# APPENDIX E – GEOTECHNICAL INVESTIGATION REPORT

# GEOTECHNICAL INVESTIGATION REPORT

# for

# Proposed Banner Self-Storage Facility
# 12121 Foothill Boulevard
# Sylmar, CA

***Prepared For:***

**Banner SoCal Developer, LLC**
**20929 Ventura Boulevard, Suite 47-521**
**Woodland Hills, CA 91364**

***Prepared By:***


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**Irvine, California 92612**


**April 8, 2021**
**Langan Project No.: 700096301**

LANGAN

April 8, 2021

Samuel Sapp and Margo Conley
Banner SoCal Developer, LLC
20929 Ventura Boulevard, Suite 47-521
Woodland Hills, California 91364

**Geotechnical Investigation Report**
**Proposed Banner Self-Storage Facility**
**12121 Foothill Boulevard**
**Sylmar, California**
**Langan Project: 700096301**

Dear Mr. Sapp and Ms. Conley:

Langan Engineering & Environmental Services, Inc. is pleased to submit this geotechnical engineering report for the proposed self-storage facility to be constructed at 12121 Foothill Boulevard in Sylmar, California.

This report was prepared in general accordance with our proposal dated February 16, 2021 that you authorized on March 5, 2021.

♦ ♦ ♦

We sincerely appreciate the opportunity to be of service to you on this project. Please contact us if you have questions regarding this report.

Sincerely,
Langan Engineering & Environmental Services, Inc.

Chris Zadoorian, G.E.
Associate

BW:SHW:CJZ:

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**APPENDIX**

# 1.0 INTRODUCTION

This report summarizes our geotechnical investigation and presents conclusions and recommendations for the proposed self-storage facility to be constructed at 12121 Foothill Boulevard in Sylmar, California as shown on Figure 1 (34.2793 Latitude, -118.3995 Longitude).

The site is located along the northeast side of Foothill Boulevard and is bound on the northeast by an ascending slope and on the southeast and northwest by commercial/industrial and/or residential developments.

The ascending slope is approximately 25 to 29 feet in height and extends upward at an average gradient of approximately 2½:1 (horizontal:vertical) to the adjacent 210 Freeway as shown on Figure 2.

The site is currently developed at the northwesterly side with two residential buildings and a single-story auxiliary (barn) structure as shown on Figure 2. The remainder of the site is undeveloped and consists primarily of an unpaved lot that is currently used for scrap materials and vehicle storage.

The existing ground surface level at the site slopes down from the northwest side to the southeast side and ranges from approximately Elevation 1,164 to 1,152.

You furnished us with a preliminary site plan dated March 29, 2021 prepared by SGW Architecture & Design depicting the proposed development. Based on our review of the preliminary site plan, the proposed development will consist of an approximately 45,000 square foot (plan area) three-story self-storage facility at the approximate location shown on Figure 2.

The lowest finish floor level of the proposed self-storage facility will be established at approximately Elevation 1156.5 within a majority of the building footprint, however the perimeter storage units on the east and west will step up to Elevation 1,161.0 and the perimeter storage units along the north side of the structure will also be established at Elevation 1,161.0 as shown on Figure 2.

Perimeter drive lanes and surface parking are also planned as part of the proposed development.

Stormwater infiltration is also being considered as part of low impact development (LID) design considerations.

Our investigation is summarized below followed by our conclusions and recommendations for the proposed self-storage facility.

# 2.0 SUBSURFACE EXPLORATIONS AND CONDITIONS

## 2.1 Subsurface Explorations

We drilled five borings (borings B-1 through B-5) at the site to depths of approximately 26½ to 51½ feet below the existing ground surface (BGS). Our borings were drilled with truck-mounted hollow-stem auger drilling equipment at the approximate locations shown on Figure 2.

We maintained a log of the subsurface materials encountered in each boring and collected relatively undisturbed and bulk samples from the borings at regular intervals.

Upon completion of drilling, we backfilled the borings B-1 through B-3 with soil cuttings and/or cement-bentonite grout and restored the ground surface to the pre-existing condition.

Upon completion of drilling in borings B-4 and B-5, we constructed field percolation test wells as summarized in Section 2.4 and the field percolation test wells were abandoned and backfilled with soil-cement.

## 2.2 Subsurface Conditions

Native soils were encountered at the ground surface level in each boring. The native soils consisted of geologically young alluvial fan deposits consisting primarily of medium stiff sandy silt and sandy clay and medium dense silty sand to depths ranging from approximately 14.5 to 23.0 feet BGS noting that a layer of soft silt was encountered in the upper five feet in boring B-1.

Stiff to very stiff sandy silt and sandy clay medium dense to dense silty sand to the maximum depth explored in our borings.

Fill soils were not encountered in our exploration borings. If fill soils are present on site, we anticipate they will be limited in thickness and generally placed for installation of underground utilities/tanks, demolition, or gravel road construction.

Logs of our borings are presented in Appendix A.

Generalized depictions of the subsurface conditions at the site are presented on Figure 3, Cross Sections A-A' and B-B''.

## 2.3 Groundwater

Regional groundwater was not encountered to the maximum depth explored of 50½ BGS during our subsurface investigation.

Based on our review of the Seismic Hazard Zone Report of the San Fernando 7.5-Minute Quadrangle, Los Angeles County, California, Seismic Hazard Zone Report 015 (California Division of Mines and Geology, 1998 now known as the California Geological Survey, CGS), the historical high groundwater level (HHGWL) at the site is on the order of 150 feet BGS at the site.

Figure 4 shows the site location and the HHGWL contour map.

## 2.4 Field Percolation Testing

As noted in Section 2.1, upon completion of drilling in borings B-4 and B-5, field percolation test wells were constructed and field percolation testing was performed at depths of approximately 28 and 30 feet BGS in the borings. Field percolation test well construction included installation of solid and slotted PVC piping within each borehole and backfilling the annular space with sand and gravel. Slotted piping was installed in the lower ten feet of each test well.

The testing was performed in general accordance with boring percolation test procedure outlined in the *County of Los Angeles, Department of Public Works, Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration Manual (GS200.2) dated June 30, 2017.*

Prior to the start of the field percolation testing, pre-soaking was performed for a period of approximately 1.5 hours. Field percolation testing included the addition of water test well and repeated measurements of the rate of percolation of the water into the soils through the slotted PVC piping. The testing was repeated in in test well until the measured rate of infiltration stabilized. Eight test trials were performed for each percolation test well.

We evaluated the results of the field percolation testing in accordance with *City of Los Angeles Planning and Land Development Handbook for Low Impact Development (LID)* dated May 9, 2016.

The results of the field percolation testing indicate a field percolation rate of approximately 1.20 inches per hour in B-4 and 0.88 inches per hour in B-5.

The results of the field percolation tests are presented in Appendix B.

### 2.5 Site-Specific Shear Wave Velocity Testing

We engaged our geophysical sub-consultant, GEOVision, to perform site-specific shear wave velocity measurements and develop an average shear-wave velocity profile of the upper 30 meters ($V_{s30}$) of the subsurface soils.

The evaluation included the use of active- and passive-source surface wave techniques. The active-source surface wave technique consisted of the multi-channel analysis of surface waves (MASW) method, and the passive-source surface wave technique consisted of the array microtremor method. These techniques measure shear wave velocities of the subsurface soils by analyzing the propagation of surface waves created from sources such as the impact of a hammer or ambient "noise".

GEOVision used the results of the geophysical survey to develop a shear wave velocity profile for the upper 30 meters (approximately 100 feet) of the subsurface.

The results of the MASW survey indicated a shear wave velocity, $V_{s30}$ of approximately 879 feet per second (268 meters per second).

The results of the MASW survey are presented in Appendix C.

## 3.0 GEOTECHNICAL LABORATORY TESTING

We performed the following geotechnical laboratory tests on samples collected during our investigation:

- In-situ Moisture Content and Dry Density
- Maximum Dry Density and Optimum Moisture Content
- Direct Shear
- Atterberg Limits
- Consolidation
- Grain Size Distribution
- Percent Passing No. 200
- Expansion Index
- Corrosivity (pH, Resistivity, Sulfate and Chloride Content)
- R-Value

The results of the geotechnical laboratory testing from our investigation are presented in Appendix A.

## 4.0 GEOLOGIC AND SEISMIC HAZARDS EVALUATION

### 4.1 General

We evaluated the geologic and seismic hazards at the site in general accordance with California Geological Survey (CGS) Special Publication 117A, "*Guidelines for Evaluating and Mitigating Seismic Hazards in California.*" The results of our evaluation as summarized below.

### 4.2 Regional and Local Geologic Setting

The site is located at the northern end of the San Fernando Valley. This valley is located within the western Transverse Ranges geomorphic province. The Los Angeles basin, which forms the northern end of the adjacent Peninsular Ranges geomorphic province, borders the Transverse Ranges to the south.

The Transverse Ranges are an east-west trending series of steep mountain ranges and valleys. The east-west structure of the Transverse Ranges is oblique to the normal northwest trend of coastal California.

The San Fernando Valley is a roughly triangular-shaped valley encompassing an area of approximately 175 square miles. The valley is bordered on the northeast by the western San Gabriel and Verdugo Mountains, on the south by the Santa Monica Mountains, and on the northwest by the Santa Susana Mountains and the Simi Hills. The valley represents a structural trough, which has been filling with sediment from all sides since at least the late Tertiary (Yerkes, 1996). Recent work by the Southern California Earthquake Center (SCEC) indicates that basement rocks in the San Fernando Valley basin are as deep as approximately 6.5 kilometers, about 4 miles (Boyd, et al, 2017).

The site is located on a relatively young alluvial fan deposit sourced from the San Gabriel Mountains to the north-northeast. This geologic deposit is described as 'unconsolidated gravel, sand and silt, bouldery along mountain fronts; deposited chiefly from flooding streams and debris flows.' The deposit is classified as Holocene to late Pleistocene in age (Campbell et al, 2014).

The data from our exploration borings is generally consistent with the geologic conditions summarized by Campbell et. al.

Figure 5 shows the site location plotted on a regional geologic map that was developed by Campbell et. al. (2014).

### 4.3 Regional Faulting

The site is located within a seismically active region of Los Angeles, surrounded by several active faults. According to the 2010 California Geological Survey Fault Activity Map (FAM) of California, multiple strands of the San Fernando section of the Sierra Madre fault zone are located as close as approximately ½ of the site to the north, northeast, and northwest. In addition, the Verdugo fault is located approximately 1¾ miles south of the site, and two pre-Quaternary, unnamed faults are located as near as approximately ½ mile south and southeast of the site.

The location of the site with respect to nearby mapped faults is presented in Figures 6A and 6B.

### 4.4 Regional Seismicity

The site is located in an active seismic area that has historically been affected by generally moderate to occasionally high levels of ground motion. Therefore, the proposed development will probably experience moderate to occasionally high levels of ground motion from nearby faults as well as ground motions from other active seismic areas of the southern California region.

A search of the USGS ANSS Comprehensive Earthquake Catalog (ComCat) using a web-based Earthquake Archive Search and URL builder tool, found that as of March 8, 2021, 59 earthquakes with magnitudes of 5.0 or greater have occurred within a 100-km radius of the site since 1800 as shown on Figure 6A.

### 4.5 Ground Surface Rupture Potential

The site is not located within an Alquist-Priolo Earthquake Fault Zone (APEFZ) based on a review of the CGS Earthquake Zones of Required Investigation map. However, the nearest APEFZ is located approximately less than ½ mile north of the site. Thus, the potential for ground surface rupture is considered low.

### 4.6 Liquefaction Potential

Liquefaction generally occurs in saturated, loose to medium dense, granular soil and in saturated, soft to moderately firm silt as a result of strong ground shaking. As the density and/or particle size of the soil increases and as the confinement (overburden pressure) increases, the potential for liquefaction decreases. Typically, saturated soil within the upper 50 feet of the ground surface or lowest adjacent grade is considered subject to liquefaction.

Based on the CGS (previously known as the California Division of Mines and Geology, CDMG) Seismic Hazard Evaluation of the San Fernando 7.5-Minute Quadrangle, Los Angeles County, California, Seismic Hazard Report 015, the site is not located within a liquefaction hazard zone as shown on Figure 7.

Groundwater was not observed to the maximum depth explored of approximately 51½ feet. Historically High Groundwater maps, produced by the State of California indicate that water is at least 150 feet BGS. Therefore, the potential for liquefaction at the site is negligible.

### 4.7 Lateral Spreading Potential

Lateral spreading is seismically-induced slope instability phenomenon wherein slope failure can occur as a result of liquefaction.

The potential for liquefaction at the site is considered to be very low and significant (in height) open-slope face conditions are neither existing nor planned. The berm associated with the 210 freeway on the northeast side of the site is likely composed of artificial fill and is well above the anticipated depth to groundwater in the area.

Thus, the potentially for lateral spreading is considered negligible.

### 4.8 Seismic (aka 'Dry') Settlement

Seismic (dry) settlement can occur in loose granular soil as a result of strong ground shaking.

The native soils present at the site generally consist of medium stiff to stiff sandy silt and sandy clay and medium dense to dense silty sand.

The native soils encountered are not considered to be subject to seismically induced settlement.

### 4.9 Earthquake-Induced Landslides

The site is not located in a zone of required investigation for confirmed or possible landslides per the CGS Seismic Hazard Zones map for the San Fernando Quadrangle. Additionally, no landslides have been mapped near the site on regional geologic maps of the area. Evidence of deep-seated landsliding was not observed during our field exploration and other than the relatively recently-placed, compacted fill berm northeast of the site no significant sloped boundary conditions exist. Therefore, the probability of earthquake-induced landsliding at the site is negligible.

### 4.10 Flood Mapping

FEMA's flood maps, known as Flood Insurance Rate Maps (FIRMS), identify areas of flood hazard, which are labeled on the flood maps starting with the letters A and V for high-hazard areas and Zone X for moderate- or low-hazard flood-risk areas. In some cases, where there is a potential for moderate to high risk of flooding, but the probability has not been determined, these areas are labeled as Zone D on the flood maps.

Based on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) Number 06037C1069F, the site is located within an area determined to be outside the 0.2 percent annual chance floodplain.

### 4.11 Tsunamis, Seiche, and Dam Inundation

Based on information and maps available from the CGS, the site is not located within a Tsunami inundation hazard zone. Based on review of adjacent water bodies, the site is not subject to inundation from seiche. A review of the California Dam Breach Inundation Maps hosted by the California Division of Safety of Dams shows that the site is not located within an inundation boundary in the case of dam breach.

### 4.12 Subsidence

Land subsidence may be induced from withdrawal of oil, gas, or water from wells. Based on a search of the CalGEM (formerly known as Division of Oil, Gas, and Geothermal Resources [DOGGR]) GIS Well Finder online tool, there are several wells located within approximately one mile of the site. All of these wells expect for one are listed as dry and plugged. The one active well is listed as idle and is located just under 1 mile east of the site. This well is identified as API 0403705108. Thus, the likelihood of land subsidence caused by oil or gas withdrawal from oil wells is very low.

### 4.13 Expansive Soils

Expansive soils swell and shrink when the moisture content in the soil changes as a result of cyclic wet/dry weather cycles, installation of irrigation systems, change in landscape plantings, or changes in grading. Swelling and shrinking soils can result in differential movement of structures including floor slabs and foundations, and site work including hardscape, utilities, and sidewalks.

Expansion index testing performed as part of this investigation indicates that near-surface soil has a very low expansion potential (Expansion Index = 4). The near-surface soils encountered in our on-site explorations are generally granular.

## 5.0 CONCLUSIONS

### 5.1 General

The site is generally free from geologic or seismic hazards that would preclude the proposed development and the proposed development is considered feasible from a geotechnical perspective provided the recommendations presented herein are followed.

The site is subject to strong ground shaking that would result from an earthquake occurring on a nearby or distant fault source; however, this hazard is common in Southern California and can be mitigated by following the seismic design requirements of the 2020 Los Angeles Building Code (LABC).

### 5.2 Foundations

The upper native soils present at the planned foundation levels consist of soft to medium stiff sandy silt. These soils are not suitable for foundation support and should be removed and replaced as properly compacted fill soils.

The proposed self-storage building may be supported on spread and continuous footings established in properly compacted fill provided the recommendations presented in Section 6.1 are followed.

### 5.3 Seismic Site Classification and Design Considerations

The results of the geophysical testing indicate an average shear wave velocity in the upper 100 feet (30 meters), $V_{s30}$, is approximately 879 feet per second (268 meter per second). In accordance with Section 20.3 of ASCE-7-16, the Site Classification is Site Class D.

Seismic design parameters are presented in Section 6.2.

### 5.4 Floor Slab Support

The recommended removal and recompaction will automatically result in placement of properly compacted fill beneath the building floor slabs.

The building floor slabs may be supported on properly compacted fill soils, provided the recommendations presented herein are followed.

Recommendations for floor slab support are presented in Section 6.3.

### 5.5 Temporary Excavations and Vertical Cuts

Temporary excavations are feasible within the on-site materials and may be utilized to perform the required grading.

Temporary vertical cuts may be performed within properly compacted fill.

Recommendations for temporary excavations are presented in Sections 6.4.

### 5.6 Stormwater Infiltration

In accordance with the City's LID Table 4.2, the field percolation test results may be used without a factor of safety for dry wells. The results of the field percolation testing indicated field percolation rates of 1.20 and 0.88 inches per hour may be used in the design of dry wells.

Field percolation is feasible at the site provided stormwater is discharged at least 10 feet below the bottom of planned footings, a horizontal distance of 10 feet and set back at least 10 feet from the property line.

The HHGWL level at the site is estimated to be on the order of 150 feet BGS; field percolation may be performed at within 10 feet of the HHGWL if needed.

### 5.7 Corrosion Potential

The results of corrosion testing are summarized in Table 1.

**Table 1 – Corrosion Test Results**

| Boring (Depth) | Soil Type | Resistivity (ohm-cm) | pH | Sulfate (%) | Chloride (%) |
|---|---|---|---|---|---|
| Boring B-4 (0 - 5 feet) | Silty Sand | 1,350 | 7.1 | 0.0242 | 0.0049 |

The results of sulfate testing indicate that the on-site soils are classified as exposure category $S_0$ in accordance with American Concrete Institute (ACI) Table 4.2.1.

The results of the chloride testing indicate that the on-site soils are classified as exposure category $C_0$ in accordance with ACI Table 4.2.1.

## 5.8 Shrinkage and Subsidence

Removal and recompaction of existing native soils will result in a loss of volume (shrinkage) because the materials are typically placed at a higher density than in their naturally-deposited state.

Additionally, subsidence of the underling native soils may also occur due to the increased weight of the compacted fill when compared to the pre-existing native soils.

Based on the moisture and density test data, we estimate the shrinkage of the on-site soils when compacted as recommended herein will be on the order of 10 to 15 percent.

Subsidence is due to the placement of compacted fill is estimated to be on the order of one-half inch or less across the site and is expected to occur during the recommended removal and recompaction.

# 6.0 RECOMMENDATIONS

## 6.1 Foundations

The proposed development may be supported on spread and continuous footings established in properly compacted fill. To provide uniform support for the spread and continuous footings, we recommend removal and re-compaction of existing soils to a minimum of 4 feet below planned foundations or to 6 feet BGS, whichever is greater. Compacted fill should extend at least 5 feet horizontally beyond the outside edges of foundations.

Spread and continuous footings a minimum of two feet wide and established at least two feet below the lowest finish floor level and/or adjacent grade may be designed using an allowable bearing pressure of 4,500 pounds per square foot (psf).

The recommended bearing pressure is a net pressure and the weight of foundation and overlying soil can be neglected for structural design purposes. The allowable bearing pressure may be increased by one-third when considering short-term wind and seismic loading conditions.

We estimate the settlement for spread and continuous footings established in properly compacted fill as recommended herein will be on the order of 1 inch or less and that differential settlement between adjacent columns will be on the order of ¼ inch or less.

When considering ultimate stress design, to resist lateral loading, an ultimate passive resistance equal to 600 psf per foot of embedment up to a maximum value of 6,000 psf and an ultimate coefficient of friction equal to 0.6 may be used.

The ultimate passive pressure and the ultimate coefficient of friction may be combined noting that the ultimate passive resistance should be reduced in this case by 50 percent in consideration of the deformation required to mobilize the full passive resistance.

For allowable stress design, to resist lateral loading, an allowable passive resistance equal to 400 psf per foot of embedment up to a maximum value of 4,000 psf and an allowable coefficient of friction equal to 0.4 may be used.

The allowable passive pressure and the allowable coefficient of friction may be combined without reduction.

## 6.2 Seismic Design

Based on the measured $V_{s30}$, the seismic site class in accordance with Chapter 20 of ASCE 7-16 is Site Class D.

We anticipate that the Exception 2 in Section 11.4.8 of ASCE 7-16 will apply to the proposed seismic design so that LABC-prescribed seismic design parameters may be utilized. Seismic design parameters in accordance with the 2020 LABC and ASCE 7-16 are presented in Table 2.

