at about 9-1/2 feet.

7.3 LA VETA LAKES

Cesare encountered fill to depths of about 3 to 11 feet in Borings LVL-1 and LVL-4 through LVL-6. LVL-1 was located at the north side of the north lake, LVL-4 and LVL-5 were at the west side of the lake at the south end, and LVL-6 was at the east side of the lake near its south end. At the central portion of the project site, generally between the two lakes, we encountered native sandy clays to depths of about 1-1/2 to 3 feet in Borings LVL-2, LVL-3, and LVL-7. We encountered interbedded claystone and sandstone below the soil that extended to the remaining depths explored.

Cesare encountered groundwater during drilling at depths of 2-1/2 to 4 feet in Borings LVL-1 and LVL-4 through LVL-7. We did not encounter groundwater in LVL-2 or LVL-3. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

Based on the drilling results, we did not excavate exploratory pits at this site due to the shallow bedrock.

7.4 MARIA STEVENS

Cesare's borings indicated the soil underlying the site consisted primarily of sandy clay to depths of about 6-1/2 to 28 feet below the ground surface. Exceptions were in Borings MS-1, MS-2, and MS-6, in which we encountered weathered claystone to 5 feet, interbedded sands and clays to 16-1/2 feet, and fill to 7 feet, respectively. We encountered claystone below the soil in all borings except MS-2 and MS-6, in which we encountered sandstone and shale, respectively. Where encountered, the claystone extended to 22-1/2 to 27 feet in Borings MS-1, MS-3, MS 4, and MS-5 and the depth explored of 34-1/2 feet in MS-2. The shale extended to the remaining depths explored in the remainder of the borings.

Cesare encountered groundwater during drilling at depths of 6 to 25 feet in all borings. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

The exploratory pits indicated about 3 to 5 feet of sandy clays over shales extending to the depth

explored of about 6 to 8 feet. Considering the backhoe penetrated the shale, it is likely excavatable with typical earthwork construction equipment.

7.5 SOUTH BAKER

The soil underlying the South Baker site in the valley's lower elevations consisted of interbedded silty, clayey, and relatively clean sands, with lesser amounts of sandy clay to depths of 7 to 22 feet. Sandstone directly underlies the soil and extended to depths of 14-1/2 feet and 41 feet in Borings SB-1 and SB-2 and the depth explored of 17 feet in SB-3. Claystone was encountered below the sandstone in SB-1 and SB-2 that extended to about 27 feet and the depth explored of 51 feet, respectively. Sandstone was found underlying the claystone in SB-1 that extended to the remaining depth explored of 29 feet.

The soil encountered at the north abutment consisted of silty sand and clayey gravel to a depth of about 10 feet. Sandstone underlies the soil that extended to the depth explored of about 14-1/2 feet. At the south abutment, we encountered sandy clays with increasing gravel and cobble contents with depth that extended to about 12 feet overlying a mixture of sand, gravel, cobbles, and boulders with a maximum size particle of about 5 feet. The soil overlay interbedded claystone and sandstone that extended to the remaining depth explored of about 70 feet.

The zone of very coarse material that was encountered in SB-4 at the south abutment could be glacial moraine; however, it is more likely landslide material. The drilling progress indicated it was unconsolidated, with blow counts varying from 35 blows for 12 inches to 50 blows for 7 inches on large particles. We cored through this zone with poor recovery between apparently large hard boulders, in which we had good recovery.

Cesare encountered groundwater during drilling at depths of 3 and 4 feet in Borings SB-2 and SB-3, respectively. We encountered no groundwater in SB-1, SB-4, and SB-5. We backfilled the borings upon drilling completion and made no additional groundwater measurements.

The exploratory pits indicated about 1-1/2 to 3 feet of silty, clayey, and silty/clayey sand overlying silty, clayey, and relatively clean gravels extending to the depths explored of 4 to 9 feet. An exception was SBP-4, in which we encountered sandstone at about 5-1/2 feet that extended to about 8 feet, the depth explored.

8. ANALYSIS

Cesare reviewed the conceptual embankment sections, field exploration results, and laboratory analysis to perform an initial evaluation of the five sites. After discussions with Applegate, we removed the La Veta Lakes and the South Baker sites from further consideration due to the lack of low permeability borrow material at these sites. Our review of these two sites is presented in Section **9. LOCATION DISCUSSIONS.**

Our analysis included performing stability and seepage analysis on the preliminary embankment sections provided to us. For any permanent water storage embankment, one must evaluate the embankment's stability, while holding water to its design capacity on a long term basis. Other

scenarios that may impact its stability, such as rapid drawdown of the stored water, shaking from earthquakes, and deterioration of the supporting soil and/or bedrock, also require stability evaluation. One must also evaluate water seepage through the embankment as it reduces the strength of most soil and causes additional forces within the embankment that reduces its stability during any of the aforementioned scenarios.

Cesare performed the analysis using the GeoStudio 2018 Suite produced by Geo-Slope International, Inc. of Calgary, Canada. The suite integrates all facets of various modeling types that allows the results of one analysis to be used directly by other analyses. More specifically, the programs used for our analysis were SEEP/W and SLOPE/W that allowed seamless analysis by initially analyzing seepage that was subsequently used in the slope stability.

Due to the very soft conditions at the Maria Stevens site, Cesare performed a strain based settlement analysis under the applied loads. We based this analysis on the timed consolidation tests performed in our laboratory. We used the Naval Facilities Engineering Command (NAVFAC) Design Manual 7.1[7] to evaluate the embankment influence at varying depths.

8.1 MATERIAL PARAMETERS

8.1.1 Seepage Parameters

Cesare used soil permeability values based on material types, published values, and our experience with these types of projects. Based on the exploration and laboratory results, the material encountered on any one site did not vary significantly in their gradations, specifically regarding their clay contents. As a result, specifically evaluating zoned embankments was not necessarily appropriate. Even so, we attempted to do so considering the material encountered, specific to their individual locations.

Some of the Packer test results presented in Table 2 indicated variation in bedrock hydraulic conductivity in the same boring ranging from 1 to 2 orders of magnitude. These variations likely relate to fracture flow, at least in the unweathered bedrock. The sandstones encountered generally varied in condition, ranging from nonindurated and unlikely to exhibit fracture flow, to moderately to well indurated and likely to exhibit fracture flow.

Fracture flow in the fresher claystone is unlikely to be uniform below the embankment, such that the claystone would be consistently relatively permeable. Work by Zhang[8] (2013) and others indicate claystone fractures tend to close under increased loading and when wetted. Cesare's opinion is a conservative approach considering fracture flow during the reservoir life is appropriate.

To be conservative, we used the highest bedrock hydraulic conductivity of each site, specific to the location. For the most part, the Packer testing indicated that the higher permeabilities existed in the upper portion of the bedrock. Using the higher permeability is, therefore, appropriate. Packer testing typically measures the horizontal flow component of in situ permeability. Cesare estimated the vertical

[7] Soil Mechanics, Desgn Manual 7.1; Department of the Navy, Naval Facilities Engineering Command; May 1982

[8] Zhang, C.-L. Experimental Evidence for Self-sealing of Fractures in Claystone. J. Phys. Chem. Earth (2011), doi:10.1016/ j.pce.2011.07.030.

flow will likely be one order of magnitude lower, thus, the ratio of vertical to horizontal permeabilities would be 0.1.

The material requiring seepage parameters for analysis include the embankment fill, native soil, and the unweathered bedrock. The values used are presented in Table 3.

TABLE 3. Permeability Parameters

Material	Britton		Bruce Canyon		Maria Stevens	
	Saturated Hydraulic Conductivity (cm/sec)	Saturated Hydraulic Conductivity (ft/sec)	Saturated Hydraulic Conductivity (cm/sec)	Saturated Hydraulic Conductivity (ft/sec)	Saturated Hydraulic Conductivity (cm/sec)	Saturated Hydraulic Conductivity (ft/sec)
Embankment core	1.00E-04	3.28E-06	1.00E-04	3.28E-06	1.00E-04	3.28E-06
Embankment shell	1.00E-04	3.28E-06	1.00E-03	3.28E-05		
Native soil, clayey					1.00E-06	3.28E-08
Native soil, granular	3.35E-01	1.10E-02	3.35E-01	1.10E-02		
Existing fill, clayey					1.00E-06	3.28E-08
Unweathered claystone	5.00E-05	1.64E-06			3.00E-05	9.84E-07
Unweathered sandstone	8.99E-04	2.95E-05	2.80E-05	9.20E-07		
Cutoff	1.00E-07	3.28E-09				

Blanks indicate the soil were not pertinent to our analysis.

8.1.2 Strength Parameters

Based on our testing, experience, and judgement, we present the strength parameters assigned to the various embankment and foundation material in Table 4.

TABLE 4. Stability Analysis Strength Parameters

Material	Friction Angle (degrees)	Cohesion (psf)	Remarks
Embankment core	25	25	Predominantly clayey sand/sandy clay
Embankment shell	25	25	Predominantly clayey sand/sandy clay
Native clay	15	0	Maria Stevens supporting surface
Claystone	0	3,000	Fresh
Sandstone	0	3,000	Fresh
Native soil	25	25	Predominantly silty sand
Slope protection	40	10	Riprap with sand bedding

8.2 SEEPAGE RESULTS

Cesare analyzed the embankment sections for Britton, Bruce Canyon, and Maria Stevens sites for steady state through the embankment at full pond. We analyzed rapid drawdown within the reservoir considering a rate of 1 foot per day, as it is a generally accepted upper bound of the preferred design range. The rapid drawdown (transient) analysis provides a phreatic surface, or wetted front, through the embankment at each daily time step.

8.3 STABILITY RESULTS

Cesare analyzed the downstream slopes considering full pool and steady state seepage. We analyzed the upstream slope during rapid drawdown at each time step. We did not analyze any slopes

considering end of construction, residual bedrock strength, or pseudo seismic forces, as these scenarios are not considered critical to site selection but must be considered during final design. Stability analysis result figures are presented in Appendix D.

8.3.1 Britton Stability Results

Results of our stability for this site are presented in Table 5 and include the State Engineer's requirements.

TABLE 5. Britton Stability Analysis Results

Analysis	Factor of Safety		Required Factor of Safety
	Block	Circular	
Full, steady state, downstream	1.92	1.90	1.5
Transient upstream*	1.01	1.47	1.2**

* Rapid drawdown
**Lowest factor of safety

The above results indicate the downstream slope provides a factor of safety against sliding well within the State Engineer's requirements. They also indicate the upstream slope requires flattening and/or adding a drain system to allow rapid pore pressure release.

8.3.2 Bruce Canyon Stability Results

Results of our stability for this site are presented in Table 6 and include the State Engineer's requirements.

TABLE 6. Bruce Canyon Stability Analysis Results

Analysis	Factor of Safety		Required Factor of Safety
	Block	Circular	
Full, steady state, downstream	1.88	1.57	1.5
Transient upstream*	1.29	1.33	1.2**

* Rapid drawdown
**Lowest factor of safety

The results indicate the downstream slope provides a factor of safety against slope failure within the State Engineer's requirements. They also indicate the upstream slope is appropriate.

8.3.3 La Veta Lakes Stability Results

Cesare did not perform stability analyses for La Veta Lakes.

8.3.4 Maria Stevens Stability Results

Results of our stability for this site are presented in Table 7 and include the State Engineer's requirements.

TABLE 7. Maria Stevens Stability Analysis Results

Analysis	Factor of Safety		Required Factor of Safety
	Block	Circular	
West embankment			
Full, steady state, downstream	1.17	1.46	1.5
Transient upstream*	0.81	1.19	1.2**
South embankment			
Full, steady state, downstream	1.44	1.47	1.5
Transient upstream*	1.77	1.69	1.2**

* Rapid drawdown
**Lowest factor of safety

Regarding the west embankment, the results indicate the downstream slope provides a factor of safety against slope failure much less than the State Engineer's requirements and will require flattening and/or improving the subgrade. They also indicate the upstream slope requires flattening and/or a adding a drain system to allow rapid pore pressure release.

Regarding the south embankment, the results indicate the downstream slope provides a factor of safety against slope failure just less than the State Engineer's requirements and may require flattening and/or improving the subgrade. They also indicate the upstream slope is conservative at 5:1, horizontal to vertical (H:V).

8.3.5 South Baker Stability Results

Cesare did not perform stability analyses for the South Baker site due to the relatively high permeability of the bedrock underlying the proposed dam site and the general scarcity of low permeability material encountered during our field exploration.

9. LOCATION DISCUSSIONS

The discussions below present general assessments of the conditions encountered at each of the sites. The seepage and stability analyses are based on our experience with similar material considering the preliminary nature of these evaluations. The comments on the seepage and slope appropriateness are based on these assumptions and would change when considering material and site conditions based on detailed exploration and specific testing.

9.1 BRITTON

Cesare's geologic evaluation indicated geologic hazards are minimal. The fracturing in the sedimentary bedrock may lead to seepage and weathering along the fractures and bedding planes. The gravels and relatively clean sands encountered in the soil overburden would require cutting off below the embankment. Notwithstanding the evaluation, little is known about the site specific geologic conditions. Detailed geologic mapping must be performed.

Packer tests performed were within the sandstone below the claystone indicating permeability rates of about 1E-3 cm/sec, a relatively high rate. The claystone encountered below the soil and above the sandstone may be appropriate to provide the embedment for the cutoff if found to be of sufficient

thickness. This would require additional evaluation, including drilling and testing for permeability and evaluating the claystone's continuity. If the claystone also exhibits a high permeability, a deep cutoff may be required. Since the claystone zone encountered in B-2 in the maximum section was about 2 to 5 feet thick and sandstone was below to the remaining depth explored, the required cutoff may extend to over 40 feet.

In our opinion, a slurry cutoff wall as proposed in the concept design has risks associated with the post construction evaluation of the slurry wall construction. Evaluating the effectiveness of a slurry cutoff requires impounding water behind it, which cannot be accomplished until the embankment is constructed. If a there is a leak in the slurry wall, repair would require excavating through the constructed embankment. We would recommend, at minimum, an open cut cutoff trench extending through permeable zones and at least 5 feet into low to nonpermeable material.

The exploratory pits within the reservoir area indicated about 5 to 8 feet of soil over assumed bedrock. The soil encountered appeared lenticular, making them potentially difficult to segregate into the appropriate zones. The more clayey material classified as clayey to silty/clayey sands with about 30% passing the #200 screen are often sufficient to provide a relatively impervious core. Both issues require specific permeability testing and seepage analysis. More extensive exploration in the reservoir area must be performed to verify sufficient quantities of the low permeability material exist. The material requires specific permeability testing.

Cesare was not able to access the abutments with our drilling equipment; thus, we do not have a clear understanding of their subsurface conditions at these locations. The geology is expected to be consistent regarding the types of material present; however, we have insufficient detail to provide accurate information on types of material and their in situ characteristics. To do so would require providing drill rig access to the abutments along the abutment slope at the dam crest elevation. A high percentage of dam failures are from seepage and/or piping through the abutments and/or abutment/embankment interface.

The stability analysis results presented in Section **8.3.1 Britton Stability Results** indicate the downstream slope may be conservative and could be steepened, depending on the material used. The upstream slope requires flattening to possibly 3:1, H:V, or flatter. Once the embankment material is identified in the reservoir area, additional laboratory and engineering analysis must be performed.

9.2 BRUCE CANYON

In Cesare's opinion, the dam centerline location should be upstream of the volcanic dike, such that the downstream embankment toe will be at or near the dike. The dike is highly fractured and therefore, has a high permeability. As such, placing the dike within the embankment could lead to seepage issues. Our geologic evaluation indicated the geologic hazards include landslides within the abutment bedrock material. When considering a potential landslide within the abutment material, the remediation could include excavating to a zone below the potential slide surface and constructing the embankment at that surface. If appropriate low permeability material is removed in this excavation, it can be reused as embankment fill. The landslide impact could be significant and requires a more detailed evaluation that would include geologic mapping, drilling and coring, and testing.

The borings indicated sandstone bedrock in the north abutment and claystone with interbedded sandstone zones in the south abutment, representing potential steeply dipping bedrock conditions. The northern abutment exhibited a large sandstone outcrop that likely indicates a harder zone of the sandstone encountered in our boring. The boring at the maximum section exhibited highly interbedded claystone/shale and sandstone. In our opinion, these claystone conditions in the south abutment will more likely impact slope stability in landslides than the sandstone. The highly interbedded claystone/shale and sandstone below the maximum section will have an effect on seepage below the dam, likely greater than the abutments. To properly evaluate this and the landslide potential would require additional drilling on the south abutment, including coring the bedrock to provide a continuous stratigraphy and condition profile. In situ permeability testing would also be required.

Packer tests indicated the permeabilities ranged from 3.7E-5 to 3.2E-6 cm/s. We consider these values typical of the bedrock in Colorado on which permanent water storage dams are often constructed. Although not considered ideal, these values are considered acceptable and can be managed in design and construction with deeper cutoffs, as necessary. The conceptual design indicated a cutoff trench excavated into the native soil. The boring logs for BC-2 indicated the soil is about 18 feet deep, with low permeability mudstone beginning at about 20 feet. This indicates an appropriate cutoff would possibly be 25 to 30 feet, at minimum, considering the cutoff extending about 10 to 15 feet into bedrock. The depth of cutoff must be based on the stratigraphy and continuity of the lower permeability bedrock and seepage flow path length analysis.

The soil encountered overlying the bedrock ranged from low to moderate blow counts, indicating soft or very loose to stiff or medium dense. This soil has the potential to consolidate significantly under surcharge loading. In addition, the more granular material likely has relatively high permeabilities. This would require detailed testing and analysis to evaluate values. This material can be excavated from below the embankment and replaced with embankment material and excavating a cutoff into bedrock to alleviate these issues. To evaluate whether removing them and placing a cutoff to bedrock, or constructing a cutoff trench and allowing the embankment to settle, requires consolidation testing and analysis to properly evaluate settlement potential.

The exploratory pits indicated about 8 to 10 feet of clayey material, including both clays and clayey sands. This indicates substantial borrow potential for the embankment. The material is such that a homogeneous embankment may be possible. More extensive exploration in the reservoir area must be performed to verify sufficient quantities of the low permeability material for embankment construction. This material requires specific permeability testing. This exploration would also be required to evaluate material quantities for shell material.

The swell/consolidation test performed on a sample from this site exhibited 9.9% collapse when wetted under load. This indicates some of the soil within the reservoir is susceptible to collapse when wetted in its natural condition. This will likely impact structural support and potentially slope stability where it is encountered around the reservoir's inundated perimeter. This material can be used for embankment construction, as it would be wetted and compacted.

The results for our stability analysis are presented in Section **8.3.2 Bruce Canyon Stability Results.** They indicate the downstream and upstream slopes appear appropriate for the conditions modeled. Specific soil mechanics testing on the potential embankment material must be performed to evaluate embankment stability. Stability analysis must be performed using the site specific strength and seepage characteristics.

9.3 LA VETA LAKES

Cesare's geologic evaluation indicated minimal geologic hazards. Constructing on the existing embankments is considered an issue at this site. The existing fill classified as sandy clay or silty/clayey sand that exhibited relatively low blow counts, indicating they are soft and compressible. Although the preliminary embankment sections indicated about 3 to 4 feet of new fill, consolidation would likely occur. The extent requires additional consolidation testing and settlement analysis. Mitigation of these would be similar to the Maria Stevens discussion in Section **9.4 MARIA STEVENS**.

The La Veta Lakes site exhibited shallow sandstone with relatively little overburden, particularly the material that was considered the primary source for the new embankment. Although we encountered about 3 feet of clay fill at the surface of the separation dike, the bedrock would be the primary embankment material. Since we did not penetrate the subsurface sufficiently, additional exploration is required, likely by coring, to verify quantities. Specific testing for remolded permeability and strength characteristics would be required.

The sandstone material would likely require significant preparation to use as embankment fill, requiring reducing the maximum particle size to less than 6 inches. As the material is granular, the slopes would require updated seepage and stability analysis, as the remolded parameters would likely significantly impact the possible slopes.

The remolded material's permeability could be acceptable; however, if not, it may require amendment with bentonite. An alternative is importing impervious material or placing an impervious upstream surface, such as hot mix asphalt.

Due to the complications described above with using the sandstone for borrow, Cesare did not perform stability or seepage analysis on this site.

9.4 MARIA STEVENS

Cesare's geologic evaluation indicated the geologic hazards include sinkholes in the limestone units. The discussion presented in Section **4.4 MARIA STEVENS** indicated the limestone was likely eroded and is no longer extant. We did not encounter any limestone within the depths we drilled. This may require more detailed geologic mapping and drilling deeper to further evaluate these conditions.

We encountered about 11 feet of relatively clean sands in Boring MS-2 above the claystone bedrock. We anticipate this material would exhibit a relatively high permeability in its present condition. It will likely require extending a cutoff trench below the embankment. With the low embankment height, a slurry cutoff trench may be appropriate.

The existing fill and native soil are clay and typically very soft to soft. This soil is weak, resulting in high consolidation potential and very low strengths. Our settlement analyses indicated potential settlement of about 3 inches under the proposed south embankment loads. The timed consolidation tests indicated the settlement would occur relatively rapidly upon load application.

Managing the settlement could include constructing the new embankment to be as flexible as possible and overbuilding the crest height to compensate for the settlement. This is difficult in that the main portion of the embankment will experience settlement and the abutments will not undergo as much, creating internal stresses in the embankment. Potential piping would become an issue that would require a downstream filter and drain. These types of drains are fairly typical but would require enough space between the embankment and the highway.

The stability analyses indicated calculated factors of safety were well below the State Engineer's requirements for the west embankment steady state and rapid drawdown and somewhat below for the south embankment steady state. Densifying, thus strengthening, the supporting soil would remediate both stability and settlement issues. An alternative is to flatten the slopes for stability issues, with settlement issues remaining to be addressed.

Improving the supporting soil by excavation and recompaction is a more conservative approach for both stability and settlement issues but considered a much lower risk alternative. This approach requires removing the soft material to a firm base, moisture conditioning by drying or wetting, as necessary, to a moisture content equal to or above optimum moisture content, and then compacting to at least 94% and not more than 98% of maximum dry density as determined by ASTM D698. We estimated depths of excavation of about 14 feet for the west embankment and 24 feet for the south embankment would be required. Borrow material could also be used to replace the native soil.

Our stability analysis results indicated the west embankment's slopes require flattening to an estimated 4:1, H:V, if the subgrade soil is not improved. Constructing an upstream graded filter and drain system may allow a steeper upstream slope.

The south embankment's downstream slope requires flattening to an estimated 3.5:1, H:V, if the supporting soil is not improved. The upstream slope can be reduced, possibly to an estimated 4:1, H:V, and likely more, if the subgrade soil is densified. Steepening the slope may require a graded filter and drain system.

The exploratory pits indicated 3 to 5 feet of clay over claystone/shale to 6 to 8 feet. This denotes potentially adequate borrow material for homogeneous embankment construction. A zoned embankment as proposed in the conceptual design would require importing the shell material. A downstream blanket drain and possibly a chimney drain within a homogeneous embankment would require importing the filter and drain material, but much less of it. Specific soil mechanics testing on the potential embankment material must be performed to evaluate embankment stability. Stability analysis must be performed using the site specific strength and seepage characteristics.

9.5 SOUTH BAKER

Cesare's geologic evaluation indicated the geologic hazards include potential slope instability due to the steeply dipping bedrock along the Boyd Mountain flanks. Boring SB-4 on the south abutment exhibited about 50 feet of unconsolidated soil overlying bedrock. This unconsolidated material is likely landslide rubble but requires further evaluation to determine its condition, including a more detailed evaluation of geologic mapping, drilling, sampling, and coring. We could not perform Packer tests in the underlying bedrock. Construction would include removing the unconsolidated material to bedrock contact and excavating a cutoff below it.

The boring at the north abutment toe exhibited a claystone zone, while the other two borings indicated sandstone bedrock. At the north abutment, we encountered about 10 feet of soil overburden, overlying sandstone. Both abutments must be further explored with associated in situ permeability testing.

The soil overburden in the lower valley elevations exhibit very low blow counts with a very shallow water table and would likely consolidate considerably under the embankment. The Packer test results in SB-2 indicated the upper portion of the bedrock is a much higher permeability than the lower portion at the maximum section and would require a cutoff. For this site, we would recommend excavating the overburden soil to bedrock contact over the entire embankment base. A cutoff trench should then be excavated to least 20 feet deep.

The South Baker site exhibited a relatively small amount of low permeability overburden soil to construct a zoned embankment, as depicted in the conceptual section. Although we encountered about 1-1/2 to 3 feet of clayey material at the surface within the reservoir area, most of the soil is granular and would require amendment with clay or importing a low permeability material. An external low permeability zone, such as asphalt pavement, is another alternative. These alternatives are generally more costly.

The proposed cutoff shown in the preliminary cross section appears to be a slurry cutoff trench. This method has been used successfully in reclaimed gravel pit reservoirs; however, the slurry for this type of cutoff is typically made with onsite excavated impervious material amended with a relatively small percentage of bentonite clay. As there is little impervious material onsite, the slurry would require amendment with imported clay, which may not be cost effective.

In our opinion, a slurry cutoff wall as proposed in the concept design has risks associated with the post construction evaluation of the slurry wall construction. Evaluating the effectiveness of a slurry cutoff requires impounding water behind it, which cannot be accomplished until the embankment is constructed. If a there is a leak in the slurry wall, repair would require excavating through the constructed embankment. We would recommend, at minimum, an open cut cutoff trench extending through permeable zones and at least 5 feet into low permeable material.

Applegate has suggested a roller compacted concrete dam as another alternative. This alternative has the benefit of allowing use of lower quality rock for aggregate used for normal concrete. This would require quarry sites to be evaluated for material, quality, and quantity. This type of

embankment requires a sound foundation and must be placed on sound bedrock that would likely require deeper excavation than for an earthfill embankment. To properly evaluate this type of embankment, the local rock must be evaluated and a source selected based on its engineering properties for use in concrete. A mix design using the proposed rock must be performed to evaluate strength before stability analysis can be performed.

Considering the above discussion regarding the lack of low permeability material and the cutoff requirements, we did not analyze seepage and stability. Specific soil mechanics testing on the potential embankment material must be performed to evaluate embankment stability. Stability analysis must be performed using the site specific strength and seepage characteristics.

10. GEOTECHNICAL RISK

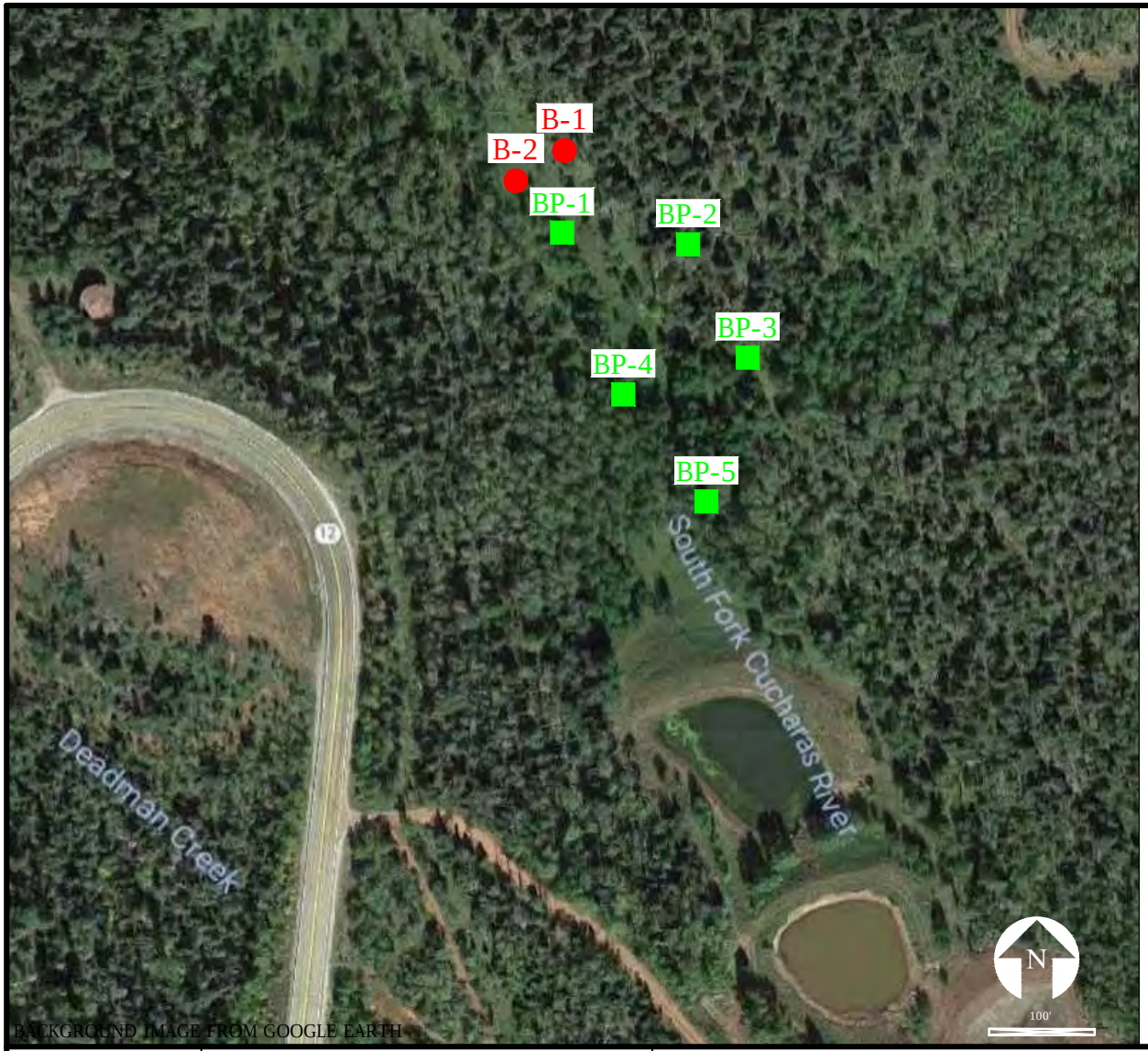
The concept of risk is an important aspect of any geotechnical evaluation. The primary reason for this is that the analytical methods used by geotechnical engineers are generally empirical and must be tempered by engineering judgment and experience, therefore, the solutions or recommendations presented in any geotechnical evaluation should not be considered risk free, and more importantly, are not a guarantee that the interaction between the soil and the proposed construction will perform as predicted, desired, or intended. The engineering evaluations presented in the preceding sections constitute our best estimate of those measures that are necessary to assess the sites regarding the ability to design and construct embankments that perform in a satisfactory manner. These evaluations are based on the information generated during this evaluation and our experience in working with these conditions.

11. LIMITATIONS

This report has been prepared for the exclusive use of our client for specific application to the project discussed and has been prepared in accordance with generally accepted geotechnical engineering practices. No warranties, either expressed or implied, are intended or made. In the event that changes in the nature, design, or location of the project as outlined in this report are planned, the conclusions contained in this report shall not be considered valid unless Cesare reviews the changes and either verifies or modifies the conclusions of this report in writing.

The borings drilled for this evaluation were located to obtain a reasonably accurate picture of underground conditions for evaluation purposes. Variations frequently occur from these conditions which are not indicated by the borings. These variations are sometimes sufficient to necessitate modifications in the evaluation. Much more detailed field exploration must be performed for design purposes, the extent of which depends on the specific site.

W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\Britton Reservoir\Britton Reservoir Boring and Exploratory Pit Locations.dwg 11/1/2018 11:16 AM



BACKGROUND IMAGE FROM GOOGLE EARTH

LEGEND:

B-1 BORING NUMBER AND LOCATION

BP-1 EXPLORATORY PIT NUMBER AND LOCATION

PROJECT NO:	18.117		
PROJECT NAME:	Cucharas Basin Collaborative Storage		
DRAWN BY:	KNZ	CHECKED BY:	JAC2
DWG DATE:	10.12.18	REV. DATE:	11/1/18

FIGURE 1**1**
Britton
Locations of Borings and Exploratory Pits

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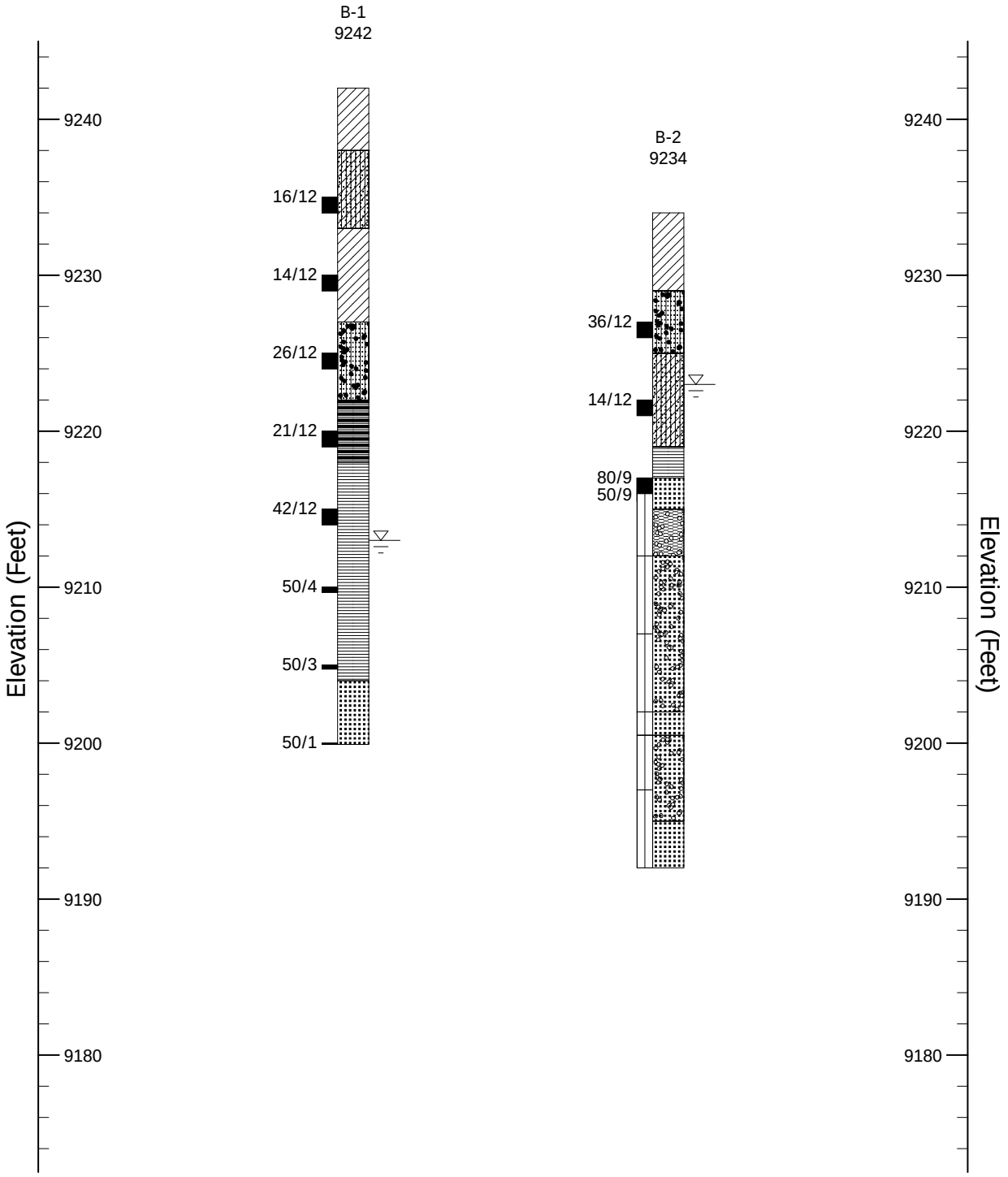
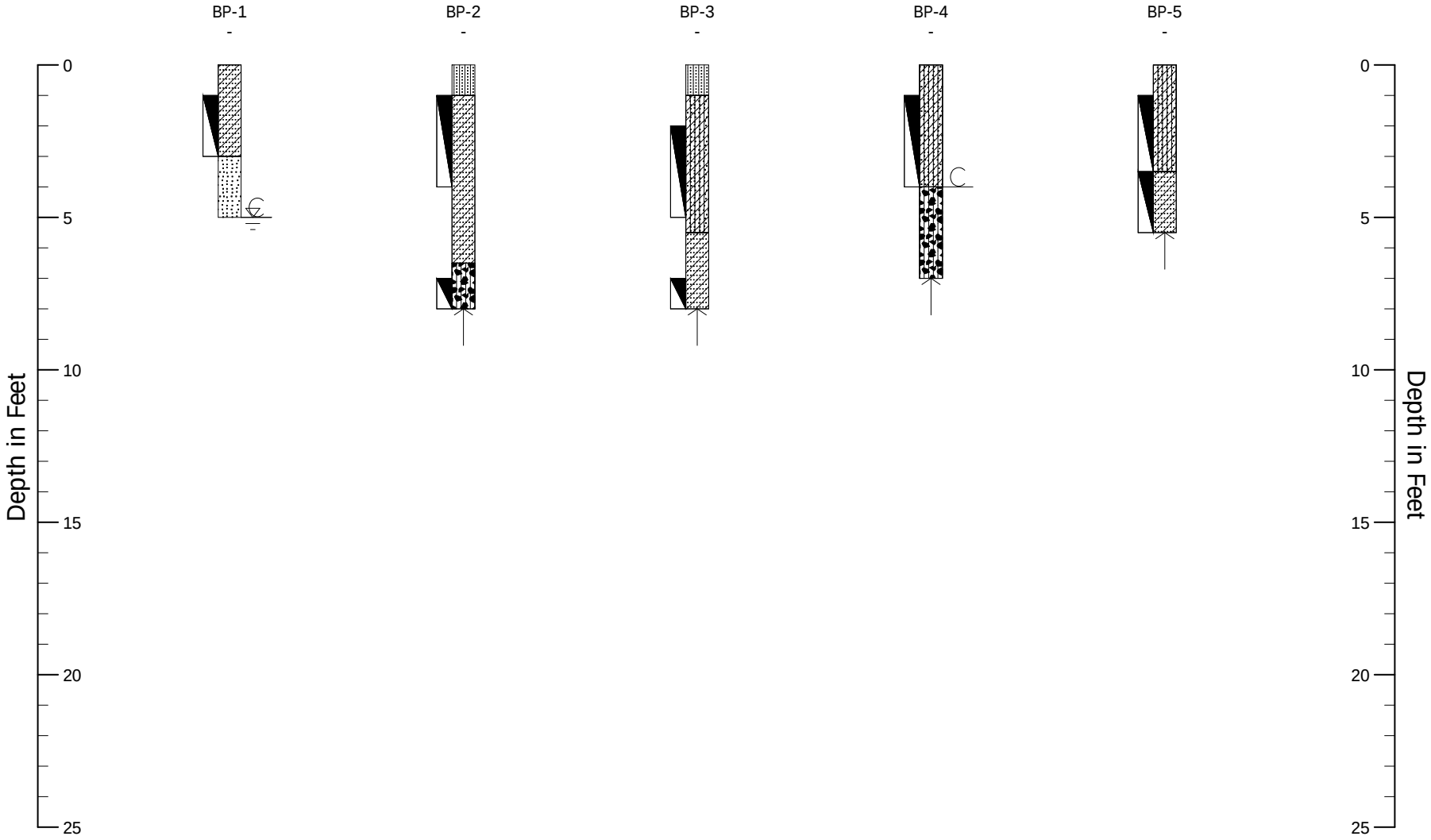


FIGURE 12

Britton Boring Logs

PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Storage Collaborative
DWG DATE:	10/28/2018

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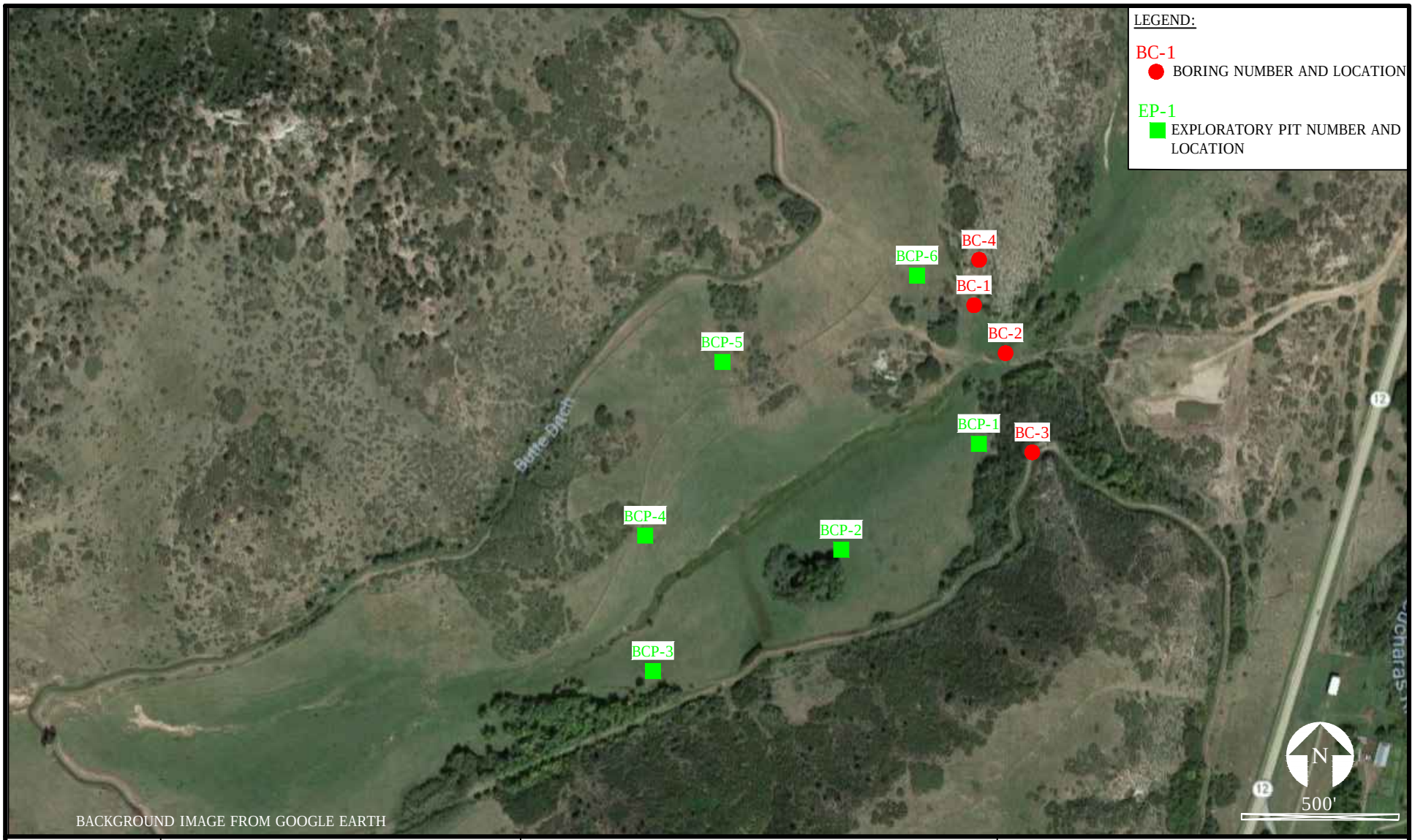
PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Storage Collaborative
DATE:	10/28/2018

FIGURE 13

Britton Exploratory Pit Logs

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

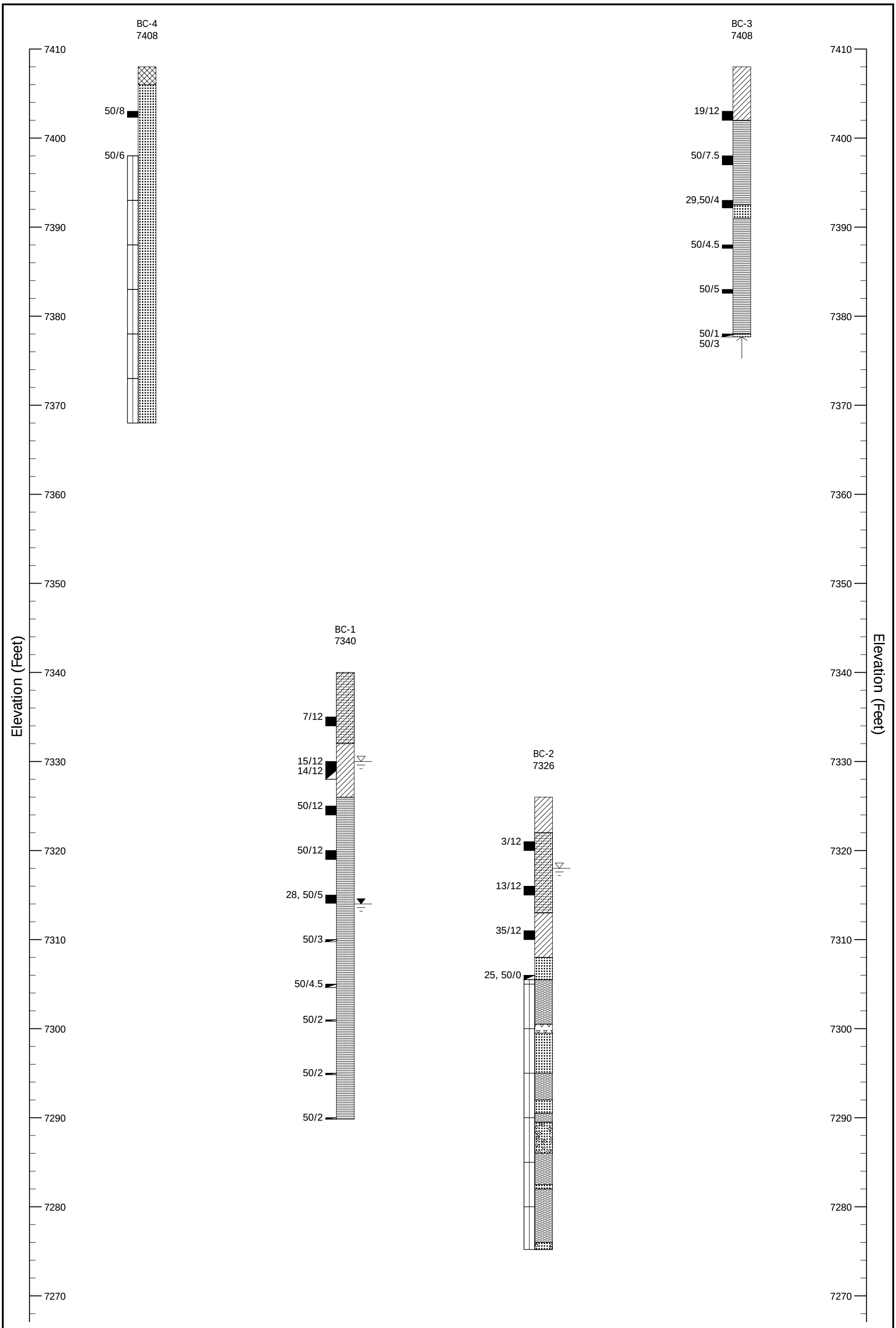
W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\Bruce Canyon\Bruce Canyon Boring and Exploratory Pit locations.dwg 10/17/2019 8:03 AM



PROJECT NO:	18.117		
PROJECT NAME:	Cucharas Basin Collaborative Storage		
DRAWN BY:	KNZ	CHECKED BY:	JAC2
DWG DATE:	10.11.18	REV. DATE:	10.17.19

FIGURE 1**4**
Bruce Canyon Reservoir
Locations of Borings and Exploratory Pits

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

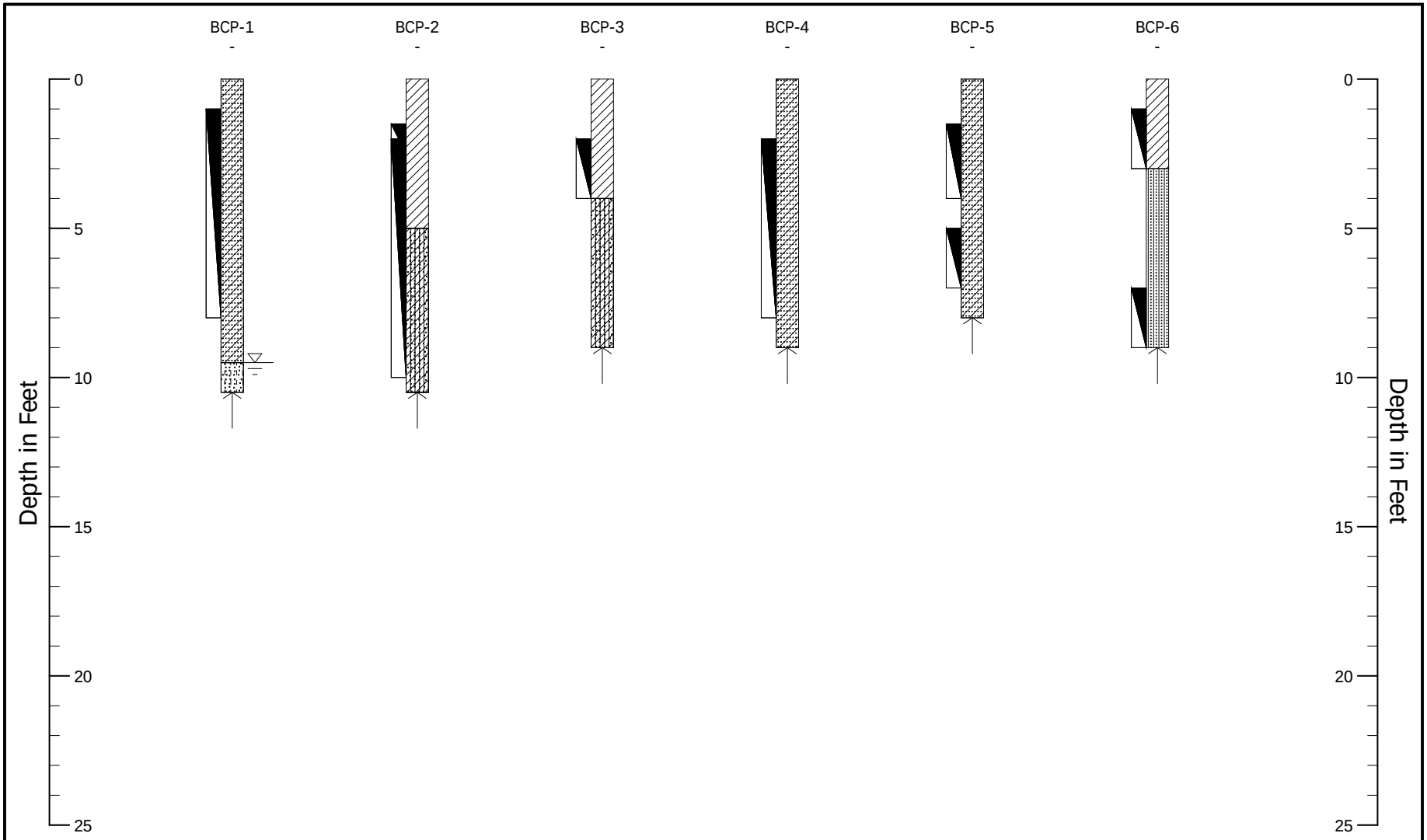


PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage Bruce Canyon
DWG DATE:	10/24/2019

FIGURE 15

Bruce Canyon Boring Logs

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PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage
DATE:	10/28/2018

FIGURE 16

Bruce Canyon Exploratory Pit Logs

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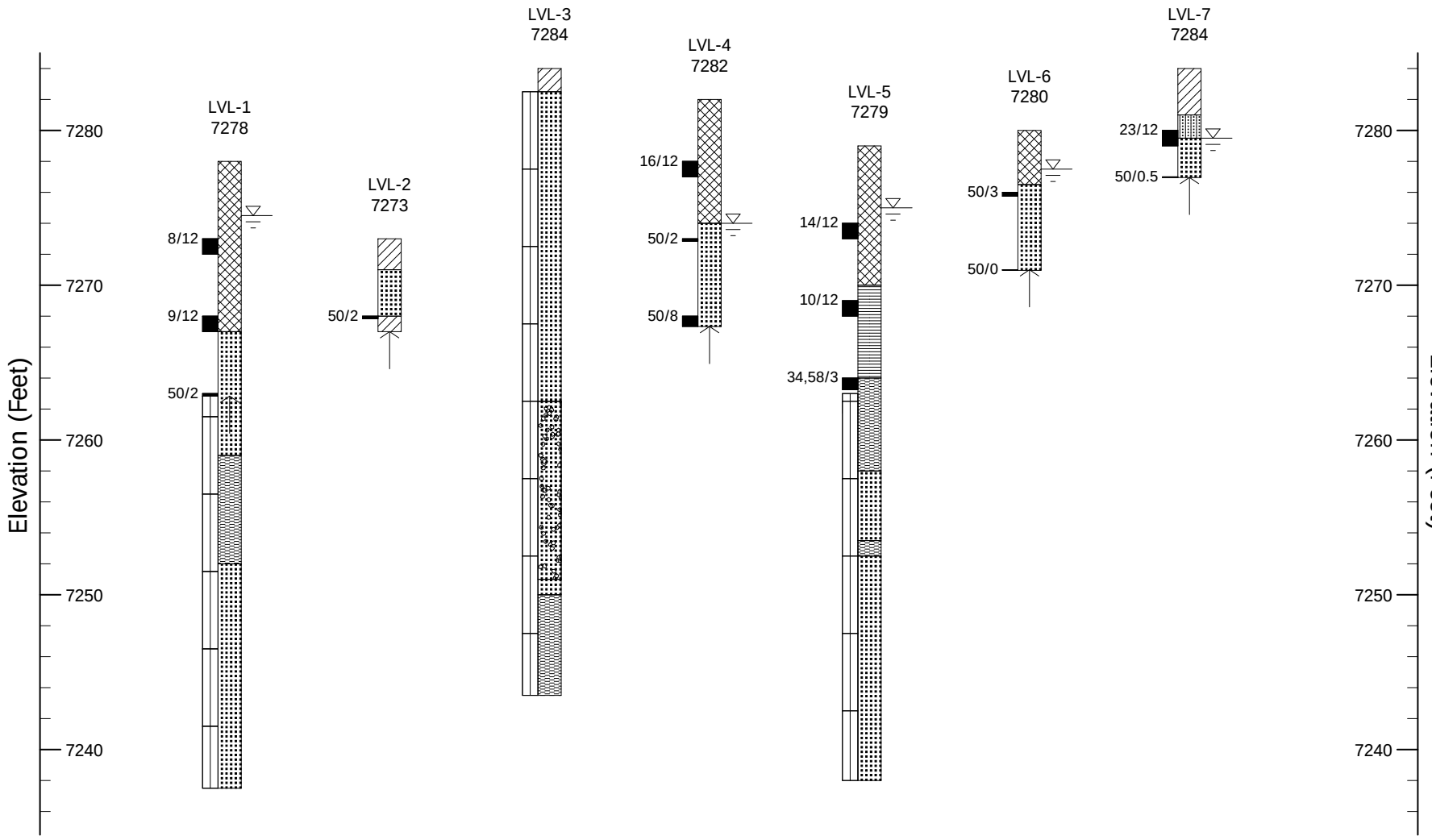
W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\La Veta\LA Veta Boring locations.dwg 11/1/2018 4:16 PM



FIGURE 17
La Veta Lakes
Locations of Borings

PROJECT NO:	18.117		
PROJECT NAME:	Cucharas Basin Collaborative Storage		
DRAWN BY:	KNZ	CHECKED BY:	JAC2
DWG DATE:	10.12.18	REV. DATE:	--

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PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage
DATE:	10/28/2018

FIGURE 18

La Veta Lakes Boring Logs

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W:\2018\Centennial\18.100\18.117.C Cucharas Basin Collaborative Storage\ACAD\Maria Stevens Reservoir\Maria Stevens Reservoir Boring and Exploratory Pit locations.dwg 11/1/2018 4:18 PM

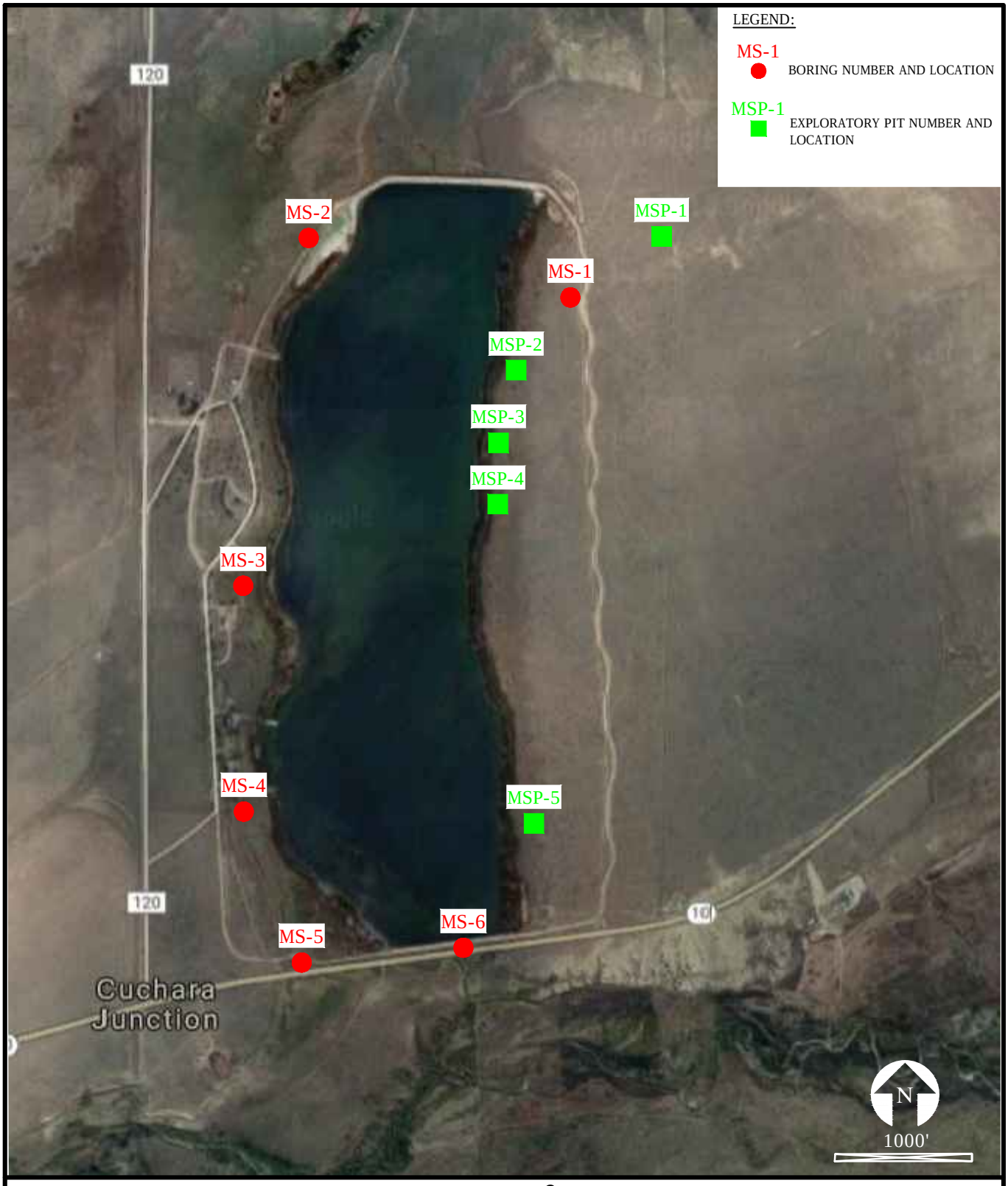
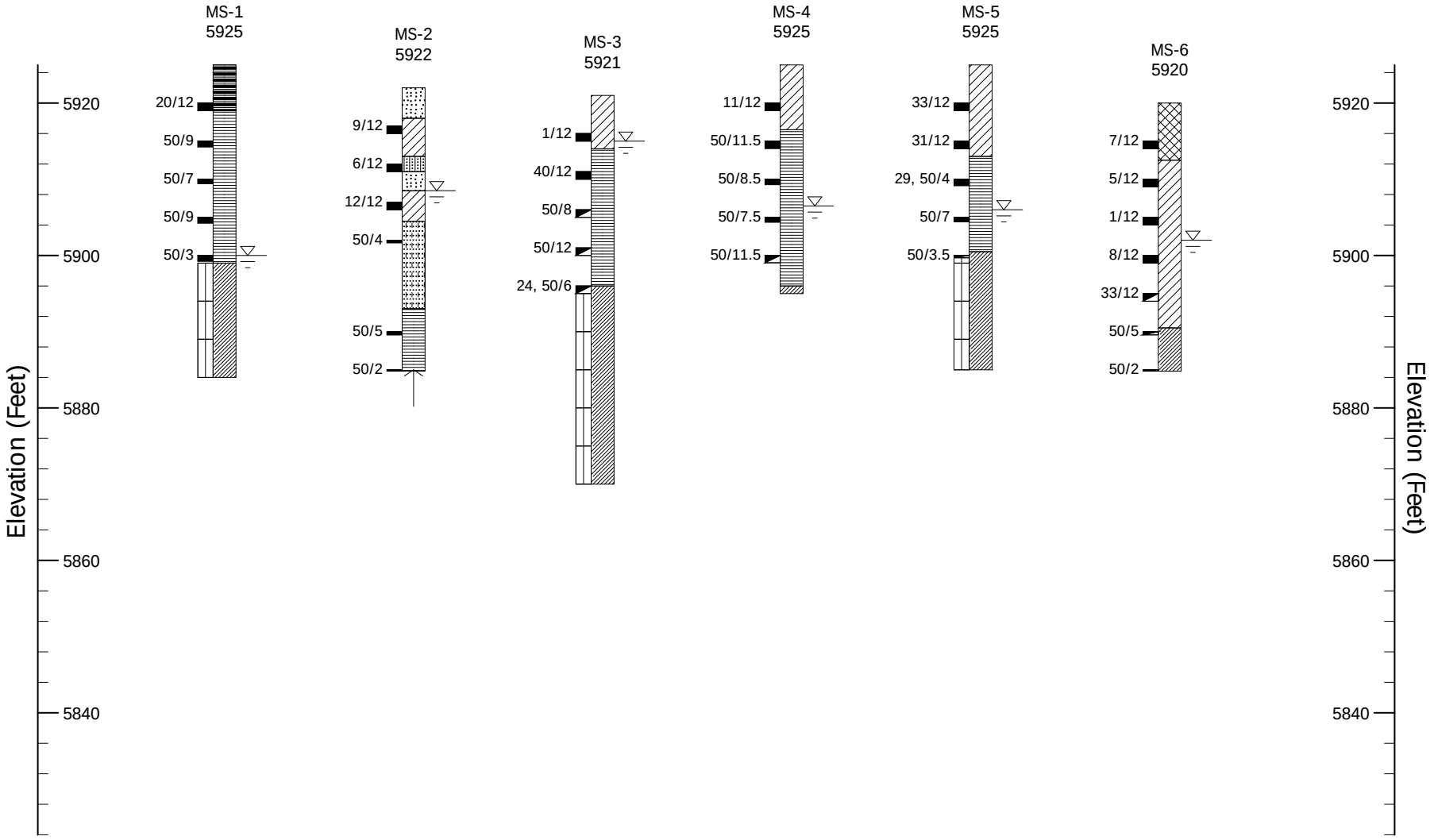


FIGURE 19
Maria Stevens
Locations of Borings and Exploratory Pits

PROJECT NO:	18.117		
PROJECT NAME:	Cucharas Basin Collaborative Storage		
DRAWN BY:	KNZ	CHECKED BY:	JAC2
DWG DATE:	10.12.18	REV. DATE:	--

CESARE, INC.
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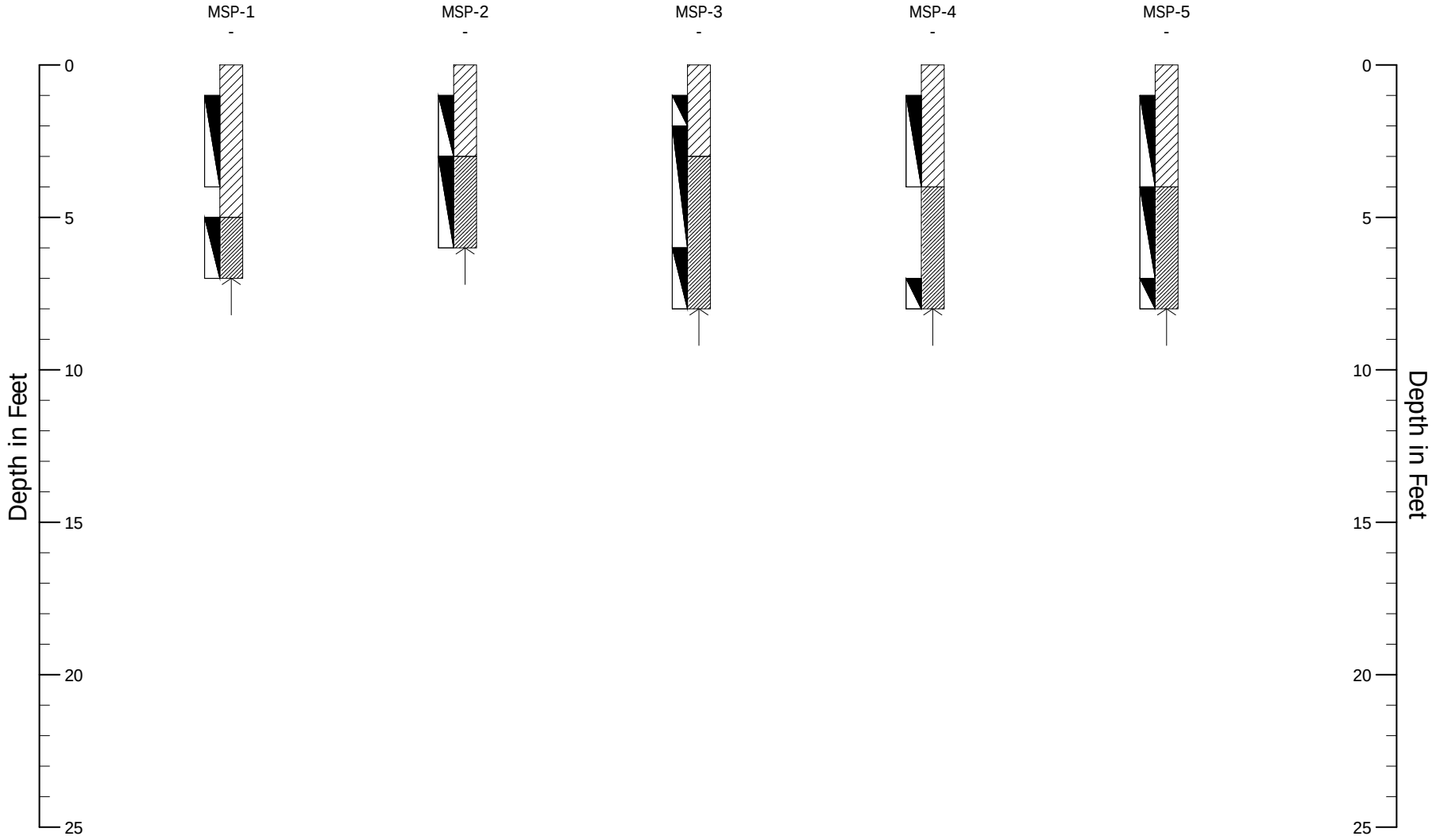


PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage
DATE:	10/30/2018

FIGURE 20

Maria Stevens Boring Logs

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Geotechnical Engineers & Construction Materials Consultants



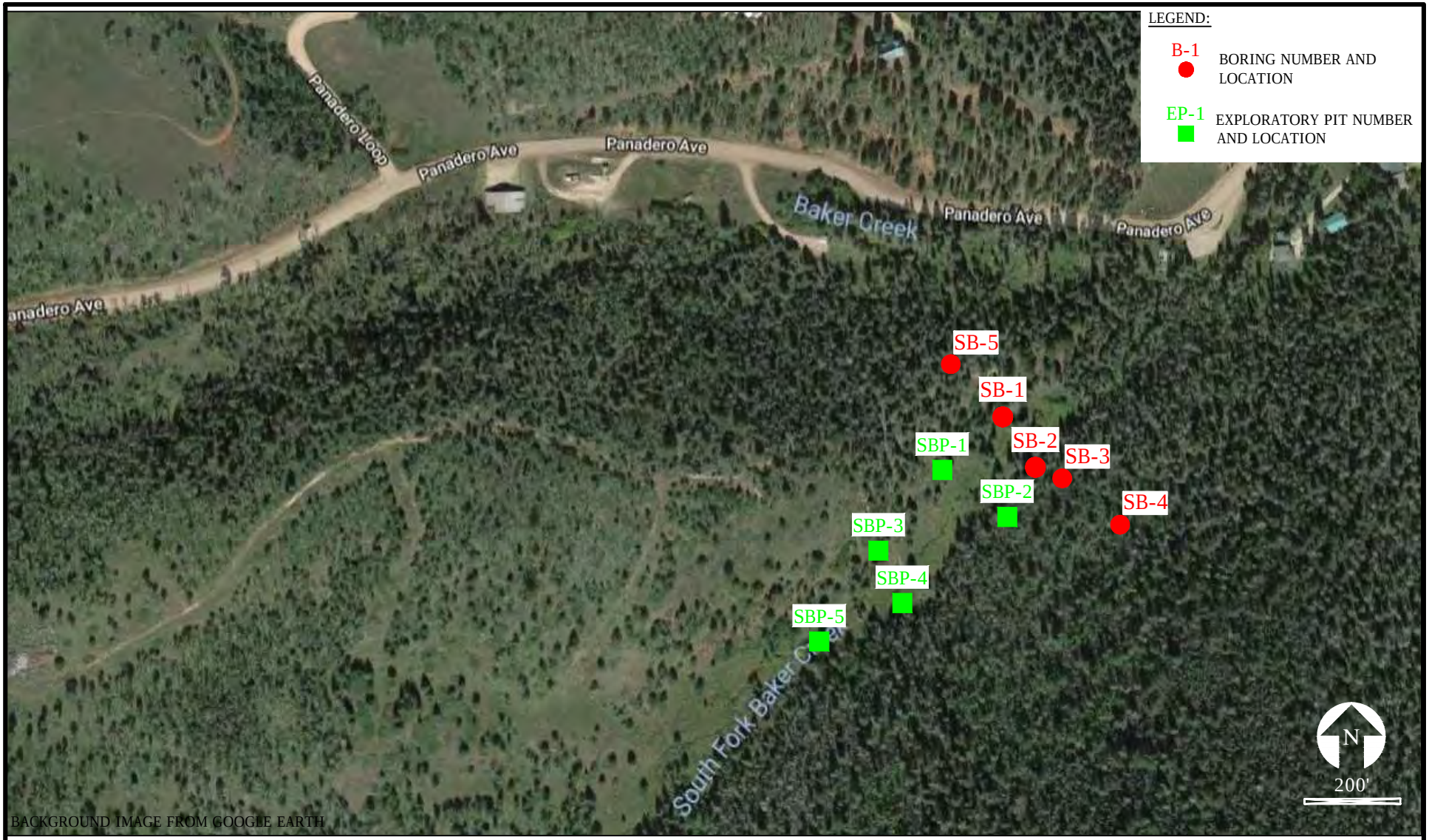
PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage
DATE:	10/28/2018

FIGURE 21

Maria Stevens Exploratory Pit Logs

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

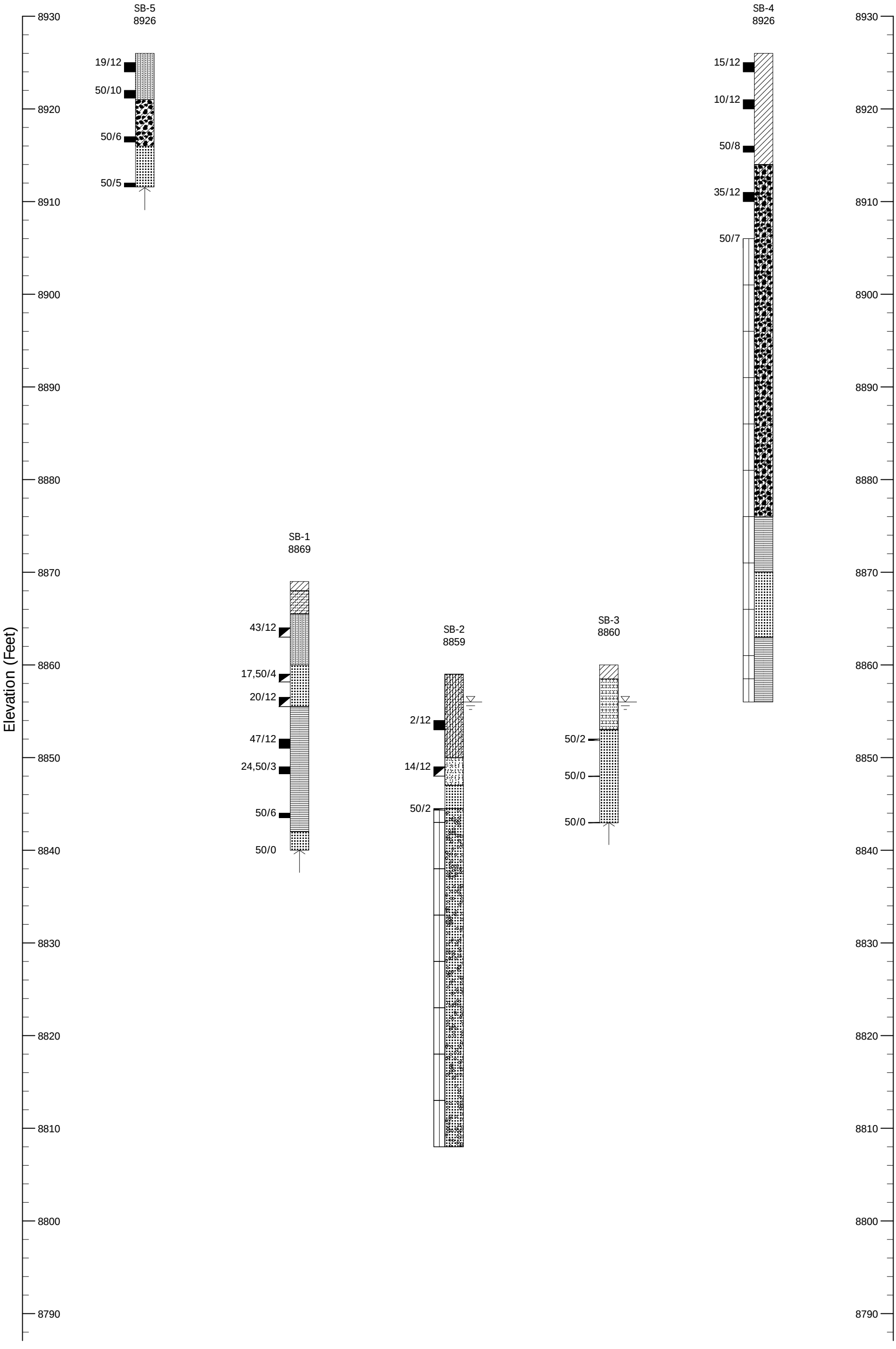
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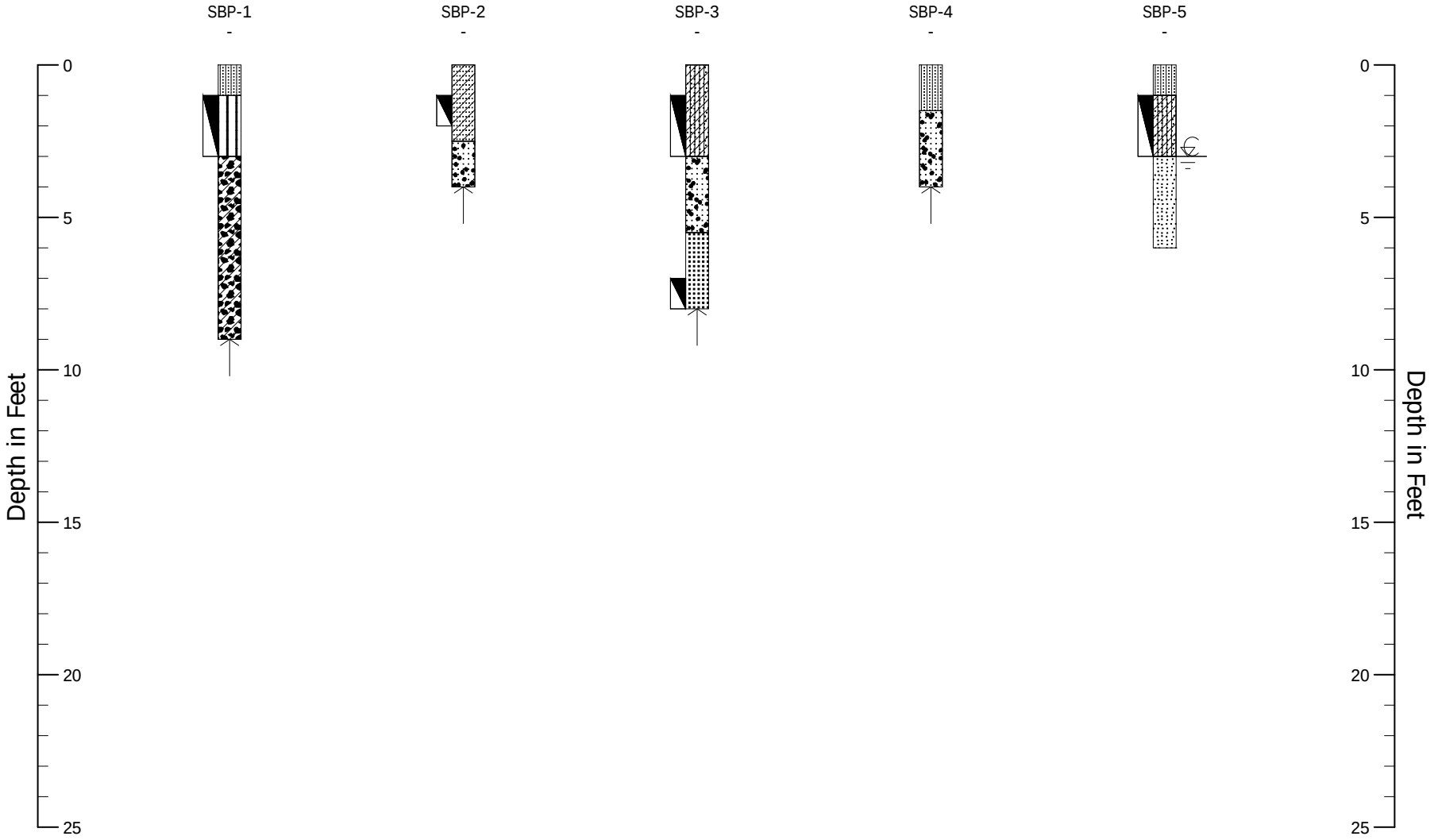
PROJECT NO:	18.117		
PROJECT NAME:	Cucharas Basin Collaborative Storage		
DRAWN BY:	KNZ	CHECKED BY:	JPC2
DWG DATE:	10.12.18	REV. DATE:	10.17.19

FIGURE **22**
South Baker
Locations of Borings and Exploratory Pits

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PROJECT NO:	18.117	**FIGURE 23**	CESARE, INC. Geotechnical Engineers & Construction Materials Consultants
PROJECT NAME:	Cucharas Basin Collaborative Storage	South Baker Boring Logs	
DWG DATE:	11/6/2019		



PROJECT NO:	18.117
PROJECT NAME:	Cucharas Basin Collaborative Storage
DATE:	10/28/2018

FIGURE 24

South Baker Exploratory Pit Logs

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APPENDIX A

Individual Boring Logs

LOG OF BORING

B-1

PROJECT Cucharas Basin Storage Collaborative	APPROXIMATE GROUND ELEVATION 9242
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 24
DATE STARTED 8/10/18	TOTAL DEPTH 42.08
DATE COMPLETED 8/10/18	REFUSAL
LOGGED BY J. Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	29 8/10/18
DRILL METHOD	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						CLAY, silty to with sand, moist, roots in upper 18 inches, reddish brown.						
5						4 ft. SAND, silty, clayey, moist medium dense, reddish brown.	16/12					
10						9 ft. CLAY, sandy, moist, stiff, reddish brown.	14/12					Smoother drilling from 9'
15						15 ft. GRAVEL, with silt and sand, moist, medium dense, reddish brown.	26/12					Hard, boulder at 15' Sandy
20						20 ft. CLAYSTONE, weathered, moist to wet, occasional thin sandstone partings, dark red.	21/12					Smoother, firm
25						24 ft. CLAYSTONE, medium hard to very hard, slightly moist to wet, occasional thin sandstone partings, dark red.	42/12					Harder at 24'
30												Very hard at 29'

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CESARE INC.

LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Storage Collaborative	18.117	**B-1**

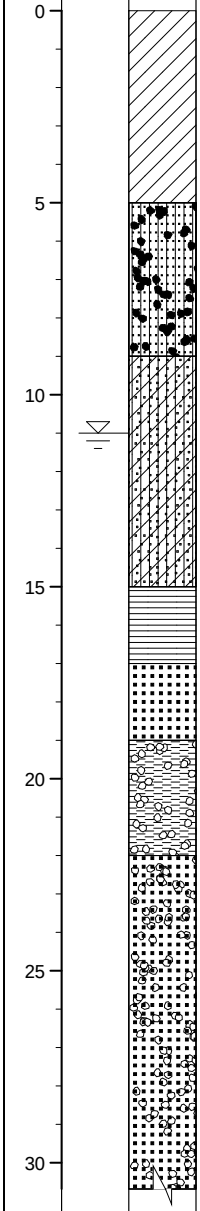
DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
35							50/4					Soft at 34' and 35'
							50/3					
						SANDSTONE, moist to wet, very hard, gray to red. 38 ft.						Harder and more dry at 38'
40							50/1					
45												
50												
55												
60												
65												

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LOG OF BORING

B-2

PROJECT Cucharas Basin Storage Collaborative	APPROXIMATE GROUND ELEVATION 9234
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 14'
DATE STARTED 8/9/18	TOTAL DEPTH 18.5
DATE COMPLETED 8/9/18	REFUSAL
LOGGED BY J. Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	11 8/9/18
DRILL METHOD ODEX, HQ core	



DEPTH (ft)	MOISTURE (dry / moist / sat)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0		CLAY, sandy, moist, medium stiff, roots in upper 12 inches, reddish brown.						
5		5 ft. GRAVEL, with silt and sand, moist to wet, dense, reddish brown.	36/12					
10		9 ft. SAND, silty, clayey, wet, medium dense, organic smell at 12-1/2 feet, cobbles at 14 feet, dark red.	14/12					
15		15 ft. CLAYSTONE, silty, moist, hard to very hard, dark red.						
		17 ft. SANDSTONE, silty, soft, fine to medium grained, massive bedding, red brown. 18'-19' tan to olive clasts	80/9	1	100	0	H7	
			50/9	2	88	29	H7	
20		19 ft. MUDSTONE, soft, massive bedding, red brown. With calcareous gray concretions 1/8" - 1/2" in diamter.						
		22 ft. SANDSTONE, slity, conglomeratic, soft, fine grained, massive bedding, dark red brown. With occasional tan to olive gray sandstone clasts.		3	77	100	H5	
25		SANDSTONE, conglomeratic, medium hard, coarse grained, massive bedding, with tan clasts in a red brown matrix.		4	80	100	H3-H5	
30								

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Storage Collaborative	18.117	B-2

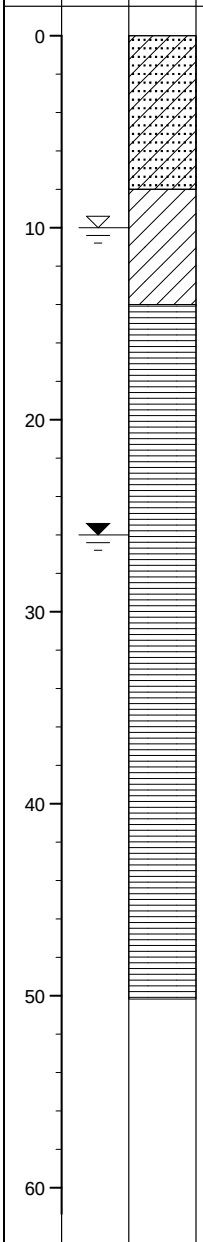
DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
						32 ft. SANDSTONE, medium hard to hard, coarse grained, massive bedding, tan to red brown.		5	100	83	H3	
						33.5 ft. SANDSTONE, conglomeratic, medium hard, massive bedding, with 1/8" - 1/2" pink to tan clasts in red brown matrix.		6	55	22	H3-H7	
35								7	73	55	H3-H7	
						39 ft. SANDSTONE, moderately hard, predominately coarse grained, with gravel, massive bedding, red brown to tan.						
40												
45												
50												
55												
60												
65												

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LOG OF BORING

BC-1

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7340
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 28
DATE STARTED 8/6/18	TOTAL DEPTH 50.17
DATE COMPLETED 8/7/18	REFUSAL
LOGGED BY H. Brunkal	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	10 8/6
DRILL METHOD HSA & HQ Core	26 8/7



DEPTH (ft)	MOISTURE (dry / moist / sat)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0		SAND, clayey, moist, loose, dark brown.	7/12					
8 ft.		CLAY, sandy, moist, stiff, low calcareous, dark brown.	15/12 14/12					
14 ft.		CLAYSTONE, slightly moist to very moist, medium hard, very calcareous, moderately indurated from 28.5', dark brown to reddish brown, olive to gray.	50/12 50/12 28, 50/5 50/3 50/4.5 50/2 50/2					
50		Stopped HSA and sampling at 50.2'.	50/2					

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LOG OF BORING

BC-2

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7326
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 18
DATE STARTED 8/2/18	TOTAL DEPTH 51
DATE COMPLETED 8/2/18	REFUSAL
LOGGED BY J Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	8 8/2/18
DRILL METHOD 6.5"	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						CLAY, sandy, moist to wet, very soft, dark brown.						
						4 ft. SAND, clayey, to with gravel, very loose to medium dense, wet, dark brown.	3/12					
10							13/12					
						13 ft. CLAY, sandy, hard, moist, medium calcareous, brown.	35/12					
20						18 ft. SANDSTONE, clayey, moderately hard to very hard, moist, gray. SANDSTONE, moderatly hard, moderately weathered, medium grained, massive bedding, tan.	25, 50/0	1	100	0	H3	
						20.5 ft. MUDSTONE, soft, moderately to highly weathered, massive bedding, dark gray to gray brown to chocolate brown. Calcareous, orange staining along fractures		2	100	48		
						25.5 ft. Breccia 25.5' - 26.5'		3	100	100	H4	
30						26.5 ft. SANDSTONE, moderately hard, fine grained, massive bedding, calcareous, arkosic, dark red brown.		4	100	40	H4	
						31 ft. MUDSTONE, soft, massive bedding, dark red brown.						
						34 ft. SANDSTONE, moderately hard, fine grained, massive bedding, calcareous, with occasional fossil debris, dark gray to red brown.		5	100	74	H6, H5	
40						35.5 ft. MUDSTONE, soft, massive bedding, dark red brown.						
						36.5 ft. SANDSTONE, silty, conglomeratic, soft, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts.		6	70	54	H6	
						SANDSTONE, conglomeratic, moderately hard, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts. SANDSTONE, silty, conglomeratic, soft, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/ 8" - 1/4" clasts.		7	100	67	H6	
50						40 ft. MUDSTONE, soft, massive bedding, calcareous, dark red brown.						
						43.5 ft. SANDSTONE, soft to moderately hard, fine grained, massive bedding, calcareous, dark red brown.						
						44 ft. MUDSTONE, soft, highly altered, massive bedding, dark red brown. 47'-49' Olive gray to tan, mottled						
						50 ft. SANDSTONE, conglomeratic, soft, highly altered, fine grained, massive bedding, mottled dark red brown to olive gray to yellow brown.						
60						Stopped coring at 50.8'						

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LOG OF BORING

BC-3

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7408
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 10
DATE STARTED 8/7/18	TOTAL DEPTH 50.25
DATE COMPLETED 8/7/18	REFUSAL
LOGGED BY H. Brunkal	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	dry 8/7/18
DRILL METHOD 6.5"	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
0						CLAY, sandy, slightly moist, very stiff, medium calcareous, brown.						
						6 ft. CLAYSTONE, sandy, slightly moist, hard, low calcareous, dark reddish brown.	19/12					
10							50/7.5					
						15.5 ft. SANDSTONE, silty, clayey, slightly moist, very hard, dark red brown.	29,50/4					
						17 ft. CLAYSTONE, sandy, slightly moist, very hard, medium calcareous, dark brown.	50/4.5					
20							50/5					
30						30 ft. SANDSTONE, slightly moist, very hard, very calcareous, very indurated, maroon.	50/1					
						Stopped HSA and sampling at 30.3.	50/3					
40												
50												
60												

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LOG OF BORING

BC-4

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7408
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 0.5
DATE STARTED 8/29/19	TOTAL DEPTH 40
DATE COMPLETED 8/30/19	REFUSAL
LOGGED BY I. Campbell	
DRILLED BY Dakota	DEPTH TO WATER / DATE
DRILL RIG CME 45 Track Mounted	None
DRILL METHOD	

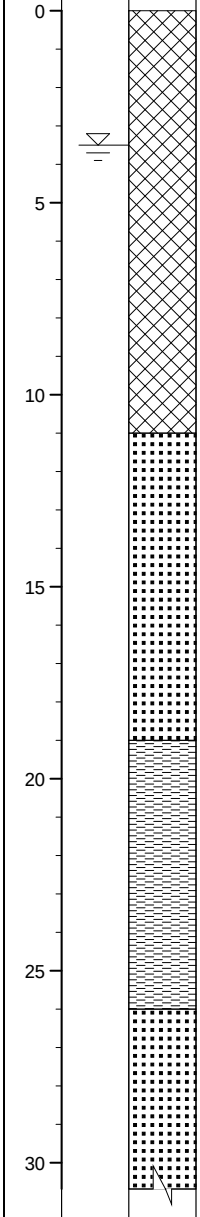
DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						FILL: DRILL PAD, SANDSTONE						
						SANDSTONE, silty, hard, unweathered, moderately fractured, banded to thickly bedded, dark gray. 2 ft.	50/8					
10						SANDSTONE, silty, hard, unweathered, intact to moderately fractured, banded to thickly bedded, light tan.	50/6	1	67	67		
						Coarse grain lense at 13 feet.		2	100	100		
20						Hard, slightly weathered, slightly to highly fractured, banded to thickly bedded, iron staining in joints with hydrothermal quartz, light tan.		3	100	100		
								4	98	98		
30						Hard to moderately hard, slightly to moderately weathered, slightly to intensely fractured, banded to thickly bedded, light tan to gray.		5	97	73		
						Thin lense of claystone at 34 feet.		6	97	75		
40						Stopped Coring at 40 feet.						
50												
60												

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LOG OF BORING

LVL-1

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7278
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 11
DATE STARTED 8/13/18	TOTAL DEPTH 40.5
DATE COMPLETED 8/13/18	REFUSAL
LOGGED BY J Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	3.5 8/13/18
DRILL METHOD 8", 3.5"	



DEPTH (ft)	MOISTURE	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0		FILL; CLAY, sandy, to SAND, clayey, medium stiff to stiff (clay), to loose (sand), slightly moist to wet, low to high plasticity, dark brown; SAN clayey, loose, slightly moist to wet, low to high plasticity (clay), dark brown.						
5			8/12					
10			9/12					
		11 ft. SANDSTONE, silty to clayey, wet, weathered to very hard, brown to black.						Hard drilling @ 11', harder drilling at 13'
15		SANDSTONE, moderately hard, slightly weathered, predominately medium-grained, intact, massive, arkosic, red brown to orange brown to tan.	50/2	1	94	83	H3	
		SANDSTONE, with clay, soft, moderately weathered, predominately fine grained, laminated to banded cross-beds, olive to orange to brown to tan. SANDSTONE, moderately hard, moderately weathered, predominately coarse grained, arkosic, medium cross-beds, tan pink to yellow brown.		2	100	72	H3	
20		19 ft. MUDSTONE, soft, predominately fine grained, massive, red brown.		3	100	100	H6/ H4/H3	
25								
		26 ft. SANDSTONE, moderately hard, predominately medium grained, arkosic, medium cross-beds, intact, tan to red to brown.		4	100	100	H3,H6, H3	
30		SANDSTONE, moderately hard, predominately fine grained, intact, massive, with occasional fossil fragments, calcareous, gray to pink to brown.						

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	LVL-1

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
								5	100	100	H3,H4, H6	
35												
								6	100	100	H3	
40												
45												
50												
55												
60												
65												

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LOG OF BORING

LVL-2

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7273
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 2
DATE STARTED 8/15/18	TOTAL DEPTH 6
DATE COMPLETED 8/15/18	REFUSAL
LOGGED BY J Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	
DRILL METHOD 4" SSA	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
0						CLAY, sandy, stiff, moist, reddish brown.						
						2 ft. SANDSTONE, silty, very hard, slightly moist, tan. Claystone parting at 4 feet.						
5						5 ft. CLAY, sandy, slightly moist, low plasticity, calcareous, tan.	50/2					
10												
15												
20												
25												
30												

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LOG OF BORING

LVL-3

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7284
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 1.5
DATE STARTED 8/13/18	TOTAL DEPTH 40.5
DATE COMPLETED 8/14/18	REFUSAL
LOGGED BY J Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	
DRILL METHOD 4.25" HSA and HQ Core	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						CLAY, sandy, with gravel, medium stiff, slightly moist, brown.						
						1.5 ft. SANDSTONE, moderately hard, medium grained, laminated to parting cross-beds, weakly calcareous, tan to yellow brown. Tight to very tight fractures 1.5'-4' and 6.5'-7.5'. Dark red staining along bedding / fracture surfaces 1.5'-2.5'.		1	92	42	H3	
5						Very coarse grained sand, massive bedding		2	100	53	H3,H2	
10						Medium grained sand, banded to medium cross-beds. 3" clast divides coarse-grained interval above from medium grained interval below at 10'.		3	100	95	H3, H5	
15						SANDSTONE, medium hard, highly weathered, medium grained, tight to very tight joints/fractures, thinly cross-bedded, olive gray to tan. 14.5'-15.5' zone of brown orange staining, with occasional thin beds of black organic material. SANDSTONE, moderately hard, slightly weathered, coarse grained, massive bedding, calcareous, tan to olive gray.		4	73	27	H3, H5	
20						SANDSTONE, soft, fine grained, massive bedding, calcareous, red brown.						
						21.5 ft. SANDSTONE, silty, conglomeratic, soft, fine grained, parting to thin horizontal beds, calcareous, occasional fossil debris, dark red brown. With occasional clasts 1/8" - 1".		5	100	87.5	H5	
25								6	100	100	H5	
30												

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	LVL-3

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
35						33 ft. SANDSTONE, soft, fine grained, massively bedded, weakly calcareous, dark red brown.		7	100	100	H5,H3, H6	
						34 ft. MUDSTONE, sandy, conglomeratic, soft, massive bedding, calcareous, dark red brown.						
						38.5' - 40.5' Mottled olive gray clasts		8	94	100	H6,H3	
40						Fossil debris						
45												
50												
55												
60												
65												

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LOG OF BORING

LVL-4

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7282
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 8
DATE STARTED 8/15/18	TOTAL DEPTH 14
DATE COMPLETED 8/15/18	REFUSAL
LOGGED BY J. Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	8 8/15/18
DRILL METHOD 4"	

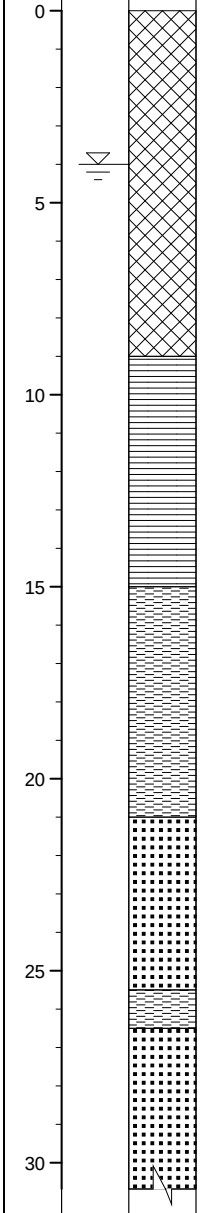
DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						FILL: CLAY, sandy, stiff, slightly moist, dark brown.						
5							16/12					
						8 ft.						
						SANDSTONE, silty, clayey, wet, very hard, greenish gray.						
10							50/2					
15							50/8					
20												
25												
30												

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LOG OF BORING

LVL-5

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7279
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 9
DATE STARTED 8/14/18	TOTAL DEPTH 41
DATE COMPLETED 8/14/18	REFUSAL
LOGGED BY J Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	4 8/14/18
DRILL METHOD 8" HSA, 3.5" HQ Wireline	



DEPTH (ft)	MOISTURE (dry / moist / sat)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0		FILL: CLAY, sandy, slightly moist, stiff, some concrete debris and organics in upper 3-1/2 feet, brown to dark brown.						
5			14/12					
9 ft.		CLAYSTONE, sandy, severely weathered to 14', very moist to moist., reddish brown.						
10			10/12					
15		15 ft. MUDSTONE, soft, massive, calcareous, red brown.	34,58/3	1	100	0	H3	
		MUDSTONE, soft, massive, red brown with calcareous olive clasts.		2	100	100	h6	
20		21 ft. SANDSTONE, moderately hard, fine to medium grained, massive bedding, red brown to gray brown, mottled, with occasional calcareous olive spots.		3	100	100	H5,H3, H5	
		Fracture with wavy sides						
25		25.5 ft. MUDSTONE, soft, massive bedding, calcareous, red brown. Fracture with wavy sides		4	100	100	H3	
		26.5 ft. SANDSTONE, soft, fine to medium grained, calcareous, gray red brown.						
30		SANDSTONE, moderately hard, fine grained, banded cross-beds, weakly						

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	LVL-5

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
						calcareous, trace soft sediment deformation, light gray to dark gray.						
								5	100	97	H3	
35						At 33.5' fracture along weak layer, up to 1/4" clay between surfaces.						
								6	100	100	H3	
40						SANDSTONE, moderately hard, coarse-grained, thinly laminated to parting bedding , light gray pink to tan. Banded to thin cross-beds.						
45												
50												
55												
60												
65												

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LOG OF BORING

LVL-6

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7280
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 3.5
DATE STARTED 8/15/18	TOTAL DEPTH 9
DATE COMPLETED 8/15/18	REFUSAL
LOGGED BY J Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	2.5 8/15/18
DRILL METHOD 4"	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
0						FILL: CLAY, sandy, stiff, moist, dark brown.						
						SANDSTONE, very hard, moist to wet fine to medium grained, gray (3.5 ft.)	50/3					Slow to advance in and out of fractures
5												
10							50/0					
15												
20												
25												
30												

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LOG OF BORING

LVL-7

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 7284
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 4.5
DATE STARTED 8/15/18	TOTAL DEPTH 7
DATE COMPLETED 8/15/18	REFUSAL
LOGGED BY J Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	4.5 8/15/18
DRILL METHOD 4"	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						CLAY, sandy, stiff, slightly moist, with fine organics, dark brown.						
						3 ft. SAND, silty, medium dense, slightly moist, dark brown.	23/12					
5						4.5 ft. SANDSTONE, silty to clayey, weathered, slightly moist, tan.	50/0.5					
10												
15												
20												
25												
30												

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LOG OF BORING

MS-1

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 5925
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 25
DATE STARTED 8/4/18	TOTAL DEPTH 41
DATE COMPLETED 8/4/18	REFUSAL
LOGGED BY H. Brunkal	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	25 8/4/18
DRILL METHOD HSA, HQ Core	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	moist	sat	DESCRIPTION	BLOWS/FT	CORE NO.	RECOVERY (%)	RQD (%)	HARDNESS	DRILLING NOTES
0						CLAYSTONE, sandy, weathered, slightly moist, moderately calcareous, dark tan.						
5							20/12					
						6 ft. CLAYSTONE, sandy, hard to very hard, slightly moist, calcareous, with sandstone gravel at 15 feet, olive to dark gray.						
10							50/9					
15							50/7					
20							50/9					
25							50/3	1	100	0	H3	
						26 ft. SHALE, moderately hard, intact, thin (up to 1/16") dark mud layers interlaminated with lighter colored wavy fossil debris rich layers (up to 1/2"), with soft sediment deformation, bioturbaded, calcareous, light gray to dark gray.		2	100	87	3
30						Moderately tight fractures along bedding (28' and 30'), with up to 1/4" of clay						

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	**MS-1**

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
						between surfaces.						
								3	100	89	3	
35												
								4	98	57	3	
						Sandstone lens at 39 feet, silty, up to 3/4" thick, olive colored, with orange staining on top and bottom.						
40												
45												
50												
55												
60												
65												

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LOG OF BORING

MS-2

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 5922
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 32
DATE STARTED 8/6/18	TOTAL DEPTH 37.17
DATE COMPLETED 8/6/18	REFUSAL
LOGGED BY H. Brunkal	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	13.5 8/6/18
DRILL METHOD HSA	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						SAND, with clay, loose, wet, brown.						
						4 ft.						
5						CLAY, sandy, moist, stiff, very calcareous, brown.	9/12					
						9 ft.						
10						SAND, silty, loose, moist, very calcareous, brown.	6/12					
						11 ft.						
						SAND, poorly graded, with gravel, medium dense, wet, brown.						
						13.5 ft.						
15						CLAY, sandy, wet, stiff, vary calcareous, dark brown.	12/12					
						17.5 ft.						
						SAND, with silt and gravel, very dense, wet, brown.						
20							50/4					
25												
						29 ft.						
30						CLAYSTONE, weathered to very hard, very moist, dark olive to black.						

