# APPENDIX C:  Geotechnical Investigation

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**Geotechnical and Pavement Investigation,**
**Bastanchury Road Widening Project**
**From Eureka Avenue to Casa Loma Avenue,**
**Yorba Linda, California**

**Prepared For**
**MICHAEL BAKER INTERNATIONAL**

October 23, 2018

GMU Project No. 18-164-00

GMU GEOTECHNICAL, INC.

50 YEARS 1967 - 2017

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# TRANSMITTAL

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DATE: October 23, 2018

PROJECT: 18-164-00

ATTENTION: Mr. Alan Su

SUBJECT: Geotechnical and Pavement Investigation, Bastanchury Road Widening Project from Eureka Avenue to Casa Loma Avenue, Yorba Linda, California

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# INTRODUCTION

## PURPOSE

This report presents the results of our geotechnical and pavement evaluation for the Bastanchury Road grade change and widening project from Eureka Avenue to Casa Loma Avenue in the City of Yorba Linda, California. The purpose of this investigation was to develop pavement and geotechnical recommendations for the design and construction of the roadway grading, widening, and proposed retaining walls based on our background review, site reconnaissance, subsurface exploration, laboratory testing, and pavement and geotechnical analyses.

## PROJECT DESCRIPTION

The subject site is a segment of Bastanchury Road between its intersections with Eureka Avenue and Casa Loma Avenue in the City of Yorba Linda, California. The general location of the project is illustrated on Plate 1 – Location Map.

Bastanchury Road consists of a total of four lanes and a median to the east of Eureka Avenue and to the west of Denver Avenue. The subject segment of Bastanchury Road from Eureka Avenue to Casa Loma Avenue currently consists of a total of two lanes and a median. The City of Yorba Linda is interested in adjusting the road profile for higher speed limits and widening the subject roadway segment to a total of 4 lanes and a median, including a dual purpose left turn lane at the intersections. The speed-related road adjustment will include raising the road profile to improve the line of sight. We understand that a 45 MPH speed limit is being considered which may require raising the road about 6 to 7 feet per Michael Baker International's (MBI) preliminary design. The additional fill will be contained by a 2:1 (Horizontal:Vertical) slope along the road's northern boundary and a retaining wall along the southern boundary. The proposed retaining wall will be slightly north of an existing block wall.

## SCOPE

Our scope of work was presented in detail in our proposal/agreement with you dated March 27, 2018. To accomplish this work, the following services were provided:

1. Reviewed project plans, previous reports, and subsurface data obtained by our firm in the vicinity of the project limits. Performed a site visit to mark the locations of the hand auger drill holes. Coordinated with Underground Services Alert (USA) to determine the locations of existing utilities and provide advance notification of subsurface drilling locations.

2. Performed a field investigation program consisting of six (6) hand-auger borings to log subsurface conditions and to collect samples for laboratory testing. Two of the borings were advanced to a depth of 10 feet at the proposed retaining wall locations and the other four borings were advanced to a depth of 5 feet in the proposed roadway widening area, at the Bastanchury Road shoulders.

3. Performed laboratory testing to evaluate various engineering properties of the materials collected from the field investigation program.

4. Performed geotechnical and pavement engineering analysis for the design and construction of the retaining walls, road embankment, and the new pavement structural section.

5. Prepared this pavement and geotechnical investigation report presenting our findings, conclusions, and recommendations for the proposed improvements.

## REVIEW OF PREVIOUS REPORTS

Based on our review of the reference (1) street improvement plans of the subject roadway segment, we understand the existing north lane of the subject roadway segment has a pavement section of 5-inches of asphalt concrete (AC) over 18 inches of aggregate base (AB).

## SUBSURFACE EXPLORATION

GMU conducted a subsurface exploration program on August 23, 2018, to evaluate the soil conditions below the proposed retaining wall and new roadway widening segment. A total of six (6) exploratory borings were performed, which consisted of the following:

- Two (2) hand-auger exploratory borings to a maximum depth of 10 feet.
- Four (4) hand-auger exploratory borings to a maximum depth of 5 feet.

The borings were marked prior to excavation, and Underground Service Alert was notified. The borings were backfilled with the soil cuttings at the completion of our field investigation. The approximate locations of the borings are shown on Plate 2 – Geotechnical Map. Our boring logs and details are included in Appendix A of this report. Samples were collected in each of the borings for subsequent laboratory testing.

## LABORATORY TESTING

Laboratory testing was performed on bulk and relatively undisturbed samples collected during our field investigation. Laboratory testing on soil samples included the following:

- In-place Moisture and Density
- Particle Size Distribution
- Atterberg Limits
- Maximum Density/Compaction
- Undisturbed Direct Shear Tests
- Expansion Index
- Consolidation and Time Rate
- R-value
- Corrosion series testing (sulfate content, chloride content, pH, and soil resistivity)

The results of our laboratory testing are summarized on Table B-1 included in Appendix B – Laboratory Testing.

# GEOLOGIC AND GEOTECHNICAL ENGINEERING FINDINGS

## SUBSURFACE MATERIALS

The following soils were encountered during our recent subsurface exploration. Our boring logs are included in Appendix A of this report. Laboratory data is summarized on Table B-1 of Appendix B.

### Artificial Fill (Qaf)

Fill soils were encountered in Drill Holes DH-1, DH-5, and DH-6 to a depth of 1 foot below existing ground surface. The fill materials consist of brownish gray to brown poorly graded gravels and silty sands. The soils are generally medium dense to dense with moisture contents ranging from dry to moist. The fills were likely placed as part of the previous grading operations for the existing roadway. However, shallower or deeper engineered fill may exist in local areas.

### Young Alluvial Fan Deposits (Qvf)

Young alluvial fan deposits were encountered beneath the fill materials in Drill Holes DH-1 and DH-5, and in Drill Hole DH-4 to a depth of 10 feet below existing ground surface. The alluvium materials were observed to consist mainly of light brown to brown sandy clays and clayey sands. The soils are generally firm to medium dense with moisture contents ranging from damp to moist. Moisture contents and dry unit weights varied as summarized on Table B-1 of Appendix B.

**Very Old Alluvial Fan Deposits (Qvof)**

Very old alluvial fan deposits were encountered beneath the fill materials in Drill Hole DH-6, and in Drill Holes DH-2 and DH-3 to a depth of 10 feet below existing ground surface. These alluvium materials were observed to consist mainly of light brown to brown sandy clays and clayey sands. The soils are generally firm to dense with moisture contents ranging from damp to moist. Moisture contents and dry unit weights varied as summarized on Table B-1 of Appendix B.

## LOCAL GROUNDWATER

Historically, the highest groundwater is documented to be approximately 0 to 30 feet below ground surface by California Geological Survey (CGS, 2005). However, groundwater was not encountered during our subsurface investigation to a depth of 10.75 feet below existing ground surface. Samples retrieved from our subsurface investigation had moistures ranging from damp to moist. For the proposed improvements, groundwater is not likely to be encountered during construction. However, fluctuations in the level of the groundwater may occur due to variations in rainfall, underground drainage patterns, and other factors not evident at the time measurements were made.

## LANDSLIDES

No existing landslides were observed at the site during our investigation, and no mapped landslides were noted during our review of background documents.

## TSUNAMI, SEICHE, AND FLOODING

Based on our review of the Federal Emergency Management Agency (FEMA) floor insurance rate maps (FIRMs), the site is in an area of minimal flood hazard (Zone X) and, therefore, not at significant risk from hazards such as tsunamis, seiches, or flooding.

## SEISMIC CONDITIONS

### Faulting and Seismicity

No known active or potentially active faults are shown on currently available geologic maps as crossing the site. The site is not within a designated Alquist-Priolo Earthquake Fault Zone (Jennings, 1994; Hart and Bryant, 2007). However, the site is located within close proximity of several surface faults that are presently zoned as active or potentially active by the California Geological Survey (CGS). The site is located approximately 1 mile from the Elsinore fault (Whittier Section), which is capable of generating a maximum earthquake magnitude ($M_w$) of 6.9, and approximately 3 miles from the Puente Hills fault (blind thrust), which is capable of generating a maximum earthquake magnitude ($M_w$) of 6.8, per Caltrans ARS Online Version 2.3.09 program.

Most of southern California is subject to some level of ground shaking (ground motion) because of movement along active and potentially active fault zones in the region. Several sizeable, historic earthquakes have occurred in southern California. Given the proximity of the site to several active and potentially active faults, the site will likely be subject to earthquake ground motions in the future. The level of ground motion at a given site resulting from an earthquake is a function of several factors including earthquake magnitude, type of faulting, rupture propagation path, distance from the epicenter, earthquake depth, duration of shaking, site topography, and site geology.

### Liquefaction

The site is located within a zone of potential liquefaction per the Seismic Hazard Zone Map for the Santa Ana Quadrangle (CGS, 2004). Soil liquefaction results from loss of strength during cyclic loading, such as imposed by earthquakes. Soils most susceptible to liquefaction are loose to moderately dense, saturated granular soils with poor drainage, such as silty sands or sands and gravels capped by or containing seams of impermeable sediment. Our subsurface investigation verified that granular soils were present; however, these soils contained a high percentage of clays (approximately 46 percent). In addition, groundwater was not encountered to a depth of 10.75 feet below existing ground surface. However, if historic high groundwater is restored in the future, the sandy soils encountered during our investigation may be susceptible to liquefaction. Thus, the potential for liquefaction appears to be low to moderate.

### Earthquake-Induced Landslides

Review of the Seismic Hazard Zone Maps for the Santa Ana Quadrangle (CGS, 2004) indicates that the site is not located within a zone susceptible to earthquake-induced landslides.

### Secondary Seismic Hazards

Depending on the lateral extent of the potential liquefiable layer or the current groundwater level, earthquake-induced settlement may be propagated to the surface or dampened through the fill if it is localized.

### Seismicity

A site-specific probabilistic seismic hazard analysis (PSHA) was performed using Caltrans ARS Online Version 2.3.09 for an average shear wave velocity, $V_{S30}$, of 770 fps (235 m/s) as presented in Table 1 below. The average $V_{S30}$ was estimated based on the closest USGS measurement at Station 645CCD, which is about 1 mile northwest of the site.

Table 1 – Design Response Spectra

| Period (sec) | SA (g) | Period (sec) | SA (g) |
|---|---|---|---|
| **0.01** | 0.57 | **0.7** | 1.06 |
| **0.05** | 0.82 | **0.85** | 1.00 |
| **0.1** | 0.95 | **1** | 0.95 |
| **0.15** | 1.10 | **1.2** | 0.82 |
| **0.2** | 1.21 | **1.5** | 0.68 |
| **0.25** | 1.22 | **2** | 0.54 |
| **0.3** | 1.24 | **3** | 0.34 |
| **0.4** | 1.18 | **4** | 0.24 |
| **0.5** | 1.13 | **5** | 0.20 |
| **0.6** | 1.09 | | |

## SOIL EXPANSION

The existing engineered fill materials within the subject site consist of predominantly sandy clays and clayey sands. Based on our expansion index testing, the on-site materials should be considered to have a low expansion potential (Expansion Index (EI) of 20).