**Table 2 – 2020 LABC Seismic Design Parameters**

| Criteria | Value |
|---|---|
| $MCE_R$ Ground Motion at Short Periods, $S_s$ | 2.479 |
| $MCE_R$ Ground Motion at 1Second Period, $S_1$ | 0.833 |
| Site Class | D |
| Site-Modified Spectral Acceleration Value at Short Periods, $S_{MS}$ | 2.975 |
| Site-Modified Spectral Acceleration Value at 1 Second Period, $S_{M1}$ | 1.416 |
| Design Spectral Response Acceleration at short periods, $S_{DS}$ | 1.983 |
| Design Spectral Response Acceleration at 1 second period, $S_{D1}$ | 0.944 |
| $MCE_G$ Peak Ground Acceleration, $PGA_M$ | 1.237 |

### 6.3 Floor Slab Support

The proposed building floor slabs may be supported on properly compacted fill soils. The recommended removal and recompaction for foundation support will automatically result in a minimum of five feet of properly compacted fill beneath and horizontally from the planned building floor slabs.

To minimize the potential of moisture transfer from the soil through the building floor slab, we recommend the installation of a capillary break section. The capillary break section should consist of six inches of gravel underlying a 15-mil HDPE membrane.

PCC for the building floor slab may be placed directly on the HDPE membrane.

### 6.4 Temporary Excavations and Vertical Cuts

Temporary and unsurcharged slopes may be excavated into the on-site sandy soils and these slopes should not exceed a 1H:1V gradient and should not exceed 10 feet in height

Temporary vertical cuts may be made into the properly compacted fill, however, vertical cuts should not exceed 4 feet in height.

Temporary vertical cuts and temporary construction slopes should be protected from erosion by directing surface water away from the top of the slope, by placing sand bags at the top of the slopes and vertical cuts, and/or covering the slopes with plastic sheeting during rain events.

Excavations performed adjacent to existing building foundations, sidewalks, and roadways should also be sloped at a minimum gradient of 1.5H:1V. Pavement Design

### 6.5 Pavement Design

#### 6.5.1 General

The required pavement and base thicknesses will depend on the expected wheel loads, traffic index (TI), and the R-value of the subgrade soils. Based on the results of our laboratory testing, we used an R-value of 50 in our pavement design.

New pavement sections be underlain by 12 inches of properly compacted fill.

Our pavement design recommendations for asphalt concrete (AC) and Portland cement concrete (PCC) are provided below.

### 6.5.2 Asphalt-Concrete Pavement Design

AC pavement for surface parking shall be designed in accordance with the CALTRANS method. Table 3 below summarizes our AC pavement recommendations for assumed TIs of 4, 5 and 7.

**Table 3 - AC Pavement Design Recommendations**

| Traffic Use | TI | AC (inches) | AB (inches) |
|---|---|---|---|
| Parking Areas | 4 | 3 | 4 |
| Drive Lanes and Fire Access | 5 | 3 | 6 |
| Loading Docks | 7 | 4 | 6 |

We can determine the recommended pavement and aggregate base thickness for other TIs if required. Careful inspection is recommended to confirm that the recommended thickness or greater is achieved and there proper construction procedures are followed.

The base should conform to requirements of Section 26 of State of California Standard Specifications for Public Works Construction (Green Book). The aggregate base should be compacted to at least 95 percent relative compaction.

### 6.5.3 Portland Cement Concrete Pavement Design

Table 4 summarizes our PCC pavement recommendations for assumed TI of 4, 5, and 7 based on minimum compressive strength of 3,000 psi for the PCC.

**Table 4 - PCC Pavement Design Recommendations**

| Traffic Use | TI | PCC (inches) | AB (inches) |
|---|---|---|---|
| Parking Areas | 4 | 6 | 4 |
| Drive Lanes and Fire Access | 5 | 6 | 4 |
| Loading Docks | 7 | 7 | 4 |

Dowels are recommended at joints to reduce any possible offsets. Careful inspection is recommended to check that the recommended thickness or greater is achieved and that proper construction procedures are followed.

State of California Department of Transportation Type II base, or equivalent, should be used in the required sections. The base should be compacted to at least 95 percent relative compaction.

## 6.6 Site Preparation and Compaction

### 6.6.1 General

Site preparation for this project will primarily include demolition of existing structures, removal of existing foundations, and removal and recompaction of the upper soils.

### 6.6.2 Bottom Preparation

Exposed excavation bottoms should be scarified and moisture-condition and compacted as recommended in Section 6.6.3.

Our field technician should probe excavation bottoms to confirm the medium stiff and/or medium dense native soils are present.

If encountered locally, excessively loose or otherwise unsuitable soils present at the planned excavation bottoms may be replaced within up to 12 inches of crushed rock to establish a firm working surface for placement and compaction of the recommended fill. Materials for Fill

The fill material should be free of organic matter and other deleterious material and, in general, should consist of particles no larger than three inches in largest dimension.

### 6.6.3 Materials for Fill

The on-site fill and native granular soil is suitable for use in the required fills noting that the upper soils consist primarily of sandy silt.

Imported fill material should be primarily granular in nature and reviewed by our field technician prior to import to the site.

### 6.6.4 Compaction

Fill placement may proceed after the bottom preparation is completed.

Granular fill soils should be moisture conditioned between 0 and 2 percent of the optimum moisture content and mechanically compacted to at least 95 percent of the maximum dry density as determined by ASTM D1557.

Cohesive fill, though not anticipated during construction for this project, should be compacted to at least 90 percent of the maximum dry density, as determined by ASTM D1557, and moisture conditioned between 2 and 4 percent over the optimum moisture content.

Fill material should be placed in loose lifts not exceeding 8 inches in thickness, properly moisture conditioned, and mechanically compacted to the minimum required density.

It should be noted that moisture conditioning and compaction of silty soils may require the use of light-weight compaction equipment and the data presented herein should be evaluated by the grading contractor to determine appropriate compaction equipment.

## 7.0 CONSTRUCTION OBSERVATION

Geotechnical testing and observation during construction is considered to be a continuing part of the geotechnical consultation. Our representative should observe, document and test (as appropriate) the following geotechnical-related construction activities:

- Removal of Upper Soils and approval of excavation bottoms
- Scarification, moisture condition and compaction of excavation bottoms
- Placement and compaction of structural backfill materials
- Foundation bottom observation and approval
- Installation of capillary break sections
- Placement and compaction of pavement subgrade materials
- Placement and compaction of utility trench backfill

## 8.0 LIMITATIONS

We have prepared this preliminary report for use by Banner SoCal Developer, LLC and members of the design and construction team for the proposed development. The data and report can be used for estimating purposes, but our report, conclusions, and interpretations should not be construed as a warranty of the subsurface conditions and are not applicable to other sites.

Soil borings indicate soil conditions only at specific locations and only to the depths penetrated. They do not necessarily reflect soil strata or water level variations that may exist between exploration locations. If subsurface conditions differing from those described are noted during the course of excavation and construction, re-evaluation will be necessary.

The recommendations presented in this report are based on the current site development plan and structural information provided to us by the project team. If design changes are made, we should be retained to review our conclusions and recommendations and to provide a written evaluation or modification.

The scope of our services does not include services related to construction safety precautions, and our recommendations are not intended to direct the contractor's methods, techniques, sequences, or procedures, except as specifically described in our report for consideration in design.

Within the limitations of scope, schedule, and budget, our services have been executed in accordance with that degree of skill and care ordinarily exercised by reputable geotechnical consultants practicing in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

## 9.0 CLOSING

We sincerely appreciate the opportunity to provide professional services for this project and look forward to working with you on this project.

Please contact us at you convenience to discuss any questions you may have regarding this report.

Sincerely,

**Langan Engineering and Environmental Services, Inc.**

CERTIFIED ENGINEERING GEOLOGIST
SHAUN H. WILKINS
No. 2665
STATE OF CALIFORNIA

Signed 4/8/21

Brandon Watkins
Staff Engineer

Shaun Wilkins
Senior Project Geologist

Christopher J. Zadoorian
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REGISTERED PROFESSIONAL ENGINEER
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Signed 4/8/21

## REFERENCES

American Concrete Institute, 2014, Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary, 2014.

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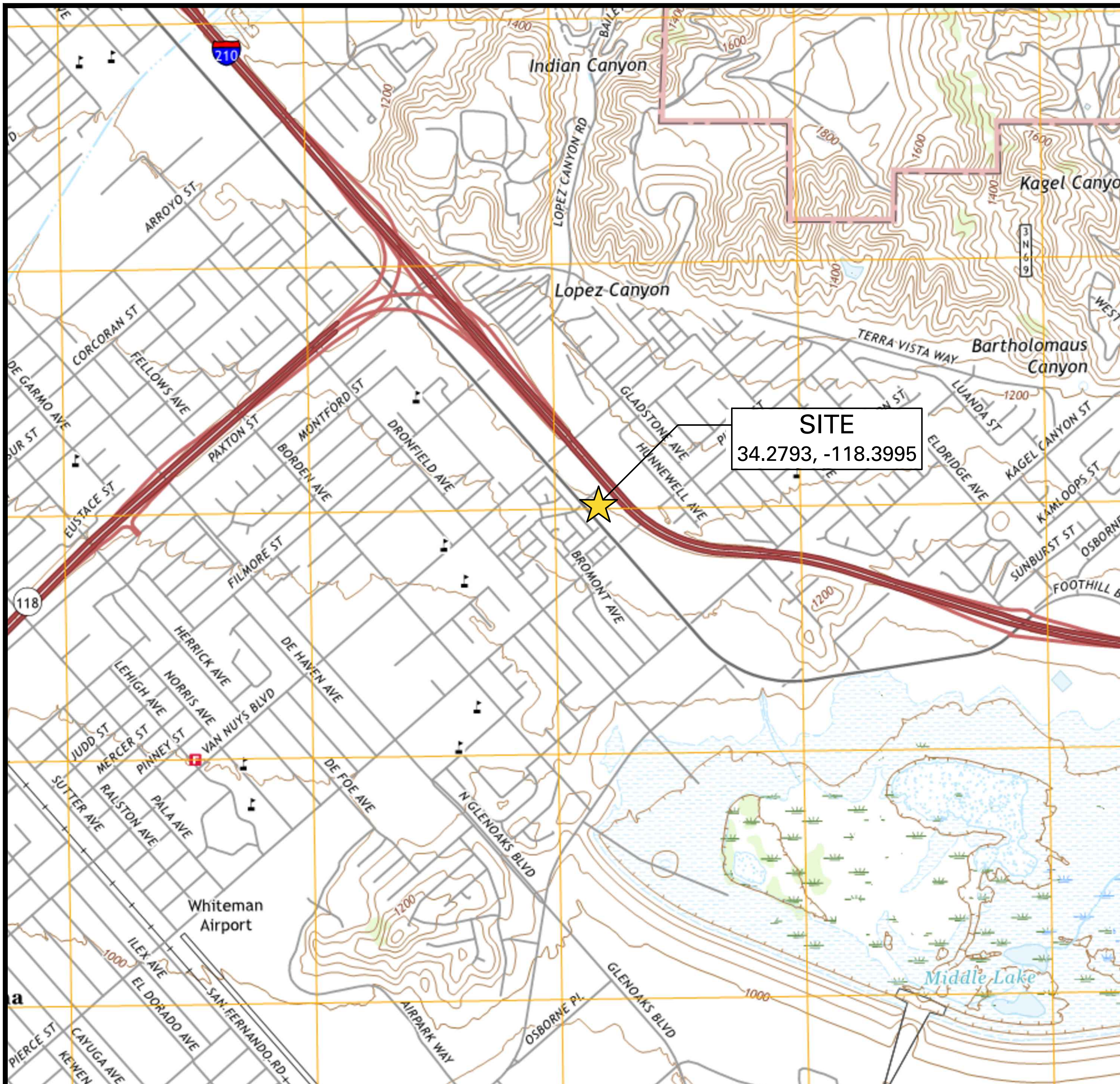
# FIGURES




**LEGEND:**

SITE LOCATION

2000 1000 0 2000

SCALE IN FEET

REFERENCE: USGS 7.5-MINUTE TOPOGRAPHIC MAP OF THE SAN FERNANDO, CALIFORNIA QUADRANGLE (2018).

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|---|---|---|---|---|



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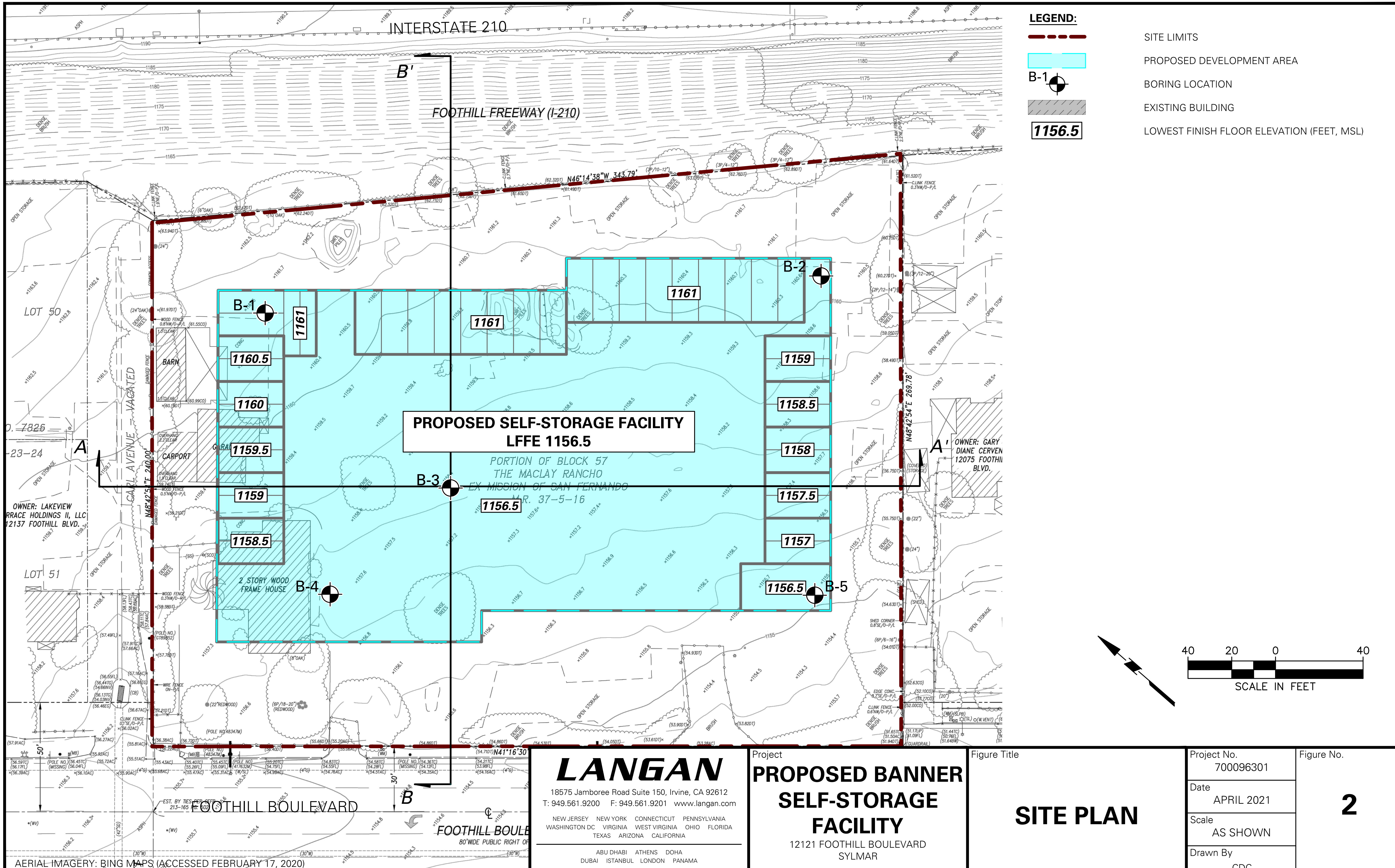


AERIAL IMAGERY: BING MAPS (ACCESSED FEBRUARY 17, 2020)

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| Project | Figure Title | Project No. | Figure No. |
|---|---|---|---|
| **PROPOSED BANNER SELF-STORAGE FACILITY**<br>12121 FOOTHILL BOULEVARD<br>SYLMAR<br>LOS ANGELES COUNTY CALIFORNIA | **SITE PLAN** | 700096301<br>Date: APRIL 2021<br>Scale: AS SHOWN<br>Drawn By: CDC | **2** |

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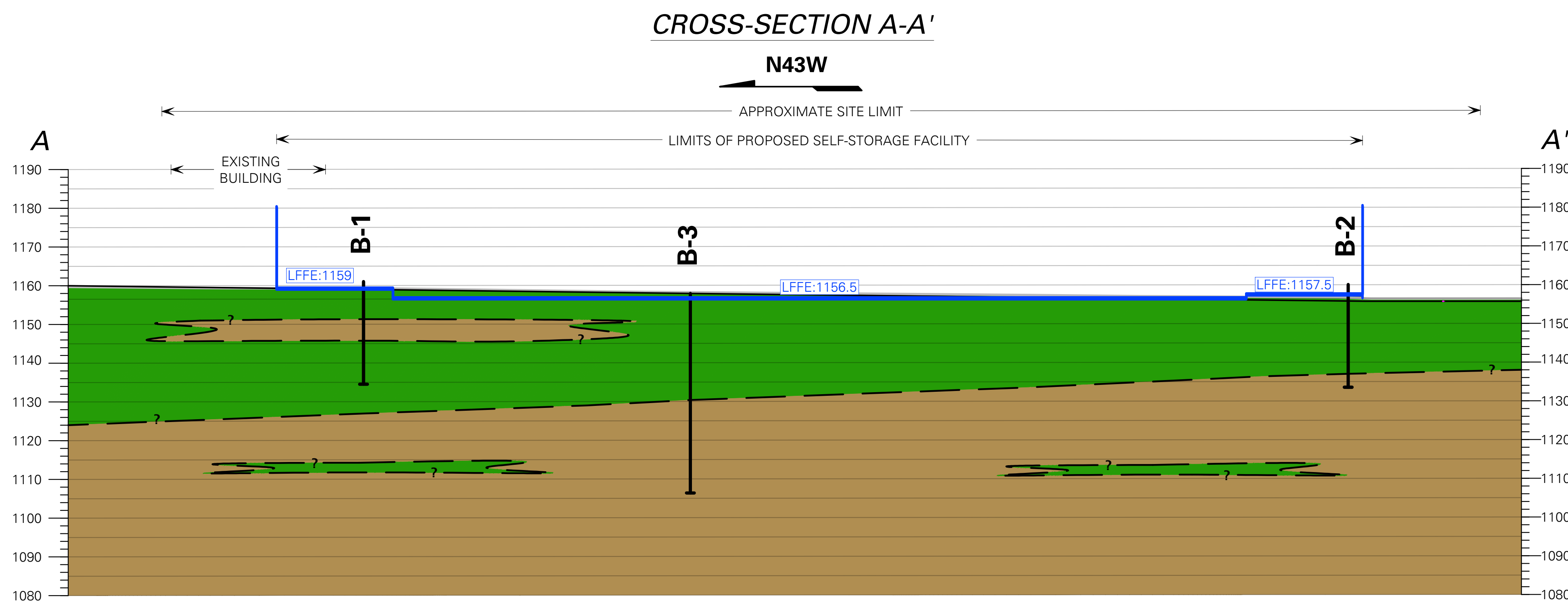
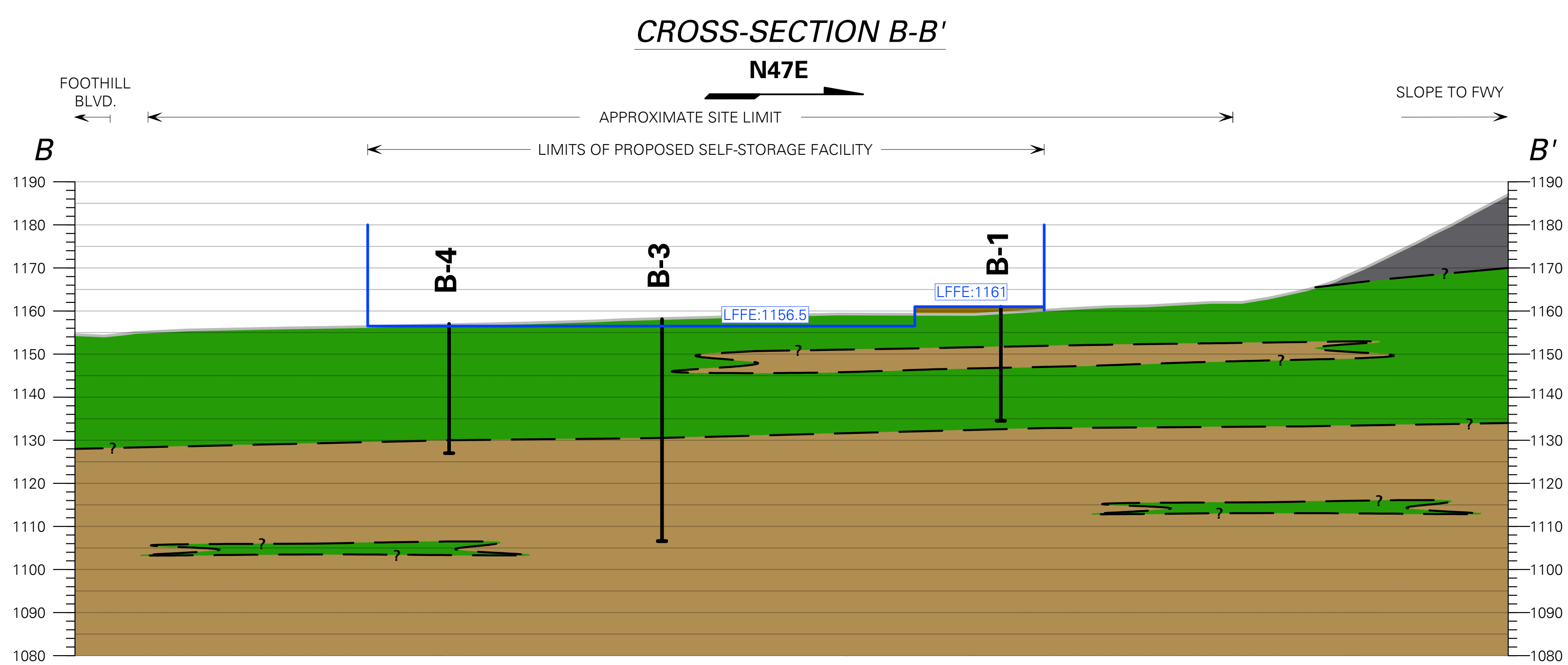


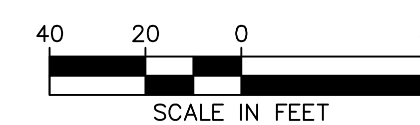




**LEGEND:**

- EXISTING GROUND SURFACE LEVEL
- —?— INFERRED GEOLOGIC CONTACT
- ARTIFICIAL FILL (af)
- PREDOMINATELY FINE GRAINED SOIL
- PREDOMINATELY COARSE GRAINED SOIL
- BORING LOCATION
- LFFE:1156.5 APPROXIMATE LOWEST FINISHED FLOOR ELEVATION (FEET, MSL)

**NOTES:**

1. FIGURE DISPLAYS GENERALIZED SUBSURFACE CONDITIONS. FOR A DETAILED DESCRIPTION OF CONDITIONS ENCOUNTERED REFER TO BORING LOGS.
2. EXISTING GROUND SURFACE LEVEL REFERENCED FROM A.L.T.A./N.S.P.S. LAND TITLE SURVEY - 12121 FOOTHILL BOULEVARD, SYLMAR, PREPARED BY DRG, INC., DATED 17 MARCH 2021.
3. REFER TO FIGURE 2 - SITE PLAN FOR LOCATION OF CROSS SECTIONS.