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	**MS-2**

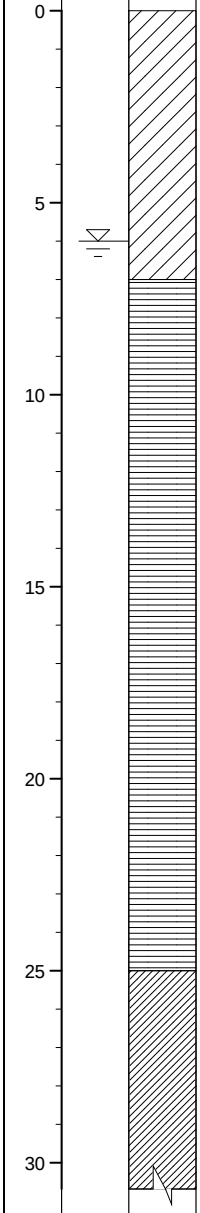
DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
35							50/5					
							50/2					
40												
45												
50												
55												
60												
65												

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LOG OF BORING

MS-3

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 5921
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 26
DATE STARTED 8/3/18	TOTAL DEPTH 26
DATE COMPLETED 8/3/18	REFUSAL
LOGGED BY H Brunkal	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	6 8/3/18
DRILL METHOD HSA and HQ Core	



DEPTH (ft)	MOISTURE dry	moist	sat	DESCRIPTION	BLOWS/FT	CORE NO.	RECOVERY (%)	RQD (%)	HARDNESS	DRILLING NOTES
0				CLAY, with sand, very soft, moist, organics in upper 1 foot, slightly calcareous, dark brown.						
5					1/12					
				7 ft. CLAYSTONE, slightly moist to very moist, medium hard to very hard, calcareous, olive to dark olive.						
10					40/12					
15					50/8					
20					50/12					
25				25 ft. SHALE, moderately hard, intact, thinly laminated, with occasional soft sediment deformation, with occasional bioturbation, with occasional fossil fragments, calcareous, dark gray.	24, 50/6	1	0	0		
						2	100	56	H3	
30										

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	**MS-3**

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
35						At 34' - fracture at 45 degree angle with up to 1/4" clay between surfaces.		3	100	68	H3	
40								4	100	100	H3	
45								5	80	96	H3	
50								6	100	100	H3	
55												
60												
65												

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LOG OF BORING

MS-4

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 5925
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 29
DATE STARTED 8/5/18	TOTAL DEPTH 24.3
DATE COMPLETED 8/6/18	REFUSAL
LOGGED BY H. Brunkal	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	18.5 8/5/18
DRILL METHOD HSA	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
0						CLAY, sandy, stiff, slightly moist, medium calcareous, brown.						
5							11/12					
						8.5 ft. CLAYSTONE, hard, slightly moist to wet, very calcareous, olive to dark olive, gray to black.						
10							50/11.5					
15							50/8.5					
20							50/7.5					
25							50/11.5					
30						29 ft. SHALE, lignite partings,						

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LOG OF BORING

MS-5

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 5925
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 24.5
DATE STARTED 8/4	TOTAL DEPTH 40
DATE COMPLETED 8/4	REFUSAL
LOGGED BY H. Brunkal	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	19 8/4
DRILL METHOD HSA and HQ Core	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						CLAY, sandy, slightly moist, hard, very calcareous, dark tan to olive.						
5							33/12					
10							31/12					
						12 ft. CLAYSTONE, slightly moist, very hard, very calcareous, olive to dark olive.						
15							29, 50/4					
20							50/7					
25						24.5 ft. SHALE, moderately hard, intact, slightly weathered, thinly laminated, calcareous, with occasional soft sediment deformation, with occasional fossil fragments, with occasional bioturbation, dark gray.	50/3.5	1	80	0	
								2	100	76	R3	
30												

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	**MS-5**

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
						SHALE, same as above, but not weathered.		3	98	100	R3	
35								4	100	100	R3	
40												
45												
50												
55												
60												
65												

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LOG OF BORING

MS-6

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 5920
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 29.5
DATE STARTED 8/5/18	TOTAL DEPTH 35.17
DATE COMPLETED 8/5/18	REFUSAL
LOGGED BY H. Brunkal	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	18 8/5/18
DRILL METHOD HSA & HQ Core	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
0						FILL: CLAY, sandy, moist, medium stiff, moderately calcareous, brown to dark brown.						
5							7/12					
						7.5 ft. CLAY, sandy, moist to very moist, very soft to hard, moderately calcareous, with gravel lenses at 25 feet, light to dark brown to olive.						
10							5/12					
15							1/12					
20							8/12					
25							33/12					
30						29.5 ft. SHALE, sandy, very moist, very hard, calcareous, dark olive to black.	50/5					

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	**MS-6**

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
35							50/2					
40												
45												
50												
55												
60												
65												

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LOG OF BORING

SB-1

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 8869
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 9
DATE STARTED 8/12/18	TOTAL DEPTH 29
DATE COMPLETED 8/12/18	REFUSAL
LOGGED BY J. Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	
DRILL METHOD 8'	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
0						CLAY, sandy, soft, slightly moist, dark brown.						
						1 ft. SAND, clayey, moist, medium dense, reddish brown.						
						3.5 ft. SAND, silty, with gravel, moist, dense, dark red brown.	43/12					
10						9 ft. SANDSTONE, clayey, moist, weathered, very dense, dark red brown. Grades to GRAVEL, poorly graded, with silt and sand, slightly moist, medium dense, reddish brown.	17,50/4					
							20/12					
						13.5 ft. CLAYSTONE, with sand, slightly moist to moist, moderately hard to very hard, reddish brown to gray.	47/12					
20							24,50/3					
							50/6					
						27 ft. SANDSTONE, moist, very hard, reddish brown.						
30						Stopped HSA and sampling at 29'.	50/0					
40												
50												
60												

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LOG OF BORING

SB-2

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 8859
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 12
DATE STARTED 8/11/18	TOTAL DEPTH 51
DATE COMPLETED 8/11/18	REFUSAL
LOGGED BY J. Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	3 8/11/18
DRILL METHOD HSA & HQ Core	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	moist	sat	DESCRIPTION	BLOWS/FT	CORE NO.	RECOVERY (%)	RQD (%)	HARDNESS	DRILLING NOTES
0						SAND, silty, clayey, moist to wet, very loose, dark brown.	2/12					
10						9 ft. SAND, poorly graded, with silt and gravel, very loose, wet, dark brown to black with organics.	14/12					
						12 ft. SANDSTONE, wet, very hard, tan to gray. Thickly interbedded with claystone below 33 feet.	50/2	1	89	38		
						14.5 ft. SANDSTONE, conglomeratic, moderately hard, medium sand to 1" gravel - sized grains, thin to medium cross-beds, red brown to pink gray.		2	100	80		
20								3	95	83		
								4	100	97		
30						SANDSTONE, silty, conglomeratic, soft, predominately fine grained, massive bedding, red brown matrix, with occasional calcareous olive gray clasts.		5	100	63		8" gray sandstone boulder
								6	100	60		
40						Predominately matrix 38.5'-47'		7	100	90		
								8	100	80		
50						Stopped coring at 51'.						
60												

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LOG OF BORING

SB-3

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 8860
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 7
DATE STARTED 8/10/18	TOTAL DEPTH 17
DATE COMPLETED 8/11/18	REFUSAL
LOGGED BY J. Edwards	
DRILLED BY HRL	DEPTH TO WATER / DATE
DRILL RIG CME-55	4 8/11/18
DRILL METHOD 4"	

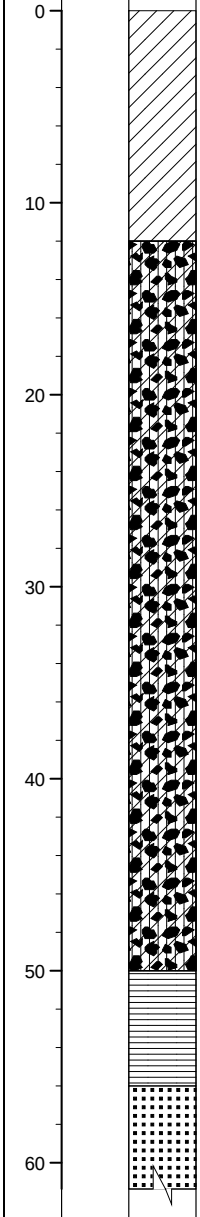
DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE dry	MOISTURE moist	MOISTURE sat	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0						CLAY, sandy, slightly moist, very soft, dark brown.						
						1.5 ft. SAND, well graded, with silt and gravel, moist to wet, loose to medium dense, reddish brown.						
10						7 ft. SAMDSTONE, wet, very hard, reddish brown.	50/2					
							50/0					
						Stopped HSA and sampling at 17'.	50/0					
20												
30												
40												
50												
60												

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LOG OF BORING

SB-4

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 8926
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 50
DATE STARTED 8/26/19	TOTAL DEPTH 70
DATE COMPLETED 8/28/19	REFUSAL
LOGGED BY I. Campbell	
DRILLED BY Dakota	DEPTH TO WATER / DATE
DRILL RIG CME 550	
DRILL METHOD 8"	



DEPTH (ft)	MOISTURE (dry / moist / sat)	DESCRIPTION	BLOWS/FT	CORE NO.	RECOVERY (%)	RQD (%)	HARDNESS	DRILLING NOTES
0		CLAY, sandy, grades to with gravel, cobbles noted, slightly moist, stiff to hard, red brown (CL, A-4).	15/12					
			10/12					
10			50/8					
		12 ft. CLAY, with gravel, cobbles, and boulders, hard, red	35/12					
20			50/7	1	23	13		
		SANDSTONE, boulder about 3 feet in diameter.		2	42	12		
30				3	65	32		
				4	15	0		
40				5	22	0		
				6	0	0		
50		50 ft. CLAYSTONE, conglomeratic, soft, slightly weathered, highly to intensely fractured, massive bedding, red.		7	68	47		
		56 ft. SANDSTONE, medium hard, slightly weathered, moderately to highly fractured, thickly bedded, red.		8	47	15		
60				9	78	38		

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LOG OF BORING

PROJECT	PROJECT NO.	BORING NO.
Cucharas Basin Collaborative Storage	18.117	**SB-4**

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
						63 ft. CLAYSTONE, soft, slightly weathered, moderately to highly fractured, thickly bedded, red.		10	53	0		
								11	90	70		
70						Stopped coring at 70'.						
80												
90												
100												
110												
120												
130												

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LOG OF BORING

SB-5

PROJECT Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION 8926
PROJECT NUMBER 18.117	DEPTH TO BEDROCK 10
DATE STARTED 8/29/19	TOTAL DEPTH 14.42
DATE COMPLETED 8/29/19	REFUSAL
LOGGED BY I. Campbell	
DRILLED BY Dakota	DEPTH TO WATER / DATE
DRILL RIG CME 55 Track Mounted	
DRILL METHOD 8"	

DEPTH (ft)	FRACTURE LOG	GRAPHIC LOG	MOISTURE: dry	MOISTURE: moist	MOISTURE: sat	DESCRIPTION	BLOWS/FT	CORE: NO.	CORE: RECOVERY (%)	CORE: RQD (%)	CORE: HARDNESS	DRILLING NOTES
0						SAND, silty, with gravel and cobbles, slightly moist, medium dense, gray (SM, A-4).	19/12					
							50/10					
						5 ft. GRAVEL, with sand and cobbles, clayey, very dense, slightly moist, gray (GC, A- 2-4).						
10						10 ft. SANDSTONE, hard, slightly weathered, highly fractured, thickly bedded, gray.	50/6					
						Stopped HSA and sampling at 14.4'.	50/5					
20												
30												
40												
50												
60												

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APPENDIX B

Core Photographs



Photo 1. LVL-5 from 15 to 25 feet.



Photo 2. LVL-5 from 25 to 34.5 feet.



Photo 3. LVL-5 from 34.5 to 41 feet.



Photo 4. B-2 from 17 to 28 feet.

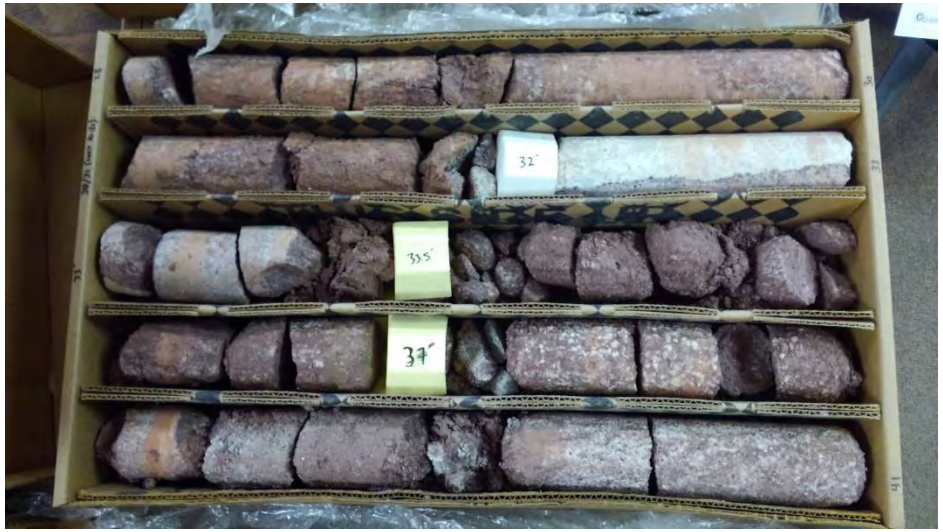


Photo 5. B-2 from 28 to 41 feet.



Photo 6. B-2 from 41 to 42 feet.



Photo 7. SB-2 from 14.5 to 24 feet.



Photo 8. SB-2 from 24 to 33 feet.



Photo 9. SB-2 from 33 to 41 feet.



Photo 10. SB-2 from 41 to 51 feet.



Photo 11. BC-2 from 20 to 30 feet.



Photo 12. BC-2 from 30 to 37.2 feet.



Photo 13. BC-2 from 37.2 to 48.9 feet.



Photo 14. BC-2 from 48.9 to 50.8 feet.



Photo 15. LVL-3 from 1.5 to 11.5 feet.



Photo 16. LVL-3 from 11.5 to 21.5 feet.



Photo 17. LVL-3 from 21.5 to 31 feet.

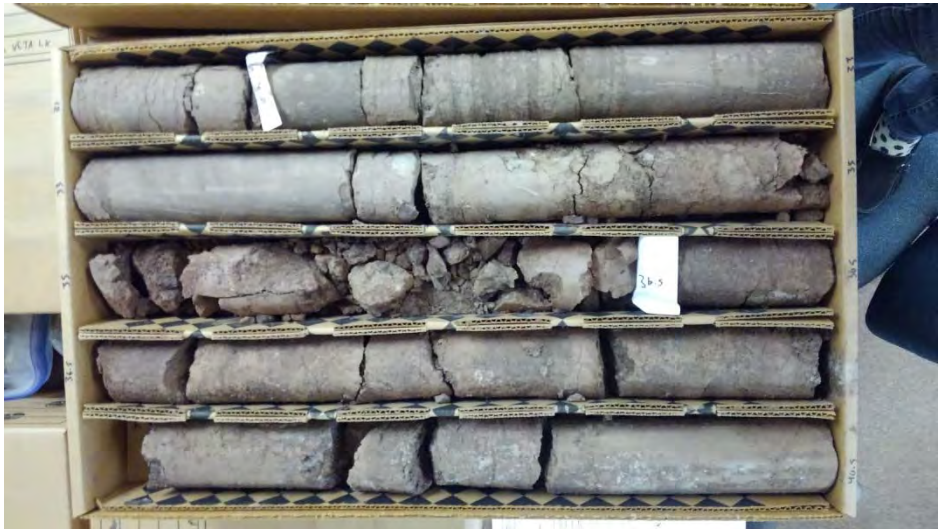


Photo 18. LVL-3 from 31 to 40.5 feet.



Photo 19. MS-3 from 26 to 35.6 feet.



Photo 20. MS-3 from 35.6 to 44.5 feet.



Photo 21. MS-3 from 44.5 to 50 feet.

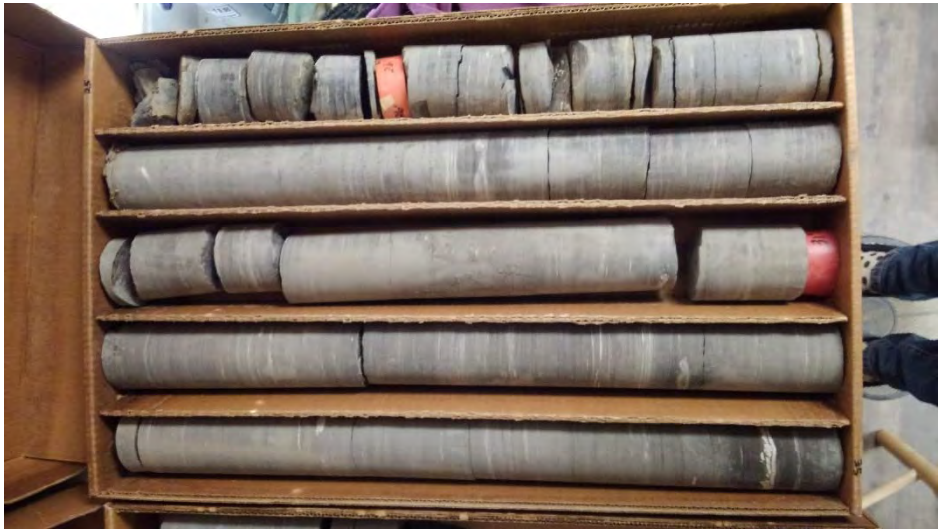


Photo 22. MS-5 from 25 to 35 feet.



Photo 23. MS-5 from 35 to 40 feet.

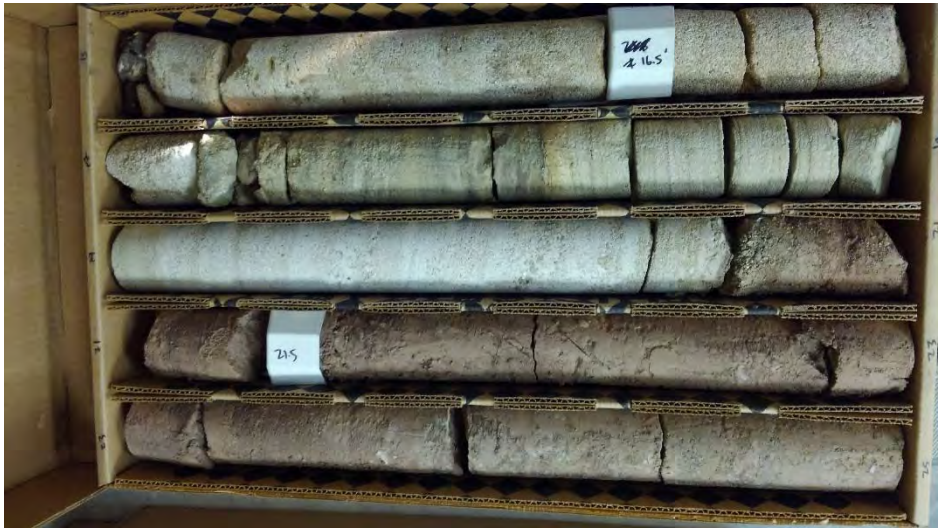


Photo 24. LVL-1 from 15 to 25 feet.



Photo 25. LVL-1 from 25 to 34 feet.

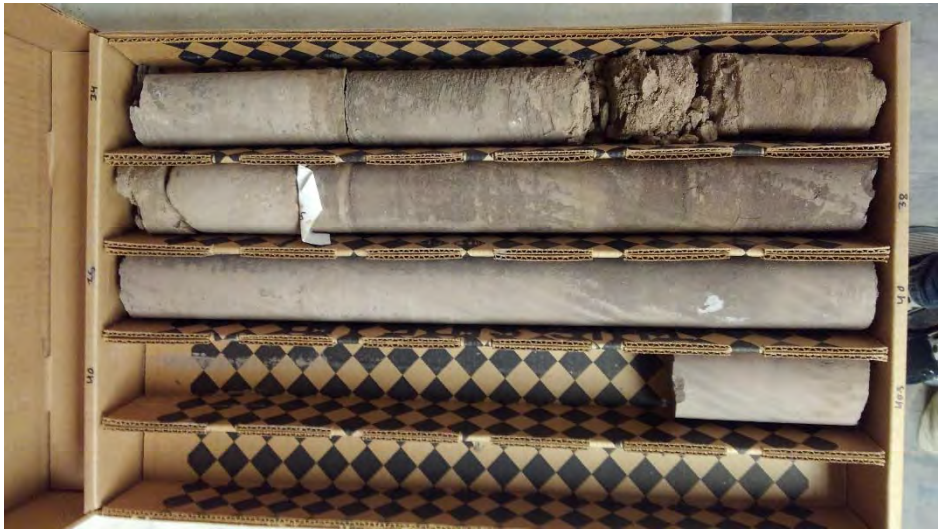


Photo 26. LVL-1 from 34 to 40.5 feet.



Photo 27. MS-1 from 25 to 34.6 feet.



Photo 28. MS-1 from 34.6 to 41 feet.



Photo 29. SB-4 from 20 to 25 feet.



Photo 30. SB-4 from 25 to 27.5 feet.



Photo 31. SB-4 from 27.5 to 30 feet.



Photo 32. SB-4 from 30 to 31.5 feet.



Photo 33. SB-4 from 31.5 to 33 feet.



Photo 34. SB-4 from 33 to 35 feet.



Photo 35. SB-4 from 35 to 40 feet.



Photo 36. SB-4 from 40 to 45 feet.



Photo 37. SB-4 from 50 to 55 feet.



Photo 38. SB-4 from 55 to 60 feet.



Photo 39. SB-4 from 60 to 65 feet.



Photo 40. SB-4 from 65 to 67.5 feet.



Photo 41. SB-4 from 67.5 to 69 feet.



Photo 42. SB-4 from 69 to 70 feet.



Photo 43. BC-4 from 10 to 15 feet.



Photo 44. BC-4 from 15 to 20 feet.



Photo 45. BC-4 from 20 to 25 feet.



Photo 46. BC-4 from 25 to 30 feet.



Photo 47. BC-4 from 30 to 35 feet.



Photo 48. BC-4 from 35 to 40 feet.

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APPENDIX C

Laboratory Test Results

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SUMMARY OF LABORATORY TEST RSULTS
Cucharas Basin Collaborative Storage
Project No. 18.117

Sample Location		Natural Dry Density (pcf)	Natural Moisture Content (%)	Gradation			Atterberg Limits		Swell/Consolidation			Permeability (cm/s)	Material Type
Boring	Depth (feet)			Gravel (%)	Sand (%)	Silt/ Clay (%)	Liquid Limit (%)	Plasticity Index (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)		
B-1	7		6.5	26	52	21.2	19	4					SAND, silty, clayey (SC-SM, A-2-4)
B-1	17		3.2	65	27	8.3	NV	NP					GRAVEL, poorly graded, with silt and sand (GP-GM, A-1-b)
B-2	7		6.9	63	28	8.7	NV	NP					GRAVEL, well graded, with silt and sand (GW-GM, A-1-a)
B-2	12		17.7		81	19.4	24	4					SAND, silty, clayey (SC-SM, A-2-4)
BP-1	1 to 3		4.5	16	56	28.3	31	9					SAND, clayey, with gravel (SC, A-2-4(0))
BP-3	2 to 5		1.8	1	65	34.2	21	5					SAND, silty, clayey (SC-SM, A-2-4)
BP-5	3.5 to 5		7.4	34	34	32.6	30	12					SAND, clayey, with gravel (SC, A-2-6(0))
BC-1	5		11.5		67	33.3	22	6					SAND, clayey (SC, A-2-4(0))
BC-1	25		12.3		39	60.8	40	16					CLAY, sandy, lean (CL, A-6(8))
BC-2	5		27.0		54	46	30	17					SAND, clayey (SC, A-6(4))
BC-2	10		16.0	17	52	30.7	23	7					SAND, clayey, with gravel (SC, A-2-4(0))
BC-3	5		5.4	1	70	29.1	24	6					SAND, silty, clayey (SC-SM, A-2-4(0))
BC-3	15		4.6		56	43.7	24	4					SAND, silty, clayey (SC-SM, A-4(0))
BC-4	10		6.1		23	76.7	30	11					CLAY, lean, with sand (CL, A-6(7))
BCP-1	1 to 8		3.0		53	46.6	27	11					SAND, clayey (SC, A-6(2))
BCP-2	2 to 10		4.1		65	34.6	23	6					SAND, silty, clayey (SC-SM, A-2-4)
BCP-4	2 to 8		1.9		64	36.0	25	9					SAND, clayey (SC, A-4)
BCP-5	2 to 8	82.8	5.1	9	48	43.5	29	12	500	-9.9	N/A		SAND, clayey (SC, A-6(2))
BCP-6	7 to 9		4.1		76	23.6	NV	NP					SAND, silty (SM, A-2-4)
LVL-1	15		10.7		59	40.6	24	5					SAND, silty, clayey (SC-SM, A-4)
LVL-4	9		16.1		63	36.7	23	6					SAND, silty, clayey (SC-SM, A-4)
LVL-5	5		14.0		48	52.5	37	20					CLAY, sandy, lean (CL, A-6(7))
LVL-7	4		4.3	1	63	36.3	19	5					SAND, silty, clayey (SC-SM, A-4)
MS-1	10		9.6	5	26	69.4	30	14					CLAY, sandy, lean (CL, A-6(7))
MS-1	20		7.4	11	30	58.5	31	16					CLAY, sandy, lean (CL, A-6(6))
MS-2	10		7.8	2	77	21.1	NV	NP					SAND, silty (SM, A-2-4)

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SUMMARY OF LABORATORY TEST RSULTS
Cucharas Basin Collaborative Storage
Project No. 18.117

Sample Location		Natural	Natural	Gradation			Atterberg Limits		Swell/Consolidation				
Boring	Depth (feet)	Dry Density (pcf)	Moisture Content (%)	Gravel (%)	Sand (%)	Silt/ Clay (%)	Liquid Limit (%)	Plasticity Index (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)	Permeability (cm/s)	Material Type
MS-2	20		16.5	17	76	6.8	NV	NP					SAND, well graded, with silt and gravel (SW-SM, A-1-b)
MS-3	5		24.5		20	79.9	39	20					CLAY, lean, with sand (CL, A-6(15))
MS-4	10		11.8		10	90.4	35	20					CLAY, lean (CL, A-6(17))
MS-5	10		12.3		12	87.8	35	17					CLAY, lean (CL, A-6(14))
MS-6	5	113.1	14.0						50	0.3	315		FILL: CLAY, sandy, lean (CL, A-6)
MS-6	10	91.3	25.9	1	28	70.2	32	15	50	0.3	125		CLAY, sandy, lean, with organics (CL, A-6(8))
MS-6	15	95.3	25.2						50	0.1	64		CLAY, sandy, lean (CL, A-6)
MS-6	20	106.9	19.5						50	0.8	605		CLAY, sandy, lean (Cl, A-6)
MS-6	25		14.4	1	30	68.1	30	11					CLAY, sandy, lean (CL, A-6(5))
MSP-2	1 to 3		6.4	1	30	68.6	36	13					CLAY, sandy, lean (CL, A-6(8))
MSP-4	2 to 4		5.3	1	24	74.7	37	16					CLAY, sandy, lean (CL, A-6(11))
MSP-5	1 to 4		5.7	6	28	66.3	35	19					CLAY, sandy, lean (CL, A-6(10))
MSP-5	4 to 7		3.6	8	29	62.9	33	16					CLAY, sandy, lean (CL, A-6(7))
SB-1	5		7.6	31	47	22.5	19	2					SAND, silty, with gravel (SM, A-1-b(0))
SB-1	12.5		0.3	52	37	10.7	NV	NP					GRAVEL, poorly graded, with silt and sand (GP-GM, A-1-b)
SB-1	20		8.7		27	72.5	30	11					CLAY, lean, with sand (CL, A-6(6))
SB-2	10		10.3	42	47	11.3	NV	NP					SAND, poorly graded, with silt and gravel (SP-SM, A-1-b)
SB-3	5		5.6	27	62	11.1	NV	NP					SAND, well graded, with silt and gravel (SW-SM, A-1-b)
SB-4	5		15.5		46	54.3	26	9					CLAY, sandy, lean (CL, A-4(2))
SB-4	15		6.0	23	28	49.1	24	8					CLAY, sandy, lean, with gravel (CL, A-4(1))
SB-4	55											3.63.E-09	CLAYSTONE, sandy
SB-5	1		6.3	4	56	40.4	19	2					SAND, silty (SM, A-4)
SBP-1	1 to 3		2.4	1	49	50.3	25	5					CLAY, silty, with sand (CL-ML, A-4(0))
SBP-3	1 to 3		2.0	3	63	33.6	24	4					SAND, silty, clayey (SC-SM, A-2-4(0))
SBP-3	6 to 8		6.0		78	21.3	28	9					SAND, clayey (SC, A-2-4(0))
SBP-5	1 to 3		6.1		58	41.3	27	6					SAND, silty, clayey (SC-SM, A-4(0))

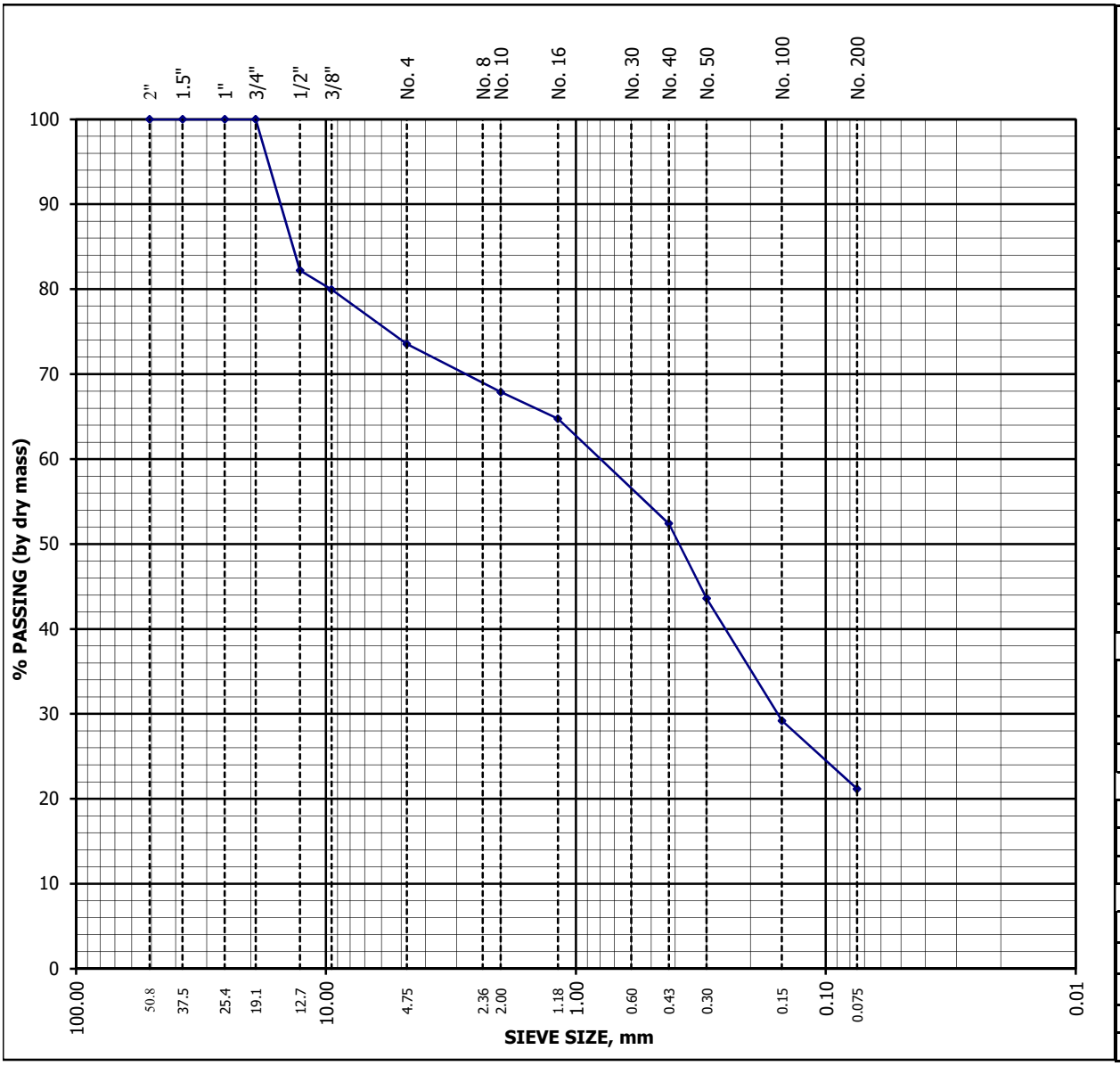
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822891	Reviewer:	J. Crystal
Sample Location:	B-1 at 7'		
Visual Description:	SAND, silty, clayey, reddish brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	100
1/2"	82
3/8"	80
#4	74
#8	
#10	68
#16	65
#30	
#40	52
#50	44
#100	29
#200	21.2

Moisture (M) & Density (D)	
M, %:	6.5
D, pcf:	

LL	19
PL	15
PI	4

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

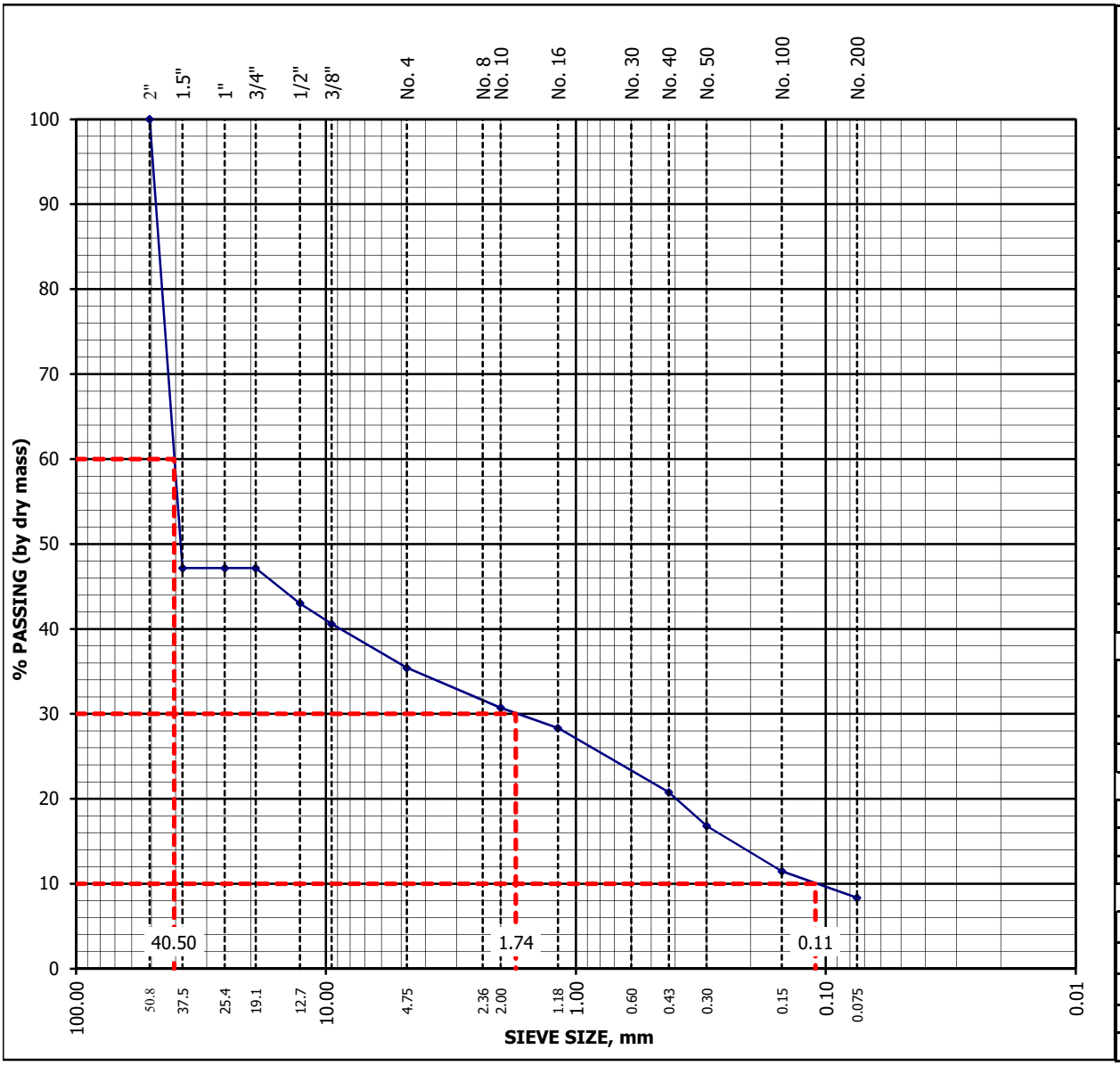
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822892	Reviewer:	J. Crystal
Sample Location:	B-1 at 17'		
Visual Description:	GRAVEL, with silt and sand, reddish brown		

AASHTO M 145 Classification: **A-1-a** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(GP-GM) Poorly graded gravel with silt and sand**



Sieve Size	% Passing
2"	100
1.5"	47
1"	47
3/4"	47
1/2"	43
3/8"	41
#4	35
#8	
#10	31
#16	28
#30	
#40	21
#50	17
#100	11
#200	8.3

Moisture (M) & Density (D)	
M, %:	3.2
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	40.50
D_{30}	1.74
D_{10}	0.11
Cu	**368.18**
Cc	**0.68**

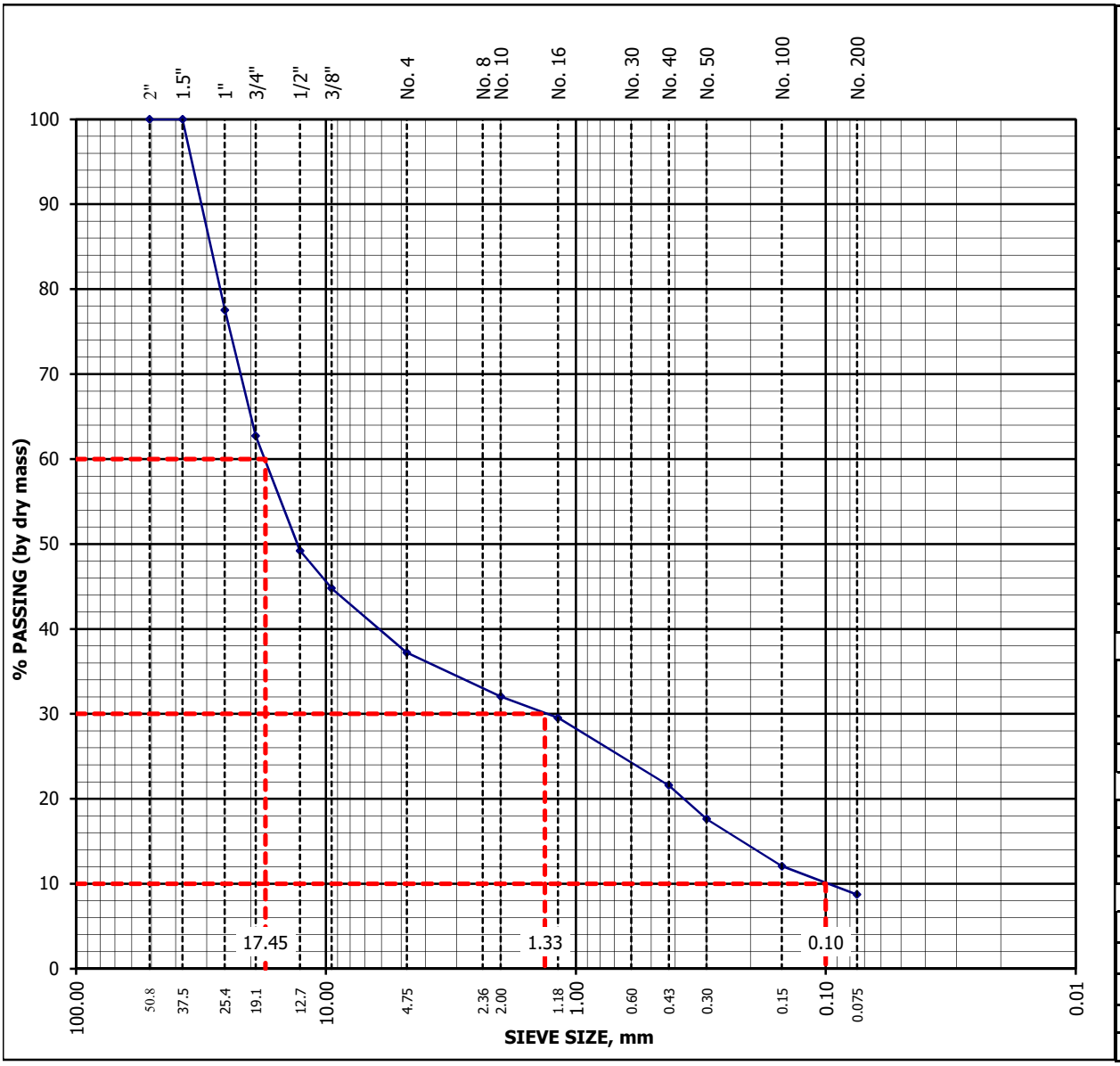
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822893	Reviewer:	J. Crystal
Sample Location:	B-2 at 7'		
Visual Description:	GRAVEL, with silt and sand, red brown		

AASHTO M 145 Classification: **A-1-a** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(GW-GM) Well graded gravel with silt and sand**



Sieve Size	% Passing
2"	
1.5"	100
1"	78
3/4"	63
1/2"	49
3/8"	45
#4	37
#8	
#10	32
#16	30
#30	
#40	22
#50	18
#100	12
#200	8.7

Moisture (M) & Density (D)	
M, %:	6.9
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	17.45
D_{30}	1.33
D_{10}	0.10
Cu	**####**
Cc	**1.01**

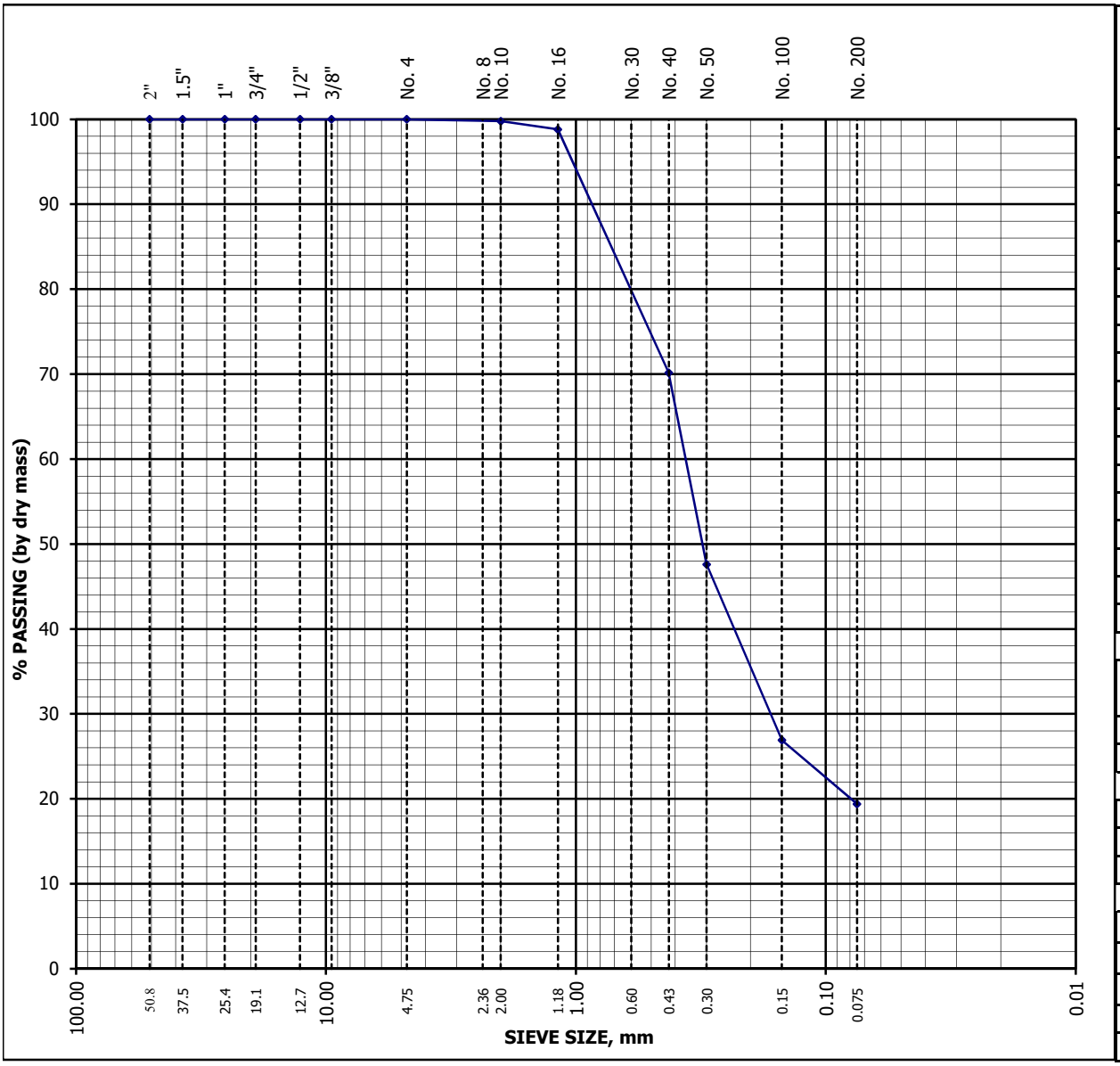
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822894	Reviewer:	J. Crystal
Sample Location:	B-2 at 12'		
Visual Description:	SAND, clay, silty, reddish brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	99
#30	
#40	70
#50	48
#100	27
#200	19.4

Moisture (M) & Density (D)	
M, %:	17.7
D, pcf:	

LL	24
PL	20
PI	4

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

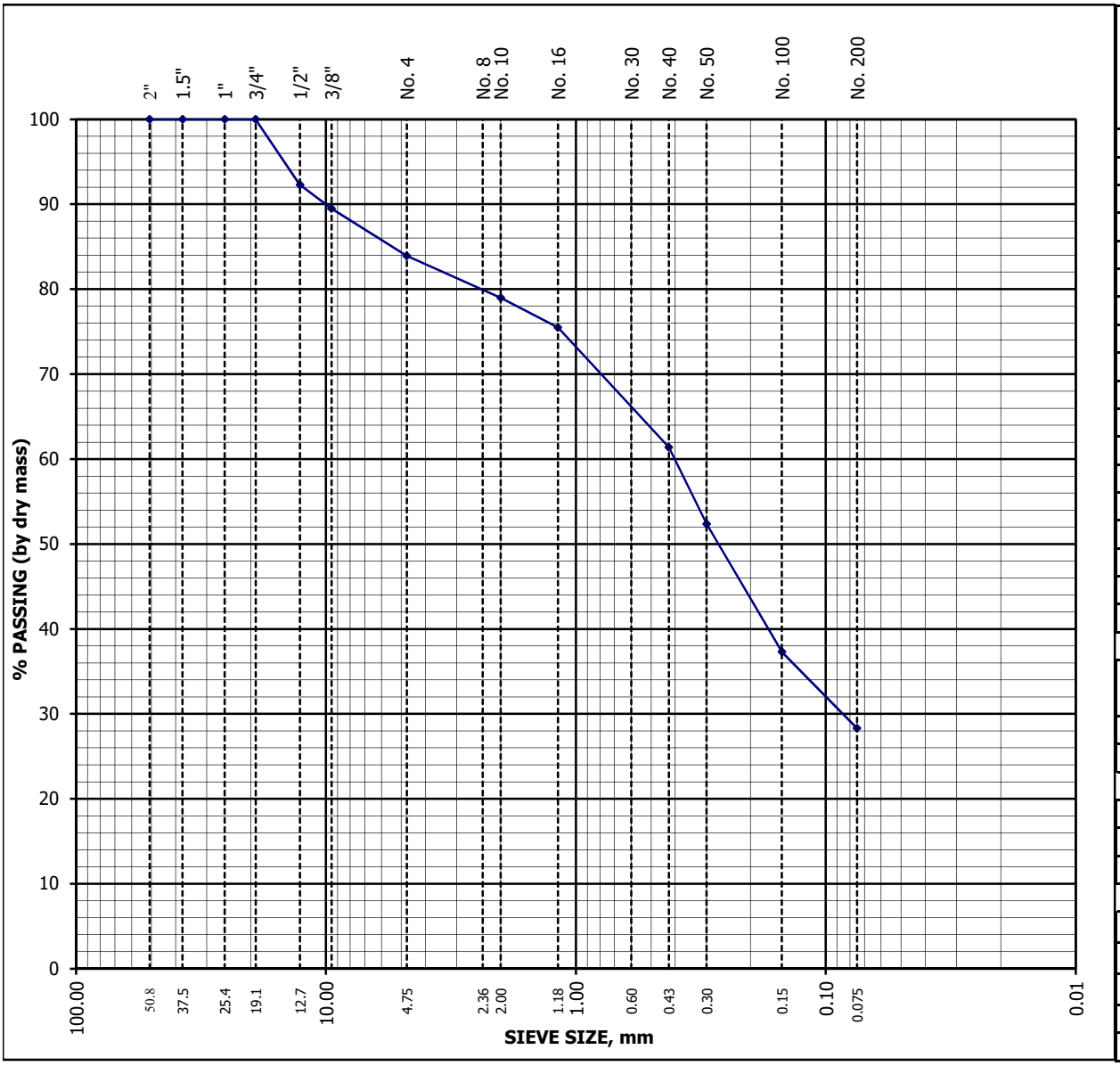
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	25-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Crystal
Lab ID Number:	1822649	Reviewer:	J. Holiman
Sample Location:	BP-1 at 1' to 3'		
Visual Description:	SAND, clay with gravel, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC)** **Clayey sand with gravel**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	100
1/2"	92
3/8"	89
#4	84
#8	
#10	79
#16	76
#30	
#40	61
#50	52
#100	37
#200	28.3

Moisture (M) & Density (D)	
M, %:	4.5
D, pcf:	

LL	31
PL	22
PI	9

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

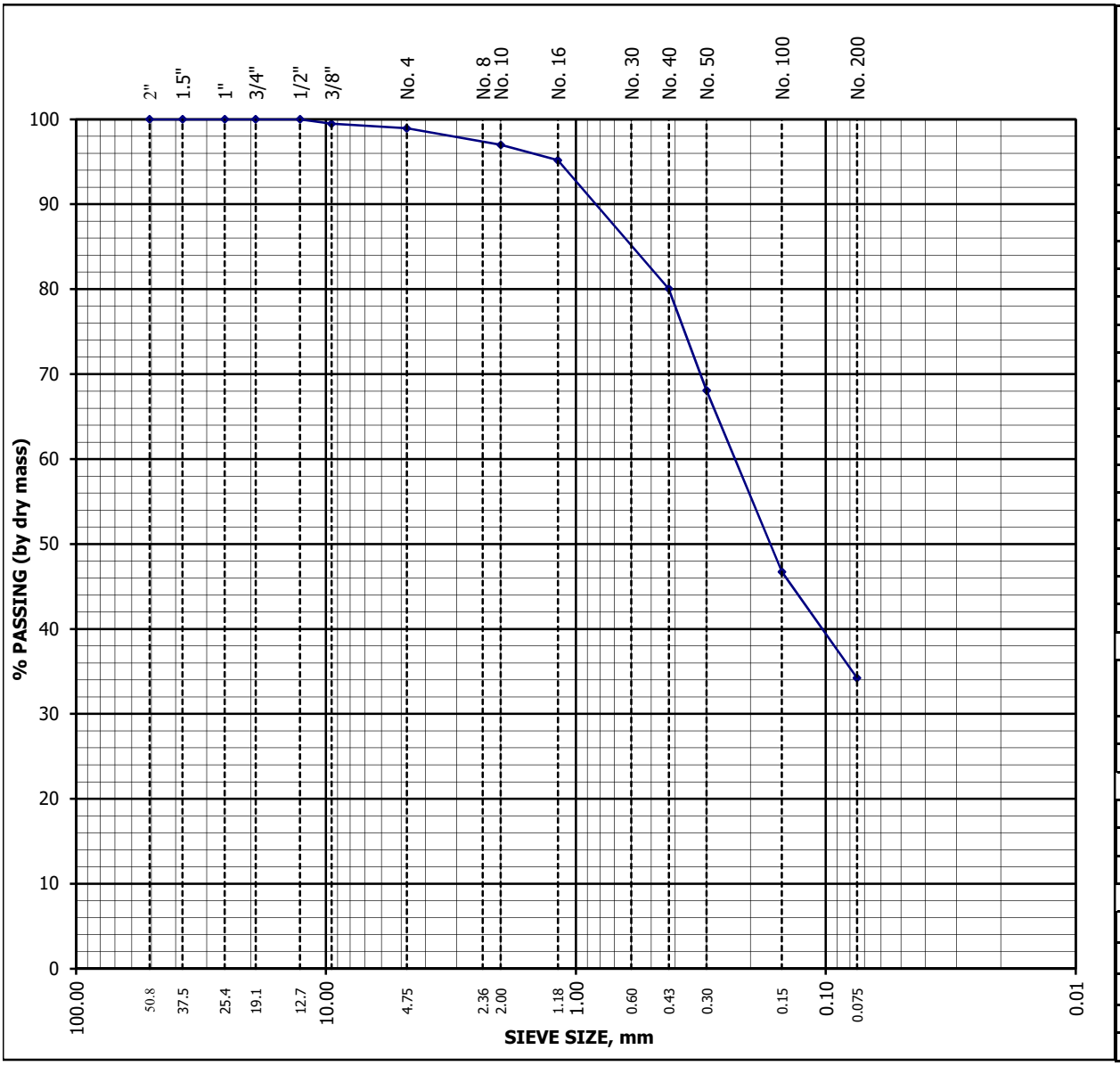
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	25-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822650	Reviewer:	J. Crystal
Sample Location:	BP-3 at 2' to 5'		
Visual Description:	SAND, silty, clayey, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	100
3/8"	99
#4	99
#8	
#10	97
#16	95
#30	
#40	80
#50	68
#100	47
#200	34.2

Moisture (M) & Density (D)	
M, %:	1.8
D, pcf:	

LL	21
PL	16
PI	5

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

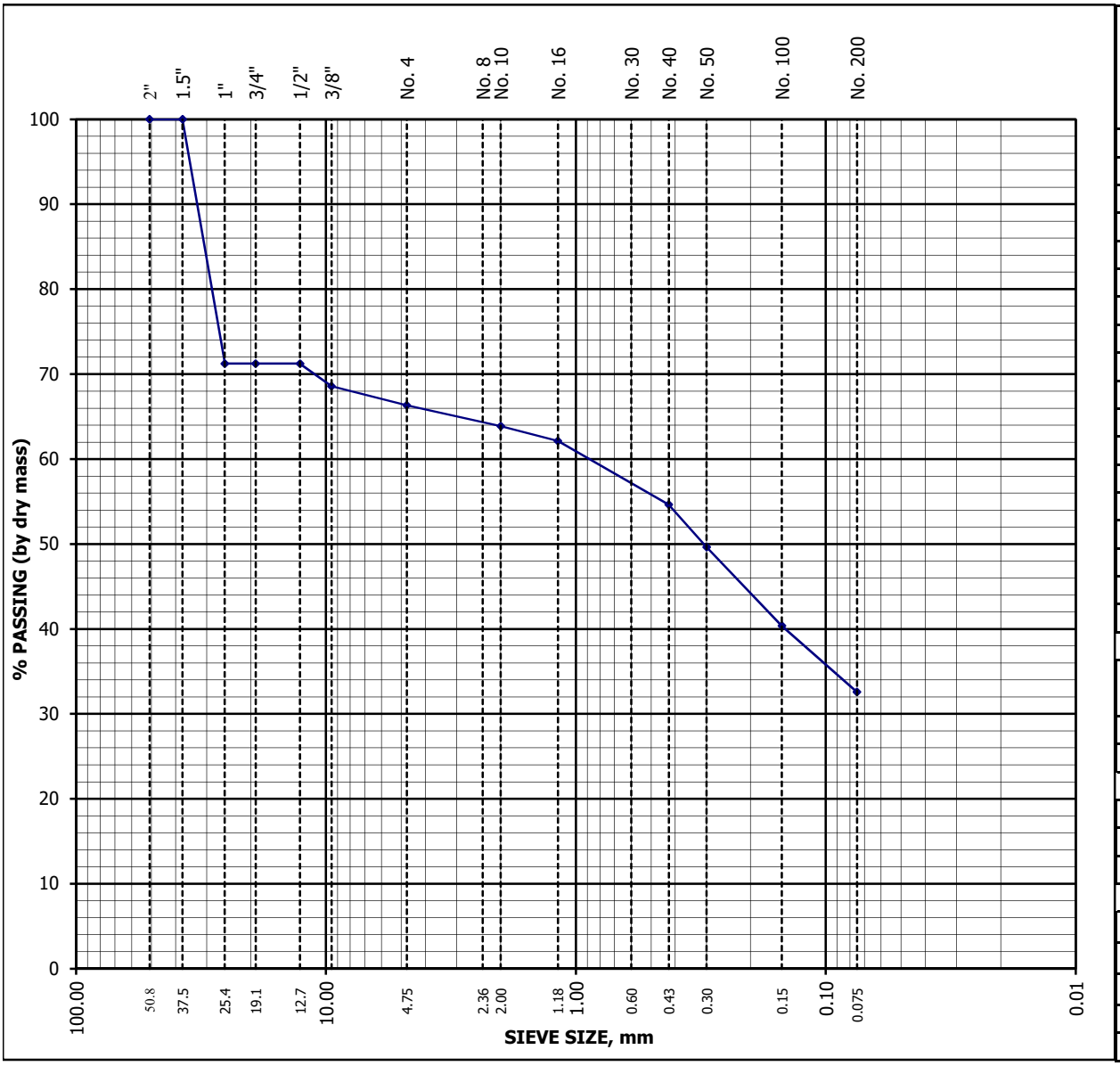
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	6-Oct-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822651	Reviewer:	J. Crystal
Sample Location:	BP-5 at 3.5' to 5'		
Visual Description:	SAND, clayey, with gravel, red brown		

AASHTO M 145 Classification: **A-2-6** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC)** **Clayey sand with gravel**



Sieve Size	% Passing
2"	
1.5"	100
1"	71
3/4"	71
1/2"	71
3/8"	69
#4	66
#8	
#10	64
#16	62
#30	
#40	55
#50	50
#100	40
#200	32.6

Moisture (M) & Density (D)	
M, %:	7.4
D, pcf:	

LL	30
PL	18
PI	12

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

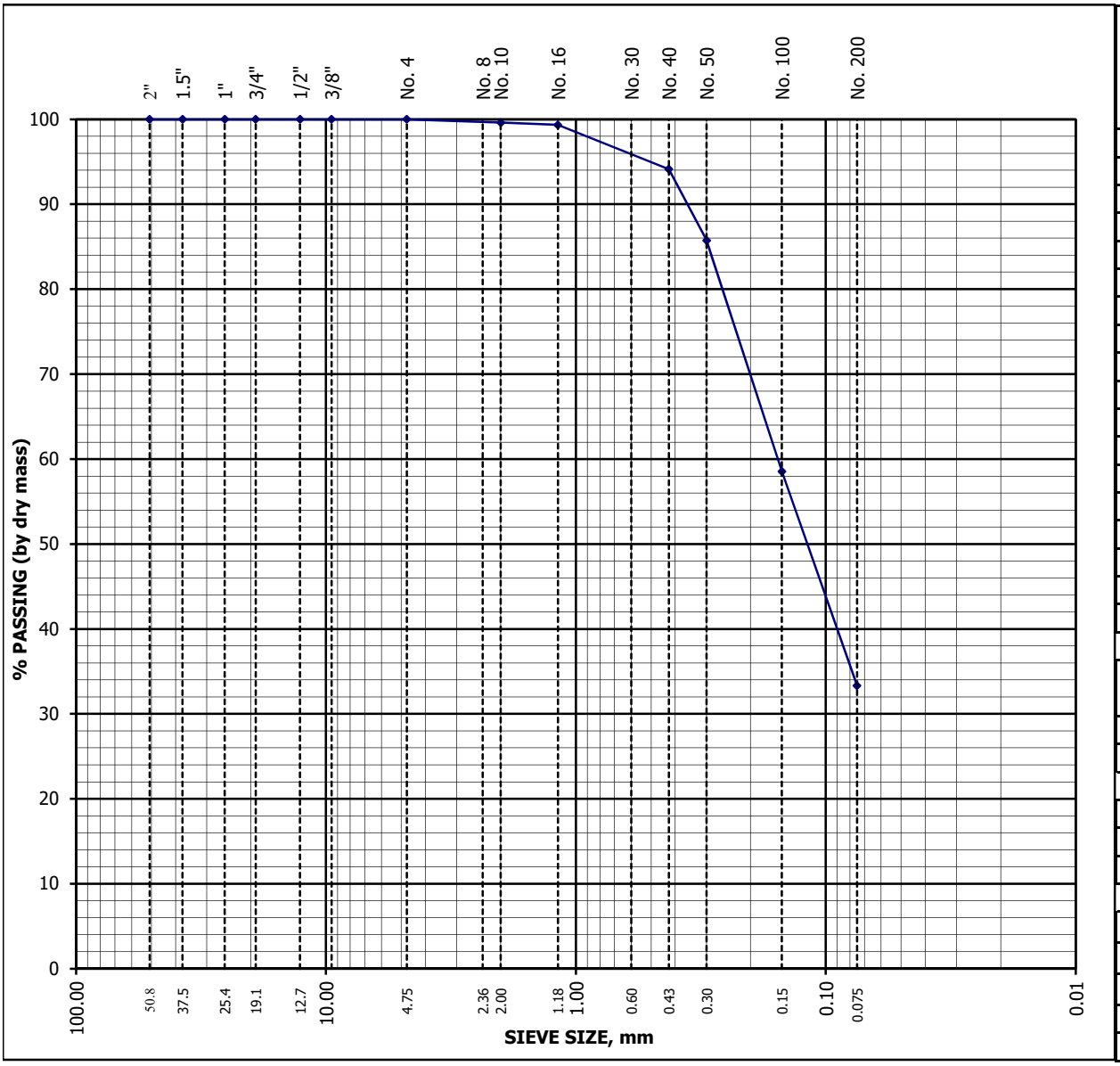
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822871	Reviewer:	J. Crystal
Sample Location:	BC-1 at 5'		
Visual Description:	SAND, clayey, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC)** **Clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	99
#30	
#40	94
#50	86
#100	59
#200	33.3

Moisture (M) & Density (D)	
M, %:	11.5
D, pcf:	

LL	22
PL	16
PI	6

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

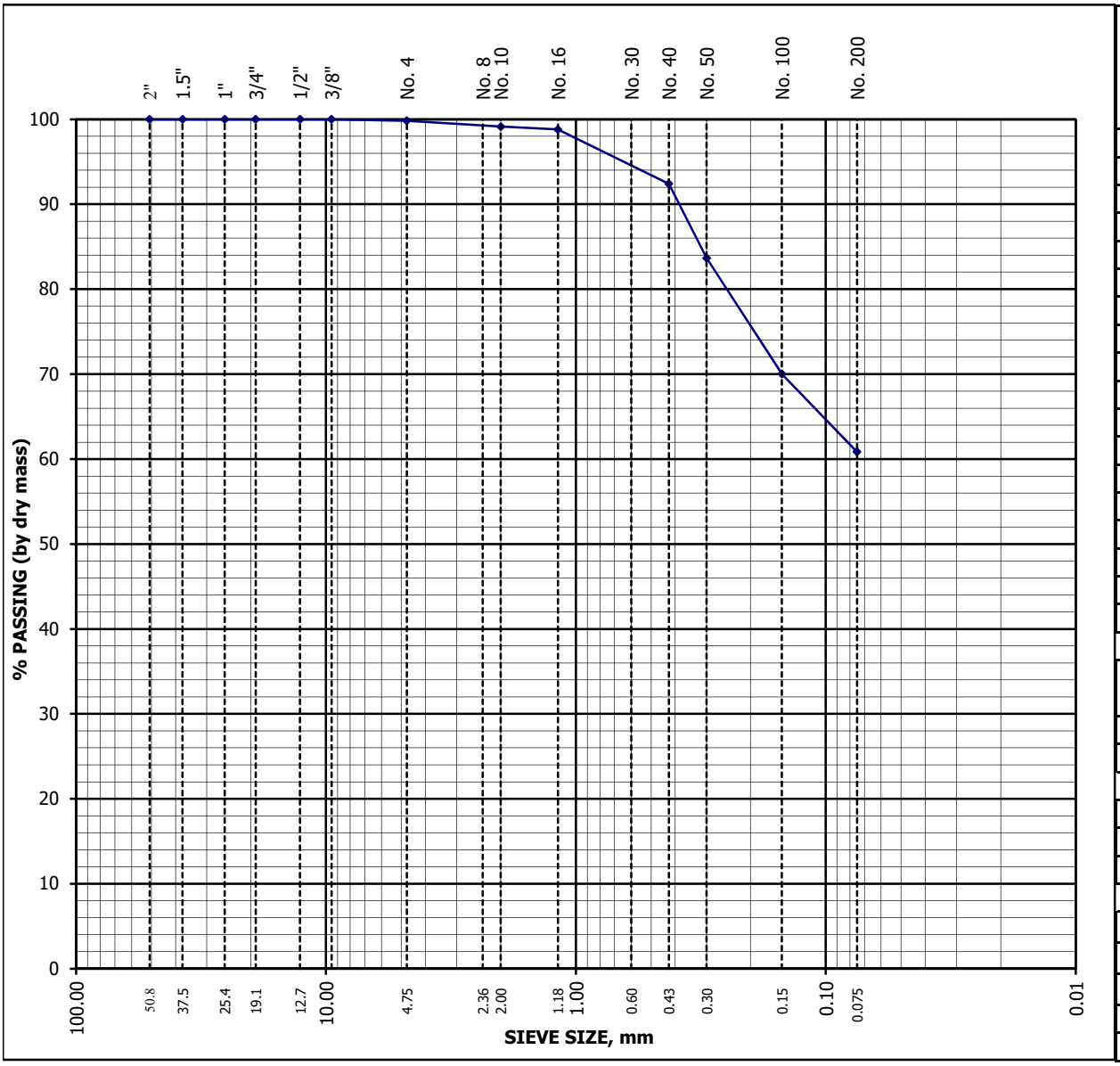
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822872	Reviewer:	J. Crystal
Sample Location:	BC-1 at 25'		
Visual Description:	CLAYSTONE: CLAY, sandy, red		

AASHTO M 145 Classification: **A-6** **Group Index:** **8**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	99
#16	99
#30	
#40	92
#50	84
#100	70
#200	60.8

Moisture (M) & Density (D)	
M, %:	12.3
D, pcf:	

LL	40
PL	24
PI	16

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

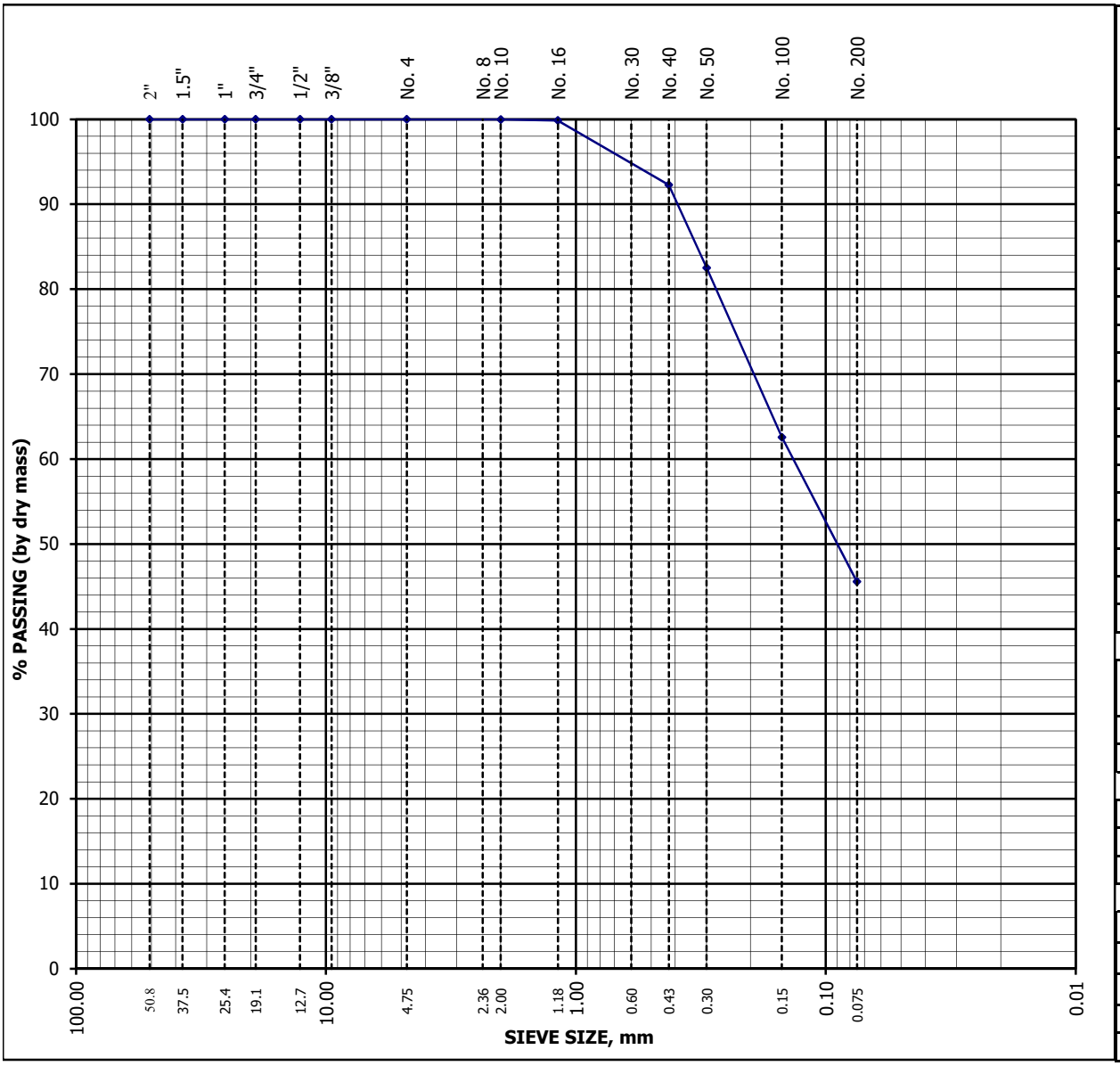
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822873	Reviewer:	J. Crystal
Sample Location:	BC-2 at 5'		
Visual Description:	SAND, clayey, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **4**

Unified Soil Classification System (ASTM D 2487): **(SC) Clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	
#8	
#10	100
#16	100
#30	
#40	92
#50	83
#100	63
#200	45.6

Moisture (M) & Density (D)	
M, %:	27.0
D, pcf:	

LL	30
PL	13
PI	17

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

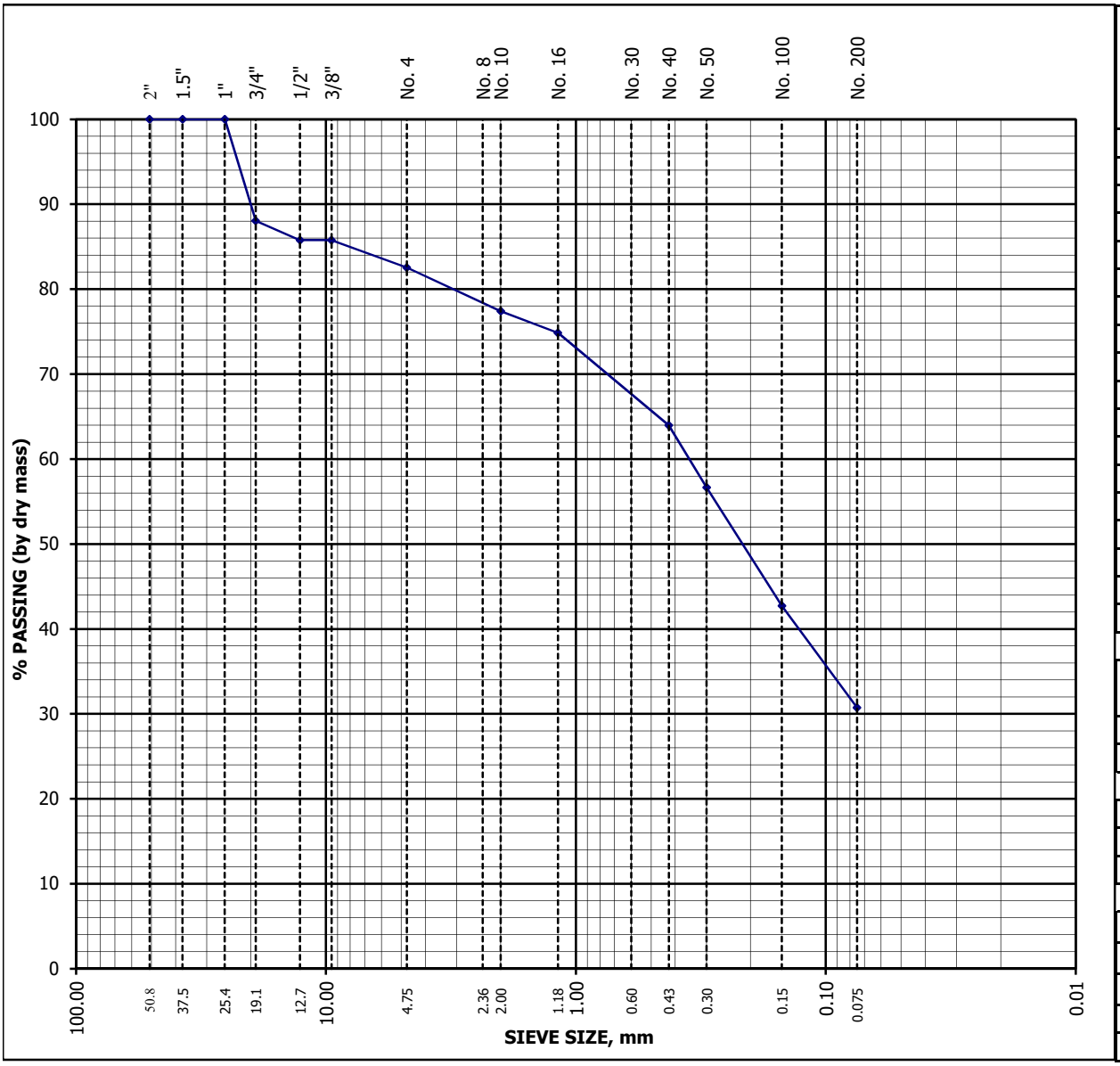
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822874	Reviewer:	J. Crystal
Sample Location:	BC-2 at 10'		
Visual Description:	SAND, clayey, with gravel, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC)** **Clayey sand with gravel**



Sieve Size	% Passing
2"	
1.5"	
1"	100
3/4"	88
1/2"	86
3/8"	86
#4	83
#8	
#10	77
#16	75
#30	
#40	64
#50	57
#100	43
#200	30.7

Moisture (M) & Density (D)	
M, %:	16.0
D, pcf:	

LL	23
PL	16
PI	7

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

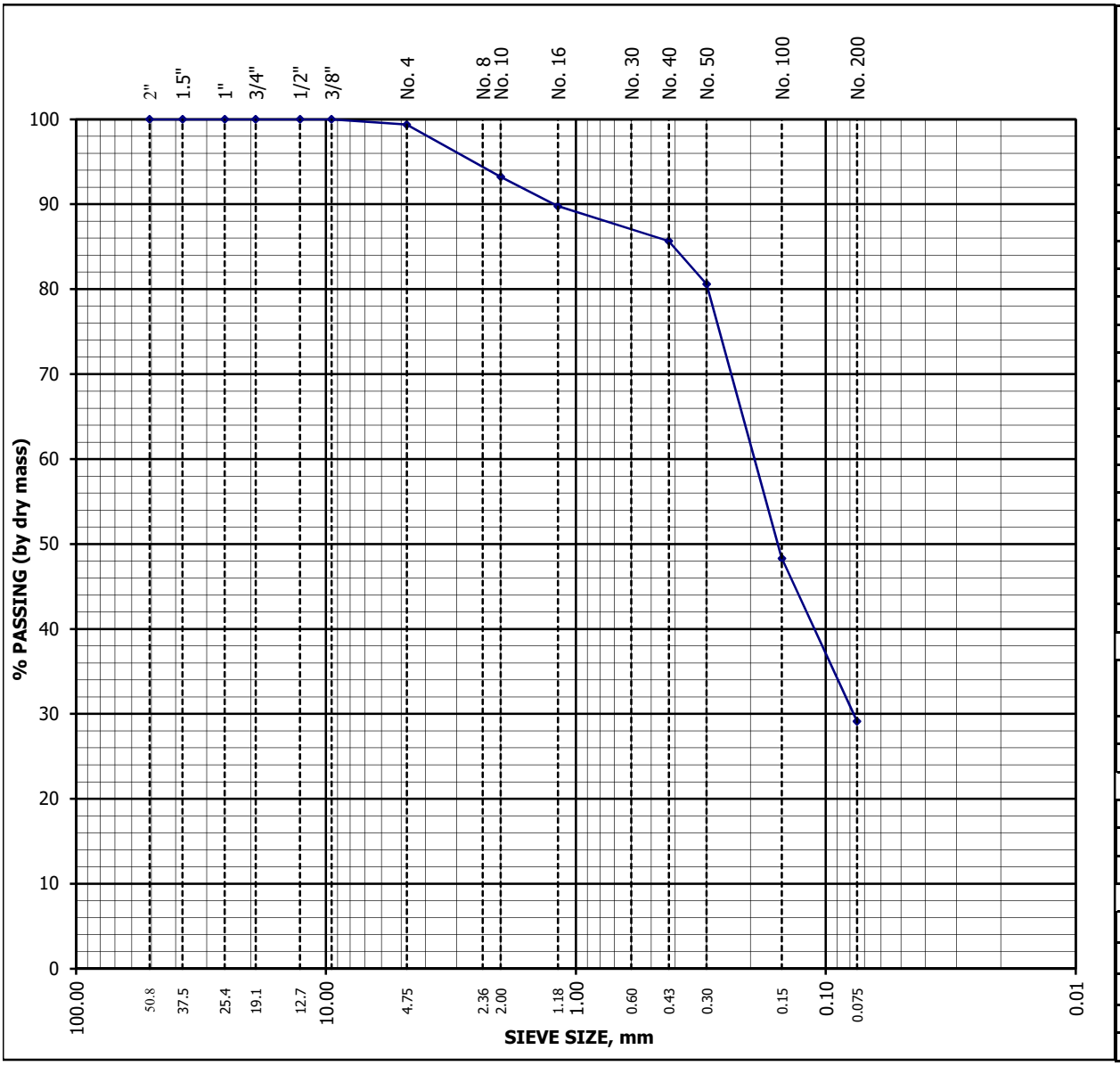
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822875	Reviewer:	J. Crystal
Sample Location:	BC-3 at 5'		
Visual Description:	SAND, silty, clayey, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	99
#8	
#10	93
#16	90
#30	
#40	86
#50	81
#100	48
#200	29.1

Moisture (M) & Density (D)	
M, %:	5.4
D, pcf:	

LL	24
PL	18
PI	6

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

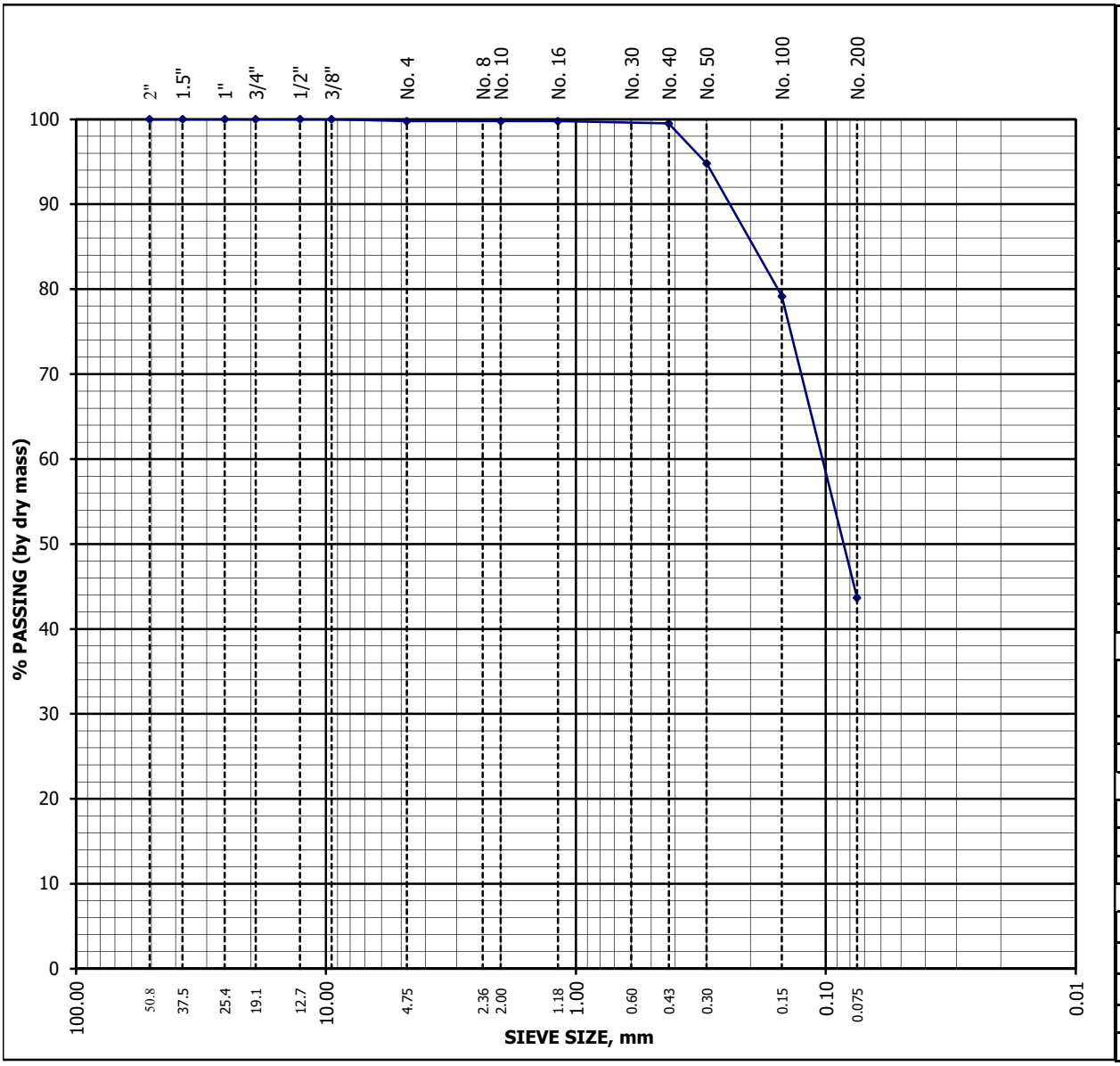
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822876	Reviewer:	J. Crystal
Sample Location:	BC-3 at 15'		
Visual Description:	SANDSTONE, silty, clayey, brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	100
#16	100
#30	
#40	99
#50	95
#100	79
#200	43.7

Moisture (M) & Density (D)	
M, %:	4.6
D, pcf:	

LL	24
PL	20
PI	4

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

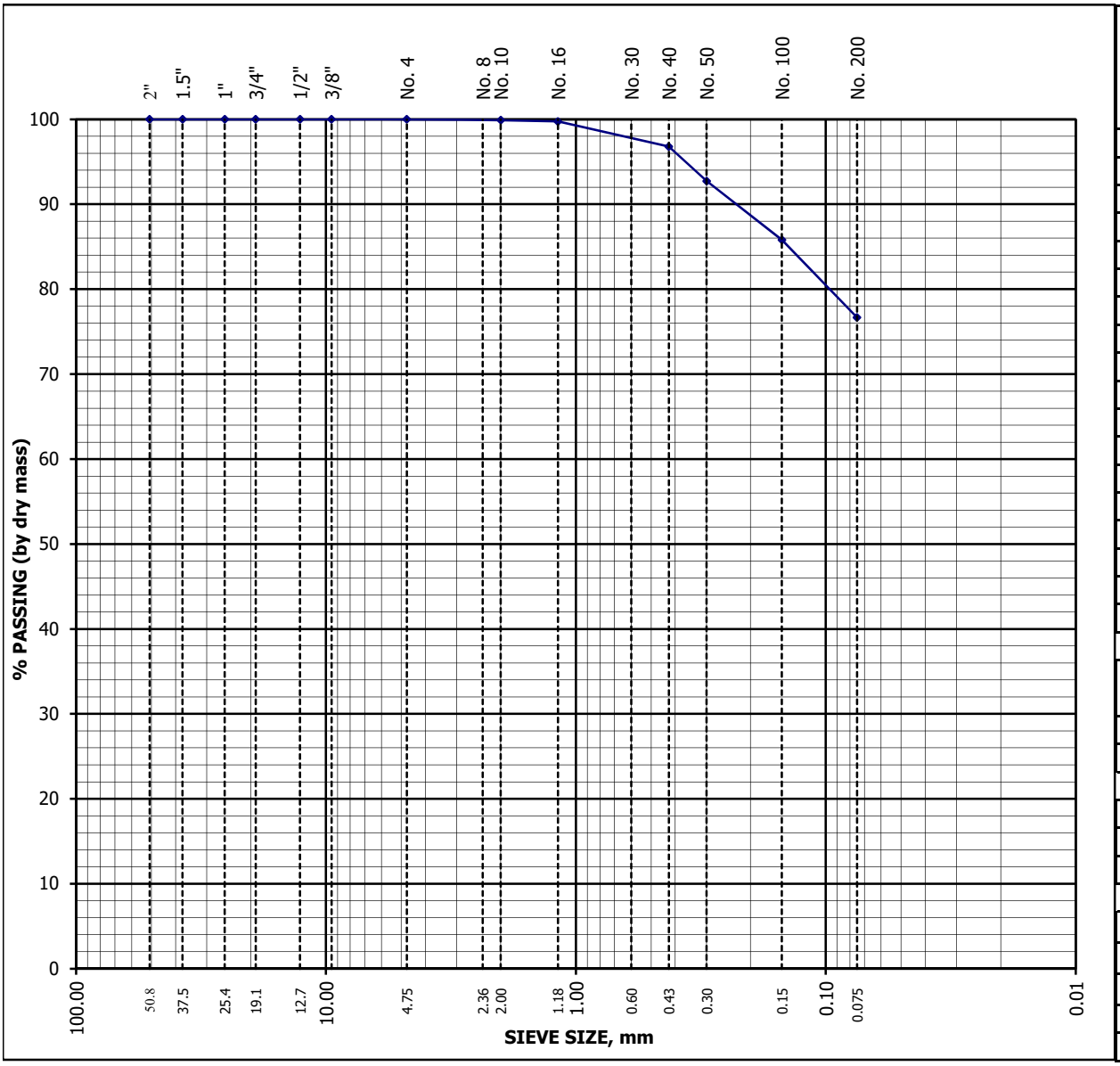
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	9-Sep-19
Project Name:	Cucharas Basin Collaborative Storage	Technician:	C. Zoetewey
Lab ID Number:	1921469	Reviewer:	J. Crystal
Sample Location:	BC-4 at 10'		
Visual Description:	CLAY, with sand, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **7**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Lean clay with sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	100
#30	
#40	97
#50	93
#100	86
#200	76.7

Moisture (M) & Density (D)	
M, %:	6.1
D, pcf:	

LL	30
PL	19
PI	11

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

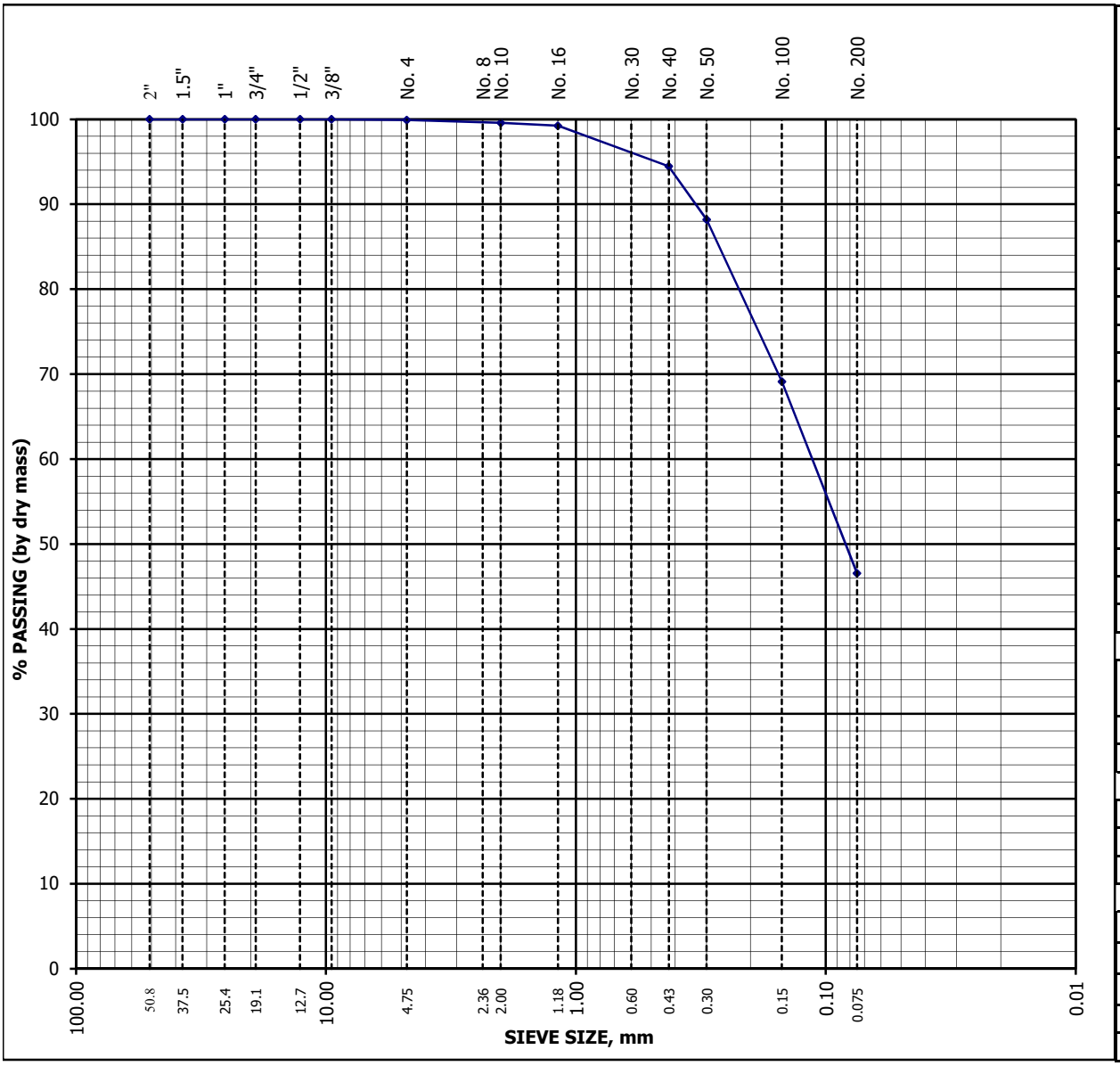
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	25-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822652	Reviewer:	J. Crystal
Sample Location:	BCP-1 at 1' to 8'		
Visual Description:	SAND, clayey, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **2**

Unified Soil Classification System (ASTM D 2487): **(SC)** **Clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	100
#16	99
#30	
#40	94
#50	88
#100	69
#200	46.6

Moisture (M) & Density (D)	
M, %:	3.0
D, pcf:	

LL	27
PL	16
PI	11

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

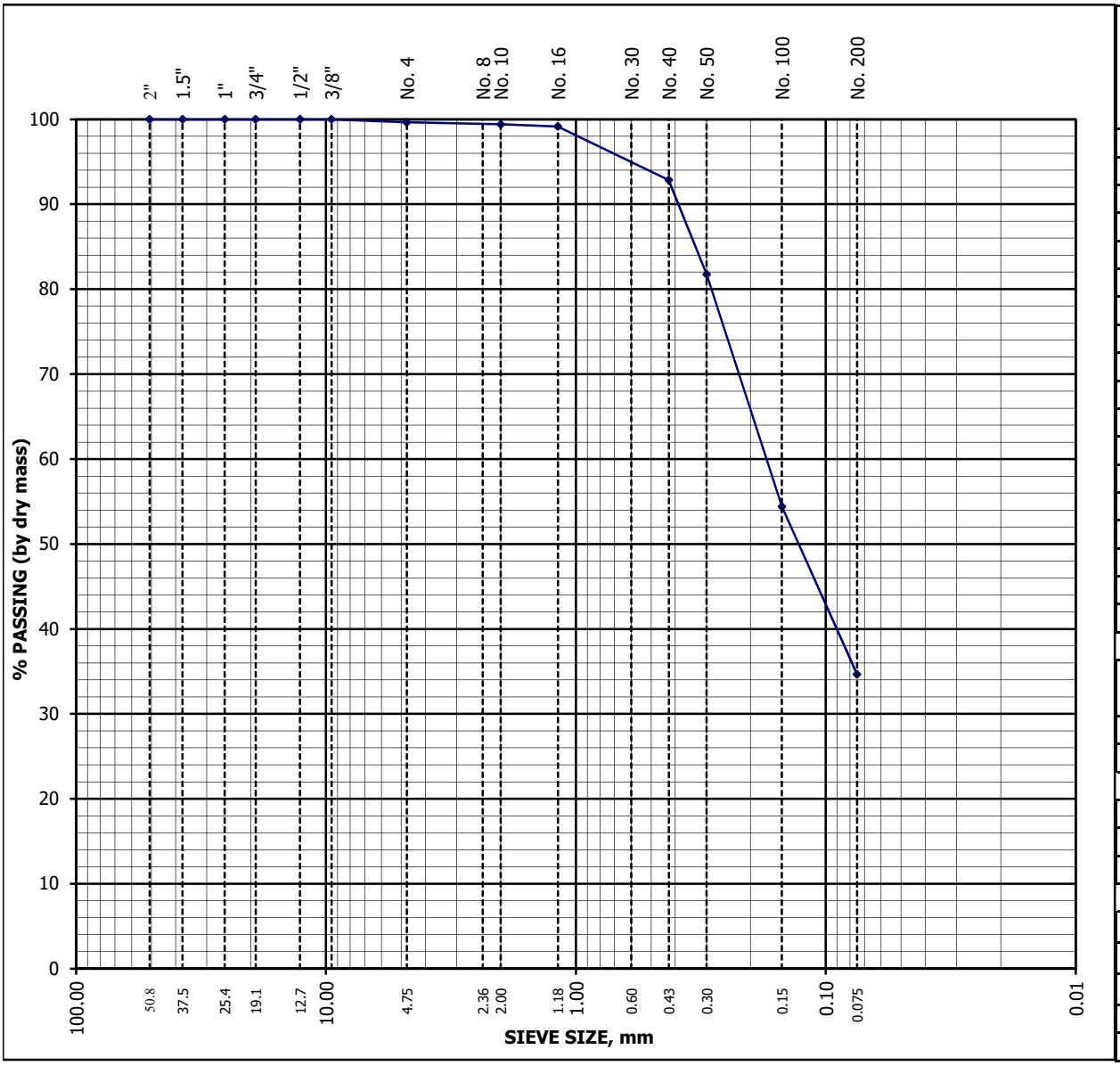
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	25-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822653	Reviewer:	J. Crystal
Sample Location:	BCP-2 at 2' to 10'		
Visual Description:	SAND, silty, clayey, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	99
#16	99
#30	
#40	93
#50	82
#100	54
#200	34.6

Moisture (M) & Density (D)	
M, %:	4.1
D, pcf:	

LL	23
PL	17
PI	6

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

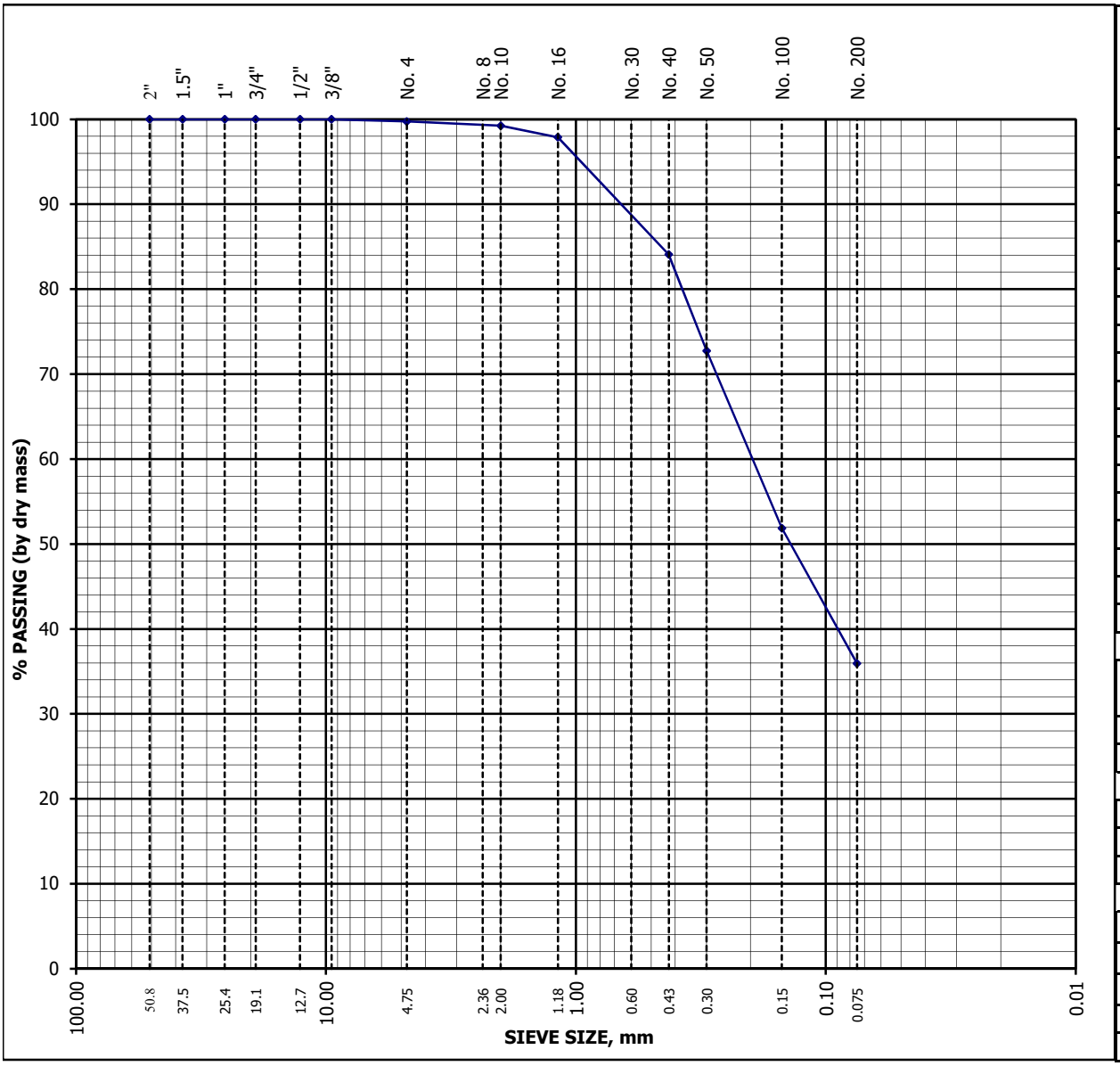
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	25-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822654	Reviewer:	J. Crystal
Sample Location:	BCP-4 at 2' to 8'		
Visual Description:	SAND, clayey, red brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC)** **Clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	99
#16	98
#30	
#40	84
#50	73
#100	52
#200	36.0

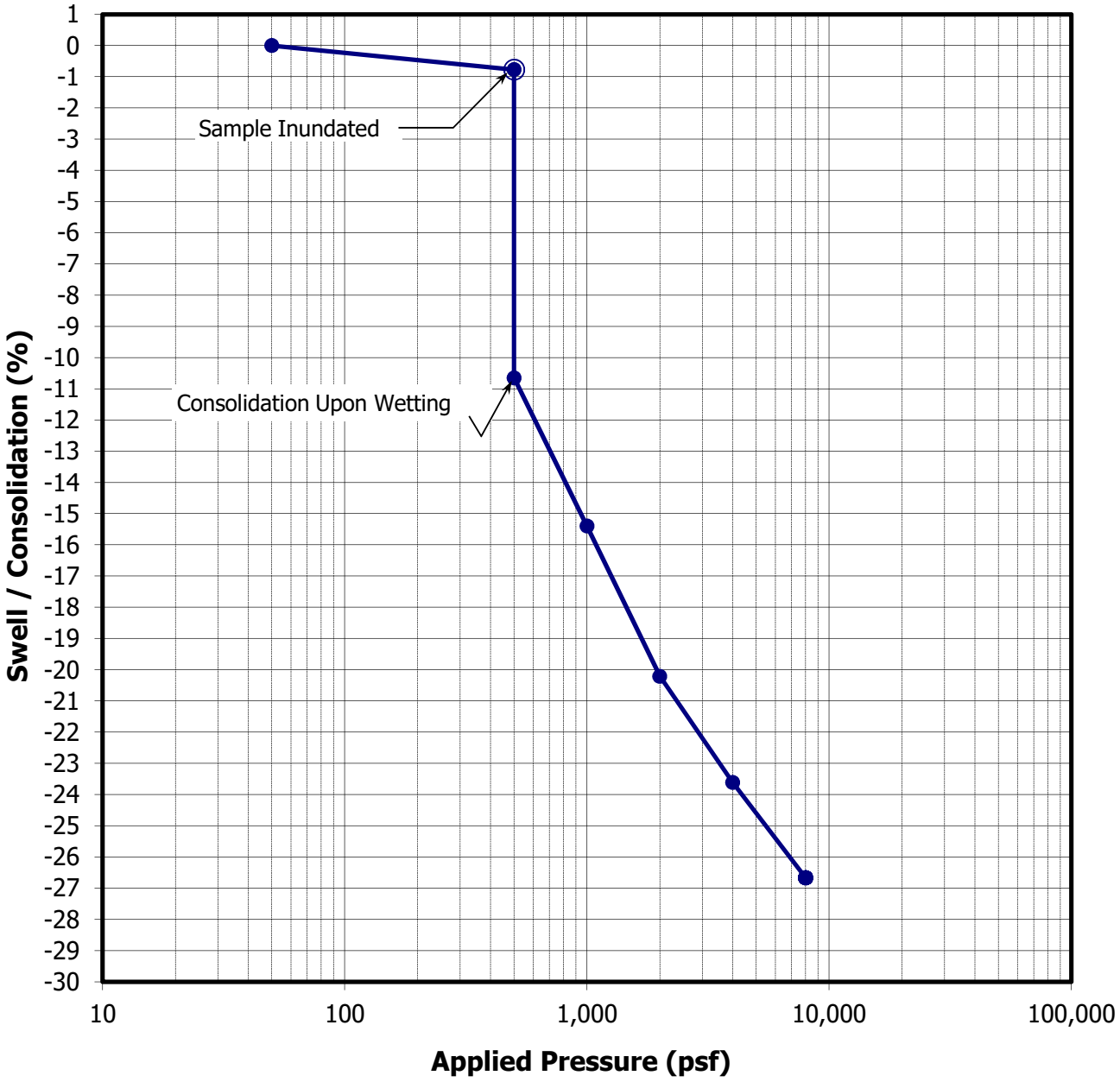
Moisture (M) & Density (D)	
M, %:	1.9
D, pcf:	

LL	25
PL	16
PI	9

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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SWELL/CONSOLIDATION PLOT



Sample Location	Sample Depth (feet)	Lab ID Number: 1822500 Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
BCP-5	0 to 8	CLAY, sandy, brown	82.8	5.1	500	-9.9	N/A

Client:	**Applegate Group**	**Project No.:**	**18.117**
Project:	**Cucharas Basin Collaborative Storage**	**Figure:**	**1822500**

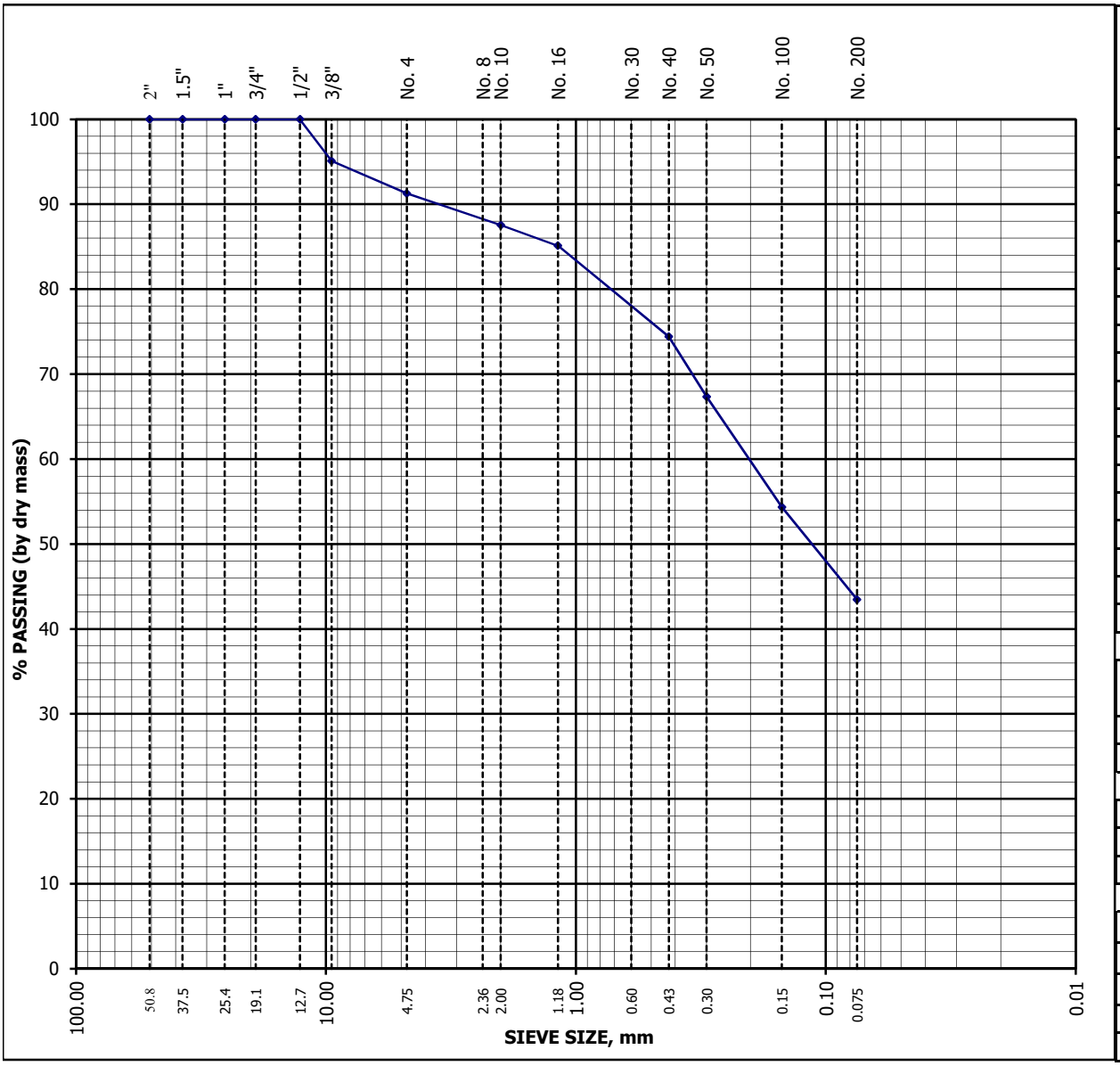
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	7-Oct-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	G. Hoyos
Lab ID Number:	1822655	Reviewer:	J. Crystal
Sample Location:	BCP-5 at 2' to 8'		
Visual Description:	SAND, clayey, reddish brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **2**

Unified Soil Classification System (ASTM D 2487): **(SC) Clayey Sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	100
3/8"	95
#4	91
#8	
#10	88
#16	85
#30	
#40	74
#50	67
#100	54
#200	43.5