Plasticity indices (PI) of the soil materials were found to range from 12 to 17. Based on the soil PI and activity, Seed et al. (1962) correlation will result in a moderate swelling potential. Based on these results and our site observations, the on-site materials should be considered ***Expansive per 2016 CBC***. The results of our expansion index, Atterberg limits, and sieve analysis are presented on Table B-1 in Appendix B.

## SOIL CORROSION

Corrosion testing was performed on two soil samples representative of on-site conditions. The results of the testing are summarized below.

| Boring | Depth (ft) | Formation; Soil Type | pH | Soluble Sulfates (ppm) | Soluble Chlorides (ppm) |
|---|---|---|---|---|---|
| DH-2 | 0-5 | $Q_{vof}$ | 8 | 621 | 264 |
| DH-6 | 0-5 | $Q_{vof}$ | 7.9 | 297 | 648 |

According to Caltrans Corrosion Guidelines (November 2012, Version 2.0), soils are considered corrosive to concrete and foundation elements if one or more of the following conditions exist: chloride concentration is 500 ppm or greater, sulfate concentration is 2000 ppm or greater, or the pH is 5.5 or less. Consequently, the site soils are considered corrosive.

## EXCAVATION CHARACTERISTICS

The soil materials underlying the proposed roadway widening and retaining wall can be excavated with conventional grading equipment such as dozers, loaders, excavators, and backhoes.

### Excavation and Trenching

We expect that excavation of utility trenches can be accomplished utilizing conventional excavating and trenching machines and backhoes. However, some localized gravels and cobbles were observed during our field investigation. Consequently, some overbreak should be anticipated during excavation activities. Trench support requirements will be limited to those required by safety laws or other locations where trench slopes will need to be flattened or supported by shoring designed to suit the specific conditions exposed.

## CONCLUSIONS AND RECOMMENDATIONS

From a geotechnical engineering viewpoint, the proposed roadway widening and retaining wall may be constructed as planned, provided design and construction are performed in accordance with the recommendations presented in this report. Detailed recommendations are presented in the following sections of this report.

## SITE PREPARATION AND GRADING

### General

All site preparation and grading should be performed in accordance with the County of Orange and City of Yorba Linda grading requirements and the recommendations presented in this report.

### Demolition, Clearing, and Suitability

Prior to construction, all existing landscape and hardscape improvements should be removed from areas to be graded.

The on-site soil materials are considered suitable for use as compacted fill from a geotechnical perspective if care is taken to remove all significant organic and other debris.

Cavities and excavations created to expose existing utility lines or other existing subsurface structures should be cleared of loose soil, shaped to provide access for backfilling and compaction equipment, then backfilled with properly compacted fill.

GMU Geotechnical (GMU) should provide periodic observation and testing services during demolition operations to document compliance with the above recommendations. In addition, should unusual or adverse soil conditions or buried structures be encountered during grading that are not described herein, these conditions should be brought to the immediate attention of the project geotechnical consultant for corrective recommendations.

### Corrective Grading

The on-site soils in the upper 10 feet below existing ground surface were found to be dry to moist and firm to dense. Therefore, it is recommended that the existing soils be removed to a minimum depth of 3 feet below existing ground surface or 2 feet below the proposed foundation bottom, whichever is deeper, and replaced with compacted fill below the proposed retaining wall foundation.

Prior to replacing the excavated materials as compacted fill, the exposed removal bottoms should be scarified to a depth of at least 6 inches, moisture conditioned (as necessary) to at least 3% above the optimum moisture content, and compacted to at least 90% relative compaction.

Horizontal limits of over-excavation and recompaction should extend at least 2 feet beyond the perimeter edges of the proposed retaining wall foundations, and all remedial grading bottoms and fill placement should be observed and approved by a representative of GMU.

## FILL MATERIAL AND PLACEMENT

### Suitability

All on-site soils are considered suitable for use as general compacted fill from a geotechnical perspective if care is taken to remove all significant organic and other decomposable debris, and separate and stockpile any rock materials larger than 6 inches in maximum diameter.

### Compaction Standard and Methodology

All soil material used as compacted fill, processed in-place, or used to backfill trenches should be moistened, dried, or blended as necessary to a minimum of 3% over the optimum moisture content (i.e., if the optimum moisture content is 10.5%, the compacted fill's moisture content shall be at least 13.5%), and compacted to at least 90% relative compaction as determined by ASTM Test Method D 1557, latest edition.

### Field Density Testing

Methods, locations, and frequency of testing should be determined by GMU for the site grading and be in accordance with the County and the City of Yorba Linda requirements.

### Material Blending

The existing fill and alluvial materials are expected to be at or below optimum moisture content, but may have variable moisture content depending on the season in which work is performed. Therefore, the materials within the site should be blended. Blending and addition of water will also be required to meet acceptable moisture ranges for sufficient compaction (i.e., minimum 3% above optimum moisture).

### Use of Oversize Material

Rock materials greater than 6 inches in diameter may be encountered during the deeper excavations (i.e., for pipelines or retaining wall foundations). Any oversize rock materials (>6") that are generated during grading should be collected and hauled off-site.

## UTILITY TRENCH BACKFILL CONSIDERATIONS

### General

New utility line pipeline trenches should be backfilled with both select bedding materials beneath and around the pipes (pipe zone) and compacted soil above the pipe bedding. Recommendations for the types of the materials to be used and the proper placement of these materials are provided in the following sections.

### Pipe Zone

The pipe bedding and shading materials should extend from at least 6 inches below the pipes to at least 12 inches above the crown of the pipes. Pipe bedding should consist of either clean sand with a sand equivalent (SE) of at least 30, or crushed rock. If crushed rock is used, it should consist of ¾-inch crushed rock that conforms to Table 200-1.2.1 (A) of the 2018 "Greenbook", and should be separated from the native soils by a geofabric layer such as Mirafi 160N or equivalent. Pipe bedding should also meet the minimum requirements of the County of Orange and City of Yorba Linda. If the requirements of the County or City are more stringent, they should take precedence over the geotechnical recommendations. Sufficient laboratory testing should be performed to verify the bedding meets the minimum requirements of the Greenbook and County of Orange and City of Yorba Linda grading codes.

Based on our subsurface exploration and knowledge of the onsite materials, the soils that will be excavated from the pipeline trenches will not meet the recommendations for pipe bedding materials; therefore, imported materials will be required for pipe bedding.

Granular pipe bedding material having a sand equivalent of 30 or greater should be properly placed in thicknesses not exceeding 3 feet, and then sufficiently flooded or jetted in place.

### Trench Backfill

All existing soil material within the limits of the site are considered suitable for use as trench backfill above the pipe bedding zone if care is taken to remove all significant organic and other decomposable debris and rock materials larger than 6 inches in maximum diameter.

Imported soils are not anticipated for backfill since the on-site soils are suitable. However, if imported soils are used, the soils should consist of clean, granular materials with physical and chemical characteristics similar to, or better than, those described herein for on-site soils. Any imported soils to be used as backfill should be evaluated and approved by GMU prior to placement.

Soils to be used as trench backfill should be moistened, dried, or blended as necessary to achieve a minimum of 3% over optimum moisture content (i.e., if the optimum moisture content is 10.5%, the compacted fill's moisture content shall be at least 13.5%), placed in loose lifts (i.e., no greater than 8 inches thick), and mechanically compacted/densified in accordance with requirements of the Greenbook to at least 90% relative compaction as determined by ASTM Test Method D 1557. Jetting is not permitted in the trench zone.

No rock or broken concrete greater than 6 inches in maximum diameter should be utilized in the trench backfills.

## RETAINING WALL DESIGN AND CONSTRUCTION CRITERIA

### General

The criteria contained in the following sections may be used for the design and construction of the retaining walls proposed within the site.

### General Foundation Design Parameters

| | |
|---|---|
| Bearing Material: | Engineered Fill |
| Minimum Depth: | 24 inches below lowest outside adjacent grade |
| Minimum Width: | 24 inches |
| Allowable Bearing Capacity*: | 3,000 psf with a minimum embedment of 24 inches (may be increased 20% for each additional foot of footing depth and by 10% for each additional foot of footing width to a maximum value of 4,000 psf). |
| Ultimate Coefficient of Friction*: | 0.3 |
| Ultimate Passive Earth Pressure*: | 300 psf/ft of depth (disregard upper 6 inches, maximum 3,000 psf). May be used with friction without reduction. |

* *These values may be increased by one-third for short duration wind or seismic loads.*

**Retaining Wall Design Parameters**

Assuming that the roadway grading is constructed using local soils or soils with similar properties, the following recommendations may be used:

Static Lateral Earth Pressures:

| | |
|---|---|
| Induced by Soils | 45 pcf (Active/Unrestrained – Level Backfill) |
| Induced by Traffic | 120 psf (based on a vertical live load traffic surcharge assumed to be equal to 2.0 feet of earth loading in accordance with AASHTO LRFD Bridge Design Specifications Table 3.11.6.4-2) |

The unrestrained values are applicable only when the walls are designed and constructed as cantilevered walls allowing sufficient wall movement to mobilize active pressure conditions. This wall movement should not be less than 0.01 H (H = height of wall) for the unrestrained values to be applicable.

| | |
|---|---|
| Seismic Lateral Earth Coefficient: | $K_H = (0.5)PGA^* = (0.5)0.57g = 0.29g$ (Active)<br>PGA = 0.57g per Caltrans ARS |
| Seismic Earthquake Pressures (EFP): | 20 pcf (Active/Unrestrained – Level Backfill) |
| Unit Weight of Backfill: | 120 pcf |
| Waterproofing: | The back side of all retaining walls should be waterproofed down to the top of the foundation prior to placing subdrains or backfill. The design and selection of the waterproofing system is outside the scope of our report and is outside our purview. |

**Backfill Requirements**

Backfill behind abutment and wing wall structures should be in conformance with Sections 19-6 and 19-3.02C of the Caltrans 2015 Standard Specifications. Materials for structure backfill should be compacted to a relative compaction not less than 95%, and the material should have a sand equivalent not less than 20. Structure backfill placed within 2 feet of finish grade should be compacted impervious materials (with no sand equivalent requirement).

**Drainage Requirements**

All retaining structures should be provided with a backdrain system in accordance with Article 5.5.3 and Article 5.7.4, Section 5 of the Caltrans 2008 Bridge Design Specifications and in accordance with Caltrans Standard Plans for drainage details.