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|---|---|---|---|
| **PROPOSED BANNER SELF-STORAGE FACILITY**<br>12121 FOOTHILL BOULEVARD<br>SYLMAR<br>LOS ANGELES COUNTY CALIFORNIA | **CROSS SECTIONS A-A' & B-B'** | 700096301<br>Date: APRIL 2021<br>Scale: AS SHOWN<br>Drawn By: CDC | **3** |



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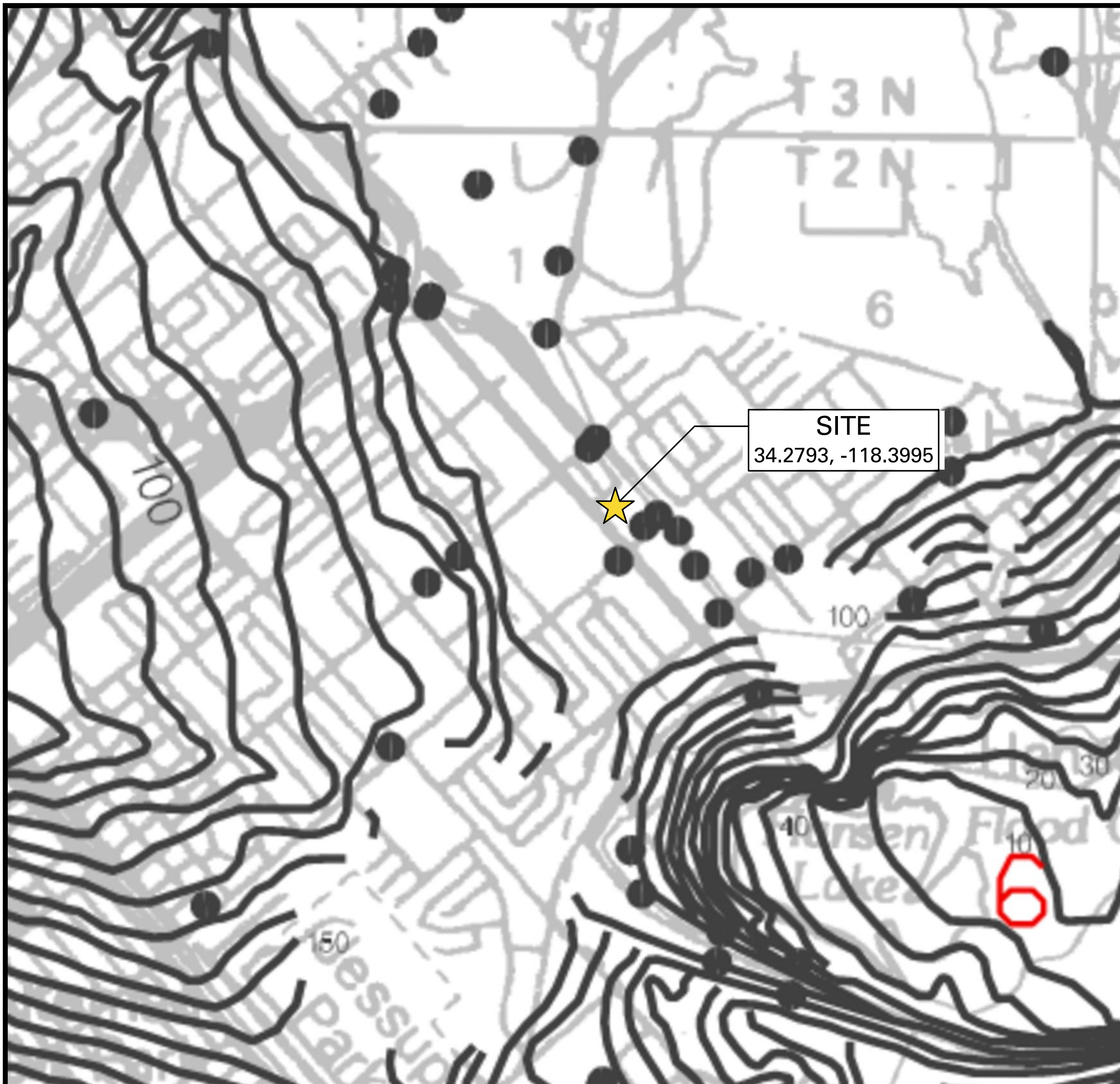


**LEGEND:**

| | | | |
|---|---|---|---|
| ★ | SITE LOCATION | ~30~ | DEPTH TO GROUNDWATER IN FEET |
| ● | BOREHOLE SITE | 6 | SITE OF HISTORICAL EARTHQUAKE - GENERATED LIQUEFACTION |

2000 1000 0 2000

SCALE IN FEET

REFERENCE: SEISMIC HAZARD ZONE REPORT FOR THE SAN FERNANDO 7.5-MINUTE QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA, PLATE 1.2 (CALIFORNIA DEPARTMENT OF CONSERVATION, 1998).

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| **PROPOSED BANNER SELF-STORAGE FACILITY**<br>12121 FOOTHILL BOULEVARD<br>SYLMAR<br>LOS ANGELES COUNTY CALIFORNIA | **HISTORICAL HIGH GROUNDWATER MAP** | 700096301<br>Date: APRIL 2021<br>Scale: AS SHOWN<br>Drawn By: CDC | **4** |



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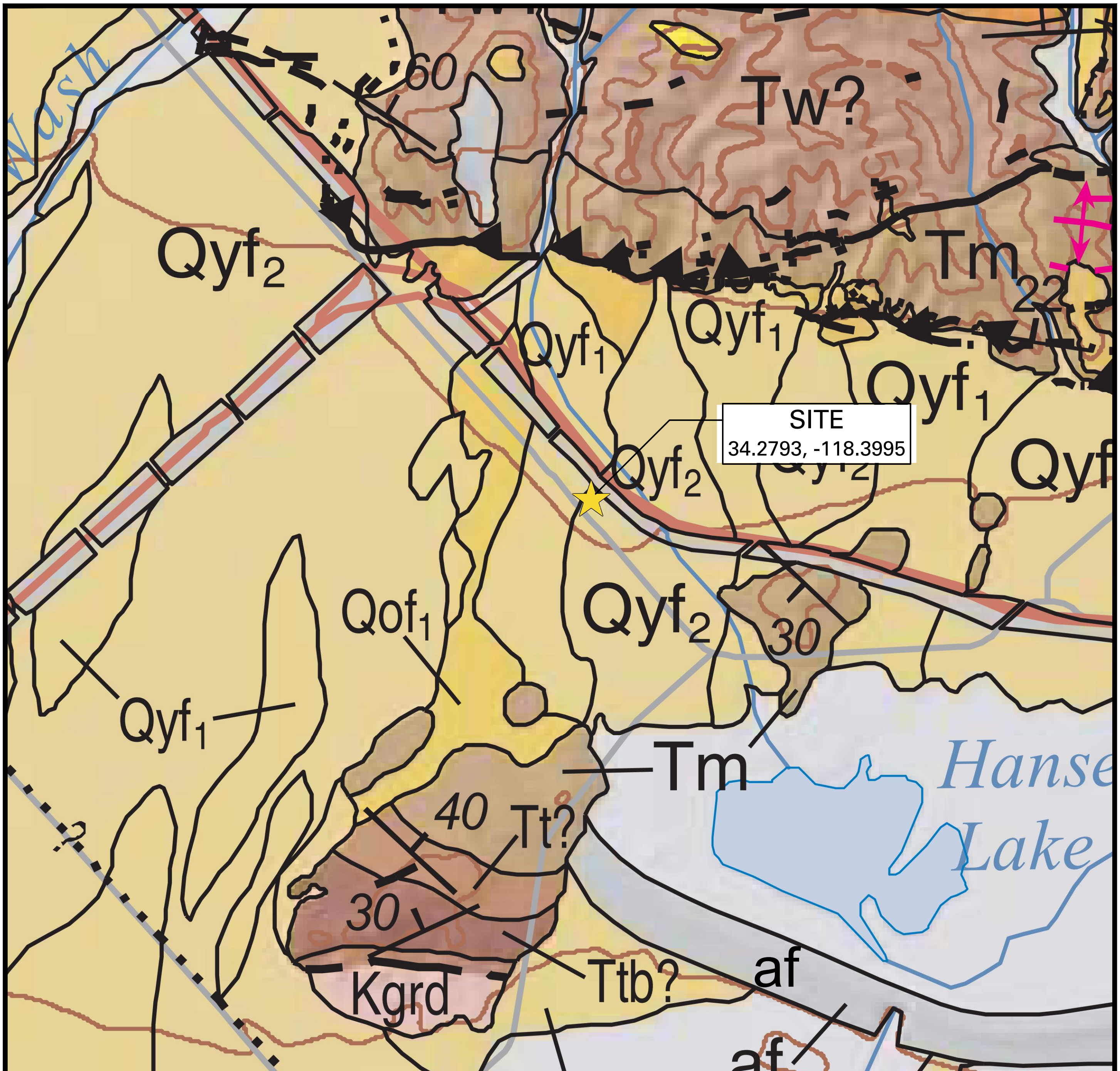
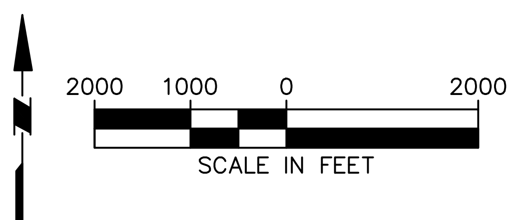



**LEGEND:**

| | |
|---|---|
| af | ARTIFICIAL FILL |
| Qyf | YOUNG ALLUVIAL FAN DEPOSITS |
| Qof | OLD ALLUVIAL FAN DEPOSITS |
| Tm | MODELO FORMATION |
| Tw | TOWSLEY FORMATION |
| Tt | TOPANGA GROUP |
| Ttb | INTRUSIVE AND EXTRUSIVE VOLCANIC ROCK |
| Kgrd | GRANODIORITE |




REFERENCE: CGS PRELIMINARY GEOLOGIC MAP OF THE LOS ANGELES 30'X60' QUADRANGLE, CALIFORNIA, VERSION 2.1 (2014).

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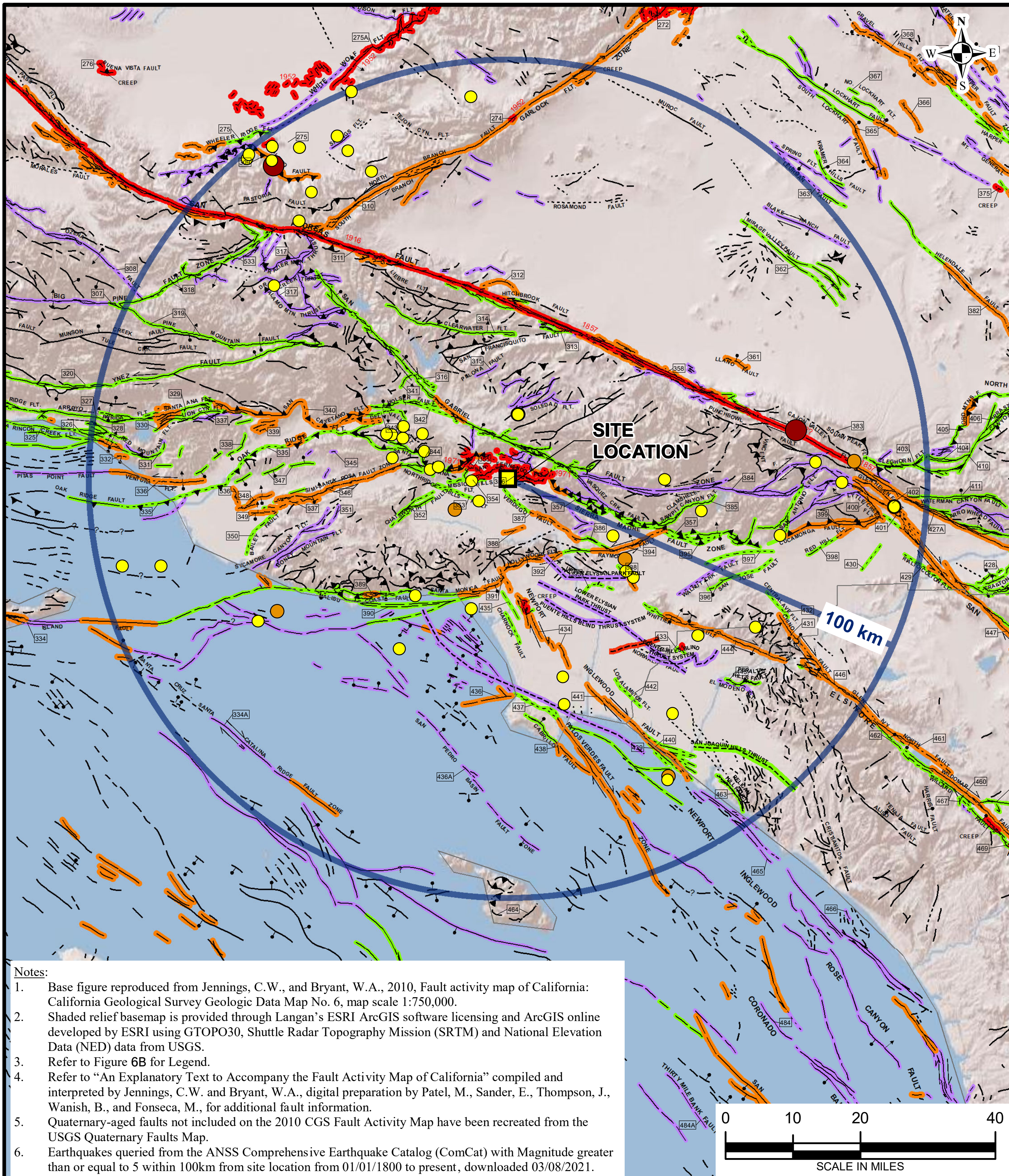
| **PROPOSED BANNER SELF-STORAGE FACILITY**<br>12121 FOOTHILL BOULEVARD<br>SYLMAR<br>LOS ANGELES COUNTY CALIFORNIA | **REGIONAL GEOLOGIC MAP** | 700096301<br>Date: APRIL 2021<br>Scale: AS SHOWN<br>Drawn By: CDC | **5** |




Notes:

1. Base figure reproduced from Jennings, C.W., and Bryant, W.A., 2010, Fault activity map of California: California Geological Survey Geologic Data Map No. 6, map scale 1:750,000.
2. Shaded relief basemap is provided through Langan's ESRI ArcGIS software licensing and ArcGIS online developed by ESRI using GTOPO30, Shuttle Radar Topography Mission (SRTM) and National Elevation Data (NED) data from USGS.
3. Refer to Figure 6B for Legend.
4. Refer to "An Explanatory Text to Accompany the Fault Activity Map of California" compiled and interpreted by Jennings, C.W. and Bryant, W.A., digital preparation by Patel, M., Sander, E., Thompson, J., Wanish, B., and Fonseca, M., for additional fault information.
5. Quaternary-aged faults not included on the 2010 CGS Fault Activity Map have been recreated from the USGS Quaternary Faults Map.
6. Earthquakes queried from the ANSS Comprehensive Earthquake Catalog (ComCat) with Magnitude greater than or equal to 5 within 100km from site location from 01/01/1800 to present, downloaded 03/08/2021.

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| Project | Figure Title | Project No. | Figure |
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| PROPOSED BANNER SELF-STORAGE FACILITY<br>12121 FOOTHILL BOULEVARD SYLMAR<br>LOS ANGELES COUNTY CALIFORNIA | QUATERNARY FAULT AND EARTHQUAKE EPICENTER MAP | 700096301<br>Date: APRIL 2021<br>Scale: 1 inch = 20 miles<br>Drawn By: NB | 6A |

**LEGEND:**

Site Location

## Fault Age

**The age classifications are based on geologic evidence to determine the youngest faulted unit and the oldest unfaulted unit along each fault of fault seciton**

- Historic
- Holocene
- Late Quaternary
- Quaternary
- 100 km

## Earthquake Epicenter

- Magnitude 5 to 5.9
- Magnitude 6 to 6.9
- Magnitude 7 to 7.4
- Magnitude 7.5 to 8

## Pre Quaternary Faults

- fault, certain
- fault, approx. located
- fault, concealed
- thrust fault, certain
- thrust fault, approx. located
- thrust fault, approx. located, queried
- fault, certain, barball
- fault, concealed, barball
- fault, approx. located, barball

## Quaternary Faults

- fault, certain
- fault, approx. located
- fault, approx. located, queried
- fault, inferred, queried
- fault, concealed
- fault, concealed, queried
- thrust fault, certain
- thrust fault, approx. located
- thrust fault, concealed
- dextral fault, certain
- dextral fault, approx. located
- dextral fault, concealed
- sinistral fault, certain
- sinistral fault, approx. located
- sinistral fault, concealed
- thrust fault, certain (2)
- thrust fault, approx. located (2)
- thrust fault, concealed (2)
- fault, solid, barball
- fault, dashed, barball
- fault, dotted, barball
- dextral fault, solid, barball
- fault, dotted, queried, ballbar
- fault, dotted, queried, ballbar (2)
- fault, solid, dip
- fault, dashed, dip
- fault, dotted, dip
- reverse fault, solid
- reverse fault, dashed
- reverse fault, dotted

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|---|---|---|---|
| PROPOSED BANNER SELF-STORAGE FACILITY<br>12121 FOOTHILL BOULEVARD SYLMAR<br>LOS ANGELES COUNTY CALIFORNIA | QUATERNARY FAULT AND EARTHQUAKE EPICENTER MAP | 700096301<br>Date<br>APRIL 2021 | 6B |



Path: \\Langan.com\data\IRV\data3\700096301\Project Data\ArcGIS\MXD\Geotech_Figures\Fault Map Legend.mxd Date: 3/8/2021 User: NBurke Time: 4:03:05 PM


**LEGEND:**

☆ SITE LOCATION

1000 500 0 1000
SCALE IN FEET

REFERENCE: CGS EARTHQUAKE ZONES OF REQUIRED INVESTIGATION FOR THE SAN FERNANDO, CALIFORNIA 7.5-MINUTE QUADRANGLE (1999).

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| Project | Figure Title | Project No. | Figure No. |
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| **PROPOSED BANNER SELF-STORAGE FACILITY**<br>12121 FOOTHILL BOULEVARD<br>SYLMAR<br>LOS ANGELES COUNTY CALIFORNIA | **SEISMIC HAZARD ZONES MAP** | 700096301<br>Date: APRIL 2021<br>Scale: AS SHOWN<br>Drawn By: CDC | **7** |

# APPENDIX A

## Field Explorations and Laboratory Testing

## APPENDIX A

## SUBSURFACE EXPLORATIONS

We explored the subsurface conditions at the site by drilling 5 borings (B-1 through B-5) to depths ranging between 26½ and 51½  feet BGS at the locations shown on Figure 2.  2R Drilling, Inc. using a truck-mounted hollow-stem auger drilling equipment drilled the borings on March 10, 2021.

The locations of the explorations were determined in the field by observing nearby landmarks/structures, which were based on site maps prepared by us.  This information should be considered accurate only to the degree implied by the methods used.

Our field engineer observed and logged the explorations.  We obtained representative samples of the various soils encountered in the explorations. Classifications and sampling intervals are presented on the exploration logs included in this appendix.

## SOIL SAMPLING

Samples were collected from the borings using modified California split-spoon samplers in general accordance with ASTM D3550 and we performed Standard Penetration Tests (SPTs) in general accordance with ASTM D1586.

