John R. Byerly
INCORPORATED

GEOTECHNICAL INVESTIGATION

NEW ADMINISTRATION BUILDING AND MAINTENACE FACILITY

160-170 BUSINESS CENTER DRIVE

BIG BEAR LAKE, CALIFORNIA

MOUNTAIN AREA REGIONAL TRANSIT AUTHORITY

GEOTECHNICAL ENGINEERS • TESTING AND INSPECTION
2257 South Lilac Ave., Bloomington, CA 92316-2903
Bloomington (909) 877-1324 Riverside (909) 783-1910 Fax (909) 877-5210

John R. Byerly
INCORPORATED

GEOTECHNICAL INVESTIGATION

APRIL 11, 2022

NEW ADMINISTRATION BUILDING AND MAINTENACE FACILITY

160-170 BUSINESS CENTER DRIVE
BIG BEAR LAKE, CALIFORNIA

MOUNTAIN AREA REGIONAL TRANSIT AUTHORITY (MARTA)
41939 FOX FARM ROAD
BIG BEAR LAKE, CALIFORNIA 92315
ATTENTION: MS. SANDY BENSON, GENERAL MANAGER

RPT. NO.: 7341
FILE NO.: S-14447

DISTRIBUTION:
(2) CLIENT
(2) CHARLES ABBOTT ASSOCIATES, INC.

GEOTECHNICAL ENGINEERS • TESTING AND INSPECTION
2257 South Lilac Ave., Bloomington, CA 92316-2903
Bloomington (909) 877-1324 Riverside (909) 783-1910 Fax (909) 877-5210

TABLE OF CONTENTS

Enclosures:

(1) Plot Plan

(2) Test Boring Logs

(3) Maximum Density Determinations

(4) Consolidation Test Results

(5) Direct Shear Test Results

(6) Expansion Index Test Results

(7) Subgrade Test Results

(8) Specifications for Aggregate Base

(9) Liquefaction and Dynamic Settlement Analysis

(10) Geologic Hazards Report

INTRODUCTION

From January through April of 2022, an investigation of the soil conditions underlying the site of the proposed administration building and maintenance facility was conducted by this firm. The purpose of our investigation was to evaluate the surface and subsurface conditions at the site with respect to safe and economical foundation types, vertical and lateral bearing values, liquefaction and seismic settlement potential, support of concrete slabs-on-grade, and site preparation. Included in the recommendations are the seismic design parameters as required by the 2019 edition of the California Building Code and ASCE Standard 7-16. Our consulting engineering geologist, Terra Geosciences, has conducted a geologic hazards analysis. The report of this analysis is presented as Enclosure 10. Recommendations are also provided for the design of asphalt concrete pavement for fire lanes and parking and driveway areas. Percolation testing was performed for the proposed bioswales and underground infiltration systems to retain and dispose of storm water runoff. The report of the results of the percolation testing is presented under separate cover. Our geotechnical investigation, together with our conclusions and recommendations, is discussed in detail in the following report.

This report has been prepared for the exclusive use of the Mountain Area Regional Transit Authority and their design consultants for specific application to the project described herein. Should the project be modified, the conclusions and recommendations presented in this report should be reviewed by the geotechnical engineer. Our professional services have been performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, express or implied.

PROJECT DESCRIPTION

For the preparation of this report, we reviewed a site plan (Site Plan, Schematic Design, New Administration Building and Maintenance Facility, Mountain Area Regional Transit Authority, Ruhnau Clarke Architects, Inc., #5-08-01, July 21, 2021) that was submitted to this office. We understand the proposed Mountain Transit Facility will consist of a 12,188 square-foot bus maintenance building and an administration building with a plan area of 11,355 square feet. The proposed buildings will be single-story structures incorporating concrete slab-on-grade floors and supported by conventional isolated and continuous footings that will exert relatively light loads on the underlying soils. The buildings will be located in the northeastern portion of the site. Four solar shade structures, bus and vehicle parking and drive areas are also planned. The shade structures will be used as parking stalls and bus stalls. The project is currently in the conceptual design stage, so it is not known if the shade structures will be supported by drilled piers or conventional shallow foundations. The drive and parking areas will be paved with asphalt concrete pavement. The administration building will be accessed by conventional passenger vehicles, and mid-size to large buses will access the maintenance building. The driveway areas will also be used as fire lanes. A masonry-block screen wall is proposed along the northwestern perimeter of the site. Bioswales and underground infiltration systems are planned to retain and dispose of storm water runoff. Major slope and retaining wall construction is not anticipated. Based on the site topography, it is anticipated that maximum cuts and fills will be on the order of 5 feet. The site configuration and proposed development are illustrated on Enclosure 1.

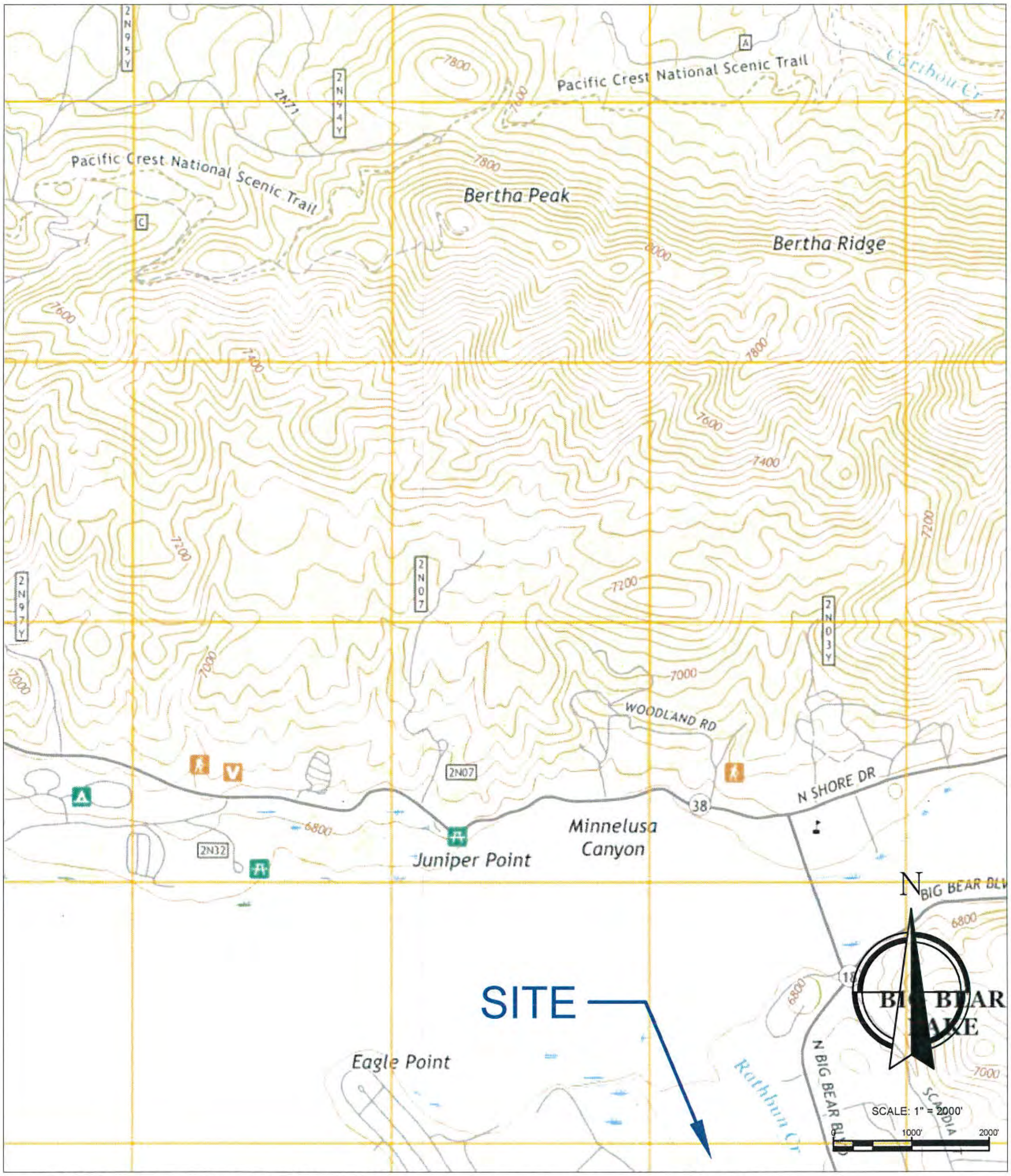
SITE CONDITIONS

The approximately 3-acre site is located on the west corner of Business Center Drive and Sandalwood Drive in the city of Big Bear Lake. An Index Map showing the general vicinity of the site is presented on the following page. The coordinates of the site are latitude 34.2505° N and longitude -116.8888° W utilizing the North American Datum (NAD) from 1983. The property is currently dirt-covered and has a very light growth of vegetation. At the time of our investigation, buildings were not present on the property, however some buses were parked on the site. The site is relatively flat, sloping downward to the northwest at a gradient of less than 4 percent. A Southwest Gas building is present to the southeast, and the property to the north is vacant.

FIELD AND LABORATORY INVESTIGATION

The soils underlying the site were explored by means of 10 test borings drilled with a truck-mounted flight-auger to depths of up to 71.5 feet below the existing ground surface. The approximate locations of the test borings are shown on Enclosure 1. The soils encountered were examined and visually classified by one of our field engineers. A summary of the soil classifications appears as Enclosure 2. The exploration logs show subsurface conditions at the dates and locations indicated, and may not be representative of other locations and times. The stratification lines presented on the logs represent the approximate boundaries between soil

INDEX MAP



SOURCE DOCUMENTS: USGS FAWNSKIN QUADRANGLE, CALIFORNIA, 7.5 MINUTE SERIES, 2018

TOWNSHIP AND RANGE: SECTION 21, T2N, R1E

LATITUDE: 34.2505° N

LONGITUDE: 116.8888° W

John R. Byerly
INCORPORATED

Rpt. No.: 7341
File No.: S-14447

types, and the transitions may be gradual. A hollow-stem auger with an outside diameter of 7.9 inches was utilized. The inside diameter of the auger was 4.3 inches.

Bulk and relatively undisturbed samples were obtained at selected levels within the explorations and delivered to our laboratory for testing and evaluation. The driving energy or blow counts required to advance the sampler at each sample interval were noted. Relatively undisturbed soil samples were recovered at various intervals in the borings with a California sampler. The California sampler was a 2.9-inch outside diameter, 2.5-inch inside diameter, split-barrel sampler lined with brass tubes. The sampler was 18 inches long. The sampler conformed to the requirements of ASTM D 3550. A 140-pound automatic trip hammer was lifted hydraulically and was dropped 30 inches for each blow. Standard penetration tests were performed as Boring 1 was advanced. The standard penetration test blow counts are shown on the logs for this boring. Standard penetration testing was performed with a 2.0-inch outside diameter, 1.5-inch inside diameter, split-barrel sampler. The sampler was 18 inches long and is machined to fit liners. The sampler was unlined and conformed to the requirements of ASTM D 1586. A 140-pound automatic trip hammer was lifted hydraulically and was dropped 30 inches for each blow. An efficiency value of 1.0 was assumed for the automatic trip hammer.

Included in our laboratory testing were moisture/density determinations on all undisturbed samples. Optimum moisture content/maximum dry density relationships were established for typical soil types so that the relative compaction of the subsoils could be determined. Consolidation testing was conducted on selected samples to evaluate the compressibility characteristics of the soil. The moisture/density data are presented on the boring logs presented in Enclosure 2. The maximum density and consolidation test results appear on Enclosures 3 and 4, respectively. Direct shear and expansion index tests were conducted on selected samples to determine their strength parameters and expansion potential, respectively. These test results are presented on Enclosures 5 and 6, respectively. Composite samples of potential subgrade soil were tested for gradation, sand equivalent and “R” value for pavement design purposes. The subgrade test results appear on Enclosure 7. Chemical testing, comprised of pH, soluble sulfate, chloride, redox potential and resistivity testing was also performed. These test results are presented in the “Chemical Test Results” section of this report.

SOIL CONDITIONS

Undocumented fill consisting of loose to very dense gravelly sands with silt and a trace of clay was encountered in the majority of the test borings to the depths shown on the following table:

BORING NO.	DEPTH OF UNDOCUMENTED FILL (ft.)	DEPTH TO COMPETENT NATURAL GROUND (ft)
1	6.0	11.5
2	3.0	3.0
3	3.0	5.0
4	6.0	9.0
5	0.0	0.0
6	4.0	8.0
7	0.0	0.0
8	2.0	9.0
9	2.0	2.0
10	2.0	2.0

The relative compaction of the fill varied from 84 percent to 93 percent (ASTM D 1557). In Boring 1 some debris was observed in the fill. The natural soils encountered in our test borings consisted of loose to very dense sands and silty sands with varying amounts of gravel and an occasional trace of clay. Some of the near-surface soils exhibited a relatively high moisture content. The loose natural soil is susceptible to hydroconsolidation. The depth to competent natural ground as encountered in each boring is also presented in the table above. Ground water was encountered in Borings 1 and 2 at depths of 26.6 feet and 29.9 feet, respectively, and at a depth of 27.4 feet in Boring 6. Bedrock was not encountered in our test borings. Refusal on very dense soil occurred in Boring 10 at a depth of 6.2 feet. The soils encountered in our test borings have a very low expansion potential in accordance with ASTM D 4829.

LIQUEFACTION AND DYNAMIC SETTLEMENT

Liquefaction is a phenomenon that occurs when a soil undergoes a transformation from a solid state to a liquefied condition due to the effects of increased pore-water pressure. Loose saturated soils with particle sizes in the medium sand to silt range are particularly susceptible to liquefaction when subjected to seismic ground shaking. Affected soils lose all strength during liquefaction, and foundation failure can occur.

Ground water was encountered in Borings 1 and 2 at depths of 26.6 feet and 29.9 feet, respectively, and at a depth of 27.4 feet in Boring 6. Currently the site is approximately 52 feet above the water level of Big Bear Lake. Our consulting engineering geologist estimates that the shallowest historic depth to ground water is expected to have been 8 feet. For the purpose of this evaluation, we have assumed an historic high ground water table of 5 feet below the ground surface. This is the value used in our liquefaction analysis.

It is anticipated that major earthquake ground shaking will occur during the lifetime of the proposed development from the North Frontal fault zone, located approximately 4.5 miles north of the site. This fault would create the most significant earthshaking event. Based on an earthquake magnitude of 7.0, a peak horizontal ground acceleration of 0.81g is assigned to the site. To evaluate the potential for seismically induced liquefaction and settlement of the subsoils, the soils were analyzed for relative density. The most effective measurement of relative density of sands with respect to liquefaction and seismic settlement potential is standard penetration resistance. Standard penetration tests were performed as Boring 1 was advanced.

Using the information presented in Table 3 of Page 73 of the publication by Idriss and Boulanger (Soil Liquefaction During Earthquakes, Idriss and Boulanger, MNO-12, 2008) an analysis was conducted to determine the sampler correction factor Cs. The SPT sampler is machined to fit liners, therefore a correction factor of 1.0 may not be appropriate. Throughout the test boring, a calculation was performed to determine the average $(N_1)_{60}$ value from which Cs was subsequently determined. An average Cs value greater than 1.3 was calculated, therefore a value of 1.3 was used in the analysis.

The standard penetration data provided input for the LiquefyPro Version 4.3 program for seismically induced liquefaction and dynamic settlement potential. As indicated in Special Publication 117A (Revised), "Guidelines for Evaluating and Mitigating Seismic Hazards in California, March 2009," a safety factor of 1.3 was used in this analysis. We have assumed that the loose and potentially liquefiable soil will be overexcavated and recompacted, and can then be represented by an N value of 30. The results of this evaluation are shown on Enclosure 9 and reveal a low potential for liquefaction. The analysis also reveals a very low potential for dynamic settlement. We conclude that neither liquefaction nor dynamic settlement need be a concern for this site after the recommended site preparation.

CONCLUSIONS

The undocumented fill is inconsistent in density and has relative compaction values ranging from 84 percent to 93 percent (ASTM D1557). The fill should be overexcavated and replaced as engineered fill below building, retaining wall, site wall, and shade structure areas. The complete stabilization of the existing soil may not be economically warranted in hardscape and pavement areas. Significant stabilization can be obtained by overexciting and recompacting the upper 3 feet of the existing artificial fill in these areas. The natural soils are in a loose to very dense condition. The lose natural soil should also be overexcavated and recompacted. With appropriate site preparation, we conclude that the soil conditions underlying the areas of the new improvements are compatible with the proposed construction. Recommendations for foundation design are provided below for soils with a very low expansion potential.

RECOMMENDATIONS

FOUNDATION DESIGN

Shallow Foundations: Where the site is prepared as recommended, the proposed buildings, shade structures, retaining walls and site walls may be founded on conventional continuous and isolated footings. Footings supporting the buildings, shade structures, and retaining walls should be at least 18 inches deep, and should be designed for a maximum safe soil bearing pressure of 2,500 pounds per square foot for dead plus live loads. Site wall footings should be at least 12 inches in depth and designed for a maximum safe soil bearing pressure of 2,000 pounds per square foot. These values may be increased by one-third for wind and seismic loading.

Continuous footings should be reinforced with at least four No. 4 bars, two placed near the top and two near the bottom of the footings. This recommendation for foundation reinforcement is based on geotechnical considerations. Structural design may require additional foundation reinforcement.

For footings thus designed and constructed, we would anticipate a maximum settlement of less than 1 inch and a maximum differential settlement slope of 1:850.

Deep Foundations: We have assumed that the existing artificial fill and loose natural soil underlying the shade structures will be overexcavated and recompacted. For the site prepared as recommended, an average skin friction of 250 pounds per square foot should be assumed for the soil for pier embedment depths of at least 9 feet. This value may be increased by one-third for wind or seismic loading. Lateral load capacity of the pier footings may be computed using any accepted pole footing formula assuming an allowable lateral earth pressure of 300 pounds per square foot per foot of depth to a maximum of 3,000 pounds per square foot. Each cast-in-place concrete pier should be filled with concrete the same day it is excavated.

SEISMIC DESIGN PARAMETERS

The seismic design coefficients as required by the 2019 California Building Code and ASCE Standard 7-16 are provided in the following table:

Factor or Coefficient	***Value***
Latitude	34.2505° N
Longitude	-116.8888° W
Mapped S_S	1.642g
Mapped S_1	0.568g
F_a	1.0
F_v	1.732
Final S_{MS}	1.818g
Final S_{M1}	1.136g
Final S_{DS}	1.210g
Final S_{D1}	0.760g
PGA	0.81g
T_L	8 seconds
Site Class	D

LATERAL LOADING

Retaining wall backfill within 6 feet of the walls should consist of granular soil exhibiting a very low (expansion potential between 0 and 21) expansion potential. For a level backfill surface and cantilever retaining wall conditions, we recommend an active earth pressure of 35 pounds per square foot per foot of depth, exclusive of surcharge loads. For braced walls with level backfill surface conditions, we recommend an at-rest earth pressure of 60 pounds per square foot per foot of depth, exclusive of surcharge loads. For shallow footings, resistance to lateral loads will be provided by passive earth pressure and basal friction. For footings bearing against compacted fill, passive earth pressure may be considered to develop at a rate of 300 pounds per square foot per foot of depth. Basal friction may be computed at 0.35 times the normal dead load. The resistance from basal friction and passive earth pressure may be combined directly without reduction. A backdrain system or weep holes should be provided to prevent buildup of hydrostatic pressure behind retaining walls. The allowable lateral resistance may be increased by one-third for wind and seismic loading.

SLABS-ON-GRADE

Concrete slab-on-grade design recommendations are presented below. The slab-on-grade recommendations assume underlying utility trench backfills and pad subgrade soils have been densified to a relative compaction of at least 90 percent (ASTM D1557).

1. It is our opinion that the compacted fill soils should provide adequate support for concrete slabs-on-grade without the use of a gravel base. The final pad surface should be rolled to provide a smooth dense surface upon which to place the concrete.

2. Slab-on-grade floors should be at least 4 inches thick – structural considerations may require a thicker slab. The concrete slabs-on-grade may be designed using a modulus of subgrade reaction of 250 pounds per cubic inch.

3. It is recommended that concrete slabs-on-grade be reinforced with at least No. 3 bars at 16 inches each way in the middle third of the slab. Structural considerations may require additional reinforcement. All slab reinforcement should be supported by chairs or precast concrete blocks to ensure positioning of reinforcement of the slab. Lifting of unsupported reinforcement during concrete placement should not be allowed.

4. Slabs to receive moisture-sensitive floor coverings should be underlain with a moisture vapor retardant membrane, such as 10-mil Stego Wrap or equivalent. The moisture vapor retardant membrane should conform to ASTM E 1745-11 (Standard Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs). The moisture vapor retardant membrane should be lapped into the footing excavations to provide

full coverage of the subgrade soils. Punctures and/or holes cut for plumbing should be taped to minimize moisture emissions through the membrane. The project superintendent and/or a representative of the geotechnical engineer should inspect the placement of the moisture vapor retardant membrane prior to covering. Installation of the moisture vapor retardant membrane should be performed in accordance with ASTM E 1643-11 (Standard Practice for Selection, Design, Installation and Inspection of Water Vapor Retarders Used in Contact with Earth or Granular Fill under Concrete Slabs).

5. A 2-inch layer of clean sand (SE>30, no more than 7 percent passing the No. 200 sieve) should be placed over the moisture vapor retardant membrane to promote uniform setting of the concrete. Concrete should be placed on the sand blanket when the sand is damp. Excess moisture should not be allowed to accumulate within the sand blanket prior to concrete placement. At the time of concrete placement, the moisture content of the sand blanket above the moisture vapor retardant membrane should not exceed 2 percent <u>below</u> the optimum moisture content.

6. In lieu of placing the sand blanket described above and to further minimize future moisture vapor emissions through the slabs-on-grade, the slab concrete may be placed directly on the moisture vapor retardant membrane. Placing concrete directly on the moisture vapor retardant membrane will increase shrinkage and curling forces and make finishing more difficult. To accommodate these concerns, the structural engineer should provide appropriate mix design criteria for concrete placed directly on the moisture vapor retardant membrane.

7. We recommend a maximum water-cement ratio of 0.50 for all building slab concrete. Architectural or structural considerations may require the utilization of a lower water-cement ratio. Where slab concrete is placed directly on the moisture vapor retardant membrane without the presence of an intervening layer of absorptive sand, a lower maximum water-cement ratio may be needed.

8. Preparation of the concrete floor slabs should conform to ASTM F 710-11 (Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring) and the manufacturer's recommendations. Moisture vapor emission tests should be performed to verify acceptable moisture emission rates prior to flooring installation.

SITE PREPARATION

We assume that the site will be prepared in accordance with the California Building Code or the current City of Big Bear Lake Grading Ordinance. The recommendations presented below are to establish additional grading criteria. These recommendations should be considered preliminary and are subject to modification or expansion based on a geotechnical review of the project foundation and grading plans.

- All areas to be graded should be stripped of organic matter and other deleterious materials. All cavities created during site clearing should be cleaned of loose and disturbed soil, shaped to provide access for construction equipment, and backfilled with fill placed and compacted as described below.

- Undocumented fill should be removed from building, retaining wall and screen wall areas. Removal of the artificial fill in hardscape and pavement areas may be limited to a depth of 3 feet. Deleterious material should be separated from the removed fill and hauled from the site. The excavated fill should be stockpiled pending replacement or be placed in previously prepared areas.

- Overexcavation
  - The loose natural soils underlying building, retaining wall, and screen wall areas should be overexcavated until competent natural soil is encountered. Competent natural soil is defined as relatively non-porous undisturbed soil exhibiting a relative compaction of at least 85 percent (ASTM D1557). The natural soil should be further overexcavated so there is at least 2 feet of recompacted soil below the bottom of the footings. The soils exposed in the bottom of the excavations should be evaluated by a representative of the geotechnical engineer.

  - Limits of overexcavation – The overexcavation should extend beyond the building areas and retaining wall and screen wall footings a horizontal distance at least equal to the depth of overexcavation below the bottom of the foundation elements or 5 feet, whichever is greater. Due to property line constraints, overexcavation may not be possible outside the northwestern perimeter of the screen wall footing.

  - <u>Asphalt concrete parking and driveway areas</u> – Undocumented fill should be removed below parking, driveway and fire lane areas to a maximum depth of 3 feet. The soils exposed in the subexcavated surface should be scarified to a depth of at least 12 inches, moisture conditioned to at least the optimum moisture content, and densified to a minimum relative compaction of 90 percent (ASTM D1557).

  - <u>Hardscape areas</u> – Undocumented fill should be removed below proposed hardscape areas to a maximum depth of 3 feet. The exposed soils below these areas should be scarified to a depth of at least 12 inches, moisture conditioned to at least the optimum moisture content and densified to a minimum relative compaction of 90 percent (ASTM D1557).

- Approved subexcavated surfaces and all other surfaces to receive fill should be scarified to a minimum depth of 12 inches, moisture conditioned to at least the optimum moisture content, and densified to a minimum relative compaction of 90 percent (ASTM D1557).

- The on-site soils should provide adequate quality fill material provided they are free from significant organic matter and other deleterious materials, and are at acceptable moisture contents. Import fill should be inorganic, granular, non-expansive soil free from rocks or lumps greater than 8 inches in maximum dimension and should exhibit a very low expansion potential (expansion index less than 21), negligible sulfate content (less than 1,000 ppm soluble sulfate by weight), and low corrosion potential. Prior to bringing import fill to the site, the contractor should obtain certification to verify that the proposed import meets the State of California Department of Toxic Substance Control (DTSC) environmental standards. Proposed import should be sampled at the source and tested by this firm for expansion index, soluble sulfate content, and corrosion potential.

- All fill should be placed in 8-inch or less lifts, moisture conditioned to at least the optimum moisture content and densified to a minimum relative compaction of 90 percent (ASTM D 1557). Where the overexcavation cannot extend to the horizontal limits recommended, the fill should be densified to a relative compaction of at least 95 percent.

- The surface of the site should be graded to provide positive drainage away from the structures. Drainage should be directed to established swales and then to appropriate drainage structures to minimize the possibility of erosion. Water should not be allowed to pond adjacent to footings.

SHRINKAGE AND SUBSIDENCE

Volume change in going from cut to fill conditions is anticipated where near-surface grading will occur. Assuming the fill will be compacted to an average relative compaction of 93 percent, an average cut-fill shrinkage of 10 to 15 percent is estimated. Further volume loss will occur through subsidence during preparation of the natural ground surface. Although the contractor's methods and equipment utilized in preparing the natural ground will have a significant effect on the amount of natural ground subsidence that will occur, our experience indicates as much as 0.10 to 0.15 foot of subsidence in areas prepared to receive fill should be anticipated. These values are exclusive of losses due to stripping or removal of subsurface obstructions.

FLOODING

Our geologist has indicated that the eastern portion of the site is situated within a flood hazard zone that is denoted as being "Special Flood Hazard Areas Subject to Inundation by the 1% Annual Chance Flood." The potential for flood hazards should be evaluated by the project civil engineer.

ASPHALT CONCRETE AND PORTLAND CEMENT CONCRETE HARDSCAPE

Representative samples of near-surface soil at the site have been tested for relevant subgrade properties. A Traffic Index of 5.0 was assumed for the new parking lots and drive areas for conventional vehicular traffic, and a Traffic Index of 7.0 was assumed for areas accommodating heavier truck and bus traffic and fire lanes. In conjunction with the test data shown on Enclosure 7, we believe the sections presented on the following table should provide durable pavement.

Asphalt Concrete Pavement

Location	TI	"R" Value	Thickness (Inches)	
			Asphalt Concrete	Aggregate Base
Conventional Passenger Vehicles	5.0	45	2.5	4.0
Fire Lane and Truck Traffic Areas	7.0	45	3.0	8.0

For hardscape areas to receive only pedestrian traffic, we recommend portland cement concrete pavement be at least 3.5 inches in thickness and be placed directly on compacted subgrade soil. Prior to the placement of hardscape concrete, we recommend that the final subgrade surface be scarified to a depth of at least 12 inches, moisture conditioned to near the optimum moisture content, and densified to a minimum relative compaction of 90 percent (ASTM D1557).

The above designs are preliminary and for estimating purposes only. We recommend that during the process of rough grading, observation and additional testing of the actual subgrade soils should be performed. Final pavement design sections can then be determined. The foregoing pavement sections assume that utility trench backfill below all proposed pavement areas will be compacted to at least 90 percent relative compaction. Prior to the placement of aggregate base, we recommend that the final subgrade surface be scarified to a depth of at least 12 inches, moisture conditioned to near the optimum moisture content, and compacted to a minimum relative compaction of 90 percent (ASTM D1557). Aggregate base should be densified to at least 95 percent relative compaction. Suggested specifications for aggregate base material are presented on Enclosure 8. The preparation of the subgrade and compaction of the aggregate base should be monitored by a representative of the geotechnical engineer.