## SURFACE DRAINAGE

Surface drainage should be carefully controlled during and after grading per Caltrans requirements to prevent ponding and uncontrolled runoff adjacent to the retaining wall or on the pavement. Particular care will be required during grading to maintain slopes, swales, and other erosion control measures needed to direct runoff toward permanent surface drainage facilities. Positive drainage of at least 2% away from the perimeters of the structures and site pavements should be incorporated into the design. In addition, it is recommended that nuisance water be directed away from the perimeter of the structure by the use of area drains in adjacent landscape and flatwork areas and roof drains tied into the site storm drain system.

## ASPHALT CONCRETE PAVEMENT ENGINEERING ANALYSIS

Asphalt concrete (AC) pavement thickness analysis was performed in accordance with the Caltrans Highway Design Manual. This design methodology considers the relationship between the subgrade soil strength, as measured by the R-value test, as well as the design traffic index (TI). "Composite" pavement consists of an AC section constructed on top of properly constructed aggregate base (AB) section on top of properly prepared subgrade. Full-depth AC pavement consists of an AC section constructed on top of properly prepared subgrade.

We have assumed that traffic indices (TI) of 5.0 to 10.0 are representative of the anticipated traffic volume and loading conditions. The Project Traffic Engineer should review and assign the appropriate TI to the road.

R-value testing (CTM 301) of the subgrade soil was performed at GMU's in-house Caltrans-certified soils and pavement laboratory. An R-value of 12 was measured and was used in the analysis per the Caltrans Highway Design Manual. The material for raising the road shall have an R-value equal or better than the assumed value. The final R-value of the subgrade shall be checked after the roadway rough grading.

## ASPAHLT CONCRETE PAVEMENT RECOMMENDATIONS

### General

We have developed the following pavement thickness recommendations for the new roadway for a 20-year design life per Caltrans Highway Design Manual. The actual service life of the pavement can be extended through proper maintenance and rehabilitation (i.e., slurry seal every 7 years, mill-and-overlay every 12-16 years, etc.)

The following table summarizes the recommended minimum AC thicknesses.

**Table 2: Conventional AC Pavement Thickness Recommendations**

| Assumed Traffic Index | Composite Pavement (AC/AB) | Full-Depth AC (AC over subgrade) |
|---|---|---|
| 5.0 | 4.0" AC over<br>7.0" AB over<br>Properly Prepared Subgrade | 7.0" AC over<br>Properly Prepared Subgrade |
| 6.0 | 4.0" AC over<br>11.5" AB over<br>Properly Prepared Subgrade | 8.5" AC over<br>Properly Prepared Subgrade |
| 7.0 | 4.5" AC over<br>14.0" AB over<br>Properly Prepared Subgrade | 10.5" AC over<br>Properly Prepared Subgrade |
| 8.0 | 5.0" AC over<br>17.5" AB over<br>Properly Prepared Subgrade | 12.0" AC over<br>Properly Prepared Subgrade |
| 9.0 | 6.0" AC over<br>19.5" AB over<br>Properly Prepared Subgrade | 13.5" AC over<br>Properly Prepared Subgrade |
| 10.0 | 6.5" AC over<br>22.5" AB over<br>Properly Prepared Subgrade | 15.5" AC over<br>Properly Prepared Subgrade |

Implementing any of these recommendations involves:

- Grading the existing site to create sufficient depth for the recommended AC or AC/AB sections;
- Processing and re-compacting the exposed subgrade material to a depth of at least 12 inches in accordance with Greenbook Section 301-1.2 and 301-1.3. The required relative compaction of the subgrade is 90% minimum with a moisture content of 3% above the optimum moisture content. Maximum density and optimum moisture content of the subgrade should be determined by ASTM D1557;
- Installing the aggregate base section to at least 95% relative compaction and moisture conditioned to near optimum moisture content. Maximum density and optimum moisture content of the aggregate base should be determined by ASTM D1557; and
- Constructing the asphalt concrete (AC) section in two lifts.

All materials used and work performed should meet the current edition of the Standard Specifications for Public Works Construction (Greenbook) with all supplements, unless superseded by the recommendations provided within this report.

Aggregate base may be Crushed Miscellaneous Base (CMB) or Crushed Aggregate Base (CAB) meeting Greenbook Section 200-2.

We recommend using the Greenbook Type IIIC3 AC mix with PG 64-10 asphalt binder for both the AC surface and AC base course sections.

**Unstable Materials**

Based on the soil types encountered and the moisture contents measured from samples collected, it is our opinion that there is relatively low potential for unstable materials to be exposed during construction. However, if unstable materials are exposed, the following recommendations can be implemented.

Soft subgrade conditions can be identified during construction by surface yielding under rubber-tired equipment loading and the inability to achieve proper compaction. The condition of the subgrade should be evaluated by GMU during the scarification and re-compaction efforts.

Drying back of localized wet soil conditions may be required to address unstable soils if time allows. If drying back soil is not a practical option, additional remedial measures would be required to stabilize the subgrade prior to placement of fill or aggregate base and/or asphalt concrete. In lieu of drying back wet soil subgrade materials, the measures to stabilize the subgrade can consist of either of the following methods:

- Removal of unstable soils to a depth of approximately 8 to 12 inches below the top of the unstable material, placement of geotextile material (Tencate HP570, Tencate RS380i, or equivalent) at the bottom of the excavation, and placement of fill or aggregate base to replace the unstable soil. Shallow utilities at this depth of excavation may be encountered and must be carefully identified and marked if this approach is selected.

- Cement treatment of the upper approximately 8 to 12 inches of soil can be performed in unstable areas to create a firm, unyielding working platform for aggregate base placement and compaction. Typical cement application rate to address unstable clayey soils is approximately 6 percent by dry weight of soil. This recommendation should be verified at the time of construction.

The recommended depths of remediation (i.e., approximately 8 to 12 inches for cement treatment or for the geogrid/aggregate base replacement) could be greater, or less, depending on the conditions encountered. Any areas that require remediation should be observed by the geotechnical or pavement engineer to confirm the effectiveness of the recommendations provided herein.

The intent of these recommended remediation methods is to achieve a non-yielding subgrade when subjected to relatively heavy, rubber-tired construction equipment loading such as a loaded water truck or loader with full bucket. The remediated areas should be proof-rolled with this type of equipment after remediation to confirm that the subgrade is unyielding. Pavement constructed on top of an unstable section may not achieve the required compaction and will likely experience reduced pavement life.

## SETTLEMENT

The proposed road embankment will be underlain by the native alluvial deposits. Based on an estimated embankment height of 7 feet, a total settlement of 2 to 2.5 inches is estimated. The settlement may occur gradually over several years requiring some additional maintenance during that period.

## SLOPE STABILITY

The stability of the 7-foot-high slope at the northern road boundary was analyzed. A friction angle of 26 degrees and a cohesion 150 psf are used based on the average of the ultimate shear strength of the two direct shear tests presented in Appendix B. A vertical live load traffic surcharge equal to 2.0 feet of earth loading was applied in accordance with AASHTO LRFD Bridge Design Specifications Table 3.11.6.4-2. Slopes were stable under static (FS>1.5) and pseudostatic (FS>1.1 with $K_h$=PGA/3=0.19) conditions. The stability analyses are provided in Appendix C.

## CONCRETE FLATWORK DESIGN

Due to the expansive nature of the on-site soils, we recommend that the subgrade for the subject concrete flatwork be moisture conditioned to 3% above optimum to a depth of 12 inches below the top of the subgrade surface and compacted to at least 90% relative compaction under sidewalks and at least 95% relative compaction under driveways. Reinforcing rebar is recommended to mitigate potential differential settlement that can become a trip hazard. Type II/V cement with a maximum water/cement ratio of 0.50 and minimum compressive strength of 3,250 psi may be used. The Concrete Flatwork Table below summarizes our flatwork recommendations:

## Table 4: Concrete Flatwork Table

| Description | Subgrade Preparation | Minimum Concrete Thickness (Full) | Cut-off Barrier or Edge Thickness | Reinforcement(2) | Joint Spacing (Maximum) | Cement Type | Sulfate Resistance |
|---|---|---|---|---|---|---|---|
| Concrete Sidewalks and Walkways (4) | 1) 3% over optimum to 12" (1), 2) 2 of sand or well graded rock (i.e., Class II base or equiv.) above moisture conditioned subgrade. | 4 inches | Not Required | 1) Slab - No. 3 bars at 18" o.c. (2) , 2) where adjacent to curbs or structures and at cold joints and expansion joints use dowels: No 3 bars @ 18" o.c. (5) | 5 feet | V | (3) |
| Concrete Driveways (4) | 1) 3% over optimum to 18" (1), 2) 1-2 full inches of sand or well graded rock (i.e., Class II base or equiv.) above moisture conditioned subgrade. | 6 inches | Where adjacent to landscape areas - 12" from adjacent finish grade. Min. 8" width | 1) Slab – No. 3 bars @ 18" o.c. (2) extend into cut-off; 2) where adjacent to curbs and structures and at cold joints and expansion joints use dowels: No. 3 bars @ 18" o.c.(5); 3) Dowel driveways into garage grade beam - #3 bars @ 18"(5). | 10 feet | V | (3) |

(1) The moisture content of the subgrade must be verified by the geotechnical consultant prior to sand/rock placement.
(2) Reinforcement to be placed at or above the mid-point of the slab (i.e., a minimum of 2.0 to 2.5 inches above the prepared subgrade).
(3) Soils having severe levels of sulfates as defined by CBC are expected. Concrete mix design shall be selected by the concrete designer such that sulfate attack mitigation is balanced with shrinkage crack control. Concrete mix design is outside the geotechnical engineer's purview.
(4) Where flatwork is adjacent a stucco surface, a ¼" to ½" foam separation/expansion joint should be used.
(5) If dowels are placed in cored holes, the core holes shall be placed at alternating in-plane angles (i.e., not cored straight into slab).

General Note: Minor deviations to the above recommendations may be required at the discretion of the soils engineer or his representative.

## PLAN REVIEW / GEOTECHNICAL TESTING DURING CONSTRUCTION

### Plan Review

GMU should review the final plans for the project to check for conformance with the recommendations presented herein and to provide additional recommendations if necessary.

### Geotechnical Observation and Testing

All earthwork operations should be performed under the observation of a GMU representative to check that the site is properly prepared, that selected fill materials are satisfactory, and that placement and compaction of fills is performed in accordance with our recommendations and the project specifications. Providing GMU sufficient notification prior to performing earthwork operations is essential.