The modified California samplers and SPTs were driven using a 140-pound hammer free falling 30 inches. The samplers were driven a total distance of 18 inches or to refusal.  The number of blow counts required to drive the sampler for each 6 inch segment was recorded (or less if refusal is met) on the exploration logs.  Sampling methods and intervals are shown on the exploration logs.

The samples collected from the borings were transported to our office for assignment of geotechnical laboratory testing.

## SOIL CLASSIFICATION

The soil samples were described in accordance with the classification legend that is included in this appendix prior to the exploration logs.  The exploration logs indicate the depths at which the soils or their characteristics change, although the change actually may be gradual.  If the change occurred between sample locations, the depth was interpreted.  Changes between geologic units or soil types on the boring logs are represented with a solid line if observed directly in the samples, and with a dashed line if inferred between sample depths. Classifications are shown on the exploration logs.

## LABORATORY TESTING

### Moisture Content and In-place Dry Density

The natural moisture content of select soil samples were performed in general accordance with ASTM D2216.  The natural moisture content is a ratio of the weight of the water to soil in a test sample and is expressed as a percentage.

Select soil samples were tested to determine the in situ dry density.  The tests were performed in general accordance with ASTM D2937.  The dry density is defined as the ratio of the dry weight of the soil sample to the volume of that sample.  The dry density typically is expressed in units of pounds per cubic foot (pcf).

The test results are presented in this appendix.

### Maximum Dry-Density and Optimum Moisture Content

Maximum dry-density and optimum moisture content testing was performed in general accordance with ASTM D 1557 on one bulk samples obtained from the explorations.  The tests determines the optimal moisture content at which sample achieves its maximum dry density.  The test results are presented in this appendix.

### Percent Passing No. 200 Sieve

Select soil samples were tested to determine the percentage of fine-grained material, defined as the amount of material finer than 75-µm (No. 200) sieve in the soil. The tests were performed in general accordance with ASTM D6913.

The test results are presented in this appendix.

### Expansion Index

Expansion index tests were performed on selected bulk samples of the on-site soils in accordance with the latest version of Test Method ASTM D4829.

The test results are presented in this appendix.

### Corrosion Testing

Chemical and electrical analyses were performed on selected bulk samples of onsite soils to determine their soluble sulfate content, chloride content, pH (acidity) and minimum electrical resistivity. These tests were performed in accordance with the latest versions of California Test Method Nos. CTM 417 (sulfate), CTM 422 (chloride), and CTM 643 (pH and resistivity) respectively.

The results of these tests are included in this appendix.

### Consolidation Testing

One-dimensional consolidation testing was performed in general accordance with ASTM D2435 on relatively undisturbed soil samples. The test measures the volume change of a soil sample under predetermined loads.

The test results are presented in this appendix.

### Strength Testing

Direct shear tests were completed on select samples obtained from the explorations. The tests were performed in general accordance with ASTM D3080. The test determines the effects upon shear resistance and displacement, and strength properties such as Mohr strength envelopes.

The test results are presented in this appendix.

### Atterberg Limits

Atterberg limit tests were completed on select samples obtained from the explorations. The tests were conducted in general accordance with ASTM D4318. The test measures the liquid limit, plastic limit, and plasticity index of soils.

The test result is presented in this appendix.

### Grain Size Analysis

Grain size analysis were completed on select samples obtained from the explorations. The tests were conducted in general accordance with ASTM D1140. The test measures the amount of material finer than 75-µm (No. 200) sieve in soils.

The test results are presented in this appendix.

### R-Value Testing

R-value tests were completed on select bulk samples obtained from the explorations. The tests were conducted in general accordance with ASTM D 2844. The test is used to measure the potential strength of subgrade, subbase, and base course materials for use in road and airfield pavements.

The test results are presented in this appendix.

| UNIFIED SOIL CLASSIFICATION SYSTEM | | | |
|---|---|---|---|
| Major Divisions | | Symbols | Typical Names |
| Coarse-Grained Soil (more than half of soil is larger than the no. 200 sieve size) | Gravels (more than half of coarse fraction is retained/> no. 4 sieve size) | GW | Well-graded GRAVELS with less than 5% fines or gravel-sand mixtures |
| | | GP | Poorly-graded GRAVELS with less than 5% fines or gravel-sand mixtures |
| | | GM | Silty gravels, gravel-sand-silt mixtures;GRAVELS with greater than 12% ML or MH fines |
| | | GC | Clayey gravels, gravel-sand-clay mixtures; GRAVELS with greater than 12% CL or CH |
| | Sands (more than half of coarse fraction passes/< no. 4 sieve size) | SW | Well-graded sands with less than 5% fines or gravelly sands, little or no fines |
| | | SP | Poorly-graded sands with less than 5% fines or gravelly sands, little or no fines |
| | | SM | Silty sands, sand-silt mixtures; SANDS with greater than 12% ML or MH fines |
| | | SC | Clayey sands, sand-clay mixtures; SANDS with greater than 12% CL or CH fines |
| Fine-Grained Soils (more than half of soil is smaller than the no. 200 sieve size) | Silts and Clays LL = < 50 | ML | Inorganic silts and clayey silts of low plasticity, sandy non-plastic SILT, gravelly SILT |
| | | CL | Inorganic clays of low to medium plasticity, silty CLAY, trace fines, sand |
| | | OL | Organic silts and organic silt-clays of non-plastic to medium plasticity |
| | Silts and Clays LL = > 50 | MH | Inorganic medium plastic silts, medium plastic to very plastic clayey silts. |
| | | CH | Inorganic plastic to very plastic CLAYS, sandy plastic CLAY |
| | | OH | Organic medium plastic to plastic silty CLAYS, and very plastic CLAYS |
| Highly Organic Soils | | PT | Peat and other highly organic soils |

| GRAIN SIZE CHART | | |
|---|---|---|
| Classification | Range of Grain Sizes | |
| | U.S. Standard Sieve Size | Grain Size in Millimeters |
| Boulders | Above 12" | Above 305 |
| Cobbles | 12" to 3" | 305 to 76.2 |
| Gravel | 3" to No. 4 | 76.2 to 4.75 |
| coarse | 3" to ¾" | 76.2 to 19.1 |
| fine | ¾" to No.4 | 19.1 to 4.75 |
| Sand | No. 4 to No. 200 | 4.76 to 0.075 |
| coarse | No. 4 to No. 10 | 4.76 to 2.00 |
| medium | No. 10 to No. 40 | 2.00 to 0.420 |
| fine | No. 40 to No. 200 | 0.240 to 0.075 |
| Silt and Clay | Below No. 200 | Below 0.075 |

SOIL DESCRIPTIONS/SYMBOLS

- Well-graded GRAVEL (GW)
- Poorly-graded GRAVEL (GP)
- Silty GRAVEL (GM)
- Clayey GRAVEL (GC)
- Well-graded SAND (SW)
- Poorly-graded SAND (SP)
- Silty SAND (SM)
- Clayey SAND (SC)
- AGGREGATE BASE
- Low-Plasticity SILT (ML)
- High-Plasticity SILT (MH)
- Low-Plasticity CLAY (CL)
- High-Plasticity CLAY (CH)
- SANDSTONE
- CLAYSTONE
- SILTSTONE
- FILL
- ASPHALT

GROUNDWATER READING

- Groundwater encountered during drilling
- Groundwater at completion
- Groundwater at 24 hours

SAMPLER TYPE

| | |
|---|---|
| CR - | Modified California (CR) split-barrel ring sampler with 3.0-inch outside diameter and a 2.5-inch inside diameter. |
| SPT - | Standard Penetration Test (SPT) split-barrel sampler with a 2.00-inch outside diameter with a 1.5-inch inside diameter |
| ST - | Shelby Tube (3.0-inch outside diameter, thin-walled tube) advanced with hydraulic pressure |
| BAG - | Bulk Sample |
| C - | Core Barrel |

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NEW JERSEY NEW YORK CONNECTICUT PENNSYLVANIA WASHINGTON DC VIRGINIA WEST VIRGINIA OHIO FLORIDA TEXAS ARIZONA CALIFORNIA

ABU DHABI ATHENS DOHA DUBAI ISTANBUL LONDON PANAMA

Langan Engineering & Environmental Services, Inc.

Figure Title

# BORING LOG LEGEND

Figure No.

# APPENDIX A

| | |
|---|---|
| Project: Proposed Banner Self-Storage Facility | Project No.: 700096301 |
| Location: 12121 Foothill Boulevard | Elevation and Datum: Approx. 1161.5 |
| Drilling Company: 2R Drilling | Date Started: 3/10/21; Date Finished: 3/10/21 |
| Drilling Equipment: CME 75 Truck Mounted Drill Rig | Completion Depth: 26.5 ft; Rock Depth: |
| Size and Type of Bit: 8-inch O.D. Hollow Stem Auger | Number of Samples: Disturbed 4; Undisturbed 4; Core - |
| Casing Diameter (in): -; Casing Depth (ft): - | Water Level (ft.): First -; Completion -; 24 HR. - |
| Casing Hammer: -; Weight (lbs): -; Drop (in): - | Drilling Foreman: Nick |
| Sampler: 2-inch O.D. SPT; 2.5-inch I.D. Mod. Cal. Split Spoon | Field Engineer: B. Watkins |
| Sampler Hammer: Automatic; Weight (lbs): 140; Drop (in): 30 | |

| Elev. (ft) | Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|
| +1161.5 | **YOUNG FAN DEPOSITS (Qyf)** Sandy Silt (ML), brown, soft, moist, fine sand, some clay. | 0 | | | | | | |
| | | 3 | S-1 | CR | 18 | 3 / 4 / 5 | | Dry Density = 93.6 pcf<br>WC = 7.7% |
| | Light brown, medium stiff, damp to moist. | 5 | S-2 | SPT | 14 | 3 / 4 / 6 | | %Pass. #200 = 51 |
| | moist, fine sand, trace coarse gravel. | 7–8 | S-3 | CR | 18 | 4 / 9 / 9 | | Dry Density = 93.2 pcf<br>WC = 12.7%<br>%Pass. #200 = 54 |
| ±1152.0 | Silty SAND (SM), light brown, medium dense, damp to moist, fine sand. | 9.5–10 | S-4 | SPT | 18 | 4 / 7 / 8 | | %Pass. #200 = 45 |
| | | 13 | S-5 | SPT | 18 | 4 / 7 / 9 | | |
| ±1147.0 | Sandy SILT (ML), light brown, stiff, moist, fine sand. | 14.5–15 | S-6 | CR | 18 | 7 / 12 / 14 | | Dry Density = 91.5 pcf<br>WC = 12.5%<br>%Pass. #200 = 70 |
| | | 20 | | | | | | |

| Project | Project No. |
|---|---|
| Proposed Banner Self-Storage Facility | 700096301 |
| **Location** | **Elevation and Datum** |
| 12121 Foothill Boulevard | Approx. 1161.5 |

| Material Symbol | Elev. (ft) | Sample Description | Depth Scale | Sample Data: Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|---|
| | +1141.5 | Very stiff. | 20–21.5 | S-7 | SPT | 18 | 6 / 10 / 15 | | |
| | | | 25–26.5 | S-8 | CR | 18 | 13 / 18 / 15 | | Dry Density = 98.4 pcf<br>WC = 8.5% |
| | +1135.0 | Total Depth = 26.5 feet<br>Groundwater not encountered.<br>Borehole backfilled with soil cuttings and bentonite plugs. | 26.5 | | | | | | |

Depth Scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45

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Log of Boring **B-2** Sheet 1 of 2

| | | | |
|---|---|---|---|
| Project: Proposed Banner Self-Storage Facility | | Project No.: 700096301 | |
| Location: 12121 Foothill Boulevard | | Elevation and Datum: Approx. 1160.5 | |
| Drilling Company: 2R Drilling | | Date Started: 3/10/21 | Date Finished: 3/10/21 |
| Drilling Equipment: CME 75 Truck Mounted Drill Rig | | Completion Depth: 26.5 ft | Rock Depth: |
| Size and Type of Bit: 8-inch O.D. Hollow Stem Auger | | Number of Samples: Disturbed 5; Undisturbed 4; Core - | |
| Casing Diameter (in): - | Casing Depth (ft): - | Water Level (ft.): First -; Completion -; 24 HR. - | |
| Casing Hammer: - Weight (lbs): - | Drop (in): - | Drilling Foreman: Nick | |
| Sampler: 2-inch O.D. SPT; 2.5-inch I.D. Mod. Cal. Split Spoon | | Field Engineer: B. Watkins | |
| Sampler Hammer: Automatic Weight (lbs): 140 | Drop (in): 30 | | |

| Elev. (ft) | Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|
| +1160.5 | **YOUNG FAN DEPOSITS (Qyf)** Sandy SILT (ML), light brown, medium stiff, damp, fine sand, some clay. | 0 | | | | | | Bulk sample collected from 0-5 feet bgs. |
| | | 2.5 | S-1 | CR | 18 | 3, 4, 6 | | Dry Density = 96.5 pcf WC = 9.0% |
| | Moist, increased fines. | 5 | S-2 | CR | 18 | 6, 6, 7 | | Dry Density = 105.0 pcf WC = 12.9% |
| | Trace clay. | 7.5 | S-3 | SPT | 12 | 3, 3, 7 | | %Pass. #200 = 57 |
| | | 10 | S-4 | CR | 18 | 4, 6, 7 | | Dry Density = 95.0 pcf WC = 13.2% |
| | | 15 | S-5 | SPT | 15 | 4, 6, 6 | | |
| | | 17.5 | S-6 | SPT | 15 | 6, 6, 6 | | %Pass. #200 = 50 |
| | | 20 | | | | | | |

\\LANGAN.COM\DATA\IRV\DATA3\700096301\PROJECT DATA_DISCIPLINE\GEOTECHNICAL\GINTLOGS\700096301 - GINT LOGS.GPJ ... 3/29/2021 11:51:32 AM ... Report: Log - LANGAN

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| Project | Project No. |
|---|---|
| Proposed Banner Self-Storage Facility | 700096301 |
| **Location** | **Elevation and Datum** |
| 12121 Foothill Boulevard | Approx. 1160.5 |

| Material Symbol | Elev. (ft) | Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|---|
| | +1140.5 | Trace fine to coarse gravel. | 20 | S-7 | CR | 18 | 6 / 7 / 12 | | Dry Density = 92.5 pcf<br>WC = 18.5% |
| | +1137.5 | Clayey SAND (SC), brown, medium dense, moist, fine sand. | 23 | | | | | | |
| | | | 25 | S-8 | SPT | 15 | 4 / 7 / 8 | | %Pass. #200 = 48 |
| | +1134.0 | Total Depth = 26.5 feet<br>Groundwater not encountered.<br>Borehole backfilled with soil cuttings and bentonite plugs. | 26.5 | | | | | | |

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45

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Log of Boring **B-3** Sheet 1 of 3

| | | | |
|---|---|---|---|
| Project | Proposed Banner Self-Storage Facility | Project No. | 700096301 |
| Location | 12121 Foothill Boulevard | Elevation and Datum | Approx. 1158 |
| Drilling Company | 2R Drilling | Date Started / Date Finished | 3/10/21 / 3/10/21 |
| Drilling Equipment | CME 75 Truck Mounted Drill Rig | Completion Depth / Rock Depth | 51.5 ft / |
| Size and Type of Bit | 8-inch O.D. Hollow Stem Auger | Number of Samples | Disturbed 8; Undisturbed 6; Core - |
| Casing Diameter (in) | - ; Casing Depth (ft) - | Water Level (ft.) | First -; Completion -; 24 HR. - |
| Casing Hammer | - ; Weight (lbs) - ; Drop (in) - | Drilling Foreman | Nick |
| Sampler | 2-inch O.D. SPT; 2.5-inch I.D. Mod. Cal. Split Spoon | Field Engineer | B. Watkins |
| Sampler Hammer | Automatic ; Weight (lbs) 140 ; Drop (in) 30 | | |

Elev. (ft) +1158.0

| Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|
| **YOUNG FAN DEPOSITS (Qyf)** Sandy SILT (ML), light brown, medium stiff, damp to moist, fine sand, trace fine to coarse gravel, some clay. | 0 | | | | | | Bulk sample collected from 0-5 feet bgs. |
| | 3 | S-1 | CR | 18 | 7 7 8 | | Dry Density = 91.8 pcf WC = 7.6% |
| No gravel. | 5 | S-2 | SPT | 18 | 3 6 6 | | %Pass. #200 = 50 |
| | 7.5 | S-3 | CR | 18 | 3 6 10 | | Dry Density = 86.7 pcf WC = 9.8% |
| Stiff. | 10 | S-4 | SPT | 18 | 6 6 7 | | |
| Moist. | 15 | S-5 | CR | 18 | 6 10 12 | | Dry Density = 93.1 pcf WC = 14.7% |
| | 20 | | | | | | |

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| Project | Project No. |
|---|---|
| Proposed Banner Self-Storage Facility | 700096301 |
| **Location** | **Elevation and Datum** |
| 12121 Foothill Boulevard | Approx. 1158 |

| Elev. (ft) | Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|
| +1138.0 | | 20 | | | | | | |
| | | 20–21.5 | S-6 | SPT | 18 | 6 / 7 / 6 | | |
| +1136.5 | Sandy CLAY (CL), brown, stiff, moist, fine sand. | 21.5 | | | | | | |
| | | 22.5–24 | S-7 | SPT | 14 | 4 / 9 / 12 | | |
| | Very stiff. | 25–26.5 | S-8 | CR | 18 | 15 / 29 / 31 | | Dry Density = 112.1 pcf<br>WC = 9.8%<br>%Pass. #200 = 51 |
| +1130.5 | Silty SAND (SM), light brown, medium dense, moist, fine to medium sand. | 27.5 | | | | | | |
| | | 30–31.5 | S-9 | SPT | 18 | 7 / 12 / 14 | | |
| | Fine sand. | 35–36.5 | S-10 | CR | 18 | 10 / 13 / 19 | | Interbedded Sandy Silt (ML) layer.<br>Dry Density = 102.1 pcf<br>WC = 13.3% |
| +1119.5 | SAND with Silt (SP-SM), light brown, medium dense, moist, fine to medium sand. | 38.5 | | | | | | |
| | | 40–41.5 | S-11 | SPT | 18 | 12 / 19 / 21 | | |
| | | 45 | | | | | | |

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| Project | Project No. |
|---|---|
| Proposed Banner Self-Storage Facility | 700096301 |
| **Location** | **Elevation and Datum** |
| 12121 Foothill Boulevard | Approx. 1158 |

| Elev. (ft) | Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|
| 1113.0 | Fine to coarse sand, trace fine gravel. | 45 | S-12 | CR | 18 | 13 / 25 / 21 | | Sandy Silt (ML) layer at the bottom of the sample. Dry Density = 102.9 pcf WC = 3.3% |
| 1110.0 | Silty SAND (SM), light brown, medium dense, moist, fine sand. | 48 | | | | | | |
| | | 50 | S-13 | SPT | 18 | 6 / 9 / 10 | | |
| 1106.5 | Total Depth = 51.5 feet<br>Groundwater not encountered.<br>Borehole backfilled with bentonite grout. | 51.5 | | | | | | |

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Log of Boring **B-4** Sheet 1 of 2

| | |
|---|---|
| Project: Proposed Banner Self-Storage Facility | Project No.: 700096301 |
| Location: 12121 Foothill Boulevard | Elevation and Datum: Approx. 1157.5 |
| Drilling Company: 2R Drilling | Date Started: 3/10/21; Date Finished: 3/10/21 |
| Drilling Equipment: CME 75 Truck Mounted Drill Rig | Completion Depth: 30 ft; Rock Depth: |
| Size and Type of Bit: 8-inch O.D. Hollow Stem Auger | Number of Samples: Disturbed 6; Undisturbed 3; Core - |
| Casing Diameter (in): -; Casing Depth (ft): - | Water Level (ft.): First -; Completion -; 24 HR. - |
| Casing Hammer: -; Weight (lbs): -; Drop (in): - | Drilling Foreman: Nick |
| Sampler: 2-inch O.D. SPT; 2.5-inch I.D. Mod. Cal. Split Spoon | Field Engineer: B. Watkins |
| Sampler Hammer: Automatic; Weight (lbs): 140; Drop (in): 30 | |

| Elev. (ft) | Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|
| +1157.5 | **YOUNG FAN DEPOSITS (Qyf)** Silty Sand (SM), light brown, damp to moist, fine sand. | 0 | | | | | | Hand augered and bulk sample collected from 0-5 feet bgs. Max Expansion Index Corrosivity R-Value Remolded Direct Shear Remolded Consolidation |
| ±1153.5 | Sandy CLAY (CL), light brown to brown, medium stiff, damp to moist, fine sand. | 4 | | | | | | |
| | | 5–6.5 | S-1 | CR | 18 | 6 10 14 | | Dry Density = 103.5 pcf WC = 10.0% |
| ±1150.5 | Sandy SILT (ML), light brown, stiff, damp to moist, fine sand. | 7 | | | | | | |
| | | 7.5–9 | S-2 | SPT | 14 | 3 6 6 | | %Pass. #200 = 55 |
| | | 10–11.5 | S-3 | CR | 18 | 4 4 6 | | Dry Density = 108.7 pcf WC = 8.7% |
| | Medium stiff, moist, fine sand, trace clay. | 15–16.5 | S-4 | SPT | 15 | 6 6 10 | | |
| | | 17.5–19 | S-5 | SPT | 10 | 6 6 7 | | |
| ±1138.0 | Sandy CLAY (CL), light brown, stiff, moist, fine sand. | 19.5–20 | | | | | | |

| Project | Project No. |
|---|---|
| Proposed Banner Self-Storage Facility | 700096301 |
| **Location** | **Elevation and Datum** |
| 12121 Foothill Boulevard | Approx. 1157.5 |

| Material Symbol | Elev. (ft) | Sample Description | Depth Scale | Sample Data: Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|---|
| | +1137.5 | | 20 | S-6 | CR | 18 | 7 / 12 / 16 | | Dry Density = 94.9 pcf<br>WC = 16.4% |
| | | Brown, decreased sand. | 25 | S-7 | SPT | 14 | 9 / 12 / 12 | | |
| | +1130.5 | Silty SAND (SM), light brown, medium dense, damp to moist, fine sand. | 27 | | | | | | |
| | | | 28.5 | S-8 | SPT | 18 | 10 / 15 / 22 | | Grain-Size Analysis |
| | +1127.5 | Total Depth = 30 feet<br>Groundwater not encountered.<br>Borehole converted into percolation well, then backfilled with soil-cement mixture. | 30 | | | | | | |