CHEMICAL TEST RESULTS

The chemical test results from a sample taken from Boring 1 between the ground surface and a depth of 5 feet are shown on the following table:

Analysis	Result	Units
Saturated Resistivity	3700	ohm-cm
Chloride	ND (Not Detected)	ppm
Sulfate	30	ppm
pH	7.7	pH units
Redox Potential	295	mV

The chemical test results from a sample taken from Boring 2 between the ground surface and a depth of 5 feet are shown on the following table:

Analysis	Result	Units
Saturated Resistivity	5000	ohm-cm
Chloride	ND (Not Detected)	ppm
Sulfate	30	ppm
pH	7.3	pH units
Redox Potential	260	mV

The soil tested in both borings exhibited negligible soluble sulfate content, therefore, sulfate-resistant concrete will not be required for this project. In addition, the results of the corrosivity testing indicate that the soil tested is not detrimentally corrosive to buried ferrous-metal pipes.

GAS ODOR

During our field investigation and during our review of the soil samples in the laboratory, there was no gas odor detected from the boreholes or from any of the samples.

FOUNDATION AND GRADING PLAN REVIEW

The project foundation and grading plans should be reviewed by the geotechnical engineer. Additional recommendations may be required at that time.

CONSTRUCTION OBSERVATIONS

All grading operations, including the preparation of the natural ground surface, should be observed and compaction tests performed by this firm. No fill should be placed on any prepared surface until that surface has been evaluated by the representative of the geotechnical engineer. The footing excavations for the buildings and shade structures should be evaluated by a representative of the geotechnical engineer. All footing excavations should be observed by the representative of the geotechnical engineer prior to placement of forms or reinforcing steel.

The conclusions and recommendations presented in this report are based upon the field and laboratory investigation described herein and represent our best engineering judgment. Should conditions be encountered in the field that appear different from those described in this report, we should be contacted immediately in order that appropriate recommendations might be prepared.

Respectfully submitted,

JOHN R. BYERLY, INC.

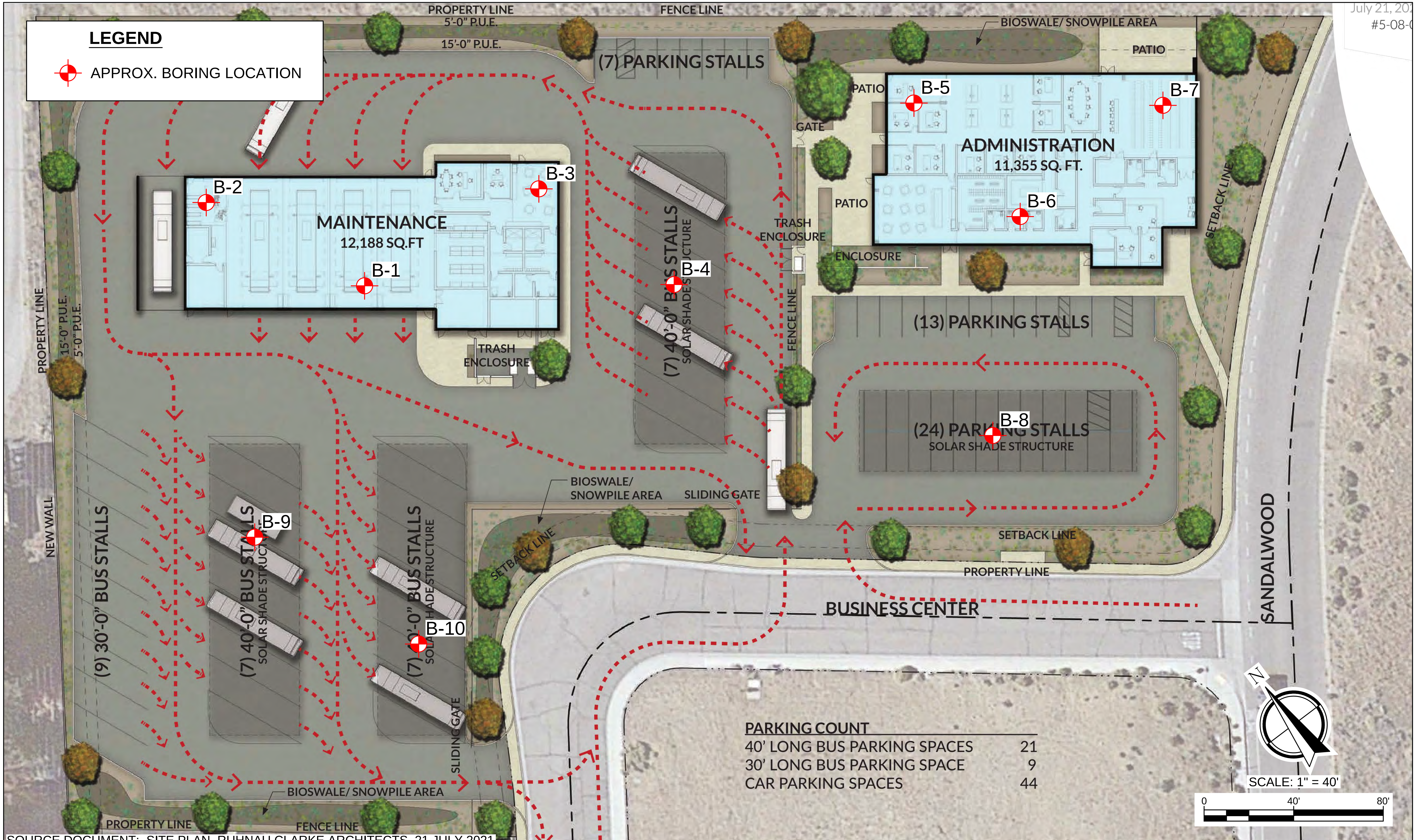
LICENSED PROFESSIONAL ENGINEER
JOHN R. BYERLY
GE 000179
EXP. 06/30/23
GEOTECHNICAL
STATE OF CALIFORNIA

John R. Byerly, Geotechnical Engineer
President

JRB:GSF:jet

Enclosures:
(1) Plot Plan
(2) Test Boring Logs
(3) Maximum Density Determinations
(4) Consolidation Test Results
(5) Direct Shear Test Data
(6) Expansion Index Test Results
(7) Subgrade Test Results
(8) Specifications for Aggregate Base
(9) Liquefaction Analysis
(10) Geologic Hazards Report

FOR REFERENCE ONLY



SOURCE DOCUMENT: SITE PLAN, RUHNAU CLARKE ARCHITECTS, 21 JULY 2021

John R. Byerly
INCORPORATED

GEOTECHNICAL INVESTIGATION

MOUNTAIN AREA REGIONAL TRANSIT AUTHORITY
160-170 BUSINESS CENTER
BIG BEAR LAKE, CALIFORNIA

Enclosure 1
Rpt. No.: 7341
File No.: S-14447

B-1

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table
0						
		50	122	8.6	91	
		50/6"	---	9.3	---	
		50/9"	124	10.6	93	
	11					
10		50/9"	---	---	---	
	13					
		50	105	23.3	81	
	29					
20		50/10"	107	19.5	92	
	42					
		50/8"	109	15.3	93	
						▼
	31					
30		43	99	36.0	---	
	83					
	58					
40	49					
	34					
50	55					
	100					
60	51					
	50					
70						

SM Red-brown gravelly fine to coarse sand with silt and a trace of clay and debris, moist and dense (FILL)
- becoming very dense at 3.5 feet

SM Light gray-brown silty fine to medium sand, moist and dense (NATURAL GROUND)
- becoming medum dense at 11.5 feet
- becoming wet and loose to medium dense at 15.0 feet

SM Light gray-brown silty fine to medium sand with a trace of clay, wet and dense
- ground water encountered at 26.6 feet

SP Light brown fine to medium sand, saturated and dense
- becoming very dense at 31.5 feet

SM Brown silty fine to medium sand, saturated and very dense
- becoming dense at 40.0 feet
- becoming very dense at 50.0 feet

SM Gray-brown silty fine to medium sand with a trace of clay, saturated and very dense

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration
Building and Maintenance Facility

Enclosure 2, Page 1
Rpt. No.: 7341
File No.: S-14447

B-1

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table			
70	81						▨	SM	Gray-brown silty fine to medium sand with a trace of clay, saturated and very dense
									Total Depth at 71.5 Feet Free Ground Water Encountered at 26.6 Feet
80									
90									
100									
110									
120									
130									
140									

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration Building and Maintenance Facility

B-2

Boring Date: 3/10/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table		
0							SM	Gray-brown gravelly fine to medium sand with silt and a trace of clay, moist and medium dense (FILL)
		14	118	12.7	89			
		15	113	11.0	86		SM	Red-brown silty fine to medium sand with gravel, moist and medium dense (NATURAL GROUND)
5		50/3"	---	---	---			- becoming very dense at 5.0 feet
							SM	Light brown silty fine to medium sand, wet to saturated and medium dense
		40	---	27.1	---			
10		50/10"	111	16.2	85			
15		45	111	26.3	85			
20		50/11"	---	24.8	---			- becoming dense at 20.0 feet
25		50/7"	119	14.8	92			
30		50/11"	110	21.1	85	▼		- ground water encountered at 29.9 feet
35								

Total Depth at 31.4 Feet
Free Ground Water Encountered at 29.9 Feet

SuperLog CivilTech Software, USA www.civiltech.com File: C:\Superlog4\PROJECT\S-14447 (Rpt. No. 7341).log Date: 4/12/2022

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration Building and Maintenance Facility

B-3

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table
		50/9"	119	12.8	90	GWT not encountered
		12	109	14.2	83	
		24	---	5.8	---	
		35	105	27.6	81	
		50/11"	107	20.6	82	
		50	110	18.7	85	

SM Gray-brown gravelly fine to medium sand with silt and a trace of clay, moist and dense (FILL)

SM Red-brown silty fine to medium sand with gravel, wet and loose (NATURAL GROUND)

- becoming damp and medium dense at 5.5 feet

SM Light brown silty fine to medium sand, wet to saturated and loose to medium dense

- becoming wet at 10.5 feet

- becoming medium dense at 15.0 feet

Total Depth at 16.5 Feet
No Free Ground Water Encountered

SuperLog CivilTech Software, USA www.civiltech.com File: C:\Superlog4\PROJECTS\S-14447 (Rpt. No. 7341).log Date: 4/11/2022

LOG OF BORING

B-4

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table		
0						GWT not encountered	SM	Red-brown gravelly fine to medium sand with silt, and a trace of clay, moist and medium dense (FILL)
		50	113	9.0	86			
		40	123	12.6	93			- becoming dense at 3.5 feet
5		45	121	9.4	92			
							SM	Brown silty fine to medium sand with gravel, moist and loose (NATURAL GROUND)
		11	110	12.3	83			
							SP	Red-brown fine to coarse sand with gravel and rock fragments, damp and dense
10		46	114	6.1	---			
							SM	Gray-brown silty fine to medium sand, wet and medium dense
15		43	110	24.0	85			
								- becoming very dense at 17.0 feet
20		50/7"	---	---	---			
								Total Depth at 20.6 Feet No Free Ground Water Encountered
25								
30								
35								

SuperLog CivilTech Software, USA www.civiltech.com File: C:\Superlog4\PROJECT\S-14447 (Rpt. No. 7341).log Date: 4/11/2022

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration Building and Maintenance Facility

Enclosure 2, Page 5
Rpt. No.: 7341
File No.: S-14447

B-5

Boring Date: 3/10/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table		
0						GWT not encountered	SM	Dark brown gravelly fine to medium sand with silt, moist and medium dense
		42	---	12.6	---			
		25	117	13.5	89		SM	Gray-brown silty fine to medium sand with gravel, moist and medium dense
5		15	114	9.3	86			
		28	---	6.4	---		SM	Light brown fine to coarse sand with gravel and rock fragments, damp and medium dense
							SM	Light gray silty fine to medium sand, moist and medium dense
10		50/10"	113	14.6	87			
15		50/9"	---	20.8	---			- becoming wet and dense at 15.0 feet
20		50	111	17.3	85			- becoming medium dense at 20.0 feet
25		50/11"	112	21.0	86			
30		50/7"	---	15.6	---			- becoming very dense at 30.0 feet
								Total Depth at 31.0 Feet No Free Ground Water Encountered
35								

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration
Building and Maintenance Facility

B-6

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table
0						
		16	111	12.8	84	
		36	118	9.0	89	
5		26	115	11.9	87	
		11	106	17.7	82	
10		50/9"	---	7.6	---	
15		50/6"	124	4.6	95	
20		50/10"	100	25.6	86	
25		50/7"	---	---	---	
						▼
30		42	---	26.6	---	
35						

SM	Dark brown gravelly fine to medium sand with silt and a trace of clay, moist and loose (FILL) - becoming medium dense at 3.5 feet
SM	Red-brown silty fine to medium sand with gravel, moist and medium dense (NATURAL GROUND)
SM	Red-brown silty fine to medium sand, wet and loose
SP	Red-brown fine to coarse sand with gravel and rock fragments, wet and dense
SM	Light gray-brown silty fine to medium sand, damp and very dense
SM	Light gray-brown silty fine to medium sand with a trace of clay, wet and medium dense to dense - becoming saturated at 27.4 feet

Total Depth at 31.5 Feet
Ground Water Encountered at 27.4 Feet

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration Building and Maintenance Facility

Enclosure 2, Page 7
Rpt. No.: 7341
File No.: S-14447

B-7

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table		
0						GWT not encountered	SM	Dark brown silty fine to medium sand with gravel, moist and medium dense
		30	115	13.8	87			
		18	117	13.4	89			
5		22	---	3.7	---			- becoming damp at 5.5 feet
		50/2"	---	---	---			- becoming very dense at 7.5 feet
10		50/6"	---	---	---			
							SM	Light gray-brown silty fine to coarse sand with a trace of clay, wet and very dense
15		50/3"	---	---	---			
20								
25								
30								
35								

Total Depth at 15.8 Feet
No Free Ground Water Encountered

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration Building and Maintenance Facility

Enclosure 2, Page 8
Rpt. No.: 7341
File No.: S-14447

B-8

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table		
0						GWT not encountered	SM	Dark brown gravelly fine to medium sand with silt and a trace of clay, moist and dense (FILL)
		50/11"	---	---	---			
		23	114	9.4	86		SM	Red-brown silty fine to medium sand with gravel, moist and medium dense (NATURAL GROUND)
5		27	114	19.5	86			
								- becoming wet at 5.5 feet
							SM	Red-brown silty fine to medium sand, moist and loose
		10	109	11.0	84			
10		50/8"	106	13.3	91		SM	Light gray-brown silty fine to medium sand with a trace of clay, wet and very dense
15		50/10"	108	18.0	93			
20		50/7"	---	---	---			
25								
30								
35								

Total Depth at 21.0 Feet
No Free Ground Water Encountered

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration Building and Maintenance Facility

Enclosure 2, Page 9
Rpt. No.: 7341
File No.: S-14447

FOR REFERENCE ONLY

B-9

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table
0						GWT not encountered
		48	115	10.0	87	
		50/6"	---	11.9	---	
5		50/9"	120	7.5	91	
		18	113	10.9	87	
10		50/9"	---	3.4	---	
15		50/10"	118	15.8	91	
20		50/8"	---	14.1	---	
25						
30						
35						

SM	Dark brown gravelly fine to medium sand with silt and a trace of clay, moist and medium dense (FILL)
SM	Red-brown silty fine to medium sand with gravel, moist and very dense (NATURAL GROUND)
SM	Red-brown silty fine to medium sand, moist and medium dense - becoming damp and dense at 10.5 feet - becoming wet at 15.5 feet - becoming very dense at 20.0 feet

Total Depth at 21.2 Feet
No Free Ground Water Encountered

SuperLog CivilTech Software, USA www.civiltech.com File: C:\Superlog4\PROJECT\S-14447 (Rpt. No. 7341).log Date: 4/12/2022

LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration
Building and Maintenance Facility

Enclosure 2, Page 10
Rpt. No.: 7341
File No.: S-14447

B-10

Boring Date: 1/20/22
Surface Elevation:
Drilling Method: Flight-Auger

Depth	Std. Pen. "N" Value	Blows/Ft.	Dry Density (PCF)	Moisture Content (%)	Rel. Compaction (%)	Water Table
0						GWT not encountered
		50/9"	120	8.0	91	
		50/8"	121	7.8	92	
5						
		50/8"	123	6.6	93	
10						
15						
20						
25						
30						
35						

SM Dark brown gravelly fine to medium sand with silt and a trace of clay, moist and dense (FILL)

SM Red-brown silty fine to medium sand with gravel, moist and very dense (NATURAL GROUND)

Refusal on Very Dense Soil at 6.2 Feet
No Free Ground Water Encountered

SuperLog CivilTech Software, USA www.civiltech.com File: C:\Superlog4\PROJECT\S-14447 (Rpt. No. 7341).log Date: 4/11/2022

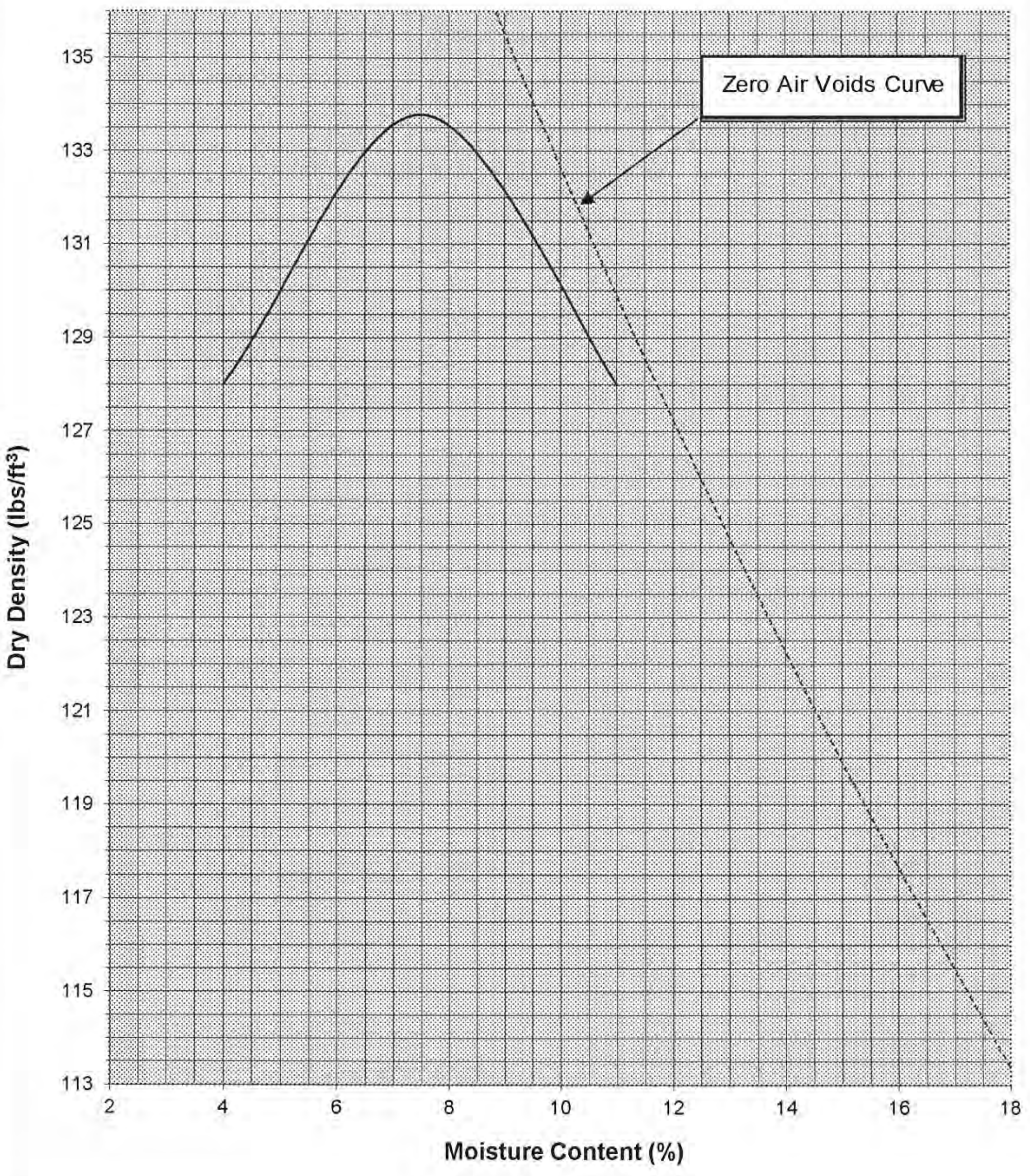
LOG OF BORING

John R. Byerly, Inc.

MARTA New Administration Building and Maintenance Facility

Enclosure 2, Page 11
Rpt. No.: 7341
File No.: S-14447

Moisture/Density Relationship
ASTM D1557 (Method A)

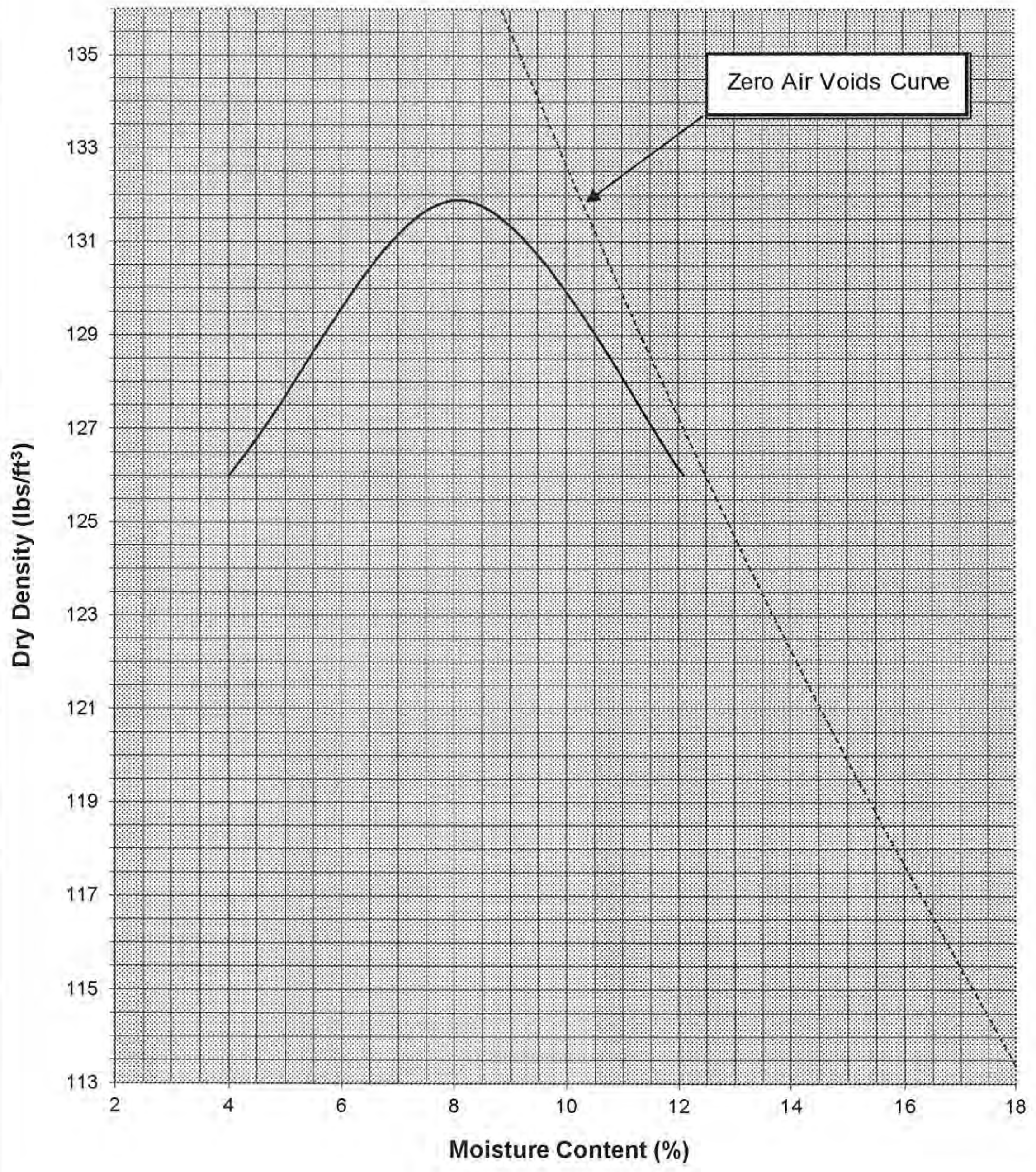


Boring No.	B-1
Depth (ft.)	3.5
Optimum Moisture (%)	7.5
Maximum Dry Density (pcf)	133.8
Soil Classification	Brown gravelly fine to coarse sand with silt and a trace of clay

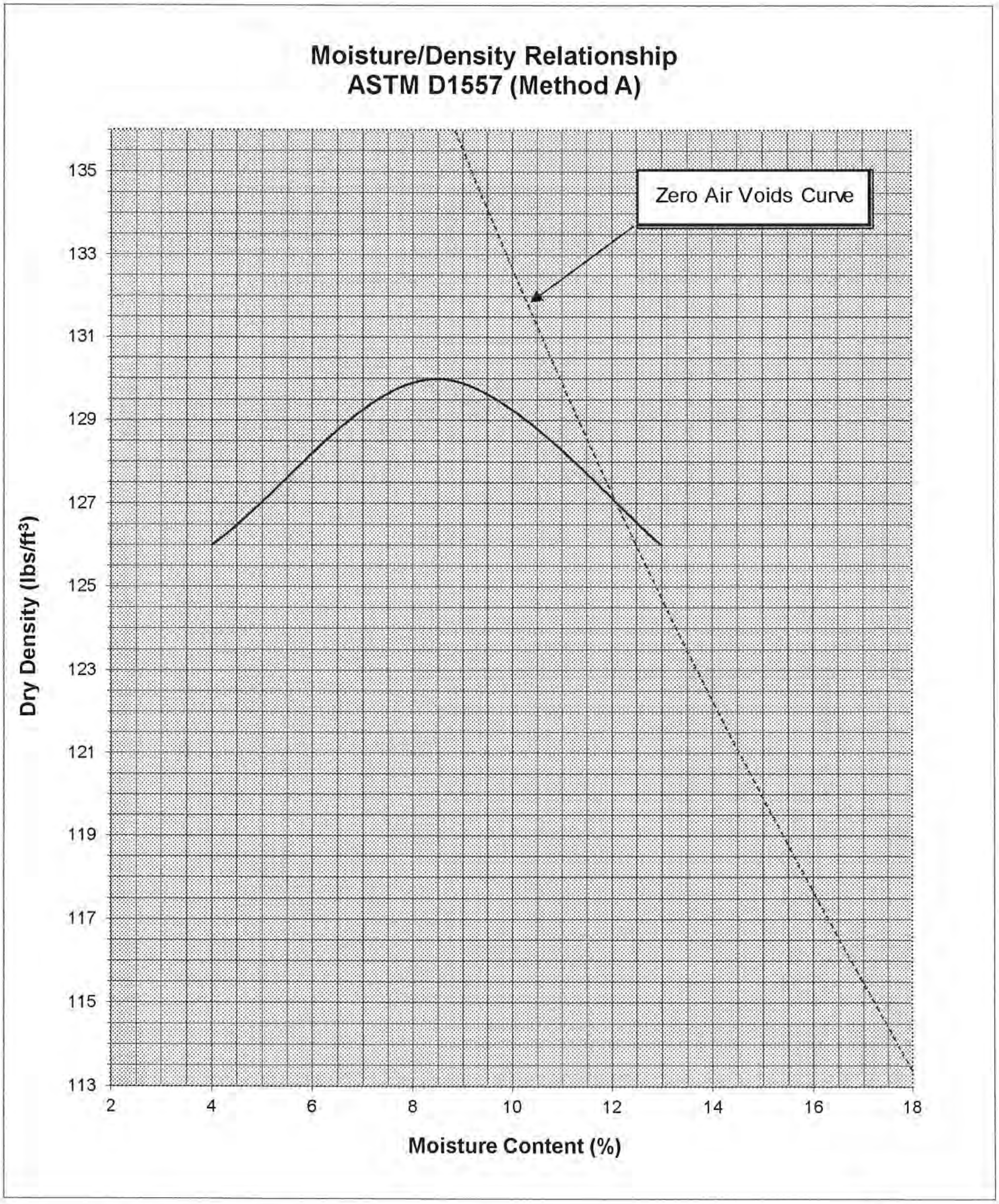
MARTA Administration Building
Big Bear Lake, California

Enclosure 3, Page 1
Rpt. No.: 7341
File No.: S-14447

Moisture/Density Relationship
ASTM D1557 (Method A)