Moisture (M) & Density (D)	
M, %:	11.8
D, pcf:	

LL	29
PL	17
PI	12

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

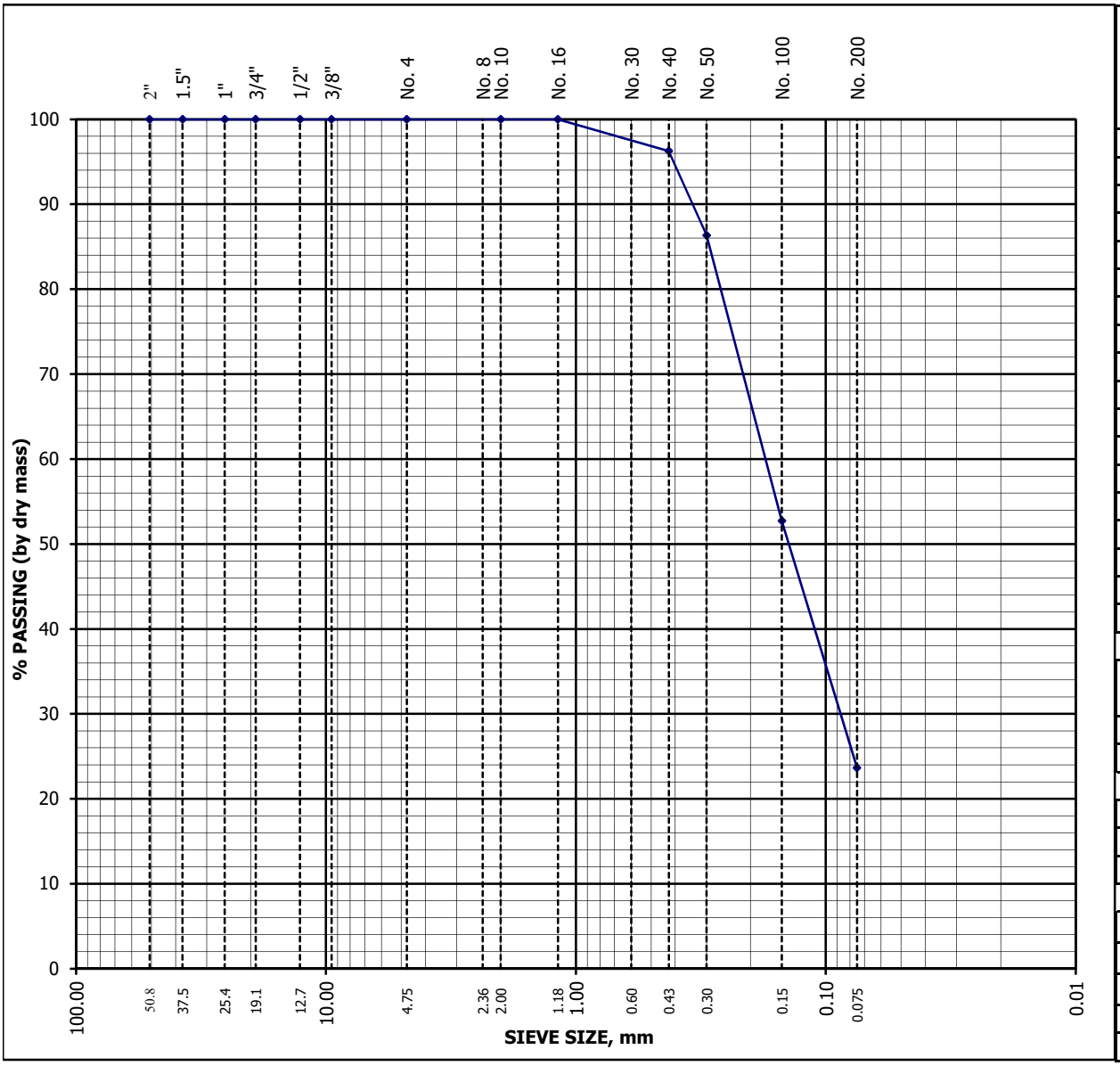
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	6-Oct-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822656	Reviewer:	J. Crystal
Sample Location:	BCP-6 at 7' to 9'		
Visual Description:	SAND, silty, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(SM)** **Silty sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	
#8	
#10	
#16	100
#30	
#40	96
#50	86
#100	53
#200	23.6

Moisture (M) & Density (D)	
M, %:	4.1
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

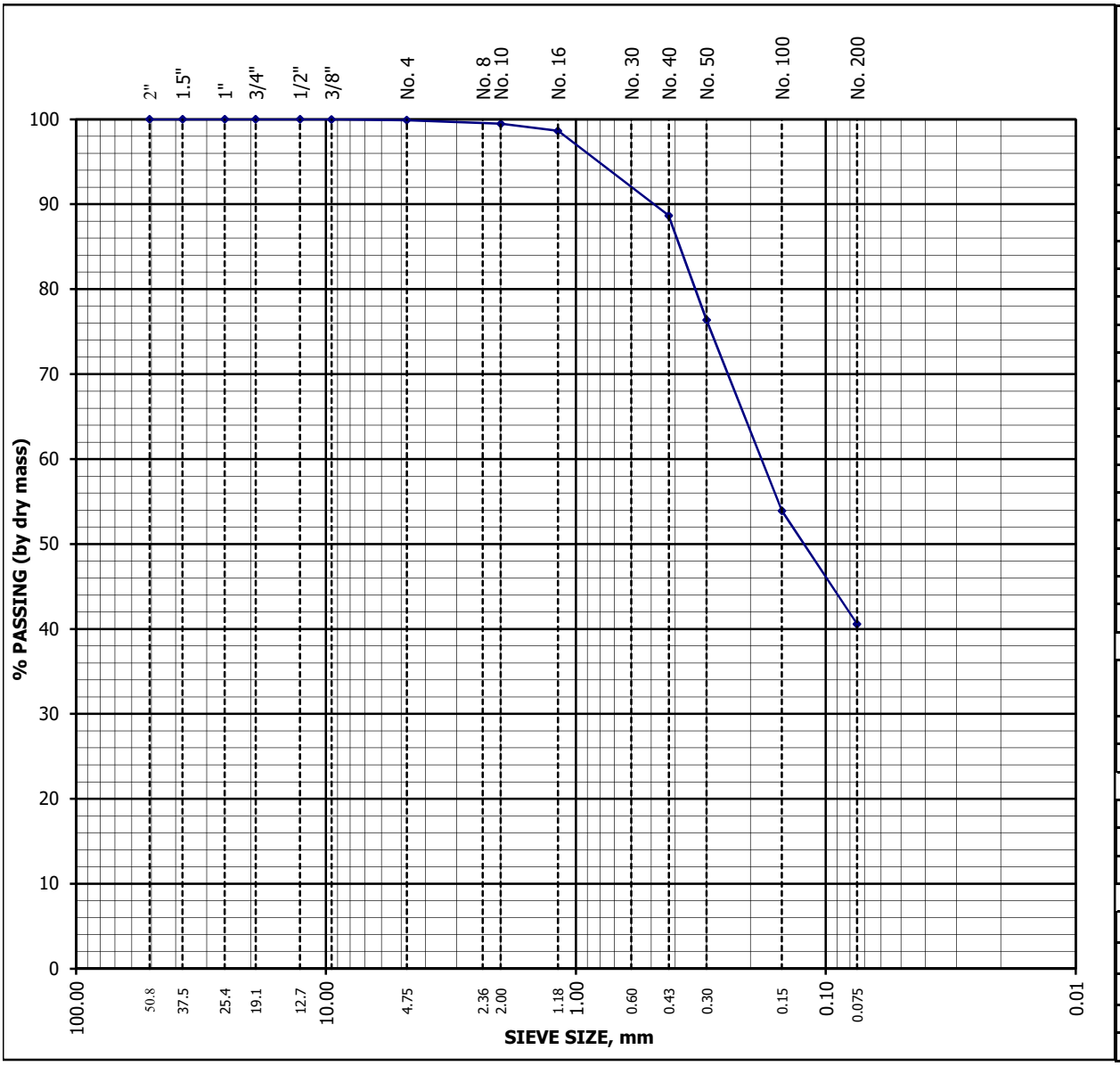
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822895	Reviewer:	J. Crystal
Sample Location:	LVL-1 at 15'		
Visual Description:	SAND, silty, clayey, brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	99
#16	99
#30	
#40	89
#50	76
#100	54
#200	40.6

Moisture (M) & Density (D)	
M, %:	10.7
D, pcf:	

LL	24
PL	19
PI	5

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

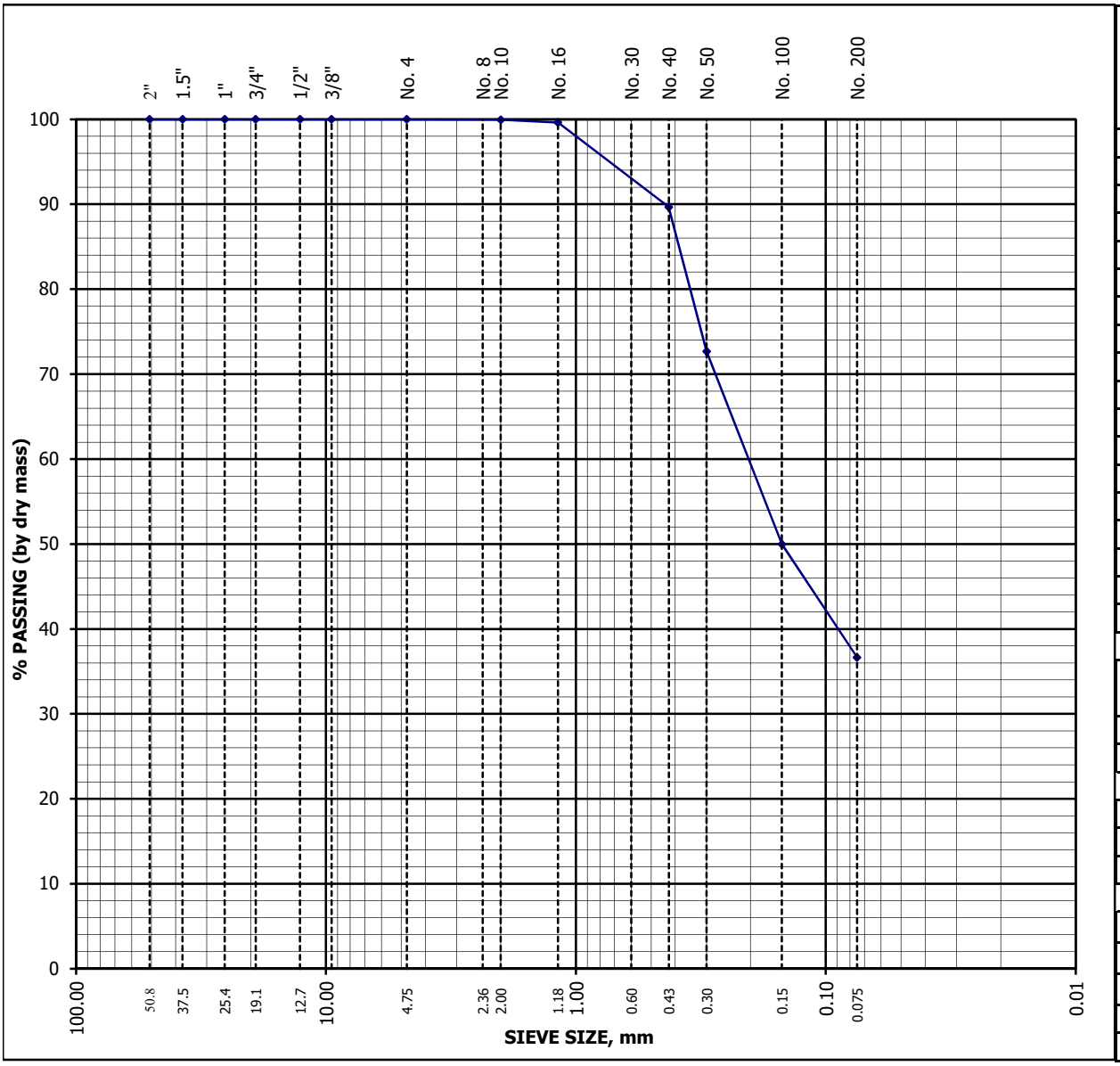
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822896	Reviewer:	J. Crystal
Sample Location:	LVL-4 at 9'		
Visual Description:	SAND, clay, silty, reddish brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	100
#30	
#40	90
#50	73
#100	50
#200	36.7

Moisture (M) & Density (D)	
M, %:	16.1
D, pcf:	

LL	23
PL	17
PI	6

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

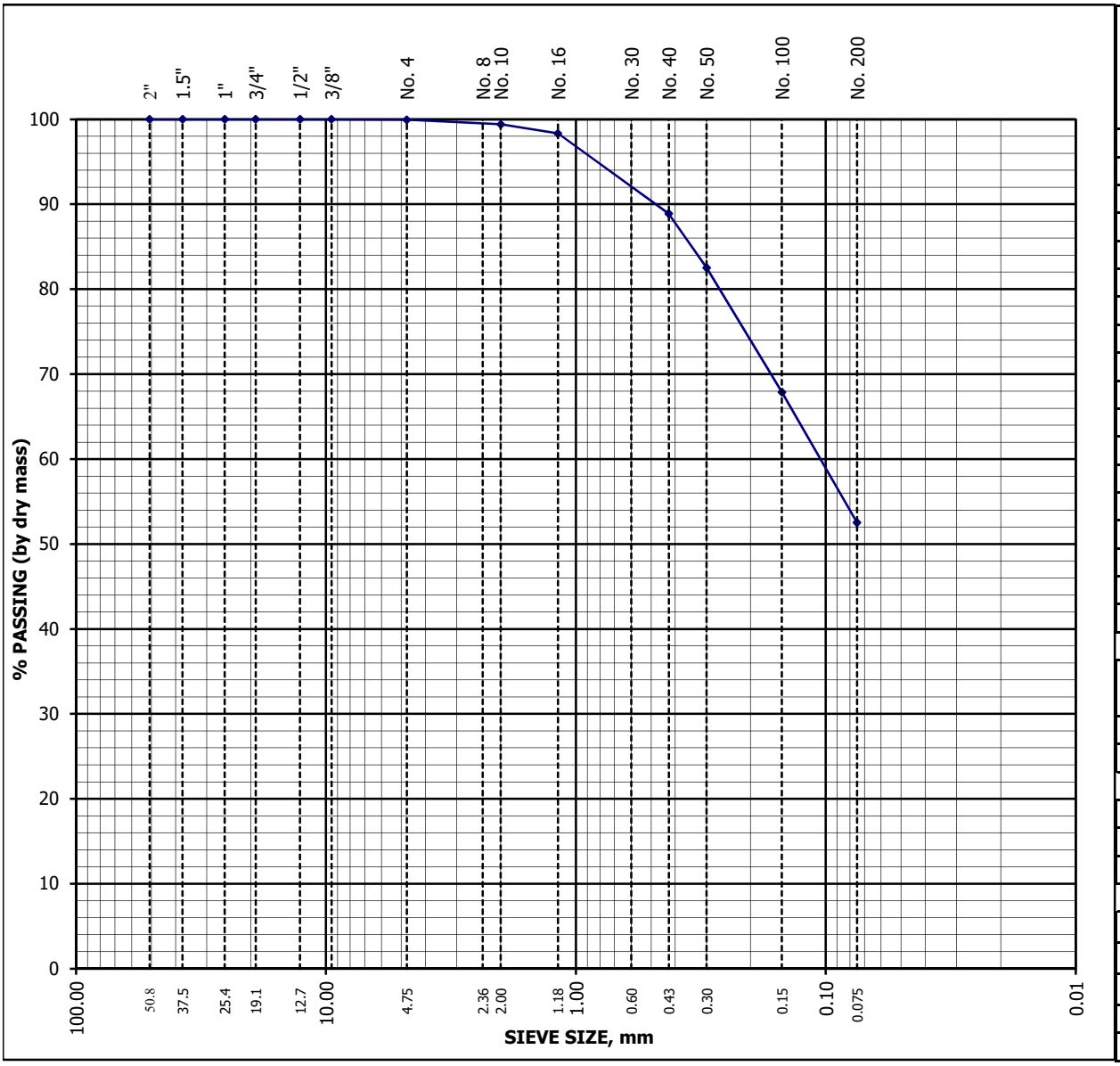
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822897	Reviewer:	J. Crystal
Sample Location:	LVL-5 at 5'		
Visual Description:	CLAY, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **7**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	99
#16	98
#30	
#40	89
#50	83
#100	68
#200	52.5

Moisture (M) & Density (D)	
M, %:	14.0
D, pcf:	

LL	37
PL	17
PI	20

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

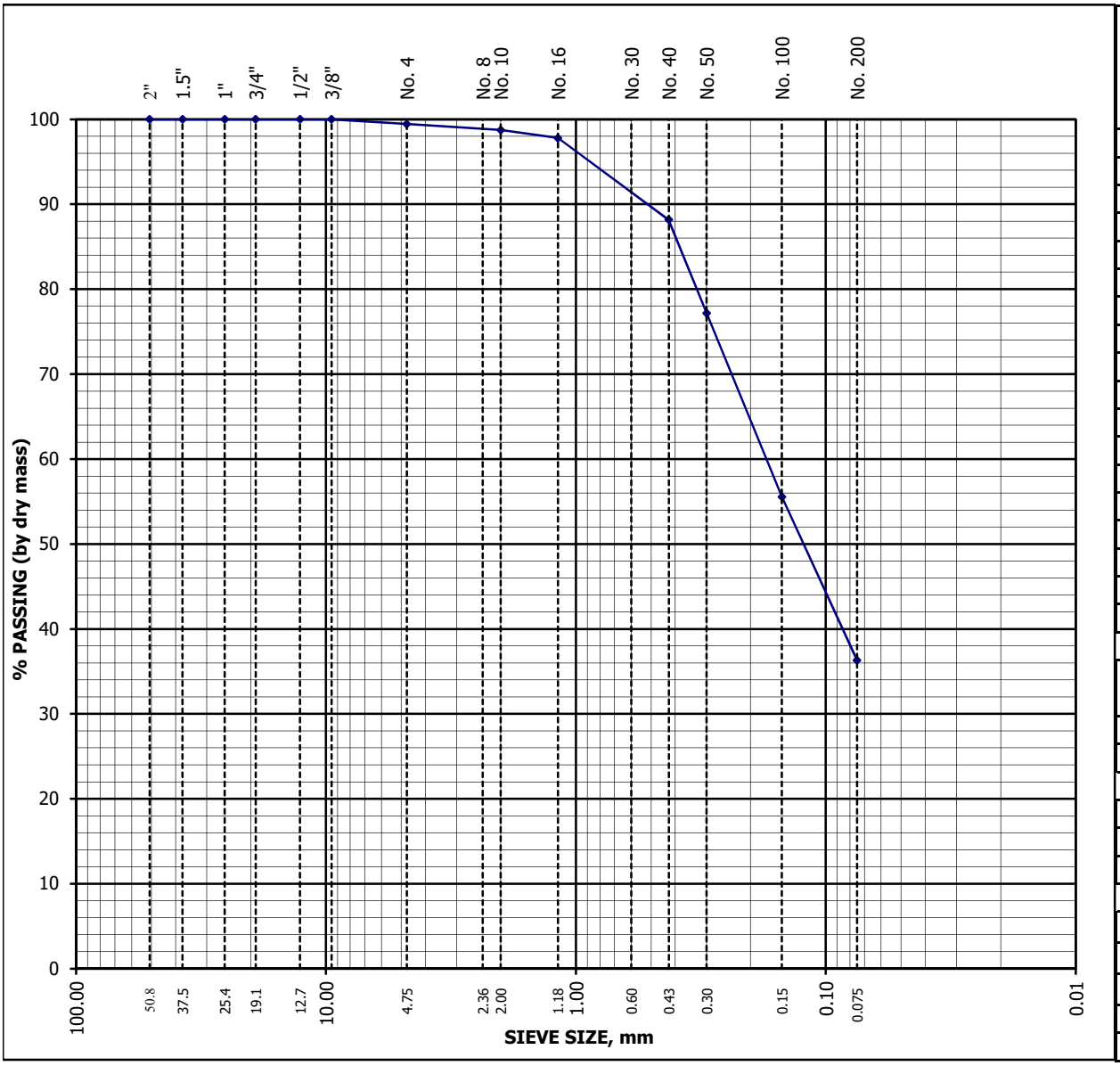
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822898	Reviewer:	J. Crystal
Sample Location:	LVL-7 at 4'		
Visual Description:	SAND, silty, clayey, brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	99
#8	
#10	99
#16	98
#30	
#40	88
#50	77
#100	56
#200	36.3

Moisture (M) & Density (D)	
M, %:	4.3
D, pcf:	

LL	19
PL	14
PI	5

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

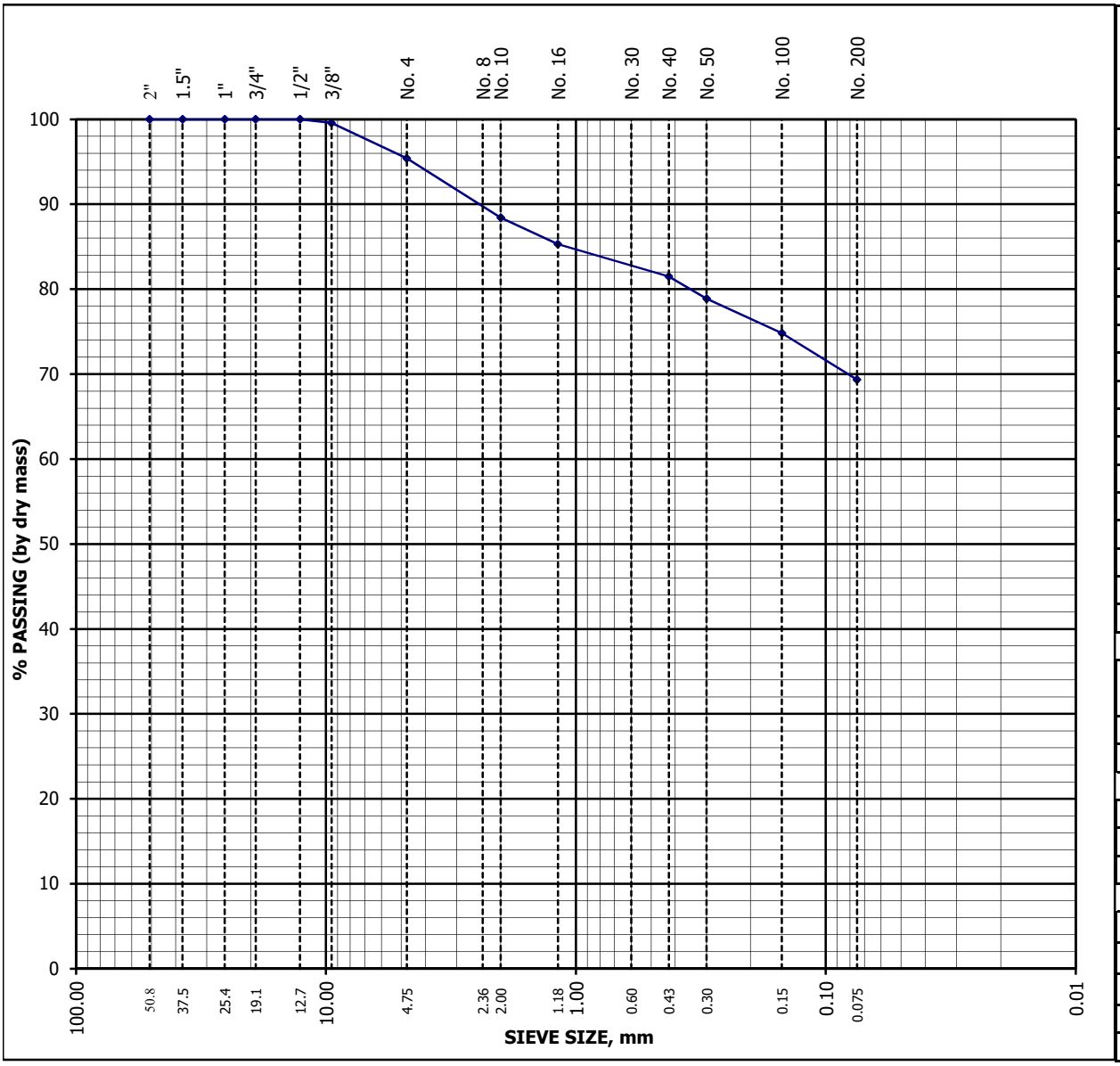
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822877	Reviewer:	J. Crystal
Sample Location:	MS-1 at 10'		
Visual Description:	CLAY, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **7**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	100
3/8"	100
#4	95
#8	
#10	88
#16	85
#30	
#40	82
#50	79
#100	75
#200	69.4

Moisture (M) & Density (D)	
M, %:	9.6
D, pcf:	

LL	30
PL	16
PI	14

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

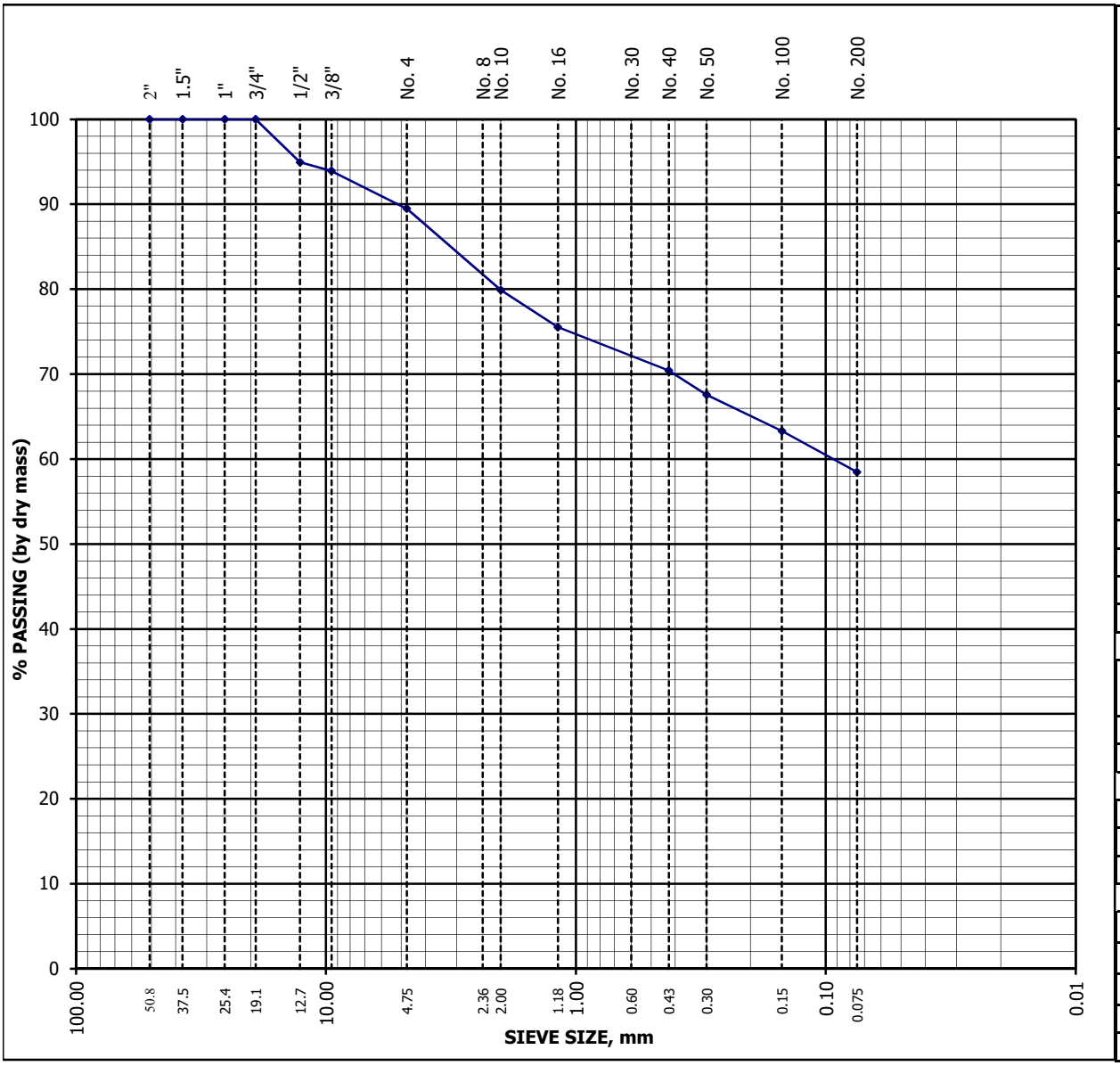
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822878	Reviewer:	J. Crystal
Sample Location:	MS-1 at 20'		
Visual Description:	CLAY, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **6**

Unified Soil Classification System (ASTM D 2487): **(CL) Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	100
1/2"	95
3/8"	94
#4	89
#8	
#10	80
#16	76
#30	
#40	70
#50	68
#100	63
#200	58.5

Moisture (M) & Density (D)	
M, %:	7.4
D, pcf:	

LL	31
PL	15
PI	16

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

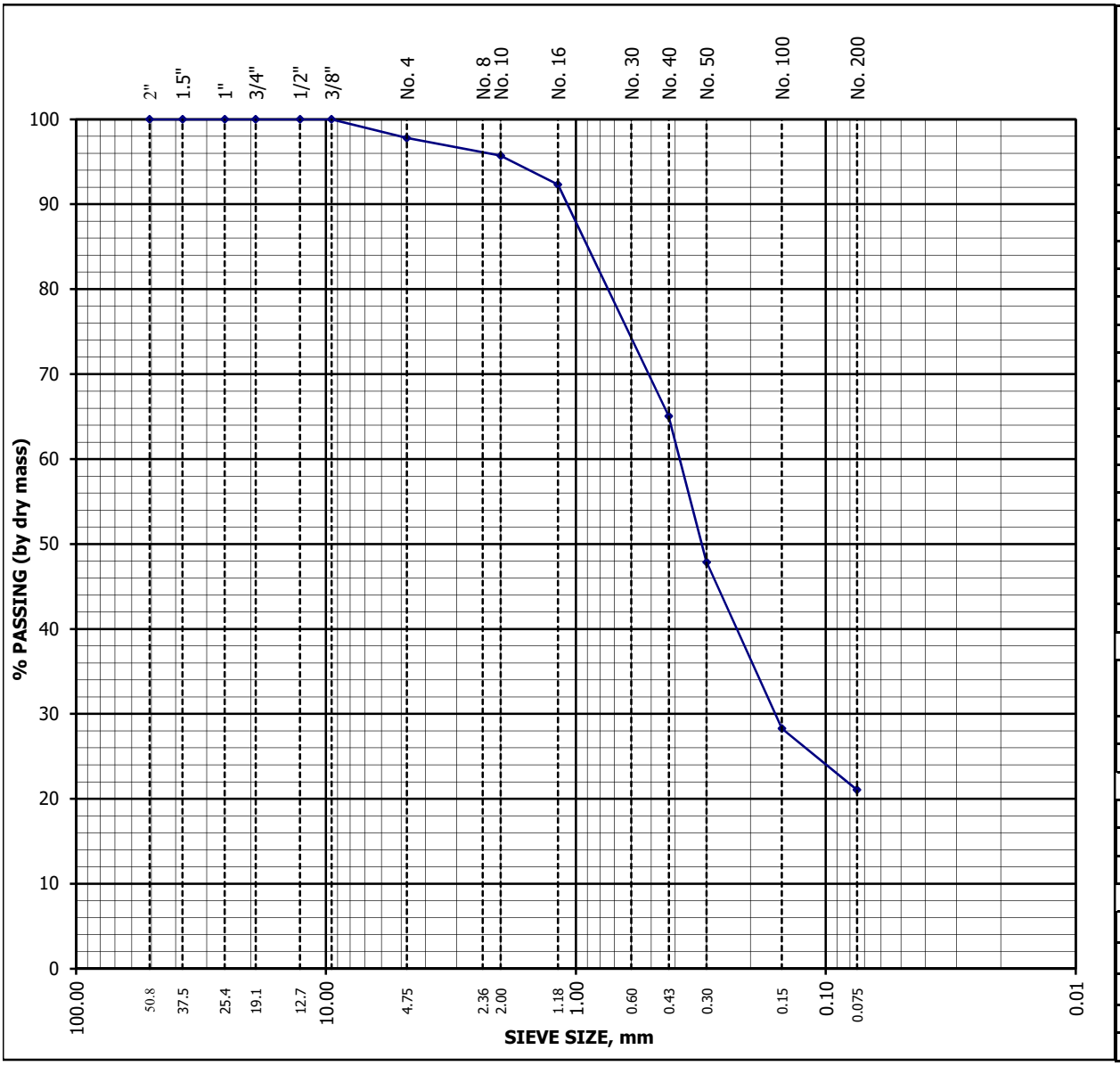
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822879	Reviewer:	J. Crystal
Sample Location:	MS-2 at 10'		
Visual Description:	SAND, silty, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(SM) Silty sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	98
#8	
#10	96
#16	92
#30	
#40	65
#50	48
#100	28
#200	21.1

Moisture (M) & Density (D)	
M, %:	7.8
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

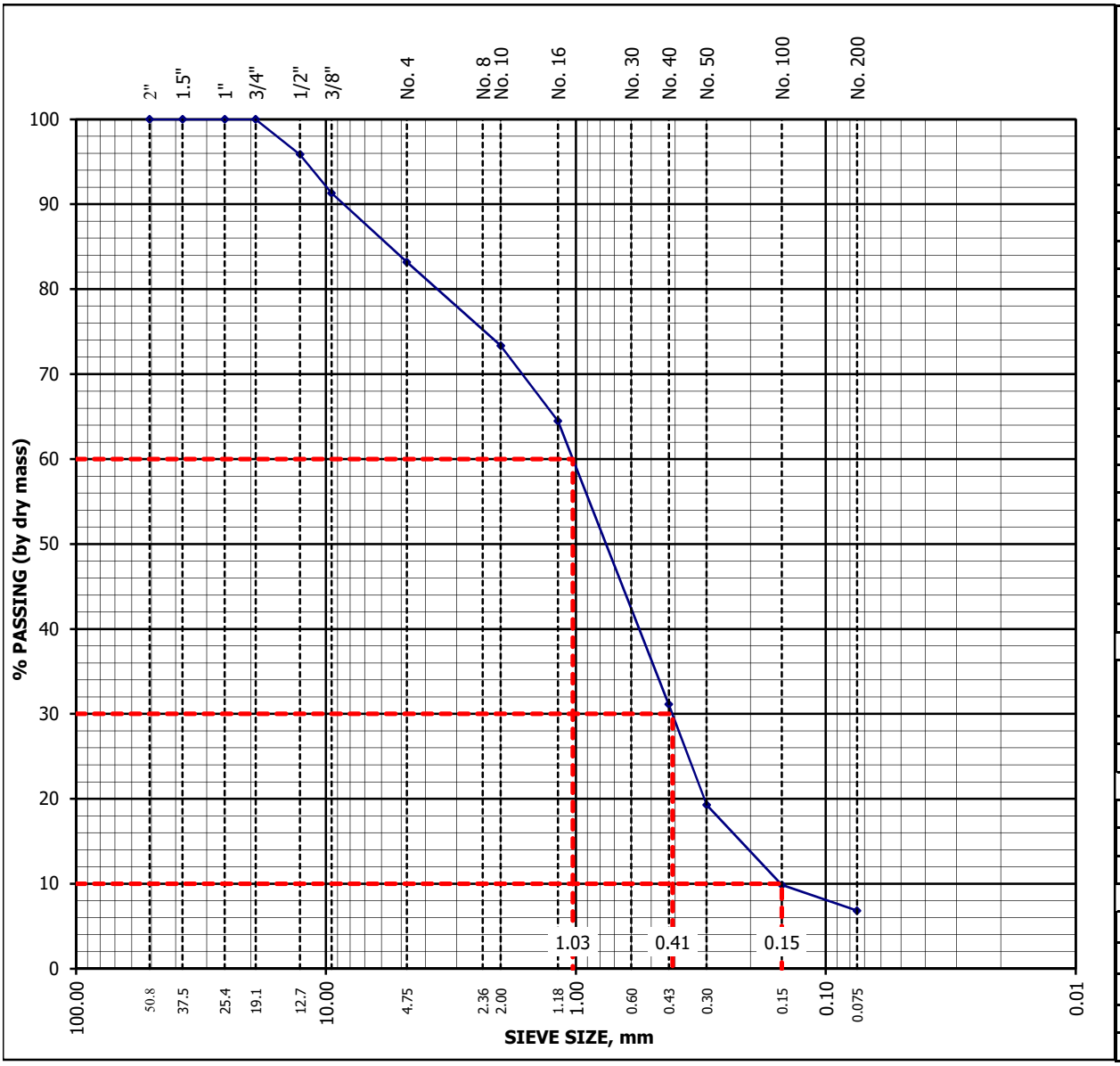
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822880	Reviewer:	J. Crystal
Sample Location:	MS-2 at 20'		
Visual Description:	SAND, with silt and gravel, brown		

AASHTO M 145 Classification: **A-1-b** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(SW-SM) Well-graded sand with silt and gravel**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	100
1/2"	96
3/8"	91
#4	83
#8	
#10	73
#16	64
#30	
#40	31
#50	19
#100	10
#200	6.8

Moisture (M) & Density (D)	
M, %:	16.5
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	1.03
D_{30}	0.41
D_{10}	0.15
Cu	**6.87**
Cc	**1.09**

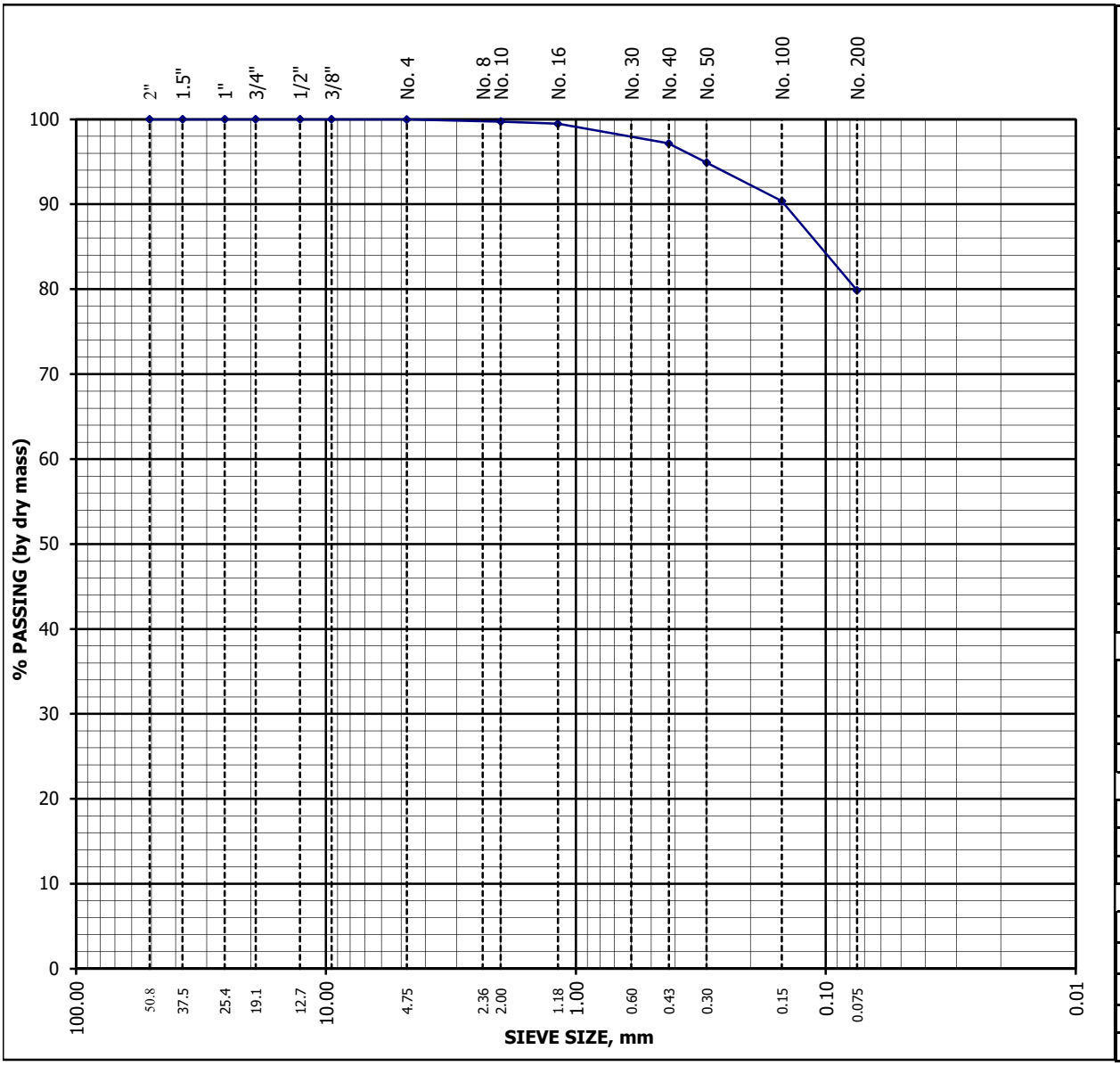
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822881	Reviewer:	J. Crystal
Sample Location:	MS-3 at 5'		
Visual Description:	CLAY, with sand, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **15**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Lean clay with sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	99
#30	
#40	97
#50	95
#100	90
#200	79.9

Moisture (M) & Density (D)	
M, %:	24.5
D, pcf:	

LL	39
PL	19
PI	20

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

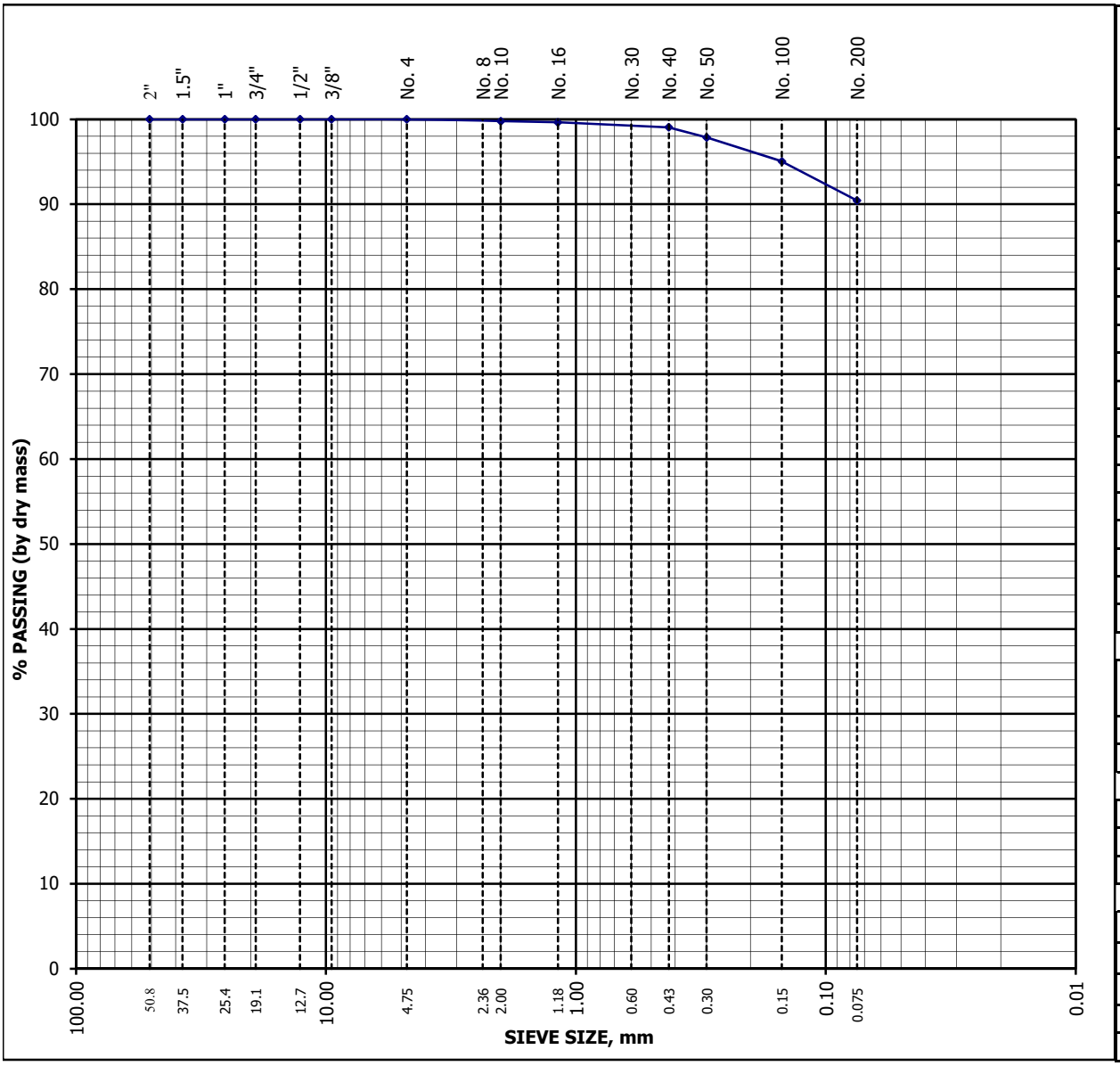
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822882	Reviewer:	J. Crystal
Sample Location:	MS-4 at 10'		
Visual Description:	CLAY, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **17**

Unified Soil Classification System (ASTM D 2487): **(CL) Lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	100
#30	
#40	99
#50	98
#100	95
#200	90.4

Moisture (M) & Density (D)	
M, %:	11.8
D, pcf:	

LL	35
PL	15
PI	20

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

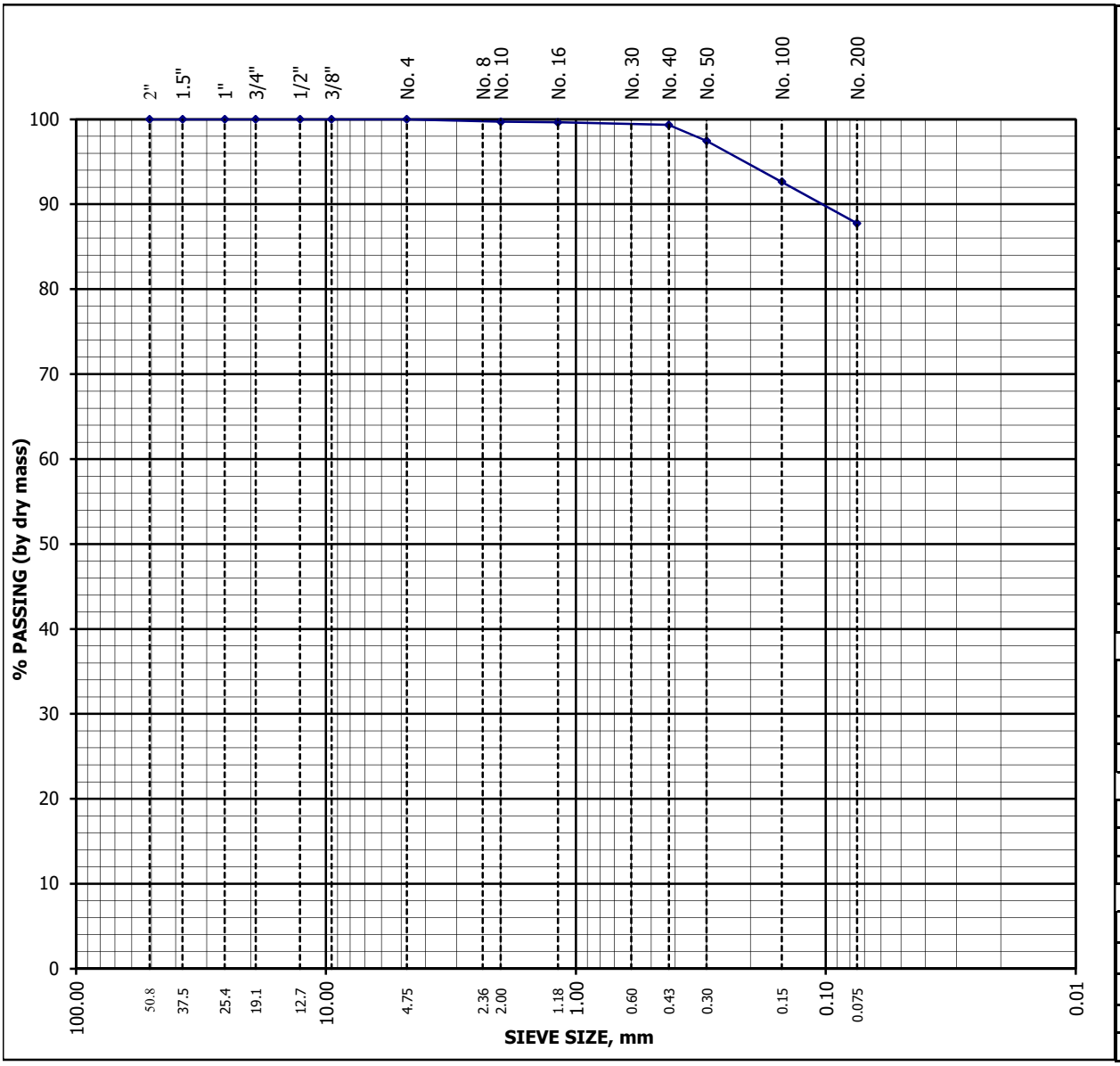
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822883	Reviewer:	J. Crystal
Sample Location:	MS-5 at 10'		
Visual Description:	CLAY, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **14**

Unified Soil Classification System (ASTM D 2487): **(CL) Lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	100
#30	
#40	99
#50	97
#100	93
#200	87.8

Moisture (M) & Density (D)	
M, %:	12.3
D, pcf:	

LL	35
PL	18
PI	17

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

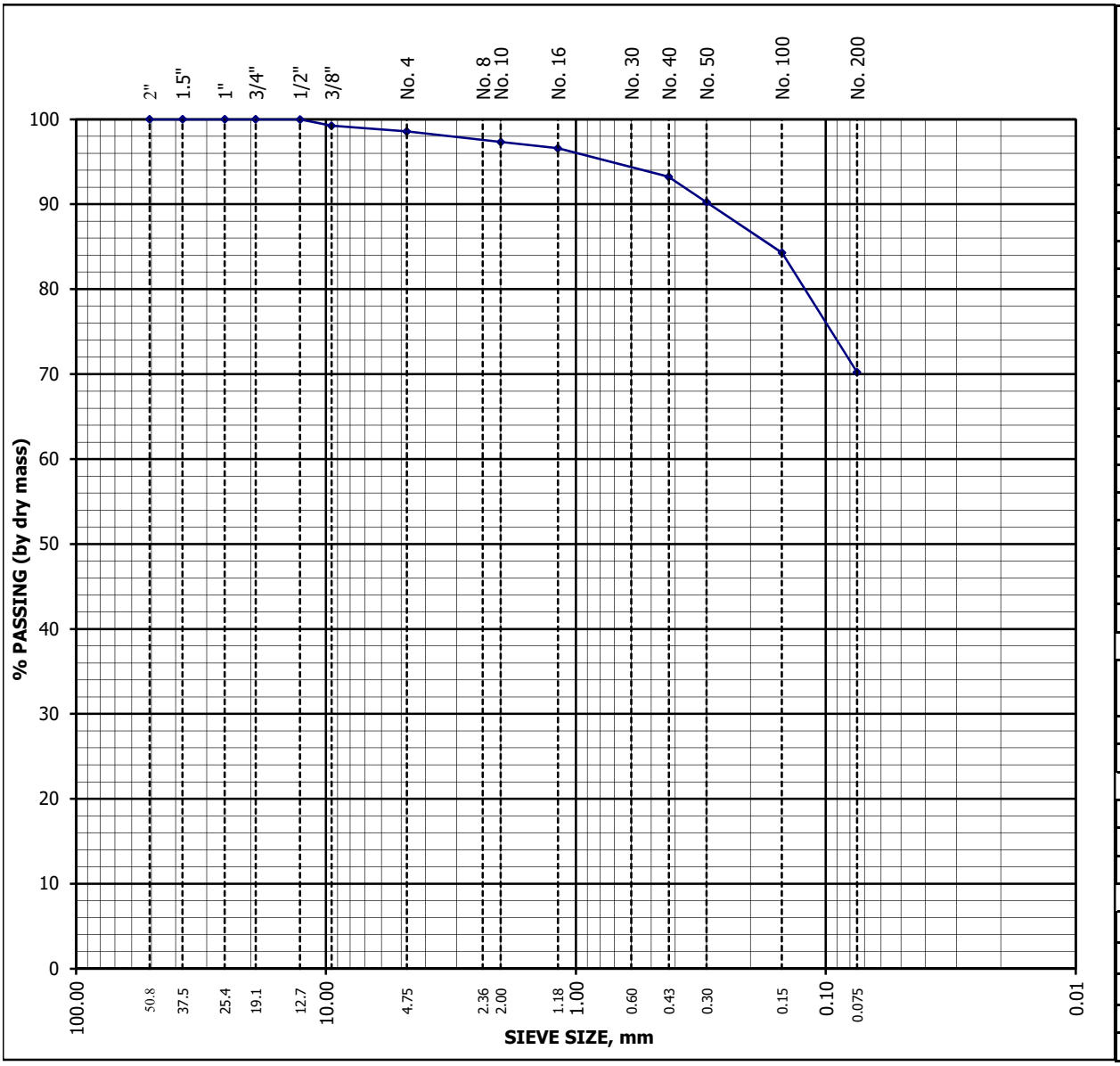
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822884	Reviewer:	J. Crystal
Sample Location:	MS-6 at 10'		
Visual Description:	CLAY, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **8**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	100
3/8"	99
#4	99
#8	
#10	97
#16	97
#30	
#40	93
#50	90
#100	84
#200	70.2

Moisture (M) & Density (D)	
M, %:	18.2
D, pcf:	

LL	32
PL	17
PI	15

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

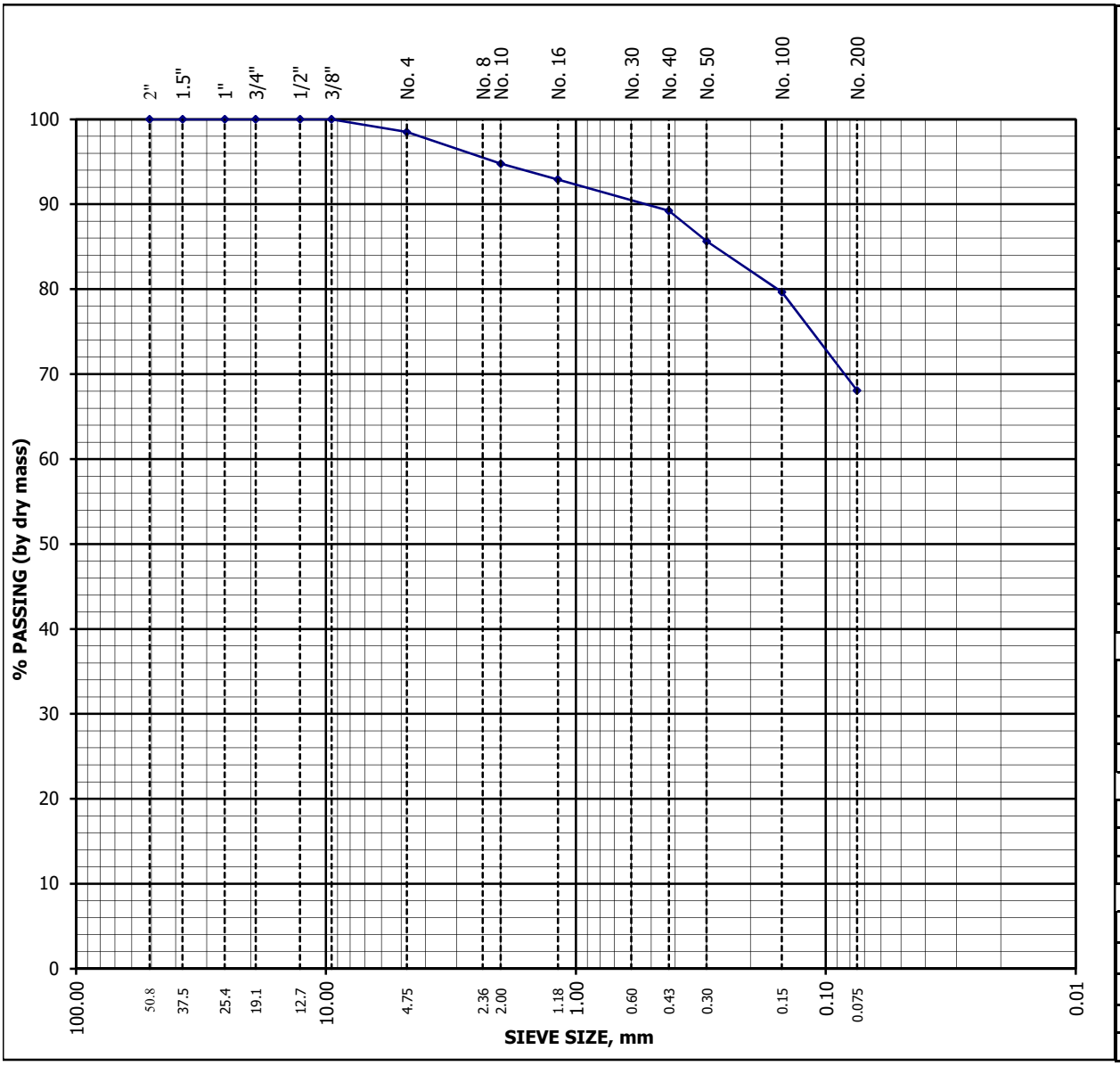
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822885	Reviewer:	J. Crystal
Sample Location:	MS-6 at 25'		
Visual Description:	CLAY, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **5**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	99
#8	
#10	95
#16	93
#30	
#40	89
#50	86
#100	80
#200	68.1

Moisture (M) & Density (D)	
M, %:	14.4
D, pcf:	

LL	30
PL	19
PI	11

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

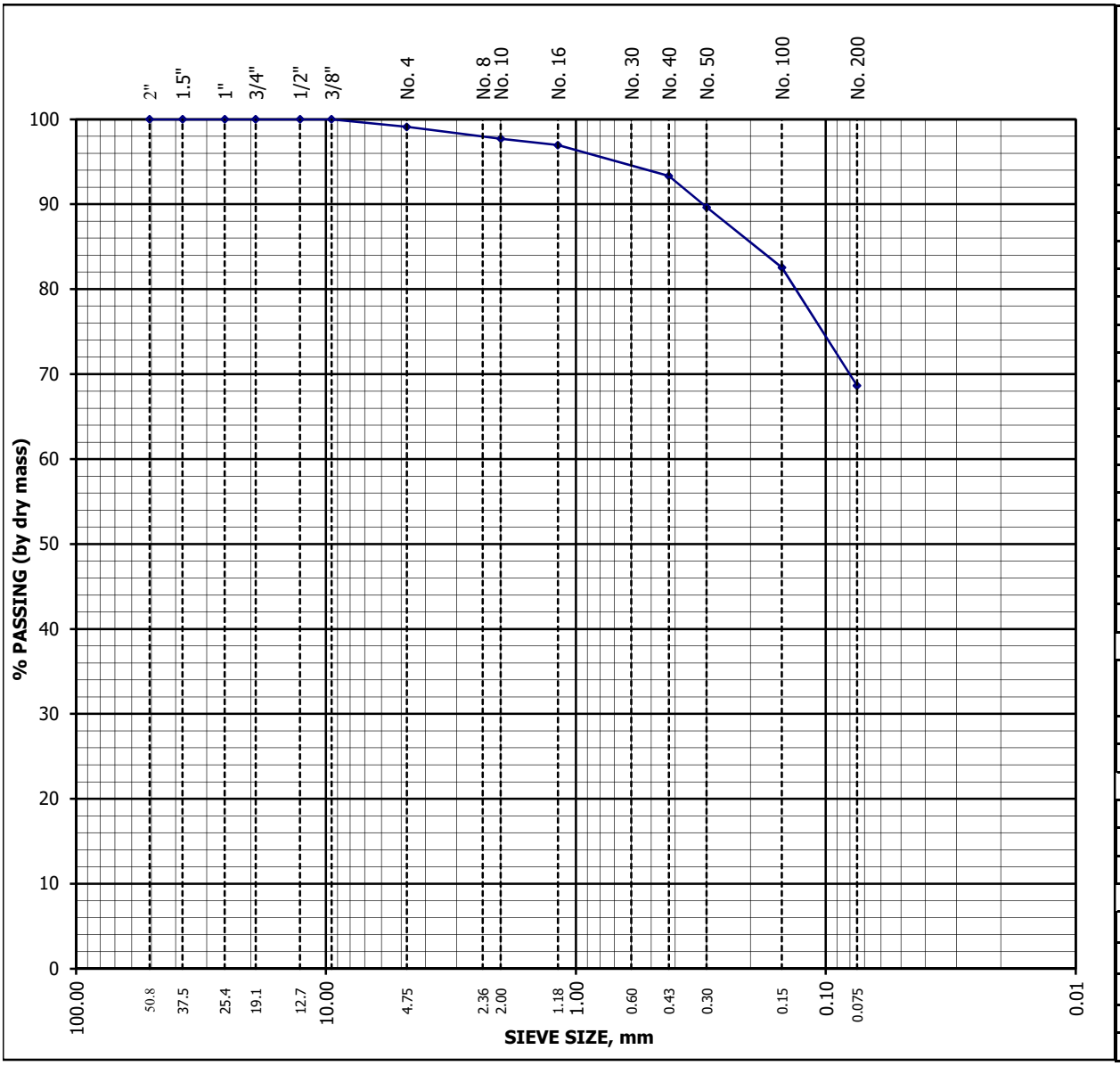
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	21-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822641	Reviewer:	J. Crystal
Sample Location:	MSP-2 at 1' to 3'		
Visual Description:	CLAY, sandy, light brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **8**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	99
#8	
#10	98
#16	97
#30	
#40	93
#50	90
#100	83
#200	68.6

Moisture (M) & Density (D)	
M, %:	6.4
D, pcf:	

LL	36
PL	23
PI	13

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

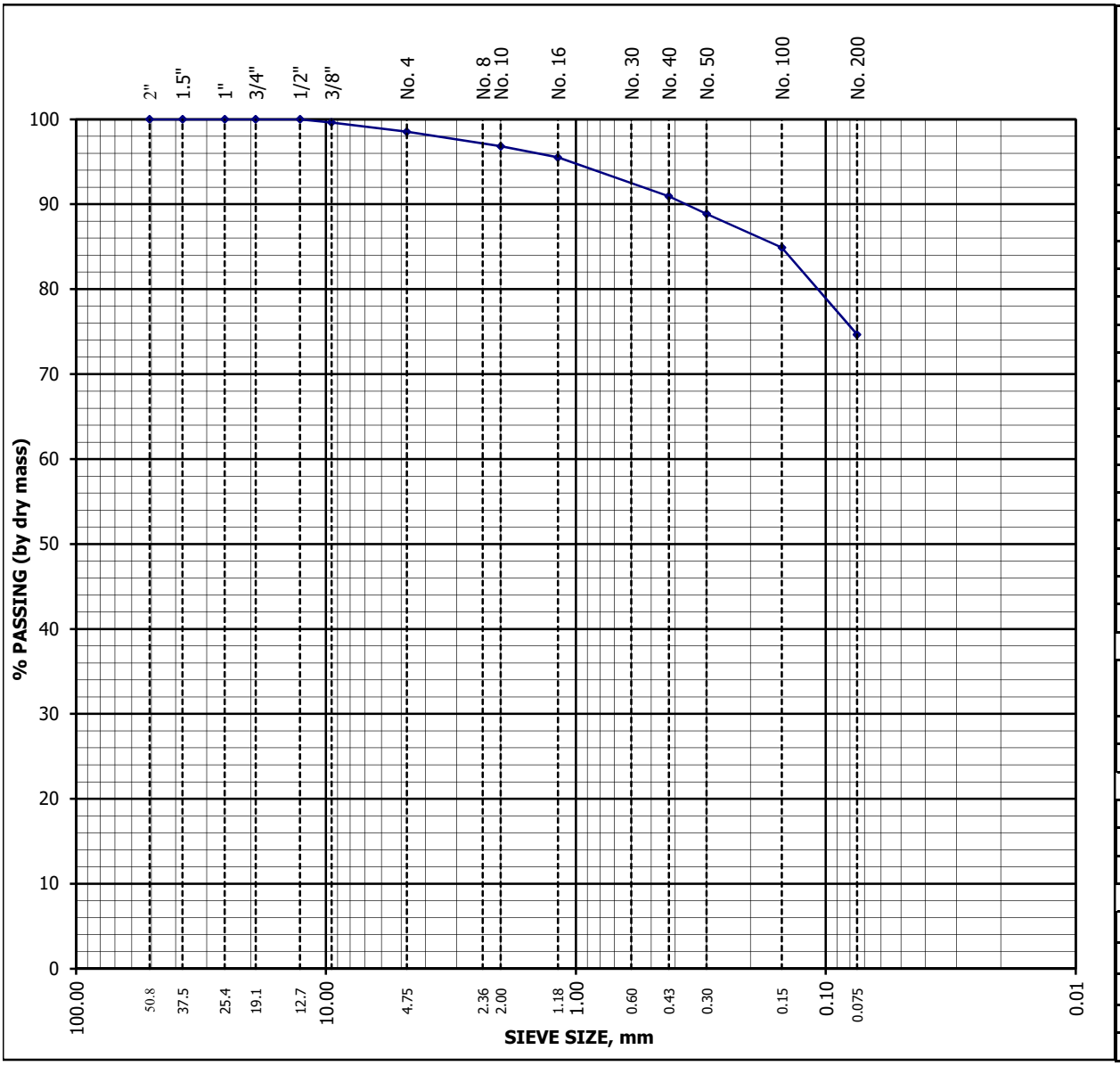
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	7-Oct-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	G. Hoyos
Lab ID Number:	1822642	Reviewer:	J. Crystal
Sample Location:	MSP-4 at 1' to 4'		
Visual Description:	CLAY, with sand, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **11**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Lean clay with sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	100
3/8"	100
#4	99
#8	
#10	97
#16	96
#30	
#40	91
#50	89
#100	85
#200	74.7

Moisture (M) & Density (D)	
M, %:	5.3
D, pcf:	

LL	37
PL	21
PI	16

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

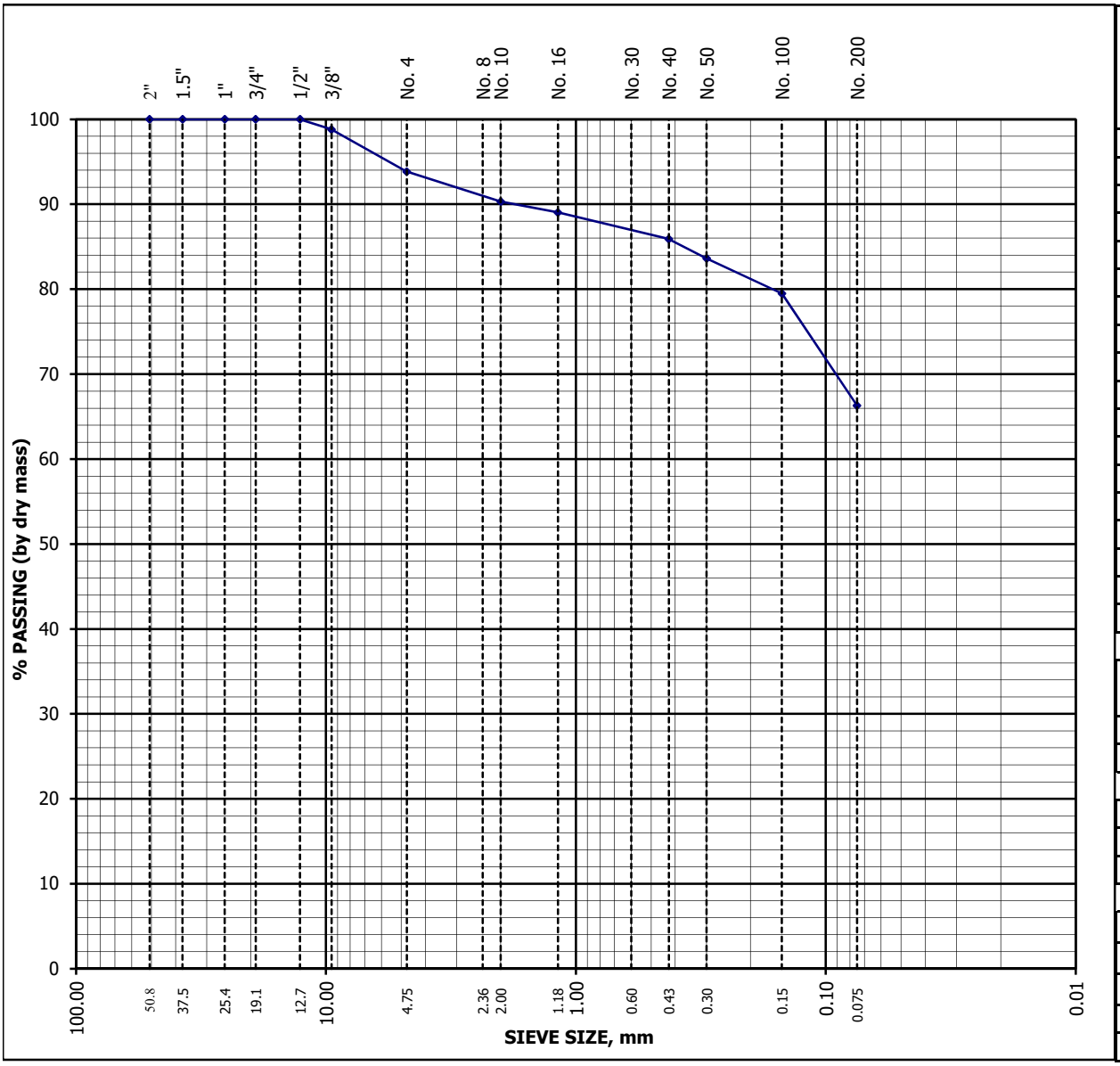
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	21-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822643	Reviewer:	J. Crystal
Sample Location:	MSP-5 at 1' to 4'		
Visual Description:	CLAY, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **10**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	100
3/8"	99
#4	94
#8	
#10	90
#16	89
#30	
#40	86
#50	84
#100	79
#200	66.3

Moisture (M) & Density (D)	
M, %:	5.7
D, pcf:	

LL	35
PL	16
PI	19

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

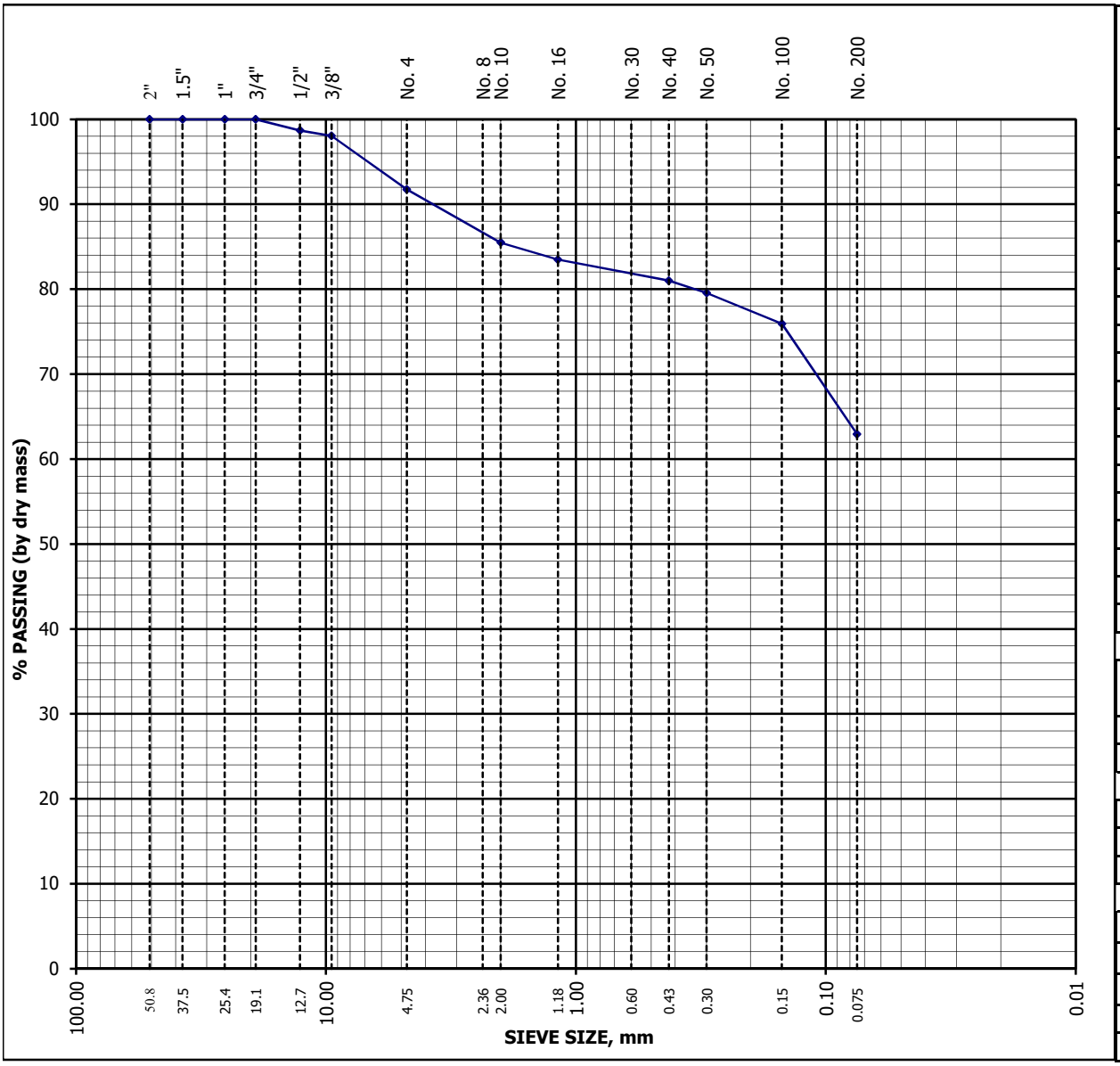
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	21-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822644	Reviewer:	J. Crystal
Sample Location:	MSP-5 at 4' to 7'		
Visual Description:	CLAYSTONE, sandy, brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **7**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	100
1/2"	99
3/8"	98
#4	92
#8	
#10	85
#16	83
#30	
#40	81
#50	80
#100	76
#200	62.9

Moisture (M) & Density (D)	
M, %:	3.6
D, pcf:	

LL	33
PL	17
PI	16

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

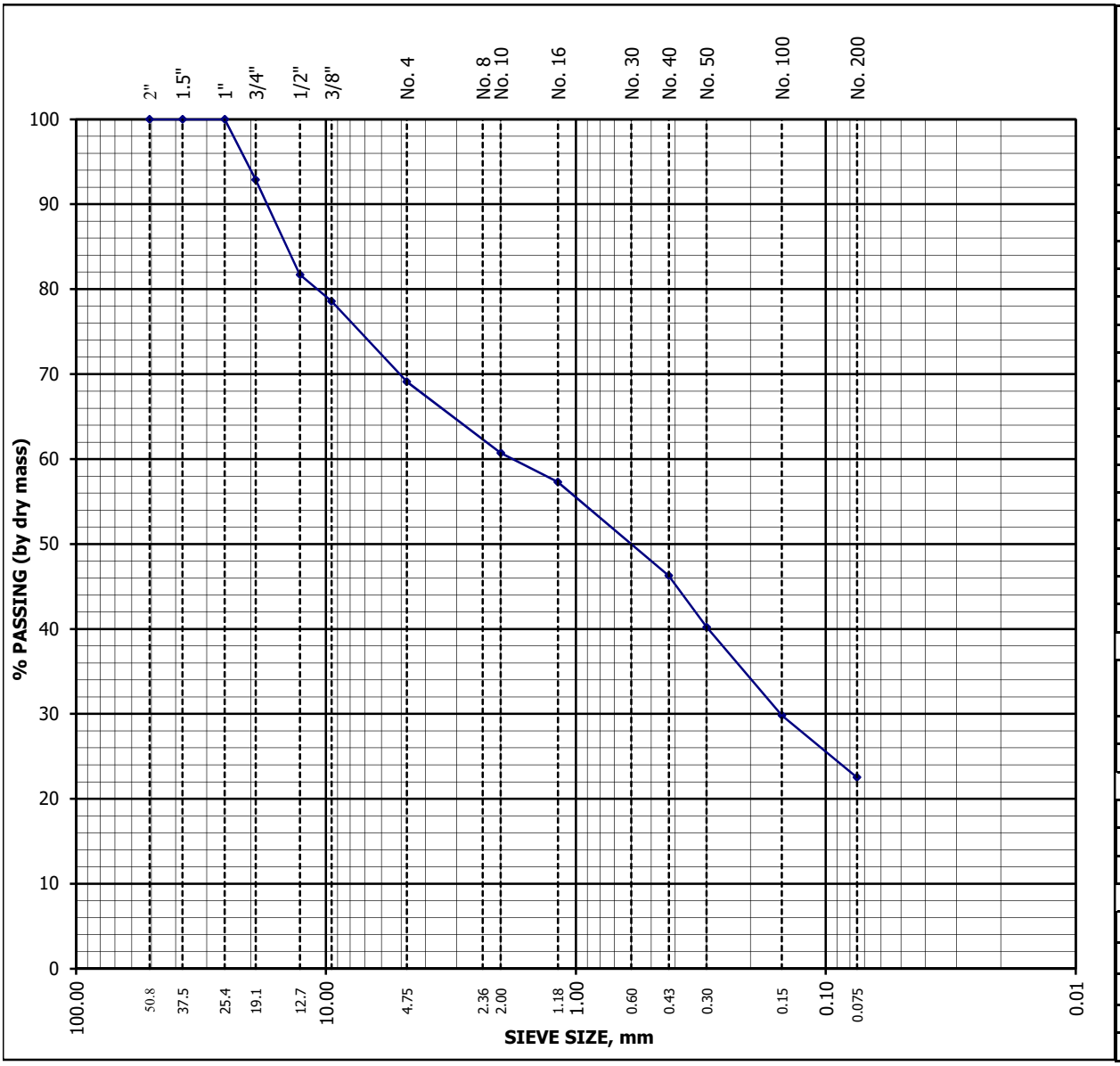
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	12-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	G. Hoyos
Lab ID Number:	1822886	Reviewer:	J. Crystal
Sample Location:	SB-1 at 5'		
Visual Description:	SAND, silty, with gravel, red		

AASHTO M 145 Classification: **A-1-b** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SM)** **Silty sand with gravel**



Sieve Size	% Passing
2"	
1.5"	
1"	100
3/4"	93
1/2"	82
3/8"	79
#4	69
#8	
#10	61
#16	57
#30	
#40	46
#50	40
#100	30
#200	22.5

Moisture (M) & Density (D)	
M, %:	7.6
D, pcf:	

LL	19
PL	17
PI	2

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

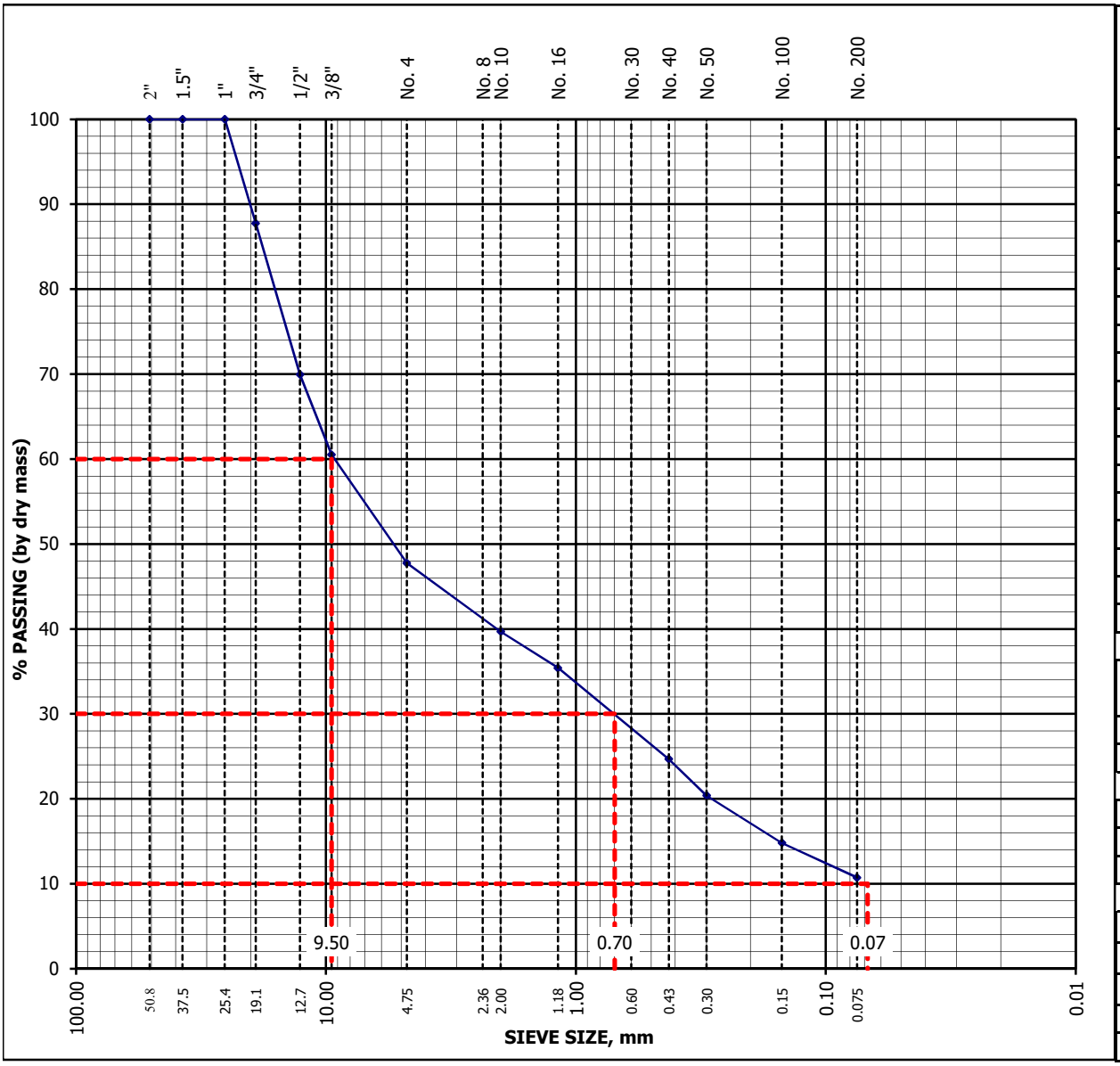
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822887	Reviewer:	J. Crystal
Sample Location:	SB-1 at 12.5'		
Visual Description:	Gravel, with silt, with sand, pink		

AASHTO M 145 Classification: **A-1-b** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(GP-GM) Poorly graded gravel with silt and sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	88
1/2"	70
3/8"	61
#4	48
#8	
#10	40
#16	35
#30	
#40	25
#50	20
#100	15
#200	10.7

Moisture (M) & Density (D)	
M, %:	0.3
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	9.50
D_{30}	0.70
D_{10}	0.07
Cu	**139.71**
Cc	**0.76**

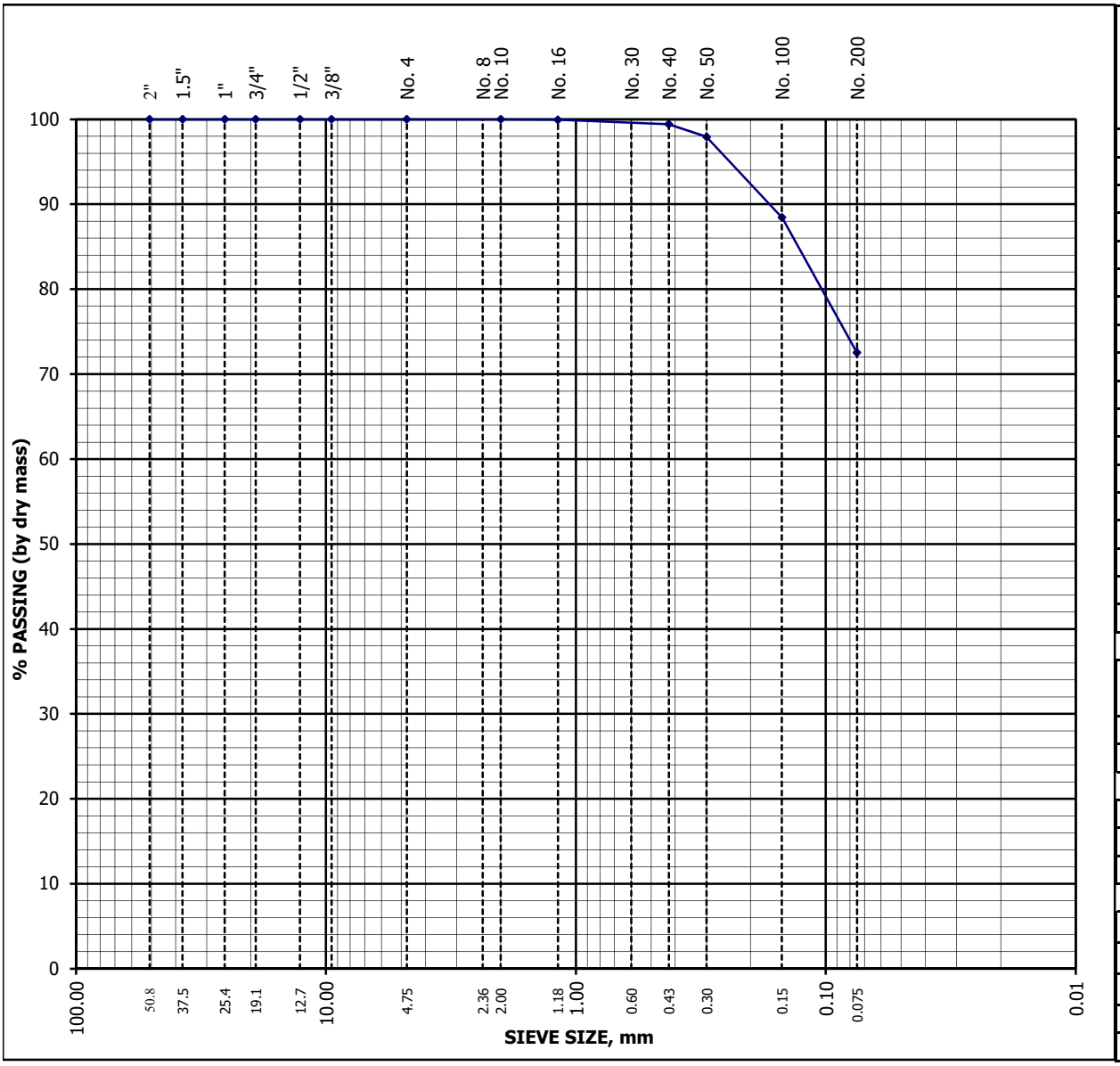
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	8-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822888	Reviewer:	J. Crystal
Sample Location:	SB-1 at 20'		
Visual Description:	CLAY, with sand, red		

AASHTO M 145 Classification: **A-6** **Group Index:** **6**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Lean clay with sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	
#8	
#10	100
#16	100
#30	
#40	99
#50	98
#100	88
#200	72.5

Moisture (M) & Density (D)	
M, %:	8.7
D, pcf:	

LL	30
PL	19
PI	11

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

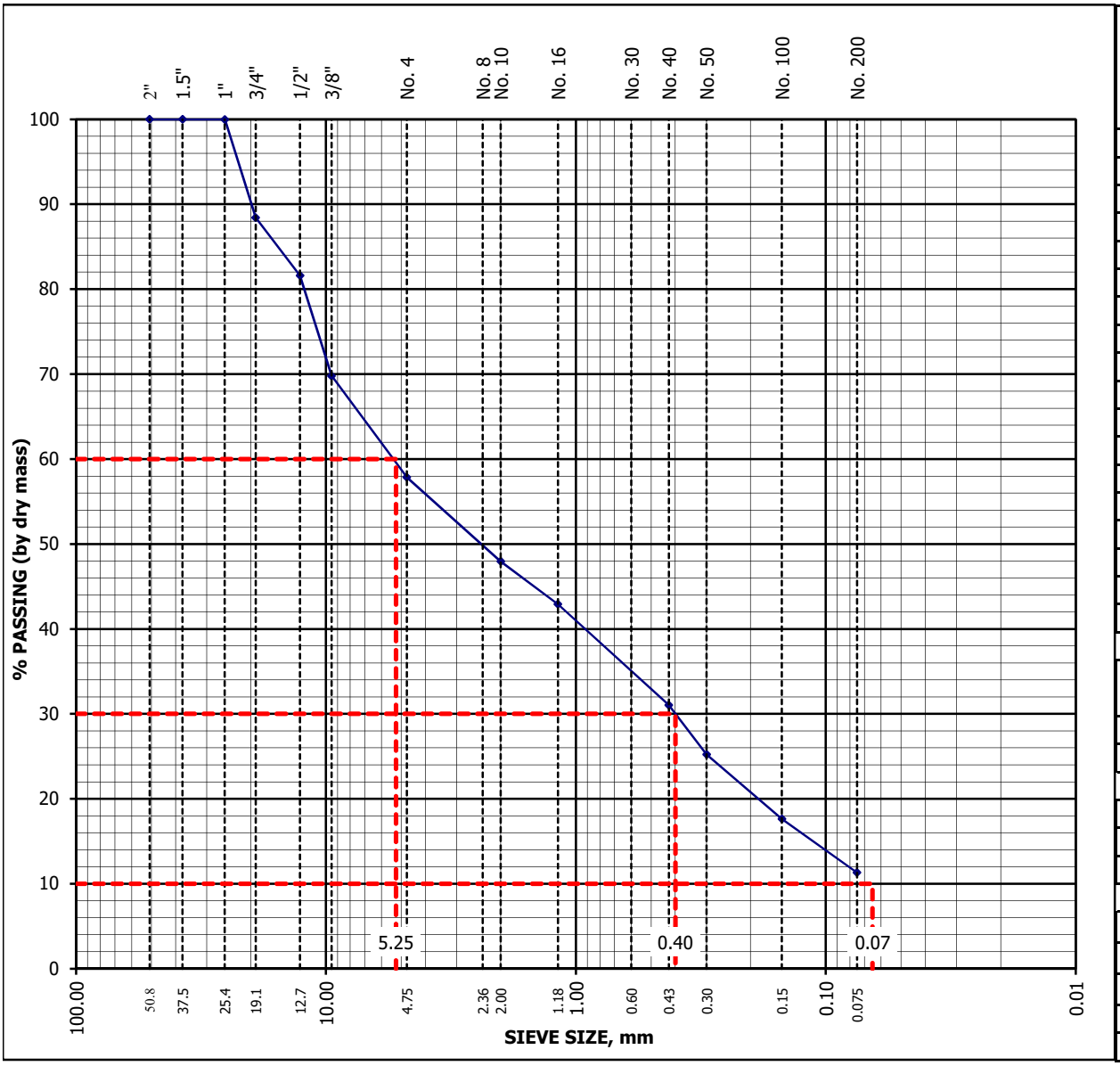
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	5-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	1822889	Reviewer:	J. Crystal
Sample Location:	SB-2 at 10'		
Visual Description:	SAND, with silt and gravel, red brown		

AASHTO M 145 Classification: **A-1-b** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(SP-SM) Poorly graded sand with silt and gravel**



Sieve Size	% Passing
2"	
1.5"	
1"	100
3/4"	88
1/2"	82
3/8"	70
#4	58
#8	
#10	48
#16	43
#30	
#40	31
#50	25
#100	18
#200	11.3

Moisture (M) & Density (D)	
M, %:	10.5
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	5.25
D_{30}	0.40
D_{10}	0.07
Cu	**80.77**
Cc	**0.47**

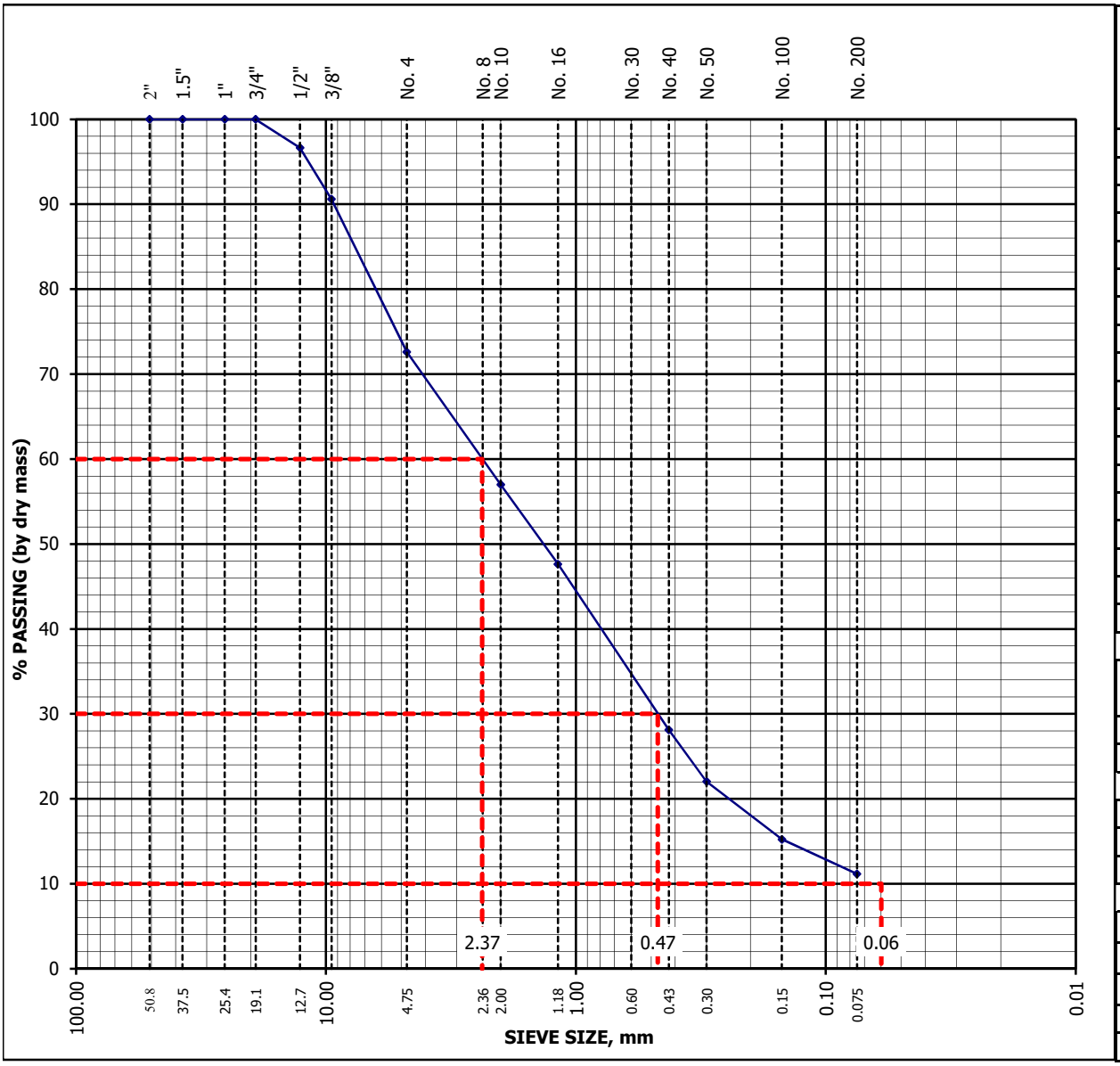
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	12-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	G. Hoyos
Lab ID Number:	1822890	Reviewer:	J. Crystal
Sample Location:	SB-3 at 5'		
Visual Description:	SAND, with silt and gravel, red		

AASHTO M 145 Classification: **A-1-b** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(SW-SM) Well graded sand with silt and gravel**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	100
1/2"	97
3/8"	91
#4	73
#8	
#10	57
#16	48
#30	
#40	28
#50	22
#100	15
#200	11.1

Moisture (M) & Density (D)	
M, %:	5.6
D, pcf:	

LL	NV
PL	NP
PI	NP

D_{60}	2.37
D_{30}	0.47
D_{10}	0.06
Cu	**39.50**
Cc	**1.55**

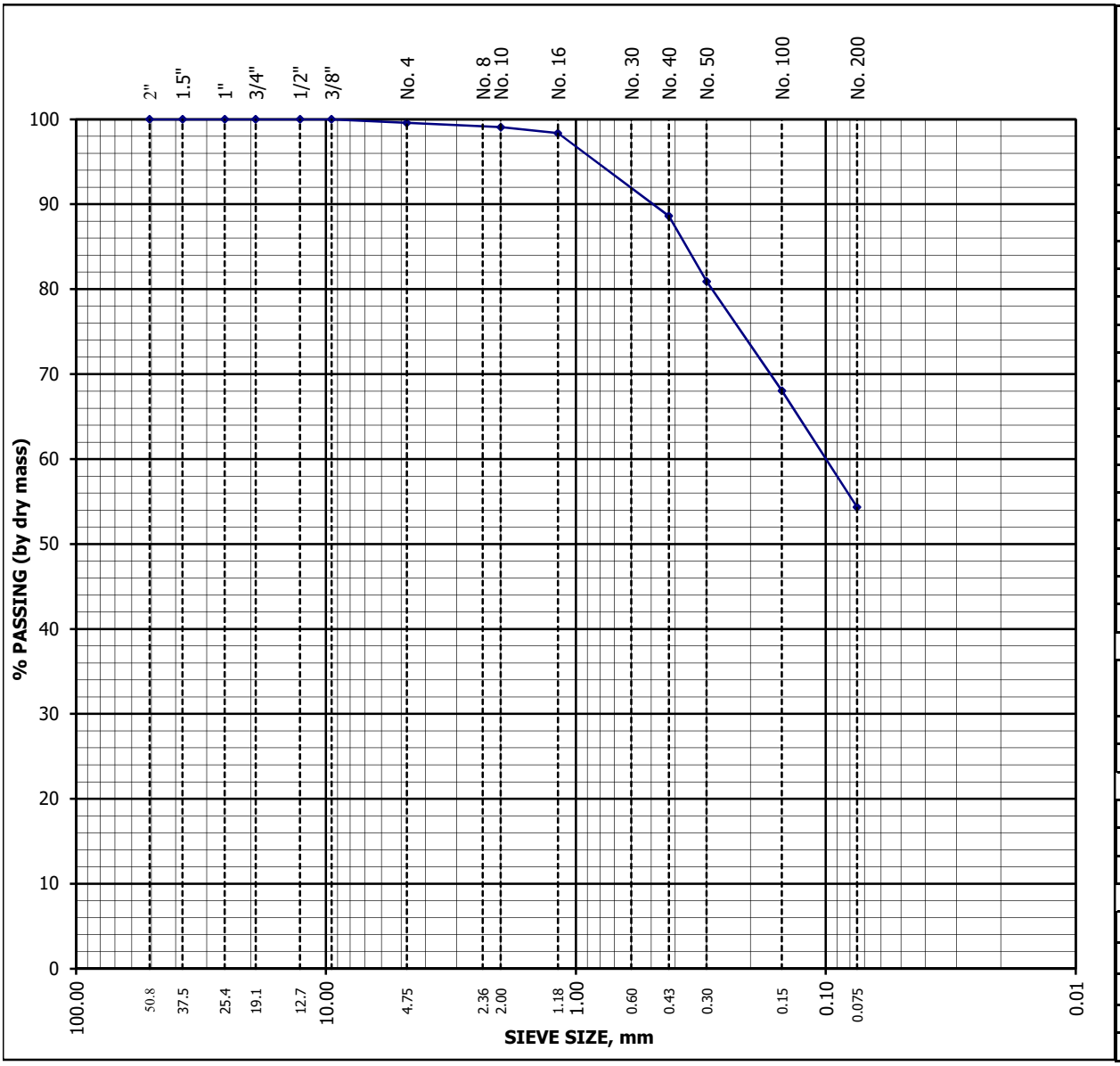
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	9-Sep-19
Project Name:	Cucharas Basin Collaborative Storage	Technician:	C. Zoetewey
Lab ID Number:	1921465	Reviewer:	J. Crystal
Sample Location:	SB-4 at 5'		
Visual Description:	CLAY, sandy, brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **2**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	99
#16	98
#30	
#40	89
#50	81
#100	68
#200	54.3

Moisture (M) & Density (D)	
M, %:	15.5
D, pcf:	

LL	26
PL	17
PI	9

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

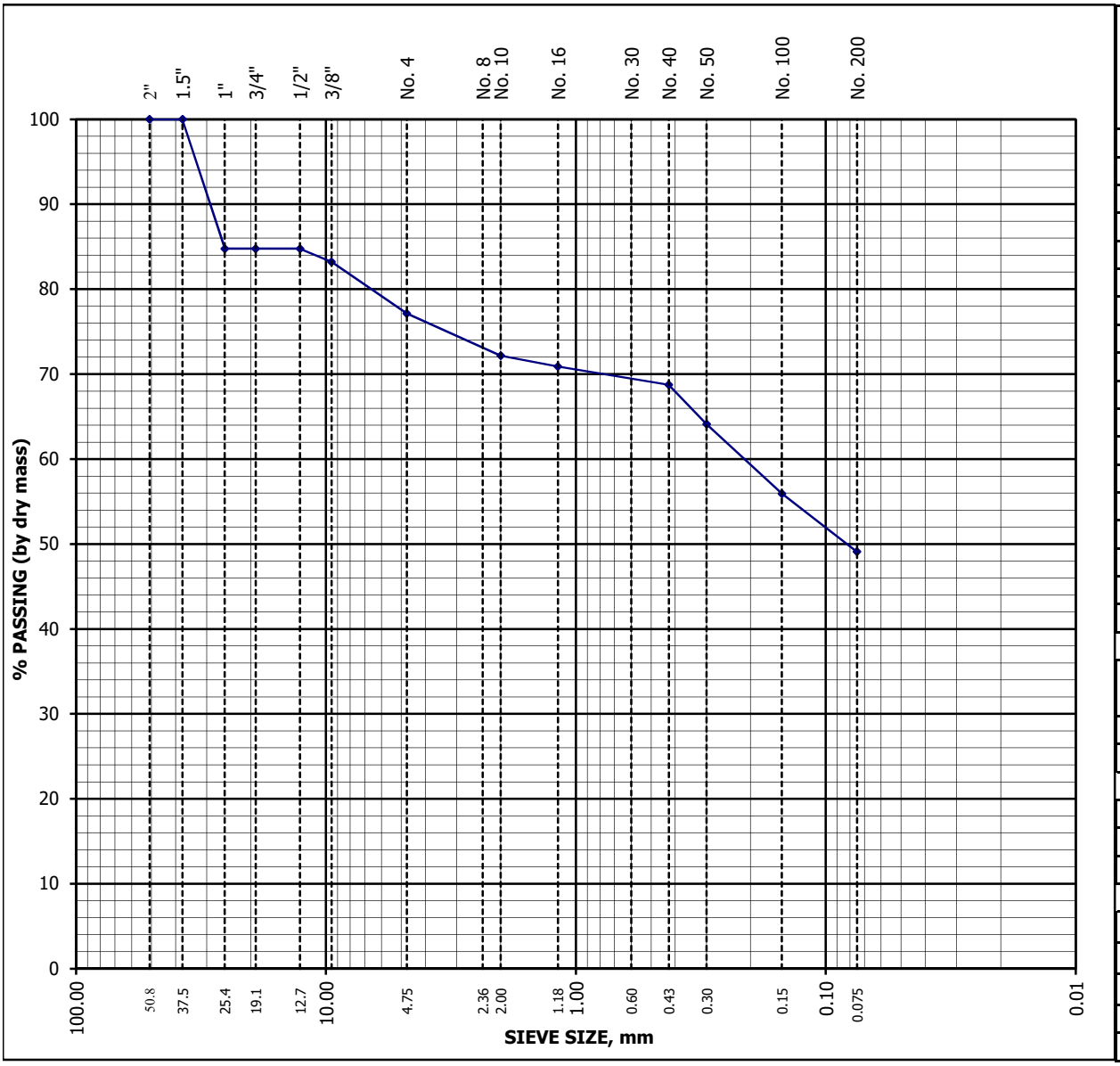
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	9-Sep-19
Project Name:	Cucharas Basin Collaborative Storage	Technician:	C. Zoetewey
Lab ID Number:	1921466	Reviewer:	J. Crystal
Sample Location:	SB-4 at 15'		
Visual Description:	CLAY, sandy, with gravel, reddish brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **1**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Sandy lean clay with gravel**



Sieve Size	% Passing
2"	
1.5"	100
1"	85
3/4"	85
1/2"	85
3/8"	83
#4	77
#8	
#10	72
#16	71
#30	
#40	69
#50	64
#100	56
#200	49.1

Moisture (M) & Density (D)	
M, %:	6.0
D, pcf:	