Depth scale: 20 – 45

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| | | | |
|---|---|---|---|
| Project: Proposed Banner Self-Storage Facility | | Project No.: 700096301 | |
| Location: 12121 Foothill Boulevard | | Elevation and Datum: Approx. 1154 | |
| Drilling Company: 2R Drilling | | Date Started: 3/10/21 | Date Finished: 3/10/21 |
| Drilling Equipment: CME 75 Truck Mounted Drill Rig | | Completion Depth: 30 ft | Rock Depth: |
| Size and Type of Bit: 8-inch O.D. Hollow Stem Auger | | Number of Samples: Disturbed 4; Undisturbed 4; Core - | |
| Casing Diameter (in): - | Casing Depth (ft): - | Water Level (ft.): First -; Completion -; 24 HR. - | |
| Casing Hammer: - Weight (lbs): - Drop (in): - | | Drilling Foreman: Nick | |
| Sampler: 2-inch O.D. SPT; 2.5-inch I.D. Mod. Cal. Split Spoon | | Field Engineer: B. Watkins | |
| Sampler Hammer: Automatic Weight (lbs): 140 Drop (in): 30 | | | |

| Material Symbol | Elev. (ft) +1154.0 | Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|---|
| | | **YOUNG FAN DEPOSITS (Qyf)** Sandy SILT (ML), light brown, medium stiff, damp, fine sand, some clay. | 0 | | | | | | |
| | | | 2.5–4 | S-1 | CR | 18 | 4 / 4 / 6 | | Dry Density = 96.5 pcf<br>WC = 7.6% |
| | | | 5–6.5 | S-2 | SPT | 18 | 4 / 4 / 5 | | %Pass. #200 = 55 |
| | | | 7.5–9 | S-3 | CR | 18 | 4 / 7 / 9 | | Dry Density = 105.1 pcf<br>WC = 10.3% |
| | | Stiff. | 10–11.5 | S-4 | SPT | 15 | 6 / 6 / 9 | | |
| | | | 15–16.5 | S-5 | CR | 18 | 9 / 10 / 11 | | Dry Density = 92.1 pcf<br>WC = 13.4% |
| | | | 20 | | | | | | |

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Log of Boring **B-5** Sheet 2 of 2

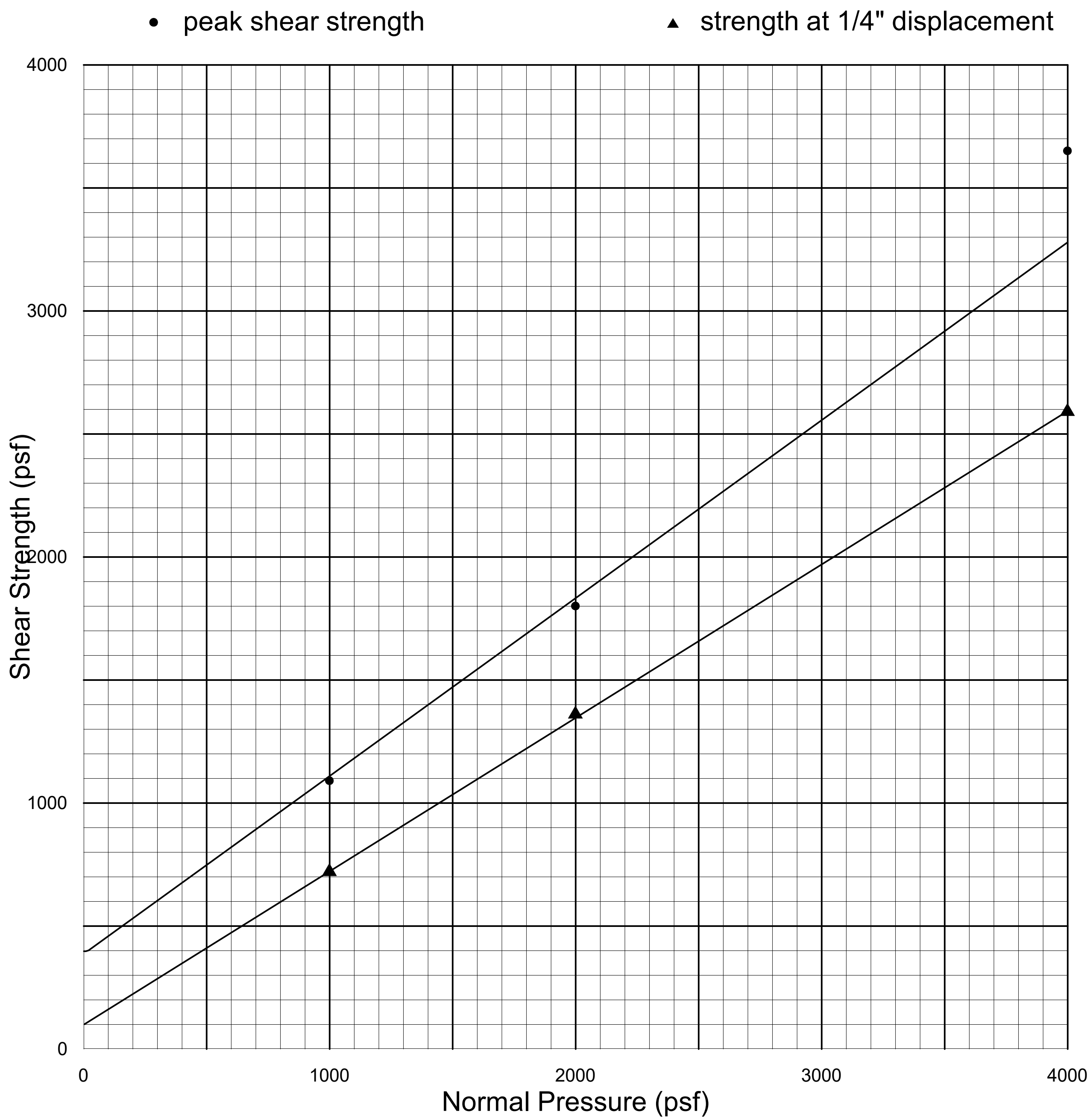
| Project | Project No. |
|---|---|
| Proposed Banner Self-Storage Facility | 700096301 |
| **Location** | **Elevation and Datum** |
| 12121 Foothill Boulevard | Approx. 1154 |

| Elev. (ft) | Sample Description | Depth Scale | Number | Type | Recov. (in) | Penetr. resist BL/6in | Water Content | Remarks (Drilling Fluid, Depth of Casing, Fluid Loss, Drilling Resistance, etc.) |
|---|---|---|---|---|---|---|---|---|
| +1134.0 | | 20 | S-6 | SPT | 18 | 6 / 9 / 9 | | |
| +1131.0 | Sandy CLAY (CL), brown, very stiff, moist, fine sand. | 23 | | | | | | |
| | | 25 | S-7 | CR | 18 | 15 / 20 / 21 | | Dry Density = 108.4 pcf<br>WC = 10.0% |
| +1126.5 | Silty SAND (SM), light brown, medium dense, moist, fine sand. | 27.5 | | | | | | |
| | | 28.5 | S-8 | SPT | 18 | 9 / 16 / 19 | | Grain-size Analysis |
| +1124.0 | Total Depth = 30 feet<br>Groundwater not encountered.<br>Borehole converted into percolation well, then backfilled with soil-cement mixture. | 30 | | | | | | |

Depth scale: 20 – 45

# DIRECT SHEAR TEST - ASTM D-3080






Strain Rate: 0.0084in. / min.

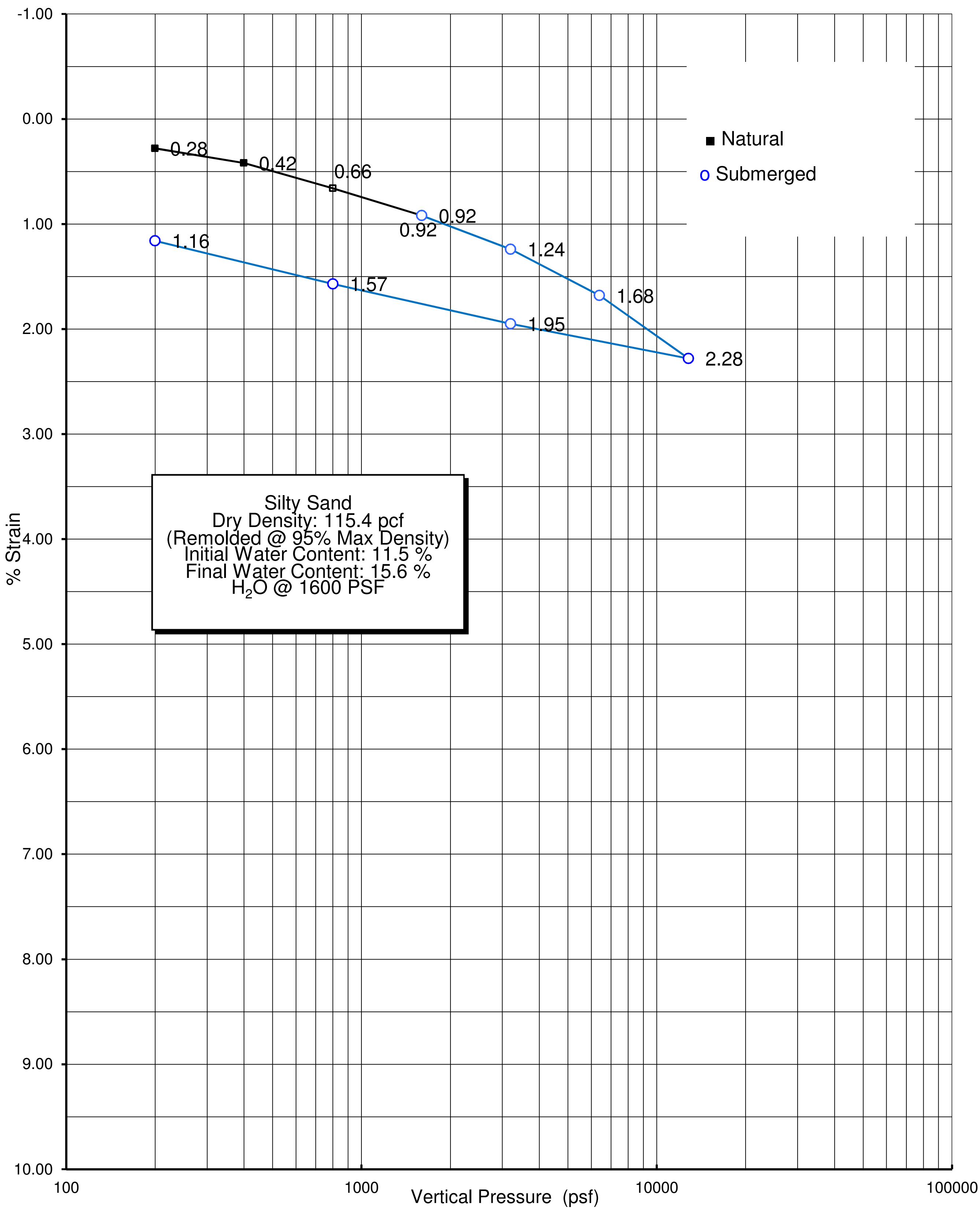
| Sample | Type | Description | Dry Density (pcf) | Initial W.C. (%) | Final W.C. (%) |
|---|---|---|---|---|---|
| B4@0-5' | Remolded & Saturated | Silty Sand | 115.4 (95% Max Density) | 11.5 | 15.4 |

| Normal Pressure (psf) | Peak Shear Strength (psf) | Ultimate Shear Strength (psf) |
|---|---|---|
| 1000 | 1090 @ 0.0505" | 720 |
| 2000 | 1800 @ 0.0505" | 1360 |
| 4000 | 3650 @ 0.0550" | 2590 |
| | C = 400 psf | C = 100 psf |
| | $\phi$ = 35.5 deg. | $\phi$ = 32 deg. |

# CONSOLIDATION TEST - ASTM D2435



| Boring / Sample No. B-4 | Depth: 0 - 5' | Date 03-23-21 |
| --- | --- | --- |



# WASH #200 SIEVE - ASTM D 1140-92

Job Name Langan # 700096301 Date 3-23-21

Job No. 2012-0057 By LD

| Sample | B-1 / S-2 | Sample | B-1 / S-3 | Sample | B-1/ S-4 |
|---|---|---|---|---|---|
| Depth (ft) | 5 | Soil Type | 7.5 | Soil Type | 10 |
| % water | | % water | | % water | |
| Wet weight | | Wet weight | | Wet weight | |
| Dry weight | 200.1 | Dry weight | 99 | Dry weight | 234.3 |
| + 200 sieve | 97.6 | + 200 sieve | 45.1 | + 200 sieve | 129 |
| % Retained | 48.8 | % Retained | 45.6 | % Retained | 55.1 |
| **%Pass. #200** | **51** | **%Pass. #200** | **54** | **%Pass. #200** | **45** |

| Sample | B-1 / S-5 | Sample | B-2 / S-3 | Sample | B-2/ S-6 |
|---|---|---|---|---|---|
| Depth | 15 | Soil Type | 7.5 | Soil Type | 17.5 |
| % water | | % water | | % water | |
| Wet weight | | Wet weight | | Wet weight | |
| Dry weight | 118.0 | Dry weight | 222.6 | Dry weight | 204.2 |
| + 200 sieve | 35.1 | + 200 sieve | 96.4 | + 200 sieve | 102.5 |
| % Retained | 29.7 | % Retained | 43.3 | % Retained | 50.2 |
| **%Pass. #200** | **70** | **%Pass. #200** | **57** | **%Pass. #200** | **50** |

| Sample | B-2 / S-8 | Sample | B-3 / S-2 | Sample | B-3/ S-8 |
|---|---|---|---|---|---|
| Soil Type | 25 | Soil Type | 5 | Soil Type | 25 |
| % water | | % water | | % water | |
| Wet weight | | Wet weight | | Wet weight | |
| Dry weight | 224.6 | Dry weight | 222.8 | Dry weight | 145.7 |
| + 200 sieve | 116.6 | + 200 sieve | 111.7 | + 200 sieve | 71.9 |
| % Retained | 51.9 | % Retained | 50.1 | % Retained | 49.3 |
| **%Pass. #200** | **48** | **%Pass. #200** | **50** | **%Pass. #200** | **51** |

| Sample | B-4 / S-2 | Sample | B-5 / S-2 | Sample | |
|---|---|---|---|---|---|
| Soil Type | 7.5 | Soil Type | 5 | Soil Type | |
| % water | | % water | | % water | |
| Wet weight | | Wet weight | | Wet weight | |
| Dry weight | 241.5 | Dry weight | 241.5 | Dry weight | |
| + 200 sieve | 108.7 | + 200 sieve | 108.7 | + 200 sieve | |
| % Retained | 45.0 | % Retained | 45.0 | % Retained | |
| **%Pass. #200** | **55** | **%Pass. #200** | **55** | **%Pass. #200** | |

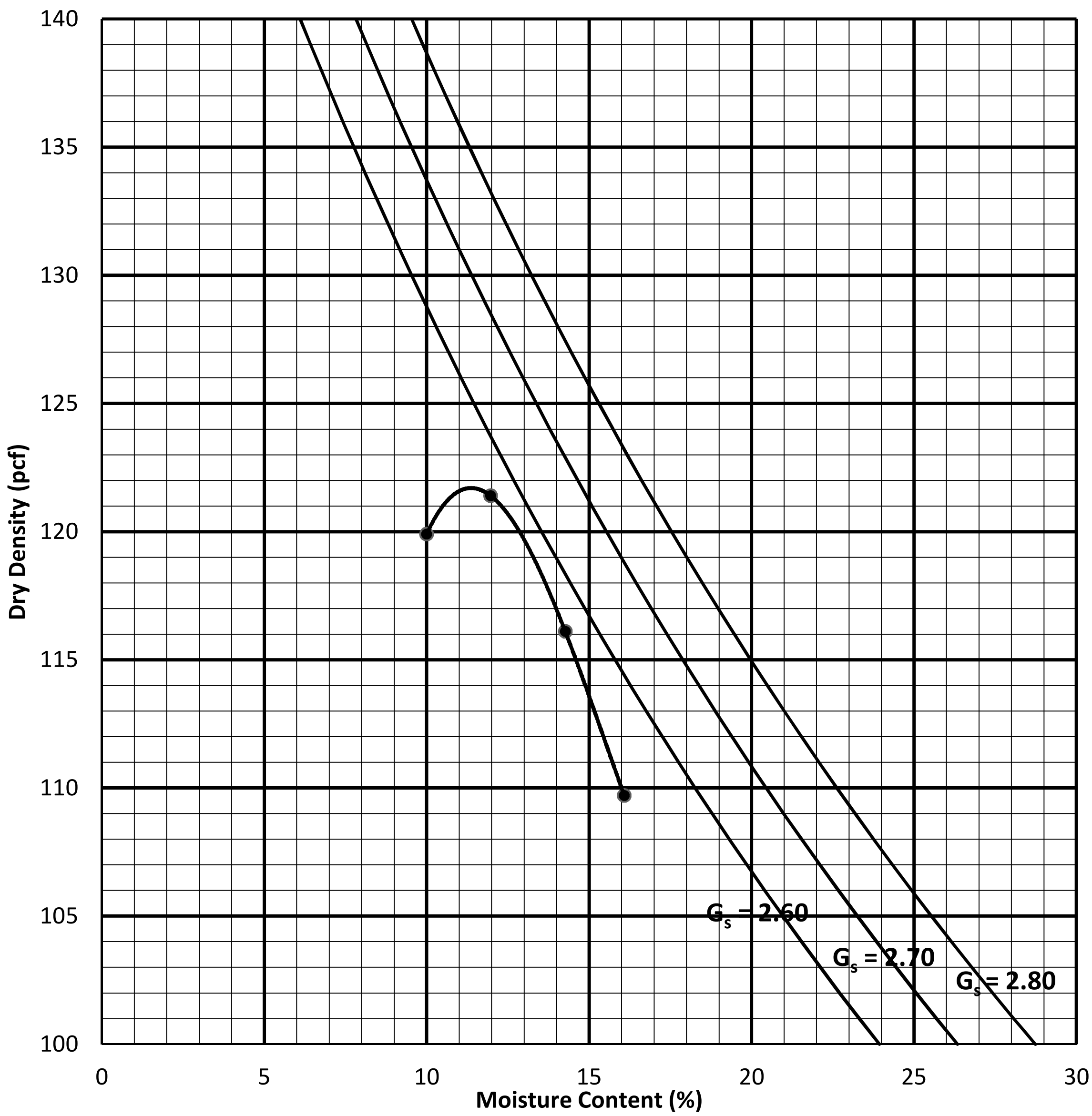
Geo-Logic ASSOCIATES

# COMPACTION TEST REPORT

**Project:** Langan # 700096301 **GLA No.** 2012-0057
**Sample:** B-4 @ 0 - 5' **Date:** 03/23/21
**Description:** Brown, Silty Sand w. Gravel **By:** LD

| ASTM D1557 | Method C | Volume (cf): 0.075 | | # Blows: 56 | # Layers: 5 |
|---|---|---|---|---|---|
| Specimen | | A | B | C | D |
| Wet Weight (lbs) | | 9.95 | 10.19 | 9.55 | 9.89 |
| Wet Density (pcf) | | 132.7 | 135.9 | 127.3 | 131.9 |
| Moisture Content (%) | | 14.3 | 12.0 | 16.1 | 10.0 |
| Dry Density (pcf) | | 116.1 | 121.4 | 109.7 | 119.9 |