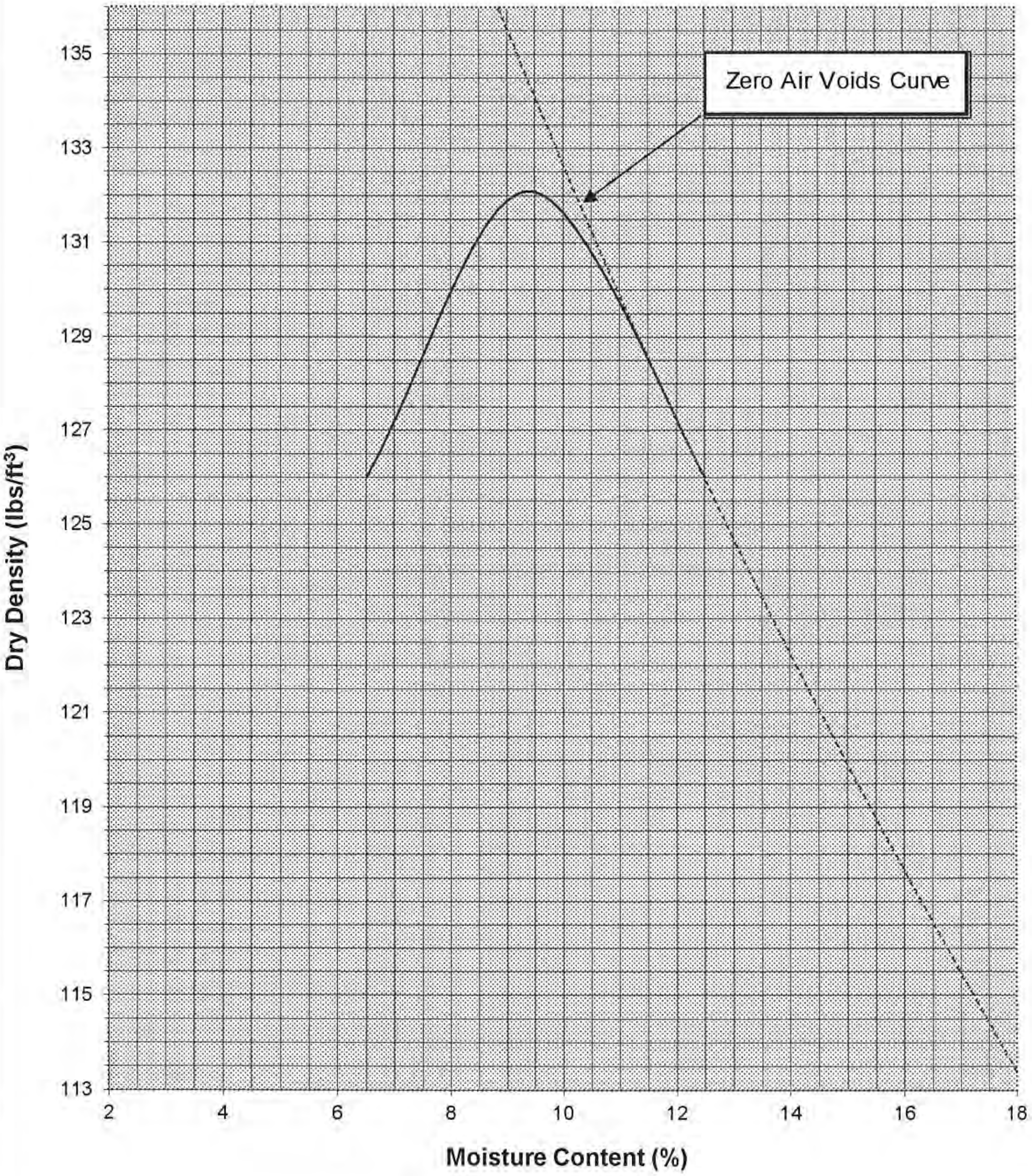


Boring No.	B-2
Depth (ft.)	5.5
Optimum Moisture (%)	8.1
Maximum Dry Density (pcf)	131.9
Soil Classification	Red-brown silty fine to medium sand with gravel (SM)



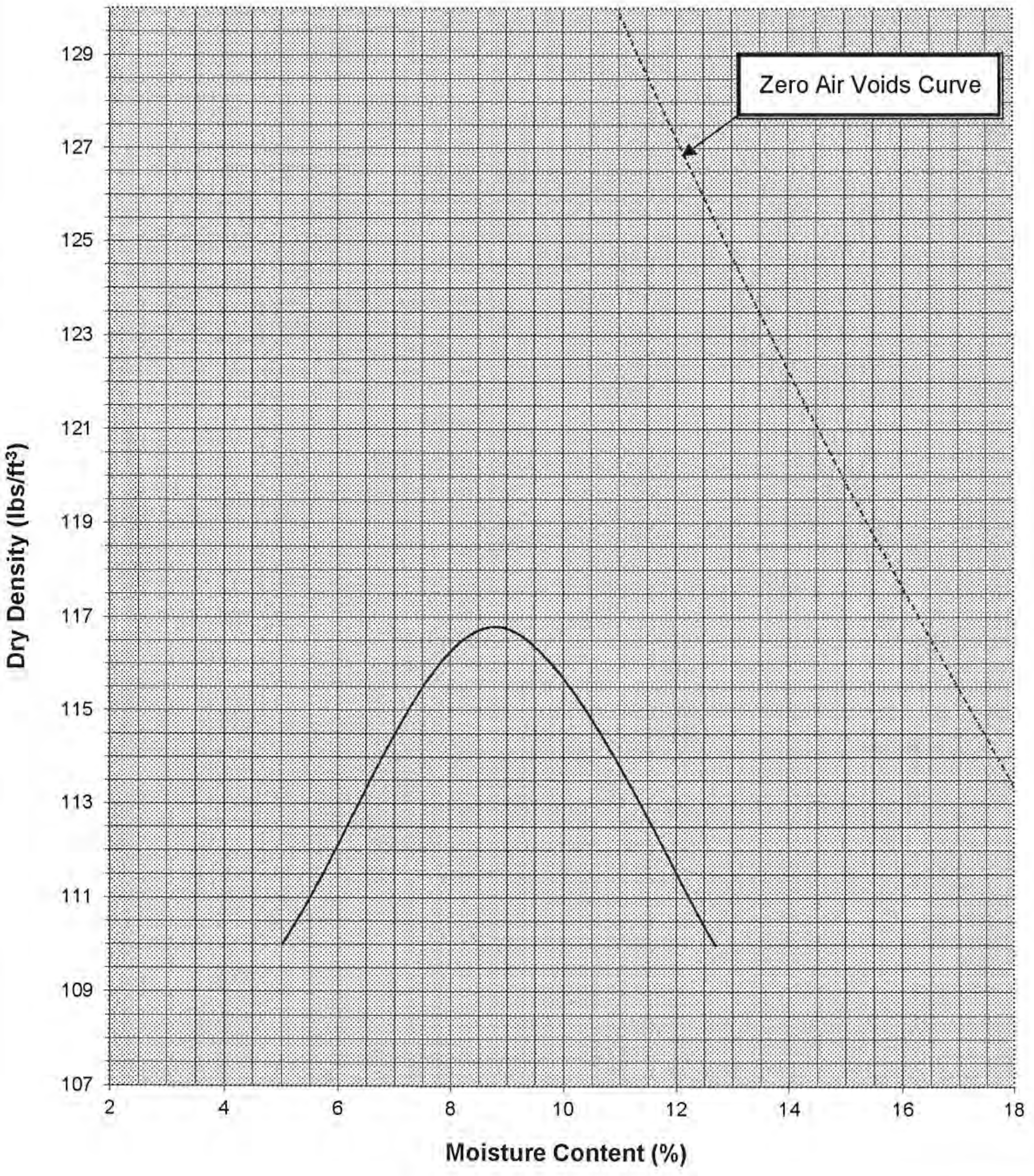
Boring No.	B-2
Depth (ft.)	7.5
Optimum Moisture (%)	8.5
Maximum Dry Density (pcf)	130.0
Soil Classification	Light brown silty fine to medium sand (SM)

Moisture/Density Relationship
ASTM D1557 (Method A)



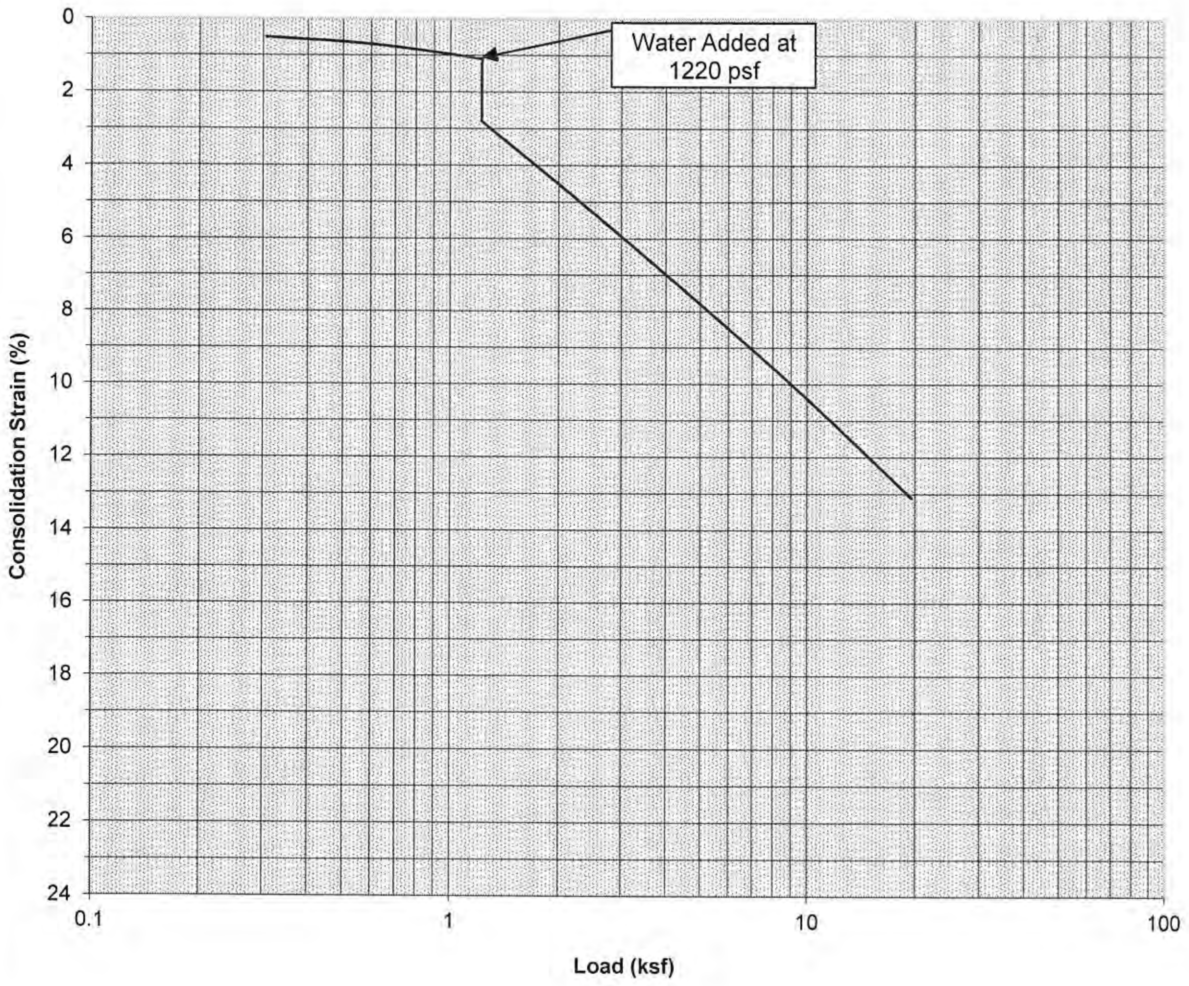
Boring No.	B-3
Depth (ft.)	1.5
Optimum Moisture (%)	9.4
Maximum Dry Density (pcf)	132.1
Soil Classification	Gray-brown gravelly f-m sand with silt and a trace of clay (SM)

Moisture/Density Relationship
ASTM D1557 (Method A)



Boring No.	B-8
Depth (ft.)	15.5
Optimum Moisture (%)	8.8
Maximum Dry Density (pcf)	116.8
Soil Classification	Light gray-brown silty fine to medium sand with a trace of clay

Consolidation Test Results



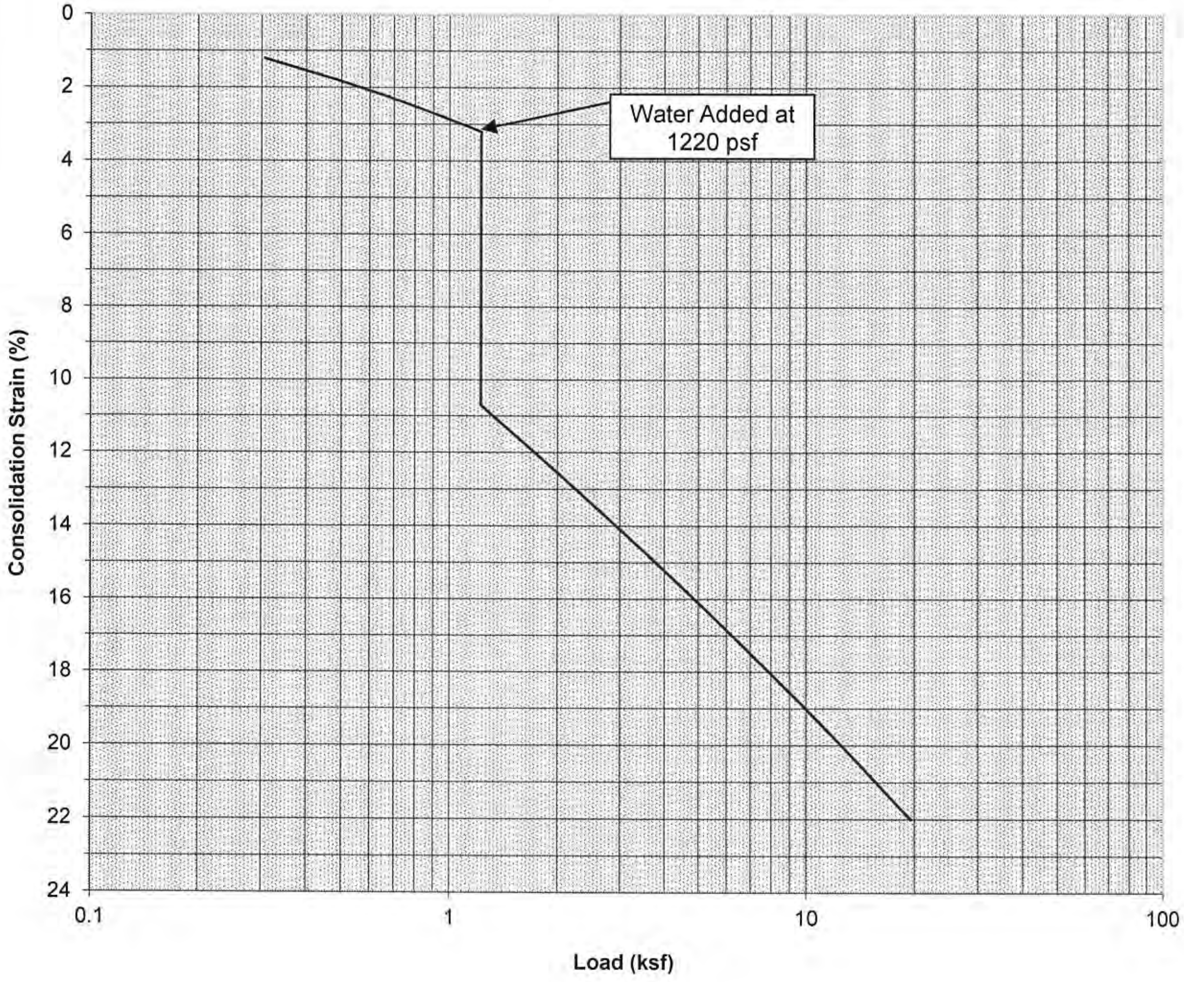
Classification: SM

Boring Number:	B-4
Depth (ft)	7.5
Specimen Diameter (in)	2.4
Specimen Thickness (in)	1.0

Initial Moisture Content (%)	12.3
Final Moisture Content (%)	15.8
Initial Dry Density (pcf)	110

Enclosure 4, Page 1
Rpt. No.: 7341
File No.: S-14447

Consolidation Test Results



Classification: SM

Boring Number:	B-8	Initial Moisture Content (%)	11.0
Depth (ft)	7.5	Final Moisture Content (%)	16.8
Specimen Diameter (in)	2.4	Initial Dry Density (pcf)	109
Specimen Thickness (in)	1.0		

John R. Byerly
INCORPORATED

DIRECT SHEAR TESTS

Test Boring No.	Depth of Sample (Ft.)	Angle of Internal Friction (°)	Cohesion (PSF)
B-4	7.5	31	50
B-8	7.5	31	50
B-9	5.5	33	0

EXPANSION INDEX TEST DATA
ASTM D 4829/ASTM D 2488

Project: Mountain Area Regional Transit Authority

Date: April 11, 2022

Soil Description: Silty fine to coarse sand with a trace of clay

Location: B-1 at 3.5'

Soil I.D.	Initial Height (0.001 in.)	Initial Water Content (%)	Initial Dry Unit Weight (0.1 lbf/ft^3)	Degree of Saturation (%)	Initial Dial Reading (0.001)	Final Dial Reading (0.001)	Final Water Content (0.1%)	Expansion Index	Classification of Potential Expansion
B-1	1.000	9.6	112.7	52.0	0.1677	0.1646	16.7	3	Very low

Expansion Index determined by adjusting the water content to achieve a degree of saturation of 50 +/- 2%.

RESULTS OF SUBGRADE SOIL TESTS

California Department of Transportation Test Methods 202, 217, & 301
ASTM Designations C136 and D2419

PROJECT: Mountain Area Regional Transit Authority

		Percent Passing Sieve Size:														
Sample No.	Location	3”	2½”	2”	1½”	1”	3/4”	1/2”	3/8”	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200	Sand Equiv.
1	B-2 at 0-5’			100	97	95	93	89	85	75	70	64	58	50	40	30	10
2	B-5 at 0-5’		100	99	96	92	86	81	75	66	64	59	53	45	36	28	10

STABILOMETER “R” VALUE

1

Sample No.		1	
Moisture Content (%)	10.3	10.7	11.1
Dry Density (lbs./cu. ft.)	125.0	123.5	122.2
Exudation Pressure (psi)	653	447	252
Expansion Pressure (psf)	108.25	64.95	34.64
“R” Value	60	52	43
“R” Value at 300 PSI Exudation		45	

Enclosure 7
Rpt. No.: 7341
File No.: S-14447

John R. Byerly
INCORPORATED

SUGGESTED SPECIFICATIONS FOR CLASS II BASE

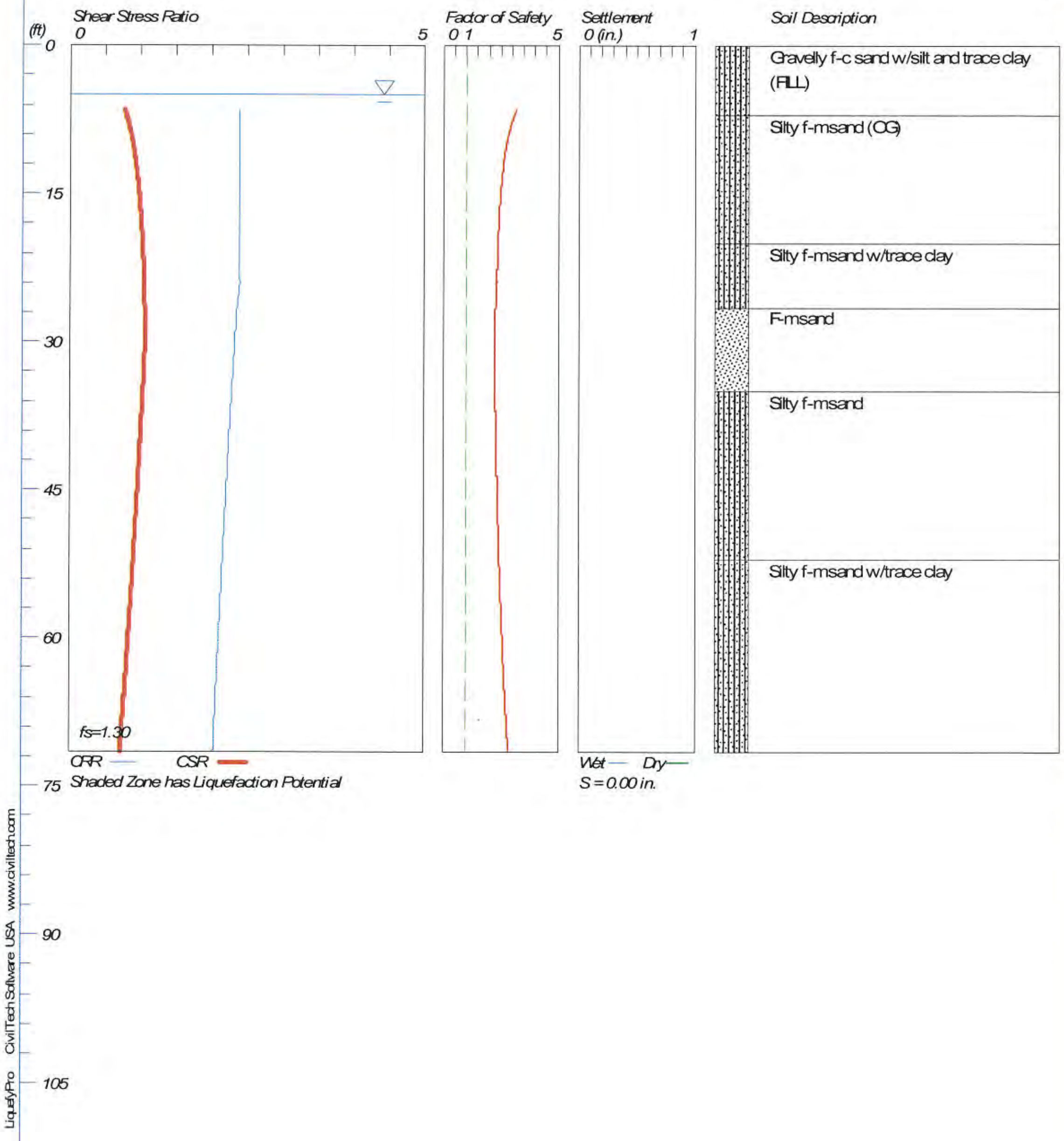
Sieve Size	Percent Finer Than
1 Inch	100
3/4 Inch	90 - 100
No. 4	35 - 60
No. 30	10 - 30
No. 200	2 - 9
Sand Equivalent (Minimum)	25
"R" Value (minimum) at 300 psi Exudation	78