It is recommended that geotechnical observation and testing be performed by GMU Geotechnical during the following stages of construction:

- Site preparation
- All earthwork and backfill activities
- Footing excavations and subgrade competency
- When trench subgrade is achieved
- Installation of pipe bedding
- Placement and compaction of all trench backfill materials
- Placement and compaction of aggregate base and asphalt concrete
- When any unusual conditions are encountered

Because subsurface conditions may vary from those predicted, and to check that our recommendations have been properly implemented, we recommend GMU Geotechnical be retained to: 1) review final construction plans and specifications, and 2) observe the earthwork and improvement construction. Also, geotechnical conditions can be affected by the construction process. For the above reasons, our geotechnical recommendations are contingent upon our firm providing geotechnical observation and testing services during construction.

## LIMITATIONS

All parties reviewing or utilizing this report should recognize that the findings, conclusions, and recommendations presented represent the results of our professional geological and geotechnical engineering efforts and judgments. Due to the inexact nature of the state of the art of these professions and the possible occurrence of undetected variables in subsurface conditions, we cannot guarantee that the conditions actually encountered during site construction will be identical to those observed, sampled, and interpreted during our study, or that there are no unknown subsurface conditions which could have an adverse effect on the use of the property.

We have exercised a degree of care comparable to the standard of practice presently maintained by other professionals in the fields of geotechnical engineering and engineering geology, and believe that our findings present a reasonably representative description of geotechnical conditions and their probable influence on the use of the proposed construction.

Because our conclusions and recommendations are based on a limited amount of current and previous geotechnical exploration and analysis, all parties should recognize the need for possible revisions to our conclusions and recommendations during construction of the project. Additionally, our conclusions and recommendations are based on the assumption that our firm will act as the geotechnical engineer of record during construction and grading of the project to observe the actual conditions exposed, to verify our design concepts and the grading contractor's general compliance with the project geotechnical specifications, and to provide our revised conclusions and recommendations should subsurface conditions differ significantly from those used as the basis for our conclusions and recommendations presented in this report. It should be further noted that the recommendations presented herein are intended solely to minimize the effects of post-construction soil movements. Consequently, minor cracking and/or distortion of all on-site improvements should be anticipated.

## CLOSURE

We are pleased to present the results of our geotechnical investigation for this project. The Plates and Appendices that complete this report are listed in the Table of Contents.

If you have any questions concerning our findings or recommendations, please do not hesitate to contact us and we will be happy to discuss them with you.

Respectfully submitted,

**GMU GEOTECHNICAL, INC.**

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C89576
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Ashley Varni

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S. Ali Bastani, Ph.D., PE, GE 2458
Director of Engineering

aav/ab/18-164-00 (10-23-2018)

## REFERENCES

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(4) California Geological Survey (CGS, formerly known as California Division of Mines and Geology, CDMG), 2005, "Seismic Hazard Zone Report for the Yorba Linda 7.5-Minute Quadrangle, Orange County, California".

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(10) Youd, T.L., Idriss, I.M., et al (2001), "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils," ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol 127, No. 10, October, 2001.

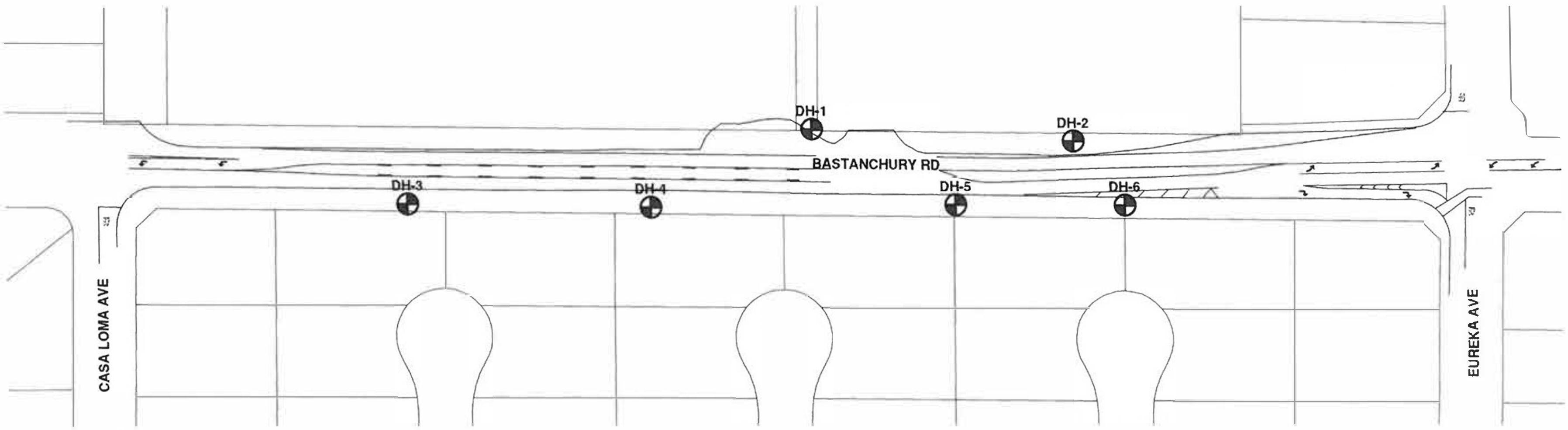

0 1000'

## Location Map

GMU GEOTECHNICAL INC

| | |
|---|---|
| Date: | October 23, 2018 |
| Project No.: | 18-164-00 |
| Plate | 1 |

DRAWING: q:\2018\18-164-00\dwg\1816400_plate 1_location map.dwg PLOTTED: 10/2/2018 1:28 PM BY: Jmezo




**GEOTECHNICAL LEGEND**

DH-6 — APPROXIMATE LOCATION OF DRILL HOLE

0 200'

## Geotechnical Map

| GMU Geotechnical, Inc. | Date: October 23, 2018 | Plate 2 |
|---|---|---|
| | Project No.: 18-164-00 | |

# APPENDIX A

## Geotechnical Exploration Procedures and Logs

GMU
GEOTECHNICAL, INC.

# APPENDIX A

## GMU GEOTECHNICAL EXPLORATION PROCEDURES AND LOGS

Our exploration at the subject site consisted of six (6) hand-auger drill holes. The estimated locations of the explorations are shown on Plate 2 – Geotechnical Map. Our drill holes were logged by a Staff Geologist and drive and bulk samples of the excavated soils were collected. "Undisturbed" samples were taken using a 3.25-inch outside-diameter drive sampler which contains a 2.416-inch-diameter brass sample sleeve 6 inches in length. The logs of each drill hole are contained in this Appendix A, and the Legend to Logs is presented as Plate A-1 and A-2.

The geologic and engineering field descriptions and classifications that appear on these logs are prepared according to Corps of Engineers and Bureau of Reclamation standards. Major soil classifications are prepared according to the Unified Soil Classification System as modified by ASTM Standard No. 2487. Since the descriptions and classifications that appear on the Log of Borings are intended to be that which most accurately describe a given interval of a boring (frequently an interval of several feet), discrepancies do occur in the Unified Soil Classification System nomenclature between that interval and a particular sample in that interval. For example, an 8-foot-thick interval in a log may be identified as silty sand (SM) while one sample taken within the interval may have individually been identified as sandy silt (ML). This discrepancy is frequently allowed to remain to emphasize the occurrence of local textural variations in the interval.

| MAJOR DIVISIONS | | | Group Letter | Symbol | TYPICAL NAMES |
|---|---|---|---|---|---|
| **COARSE-GRAINED SOILS** More Than 50% Retained On No.200 Sieve<br>Based on The Material Passing The 3-Inch (75mm) Sieve.<br>Reference: ASTM Standard D2487 | **GRAVELS** 50% or More of Coarse Fraction Retained on No.4 Sieve | Clean Gravels | GW | | Well Graded Gravels and Gravel-Sand Mixtures, Little or No Fines. |
| | | | GP | | Poorly Graded Gravels and Gravel-Sand Mixtures Little or No Fines. |
| | | Gravels With Fines | GM | | Silty Gravels, Gravel-Sand-Silt Mixtures. |
| | | | GC | | Clayey Gravels, Gravel-Sand-Clay Mixtures. |
| | **SANDS** More Than 50% of Coarse Fraction Passes No.4 Sieve | Clean Sands | SW | | Well Graded Sands and Gravelly Sands, Little or No Fines. |
| | | | SP | | Poorly Graded Sands and Gravelly Sands, Little or No Fines. |
| | | Sands With Fines | SM | | Silty Sands, Sand-Silt Mixtures. |
| | | | SC | | Clayey Sands, Sand-Clay Mixtures. |
| **FINE-GRAINED SOILS** 50% or More Passe The No.200 Sieve<br>Based on The Material Passing The 3-Inch (75mm) Sieve.<br>Reference: ASTM Standard D2487 | **SILTS AND CLAYS** Liquid Limit Less Than 50% | | ML | | Inorganic Silts, Very Fine Sands, Rock Flour, Silty or Clayey Fine Sands or Clayey Silts With Slight Plasticity. |
| | | | CL | | Inorganic Clays of Low To Medium Plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays. |
| | | | OL | | Organic Silts and Organic Silty Clays of Low Plasticity |
| | **SILTS AND CLAYS** Liquid Limit 50% or Greater | | MH | | Inorganic Silts, Micaceous or Diatomaceous Fine Sandy or Silty Soils, Elastic Silts. |
| | | | CH | | Inorganic Clays of High Plasticity, Fat Clays. |
| | | | OH | | Organic Clays of Medium To High Plasticity, Organic Silts. |
| **HIGHLY ORGANIC SOILS** | | | PT | | Peat and Other Highly Organic Soils. |

The descriptive terminology of the logs is modified from current ASTM Standards to suit the purposes of this study

## ADDITIONAL TESTS

- DS = Direct Shear
- HY = Hydrometer Test
- TC = Triaxial Compression Test
- UC = Unconfined Compression
- CN = Consolidation Test
- (T) = Time Rate
- EX = Expansion Test
- CP = Compaction Test
- PS = Particle Size Distribution
- EI = Expansion Index
- SE = Sand Equivalent Test
- AL = Atterberg Limits
- FC = Chemical Tests
- RV = Resistance Value
- SG = Specific Gravity
- SU = Sulfates
- CH = Chlorides
- MR = Minimum Resistivity
- pH
- (N) = Natural Undisturbed Sample
- (R) = Remolded Sample
- CS = Collapse Test/Swell-Settlement

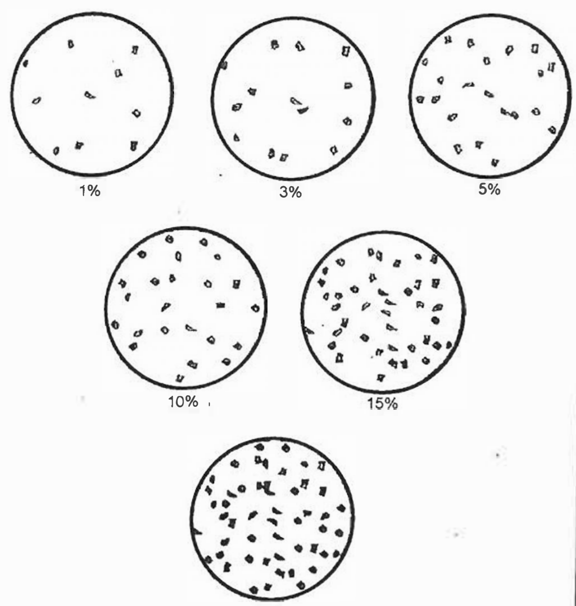
## GEOLOGIC NOMENCLATURE

B = Bedding  C = Contact  J = Joint
F = Fracture  Flt = Fault  S = Shear
RS = Rupture Surface  = Seepage
= Groundwater

## SAMPLE SYMBOLS

- Undisturbed Sample (California Sample)
- Undisturbed Sample (Shelby Tube)
- Bulk Sample
- Unsuccessful Sampling Attempt
- SPT Sample

10: 10 Blows for 12-Inches Penetration
6/4: 6 Blows Per 4-Inches Penetration
P: Push
(13): Uncorrected Blow Counts ("N" Values) for 12-Inches Penetration - Standard Penetration Test (SPT)




GMU GEOTECHNICAL, INC.