LL	24
PL	16
PI	8

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

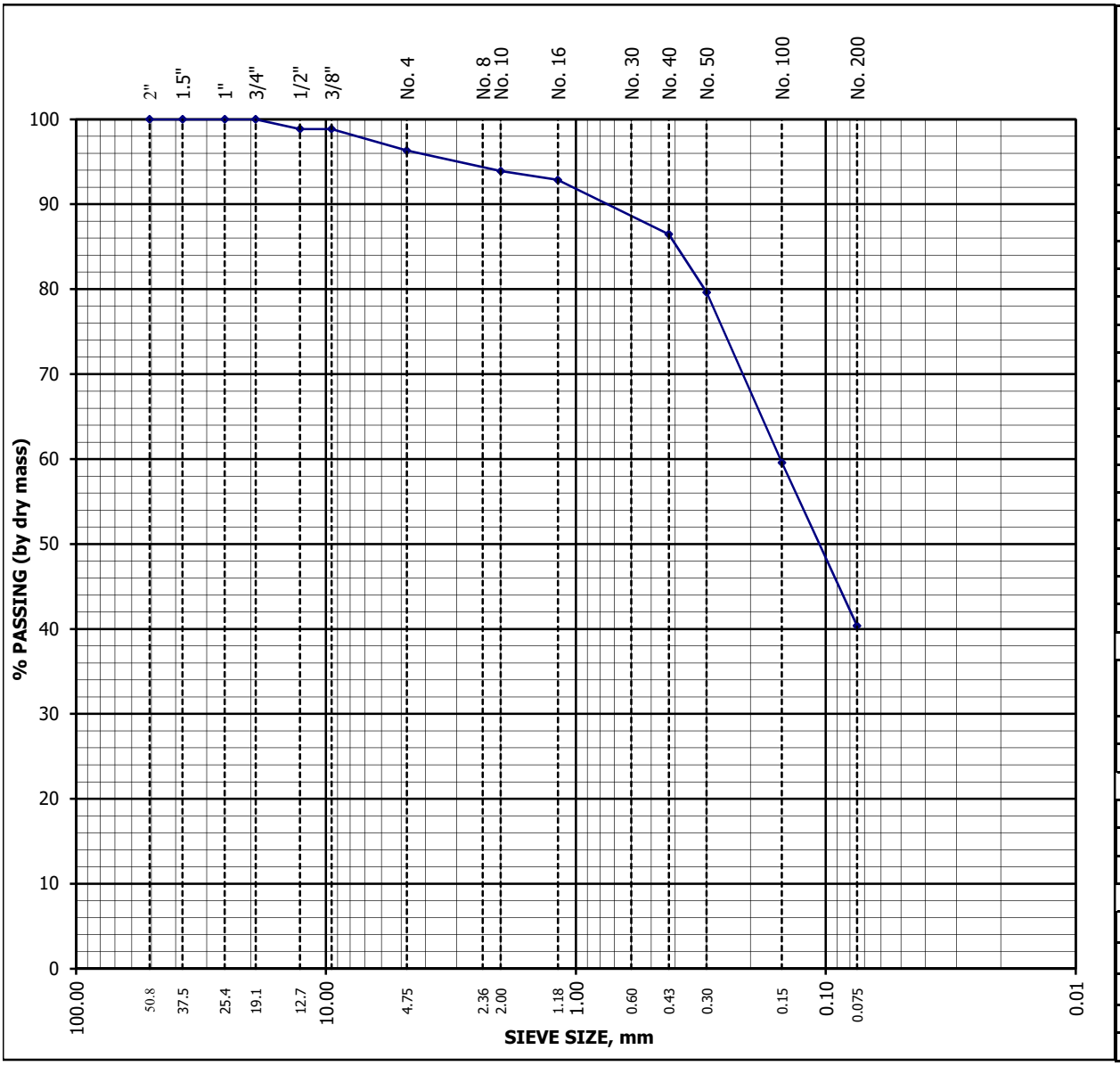
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	9-Sep-19
Project Name:	Cucharas Basin Collaborative Storage	Technician:	C. Zoetewey
Lab ID Number:	1921468	Reviewer:	J. Crystal
Sample Location:	SB-5 at 1'		
Visual Description:	SAND, silty, reddish brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SM)** **Silty sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	100
1/2"	99
3/8"	99
#4	96
#8	
#10	94
#16	93
#30	
#40	86
#50	80
#100	60
#200	40.4

Moisture (M) & Density (D)	
M, %:	6.3
D, pcf:	

LL	19
PL	17
PI	2

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

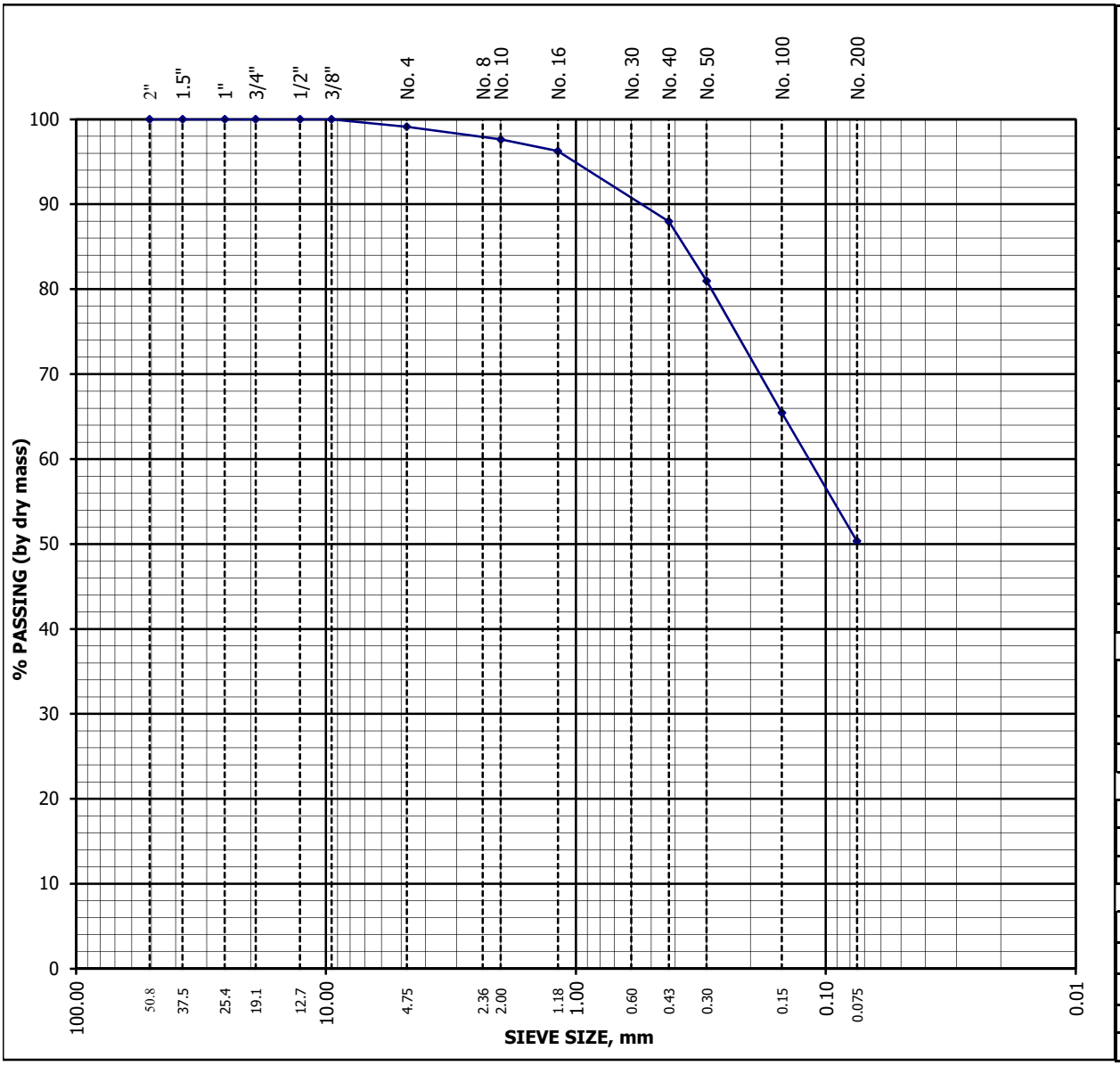
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	21-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822645	Reviewer:	J. Crystal
Sample Location:	SBP-1 at 1' to 3'		
Visual Description:	CLAY, sandy, red		

AASHTO M 145 Classification: **A-4** **Group Index:** **0**

Unified Soil Classification System (ASTM D 2487): **(CL-ML) Silty clay with sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	99
#8	
#10	98
#16	96
#30	
#40	88
#50	81
#100	65
#200	50.3

Moisture (M) & Density (D)	
M, %:	2.4
D, pcf:	

LL	25
PL	20
PI	5

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

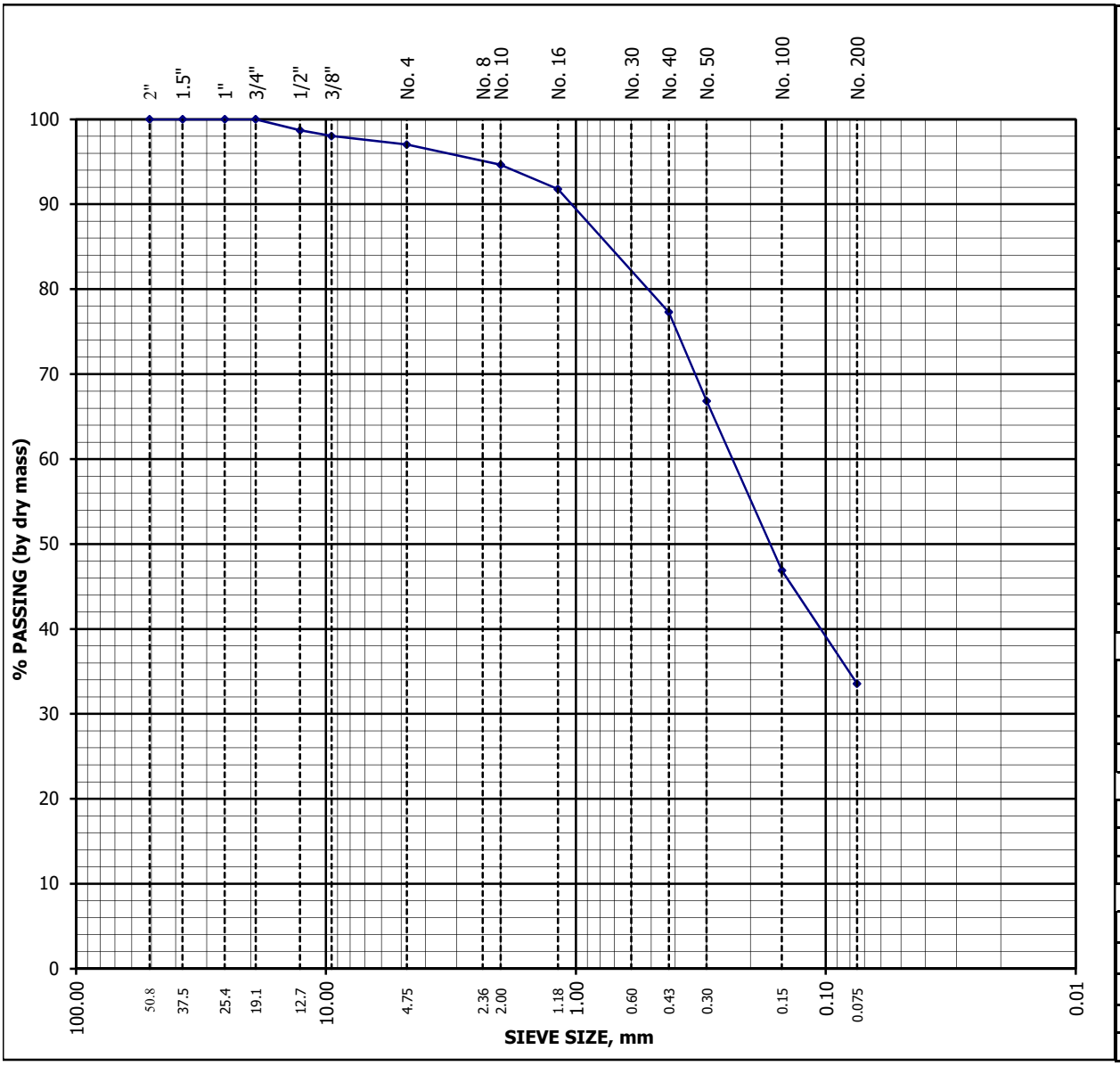
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	25-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822646	Reviewer:	J. Crystal
Sample Location:	SBP-3 at 1' to 3'		
Visual Description:	SAND, clayey, with silt, brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	100
1/2"	99
3/8"	98
#4	97
#8	
#10	95
#16	92
#30	
#40	77
#50	67
#100	47
#200	33.6

Moisture (M) & Density (D)	
M, %:	2.0
D, pcf:	

LL	24
PL	20
PI	4

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

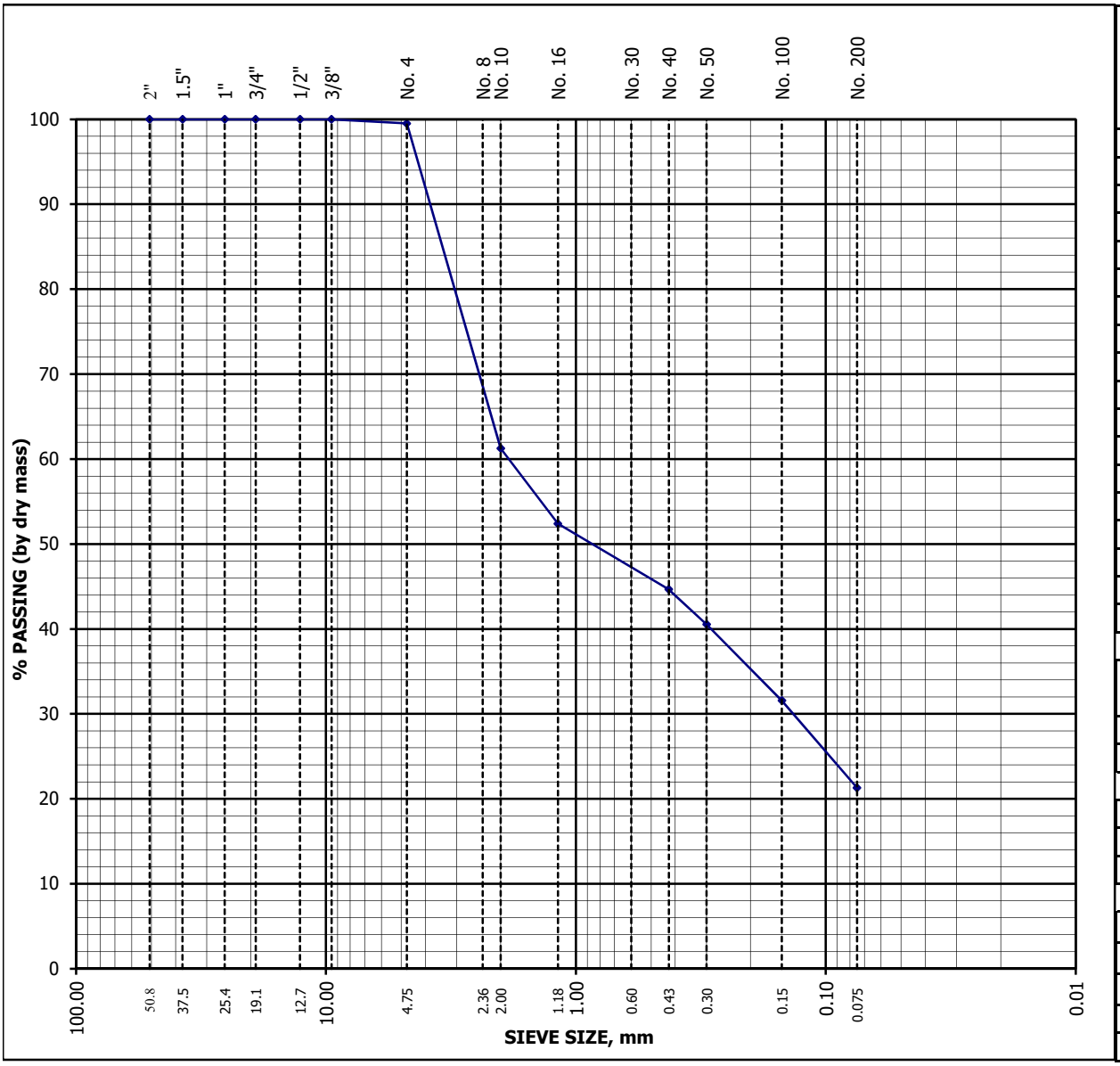
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	6-Oct-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822647	Reviewer:	J. Crystal
Sample Location:	SBP-3 at 6' to 8'		
Visual Description:	SAND, clayey, red brown		

AASHTO M 145 Classification: **A-2-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC)** **Clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	61
#16	52
#30	
#40	45
#50	41
#100	32
#200	21.3

Moisture (M) & Density (D)	
M, %:	6.0
D, pcf:	

LL	28
PL	19
PI	9

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

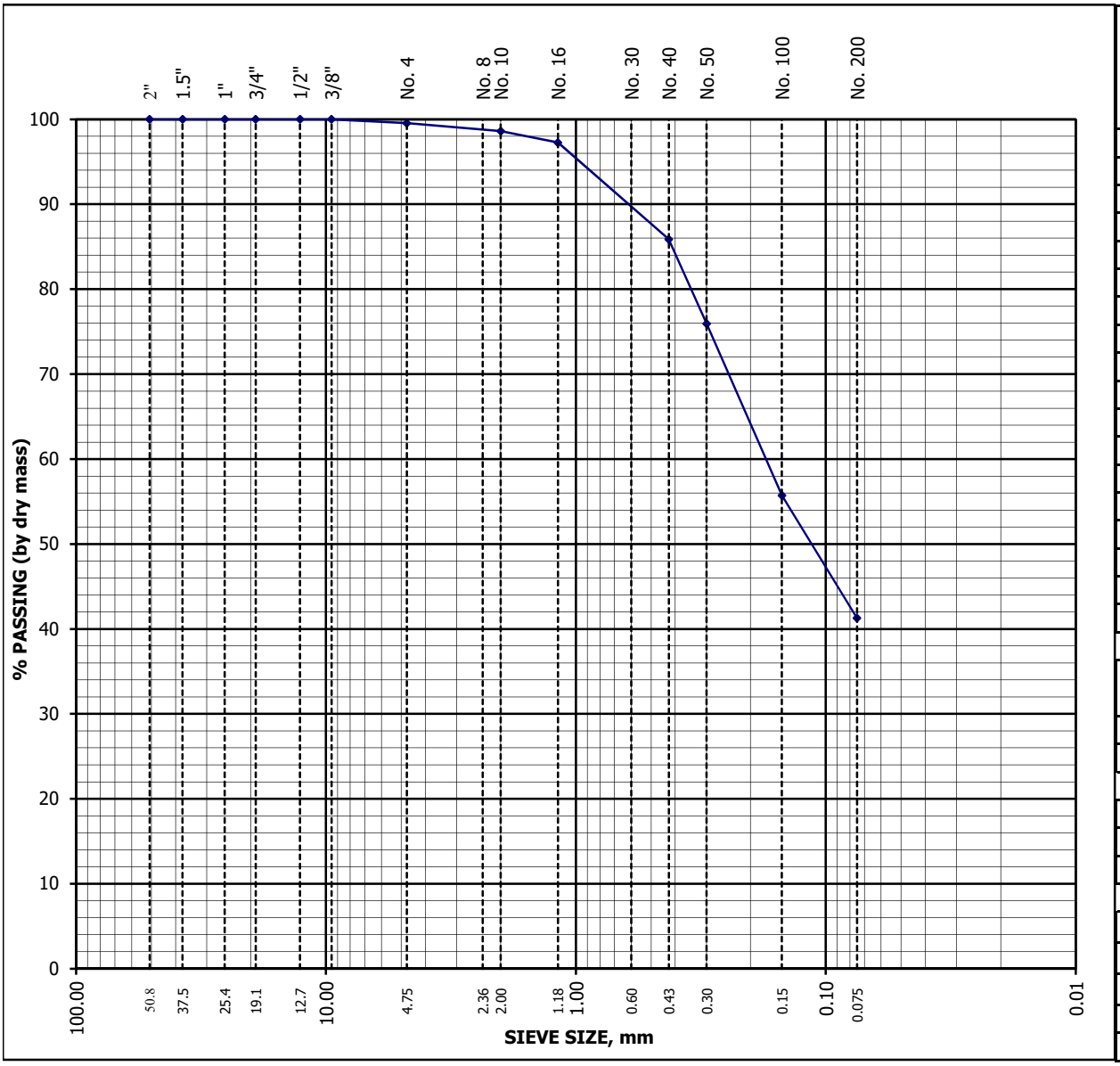
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	25-Sep-18
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	1822648	Reviewer:	J. Crystal
Sample Location:	SBP-5 at 1' to 3'		
Visual Description:	SAND, silty, clayey, brown		

AASHTO M 145 Classification: **A-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	99
#16	97
#30	
#40	86
#50	76
#100	56
#200	41.3

Moisture (M) & Density (D)	
M, %:	6.1
D, pcf:	

LL	27
PL	21
PI	6

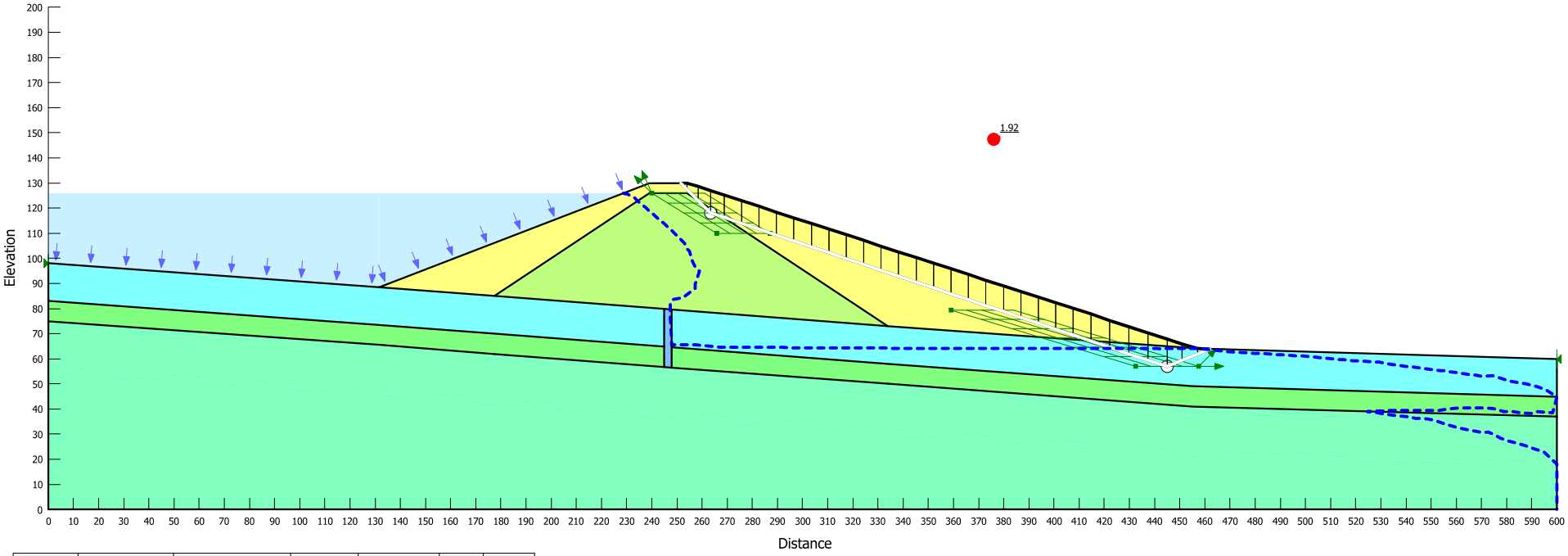
D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

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APPENDIX D

Stability Analysis Results

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

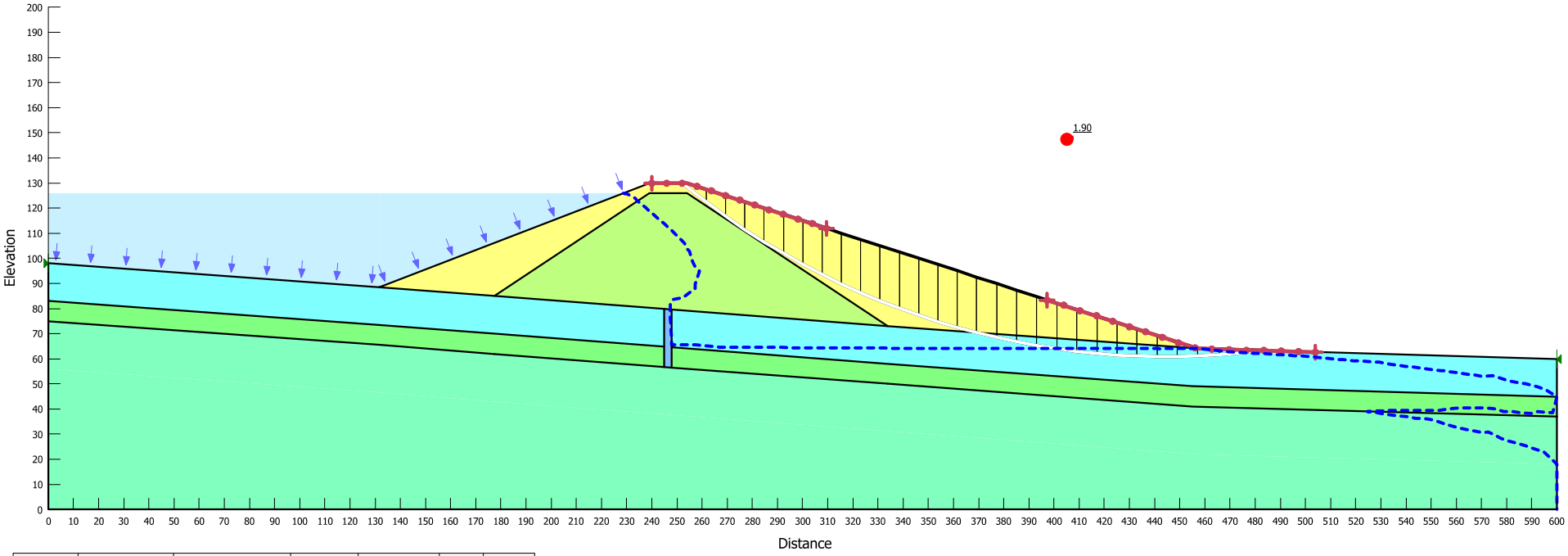


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Core	Mohr-Coulomb	125	25	30	0
	Cutoff	Mohr-Coulomb	125	10	11	0
	Overburden	Mohr-Coulomb	130	10	30	0
	Sandstone	Mohr-Coulomb	140	3,000	0	0
	Shell	Mohr-Coulomb	132	25	30	0

Steady State Seepage Stability, Block Failure

Britton

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

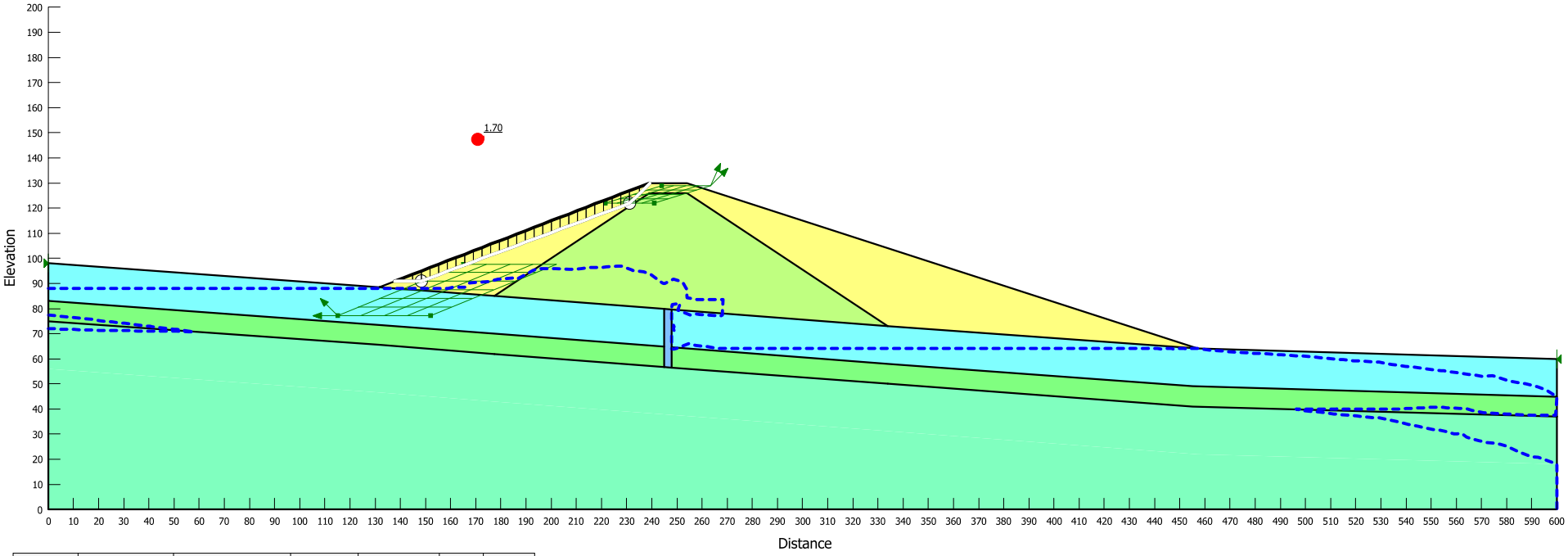


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Core	Mohr-Coulomb	125	25	30	0
	Cutoff	Mohr-Coulomb	125	10	11	0
	Overburden	Mohr-Coulomb	130	10	30	0
	Sandstone	Mohr-Coulomb	140	3,000	0	0
	Shell	Mohr-Coulomb	132	25	30	0

Steady State Seepage Stability, Circular Failure

Britton

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

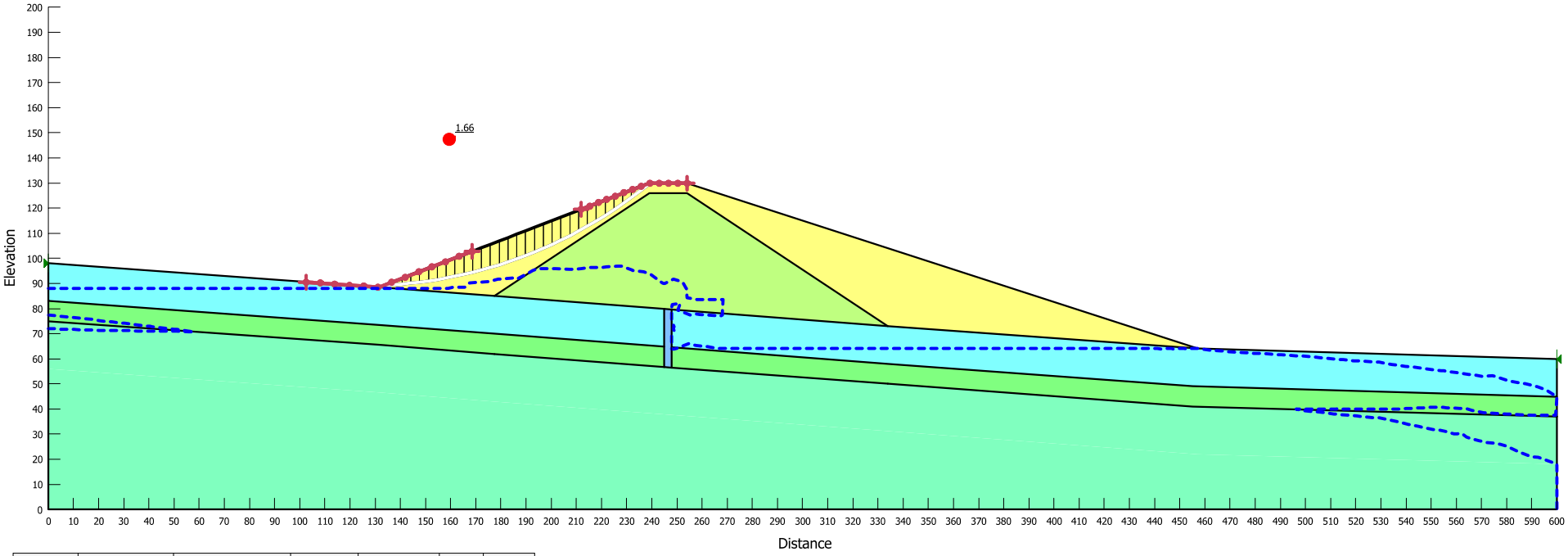


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Core	Mohr-Coulomb	125	25	30	0
	Cutoff	Mohr-Coulomb	125	10	11	0
	Overburden	Mohr-Coulomb	130	10	30	0
	Sandstone	Mohr-Coulomb	140	3,000	0	0
	Shell	Mohr-Coulomb	132	25	30	0

Transient Seepage Stability, Block Failure, Eleventh Day

Britton

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

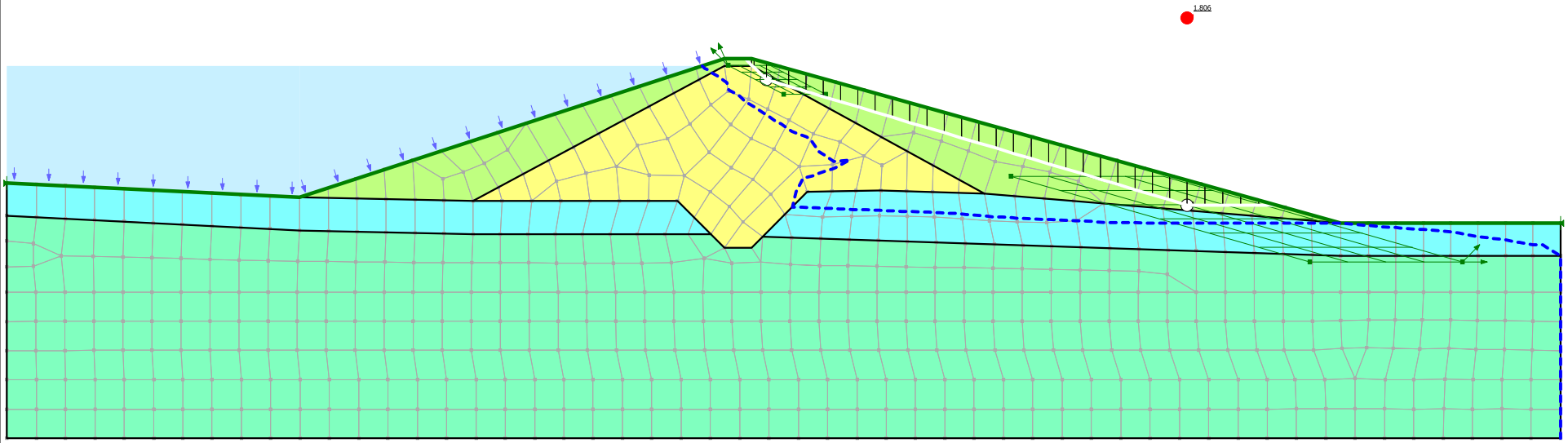


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Core	Mohr-Coulomb	125	25	30	0
	Cutoff	Mohr-Coulomb	125	10	11	0
	Overburden	Mohr-Coulomb	130	10	30	0
	Sandstone	Mohr-Coulomb	140	3,000	0	0
	Shell	Mohr-Coulomb	132	25	30	0

Transient Seepage Stability, Circular Failure, Twentieth Day

Britton

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

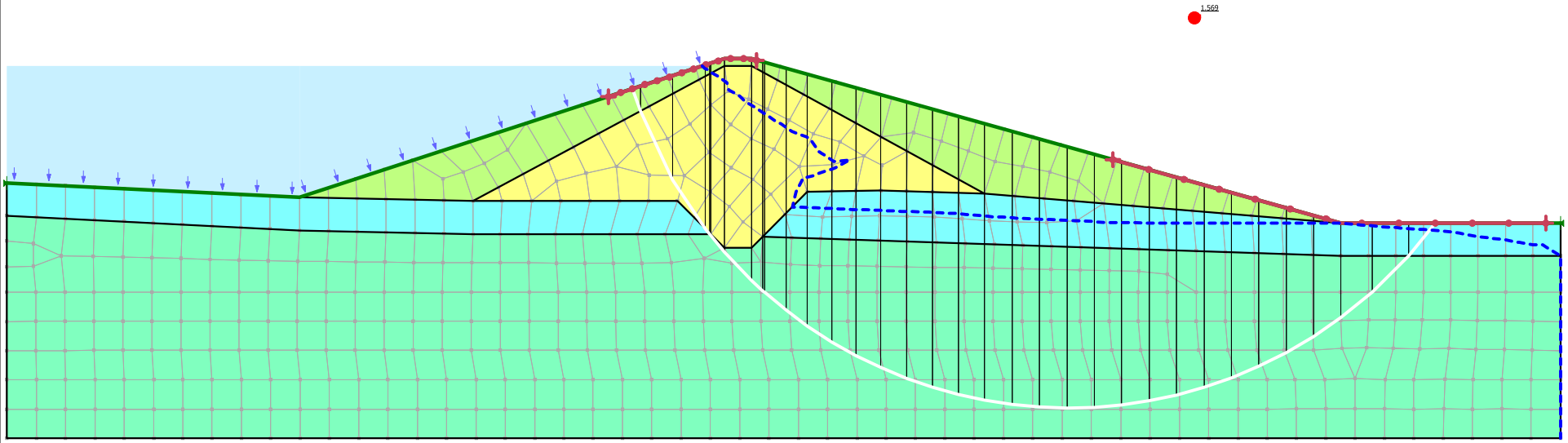


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Core	Mohr-Coulomb	125	25	25	0
	Gravel	Mohr-Coulomb	132	10	35	0
	Sandstone	Mohr-Coulomb	140	3,000	0	0
	Shell	Mohr-Coulomb	125	25	25	0

Steady State Seepage Stability, Block Failure

Bruce Canyon

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

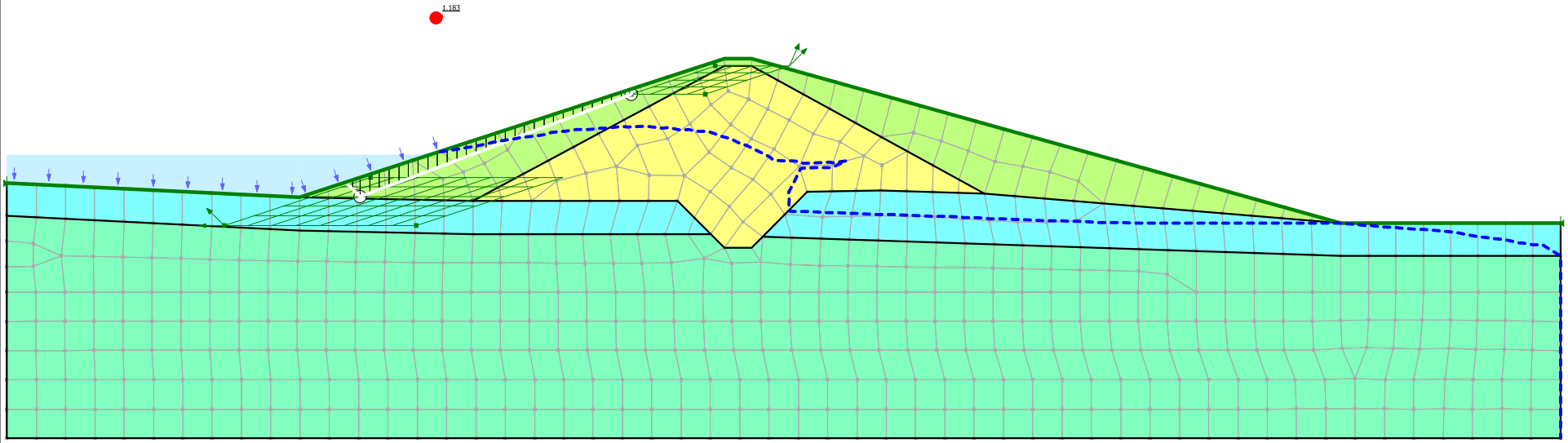


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Core	Mohr-Coulomb	125	25	25	0
	Gravel	Mohr-Coulomb	132	10	35	0
	Sandstone	Mohr-Coulomb	140	3,000	0	0
	Shell	Mohr-Coulomb	125	25	25	0

Steady State Seepage Stability, Circular Failure

Bruce Canyon

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

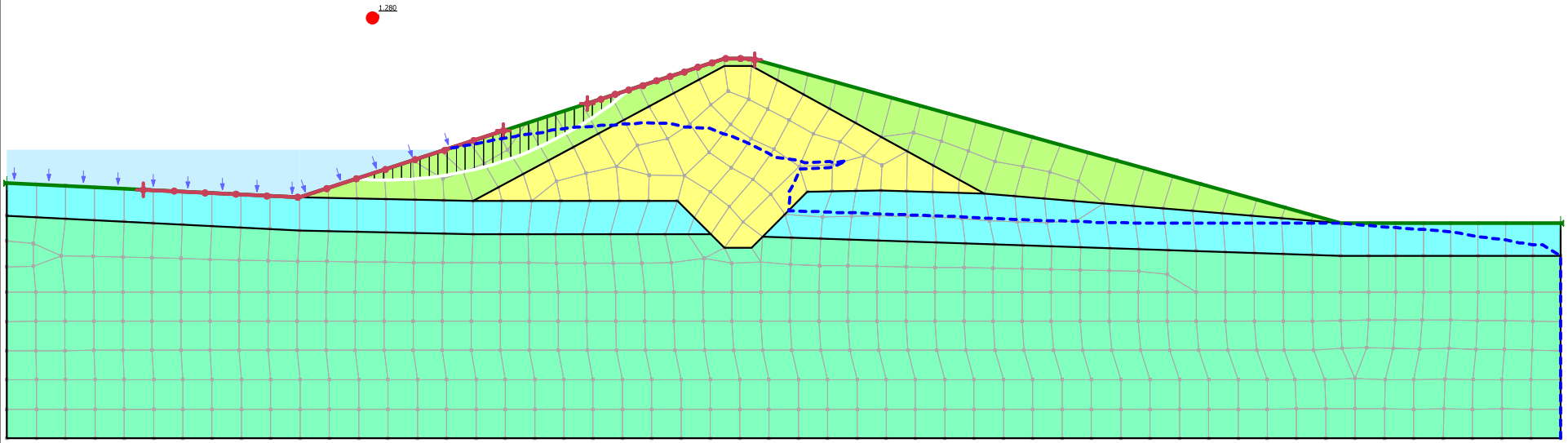


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Core	Mohr-Coulomb	125	25	25	0
	Gravel	Mohr-Coulomb	132	10	35	0
	Sandstone	Mohr-Coulomb	140	3,000	0	0
	Shell	Mohr-Coulomb	125	25	25	0

Transient Seepage Stability, Block Failure, 52nd Day

Bruce Canyon

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

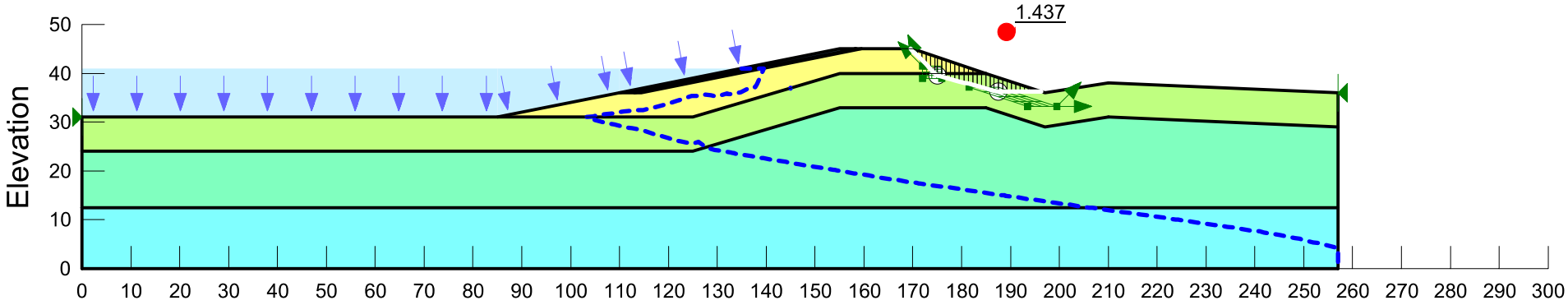


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Core	Mohr-Coulomb	125	25	25	0
	Gravel	Mohr-Coulomb	132	10	35	0
	Sandstone	Mohr-Coulomb	140	3,000	0	0
	Shell	Mohr-Coulomb	125	25	25	0

Transient Seepage Stability, Circular Failure, 48th Day

Bruce Canyon

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

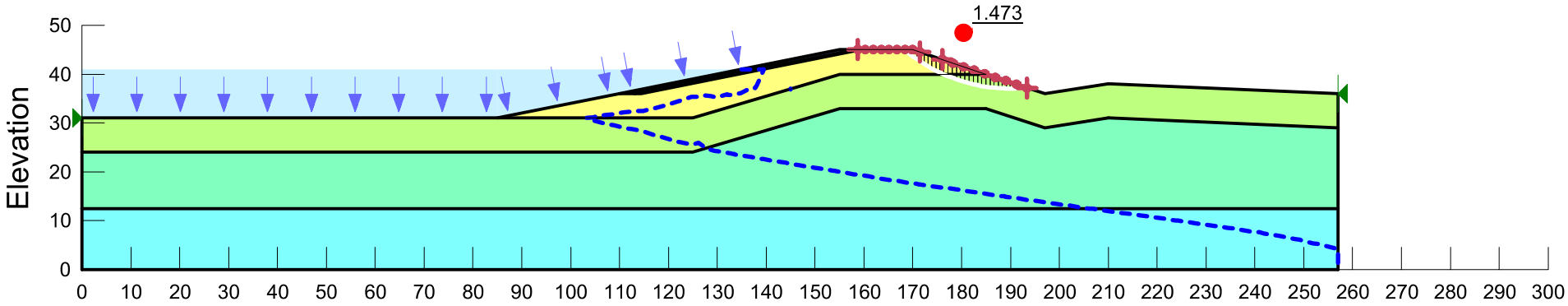


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Clay Embankment	Mohr-Coulomb	125	25	25	0
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Existing Fill	Mohr-Coulomb	115	10	20	0
	Native Clay	Mohr-Coulomb	115	10	15	0
	Rip Rap	Mohr-Coulomb	135	10	40	0
	Sand Bedding	Mohr-Coulomb	125	10	30	0

Steady State Seepage Stability, Block Failure

Maria Stevens South

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

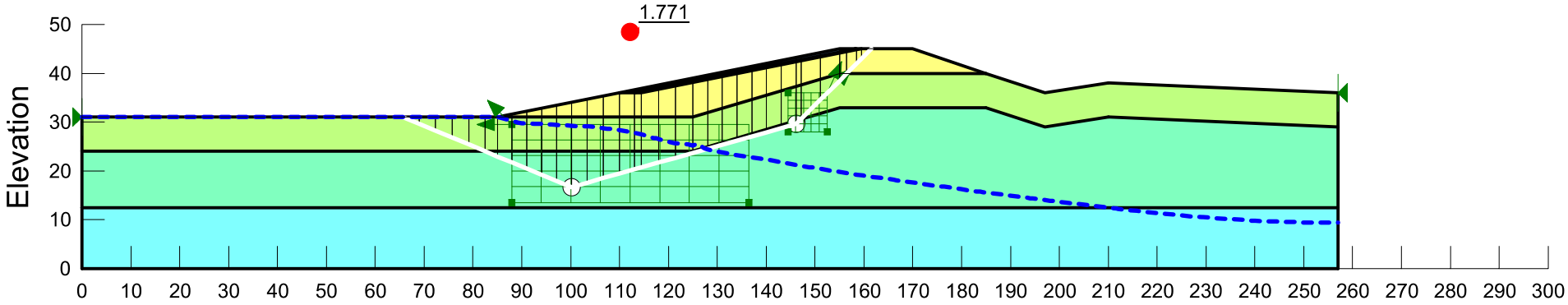


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Clay Embankment	Mohr-Coulomb	125	25	25	0
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Existing Fill	Mohr-Coulomb	115	10	20	0
	Native Clay	Mohr-Coulomb	115	10	15	0
	Rip Rap	Mohr-Coulomb	135	10	40	0
	Sand Bedding	Mohr-Coulomb	125	10	30	0

Steady State Seepage Stability, Circular Failure

Maria Stevens South

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

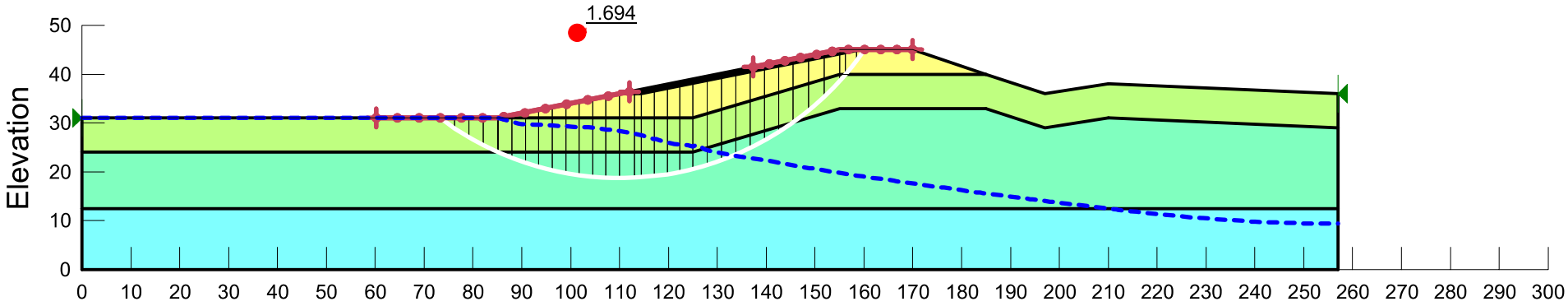


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Clay Embankment	Mohr-Coulomb	125	25	25	0
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Existing Fill	Mohr-Coulomb	115	10	20	0
	Native Clay	Mohr-Coulomb	115	10	15	0
	Rip Rap	Mohr-Coulomb	135	10	40	0
	Sand Bedding	Mohr-Coulomb	125	10	30	0

Transient Seepage Stability, Block Failure, Tenth Day

Maria Stevens South

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117

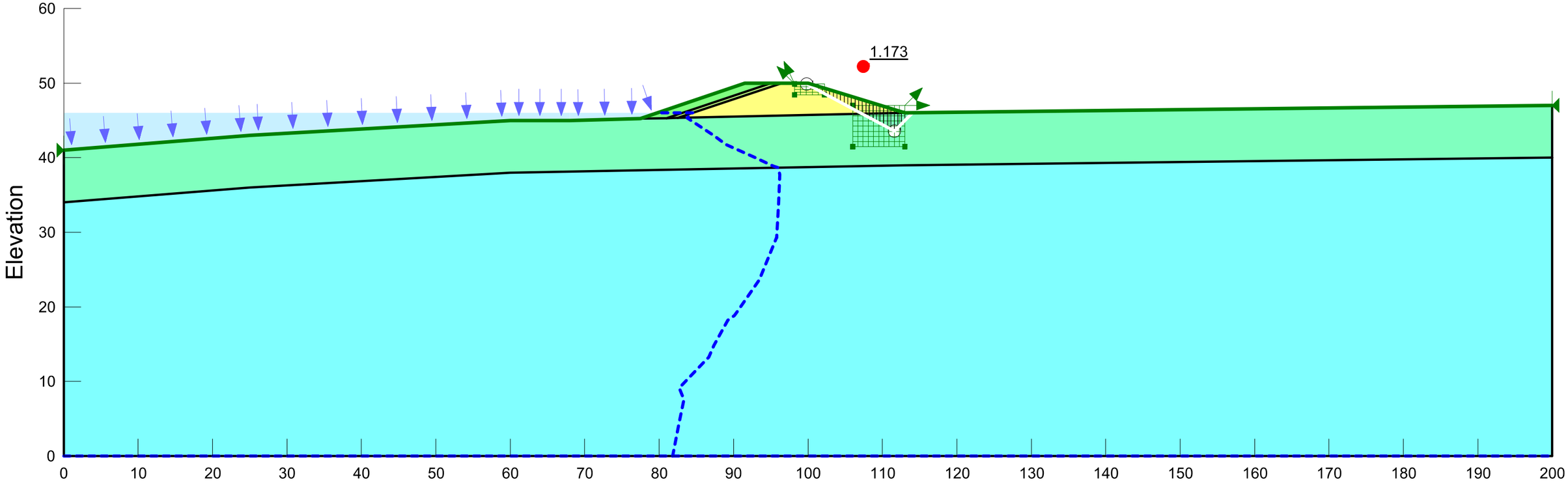


Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Clay Embankment	Mohr-Coulomb	125	25	25	0
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Existing Fill	Mohr-Coulomb	115	10	20	0
	Native Clay	Mohr-Coulomb	115	10	15	0
	Rip Rap	Mohr-Coulomb	135	10	40	0
	Sand Bedding	Mohr-Coulomb	125	10	30	0

Transient Seepage Stability, Circular Failure, Tenth Day

Maria Stevens South

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117



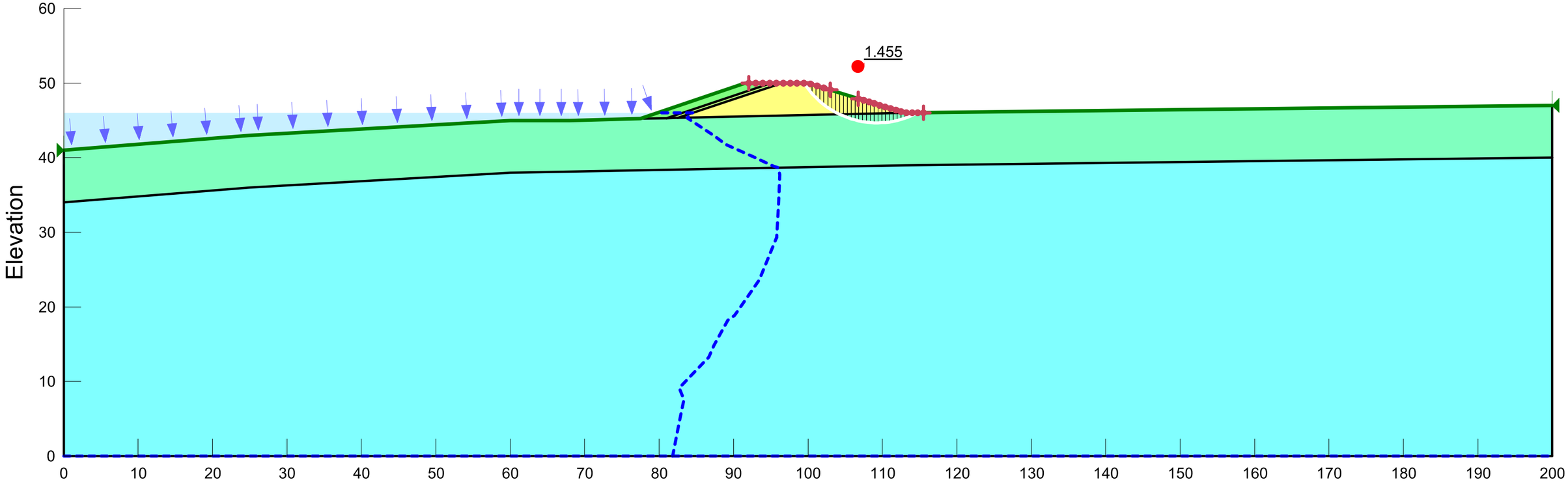
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Clay Embankment	Mohr-Coulomb	125	25	25	0
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Native Clay	Mohr-Coulomb	115	0	15	0
	Rip Rap	Mohr-Coulomb	135	10	40	0
	Sand Bedding	Mohr-Coulomb	125	10	30	0

Steady State Seepage, Block Failure Stability Analysis

Maria Stevens West.gsz

10/24/2018 1:159

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117



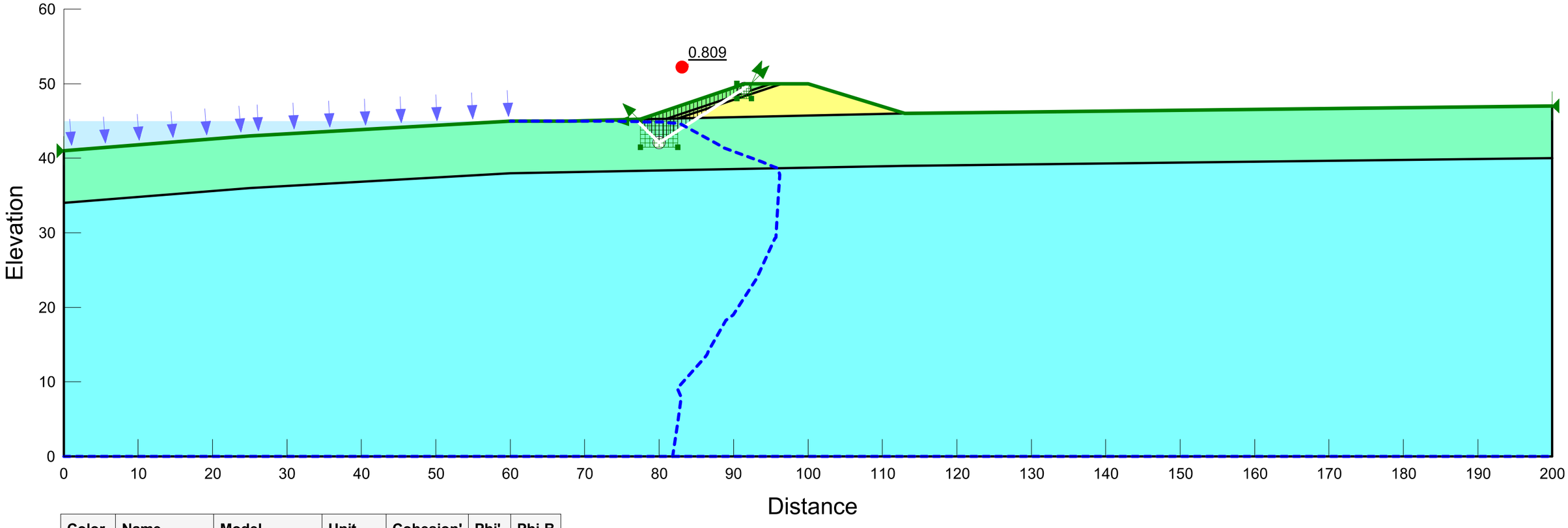
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Clay Embankment	Mohr-Coulomb	125	25	25	0
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Native Clay	Mohr-Coulomb	115	0	15	0
	Rip Rap	Mohr-Coulomb	135	10	40	0
	Sand Bedding	Mohr-Coulomb	125	10	30	0

Transient Seepage, First Day Circular Failure Stability Analysis

Maria Stevens West.gsz

10/24/2018 1:159

CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117



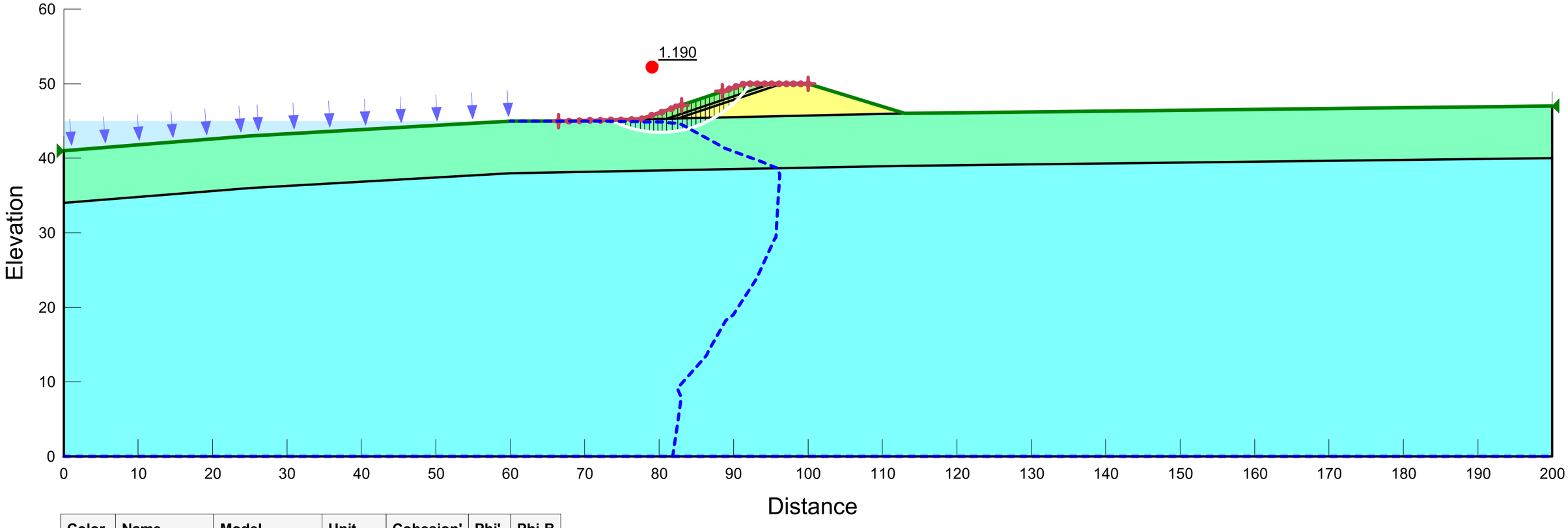
Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Clay Embankment	Mohr-Coulomb	125	25	25	0
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Native Clay	Mohr-Coulomb	115	0	15	0
	Rip Rap	Mohr-Coulomb	135	10	40	0
	Sand Bedding	Mohr-Coulomb	125	10	30	0

Transient Seepage, First Day Circular Failure Stability Analysis

Maria Stevens West.gsz

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CUCHARAS BASIN COLLABORATIVE STORAGE
PROJECT NO. 18.117



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Clay Embankment	Mohr-Coulomb	125	25	25	0
	Claystone	Mohr-Coulomb	135	3,000	0	0
	Native Clay	Mohr-Coulomb	115	0	15	0
	Rip Rap	Mohr-Coulomb	135	10	40	0
	Sand Bedding	Mohr-Coulomb	125	10	30	0

Transient Seepage, First Day Circular Failure Stability Analysis

Maria Stevens West.gsz

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CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

APPENDIX B

Laboratory Testing

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

SUMMARY OF LABORATORY TEST RSULTS
Cucharas Basin Collaborative Storage
Project No. 18.117

Sample Location		Natural Dry Density (pcf)	Natural Moisture Content (%)	Gradation			Atterberg Limits		Swell/Consolidation			Permeability (cm/s)	Material Type
Boring	Depth (feet)			Gravel (%)	Sand (%)	Silt/ Clay (%)	Liquid Limit (%)	Plasticity Index (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)		
B-1	7		6.5	26	52	21.2	19	4					SAND, silty, clayey (SC-SM, A-2-4)
B-1	17		3.2	65	27	8.3	NV	NP					GRAVEL, poorly graded, with silt and sand (GP-GM, A-1-b)
B-2	7		6.9	63	28	8.7	NV	NP					GRAVEL, well graded, with silt and sand (GW-GM, A-1-a)
B-2	12		17.7		81	19.4	24	4					SAND, silty, clayey (SC-SM, A-2-4)
BP-1	1 to 3		4.5	16	56	28.3	31	9					SAND, clayey, with gravel (SC, A-2-4(0))
BP-3	2 to 5		1.8	1	65	34.2	21	5					SAND, silty, clayey (SC-SM, A-2-4)
BP-5	3.5 to 5		7.4	34	34	32.6	30	12					SAND, clayey, with gravel (SC, A-2-6(0))
BC-1	5		11.5		67	33.3	22	6					SAND, clayey (SC, A-2-4(0))
BC-1	25		12.3		39	60.8	40	16					CLAY, sandy, lean (CL, A-6(8))
BC-2	5		27.0		54	46	30	17					SAND, clayey (SC, A-6(4))
BC-2	10		16.0	17	52	30.7	23	7					SAND, clayey, with gravel (SC, A-2-4(0))
BC-3	5		5.4	1	70	29.1	24	6					SAND, silty, clayey (SC-SM, A-2-4(0))
BC-3	15		4.6		56	43.7	24	4					SAND, silty, clayey (SC-SM, A-4(0))
BC-4	10		6.1		23	76.7	30	11					CLAY, lean, with sand (CL, A-6(7))
BCP-1	1 to 8		3.0		53	46.6	27	11					SAND, clayey (SC, A-6(2))
BCP-2	2 to 10		4.1		65	34.6	23	6					SAND, silty, clayey (SC-SM, A-2-4)
BCP-4	2 to 8		1.9		64	36.0	25	9					SAND, clayey (SC, A-4)
BCP-5	2 to 8	82.8	5.1	9	48	43.5	29	12	500	-9.9	N/A		SAND, clayey (SC, A-6(2))
BCP-6	7 to 9		4.1		76	23.6	NV	NP					SAND, silty (SM, A-2-4)
LVL-1	15		10.7		59	40.6	24	5					SAND, silty, clayey (SC-SM, A-4)
LVL-4	9		16.1		63	36.7	23	6					SAND, silty, clayey (SC-SM, A-4)
LVL-5	5		14.0		48	52.5	37	20					CLAY, sandy, lean (CL, A-6(7))
LVL-7	4		4.3	1	63	36.3	19	5					SAND, silty, clayey (SC-SM, A-4)
MS-1	10		9.6	5	26	69.4	30	14					CLAY, sandy, lean (CL, A-6(7))
MS-1	20		7.4	11	30	58.5	31	16					CLAY, sandy, lean (CL, A-6(6))
MS-2	10		7.8	2	77	21.1	NV	NP					SAND, silty (SM, A-2-4)

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

SUMMARY OF LABORATORY TEST RSULTS
Cucharas Basin Collaborative Storage
Project No. 18.117

Sample Location		Natural	Natural	Gradation			Atterberg Limits		Swell/Consolidation				
Boring	Depth (feet)	Dry Density (pcf)	Moisture Content (%)	Gravel (%)	Sand (%)	Silt/ Clay (%)	Liquid Limit (%)	Plasticity Index (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)	Permeability (cm/s)	Material Type
MS-2	20		16.5	17	76	6.8	NV	NP					SAND, well graded, with silt and gravel (SW-SM, A-1-b)
MS-3	5		24.5		20	79.9	39	20					CLAY, lean, with sand (CL, A-6(15))
MS-4	10		11.8		10	90.4	35	20					CLAY, lean (CL, A-6(17))
MS-5	10		12.3		12	87.8	35	17					CLAY, lean (CL, A-6(14))
MS-6	5	113.1	14.0						50	0.3	315		FILL: CLAY, sandy, lean (CL, A-6)
MS-6	10	91.3	25.9	1	28	70.2	32	15	50	0.3	125		CLAY, sandy, lean, with organics (CL, A-6(8))
MS-6	15	95.3	25.2						50	0.1	64		CLAY, sandy, lean (CL, A-6)
MS-6	20	106.9	19.5						50	0.8	605		CLAY, sandy, lean (Cl, A-6)
MS-6	25		14.4	1	30	68.1	30	11					CLAY, sandy, lean (CL, A-6(5))
MSP-2	1 to 3		6.4	1	30	68.6	36	13					CLAY, sandy, lean (CL, A-6(8))
MSP-4	2 to 4		5.3	1	24	74.7	37	16					CLAY, sandy, lean (CL, A-6(11))
MSP-5	1 to 4		5.7	6	28	66.3	35	19					CLAY, sandy, lean (CL, A-6(10))
MSP-5	4 to 7		3.6	8	29	62.9	33	16					CLAY, sandy, lean (CL, A-6(7))
SB-1	5		7.6	31	47	22.5	19	2					SAND, silty, with gravel (SM, A-1-b(0))
SB-1	12.5		0.3	52	37	10.7	NV	NP					GRAVEL, poorly graded, with silt and sand (GP-GM, A-1-b)
SB-1	20		8.7		27	72.5	30	11					CLAY, lean, with sand (CL, A-6(6))
SB-2	10		10.3	42	47	11.3	NV	NP					SAND, poorly graded, with silt and gravel (SP-SM, A-1-b)
SB-3	5		5.6	27	62	11.1	NV	NP					SAND, well graded, with silt and gravel (SW-SM, A-1-b)
SB-4	5		15.5		46	54.3	26	9					CLAY, sandy, lean (CL, A-4(2))
SB-4	15		6.0	23	28	49.1	24	8					CLAY, sandy, lean, with gravel (CL, A-4(1))
SB-4	55											3.63.E-09	CLAYSTONE, sandy
SB-5	1		6.3	4	56	40.4	19	2					SAND, silty (SM, A-4)
SBP-1	1 to 3		2.4	1	49	50.3	25	5					CLAY, silty, with sand (CL-ML, A-4(0))
SBP-3	1 to 3		2.0	3	63	33.6	24	4					SAND, silty, clayey (SC-SM, A-2-4(0))
SBP-3	6 to 8		6.0		78	21.3	28	9					SAND, clayey (SC, A-2-4(0))
SBP-5	1 to 3		6.1		58	41.3	27	6					SAND, silty, clayey (SC-SM, A-4(0))

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Geotechnical Engineers & Construction Materials Consultants

SUMMARY OF LABORATORY TEST RESULTS
Bruce Canyon 50% Design
Project No. 18.117

Sample Location									Standard Proctor (ASTM D698)		Gradation					Atterberg Limits		Direct Shear				Triaxial Shear					Swell/Consolidation			
Boring	Depth (feet)	Natural Dry Density (pcf)	Natural Moisture Content (%)	pH	Water Soluble Chloride (mg/l)	Water Soluble Sulfates (%)	Resistivity (ohms*cms)	Dispersivity	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Gravel (%)	Sand (%)	Silt/ Clay (%)	Silt (%)	Clay (%)	Liquid Limit (%)	Plasticity Index (%)	Peak Shear Angle (ϕ)	Peak Cohesion c (psf)	Ultimate Shear Angle (ϕ)	Ultimate Cohesion c (psf)	Total Shear Angle (f)	Total Cohesion c (psf)	Effective Shear Angle (f)	Effective Cohesion c (psf)	Hydraulic Conductivity (cm/s)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)	Material Type
B-1	15	110.9*	11.0*									23	79.6			39	17	29.6	0	21.2	0									CLAYSTONE: CLAY, lean, with sand (CL, A-6(12))
B-1	20										1	53	45.5			36	13													SANDSTONE: SAND, silty (SM, A-6(3))
B-2	15							ND1				24	76.3			46	20													CLAY, lean, with sand (CL, A-7-6(16))
BCP-1 BCP-5	1 to 8 2 to 8	113.8**	12.8**	8.3	8.9	0.00	1500	D2	117.6	12.4		47	53.5	25.7	27.8	26	12					16.5	342	35.2	0	1..65E-07	250	0.0	NA	CLAY, lean, sandy (CL, A-6(3))
BCP-2 BCP-4	2 to 10 2 to 8	116.6**	11.8**	8.1	3.5	0.01	2600	ND2	120.7	11.0		62	38.2	17.2	21.0	23	7					12.7	1270	28.4	282	2.21E-06	250	0.0	NA	SAND, silty, clayey (SM-SC, A-4)
BCP-3	2 to 4											60	39.5			23	6													SAND, silty, clayey (SM-SC, A-4)
BCP-6	7 to 9	110.7**	12.2**	7.3	3.7	0.00	5000	ND3	114.6	11.8		79	21.0	5.7	15.3	NV	NP	29.3	380	28.7	217					3.18E-05	250	0.0	NA	SAND, silty (SM, A-2-4)

*Averaged values.
**Remolded Values for swell/consolidation

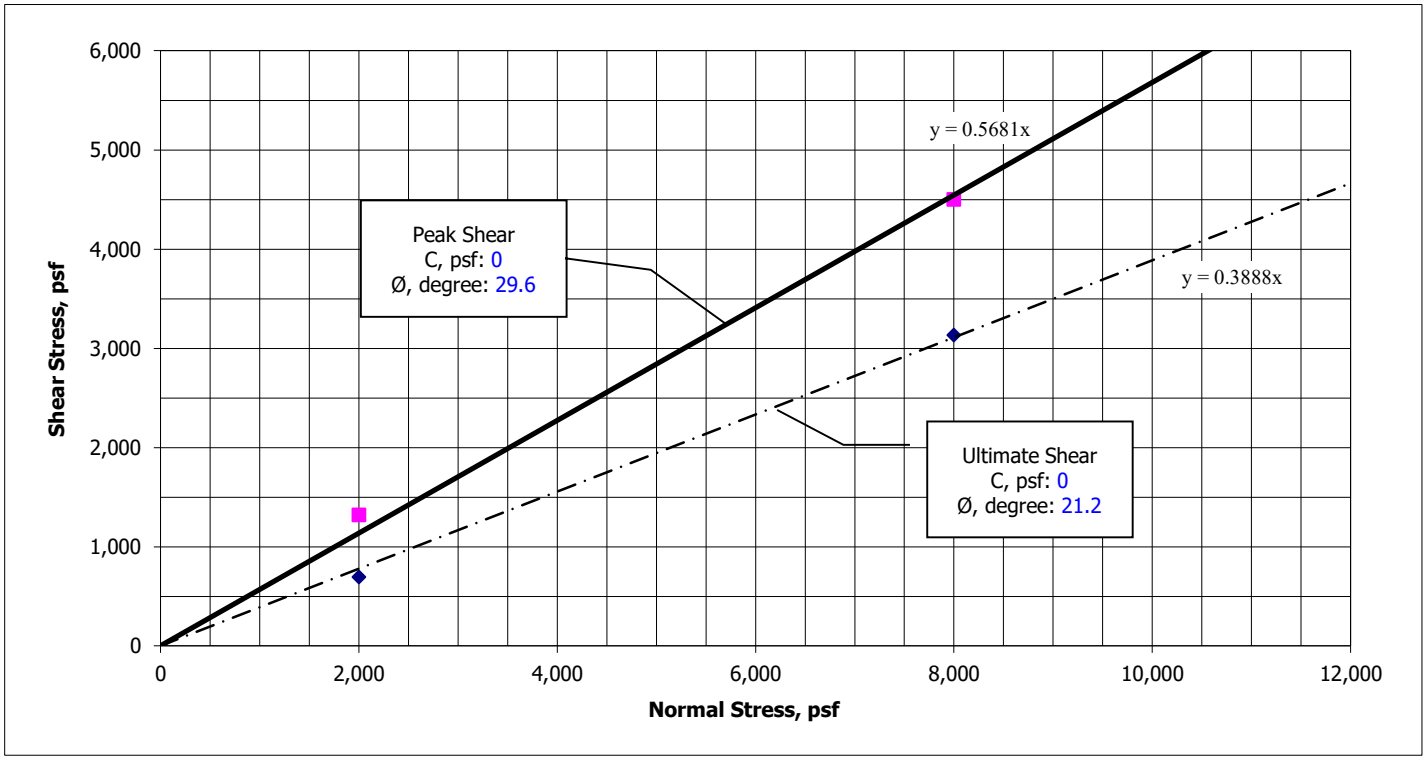
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Direct Shear (ASTM D 3080)

Project Name:	Cucharas Basin Collaborative Storage	Date:	07/29/20
Project No.:	18.117, Applegate Group	Tested By:	G. Hoyos
Lab ID:	202771	Checked By:	J. Crystal

Sample:	BC-1 at 15'
Visual Description:	CLAYSTONE: CLAY, with sand, dusky red

Direct Shear Tangents



REMARKS:

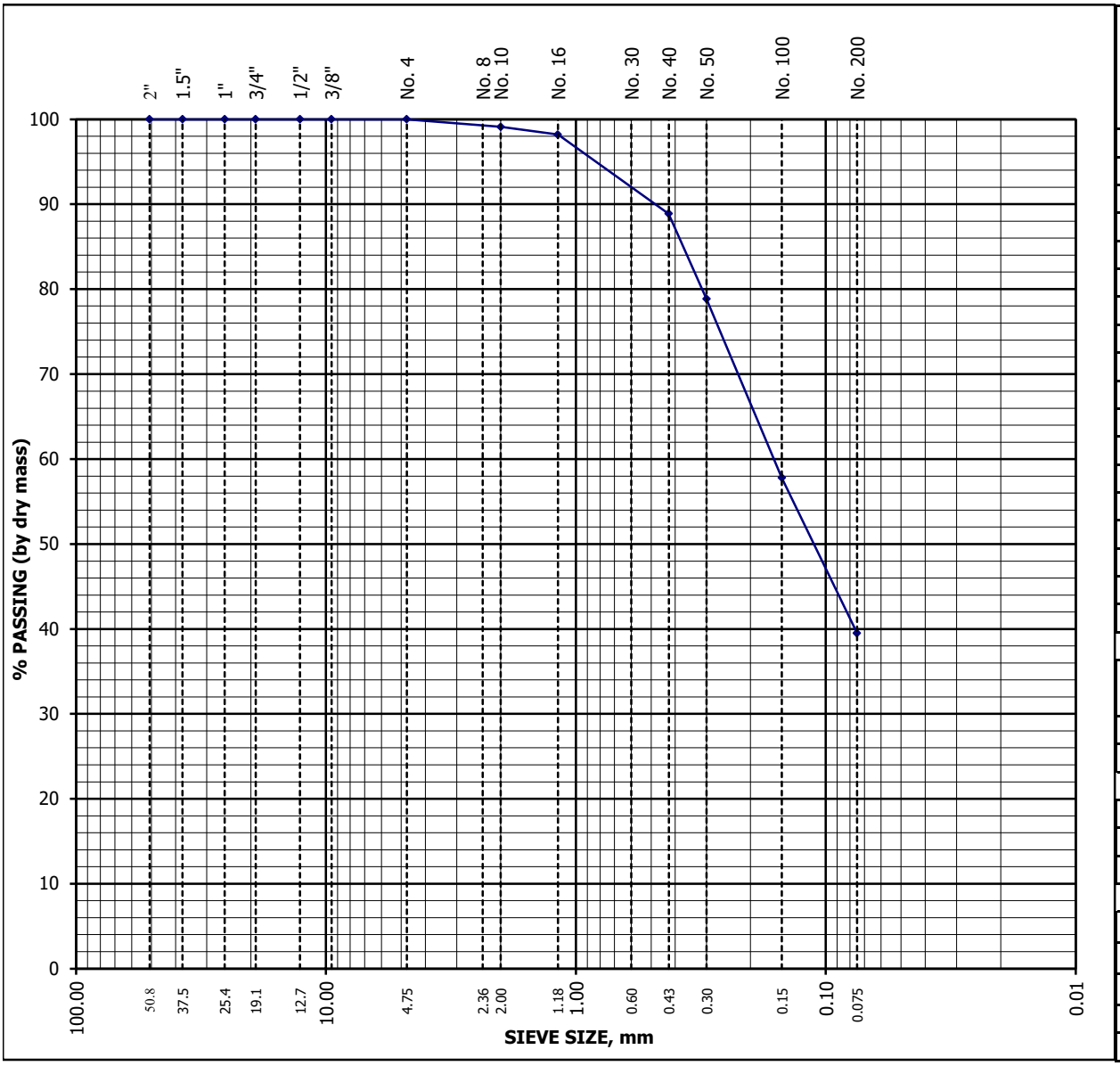
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	29-Jul-20
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Weinerth
Lab ID Number:	202770	Reviewer:	J. Crystal
Sample Location:	BCP-3 at 2' to 4'		
Visual Description:	SAND, silty, clayey, dusky red		

AASHTO M 145 Classification: **A-4** **Group Index:** **(0)**

Unified Soil Classification System (ASTM D 2487): **(SC-SM) Silty, clayey sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	99
#16	98
#30	
#40	89
#50	79
#100	58
#200	39.5

Moisture (M) & Density (D)	
M, %:	1.6
D, pcf:	

LL	23
PL	17
PI	6

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

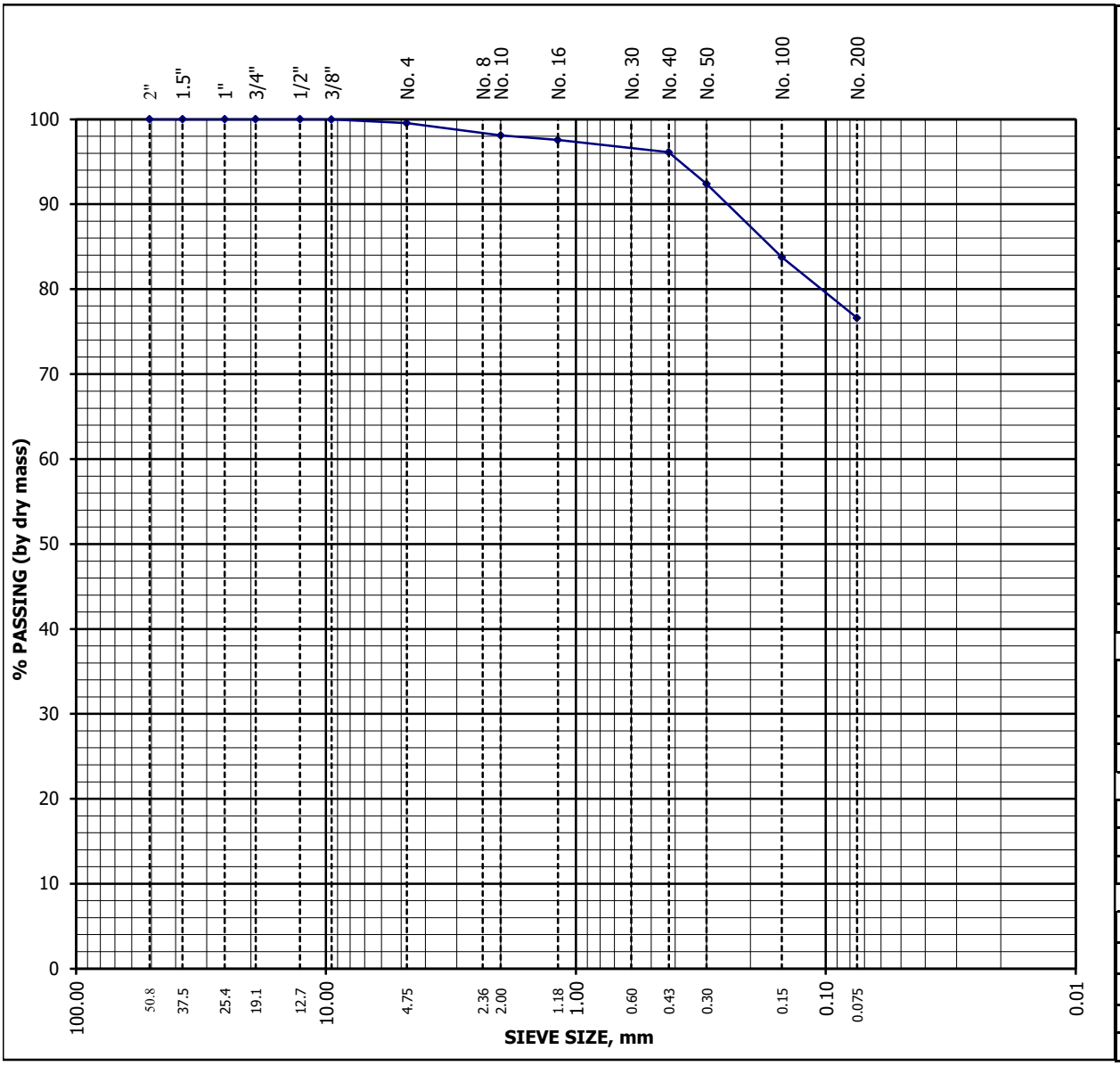
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	29-Jul-20
Project Name:	Cucharas Basin Collaborative Storage	Technician:	G. Hoyos
Lab ID Number:	202771	Reviewer:	J. Crystal
Sample Location:	BC-1 at 15'		
Visual Description:	CLAYSTONE: CLAY, with sand, dusky red		

AASHTO M 145 Classification: **A-6** **Group Index:** **12**

Unified Soil Classification System (ASTM D 2487): **(CL)** **Lean clay with sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	100
#8	
#10	98
#16	98
#30	
#40	96
#50	92
#100	84
#200	76.6

Moisture (M) & Density (D)	
M, %:	11.2
D, pcf:	

LL	39
PL	22
PI	17

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

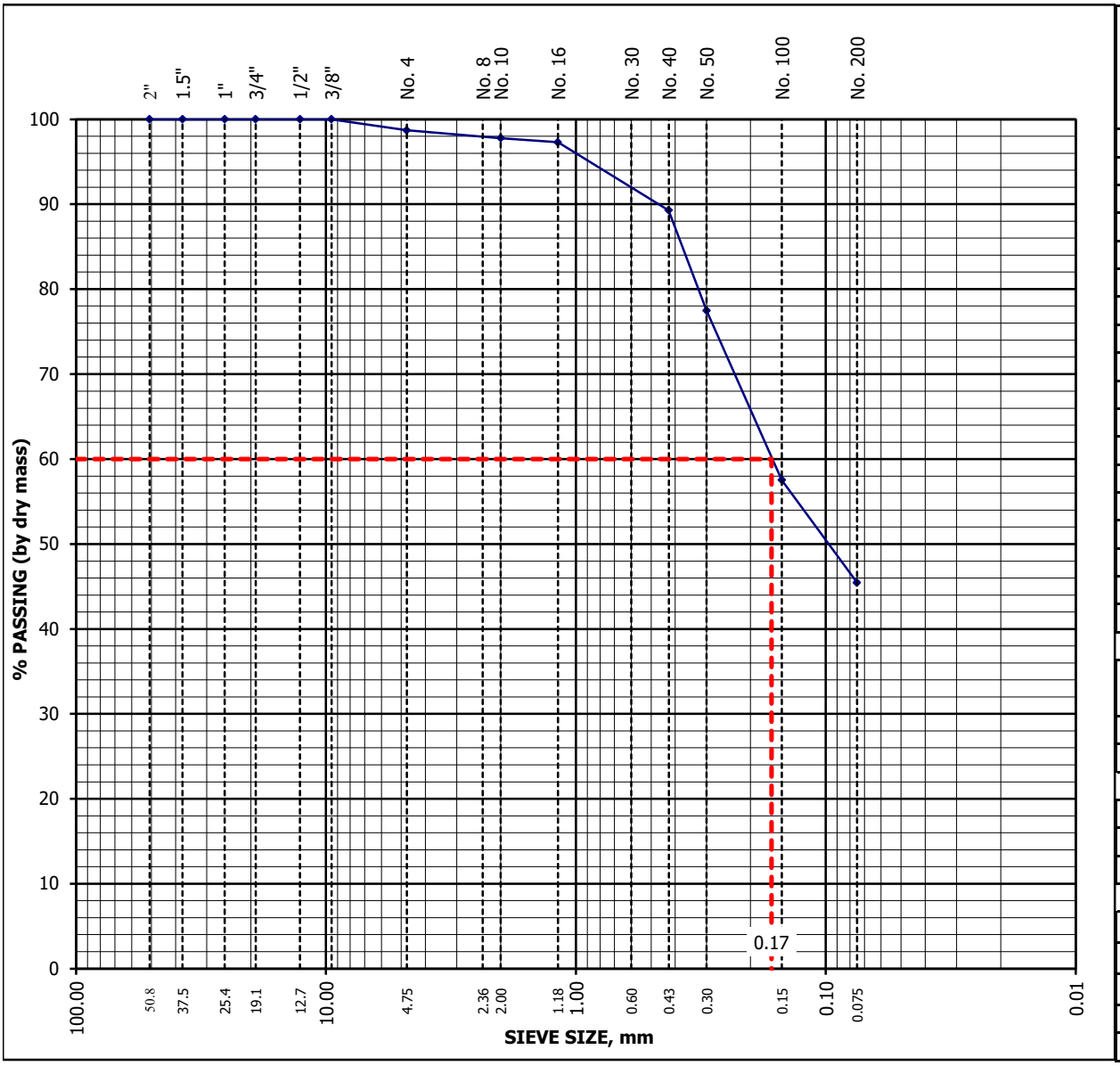
CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	22-Jul-20
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	202772	Reviewer:	J. Crystal
Sample Location:	BC-1 at 20'		
Visual Description:	SANDSTONE: SAND, silty, reddish brown		

AASHTO M 145 Classification: **A-6** **Group Index:** **3**

Unified Soil Classification System (ASTM D 2487): **(SM)** **Silty sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	100
#4	99
#8	
#10	98
#16	97
#30	
#40	89
#50	77
#100	58
#200	45.5

Moisture (M) & Density (D)	
M, %:	11.1
D, pcf:	

LL	36
PL	23
PI	13

D_{60}	0.17
D_{30}	
D_{10}	
Cu	
Cc	

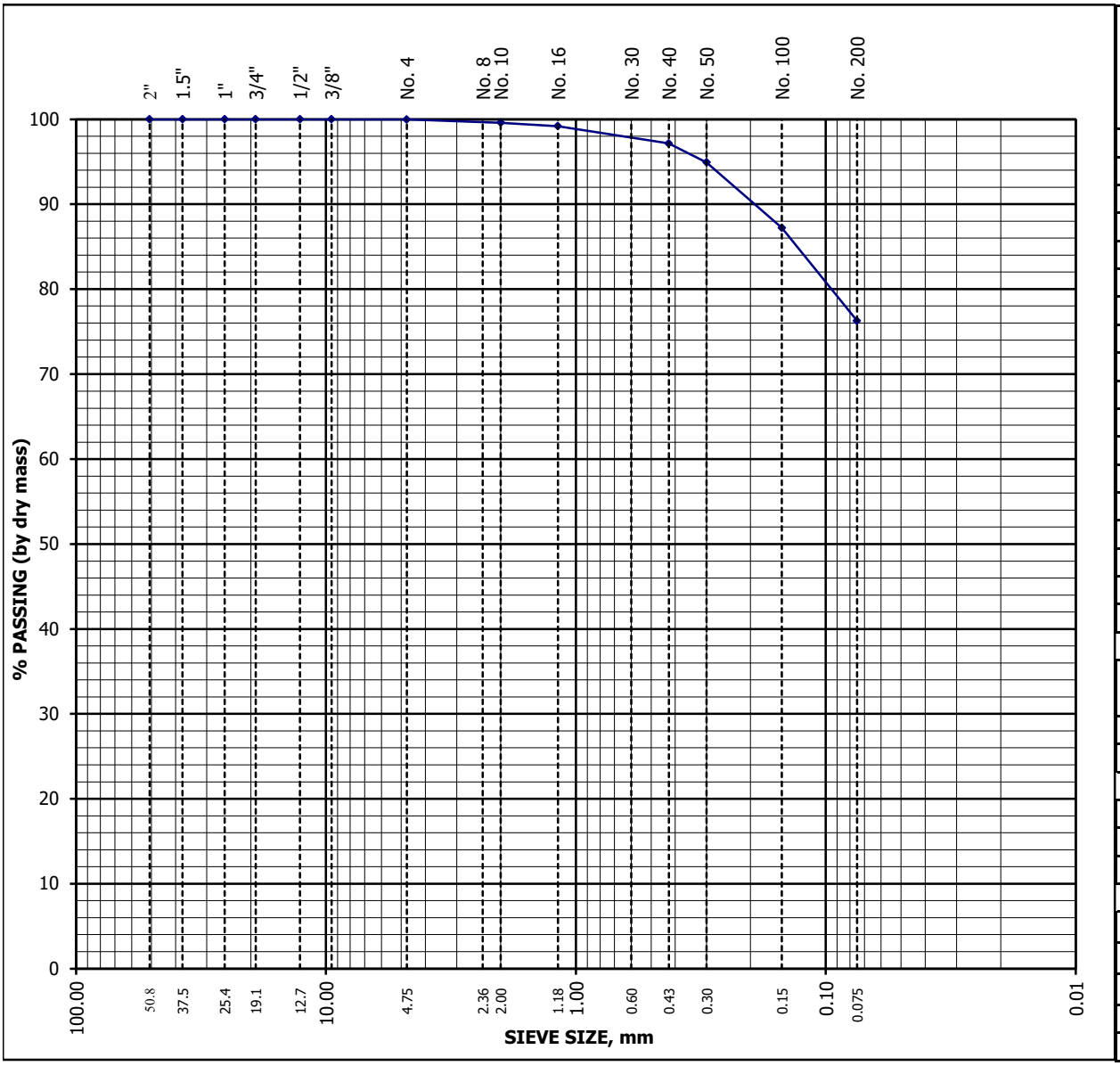
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GRADATION PLOT - SOIL & AGGREGATE

Project Number:	18.117, Applegate Group	Date:	20-Jul-20
Project Name:	Cucharas Basin Collaborative Storage	Technician:	G. Hoyos
Lab ID Number:	202773	Reviewer:	J. Crystal
Sample Location:	BC-2 at 15'		
Visual Description:	CLAY, with sand, dusky red		

AASHTO M 145 Classification: **A-7-6** **Group Index:** **16**

Unified Soil Classification System (ASTM D 2487): **CL** **Lean clay, with sand**



Sieve Size	% Passing
2"	
1.5"	
1"	
3/4"	
1/2"	
3/8"	
#4	100
#8	
#10	100
#16	99
#30	
#40	97
#50	95
#100	87
#200	76.3

Moisture (M) & Density (D)	
M, %:	13.4
D, pcf:	

LL	46
PL	26
PI	20

D_{60}	
D_{30}	
D_{10}	
Cu	
Cc	

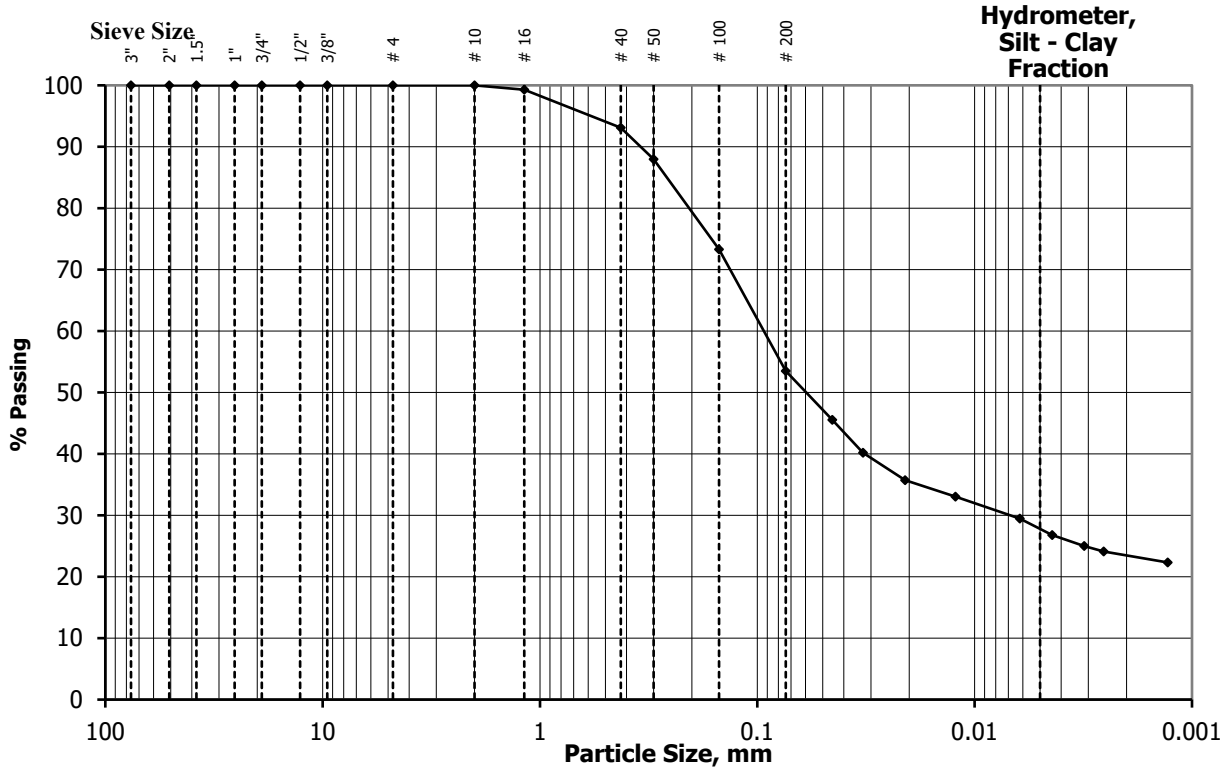
CESARE, INC.
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PARTICLE SIZE ANALYSIS (ASTM D422)

Project Number:	18.117, Applegate Group	Date:	07/18/20
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	202767	Reviewer:	J. Crystal
Sample Location:	BCP-1 at 1' to 8' and BCP-5 at 2' to 8'		
Visual Description:	CLAY, sandy, red brown		
Soil Classification (USCS):	**CL**	**A-6(3)**	

Sieve Size	% Passing
3"	100
2"	100
1-1/2"	100
1"	100
3/4"	100
1/2"	100
3/8"	100
#4	100
#10	100
#16	99
#40	93
#50	88
#100	73
#200	53.5

Hydrometer	
Particle Size	**% Passing**
45 Micron	46
33 Micron	40
21 Micron	36
12 Micron	33
6 Micron	29
4.4 Micron	27
3.1 Micron	25
2.5 Micron	24
1.3 Micron	22
% Gravel:	**0**
% Sand:	**47**
% Silt:	**25.7**
% Clay (< 5 micron):	**27.8**



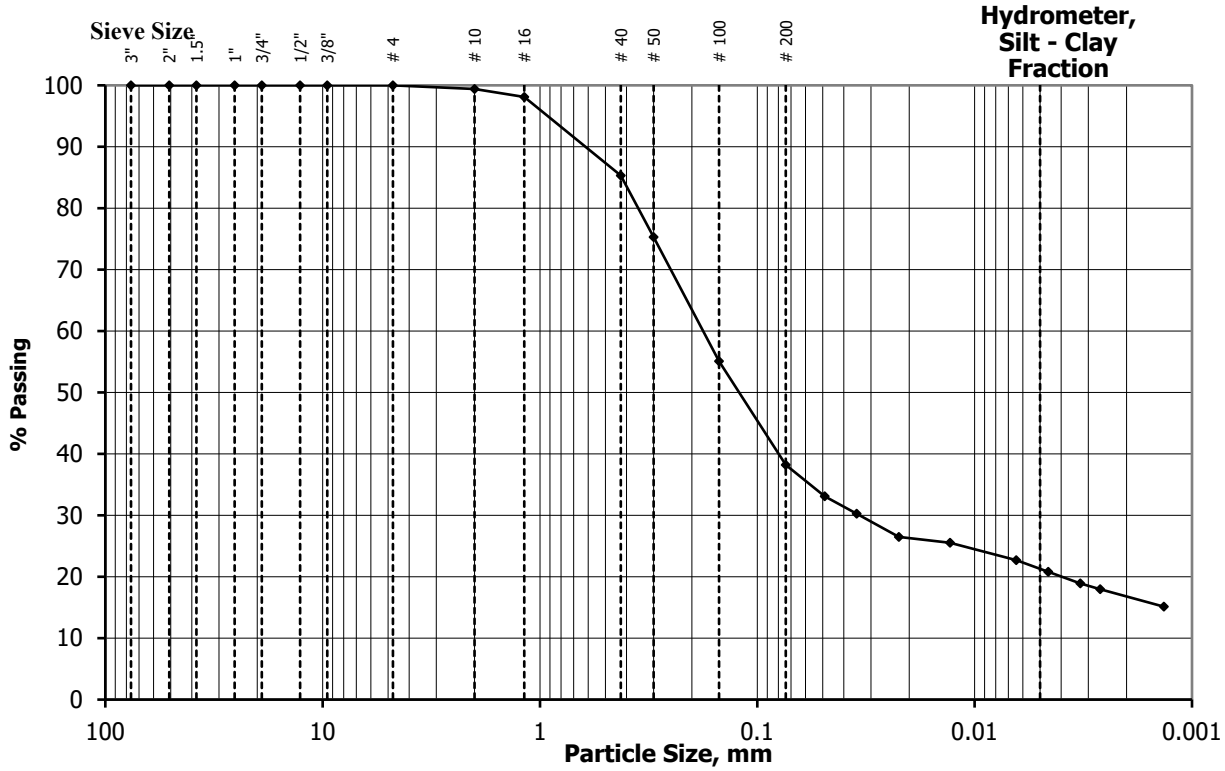
CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PARTICLE SIZE ANALYSIS (ASTM D422)

Project Number:	18.117, Applegate Group	Date:	07/18/20
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	202768	Reviewer:	J. Crystal
Sample Location:	BCP-2 at 2' to 10' and BCP-4 at 2' to 8'		
Visual Description:	SAND, silty, clayey		
Soil Classification (USCS):	**SM-SC** **A-4**		

Sieve Size	% Passing
3"	100
2"	100
1-1/2"	100
1"	100
3/4"	100
1/2"	100
3/8"	100
#4	100
#10	99
#16	98
#40	85
#50	75
#100	55
#200	38.2

Hydrometer	
Particle Size	**% Passing**
49 Micron	33
35 Micron	30
22 Micron	26
13 Micron	26
6 Micron	23
4.6 Micron	21
3.3 Micron	19
2.6 Micron	18
1.3 Micron	15
% Gravel:	**0**
% Sand:	**62**
% Silt:	**17.2**
% Clay (< 5 micron):	**21.0**



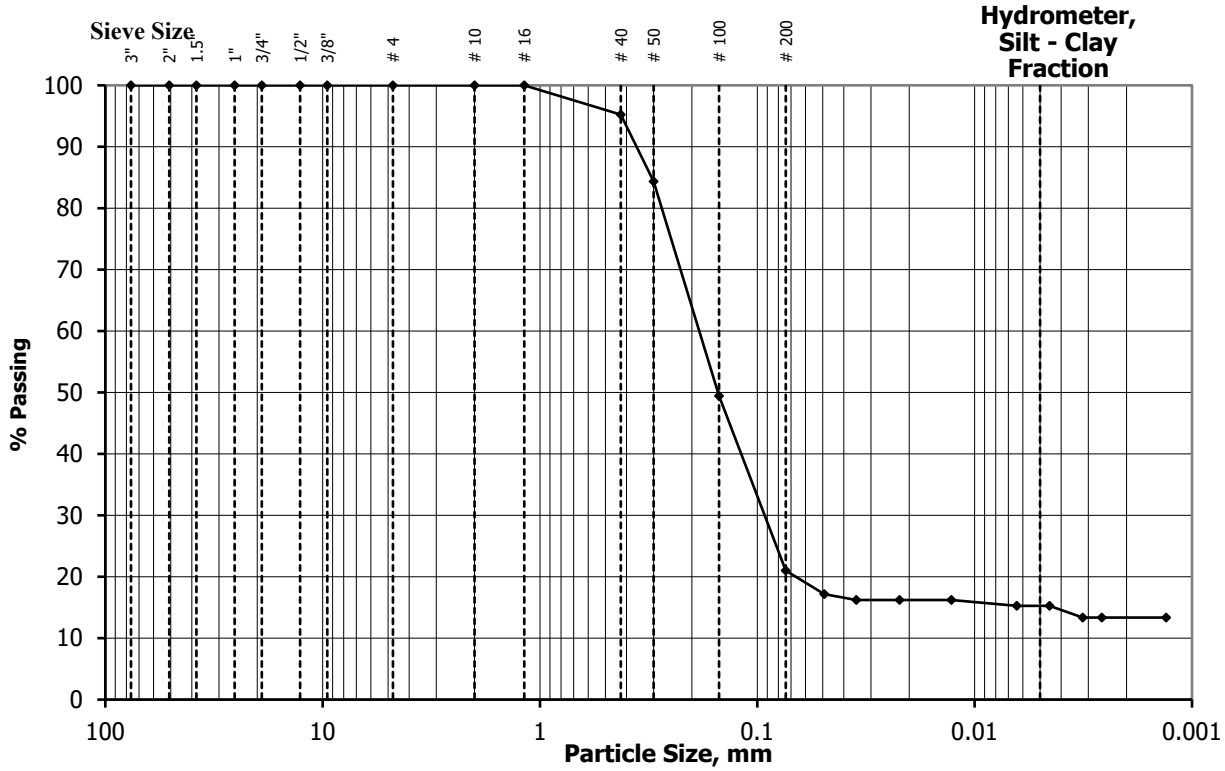
CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

PARTICLE SIZE ANALYSIS (ASTM D422)

Project Number:	18.117, Applegate Group	Date:	07/18/20
Project Name:	Cucharas Basin Collaborative Storage	Technician:	J. Holiman
Lab ID Number:	202769	Reviewer:	J. Crystal
Sample Location:	BCP-6 at 7' to 9'		
Visual Description:	SAND, silty		
Soil Classification (USCS):	**SM** **A-2-4**		

Sieve Size	% Passing
3"	100
2"	100
1-1/2"	100
1"	100
3/4"	100
1/2"	100
3/8"	100
#4	100
#10	100
#16	100
#40	95
#50	84
#100	49
#200	21.0