LIQUEFACTION ANALYSIS

MARTA - NEW ADMINISTRATION BUILDING AND MAINTENANCE FACILITY

Hole No.=B-1 Water Depth=5.0 ft Surface Elev.=6779 feet AMSL

Magnitude=7.0
Acceleration=0.81g



```
*************************************************************************************
*******************
                                        LIQUEFACTION ANALYSIS CALCULATION SHEET

                                                    Version 4.3
                                             Copyright by CivilTech Software
                                                   www.civiltech.com
                                          (425) 453-6488   Fax (425) 453-5848

*************************************************************************************
*******************
        Licensed to John R Byerly, John R. Byerly, Inc. 4/12/2022       3:04:31 PM

        Input File Name: T:\Liquefy4\S-14447.1.liq
        Title:  MARTA - NEW ADMINISTRATION BUILDING AND MAINTENANCE FACILITY
        Subtitle:  S-14447

        Surface Elev.=6779 feet AMSL
        Hole No.=B-1
        Depth of Hole= 71.5 ft
        Water Table during Earthquake= 5.0 ft
        Water Table during In-Situ Testing= 26.6 ft
        Max. Acceleration= 0.81 g
        Earthquake Magnitude= 7.0
        User defined factor of safty (applied to CSR)        User fs=1.3
        fs=user,  Plot one CSR (fs=user)

        Hammer Energy Ratio, Ce=1
        Borehole Diameter, Cb=1.15
        Sampeling Method, Cs=1.3
        SPT Fines Correction Method: Stark/Olson et al.*
        Settlement Analysis Method: Ishihara / Yoshimine*
        Fines Correction for Liquefaction: Stark/Olson et al.*
        Fine Correction for Settlement: Post-Liq. Correction *
        Average Input Data: Smooth*
        * Recommended Options

Input Data:
        Depth     SPT      Gamma    Fines
        ft                 pcf      %
        ____________________________________
        6.5       30.0     130.0    28.0
        11.5      30.0     130.0    20.0
        16.5      29.0     129.0    20.0
        21.5      42.0     128.0    25.0
        26.5      31.0     135.0    1.0
        31.5      83.0     135.0    1.0
        35.0      58.0     135.0    15.0
        40.0      49.0     135.0    15.0
        45.0      34.0     135.0    15.0
        50.0      55.0     135.0    15.0
        55.0      100.0    135.0    25.0
        60.0      51.0     135.0    25.0
        65.0      50.0     135.0    25.0
        70.0      81.0     135.0    25.0
        ____________________________________

Output Results:
        Settlement of saturated sands=0.00 in.
        Settlement of dry sands=0.00 in.
        Total settlement of saturated and dry sands=0.00 in.
```

```
Differential Settlement=0.000 to 0.000 in.

Depth   CRRm    CSRfs   F.S.    S_sat.  S_dry   S_all
ft              w/fs            in.     in.     in.
_______________________________________________________
6.50    2.39    0.76    3.15    0.00    0.00    0.00
7.50    2.39    0.80    2.98    0.00    0.00    0.00
8.50    2.39    0.84    2.85    0.00    0.00    0.00
9.50    2.39    0.87    2.75    0.00    0.00    0.00
10.50   2.39    0.89    2.67    0.00    0.00    0.00
11.50   2.39    0.91    2.61    0.00    0.00    0.00
12.50   2.39    0.93    2.56    0.00    0.00    0.00
13.50   2.39    0.95    2.51    0.00    0.00    0.00
14.50   2.39    0.96    2.47    0.00    0.00    0.00
15.50   2.39    0.98    2.44    0.00    0.00    0.00
16.50   2.39    0.99    2.41    0.00    0.00    0.00
17.50   2.39    1.00    2.39    0.00    0.00    0.00
18.50   2.39    1.01    2.36    0.00    0.00    0.00
19.50   2.39    1.02    2.34    0.00    0.00    0.00
20.50   2.39    1.02    2.33    0.00    0.00    0.00
21.50   2.39    1.03    2.31    0.00    0.00    0.00
22.50   2.39    1.04    2.30    0.00    0.00    0.00
23.50   2.39    1.04    2.29    0.00    0.00    0.00
24.50   2.39    1.05    2.28    0.00    0.00    0.00
25.50   2.37    1.05    2.26    0.00    0.00    0.00
26.50   2.36    1.05    2.24    0.00    0.00    0.00
27.50   2.35    1.05    2.23    0.00    0.00    0.00
28.50   2.34    1.06    2.21    0.00    0.00    0.00
29.50   2.33    1.06    2.20    0.00    0.00    0.00
30.50   2.32    1.06    2.20    0.00    0.00    0.00
31.50   2.31    1.05    2.20    0.00    0.00    0.00
32.50   2.30    1.04    2.21    0.00    0.00    0.00
33.50   2.30    1.04    2.21    0.00    0.00    0.00
34.50   2.29    1.03    2.22    0.00    0.00    0.00
35.50   2.28    1.02    2.23    0.00    0.00    0.00
36.50   2.27    1.02    2.23    0.00    0.00    0.00
37.50   2.26    1.01    2.24    0.00    0.00    0.00
38.50   2.26    1.00    2.25    0.00    0.00    0.00
39.50   2.25    1.00    2.26    0.00    0.00    0.00
40.50   2.24    0.99    2.27    0.00    0.00    0.00
41.50   2.23    0.98    2.28    0.00    0.00    0.00
42.50   2.23    0.97    2.29    0.00    0.00    0.00
43.50   2.22    0.97    2.30    0.00    0.00    0.00
44.50   2.21    0.96    2.31    0.00    0.00    0.00
45.50   2.20    0.95    2.32    0.00    0.00    0.00
46.50   2.20    0.94    2.33    0.00    0.00    0.00
47.50   2.19    0.93    2.35    0.00    0.00    0.00
48.50   2.18    0.92    2.36    0.00    0.00    0.00
49.50   2.17    0.92    2.37    0.00    0.00    0.00
50.50   2.17    0.91    2.39    0.00    0.00    0.00
51.50   2.16    0.90    2.40    0.00    0.00    0.00
52.50   2.15    0.89    2.42    0.00    0.00    0.00
53.50   2.15    0.88    2.43    0.00    0.00    0.00
54.50   2.14    0.87    2.45    0.00    0.00    0.00
55.50   2.13    0.86    2.47    0.00    0.00    0.00
56.50   2.13    0.86    2.48    0.00    0.00    0.00
57.50   2.12    0.85    2.50    0.00    0.00    0.00
58.50   2.11    0.84    2.52    0.00    0.00    0.00
59.50   2.11    0.83    2.54    0.00    0.00    0.00
60.50   2.10    0.82    2.56    0.00    0.00    0.00
61.50   2.09    0.81    2.58    0.00    0.00    0.00
62.50   2.09    0.80    2.60    0.00    0.00    0.00
63.50   2.08    0.79    2.62    0.00    0.00    0.00
```

```
        64.50    2.07     0.78     2.65     0.00     0.00     0.00
        65.50    2.07     0.77     2.67     0.00     0.00     0.00
        66.50    2.06     0.77     2.69     0.00     0.00     0.00
        67.50    2.06     0.76     2.72     0.00     0.00     0.00
        68.50    2.05     0.75     2.75     0.00     0.00     0.00
        69.50    2.04     0.74     2.77     0.00     0.00     0.00
        70.50    2.04     0.73     2.80     0.00     0.00     0.00
        71.50    2.03     0.72     2.83     0.00     0.00     0.00
        _______________________________________________________
        * F.S.<1, Liquefaction Potential Zone
        (F.S. is limited to 5,  CRR is limited to 2,    CSR is limited to 2)

        Units           Depth = ft, Stress or Pressure = tsf (atm), Unit Weight =
pcf, Settlement = in.

_________________________________________________________________________________
        CRRm            Cyclic resistance ratio from soils
        CSRfs           Cyclic stress ratio induced by a given earthquake (with user
request factor of safety)
        F.S.            Factor of Safety against liquefaction, F.S.=CRRm/CSRfs
        S_sat           Settlement from saturated sands
        S_dry           Settlement from dry sands
        S_all           Total settlement from saturated and dry sands
        NoLiq           No-Liquefy Soils
```

```
************************************************************************************
*******************
                                LIQUEFACTION ANALYSIS CALCULATION SHEET

                                                Version 4.3
                                      Copyright by CivilTech Software
                                            www.civiltech.com
                                     (425) 453-6488  Fax (425) 453-5848

************************************************************************************
*******************
        Licensed to John R Byerly, John R. Byerly, Inc. 4/12/2022      3:04:40 PM

        Input File Name: T:\Liquefy4\S-14447.1.liq
        Title:  MARTA - NEW ADMINISTRATION BUILDING AND MAINTENANCE FACILITY
        Subtitle:  S-14447

 Input Data:

        Surface Elev.=6779 feet AMSL
        Hole No.=B-1
        Depth of Hole=71.5 ft
        Water Table during Earthquake= 5.0 ft
        Water Table during In-Situ Testing= 26.6 ft
        Max. Acceleration=0.81 g
        Earthquake Magnitude=7.0
        User defined factor of safty (applied to CSR)        User fs=1.3
        fs=user,  Plot one CSR (fs=user)

        Hammer Energy Ratio, Ce=1
        Borehole Diameter, Cb=1.15
        Sampeling Method, Cs=1.3
        SPT Fines Correction Method: Stark/Olson et al.*
        Settlement Analysis Method: Ishihara / Yoshimine*
        Fines Correction for Liquefaction: Stark/Olson et al.*
        Fine Correction for Settlement: Post-Liq. Correction *
        Average Input Data: Smooth*
        * Recommended Options

        Depth    SPT      Gamma    Fines
        ft                pcf      %
        ____________________________________
        6.5      30.0     130.0    28.0
        11.5     30.0     130.0    20.0
        16.5     29.0     129.0    20.0
        21.5     42.0     128.0    25.0
        26.5     31.0     135.0    1.0
        31.5     83.0     135.0    1.0
        35.0     58.0     135.0    15.0
        40.0     49.0     135.0    15.0
        45.0     34.0     135.0    15.0
        50.0     55.0     135.0    15.0
        55.0     100.0    135.0    25.0
        60.0     51.0     135.0    25.0
        65.0     50.0     135.0    25.0
        70.0     81.0     135.0    25.0
        ____________________________________

 Output Results:            (Interval = 1.00 ft)
```

```
CSR Calculation:
Depth    gamma    sigma    gamma'   sigma'   rd      CSR     fs      CSRfs
ft       pcf      tsf      pcf      tsf                      (user)  w/fs
__________________________________________________________________________
6.50     130.0    0.423    67.6     0.376    0.98    0.58    1.3     0.76
7.50     130.0    0.488    67.6     0.410    0.98    0.62    1.3     0.80
8.50     130.0    0.553    67.6     0.443    0.98    0.64    1.3     0.84
9.50     130.0    0.618    67.6     0.477    0.98    0.67    1.3     0.87
10.50    130.0    0.683    67.6     0.511    0.98    0.69    1.3     0.89
11.50    130.0    0.748    67.6     0.545    0.97    0.70    1.3     0.91
12.50    129.8    0.812    67.4     0.578    0.97    0.72    1.3     0.93
13.50    129.6    0.877    67.2     0.612    0.97    0.73    1.3     0.95
14.50    129.4    0.942    67.0     0.646    0.97    0.74    1.3     0.96
15.50    129.2    1.007    66.8     0.679    0.96    0.75    1.3     0.98
16.50    129.0    1.071    66.6     0.712    0.96    0.76    1.3     0.99
17.50    128.8    1.136    66.4     0.746    0.96    0.77    1.3     1.00
18.50    128.6    1.200    66.2     0.779    0.96    0.78    1.3     1.01
19.50    128.4    1.264    66.0     0.812    0.95    0.78    1.3     1.02
20.50    128.2    1.328    65.8     0.845    0.95    0.79    1.3     1.02
21.50    128.0    1.393    65.6     0.878    0.95    0.79    1.3     1.03
22.50    129.4    1.457    67.0     0.911    0.95    0.80    1.3     1.04
23.50    130.8    1.522    68.4     0.945    0.95    0.80    1.3     1.04
24.50    132.2    1.588    69.8     0.979    0.94    0.80    1.3     1.05
25.50    133.6    1.654    71.2     1.014    0.94    0.81    1.3     1.05
26.50    135.0    1.721    72.6     1.050    0.94    0.81    1.3     1.05
27.50    135.0    1.789    72.6     1.087    0.94    0.81    1.3     1.05
28.50    135.0    1.856    72.6     1.123    0.93    0.81    1.3     1.06
29.50    135.0    1.924    72.6     1.159    0.93    0.81    1.3     1.06
30.50    135.0    1.991    72.6     1.196    0.93    0.81    1.3     1.06
31.50    135.0    2.059    72.6     1.232    0.92    0.81    1.3     1.05
32.50    135.0    2.126    72.6     1.268    0.91    0.80    1.3     1.04
33.50    135.0    2.194    72.6     1.304    0.90    0.80    1.3     1.04
34.50    135.0    2.261    72.6     1.341    0.89    0.79    1.3     1.03
35.50    135.0    2.329    72.6     1.377    0.89    0.79    1.3     1.02
36.50    135.0    2.396    72.6     1.413    0.88    0.78    1.3     1.02
37.50    135.0    2.464    72.6     1.450    0.87    0.78    1.3     1.01
38.50    135.0    2.531    72.6     1.486    0.86    0.77    1.3     1.00
39.50    135.0    2.599    72.6     1.522    0.85    0.77    1.3     1.00
40.50    135.0    2.666    72.6     1.559    0.84    0.76    1.3     0.99
41.50    135.0    2.734    72.6     1.595    0.84    0.75    1.3     0.98
42.50    135.0    2.801    72.6     1.631    0.83    0.75    1.3     0.97
43.50    135.0    2.869    72.6     1.667    0.82    0.74    1.3     0.97
44.50    135.0    2.936    72.6     1.704    0.81    0.74    1.3     0.96
45.50    135.0    3.004    72.6     1.740    0.80    0.73    1.3     0.95
46.50    135.0    3.071    72.6     1.776    0.80    0.72    1.3     0.94
47.50    135.0    3.139    72.6     1.813    0.79    0.72    1.3     0.93
48.50    135.0    3.206    72.6     1.849    0.78    0.71    1.3     0.92
49.50    135.0    3.274    72.6     1.885    0.77    0.71    1.3     0.92
50.50    135.0    3.341    72.6     1.922    0.76    0.70    1.3     0.91
51.50    135.0    3.409    72.6     1.958    0.75    0.69    1.3     0.90
52.50    135.0    3.476    72.6     1.994    0.75    0.69    1.3     0.89
53.50    135.0    3.544    72.6     2.030    0.74    0.68    1.3     0.88
54.50    135.0    3.611    72.6     2.067    0.73    0.67    1.3     0.87
55.50    135.0    3.679    72.6     2.103    0.72    0.67    1.3     0.86
56.50    135.0    3.746    72.6     2.139    0.71    0.66    1.3     0.86
57.50    135.0    3.814    72.6     2.176    0.71    0.65    1.3     0.85
58.50    135.0    3.881    72.6     2.212    0.70    0.64    1.3     0.84
59.50    135.0    3.949    72.6     2.248    0.69    0.64    1.3     0.83
60.50    135.0    4.016    72.6     2.285    0.68    0.63    1.3     0.82
61.50    135.0    4.084    72.6     2.321    0.67    0.62    1.3     0.81
62.50    135.0    4.151    72.6     2.357    0.67    0.62    1.3     0.80
63.50    135.0    4.219    72.6     2.393    0.66    0.61    1.3     0.79
64.50    135.0    4.286    72.6     2.430    0.65    0.60    1.3     0.78
```

```
          65.50     135.0     4.354     72.6      2.466     0.64      0.60      1.3       0.77
          66.50     135.0     4.421     72.6      2.502     0.63      0.59      1.3       0.77
          67.50     135.0     4.489     72.6      2.539     0.62      0.58      1.3       0.76
          68.50     135.0     4.556     72.6      2.575     0.62      0.57      1.3       0.75
          69.50     135.0     4.624     72.6      2.611     0.61      0.57      1.3       0.74
          70.50     135.0     4.691     72.6      2.648     0.60      0.56      1.3       0.73
          71.50     135.0     4.759     72.6      2.684     0.59      0.55      1.3       0.72
          __________________________________________________________________________________________
          CSR is based on water table at 5.0 during earthquake

          CRR Calculation from SPT or BPT data:
          Depth     SPT       Cebs      Cr        sigma'    Cn        (N1)60    Fines     d(N1)60
(N1)60f   CRR7.5
          ft                                                                    %

__________________________________________________________________________________________________________
_
          6.50      30.00     1.49      0.75      0.423     1.54      51.75     28.0      5.52
57.27     2.00
          7.50      30.00     1.49      0.75      0.488     1.43      48.18     26.4      5.14
53.31     2.00
          8.50      30.00     1.49      0.85      0.553     1.35      51.29     24.8      4.75
56.04     2.00
          9.50      30.00     1.49      0.85      0.618     1.27      48.51     23.2      4.37
52.88     2.00
          10.50     30.00     1.49      0.85      0.683     1.21      46.15     21.6      3.98
50.13     2.00
          11.50     30.00     1.49      0.85      0.748     1.16      44.09     20.0      3.60
47.69     2.00
          12.50     29.80     1.49      0.85      0.812     1.11      42.01     20.0      3.60
45.61     2.00
          13.50     29.60     1.49      0.85      0.877     1.07      40.16     20.0      3.60
43.76     2.00
          14.50     29.40     1.49      0.85      0.942     1.03      38.49     20.0      3.60
42.09     2.00
          15.50     29.20     1.49      0.95      1.007     1.00      41.33     20.0      3.60
44.93     2.00
          16.50     29.00     1.49      0.95      1.071     0.97      39.79     20.0      3.60
43.39     2.00
          17.50     31.60     1.49      0.95      1.136     0.94      42.11     21.0      3.84
45.95     2.00
          18.50     34.20     1.49      0.95      1.200     0.91      44.34     22.0      4.08
48.42     2.00
          19.50     36.80     1.49      0.95      1.264     0.89      46.48     23.0      4.32
50.80     2.00
          20.50     39.40     1.49      0.95      1.328     0.87      48.55     24.0      4.56
53.11     2.00
          21.50     42.00     1.49      0.95      1.393     0.85      50.55     25.0      4.80
55.35     2.00
          22.50     39.80     1.49      0.95      1.457     0.83      46.83     20.2      3.65
50.48     2.00
          23.50     37.60     1.49      0.95      1.522     0.81      43.29     15.4      2.50
45.78     2.00
          24.50     35.40     1.49      0.95      1.588     0.79      39.90     10.6      1.34
41.25     2.00
          25.50     33.20     1.49      0.95      1.654     0.78      36.66     5.8       0.19
36.86     2.00
          26.50     31.00     1.49      0.95      1.721     0.76      33.56     1.0       0.00
33.56     2.00
          27.50     41.40     1.49      0.95      1.762     0.75      44.29     1.0       0.00
44.29     2.00
          28.50     51.80     1.49      1.00      1.798     0.75      57.74     1.0       0.00
57.74     2.00
```

```
         29.50    62.20    1.49     1.00     1.835    0.74     68.65    1.0      0.00
68.65    2.00
         30.50    72.60    1.49     1.00     1.871    0.73     79.35    1.0      0.00
79.35    2.00
         31.50    83.00    1.49     1.00     1.907    0.72     89.84    1.0      0.00
89.84    2.00
         32.50    75.86    1.49     1.00     1.944    0.72     81.35    5.0      0.00
81.35    2.00
         33.50    68.72    1.49     1.00     1.980    0.71     73.01    9.0      0.96
73.97    2.00
         34.50    61.57    1.49     1.00     2.016    0.70     64.83    13.0     1.92
66.75    2.00
         35.50    57.10    1.49     1.00     2.053    0.70     59.58    15.0     2.40
61.98    2.00
         36.50    55.30    1.49     1.00     2.089    0.69     57.20    15.0     2.40
59.60    2.00
         37.50    53.50    1.49     1.00     2.125    0.69     54.87    15.0     2.40
57.27    2.00
         38.50    51.70    1.49     1.00     2.161    0.68     52.57    15.0     2.40
54.97    2.00
         39.50    49.90    1.49     1.00     2.198    0.67     50.32    15.0     2.40
52.72    2.00
         40.50    47.50    1.49     1.00     2.234    0.67     47.51    15.0     2.40
49.91    2.00
         41.50    44.50    1.49     1.00     2.270    0.66     44.15    15.0     2.40
46.55    2.00
         42.50    41.50    1.49     1.00     2.307    0.66     40.85    15.0     2.40
43.25    2.00
         43.50    38.50    1.49     1.00     2.343    0.65     37.60    15.0     2.40
40.00    2.00
         44.50    35.50    1.49     1.00     2.379    0.65     34.41    15.0     2.40
36.81    2.00
         45.50    36.10    1.49     1.00     2.416    0.64     34.72    15.0     2.40
37.12    2.00
         46.50    40.30    1.49     1.00     2.452    0.64     38.47    15.0     2.40
40.87    2.00
         47.50    44.50    1.49     1.00     2.488    0.63     42.17    15.0     2.40
44.57    2.00
         48.50    48.70    1.49     1.00     2.524    0.63     45.82    15.0     2.40
48.22    2.00
         49.50    52.90    1.49     1.00     2.561    0.62     49.42    15.0     2.40
51.82    2.00
         50.50    59.50    1.49     1.00     2.597    0.62     55.19    16.0     2.64
57.83    2.00
         51.50    68.50    1.49     1.00     2.633    0.62     63.10    18.0     3.12
66.22    2.00
         52.50    77.50    1.49     1.00     2.670    0.61     70.91    20.0     3.60
74.51    2.00
         53.50    86.50    1.49     1.00     2.706    0.61     78.61    22.0     4.08
82.69    2.00
         54.50    95.50    1.49     1.00     2.742    0.60     86.21    24.0     4.56
90.77    2.00
         55.50    95.11    1.49     1.00     2.779    0.60     85.30    25.0     4.80
90.10    2.00
         56.50    85.31    1.49     1.00     2.815    0.60     76.01    25.0     4.80
80.81    2.00
         57.50    75.51    1.49     1.00     2.851    0.59     66.85    25.0     4.80
71.65    2.00
         58.50    65.71    1.49     1.00     2.888    0.59     57.81    25.0     4.80
62.61    2.00
         59.50    55.91    1.49     1.00     2.924    0.58     48.88    25.0     4.80
53.68    2.00
         60.50    50.90    1.49     1.00     2.960    0.58     44.23    25.0     4.80
```

```
49.03   2.00
        61.50   50.70   1.49    1.00    2.996   0.58    43.79   25.0    4.80
48.59   2.00
        62.50   50.50   1.49    1.00    3.033   0.57    43.35   25.0    4.80
48.15   2.00
        63.50   50.30   1.49    1.00    3.069   0.57    42.93   25.0    4.80
47.73   2.00
        64.50   50.10   1.49    1.00    3.105   0.57    42.50   25.0    4.80
47.30   2.00
        65.50   53.10   1.49    1.00    3.142   0.56    44.78   25.0    4.80
49.58   2.00
        66.50   59.30   1.49    1.00    3.178   0.56    49.73   25.0    4.80
54.53   2.00
        67.50   65.50   1.49    1.00    3.214   0.56    54.62   25.0    4.80
59.42   2.00
        68.50   71.70   1.49    1.00    3.251   0.55    59.45   25.0    4.80
64.25   2.00
        69.50   77.90   1.49    1.00    3.287   0.55    64.24   25.0    4.80
69.04   2.00
        70.50   81.00   1.49    1.00    3.323   0.55    66.43   25.0    4.80
71.23   2.00
        71.50   81.00   1.49    1.00    3.359   0.55    66.07   25.0    4.80
70.87   2.00
______________________________________________________________________________________
-
        CRR is based on water table at 26.6 during In-Situ Testing

        Factor of Safety,  - Earthquake Magnitude= 7.0:
        Depth   sigC'   CRR7.5  Ksigma  CRRv    MSF     CRRm    CSRfs   F.S.
        ft      tsf     tsf                                     w/fs    CRRm/CSRfs
        _____________________________________________________________________________
        6.50    0.27    2.00    1.00    2.00    1.19    2.39    0.76    3.15
        7.50    0.32    2.00    1.00    2.00    1.19    2.39    0.80    2.98
        8.50    0.36    2.00    1.00    2.00    1.19    2.39    0.84    2.85
        9.50    0.40    2.00    1.00    2.00    1.19    2.39    0.87    2.75
        10.50   0.44    2.00    1.00    2.00    1.19    2.39    0.89    2.67
        11.50   0.49    2.00    1.00    2.00    1.19    2.39    0.91    2.61
        12.50   0.53    2.00    1.00    2.00    1.19    2.39    0.93    2.56
        13.50   0.57    2.00    1.00    2.00    1.19    2.39    0.95    2.51
        14.50   0.61    2.00    1.00    2.00    1.19    2.39    0.96    2.47
        15.50   0.65    2.00    1.00    2.00    1.19    2.39    0.98    2.44
        16.50   0.70    2.00    1.00    2.00    1.19    2.39    0.99    2.41
        17.50   0.74    2.00    1.00    2.00    1.19    2.39    1.00    2.39
        18.50   0.78    2.00    1.00    2.00    1.19    2.39    1.01    2.36
        19.50   0.82    2.00    1.00    2.00    1.19    2.39    1.02    2.34
        20.50   0.86    2.00    1.00    2.00    1.19    2.39    1.02    2.33
        21.50   0.91    2.00    1.00    2.00    1.19    2.39    1.03    2.31
        22.50   0.95    2.00    1.00    2.00    1.19    2.39    1.04    2.30
        23.50   0.99    2.00    1.00    2.00    1.19    2.39    1.04    2.29
        24.50   1.03    2.00    1.00    2.00    1.19    2.39    1.05    2.28
        25.50   1.08    2.00    0.99    1.99    1.19    2.37    1.05    2.26
        26.50   1.12    2.00    0.99    1.98    1.19    2.36    1.05    2.24
        27.50   1.15    2.00    0.98    1.97    1.19    2.35    1.05    2.23
        28.50   1.17    2.00    0.98    1.96    1.19    2.34    1.06    2.21
        29.50   1.19    2.00    0.98    1.95    1.19    2.33    1.06    2.20
        30.50   1.22    2.00    0.97    1.95    1.19    2.32    1.06    2.20
        31.50   1.24    2.00    0.97    1.94    1.19    2.31    1.05    2.20
        32.50   1.26    2.00    0.97    1.93    1.19    2.30    1.04    2.21
        33.50   1.29    2.00    0.96    1.92    1.19    2.30    1.04    2.21
        34.50   1.31    2.00    0.96    1.92    1.19    2.29    1.03    2.22
        35.50   1.33    2.00    0.96    1.91    1.19    2.28    1.02    2.23
        36.50   1.36    2.00    0.95    1.90    1.19    2.27    1.02    2.23
```

```
37.50   1.38    2.00    0.95    1.90    1.19    2.26    1.01    2.24
38.50   1.40    2.00    0.95    1.89    1.19    2.26    1.00    2.25
39.50   1.43    2.00    0.94    1.89    1.19    2.25    1.00    2.26
40.50   1.45    2.00    0.94    1.88    1.19    2.24    0.99    2.27
41.50   1.48    2.00    0.94    1.87    1.19    2.23    0.98    2.28
42.50   1.50    2.00    0.93    1.87    1.19    2.23    0.97    2.29
43.50   1.52    2.00    0.93    1.86    1.19    2.22    0.97    2.30
44.50   1.55    2.00    0.93    1.85    1.19    2.21    0.96    2.31
45.50   1.57    2.00    0.92    1.85    1.19    2.20    0.95    2.32
46.50   1.59    2.00    0.92    1.84    1.19    2.20    0.94    2.33
47.50   1.62    2.00    0.92    1.83    1.19    2.19    0.93    2.35
48.50   1.64    2.00    0.91    1.83    1.19    2.18    0.92    2.36
49.50   1.66    2.00    0.91    1.82    1.19    2.17    0.92    2.37
50.50   1.69    2.00    0.91    1.82    1.19    2.17    0.91    2.39
51.50   1.71    2.00    0.91    1.81    1.19    2.16    0.90    2.40
52.50   1.74    2.00    0.90    1.81    1.19    2.15    0.89    2.42
53.50   1.76    2.00    0.90    1.80    1.19    2.15    0.88    2.43
54.50   1.78    2.00    0.90    1.79    1.19    2.14    0.87    2.45
55.50   1.81    2.00    0.89    1.79    1.19    2.13    0.86    2.47
56.50   1.83    2.00    0.89    1.78    1.19    2.13    0.86    2.48
57.50   1.85    2.00    0.89    1.78    1.19    2.12    0.85    2.50
58.50   1.88    2.00    0.89    1.77    1.19    2.11    0.84    2.52
59.50   1.90    2.00    0.88    1.77    1.19    2.11    0.83    2.54
60.50   1.92    2.00    0.88    1.76    1.19    2.10    0.82    2.56
61.50   1.95    2.00    0.88    1.76    1.19    2.09    0.81    2.58
62.50   1.97    2.00    0.87    1.75    1.19    2.09    0.80    2.60
63.50   1.99    2.00    0.87    1.74    1.19    2.08    0.79    2.62
64.50   2.02    2.00    0.87    1.74    1.19    2.07    0.78    2.65
65.50   2.04    2.00    0.87    1.73    1.19    2.07    0.77    2.67
66.50   2.07    2.00    0.86    1.73    1.19    2.06    0.77    2.69
67.50   2.09    2.00    0.86    1.72    1.19    2.06    0.76    2.72
68.50   2.11    2.00    0.86    1.72    1.19    2.05    0.75    2.75
69.50   2.14    2.00    0.86    1.71    1.19    2.04    0.74    2.77
70.50   2.16    2.00    0.85    1.71    1.19    2.04    0.73    2.80
71.50   2.18    2.00    0.85    1.70    1.19    2.03    0.72    2.83
-------------------------------------------------------------------------
* F.S.<1: Liquefaction Potential Zone.  (If above water table: F.S.=5)
(F.S. is limited to 5,  CRR is limited to 2,   CSR is limited to 2)


CPT convert to SPT for Settlement Analysis:
Fines Correction for Settlement Analysis:
Depth   Ic      qc/N60  qc1     (N1)60  Fines   d(N1)60 (N1)60s
ft                      tsf             %
-------------------------------------------------------------------
6.50    -       -       -       51.75   28.0    2.41    54.16
7.50    -       -       -       48.18   26.4    2.29    50.47
8.50    -       -       -       51.29   24.8    2.17    53.46
9.50    -       -       -       48.51   23.2    2.04    50.56
10.50   -       -       -       46.15   21.6    1.92    48.06
11.50   -       -       -       44.09   20.0    1.79    45.88
12.50   -       -       -       42.01   20.0    1.79    43.80
13.50   -       -       -       40.16   20.0    1.79    41.95
14.50   -       -       -       38.49   20.0    1.79    40.28
15.50   -       -       -       41.33   20.0    1.79    43.12
16.50   -       -       -       39.79   20.0    1.79    41.58
17.50   -       -       -       42.11   21.0    1.87    43.98
18.50   -       -       -       44.34   22.0    1.95    46.29
19.50   -       -       -       46.48   23.0    2.03    48.51
20.50   -       -       -       48.55   24.0    2.11    50.66
21.50   -       -       -       50.55   25.0    2.19    52.73
22.50   -       -       -       46.83   20.2    1.80    48.64
23.50   -       -       -       43.29   15.4    1.41    44.69
```

```
    24.50   -       -       -       39.90   10.6    0.99    40.89
    25.50   -       -       -       36.66   5.8     0.55    37.21
    26.50   -       -       -       33.56   1.0     0.10    33.66
    27.50   -       -       -       44.29   1.0     0.10    44.39
    28.50   -       -       -       57.74   1.0     0.10    57.84
    29.50   -       -       -       68.65   1.0     0.10    68.75
    30.50   -       -       -       79.35   1.0     0.10    79.44
    31.50   -       -       -       89.84   1.0     0.10    89.94
    32.50   -       -       -       81.35   5.0     0.48    81.82
    33.50   -       -       -       73.01   9.0     0.84    73.85
    34.50   -       -       -       64.83   13.0    1.20    66.03
    35.50   -       -       -       59.58   15.0    1.37    60.96
    36.50   -       -       -       57.20   15.0    1.37    58.57
    37.50   -       -       -       54.87   15.0    1.37    56.24
    38.50   -       -       -       52.57   15.0    1.37    53.94
    39.50   -       -       -       50.32   15.0    1.37    51.69
    40.50   -       -       -       47.51   15.0    1.37    48.88
    41.50   -       -       -       44.15   15.0    1.37    45.52
    42.50   -       -       -       40.85   15.0    1.37    42.22
    43.50   -       -       -       37.60   15.0    1.37    38.98
    44.50   -       -       -       34.41   15.0    1.37    35.78
    45.50   -       -       -       34.72   15.0    1.37    36.09
    46.50   -       -       -       38.47   15.0    1.37    39.85
    47.50   -       -       -       42.17   15.0    1.37    43.55
    48.50   -       -       -       45.82   15.0    1.37    47.19
    49.50   -       -       -       49.42   15.0    1.37    50.79
    50.50   -       -       -       55.19   16.0    1.46    56.65
    51.50   -       -       -       63.10   18.0    1.62    64.73
    52.50   -       -       -       70.91   20.0    1.79    72.69
    53.50   -       -       -       78.61   22.0    1.95    80.56
    54.50   -       -       -       86.21   24.0    2.11    88.32
    55.50   -       -       -       85.30   25.0    2.19    87.48
    56.50   -       -       -       76.01   25.0    2.19    78.20
    57.50   -       -       -       66.85   25.0    2.19    69.04
    58.50   -       -       -       57.81   25.0    2.19    59.99
    59.50   -       -       -       48.88   25.0    2.19    51.06
    60.50   -       -       -       44.23   25.0    2.19    46.41
    61.50   -       -       -       43.79   25.0    2.19    45.97
    62.50   -       -       -       43.35   25.0    2.19    45.54
    63.50   -       -       -       42.93   25.0    2.19    45.11
    64.50   -       -       -       42.50   25.0    2.19    44.69
    65.50   -       -       -       44.78   25.0    2.19    46.97
    66.50   -       -       -       49.73   25.0    2.19    51.91
    67.50   -       -       -       54.62   25.0    2.19    56.80
    68.50   -       -       -       59.45   25.0    2.19    61.64
    69.50   -       -       -       64.24   25.0    2.19    66.42
    70.50   -       -       -       66.43   25.0    2.19    68.61
    71.50   -       -       -       66.07   25.0    2.19    68.25
    _______________________________________________________________________

    Settlement of Saturated Sands:
    Settlement Analysis Method: Ishihara / Yoshimine*
    Depth   CSRfs   F.S.    Fines   (N1)60s Dr      ec      dsz     dsv     S
    ft      w/fs            %               %       %       in.     in.     in.

_______________________________________________________________________________
    71.45   0.72    2.83    25.0    68.27   100.00  0.000   0.000   0.000
0.000
    70.50   0.73    2.80    25.0    68.61   100.00  0.000   0.000   0.000
0.000
    69.50   0.74    2.77    25.0    66.42   100.00  0.000   0.000   0.000
0.000
```

```
      68.50    0.75    2.75    25.0    61.64   100.00   0.000   0.000   0.000
0.000
      67.50    0.76    2.72    25.0    56.80   100.00   0.000   0.000   0.000
0.000
      66.50    0.77    2.69    25.0    51.91   100.00   0.000   0.000   0.000
0.000
      65.50    0.77    2.67    25.0    46.97   100.00   0.000   0.000   0.000
0.000
      64.50    0.78    2.65    25.0    44.69   100.00   0.000   0.000   0.000
0.000
      63.50    0.79    2.62    25.0    45.11   100.00   0.000   0.000   0.000
0.000
      62.50    0.80    2.60    25.0    45.54   100.00   0.000   0.000   0.000
0.000
      61.50    0.81    2.58    25.0    45.97   100.00   0.000   0.000   0.000
0.000
      60.50    0.82    2.56    25.0    46.41   100.00   0.000   0.000   0.000
0.000
      59.50    0.83    2.54    25.0    51.06   100.00   0.000   0.000   0.000
0.000
      58.50    0.84    2.52    25.0    59.99   100.00   0.000   0.000   0.000
0.000
      57.50    0.85    2.50    25.0    69.04   100.00   0.000   0.000   0.000
0.000
      56.50    0.86    2.48    25.0    78.20   100.00   0.000   0.000   0.000
0.000
      55.50    0.86    2.47    25.0    87.48   100.00   0.000   0.000   0.000
0.000
      54.50    0.87    2.45    24.0    88.32   100.00   0.000   0.000   0.000
0.000
      53.50    0.88    2.43    22.0    80.56   100.00   0.000   0.000   0.000
0.000
      52.50    0.89    2.42    20.0    72.69   100.00   0.000   0.000   0.000
0.000
      51.50    0.90    2.40    18.0    64.73   100.00   0.000   0.000   0.000
0.000
      50.50    0.91    2.39    16.0    56.65   100.00   0.000   0.000   0.000
0.000
      49.50    0.92    2.37    15.0    50.79   100.00   0.000   0.000   0.000
0.000
      48.50    0.92    2.36    15.0    47.19   100.00   0.000   0.000   0.000
0.000
      47.50    0.93    2.35    15.0    43.55   100.00   0.000   0.000   0.000
0.000
      46.50    0.94    2.33    15.0    39.85   100.00   0.000   0.000   0.000
0.000
      45.50    0.95    2.32    15.0    36.09   100.00   0.000   0.000   0.000
0.000
      44.50    0.96    2.31    15.0    35.78   100.00   0.000   0.000   0.000
0.000
      43.50    0.97    2.30    15.0    38.98   100.00   0.000   0.000   0.000
0.000
      42.50    0.97    2.29    15.0    42.22   100.00   0.000   0.000   0.000
0.000
      41.50    0.98    2.28    15.0    45.52   100.00   0.000   0.000   0.000
0.000
      40.50    0.99    2.27    15.0    48.88   100.00   0.000   0.000   0.000
0.000
      39.50    1.00    2.26    15.0    51.69   100.00   0.000   0.000   0.000
0.000
      38.50    1.00    2.25    15.0    53.94   100.00   0.000   0.000   0.000
0.000
      37.50    1.01    2.24    15.0    56.24   100.00   0.000   0.000   0.000
```

```
0.000
        36.50    1.02     2.23     15.0     58.57    100.00   0.000    0.000    0.000
0.000
        35.50    1.02     2.23     15.0     60.96    100.00   0.000    0.000    0.000
0.000
        34.50    1.03     2.22     13.0     66.03    100.00   0.000    0.000    0.000
0.000
        33.50    1.04     2.21     9.0      73.85    100.00   0.000    0.000    0.000
0.000
        32.50    1.04     2.21     5.0      81.82    100.00   0.000    0.000    0.000
0.000
        31.50    1.05     2.20     1.0      89.94    100.00   0.000    0.000    0.000
0.000
        30.50    1.06     2.20     1.0      79.44    100.00   0.000    0.000    0.000
0.000
        29.50    1.06     2.20     1.0      68.75    100.00   0.000    0.000    0.000
0.000
        28.50    1.06     2.21     1.0      57.84    100.00   0.000    0.000    0.000
0.000
        27.50    1.05     2.23     1.0      44.39    100.00   0.000    0.000    0.000
0.000
        26.50    1.05     2.24     1.0      33.66    98.98    0.000    0.000    0.000
0.000
        25.50    1.05     2.26     5.8      37.21    100.00   0.000    0.000    0.000
0.000
        24.50    1.05     2.28     10.6     40.89    100.00   0.000    0.000    0.000
0.000
        23.50    1.04     2.29     15.4     44.69    100.00   0.000    0.000    0.000
0.000
        22.50    1.04     2.30     20.2     48.64    100.00   0.000    0.000    0.000
0.000
        21.50    1.03     2.31     25.0     52.73    100.00   0.000    0.000    0.000
0.000
        20.50    1.02     2.33     24.0     50.66    100.00   0.000    0.000    0.000
0.000
        19.50    1.02     2.34     23.0     48.51    100.00   0.000    0.000    0.000
0.000
        18.50    1.01     2.36     22.0     46.29    100.00   0.000    0.000    0.000
0.000
        17.50    1.00     2.39     21.0     43.98    100.00   0.000    0.000    0.000
0.000
        16.50    0.99     2.41     20.0     41.58    100.00   0.000    0.000    0.000
0.000
        15.50    0.98     2.44     20.0     43.12    100.00   0.000    0.000    0.000
0.000
        14.50    0.96     2.47     20.0     40.28    100.00   0.000    0.000    0.000
0.000
        13.50    0.95     2.51     20.0     41.95    100.00   0.000    0.000    0.000
0.000
        12.50    0.93     2.56     20.0     43.80    100.00   0.000    0.000    0.000
0.000
        11.50    0.91     2.61     20.0     45.88    100.00   0.000    0.000    0.000
0.000
        10.50    0.89     2.67     21.6     48.06    100.00   0.000    0.000    0.000
0.000
        9.50     0.87     2.75     23.2     50.56    100.00   0.000    0.000    0.000
0.000
        8.50     0.84     2.85     24.8     53.46    100.00   0.000    0.000    0.000
0.000
        7.50     0.80     2.98     26.4     50.47    100.00   0.000    0.000    0.000
0.000
        6.50     0.76     3.15     28.0     54.16    100.00   0.000    0.000    0.000
0.000
```

```
_______________________________________________________________________________
        Settlement of Saturated Sands=0.000 in.
        dsz is per each segment: dz=0.05 ft
        dsv is per each print interval: dv=1 ft
        S is cumulated settlement at this depth

        Settlement of Dry Sands:
        Depth   sigma'  sigC'   (N1)60s CSRfs   Gmax    g*Ge/Gm  g_eff   ec7.5   Cec
ec      dsz     dsv     S
        ft      tsf     tsf             w/fs    tsf                      %
%       in.     in.     in.

___________________________________________________________________________________
____________________________

___________________________________________________________________________________
____________________________
        Settlement of Dry Sands=0.000 in.
        dsz is per each segment: dz=0.05 ft
        dsv is per each print interval: dv=1 ft
        S is cumulated settlement at this depth

        Total Settlement of Saturated and Dry Sands=0.000 in.
        Differential Settlement=0.000 to 0.000 in.

        Units           Depth = ft, Stress or Pressure = tsf (atm), Unit Weight =
pcf, Settlement = in.

___________________________________________________________________________________
_____________
        SPT             Field data from Standard Penetration Test (SPT)
        BPT             Field data from Becker Penetration Test (BPT)
        qc              Field data from Cone Penetration Test (CPT)
        fc              Friction from CPT testing
        Gamma           Total unit weight of soil
        Gamma'          Effective unit weight of soil
        Fines           Fines content [%]
        D50             Mean grain size
        Dr              Relative Density
        sigma           Total vertical stress [tsf]
        sigma'          Effective vertical stress [tsf]
        sigC'           Effective confining pressure [tsf]
        rd              Stress reduction coefficient
        CSR             Cyclic stress ratio induced by earthquake
        fs              User request factor of safety, apply to CSR
        w/fs            With user request factor of safety inside
        CSRfs           CSR with User request factor of safety
        CRR7.5          Cyclic resistance ratio (M=7.5)
        Ksigma          Overburden stress correction factor for CRR7.5
        CRRv            CRR after overburden stress correction, CRRv=CRR7.5 * Ksigma
        MSF             Magnitude scaling factor for CRR (M=7.5)
        CRRm            After magnitude scaling correction CRRm=CRRv * MSF
        F.S.            Factor of Safety against liquefaction F.S.=CRRm/CSRfs
        Cebs            Energy Ratio, Borehole Dia., and Sample Method Corrections
        Cr              Rod Length Corrections
        Cn              Overburden Pressure Correction
        (N1)60          SPT after corrections, (N1)60=SPT * Cr * Cn * Cebs
        d(N1)60         Fines correction of SPT
        (N1)60f         (N1)60 after fines corrections, (N1)60f=(N1)60 + d(N1)60
        Cq              Overburden stress correction factor
        qc1             CPT after Overburden stress correction
        dqc1            Fines correction of CPT
```