**LEGEND TO LOGS**
ASTM Designation: D 2487
(Based on Unified Soil Classification System)

Plate
**A-1**

P8-11/16/2012

## SOIL DENSITY/CONSISTENCY

### FINE GRAINED

| Consistency | Field Test | SPT (#blows/foot) | Mod (#blows/foot) |
|---|---|---|---|
| Very Soft | Easily penetrated by thumb, exudes between fingers | <2 | <3 |
| Soft | Easily penetrated one inch by thumb, molded by fingers | 2-4 | 3-6 |
| Firm | Penetrated over 1/2 inch by thumb with moderate effort | 4-8 | 6-12 |
| Stiff | Penetrated about 1/2 inch by thumb with great effort | 8-15 | 12-25 |
| Very Stiff | Readily indented by thumbnail | 15-30 | 25-50 |
| Hard | Indented with difficulty by thumbnail | >30 | >50 |

### COARSE GRAINED

| Density | Field Test | SPT (#blows/foot) | Mod (#blows/foot) |
|---|---|---|---|
| Very Loose | Easily penetrated with 0.5" rod pushed by hand | <4 | <5 |
| Loose | Easily penetrated with 0.5" rod pushed by hand | 4-10 | 5-12 |
| Medium Dense | Easily penetrated 1' with 0.5" rod driven by 5lb hammer | 10-30 | 12-35 |
| Dense | Dificult to penetrat 1' with 0.5" rod driven by 5lb hammer | 31-50 | 35-60 |
| Very Dense | Penetrated few inches with 0.5" rod driven by 5lb hammer | >50 | >60 |

## BEDROCK HARDNESS

| Density | Field Test | SPT (#blows/foot) |
|---|---|---|
| Soft | Can be crushed by hand, soil like and structureless | 1-30 |
| Moderately Hard | Can be grooved with fingernails, crumbles with hammer | 30-50 |
| Hard | Can't break by hand, can be grooved with knife | 50-100 |
| Very Hard | Scratches with knife, chips with hammer blows | >100 |

## MODIFIERS

| | |
|---|---|
| Trace | 1% |
| Few | 1-5% |
| Some | 5-12% |
| Numerous | 12-20% |
| Abundant | >20% |

## GRAIN SIZE

| Description | | Sieve Size | Grain Size | Approximate Size |
|---|---|---|---|---|
| Boulders | | >12" | >12" | Larger than a basketball |
| Cobbles | | 3-12" | 3-12" | Fist-sized to basketball-sized |
| Gravel | Coarse | 3/4-3" | 3/4-3" | Thumb-sized to fist-sized |
| | Fine | #4-3/4" | 0.19-0.75" | Pea-sized to thumb-sized |
| Sand | Coarse | #10-#4 | 0.079-0.19" | Rock-salt-sized to pea-sized |
| | Medium | #40-#10 | 0.017-0.079" | Sugar-sized to rock salt-sized |
| | Fine | #200-#40 | 0.0029-0.017" | Flour-sized to sugar-sized |
| Fines | | passing #200 | <0.0029" | Flour-sized and smaller |

## MOISTURE CONTENT

Dry- Very little or no moisture
Damp- Some moisture but less than optimum
Moist- Near optimum
Very Moist- Above optimum
Wet/Saturated- Contains free moisture

GMU GEOTECHNICAL, INC.

**LEGEND TO LOGS**
ASTM Designation: D 2487
(Based on Unified Soil Classification System)

Plate **A-2**

P8-11/16/2012

**Project:** Bastanchury Road Widening
**Project Location:** Bastanchury Road - Yorba Linda, CA
**Project Number:** 18-164-00

# Log of Drill Hole DH-1



| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 8/23/18 | Logged By | JSM | Checked By | AAV |
| Drilling Method | Hand Auger | Drilling Contractor | Mike's Excavating | Total Depth of Drill Hole | 5.5 feet |
| Drill Rig Type | Hand Auger | Diameter(s) of Hole, inches | 4" | Approx. Surface Elevation, ft MSL | 405.0 |
| Groundwater Depth [Elevation], feet | NA [0.0] | Sampling Method(s) | Open drive sampler with 6-inch sleeve | Drill Hole Backfill | Native |
| Remarks | | | | Driving Method and Drop | NA |

| ELEVATION, feet | DEPTH, feet | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION AND DESCRIPTION | ORIENTATION DATA | ENGINEERING CLASSIFICATION AND DESCRIPTION | SAMPLE DATA: SAMPLE | SAMPLE DATA: NUMBER OF BLOWS / 6" | SAMPLE DATA: DRIVING WEIGHT, lbs | TEST DATA: MOISTURE CONTENT, % | TEST DATA: DRY UNIT WEIGHT, pcf | TEST DATA: ADDITIONAL TESTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **ARTIFICIAL FILL (Qaf)** | | POORLY GRADED GRAVEL (GP); brownish gray, dry to damp, medium dense to dense, gravel is fine, some fine to coarse sand | | | | 12 | | |
| | | | **YOUNG ALLUVIAL FAN DEPOSITS (Qyf)** | | CLAYEY SAND (SC); light brown to brown, damp, medium dense, sand is medium grained, with trace fine gravel | | | | | | |
| | | | | | becomes brown to dark brown | | | | 12 | 103 | |
| 400 | 5 | | | | | | | | 12 | 93 | |
| | | | | | Total Depth = 5.5 feet<br>No Groundwater | | | | | | |

DH_REV3 18-164-00.GPJ GMULAB.GPJ 9/19/18

GMU GEOTECHNICAL, INC.

| Project: Bastanchury Road Widening<br>Project Location: Bastanchury Road - Yorba Linda, CA<br>Project Number: 18-164-00 | # Log of Drill Hole DH-2<br>Sheet 1 of 1 |
|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 8/23/18 | Logged By | JSM | Checked By | AAV |
| Drilling Method | Hand Auger | Drilling Contractor | Mike's Excavating | Total Depth of Drill Hole | 5.5 feet |
| Drill Rig Type | Hand Auger | Diameter(s) of Hole, inches | 4" | Approx. Surface Elevation, ft MSL | 416.0 |
| Groundwater Depth [Elevation], feet | NA [0.0] | Sampling Method(s) | Open drive sampler with 6-inch sleeve | Drill Hole Backfill | Native |
| Remarks | | | | Driving Method and Drop | NA |

| ELEVATION, feet | DEPTH, feet | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION AND DESCRIPTION | ORIENTATION DATA | ENGINEERING CLASSIFICATION AND DESCRIPTION | SAMPLE DATA: SAMPLE | NUMBER OF BLOWS / 6" | DRIVING WEIGHT, lbs | TEST DATA: MOISTURE CONTENT, % | DRY UNIT WEIGHT, pcf | ADDITIONAL TESTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **VERY OLD ALLUVIAL FAN DEPOSITS (Qvof)** | | SANDY CLAY (CL); light brown, damp, firm to stiff, sand is medium grained, with trace fine gravel | | | | 11 | | |
| 415 | | | | | becomes brown and moist | | | | | | |
| | | | | | decrease in sand content | | | | | | |
| | | | | | | | | | 12 | 97 | |
| | | | | | dark brown | | | | | | |
| | 5 | | | | | | | | 14 | 114 | |
| | | | | | Total Depth = 5.5 feet<br>No Groundwater | | | | | | |

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GMU GEOTECHNICAL, INC.

Drill Hole DH-2

| Project: Bastanchury Road Widening<br>Project Location: Bastanchury Road - Yorba Linda, CA<br>Project Number: 18-164-00 | # Log of Drill Hole DH-3<br>Sheet 1 of 1 |
|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 8/23/18 | Logged By | JSM | Checked By | AAV |
| Drilling Method | Hand Auger | Drilling Contractor | Mike's Excavating | Total Depth of Drill Hole | 5.5 feet |
| Drill Rig Type | Hand Auger | Diameter(s) of Hole, inches | 4" | Approx. Surface Elevation, ft MSL | 406.0 |
| Groundwater Depth [Elevation], feet | NA [0.0] | Sampling Method(s) | Open drive sampler with 6-inch sleeve | Drill Hole Backfill | Native |
| Remarks | | | | Driving Method and Drop | NA |

| ELEVATION, feet | DEPTH, feet | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION AND DESCRIPTION | ORIENTATION DATA | ENGINEERING CLASSIFICATION AND DESCRIPTION | SAMPLE DATA: SAMPLE | SAMPLE DATA: NUMBER OF BLOWS / 6" | SAMPLE DATA: DRIVING WEIGHT, lbs | TEST DATA: MOISTURE CONTENT, % | TEST DATA: DRY UNIT WEIGHT, pcf | TEST DATA: ADDITIONAL TESTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 405 | | | **VERY OLD ALLUVIAL FAN DEPOSITS (Qvof)** | | CLAYEY SAND (SC) to SANDY CLAY (CL); brown, moist, dense to stiff, sand is coarse grained, trace fine gravel | | | | 12 | | |
| | | | | | becomes light brown, damp, decrease in clay content | | | | 10 | 116 | |
| | 5 | | | | | | | | 7 | 97 | |
| | | | | | Total Depth = 5.5 feet<br>No Groundwater | | | | | | |

DH_REV3 18-164-00.GPJ GMULAB.GPJ 9/19/18

GMU GEOTECHNICAL, INC.