**Max. Dry Density : 121.5 pcf**
**Opt. Water Content: 11.5%**




Geo-Logic ASSOCIATES

# EXPANSION INDEX - UBC 18-2 & ASTM D 4829-88

PROJECT Langan # 700096301 JOB NO. 2012-0057

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample | B-4 @ 0 - 5' | | By | LD | Sample | | | By | |
| Sta. No. | | | | | Sta. No. | | | | |
| Soil Type | Brown, Silty Sand | | | | Soil Type | | | | |
| Date | Time | Dial Reading | Wet+Tare | 620.7 | Date | | Dial Reading | Wet+Tare | |
| 3/22/2021 | 16:20 | 0.3261 | Tare | 217.9 | | | | Tare | |
| | | H2O | Net Weight | 402.8 | | | | Net Weight | |
| 3/23/2021 | 10:00 | 0.3225 | % Water | 9.5 | | | | % Water | |
| | | | Dry Dens. | 111.5 | | | | Dry Dens. | |
| | | | % Max | | | | | % Max | |
| | | | Wet+Tare | 652.9 | | | | Wet+Tare | |
| | | | Tare | 217.9 | | | | Tare | |
| | | | Net Weight | 435 | | | | Net Weight | |
| **INDEX** | 4 | 0.4% | % Water | 18.3 | **INDEX** | | | % Water | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sample | | | By | | Sample | | | By | |
| Sta. No. | | | | | Sta. No. | | | | |
| Soil Type | | | | | Soil Type | | | | |
| Date | | Dial Reading | Wet+Tare | | Date | | Dial Reading | Wet+Tare | |
| | | | Tare | | | | | Tare | |
| | | | Net Weight | | | | | Net Weight | |
| | | | % Water | | | | | % Water | |
| | | | Dry Dens. | | | | | Dry Dens. | |
| | | | % Max | | | | | % Max | |
| | | | Wet+Tare | | | | | Wet+Tare | |
| | | | Tare | | | | | Tare | |
| | | | Net Weight | | | | | Net Weight | |
| **INDEX** | | | % Water | | **INDEX** | | | % Water | |

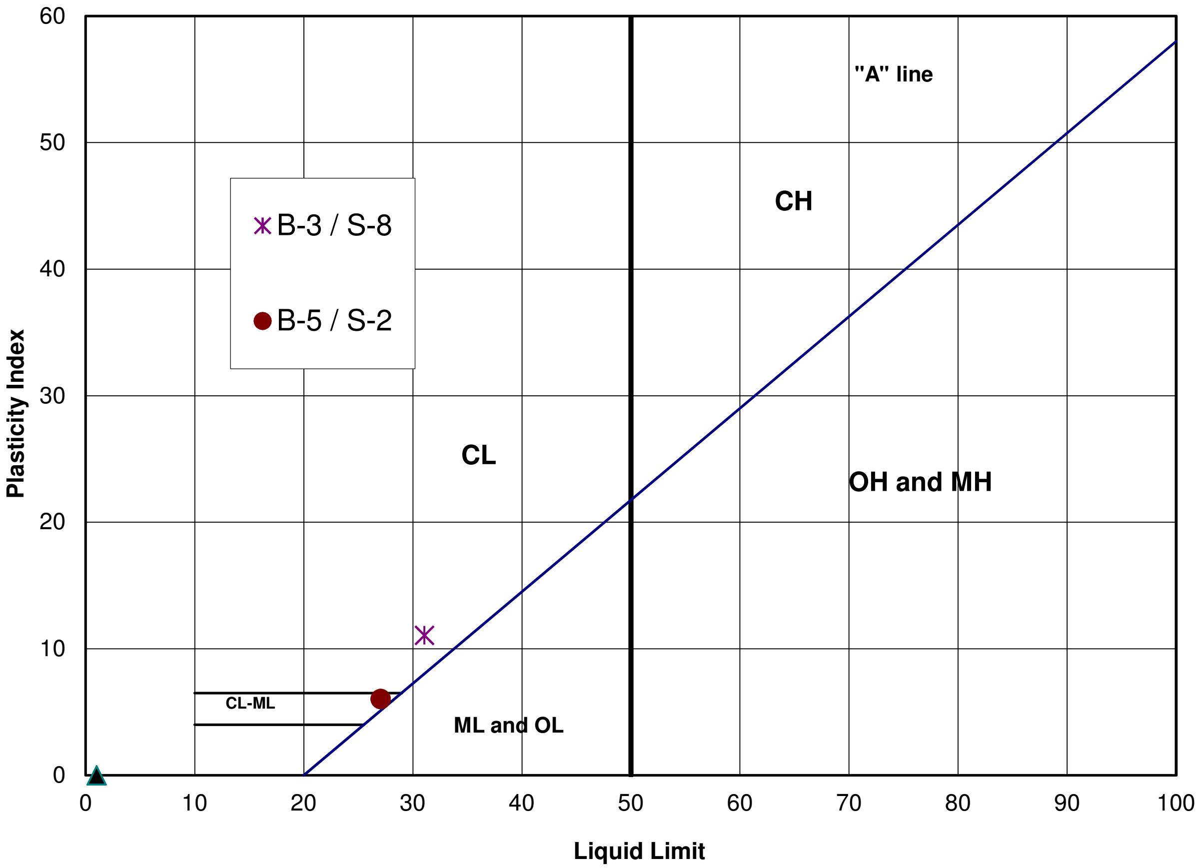
Geo-Logic ASSOCIATES

*Langan Engineering # 700096301* SOIL TEST RESULTS *Job No. 2012-0057*

| SAMPLE NO.: | B-4 @ 0 - 5' | | | | |
|---|---|---|---|---|---|
| DESCRIPTION | Silty Sand | | | | |
| DIRECT SHEAR TEST (type) | | | | | |
| Initial Moisture Content % | | | | | |
| Dry Density (pcf) | | | | | |
| Normal Stress (psf) | | | | | |
| Peak Shear Stress (psf) | | | | | |
| Ultimate Shear Stress (psf) | | | | | |
| Cohesion (psf) | | | | | |
| Internal Friction Angle (degrees) | | | | | |
| EXPANSION TEST UBC STD 18-2 | | | | | |
| Initial Dry Density (pcf) | | | | | |
| Initial Moisture Content % | | | | | |
| Final Moisture Content % | | | | | |
| Pressure (psf) | | | | | |
| Expansion Index / Swell % | | | | | |
| CORROSIVITY TEST | | | | | |
| Resistivity (CTM 643) (ohm-cm) | 1350 | | | | |
| pH (ASTM D1293) | 7.1 | | | | |
| CHEMICAL TESTS | | | | | |
| Soluble Sulfate (CTM 417) (%) | 0.0242 | | | | |
| Chloride Content (CTM 422) (%) | 0.0049 | | | | |
| Wash #200 Sieve (ASTM-1140) % | | | | | |
| Sand Equivalent (ASTM D2419) | | | | | |

Geo-Logic ASSOCIATES

# PLASTICITY INDEX _ ASTM D4318




| Sample | Depth | LL | PL | PI | USCS | Material Description |
|---|---|---|---|---|---|---|
| B-3 / S-8 | 25' | 31 | 20 | 11 | CL | |
| B-5 / S-2 | 5' | 27 | 21 | 6 | CL-ML | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

Job Name Langan # 700096301 Date: 3-25-21

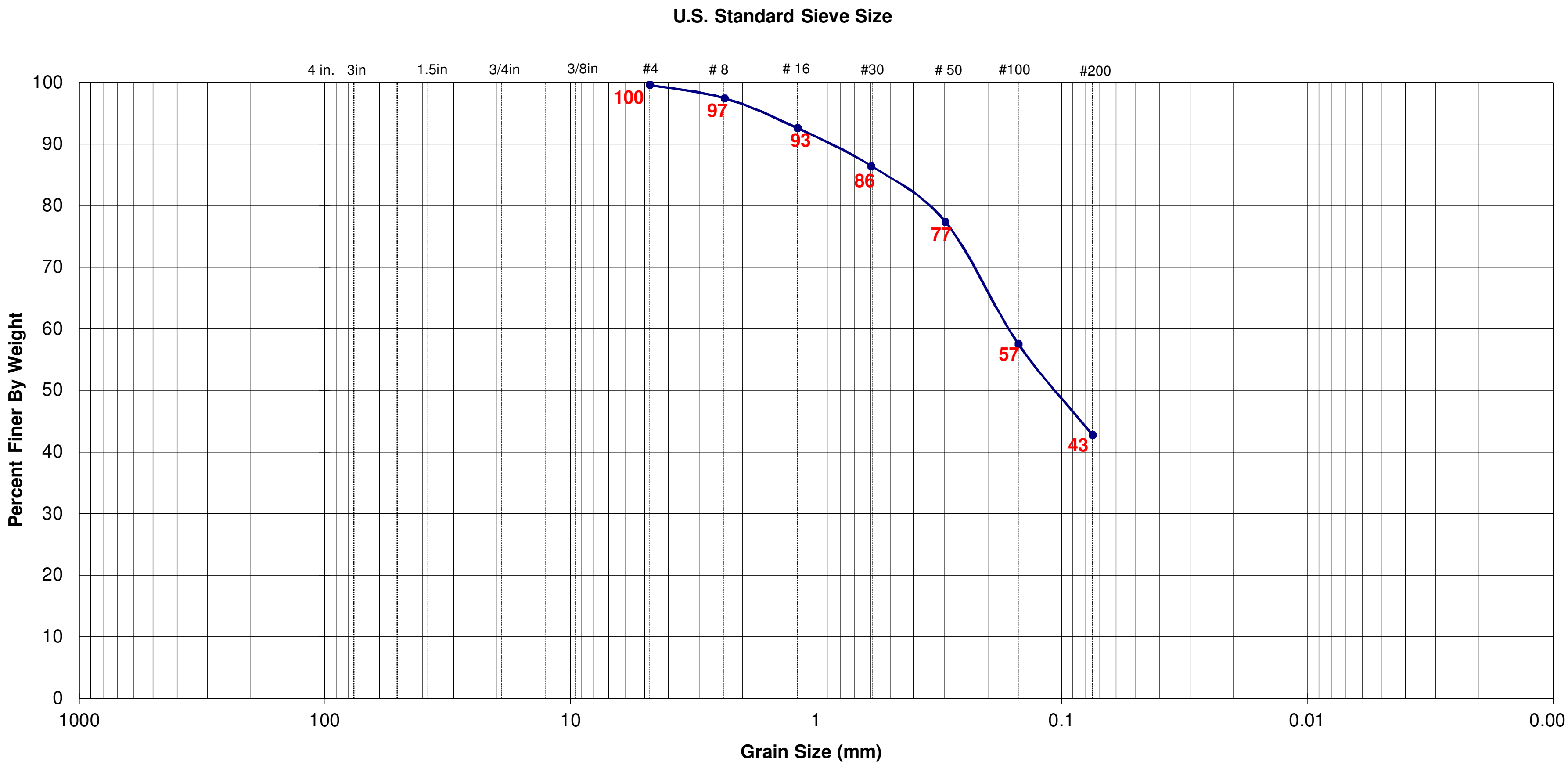
Job No.: 2012-0057

Geo-Logic ASSOCIATES

# GRAIN SIZE ANALYSIS - ASTM D 422



Date: 3/23/21

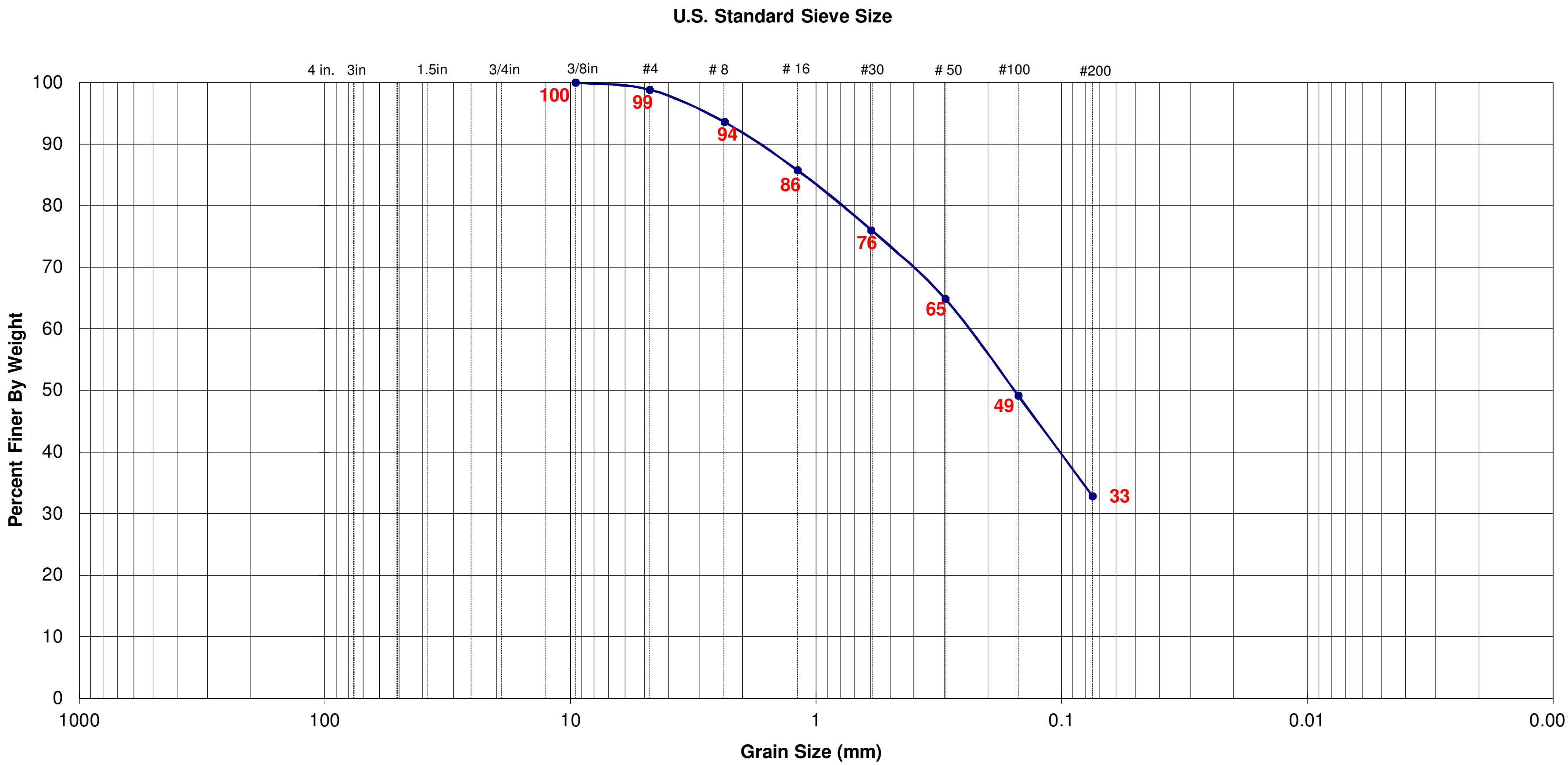



| Boring / Sample No. | Initial Dry Density (pcf) | Initial Moist. (%) | Test Dry Density (pcf) | Test Moist. (%) | Permeabilty, k (cm/sec) | LL | PL | PI | Unified Soil Class. | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| B-5 / S-8 | | | | | | | | | SC | |
| | | | | | | | | | | |
| | | | | | | | | | | |

## GRAIN SIZE ANALYSIS - ASTM D 422



Date: 3/23/21




| Boring / Sample No. | Initial Dry Density (pcf) | Initial Moist. (%) | Test Dry Density (pcf) | Test Moist. (%) | Permeabilty, k (cm/sec) | LL | PL | PI | Unified Soil Class. | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| B-4 / S-8 | | | | | | | | | SM | |
| | | | | | | | | | | |
| | | | | | | | | | | |

Geo-Logic ASSOCIATES

# 'R' VALUE CA 301

Client: Langan | Date: 3/23/21 | By: LD

Client's Job No.: **700096301** | Sample No.: B-4 @ 0-5'

GLA Reference: 2012-0057 | Soil Type: Brown, Silty Sand w. Gravel

| TEST SPECIMEN | | A | B | C | D |
|---|---|---|---|---|---|
| Compactor Air Pressure | psi | **350** | **350** | **350** | |
| Initial Moisture Content | % | **9.8** | **9.8** | **9.8** | |
| Water Added | ml | **20** | **28** | **24** | |
| Moisture at Compaction | % | 11.8 | 12.6 | 12.2 | |
| Sample & Mold Weight | gms | **3181** | **3180** | **3182** | |
| Mold Weight | gms | **2098** | **2107** | **2096** | |
| Net Sample Weight | gms | 1083 | 1073 | 1086 | |
| Sample Height | in. | **2.478** | **2.46** | **2.482** | |
| Dry Density | pcf | 118.5 | 117.4 | 118.2 | |
| Pressure | lbs | **8910** | **3610** | **4980** | |
| Exudation Pressure | psi | 709 | 287 | 396 | |
| Expansion Dial | x 0.0001 | **0** | **0** | **0** | |
| Expansion Pressure | psf | 0 | 0 | 0 | |
| Ph at 1000lbs | psi | **15** | **21** | **17** | |
| Ph at 2000lbs | psi | **28** | **38** | **33** | |
| Displacement | turns | **4.68** | **4.88** | **4.72** | |
| R' Value | | 72 | 62 | 67 | |
| Corrected 'R' Value | | **72** | **62** | **67** | |

| FINAL 'R' VALUE | |
|---|---|
| By Exudation Pressure (@ 300 psi): | **63** |
| By Epansion Pressure : | **N/A** |
| **TI = 5** | |

Geo-Logic ASSOCIATES

# DENSITY TESTS

PROJECT Langan # 700096301 JOB NO. 2012-0057 BY LD DATE 03/23/21

| Sample No. | B-1 / S-1 | B-1 / S-3 | B-1 / S-6 | B-1 / S-8 | B-2 / S-1 | B-2 / S-2 | B-2 / S-4 | B-2 / S-7 |
|---|---|---|---|---|---|---|---|---|
| Depth (ft) | 2.5 | 7.5 | 15.0 | 25.0 | 2.5 | 5.0 | 10.0 | 20.0 |
| P.P. | | | | | | | | |
| Soil Type | Brown, Silty Sand | Brown, F.M. Sandy Clay | Brown, F.M. Clayey Sand | Brown, Silty Sand | Brown, Silty Sand | Brown, Silty Sand | Brown, Silty Sand | Brown, Silty Sand |
| Wet+Tare | 997.3 | 856.6 | 1012.3 | 866.3 | 1028.1 | 1124.4 | 1044.7 | 1060.8 |
| No. Ring | 6 | 5 | 6 | 5 | 6 | 6 | 6 | 6 |
| Wet Weight | 122.7 | 146.0 | 132.8 | 104.9 | 126.2 | 120.4 | 126.3 | 115.1 |
| Dry Weight | 113.9 | 129.5 | 118.0 | 96.7 | 115.8 | 106.6 | 111.6 | 97.1 |
| Wet density | 100.9 | 105.1 | 102.9 | 106.7 | 105.1 | 118.6 | 107.5 | 109.7 |
| % Water | 7.7 | 12.7 | 12.5 | 8.5 | 9.0 | 12.9 | 13.2 | 18.5 |
| Dry Density | 93.6 | 93.2 | 91.5 | 98.4 | 96.5 | 105.0 | 95.0 | 92.5 |
| O.B.Press(psf) | | | | | | | | |
| **Sample No.** | **B-3 / S-1** | **B-3 / S-3** | **B-3 / S-5** | **B-3 / S-8** | **B-3 / S-10** | **B-3 / S-12** | | |
| Depth (ft) | 2.5 | 7.5 | 15.0 | 25.0 | 35.0 | 45.0 | | |
| P.P. | | | | | | | | |
| Soil Type | Brown, Silty Sand | Brown, Silty Sand | Brown, F.M. Clayey Sand | Brown, F.M. Sandy Clay | Brown, F.M. Clayey Sand | Brown, Silty Sand | | |
| Wet+Tare | 982.1 | 797.5 | 1040.0 | 963.5 | 1103.7 | 518.2 | | |
| No. Ring | 6 | 5 | 6 | 5 | 6 | 3 | | |
| Wet Weight | 115.3 | 107.2 | 130.7 | 436.5 | 157.2 | 122.9 | | |
| Dry Weight | 107.2 | 97.6 | 113.9 | 397.7 | 138.8 | 119.0 | | |
| Wet density | 98.7 | 95.2 | 106.8 | 123.0 | 115.7 | 106.3 | | |
| % Water | 7.6 | 9.8 | 14.7 | 9.8 | 13.3 | 3.3 | | |
| Dry Density | 91.8 | 86.7 | 93.1 | 112.1 | 102.1 | 102.9 | | |
| O.B.Press(psf) | | | | | | | | |

Geo-Logic ASSOCIATES

# DENSITY TESTS

PROJECT Langan # 700096301 JOB NO. 2012-0057 BY LD DATE 03/23/21

| Sample No. | B-4 / S-1 | B-4 / S-3 | B-4 / S-6 | B-5 / S-1 | B-5 / S-3 | B-5 / S-5 | B-5 / S-7 | |
|---|---|---|---|---|---|---|---|---|
| Depth (ft) | 5.0 | 10.0 | 20.0 | 2.5 | 7.5 | 15.0 | 25.0 | |
| P.P. | | | | | | | | |
| Soil Type | Brown, Silty Sand | Brown, Silty Sand | Brown, F.M. Clayey Sand | Brown, Silty Sand | Brown, Silty Sand | Brown, Silty Sand | Brown, F.M. Clayey Sand | |
| Wet+Tare | 909.1 | 1121.6 | 1065.8 | 849.2 | 921.7 | 1022.8 | 941.3 | |
| No. Ring | 5 | 6 | 6 | 5 | 5 | 6 | 5 | |
| Wet Weight | 115.0 | 138.1 | 161.2 | 111.6 | 119.5 | 135.3 | 118.6 | |
| Dry Weight | 104.5 | 127.0 | 138.5 | 103.7 | 108.3 | 119.3 | 107.8 | |
| Wet density | 113.9 | 118.2 | 110.4 | 103.9 | 116.0 | 104.4 | 119.3 | |
| % Water | 10.0 | 8.7 | 16.4 | 7.6 | 10.3 | 13.4 | 10.0 | |
| Dry Density | 103.5 | 108.7 | 94.9 | 96.5 | 105.1 | 92.1 | 108.4 | |
| O.B.Press(psf) | | | | | | | | |
| Sample No. | | | | | | | | |
| Depth (ft) | | | | | | | | |
| P.P. | | | | | | | | |
| Soil Type | | | | | | | | |
| Wet+Tare | | | | | | | | |
| No. Ring | | | | | | | | |
| Wet Weight | | | | | | | | |
| Dry Weight | | | | | | | | |
| Wet density | | | | | | | | |
| % Water | | | | | | | | |
| Dry Density | | | | | | | | |
| O.B.Press(psf) | | | | | | | | |