qc1f	CPT after Fines and Overburden correction, qc1f=qc1 + dqc1
qc1n	CPT after normalization in Robertson's method
Kc	Fine correction factor in Robertson's Method
qc1f	CPT after Fines correction in Robertson's Method
Ic	Soil type index in Suzuki's and Robertson's Methods
(N1)60s	(N1)60 after seattlement fines corrections
ec	Volumetric strain for saturated sands
ds	Settlement in each Segment dz
dz	Segment for calculation, dz=0.050 ft
Gmax	Shear Modulus at low strain
g_eff	gamma_eff, Effective shear Strain
g*Ge/Gm	gamma_eff * G_eff/G_max, Strain-modulus ratio
ec7.5	Volumetric Strain for magnitude=7.5
Cec	Magnitude correction factor for any magnitude
ec	Volumetric strain for dry sands, ec=Cec * ec7.5
NoLiq	No-Liquefy Soils

References:

NCEER Workshop on Evaluation of Liquefaction Resistance of Soils. Youd, T.L., and Idriss, I.M., eds., Technical Report NCEER 97-0022.

SP117. Southern California Earthquake Center. Recommended Procedures for Implementation of DMG Special Publication 117, Guidelines for Analyzing and Mitigating Liquefaction in California. University of Southern California. March 1999.

TERRA
GEOSCIENCES

GEOLOGIC HAZARDS REPORT

MOUNTAIN TRANSIT ADMINISTRATIVE FACILITY PROJECT

160-170 BUSINESS CENTER DRIVE

BIG BEAR LAKE, SAN BERNARDINO COUNTY, CALIFORNIA

Project No. 223769-1

February 7, 2022

Prepared for:

John R. Byerly, Inc.
2257 South Lilac Avenue
Bloomington, CA 92316

John R. Byerly, Inc.
2257 South Lilac Avenue
Bloomington, CA 92316

Attention: Mr. John R. Byerly

Regarding: Geologic Hazards Report
Mountain Transit Administrative Facility Project
160-170 Business Center Drive
Big Bear Lake, San Bernardino County, California
JRB File No. S-14447

INTRODUCTION

At your request, this firm has prepared a geologic hazards report for the proposed administrative building and maintenance facility project. The purpose of this study was to evaluate the existing geologic conditions and any corresponding potential geologic and/or seismic hazards, with respect to the proposed development from a geologic standpoint, as this property lies within the San Bernardino County Geologic Hazard Overlay District (San Bernardino County, 2010a & 2010b). We understand that the subject property will be utilized for construction of a 12,188 square-foot bus maintenance building, an 11,355 square-foot administrative building, along with various site improvements, appurtenances, and landscaping. The scope of services provided for this evaluation included the following:

- ***Review of available published and unpublished geologic/seismic data in our files pertinent to the site, including the provided site-specific boring logs.***
- ***Performing a seismic surface-wave survey by a licensed State of California Professional Geophysicist that included one traverse for shear-wave velocity analysis purposes.***
- ***Evaluation of the local and regional tectonic setting and historical seismic activity, including performing a site-specific CBC ground motion analysis.***
- ***Preparation of this report presenting our findings, conclusions, and recommendations from a geologic standpoint.***

Accompanying Maps, Illustrations, and Appendices

Plate 1	-	Regional Geologic Map
Plate 2	-	Geologic Hazard Overlay Map
Plate 3	-	Google™ Earth Imagery Map
Plate 4	-	Site Plan
Appendix A	-	Shear-Wave Survey
Appendix B	-	Site-Specific Ground Motion Analysis
Appendix C	-	References

GEOLOGIC SETTING

The subject property is regionally situated within a natural geomorphic province in Southern California known as the Transverse Ranges. The Transverse Ranges consist of a set of easterly-trending mountains and geologic structures that are distinct from the general northwest-southeast grain of the other provinces of California. More specifically, the site is located within the San Bernardino Mountains, an easterly-trending structural block that is roughly 55 miles long and 20 miles wide. This mountain range was formed by intense folding and faulting in very late geologic time (predominantly Tertiary time).

The geomorphology of this region of the San Bernardino Mountains indicates that the range is very young, from a geologic standpoint, whereas it was uplifted tectonically predominantly during Quaternary time. Regionally, the site is located within the northern block of the San Bernardino Mountain Range, which is an old erosion surface generally forming a broad plateau. Originally, this portion of the San Bernardino Mountains regionally was a part of the crystalline bedrock complex of the southern Mojave Desert prior to its uplift. The northern block of the San Bernardino Mountains is bordered on the north by a zone of south-dipping thrust faults (North Frontal Fault System), and along the south by the San Andreas Fault.

Locally, as mapped by Miller et al. (2001) and as shown on the Regional Geologic Map (see Plate 1), the subject site is shown to be mantled by late Holocene age active-wash deposits (map symbol Qw), generally described as being unconsolidated to locally cemented sand and gravel deposits in active washes of streams and on active surfaces of alluvial fans. These surficial deposits are noted to range from a few centimeters to only a few meters in thickness.

Underlying these surficial deposits at depth, such as mapped locally to the east and west of the site (map symbol Tsl), are believed to be Miocene age moderately-well consolidated sedimentary rocks comprised of siltstone, fine- to coarse-grained sandstone, pebble sandstone, and greenish mudstone. These sedimentary rocks overlie the deeper basement rocks that are found throughout most of the Big Bear area, which are estimated to be around 400± feet thick locally (United States Geological Survey, 2012).

EARTH MATERIALS

Based on the subsurface exploration performed by JRB (2022), the upper 7± feet of the site locally appear to consist of artificial fill comprised generally of silty fine- to coarse-grained sand with gravel, cobbles and occasional debris. Underlying these fill materials are interbedded silty fine- to medium-grained sand and silty-clayey fine- to medium-grained sand. These deposits were found to be in a dense to very-dense condition, to a depth of at least 71 feet.

GROUNDWATER

The subject site is located within the Bear Valley Groundwater Basin, which is situated within the Big Bear Lake and Baldwin Lake surface-water drainage basins. This basin is bounded by crystalline rocks of the San Bernardino Mountains that locally surround Bear Valley on all sides (California Department of Water Resources, 2003). Here groundwater is found primarily within unconsolidated Quaternary age alluvial deposits, which is recharged from percolation and runoff, and underflow from fractured crystalline rocks. More specifically, the site is located within a subbasin referred to as the Village Basin, that is defined by surface-water drainage divides.

The nearest groundwater well is located 1,300± feet to the northwest (Well Site Code 342535N1168920W001), where the groundwater ranges from 8 to 20 feet in depth during the time period of 2015 to 2021 (California Department of Water Resources, 2022). Another nearby well located 1,400± feet to the southeast (Well Site Code 342471N1168864W001), has groundwater ranging from 11 to 38 feet in depth during the time period of 2015 to 2021.

Currently, the subject site is located approximately 52± feet above the current water level of Big Bear Lake (Big Bear Municipal Water District, 2022). Based on the exploratory borings performed by John R. Byerly, Inc. (JRB, 2022), groundwater was encountered as shallow as 26½ feet in depth.

FAULTING

There are at least thirty-seven major late Quaternary active/potentially active faults that are located within a 100-kilometer (62-mile) radius of the subject site (Blake, 1989-2000). Of these, there are no "active" faults known to traverse the site, nor were any indications of active faulting or related features observed at the site during our field reconnaissance or photogeologic analysis. In addition, the site is not located within a State of California "Alquist-Priolo Earthquake Fault Zone" for surface fault rupture hazard (CGS, 2018 and C.D.M.G.,1988), defined as activity along a fault that has occurred during the Holocene time period. The nearest such zone is located approximately 7± miles to the north (North Frontal Fault Zone, M_W6.9, eastern segment). This fault has also been referred to as the North Frontal Fault System, which is comprised of numerous reverse fault segments which, in subsurface, may or may not form a single through-going fault (Miller, 1980).

Earthquake activity relating to the Landers-Big Bear events of June 28, 1992, and thereafter have led speculation into the fault mechanics in this region. The 6.7 magnitude earthquake (M_W6.3) that struck the Big Bear region was epicentered just south of the Sugarloaf area, approximately 5± miles to the southeast. This earthquake had a deep hypocenter being 5½± kilometers in depth and has an overall northeasterly trend, dipping steeply to the southeast. The subsurface fault is characterized leftlateral, strike-slip movement and no known surface fault rupture has been documented to date. Since no active surface trace has been identified to date, the actual location of this fault is unable to be defined. However, it can be assumed that based on the aftershock sequence pattern that has been recorded since the main shock, the most likely area of possible surface rupture would be located along a northeast trend, with the greater Sugarloaf area for a central reference. Because this fault has never been previously identified or postulated, and the fact that the Big Bear area is characterized generally by northwest-trending faults, the mechanics are not well known and much scientific work will have to be performed before an understanding of the local seismic parameters and conditions can be better understood. This fault is for discussion purposes only, and should not be used for permanent location or design purposes.

For preliminary evaluation purposes only, the Big Bear Fault has been tentatively estimated to have a maximum moment magnitude event of M_W6.9 using the "empirical earthquake size-fault-rupture-length relation" of dePolo and Slemmons (1990). This equation basically relates the length parameter of a fault to an earthquake size, based on historical earthquake data. This design event is considered very tentative and possibly conservative due to the lack of unknown seismic parameters (i.e., slip-rate, length, characteristic rate, etc.). The length of the Big Bear Fault was chosen to include the San Andreas Fault as the southwest terminus end and the area of the Landers surface fault ruptures (Johnson Valley Fault, Camp Rock Fault, etc.) as the northeast terminus end as visually shown on the recorded aftershock sequence patterns, which correlates to a length of approximately 42 miles.

Another nearby significant mapped fault is the southern terminus of the Helendale-South Lockhart Fault Zone, located 6± miles to the northeast. The southern terminus is not zoned as “active” by the State of California, but is zoned at a distance of 7½± miles farther to the north where it intersects the North Frontal Fault Zone.

GROUND MOTION ANALYSIS

According to California Geological Survey Note 48 (CGS, 2019), a site-specific ground motion analysis is required for the subject site (CBC, 2019, Section 1613 and also as required by ASCE 7-16, Chapter 21), the detailed results of which are presented within Appendix B. Additionally, a seismic shear-wave survey was conducted for this study by our firm as presented within Appendix A of this report, for purposes of determining the Site Classification and V_{S30} input values for the ground motion analysis. Geographically, the proposed construction area is located at Longitude -116.8888 and Latitude 34.2505 (World Geodetic System of 1984 coordinates). The mapped spectral acceleration parameters, coefficients, and other related seismic parameters, were evaluated using the OSHPD Seismic Design Maps (OSHPD, 2022) and the California Building Code criteria (CBC, 2019), with the site-specific ground motion analysis being performed following Section 21 of the ASCE 7-16 Standard (2017). The results of this site-specific analysis have been summarized and are tabulated below:

TABLE 1 – SUMMARY OF SEISMIC DESIGN PARAMETERS

Factor or Coefficient	Value
S_S	**1.642g**
S_1	**0.568g**
F_a	**1.0**
F_v	**1.732**
S_{DS}	**1.210g**
S_{D1}	**0.760g**
S_{MS}	**1.818g**
S_{M1}	**1.136g**
T_L	**8 Seconds**
MCE_G PGA	**0.81g**
Shear-Wave Velocity (V100)	**1,163.1 ft/sec**
Site Classification	**D**
Risk Category	**II**

HISTORIC SEISMICITY

A computerized search, based on Southern California historical earthquake catalogs, has been performed using the programs EQSEARCH (Blake, 1989-2021) and the ANSS Comprehensive Earthquake Catalog (U.S.G.S., 2022). The following table and discussion summarizes the historic seismic events (greater than or equal to M4.0) that have been estimated and/or recorded during this time period of 1800 to January 2022, within a 100-kilometer radius of the site.

TABLE 2 - HISTORIC SEISMIC EVENTS; 1800-2022 (100-kilometer radius)

4.0 - 4.9	563
5.0 - 5.9	70
6.0 - 6.9	14
7.0 - 7.9	2
8.0+	0

These data have been compiled generally based on the reported intensities throughout the region, thus focusing in on the most likely epicentral location. Seismic instrumentation beyond 1932 has greatly increased the accuracy of locating earthquake epicenters. It should be noted that pre-instrumental seismic events (occurring generally before 1932) have been estimated from isoseismal maps (Toppozada, et al., 1981 and 1982).

A summary of the historic earthquake data is as follows:

- The closest recorded earthquake epicenter (>M4.0) was located approximately 1,000± feet south of the site (June 30, 1979, M4.4).
- The nearest estimated significant historic earthquake epicenter (pre-1932) was approximately five miles southwest of the site (January 16, 1930, M5.2).
- The nearest recorded significant historic earthquake epicenter was located approximately 1¼ miles west-northwest of the site (June 28, 1992, M5.3).
- The largest estimated historical earthquake epicenter (pre-1932) within a 62-mile radius of the site is a M6.9 event of December 8, 1812 (44± miles southwest).
- The largest recorded historical earthquake was the M7.6 (M_W 7.3) Landers's event, located approximately 26 miles to the east-southeast (June 28, 1992).
- The largest estimated ground acceleration estimated to have been experienced at the site was 0.421g which resulted from the M6.7 (M_W 6.3) Big Bear event of June 28, 1992, which was located approximately five miles southeast of the subject site (Blake, 1989-2000b).

An Earthquake Epicenter Map which includes magnitudes 4.0 and greater for a 100-kilometer (62-mile) radius has been included below as Figure 1, for reference (Blue circle), with the site shown as the central blue dot. This map was prepared using the ANSS Comprehensive Earthquake Catalog (U.S.G.S., 2022) of instrumentally recorded events that have occurred from the period of 1932 to January 2022, superimposed on a captured Google™ Earth image (Google™ Earth, 2022).

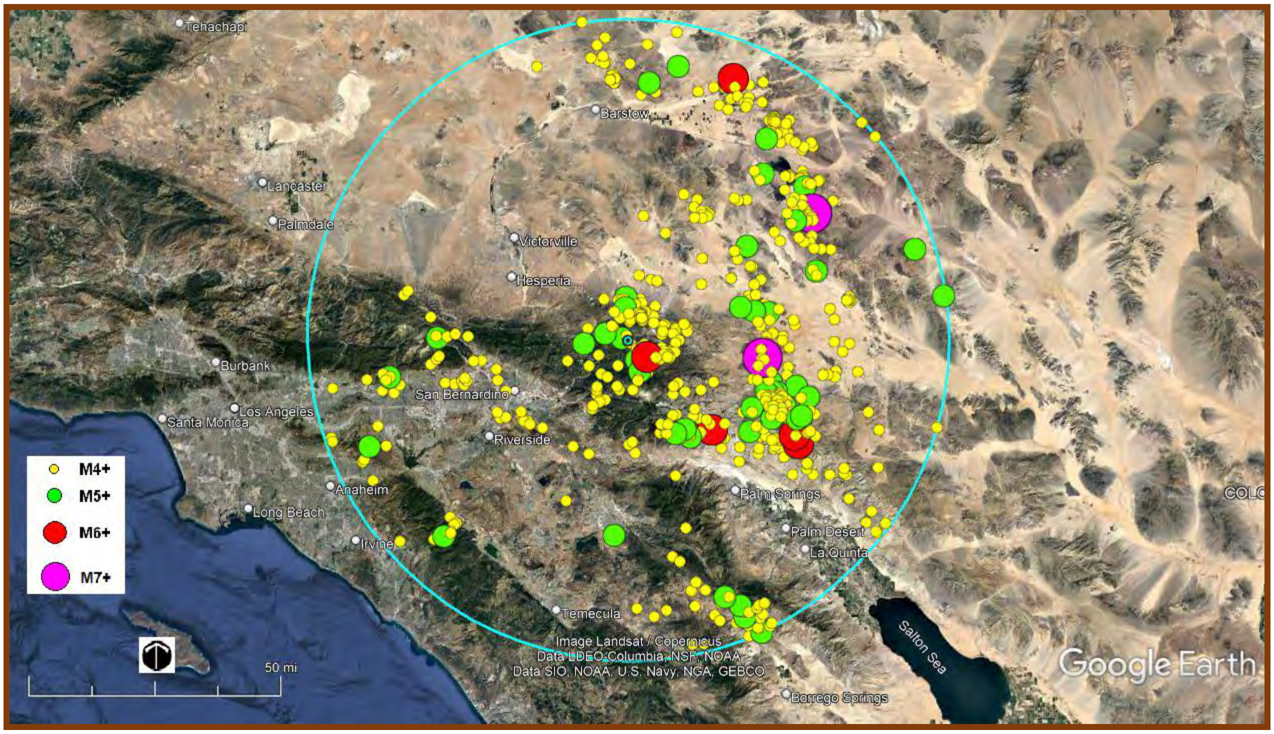


FIGURE 1- Earthquake Epicenter Map showing events of M4.0+ within a 100-kilometer radius.

SECONDARY SEISMIC HAZARDS

Secondary permanent or transient seismic hazards that are generally associated with severe ground shaking during an earthquake include ground rupture, liquefaction, seiches or tsunamis, ground lurching/lateral spreading, flooding (water storage facility failure), landsliding, rockfalls, and seismically-induced settlement, which are discussed below.

Ground Rupture:

Ground rupture is generally considered most likely to occur along pre-existing faults. Since there are no faults that are known to traverse the site, the potential for ground rupture is considered to be very low to nil.

Ground Lurching/Lateral Spreading:

Ground lurching is the horizontal movement of soil, sediments, or fill located on relatively steep embankments or scarps as a result of seismic activity, forming irregular ground surface cracks. The potential for lateral spreading or lurching is highest in areas underlain by soft, saturated materials, especially where bordered by steep banks or adjacent hard ground. Due to the relatively flat-lying nature of the site and distance from embankments, the potential for ground lurching and/or lateral spreading is considered to be nil.

Liquefaction:

In general, liquefaction is a phenomenon that occurs where there is a loss of strength or stiffness in the soils that can result in the settlement of buildings, ground failures, or other related hazards. The main factors contributing to this phenomenon are: 1) cohesionless, granular soils having relatively low densities (usually of Holocene age); 2) shallow groundwater (generally less than 50 feet); and 3) moderate-high seismic ground shaking. According to San Bernardino County (2010a & 2010b), the subject property is shown to be located within a "Zone of Suspected Liquefaction Susceptibility", as shown on Plate 2. Additionally, groundwater was encountered within the exploratory borings drilled at the site at a depth of 26½ feet, therefore there may be a potential for liquefaction to occur.

Seiches/Tsunamis:

Based on the far distance of large, open bodies of water and the elevation of the site with respect to sea level or Big Bear Lake, the possibility of seiches/tsunamis is considered nil. Additionally, mapping by the California Geological Survey (2014) does not indicate the site to be located within a tsunami inundation zone.

Rockfalls:

Since no large rock outcrops are present at or adjacent to the site, the possibility of rockfalls during seismic shaking is nil.

Landsliding:

Due to the low-lying relief of the site and adjacent areas, landsliding due to seismic shaking is considered nil. Additionally, mapping by Tan (1990) does not indicate the subject property to be located within a mapped area susceptible to landsliding. According to the County of San Bernardino (2010a & 2010b) the subject property is not shown to be located within a "Zone of Suspected Landslide Susceptibility", as shown on Plate 2.

Flooding (Water Storage Facility Failure):

There are no water storage facilities on or near the site that could cause flooding due to failure during a seismic event.