Drill Hole DH-3

| | |
|---|---|
| **Project:** Bastanchury Road Widening<br>**Project Location:** Bastanchury Road - Yorba Linda, CA<br>**Project Number:** 18-164-00 | **Log of Drill Hole DH-4**<br>Sheet 1 of 1 |

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | **8/23/18** | Logged By | **JSM** | Checked By | **AAV** |
| Drilling Method | **Hand Auger** | Drilling Contractor | **Mike's Excavating** | Total Depth of Drill Hole | **10.8 feet** |
| Drill Rig Type | **Hand Auger** | Diameter(s) of Hole, inches | **4"** | Approx. Surface Elevation, ft MSL | **417.0** |
| Groundwater Depth [Elevation], feet | **NA [0.0]** | Sampling Method(s) | **Open drive sampler with 6-inch sleeve** | Drill Hole Backfill | **Native** |
| Remarks | | | | Driving Method and Drop | **NA** |

| ELEVATION, feet | DEPTH, feet | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION AND DESCRIPTION | ORIENTATION DATA | ENGINEERING CLASSIFICATION AND DESCRIPTION | SAMPLE DATA: SAMPLE | SAMPLE DATA: NUMBER OF BLOWS / 6" | SAMPLE DATA: DRIVING WEIGHT, lbs | TEST DATA: MOISTURE CONTENT, % | TEST DATA: DRY UNIT WEIGHT, pcf | TEST DATA: ADDITIONAL TESTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **YOUNG ALLUVIAL FAN DEPOSITS (Qyf)** | | SANDY CLAY (CL); light brown, damp, firm, sand is medium to coarse grained, with trace fine gravel | | | | | | |
| 415 | | | | | | | | | | | |
| | | | | | | | | | 15 | 100 | |
| | 5 | | | | increase in sand content | | | | 6 | 121 | |
| 410 | | | | | increase in gravel content | | | | | | |
| | | | | | | | | | 8 | 112 | |
| | 10 | | | | | | | | 8 | 109 | |
| | | | | | Total Depth = 10.75 feet<br>No Groundwater | | | | | | |

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GMU GEOTECHNICAL, INC.

**Drill Hole DH-4**

**Project:** Bastanchury Road Widening
**Project Location:** Bastanchury Road - Yorba Linda, CA
**Project Number:** 18-164-00

# Log of Drill Hole DH-5

Sheet 1 of 1

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 8/23/18 | Logged By | JSM | Checked By | AAV |
| Drilling Method | Hand Auger | Drilling Contractor | Mike's Excavating | Total Depth of Drill Hole | 10.5 feet |
| Drill Rig Type | Hand Auger | Diameter(s) of Hole, inches | 4" | Approx. Surface Elevation, ft MSL | 404.0 |
| Groundwater Depth [Elevation], feet | NA [0.0] | Sampling Method(s) | Open drive sampler with 6-inch sleeve | Drill Hole Backfill | Native |
| Remarks | | | | Driving Method and Drop | NA |

| ELEVATION, feet | DEPTH, feet | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION AND DESCRIPTION | ORIENTATION DATA | ENGINEERING CLASSIFICATION AND DESCRIPTION | SAMPLE DATA: SAMPLE | SAMPLE DATA: NUMBER OF BLOWS / 6" | SAMPLE DATA: DRIVING WEIGHT, lbs | TEST DATA: MOISTURE CONTENT, % | TEST DATA: DRY UNIT WEIGHT, pcf | TEST DATA: ADDITIONAL TESTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **ARTIFICIAL FILL (Qaf)** | | SITLY SAND (SM); brown, moist, medium dense, sand is coarse grained, with trace fine grained gravel | | | | 12 | | |
| | | | **YOUNG ALLUVIAL FAN DEPOSITS (Qyf)** | | SANDY CLAY (CL); brown, moist, firm, sand is medium grained, with trace fine gravel<br>numerous fine gravel | | | | 12 | 108 | |
| 400 | | | | | becomes moist | | | | | | |
| | 5 | | | | | | | | 8 | 126 | |
| | | | | | becomes damp and hard<br>becomes dark brown to black, dry, with trace cobbles | | | | 6 | 115 | |
| 395 | | | | | | | | | | | |
| | 10 | | | | | | | | 8 | 110 | |
| | | | | | Total Depth = 10 feet<br>No Groundwater | | | | | | |

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GMU GEOTECHNICAL, INC.

| Project: Bastanchury Road Widening<br>Project Location: Bastanchury Road - Yorba Linda, CA<br>Project Number: 18-164-00 | # Log of Drill Hole DH-6<br>Sheet 1 of 1 |
|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 8/23/18 | Logged By | JSM | Checked By | AAV |
| Drilling Method | Hand Auger | Drilling Contractor | Mike's Excavating | Total Depth of Drill Hole | 5.5 feet |
| Drill Rig Type | Hand Auger | Diameter(s) of Hole, inches | 4" | Approx. Surface Elevation, ft MSL | 411.0 |
| Groundwater Depth [Elevation], feet | NA [0.0] | Sampling Method(s) | Open drive sampler with 6-inch sleeve | Drill Hole Backfill | Native |
| Remarks | | | | Driving Method and Drop | NA |

| ELEVATION, feet | DEPTH, feet | GRAPHIC LOG | GEOLOGICAL CLASSIFICATION AND DESCRIPTION | ORIENTATION DATA | ENGINEERING CLASSIFICATION AND DESCRIPTION | SAMPLE DATA: SAMPLE | SAMPLE DATA: NUMBER OF BLOWS / 6" | SAMPLE DATA: DRIVING WEIGHT, lbs | TEST DATA: MOISTURE CONTENT, % | TEST DATA: DRY UNIT WEIGHT, pcf | TEST DATA: ADDITIONAL TESTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ARTIFICIAL FILL (Qaf) | | SITLY SAND (SM); brown, moist, medium dense, sand is coarse grained, with trace fine grained gravel | | | | 8 | | |
| 410 | | | VERY OLD ALLUVIAL FAN DEPOSITS (Qvof) | | SANDY CLAY (CL) with GRAVEL; brown, moist, firm, sand is coarse grained, gravel is fine to coarse<br>becomes stiff with less sand<br>increase in clay content | | | | 11 | 104 | |
| | | | | | increase in gravel content | | | | | | |
| | 5 | | | | | | | | 6 | 117 | |
| | | | | | Total Depth = 5.5 feet<br>No Groundwater | | | | | | |

DH_REV3 18-164-00.GPJ GMULAB.GPJ 9/19/18

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# APPENDIX B

## Geotechnical Laboratory Procedures and Test Results

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# APPENDIX B

# GMU GEOTECHNICAL LABORATORY PROCEDURES AND TEST RESULTS

## MOISTURE AND DENSITY

Field moisture content and in-place density were determined for each 6-inch sample sleeve of undisturbed soil material obtained from the drill holes. The field moisture content was determined in general accordance with ASTM Test Method D 2216 by obtaining one-half the moisture sample from each end of the 6-inch sleeve. The in-place dry density of the sample was determined by using the wet weight of the entire sample.

At the same time the field moisture content and in-place density were determined, the soil material at each end of the sleeve was classified according to the Unified Soil Classification System. The results of the field moisture content and in-place density determinations are presented on the right-hand column of the Log of Drill Hole and are summarized on Table B-1. The results of the visual classifications were used for general reference.

## PARTICLE SIZE DISTRIBUTION

As part of the engineering classification of the materials underlying the site, samples were tested to determine the distribution of particle sizes. The distribution was determined in general accordance with ASTM Test Method D 422 using U.S. Standard Sieve Openings 3", 1.5", 3/4, 3/8, and U.S. Standard Sieve Nos. 4, 10, 20, 40, 60, 100, and 200. In addition, a standard hydrometer test was performed one each sample to determine the distribution of particle sizes passing the No. 200 sieve (i.e., silt and clay-size particles). The results of the tests are contained in this Appendix B. Key distribution categories (% gravel; % sand, etc.) are contained on Table B-1.

## ATTERBERG LIMITS

As part of the engineering classification of the soil material, samples of the on-site soil material were tested to determine relative plasticity. This relative plasticity is based on the Atterberg limits determined in general accordance with ASTM Test Method D 4318. The results of these tests are contained in this Appendix B and also Table B-1.

## EXPANSION TESTS

To provide a standard definition of one-dimensional expansion, a test was performed on typical on-site materials in general accordance with ASTM Test Method D 4829. The result from this test procedure is reported as an "expansion index". The results of this test are contained in this Appendix B and also Table B-1.

## CHEMICAL TESTS

The corrosion potential of typical on-site materials under long-term contact with both metal and concrete was determined by chemical and electrical resistance tests. The soluble sulfate test for potential concrete corrosion was performed in general accordance with California Test Method 417, the minimum resistivity test for potential metal corrosion was performed in general accordance with California Test Method 643, and the concentration of soluble chlorides was determined in general accordance with California Test Method 422. The results of these tests are contained in this Appendix B and also Table B-1.

## COMPACTION TESTS

A bulk sample representative of the on-site materials was tested to determine the maximum dry density and optimum moisture content of the soil. These compactive characteristics were determined in general accordance with ASTM Test Method D 1557. The results of this test are contained in this Appendix B and also Table B-1.

## CONSOLIDATION TESTS

The one-dimensional consolidation properties of an "undisturbed" sample was evaluated in general accordance with the provisions of ASTM Test Method D 2435. Sample diameter was 2.416 inches and sample height was 1.00 inch. Water was added during the test at various normal loads to evaluate the potential for hydro-collapse and to produce saturation during the remainder of the testing. Consolidation readings were taken regularly during each load increment until the change in sample height was less than approximately 0.0001 inch over a two-hour period. The graphic presentation of consolidation data is a representation of volume change in change in axial load. In addition, time rate tests were performed. The results of these tests are contained in this Appendix B.

## DIRECT SHEAR STRENGTH TESTS

Direct shear tests were performed on typical on-site materials. The general philosophy and procedure of the tests were in accord with ASTM Test Method D 3080 - "Direct Shear Tests for Soils Under Consolidated Drained Conditions".

The tests are single shear tests and are performed using a sample diameter of 2.416 inches and a height of 1.00 inch. The normal load is applied by a vertical dead load system. A constant rate of strain is applied to the upper one-half of the sample until failure occurs. Shear stress is monitored by a strain gauge-type precision load cell and deflection is measured with a digital dial indicator. This data is transferred electronically to data acquisition software which plots shear strength vs. deflection. The shear strength plots are then interpreted to determine either peak or ultimate shear strengths. Residual strengths were obtained through multiple shear box reversals. A strain rate compatible with the grain size distribution of the soils was utilized. The interpreted results of these tests are shown in this Appendix B.