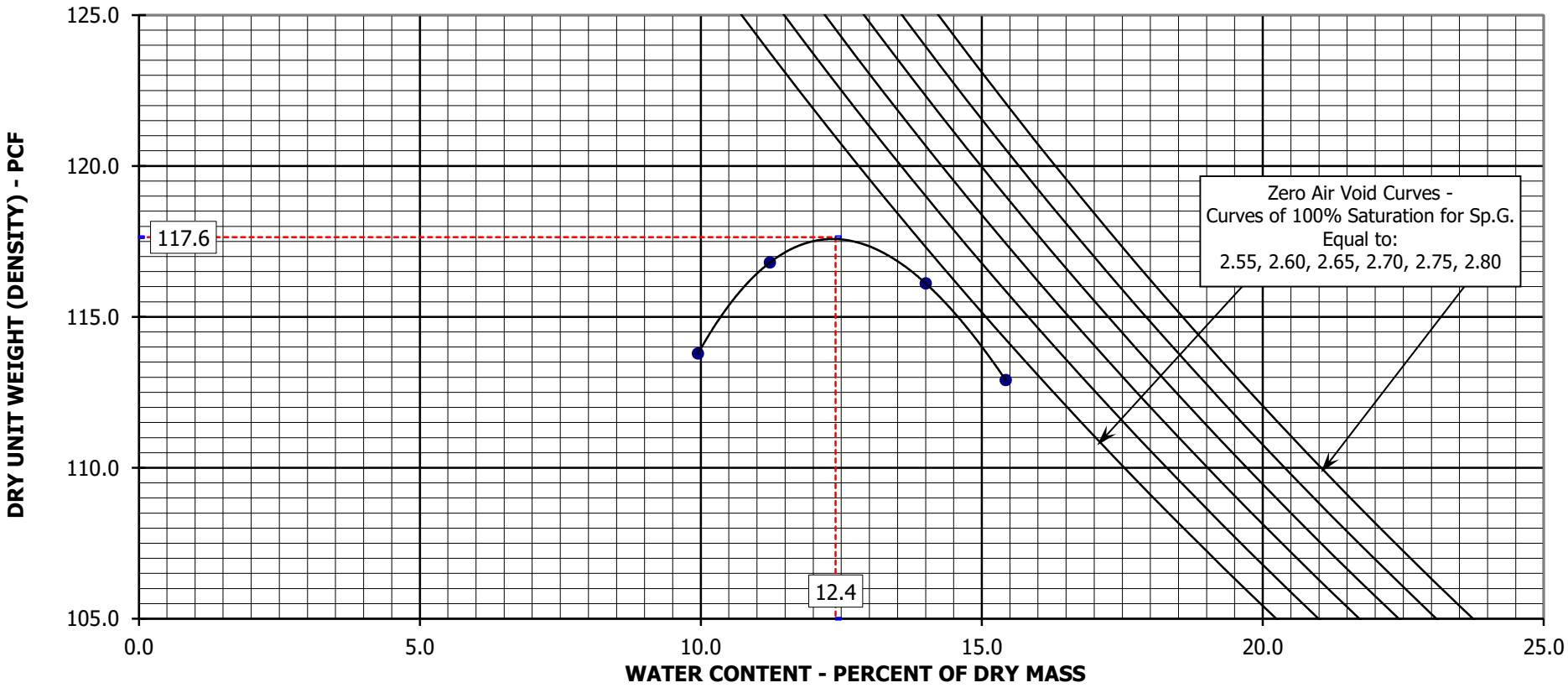
Hydrometer	
Particle Size	**% Passing**
49 Micron	17
35 Micron	16
22 Micron	16
13 Micron	16
6 Micron	15
4.5 Micron	15
3.2 Micron	13
2.6 Micron	13
1.3 Micron	13
% Gravel:	**0**
% Sand:	**79**
% Silt:	**5.7**
% Clay (< 5 micron):	**15.3**



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ASTM/AASHTO Compaction
Test Procedure Designation: ASTM D 698 (Standard)
Method: A

Laboratory Maximum Dry Unit Weight (Density): 117.6 pcf
Laboratory Optimum Moisture Content (OMC): 12.4 %



Sample Location	Elev. or Depth, ft	LL	PL	PI	-#200, %	Soil Description & Classification
BCP-1 and BCP-5	1 to 8	26	14	12	53	Visual: CLAY, sandy AASHTO: A-6(3) USCS: CL

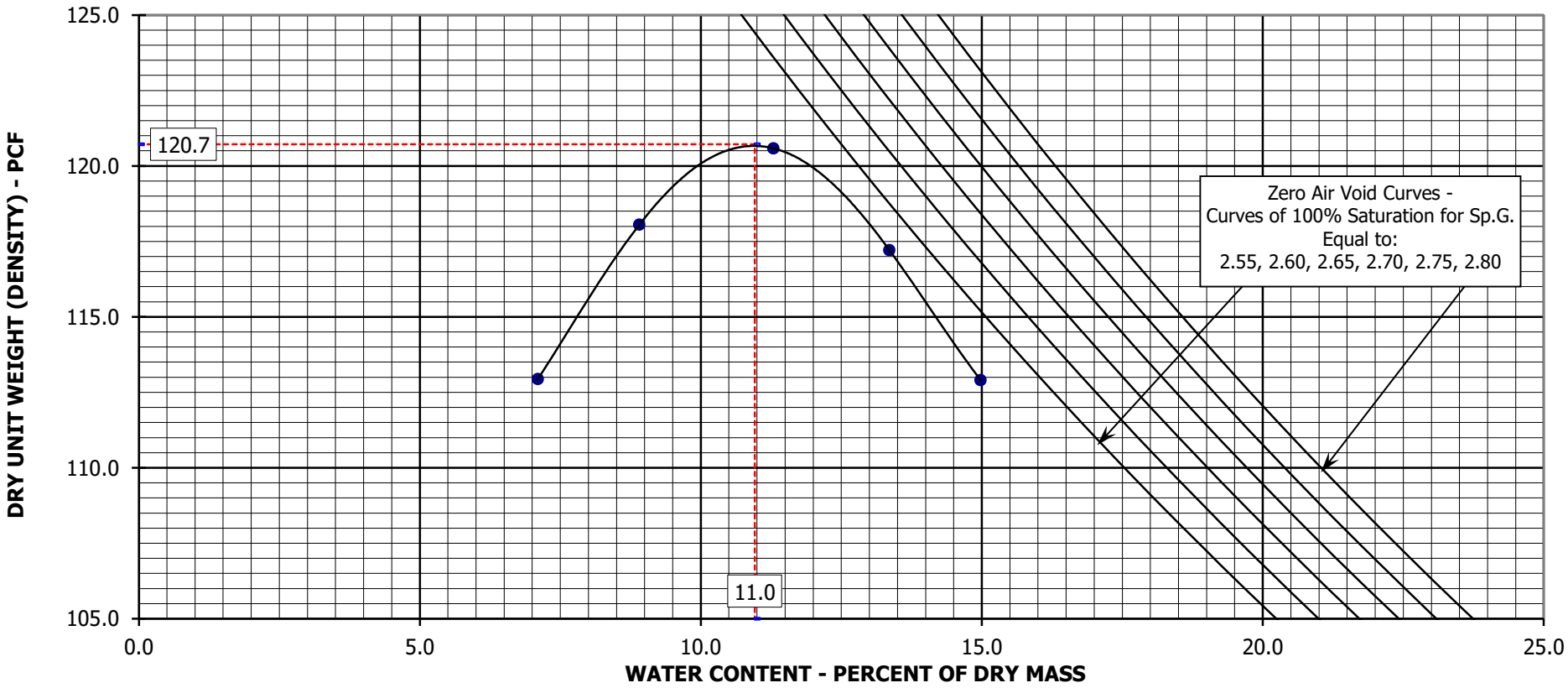
Moisture/Density Relationship (Proctor) Test

Project Number:	18.117, Applegate Group		
Project Name:	Cucharas Basin Collaborative Storage		
Drawn By:	G. Hoyos	Tested by:	J. Weinerth
Checked By:	J. Crystal	Date:	21-Jul-20
Date:	22-Jul-20	Lab ID Number:	202767

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

ASTM/AASHTO Compaction
Test Procedure Designation: ASTM D 698 (Standard)
Method: A

Laboratory Maximum Dry Unit Weight (Density): 120.7 pcf
Laboratory Optimum Moisture Content (OMC): 11.0 %



Sample Location	Elev. or Depth, ft	LL	PL	PI	-#200, %	Soil Description & Classification
BCP-2 and BCP-4	2 to 10	23	16	7	38	Visual: SAND, silty, clayey AASHTO: A-4 USCS: SM-SC

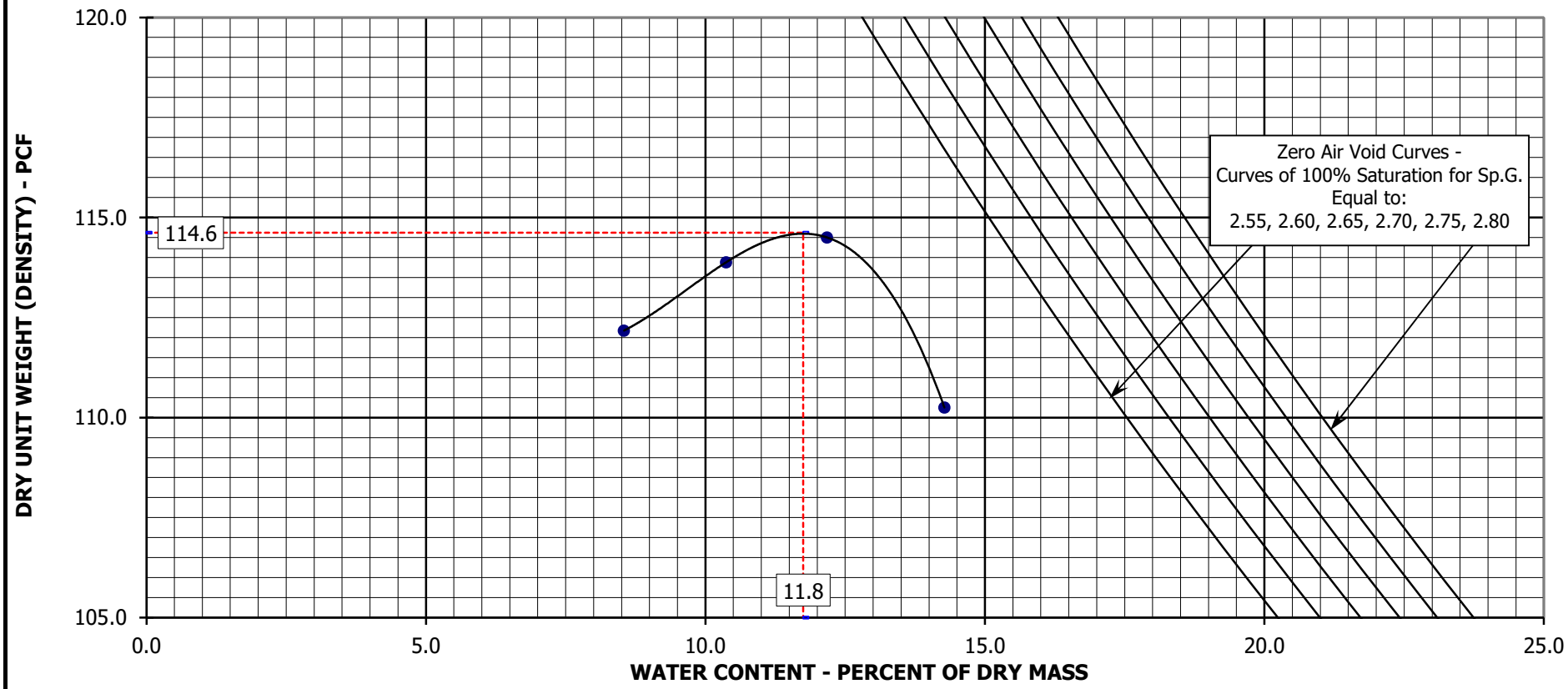
Moisture/Density Relationship (Proctor) Test

Project Number: 18.117, Applegate Group
Project Name: Cucharas Basin Collaborative Storage
Drawn By: G. Hoyos — Tested by: K. Zimmerman
Checked By: j. Crystal — Date: 21-Jul-20
Date: 22-Jul-20 — Lab ID Number: 202768

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

ASTM/AASHTO Compaction
Test Procedure Designation: ASTM D 698 (Standard)
Method: A

Laboratory Maximum Dry Unit Weight (Density): 114.6 pcf
Laboratory Optimum Moisture Content (OMC): 11.8 %



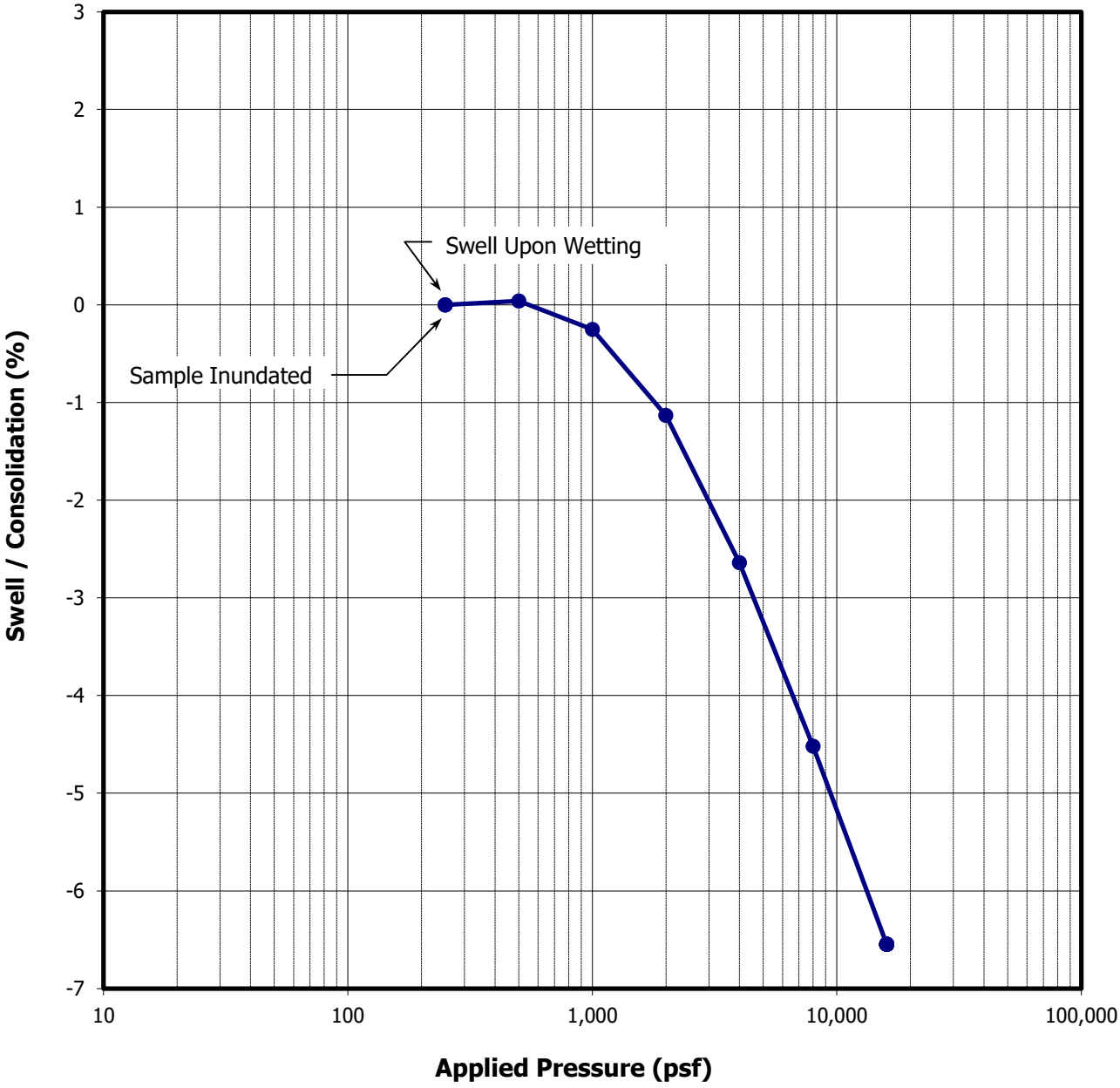
Sample Location	Elev. or Depth, ft	LL	PL	PI	-#200, %	Soil Description & Classification
BCP-6	7 to 9	NV	NV	NP	21	Visual: SAND, silty, dark brown AASHTO: A-2-4 USCS: SM

Moisture/Density Relationship (Proctor) Test

Project Number:	18.117, Applegate Group		
Project Name:	Cucharas Basin Collaborative Storage		
Drawn By:	G. Hoyos	Tested by:	K. Zimmerman
Checked By:	J. Crystal	Date:	21-Jul-20
Date:	22-Jul-20	Lab ID Number:	202769

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SWELL/CONSOLIDATION PLOT

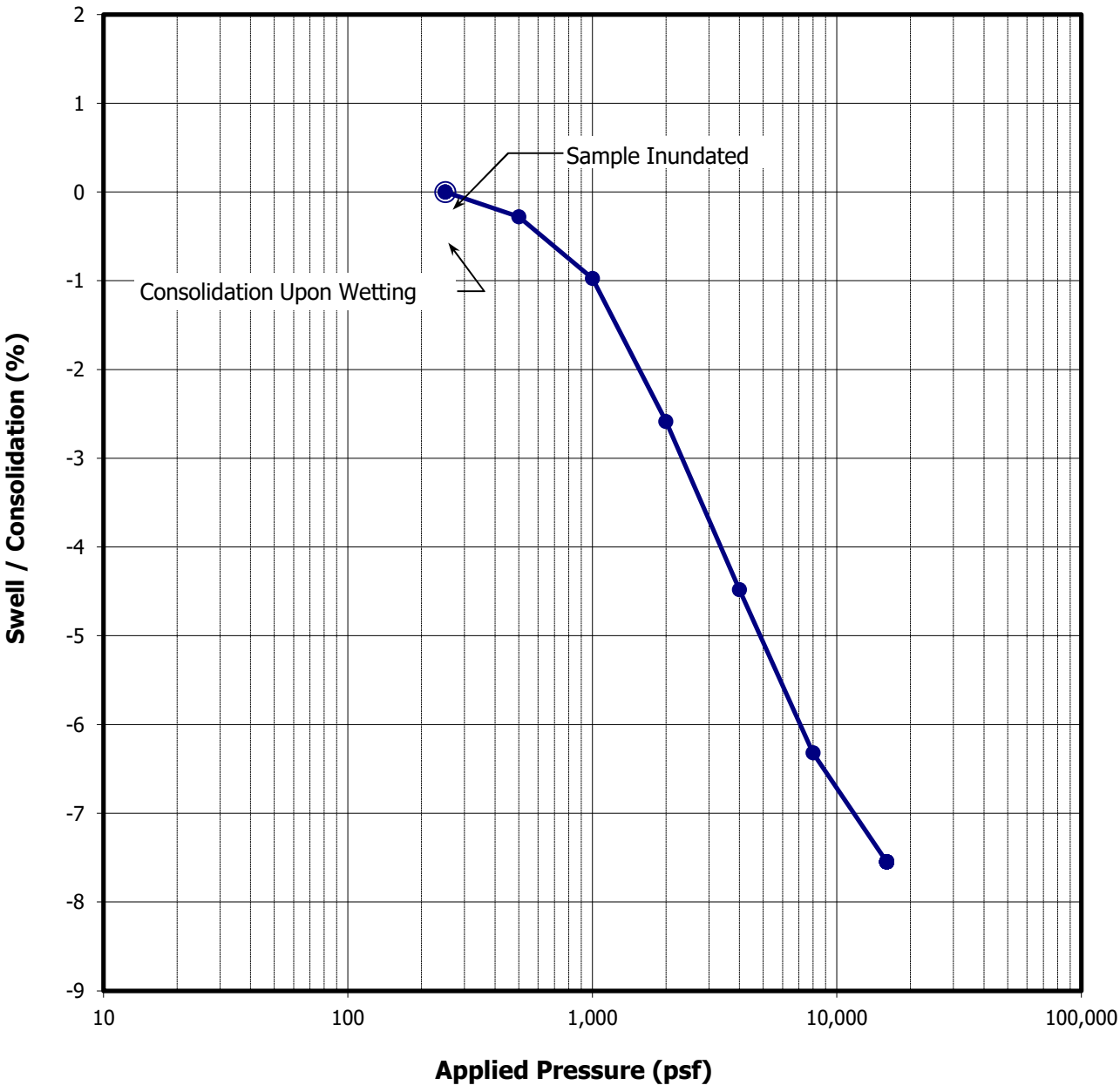


Sample Location	Sample Depth (feet)	Lab ID Number: 202767 Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
BCP-1 BCP-5	1' to 8' 2' to 8'	CLAY, sandy, red brown	113.8	12.8	250	0.0	NA

Client:	**Applegate**	**Project No.:**	**18.117**
Project:	**Cucharas Basin Collaborative Storage**	**Figure:**	**202767**

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Geotechnical Engineers & Construction Materials Consultants

SWELL/CONSOLIDATION PLOT

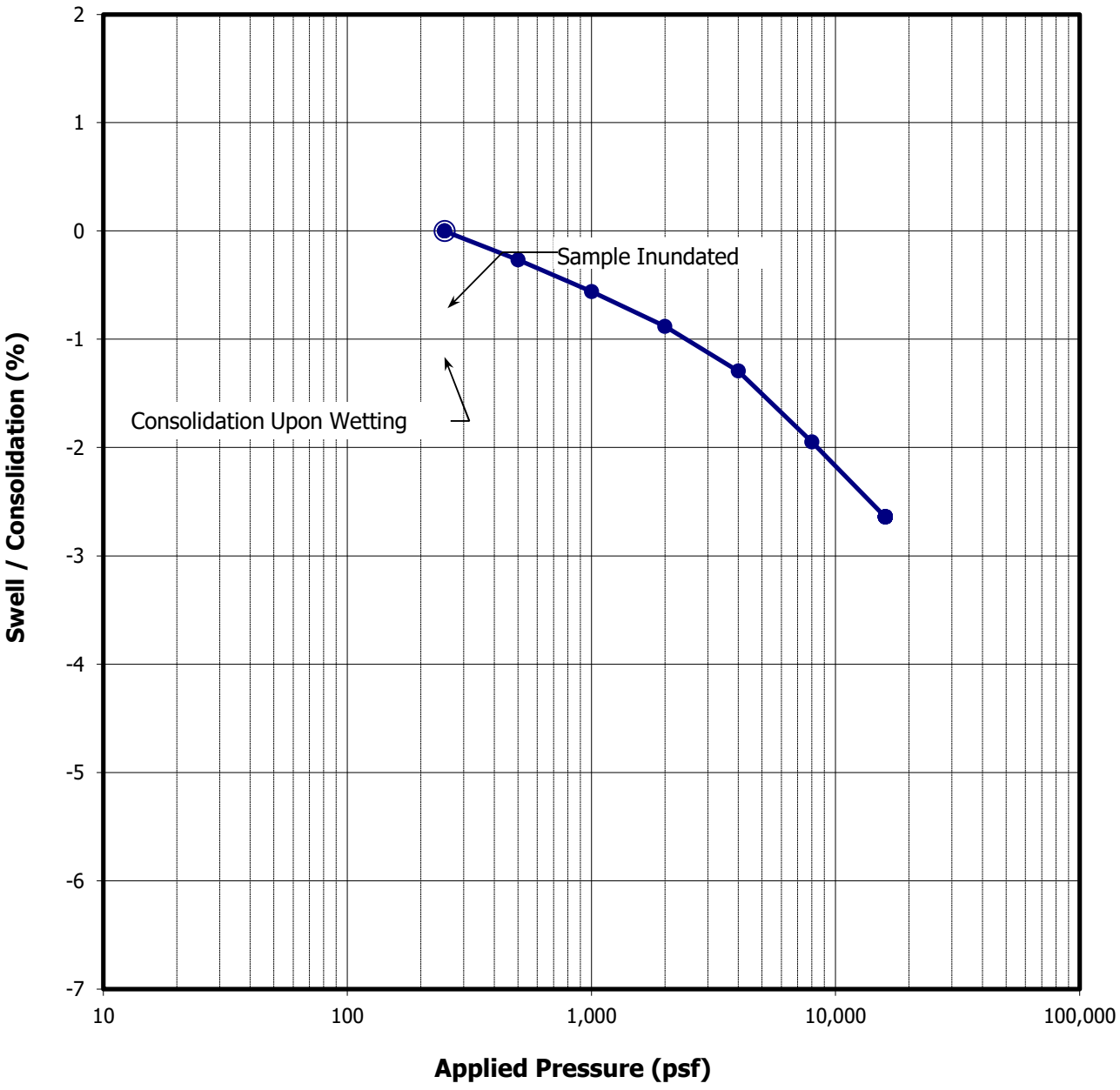


Sample Location	Sample Depth (feet)	Lab ID Number: 202768 Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
BCP-2 & BCP-4	2'-10' & 2'-8'	SAND, silty, clayey, dark red brown	116.6	11.8	250	0.0	N/A

Client:	**Applegate**	**Project No.:**	**18.117**
Project:	**Cucharas Basin Collaborative Storage**	**Figure:**	

CESARE, INC.
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SWELL/CONSOLIDATION PLOT



Sample Location	Sample Depth (feet)	Lab ID Number: 202769 Visual Description of Sample	Dry Density (pcf)	Moisture Content (%)	Inundation Pressure (psf)	Volume Change (%)	Swell Pressure (psf)
BCP-6	7 to 9	SAND, silty, red brown	110.7	12.2	250	0.0	N/A

Client:	**Applegate**	**Project No.:**	**18.117**
Project:	**Cucharas Basin Collaborative Storage**	**Figure:**	**202769**

ADVANCED TERRA TESTING

Constant Rate of Flow
Flexible Wall Hydraulic Conductivity

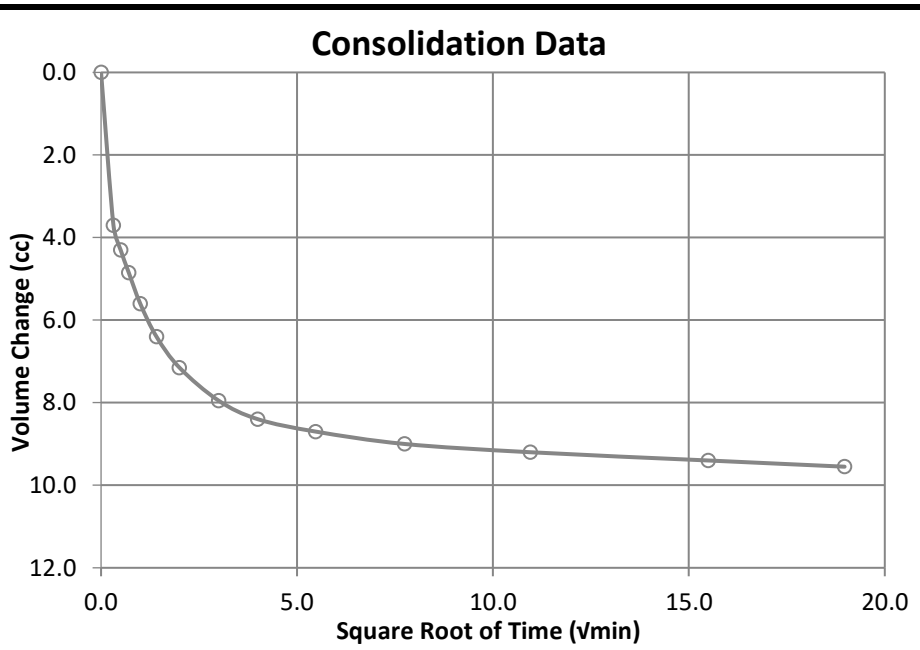
ASTM D 5084 Method D

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation

Initial Saturation (%):	83.7	Initial Volume of Sample (cc):	225.2
Final Saturation (%):	100.0	Final Volume of Sample (cc):	214.0
Cell Pressure (psi):	88.0	Volume Change After Consolidation (cc):	25.7
Back Pressure (psi):	58.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	30.0	Final Dial Reading (in):	0.224
Effective Stress (kPa):	206.8	Height Change (in):	0.024
Cell Expansion Correction (cc):	14.57	Initial Area (cm²):	29.38
Cell ID:	4P	Final Area (cm²):	28.15

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	0.80	0.00
0.1	0.32	4.50	3.70
0.25	0.50	5.10	4.30
0.5	0.71	5.65	4.85
1	1.00	6.40	5.60
2	1.41	7.20	6.40
4	2.00	7.95	7.15
9	3.00	8.75	7.95
16	4.00	9.20	8.40
30	5.48	9.50	8.70
60	7.75	9.80	9.00
120	10.95	10.00	9.20
240	15.49	10.20	9.40
360	18.97	10.35	9.55



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	39.2	47.8	14.40	15.40	38.0	1.00	2.0	8.6	0.86
50.0	60.0	49.2	58.3	15.80	16.60	48.0	0.80	2.0	9.1	0.91
60.0	70.0	59.2	68.7	17.60	17.70	58.0	0.10	2.0	9.5	0.95

File name: 2884057__Permeability Method D ASTM D5084_0.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

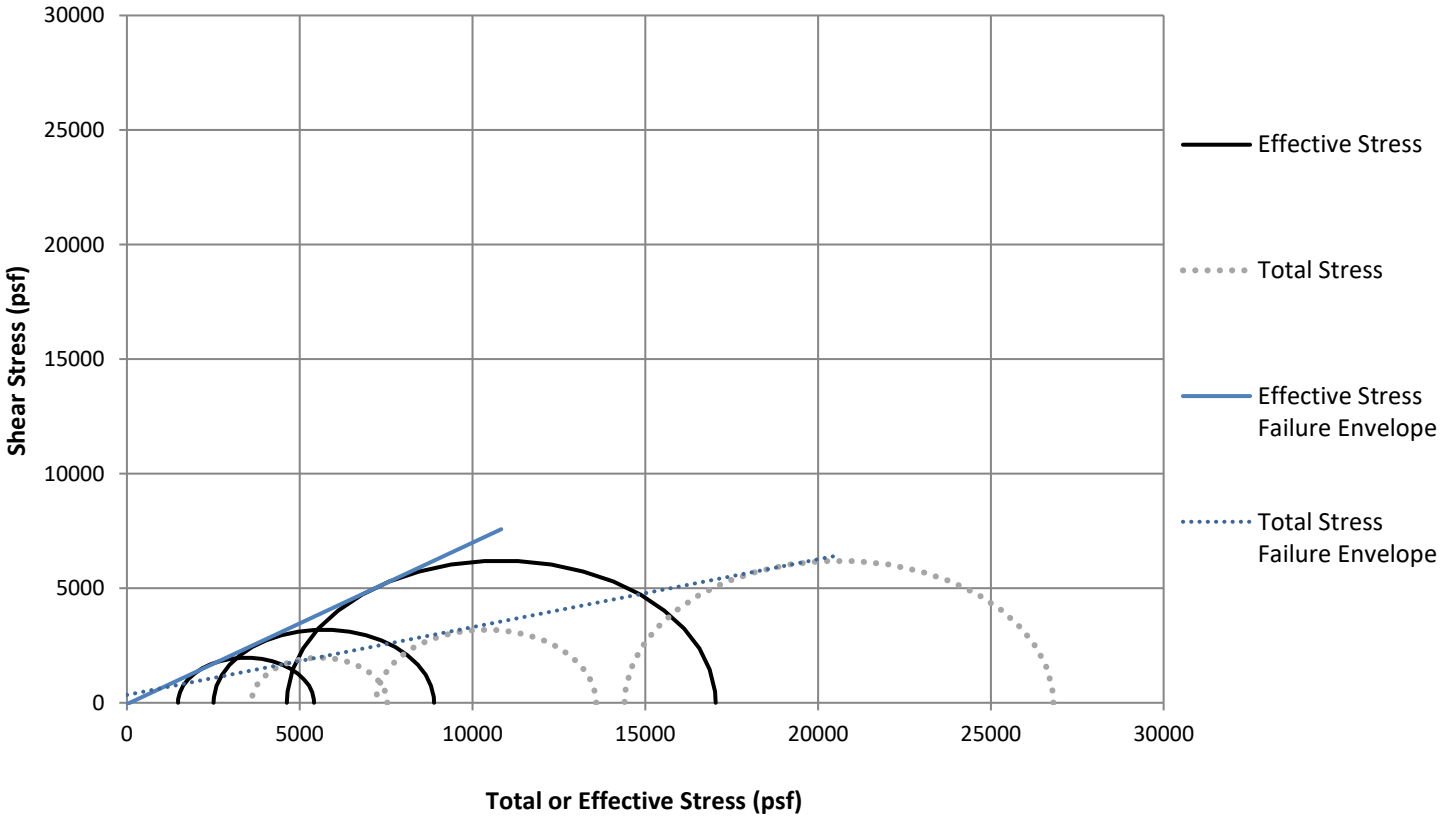
ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Effective Stress		Total Stress	
Internal Friction Angle - ϕ:	35.2	Internal Friction Angle - ϕ:	16.5
Cohesion (psf):	--	Cohesion (psf):	342
Cohesion (kPa):	--	Cohesion (kPa):	16.4
Modified Friction Angle - ψ:	29.9	Modified Friction Angle - ψ:	15.8
Modified Cohesion - a (psf):	--	Modified Cohesion - a (psf):	328
Modified Cohesion - a (kPa):	--	Modified Cohesion - a (kPa):	15.7

Raw Data Files	2884057_CUPP_202767_PTA.trx, 2884057_CUPP_202767_PTB.trx, 2884057_CUPP_202767_PTC.trx,

Mohr Stress Circles



NOTES:

Data entry by:	CL	Date: 08/07/20
Checked by:	KR	Date: 08/20/20
File name:	2884057__TxCuPP ASTM D4767_0.xlsm	Page 1 of 8

ADVANCED TERRA TESTING

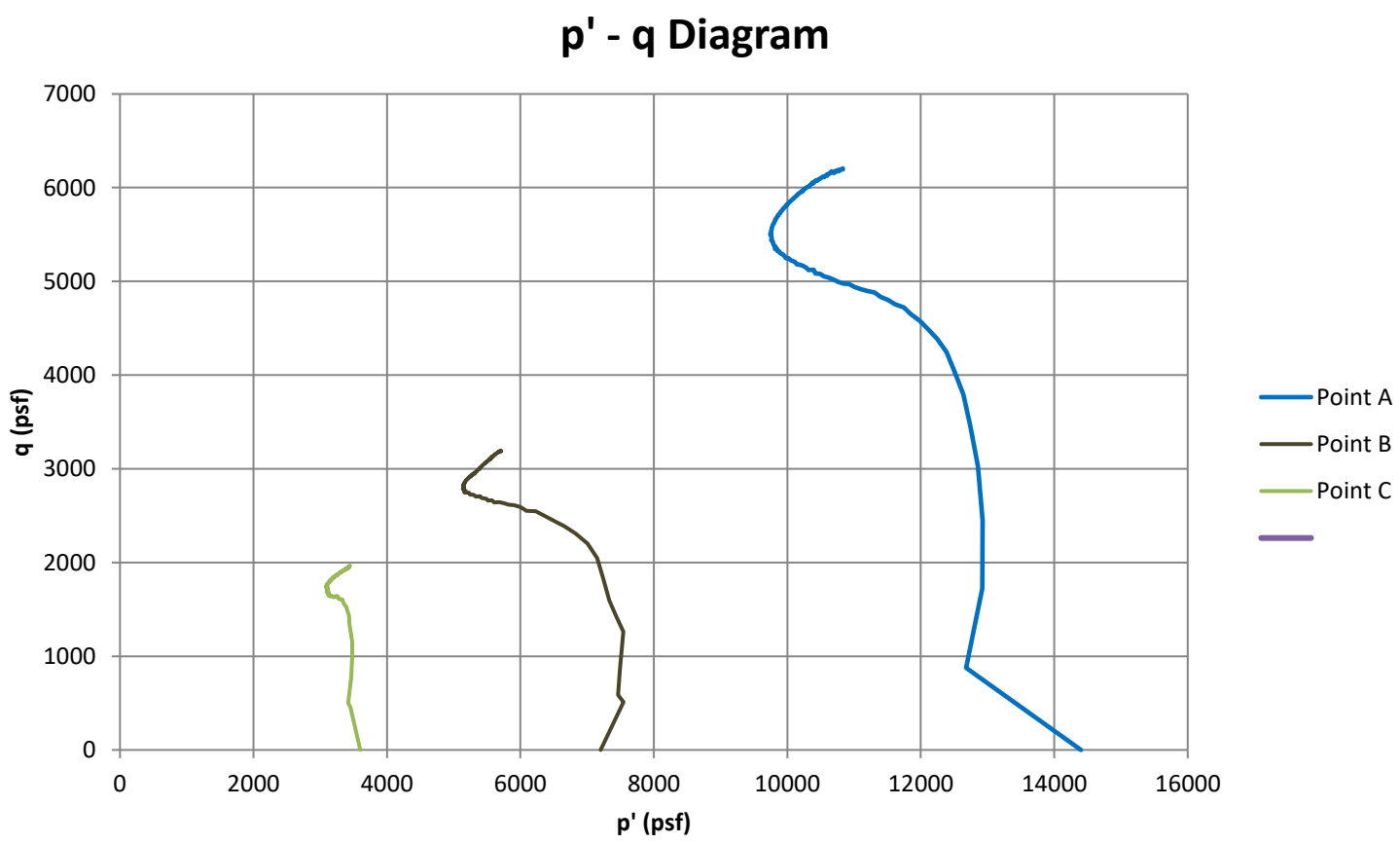
Consolidated Undrained Triaxial Compression

ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Shear Summary at Peak Deviator Stress

	Point A	Point B	Point C
Peak Deviator Stress (psf) :	12410	6383	3935
Peak Deviator Stress (kPa) :	594.2	305.6	188.4
Major Principal Stress (psf) - σ_{1f} :	26810	13583	7535
Major Principal Stress (kPa) - σ_{1f} :	1283.7	650.4	360.8
Minor Principal Stress (psf) - σ_{3f} :	14400	7200	3600
Minor Principal Stress (kPa) - σ_{3f} :	689.5	344.7	172.4
Effective Major Principal Stress (psf) - σ'_{1f} :	17037	8888	5415
Effective Major Principal Stress (kPa) - σ'_{1f} :	815.7	425.6	259.2
Effective Minor Principal Stress (psf) - σ'_{3f} :	4627	2505	1480
Effective Minor Principal Stress (kPa) - σ'_{3f} :	221.5	120.0	70.9



File name: 2884057__TxCuPP ASTM D4767_0.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Point A

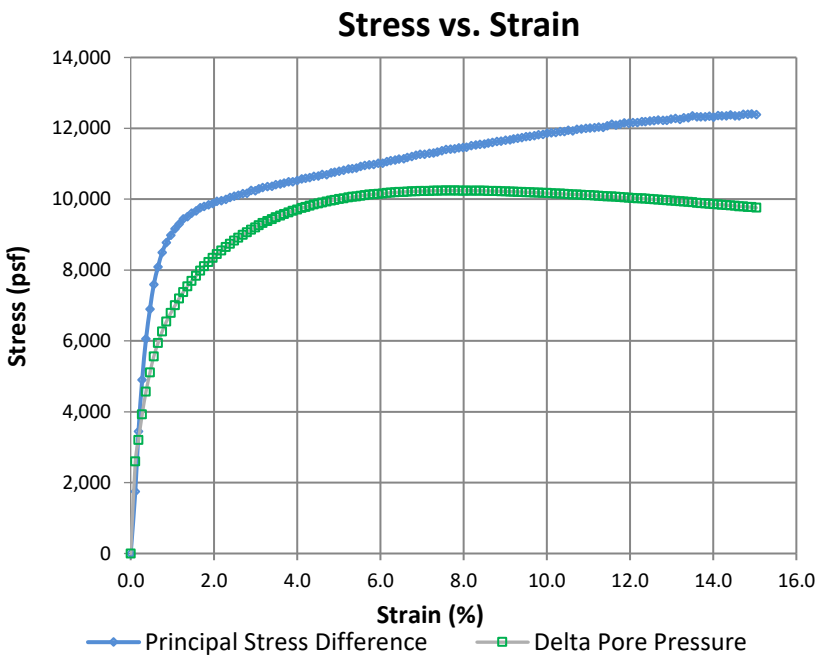
Before Test Mass of Wet Soil (g):	767.25	Initial Wet Density (pcf):	128.6
After Test Mass of Wet Soil (g):	766.20	Initial Dry Density (pcf):	111.6
Mass of Dry Soil and Pan (g):	926.20	Initial Wet Density (kg/m³):	2060
Mass of Pan (g):	260.68	Initial Dry Density (kg/m³):	1787
Diameter (in):	2.402	Initial Moisture (%):	15.3
Initial Sample Height (in):	5.015	Final Wet Density (pcf):	140.2
After Consolidation Height (in):	4.889	Final Dry Density (pcf):	121.8
Assumed Specific Gravity:	2.65	Final Wet Density (kg/m³):	2245
		Final Dry Density (kg/m³):	1950
Back Pressure (psi):	68.0	Final Moisture (%):	15.1
Cell Pressure (psi):	168.0		
Initial Effective Stress (psi):	100.0	Membrane Correction Factor (lb/in²):	72.64
Initial Effective Stress (kPa):	689.5	Filter Paper Load Capacity (lb/in):	1.1
Strain Rate (in/min):	0.0082		

Triaxial Compression Data

Peak Deviator Stress (psf):	12410
Peak Deviator Stress (kPa):	594.2

Parameters at Peak Deviator Stress

Major Principal Stress (psf) - σ_{1f} :	26810
Major Principal Stress (kPa) - σ_{1f} :	1283.7
Minor Principal Stress (psf) - σ_{3f} :	14400
Minor Principal Stress (kPa) - σ_{3f} :	689.5
Induced Pore Pressure (psf) :	9773.29
Induced Pore Pressure (kPa) :	467.95
Effective Major Principal Stress (psf) - σ'_{1f} :	17036.89
Effective Major Principal Stress (kPa) - σ'_{1f} :	815.73
Effective Minor Principal Stress (psf) - σ'_{3f} :	4626.71
Effective Minor Principal Stress (kPa) - σ'_{3f} :	221.53
p' (psf) :	10832
q (psf) :	6205
p' (kPa) :	518.6
q (kPa) :	297.1
Strain (%) :	14.93



File name: 2884057__TxCuPP ASTM D4767_0.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

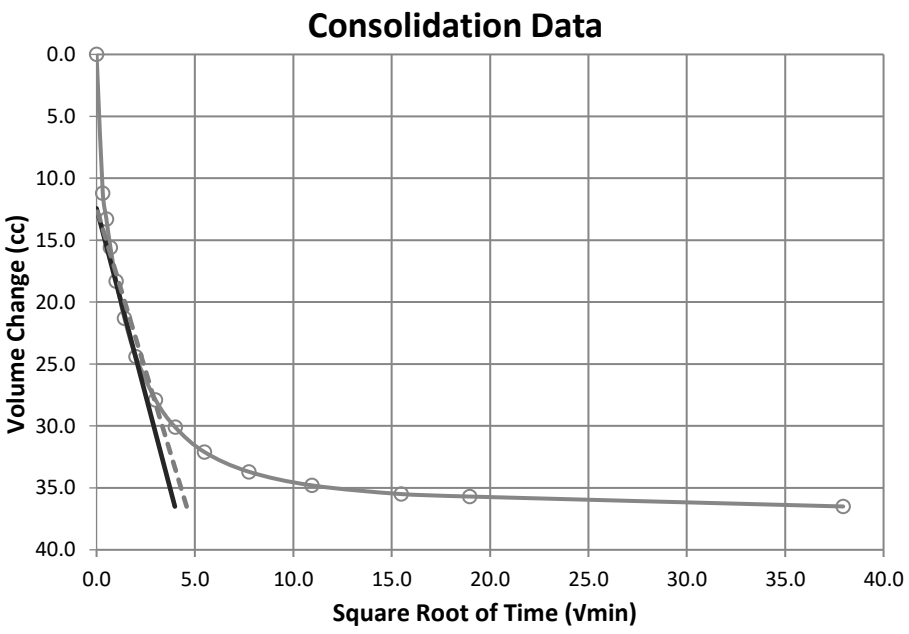
ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation - Point A

Initial Saturation (%):	83.9	Initial Volume of Sample (cc):	372.4
Final Saturation (%):	100.0	Final Volume of Sample (cc):	341.2
Cell Pressure (psi):	168.0	Volume Change After Consolidation (cc):	52.1
Back Pressure (psi):	68.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	100.0	Final Dial Reading (in):	0.326
Effective Stress (kPa):	689.5	Height Change (in):	0.1261
Cell Expansion Correction (cc):	20.93	Initial Area (cm²):	29.24
Cell ID:	24S	Final Area (cm²):	27.48
T50 (min):	2.46		

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	0.50	0.00
0.1	0.32	11.70	11.20
0.25	0.50	13.80	13.30
0.5	0.71	16.10	15.60
1	1.00	18.80	18.30
2	1.41	21.80	21.30
4	2.00	24.90	24.40
9	3.00	28.40	27.90
16	4.00	30.60	30.10
30	5.48	32.60	32.10
60	7.75	34.20	33.70
120	10.95	35.30	34.80
240	15.49	36.00	35.50
360	18.97	36.20	35.70
1440	37.95	37.00	36.50



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	38.8	47.0	15.10	16.80	38.0	1.70	2.0	8.2	0.82
50.0	60.0	48.8	57.6	16.40	17.60	48.0	1.20	2.0	8.8	0.88
60.0	70.0	58.7	68.0	17.50	18.50	58.0	1.00	2.0	9.3	0.93
70.0	80.0	68.8	78.3	18.30	18.60	68.0	0.30	2.0	9.5	0.95

File name: 2884057__TxCuPP ASTM D4767_0.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Point B

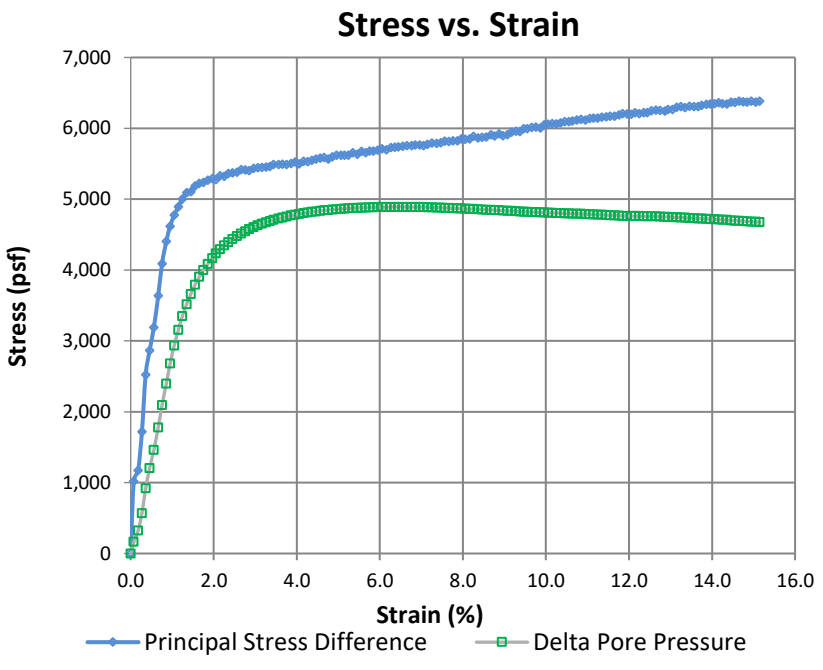
Before Test Mass of Wet Soil (g):	767.04	Initial Wet Density (pcf):	127.5
After Test Mass of Wet Soil (g):	775.52	Initial Dry Density (pcf):	110.5
Mass of Dry Soil and Pan (g):	926.89	Initial Wet Density (kg/m³):	2042
Mass of Pan (g):	262.22	Initial Dry Density (kg/m³):	1770
Diameter (in):	2.410	Initial Moisture (%):	15.4
Initial Sample Height (in):	5.024	Final Wet Density (pcf):	137.7
After Consolidation Height (in):	4.984	Final Dry Density (pcf):	118.1
Assumed Specific Gravity:	2.65	Final Wet Density (kg/m³):	2206
		Final Dry Density (kg/m³):	1891
Back Pressure (psi):	68.0	Final Moisture (%):	16.7
Cell Pressure (psi):	118.0		
Initial Effective Stress (psi):	50.0	Membrane Correction Factor (lb/in²):	72.64
Initial Effective Stress (kPa):	344.7	Filter Paper Load Capacity (lb/in):	1.1
Strain Rate (in/min):	0.01		

Triaxial Compression Data

Peak Deviator Stress (psf):	6383
Peak Deviator Stress (kPa):	305.6

Parameters at Peak Deviator Stress

Major Principal Stress (psf) - σ_{1f} :	13583
Major Principal Stress (kPa) - σ_{1f} :	650.4
Minor Principal Stress (psf) - σ_{3f} :	7200
Minor Principal Stress (kPa) - σ_{3f} :	344.7
Induced Pore Pressure (psf) :	4694.77
Induced Pore Pressure (kPa) :	224.79
Effective Major Principal Stress (psf) - σ'_{1f} :	8888.28
Effective Major Principal Stress (kPa) - σ'_{1f} :	425.57
Effective Minor Principal Stress (psf) - σ'_{3f} :	2505.23
Effective Minor Principal Stress (kPa) - σ'_{3f} :	119.95
p' (psf) :	5697
q (psf) :	3192
p' (kPa) :	272.8
q (kPa) :	152.8
Strain (%) :	14.65



File name: 2884057__TxCuPP ASTM D4767_0.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

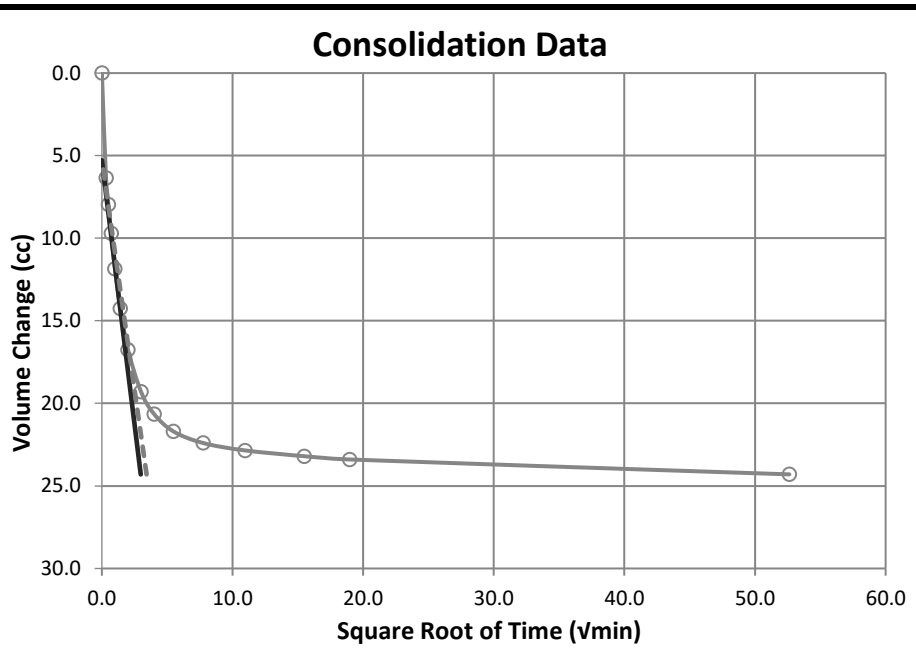
ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation - Point B

Initial Saturation (%):	82.1	Initial Volume of Sample (cc):	375.6
Final Saturation (%):	100.0	Final Volume of Sample (cc):	351.5
Cell Pressure (psi):	118.0	Volume Change After Consolidation (cc):	38.3
Back Pressure (psi):	68.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	50.0	Final Dial Reading (in):	0.240
Effective Stress (kPa):	344.7	Height Change (in):	0.04
Cell Expansion Correction (cc):	14.23	Initial Area (cm²):	29.43
Cell ID:	8S	Final Area (cm²):	27.77
T50 (min):	1.38		

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	1.00	0.00
0.1	0.32	7.35	6.35
0.25	0.50	8.95	7.95
0.5	0.71	10.70	9.70
1	1.00	12.85	11.85
2	1.41	15.25	14.25
4	2.00	17.75	16.75
9	3.00	20.30	19.30
16	4.00	21.65	20.65
30	5.48	22.70	21.70
60	7.75	23.40	22.40
120	10.95	23.85	22.85
240	15.49	24.20	23.20
360	18.97	24.40	23.40
2770	52.63	25.30	24.30



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	38.7	47.1	12.80	14.30	38.0	1.50	2.0	8.4	0.84
50.0	60.0	48.8	57.4	14.40	15.60	48.0	1.20	2.0	8.6	0.86
60.0	70.0	58.8	67.9	15.50	16.05	58.0	0.55	2.0	9.1	0.91
70.0	80.0	68.7	78.2	16.70	16.80	68.0	0.10	2.0	9.5	0.95

File name: 2884057__TxCuPP ASTM D4767_0.xlsm

Consolidated Undrained Triaxial Compression

ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Point C

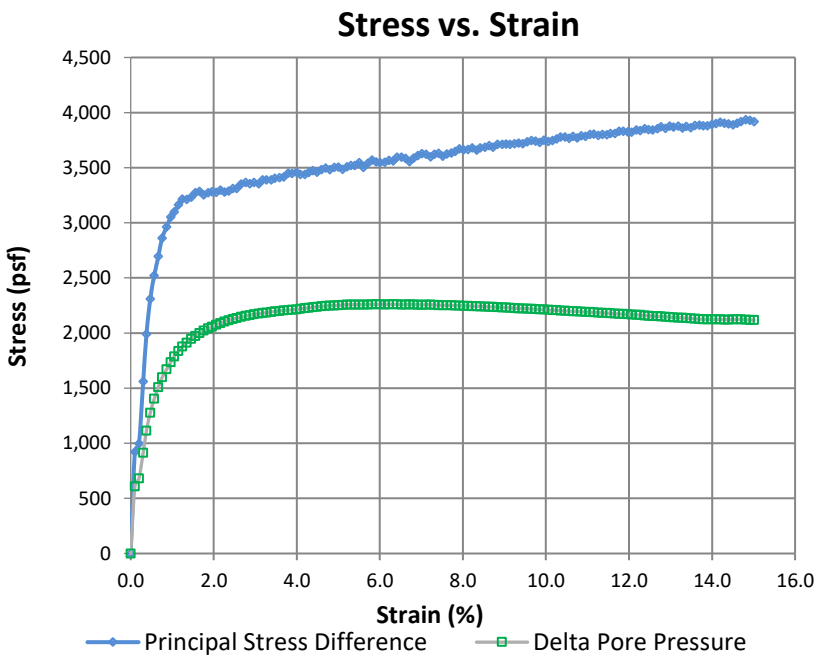
Before Test Mass of Wet Soil (g):	767.22	Initial Wet Density (pcf):	128.2
After Test Mass of Wet Soil (g):	782.19	Initial Dry Density (pcf):	111.0
Mass of Dry Soil and Pan (g):	924.43	Initial Wet Density (kg/m³):	2053
Mass of Pan (g):	260.20	Initial Dry Density (kg/m³):	1777
Diameter (in):	2.406	Initial Moisture (%):	15.5
Initial Sample Height (in):	5.016	Final Wet Density (pcf):	134.8
After Consolidation Height (in):	4.944	Final Dry Density (pcf):	114.4
Assumed Specific Gravity:	2.65	Final Wet Density (kg/m³):	2159
		Final Dry Density (kg/m³):	1833
Back Pressure (psi):	68.0	Final Moisture (%):	17.8
Cell Pressure (psi):	93.0		
Initial Effective Stress (psi):	25.0	Membrane Correction Factor (lb/in²):	72.64
Initial Effective Stress (kPa):	344.7	Filter Paper Load Capacity (lb/in):	1.1
Strain Rate (in/min):	0.0099		

Triaxial Compression Data

Peak Deviator Stress (psf):	3935
Peak Deviator Stress (kPa):	188.4

Parameters at Peak Deviator Stress

Major Principal Stress (psf) - σ_{1f} :	7535
Major Principal Stress (kPa) - σ_{1f} :	360.8
Minor Principal Stress (psf) - σ_{3f} :	3600
Minor Principal Stress (kPa) - σ_{3f} :	172.4
Induced Pore Pressure (psf) :	2120.12
Induced Pore Pressure (kPa) :	101.51
Effective Major Principal Stress (psf) - σ'_{1f} :	5414.53
Effective Major Principal Stress (kPa) - σ'_{1f} :	259.25
Effective Minor Principal Stress (psf) - σ'_{3f} :	1479.88
Effective Minor Principal Stress (kPa) - σ'_{3f} :	70.86
p' (psf) :	3447
q (psf) :	1967
p' (kPa) :	165.1
q (kPa) :	94.2
Strain (%) :	14.81



File name: 2884057__TxCuPP ASTM D4767_0.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

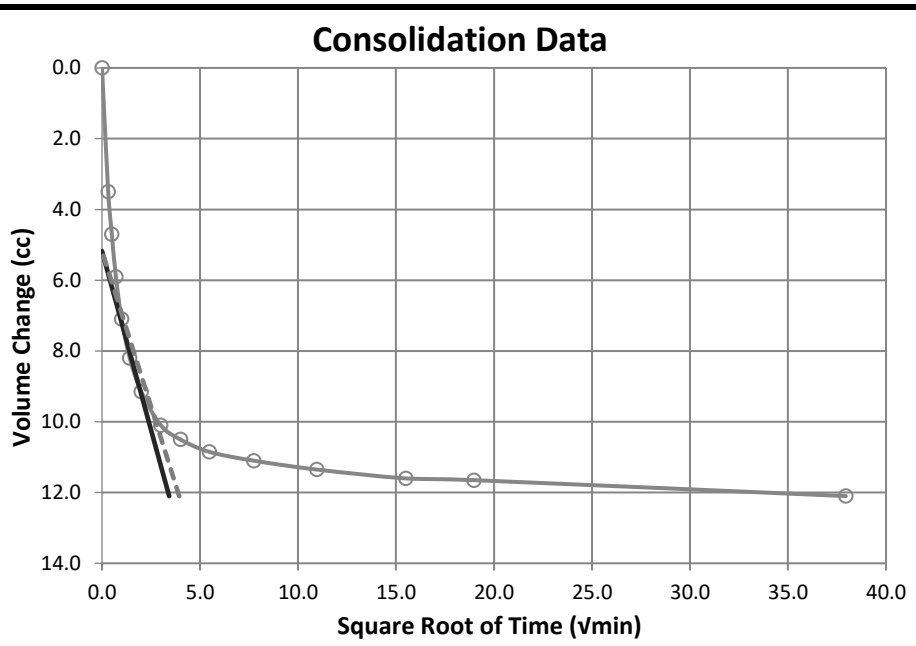
ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-1 & BCP-5
JOB NO.	2884-057	DEPTH	1-8' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202767
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/28/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation - Point C

Initial Saturation (%):	83.7	Initial Volume of Sample (cc):	373.7
Final Saturation (%):	100.0	Final Volume of Sample (cc):	362.3
Cell Pressure (psi):	93.0	Volume Change After Consolidation (cc):	25.5
Back Pressure (psi):	68.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	25.0	Final Dial Reading (in):	0.272
Effective Stress (kPa):	172.4	Height Change (in):	0.0719
Cell Expansion Correction (cc):	14.12	Initial Area (cm²):	29.33
Cell ID:	21S	Final Area (cm²):	28.85
T50 (min):	2.04		

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	0.70	0.00
0.1	0.32	4.20	3.50
0.25	0.50	5.40	4.70
0.5	0.71	6.60	5.90
1	1.00	7.80	7.10
2	1.41	8.90	8.20
4	2.00	9.85	9.15
9	3.00	10.80	10.10
16	4.00	11.20	10.50
30	5.48	11.55	10.85
60	7.75	11.80	11.10
120	10.95	12.05	11.35
240	15.49	12.30	11.60
360	18.97	12.35	11.65
1440	37.95	12.80	12.10



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	39.1	47.2	13.10	14.40	38.0	1.30	2.0	8.1	0.81
50.0	60.0	49.1	57.8	14.15	15.30	48.0	1.15	2.0	8.7	0.87
60.0	70.0	59.3	68.4	15.30	16.20	58.0	0.90	2.0	9.1	0.91
70.0	80.0	69.1	78.7	16.50	16.70	68.0	0.20	2.0	9.6	0.96

File name: 2884057__TxCuPP ASTM D4767_0.xlsm

ADVANCED TERRA TESTING

Direct Shear

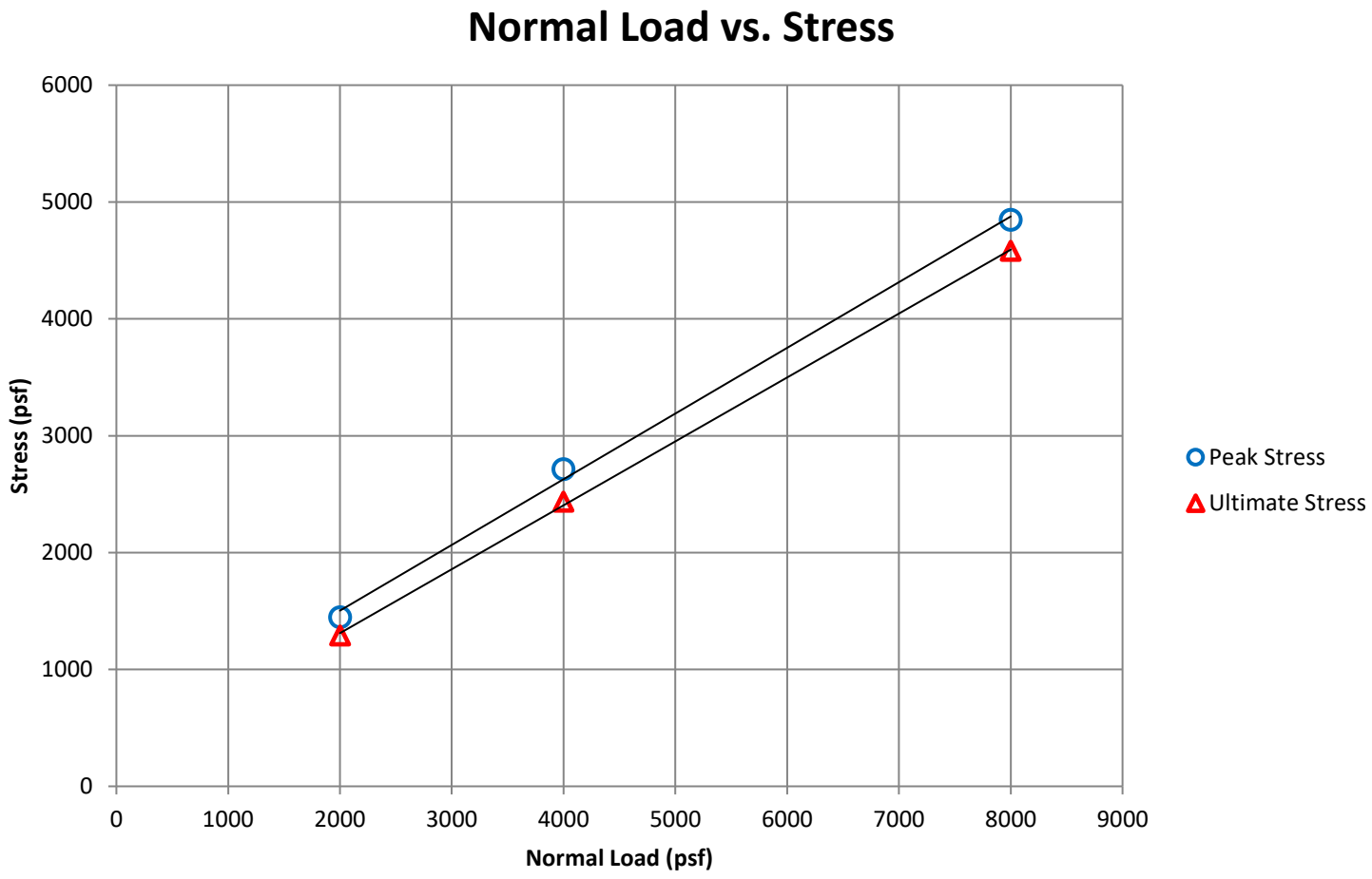
ASTM D 3080

CLIENT	Cesare Inc	BORING NO.	BCP-6
JOB NO.	2884-057	DEPTH	7-9'
PROJECT	Cuxharas Basin	SAMPLE NO.	202769
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	DESCRIPTION	Remolded -#4
DATE TESTED	08/05/20		
TECHNICIAN	ALH		

Direct Shear Results

Point:	A	B	C
Normal Load (psf):	8000	4000	2000
Normal Load (kPa):	383.0	191.5	95.8
Peak Strength (psf):	4848	2713	1447
Ultimate Strength (psf):	4582	2436	1290
Peak Strength (kPa):	232.1	129.9	69.3
Ultimate Strength (kPa):	219.4	116.6	61.8

Peak Strength		Ultimate Strength	
Friction Angle:	29.3	Friction Angle:	28.7
Cohesion (psf):	380	Cohesion (psf):	217
Cohesion (kPa):	18.2	Cohesion (kPa):	10.4



Data entry by:	DPM	Date: 08/07/20
Checked by:	ALH	Date: 08/07/20
File name:	2884057__Direct Shear ASTM D3080_0.xlsm	Page 1 of 2

ADVANCED TERRA TESTING

Direct Shear

ASTM D 3080

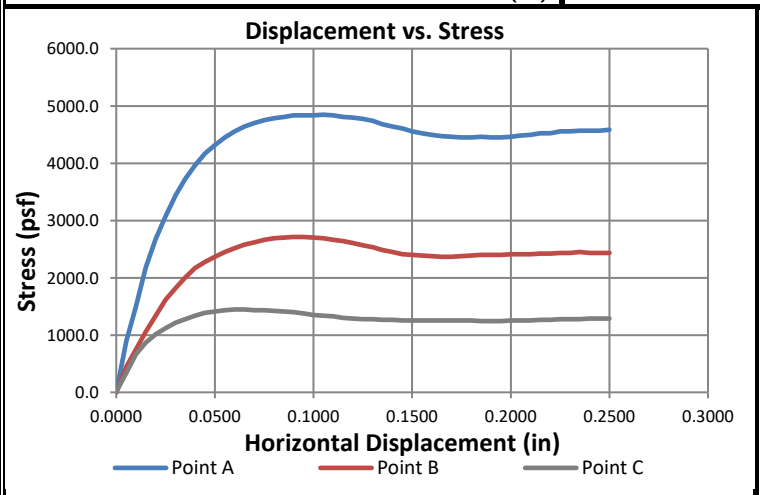
CLIENT	Cesare Inc	BORING NO.	BCP-6
JOB NO.	2884-057	DEPTH	7-9'
PROJECT	Cuxharas Basin	SAMPLE NO.	202769
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	DESCRIPTION	Remolded -#4
DATE TESTED	08/05/20		
TECHNICIAN	ALH		

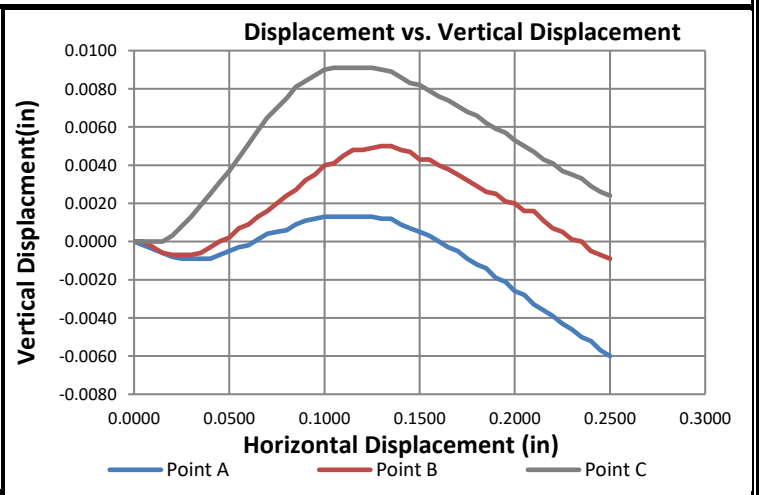
Test Parameters

Displacement Rate (in/min): 0.008 Displacement Rate (cm/min): 0.02032

Raw Data Files: CIDS679A.DAT, CIDS679B.DAT, CIDS679C.DAT,

Before Test Mass of Wet Soil and Ring (g):	186.12	186.17	190.28
After Test Mass of Wet Soil and Pan (g):	163.54	164.31	161.25
Mass of Dry Soil and Pan (g):	138.77	138.78	138.58
Mass of Ring (g):	37.45	37.45	41.47
Mass of Pan (g):	6.74	6.70	6.61
Diameter (in):	2.41	2.41	2.41
Initial Height (in):	1.00	1.00	1.00
Height Change (in):	0.042	0.03115	0.0229
Area (in²):	4.56	4.56	4.56
Initial Wet Density (pcf):	124.2	124.2	124.3
Initial Dry Density (pcf):	110.3	110.3	110.2
Initial Wet Density (kg/m³):	1989	1990	1991
Initial Dry Density (kg/m³):	1766	1767	1765
Initial Moisture (%):	12.6	12.6	12.8
Final Wet Density (pcf):	136.7	135.9	132.2
Final Dry Density (pcf):	115.1	113.9	112.8
Final Wet Density (kg/m³):	2190	2176	2117
Final Dry Density (kg/m³):	1844	1824	1807
Final Moisture (%):	18.8	19.3	17.2





NOTES:

File name: 2884057__Direct Shear ASTM D3080_0.xlsm

ADVANCED TERRA TESTING

Constant Rate of Flow
Flexible Wall Hydraulic Conductivity

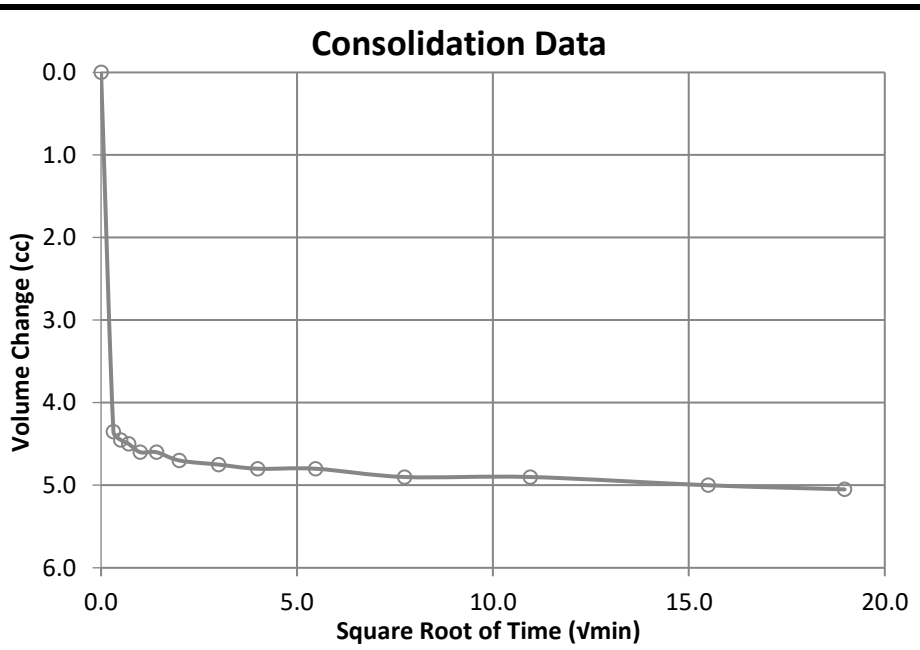
ASTM D 5084 Method D

CLIENT	Cesare Inc	BORING NO.	BGP-6
JOB NO.	2884-057	DEPTH	7'-9'
PROJECT	Cuxharas Basin	SAMPLE NO.	202769
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation

Initial Saturation (%):	66.0	Initial Volume of Sample (cc):	224.6
Final Saturation (%):	100.0	Final Volume of Sample (cc):	213.7
Cell Pressure (psi):	88.0	Volume Change After Consolidation (cc):	22.7
Back Pressure (psi):	58.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	30.0	Final Dial Reading (in):	0.266
Effective Stress (kPa):	206.8	Height Change (in):	0.066
Cell Expansion Correction (cc):	11.80	Initial Area (cm²):	29.45
Cell ID:	5P	Final Area (cm²):	28.65

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	0.20	0.00
0.1	0.32	4.55	4.35
0.25	0.50	4.65	4.45
0.5	0.71	4.70	4.50
1	1.00	4.80	4.60
2	1.41	4.80	4.60
4	2.00	4.90	4.70
9	3.00	4.95	4.75
16	4.00	5.00	4.80
30	5.48	5.00	4.80
60	7.75	5.10	4.90
120	10.95	5.10	4.90
240	15.49	5.20	5.00
360	18.97	5.25	5.05



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	38.9	47.3	15.50	16.30	38.0	0.80	2.0	8.4	0.84
50.0	60.0	48.8	57.8	17.50	18.20	48.0	0.70	2.0	9.0	0.90
60.0	70.0	58.4	68.1	20.00	20.00	58.0	0.00	2.0	9.7	0.97

File name: 2884057__Permeability Method D ASTM D5084_1.xlsm

ADVANCED TERRA TESTING

Constant Rate of Flow
Flexible Wall Hydraulic Conductivity

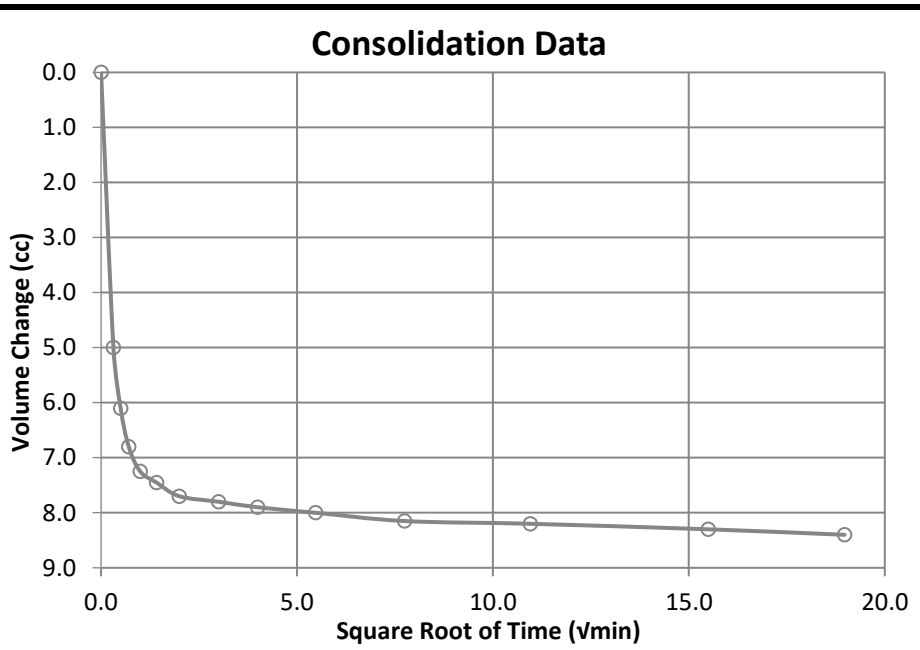
ASTM D 5084 Method D

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2'-10' & 2'-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation

Initial Saturation (%):	76.2	Initial Volume of Sample (cc):	225.1
Final Saturation (%):	100.0	Final Volume of Sample (cc):	221.2
Cell Pressure (psi):	78.0	Volume Change After Consolidation (cc):	18.3
Back Pressure (psi):	48.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	30.0	Final Dial Reading (in):	0.261
Effective Stress (kPa):	206.8	Height Change (in):	0.061
Cell Expansion Correction (cc):	14.38	Initial Area (cm²):	29.43
Cell ID:	6P	Final Area (cm²):	29.52

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	0.50	0.00
0.1	0.32	5.50	5.00
0.25	0.50	6.60	6.10
0.5	0.71	7.30	6.80
1	1.00	7.75	7.25
2	1.41	7.95	7.45
4	2.00	8.20	7.70
9	3.00	8.30	7.80
16	4.00	8.40	7.90
30	5.48	8.50	8.00
60	7.75	8.65	8.15
120	10.95	8.70	8.20
240	15.49	8.80	8.30
360	18.97	8.90	8.40



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	39.0	48.2	9.70	10.60	38.0	0.90	2.0	9.2	0.92
50.0	60.0	48.9	58.4	10.80	10.80	48.0	0.00	2.0	9.5	0.95

File name: 2884057__Permeability Method D ASTM D5084_2.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

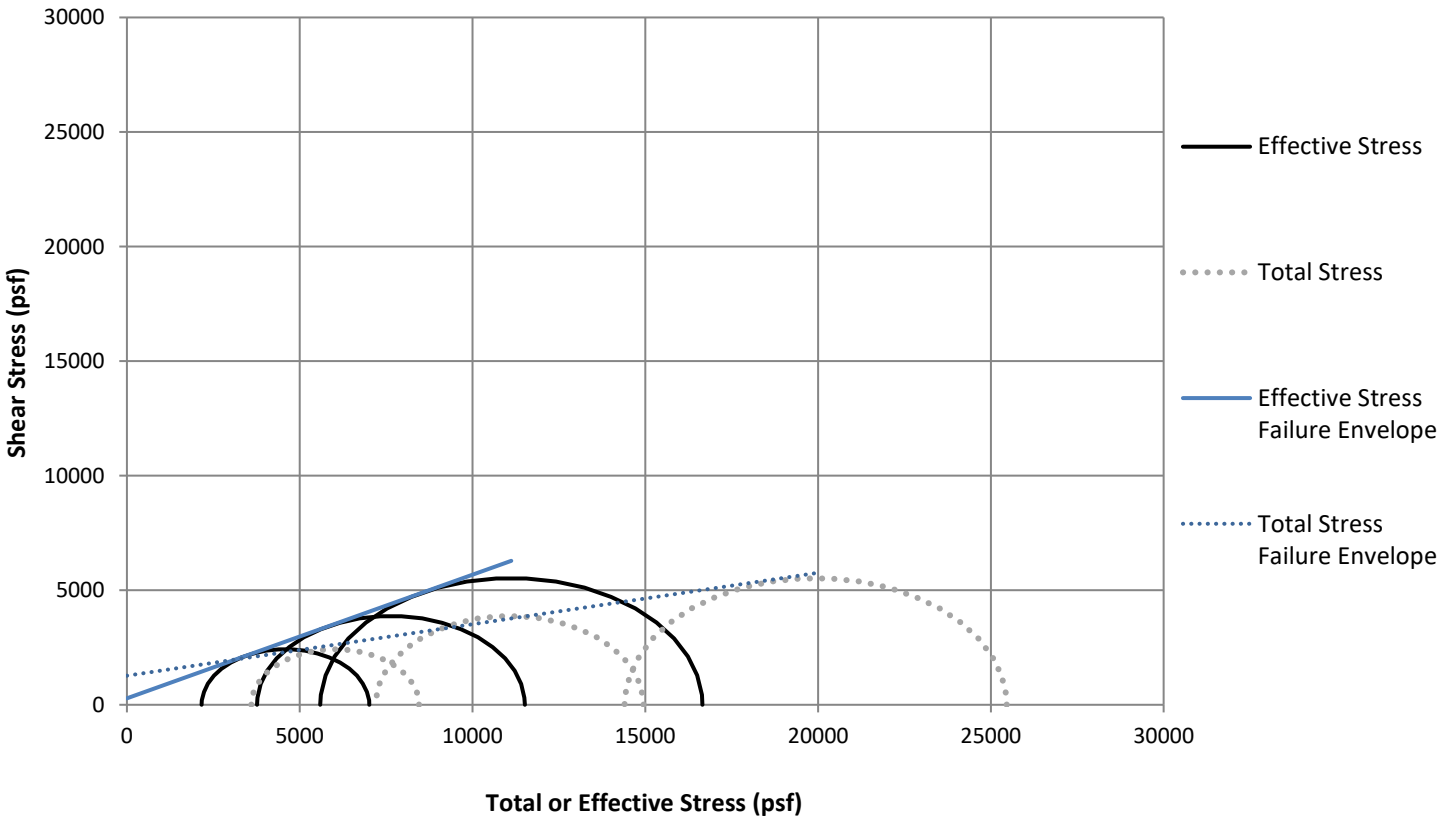
ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2-10' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Effective Stress		Total Stress	
Internal Friction Angle - ϕ:	28.4	Internal Friction Angle - ϕ:	12.7
Cohesion (psf):	282	Cohesion (psf):	1270
Cohesion (kPa):	13.5	Cohesion (kPa):	60.8
Modified Friction Angle - ψ:	25.4	Modified Friction Angle - ψ:	12.4
Modified Cohesion - a (psf):	248	Modified Cohesion - a (psf):	1239
Modified Cohesion - a (kPa):	11.9	Modified Cohesion - a (kPa):	59.3

Raw Data Files	2884057_CUPP_202768_PTA.trx, 2884057_CUPP_202768_PTB.trx, 2884057_CUPP_202768_PTC.trx,

Mohr Stress Circles



NOTES:

Data entry by:	CAL	Date: 08/16/20
Checked by:	DPM	Date: 08/17/20
File name:	2884057__TxCuPP ASTM D4767_1.xlsm	Page 1 of 8

ADVANCED TERRA TESTING

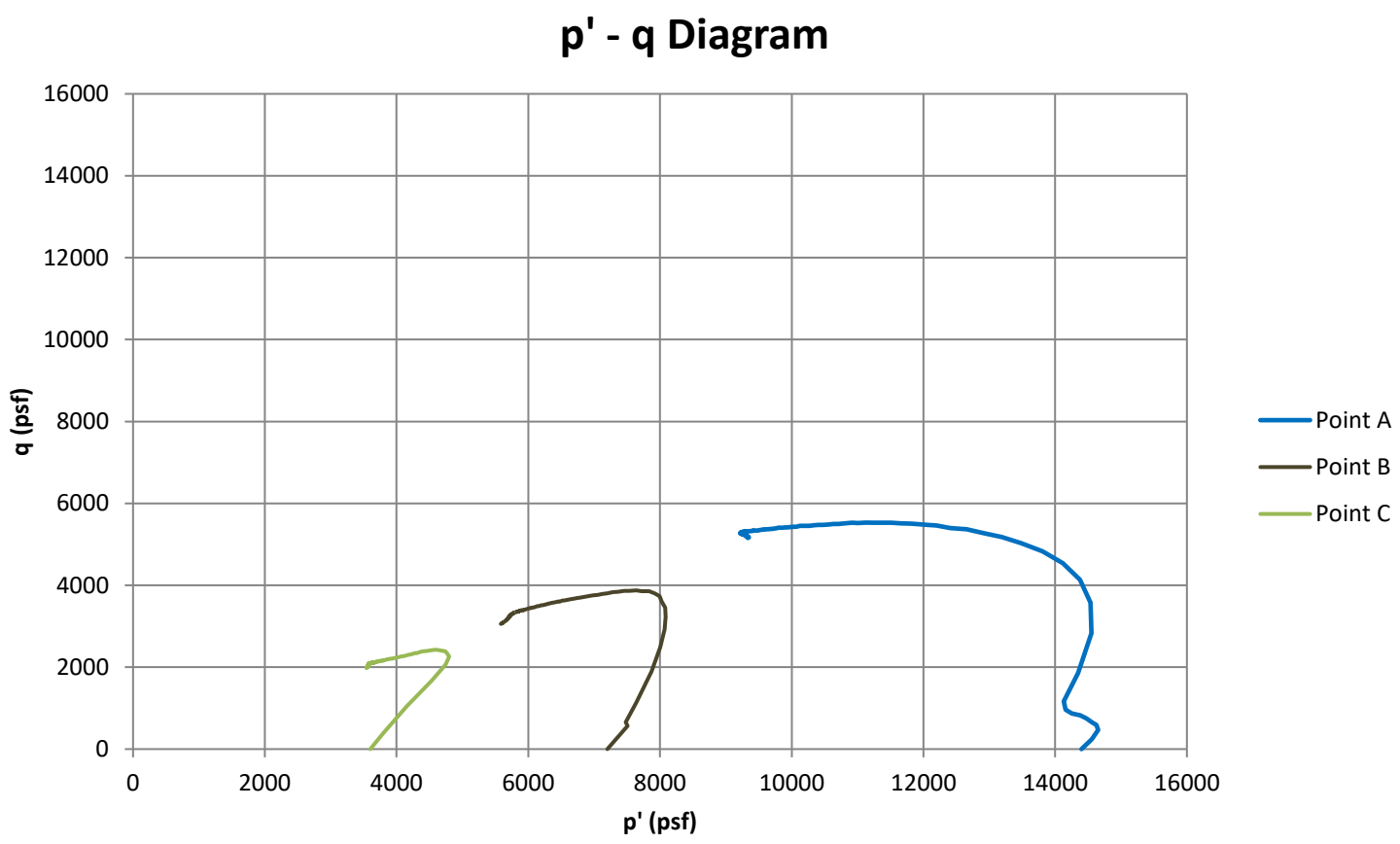
Consolidated Undrained Triaxial Compression

ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2-10' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Shear Summary at Peak Deviator Stress

	Point A	Point B	Point C
Peak Deviator Stress (psf) :	11060	7751	4853
Peak Deviator Stress (kPa) :	529.6	371.1	232.3
Major Principal Stress (psf) - σ_{1f} :	25460	14951	8453
Major Principal Stress (kPa) - σ_{1f} :	1219.0	715.9	404.7
Minor Principal Stress (psf) - σ_{3f} :	14400	7200	3600
Minor Principal Stress (kPa) - σ_{3f} :	689.5	344.7	172.4
Effective Major Principal Stress (psf) - σ'_{1f} :	16653	11516	7013
Effective Major Principal Stress (kPa) - σ'_{1f} :	797.4	551.4	335.8
Effective Minor Principal Stress (psf) - σ'_{3f} :	5593	3765	2161
Effective Minor Principal Stress (kPa) - σ'_{3f} :	267.8	180.3	103.5



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ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2-10' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Point A

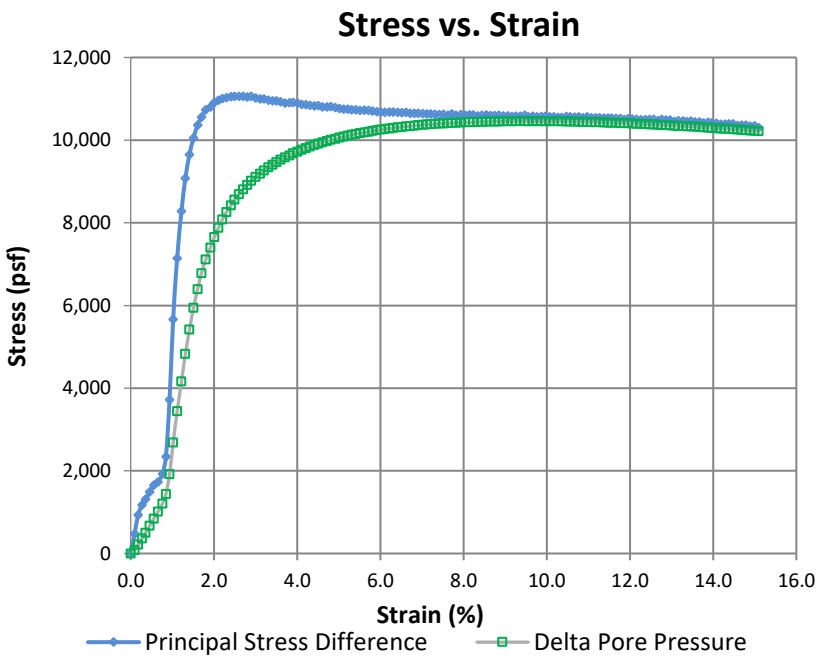
Before Test Mass of Wet Soil (g):	777.47	Initial Wet Density (pcf):	130.1
After Test Mass of Wet Soil (g):	792.77	Initial Dry Density (pcf):	115.9
Mass of Dry Soil and Pan (g):	1064.46	Initial Wet Density (kg/m³):	2084
Mass of Pan (g):	371.79	Initial Dry Density (kg/m³):	1857
Diameter (in):	2.410	Initial Moisture (%):	12.2
Initial Sample Height (in):	4.990	Final Wet Density (pcf):	141.5
After Consolidation Height (in):	4.963	Final Dry Density (pcf):	123.7
Assumed Specific Gravity:	2.65	Final Wet Density (kg/m³):	2267
		Final Dry Density (kg/m³):	1981
Back Pressure (psi):	68.0	Final Moisture (%):	14.5
Cell Pressure (psi):	168.0		
Initial Effective Stress (psi):	100.0	Membrane Correction Factor (lb/in²):	72.64
Initial Effective Stress (kPa):	689.5	Filter Paper Load Capacity (lb/in):	1.1
Strain Rate (in/min):	0.01		

Triaxial Compression Data

Peak Deviator Stress (psf):	11060
Peak Deviator Stress (kPa):	529.6

Parameters at Peak Deviator Stress

Major Principal Stress (psf) - σ_{1f} :	25460
Major Principal Stress (kPa) - σ_{1f} :	1219.0
Minor Principal Stress (psf) - σ_{3f} :	14400
Minor Principal Stress (kPa) - σ_{3f} :	689.5
Induced Pore Pressure (psf) :	8806.97
Induced Pore Pressure (kPa) :	421.68
Effective Major Principal Stress (psf) - σ'_{1f} :	16653.16
Effective Major Principal Stress (kPa) - σ'_{1f} :	797.36
Effective Minor Principal Stress (psf) - σ'_{3f} :	5593.03
Effective Minor Principal Stress (kPa) - σ'_{3f} :	267.80
p' (psf) :	11123
q (psf) :	5530
p' (kPa) :	532.6
q (kPa) :	264.8
Strain (%) :	2.70



File name: 2884057__TxCuPP ASTM D4767_1.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

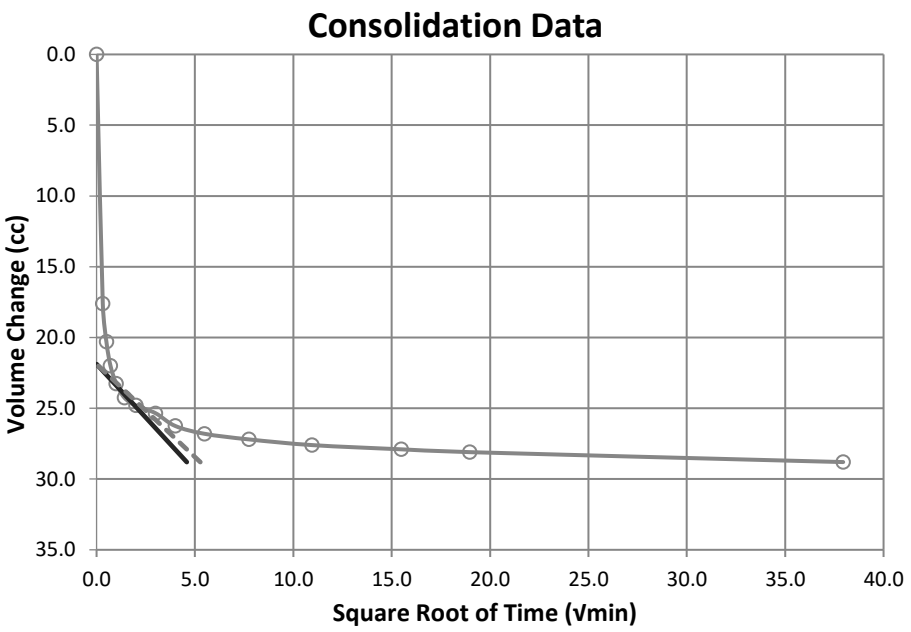
ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2-10' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation - Point A

Initial Saturation (%):	76.0	Initial Volume of Sample (cc):	373.0
Final Saturation (%):	100.0	Final Volume of Sample (cc):	349.7
Cell Pressure (psi):	168.0	Volume Change After Consolidation (cc):	44.1
Back Pressure (psi):	68.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	100.0	Final Dial Reading (in):	0.227
Effective Stress (kPa):	689.5	Height Change (in):	0.027
Cell Expansion Correction (cc):	20.78	Initial Area (cm²):	29.43
Cell ID:	9S	Final Area (cm²):	27.74
T50 (min):	1.76		

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	0.20	0.00
0.1	0.32	17.80	17.60
0.25	0.50	20.50	20.30
0.5	0.71	22.20	22.00
1	1.00	23.45	23.25
2	1.41	24.45	24.25
4	2.00	25.00	24.80
9	3.00	25.55	25.35
16	4.00	26.45	26.25
30	5.48	27.00	26.80
60	7.75	27.40	27.20
120	10.95	27.80	27.60
240	15.49	28.10	27.90
360	18.97	28.30	28.10
1440	37.95	29.00	28.80



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	38.5	46.6	14.20	15.50	38.0	1.30	2.0	8.1	0.81
50.0	60.0	48.5	57.6	16.00	17.10	48.0	1.10	2.0	9.1	0.91
60.0	70.0	58.6	67.6	17.50	18.40	58.0	0.90	2.0	9.0	0.90
70.0	80.0	68.2	77.9	18.60	18.70	68.0	0.10	2.0	9.7	0.97

File name: 2884057__TxCuPP ASTM D4767_1.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2-10' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Point B

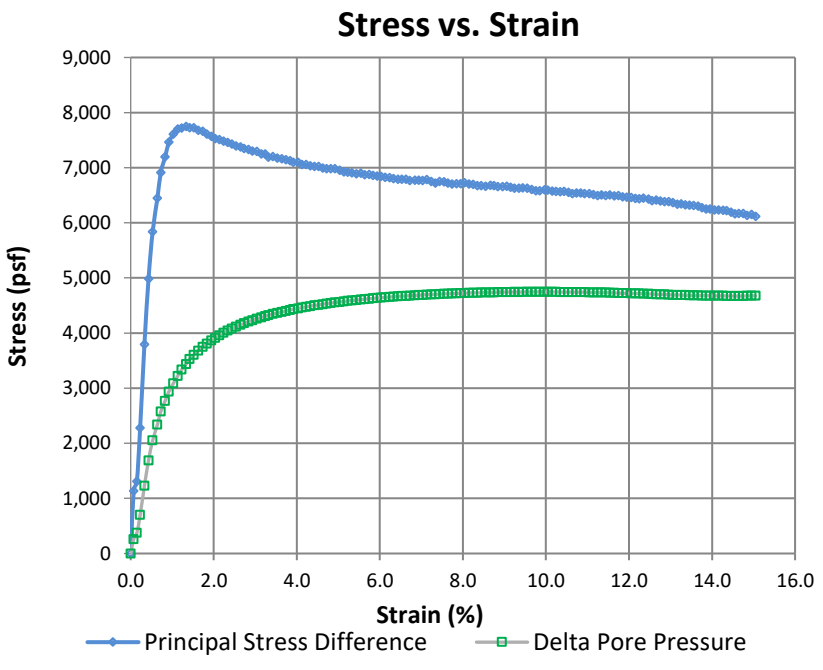
Before Test Mass of Wet Soil (g):	777.22	Initial Wet Density (pcf):	129.9
After Test Mass of Wet Soil (g):	802.78	Initial Dry Density (pcf):	116.0
Mass of Dry Soil and Pan (g):	1064.23	Initial Wet Density (kg/m³):	2081
Mass of Pan (g):	370.11	Initial Dry Density (kg/m³):	1858
Diameter (in):	2.410	Initial Moisture (%):	12.0
Initial Sample Height (in):	4.997	Final Wet Density (pcf):	140.7
After Consolidation Height (in):	4.961	Final Dry Density (pcf):	121.7
Assumed Specific Gravity:	2.65	Final Wet Density (kg/m³):	2254
		Final Dry Density (kg/m³):	1949
Back Pressure (psi):	78.0	Final Moisture (%):	15.7
Cell Pressure (psi):	128.0		
Initial Effective Stress (psi):	50.0	Membrane Correction Factor (lb/in²):	72.64
Initial Effective Stress (kPa):	344.7	Filter Paper Load Capacity (lb/in):	1.1
Strain Rate (in/min):	0.01		

Triaxial Compression Data

Peak Deviator Stress (psf):	7751
Peak Deviator Stress (kPa):	371.1

Parameters at Peak Deviator Stress

Major Principal Stress (psf) - σ_{1f} :	14951
Major Principal Stress (kPa) - σ_{1f} :	715.9
Minor Principal Stress (psf) - σ_{3f} :	7200
Minor Principal Stress (kPa) - σ_{3f} :	344.7
Induced Pore Pressure (psf) :	3435.26
Induced Pore Pressure (kPa) :	164.48
Effective Major Principal Stress (psf) - σ'_{1f} :	11516.04
Effective Major Principal Stress (kPa) - σ'_{1f} :	551.39
Effective Minor Principal Stress (psf) - σ'_{3f} :	3764.74
Effective Minor Principal Stress (kPa) - σ'_{3f} :	180.26
p' (psf) :	7640
q (psf) :	3876
p' (kPa) :	365.8
q (kPa) :	185.6
Strain (%) :	1.33



File name: 2884057__TxCuPP ASTM D4767_1.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

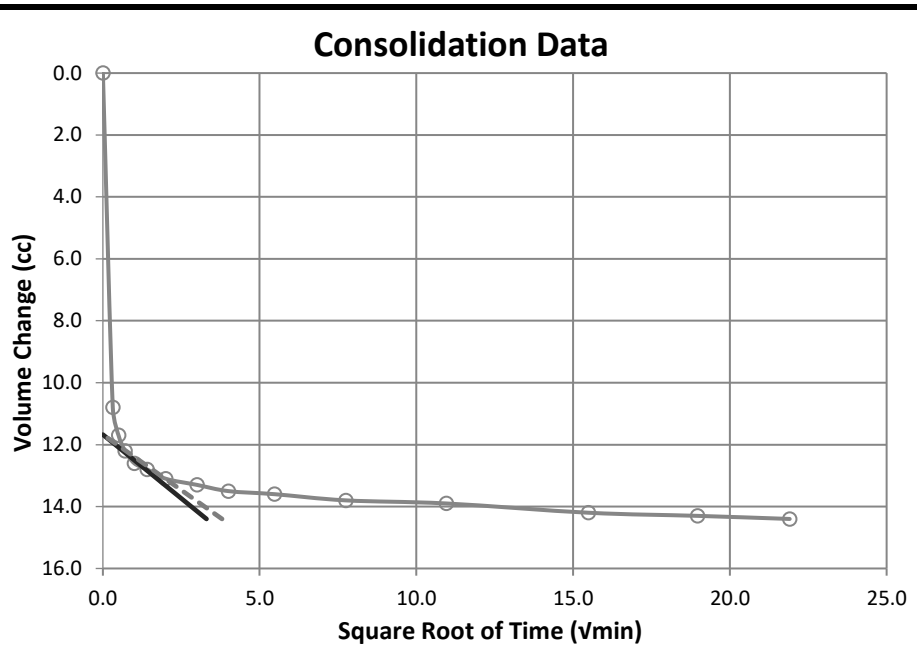
ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2-10' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation - Point B

Initial Saturation (%):	74.5	Initial Volume of Sample (cc):	373.5
Final Saturation (%):	100.0	Final Volume of Sample (cc):	356.1
Cell Pressure (psi):	128.0	Volume Change After Consolidation (cc):	33.5
Back Pressure (psi):	78.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	50.0	Final Dial Reading (in):	0.236
Effective Stress (kPa):	344.7	Height Change (in):	0.036
Cell Expansion Correction (cc):	16.11	Initial Area (cm²):	29.43
Cell ID:	22S	Final Area (cm²):	28.26
T50 (min):	1.18		

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	1.00	0.00
0.1	0.32	11.80	10.80
0.25	0.50	12.70	11.70
0.5	0.71	13.20	12.20
1	1.00	13.60	12.60
2	1.41	13.80	12.80
4	2.00	14.10	13.10
9	3.00	14.30	13.30
16	4.00	14.50	13.50
30	5.48	14.60	13.60
60	7.75	14.80	13.80
120	10.95	14.90	13.90
240	15.49	15.20	14.20
360	18.97	15.30	14.30
480	21.91	15.40	14.40



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	38.6	46.3	15.10	16.20	38.0	1.10	2.0	7.7	0.77
50.0	60.0	48.6	57.0	17.60	18.40	48.0	0.80	2.0	8.4	0.84
60.0	70.0	58.7	67.5	18.80	19.50	58.0	0.70	2.0	8.8	0.88
70.0	80.0	68.3	77.7	19.70	20.40	68.0	0.70	2.0	9.4	0.94
80.0	90.0	78.3	87.8	20.60	20.60	78.0	0.00	2.0	9.5	0.95

File name: 2884057__TxCuPP ASTM D4767_1.xlsm

Consolidated Undrained Triaxial Compression

ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2-10' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Point C

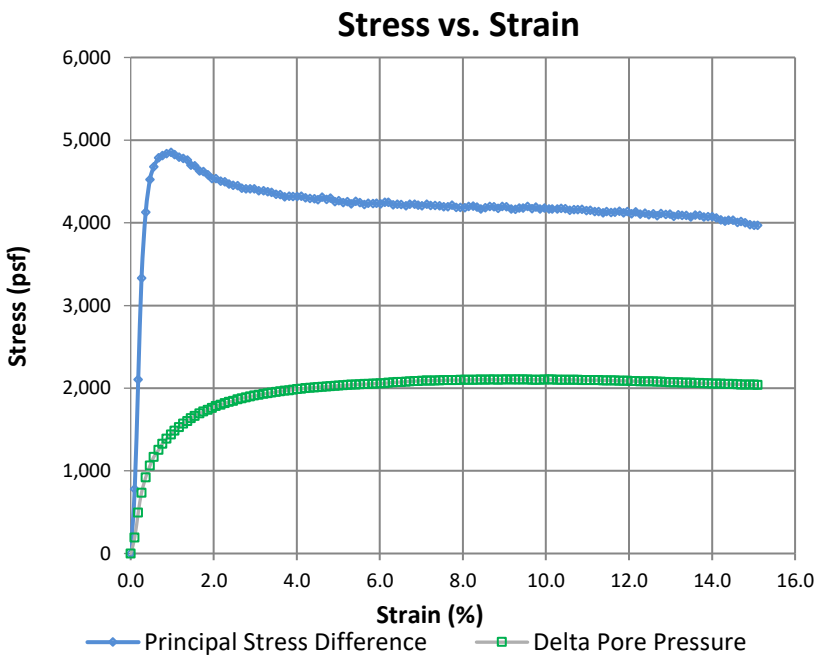
Before Test Mass of Wet Soil (g):	777.45	Initial Wet Density (pcf):	129.3
After Test Mass of Wet Soil (g):	802.40	Initial Dry Density (pcf):	114.9
Mass of Dry Soil and Pan (g):	1061.61	Initial Wet Density (kg/m³):	2072
Mass of Pan (g):	370.89	Initial Dry Density (kg/m³):	1841
Diameter (in):	2.410	Initial Moisture (%):	12.6
Initial Sample Height (in):	5.020	Final Wet Density (pcf):	137.0
After Consolidation Height (in):	4.968	Final Dry Density (pcf):	117.9
Assumed Specific Gravity:	2.65	Final Wet Density (kg/m³):	2194
		Final Dry Density (kg/m³):	1889
Back Pressure (psi):	78.0	Final Moisture (%):	16.2
Cell Pressure (psi):	103.0		
Initial Effective Stress (psi):	25.0	Membrane Correction Factor (lb/in²):	72.64
Initial Effective Stress (kPa):	344.7	Filter Paper Load Capacity (lb/in):	1.1
Strain Rate (in/min):	0.01		

Triaxial Compression Data

Peak Deviator Stress (psf):	4853
Peak Deviator Stress (kPa):	232.3

Parameters at Peak Deviator Stress

Major Principal Stress (psf) - σ_{1f} :	8453
Major Principal Stress (kPa) - σ_{1f} :	404.7
Minor Principal Stress (psf) - σ_{3f} :	3600
Minor Principal Stress (kPa) - σ_{3f} :	172.4
Induced Pore Pressure (psf) :	1439.36
Induced Pore Pressure (kPa) :	68.92
Effective Major Principal Stress (psf) - σ'_{1f} :	7013.35
Effective Major Principal Stress (kPa) - σ'_{1f} :	335.80
Effective Minor Principal Stress (psf) - σ'_{3f} :	2160.64
Effective Minor Principal Stress (kPa) - σ'_{3f} :	103.45
p' (psf) :	4587
q (psf) :	2426
p' (kPa) :	219.6
q (kPa) :	116.2
Strain (%) :	0.97