Seismically-Induced Settlement:

Seismically-induced settlement generally occurs within areas of loose, granular soils during periods of strong ground motion. Since the subject site is underlain by generally dense to very dense sediments, and based on the subsurface data and SPT blow counts from the exploratory boring excavations performed by JRB (2022), to a depth of at least 71 feet, seismically-induced settlement is considered very low.

FLOODING

According to the Federal Emergency Management Agency (FEMA, 2008a & 2008b), the subject site is shown to be partially located within the boundaries of a designated flood hazard zone. This map indicates that the eastern portion of the site is located within “Zone AE,” which is defined as “Special Flood Hazard Areas Subject to Inundation by the 1% Annual Chance Flood (Base flood elevations determined),” as shown on Figure 2 below for reference. The remainder of the western portion of the site is not located within a flood hazard zone and is included within “Zone X” which is defined as “Areas to be Outside the 0.2% Annual Chance Floodplain.” During peak periods of rainfall, however, heavy runoff could be anticipated.

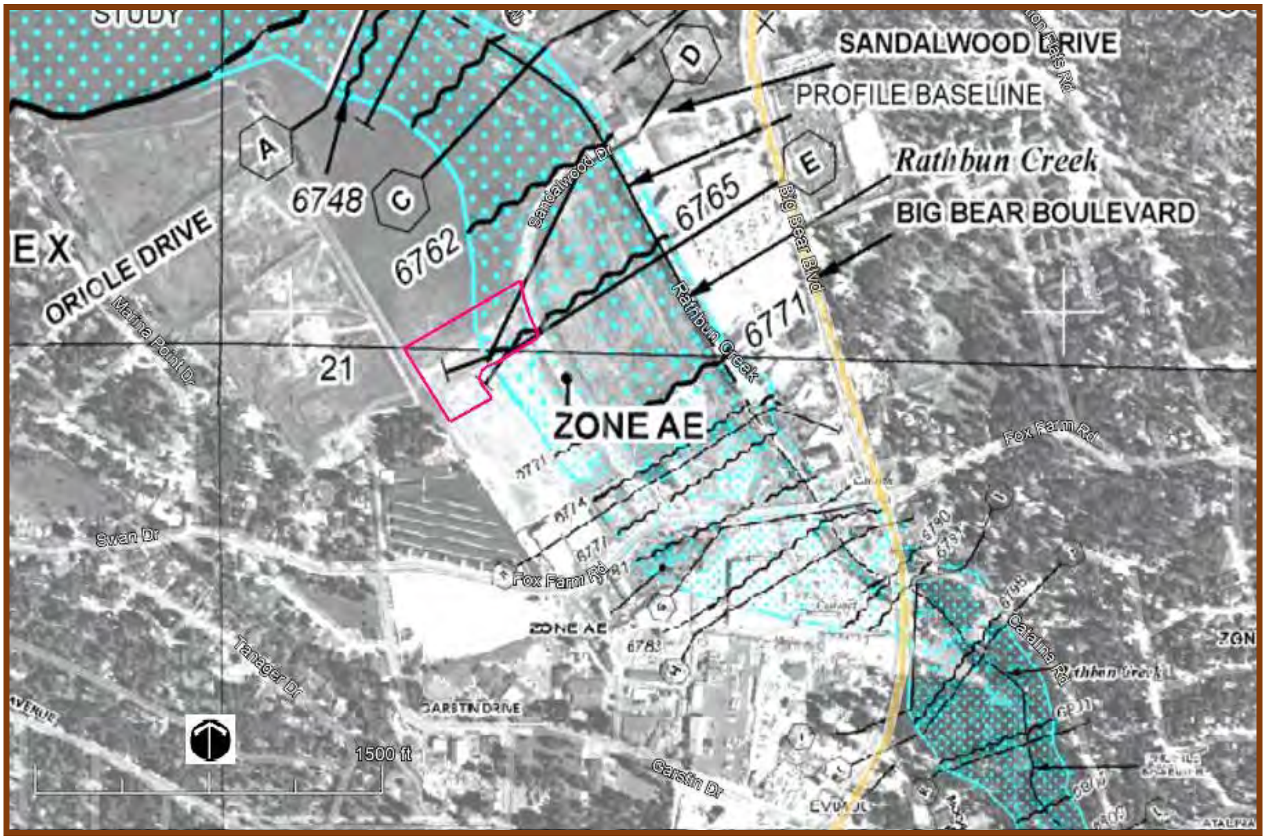


FIGURE 2- FEMA Flood Map; Site boundaries approximated by red outline.

OTHER GEOLOGIC HAZARDS

There are other potential geologic hazards not necessarily associated with seismic activity that occur statewide. These hazards include; natural hazardous materials (such as methane gas, hydrogen-sulfide gas, and tar seeps); Radon-222 gas (EPA, 1993); naturally occurring asbestos; volcanic hazards (Martin, 1982); and regional subsidence. Of these hazards, there are none that appear to impact the site.

CONCLUSIONS AND RECOMMENDATIONS

General:

Based on our field reconnaissance and review of available pertinent published and unpublished geologic/seismic literature, construction of the proposed administrative building and maintenance facility appears to be feasible from a geologic standpoint, providing our recommendations are considered during planning and construction.

Conclusions:

1. Available published geologic data indicates that the subject property is mantled by late Holocene age active-wash deposits, generally described as being unconsolidated to locally cemented sand and gravel deposits. Underlying these surficial deposits are believed to be Miocene age moderately-well consolidated sedimentary rocks comprised of siltstone, fine- to coarse-grained sandstone, pebble sandstone, and greenish mudstone. The provided exploratory boring log indicates that the site is mantled by 7± feet of artificial fill comprised generally of silty fine- to coarse-grained sand with gravel, cobbles and occasional debris. These materials are in turn underlain by interbedded silty fine- to medium-grained sand and silty-clayey fine- to medium-grained sand, to a depth of at least 71 feet. These deposits were found to be in a dense to very-dense condition.

2. Groundwater was encountered during subsurface exploration within the proposed project area at a depth of 26½ feet. Groundwater levels are expected to fluctuate in response to the water level of Big Bear Lake, which is located 2,000± feet to the north. Currently the lake water level is approximately 15± feet below the "full" lake level, suggesting that groundwater could approach within 11½± feet of the surface, which includes the height of the 7± foot-high artificial fill locally placed at the site.

3. There are no active faults that are known to traverse the subject site based on published literature. Additionally, no geomorphic or photogeologic evidence was observed that would suggest the presence of active faulting traversing through or towards the site. In addition, the subject site is not located within a designated Alquist-Priolo Earthquake Fault Zone that would indicate a potential for surface-fault rupture hazards. The nearest known "active" fault which is <u>zoned</u> by the State of California is the North Frontal Fault, located 7±-miles to the north.

4. The <u>primary</u> geologic hazard that exists at the site is that of ground shaking. Moderate to severe ground shaking could be anticipated during the life of the proposed facility. Ground shaking from earthquakes accounts for nearly all earthquake losses.

5. Other than the potential for liquefaction, there do not appear to be any potential permanent or transient secondary seismic hazards that would affect the proposed project development.

6. The eastern portion of the site is shown to be located within a flood hazard zone that is denoted as being "Special Flood Hazard Areas Subject to Inundation by the 1% Annual Chance Flood (Base flood elevations determined)".

Recommendations:

1. It is recommended that all structures be designed to at least meet the current California Building Code provisions in the latest 2019 CBC edition and the ASCE Standard 7-16, where applicable. However, it should be noted that the building code is intended as a minimum construction design and is often the maximum level to which structures are designed. It is the responsibility of both the property owner and project structural engineer to determine the risk factors with respect to using CBC minimum design values for the proposed facilities.

2. The potential for liquefaction should be properly evaluated by the project Geotechnical Engineer. Any appropriate site-specific mitigation measures should be implemented as recommended, if warranted.

3. Any possible flood hazards associated within this zone, or elsewhere within the site should be properly evaluated by the design Civil Engineer.

CLOSURE

Our conclusions and recommendations are based on a review of available existing geologic/seismic data and the provided site-specific provided subsurface exploratory boring logs. No subsurface exploration was performed by this firm for this evaluation. We make no warranty, either express or implied. Should conditions be encountered at a later date or more information becomes available that appear to be different than those indicated in this report, we reserve the right to reevaluate our conclusions and recommendations and provide appropriate mitigation measures, if warranted. It is assumed that all the conclusions and recommendations outlined in this report are understood and followed. If any portion of this report is not understood, it is the responsibility of the owner, contractor, engineer, and/or governmental agency, etc., to contact this office for further clarification.

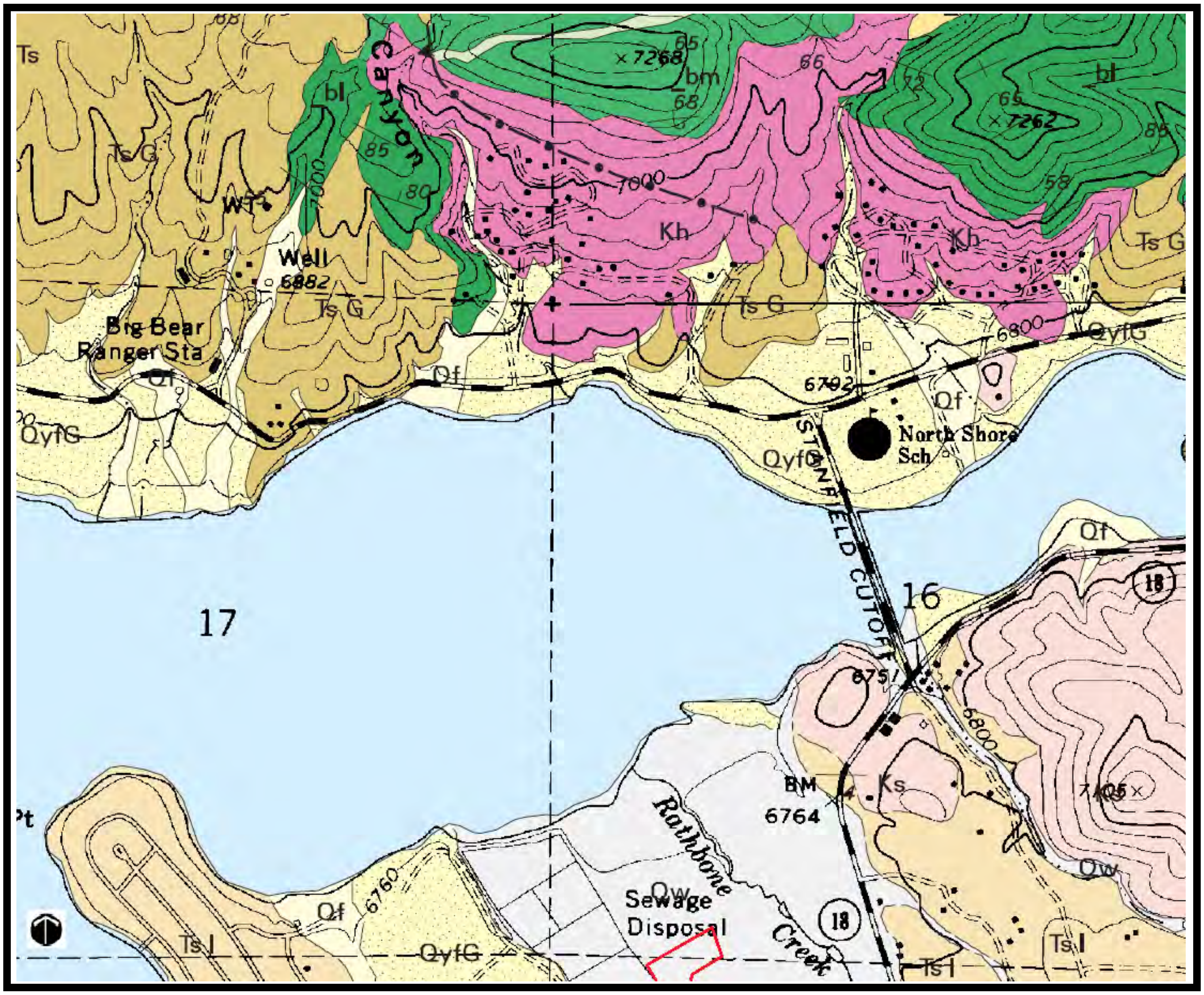
Respectfully submitted,
TERRA GEOSCIENCES

Donn C. Schwartzkopf
Principal Geologist / Geophysicist
CEG 1459 / PGP 1002

PROFESSIONAL GEOLOGIST
DONN C. SCHWARTZKOPF
CERTIFIED ENGINEERING GEOLOGIST
No. 1459
STATE OF CALIFORNIA

PROFESSIONAL GEOPHYSICIST
DONN C. SCHWARTZKOPF
No. 1002
STATE OF CALIFORNIA

REGIONAL GEOLOGIC MAP



BASE MAP: Miller et al. (2001), U.S.G.S. Open-File Report 98-579, Site partially outlined in red.

PARTIAL LEGEND

Qw	**WASH DEPOSITS**	Unconsolidated to locally cemented sand and gravel deposits in active washes of streams and on active surfaces of alluvial fans (late Holocene).
— - - -	**GEOLOGIC CONTACT**	Solid where located within ±15 meters, dashed where located within ±30 meters.

GEOLOGIC HAZARD OVERLAY MAP

BASE MAP: San Bernardino County (2010), Map Nos. FI09-C & FI71-C, Site outlined in red.

PARTIAL LEGEND

Zone of Suspected Liquefaction Susceptibility

▨ Zone of Susceptibility

Generalized Liquefaction Susceptibility

🟦 Low

🟦 Medium

🟦 High

Generalized Landslide Susceptibility

▤ Low to moderate

▤ Moderate to high

▥ Mapped, Existing Landslide

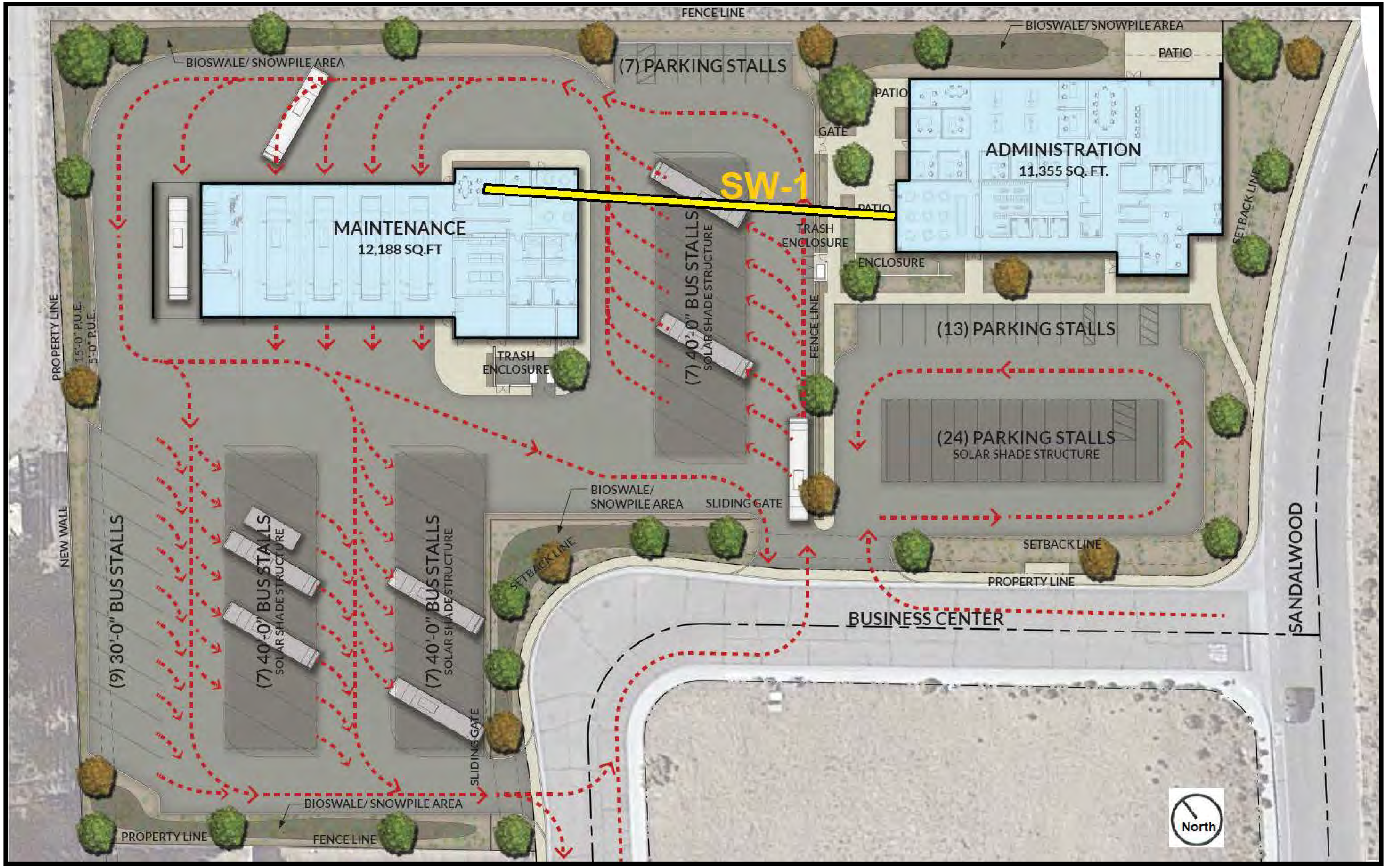
GOOGLE™ EARTH IMAGERY MAP

Base Map: Google™ Earth (2022); Seismic shear-wave traverse SW-1 shown as yellow line, approximate project boundaries outlined in red.

PROJECT NO. 223769-1

PLATE 3

SITE PLAN



BASE MAP: Partial modified copy of the Site Plan (Ruhnau Clarke Architects); Seismic shear-wave traverse SW-1 shown as black/yellow line.

APPENDIX A

SHEAR-WAVE SURVEY

SHEAR-WAVE SURVEY

Methodology

The fundamental premise of this survey uses the fact that the Earth is always in motion at various seismic frequencies. These relatively constant vibrations of the Earth's surface are called microtremors, which are very small with respect to amplitude and are generally referred to as background "noise" that contain abundant surface waves. These microtremors are caused by both human activity (i.e., cultural noise, traffic, factories, etc.) and natural phenomenon (i.e., wind, wave motion, rain, atmospheric pressure, etc.) which have now become regarded as useful signal information. Although these signals are generally very weak, the recording, amplification, and processing of these surface waves has greatly improved by the use of technologically improved seismic recording instrumentation and recently developed computer software. For this application, we are mainly concerned with the Rayleigh wave portion of the seismic signals, which is also referred to as "ground roll" since the Rayleigh wave is the dominant component of ground roll.

For the purposes of this study, there are two ways that the surface waves were recorded, one being "active" and the other being "passive." Active means that seismic energy is intentionally generated at a specific location relative to the survey spread and recording begins when the source energy is imparted into the ground (i.e., MASW survey technique). Passive surveying, also called "microtremor surveying," is where the seismograph records ambient background vibrations (i.e., MAM survey technique), with the ideal vibration sources being at a constant level. Longer wavelength surface waves (longer-period and lower-frequency) travel deeper and thus contain more information about deeper velocity structure and are generally obtained with passive survey information. Shorter wavelength (shorter-period and higher-frequency) surface waves travel shallower and thus contain more information about shallower velocity structure and are generally collected with the use of active sources.

For the most part, higher frequency active source surface waves will resolve the shallower velocity structure and lower frequency passive source surface waves will better resolve the deeper velocity structure. Therefore, the combination of both of these surveying techniques provides a more accurate depiction of the subsurface velocity structure.

The assemblage of the data that is gathered from these surface wave surveys results in development of a dispersion curve. Dispersion, or the change in phase velocity of the seismic waves with frequency, is the fundamental property utilized in the analysis of surface wave methods. The fundamental assumption of these survey methods is that the signal wavefront is planar, stable, and isotropic (coming from all directions) making it independent of source locations and for analytical purposes uses the spatial autocorrelation method (SPAC). The SPAC method is based on theories that are able to detect "signals" from background "noise" (Okada, 2003). The shear wave velocity (V_s) can then be calculated by mathematical inversion of the dispersive phase velocity of the surface waves which can be significant in the presence of velocity layering, which is common in the near-surface environment.

Field Procedures

One shear-wave survey traverse (SW-1) was performed within the proposed construction area, as approximated on Plates 3 and 4. For data collection, the field survey employed a twenty-four channel Geometrics StrataVisor^{TM} NZXP model signal-enhancement refraction seismograph. This survey employed both active source (MASW) and passive (MAM) methods to ensure that both quality shallow and deeper shear-wave velocity information was recorded (Park et al., 2005).

Both the MASW and MAM survey lines used the same linear geometry array that consisted of a 184-foot-long spread using a series of twenty-four 4.5-Hz geophones that were spaced at regular eight-foot intervals. For the active source MASW survey, the ground vibrations were recorded using a one second record length at a sampling rate of 0.5-milliseconds. Two separate seismic records were obtained using a 30-foot shot offset at both ends of the line utilizing a 16-pound sledge-hammer as the energy source to produce the seismic waves. Numerous seismic impacts were used at each shot location to improve the signal-to-noise ratio.

The MAM survey did not require the introduction of any artificial seismic sources with only background ambient noise (i.e., air and vehicle traffic, etc.) being necessary. These ambient ground vibrations were recorded using a thirty-two second record length at a two-millisecond sampling rate with 30 separate seismic records being obtained for quality control purposes. The frequency spectrum data that was displayed on the seismograph screen were used to assess the recorded seismic wave data for quality control purposes in the field. The acceptable records were digitally recorded on the in-board seismograph computer and subsequently transferred to a flash drive so that they could be subsequently transferred to our office computer for analysis.

Data Reduction

For analysis and presentation of the shear-wave profile and supportive illustration, this study used the **SeisImager/SW™** computer software program that was developed by Geometrics, Inc. (2009). Both the active (MASW) and passive (MAM) survey results were combined for this analysis (Park et al., 2005). The combined results maximize the resolution and overall depth range in order to obtain one high resolution V_s curve over the entire sampled depth range. These methods economically and efficiently estimate one-dimensional subsurface shear-wave velocities using data collected from standard primary-wave (P-wave) refraction surveys.

However, it should be noted that surface waves by their physical nature cannot resolve relatively abrupt or small-scale velocity anomalies and this model should be considered as an approximation. Processing of the data then proceeded by calculating the dispersion curve from the input data from both the active and passive data records, which were subsequently combined creating an initial shear-wave (V_s) model based on the observed data. This initial model was then inverted in order to converge on the best fit of the initial model and the observed data, creating the final V_s curve as presented within this appendix.

Summary of Data Analysis

Data acquisition went very smoothly and the quality was considered to be good. Analysis revealed that the average shear-wave velocity (“weighted average”) in the upper 100 feet of the subject survey area is **1,163.1** feet per second as shown on the shear-wave model for Seismic Line SW-1, as presented within this appendix. This average velocity classifies the underlying soils to that of Site Class “**D**” (Stiff Soil), which has a velocity range from 600 to 1,200 ft/sec (ASCE, 2017; Table 20.3-1).

The “weighted average” velocity is computed from a formula that is used by the ASCE (2017; Section 20.4, Equation 20.4-1) to determine the average shear-wave velocity for the upper 100 feet of the subsurface (V100).

$$\mathbf{Vs = 100/[(d1/v1) + (d2/v2) + ...+ (dn/vn)]}$$

Where d1, d2, d3,...,tn, are the thicknesses for layers 1, 2, 3,...n, up to 100 feet, and v1, v2, v3,...,vn, are the seismic velocities (feet/second) for layers 1, 2, 3,...n. The detailed shear-wave model displays these calculated layer boundaries/depths and associated velocities (feet/second) for the 218-foot profile where locally measured. The constrained data is represented by the dark-gray shading on the shear-wave model. The associated Dispersion Curves (for both the active and passive methods) which show the data quality and picks, along with the resultant combined dispersion curve model, are also included within this appendix, for reference purposes.

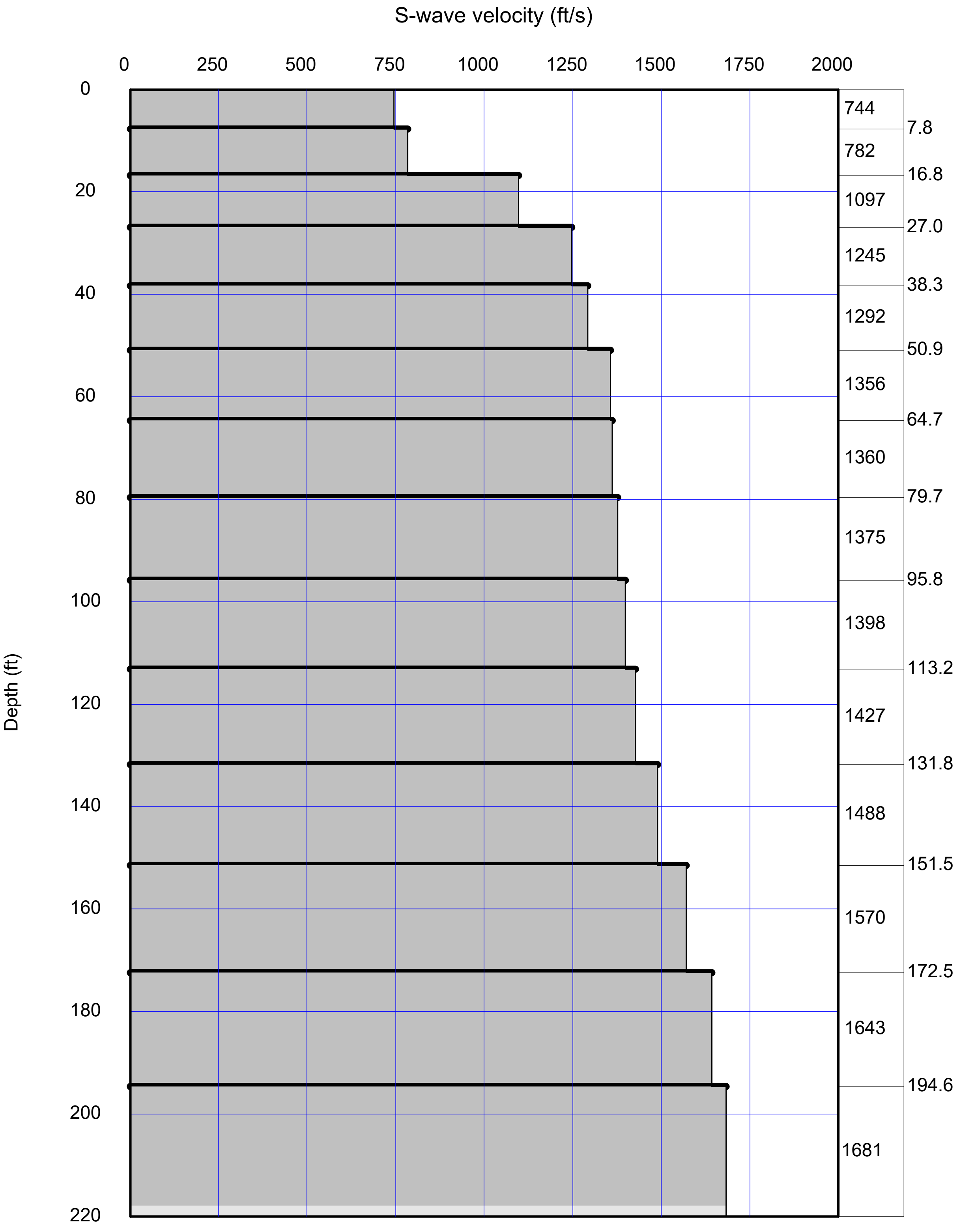
SURVEY LINE PHOTOGRAPHS

View looking northeast along Seismic Line SW-1.

View looking southwest along Seismic Line SW-1.