Geo-Logic ASSOCIATES

# APPENDIX B

## Percolation Test Results

**LANGAN**

# PERCOLATION TEST DATA SHEET

| | | | | | |
|---|---|---|---|---|---|
| Project: | Banner Self-Storage Facility | Project No.: | 700096301 | Date: | 3/11/2021 |
| Test Hole No.: | B-4 | Tested By: | BW | | |
| Depth of Test Hole (ft): | 30 | USCS Soil Classification: | Silty Sand | | |
| length of slotted pipe (ft): | 10 | Test Hole Diameter (in): | 10 | | |
| Presoak Duration: | 1.5 hours | Depth of Presoak (ft): | 20 | | |

| Trial No. | Date | Time of Measurement | Initial Depth to Water (ft) | Time of Measurement | Final Depth to Water (ft) | Elapsed Time (min) | Time Interval (min) | Change in Water Level (in) | Percolation Rate, $K_{sat, measured}$ (in/hr) |
|---|---|---|---|---|---|---|---|---|---|
| Time Interval | 3/11/2021 | 11:30 AM | 29.00 | 12:00 PM | 29.31 | 30 | 30 | 3.72 | -- |
| | | | | | | | | | |
| 1 | 3/11/2021 | 12:10 PM | 28.00 | 12:40 PM | 28.52 | 30 | 30 | 6.24 | 1.18 |
| 2 | 3/11/2021 | 12:42 PM | 28.00 | 1:12 PM | 28.54 | 62 | 30 | 6.48 | 1.22 |
| 3 | 3/11/2021 | 1:13 PM | 28.00 | 1:43 PM | 28.56 | 93 | 30 | 6.72 | 1.27 |
| 4 | 3/11/2021 | 1:45 PM | 28.00 | 2:15 PM | 28.52 | 125 | 30 | 6.24 | 1.18 |
| 5 | 3/11/2021 | 2:17 PM | 28.00 | 2:47 PM | 28.55 | 157 | 30 | 6.60 | 1.25 |
| 6 | 3/11/2021 | 2:50 PM | 28.00 | 3:20 PM | 28.53 | 190 | 30 | 6.36 | 1.20 |
| 7 | 3/11/2021 | 4:00 PM | 28.00 | 4:30 PM | 28.54 | 260 | 30 | 6.48 | 1.22 |
| 8 | 3/11/2021 | 4:33 PM | 28.00 | 5:03 PM | 28.52 | 293 | 30 | 6.24 | 1.18 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | Raw percolation rate (in/hr) | 1.20 |
| | | | | | | | | | |

| | |
|---|---|
| Comments: | 1. Percolation test was performed in general accordance with the "Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration - GS200.2" prepared by County of Los Angeles Department of Public Works, dated 30 June 2017. |
| | 2. Weather: overcast |

LANGAN

# PERCOLATION TEST DATA SHEET

| | | | | | |
|---|---|---|---|---|---|
| Project: | Banner Self-Storage Facility | Project No.: | 700096301 | Date: | 3/11/2021 |
| Test Hole No.: | B-5 | Tested By: | BW | | |
| Depth of Test Hole (ft): | 30 | USCS Soil Classification: | Silty Sand | | |
| length of slotted pipe (ft): | 10 | Test Hole Diameter (in): | 10 | | |
| Presoak Durration: | 1.5 hours | Depth of Presoak (ft): | 20 | | |

| Trial No. | Date | Time of Measurement | Initial Depth to Water (ft) | Time of Measurement | Final Depth to Water (ft) | Elapsed Time (min) | Time Interval (min) | Change in Water Level (in) | Percolation Rate, $K_{sat, measured}$ (in/hr) |
|---|---|---|---|---|---|---|---|---|---|
| Time Interval | 3/11/2021 | 11:15 AM | 29.00 | 11:45 AM | 29.23 | 30 | 30 | 2.76 | -- |
| | | | | | | | | | |
| 1 | 3/11/2021 | 11:48 AM | 28.00 | 12:18 PM | 28.40 | 30 | 30 | 4.80 | 0.91 |
| 2 | 3/11/2021 | 12:21 PM | 28.00 | 12:51 PM | 28.39 | 63 | 30 | 4.68 | 0.88 |
| 3 | 3/11/2021 | 12:54 PM | 28.00 | 1:24 PM | 28.38 | 96 | 30 | 4.56 | 0.86 |
| 4 | 3/11/2021 | 1:27 PM | 28.00 | 1:57 PM | 28.42 | 129 | 30 | 5.04 | 0.95 |
| 5 | 3/11/2021 | 2:00 PM | 28.00 | 2:30 PM | 28.39 | 162 | 30 | 4.68 | 0.88 |
| 6 | 3/11/2021 | 2:35 PM | 28.00 | 3:05 PM | 28.40 | 197 | 30 | 4.80 | 0.91 |
| 7 | 3/11/2021 | 4:05 PM | 28.00 | 4:35 PM | 28.38 | 287 | 30 | 4.56 | 0.86 |
| 8 | 3/11/2021 | 4:40 PM | 28.00 | 5:10 PM | 28.39 | 322 | 30 | 4.68 | 0.88 |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | Raw percolation rate (in/hr) | | 0.88 |
| | | | | | | | | | |

Comments:

1. Percolation test was performed in general accordance with the "Guidelines for Geotechnical Investigation and Reporting Low Impact Development Stormwater Infiltration - GS200.2" prepared by County of Los Angeles Department of Public Works, dated 30 June 2017.
2. Weather: overcast

# APPENDIX C
## Geophysical Survey Report

# REPORT

# SURFACE WAVE MEASUREMENTS

# 12121 FOOTHILL BOULEVARD
# SYLMAR, CALIFORNIA

**GEO***Vision* Project No. 21047

*Prepared for*

Langan
17875 Von Karman Avenue, Suite 150
Irvine, California 92614

*Prepared by*

**GEO***Vision*, Inc.
1124 Olympic Drive
Corona, California 92881
(951) 549-1234

Report 21047-01 Rev 1

March 23, 2021

# TABLE OF CONTENTS



# LIST OF TABLES



# LIST OF FIGURES

# 1 INTRODUCTION

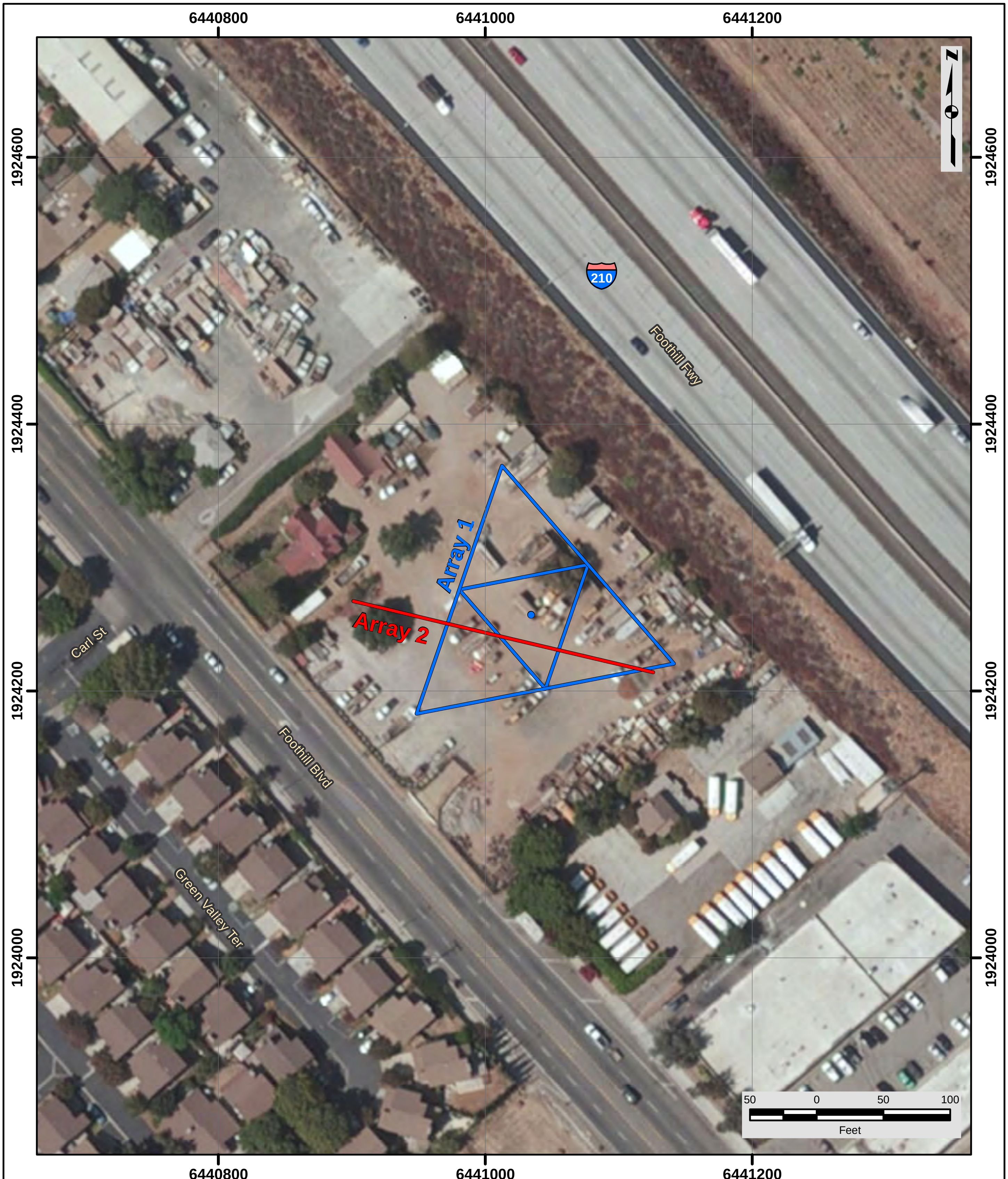
In-situ seismic measurements using active- and passive-source surface wave techniques were performed at the property located at 12121 Sepulveda Boulevard, Sylmar, California on March 9, 2021. The purpose of this investigation was to provide a shear (S) wave velocity profile to a depth of 30 m (100 ft), or greater, and estimate the average S-wave velocity of the upper 100 ft ($V_{S100ft}$). The active-source surface wave technique utilized during this investigation consisted of the multi-channel analysis of surface waves (MASW) method. The passive-source surface wave technique consisted of the array microtremor method. The locations of the active- and passive-source surface wave testing locations are shown on Figure 1. Array microtremor measurements were made using a triangle-shaped array (Array 1) and MASW measurements made on a linear array within the interior of Array 1 (Array 2).

$V_{S30}$ is used in the NEHRP provisions and the Uniform Building Code (UBC) to separate sites into classes for earthquake engineering design (BSSC, 2009). $V_{S100ft}$ is used in the International Building Code (IBC) for site classification. These site classes are as follows:

Class A – hard rock – $V_{S30} > 1500$ m/s (UBC) or $V_{S100ft} > 5{,}000$ ft/s (IBC)
Class B – rock – $760 < V_{S30} \leq 1500$ m/s (UBC) or $2{,}500 < V_{S100ft} \leq 5{,}000$ ft/s (IBC)
Class C – very dense soil and soft rock – $360 < V_{S30} \leq 760$ m/s (UBC)
or $1{,}200 < V_{S100ft} \leq 2{,}500$ ft/s (IBC)
Class D – stiff soil – $180 < V_{S30} \leq 360$ m/s (UBC) or $600 < V_{S100ft} \leq 1{,}200$ ft/s (IBC)
Class E – soft soil – $V_{S30} < 180$ m/s (UBC) or $V_{S100ft} < 600$ ft/s (IBC)
Class F – soils requiring site-specific evaluation

At many sites, active surface wave techniques (MASW) with the utilization of portable energy sources, such as hammers and weight drops, are sufficient to obtain S-wave velocity sounding to 30 m (100 ft) depth. At sites with high ambient noise levels and/or very soft soils, these energy sources may not be sufficient to image to this depth and a larger energy source, such as a bulldozer, is necessary. Alternatively, passive surface wave techniques, such as the array microtremor technique can be used to extend the depth of investigation at sites that have adequate ambient noise conditions. It should be noted that two-dimensional passive-source surface wave arrays (e.g., triangular, circular, or L-shaped arrays) are expected to perform better than linear arrays.

This report contains the results of the active and passive surface wave measurements conducted at the site. An overview of the surface wave methods is given in Section 2. Field and data reduction procedures are discussed in Sections 3 and 4, respectively. Data modeling is presented in Section 5 and interpretation and results are presented in Section 6. References and our professional certification are presented in Sections 7 and 8, respectively.




Active Surface Wave Array (MASW)
Passive Surface Wave Array (Triangle)

NOTES:
1. Coordinate System: California State Plane, NAD83, Zone V (0405), US Survey Feet
2. Base map source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

GEOVision geophysical services

| | |
|---|---|
| Date: | 3/19/2021 |
| GV Project: | 21047 |
| Developed by: | C Martinez |
| Drawn by: | T Rodriguez |
| Approved by: | A Martin |
| File Name: | 21047-1.MXD |

**FIGURE 1**
**SITE MAP**

**PROPOSED STORAGE FACILITY**
**12121 FOOTHILL BLVD**
**SYLMAR, CALIFORNIA**

**PREPARED FOR**
**LANGAN ENGINEERING AND ENVIRONMENTAL SERVICES, INC.**

# 2 OVERVIEW OF SURFACE WAVE TECHNIQUES

## 2.1 Introduction

Active- and passive-source (ambient vibration) surface wave techniques are routinely utilized for site characterization. Active surface wave techniques include the spectral analysis of surface waves (SASW) and multi-channel array surface wave (MASW) methods. Passive surface wave techniques include the horizontal over vertical spectral ratio (HVSR) technique and the array and refraction microtremor methods.

The basis of surface wave methods is the dispersive characteristic of Rayleigh and Love waves when propagating in a layered medium. Surface waves of different wavelengths ($\lambda$) or frequencies (f) sample different depth. As a result of the variance in the shear stiffness of the distinct layers, waves with different wavelengths propagate at different phase velocities; hence, dispersion. A surface wave dispersion curve is the variation of $V_R$ or $V_L$ with $\lambda$ or f. The Rayleigh wave phase velocity ($V_R$) depends primarily on the material properties ($V_S$, mass density, and Poisson's ratio or compression wave velocity) over a depth of approximately one wavelength. The Love wave phase velocity ($V_L$) depends primarily on $V_S$ and mass density. Rayleigh and Love wave propagation are also affected by damping or seismic quality factor (Q). Rayleigh wave techniques are utilized to measure vertically polarized S-waves ($S_V$-wave); whereas Love wave techniques are utilized to measure horizontally polarized S-waves ($S_H$-wave).

## 2.2 Surface Wave Techniques

The MASW and array microtremor techniques were utilized during this investigation and are discussed below.

### 2.2.1 MASW Technique

A description of the MASW method is given by Park, 1999a and 1999b and Foti, 2000. Ground motions are typically recorded by 24, or more, geophones typically spaced 1 to 3 m apart along a linear array and connected to a seismograph. Energy sources for shallow investigations include various sized hammers and vehicle mounted weight drops. When applying the MASW technique to develop a one-dimensional (1-D) $V_S$ model, it is preferable to use multiple-source offsets from both ends of the array. The most commonly applied MASW technique is the Rayleigh-wave based MASW method, which we refer to as $MAS_RW$ to distinguish from Love-wave based MASW ($MAS_LW$). $MAS_RW$ and $MAS_LW$ acquisition can easily be combined with P- and S-wave seismic refraction acquisition, respectively. $MAS_RW$ data are generally recorded using a vertical source and vertical geophone but may also be recorded using a horizontal geophone with radial (in-line) orientation. $MAS_LW$ data are recorded using transversely orientated horizontal source and transverse horizontal geophone.

A wavefield transform is applied to the time-history data to convert the seismic record from time-offset space to frequency-wavenumber (f-k) space in which the fundamental or higher surface-wave modes can be easily identified as energy maxima and picked. Frequency and/or wavenumber can easily be mapped to phase velocity, slowness, or wavelength using the following properties: $k = 2\pi/\lambda$, $\lambda = v/f$. Common wave-field transforms include: the f-k transform (a 2D fast Fourier transform), slant-stack transform (also referred to as interceptslowness or τ-p transform and equivalent to linear Radon transform), frequency domain beamformer, and phase-shift transform. The minimum wavelength that can be recovered from MASW data set without spatial aliasing is equal to the minimum receiver spacing. Occasionally, SASW analysis procedures are used to extract surface wave dispersion data, from fixed receiver pairs, at smaller wavelengths than can be recovered by wavefield transformation. Construction of a dispersion curve over the wide frequency/wavelength range necessary to develop a robust $V_S$ model while also limiting the maximum wavelength based on an established near-field criterion (e.g. Yoon and Rix, 2009; Li and Rosenblad, 2011), generally requires multiple source offsets.

Although the clear majority of MASW surveys record Rayleigh waves, it has been shown that Love wave techniques can be more effective in some environments, particularly shallow rock sites and sites with a highly attenuative, low velocity surface layer (Xia, et al., 2012; **GEO***Vision*, 2012; Yong, et al., 2013; Martin, et al., 2014). Rayleigh wave techniques, however, are generally more effective at sites where velocity gradually increases with depth because larger energy sources are readily available for the generation of Rayleigh waves. Rayleigh wave techniques are also more applicable to sites with high velocity layers and/or velocity inversions because the presence of such structures is more apparent in the Rayleigh wave dispersion curves than in Love wave dispersion curves. Rayleigh wave techniques are preferable at sites with a high velocity surface layer because Love waves do not theoretically exist in such environments. Occasionally, the horizontal radial component of a Rayleigh wave may yield higher quality dispersion data than the vertical component because different modes of propagation may have more energy in one component than the other. Recording both the vertical and horizontal components of the Rayleigh wave is particularly useful at sites with complex modes of propagation or when attempting to recover multiple Rayleigh wave modes for multi-mode modeling as demonstrated in Dal Moro, et al, 2015. Joint inversion of Rayleigh and Love wave data may yield more accurate $V_S$ models and also offer a means to investigate anisotropy, where $S_V$- and $S_H$-wave velocity are not equal, as shown in Dal Moro and Ferigo, 2011.

### 2.2.2 Array Microtremor Technique

A detailed discussion of the array microtremor method can be found in Okada, 2003. Unlike active source techniques which use an active energy source (i.e. hammer), the array microtremor technique (also referred to as passive surface wave or array ambient vibration method) records background noise (ambient vibrations) emanating from ocean wave activity, wind noise, traffic, industrial activity, construction, etc. The technique uses 4, or more, receivers aligned in a 2-dimensional array. Triangle, circle, semi-circle, and "L" shaped arrays are commonly used, although any 2-dimensional arrangement of receivers can be used. For investigations of the upper 100 m, receivers typically consist of 1 to 4.5 Hz geophones. For deeper investigations, 5 to 120 s seismometers are generally utilized. The nested triangle array, which consists of several embedded equilateral triangles, is popular as it provides accurate dispersion curves with a relatively small number of geophones. The "L" array is useful at sites located at the corner of intersecting streets. The maximum receiver separation in an array should be at a minimum equal to the desired depth of investigation. Typically, 15 to 60 minutes of ambient vibration data is recorded depending on the size of the array, desired depth of investigation, and noise conditions. Investigations to depths on the order of 1 km may require that ambient vibrations are recorded for a much longer duration. The surface wave dispersion curve is typically estimated from array microtremor data using various f-k methods such as beamforming (Lacoss, et al., 1969), and maximum-likelihood (Capon, 1969), and the spatial-autocorrelation (SPAC) method. The beam-forming and maximum-likelihood methods are generally referred to as the frequency wavenumber (FK) and high-resolution frequency wavenumber (HRFK or HFK) methods. The SPAC method was originally based on work by Aki, 1957 and has since been extended and modified (Ling and Okada, 1993 and Ohori *et al*., 2002) to permit the use of noncircular arrays, and is now collectively referred to as extended spatial autocorrelation (ESPAC or ESAC). Further modifications to the SPAC method permit the use of irregular or random arrays (Bettig *et al*., 2001). Although it is common to apply SPAC methods to obtain a surface wave dispersion curve for modeling, other approaches involve direct modeling of the coherency data, also referred to as SPAC coefficients (Asten, 2006 and Asten, *et al*., 2015). The beam-forming and maximum-likelihood methods are generally referred to as the frequency wavenumber (FK) and high-resolution frequency wavenumber (HRFK or HFK) methods, respectively. More recently, a Rayleigh wave three-component beamforming method (RTBF) has been developed (Wathelet, et al., 2018) and appears to offer significant resolution enhancements over other methods.

FK, HRFK and RTBF methods are generally expected to perform better when ambient vibration sources are not azimuthally well-distributed (e.g. rural area where the primary noise source is a large industrial facility). SPAC methods are expected to perform better when noise sources are azimuthally well-distributed (e.g. in a large urbanized area).