File name: 2884057__TxCuPP ASTM D4767_1.xlsm

ADVANCED TERRA TESTING

Consolidated Undrained Triaxial Compression

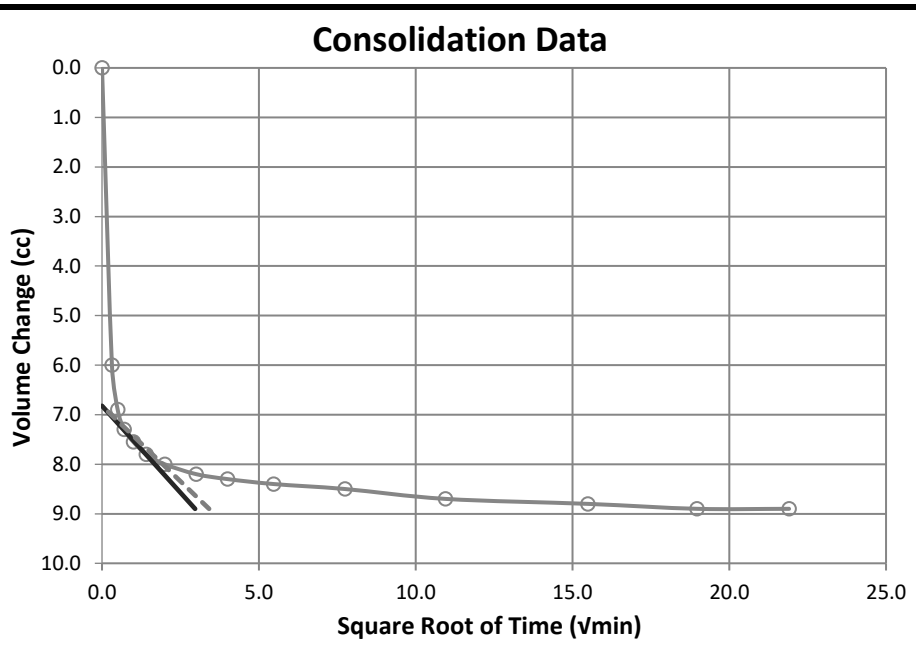
ASTM D 4767

CLIENT	Cesare Inc	BORING NO.	BCP-2 & BCP-4
JOB NO.	2884-057	DEPTH	2-10' & 2-8'
PROJECT	Cuxharas Basin	SAMPLE NO.	202768
PROJECT NO.	18.117	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	07/29/20	DESCRIPTION	remolded -#4
TECHNICIAN	CAL		

Consolidation - Point C

Initial Saturation (%):	75.7	Initial Volume of Sample (cc):	375.3
Final Saturation (%):	100.0	Final Volume of Sample (cc):	365.7
Cell Pressure (psi):	103.0	Volume Change After Consolidation (cc):	24.3
Back Pressure (psi):	78.0	Initial Dial Reading (in):	0.200
Effective Stress (psi):	25.0	Final Dial Reading (in):	0.252
Effective Stress (kPa):	172.4	Height Change (in):	0.052
Cell Expansion Correction (cc):	14.70	Initial Area (cm²):	29.43
Cell ID:	19S	Final Area (cm²):	28.98
T50 (min):	1.06		

Elapsed Time (min)	Square Root of Time (√min)	Burette Reading (cc)	Volume Change (cc)
0	0.00	0.50	0.00
0.1	0.32	6.50	6.00
0.25	0.50	7.40	6.90
0.5	0.71	7.80	7.30
1	1.00	8.05	7.55
2	1.41	8.30	7.80
4	2.00	8.50	8.00
9	3.00	8.70	8.20
16	4.00	8.80	8.30
30	5.48	8.90	8.40
60	7.75	9.00	8.50
120	10.95	9.20	8.70
240	15.49	9.30	8.80
360	18.97	9.40	8.90
480	21.91	9.40	8.90



Saturation

Cell Pressure (psi)		Pore Pressure (psi)		Burette Reading (cc)		Back Pressure (psi)	Volume Change (cc)	Effective Stress (psi)	Δu (psi)	B
Initial	Final	Initial	Final	Initial	Final					
40.0	50.0	39.3	47.1	12.50	13.70	38.0	1.20	2.0	7.8	0.78
50.0	60.0	49.5	57.9	14.70	15.50	48.0	0.80	2.0	8.4	0.84
60.0	70.0	59.5	68.4	15.70	16.70	58.0	1.00	2.0	8.9	0.89
70.0	80.0	69.2	78.5	16.80	17.50	68.0	0.70	2.0	9.3	0.93
80.0	90.0	79.1	88.7	17.70	17.80	78.0	0.10	2.0	9.6	0.96

File name: 2884057__TxCuPP ASTM D4767_1.xlsm

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

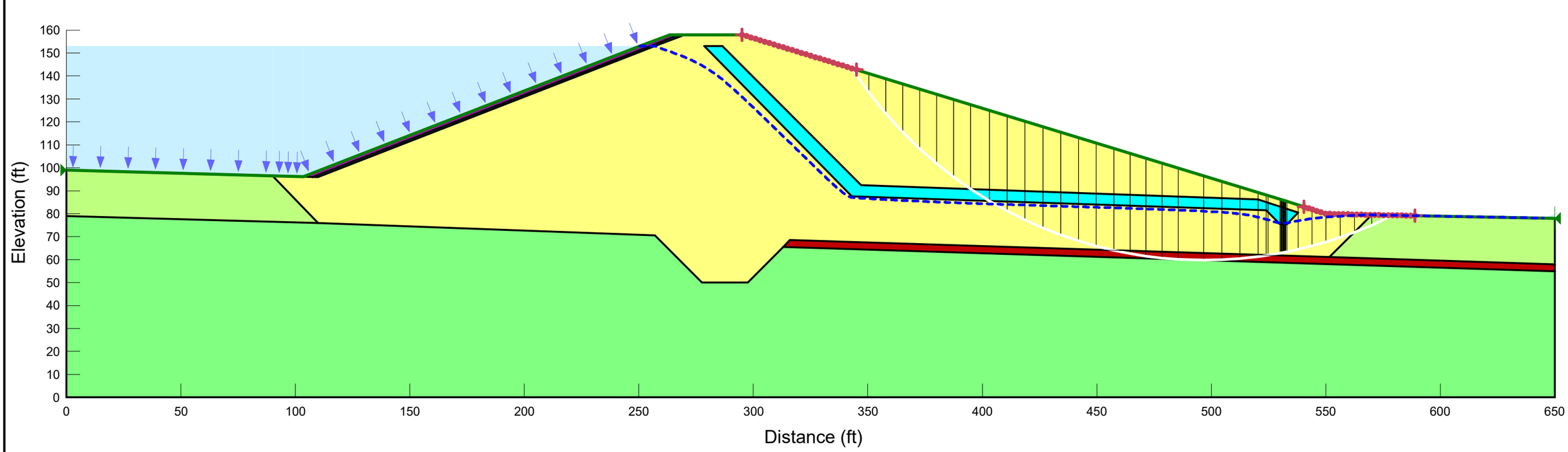
APPENDIX C

Seepage and Stability Analysis

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0

1.68

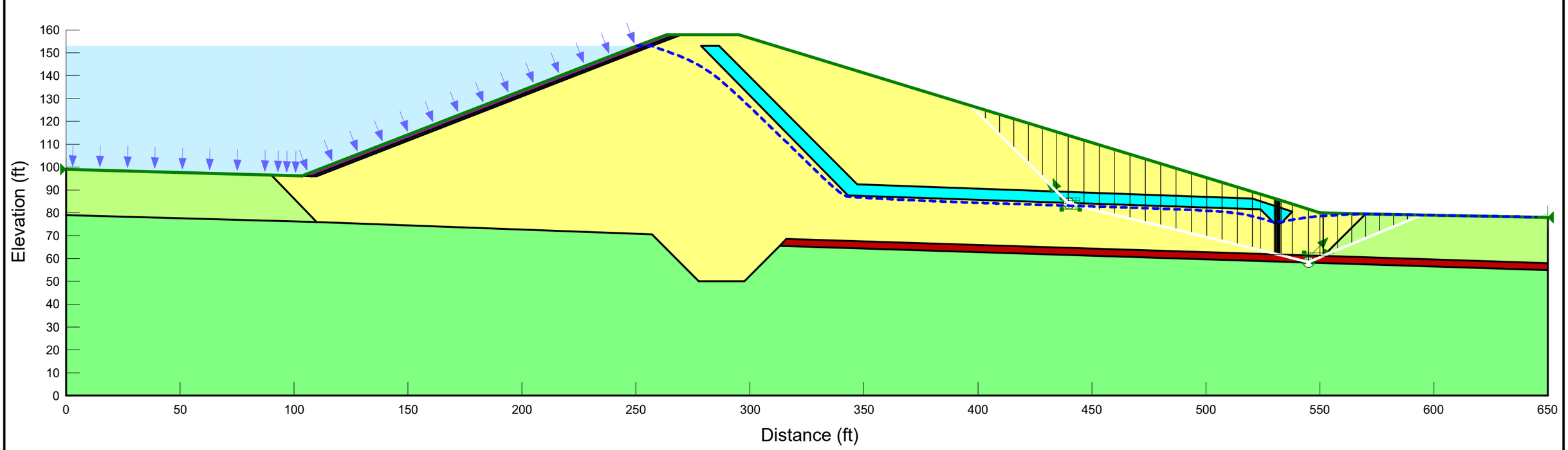


Bruce Canyon 50%	
Steady State Seepage, Circular Analysis	
09/08/2020	1:513

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0

1.75

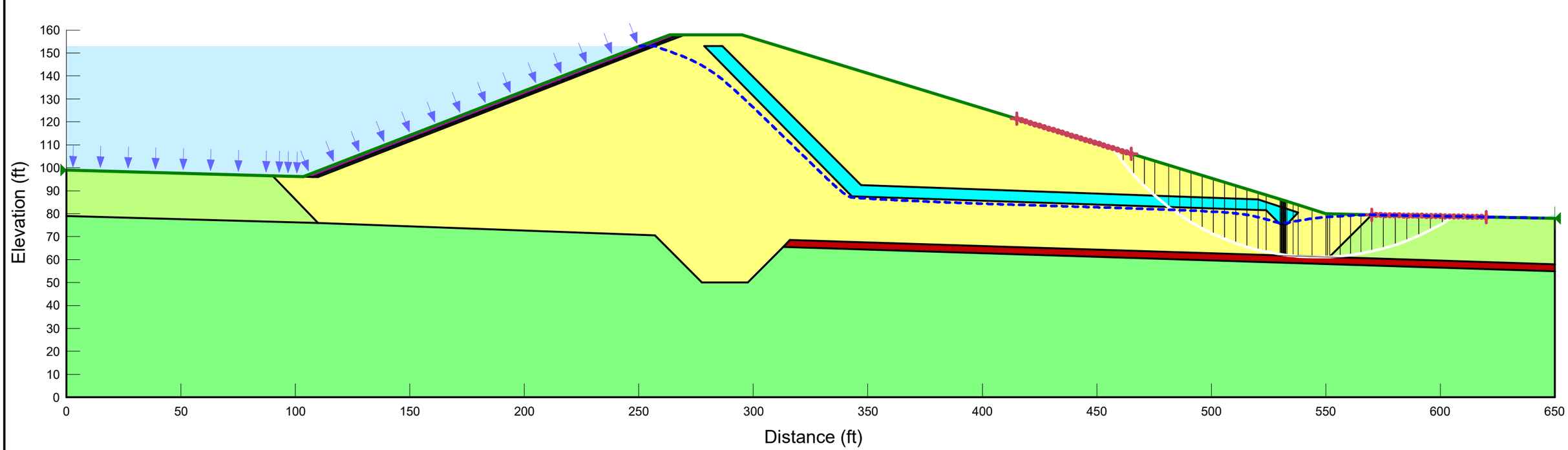


Bruce Canyon 50%	
Steady State Seepage, Block Analysis	
09/08/2020	1:513

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	50	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0

1.10

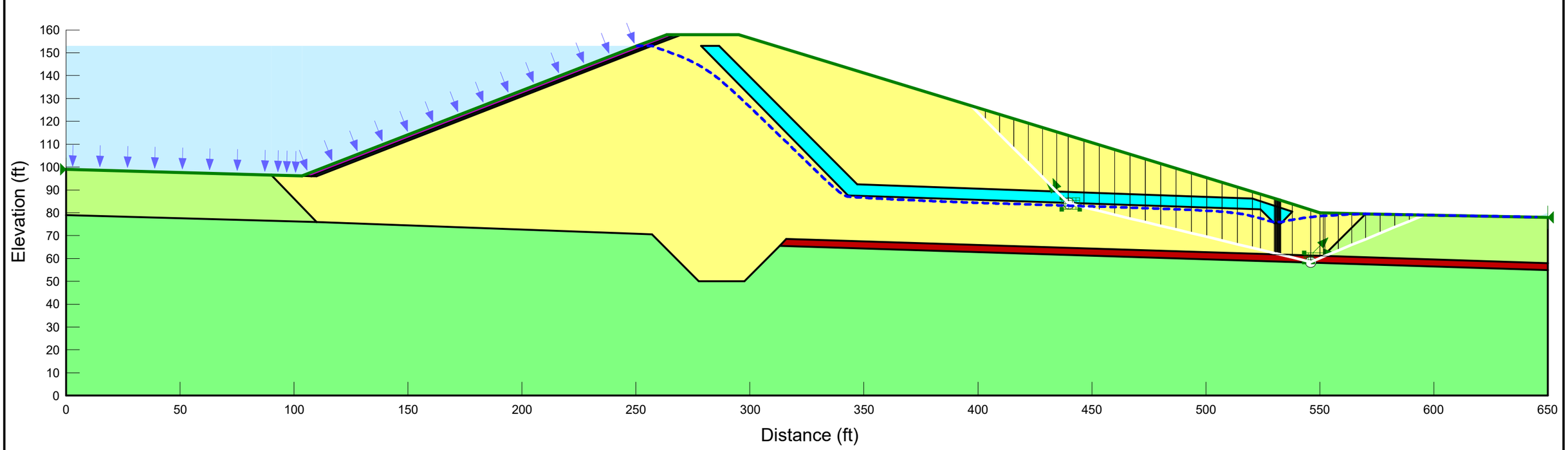


Bruce Canyon 50%
Steady State Seepage, Circular Analysis, Pseudo Seismic 0.1g
09/08/2020 1:513

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	50	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0

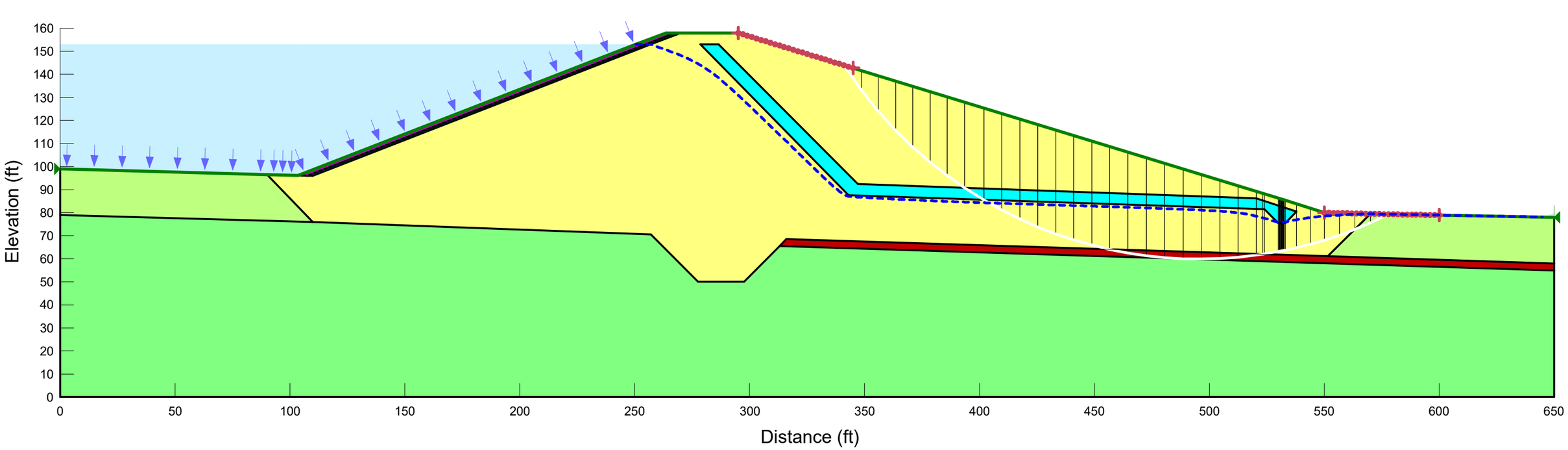
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Bruce Canyon 50%
Steady State Seepage, Block Analysis, Pseudo Seismic 0.1g
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Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	0	15	0

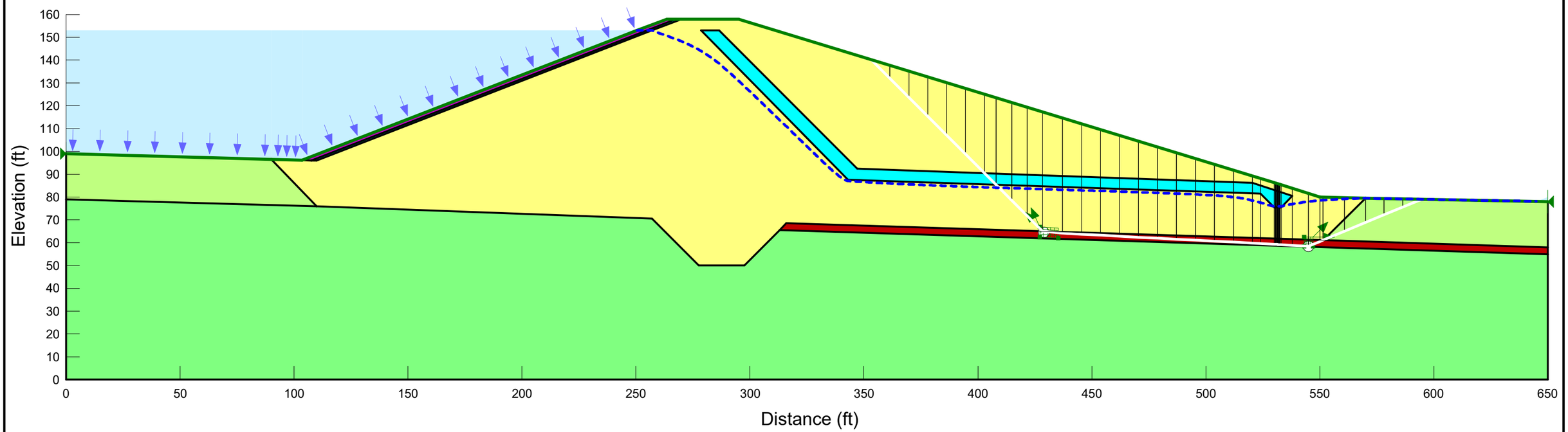


Bruce Canyon 50%	
Steady State Seepage, Residual Bedrock, Circular Analysis	
09/08/2020	1:513

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	0	15	0

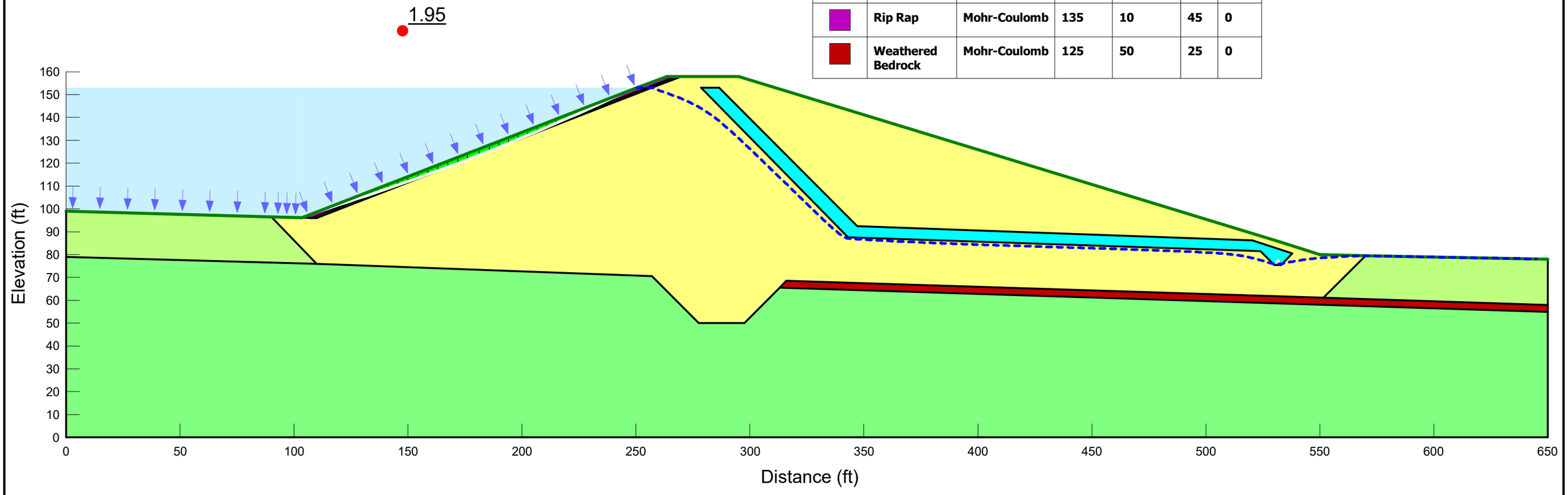
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Bruce Canyon 50%
Steady State Seepage, Residual Bedrock, Block Analysis
09/08/2020 1:513

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0



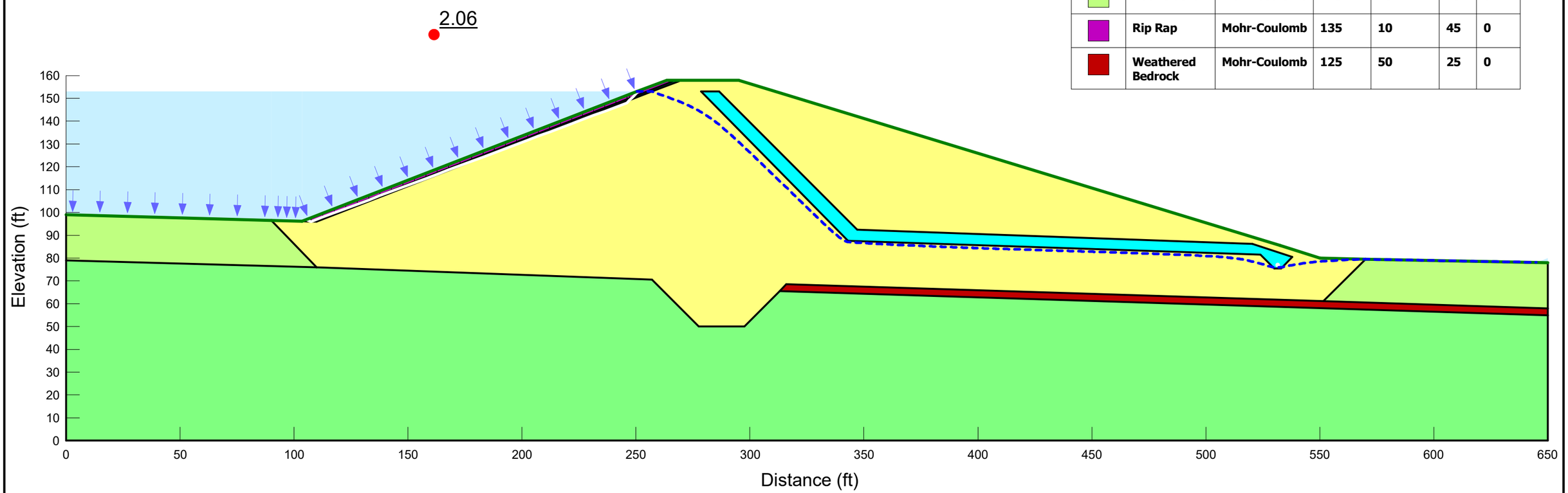
Bruce Canyon 50%

Steady State Seepage, Circular

09/08/2020

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
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	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0



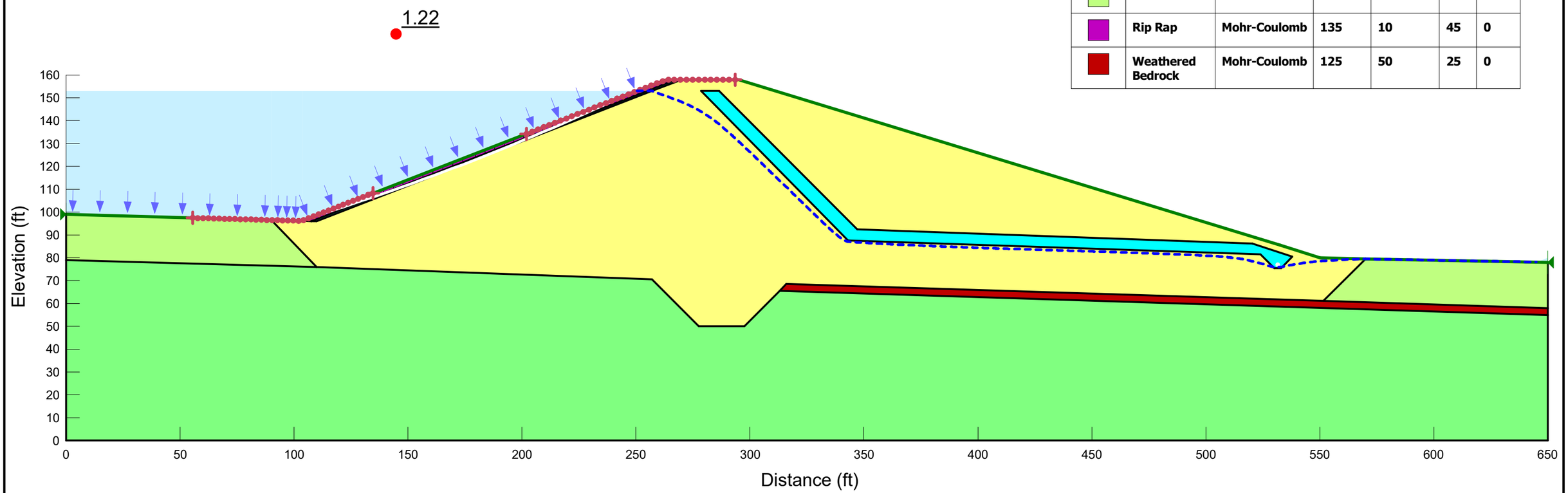
Bruce Canyon 50%

Steady State Seepage, Block

09/08/2020

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
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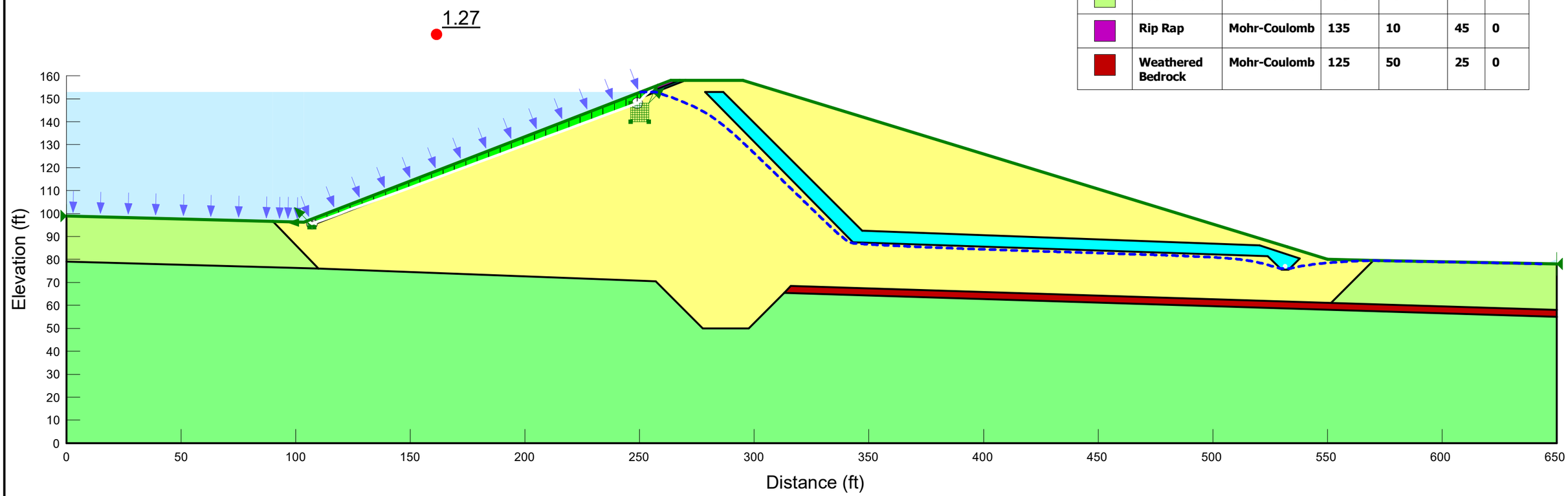
Bruce Canyon 50%

Steady State Seepage, Circular Analysis, Pseudo Seismic 0.1g

09/11/2020

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	10	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0



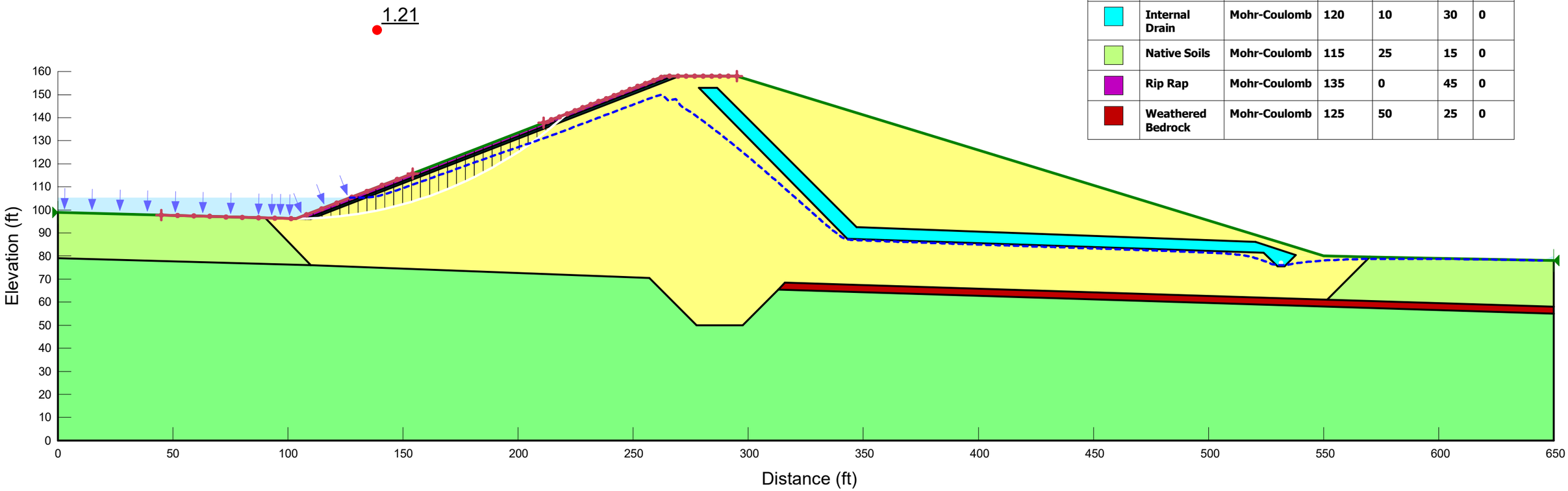
Bruce Canyon 50%

Steady State Seepage, Block Analysis, Pseudo Seismic 0.1g

09/11/2020

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	0	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0

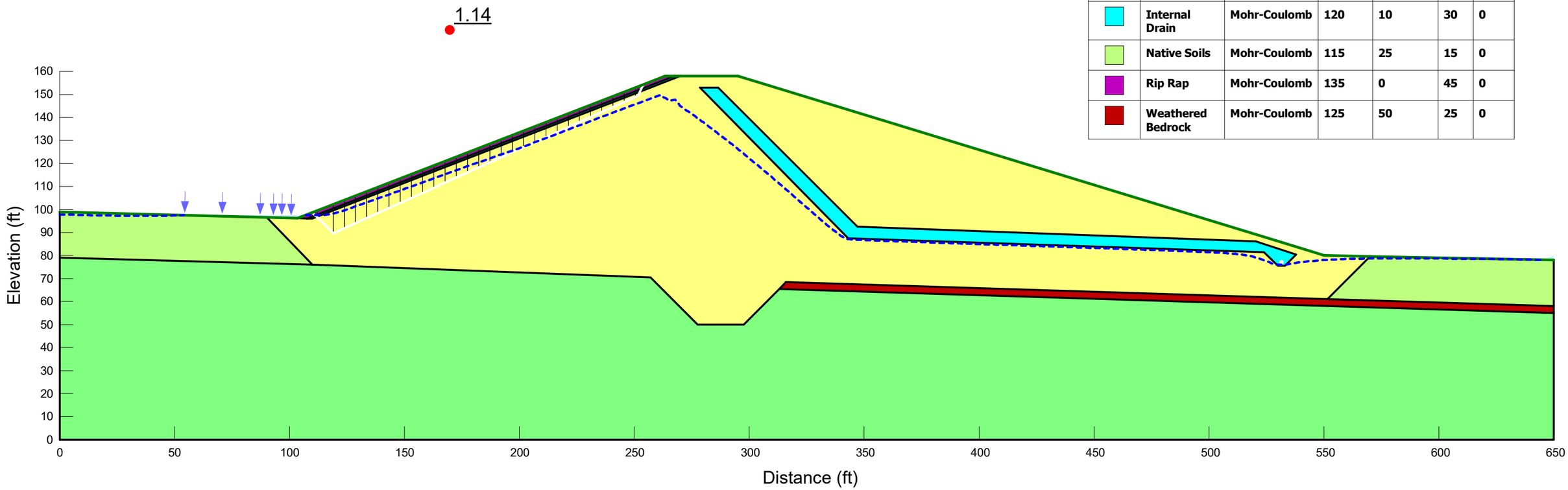


Bruce Canyon 50%

Transient Seepage, Circular, Lowest FS-Time Step: 31

09/03/2020 1:513

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Mohr-Coulomb	135	5,000	0	0
	Embankment	Mohr-Coulomb	125	75	25	0
	Internal Drain	Mohr-Coulomb	120	10	30	0
	Native Soils	Mohr-Coulomb	115	25	15	0
	Rip Rap	Mohr-Coulomb	135	0	45	0
	Weathered Bedrock	Mohr-Coulomb	125	50	25	0

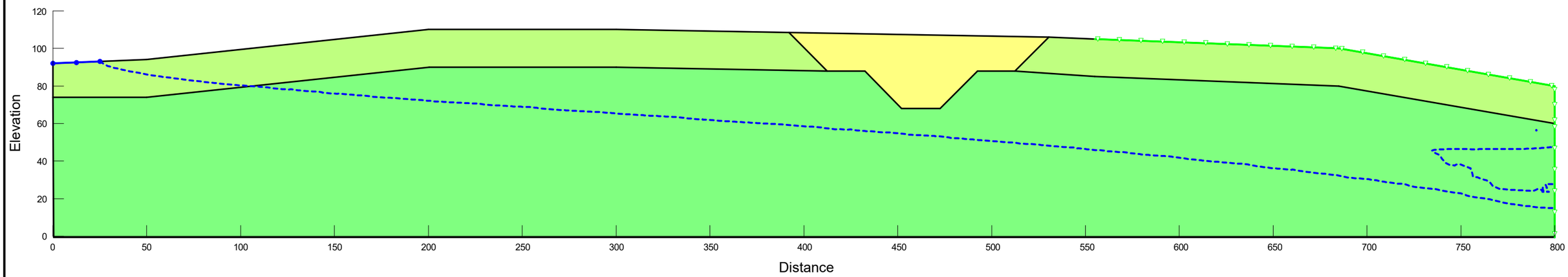
Bruce Canyon 50%

Transient Seepage, Block, Lowest FS-Time Step: 36

09/03/2020

Cucharas Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117

Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio
	Bedrock	Saturated / Unsaturated	Claystone	Claystone	0.1
	Embankment	Saturated / Unsaturated	Embankment	Embankment	1
	Native Solis	Saturated / Unsaturated	Native Soils	Native Soils	1

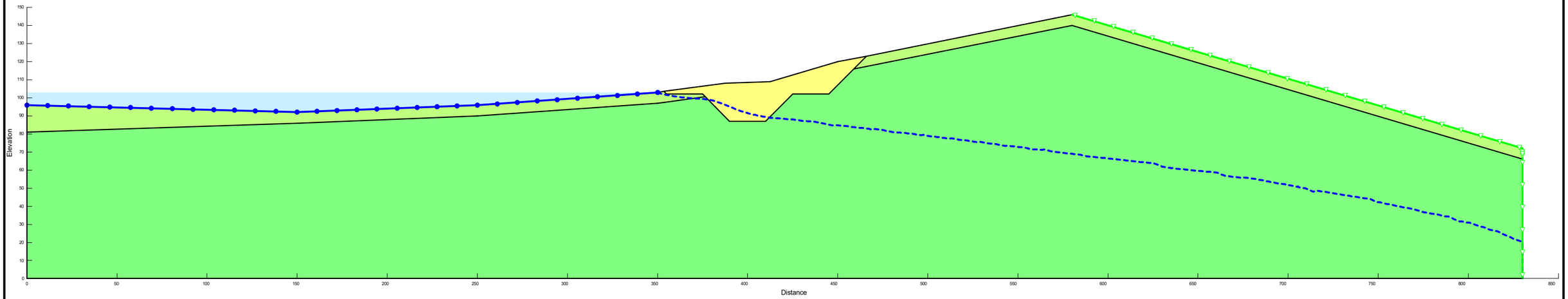


Bruce Canyon North Abutment Sta. 1+00

Steady-State Seepage

09/30/2020 1:626

Cuchara Basin Collaborative Storage
Bruce Canyon 50%
Project No. 18.117



Color	Name	Model	Vol. WC. Function	K-Function	Ky'/Kx' Ratio
	Bedrock	Saturated / Unsaturated	Claystone	Claystone	0.1
	Embankment	Saturated / Unsaturated	Embankment	Embankment	1
	Native Soils	Saturated / Unsaturated	Native Soils	Native Soils	1

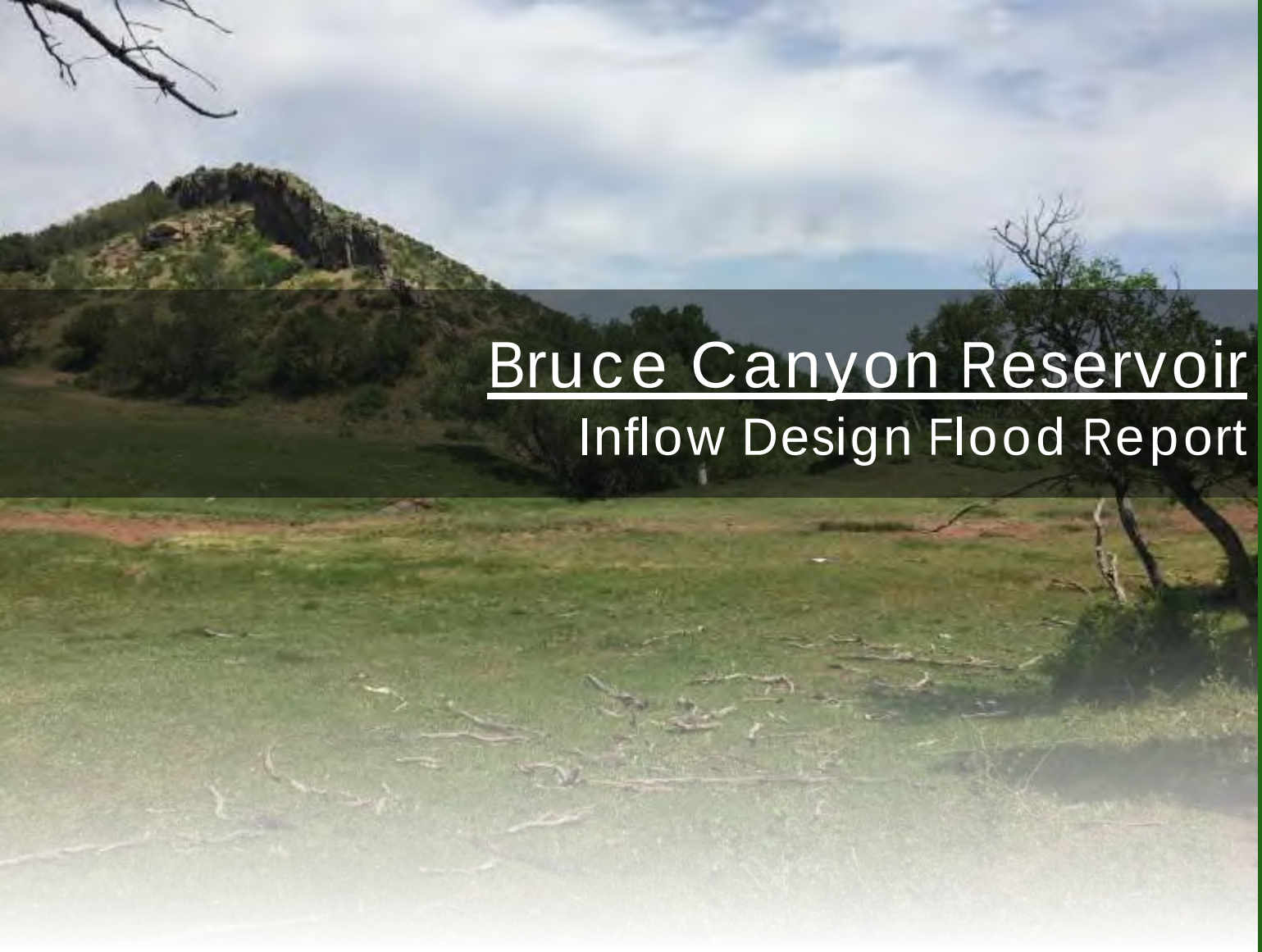
Bruce Canyon 50%, South Abutment, Station 11+70

Steady State Seepage

09/09/2020 1:649

APPENDIX B

HYDROLOGY REPORT



Bruce Canyon Reservoir

Inflow Design Flood Report

December, 2021

AG File # 18-117

HUERFANO COUNTY WATER CONSERVANCY DISTRICT

Applegate Group, Inc.
Water Resource Advisors for the West
www.applegategroup.com
303-452-6611

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INTRODUCTION

The Bruce Canyon dam will be a new homogeneous embankment dam located in Huerfano County approximately 2.5 miles southwest of La Veta Colorado. The dam would be owned by the Cucharas Basin Collaborative, or likely one of the participants within the Collaborative Storage group. The dam will be located in the northwest ¼ of Section 5, Township 30 South, Range 68 West, of the Sixth P.M., at a ground surface elevation of approximately 7350 feet. The reservoir would be filled with diversions from the Cucharas River via the Butte Ditch. A conditional storage right of 1,406 ac-ft was decreed for Bruce Canyon Reservoir in Case No. 17CW3075, which also includes conditional exchanges to the Butte Ditch of up to 31.1 cfs to fill Bruce Canyon Reservoir and conditional exchanges of up to 8 cfs for releases from Bruce Canyon Reservoir to the Cucharas River. The reservoir will likely be filled in the first part of the irrigation season when there is exchange potential from downstream sources, and releases may be made throughout the year for augmentation purposes.

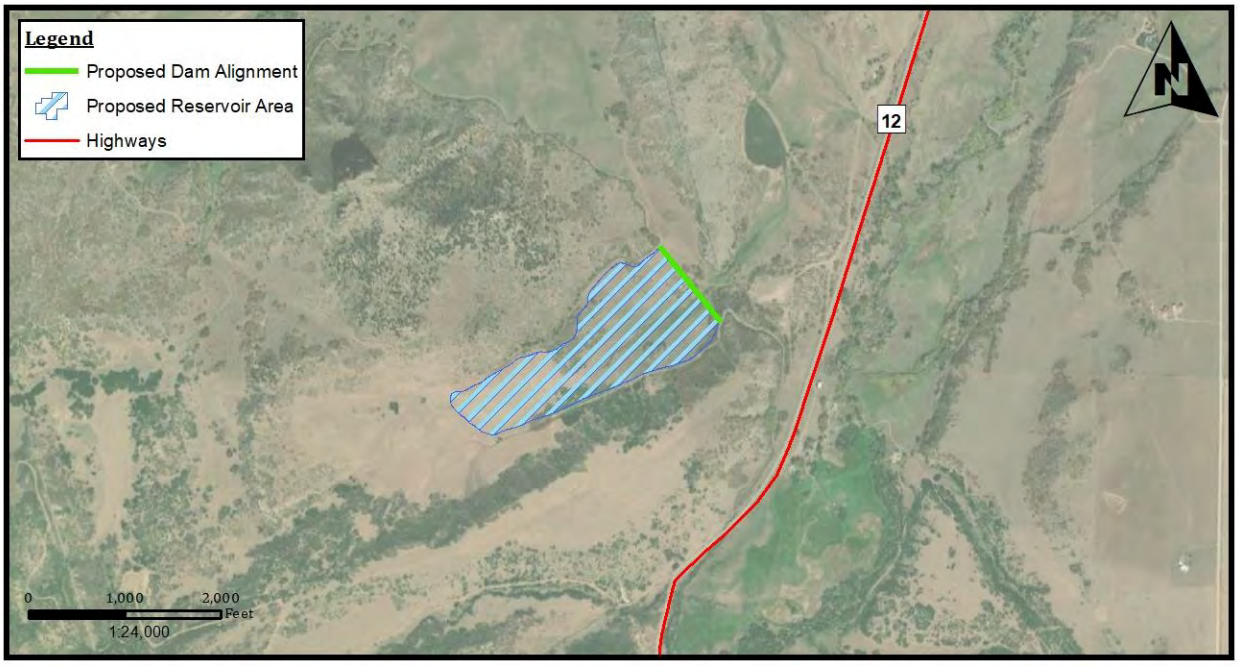


FIGURE 1 - PROPOSED BRUCE CANYON DAM AND RESERVOIR VICINITY MAP

The objective of this report is to present the Hydrologic Analysis of Bruce Canyon Dam completed by Applegate Group, Inc. (Applegate) for the Huerfano County Water Conservancy District. This report will focus on determination of the inflow design flood (IDF).

The hydrologic analysis summarized in this report adheres to Rule 6 of the *Rules and Regulations for Dam Safety and Dam Construction*[1] and follows guidance presented in *Hydrologic Basin Response Parameter Estimate Guidelines*[2] and *Guidelines for the Use of Regional Extreme Precipitation Study*[3]. Spreadsheets

[1] Rules and Regulations for Dam Safety and Dam Construction. Colorado Division of Water Resources, Office of the State Engineer, Dam Safety. Effective January 1, 2020.
[2] Hydrologic Basin Response Parameter Estimation Guidelines, Office of the State Engineer, Dam Safety Branch. Revised May 2008.
[3] Guidelines for the Use of Regional Extreme Precipitation Study (REPS) Rainfall Estimation Tools. Colorado Division of Water Resources, Office of the State Engineer, Dam Safety. Effective January 7, 2020.

and rainfall analysis tools available from the Colorado Division of Water Resources website were utilized for the hydrologic analysis presented in this report a copy of which accompanies this submittal.

PROPOSED RESERVOIR CONDITIONS

Bruce Canyon reservoir will be an off-channel reservoir impounded by a 1,160 feet long and 78 feet tall homogenous earthen embankment constructed in a natural valley. The following table summarizes conditions, geometries, and characteristics proposed for Bruce Canyon dam and reservoir that are pertinent to understanding the hydrologic analysis discussed later in this report:

TABLE 1 - PROPOSED BRUCE CANYON CHARACTERISTICS

Dam Element	Value
Jurisdictional Height	74 Feet
Structural Height	78 Feet
Spillway Invert Elevation	7409 Feet
Normal Storage Capacity	1,233 Acre-feet
Max Storage Capacity	1,552 Acre-feet
Dam Crest Elevation	7414 Feet
Dam Crest Width	25 Feet
Normal Freeboard	5 Feet
Upstream Dam Face Slope	3H:1V
Downstream Dam Face Slope	2.5H:1V

The proposed stage-area-storage curve for Bruce Canyon Dam is shown below.

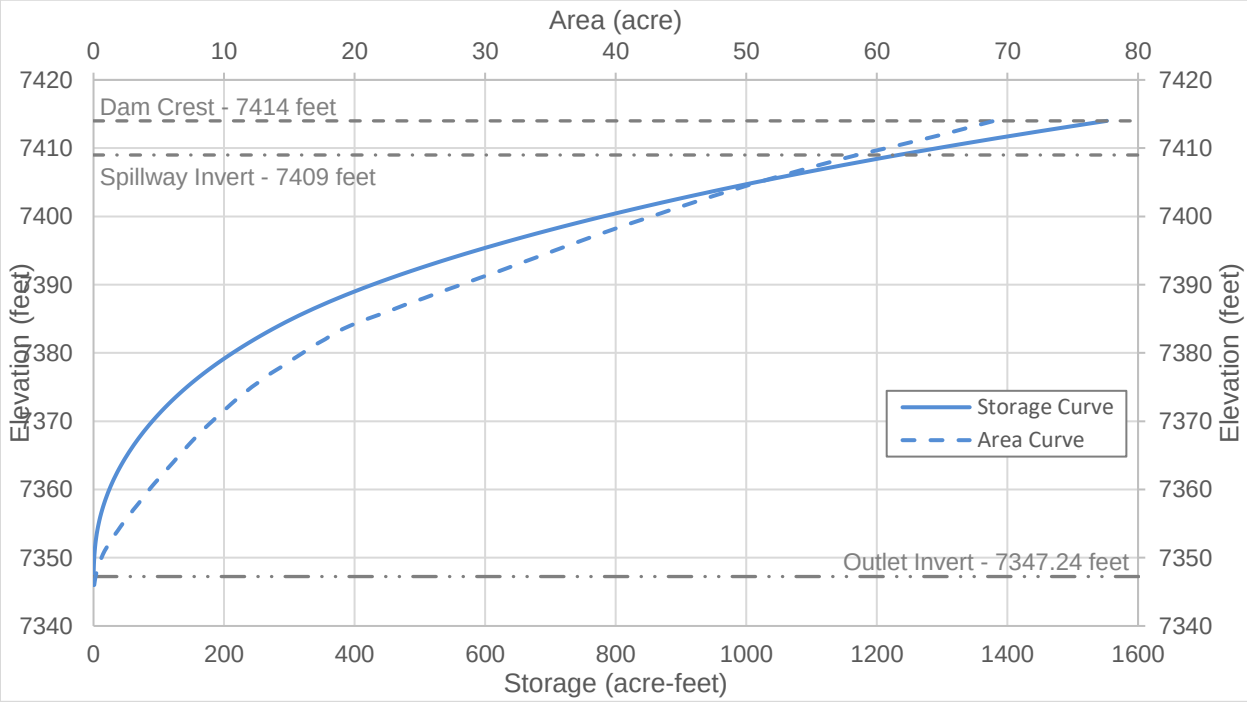


FIGURE 2 - PROPOSED BRUCE CANYON DAM STAGE-STORAGE-AREA CURVE

Please note that the Bruce Canyon Dam and Reservoir project is only at the 50% design stage at the time this report was prepared. A *Design Report* in accordance with Rule 6.8 of the *Rules and Regs* will be submitted to the SEO at the 90% design phase when formal construction drawings and specifications will be submitted to Dam Safety.

HYDROLOGIC HAZARD ANALYSIS

An extreme hydrologic hazard has been conservatively assumed for purposes of this hydrologic analysis. A formal hydrologic hazard analysis will be completed at the 90% design stage and submitted to Colorado Dam Safety at that time.

HYDROLOGY

Hydrologic analysis of Bruce Canyon dam was prepared in accordance with *Rules and Regulations for Dam Safety and Construction (Rules and Regs)* as well as recommendations found in *Hydrologic Basin Response Parameter Estimation Guidelines (Hydrology Guidelines)* both published by the SEO. The Inflow Design Flood (IDF) for Bruce Canyon dam was determined according to the Prescriptive Method described in Rule 7.2 of the *Rules and Regs* assuming an Extreme Hydrologic Hazard designation for the structure.

DRAINAGE BASIN

The contributing drainage basins for Bruce Canyon dam was determined using the *USGS Colorado StreamStats Web Application*. The drainage basin for Bruce Canyon dam was determined to be relatively small at only 346 acres or 0.54 square miles. A map of the contributing drainage basin to Bruce Canyon dam is shown in the following figure.

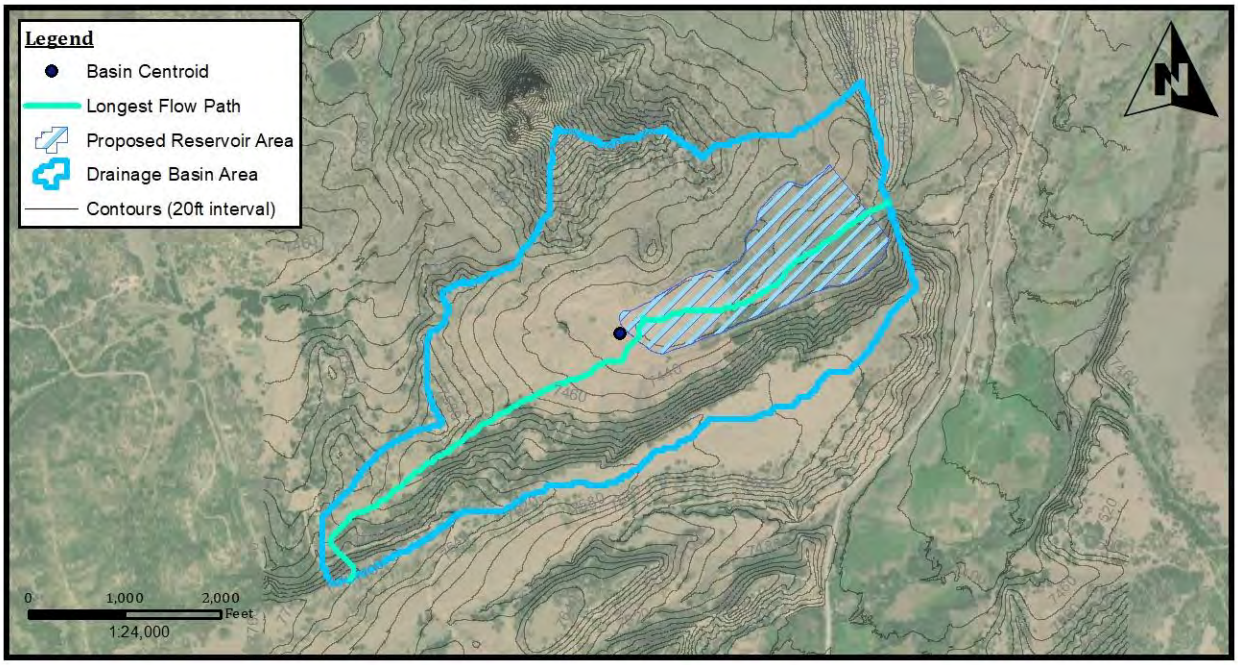


FIGURE 3 – BRUCE CANYON RESERVOIR DRAINAGE AREA

Most of the drainage basin is classified as shrub/scrub land cover type with small portions classified as deciduous forest, evergreen forest, and grasslands/herbaceous per a review of the USGS National land Cover Dataset.

LOSS PARAMETERS

The Green and Ampt Infiltration Method was used to calculate rainfall losses according to *Hydrology Guidelines*. The Green & Ampt Infiltration Method involves hydraulic conductivity (XKSAT), wetting front capillary suction (PSIF), initial volumetric soil moisture deficit (DTHETA), surface retention loss (IA), and effective impervious area (RTIMP) parameters to model infiltration of rainfall into the soil; development of these parameters are described below:

- **Hydraulic Conductivity, XKSAT:** The NRCS Web Soil Survey database was utilized to determine USDA texture classes for map units occurring within Bruce Canyon dam's drainage basin shown in Appendix A.

  Bare ground XKSAT values were applied to individual components of each map unit according to Table 10 of the *Hydrology Guidelines* utilizing the lowest XKSAT value occurring within soil horizons down to a depth of 18 inches. A vegetation cover correction factor was applied bare ground XKSAT values, except those for sand and loamy sand textures, according to the following equation.

$$C_k = \frac{V_c - 10}{90} + 1.0$$

Where:

C_k = *Ratio of XKSAT to Bare Ground XKSAT*

V_c = *Vegetation Cover % (assumed to be 75% for this analysis based on a review of aerial imagery of the basin)*

  A composite XKSAT for the basin was developed excluding components containing 'unweathered bedrock' USDA textures.
- **Wetting Front Capillary Suction, PSIF & Initial Volumetric Soil Moisture Deficit, DTHETA:** These parameters were determined according to Figure 4 of the *Hydrology Guidelines* utilizing the composite bare ground XKSAT described above assuming a normal antecedent soil moisture condition.
- **Surface Retention Loss, IA:** Table 8 of the *Hydrology Guidelines* was referenced to determine a surface retention loss parameter value for the basin assuming 75% vegetation cover and an average slope of 15% which was ascertained from USGS Colorado StreamStats Web Application.
- **Effective Impervious Area, RTIMP:** Areas of soil map units containing weathered bedrock USDA textures within the first 18 inches of depth were assumed to contribute to the effective imperious area along with the area associated with normal operating pool of the proposed reservoir.

Spreadsheet for Computing Rainfall Losses tool was obtained from the Dam Safety Branch website and was utilized to calculate the parameters described above and is included in Appendix B. Final Green and Ampt Infiltration parameter values utilized in this analysis are summarized in Table 2 **Error! Reference source not found.**.

TABLE 2 - GREEN AND AMPT INFILTRATION PARAMETERS

Parameter	Value
Weighted Average % Vegetation Cover	75%
Initial Abstraction (IA)	0.3 inches
Wetting Front Capillary Suction (PSIF)	11 inches
Volumetric Soil Moisture Deficit at the start of rainfall (DTHETA)	0.11
Adjusted Hydrologic Conductivity at Natural Saturation adjusted for vegetation (XKSAT)	0.04 inches/hour
Effective Impervious Area (RTIMP)	30%

UNIT HYDROGRAPH

A Clark Unit Hydrograph was utilized to model drainage basin of Bruce Canyon dam response to excess rainfall from the design precipitation per *Hydrologic Basin Response Parameter Estimation Guidelines*. The Clark Unit Hydrograph relies on the time of concentration (T_c), storage coefficient (R), and the time-area relation parameters which are described below:

- **Time of Concentration, T_c:** Time of concentration was calculated according to the following equation, which is recommended for rocky mountain, great plains, or Colorado Plateau type watersheds:

$$T_c = 2.4A^{0.1}L^{0.25}L_{ca}^{0.25}S^{-0.2}$$

  The area (A), length of longest flow path (L), length from concentration point to point along L perpendicular basin centroid (L_{ca}), and watercourse slope (S) were determined utilizing ArcGIS software to analyze USGS StreamStats Colorado data outputs along with LiDAR topographic of the drainage basin obtained from *Colorado Hazard Mapping & Risk Map Portal*. The map shown in **Error! Reference source not found.** shows the parameters utilized to calculate the time of concentration for Bruce Canyon dam's drainage basin
- **Storage Coefficient, R:** The storage coefficient for Bruce Canyon Dam drainage basin was calculated according to the following equation utilizing the aforementioned parameters:

$$R = 0.37T_c^{1.11}L^{0.80}A^{-0.57}$$

- **Time-Area Relation:** A Curve C dimensionless synthetic time-area relation was selected for Bruce Canyon dam's drainage basin which is recommended for undeveloped mountain or plains areas with interspersed agriculture fields.

Table 3 summarizes pertinent Clark Unit Hydrograph parameters.

TABLE 3 - CLARK UNIT HYDROGARPH PARAMETERS

Parameter	Value
A	0.543 miles^2
L	1.512 miles
L_{ca}	0.648 miles
S	260.582 ft/mile
T_c	0.738 hours
R	0.521 hours

DESIGN STORM

Probable Maximum Precipitation (PMP) storm events are required to determine the IDF for Extreme Hydrologic Hazard dams per Rule 7.2.1 of the *Rules and Regs*. Probable Maximum Precipitation storm hyetograph data was gathered utilizing *CO-NM REPS PMP Tool* within ArcGIS using a shapefile of Bruce Canyon dam's contributing drainage basin as an input. An Atmospheric Moisture Factor of 1.07 was applied to each PMP storm event considered for Bruce Canyon which are summarized in the following table:

TABLE 4 - DESIGN RAINFALL SUMMARY

Hydrologic Hazard	Storm	Total Rainfall *(inches)*	Total Rainfall x 1.07 *(inches)*
Extreme	Local Storm 2-hour Stacked PMP	11.04	11.81
	Local Storm 6-hour Synthetic East PMP	16.10	17.23
	Local Storm 24-hour Synthetic Hybrid PMP	21.54	23.05
	General Storm 72-hour Synthetic East PMP	20.41	21.84
	Tropical Storm 72-hour Synthetic East PMP	12.71	13.60

INFLOW DESIGN FLOOD

A HEC-HMS 4.8 model was generated utilizing the hydrologic parameters described above to simulate the Inflow Design Flood into the proposed Bruce Canyon Reservoir; a copy of the HEC-HMS 4.8 model accompanies this submittal. Model results for IDFs generated from the PMP storm event variants are summarized in Table 5 below.

TABLE 5 - HEC-HMS IDF ROUTING RESULTS

Storm Event	Design Rainfall (in)	Runoff Volume (ac-ft)	Peak Runoff (cfs)
Local Storm 2-hour Stacked PMP	11.81	326.4	2,193.4
Local Storm 6-hour Synthetic East PMP	17.23	475.8	1,721.4
Local Storm 24-hour Synthetic Hybrid PMP	23.05	624.7	1,371.7
General Storm 72-hour Synthetic East PMP	21.84	535.7	524.5
Tropical Storm 72-hour Synthetic East PMP	13.60	321.5	349.7

The Local Storm 24-hour Synthetic Hybrid PMP was the critical IDF for sizing the spillway of Bruce Canyon dam assuming an Extreme Hydrologic Hazard designation. Hydrographs of design IDFs considered as part of this analysis are shown in the following figure.

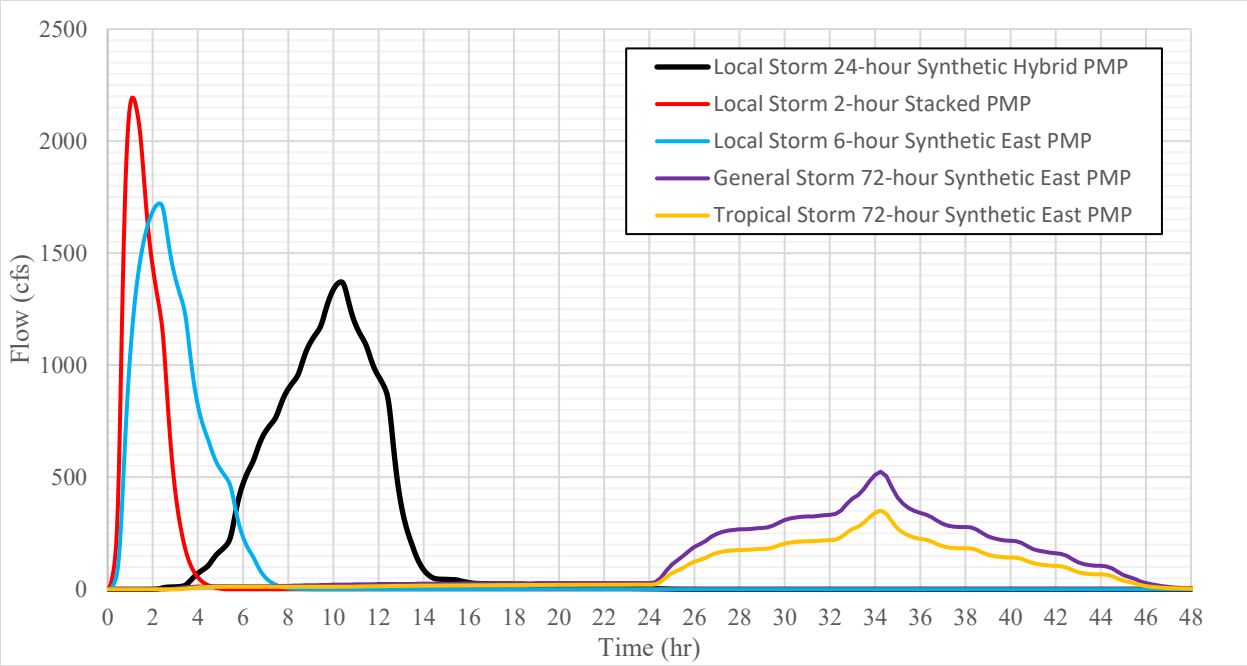


FIGURE 4 – IDF HYDROGRAPHS

Discussion

Please note the IDF, and thus costs associated with spillway construction, can be significantly reduced if efforts are taken to justify a High Hydrologic Hazard designation for Bruce Canyon dam. The 0.01% Annual Exceed Probability (AEP) storm events associated with a High Hydrologic Hazard classification are significantly less than the PMP storm events described above. High Hydrologic Hazard storm event hyetographs were gathered utilizing the *CO-NM Reps MetPortal PF Tool* web application to generate IDFs for those storms adhering to the same hydrologic analysis methods described above. The following table shows IDF characteristics generated from the PMP storm events and 0.01% AEP storm events for comparison purposes.

TABLE 6 - EXTREME VS HIGH HYDROLOGIC HAZARD DESIGN IDF COMPARISON

Hydrologic Hazard Group	Storm Event	Design Rainfall (in)	Runoff Volume (ac-ft)	Peak Runoff (cfs)
Extreme	PMP Local Storm 2-hour Stacked	11.81	326.4	2,193.4
Extreme	PMP Local Storm 6-hour Synthetic East	17.23	475.8	1,721.4
Extreme	PMP Local Storm 24-hour Synthetic Hybrid	23.05	624.7	1,371.7
Extreme	PMP General Storm 72-hour Synthetic East	21.84	535.7	524.5
Extreme	PMP Tropical Storm 72-hour Synthetic East	13.60	321.5	349.7
High	0.01% AEP Local Storm 2-hour Storm	4.59	114.8	1,063.3
High	0.01% AEP Mesoscale with Embedded Convection 6-hour Back-Loaded Synthetic Storm	6.01	148.3	773.6
High	0.01% AEP Mesoscale with Embedded Convection 6-hour Front-Loaded Synthetic Storm	5.65	140.1	801.1
High	0.01% AEP Mid-Latitude Cyclone/Tropical Storm Remnants 48-hour Back-Loaded Synthetic Strom	10.13	223.4	500.4
High	0.01% AEP Mid-Latitude Cyclone/Tropical Storm Remnants 48-hour Center-Loaded Synthetic Strom	10.03	217.1	269.6

Table 6 demonstrates the dramatic difference in the IDF and thus spillway sizing requirements between Extreme and High Hydrologic Hazard design storms. The runoff volume generated from storm events associated with a High Hydrologic Hazard designation can be stored within the dam's freeboard alone without accounting for any spillway discharge. The *Rules and Regulations* require auxiliary spillways for dams regardless, but the spillway sized for a 0.01% AEP storm event would result in significantly less effort than a spillway sized for a PMP storm event. **Applegate recommends further study to verify the Hydrologic Hazard Designation of the structure during the 90% design phase.** The spillway proposed during final design will be designed to pass the design IDF for the structure, pending results of the Hydrologic Hazard Analysis, with a minimum of 1 foot of residual freeboard. Although an Extreme Hydrologic Hazard designation has been assumed at this stage of design, the hydrologic parameters between an Extreme and High Hydrologic Hazard rating remain the same when generating and IDF and only differ in the design storm hyetograph.

APPENDIX C

50% DESIGN DRAWINGS

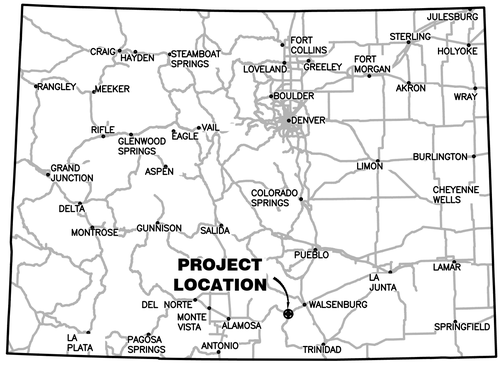
CUCHARAS COLLABORATIVE
BRUCE CANYON DAM
CONSTRUCTION PLANS
HUERFANO COUNTY, COLORADO

DECEMBER, 2021

OWNER: HUERFANO COUNTY WATER CONSERVANCY DISTRICT
P.O. BOX 442
LA VETA, CO 80155
(719) 989-7259

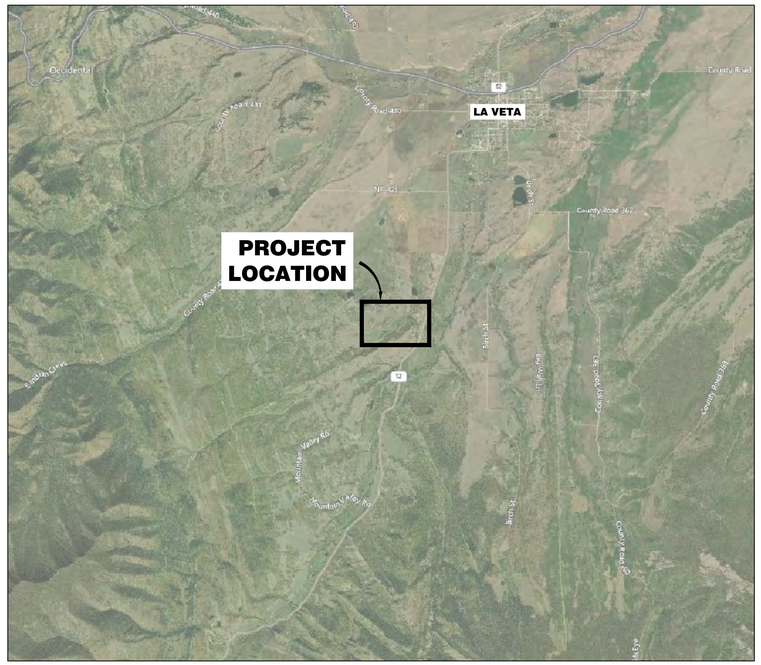
ENGINEER: APPLEGATE GROUP, INC.
1490 W. 121st AVENUE
SUITE 100
DENVER, CO 80234
(303) 452-6611

GEOTECH: CEASARE, INC.
108 SOUTH ALEON
BUILDING B
CENTENNIAL C 80112
(303) 220-0300



LOCATION MAP
NOT TO SCALE

VICINITY MAP
SCALE 1" = 5000'



5000 2500 0 5000
SCALE IN FEET

These plans have been prepared by me or under my direct supervision.

Craig Ullmann
Colorado P.E. No. 38551

Approved on the ____ day of _____, 20__

State Engineer

By:_____
Bill McCormick, Chief, Colorado Dam Safety
Colorado P.E. 29127

These plans represent the AS-CONSTRUCTED conditions of _____ Dam to the best of my knowledge and judgment, based in part on information furnished by others, as of the _____ day of _____, 20__.

Craig Ullmann

Colorado P.E. No. 38551

COLORADO 811
KNOW WHAT'S BELOW. CALL BEFORE YOU DIG.

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Applegate Group, Inc.
Water Resource Advisors for the West
1490 West 121st Ave., Suite 100
Denver, CO 80234
(303) 452-6611
Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

PROPOSED BRUCE DAM LOCATION

COVER SHEET

CUCHARAS COLLABORATIVE

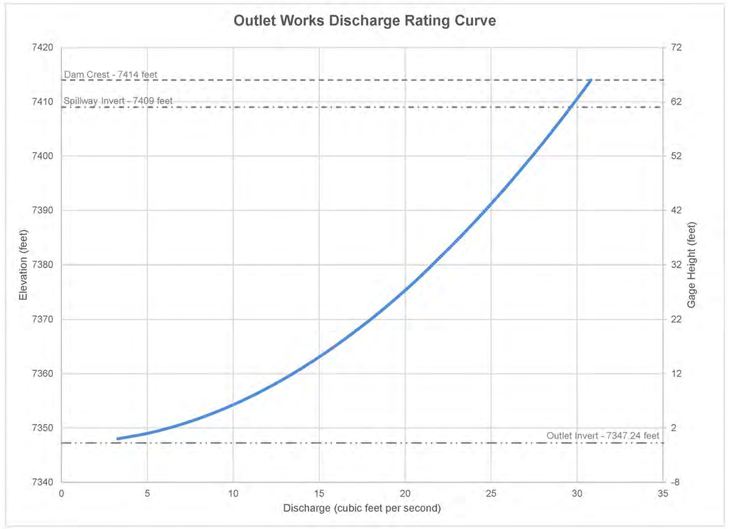
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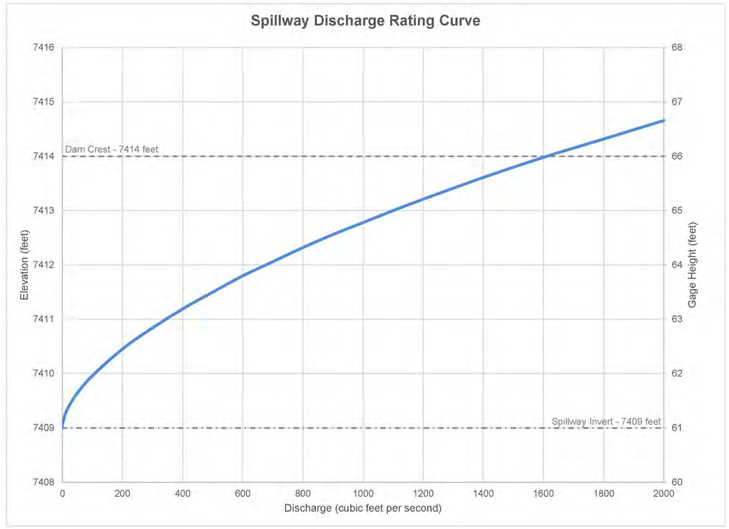
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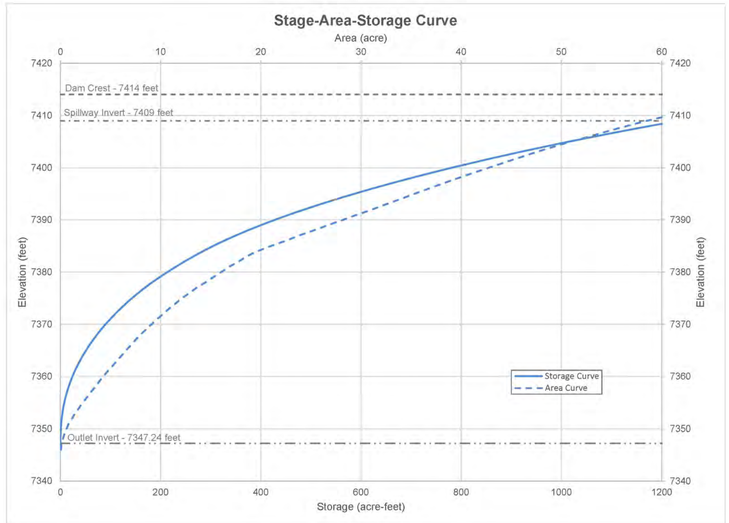
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Hydraulics Table

Gage Height (ft)	Stage (ft)	Surface Area (ac)	Storage (ac-ft)	Outlet Works Discharge (cfs)	Spillway Discharge (cfs)
-0.24	7347	0.13	0.09	0.0	-
0.76	7348	0.25	0.28	3.3	-
1.76	7349	0.41	0.61	5.0	-
2.76	7350	0.61	1.1	6.3	-
3.76	7351	0.85	1.8	7.3	-
4.76	7352	1.2	2.9	8.2	-
5.76	7353	1.5	4.2	9.0	-
6.76	7354	1.9	5.9	9.8	-
7.76	7355	2.2	7.9	10.5	-
8.76	7356	2.7	10.4	11.2	-
9.76	7357	3.0	13.2	11.8	-
10.76	7358	3.5	16.5	12.4	-
11.76	7359	3.9	20.1	12.9	-
12.76	7360	4.3	24.2	13.5	-
13.76	7361	4.7	28.7	14.0	-
14.76	7362	5.2	33.7	14.5	-
15.76	7363	5.6	39.1	15.0	-
16.76	7364	6.1	45.0	15.4	-
17.76	7365	6.6	51.3	15.9	-
18.76	7366	7.0	58.1	16.3	-
19.76	7367	7.5	65.4	16.8	-
20.76	7368	8.0	73.1	17.2	-
21.76	7369	8.5	81.4	17.6	-
22.76	7370	9.1	90.2	18.0	-
23.76	7371	9.7	99.6	18.4	-
24.76	7372	10.2	109.5	18.8	-
25.76	7373	10.8	120.1	19.1	-
26.76	7374	11.5	131.2	19.5	-
27.76	7375	12.1	143.0	19.9	-
28.76	7376	12.9	155.5	20.2	-
29.76	7377	13.6	168.7	20.6	-
30.76	7378	14.4	182.7	20.9	-
31.76	7379	15.2	197.6	21.2	-
32.76	7380	16.0	213.2	21.6	-
33.76	7381	16.8	229.6	21.9	-
34.76	7382	17.7	246.9	22.2	-
35.76	7383	18.6	265.0	22.5	-
36.76	7384	19.7	284.1	22.9	-
37.76	7385	21.0	304.5	23.2	-
38.76	7386	22.5	326.2	23.5	-
39.76	7387	23.8	349.3	23.8	-
40.76	7388	25.3	373.9	24.1	-
41.76	7389	26.7	399.8	24.4	-
42.76	7390	28.2	427.2	24.7	-
43.76	7391	29.6	456.1	24.9	-
44.76	7392	31.1	486.4	25.2	-
45.76	7393	32.5	518.2	25.5	-
46.76	7394	33.9	551.4	25.8	-
47.76	7395	35.3	586.0	26.1	-
48.76	7396	36.7	622.1	26.3	-
49.76	7397	38.2	659.5	26.6	-
50.76	7398	39.7	698.4	26.9	-
51.76	7399	41.2	738.8	27.1	-
52.76	7400	42.8	780.8	27.4	-
53.76	7401	44.3	824.3	27.6	-
54.76	7402	45.9	869.4	27.9	-
55.76	7403	47.5	916.1	28.2	-
56.76	7404	49.2	964.4	28.4	-
57.76	7405	50.9	1014.4	28.7	-
58.76	7406	52.8	1066.3	28.9	-
59.76	7407	54.6	1119.9	29.1	-
60.76	7408	56.5	1175.5	29.4	-
61.76	7409	58.5	1233.0	29.6	0
62.76	7410	60.7	1292.6	29.9	108.2
63.76	7411	62.9	1354.4	30.1	345.7
64.76	7412	65.0	1418.3	30.3	676.9
65.76	7413	67.0	1484.3	30.6	1100
66.76	7414	69.0	1552.3	30.8	1611.8



Sheet List Table

No.	Sheet Title
1	COVER SHEET
2	HYDRAULIC DATA and SHEET LIST
3	EXISTING SITE PLAN
4	GEOTECHNICAL INFORMATION
5	PROPOSED SITE PLAN
6	DAM PLAN AND PROFILE
7	DAM OUTLET PLAN AND PROFILE
9	DAM ABUTMENT SECTIONS
10	SPILLWAY PLAN AND PROFILE
11	SPILLWAY SECTIONS
12	INLET DETAILS
13	OUTLET PIPE DETAILS
14	OUTLET STRUCTURE DETAILS

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Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

PROPOSED BRUCE DAM LOCATION

HYDRAULIC DATA and SHEET LIST

CUCHARAS COLLABORATIVE

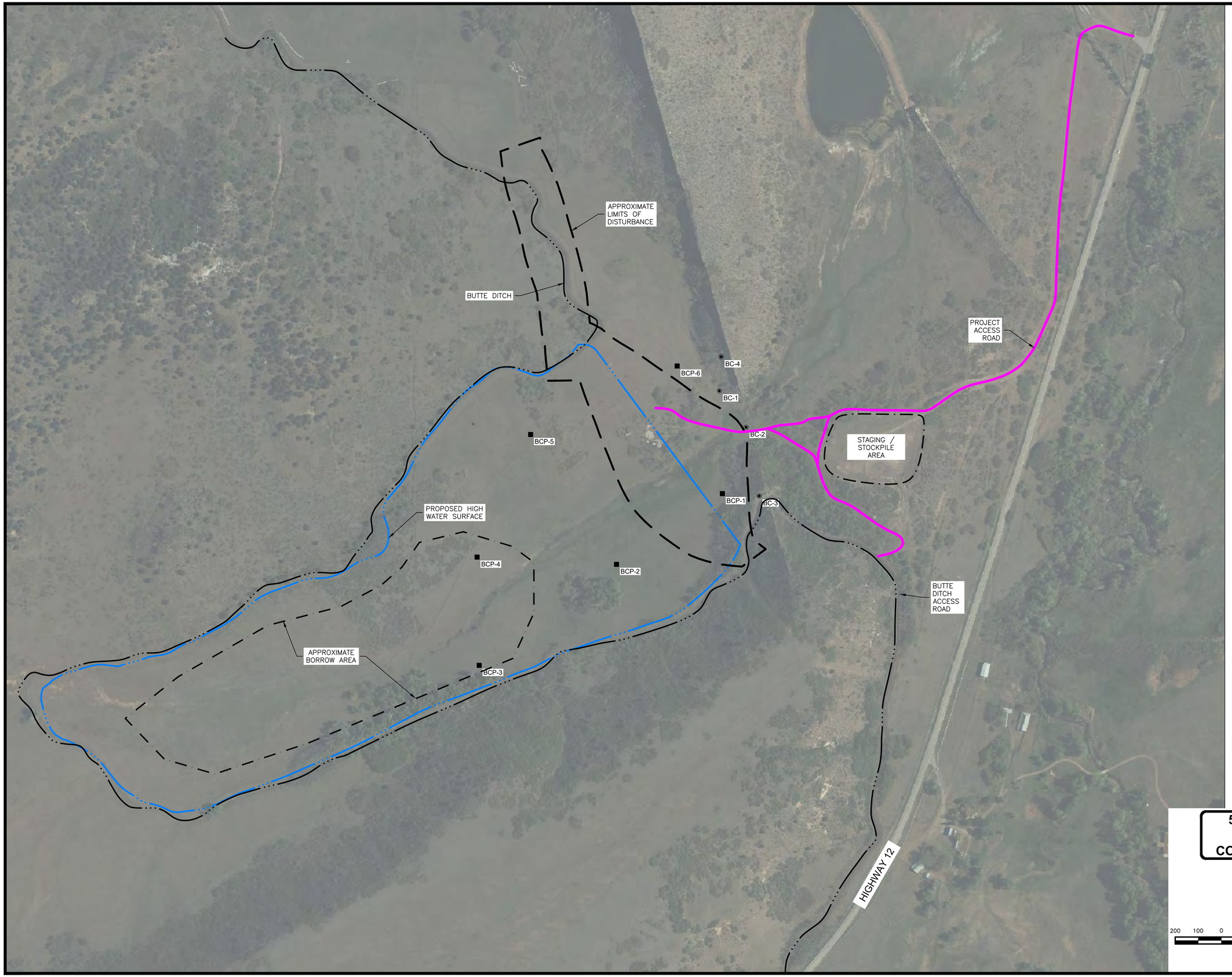
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Design:
Checked:
Scale: As Noted

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200 100 0 200 400 600
SCALE IN FEET

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PROPOSED BRUCE DAM LOCATION

EXISTING SITE PLAN

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

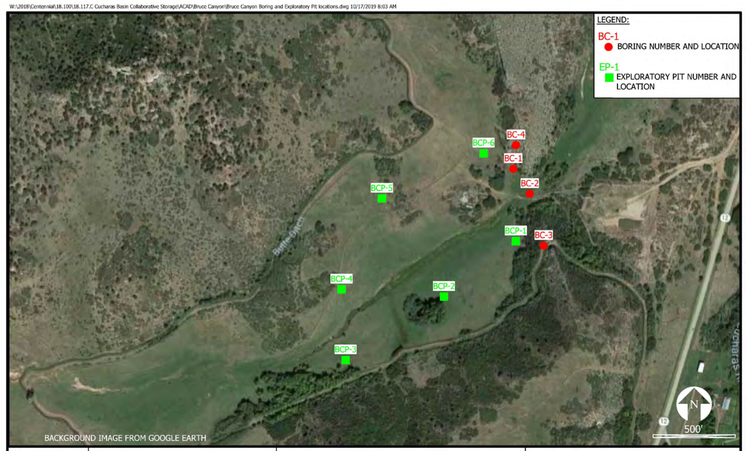
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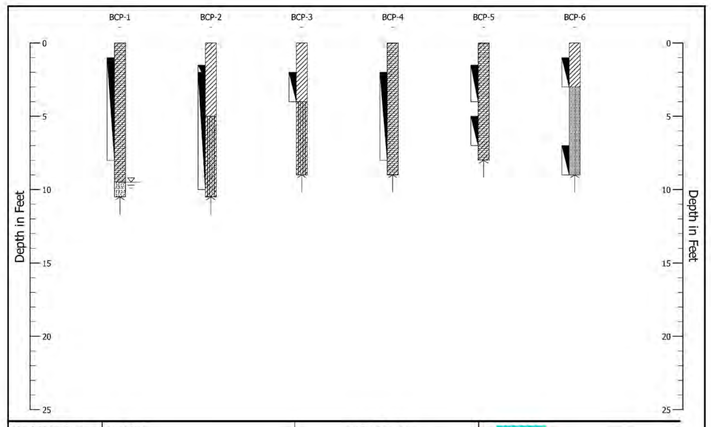
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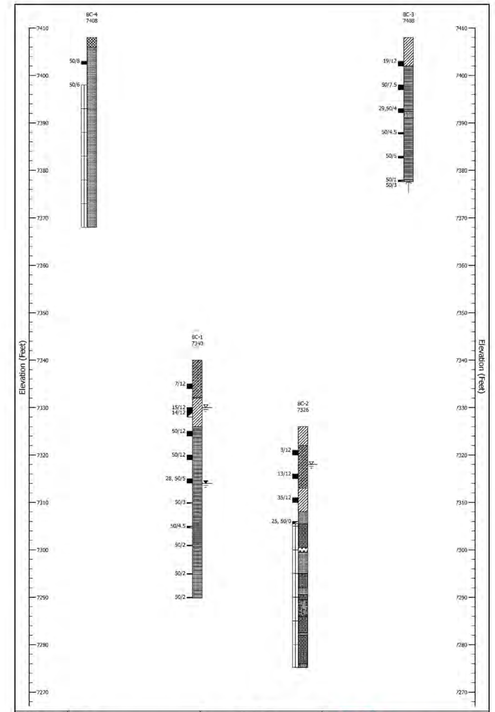
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PROJECT NAME:	Cucharas Basin Collaborative Storage		
DRAWN BY:	KNZ	CHECKED BY:	JAC2
DWG DATE:	10.11.18	REV. DATE:	10.17.19

FIGURE 14
Bruce Canyon Reservoir
Locations of Borings and Exploratory Pits

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants



PROJECT NO:	18.117	**FIGURE 16**	CESARE, INC.
PROJECT NAME:	Cucharas Basin Collaborative Storage	Bruce Canyon Exploratory Pit Logs	Geotechnical Engineers & Construction Materials Consultants
DATE:	10/28/2018		



PROJECT NO:	18.117	**FIGURE 15**	CESARE, INC.
PROJECT NAME:	Cucharas Basin Collaborative Storage Bruce Canyon	Bruce Canyon Boring Logs	Geotechnical Engineers & Construction Materials Consultants
DWG DATE:	10/24/2019		

LOG OF BORING — BC-1

PROJECT	Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION	7340
PROJECT NUMBER	18.117	DEPTH TO BEDROCK	28
DATE STARTED	8/6/18	TOTAL DEPTH	50.17
DATE COMPLETED	8/7/18	REFUSAL	
LOGGED BY	H. Brunkal		
DRILLED BY	HRL	DEPTH TO WATER / DATE	
DRILL RIG	CME-55	10	8/6
DRILL METHOD	HSA & HQ Core	26	8/7

DEPTH (ft)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0	SAND, clayey, moist, loose, dark brown.	7/12					
8 ft.	CLAY, sandy, moist, stiff, low calcareous, dark brown.	15/12 14/12					
14 ft.	CLAYSTONE, slightly moist to very moist, medium hard, very calcareous, moderately indurated from 28.5', dark brown to reddish brown, olive to gray.	50/12					
20		50/12					
28		28, 50/5					
30		50/3					
40		50/4.5					
		50/2					
		50/2					
50	Stopped HSA and sampling at 50.2'.	50/2					
60							

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

LOG OF BORING — BC-2

PROJECT	Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION	7326
PROJECT NUMBER	18.117	DEPTH TO BEDROCK	18
DATE STARTED	8/2/18	TOTAL DEPTH	51
DATE COMPLETED	8/2/18	REFUSAL	
LOGGED BY	J Edwards		
DRILLED BY	HRL	DEPTH TO WATER / DATE	
DRILL RIG	CME-55	8	8/2/18
DRILL METHOD	6.5"		

DEPTH (ft)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0	CLAY, sandy, moist to wet, very soft, dark brown.						
4 ft.	SAND, clayey, to with gravel, very loose to medium dense, wet, dark brown.	3/12					
		13/12					
13 ft.	CLAY, sandy, hard, moist, medium calcareous, brown.	35/12					
18 ft.	SANDSTONE, clayey, moderately hard to very hard, moist, gray.	25, 50/0	1	100	0	H3	
	SANDSTONE, moderately hard, moderately weathered, medium grained, massive bedding, tan.		2	100	48		
20.5 ft.	MUDSTONE, soft, moderately to highly weathered, massive bedding, dark gray to gray brown to chocolate brown. Calcareous, orange staining along fractures		3	100	100	H4	
25.5 ft.	Brecoia 25.5' - 26.5'						
26.5 ft.	SANDSTONE, moderately hard, fine grained, massive bedding, calcareous, arkosic, dark red brown.		4	100	40	H4	
31 ft.	MUDSTONE, soft, massive bedding, dark red brown.						
34 ft.	SANDSTONE, moderately hard, fine grained, massive bedding, calcareous, with occasional fossil debris, dark gray to red brown.		5	100	74	H6, H5	
35.5 ft.	MUDSTONE, soft, massive bedding, dark red brown.						
36.5 ft.	SANDSTONE, silty, conglomeratic, soft, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts. SANDSTONE, conglomeratic, moderately hard, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts. SANDSTONE, silty, conglomeratic, soft, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/ 8" - 1/4" clasts.		6	70	54	H6	
40 ft.	MUDSTONE, soft, massive bedding, calcareous, dark red brown.		7	100	67	H6	
43.5 ft.	SANDSTONE, soft to moderately hard, fine grained, massive bedding, calcareous, dark red brown.						
44 ft.	MUDSTONE, soft, highly altered, massive bedding, dark red brown. 47'-49' Olive gray to tan, mottled						
50 ft.	SANDSTONE, conglomeratic, soft, highly altered, fine grained, massive bedding, mottled dark red brown to olive gray to yellow brown. Stopped coring at 50.8'						
60							

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

LOG OF BORING — BC-3

PROJECT	Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION	7408
PROJECT NUMBER	18.117	DEPTH TO BEDROCK	10
DATE STARTED	8/7/18	TOTAL DEPTH	50.25
DATE COMPLETED	8/7/18	REFUSAL	
LOGGED BY	H. Brunkal		
DRILLED BY	HRL	DEPTH TO WATER / DATE	
DRILL RIG	CME-55	dry	8/7/18
DRILL METHOD	6.5"		

DEPTH (ft)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0	CLAY, sandy, slightly moist, very stiff, medium calcareous, brown.						
6 ft.	CLAYSTONE, sandy, slightly moist, hard, low calcareous, dark reddish brown.	19/12					
		50/7.5					
15.5 ft.	SANDSTONE, silty, clayey, slightly moist, very hard, dark red brown.	29,50/4					
17 ft.	CLAYSTONE, sandy, slightly moist, very hard, medium calcareous, dark brown.	50/4.5					
		50/5					
30 ft.	SANDSTONE, slightly moist, very hard, very calcareous, very indurated. maroon. Stopped HSA and sampling at 30.2.	50/1 50/3					
40							
50							
60							

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants

LOG OF BORING — BC-4

PROJECT	Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION	7408
PROJECT NUMBER	18.117	DEPTH TO BEDROCK	0.5
DATE STARTED	8/29/19	TOTAL DEPTH	40
DATE COMPLETED	8/30/19	REFUSAL	
LOGGED BY	I. Campbell		
DRILLED BY	Dakota	DEPTH TO WATER / DATE	
DRILL RIG	CME 45 Track Mounted	None	
DRILL METHOD			

DEPTH (ft)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0	FILL: DRILL PAD, SANDSTONE						
2 ft.	SANDSTONE, silty, hard, unweathered, moderately fractured, banded to thickly bedded, dark gray.	50/8					
	SANDSTONE, silty, hard, unweathered, intact to moderately fractured, banded to thickly bedded, light tan.	50/6	1	67	67		
	Coarse grain lense at 13 feet.		2	100	100		
	Hard, slightly weathered, slightly to highly fractured, bonded to thickly bedded, iron staining in joints with hydrothermal quartz, light tan.		3	100	100		
			4	98	98		
	Hard to moderately hard, slightly to moderately weathered, slightly to intensely fractured, banded to thickly bedded, light tan to gray.		5	97	73		
	Thin lense of claystone at 34 feet.		6	97	75		
40	Stopped Coring at 40 feet.						
50							
60							

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email: info@applegategroup.com Website: www.applegategroup.com

PROPOSED BRUCE DAM LOCATION

GEOTECHNICAL INFORMATION

CUCHARAS COLLABORATIVE

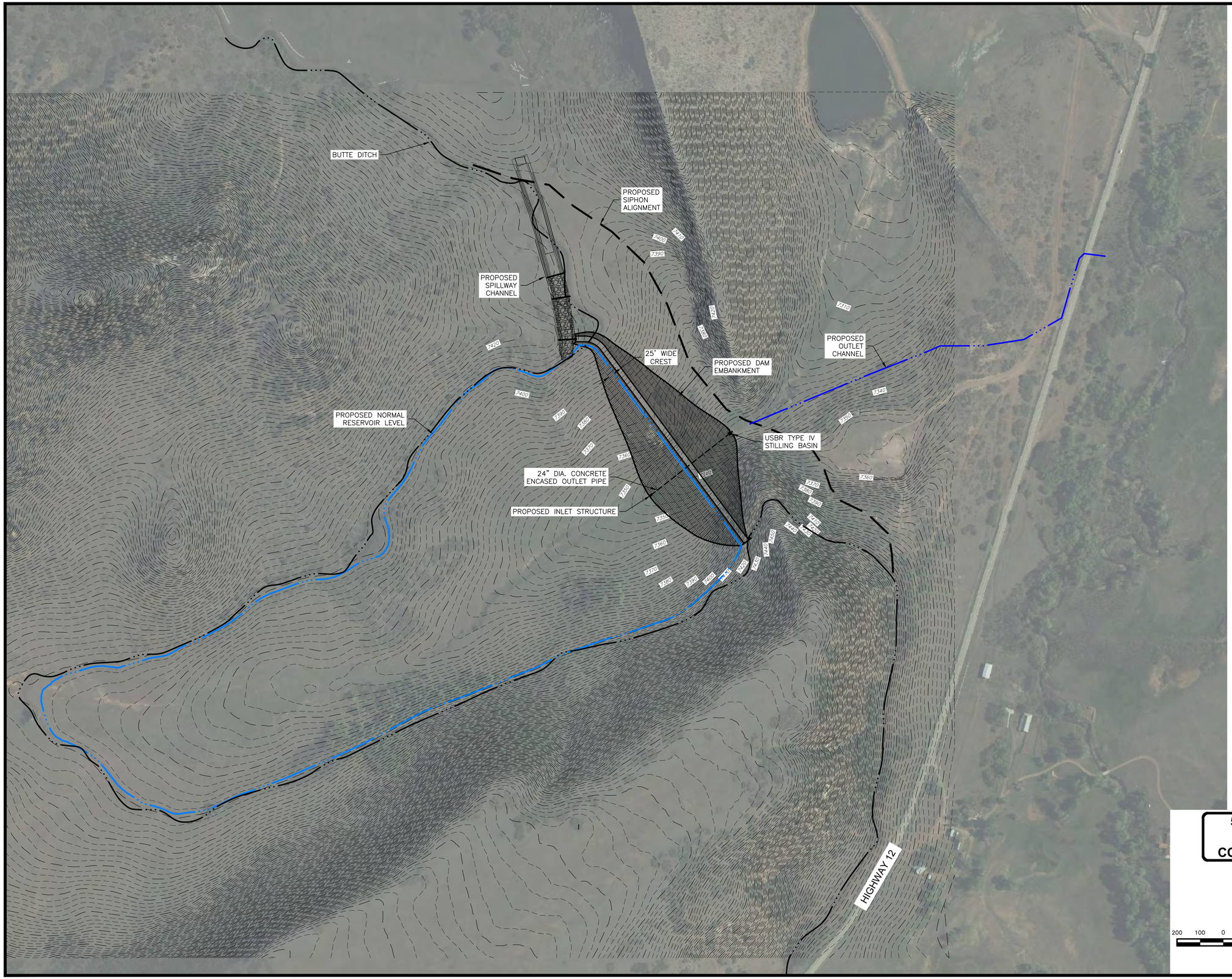
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				REVISIONS

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50% DESIGN
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CONSTRUCTION

Scale 1" = 200'
2' CONTOUR INTERVAL

200 100 0 200 400 600
SCALE IN FEET

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PROPOSED BRUCE DAM LOCATION

PROPOSED SITE PLAN

CUCHARAS COLLABORATIVE

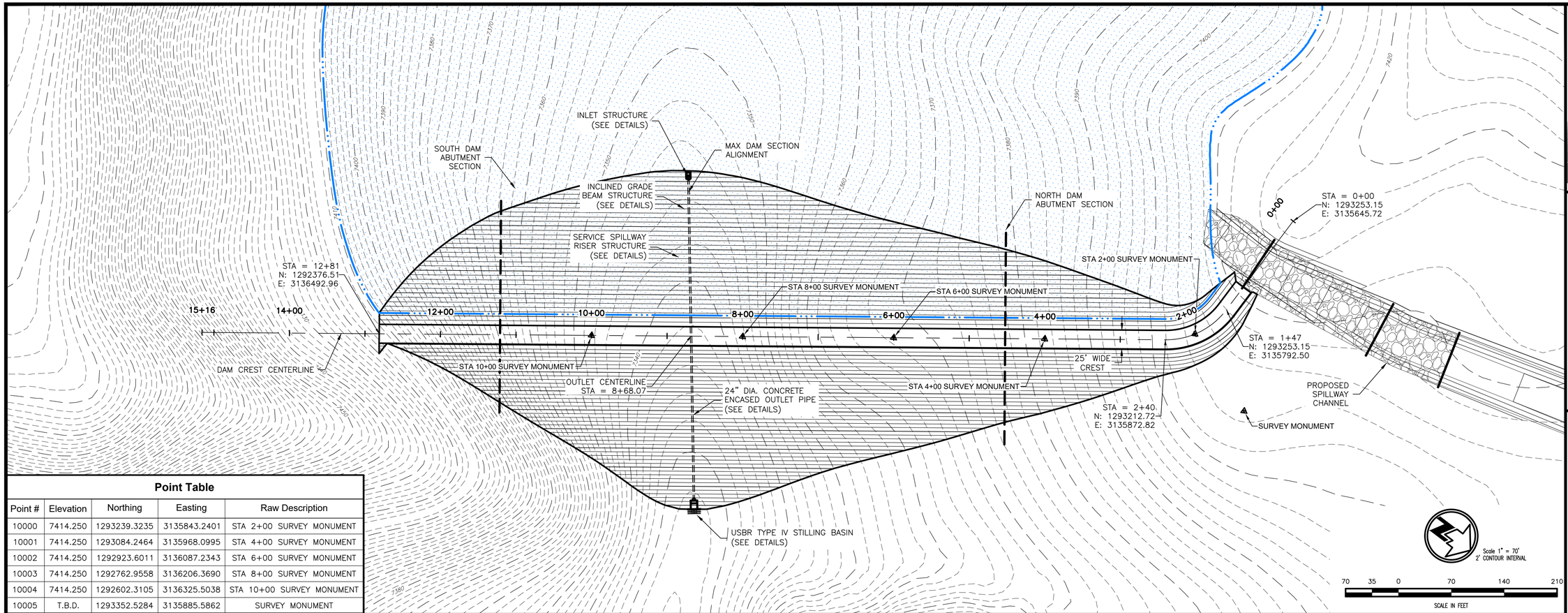
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				REVISIONS

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Drawn: LD
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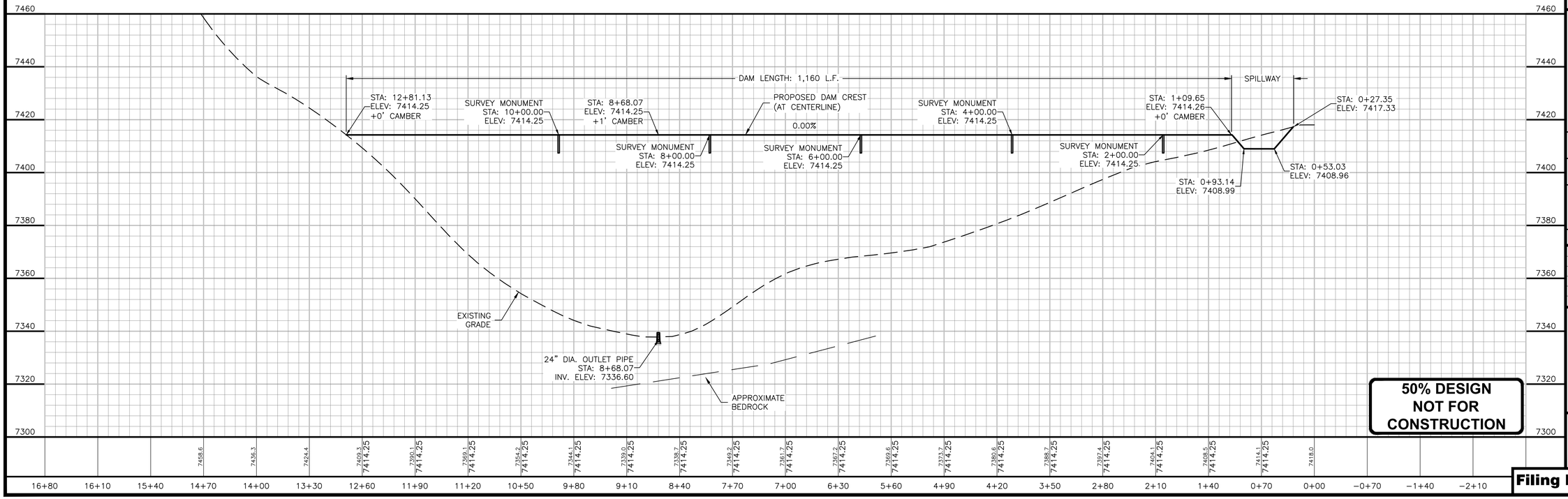
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Point Table

Point #	Elevation	Northing	Easting	Raw Description
10000	7414.250	1293239.3235	3135843.2401	STA 2+00 SURVEY MONUMENT
10001	7414.250	1293084.2464	3135968.0995	STA 4+00 SURVEY MONUMENT
10002	7414.250	1292923.6011	3136087.2343	STA 6+00 SURVEY MONUMENT
10003	7414.250	1292762.9558	3136206.3690	STA 8+00 SURVEY MONUMENT
10004	7414.250	1292602.3105	3136325.5038	STA 10+00 SURVEY MONUMENT
10005	T.B.D.	1293352.5284	3135885.5862	SURVEY MONUMENT