## R-VALUE TESTS

A bulk sample representative of the underlying on-site materials was tested to measure the response of a compacted sample to a vertically applied pressure under specific conditions. The R-value of a material is determined when the material is in a state of saturation such that water will be exuded from the compacted test specimen when a 16.8 kN load (2.07 MPa) is applied. The results from these test procedures are reported in this Appendix B.

# TABLE B-1
# SUMMARY OF SOIL LABORATORY DATA

| Sample Information | | | | | | | | Sieve/Hydrometer | | | | Atterberg Limits | | | Compaction | | | | Chemical Test Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boring Number | Depth, feet | Elevation, feet | Geologic Unit | USCS Group Symbol | In Situ Water Content, % | In Situ Dry Unit Weight, pcf | In Situ Saturation, % | Gravel, % | Sand, % | <#200, % | <2µ, % | LL | PL | PI | Maximum Dry Unit Weight, pcf | Optimum Water Content, % | Expansion Index | R-Value | pH | Sulfate (ppm) | Chloride (ppm) | Min. Resistivity (ohm/cm) |
| DH-1 | 0 | 405.0 | | SC | 11.8 | | | 4 | 50 | 46 | 13 | 32 | 18 | 14 | | | | | | | | |
| DH-1 | 2.5 | 402.5 | | SC | 11.6 | 103 | 51 | | | | | | | | | | | | | | | |
| DH-1 | 5 | 400.0 | | SC | 11.6 | 93 | 40 | | | | | | | | | | | | | | | |
| DH-2 | 0 | 416.0 | | CL | 11.4 | | | 7 | 32 | 62 | 14 | 28 | 16 | 12 | | | 20 | | 8 | 621 | 264 | 1984 |
| DH-2 | 2.5 | 413.5 | | CL | 12.1 | 97 | 45 | | | | | | | | | | | | | | | |
| DH-2 | 5 | 411.0 | | CL | 13.7 | 114 | 81 | | | | | | | | | | | | | | | |
| DH-3 | 0 | 406.0 | | SC-CL | 11.5 | | | | | | | | | | 126.0 | 10.5 | | | | | | |
| DH-3 | 2.5 | 403.5 | | SC-CL | 10.2 | 116 | 64 | | | | | | | | | | | | | | | |
| DH-3 | 5 | 401.0 | | SC-CL | 7.2 | 97 | 27 | | | | | | | | | | | | | | | |
| DH-4 | 2.5 | 414.5 | | CL | 15.2 | 100 | 62 | | | | | | | | | | | | | | | |
| DH-4 | 5 | 412.0 | | CL | 6.2 | 121 | 44 | | | | | | | | | | | | | | | |
| DH-4 | 7.5 | 409.5 | | CL | 7.9 | 112 | 44 | | | | | | | | | | | | | | | |
| DH-4 | 10 | 407.0 | | CL | 8.4 | 109 | 43 | | | | | | | | | | | | | | | |
| DH-5 | 0 | 404.0 | | CL | 11.5 | | | | | | | | | | | | | 12 | | | | |
| DH-5 | 2.5 | 401.5 | | CL | 12.0 | 108 | 60 | | | | | | | | | | | | | | | |
| DH-5 | 5 | 399.0 | | CL | 7.6 | 126 | 64 | | | | | | | | | | | | | | | |
| DH-5 | 7.5 | 396.5 | | CL | 5.5 | 115 | 33 | | | | | | | | | | | | | | | |
| DH-5 | 10 | 394.0 | | CL | 7.9 | 110 | 41 | | | | | | | | | | | | | | | |
| DH-6 | 0 | 411.0 | | CL | 8.3 | | | 16 | 29 | 55 | 21 | 33 | 16 | 17 | | | | | 7.9 | 297 | 648 | 648 |
| DH-6 | 2.5 | 408.5 | | CL | 11.1 | 104 | 50 | | | | | | | | | | | | | | | |
| DH-6 | 5 | 406.0 | | CL | 5.8 | 117 | 37 | | | | | | | | | | | | | | | |

GMU_TABLE_SOIL_LAB_DATA 18-164-00.GPJ FNC AB GWGN01.GDT 9/19/18

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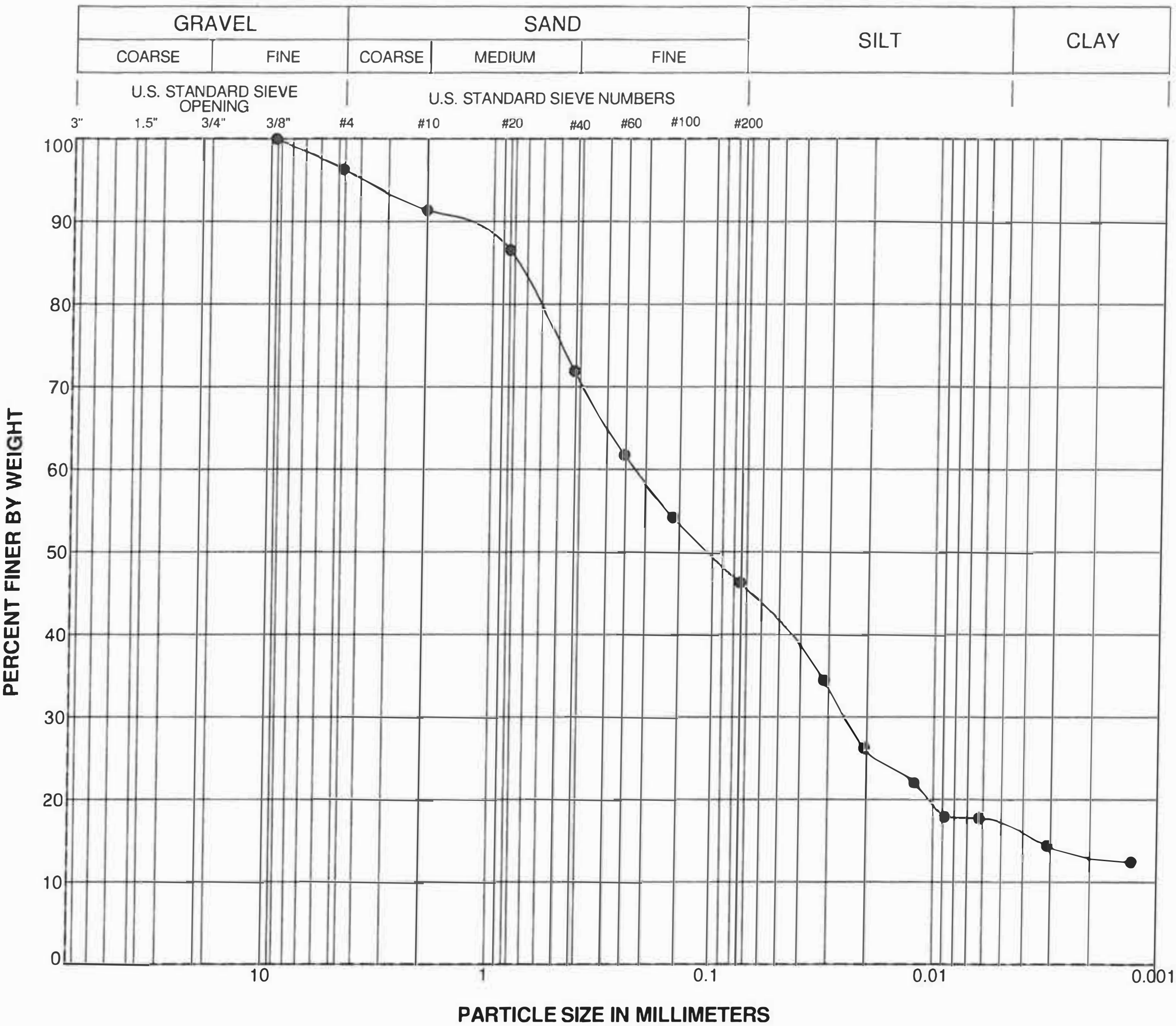
Project: Bastanchury Road Widening
Project No. 18-164-00




| Boring Number | Depth (feet) | Geologic Unit | Symbol | LL | PI | Classification |
|---|---|---|---|---|---|---|
| DH-1 | 0.0 | | ● | 32 | 14 | CLAYEY SAND (SC) |