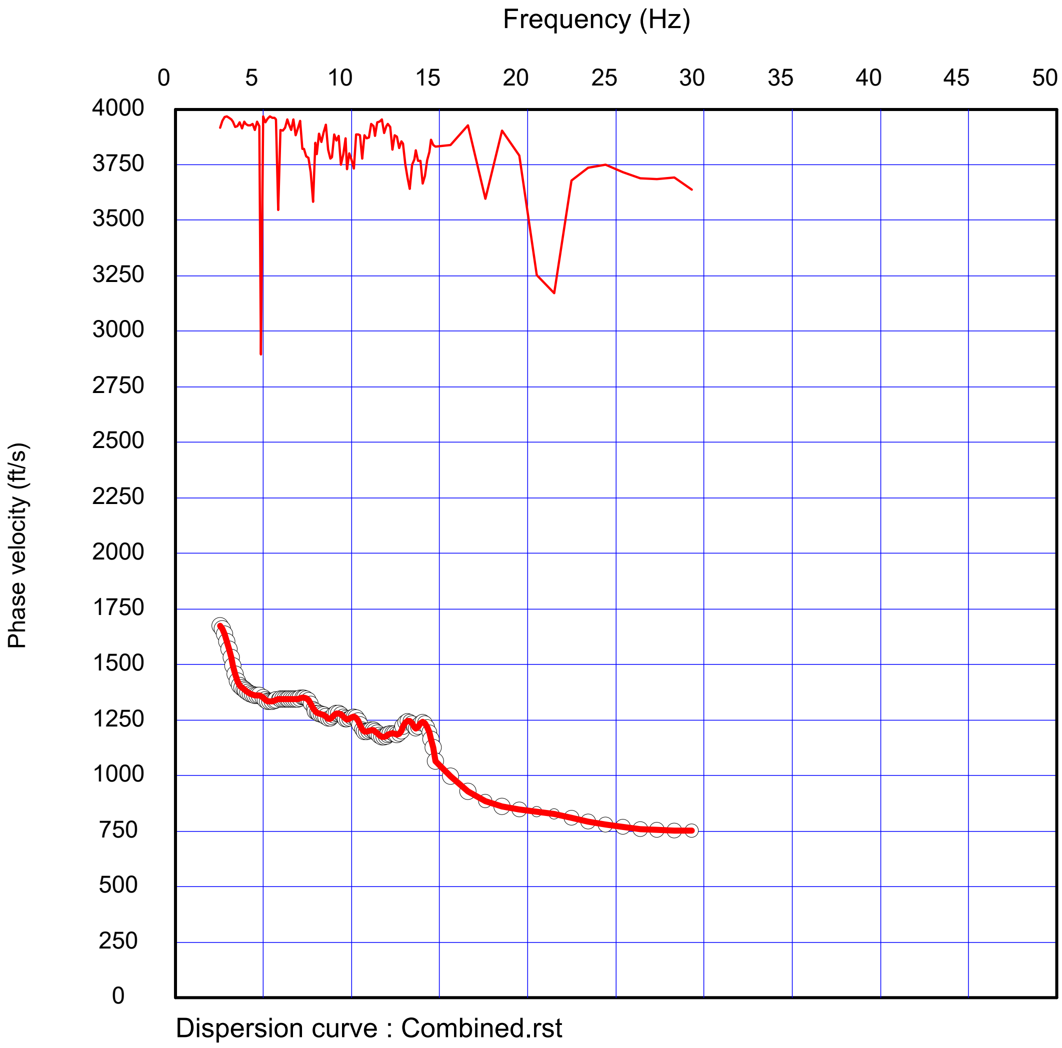
SEISMIC LINE SW-1

SHEAR-WAVE MODEL



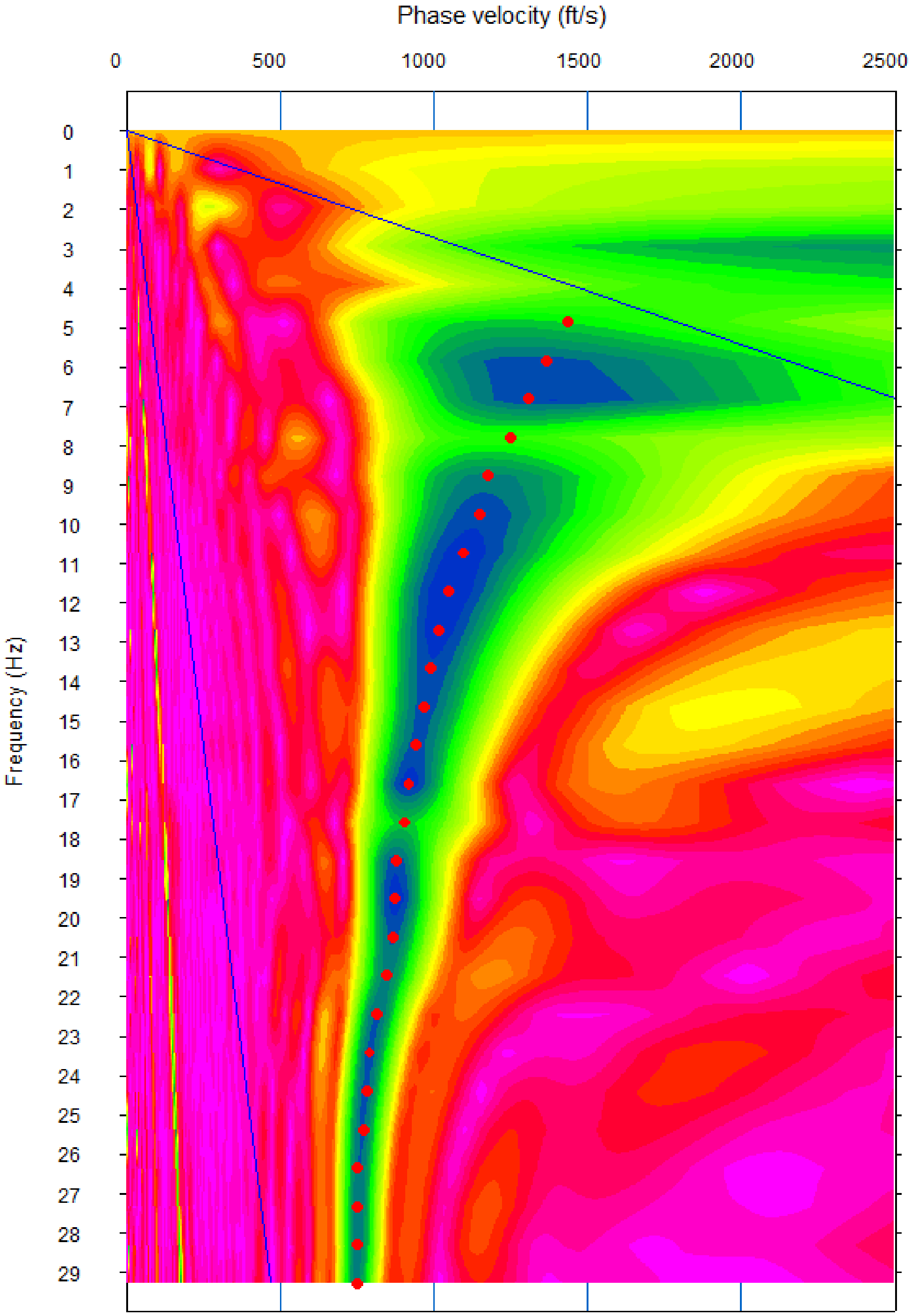
S-wave velocity model (inverted) : Final.rst **Average Vs 100ft = 1163.1 ft/sec**

SHEAR-WAVE MODEL SW-1



COMBINED DISPERSION CURVE

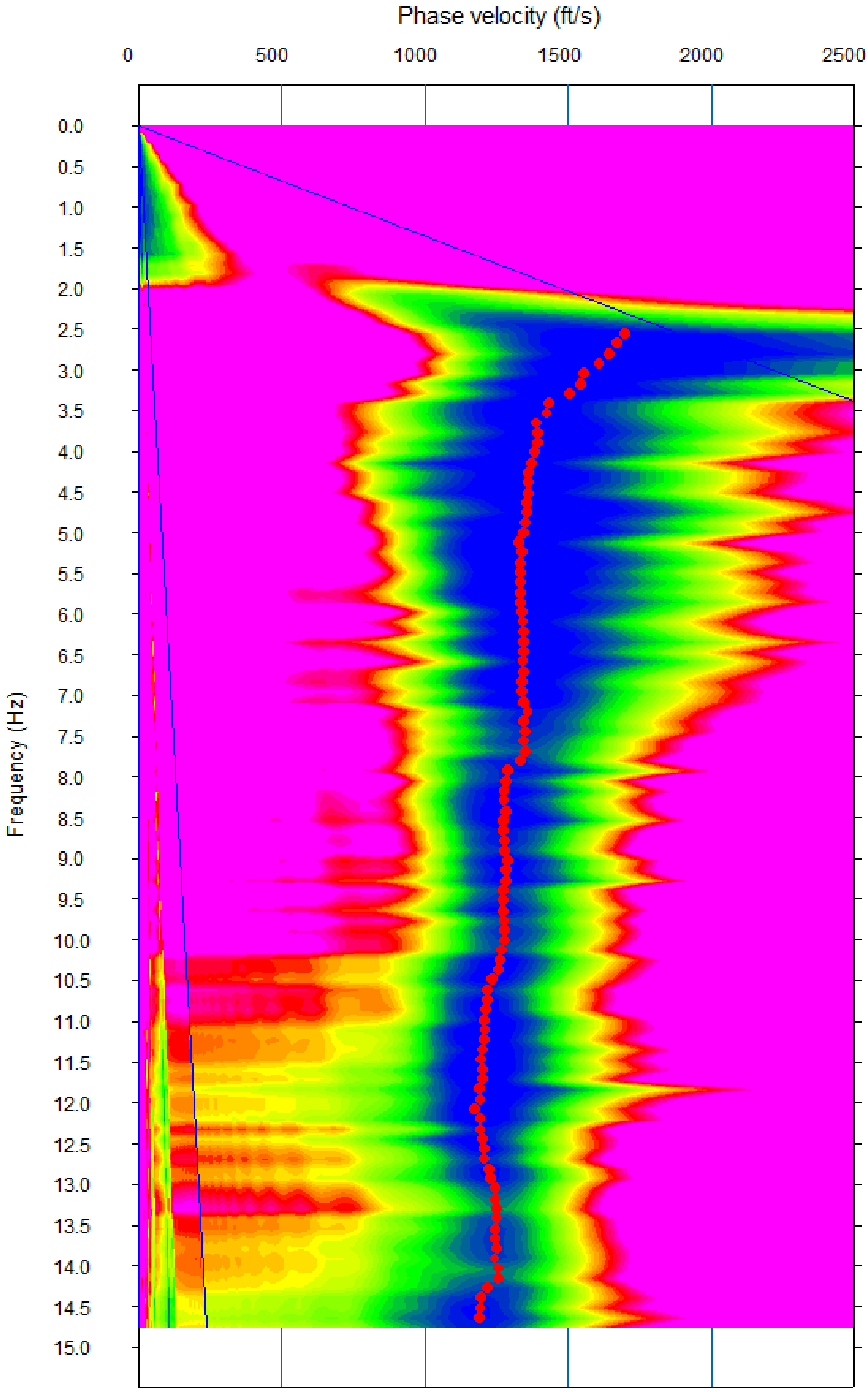
SEISMIC LINE SW-1



Dispersion Cure: Active.dat

ACTIVE DISPERSION CURVE

SEISMIC LINE SW-1



Dispersion Curve: Passive.dat

PASSIVE DISPERSION CURVE

APPENDIX B

SITE-SPECIFIC GROUND MOTION ANALYSIS

SITE-SPECIFIC GROUND MOTION ANALYSIS

A detailed summary of the site-specific ground motion analysis, which follows Section 21 of the ASCE Standard 7-16 (2017) and the 2019 California Building Code is presented below, with the Seismic Design Parameters Summary included within this appendix following the summary text.

- **Mapped Spectral Acceleration Parameters (CBC 1613.2.1)**-

  Based on maps prepared by the U.S.G.S (Risk-Adjusted Maximum Considered Earthquake (MCE_R) Ground Motion Parameter for the Conterminous United States for the 0.2 and 1-second Spectral Response Acceleration (5% of Critical Damping; Site Class B/C), a value of **1.642g** for the 0.2 second period (S_s) and **0.568** for the 1.0 second period (S_1) was calculated (ASCE 7-16 Figures 22-1, 22-2 and CBC 1613.2.1).

- **Site Classification (CBC 1613.2.2 & ASCE 7-16 Chapter 20)**-

  Based on the site-specific measured shear-wave value of 1,163.1 feet/second (354.1 m/sec), the soil profile type used should be Site Class **"D."** This Class is defined as having the upper 100 feet (30 meters) of the subsurface being underlain by "Stiff Soil" with average shear-wave velocities of 600 to 1,200 feet/second (180 to 360 meters/second), as detailed within Appendix A.

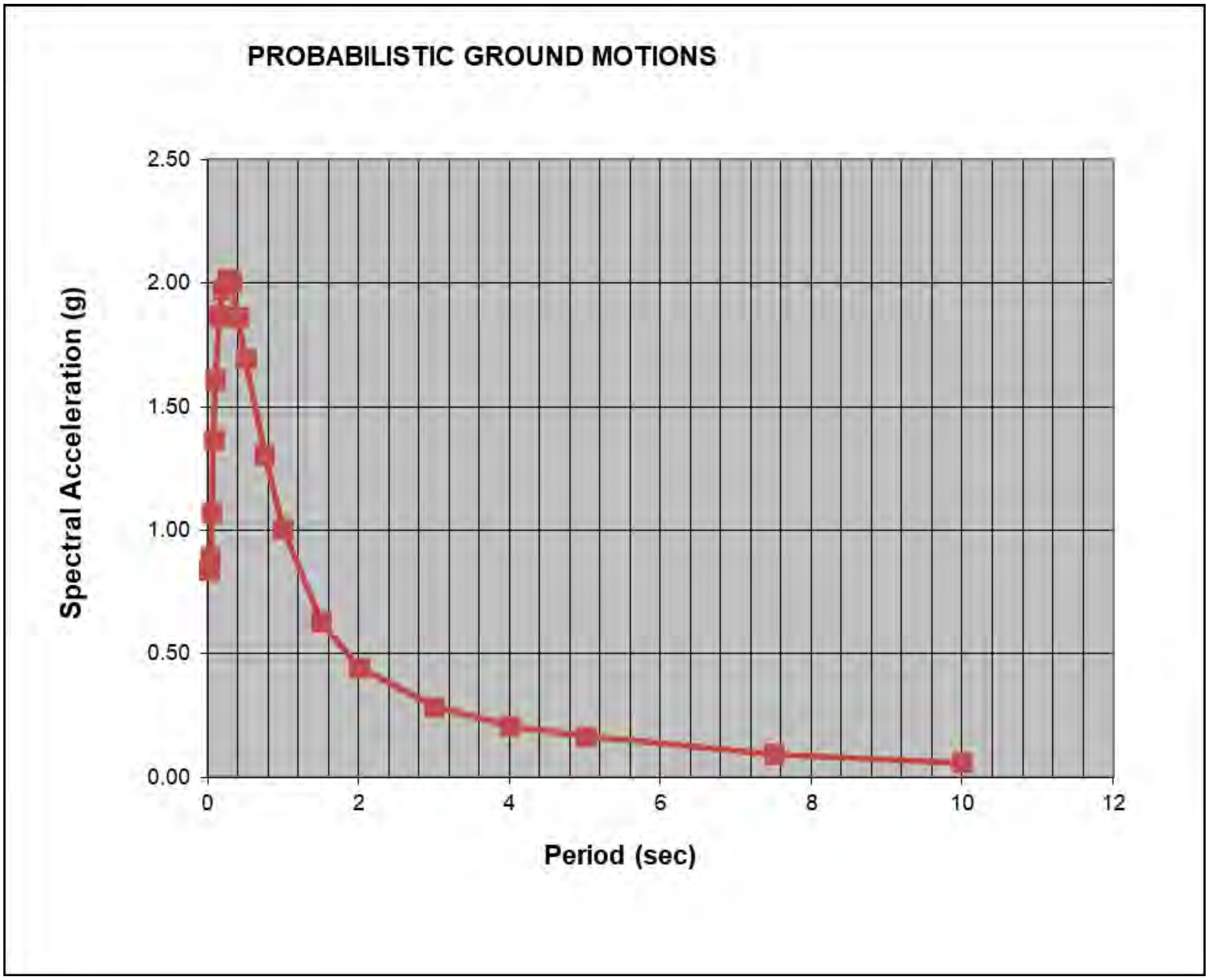
- **Site Coefficients (CBC 1613.2.3)**-

  Based on CBC Tables 1613.2.3(1) and 1613.2.3(2), the site coefficient **F_a = 1.0** and **F_v = 1.732**, respectively.

- **Probabilistic (MCE_R) Ground Motions (ASCE 7 Section 21.2.1)**-

  Per Section 21.2.1.1 (**Method 1**), the probabilistic MCE spectral accelerations shall be taken as the spectral response accelerations in the direction of maximum response represented by a five percent damped acceleration response spectrum that is expected to achieve a one percent probability of collapse within a 50-year period.

  The probabilistic analysis included the use of the Open Seismic Hazard Analysis (OpenSHA). The selected Earthquake Rupture Forecast (ERF) was UCERF3 along with a Probability of Exceedance of 2% in 50 Years. The average of four Next Generation Attenuation West-2 Relations (2014 NGA) were utilized to produce a response spectrum. These included Chiou & Youngs (2014), Abrahamsom et al. (2014), Campbell & Bozorgnia (2014), Boore et al. (2014), and Campbell & Bozorgnia (2014). The Probabilistic Risk Targeted Response Spectrum was determined as the product of the ordinates of the probabilistic response spectrum and the applicable risk coefficient (C_R). These values were then modified to produce a spectrum based upon the maximum rotated components of ground motion. The resulting MCE_R Response Spectrum is indicated below:



- ***Deterministic Spectral Response Analyses (ASCE 7 Section 21.2.2)***-

The deterministic MCE_R response acceleration at each period shall be calculated as an 84th-percentile 5 percent damped spectral response acceleration in the direction of maximum horizontal response computed at that period. The largest such acceleration calculated for the characteristic earthquakes on all known active faults within the region shall be used. Analyses were conducted using the average of four Next Generation Attenuation West-2 Relations (2014 NGA), including Chiou & Youngs (2014), Abrahamsom et al. (2014), Boore et al. (2014), and Campbell & Bozorgnia (2014).

Based on our review of the Fault Section Database within the Uniform California Earthquake Rupture Forecast (UCERF 3; Field et al., 2013) and other published geologic data and maps, the Helendale-South Lockhart Fault Zone (M_W 7.4), the North Frontal Fault Zone (Eastern section, M_W 7.0), and the San Andreas Fault Zone (San Bernardino Section, M_W 8.3) were used for this analysis.

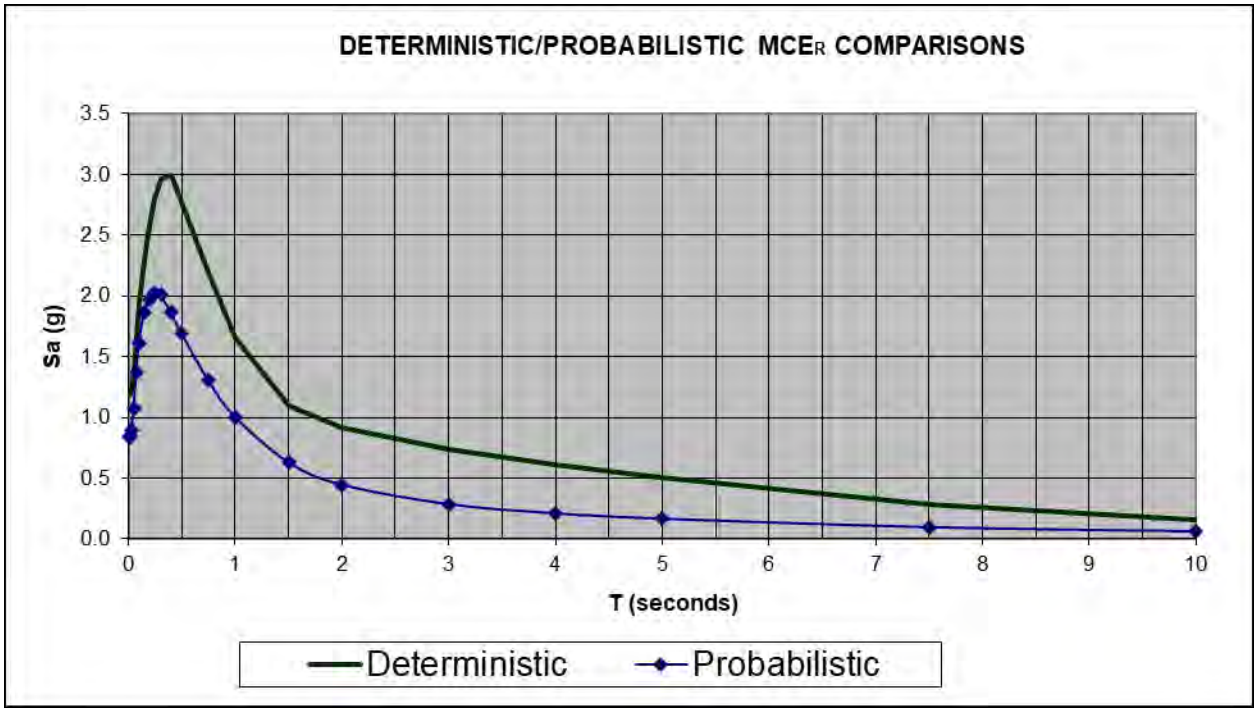
- **Site Specific MCE_R (ASCE 7 Section 21.2.3)-**

  The site-specific MCE_R spectral response acceleration at any period, S_{aM}, shall be taken as the lesser of the spectral response accelerations from the probabilistic ground motions of Section 21.2.1 and the deterministic ground motions of Section 21.2.2. The deterministic ground motions were compared with the probabilistic ground motions that were determined in accordance with Section 21.2.1. These results are tabulated below:

Comparison of Deterministic MCE_R Values with Probabilistic MCE_R Values - Section 21.2.3

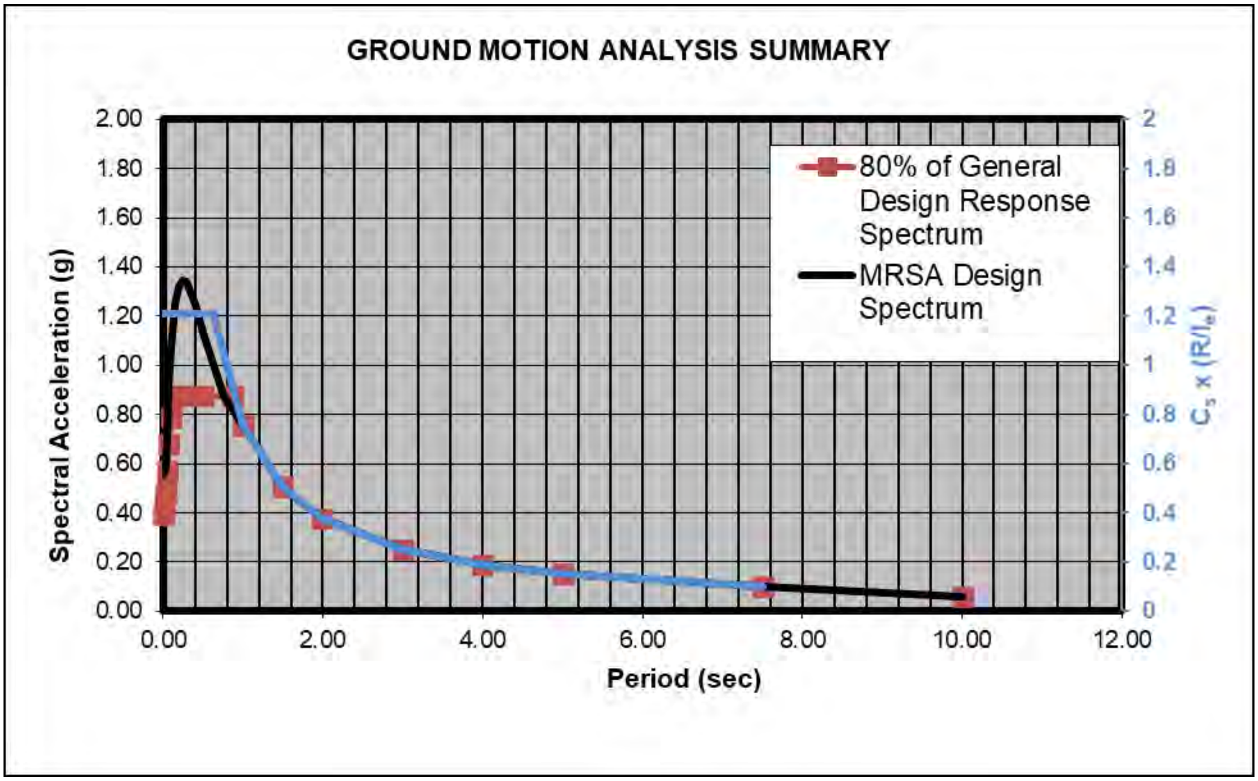
Period	Deterministic	Probabilistic	Lower Value (Site Specific MCE_R)	Governing Method
T	MCE_R	MCE_R		
0.010	1.18	0.84	0.84	Probabilistic Governs
0.020	1.19	0.84	0.84	Probabilistic Governs
0.030	1.23	0.89	0.89	Probabilistic Governs
0.050	1.39	1.07	1.07	Probabilistic Governs
0.075	1.68	1.37	1.37	Probabilistic Governs
0.100	1.94	1.61	1.61	Probabilistic Governs
0.150	2.30	1.87	1.87	Probabilistic Governs
0.200	2.58	1.98	1.98	Probabilistic Governs
0.250	2.80	2.02	2.02	Probabilistic Governs
0.300	2.97	2.01	2.01	Probabilistic Governs
0.400	2.99	1.87	1.87	Probabilistic Governs
0.500	2.77	1.70	1.70	Probabilistic Governs
0.750	2.20	1.31	1.31	Probabilistic Governs
1.000	1.66	1.01	1.01	Probabilistic Governs
1.500	1.09	0.63	0.63	Probabilistic Governs
2.000	0.91	0.45	0.45	Probabilistic Governs
3.000	0.73	0.28	0.28	Probabilistic Governs
4.000	0.61	0.21	0.21	Probabilistic Governs
5.000	0.51	0.17	0.17	Probabilistic Governs
7.500	0.29	0.09	0.09	Probabilistic Governs
10.000	0.16	0.06	0.06	Probabilistic Governs

These comparisons are plotted in the following diagram:



- **Design Response Spectrum (ASCE 7 Section 21.3)**-

In accordance with Section 21.3, the Design Response Spectrum was developed by the following equation: $S_a = 2/3S_{aM}$, where S_{aM} is the MCE$_R$ spectral response acceleration obtained from Section 21.1 or 21.2. The design spectral response acceleration shall not be taken less than 80 percent of S_a. These are plotted and compared with 80% of the CBC Spectrum values in the following diagram:



♦ Design Acceleration Parameters (ASCE 7 Section 21.4)-

Where the site-specific procedure is used to determine the design ground motion in accordance with Section 21.3, the parameter S_{DS} shall obtained from the site-specific spectra at a period of 0.2 s, except that it shall not be taken less than 90 percent of the peak spectral acceleration, S_a, at any period larger than 0.2 s. The parameter S_{D1} shall be taken as the greater of the products of Sa * T for periods between 1 and 5 seconds. The parameters S_{MS}, and S_{M1} shall be taken as 1.5 times S_{DS} and S_{D1}, respectively. The values so obtained shall not be less than 80 percent of the values determined in accordance with Section 11.4.4 for S_{MS}, and S_{M1} and Section 11.4.5 for S_{DS} and S_{D1}.

♦ Site Specific Design Parameters -

For the 0.2 second period (S_{DS}), a value of 1.21g was computed, based upon the average spectral accelerations. The maximum average acceleration for any period exceeding 0.2 seconds was 1.35g occurring at T=0.25 seconds. This was multiplied by 0.9 to produce a value of 1.21g making this the applicable value. A value of 0.76g was calculated for S_{D1} at a period of 1 second (ASCE 7-16, 21.4). For the MCE_R 0.2 second period, a value of 1.818g (S_{MS}) was computed, along with a value of 1.136g (S_{M1}) for the MCE_R 1.0 second period was also calculated (ASCE 7-16, 21.2.3).

♦ Site-Specific MCE_G Peak Ground Accelerations (ASCE 7 Section 21.5)-

The probabilistic geometric mean peak ground acceleration (2 percent probability of exceedance within a 50-year period) was calculated as 0.81g. The deterministic geometric mean peak ground acceleration (largest 84th percentile geometric mean peak ground acceleration for characteristic earthquakes on all known active faults within the site region) was calculated as 1.07g. The site-specific MCE_G peak ground acceleration was calculated to be **0.81g**, which was determined by using the lesser of the probabilistic (0.81g) or the deterministic (1.07g) geometric mean peak ground accelerations, but not taken as less than 80 percent of PGA_M (i.e., 0.76g x 0.80 = 0.61g).