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PROPOSED BRUCE DAM LOCATION

DAM PLAN AND PROFILE

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

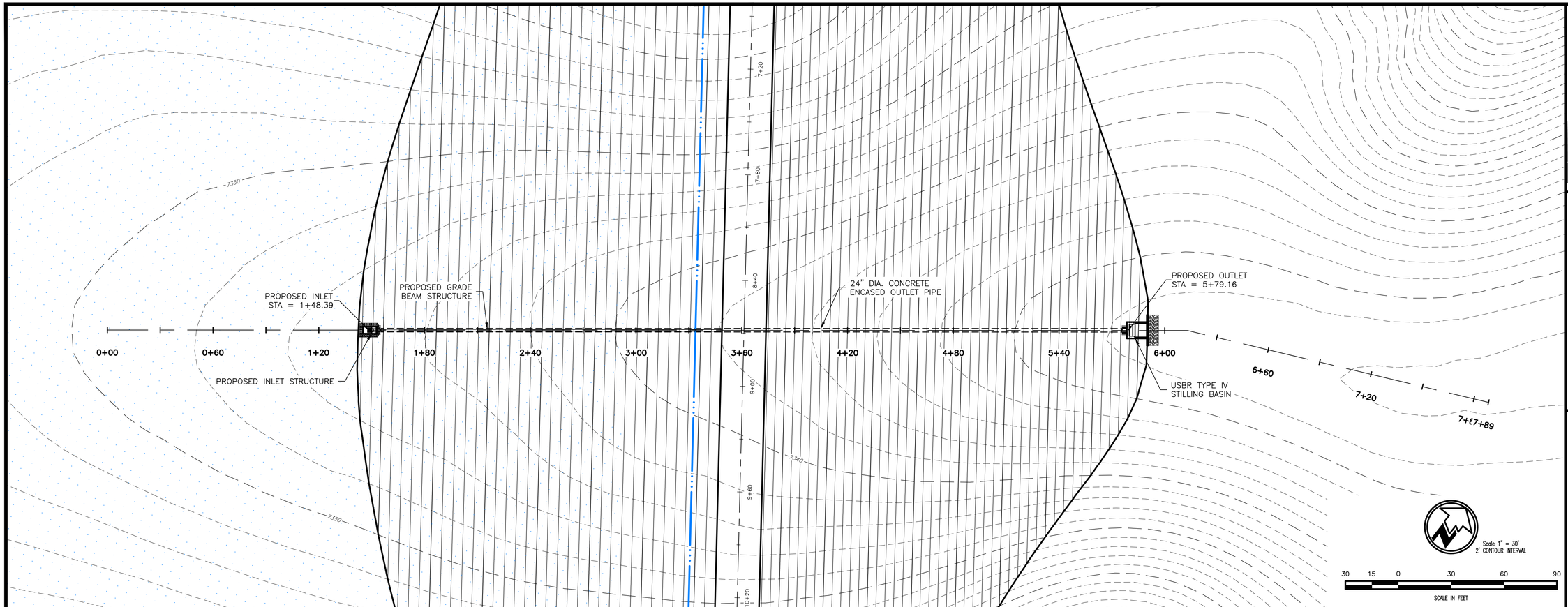
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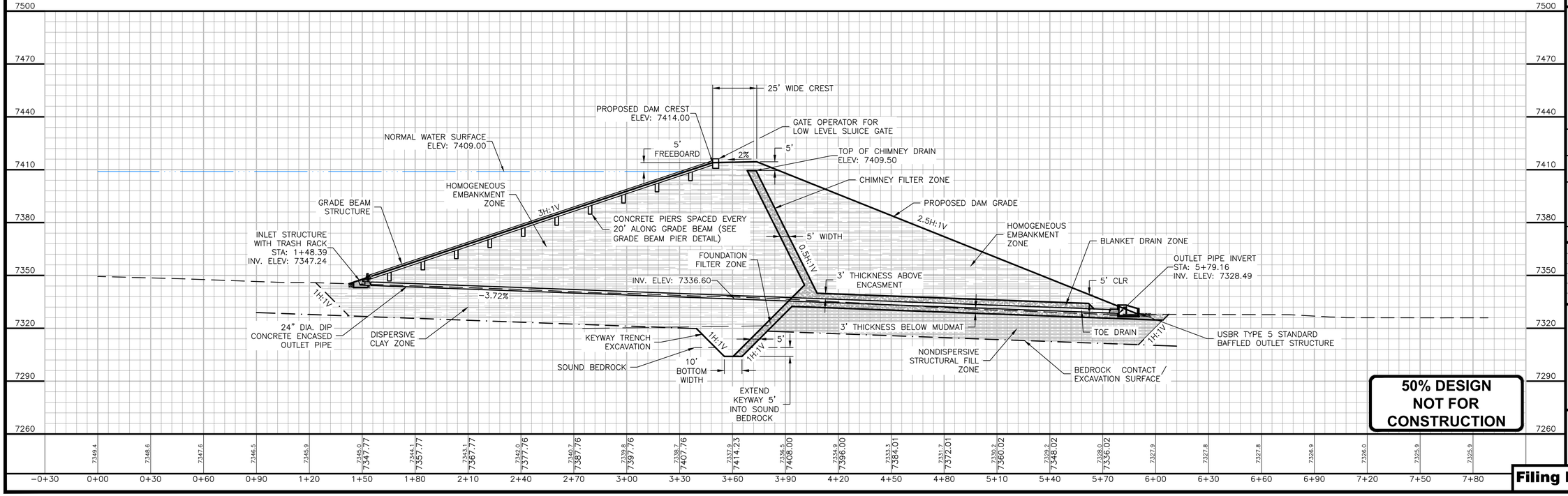
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PROPOSED BRUCE DAM LOCATION

DAM OUTLET PLAN AND PROFILE

CUCHARAS COLLABORATIVE

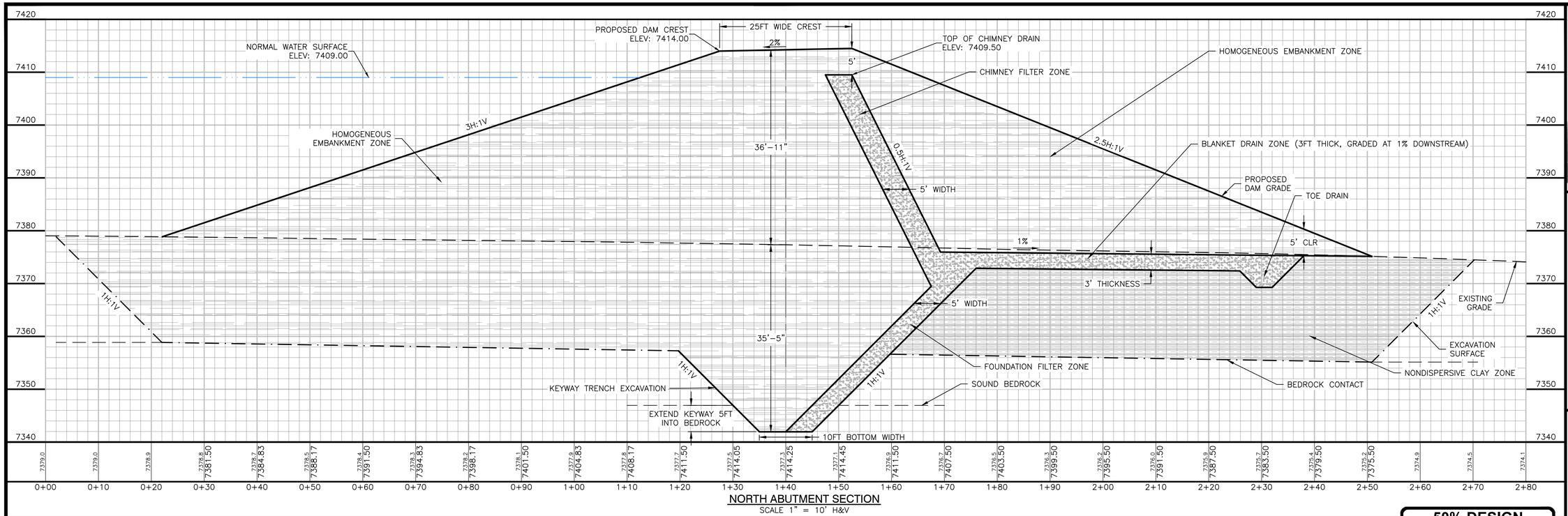
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REVISIONS				

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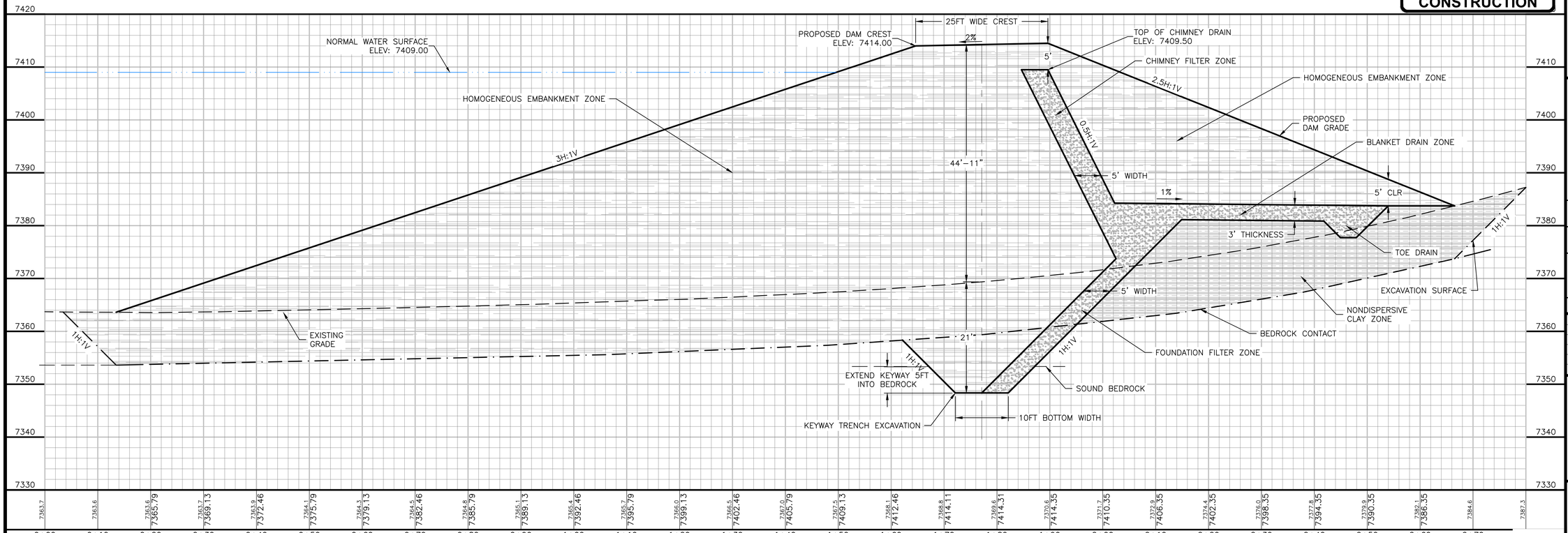
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NORTH ABUTMENT SECTION
SCALE 1" = 10' H&V



SOUTH ABUTMENT SECTION
SCALE 1" = 10' H&V

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PROPOSED BRUCE DAM LOCATION

DAM ABUTMENT SECTIONS

CUCHARAS COLLABORATIVE

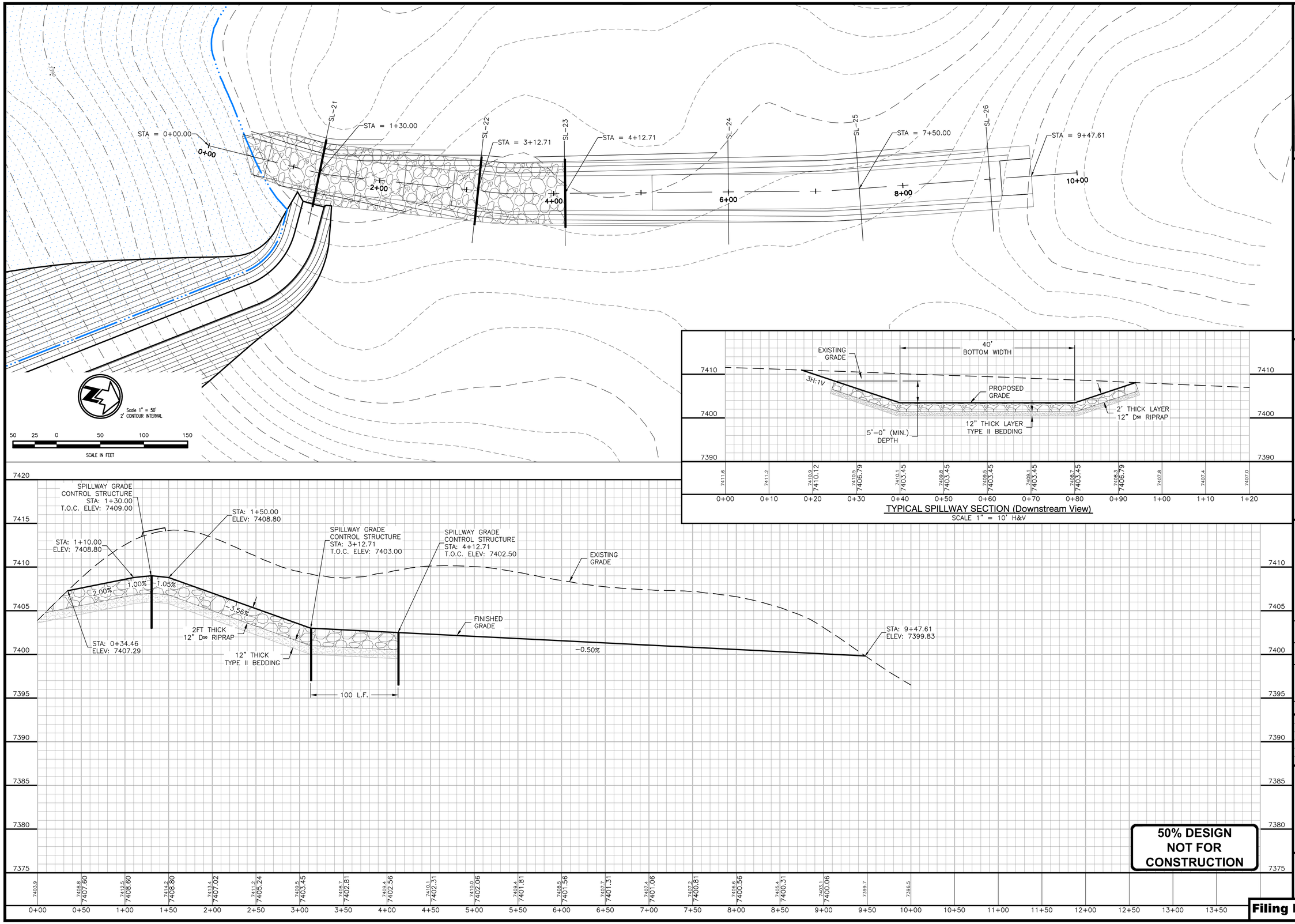
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Job No:	16-106
Drawn:	LD
Design:	
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Sheet: **9**
Of:

Filing No. C-

Plot Date: 12/07/21-8:31am, Plotted by:mtod, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Bruce\Design\Drawing Name\Bruce Abutment Plan exhibit.dwg



TYPICAL SPILLWAY SECTION (Downstream View)
SCALE 1" = 10' H&V

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PROPOSED BRUCE DAM LOCATION

SPILLWAY PLAN AND PROFILE

CUCHARAS COLLABORATIVE

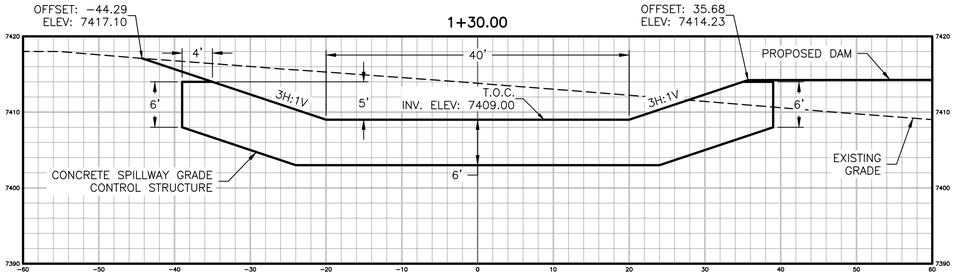
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				REVISIONS

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Job No:	16-106
Drawn:	LD
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Scale:	1"=50'H/1"=5'V

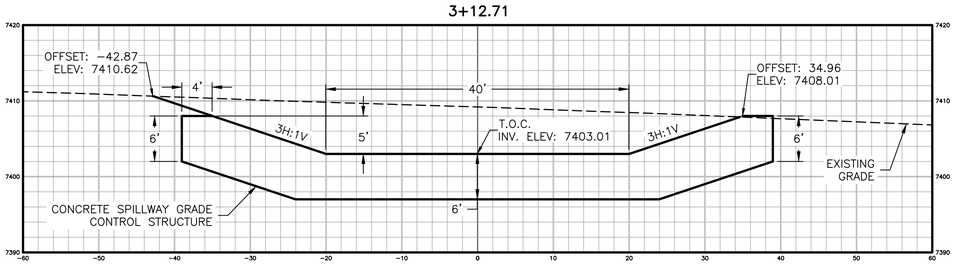
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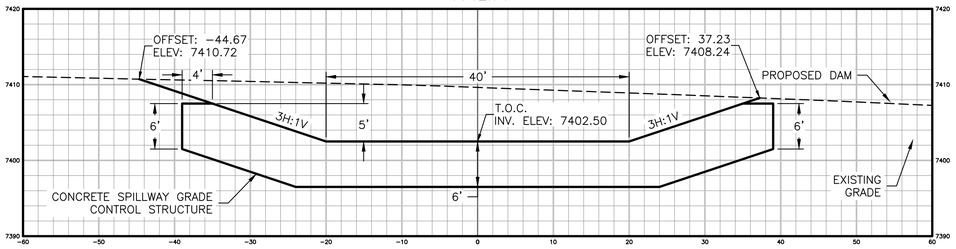
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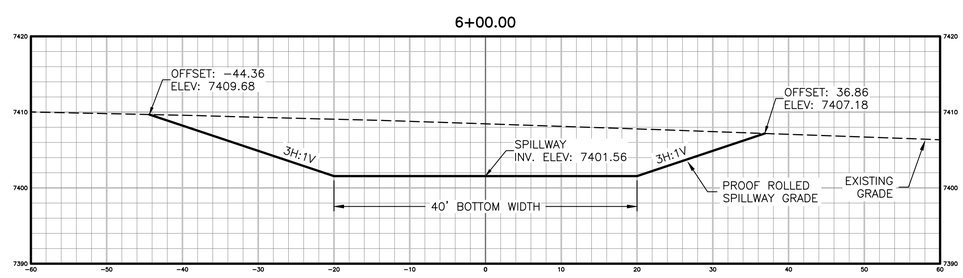
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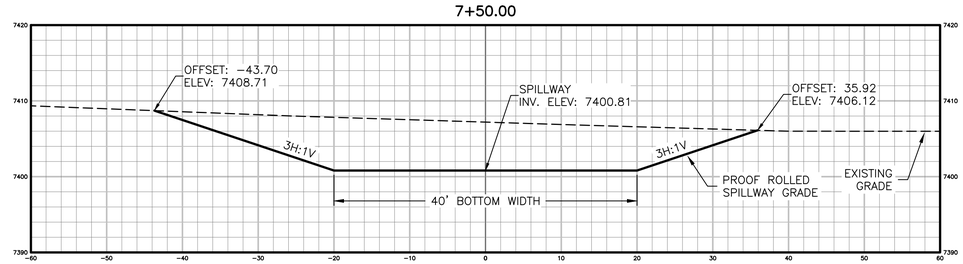
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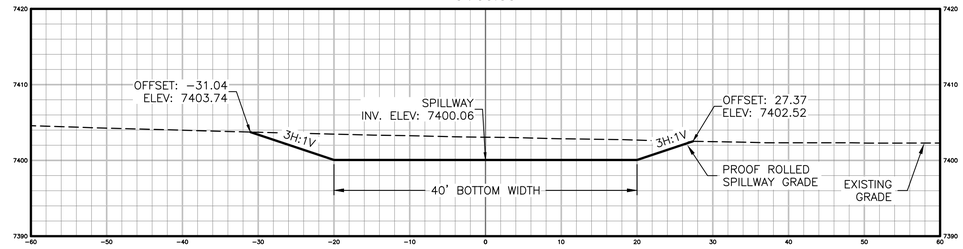
SL-23



SL-24



SL-25



SL-26

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PROPOSED BRUCE DAM LOCATION

SPILLWAY SECTIONS

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION
				REVISIONS

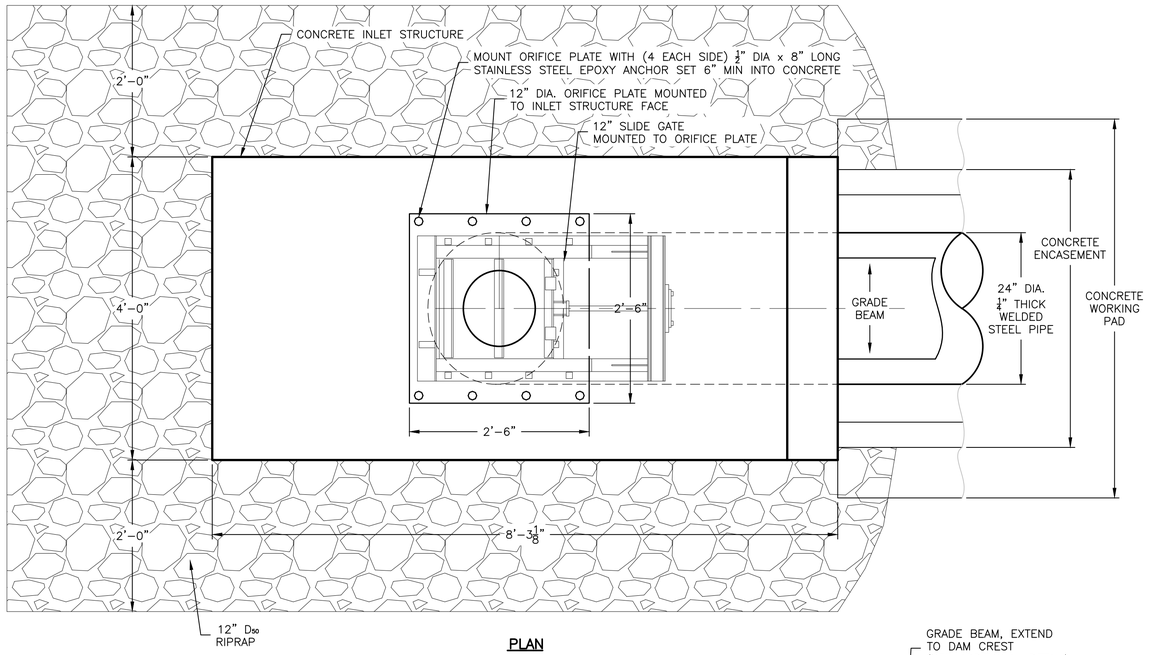
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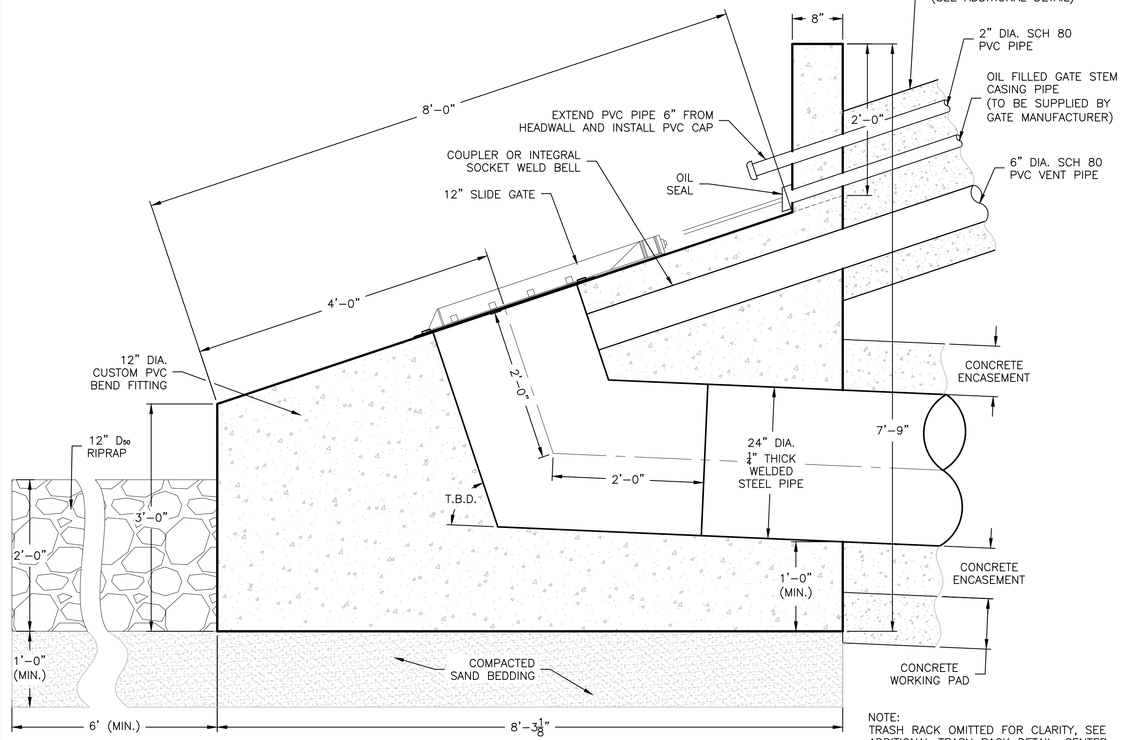
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PLAN

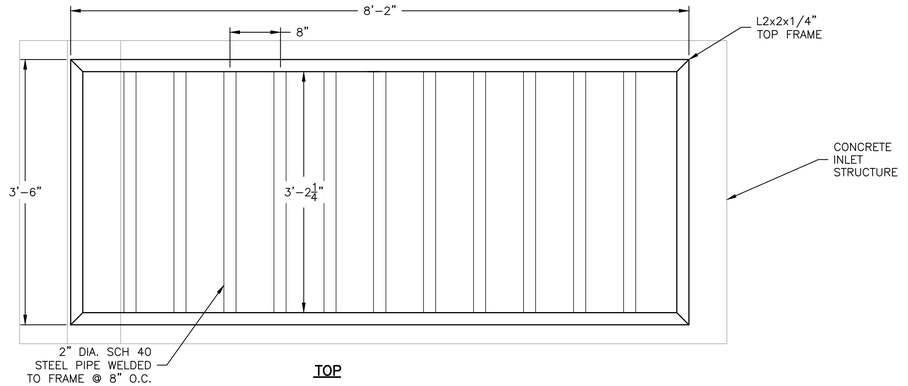


NOTE:
TRASH RACK OMITTED FOR CLARITY, SEE ADDITIONAL TRASH RACK DETAIL. CENTER TRASH RACK ON INLET STRUCTURE FACE.

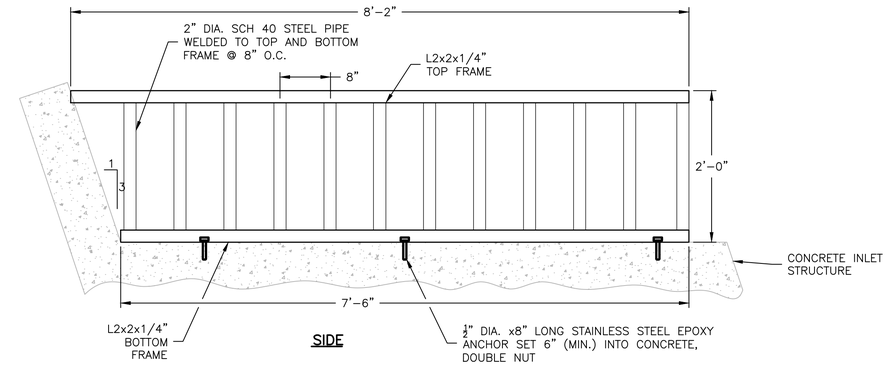
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CONCRETE INLET STRUCTURE
SCALE 1" = 1'

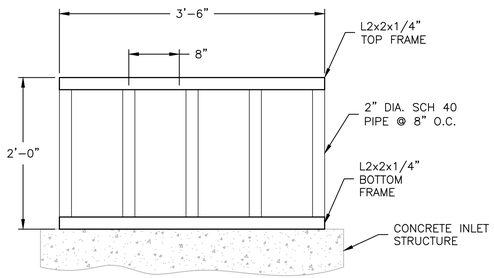
0 0.5 1 2
SCALE IN FEET



TOP



SIDE

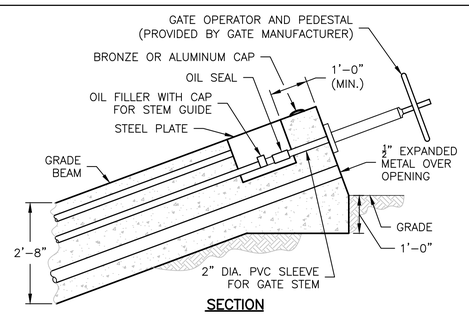


FRONT

NOTES:
1. LEAVE BACK OF FRAME OPEN TO ACCOMMODATE VALVE STEM AND 2" DIA. SCH 80 PIPE.
2. ALL STEEL SHALL BE EITHER GALVANIZED OR COATED WITH A POLYURETHANE OR 2 PART EPOXY PAINT RATED FOR SUBMERGED SERVICE.

TRASHRACK DETAIL
SCALE 1" = 1'–0"

0 0.5 1 2
SCALE IN FEET



SECTION

GATE PEDESTAL DETAIL
NOT TO SCALE

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PROPOSED BRUCE DAM LOCATION

INLET DETAILS

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

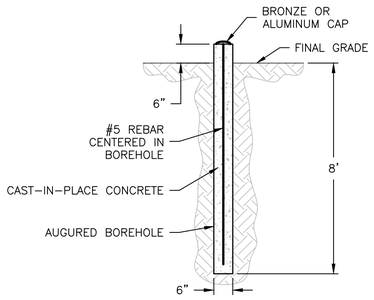
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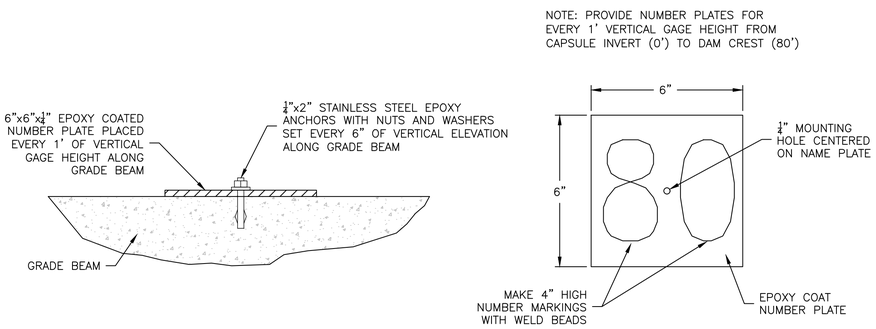
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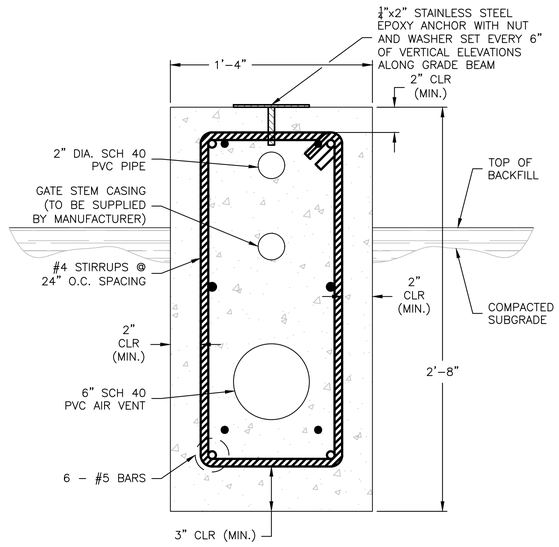
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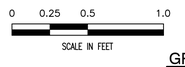


SURVEY MONUMENT
NOT TO SCALE

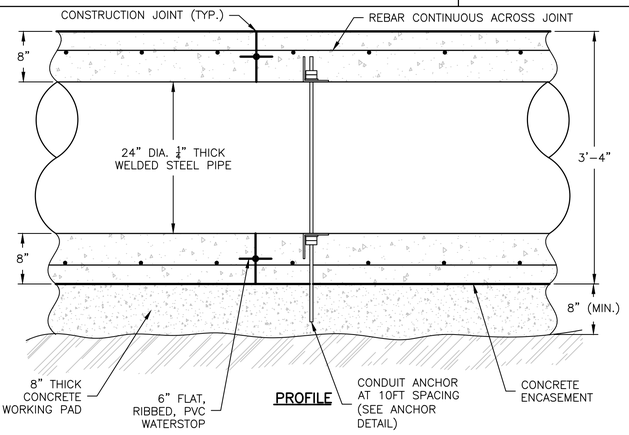


STAFF GAGE DETAIL
NOT TO SCALE

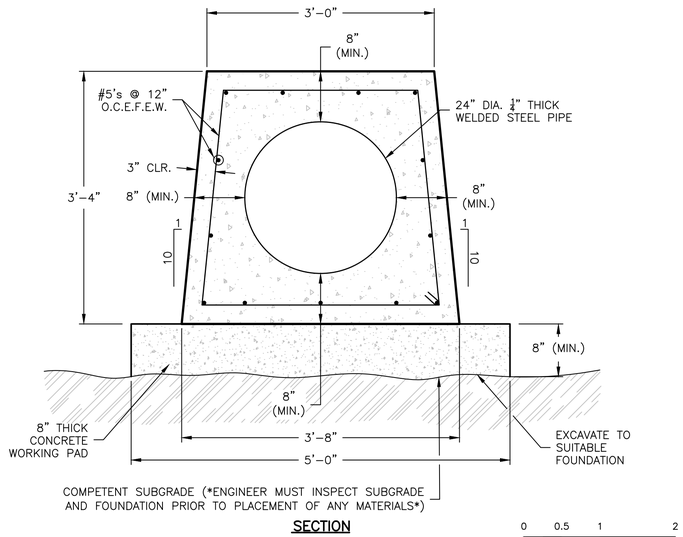




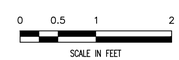
GRADE BEAM DETAIL
SCALE 1" = 0'-6"

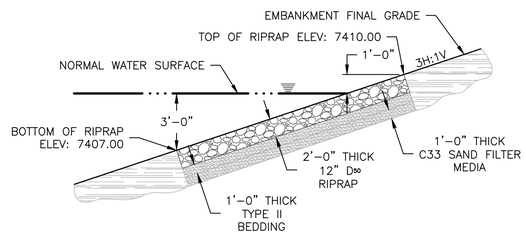


PROFILE

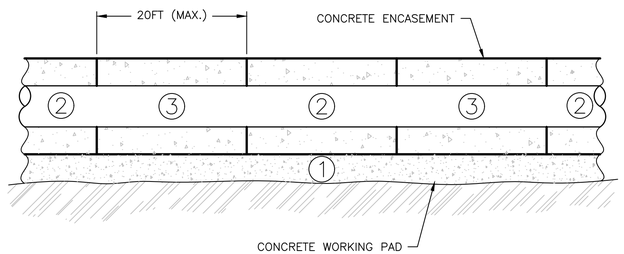


SECTION
CONCRETE ENCASEMENT DETAIL
SCALE 1" = 1'



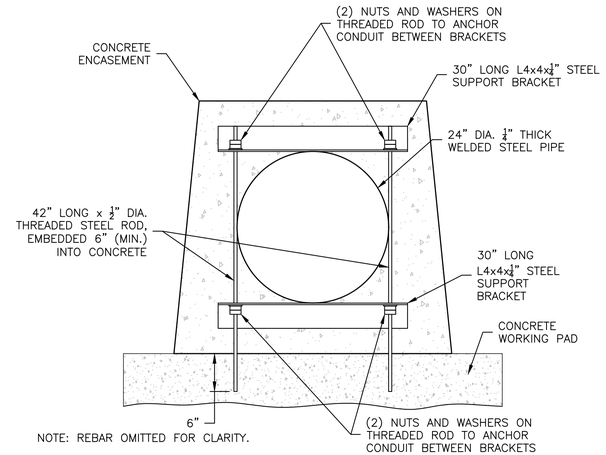


UPSTREAM SLOPE PROTECTION DETAIL
NOT TO SCALE



NOTES:
1. CONCRETE WORKING PAD WITH REBAR ANCHORS CAST FIRST PRIOR TO CONCRETE ENCASEMENT.
2. CONCRETE ENCASEMENT SHALL BE CAST IN 20FT SECTION ALTERNATING AS SHOWN WITH #2 SECTIONS CAST FIRST, FOLLOWED BY #3 SECTIONS.
3. SPACE ANCHORING SYSTEM EVERY 10FT ALONG CONDUIT ALIGNMENT.

ENCASEMENT SEQUENCING
NOT TO SCALE



CONDUIT ANCHOR DETAIL
SCALE 1" = 1'

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PROPOSED BRUCE DAM LOCATION

OUTLET PIPE DETAILS

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

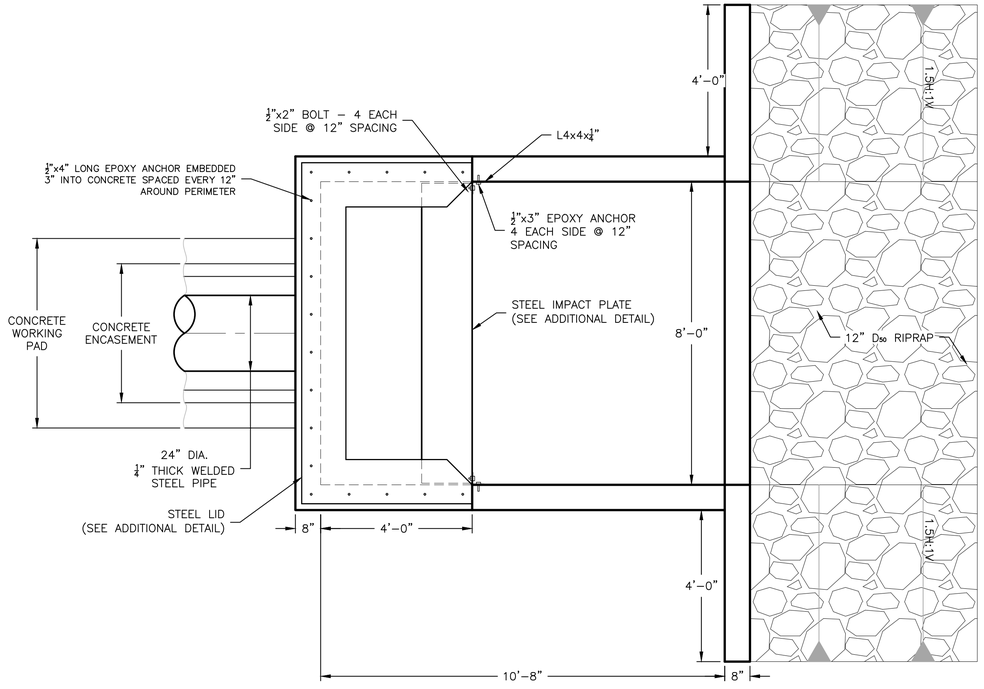
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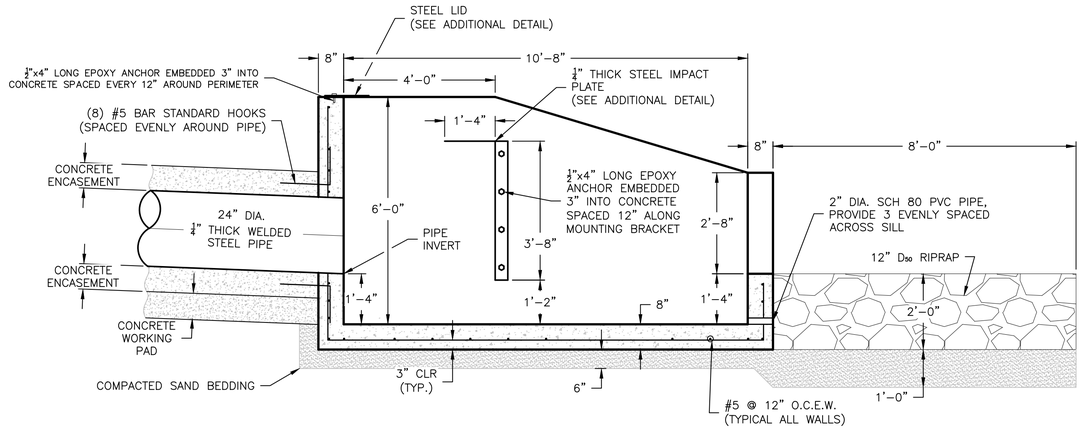
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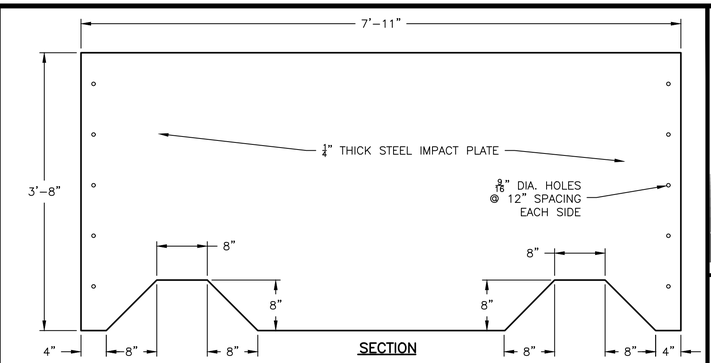


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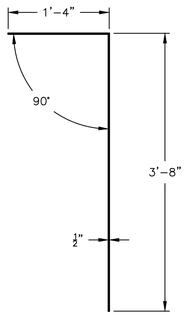
0 1 2 4

SCALE IN FEET

CONCRETE IMPACT BASIN
SCALE 1" = 2'

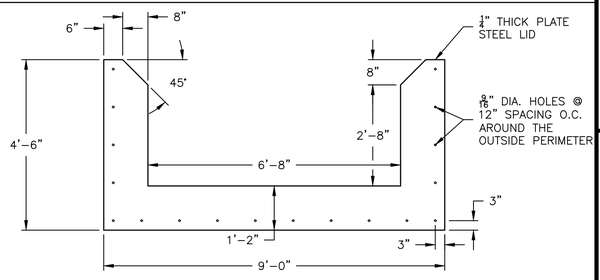


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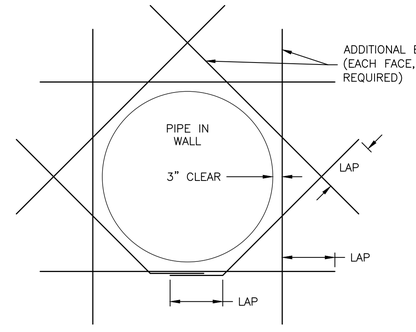


PROFILE

STEEL IMPACT PLATE DETAIL
NOT TO SCALE



STEEL LID DETAIL
NOT TO SCALE



REINFORCEMENT AROUND OPENINGS
NOT TO SCALE

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PROPOSED BRUCE DAM LOCATION

OUTLET STRUCTURE DETAILS

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

REVISIONS

Date:	07/DEC/21
Job No:	16-106
Drawn:	LD
Design:	
Checked:	
Scale:	As Noted

Sheet: **14**

OF:

Filing No. C-

Plot Date: 12/07/21 - 8:32am, Plotted by:stock, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Stock\Design\Drawing Name:Bruce Detail Sheet.dwg

APPENDIX D

SPECIFICATION TABLE OF CONTENTS

TABLE OF CONTENTS

STANDARD TECHNICAL SPECIFICATIONS

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01 14 13 CONTRACTOR' S USE OF PREMISES
01 14 50 SEO NOTIFICATION
01 29 00 MEASUREMENT AND PAYMENT
01 32 00 CONSTRUCTION SCHEDULES
01 32 10 CONSTRUCTION PROGRESS DOCUMENTATION
01 33 00 SUBMITTAL PROCEDURES
01 40 00 QUALITY REQUIREMENTS (NON-SPECIALIZED)
01 50 00 CONSTRUCTION FACILITIES AND TEMP. CONTROLS
01 71 00 SITE CONDITIONS
01 71 23 CONSTRUCTION SURVEYING
01 74 50 ENVIRONMENTAL CONTROLS
01 77 00 CONTRACT CLOSE-OUT

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03 10 00 CONCRETE FORMING
03 15 13 POLYVINYL CHLORIDE WATERSTOP
03 21 00 REINFORCING STEEL
03 30 00 CAST-IN-PLACE CONCRETE
03 39 00 CONCRETE CURING
03 63 00 EPOXY GROUTING
03 68 00 CONCRETE CRACK REPAIR

DIVISION 5 – METALS

05 10 00 MISCELLANEOUS METALS

DIVISION 31 – EARTHWORK

31 23 13 FOUNDATION PREPARATION
31 23 16 EXCAVATION
31 23 16.26 ROCK REMOVAL
31 23 19 WATER CONTROL AND DEWATERING
31 23 23 FILL AND BACKFILL
31 32 13.19 LIME SOIL STABILIZATION
31 37 00 RIPRAP AND RIPRAP BEDDING
31 43 13 PRESSURE GROUTING

DIVISION 32 – EXTERIOR IMPROVEMENTS

32 92 00 SITE RECLAMATION

DIVISION 33 – UTILITIES

33 11 00 PIPING – GENERAL

DIVISION 35 – WATERWAY AND MARINE CONSTRUCTION

35 20 16 CAST IRON SLIDE GATES

APPENDIX E

OPINION OF PROBABLE COST

Engineer's Opinion of Probable Cost

Applegate Group, Inc.
1490 W. 121st Ave., Suite 100
Denver, CO 80234
Phone: (303) 452-6611
Fax: (303) 452-2759

Bruce Canyon Reservoir
50% Design

Huerfano County, Colorado

Job No.:	18-117
By:	DAB
Date:	12/7/2021
Project:	Cucharas Collaborative Storage
Client:	Huerfano County Water Conservancy District

	DESCRIPTION	NUMBER OF UNITS	UNIT TYPE	UNIT COST	ESTIMATED COST
	CONTRACTOR COSTS				
a.	**Site Preparation**				
1	Mobilization and Demobilization	1	LS	$ 200,000	$ 200,000
2	Construction Dewatering	1	LS	$ 50,000	$ 50,000
6	Clear and Grub (Upstream and Downstream Slopes, Dam Crest, Emergency Spillway Channel)	10	AC	$ 5,000	$ 50,000
			Subtotal for Site Preparation		**$ 300,000**
b.	**Sitework, Grading and Foundation Preparation**				
1	Earthwork - Excavation for Foundation Preparation (to Bedrock Contact)	156,700	CY	$ 7	$ 1,096,900
2	Earthwork - Keyway Excavation (Bedrock)	9,400	CY	$ 20	$ 188,000
3	Earthwork - Furnish and Place Compacted Homogeneous Fill for Foundation	91,800	CY	$ 18	$ 1,652,400
4	Earthwork - Furnish and Place Processed Clay (Nondispersive) for Foundation	55,800	CY	$ 18	$ 1,004,400
5	Earthwork - Furnish and Place Compacted Homogeneous Fill for Dam Embankment	304,800	CY	$ 18	$ 5,486,400
6	Furnish and Place CDOT Class A Filter Material / Type II Bedding for Upstream Slope Protection	500	CY	$ 110	$ 55,000
7	Furnish and Place 12" D50 Riprap for Upstream Slope Protection	1,000	CY	$ 130	$ 130,000
			Subtotal for Sitework, Grading and Foundation Preparation		**$ 9,613,100**
c.	**Filter Drain System**				
1	Furnish and Place Two-Stage Filter Drain (#8 Coarse Aggregate, 8" ADS N-12 and C33 Concrete Sand)	800	LF	$ 70	$ 56,000
2	Earthwork - Furnish and Place Filter Material for Foundation, Chimney and Blanket Drain	24,500	CY	$ 120	$ 2,940,000
3	Furnish and Install PVC Cleanouts	5	EA	$ 1,100	$ 5,500
4	Furnish and Place Solid Discharge Pipe for Toe Drain	15	LF	$ 70	$ 1,050
			Subtotal for Infrastructure		**$ 3,002,550**
d.	**Emergency Spillway**				
1	Earthwork - Excavation (Cut) for Emergency Spillway	14,900	CY	$ 7	$ 104,300
2	Furnish and Place Concrete Grade Control Structures	3	EA	$ 24,000	$ 72,000
3	Furnish and Place CDOT Class A Filter Material / Type II Bedding for Emergency Spillway Channel	1,100	CY	$ 110	$ 121,000
4	Furnish and Place 12" D50 Riprap for Emergency Spillway Channel	2,100	CY	$ 130	$ 273,000
			Subtotal for Emergency Spillway Construction		**$ 570,300**
e.	**Infrastructure**				
1	Furnish and Place Reinforced Concrete for Inlet Structure	4	CY	$ 2,500	$ 10,000
2	Furnish and Install 24-in Concrete Encased Steel Pipe (1/4" Thick)	430	LF	$ 750	$ 322,500
3	Furnish and Install 12-inch Heavy Duty Slide Gate	1	LS	$ 25,000	$ 25,000
4	Furnish and Install Steel Pipe Trash Rack	1	LS	$ 5,000	$ 5,000
5	Furnish and Place Reinforced Concrete Grade Beam (4" & 2" Dia. Schedule 80 Conduits and Staff Gage)	200	LF	$ 350	$ 70,000
6	Furnish and Place Reinforced Concrete for Impact Basin	6	CY	$ 3,200	$ 19,200
7	Furnish and Install Steel Impact Plate for Low-Level Outlet (1/4" thick, galvanized steel - includes angle and assembly hardware)	1	LS	$ 3,000	$ 3,000
8	Furnish and Place CDOT Class A Filter Material / Type II Bedding for Outlet Protection	70	CY	$ 110	$ 7,700
9	Furnish and Place 12" D50 Riprap for Outlet Protection	140	CY	$ 130	$ 18,200
10	Butte Ditch Siphon (24 in PVC)	2,500	FT	$ 80	$ 200,000
11	Outlet Channel - Open Channel Unlined Ditch	1,100	FT	$ 20	$ 22,000
12	Outlet Channel - 24" RCP Piped Section	750	FT	$ 140	$ 105,000
			Subtotal for Infrastructure		**$ 680,600**
f.	**Survey**				
1	Pre-construction Survey and Staking	1	LS	$ 30,000	$ 30,000
2	As-built Survey (Includes 4 Survey Monuments)	1	LS	$ 5,000.00	$ 5,000
			Subtotal for Survey and Testing		**$ 35,000**
				Contingency (20%)	**$ 2,840,310**
				Total Estimated Project Cost	**$ 17,041,860**

APPENDIX F

CALCULATIONS

Stage-discharge curve for overflow spillway
Circular drop inlet spillway -- control at riser crest or outlet pipe (inlet or outlet control)
Bruce Canyon Dam, 11/23/2023

Note: Tinted boxes indicate user input required.

Spillway geometry

Input	Riser diameter, D_r =	1.0	ft.
	Rim length =	3.1	ft.
Input	% effective length =	100	%
Input	Weir length, L_w =	3.1	ft.
Input	Weir coeff., C_w =	3.1	
Input	% obstructed =	0	
	Riser X-area =	0.8	sq.ft.
Input	% effective area =	100	%
	Orifice area, A_o =	0.8	sq.ft.
Input	Orifice coeff., C_o =	4.8	
Input	% obstructed =	0	
	Convergence L_o =	0.5	ft.
	Convergence H =	0.2	ft.
	Convergence WL =	7347.4	ft.
	Transition H =	0.4	ft.
	Transition WL =	7347.6	ft.
Input	Riser crest elev. =	7347.2	ft.
Input	Emergency spillway elevation =	7409.0	ft.
Input	Dam crest elev. =	7414.0	ft.
Input	"H" increment =	3.0	ft.
Input	Low-level inflow =	0	cfs

Key equations

Control at riser crest

Weir flow

$Q_w = C_w\ (L_w)\ (H_r\text{^}1.5)\ (1 - \%\ obstr / 100)$

C_w = 3.1 obstr = 0 % weir eff. = 1.00

Orifice flow

$Q_o = C_o\ (A_o)\ (H_r\text{^}0.5)\ (1 - \%\ obstr / 100)$

C_o = 4.8 obstr = 0 % orfc eff. = 1.00

Weir flow convergence to seal opening

$H_r > 0.4\ L_o$, where typical $L_o = R_o = 1/2\ D_r$

Input This case: L_o / D_r = 0.5 L_o = 0.5 ft

Transition from weir flow to orifice flow at riser

$Q_w = Q_o$; $C_w\ L_w\ H_r$ (weir eff.) = $C_o\ A_o$ (orfc eff.)

$H_r = (C_o/C_w)\ (A_o/L_w)$ (orfc/weir eff.) = 0.39 * D_r

Head H_r = WL - riser crest elev.

Inflow Q_i = low-level inflow to riser (calculated separately)

Q_i = 0 cfs

$Q_r = Q_i + \min(Q_w, Q_o)$ = total inflow to riser

Spillway geometry

Outlet pipe/conduit:

Input	Pipe diameter =	2.0	ft.

Inlet

Input	Pipe invert elev. =	7346.0	ft.
	Pipe centroid elev. =	7347.0	ft.
	Pipe crown elev. =	7348.0	ft.
	Pipe X-area =	3.14	sq.ft.
Input	Orifice coeff., Cc =	4.8	

Outlet

Input	Pipe invert elev. =	7328.0	ft.
	Pipe centroid elev. =	7329.0	ft.
	Pipe crown elev. =	7330.0	ft.
Input	TW > pipe crown =	7330.0	ft.
Input	Pipe length =	490.0	ft.
Input	Pipe roughness **n** =	0.012	
	Pipe X-area =	3.14	sq.ft.

Loss coefficients

Input	Entrance Ke =	0.5
Input	Exit Ko =	1.0

Key equations

Control at outlet pipe/conduit

Inlet control, orifice approximation

$Q_c = C_c\ (A_p)\ (H_c^{0.5})$

Cc = 4.8

Comparison :

Typical value, Cc = 4.8

Culvert eqn's, Cc =

Hydraulic coefficients for deflector plate

centroid = 0.5

top pipe = 1.0

X-area = 1.0

(Note: Values of 0.5, 1.0, 1.0 are for no deflector plate at pipe inlet.)

H_c = *WL - pipe inlet centroid elev.*

Outlet control, full pipe approximation

$H_L = [K_e + K_f + K_o]\ (V^2/2g) = [\mathbf{K}]\ (Q^2 / (2g\ A^2))$

Ke = 0.5 Ko = 1.0

$K_f = [(29\ n^2\ L) / (R_h^{4/3})] = [(184\ n^2\ L) / (d_p^{4/3})]$

Kf = 5.152 **K** = 6.652

$Q^2 = [(2g / \mathbf{K})]\ A_p^2\ H_L$

$Q_p = [(2g / \mathbf{K})]^{0.5}\ A_p\ H_L^{0.5}$

Qp = 3.11 * Ap * HL^0.5

H_L = *WL - TW elev. (TW > pipe outlet crown elev.)*

Spillway discharge

$\mathbf{Q} = \min (Q_r, Q_c, Q_p)$

[HCWCD; Project file no. 18-117]

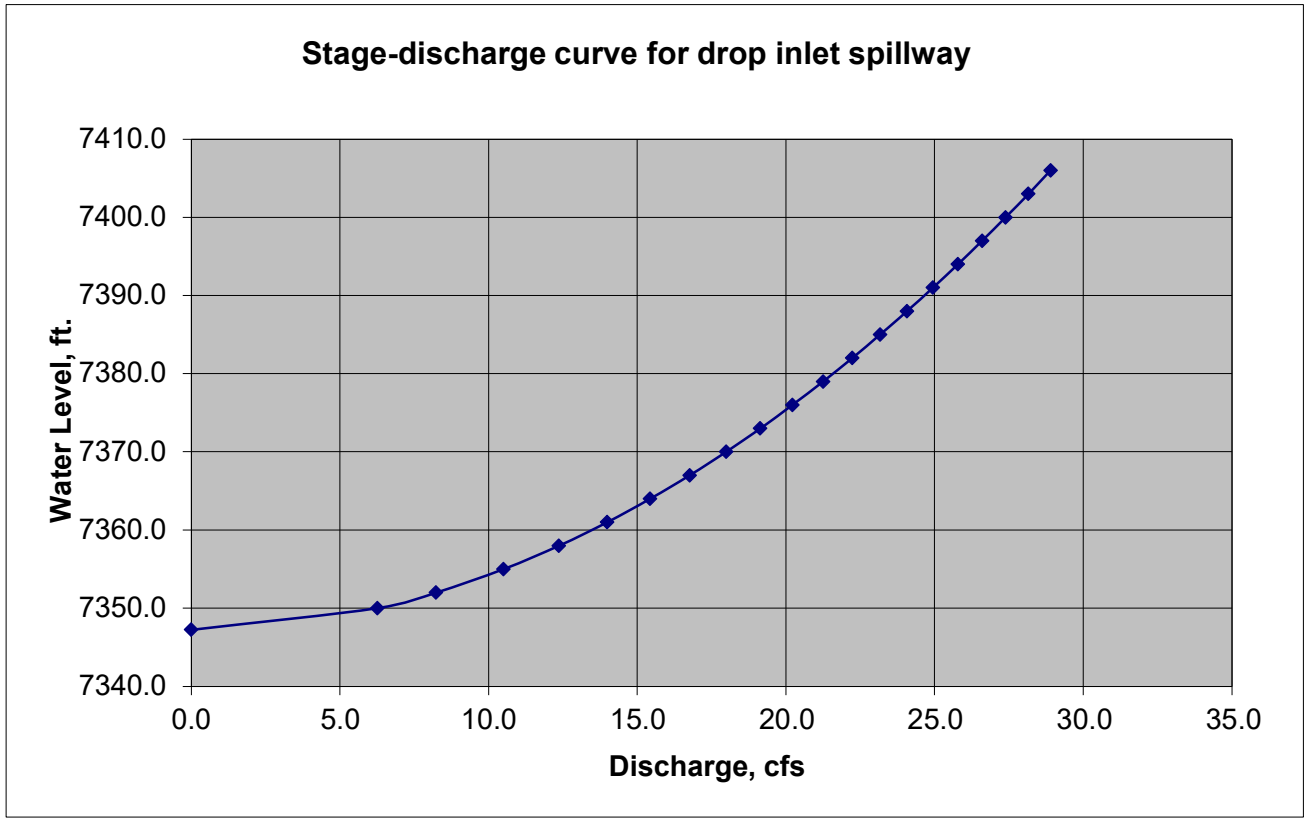
Stage-discharge curve for overflow spillway
Circular drop inlet spillway -- control at riser crest or outlet pipe (inlet or outlet control)
Bruce Canyon Dam, 11/23/2023

									Input		
Pond	Riser Crest				Outlet Pipe					Spillway	*User*
WL, ft.	head	weir	orifice	control	inlet control		outlet control		TW, ft.	**Q**, cfs	*comments*
	Hr, ft.	Qw, cfs	Qo, cfs	Qr, cfs	Hc, ft.	Qc, cfs	HL, ft.	Qp, cfs			
7347.2	0.0	0.0	0.0	0.0	0.2	7.4	17.2	40.6	7330.0	0.0	orifice flow throughout
7350.0	2.8	44.7	6.3	6.3	3.0	26.1	20.0	43.7	7330.0	6.3	
7352.0	4.8	101.1	8.2	8.2	5.0	33.7	22.0	45.8	7330.0	8.2	
7355.0	7.8	210.5	10.5	10.5	8.0	42.7	25.0	48.9	7330.0	10.5	
7358.0	10.8	343.7	12.4	12.4	11.0	50.0	28.0	51.7	7330.0	12.4	
7361.0	13.8	497.1	14.0	14.0	14.0	56.4	31.0	54.4	7330.0	14.0	
7364.0	16.8	668.2	15.4	15.4	17.0	62.2	34.0	57.0	7330.0	15.4	
7367.0	19.8	855.4	16.8	16.8	20.0	67.4	37.0	59.5	7330.0	16.8	
7370.0	22.8	1057.5	18.0	18.0	23.0	72.3	40.0	61.8	7330.0	18.0	
7373.0	25.8	1273.3	19.1	19.1	26.0	76.9	43.0	64.1	7330.0	19.1	
7376.0	28.8	1502.1	20.2	20.2	29.0	81.2	46.0	66.3	7330.0	20.2	
7379.0	31.8	1743.1	21.2	21.2	32.0	85.3	49.0	68.4	7330.0	21.2	
7382.0	34.8	1995.9	22.2	22.2	35.0	89.2	52.0	70.5	7330.0	22.2	
7385.0	37.8	2259.8	23.2	23.2	38.0	93.0	55.0	72.5	7330.0	23.2	
7388.0	40.8	2534.3	24.1	24.1	41.0	96.6	58.0	74.4	7330.0	24.1	
7391.0	43.8	2819.2	24.9	24.9	44.0	100.0	61.0	76.3	7330.0	24.9	
7394.0	46.8	3114.0	25.8	25.8	47.0	103.4	64.0	78.2	7330.0	25.8	
7397.0	49.8	3418.5	26.6	26.6	50.0	106.6	67.0	80.0	7330.0	26.6	
7400.0	52.8	3732.2	27.4	27.4	53.0	109.8	70.0	81.8	7330.0	27.4	
7403.0	55.8	4055.1	28.2	28.2	56.0	112.8	73.0	83.5	7330.0	28.2	
7406.0	58.8	4386.7	28.9	28.9	59.0	115.8	76.0	85.2	7330.0	28.9	
7409.0	61.8	4726.9	29.6	29.6	62.0	118.7	79.0	86.9	7330.0	29.6	
7412.0	64.8	5075.4	30.3	30.3	65.0	121.6	82.0	88.5	7330.0	30.3	
7414.0	66.8	5312.4	30.8	30.8	67.0	123.4	84.0	89.6	7330.0	30.8	dam crest
7415.0	67.8	5432.2	31.0	31.0	68.0	124.4	85.0	90.1	7330.0	31.0	Note: normal depth ca

[HCWCD; Project file no. 18-117]

Stage-discharge curve for overflow spillway
Circular drop inlet spillway -- control at riser crest or outlet pipe (inlet or outlet control)
Bruce Canyon Dam, 11/23/2023

Spillway **Q**, cfs	Pond WL, ft.
0.0	7347.2
6.3	7350.0
8.2	7352.0
10.5	7355.0
12.4	7358.0
14.0	7361.0
15.4	7364.0
16.8	7367.0
18.0	7370.0
19.1	7373.0
20.2	7376.0
21.2	7379.0
22.2	7382.0
23.2	7385.0
24.1	7388.0
24.9	7391.0
25.8	7394.0
26.6	7397.0
27.4	7400.0
28.2	7403.0
28.9	7406.0



Pressure sag at inlet to outlet pipe/conduit, venturi approximation :

Key equations :

HGL = HW - $K_e V_p^2/2g$ - $V_c^2/2g$

use entrance loss coefficient K_e = 0.5

HW depth = HW elev. - pipe invert elev.

Air pressure at outlet pipe crown :

AGL = HGL - pipe diameter ; units = feet of water equiv.

Valid for HW depth > pipe diameter

Inlet control, orifice approximation :

$Q = C_c (A_p) (H_c^{0.5})$ => $H_c^{0.5} = Q / (C_c A_p)$ => $H_c = [Q / (C_c A_p)]^2$

HW elev. = H_c + pipe centroid elev. use: C_c = 4.8

Comparison :

Typical value, C_c = 4.8

Culvert eqn's, C_c =

Outlet control, full pipe approximation:

$H_L = [K_e + K_f + K_o] (V^2/2g) = [\mathbf{K}] (Q^2 / (2g A_p^2))$

K_e = 0.5 K_o = 1.0

$K_f = [(29 n^2 L) / (R_h^{4/3})] = [(184 n^2 L) / (d_p^{4/3})]$

K_f = 5.152 **K** = 6.652

HW elev. = H_L + TW elev. (TW > pipe outlet crown elev.)

Inlet vs. Outlet control :

Max HW governs water level in riser

This project :

				Pipe inlet			***Pipe outlet***	
	Pipe diameter	=	2.0 ft.	Pipe invert elev.	=	7346.0 ft.	Pipe invert elev.	= 7328.0 ft.
	Pipe X-area A_p	=	3.14 sq.ft.	Pipe centroid elev	=	7347.0 ft.	Pipe crown elev.	= 7330.0 ft.
Input	Contraction coeff.	=	0.611	Pipe crown elev.	=	7348.0 ft.	TW > pipe crown	= 7330.0 ft.
	Vena contracta A_c	=	1.92 sq.ft.	Riser crest elev.	=	7347.2 ft.	Pipe length	= 490.0 ft.
				Dam crest elev.	=	7414.0 ft.	Pipe roughness **n**	= 0.012
				Pipe X-area A_p	=	3.14 sq.ft.	Pipe X-area A_p	= 3.14 sq.ft.

[HCWCD; Project file no. 18-117]

Stage-discharge curve for overflow spillway
Circular drop inlet spillway -- control at riser crest or outlet pipe (inlet or outlet control)
Bruce Canyon Dam, 11/23/2023

Pipe crown elev. = 7348.0 Pipe dia = 2.0 ft.

Spillway **Q**, cfs	Inlet Hc, ft.	Outlet HL, ft.	HW elev.	HW depth	Vp, fps	Vc, fps	KeVp^2/2g	Vc^2/2g	HGL, ft.	AGL, ft.	*User comments*
0.0	0.0	0.0	7347.0	1.0	0.0	0.0	0.00	0.00	1.00	-1.00	
6.3	0.2	0.4	7347.2	1.2	2.0	3.3	0.03	0.17	0.98	-1.02	
8.2	0.3	0.7	7347.3	1.3	2.6	4.3	0.05	0.29	0.96	-1.04	HW < pipe dia.
10.5	0.5	1.2	7347.5	1.5	3.3	5.5	0.09	0.46	0.93	-1.07	HW > pipe dia.
12.4	0.7	1.6	7347.7	1.7	3.9	6.4	0.12	0.64	0.91	-1.09	
14.0	0.9	2.0	7347.9	1.9	4.5	7.3	0.15	0.82	0.88	-1.12	
15.4	1.0	2.5	7348.0	2.0	4.9	8.0	0.19	1.00	0.86	-1.14	
16.8	1.2	2.9	7348.2	2.2	5.3	8.7	0.22	1.18	0.83	-1.17	
18.0	1.4	3.4	7348.4	2.4	5.7	9.4	0.25	1.36	0.80	-1.20	HW > riser crest
19.1	1.6	3.8	7348.6	2.6	6.1	10.0	0.29	1.54	0.78	-1.22	
20.2	1.8	4.3	7348.8	2.8	6.4	10.5	0.32	1.72	0.75	-1.25	
21.2	2.0	4.7	7349.0	3.0	6.8	11.1	0.36	1.90	0.73	-1.27	
22.2	2.2	5.2	7349.2	3.2	7.1	11.6	0.39	2.08	0.70	-1.30	
23.2	2.4	5.6	7349.4	3.4	7.4	12.1	0.42	2.26	0.68	-1.32	
24.1	2.5	6.1	7349.5	3.5	7.7	12.5	0.46	2.44	0.65	-1.35	
24.9	2.7	6.5	7349.7	3.7	7.9	13.0	0.49	2.62	0.62	-1.38	
25.8	2.9	7.0	7349.9	3.9	8.2	13.4	0.52	2.80	0.60	-1.40	
26.6	3.1	7.4	7350.1	4.1	8.5	13.9	0.56	2.98	0.57	-1.43	
27.4	3.3	7.8	7350.3	4.3	8.7	14.3	0.59	3.16	0.55	-1.45	
28.2	3.5	8.3	7350.5	4.5	9.0	14.7	0.62	3.34	0.52	-1.48	
28.9	3.7	8.7	7350.7	4.7	9.2	15.1	0.66	3.52	0.50	-1.50	HW = dam crest

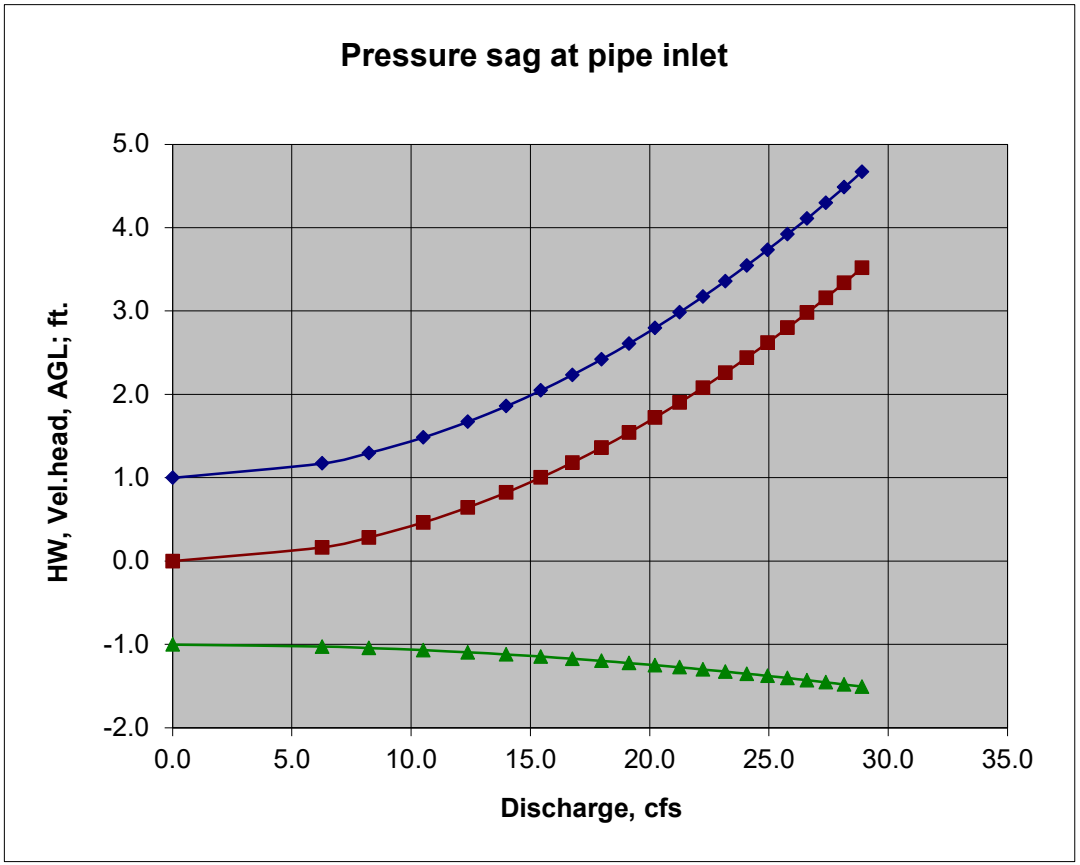
Note : **AGL < 0 confirms need for air vent to relieve negative pressures within outlet pipe.**

[HCWCD; Project file no. 18-117]

Stage-discharge curve for overflow spillway
Circular drop inlet spillway -- control at riser crest or outlet pipe (inlet or outlet control)
Bruce Canyon Dam, 11/23/2023

Pressure sag at pipe inlet

Q, cfs	HW depth	Vc^2/2g	AGL, ft.
0.0	1.0	0.0	-1.0
6.3	1.2	0.2	-1.0
8.2	1.3	0.3	-1.0
10.5	1.5	0.5	-1.1
12.4	1.7	0.6	-1.1
14.0	1.9	0.8	-1.1
15.4	2.0	1.0	-1.1
16.8	2.2	1.2	-1.2
18.0	2.4	1.4	-1.2
19.1	2.6	1.5	-1.2
20.2	2.8	1.7	-1.2
21.2	3.0	1.9	-1.3
22.2	3.2	2.1	-1.3
23.2	3.4	2.3	-1.3
24.1	3.5	2.4	-1.3
24.9	3.7	2.6	-1.4
25.8	3.9	2.8	-1.4
26.6	4.1	3.0	-1.4
27.4	4.3	3.2	-1.5
28.2	4.5	3.3	-1.5
28.9	4.7	3.5	-1.5



Baffled Outlet Impact Basin Sizing Sheet

Applegate Group, Inc.
Water Resource Advisors for the West

Bruce Canyon Dam
Outlet Structure Design Sheet

Job No. :	18-117
By:	TJD
Date:	11/23/2021
Client:	Huerfano County Water Conservancy District

Input

Input Parameters		
Select Sizing Criteria:	Froude #	
Design Froude #:	2.9	unitless
Flow Area:	1.9	sq-ft

Calculated Parameters		
V:	n/a	ft/s
D:	1.38	ft
Froude #:	2.90	
W/D:	5.29	

Design Check/Notes:

•Verify design velocity does not exceed recommended velocity limit of 50 ft/s

•Verify approach velocity does not exceed 12 ft/s

•Approach pipe should be horizontal for a length of at least 3 pipe diameters upstream of the impact basin

•The calculated W/D ratio is within the recommended range of 3 to 10

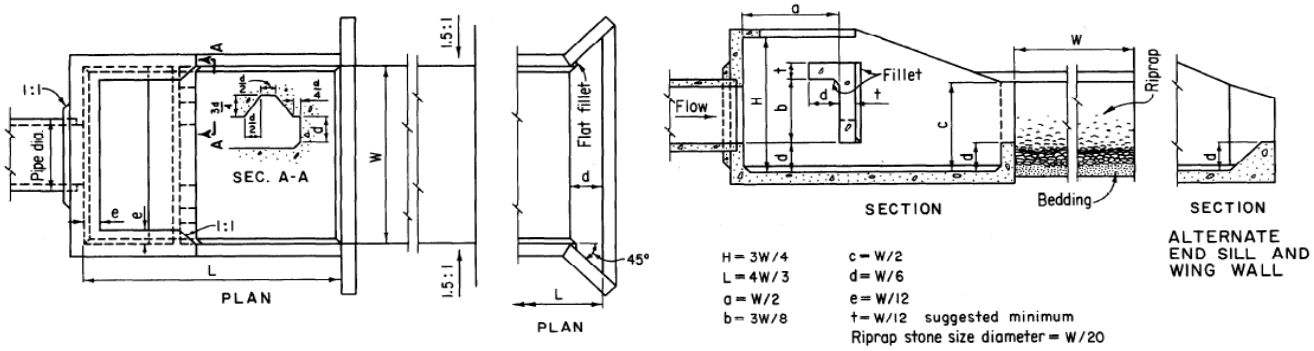
Output

Impact Basin Dimensions		
W:	7.30	ft
H:	5.47	ft
L:	9.73	ft
a:	3.65	ft
b:	2.74	ft
c:	3.65	ft
d:	1.22	ft
e:	0.61	ft
t:	0.61	ft
Riprap Diameter:	4.38	in
Recommended Tailwater Depth:	2.58	ft

Recommended Standard Baffled Outlet

USBR Type 5 Baffled Outlet meets the design Criteria

Concrete:	7.7	CY
Reinforcement Steel:	600	lbs



General Notes: This spreadsheet adheres to guidance recommended by the USBR for design of Baffled Outlets. The 'Design Flow' sizing criteria method generally follows the procedure set forth in *Monograph 24* while the 'Theoritecal Velocity' methods follows guidance in *Design of Small Canal Structures* .

References:

Beichley, G. L. USBR. (1978). *Hydraulic Design of Stilling Basin for Pipe or Channel Outlets (Report No.24)* . Denver: US Gov. Printing Office

Aisenbrey, A. J., Hayes, R. B., Warren, H. J., Winsett, D. L., Young, R. B. USBR. (1978). *Design of Small Canal Structures* . Denver: US Gov. Printing Office

Bruce Canyon Dam

Long Term Evaluation of Main Conduit with Reservoir at Dam Crest

Pipe Type: 24" Dia. 1/4" Wall Thickness Steel Pipe Encased in Reinforced Concrete

General Information: This spreadsheet calculates flexible pipe resistance to wall buckling due to hydrostatic pressure and wall crushing due to hydrostatic pressure and soil loading. It also calculate concrete encasement resistance to wall crushing due to hydrostatic pressure and soil loading. This Spreadsheet is based on encased plastic pipe design guidance found in FEMA's *Technical Manual: Plastic Pipe Used in Embankment Dams* . AWWA M11 was used for steel pipe calculations which are very similar to the previous stated reference.

Key Assumptions:

*Calcuations assume that pipe has a SOLID WALL

*long term loading condition is assumed, this effects the design modulus of elasticity and poisson's ratio of pipe

*concrete encasement assumed to have square cross section that fully encases pipe with a width equal to the trench width

*Soil loading calculations assume a postive projecting conduit in the projection condition, please verify that the conduit installation meets this criteria

*value of ku is assumed to be 0.19

*value of DF is assumed to be 0.5 which effects the HDB of plastic pipe

Input

Pipe/Installation Data Data

Pipe Material	Steel
Outside Diameter (ft)	2
Pressure Rating (psi)	n/a
wall thickness (in)	0.25
Compressive Strength of Concrete (psi)	4000
Trench width/Encasement Width for pipe installation (ft)	3.33

Soil/Hydraluic Loading Data

Design Hydraulic Head (ft)	86
H, Design Soil Height (above pipe) (ft)	72
Soil Unit Weight (pcf)	120

outlet invert at DS end of conduit used to develop these values

Condition of fill material adjacent to pipe and encasement	Dense/well compacted soil
Positive Projection Condition	Incomplete Projection Condition

Pipe Wall Buckling (unconstrained)

Hydrostatic Loading Pressure (psf)	5366.40
P_{CR}, Unconstrained Collapse Pressure of Pipe (psf)	10731.46
FOS[1] ✓	**2.00**

Pipe Wall Crushing

A_{pw}, Required wall cross-sectional area (in^2)	0.144
Actual wall cross section area (in^2)	0.250
FOS[2] ✓	**1.73**

Encasement Crushing

Design Load Pressure (psf)[3]	70521.4
Encasement Compressive Strength (psf)[3]	576000
FOS[1] ✓	**8.17**

[1] Calculated on pressure basis [2] Calculated on area basis [3] Caluclated at weakest point of concrete encasement which was assumed to be at springline of encased pipe

Inverted Siphon Spreadsheet - Butte Ditch Siphon Bypass

Inputs		
Discharge	13	(cfs)
Inside Pipe Diameter	24	(in)
Hazen Williams Coefficient	150	**<--- PVC Pipe**
Siphon Length	2540	(ft)
Entrance Loss Coeff	0.5	*Small Canal Structures*
Exit Loss Coeff	1.0	*Small Canal Structures*
Total Bend Loss Coeff	0.25	*AWWA M 11*
Misc. Fitting Loss Coeff	0.15	*AWWA M 11*
Upstream Channel Velocity	0.0	(ft/s)
Dowstream Channel Velocity	0.0	(ft/s)
Dowstream Channel WSE	7406.00	(ft)
Calculated Values		
Flow Area	3.14	(ft^2)
Pipe Velocity	4.14	(ft/s)
Friction Loss	4.42	(ft)
Entrance Loss	0.13	(ft)
Exit Loss	0.27	(ft)
Fitting Loss	0.11	(ft)
Total Loss X 1.1 FOS	5.42	(ft)
Results		
Upstream WSE	**7411.42**	(ft)**<- can't exceed 7412**
Required Hydraulic Seal	**0.40**	(ft)
Siphon Pipe Invert Elev.	**7409.02**	(ft)

Inputs		
Discharge	13	(cfs)
Inside Pipe Diameter	24	(in)
Hazen Williams Coefficient	140	**<--- HDPE Pipe**
Siphon Length	2540	(ft)
Entrance Loss Coeff	0.5	*Small Canal Structures*
Exit Loss Coeff	1	*Small Canal Structures*
Total Bend Loss Coeff	0.25	*AWWA M 11*
Misc. Fitting Loss Coeff	0.15	*AWWA M 11*
Upstream Channel Velocity	0	(ft/s)
Dowstream Channel Velocity	0.0	(ft/s)
Dowstream Channel WSE	7406.00	(ft)
Calculated Values		
Flow Area	3.14	(ft^2)
Pipe Velocity	4.14	(ft/s)
Friction Loss	5.03	(ft)
Entrance Loss	0.13	(ft)
Exit Loss	0.27	(ft)
Fitting Loss	0.11	(ft)
Total Loss X 1.1 FOS	6.08	(ft)
Results		
Upstream WSE	**7412.08**	(ft)**<- can't exceed 7412**
Required Hydraulic Seal	**0.40**	(ft)
Siphon Pipe Invert Elev.	**7409.68**	(ft)

Checking Inlet Conditions - Froude Number and Normal Depth calculated using Hydraulic Toolbox

Slope at Hydraulic Jump	0.09	ft/ft
Assumed Pipe Diameter, D	24	inches
Froude Number, F_1	6.427	
Normal Depth, y_1	0.431	ft
y_1/D	0.22	

Slope at Hydraulic Jump	0.05	ft/ft
Assumed Pipe Diameter	24	inches
Froude Number, F_1	4.837	
Normal Depth, y_1	0.615	ft
y_1/D	0.31	

Embankment Soil to Filter Sand - Compatibility Calcs

Calculated using "Filters for Embankment Dams, Best Practices for Design and Construction", FEMA, October 2011

		Grain Size	
Point	ID	(mm)	
A	$D15_{Fmax}$	0.49	15.0%
B	$D15_{Fmin}$	0.10	15.0%
C	$D10_{Fmax}$	0.34	10.0%
D	$D10_{Fmin}$	0.075	10.0%
E	$D60_{Fmax}$	2.06	60.0%
F	$D60_{Fmin}$	0.15	60.0%
G	G	0.41	60.0%
H	H	2.06	60.0%
I	$D5_{Fmin}$	0.075	5.0%
J	$D100_{Fmax}$	50.80	100.0%
K	$D90_{Fmax}$	20.00	90.0%

Base Material	
Gradation	Particle Size
$D_{85}B$	0.3
$D_{15}B$*	0.001

Filter Material Calculations:

Step 1: Use "Base Gradation" developed from average values viable dam embankment materials encountered in borrow area. Laboratory testings results from samples labeled "Gradation 202770", "Hydrometer 202768", and "Hydrometer 202767" were

Step 2/ Step 3: Regrade so that base soil does not include gravel sized particles (>#4 sieve) if applicable ***REGRADE NOT REQUIRED***

Step 4: Regraded sample has 48.8% finer than #200 sieve, therefore **Base Soil Category 2: Sandy, silts, clays, and silty and sands.** Most samples used to develop base gradation would also fall into this category except for one which falls in between Base Soil Category 2 and 3.

Step 5: Table 5-2. Filtering Criteria:
For Base Soil Category 2, Max $D_{15}F$ ≤ 0.7mm unless soil is dispersive, in which case $D_{15}F$ < 0.5mm.
Pinhole Dispersion Testing completed by Cesare indicated base gradation material may be dispersive.
Max $D_{15}F$ of 0.49mm furthered to achieve main goal of particle retention while satifsying requirements of Step 7.
Max $D_{15}F$= 0.49 mm *(Point A)*

Step 6: Satisfy permeability requirements
Min $D_{15}F$ ≥ 3 to 5 times Max $D_{15}B$ but not < 0.1 mm before regrade. $D_{15}B$=0.001
$(D_{15}B)$*5 = 0.005mm which is <0.1mm, therefore 0.1mm is furthered
Min $D_{15}F$= 0.10 mm *(Point B)*

Step 7: Limit width of filter band and prevent gap-graded filter design.
Max D_{15F} ÷ Min D_{15F} = 4.90 < 5, therefore **OK**
Check D10 and D60 size limits to ensure 2 ≤ Cu ≤ 6
a. $D_{10max} = D_{15max} * 0.7$ = 0.343 mm *(Point C)*
b. $D_{10min} = D_{15min} * 0.7$ = 0.070 mm
Per Table 5-3, D_5F ≥ 0.075 mm, therefore, D_{10}min = 0.075 mm *(Point D)*
c. $D_{60max} = D_{10max} * 6$ = 2.058 mm *(Point E)*
d. $D_{60min} = D_{10min} * 2$ = 0.150 mm *(Point F)*
e. GH bar:
at $D_{60}F$ limits, GH bar can slide back and forth between pts E and F.
0.15 < G < 2.06
H = G * 5

Step 8: Limit fines and oversized material
Table 5-3. Max and Min Particle Size Criteria:
Max $D_{100}F$ ≤ 2 in *(Point J)*
Min D_5F = 0.075 mm *(Point I)*

Step 9: Limit segregation potential
Table 5-4. Segregation Criteria:
D_{10min} = 0.075 mm < 0.5 mm, therefore D_{90max} = 20 mm *(Point K)*

Step 10: Determine the filter gradation band wihtin the control points
C-33 Concrete Sand meets embankment filter compatibility criteria …. Whoa shocker -__-

Step 5.2.1: Drainpipe Perforation Sizing (FEMA, 2011)
Max pipe perforation dimension must be ≤ finer side of $D_{50}F$
$D_{50}F$ = 0.375 mm = minimum slot width/perforation diameter
Gravel envelope necessary as 0.375 mm slot width/ perforation diameter is not feasible.

Filter Sand to Filter Gravel and Slotted Pipe - Compatibility Calcs

Calculated using "Filters for Embankment Dams, Best Practices for Design and Construction", FEMA, October 2011

		Grain Size	
Point	ID	(mm)	
A	$D15_{Emax}$	7.60	15.0%
B	$D15_{Emin}$	1.80	15.0%
C	$D10_{Emax}$	5.32	10.0%
D	$D10_{Emin}$	1.260	10.0%
E	$D60_{Emax}$	26.60	60.0%
F	$D60_{Emin}$	2.52	60.0%
G	G	3.50	60.0%
H	H	17.50	60.0%
I	$D5_{Emin}$	0.075	5.0%
J	$D100_{Emax}$	50.80	100.0%
K	$D90_{Emax}$	30.00	90.0%

Base Soil (C-33 Sand)	
Gradation	Particle Size
$D_{85avg}F$	1.9
$D_{15max}F$	0.45

Drain Envelope Calculations:

Step 1: Use gradation plot for finer gradation limit of C-33 sand to maximize particle retention

Step 2/ Step 3: Regrade so that filter material does not include gravel sized particles (>#4 sieve)

Step 4: Sample has 2% finer than #200 sieve, therefore **Base Soil Category 4: Sands and Gravels**

Step 5: Table 5-2. Filtering Criteria:
For Base Soil Category 4, Max $D_{15}E \leq 4 \times D_{85}F$
Max $D_{15}E$= 7.6 mm *(Point A)*

Step 6: Satisfy permeability requirements
(Min $D_{15}E$) ≥ 3 to 5 * (Max $D_{15}F$) but not less than 0.1mm before regrade; (Max $D_{15}F$) * 4 = 1.8mm
Min $D_{15}E$= 1.80 mm *(Point B)*

Step 7: Limit width of filter band and prevent gap-graded filter design.
Max $D_{15}E \div$ Min $D_{15}E$ = 4.22 < 5, therefore **OK**
Check D10 and D60 size limits to ensure 2 ≤ Cu ≤ 6

a. $D_{10max} = D_{15max} * 0.7$ = 5.320 mm *(Point C)*
b. $D_{10min} = D_{15min} * 0.7$ = 1.260 mm *(Point D)*
c. $D_{60max} = D_{10max} * 5$ = 26.600 mm *(Point E)*
d. $D_{60min} = D_{10min} * 2$ = 2.520 mm (Point F)

Note: Upper limit of Cu criteria reduced to 5 so Point E is less than Point K

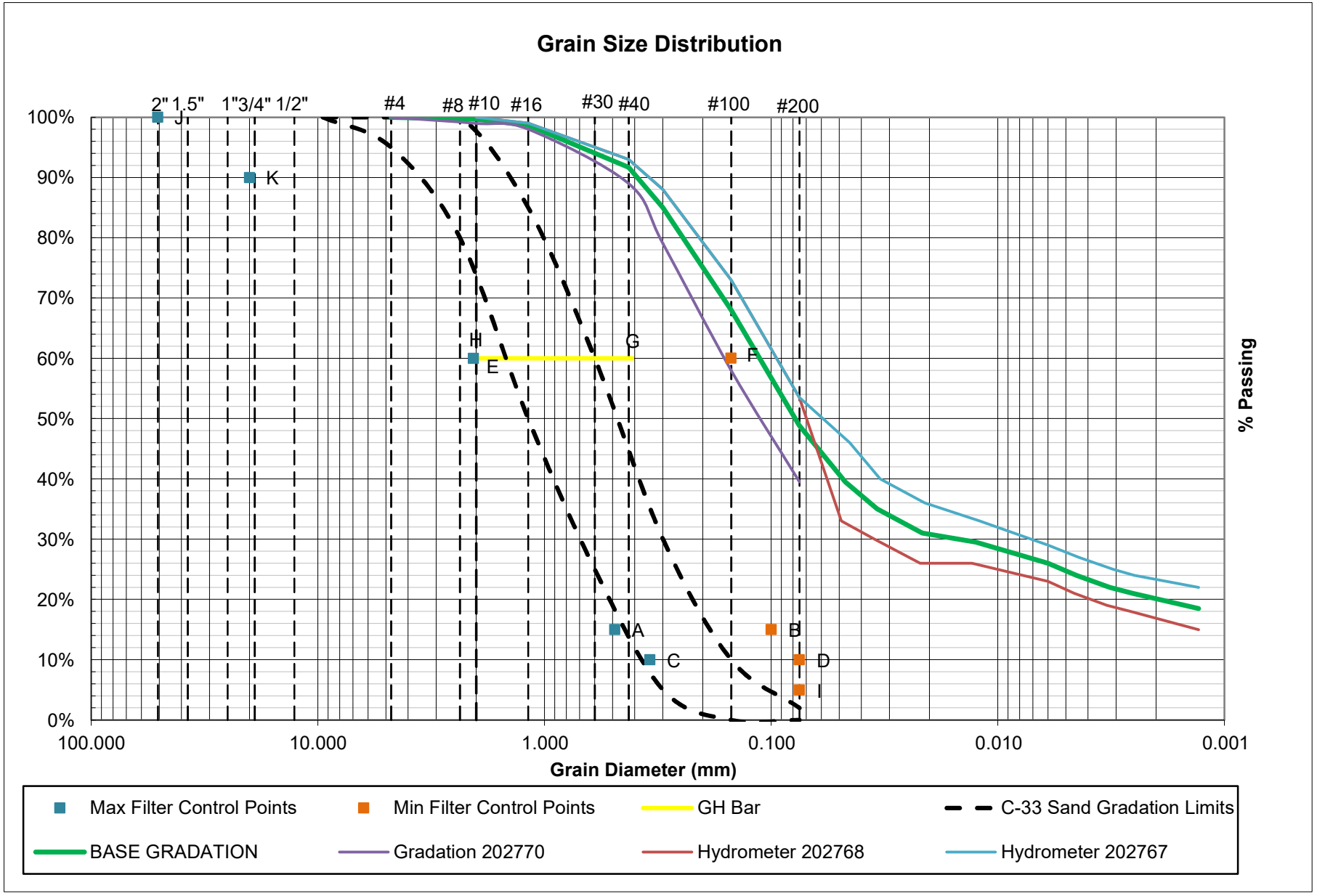
e. GH bar:
at D_{60} limits, GH bar can slide back and forth between pts E and F.
2.52 < G < 26.60
H = G * 5

Step 8: Limit fines and oversized material
Table 5-3. Max and Min Particle Size Criteria:
Max $D_{100}E \leq$ 2 in *(Point J)*
Min D_5E = 0.075 mm *(Point I)*

Step 9: Limit segregation potential
Table 5-4. Segregation Criteria:
0.5mm < (D_{10min} = 1.26 mm) < 1mm, therefore D_{90max} = 30 mm *(Point K)*

Step 10: Determine the filter gradation band wihtin the control points
*see plot for acceptable envelope materials

Step 5.2.1: Drainpipe Perforations (FEMA, 2011)
Max pipe perforation dimension must be ≤ finer side of $D_{50}F$
$D_{50}F$ = 6.000 mm = minimum slot width/perforation diameter


Grain Size Distribution
2" 1.5" 1"3/4" 1/2" #4 #8 #10 #16 #30 #40 #100 #200
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
J
K
H
E
G
F
A
C
B
D
I
100.000
10.000
1.000
0.100
0.010
0.001
Grain Diameter (mm)
% Passing
Max Filter Control Points
Min Filter Control Points
GH Bar
C-33 Sand Gradation Limits
BASE GRADATION
Gradation 202770
Hydrometer 202768
Hydrometer 202767

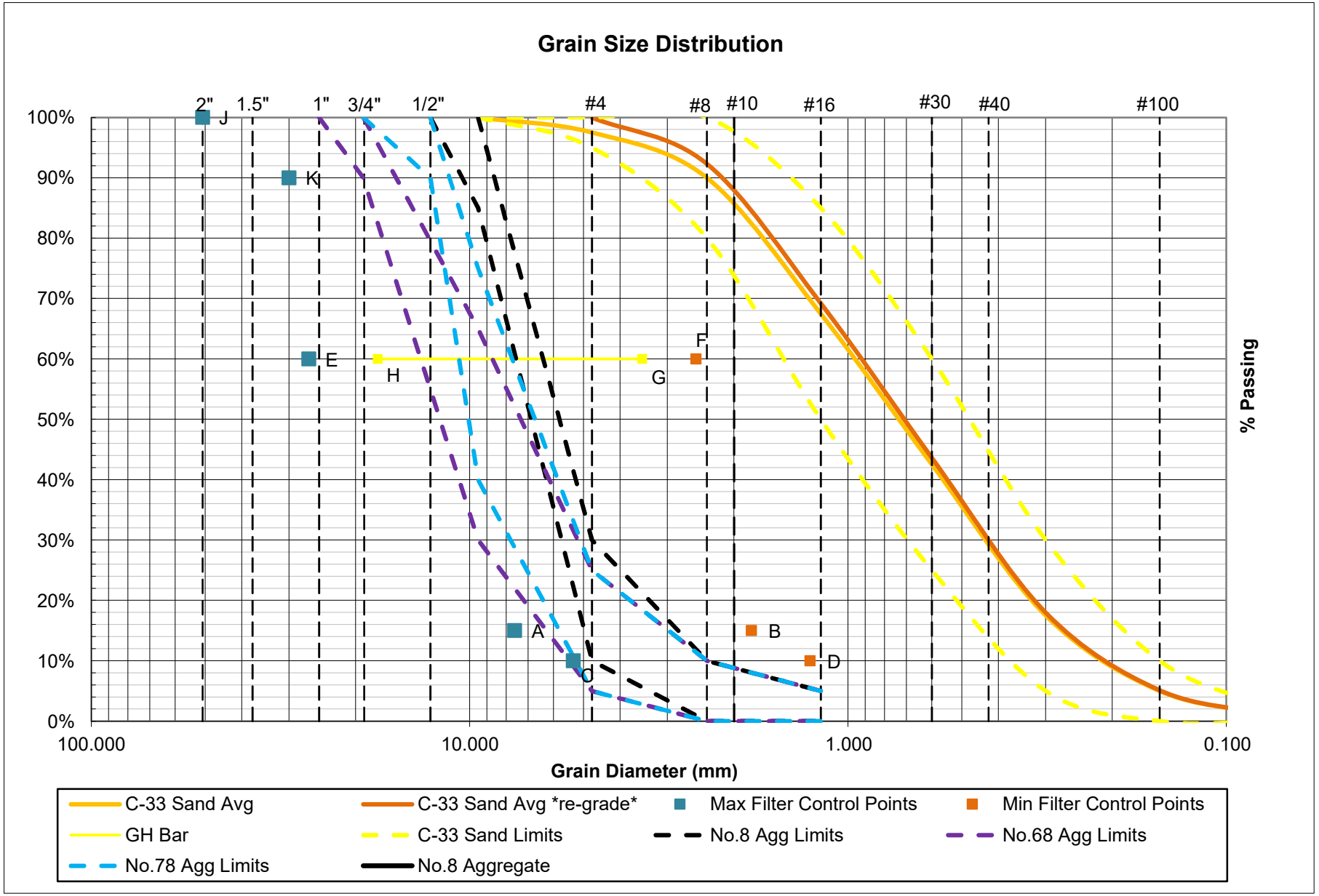

Grain Size Distribution
2"
1.5"
1"
3/4"
1/2"
#4
#8
#10
#16
#30
#40
#100
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
J
K
E
H
G
F
A
B
D
C
100.000
10.000
1.000
0.100
Grain Diameter (mm)
% Passing
C-33 Sand Avg
C-33 Sand Avg *re-grade*
Max Filter Control Points
Min Filter Control Points
GH Bar
C-33 Sand Limits
No.8 Agg Limits
No.68 Agg Limits
No.78 Agg Limits
No.8 Aggregate

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31 23 23 FILL AND BACKFILL
31 32 13.19 LIME SOIL STABILIZATION
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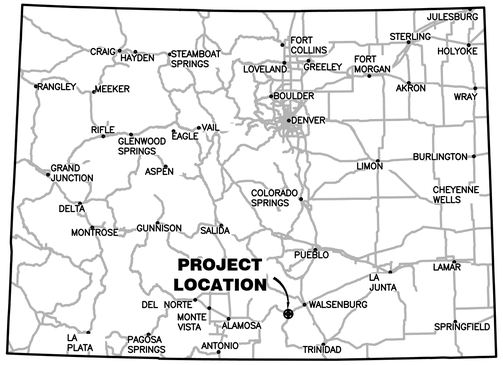
CUCHARAS COLLABORATIVE
BRUCE CANYON DAM
CONSTRUCTION PLANS
HUERFANO COUNTY, COLORADO

DECEMBER, 2021

OWNER: HUERFANO COUNTY WATER CONSERVANCY DISTRICT
P.O. BOX 442
LA VETA, CO 80155
(719) 989-7259

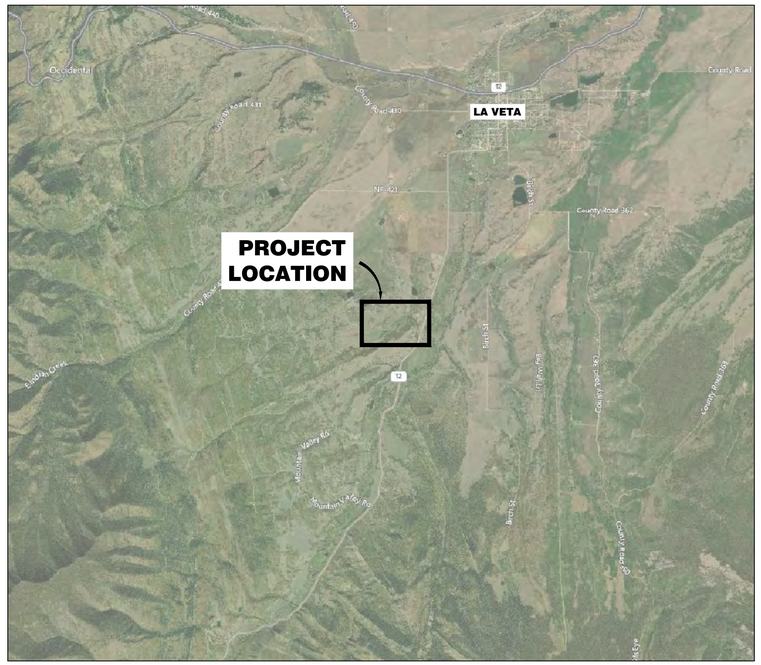
ENGINEER: APPLEGATE GROUP, INC.
1490 W. 121st AVENUE
SUITE 100
DENVER, CO 80234
(303) 452-6611

GEOTECH: CEASARE, INC.
108 SOUTH ALEON
BUILDING B
CENTENNIAL C 80112
(303) 220-0300



LOCATION MAP
NOT TO SCALE

VICINITY MAP
SCALE 1" = 5000'



5000 2500 0 5000
SCALE IN FEET

These plans have been prepared by me or under my direct supervision.

Craig Ullmann
Colorado P.E. No. 38551

Approved on the ____ day of _____, 20__

State Engineer

By:_____
Bill McCormick, Chief, Colorado Dam Safety
Colorado P.E. 29127

These plans represent the AS-CONSTRUCTED conditions of _____ Dam to the best of my knowledge and judgment, based in part on information furnished by others, as of the _____ day of _____, 20__.

Craig Ullmann

Colorado P.E. No. 38551

COLORADO 811
KNOW WHAT'S BELOW. CALL BEFORE YOU DIG.