The minimum wavelength surface wave that can be extracted from an array microtremor dataset acquired utilizing a symmetric array is typically set equal to the minimum receiver spacing. The maximum wavelength is often set equal to twice the maximum receiver separation for SPAC analysis and the maximum receiver spacing for FK analysis.

## 2.3 Surface Wave Dispersion Curve Modeling

The dispersion curves generated from the active and passive surface wave soundings are generally combined and modeled using iterative forward and inverse modeling routines. The final model profile is assumed to represent actual site conditions. The theoretical model used to interpret the dispersion curve assumes horizontally layered, laterally invariant, homogeneous-isotropic material. Although these conditions are seldom strictly met at a site, the results of active and/or passive surface wave testing provide a good “global” estimate of the material properties along the array. The results may be more representative of the site than a borehole “point” estimate.

The surface wave forward problem is typically solved using the Thomson-Haskell transfer-matrix (Thomson, 1950; Haskell, 1953) later modified by Dunkin (1965) and Knopoff (1964), dynamic stiffness matrix (Kausel and Roësset, 1981), or reflection and transmission coefficient (Kennett, 1974) methods. All of these methods can determine fundamental- and higher-mode phase velocities, which correspond to plane waves in 2-D space. The transfer-matrix method is often used in MASW and passive surface-wave software packages, whereas the dynamic stiffness matrix is utilized in many SASW software packages. $MAS_RW$ and/or passive surface-wave modeling may involve modeling of the fundamental mode, some form of effective mode, or multiple individual modes (multi-mode). As outlined in Roësset et al. (1991), several options exist for forward modeling of Rayleigh wave SASW data. One formulation takes into account only fundamental mode plane Rayleigh-wave motion (called the 2-D solution), whereas another includes all stress waves (e.g. body, fundamental, and higher mode surface waves) and incorporates a generalized receiver geometry (3-D global solution) or actual receiver geometry (3-D array solution).

The fundamental mode assumption is generally applicable to modeling Rayleigh-wave dispersion data collected at normally dispersive sites, providing there are not abrupt increases in velocity or steep velocity gradients. Effective-mode or multi-mode approaches are often required for irregularly dispersive sites and sites with steep velocity gradients at shallow depth. If active and passive surface wave data are combined or $MAS_RW$ data are combined from multiple seismic records with different source offsets and receiver gathers, then effective-mode computations are limited to algorithms that assume far-field plane Rayleigh wave propagation. Local search (e.g. linearized matrix inversion methods) or global search methods (e.g., Monte Carlo approaches such as simulated annealing, generic algorithms and neighborhood algorithm) are typically used to solve the inverse problem.

The maximum wavelength ($\lambda_{max}$) recovered from a surface wave data set is typically used to estimate depth of investigation although a sensitivity analysis of the $V_S$ models would be a more robust means to estimate depth of investigation. For normally dispersive velocity profiles with a gradual increase in $V_S$ with depth, the maximum depth of investigation is on the order of $\lambda_{max}/2$ for both Rayleigh and Love wave dispersion data. For velocity profiles with an abrupt increase in $V_S$ at depth, the maximum depth of investigation is on the order of $\lambda_{max}/3$ for Rayleigh wave dispersion data but less than $\lambda_{max}/3$ for Love wave dispersion data. The depth of investigation can be highly variable for sites with complex velocity structure (e.g. high velocity layers).

As with all surface geophysical methods, the inversion of surface wave dispersion data does not yield a unique $V_S$ model and multiple possible solutions may equally fit the experimental data. Based on experience at other sites, the shear wave velocity models ($V_S$ and layer thicknesses) determined by surface wave testing are within 20% of the velocities and layer thicknesses that would be determined by other seismic methods (Brown, 1998). The average velocity of the upper 30 m, however, is much more accurate, often to better than 5%, because it is not sensitive to the layering in the model. Because $V_{S30}$ is not significantly affected by the non-uniqueness inherent in $V_S$ models derived from surface wave dispersion curves (Martin et al., 2006, Comina et al., 2011), a single $V_S$ model is considered adequate for estimating $V_{S30}$.

It may not always be possible to develop a coherent, fundamental mode dispersion curve over sufficient frequency range for modeling due to dominant higher modes with the higher modes not clearly identifiable for multi-mode modeling. It may, however, be possible to identify the Rayleigh wave phase velocity of the fundamental mode at 40 m wavelength ($V_{R40}$) in which case $V_{S30}$ can at least be estimated using the Brown et al., 2000 relationship:

$$V_{S30} = 1.045V_{R40}$$

This relationship was established based on a statistical analysis of a large number of surface wave data sets from sites with control by velocities measured in nearby boreholes and has been further evaluated by Martin and Diehl, 2004, and Albarello and Gargani, 2010. Further investigation of this approach has revealed that $V_{S30}$ is generally between $V_{R40}$ and $V_{R45}$ with $V_{R40}$ often being most appropriate for shallow groundwater sites and $V_{R45}$ for deep ground water sites. A detailed study of such an approach for Love wave dispersion data has not been conducted; however, preliminary analysis demonstrates that $V_{S30}$ is generally between $V_{L50}$ and

$V_{L55}$. Although we do not recommend that these empirical $V_{S30}$ estimates replace modeling of surface wave dispersion data, they do offer a means of cost effectively evaluating $V_{S30}$ over a large area. $V_{R40}$ or $V_{L55}$ can also be used to quantify error in $V_{S30}$ by evaluating the scatter in the dispersion data at these wavelengths.

# 3 FIELD PROCEDURES

The active- and passive-source surface wave sounding locations at the site were established by **GEO***Vision* personnel and are shown in Figure 1. Two types of surface wave data were acquired at the site: an active-source surface wave array to characterize near-surface velocity structure and a passive-source surface wave array to characterize deeper velocity structure. Passive surface wave data were acquired along Array 1 using the array microtremor method. Active surface wave data were acquired along Array 2 using the MASW technique.

The passive surface wave equipment consisted of two Geometrics Geode signal enhancement seismographs, 4.5 Hz vertical geophones, and seismic cables. The triangle-shaped Array 1 consisted of 43, 4.5 Hz geophones spaced 6 – 7.5 m (19.7 – 23 ft) apart with the outer dimensions of the array being 60 m (197 ft).

Ambient noise measurements were made along the passive array for about 40 minutes (80, 30 second seismic records) with a 2 ms sample rate. All passive surface wave data were stored on a laptop computer for later processing. The field geometry and associated files names were documented in field notes.

MASW equipment used during this investigation consisted of a Geometrics Geode signal enhancement seismographs 4.5 Hz vertical geophones, seismic cable, a 4 lb hammer, a 12 lb sledgehammer, and a 240 lb. accelerated weight drop (AWD). MASW data were acquired along a linear array of 48 geophones spaced 1.5 m (4.9 ft) apart. Shot points were located between 1.5 and 10 m (4.9 and 32.8 ft) from the end geophone locations and at 12 m (39.4 ft) intervals in the interior of the array. The 4 lb hammer and 12 lb sledgehammer were used for the near offset source locations and interior source locations. The AWD was used for source locations offset from the ends of the array. Data from the transient impacts (hammers) were generally averaged 8 to 15 times to improve the signal-to-noise ratio. All field data were saved to hard disk and documented on field data acquisition forms.

# 4 DATA REDUCTION

The MASW data were reduced using the software Seismic Pro Surface V9.0 developed by Geogiga and multiple in-house scripts for various data extraction and formatting tasks, with all data reduction documented in a Microsoft Excel spreadsheet.

The following steps were used for data reduction:

- Input seismic records to be used for analysis into software package.
- Check and correct source and receiver geometry as necessary.
- Select offset range used for analysis (multiple offset ranges utilized for each seismic record as discussed below) and document in spreadsheet.
- Apply phase shift transform to seismic record to convert the data from time – offset to frequency – phase velocity space.
- Identify, pick, save, and document dispersion curve.
- Change the receiver offset range and repeat process.
- Repeat process for all seismic records.
- Use in-house script to apply near-field criteria with maximum wavelength set equal to 1.0 times the source to midpoint of receiver array distance.
- Use in-house script to merge multiple dispersion curves extracted from the MASW data collected along each seismic line for a specific source type (different source locations, different receiver offset ranges, etc.).
- Edit dispersion data, as necessary (e.g. delete poor quality curves and outliers).
- Calculate a representative dispersion curve at equal log-frequency or log-wavelength spacing for the MASW dispersion data using a moving average, polynomial curve fitting routine.

This unique data reduction strategy, which can involve combination of over 50 dispersion curves for a 1D sounding, is designed for characterizing sites with complex velocity structure that do not yield surface wave dispersion data over a wide frequency range from a single source type or source location. The data reduction strategy ensures that the dispersion curve selected for modeling is representative of average conditions beneath the array and spans as broad a frequency/wavelength range as possible while considering near field effects.

The array microtremor data were reduced using the Seisimager software package developed by Oyo Corporation/Geometrics, Inc. and the following steps:

The processing sequence for implementation of the ESAC method in the SeisImager software package is as follows:

- Input all seismic records for a dataset into software.
- Load receiver geometry (x and y positions) for each channel in seismic record.
- Calculate the SPAC coefficients for each seismic record and average.
- Optionally, select a subset of receiver offset ranges for analysis (e.g. only select receiver pairs with multiple azimuths).
- For each frequency calculate the RMS error between the SPAC coefficients and a Bessel function of the first kind and order zero over a user defined phase velocity range and velocity step.

- Plot an image of RMS error as a function for frequency (f) and phase velocity (v).
- Identify and pick the dispersion curve as the continuous trend on the f-v image with the lowest RMS error.
- Repeat the process for all arrays and time blocks.
- Use an in-house script to convert dispersion curves to appropriate format for editing.
- Edit dispersion data, as necessary, and use in-house script to combine all dispersion data after setting maximum wavelength to about 2 to 3 times the maximum receiver spacing.
- Calculate a representative dispersion curve for the passive dispersion data from each array using a moving average polynomial curve fitting routine.

The representative dispersion curves from the active and passive surface wave data were combined and the moving average polynomial curve fitting routine in WinSASW V3 was used to generate a composite representative dispersion curve for modeling. During this process, the active and passive surface wave dispersion data were given similar weights and an equal logarithm wavelength sample rate was used to reflect the gradual loss in model resolution with depth.

# 5 DATA MODELING

Surface wave data were modeled using the effective mode routine in the Seisimager software package. During this process, an initial velocity model was generated based on general characteristics of the dispersion curve and the inverse modeling routine utilized to adjust the layer $V_S$ until an acceptable agreement with the observed data was obtained. Layer thicknesses were adjusted, and the inversion process repeated until a $V_S$ model was developed with low RMS error between the observed and calculated dispersion curves. In many cases, once an acceptable $V_S$ model is developed, layer thicknesses are again adjusted, and the inversion process repeated to develop an ensemble of $V_S$ models with similar RMS error to quantify non-uniqueness. The primary purpose of this investigation was to estimate $V_{S30}$ and, therefore, it was not considered necessary to develop multiple $V_S$ models. Data inputs into the modeling software include layer thickness, S-wave velocity, P-wave velocity or Poisson's ratio, and mass density. P-wave velocity and mass density only have a very small influence (i.e., less than 10%) on the S-wave velocity model generated from a surface wave dispersion curve. However, realistic assumptions for P-wave velocity, which is significantly impacted by the location of the saturated zone, and mass density will slightly improve the accuracy of the S-wave velocity model.

Constant mass density values of 1.81 to 2.05 gm/cm$^3$ (113 to 128 lb/ft$^3$) were used in the velocity profiles for subsurface soils/rock depending on P- and S-wave velocity. Within the normal range encountered in geotechnical engineering, variation in mass density has a negligible (±2%) effect on the estimated $V_S$ from surface wave dispersion data. During modeling of Rayleigh wave dispersion data, the compression wave velocity, $V_P$, for unsaturated sediments was estimated using a Poisson's ratio, $v$, of 0.3 and the relationship:

$$V_P = V_S\,[(2(1-v))/(1-2v)]^{0.5}$$

Poisson's ratio has a larger effect than density on the estimated $V_S$ from Rayleigh wave dispersion data. Achenbach (1973) provides approximate relationship between Rayleigh wave velocity ($V_R$), $V_S$ and $v$:

$$V_R = V_S\,[(0.862 + 1.14\,v)/(1+ v)]$$

Using this relationship, it can be shown that $V_S$ derived from $V_R$ only varies by about 10% over possible 0 to 0.5 range for Poisson's ratio where:

$$V_S = 1.16V_R \text{ for } v = 0$$
$$V_S = 1.05V_R \text{ for } v = 0.5$$

The realistic range of the Poisson's ratio for typical unsaturated sediments is about 0.25 to 0.35. Over this range, $V_S$ derived from modeling of Rayleigh wave dispersion data will vary by about 5%. An intermediate Poisson's ratio of 0.333 was selected for modeling to minimize any error associated with the assumed Poisson's ratio. The water table was not observed based on interactive analysis of seismic refraction first arrival data and is not included in the model.

# 6 INTERPRETATION AND RESULTS

The fit of the calculated effective mode dispersion curve to the experimental data collected along Arrays 1 and 2 and the modeled $V_S$ profile for the surface wave sounding are presented as Figure 2. The resolution decreases gradually with depth due to the loss of sensitivity of the dispersion curve to changes in $V_S$ at greater depth. The $V_S$ profile used to match the field data is provided in tabular form in both metric and Imperial units as Tables 1 and 2.

The Rayleigh wave phase velocities from the passive surface wave array are in acceptable agreement with those from the MASW data in the region of overlapping wavelength. Differences in dispersion data from the two methods are expected to be associated with lateral velocity variability beneath the respective arrays. Scatter in the dispersion data from each technique is expected to be primarily associated with lateral velocity variability beneath the array.

The estimated depth of investigation for the combined active and passive surface wave sounding is about 60 m (197 ft). The $V_S$ model indicates that $V_S$ gradually increases with depth from about 188 m/s (617 ft/s) immediately below the surface to about 577 m/s (1,893 ft/s) at a depth of about 55 m (180 ft).

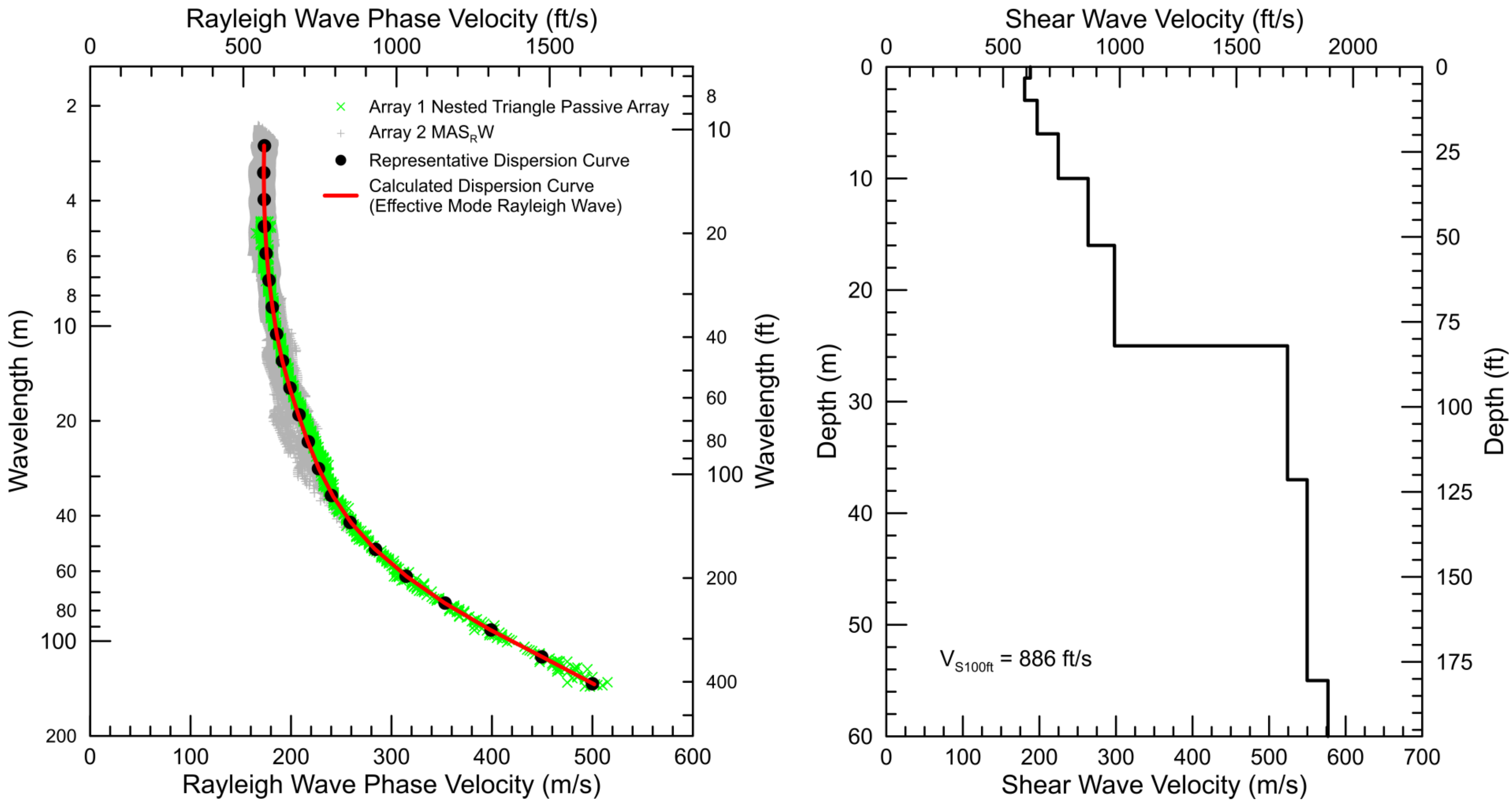
The average shear wave velocity to a depth of 100 ft ($V_{S100ft}$) is 886 ft/s for the $V_S$ model. Therefore, according to the NEHRP provisions of the Uniform Building Code, the area in the vicinity of Arrays 1 and 2 is classified as Site Class D, stiff soil.

**Table 1 Arrays 1 and 2 $V_S$ Model (Metric Units)**

| Depth to Top of Layer (m) | Layer Thickness (m) | S-Wave Velocity (m/s) | Inferred P-Wave Velocity (m/s) | Inferred Poisson's Ratio | Inferred Density (g/cm$^3$) |
|---|---|---|---|---|---|
| 0 | 1 | 188 | 376 | 0.333 | 1.81 |
| 1 | 2 | 181 | 361 | 0.333 | 1.80 |
| 3 | 3 | 197 | 394 | 0.333 | 1.82 |
| 6 | 4 | 225 | 449 | 0.333 | 1.86 |
| 10 | 6 | 264 | 527 | 0.333 | 1.90 |
| 16 | 9 | 298 | 596 | 0.333 | 1.93 |
| 25 | 12 | 524 | 1048 | 0.333 | 2.03 |
| 37 | 18 | 550 | 1099 | 0.333 | 2.04 |
| 55 | Half Space | 577 | 1154 | 0.333 | 2.05 |

**Table 2 Arrays 1 and 2 $V_S$ Model (Imperial Units)**

| Depth to Top of Layer (ft) | Layer Thickness (ft) | S-Wave Velocity (ft/s) | Inferred P-Wave Velocity (ft/s) | Inferred Poisson's Ratio | Inferred Density ($lb/ft^3$) |
|---|---|---|---|---|---|
| 0.0 | 3.3 | 617 | 1234 | 0.333 | 113 |
| 3.3 | 6.6 | 593 | 1186 | 0.333 | 112 |
| 9.8 | 9.8 | 646 | 1293 | 0.333 | 114 |
| 19.7 | 13.1 | 737 | 1474 | 0.333 | 116 |
| 32.8 | 19.7 | 865 | 1730 | 0.333 | 119 |
| 52.5 | 29.5 | 978 | 1956 | 0.333 | 120 |
| 82.0 | 39.4 | 1719 | 3437 | 0.333 | 127 |
| 121.4 | 59.1 | 1803 | 3607 | 0.333 | 127 |
| 180.4 | Half Space | 1893 | 3787 | 0.333 | 128 |




**Arrays 1 & 2 - Field, representative, and calculated surface wave dispersion data (left) and associated $V_S$ model (right)**

| GEOVision geophysical services | FIGURE 2<br>ARRAYS 1 & 2: SURFACE WAVE MODEL |
|---|---|
| Project No.: 21047<br>Date: March 23, 2021 | 12121 FOOTHILL BOULEVARD<br>SYLMAR, CALIFORNIA |
| Drawn By: C. Martinez<br>Approved By: A. Martin | PREPARED FOR<br>LANGAN |

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# 8 CERTIFICATION

All geophysical data, analysis, interpretations, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by a **GEO*Vision*** California Professional Geophysicist.

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Date

* This geophysical investigation was conducted under the supervision of a California Professional Geophysicist using industry standard methods and equipment. A high degree of professionalism was maintained during all aspects of the project from the field investigation and data acquisition, through data processing interpretation and reporting. All original field data files, field notes and observations, and other pertinent information are maintained in the project files and are available for the client to review for a period of at least one year.

  A professional geophysicist's certification of interpreted geophysical conditions comprises a declaration of his/her professional judgment. It does not constitute a warranty or guarantee, expressed or implied, nor does it relieve any other party of its responsibility to abide by contract documents, applicable codes, standards, regulations or ordinances.