SEISMIC DESIGN PARAMETERS SUMMARY

Project:	Mountain Area Regional Transit Authority	Lattitude:	34.2505
Project #:	223769-1	Longitude:	-116.8888
Date:	1/21/22		

CALIFORNIA BUILDING CODE CHAPTER 16/ASCE7-16

Mapped Acceleration Parameters per ASCE 7-16, Chapter 22

S_s=	1.642	Figure 22-1
S_1=	0.568	Figure 22-2

Site Class per Table 20.3-1

Site Class=	D - Stiff Soil

Site Coefficients per ASCE 7-16 CHAPTER 11

F_a=	1	Table 11.4-1	=	1	For Site Specific Analysis per ASCE7-16 21.3
F_v=	1.732	Table 11.4-2	=	2.50	For Site Specific Analysis per ASCE7-16 21.3

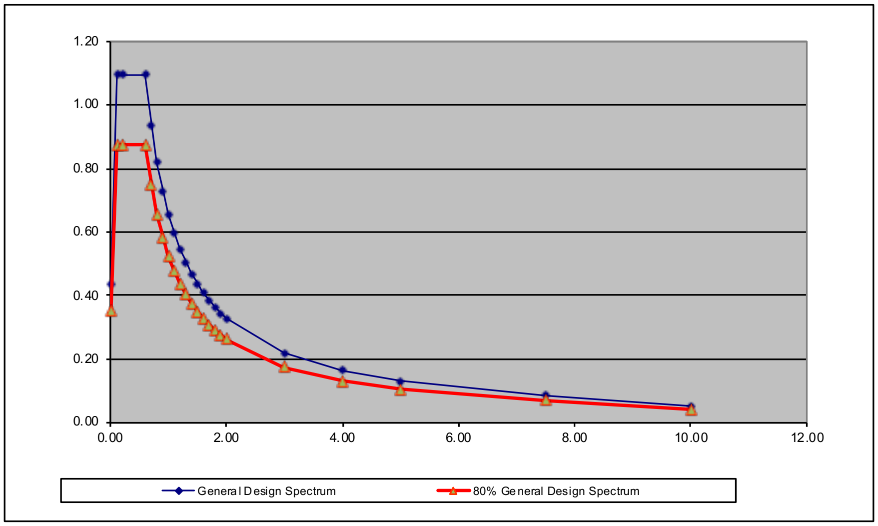
Mapped Design Spectral Response Acceleration Parameters

S_{MS}=	1.642	Equation 11.4-1	1.642	For Site Specific Analysis per ASCE7-16 21.3
S_{M1}=	0.984	Equation 11.4-2	1.420	For Site Specific Analysis per ASCE7-16 21.3

T_0=	0.120	sec	
T_S=	0.599	sec	
T_L=	8	sec	From Fig 22-12
PGA	0.69	g	
F_{PGA}=	1.1		From Table 11.8-1
C_{RS}=	0.936		Figure 22-17
C_{R1}=	0.915		Figure 22-18

S_{DS}=	1.095	Equation 11.4-3
S_{D1}=	0.656	Equation 11.4-4

Period (T)	Sa (ASCE7-16 - 11.4.6)	80% General Design Spectrum
0.01	0.44	0.35
0.12	1.09	0.88
0.20	1.09	0.88
0.60	1.09	0.88
0.70	0.94	0.75
0.80	0.82	0.66
0.90	0.73	0.58
1.00	0.66	0.52
1.10	0.60	0.48
1.20	0.55	0.44
1.30	0.50	0.40
1.40	0.47	0.37
1.50	0.44	0.35
1.60	0.41	0.33
1.70	0.39	0.31
1.80	0.36	0.29
1.90	0.35	0.28
2.00	0.33	0.26
3.00	0.22	0.17
4.00	0.16	0.13
5.00	0.13	0.10
7.50	0.09	0.07
10.00	0.05	0.04



ASCE 7-16 - RISK-TARGETED MAXIMUM CONSIDERED EARTHQUAKE GROUND MOTION ANALYSIS

Use Maximum Rotated Horizontal Component?* (Y/N) y

Presented data are the average of Chiou & Youngs (2014), Abrahamson et. al. (2014) , Boore et. al (2014) and Campbell & Bozorgnia (2014) NGA West-2 Relationships

PROBABILISTIC MCER per 21.2.1.1 **Method 1**

Earthquake Rupture Forecast - UCERF3

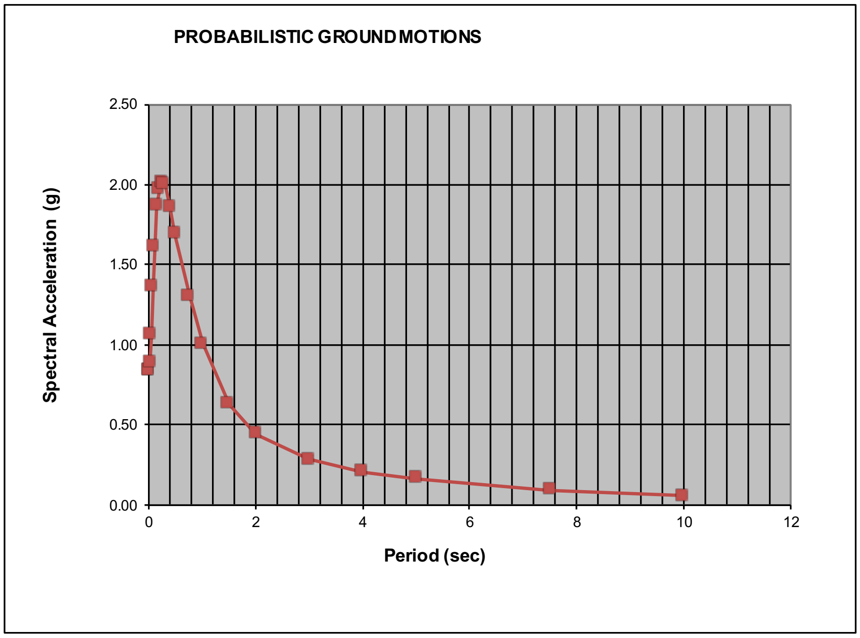
Field, E.H., T.H. Jordan, and C.A. Cornell (2003), OpenSHA: A Developing Community-Modeling Environment for Seismic Hazard Analysis, Seismological Research Letters, 74, no. 4, p. 406-419.

OpenSHA data

2% Probability Of Exceedance in 50 years

Maximum Rotated Horizontal Component determined per ASCE7-16

T	Sa 2% in 50	MCER
0.01	0.90	0.84
0.02	0.90	0.84
0.03	0.95	0.89
0.05	1.14	1.07
0.08	1.46	1.37
0.10	1.72	1.61
0.15	2.00	1.87
0.20	2.11	1.98
0.25	2.16	2.02
0.30	2.15	2.01
0.40	2.00	1.87
0.50	1.83	1.70
0.75	1.42	1.31
1.00	1.10	1.01
1.50	0.69	0.63
2.00	0.49	0.45
3.00	0.31	0.28
4.00	0.23	0.21
5.00	0.18	0.17
7.50	0.10	0.09
10.00	0.07	0.06



S_s=	2.11	1.98
S_1=	1.10	1.01
PGA	0.81 g	

Risk Coefficients:			
C_{RS}	0.936	Figure 22-18	Get from Mapped Values
C_{R1}	0.915	Figure 22-19	
Fa=	1	Table 11.4-1	Per ASCE7-16 - 21.2.3
Is $Sa_{(max)}$<1.2XFa?		NO	If "YES", Probabilistic Spectrum prevails

DETERMINISTIC MCE per 21.2.2

Input Parameters				
Fault		endale-S. Lock	North Frontal (Eastern)	San Andreas (San Bernardino S)
M	= Moment magnitude	7.4	7	8.3
R_{RUP}	= Closest distance to coseismic rupture (km)	9.6	7.3	22
R_{JB}	= Closest distance to surface projection of coseismic rupture (km)	9.6	0	19.08
Rx	= Horizontal distance to top edge of rupture measured perpendicular to strike (km)	9.6	11.2	19.08
U	= Unspecified Faulting Flag (Boore et.al.)	0	0	0
F_{RV}	= Reverse-faulting factor: 0 for strike slip, normal, normal-oblique; 1 for reverse, reverse-oblique and thrust	0	1	0
F_{NM}	= Normal-faulting factor: 0 for strike slip, reverse, reverse-oblique and thrust; 1 for normal and normal-obliqu	0	0	0
F_{HW}	= Hanging-wall factor: 1 for site on down-dip side of top of rupture; 0 otherwise, used in AS08 and CY08	0	1	0
Z_{TOR}	= Depth to top of coseismic rupture (km)	0	0	0
δ	= Average dip of rupture plane (degrees)	90	41	90
V_{S30}	= Average shear-wave velocity in top 30m of site profile	354.5	354.5	354.5
$F_{Measured}$		1	1	1
$Z_{1.0}$	= Depth to Shear Wave Velocity of 1.0 km/sec (km)	0.06	0.06	60
$Z_{2.5}$	= Depth to Shear Wave Velocity of 2.5 km/sec (km)	1.35	1.35	1.35
Site Class		D	D	D
W (km)	= Fault rupture width (km)	12.8	25.3	12.8
F_{AS}	= 0 for mainshock; 1 for aftershock	0	0	0
σ	=Standard Deviation	1	1	1

Deterministic Summary - Section 21.2.2 (Supplement 1)

T	Helendale-S. Lockhart	North Frontal (Eastern)	San Andreas (San Bernardino S)	Maximum $S_{a\ (Average)}$	*Corrected* S_a (per ASCE7-16)*	*Scaled $S_{a(Average)}$*	Controlling Fault
0.010	0.61	1.07	0.67	1.07	1.18	1.18	North Frontal (Eastern)
0.020	0.61	1.08	0.67	1.08	1.19	1.19	North Frontal (Eastern)
0.030	0.64	1.12	0.69	1.12	1.23	1.23	North Frontal (Eastern)
0.050	0.73	1.27	0.64	1.27	1.39	1.39	North Frontal (Eastern)
0.075	0.89	1.52	0.77	1.52	1.68	1.68	North Frontal (Eastern)
0.100	1.04	1.77	1.00	1.77	1.94	1.94	North Frontal (Eastern)
0.150	1.26	2.09	1.05	2.09	2.30	2.30	North Frontal (Eastern)
0.200	1.40	2.35	1.27	2.35	2.58	2.58	North Frontal (Eastern)
0.250	1.47	2.52	1.24	2.52	2.80	2.80	North Frontal (Eastern)
0.300	1.49	2.64	1.32	2.64	2.97	2.97	North Frontal (Eastern)
0.400	1.43	2.60	1.35	2.60	2.99	2.99	North Frontal (Eastern)
0.500	1.31	2.36	1.34	2.36	2.77	2.77	North Frontal (Eastern)
0.750	0.98	1.78	1.16	1.78	2.20	2.20	North Frontal (Eastern)
1.000	0.75	1.27	1.03	1.27	1.66	1.66	North Frontal (Eastern)
1.500	0.47	0.72	0.82	0.82	1.09	1.09	San Andreas (San Bernardino S)
2.000	0.32	0.45	0.68	0.68	0.91	0.91	San Andreas (San Bernardino S)
3.000	0.20	0.22	0.52	0.52	0.73	0.73	San Andreas (San Bernardino S)
4.000	0.13	0.12	0.42	0.42	0.61	0.61	San Andreas (San Bernardino S)
5.000	0.10	0.08	0.34	0.34	0.51	0.51	San Andreas (San Bernardino S)
7.500	0.05	0.04	0.19	0.19	0.29	0.29	San Andreas (San Bernardino S)
10.000	0.03	0.02	0.11	0.11	0.16	0.16	San Andreas (San Bernardino S)
PGA	0.61	1.07	0.54	1.07		1.07	g
Max Sa=	2.99						
Fa =	1.00	Per ASCE7-16 21.2.2					
1.5XFa=	1.5						
Scaling Factor=	1.00						

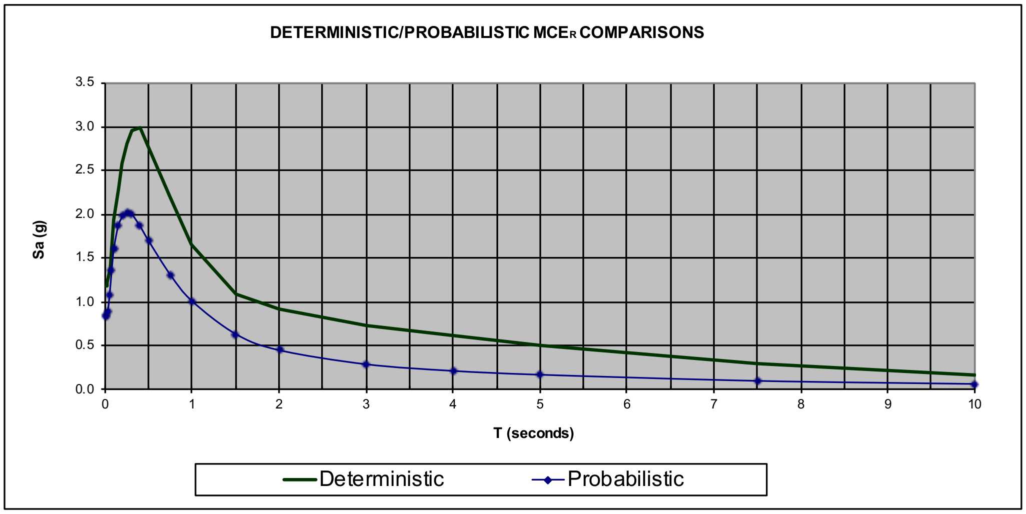
* Correction is the adjustment for Maximum Rotated Value if Applicable

Enclosure 10, Page 34
Rpt. No.: 7341
File No.: S-14447

SITE SPECIFIC MCE$_R$ - Compare Deterministic MCE$_R$ Values (S_a) with Probabilistic MCE$_R$ Values (S_a) per 21.2.3

Presented data are the average of Chiou & Youngs (2014), Abrahamson et. al. (2014) , Boore et. al (2014) and Campbell & Bozorgnia (2014) NGA West-2 Relationships

Period	Deterministic	Probabilistic	Lower Value (Site Specific MCE$_{R)}$	Governing Method
T	MCE$_R$	MCE$_R$		
0.010	1.18	0.84	0.84	ProbabilisticGoverns
0.020	1.19	0.84	0.84	ProbabilisticGoverns
0.030	1.23	0.89	0.89	ProbabilisticGoverns
0.050	1.39	1.07	1.07	ProbabilisticGoverns
0.075	1.68	1.37	1.37	ProbabilisticGoverns
0.100	1.94	1.61	1.61	ProbabilisticGoverns
0.150	2.30	1.87	1.87	ProbabilisticGoverns
0.200	2.58	1.98	1.98	ProbabilisticGoverns
0.250	2.80	2.02	2.02	ProbabilisticGoverns
0.300	2.97	2.01	2.01	ProbabilisticGoverns
0.400	2.99	1.87	1.87	ProbabilisticGoverns
0.500	2.77	1.70	1.70	ProbabilisticGoverns
0.750	2.20	1.31	1.31	ProbabilisticGoverns
1.000	1.66	1.01	1.01	ProbabilisticGoverns
1.500	1.09	0.63	0.63	ProbabilisticGoverns
2.000	0.91	0.45	0.45	ProbabilisticGoverns
3.000	0.73	0.28	0.28	ProbabilisticGoverns
4.000	0.61	0.21	0.21	ProbabilisticGoverns
5.000	0.51	0.17	0.17	ProbabilisticGoverns
7.500	0.29	0.09	0.09	ProbabilisticGoverns
10.000	0.16	0.06	0.06	ProbabilisticGoverns



DESIGN RESPONSE SPECTRUM per Section 21.3

DESIGN ACCELERATION PARAMETERS per Section 21.4 (MRSA)

Period	2/3*MCE$_R$	80% General Design Response Spectrum (per ASCE 7-16 23.3-1)	Design Response Spectrum	TXSa
0.01	0.56	0.39	0.56	
0.02	0.56	0.44	0.56	
0.03	0.59	0.48	0.59	
0.05	0.71	0.57	0.71	
0.08	0.91	0.68	0.91	
0.10	1.07	0.79	1.07	
0.15	1.25	0.88	1.25	
0.20	1.32	0.88	1.32	
0.25	1.35	0.88	1.35	
0.30	1.34	0.88	1.34	
0.40	1.24	0.88	1.24	
0.50	1.13	0.88	1.13	
0.75	0.87	0.88	0.88	
1.00	0.67	0.76	0.76	0.76
1.50	0.42	0.50	0.50	0.76
2.00	0.30	0.38	0.38	0.76
3.00	0.19	0.25	0.25	0.76
4.00	0.14	0.19	0.19	0.76
5.00	0.11	0.15	0.15	0.76
7.50	0.06	0.10	0.10	
10.00	0.04	0.06	0.06	

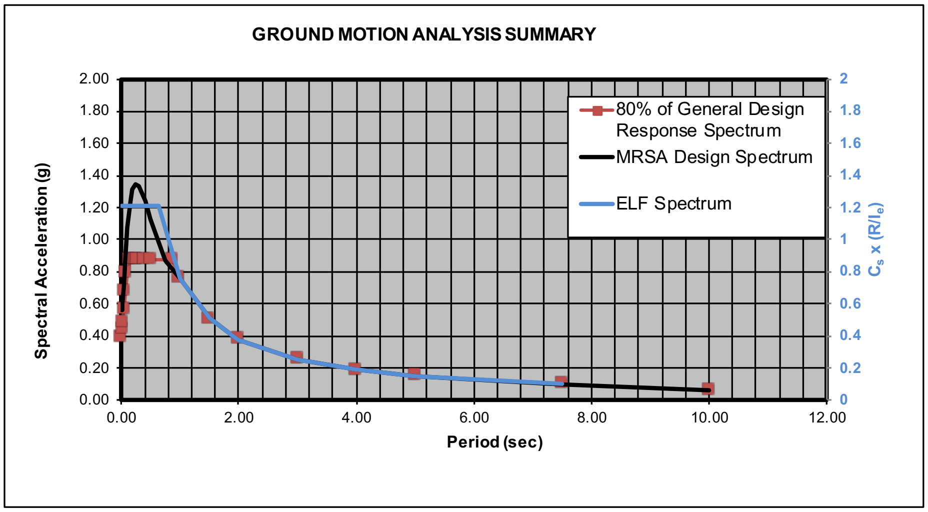
Highest value of S_a for any period exceeding 0.2 sec.=	1.35
90%of Highest Value =	1.21
80% of Mapped S_{DS}=	0.88
Maximum TXSa from T=1s-5s =	0.76
80% of Mapped S_{D1}=	0.52

S_{DS}=	1.21
S_{D1}=	0.76
T_s =	0.62

S_{MS}=	1.818
S_{M1}=	1.136

PGA Determination:

Site Coefficient F_{PGA}=	1.1	
Mapped PGA=	0.69	Figure 22-7
PGA_M =	0.76	g
Deterministic PGA =	1.07	g
Probabilistic PGA =	0.81	g
Lesser of Deterministic/Probabilistic =	0.81	g
80% of $PGA_{M=}$	0.61	g
MCE_G PGA=	0.81	g



APPENDIX C

REFERENCES

REFERENCES

American Society of Civil Engineers (ASCE), 2017, Minimum Design Loads and Associated Criteria for Buildings and other Structures, ASCE Standard 7-16, 889pp.

Blake, T.F. 1989-2000, EQFAULT, A computer program for the deterministic prediction of peak horizontal acceleration from digitized California faults, Version 2.03, revised 1993.

Blake, T.F. 1989-2021, EQSEARCH, A computer program for the estimation of peak horizontal acceleration from Southern California Historical Earthquake Catalog, Version 3.00b.

Big Bear Municipal Water District, 2022, Current Lake Status Web Page (http://www.bbmwd.com/current-lake-status/).

Boore, D.M., Joyner, W.B., and Fumal, T.E., 1997, Equations for Estimating Horizontal Response Spectra and Peak Acceleration from Western North American Earthquakes: A Summary of Recent Work, *in*, Seismological Research Letters, Volume 68, pp. 128-153.

California Building Standards Commission (CBSC), 2019, 2019 California Building Code, California Code of Regulations, Title 24, Part 2, Volume 2 of 2.

California Department of Water Resources (C.D.W.R.), 2003, California's Groundwater, DWR Bulletin 118, 2003 Update, 266 pp.

California Department of Water Resources (C.D.W.R.), 2022, California Statewide Groundwater Elevation Monitoring System (CASGEM) Online System-Public Portal, https://www.casgem.water.ca.gov/OSS/(S(55ycplfqqslsga0raytn2oln))/Public/ApplicationHome.aspx

California Division of Mines & Geology (C.D.M.G.), 1993, California Geology, The Landers-Big Bear Earthquakes, January/February 1993, Volume 42, No. 1.

California Division of Mines & Geology (C.D.M.G.), 1986, "Guidelines to Geologic/Seismic Reports," Note No. 42.

California Division of Mines & Geology (C.D.M.G.), 1996, Probabilistic Seismic Hazard Assessment for the State of California, C.D.M.G. Open File Report 96-08.

California Geological Survey (C.G.S.), 2008, Guidelines for Evaluating and Mitigating Seismic Hazards, in California C.D.M.G. Special Publication 117.

California Geological Survey (C.G.S.), 2018, Earthquake Fault Zones: A Guide for Government Agencies, Property Owners/Developers, and Geoscience Practitioners for Assessing Fault Rupture Hazards in California, CGS Special Publication 42, 93 pp.

California's Office of Statewide Health Planning and Development (OSHPD), 2022, OSHPD Seismic Design Maps Tool web application, https://seismicmaps.org/.

California State Board for Geologists and Geophysicists, Department of Consumer Affairs, 1998, Guidelines for Geophysical Reports for Environmental and Engineering Geology, 5 pp.

Cao, T., Bryant, W.A., Rowshandel, B., Branum, D., and Wills, C.J., 2003, The Revised 2002 California Probabilistic Seismic Hazard Maps, California Geological Survey.

dePolo, Craig M., and Slemmons, D. Gurton, 990, Estimation of Earthquake Size for Seismic Hazards, in Krinitzsky, E.L., and Slemmons, D.B., Neotectonics in earthquake evaluation: Boulder, Colorado, Geological Society of America Reviews in Engineering Geology, Volume 8, pp. 1-28.

Dibblee, T.W., Jr., 1971, Regional Geologic Map of San Andreas and Related Faults in Eastern San Gabriel Mountains, San Bernardino Mountains, Western San Jacinto Mountains and Vicinity, Los Angeles, San Bernardino and Riverside Counties, California, U.S.G.S. Open File Report 71-0088.

Dibblee, T.W., Jr., 1975, Late Quaternary Uplift of the San Bernardino Mountains on the San Andreas and Related Faults, in San Andreas Fault in Southern California, C.D.M.G. Special Report 118, pp. 127-135.

Dibblee, T.W., Jr., 1982, Geology of the San Bernardino Mountains, Southern California, in Geology and Mineral Wealth of the California Transverse Ranges, South Coast Geological Society.

Geometrics, Inc., 2012, StrataVisor™ NZXP Operation and Reference Manual, Revision M, Software Version 9.3, San Jose, California, 226 pp.

Geometrics, Inc., 2004-2021, SeisImager/SW Analysis of Surface Waves, Version 6.0.2.1.

Google™ Earth, 2022, http://earth.google.com/, Version 7.3.4.8248 (64-bit).

Glenn Brown and Associates, 1974, Geology and Groundwater Geology of Big Bear Valley, *in*, Geologic Guide to the San Bernardino Mountains, Southern California, Prepared by Association of Engineering Geologists, Annual Spring Filed Trip Guidebook, May 22, 1976, pp 73-95.

John R. Byerly, Inc., 2022, Exploratory Boring Log B-1, File No. S-14447, dated January 20, 2022.

Larson, R., and Slosson, J., 1992, The Role of Seismic Hazard Evaluation in Engineering Reports, in Engineering Geology Practice in Southern California, AEG Special Publication No. 4, pp. 191-194.

Louie, J.N., 2001, Faster, Better: Shear-Wave Velocity to 100 Meters Depth from Refraction Microtremor Arrays, *in,* Bulletin of the Seismological Society of America, Volume 91, pp. 347-364.

Martin, R.C., and Davis, J.F., 1982, Status of Volcanic Prediction and Emergency Response Capabilities in Volcanic Hazard Zones of California, C.D.M.G. Special Publication 63.

Matti, J.C., Morton, D.M., and Cox, B.F., 1985, Distribution and Geologic Relations of Fault Systems in the Vicinity of the Central Transverse Ranges, Southern California, U.S.G.S. Open File Report 85-365.

Okada, H., 2003, The Microtremor Survey Method, Society of Exploration Geophysicists, Geophysical Monograph Series Number 12, 135 pp.

Park, C.B, Milner, R.D., Rynden, N., Xia, J., and Ivanov, J., 2005, Combined use of Active and Passive Surface Waves, *in*, Journal of Environmental and Engineering Geophysics, Volume 10, Issue 3, pp. 323-334.

Petersen, M.D. et al., 2008, Documentation for the 2008 Update of the United States National Seismic Hazard Maps, United States Geological Survey Open-File Report 2008-1128.

Toppozada, T.R. et al., 1981, Preparation of Isoseismal Maps and Summaries of Reported Effects for pre-1900 California Earthquakes, C.D.M.G. Open File Report 81-11.

Toppozada, T.R., and Parke, D.L., 1982, Areas Damaged by California Earthquakes, 1900 - 1949, C.D.M.G. Open File Report 82-17.

United States Environmental Protection Agency (EPA), 1993, EPA's Map of Radon Zones, California, Manual 402-R-93-025, 78 pp.

United States Geological Survey (U.S.G.S.), 1987, Recent Reverse Faulting in the Transverse Ranges, California, Professional Paper 1339.

United States Geological Survey (U.S.G.S.), 2012, Geohydrology of Big Bear Valley, California: Phase 1 – Geologic Framework, Recharge, and Preliminary Assessment of the Source and Age of Groundwater, *ed. Flint, L. E. and Martin, P*., Scientific Investigations Report 2012-5100, 130 pp.

United States Geological Survey (U.S.G.S.), 2021, Hazard Spectrum Application, Version 1.5.2, http://opensha.org.

United States Geological Survey (U.S.G.S.), 2022, ANSS Comprehensive Earthquake Catalog (ComCat), https://earthquake.usgs.gov/data/comcat/.

MAPS UTILIZED

California Division of Mines and Geology, 1988, Big Bear City Special Studies Zone Map, Scale 1: 24,000.

California Division of Mines and Geology, 1988, Fawnskin Special Studies Zone Map, Scale 1: 24,000.

California Geological Survey, 2014, Tsunami Inundation Maps, California Department of Conservation, (http://www.quake.ca.gov/gmaps/tsunami/tsunami_maps.htm).

Dibblee, T. W. Jr., 1964, Geologic Map of the San Gorgonio Mountain Quadrangle, San Bernardino and Riverside Counties, California, U.S.G.S. Miscellaneous Geologic Investigation Map 1-431.

Federal Emergency Management Agency (FEMA), 2008a, Flood Insurance Rate Map, Community Panel Number 06071C7295H, August 28, 2008, Scale 1: 24,000.

Federal Emergency Management Agency (FEMA), 2008b, Flood Insurance Rate Map, Community Panel Number 06071C8007H, August 28, 2008, Scale 1: 24,000.

Gutierrez, C., Bryant, W.A., Saucedo, G., and Wills, C., 2010, 2010 Fault Activity Map of California, Scale 1: 750,000, California Geological Survey, Geologic Data Map No. 6. Scale 1:750,000.

Miller, F.K., 2004, Preliminary Geologic Map of the Big Bear City 7.5-Minute Quadrangle, San Bernardino County, California, U.S.G.S. Open File Report 2004-1193, Scale 1: 24,000.

Miller, F.K., Matti, J.C., Brown, H.J., and Powell, R.E., 2001, Preliminary Geologic Map of the Fawnskin 7.5-Minute Quadrangle, San Bernardino County, California, U.S.G.S. Open File Report 98-579, Scale 1: 24,000.

San Bernardino County, 2010a, San Bernardino County Land Use Plan, GENERAL PLAN, Geologic Hazard Overlays, Big Bear Lake Map No. FI17-C, Scale 1: 14,000.

San Bernardino County, 2010b, San Bernardino County Land Use Plan, GENERAL PLAN, Geologic Hazard Overlays, Fawnskin Map No. FI09-C, Scale 1: 14,000.

Tan, S.S., 1990, Landslide Hazards in the Lake Arrowhead and Big Bear Lake Region, San Bernardino County, California, Landslide Hazard Identification Map No. 15, C.D.M.G. Open File Report 89-7.

Toppozada, T.R., et al. 2000, Epicenters of and Areas Damaged by M≥4 California Earthquakes, Map Sheet 49, Scale 1" =25 Miles.

AERIAL PHOTOGRAPHS UTILIZED

Nationwide Environmental Title Research, LLC (NETR), 2022, Historical Aerials, (https://www.historicaerials.com/).

U.S.D.A., 1938, Photo Nos. AXL-74-9 and 10, Scale 1" = 1667', dated July 28, 1938.

U.S.D.A., 1953, Photo Nos. AXL-47K-154 and 155, Scale 1" = 1667', dated February 22, 1953.

U.S. Forest Service, 1979, Photo Nos. 26 and 27, Scale 1" = 1000', dated May 29, 1979.