50% DESIGN NOT FOR CONSTRUCTION

Applegate Group, Inc.
Water Resource Advisors for the West
1490 West 121st Ave., Suite 100
Denver, CO 80234
(303) 452-6611
Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

PROPOSED BRUCE DAM LOCATION

COVER SHEET

CUCHARAS COLLABORATIVE

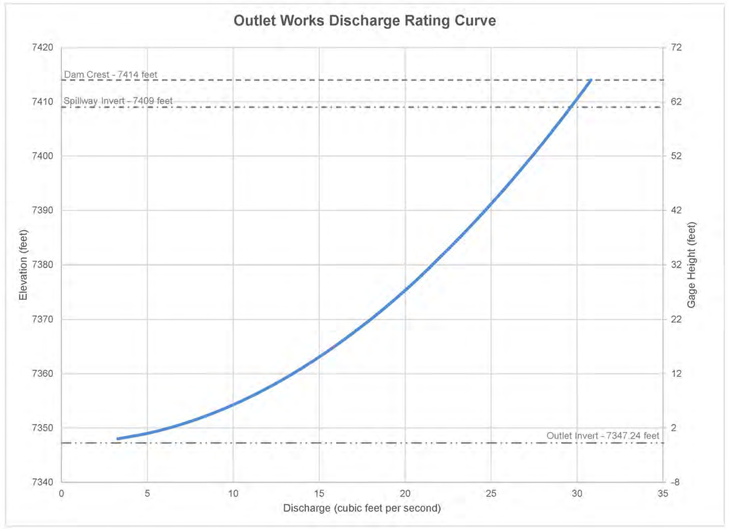
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				REVISIONS

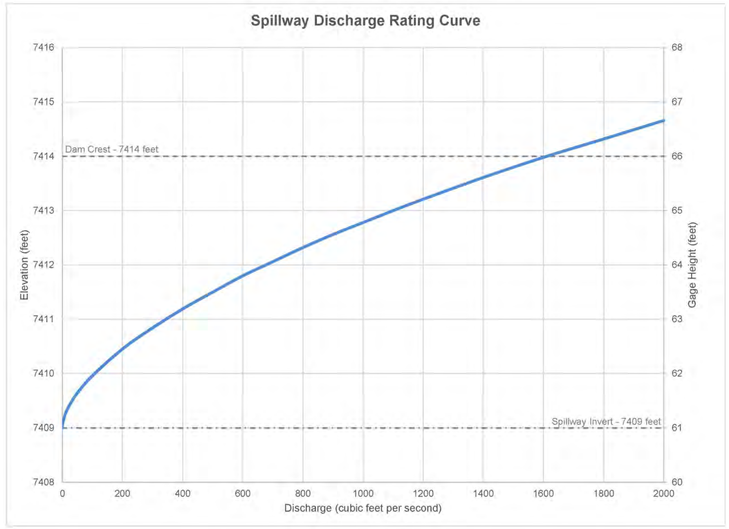
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Checked:	
Scale:	As Noted

Sheet: 1
Of:

Filing No. C-

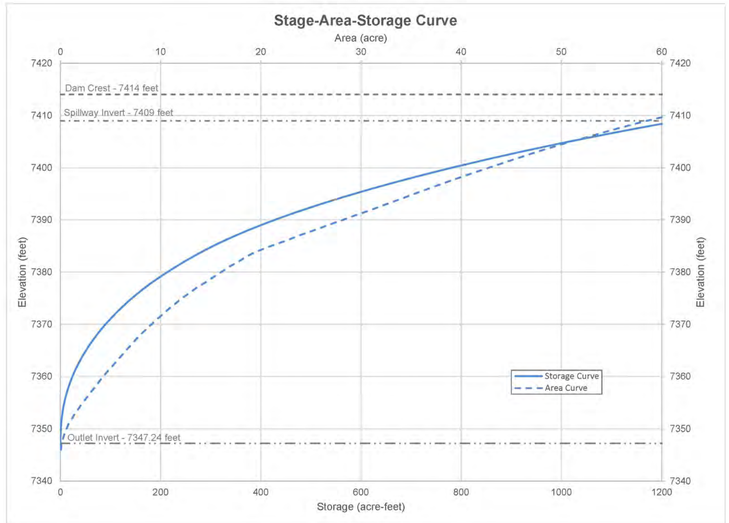
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Hydraulics Table

Gage Height (ft)	Stage (ft)	Surface Area (ac)	Storage (ac-ft)	Outlet Works Discharge (cfs)	Spillway Discharge (cfs)
-0.24	7347	0.13	0.09	0.0	-
0.76	7348	0.25	0.28	3.3	-
1.76	7349	0.41	0.61	5.0	-
2.76	7350	0.61	1.1	6.3	-
3.76	7351	0.85	1.8	7.3	-
4.76	7352	1.2	2.9	8.2	-
5.76	7353	1.5	4.2	9.0	-
6.76	7354	1.9	5.9	9.8	-
7.76	7355	2.2	7.9	10.5	-
8.76	7356	2.7	10.4	11.2	-
9.76	7357	3.0	13.2	11.8	-
10.76	7358	3.5	16.5	12.4	-
11.76	7359	3.9	20.1	12.9	-
12.76	7360	4.3	24.2	13.5	-
13.76	7361	4.7	28.7	14.0	-
14.76	7362	5.2	33.7	14.5	-
15.76	7363	5.6	39.1	15.0	-
16.76	7364	6.1	45.0	15.4	-
17.76	7365	6.6	51.3	15.9	-
18.76	7366	7.0	58.1	16.3	-
19.76	7367	7.5	65.4	16.8	-
20.76	7368	8.0	73.1	17.2	-
21.76	7369	8.5	81.4	17.6	-
22.76	7370	9.1	90.2	18.0	-
23.76	7371	9.7	99.6	18.4	-
24.76	7372	10.2	109.5	18.8	-
25.76	7373	10.8	120.1	19.1	-
26.76	7374	11.5	131.2	19.5	-
27.76	7375	12.1	143.0	19.9	-
28.76	7376	12.9	155.5	20.2	-
29.76	7377	13.6	168.7	20.6	-
30.76	7378	14.4	182.7	20.9	-
31.76	7379	15.2	197.6	21.2	-
32.76	7380	16.0	213.2	21.6	-
33.76	7381	16.8	229.6	21.9	-
34.76	7382	17.7	246.9	22.2	-
35.76	7383	18.6	265.0	22.5	-
36.76	7384	19.7	284.1	22.9	-
37.76	7385	21.0	304.5	23.2	-
38.76	7386	22.5	326.2	23.5	-
39.76	7387	23.8	349.3	23.8	-
40.76	7388	25.3	373.9	24.1	-
41.76	7389	26.7	399.8	24.4	-
42.76	7390	28.2	427.2	24.7	-
43.76	7391	29.6	456.1	24.9	-
44.76	7392	31.1	486.4	25.2	-
45.76	7393	32.5	518.2	25.5	-
46.76	7394	33.9	551.4	25.8	-
47.76	7395	35.3	586.0	26.1	-
48.76	7396	36.7	622.1	26.3	-
49.76	7397	38.2	659.5	26.6	-
50.76	7398	39.7	698.4	26.9	-
51.76	7399	41.2	738.8	27.1	-
52.76	7400	42.8	780.8	27.4	-
53.76	7401	44.3	824.3	27.6	-
54.76	7402	45.9	869.4	27.9	-
55.76	7403	47.5	916.1	28.2	-
56.76	7404	49.2	964.4	28.4	-
57.76	7405	50.9	1014.4	28.7	-
58.76	7406	52.8	1066.3	28.9	-
59.76	7407	54.6	1119.9	29.1	-
60.76	7408	56.5	1175.5	29.4	-
61.76	7409	58.5	1233.0	29.6	0
62.76	7410	60.7	1292.6	29.9	108.2
63.76	7411	62.9	1354.4	30.1	345.7
64.76	7412	65.0	1418.3	30.3	676.9
65.76	7413	67.0	1484.3	30.6	1100
66.76	7414	69.0	1552.3	30.8	1611.8



Sheet List Table

No.	Sheet Title
1	COVER SHEET
2	HYDRAULIC DATA and SHEET LIST
3	EXISTING SITE PLAN
4	GEOTECHNICAL INFORMATION
5	PROPOSED SITE PLAN
6	DAM PLAN AND PROFILE
7	DAM OUTLET PLAN AND PROFILE
9	DAM ABUTMENT SECTIONS
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11	SPILLWAY SECTIONS
12	INLET DETAILS
13	OUTLET PIPE DETAILS
14	OUTLET STRUCTURE DETAILS

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PROPOSED BRUCE DAM LOCATION

HYDRAULIC DATA and SHEET LIST

CUCHARAS COLLABORATIVE

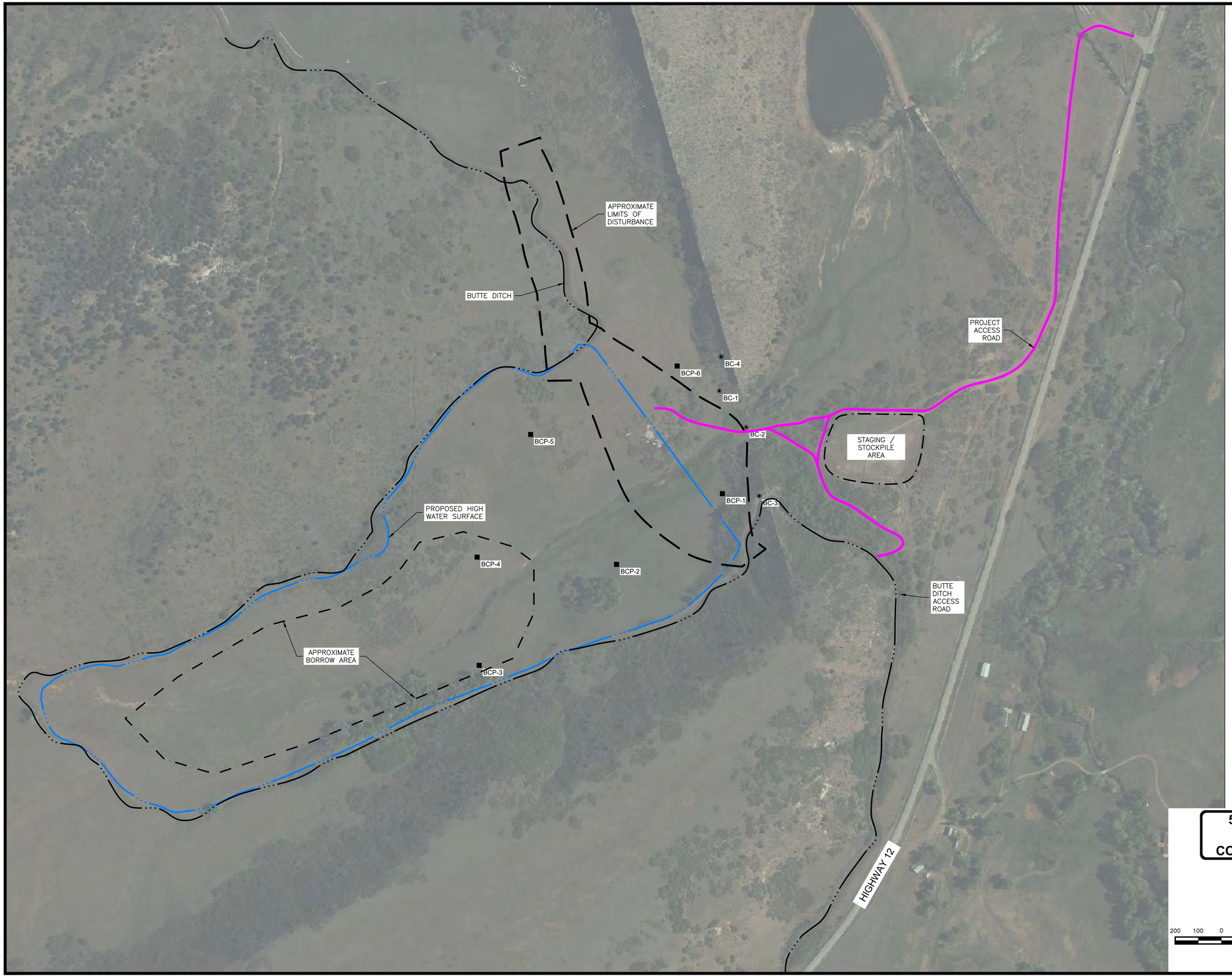
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REVISIONS				

Date: 26/AUG/20
Job No: 16-106
Drawn: LD
Design:
Checked:
Scale: As Noted

Sheet: **2**
Of:

Filing No. C-

Plot Date: 12/07/21 - 8:30am, Plotted by:ntoll, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Bruce\Design\Drawing Name:Bruce data Sheet exhibit.dwg



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Scale 1" = 200'
2' CONTOUR INTERVAL

200 100 0 200 400 600
SCALE IN FEET

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PROPOSED BRUCE DAM LOCATION

EXISTING SITE PLAN

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

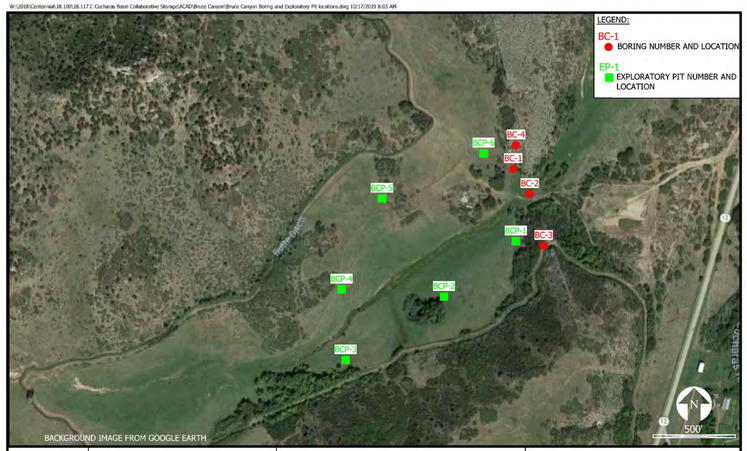
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Of:

Filing No. C-

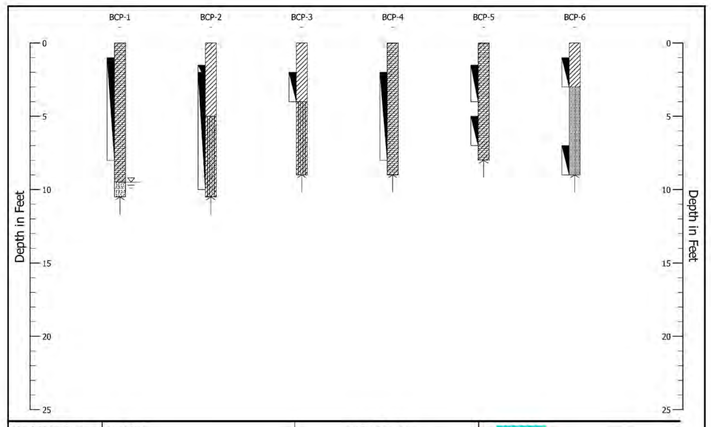
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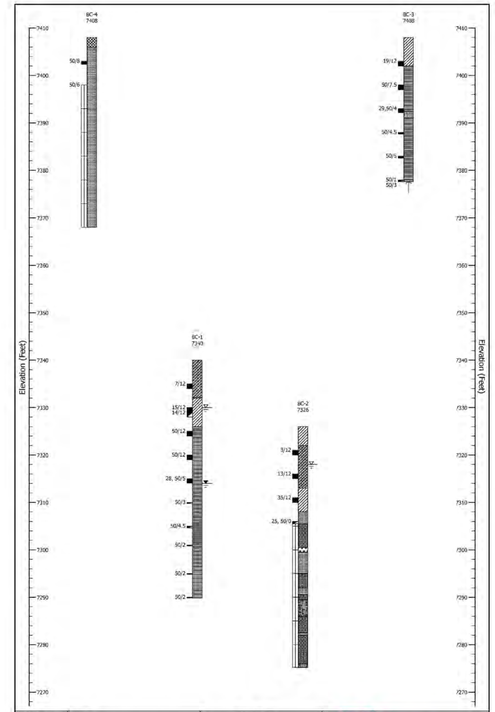
PROJECT NO:	18.117		
PROJECT NAME:	Cucharas Basin Collaborative Storage		
DRAWN BY:	KNZ	CHECKED BY:	JAC2
DWG DATE:	10.11.18	REV. DATE:	10.17.19

FIGURE 14
Bruce Canyon Reservoir
Locations of Borings and Exploratory Pits

CESARE, INC.
Geotechnical Engineers & Construction Materials Consultants



PROJECT NO:	18.117	**FIGURE 16**	CESARE, INC.
PROJECT NAME:	Cucharas Basin Collaborative Storage	Bruce Canyon Exploratory Pit Logs	Geotechnical Engineers & Construction Materials Consultants
DATE:	10/28/2018		



PROJECT NO:	18.117	**FIGURE 15**	CESARE, INC.
PROJECT NAME:	Cucharas Basin Collaborative Storage Bruce Canyon	Bruce Canyon Boring Logs	Geotechnical Engineers & Construction Materials Consultants
DWG DATE:	10/24/2019		

LOG OF BORING — BC-1

PROJECT	Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION	7340
PROJECT NUMBER	18.117	DEPTH TO BEDROCK	28
DATE STARTED	8/6/18	TOTAL DEPTH	50.17
DATE COMPLETED	8/7/18	REFUSAL	
LOGGED BY	H. Brunkal		
DRILLED BY	HRL	DEPTH TO WATER / DATE	
DRILL RIG	CME-55	10	8/6
DRILL METHOD	HSA & HQ Core	26	8/7

DEPTH (ft)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0	SAND, clayey, moist, loose, dark brown.	7/12					
8 ft.	CLAY, sandy, moist, stiff, low calcareous, dark brown.	15/12 14/12					
14 ft.	CLAYSTONE, slightly moist to very moist, medium hard, very calcareous, moderately indurated from 28.5', dark brown to reddish brown, olive to gray.	50/12					
20		50/12					
28		28, 50/5					
30		50/3					
40		50/4.5					
		50/2					
		50/2					
50	Stopped HSA and sampling at 50.2'.	50/2					
60							

CESARE, INC.
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LOG OF BORING — BC-2

PROJECT	Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION	7326
PROJECT NUMBER	18.117	DEPTH TO BEDROCK	18
DATE STARTED	8/2/18	TOTAL DEPTH	51
DATE COMPLETED	8/2/18	REFUSAL	
LOGGED BY	J Edwards		
DRILLED BY	HRL	DEPTH TO WATER / DATE	
DRILL RIG	CME-55	8	8/2/18
DRILL METHOD	6.5"		

DEPTH (ft)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0	CLAY, sandy, moist to wet, very soft, dark brown.						
4 ft.	SAND, clayey, to with gravel, very loose to medium dense, wet, dark brown.	3/12					
		13/12					
13 ft.	CLAY, sandy, hard, moist, medium calcareous, brown.	35/12					
18 ft.	SANDSTONE, clayey, moderately hard to very hard, moist, gray.	25, 50/0	1	100	0	H3	
	SANDSTONE, moderately hard, moderately weathered, medium grained, massive bedding, tan.		2	100	48		
20.5 ft.	MUDSTONE, soft, moderately to highly weathered, massive bedding, dark gray to gray brown to chocolate brown. Calcareous, orange staining along fractures		3	100	100	H4	
25.5 ft.	Brecoia 25.5' - 26.5'						
26.5 ft.	SANDSTONE, moderately hard, fine grained, massive bedding, calcareous, arkosic, dark red brown.		4	100	40	H4	
31 ft.	MUDSTONE, soft, massive bedding, dark red brown.						
34 ft.	SANDSTONE, moderately hard, fine grained, massive bedding, calcareous, with occasional fossil debris, dark gray to red brown.		5	100	74	H6, H5	
35.5 ft.	MUDSTONE, soft, massive bedding, dark red brown.						
36.5 ft.	SANDSTONE, silty, conglomeratic, soft, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts. SANDSTONE, conglomeratic, moderately hard, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/8" - 1/4" clasts. SANDSTONE, silty, conglomeratic, soft, fine grained, massive bedding, dark red brown to olive gray. With occasional 1/ 8" - 1/4" clasts.		6	70	54	H6	
40 ft.	MUDSTONE, soft, massive bedding, calcareous, dark red brown.		7	100	67	H6	
43.5 ft.	SANDSTONE, soft to moderately hard, fine grained, massive bedding, calcareous, dark red brown.						
44 ft.	MUDSTONE, soft, highly altered, massive bedding, dark red brown. 47'-49' Olive gray to tan, mottled						
50 ft.	SANDSTONE, conglomeratic, soft, highly altered, fine grained, massive bedding, mottled dark red brown to olive gray to yellow brown. Stopped coring at 50.8'						
60							

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LOG OF BORING — BC-3

PROJECT	Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION	7408
PROJECT NUMBER	18.117	DEPTH TO BEDROCK	10
DATE STARTED	8/7/18	TOTAL DEPTH	50.25
DATE COMPLETED	8/7/18	REFUSAL	
LOGGED BY	H. Brunkal		
DRILLED BY	HRL	DEPTH TO WATER / DATE	
DRILL RIG	CME-55	dry	8/7/18
DRILL METHOD	6.5"		

DEPTH (ft)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0	CLAY, sandy, slightly moist, very stiff, medium calcareous, brown.						
6 ft.	CLAYSTONE, sandy, slightly moist, hard, low calcareous, dark reddish brown.	19/12					
		50/7.5					
15.5 ft.	SANDSTONE, silty, clayey, slightly moist, very hard, dark red brown.	29,50/4					
17 ft.	CLAYSTONE, sandy, slightly moist, very hard, medium calcareous, dark brown.	50/4.5					
		50/5					
30 ft.	SANDSTONE, slightly moist, very hard, very calcareous, very indurated. maroon. Stopped HSA and sampling at 30.2.	50/1 50/3					
40							
50							
60							

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LOG OF BORING — BC-4

PROJECT	Cucharas Basin Collaborative Storage	APPROXIMATE GROUND ELEVATION	7408
PROJECT NUMBER	18.117	DEPTH TO BEDROCK	0.5
DATE STARTED	8/29/19	TOTAL DEPTH	40
DATE COMPLETED	8/30/19	REFUSAL	
LOGGED BY	I. Campbell		
DRILLED BY	Dakota	DEPTH TO WATER / DATE	
DRILL RIG	CME 45 Track Mounted	None	
DRILL METHOD			

DEPTH (ft)	DESCRIPTION	BLOWS/FT	CORE NO.	CORE RECOVERY (%)	CORE RQD (%)	CORE HARDNESS	DRILLING NOTES
0	FILL: DRILL PAD, SANDSTONE						
2 ft.	SANDSTONE, silty, hard, unweathered, moderately fractured, banded to thickly bedded, dark gray.	50/8					
	SANDSTONE, silty, hard, unweathered, intact to moderately fractured, banded to thickly bedded, light tan.	50/6	1	67	67		
	Coarse grain lense at 13 feet.		2	100	100		
	Hard, slightly weathered, slightly to highly fractured, bonded to thickly bedded, iron staining in joints with hydrothermal quartz, light tan.		3	100	100		
			4	98	98		
	Hard to moderately hard, slightly to moderately weathered, slightly to intensely fractured, banded to thickly bedded, light tan to gray.		5	97	73		
	Thin lense of claystone at 34 feet.		6	97	75		
40	Stopped Coring at 40 feet.						
50							
60							

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PROPOSED BRUCE DAM LOCATION

GEOTECHNICAL INFORMATION

CUCHARAS COLLABORATIVE

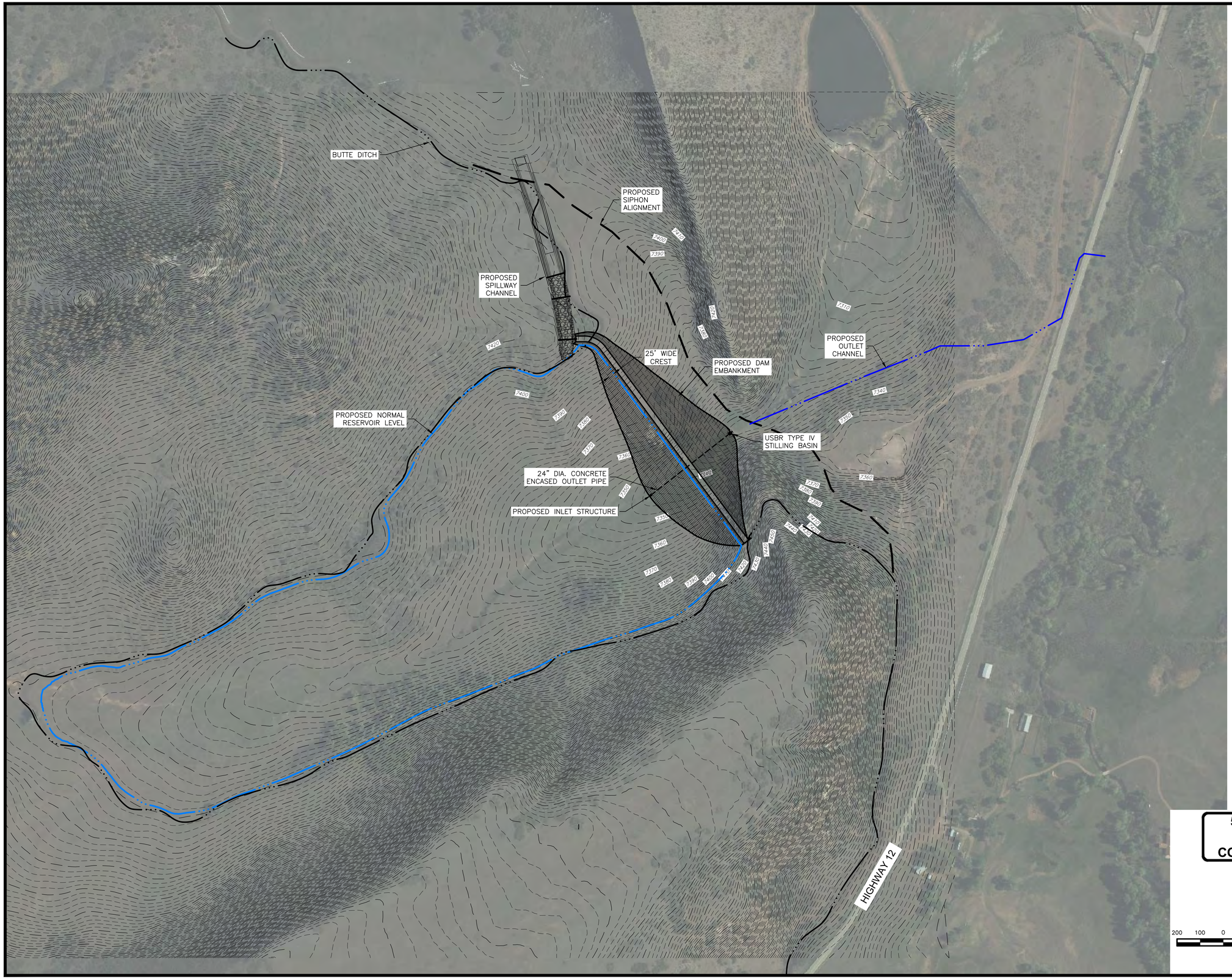
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Plot Date: 12/07/21 - 8:31am, Plotted by:mlick, Drawing Path: N:\16106 Cucharas Study\Drawings\Proj Set\Bruce\Design\Drawing Name\Bruce Dam Geotech exhibit.dwg



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Scale 1" = 200'
2' CONTOUR INTERVAL

200 100 0 200 400 600
SCALE IN FEET

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PROPOSED BRUCE DAM LOCATION

PROPOSED SITE PLAN

CUCHARAS COLLABORATIVE

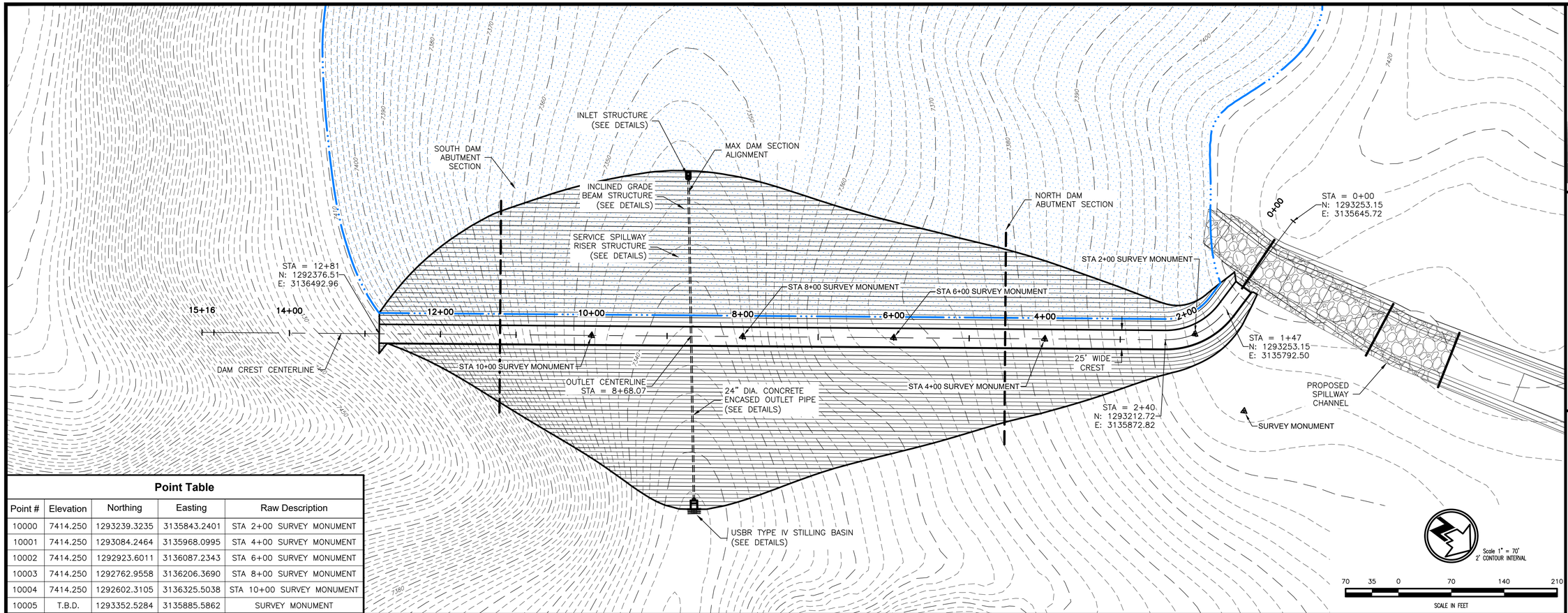
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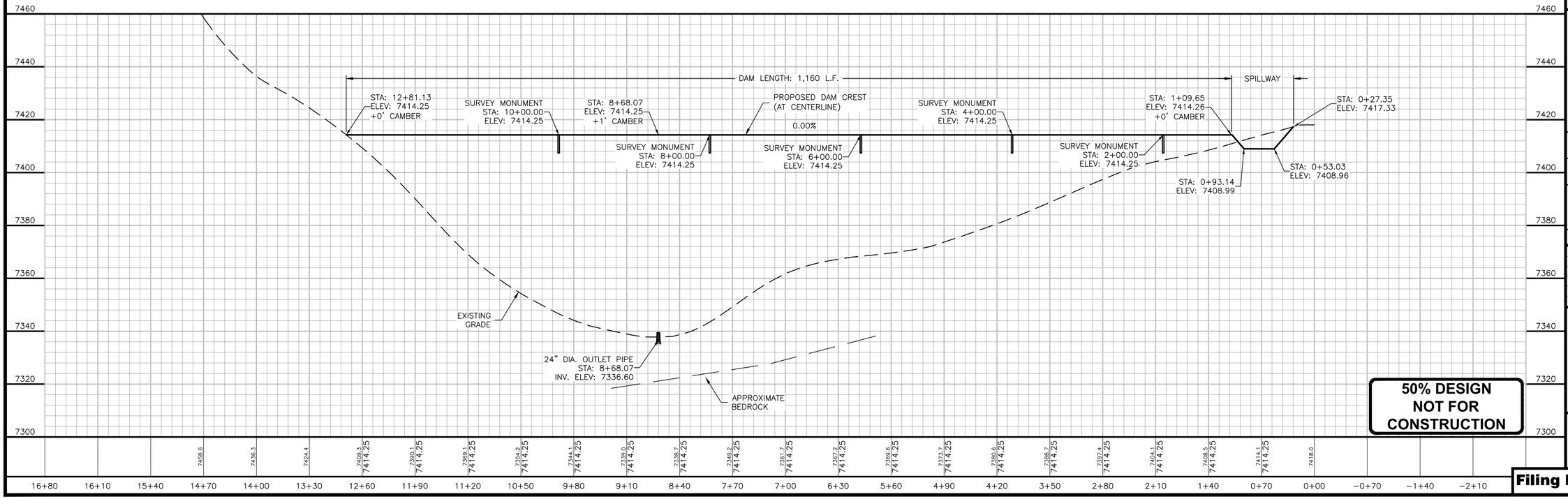
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10002	7414.250	1292923.6011	3136087.2343	STA 6+00 SURVEY MONUMENT
10003	7414.250	1292762.9558	3136206.3690	STA 8+00 SURVEY MONUMENT
10004	7414.250	1292602.3105	3136325.5038	STA 10+00 SURVEY MONUMENT
10005	T.B.D.	1293352.5284	3135885.5862	SURVEY MONUMENT



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PROPOSED BRUCE DAM LOCATION

DAM PLAN AND PROFILE

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

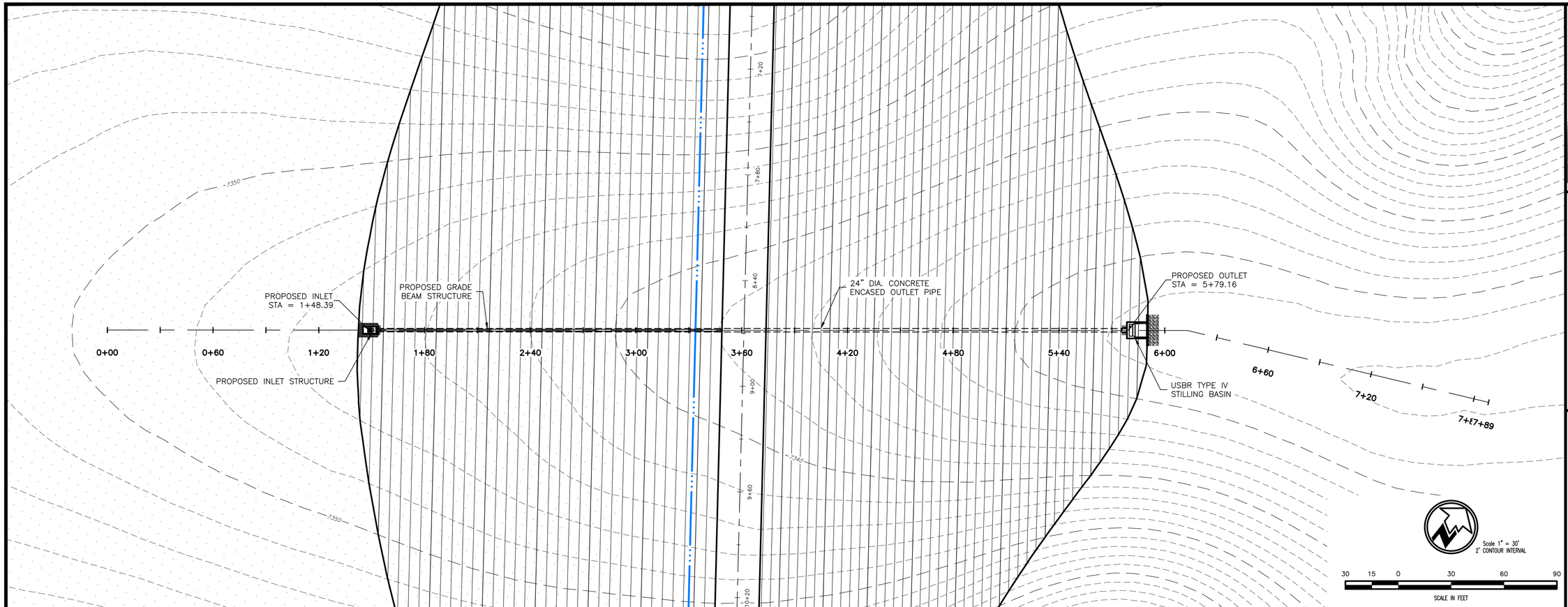
REVISIONS

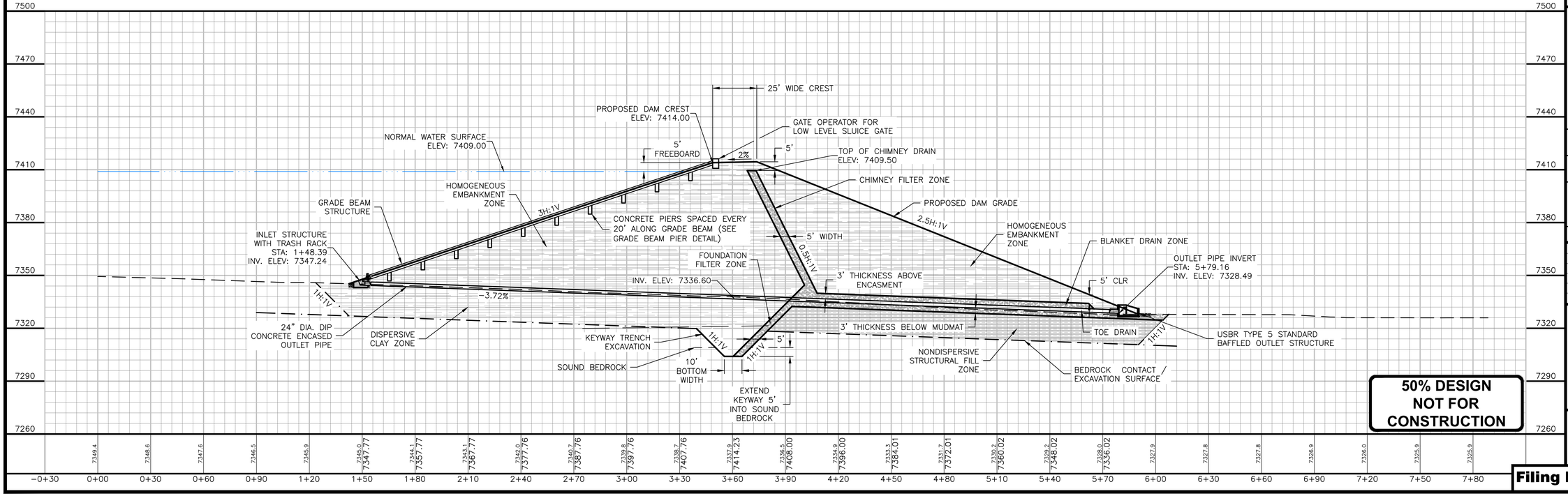
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PROPOSED BRUCE DAM LOCATION

DAM OUTLET PLAN AND PROFILE

CUCHARAS COLLABORATIVE

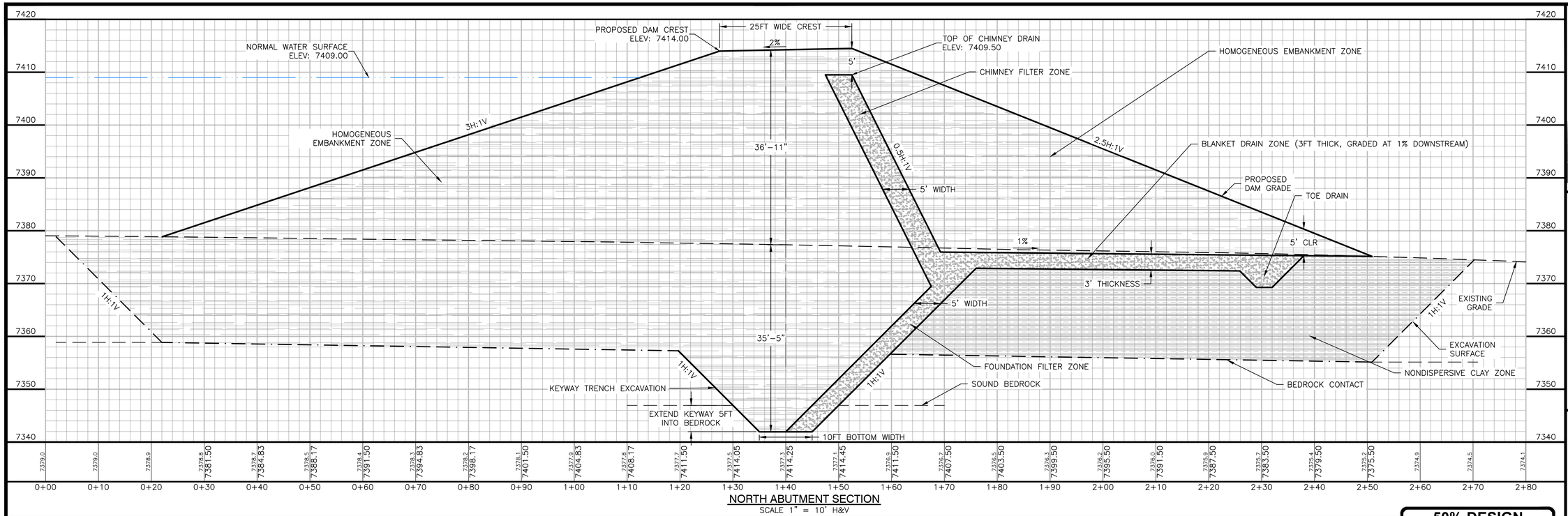
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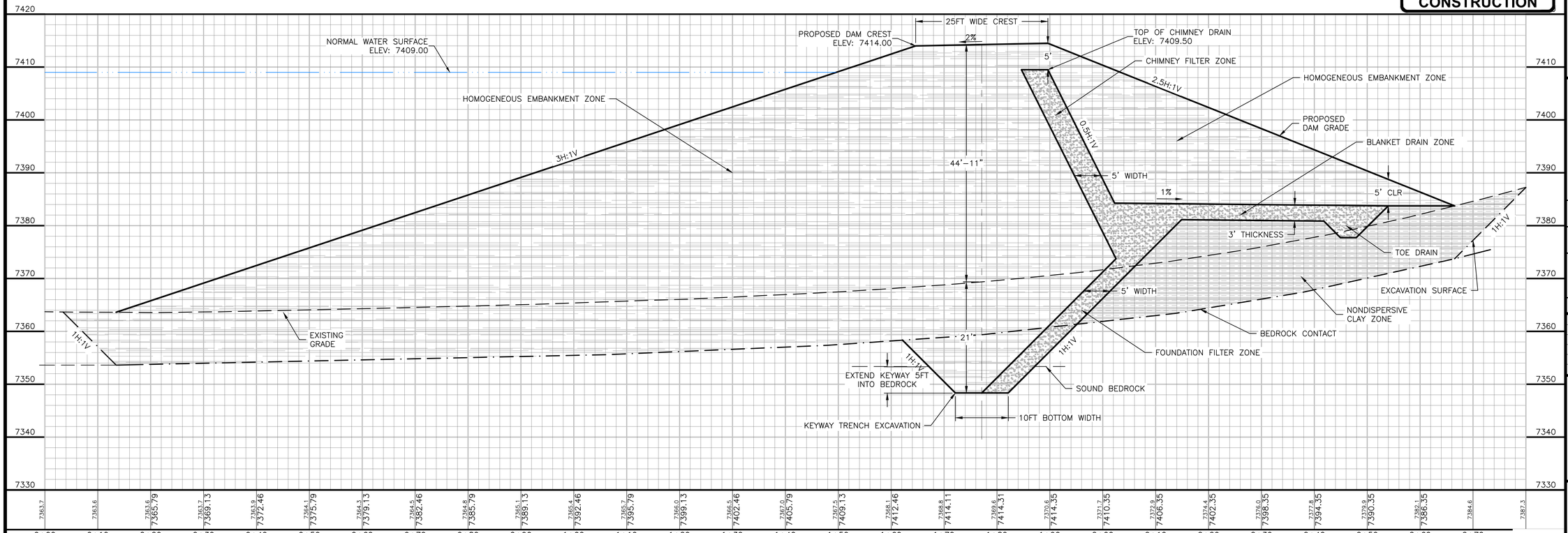
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NORTH ABUTMENT SECTION
SCALE 1" = 10' H&V



SOUTH ABUTMENT SECTION
SCALE 1" = 10' H&V

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PROPOSED BRUCE DAM LOCATION

DAM ABUTMENT SECTIONS

CUCHARAS COLLABORATIVE

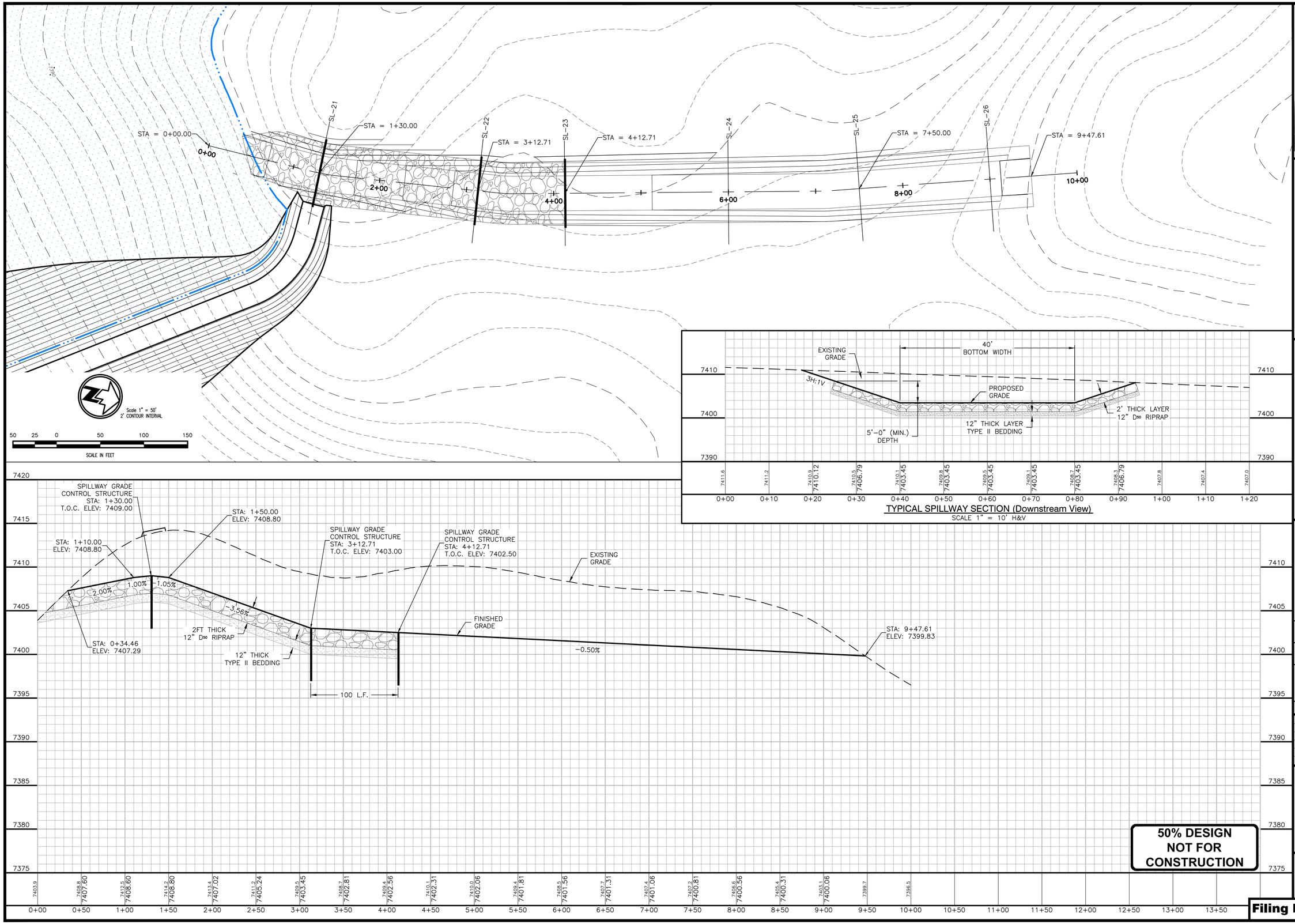
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TYPICAL SPILLWAY SECTION (Downstream View)
SCALE 1" = 10' H&V

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PROPOSED BRUCE DAM LOCATION

SPILLWAY PLAN AND PROFILE

CUCHARAS COLLABORATIVE

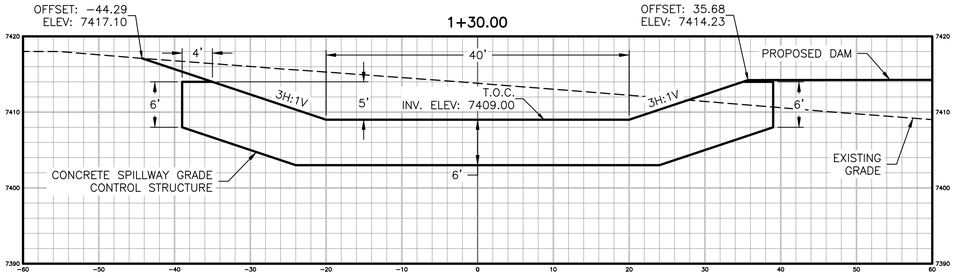
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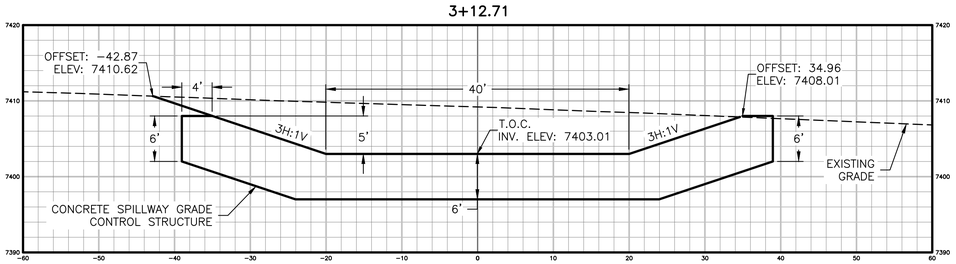
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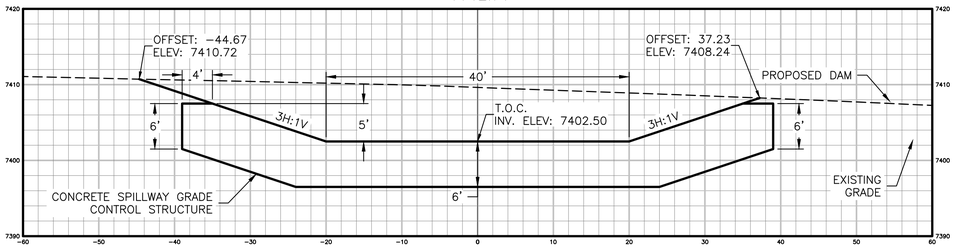
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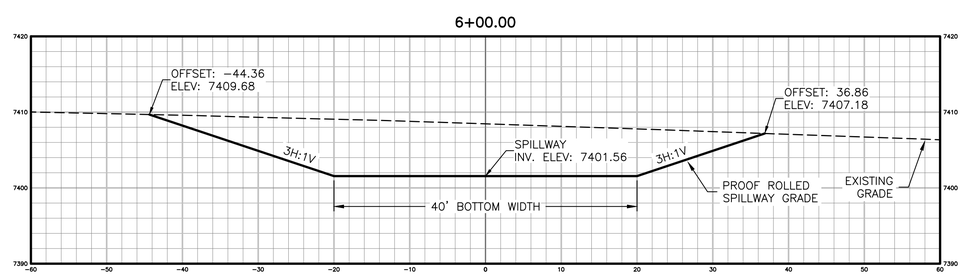
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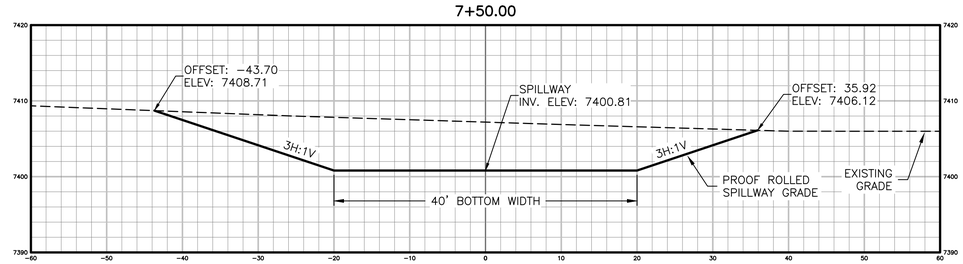
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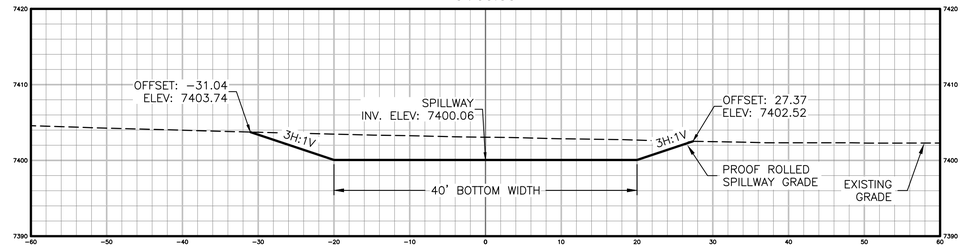
SL-23



SL-24



SL-25



SL-26

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PROPOSED BRUCE DAM LOCATION

SPILLWAY SECTIONS

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION
				REVISIONS

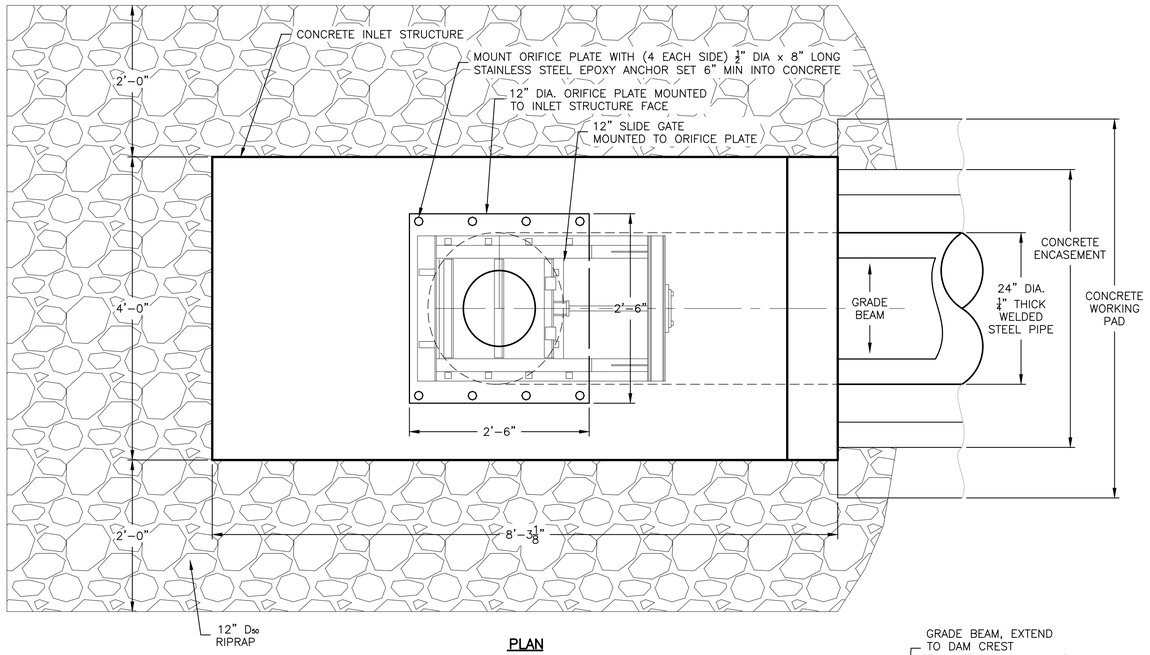
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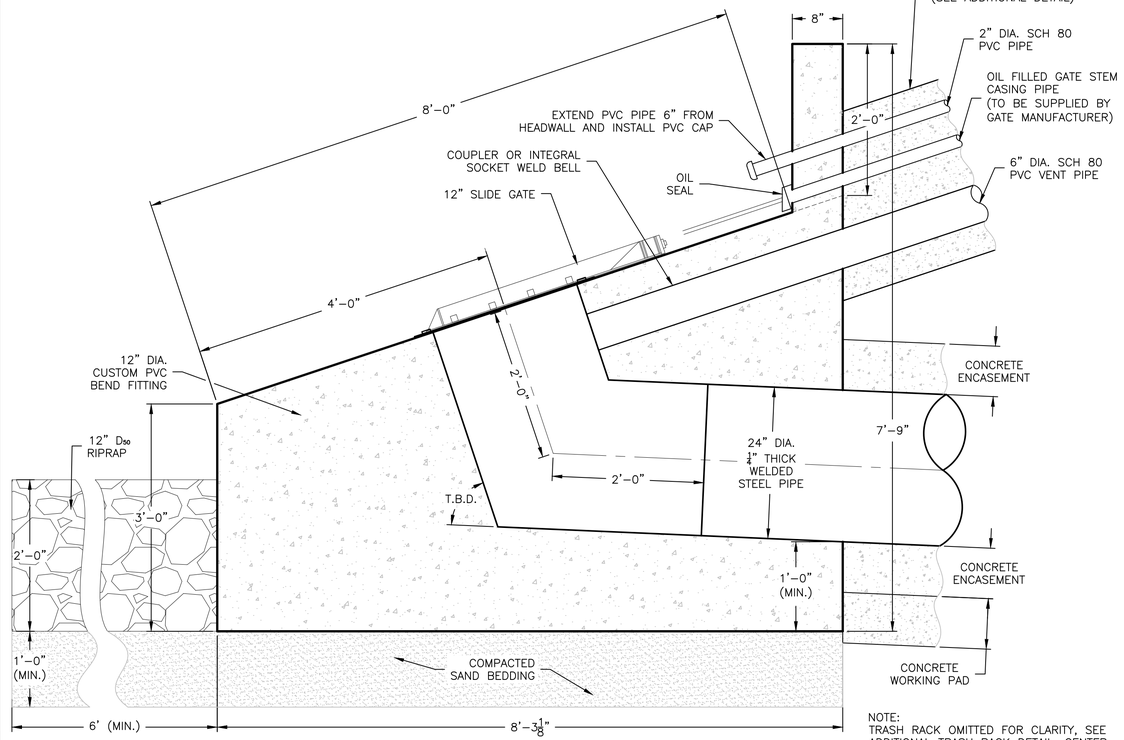
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PLAN

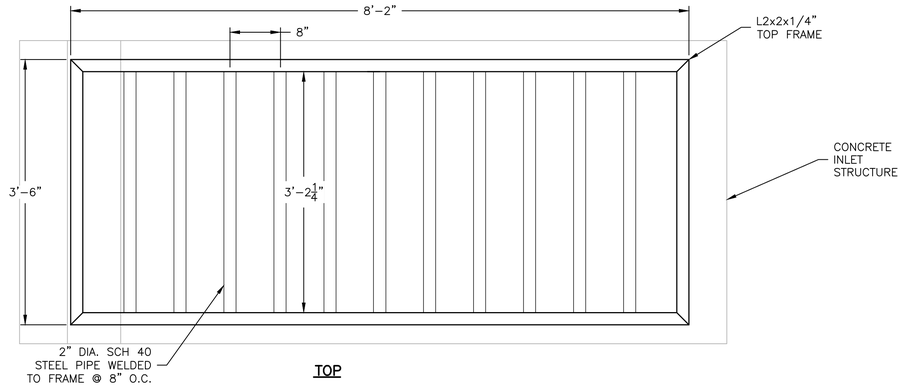


NOTE:
TRASH RACK OMITTED FOR CLARITY, SEE ADDITIONAL TRASH RACK DETAIL. CENTER TRASH RACK ON INLET STRUCTURE FACE.

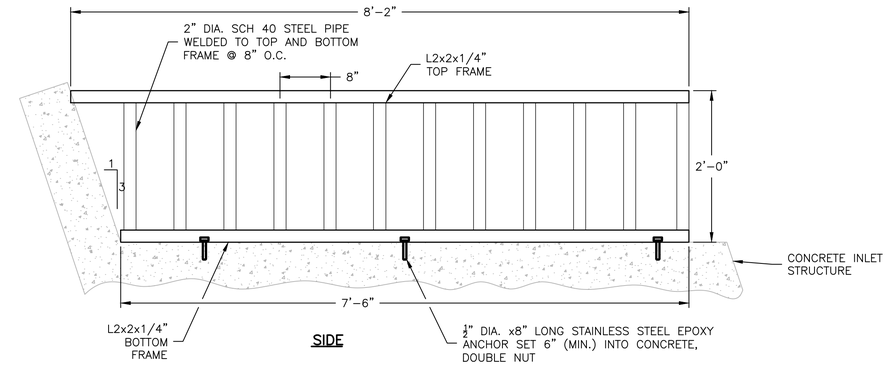
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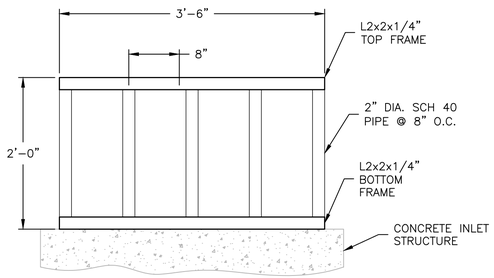
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SCALE IN FEET



TOP



SIDE

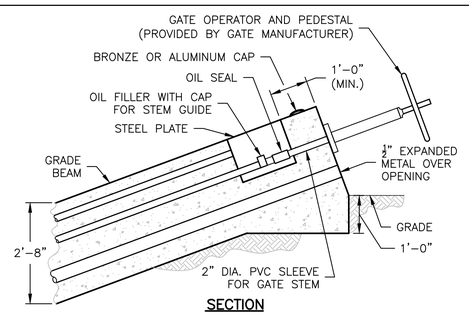


FRONT

NOTES:
1. LEAVE BACK OF FRAME OPEN TO ACCOMMODATE VALVE STEM AND 2" DIA. SCH 80 PIPE.
2. ALL STEEL SHALL BE EITHER GALVANIZED OR COATED WITH A POLYURETHANE OR 2 PART EPOXY PAINT RATED FOR SUBMERGED SERVICE.

TRASHRACK DETAIL
SCALE 1" = 1'–0"

0 0.5 1 2
SCALE IN FEET



SECTION

GATE PEDESTAL DETAIL
NOT TO SCALE

50% DESIGN NOT FOR CONSTRUCTION

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Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

PROPOSED BRUCE DAM LOCATION

INLET DETAILS

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

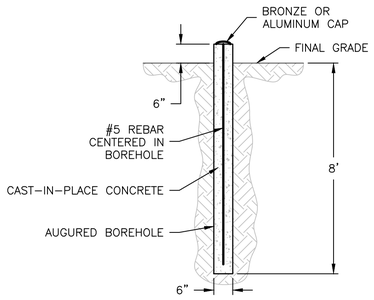
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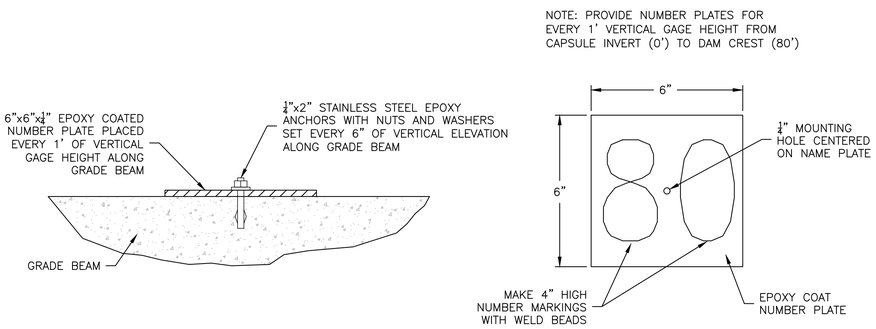
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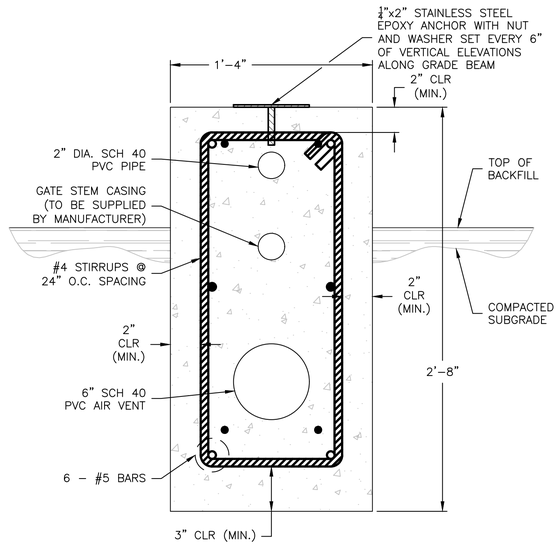
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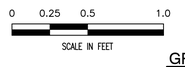


SURVEY MONUMENT
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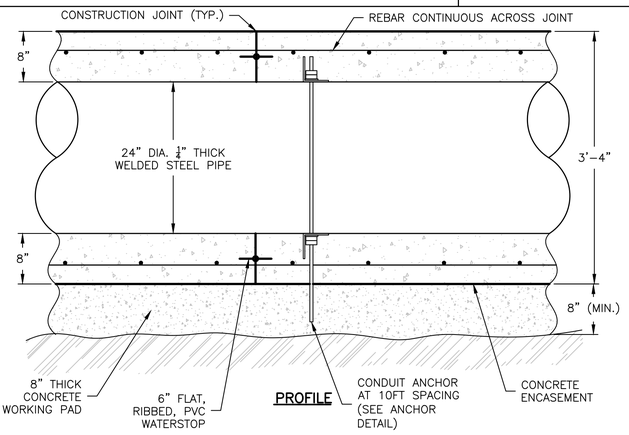


STAFF GAGE DETAIL
NOT TO SCALE

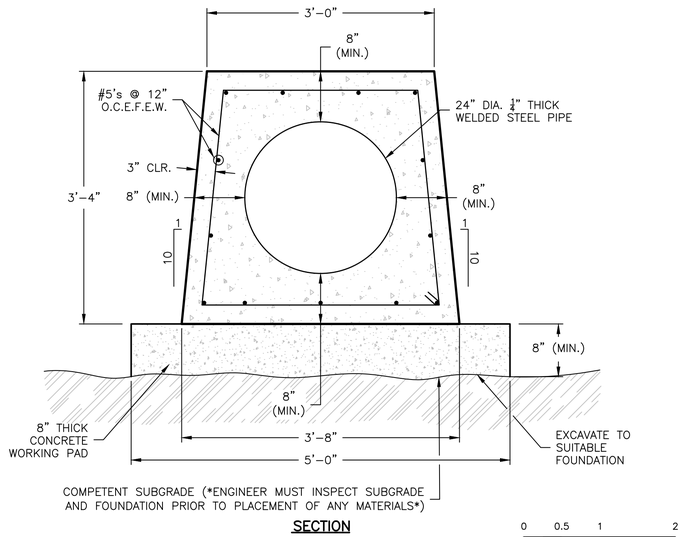




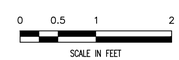
GRADE BEAM DETAIL
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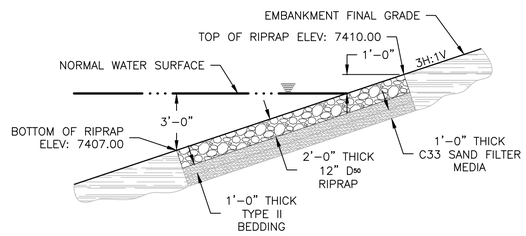


PROFILE

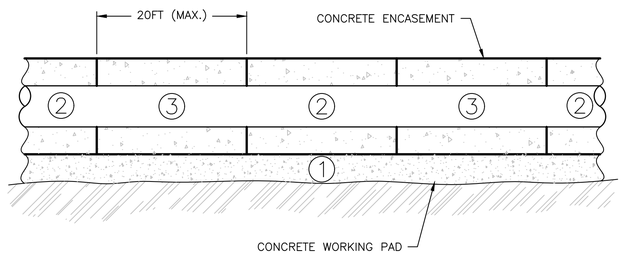


SECTION
CONCRETE ENCASEMENT DETAIL
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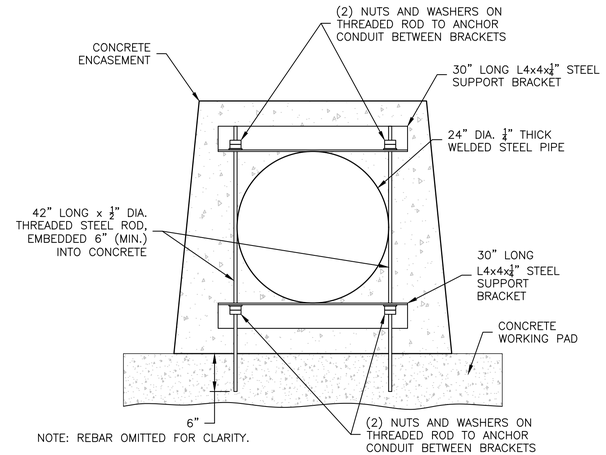


UPSTREAM SLOPE PROTECTION DETAIL
NOT TO SCALE



NOTES:
1. CONCRETE WORKING PAD WITH REBAR ANCHORS CAST FIRST PRIOR TO CONCRETE ENCASEMENT.
2. CONCRETE ENCASEMENT SHALL BE CAST IN 20FT SECTION ALTERNATING AS SHOWN WITH #2 SECTIONS CAST FIRST, FOLLOWED BY #3 SECTIONS.
3. SPACE ANCHORING SYSTEM EVERY 10FT ALONG CONDUIT ALIGNMENT.

ENCASEMENT SEQUENCING
NOT TO SCALE



CONDUIT ANCHOR DETAIL
SCALE 1" = 1'

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Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

PROPOSED BRUCE DAM LOCATION

OUTLET PIPE DETAILS

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

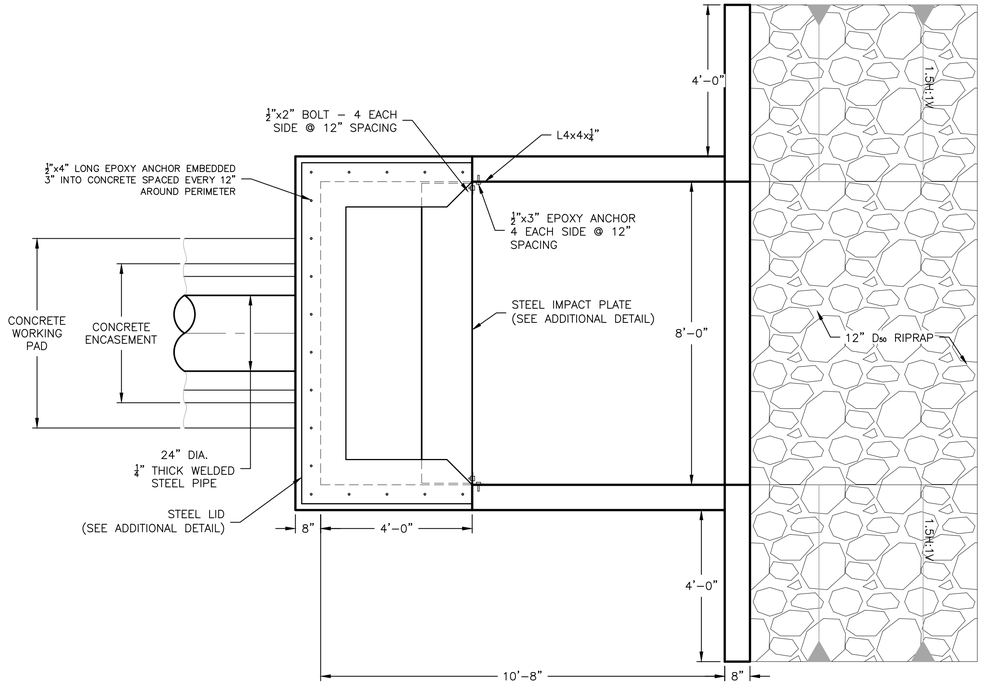
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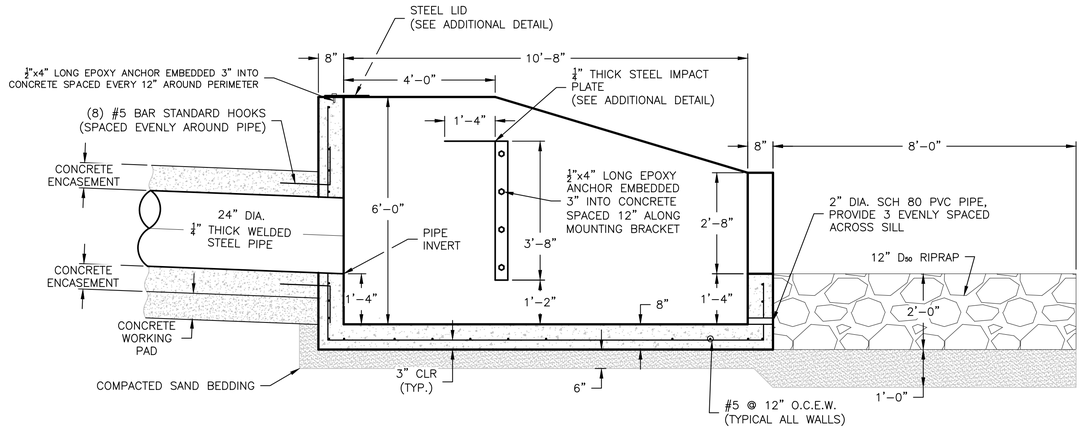
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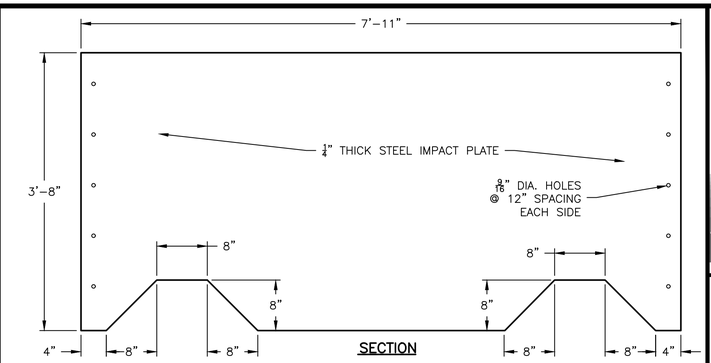


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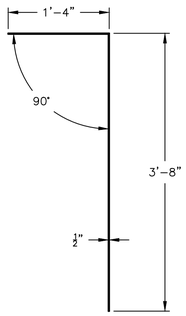
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SCALE IN FEET

CONCRETE IMPACT BASIN
SCALE 1" = 2'

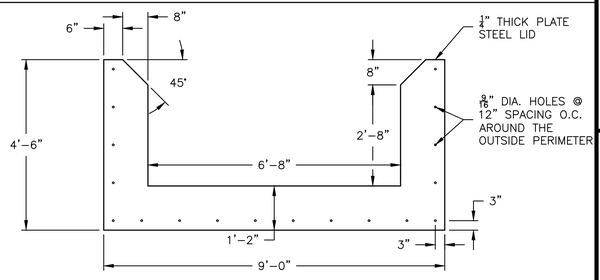


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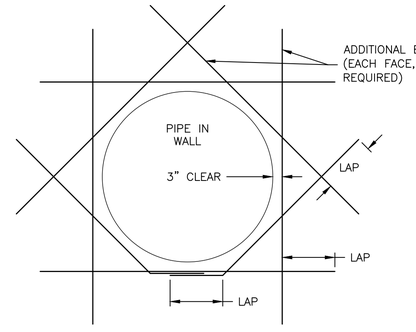


PROFILE

STEEL IMPACT PLATE DETAIL
NOT TO SCALE



STEEL LID DETAIL
NOT TO SCALE



REINFORCEMENT AROUND OPENINGS
NOT TO SCALE

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email: info@applegategroup.com Website: www.applegategroup.com

PROPOSED BRUCE DAM LOCATION

OUTLET STRUCTURE DETAILS

CUCHARAS COLLABORATIVE

NO	DATE	BY	CHK'D	DESCRIPTION

REVISIONS

Date:	07/DEC/21
Job No:	16-106
Drawn:	LD
Design:	
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Plot date: 12/07/21 - 8:32am, Plotted by:stock, Drawing Path: N:\16106 Cucharas Study\Drawings\Plan Set\Stock\Design\Drawing Name:Bruce Detail Sheet.dwg

Engineer's Opinion of Probable Cost

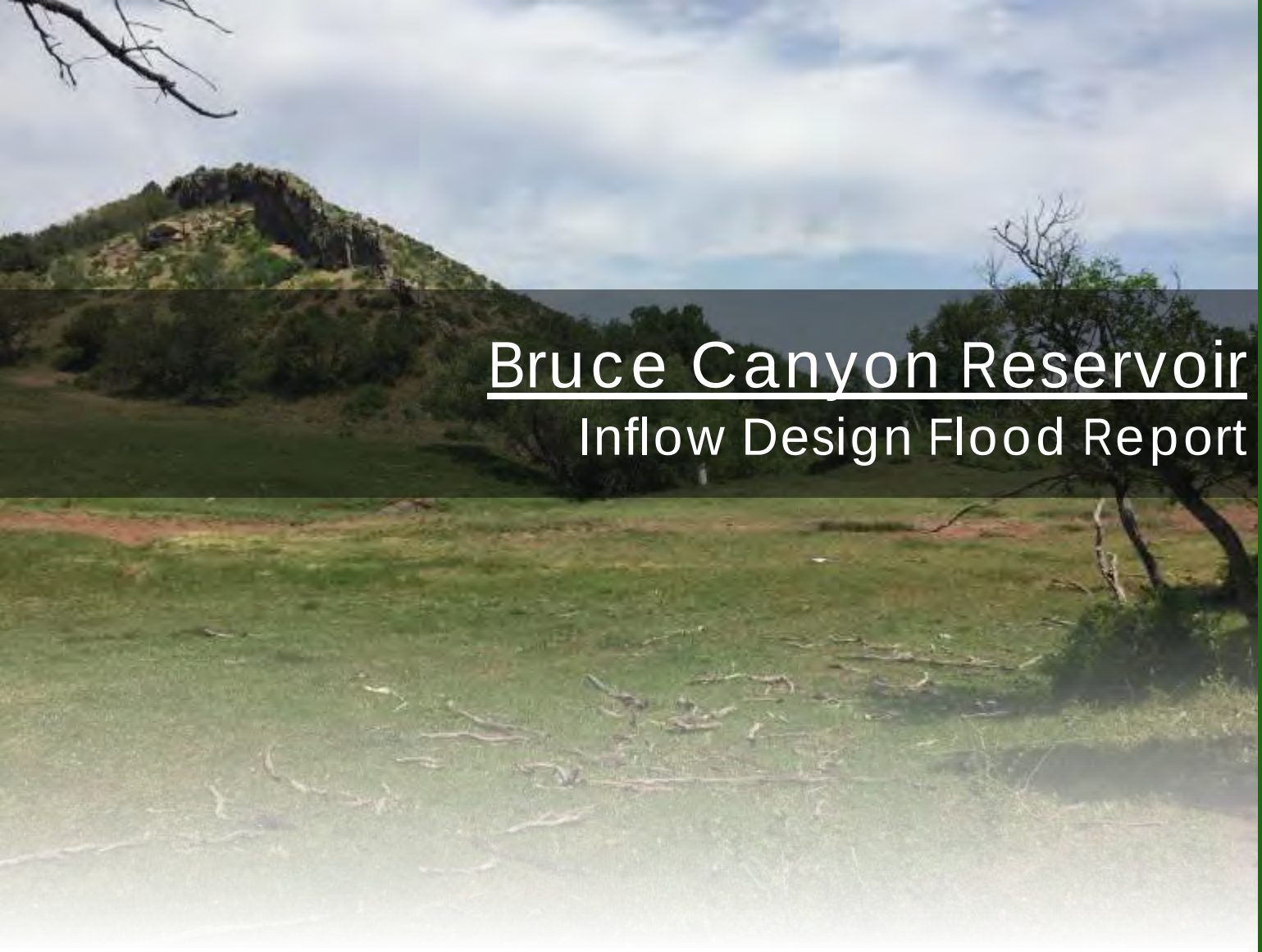
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1490 W. 121st Ave., Suite 100
Denver, CO 80234
Phone: (303) 452-6611
Fax: (303) 452-2759

Bruce Canyon Reservoir
50% Design

Huerfano County, Colorado

Job No.:	18-117
By:	DAB
Date:	12/7/2021
Project:	Cucharas Collaborative Storage
Client:	Huerfano County Water Conservancy District

	DESCRIPTION	NUMBER OF UNITS	UNIT TYPE	UNIT COST	ESTIMATED COST
	CONTRACTOR COSTS				
a.	**Site Preparation**				
1	Mobilization and Demobilization	1	LS	$ 200,000	$ 200,000
2	Construction Dewatering	1	LS	$ 50,000	$ 50,000
6	Clear and Grub (Upstream and Downstream Slopes, Dam Crest, Emergency Spillway Channel)	10	AC	$ 5,000	$ 50,000
				Subtotal for Site Preparation	**$ 300,000**
b.	**Sitework, Grading and Foundation Preparation**				
1	Earthwork - Excavation for Foundation Preparation (to Bedrock Contact)	156,700	CY	$ 7	$ 1,096,900
2	Earthwork - Keyway Excavation (Bedrock)	9,400	CY	$ 20	$ 188,000
3	Earthwork - Furnish and Place Compacted Homogeneous Fill for Foundation	91,800	CY	$ 18	$ 1,652,400
4	Earthwork - Furnish and Place Processed Clay (Nondispersive) for Foundation	55,800	CY	$ 18	$ 1,004,400
5	Earthwork - Furnish and Place Compacted Homogeneous Fill for Dam Embankment	304,800	CY	$ 18	$ 5,486,400
6	Furnish and Place CDOT Class A Filter Material / Type II Bedding for Upstream Slope Protection	500	CY	$ 110	$ 55,000
7	Furnish and Place 12" D50 Riprap for Upstream Slope Protection	1,000	CY	$ 130	$ 130,000
				Subtotal for Sitework, Grading and Foundation Preparation	**$ 9,613,100**
c.	**Filter Drain System**				
1	Furnish and Place Two-Stage Filter Drain (#8 Coarse Aggregate, 8" ADS N-12 and C33 Concrete Sand)	800	LF	$ 70	$ 56,000
2	Earthwork - Furnish and Place Filter Material for Foundation, Chimney and Blanket Drain	24,500	CY	$ 120	$ 2,940,000
3	Furnish and Install PVC Cleanouts	5	EA	$ 1,100	$ 5,500
4	Furnish and Place Solid Discharge Pipe for Toe Drain	15	LF	$ 70	$ 1,050
				Subtotal for Infrastructure	**$ 3,002,550**
d.	**Emergency Spillway**				
1	Earthwork - Excavation (Cut) for Emergency Spillway	14,900	CY	$ 7	$ 104,300
2	Furnish and Place Concrete Grade Control Structures	3	EA	$ 24,000	$ 72,000
3	Furnish and Place CDOT Class A Filter Material / Type II Bedding for Emergency Spillway Channel	1,100	CY	$ 110	$ 121,000
4	Furnish and Place 12" D50 Riprap for Emergency Spillway Channel	2,100	CY	$ 130	$ 273,000
				Subtotal for Emergency Spillway Construction	**$ 570,300**
e.	**Infrastructure**				
1	Furnish and Place Reinforced Concrete for Inlet Structure	4	CY	$ 2,500	$ 10,000
2	Furnish and Install 24-in Concrete Encased Steel Pipe (1/4" Thick)	430	LF	$ 750	$ 322,500
3	Furnish and Install 12-inch Heavy Duty Slide Gate	1	LS	$ 25,000	$ 25,000
4	Furnish and Install Steel Pipe Trash Rack	1	LS	$ 5,000	$ 5,000
5	Furnish and Place Reinforced Concrete Grade Beam (4" & 2" Dia. Schedule 80 Conduits and Staff Gage)	200	LF	$ 350	$ 70,000
6	Furnish and Place Reinforced Concrete for Impact Basin	6	CY	$ 3,200	$ 19,200
7	Furnish and Install Steel Impact Plate for Low-Level Outlet (1/4" thick, galvanized steel - includes angle and assembly hardware)	1	LS	$ 3,000	$ 3,000
8	Furnish and Place CDOT Class A Filter Material / Type II Bedding for Outlet Protection	70	CY	$ 110	$ 7,700
9	Furnish and Place 12" D50 Riprap for Outlet Protection	140	CY	$ 130	$ 18,200
10	Butte Ditch Siphon (24 in PVC)	2,500	FT	$ 80	$ 200,000
11	Outlet Channel - Open Channel Unlined Ditch	1,100	FT	$ 20	$ 22,000
12	Outlet Channel - 24" RCP Piped Section	750	FT	$ 140	$ 105,000
				Subtotal for Infrastructure	**$ 680,600**
f.	**Survey**				
1	Pre-construction Survey and Staking	1	LS	$ 30,000	$ 30,000
2	As-built Survey (Includes 4 Survey Monuments)	1	LS	$ 5,000.00	$ 5,000
				Subtotal for Survey and Testing	**$ 35,000**
				Contingency (20%)	**$ 2,840,310**
				Total Estimated Project Cost	**$ 17,041,860**



Bruce Canyon Reservoir

Inflow Design Flood Report

December, 2021

AG File # 18-117

HUERFANO COUNTY WATER CONSERVANCY DISTRICT

Applegate Group, Inc.
Water Resource Advisors for the West
www.applegategroup.com
303-452-6611

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Proposed Reservoir Conditions 3
Hydrologic Hazard Analysis 4
Hydrology 4
Drainage Basin 4
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Unit Hydrograph 6
Design Storm 7
Inflow Design Flood 7

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INTRODUCTION

The Bruce Canyon dam will be a new homogeneous embankment dam located in Huerfano County approximately 2.5 miles southwest of La Veta Colorado. The dam would be owned by the Cucharas Basin Collaborative, or likely one of the participants within the Collaborative Storage group. The dam will be located in the northwest ¼ of Section 5, Township 30 South, Range 68 West, of the Sixth P.M., at a ground surface elevation of approximately 7350 feet. The reservoir would be filled with diversions from the Cucharas River via the Butte Ditch. A conditional storage right of 1,406 ac-ft was decreed for Bruce Canyon Reservoir in Case No. 17CW3075, which also includes conditional exchanges to the Butte Ditch of up to 31.1 cfs to fill Bruce Canyon Reservoir and conditional exchanges of up to 8 cfs for releases from Bruce Canyon Reservoir to the Cucharas River. The reservoir will likely be filled in the first part of the irrigation season when there is exchange potential from downstream sources, and releases may be made throughout the year for augmentation purposes.

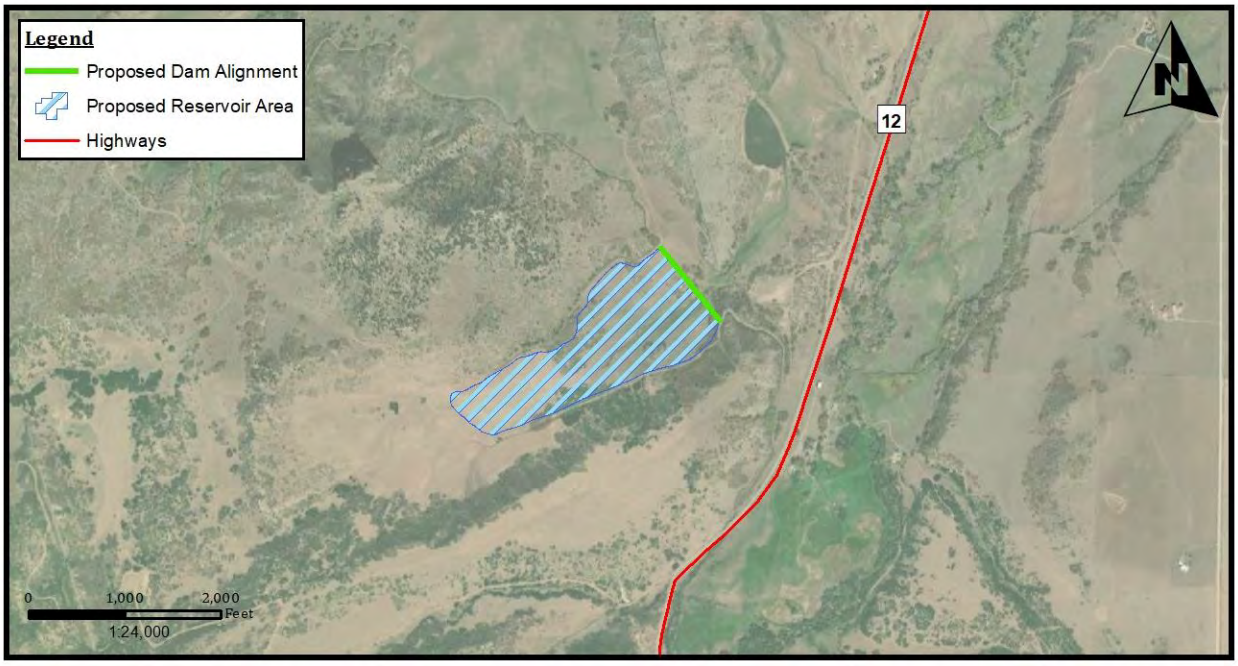


FIGURE 1 - PROPOSED BRUCE CANYON DAM AND RESERVOIR VICINITY MAP

The objective of this report is to present the Hydrologic Analysis of Bruce Canyon Dam completed by Applegate Group, Inc. (Applegate) for the Huerfano County Water Conservancy District. This report will focus on determination of the inflow design flood (IDF).

The hydrologic analysis summarized in this report adheres to Rule 6 of the *Rules and Regulations for Dam Safety and Dam Construction*[1] and follows guidance presented in *Hydrologic Basin Response Parameter Estimate Guidelines*[2] and *Guidelines for the Use of Regional Extreme Precipitation Study*[3]. Spreadsheets

[1] Rules and Regulations for Dam Safety and Dam Construction. Colorado Division of Water Resources, Office of the State Engineer, Dam Safety. Effective January 1, 2020.
[2] Hydrologic Basin Response Parameter Estimation Guidelines, Office of the State Engineer, Dam Safety Branch. Revised May 2008.
[3] Guidelines for the Use of Regional Extreme Precipitation Study (REPS) Rainfall Estimation Tools. Colorado Division of Water Resources, Office of the State Engineer, Dam Safety. Effective January 7, 2020.

and rainfall analysis tools available from the Colorado Division of Water Resources website were utilized for the hydrologic analysis presented in this report a copy of which accompanies this submittal.

PROPOSED RESERVOIR CONDITIONS

Bruce Canyon reservoir will be an off-channel reservoir impounded by a 1,160 feet long and 78 feet tall homogenous earthen embankment constructed in a natural valley. The following table summarizes conditions, geometries, and characteristics proposed for Bruce Canyon dam and reservoir that are pertinent to understanding the hydrologic analysis discussed later in this report:

TABLE 1 - PROPOSED BRUCE CANYON CHARACTERISTICS

Dam Element	Value
Jurisdictional Height	74 Feet
Structural Height	78 Feet
Spillway Invert Elevation	7409 Feet
Normal Storage Capacity	1,233 Acre-feet
Max Storage Capacity	1,552 Acre-feet
Dam Crest Elevation	7414 Feet
Dam Crest Width	25 Feet
Normal Freeboard	5 Feet
Upstream Dam Face Slope	3H:1V
Downstream Dam Face Slope	2.5H:1V

The proposed stage-area-storage curve for Bruce Canyon Dam is shown below.

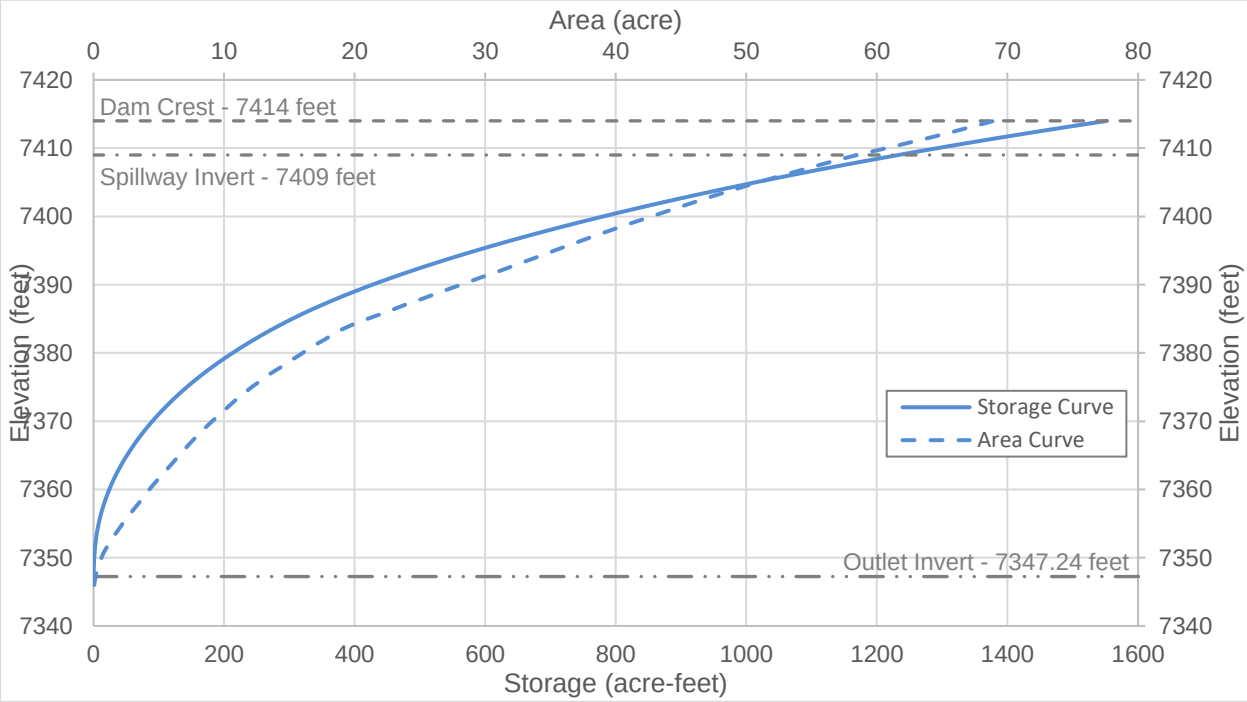


FIGURE 2 - PROPOSED BRUCE CANYON DAM STAGE-STORAGE-AREA CURVE

Please note that the Bruce Canyon Dam and Reservoir project is only at the 50% design stage at the time this report was prepared. A *Design Report* in accordance with Rule 6.8 of the *Rules and Regs* will be submitted to the SEO at the 90% design phase when formal construction drawings and specifications will be submitted to Dam Safety.

HYDROLOGIC HAZARD ANALYSIS

An extreme hydrologic hazard has been conservatively assumed for purposes of this hydrologic analysis. A formal hydrologic hazard analysis will be completed at the 90% design stage and submitted to Colorado Dam Safety at that time.

HYDROLOGY

Hydrologic analysis of Bruce Canyon dam was prepared in accordance with *Rules and Regulations for Dam Safety and Construction (Rules and Regs)* as well as recommendations found in *Hydrologic Basin Response Parameter Estimation Guidelines (Hydrology Guidelines)* both published by the SEO. The Inflow Design Flood (IDF) for Bruce Canyon dam was determined according to the Prescriptive Method described in Rule 7.2 of the *Rules and Regs* assuming an Extreme Hydrologic Hazard designation for the structure.

DRAINAGE BASIN

The contributing drainage basins for Bruce Canyon dam was determined using the *USGS Colorado StreamStats Web Application*. The drainage basin for Bruce Canyon dam was determined to be relatively small at only 346 acres or 0.54 square miles. A map of the contributing drainage basin to Bruce Canyon dam is shown in the following figure.

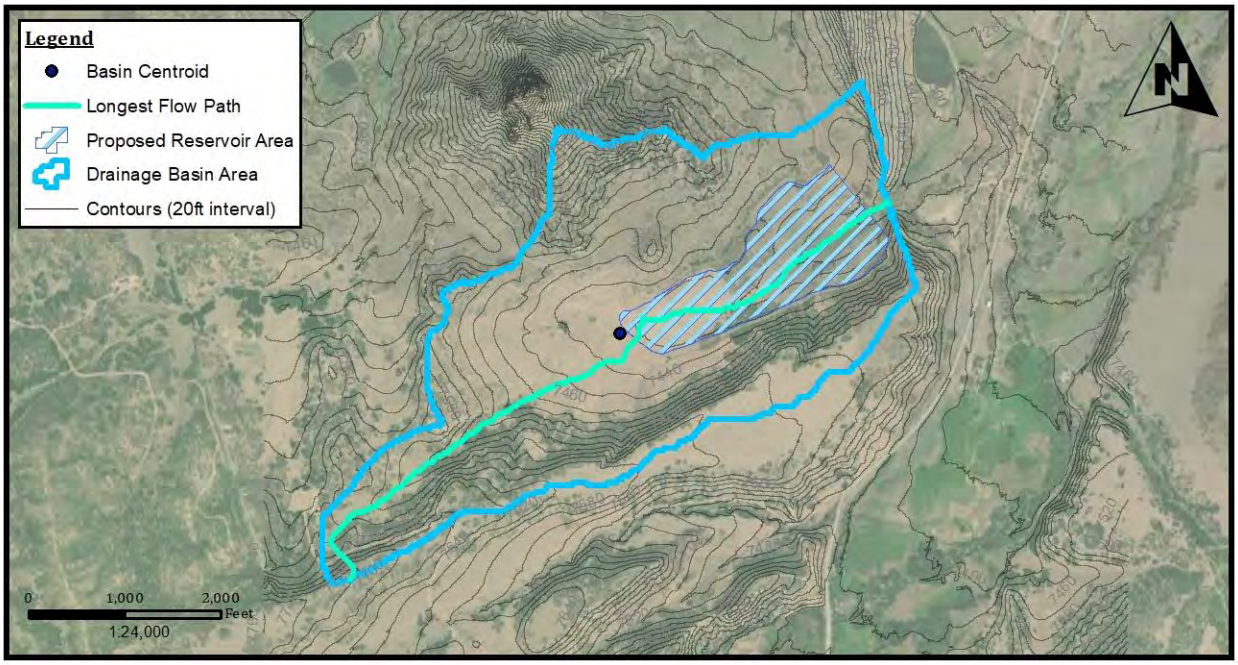


FIGURE 3 – BRUCE CANYON RESERVOIR DRAINAGE AREA

Most of the drainage basin is classified as shrub/scrub land cover type with small portions classified as deciduous forest, evergreen forest, and grasslands/herbaceous per a review of the USGS National land Cover Dataset.

LOSS PARAMETERS

The Green and Ampt Infiltration Method was used to calculate rainfall losses according to *Hydrology Guidelines*. The Green & Ampt Infiltration Method involves hydraulic conductivity (XKSAT), wetting front capillary suction (PSIF), initial volumetric soil moisture deficit (DTHETA), surface retention loss (IA), and effective impervious area (RTIMP) parameters to model infiltration of rainfall into the soil; development of these parameters are described below:

- **Hydraulic Conductivity, XKSAT:** The NRCS Web Soil Survey database was utilized to determine USDA texture classes for map units occurring within Bruce Canyon dam's drainage basin shown in Appendix A.

  Bare ground XKSAT values were applied to individual components of each map unit according to Table 10 of the *Hydrology Guidelines* utilizing the lowest XKSAT value occurring within soil horizons down to a depth of 18 inches. A vegetation cover correction factor was applied bare ground XKSAT values, except those for sand and loamy sand textures, according to the following equation.

$$C_k = \frac{V_c - 10}{90} + 1.0$$

Where:

C_k = *Ratio of XKSAT to Bare Ground XKSAT*

V_c = *Vegetation Cover % (assumed to be 75% for this analysis based on a review of aerial imagery of the basin)*

  A composite XKSAT for the basin was developed excluding components containing 'unweathered bedrock' USDA textures.
- **Wetting Front Capillary Suction, PSIF & Initial Volumetric Soil Moisture Deficit, DTHETA:** These parameters were determined according to Figure 4 of the *Hydrology Guidelines* utilizing the composite bare ground XKSAT described above assuming a normal antecedent soil moisture condition.
- **Surface Retention Loss, IA:** Table 8 of the *Hydrology Guidelines* was referenced to determine a surface retention loss parameter value for the basin assuming 75% vegetation cover and an average slope of 15% which was ascertained from USGS Colorado StreamStats Web Application.
- **Effective Impervious Area, RTIMP:** Areas of soil map units containing weathered bedrock USDA textures within the first 18 inches of depth were assumed to contribute to the effective imperious area along with the area associated with normal operating pool of the proposed reservoir.

Spreadsheet for Computing Rainfall Losses tool was obtained from the Dam Safety Branch website and was utilized to calculate the parameters described above and is included in Appendix B. Final Green and Ampt Infiltration parameter values utilized in this analysis are summarized in Table 2 **Error! Reference source not found.**.

TABLE 2 - GREEN AND AMPT INFILTRATION PARAMETERS

Parameter	Value
Weighted Average % Vegetation Cover	75%
Initial Abstraction (IA)	0.3 inches
Wetting Front Capillary Suction (PSIF)	11 inches
Volumetric Soil Moisture Deficit at the start of rainfall (DTHETA)	0.11
Adjusted Hydrologic Conductivity at Natural Saturation adjusted for vegetation (XKSAT)	0.04 inches/hour
Effective Impervious Area (RTIMP)	30%

UNIT HYDROGRAPH

A Clark Unit Hydrograph was utilized to model drainage basin of Bruce Canyon dam response to excess rainfall from the design precipitation per *Hydrologic Basin Response Parameter Estimation Guidelines*. The Clark Unit Hydrograph relies on the time of concentration (T_c), storage coefficient (R), and the time-area relation parameters which are described below:

- **Time of Concentration, T_c:** Time of concentration was calculated according to the following equation, which is recommended for rocky mountain, great plains, or Colorado Plateau type watersheds:

$$T_c = 2.4A^{0.1}L^{0.25}L_{ca}^{0.25}S^{-0.2}$$

  The area (A), length of longest flow path (L), length from concentration point to point along L perpendicular basin centroid (L_{ca}), and watercourse slope (S) were determined utilizing ArcGIS software to analyze USGS StreamStats Colorado data outputs along with LiDAR topographic of the drainage basin obtained from *Colorado Hazard Mapping & Risk Map Portal*. The map shown in **Error! Reference source not found.** shows the parameters utilized to calculate the time of concentration for Bruce Canyon dam's drainage basin
- **Storage Coefficient, R:** The storage coefficient for Bruce Canyon Dam drainage basin was calculated according to the following equation utilizing the aforementioned parameters:

$$R = 0.37T_c^{1.11}L^{0.80}A^{-0.57}$$

- **Time-Area Relation:** A Curve C dimensionless synthetic time-area relation was selected for Bruce Canyon dam's drainage basin which is recommended for undeveloped mountain or plains areas with interspersed agriculture fields.

Table 3 summarizes pertinent Clark Unit Hydrograph parameters.

TABLE 3 - CLARK UNIT HYDROGARPH PARAMETERS

Parameter	Value
A	0.543 miles^2
L	1.512 miles
L_{ca}	0.648 miles
S	260.582 ft/mile
T_c	0.738 hours
R	0.521 hours

DESIGN STORM

Probable Maximum Precipitation (PMP) storm events are required to determine the IDF for Extreme Hydrologic Hazard dams per Rule 7.2.1 of the *Rules and Regs*. Probable Maximum Precipitation storm hyetograph data was gathered utilizing *CO-NM REPS PMP Tool* within ArcGIS using a shapefile of Bruce Canyon dam's contributing drainage basin as an input. An Atmospheric Moisture Factor of 1.07 was applied to each PMP storm event considered for Bruce Canyon which are summarized in the following table:

TABLE 4 - DESIGN RAINFALL SUMMARY

Hydrologic Hazard	Storm	Total Rainfall *(inches)*	Total Rainfall x 1.07 *(inches)*
Extreme	Local Storm 2-hour Stacked PMP	11.04	11.81
	Local Storm 6-hour Synthetic East PMP	16.10	17.23
	Local Storm 24-hour Synthetic Hybrid PMP	21.54	23.05
	General Storm 72-hour Synthetic East PMP	20.41	21.84
	Tropical Storm 72-hour Synthetic East PMP	12.71	13.60

INFLOW DESIGN FLOOD

A HEC-HMS 4.8 model was generated utilizing the hydrologic parameters described above to simulate the Inflow Design Flood into the proposed Bruce Canyon Reservoir; a copy of the HEC-HMS 4.8 model accompanies this submittal. Model results for IDFs generated from the PMP storm event variants are summarized in Table 5 below.

TABLE 5 - HEC-HMS IDF ROUTING RESULTS

Storm Event	Design Rainfall (in)	Runoff Volume (ac-ft)	Peak Runoff (cfs)
Local Storm 2-hour Stacked PMP	11.81	326.4	2,193.4
Local Storm 6-hour Synthetic East PMP	17.23	475.8	1,721.4
Local Storm 24-hour Synthetic Hybrid PMP	23.05	624.7	1,371.7
General Storm 72-hour Synthetic East PMP	21.84	535.7	524.5
Tropical Storm 72-hour Synthetic East PMP	13.60	321.5	349.7

The Local Storm 24-hour Synthetic Hybrid PMP was the critical IDF for sizing the spillway of Bruce Canyon dam assuming an Extreme Hydrologic Hazard designation. Hydrographs of design IDFs considered as part of this analysis are shown in the following figure.

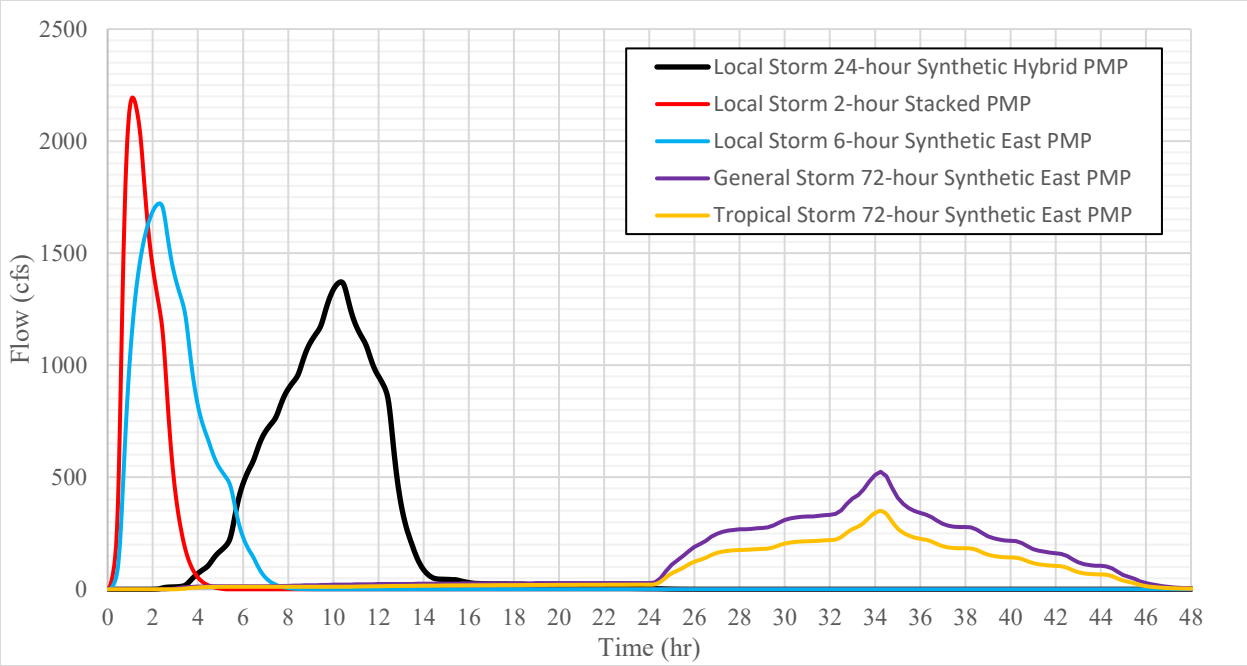


FIGURE 4 – IDF HYDROGRAPHS

Discussion

Please note the IDF, and thus costs associated with spillway construction, can be significantly reduced if efforts are taken to justify a High Hydrologic Hazard designation for Bruce Canyon dam. The 0.01% Annual Exceed Probability (AEP) storm events associated with a High Hydrologic Hazard classification are significantly less than the PMP storm events described above. High Hydrologic Hazard storm event hyetographs were gathered utilizing the *CO-NM Reps MetPortal PF Tool* web application to generate IDFs for those storms adhering to the same hydrologic analysis methods described above. The following table shows IDF characteristics generated from the PMP storm events and 0.01% AEP storm events for comparison purposes.

TABLE 6 - EXTREME VS HIGH HYDROLOGIC HAZARD DESIGN IDF COMPARISON

Hydrologic Hazard Group	Storm Event	Design Rainfall (in)	Runoff Volume (ac-ft)	Peak Runoff (cfs)
Extreme	PMP Local Storm 2-hour Stacked	11.81	326.4	2,193.4
Extreme	PMP Local Storm 6-hour Synthetic East	17.23	475.8	1,721.4
Extreme	PMP Local Storm 24-hour Synthetic Hybrid	23.05	624.7	1,371.7
Extreme	PMP General Storm 72-hour Synthetic East	21.84	535.7	524.5
Extreme	PMP Tropical Storm 72-hour Synthetic East	13.60	321.5	349.7
High	0.01% AEP Local Storm 2-hour Storm	4.59	114.8	1,063.3
High	0.01% AEP Mesoscale with Embedded Convection 6-hour Back-Loaded Synthetic Storm	6.01	148.3	773.6
High	0.01% AEP Mesoscale with Embedded Convection 6-hour Front-Loaded Synthetic Storm	5.65	140.1	801.1
High	0.01% AEP Mid-Latitude Cyclone/Tropical Storm Remnants 48-hour Back-Loaded Synthetic Strom	10.13	223.4	500.4
High	0.01% AEP Mid-Latitude Cyclone/Tropical Storm Remnants 48-hour Center-Loaded Synthetic Strom	10.03	217.1	269.6

Table 6 demonstrates the dramatic difference in the IDF and thus spillway sizing requirements between Extreme and High Hydrologic Hazard design storms. The runoff volume generated from storm events associated with a High Hydrologic Hazard designation can be stored within the dam's freeboard alone without accounting for any spillway discharge. The *Rules and Regulations* require auxiliary spillways for dams regardless, but the spillway sized for a 0.01% AEP storm event would result in significantly less effort than a spillway sized for a PMP storm event. **Applegate recommends further study to verify the Hydrologic Hazard Designation of the structure during the 90% design phase.** The spillway proposed during final design will be designed to pass the design IDF for the structure, pending results of the Hydrologic Hazard Analysis, with a minimum of 1 foot of residual freeboard. Although an Extreme Hydrologic Hazard designation has been assumed at this stage of design, the hydrologic parameters between an Extreme and High Hydrologic Hazard rating remain the same when generating and IDF and only differ in the design storm hyetograph.