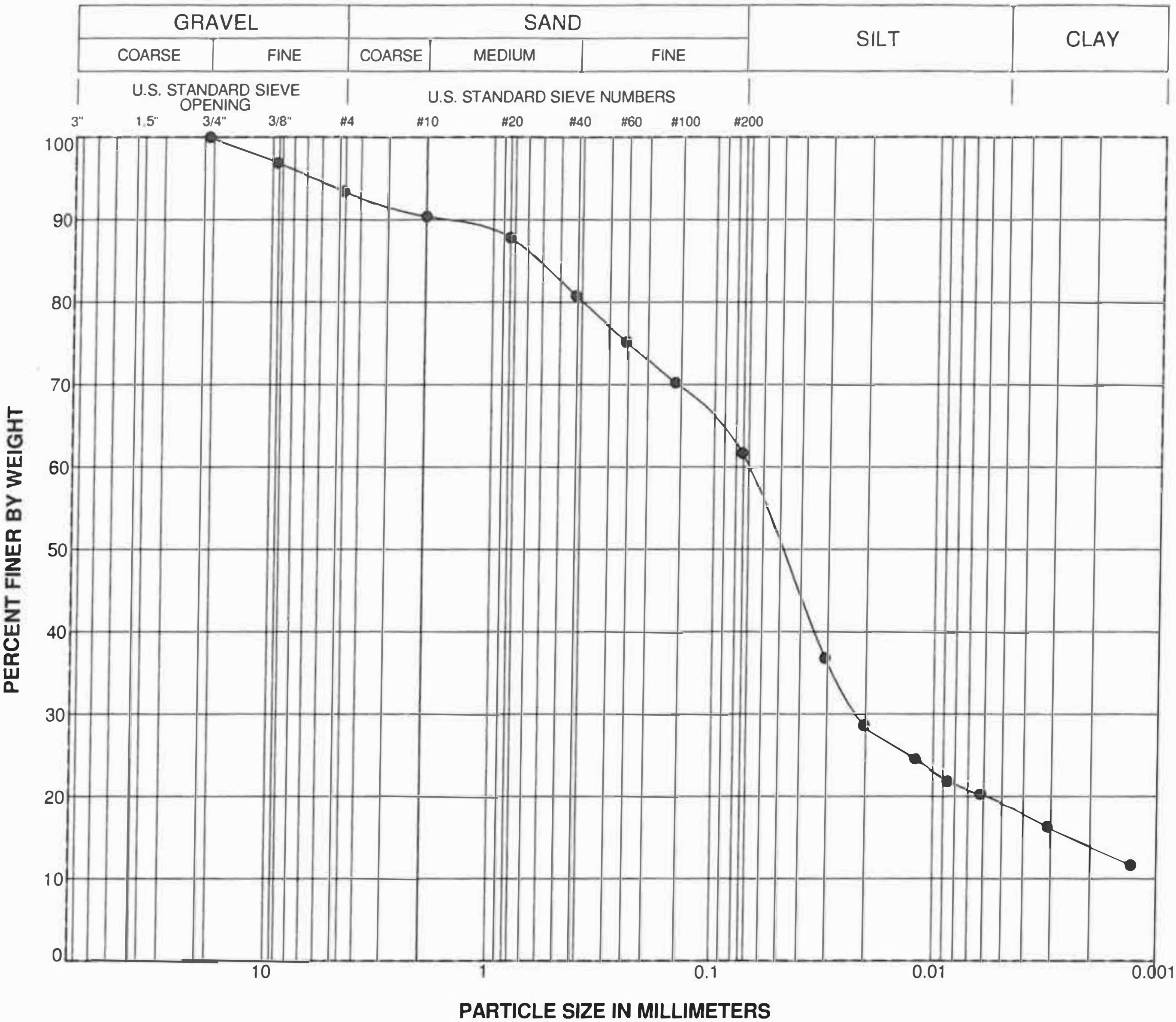
GMU_GRAIN_SIZE 18-164-00.GPJ 9/19/18

# PARTICLE SIZE DISTRIBUTION

Project: Bastanchury Road Widening

Project No. 18-164-00

GMU GEOTECHNICAL, INC.




| Boring Number | Depth (feet) | Geologic Unit | Symbol | LL | PI | Classification |
|---|---|---|---|---|---|---|
| DH-2 | 0.0 | | ● | 28 | 12 | SANDY LEAN CLAY (CL) |

GMU_GRAIN_SIZE 18-164-00.GPJ 9/19/18

# PARTICLE SIZE DISTRIBUTION

Project: Bastanchury Road Widening

Project No. 18-164-00

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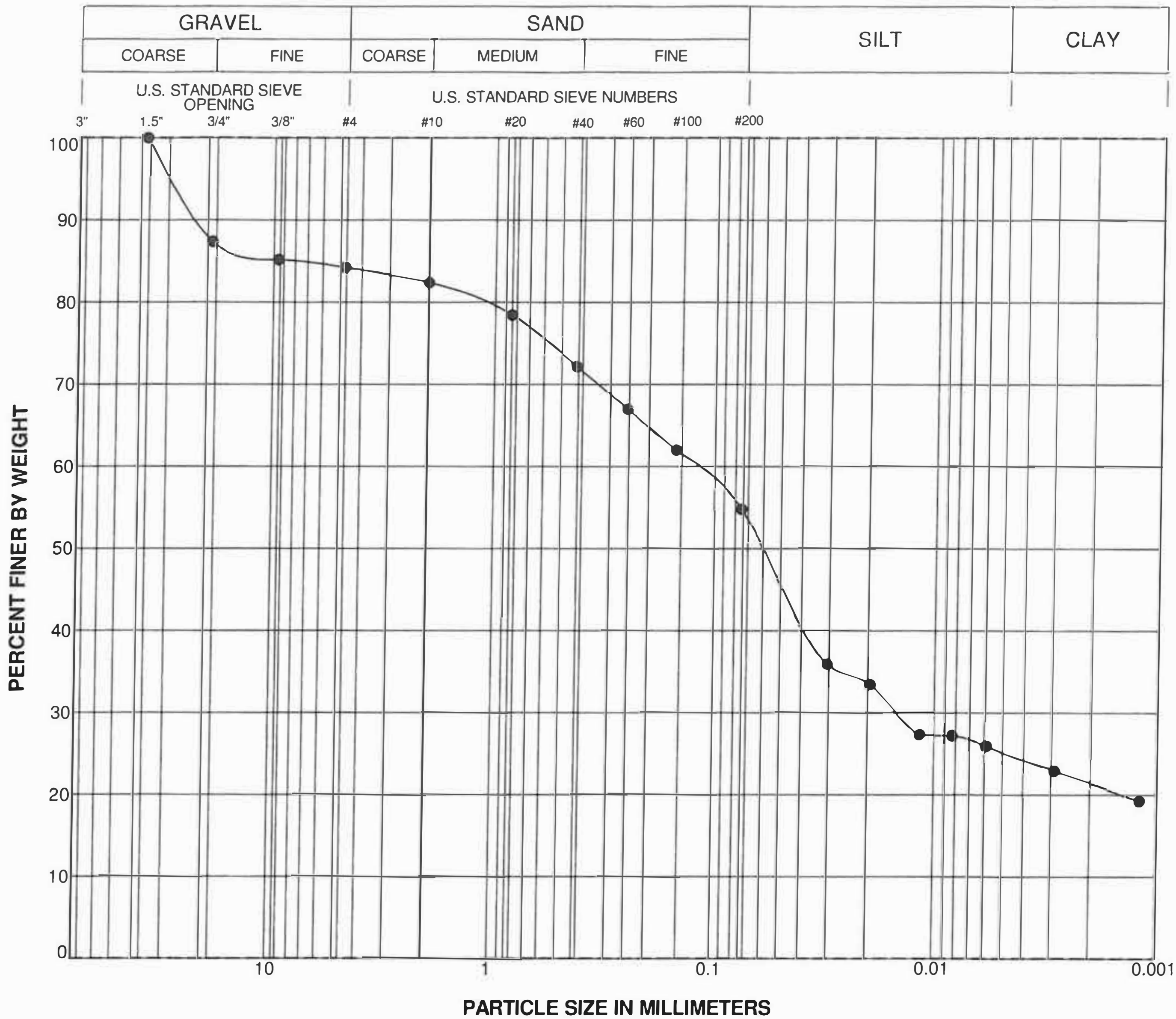



| Boring Number | Depth (feet) | Geologic Unit | Symbol | LL | PI | Classification |
|---|---|---|---|---|---|---|
| DH-6 | 0.0 | | ● | 33 | 17 | SANDY LEAN CLAY with GRAVEL (CL) |

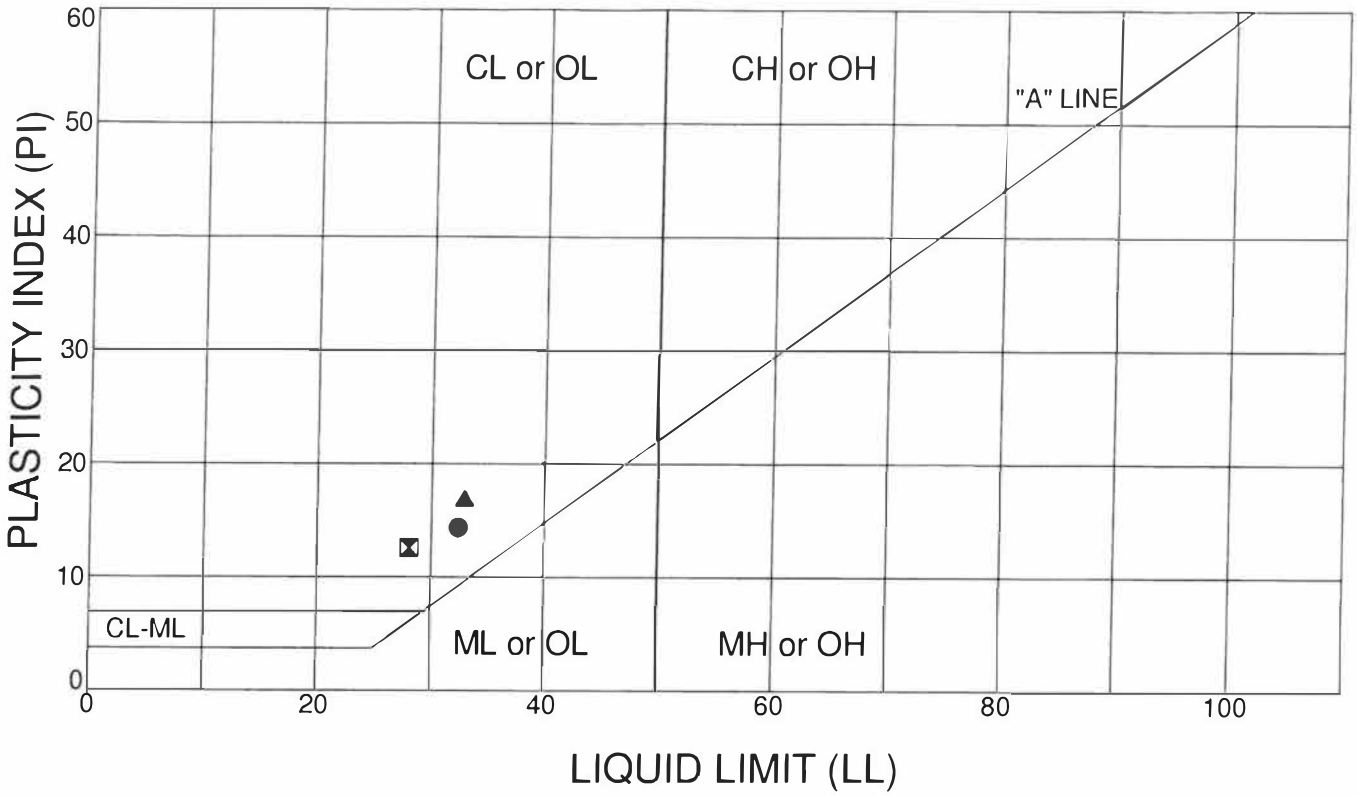
GMU_GRAIN_SIZE 18-164-00.GPJ 9/19/18

# PARTICLE SIZE DISTRIBUTION

Project: Bastanchury Road Widening

Project No. 18-164-00

GMU GEOTECHNICAL, INC.




| Boring Number | Depth (feet) | Geologic Unit | Test Symbol | Insitu Water Content (%) | LL | PL | PI | Classification |
|---|---|---|---|---|---|---|---|---|
| DH-1 | 0.0 | | ● | 12 | 32 | 18 | 14 | CLAYEY SAND (SC) |
| DH-2 | 0.0 | | ⊠ | 11 | 28 | 16 | 12 | SANDY LEAN CLAY (CL) |
| DH-6 | 0.0 | | ▲ | 8 | 33 | 16 | 17 | SANDY LEAN CLAY with GRAVEL (CL) |
| | | | | | | | | |
| | | | | | | | | |
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LIMITS 18-164-00.GPJ 9/19/18

# ATTERBERG LIMITS

Project: Bastanchury Road Widening

Project No. 18-164-00

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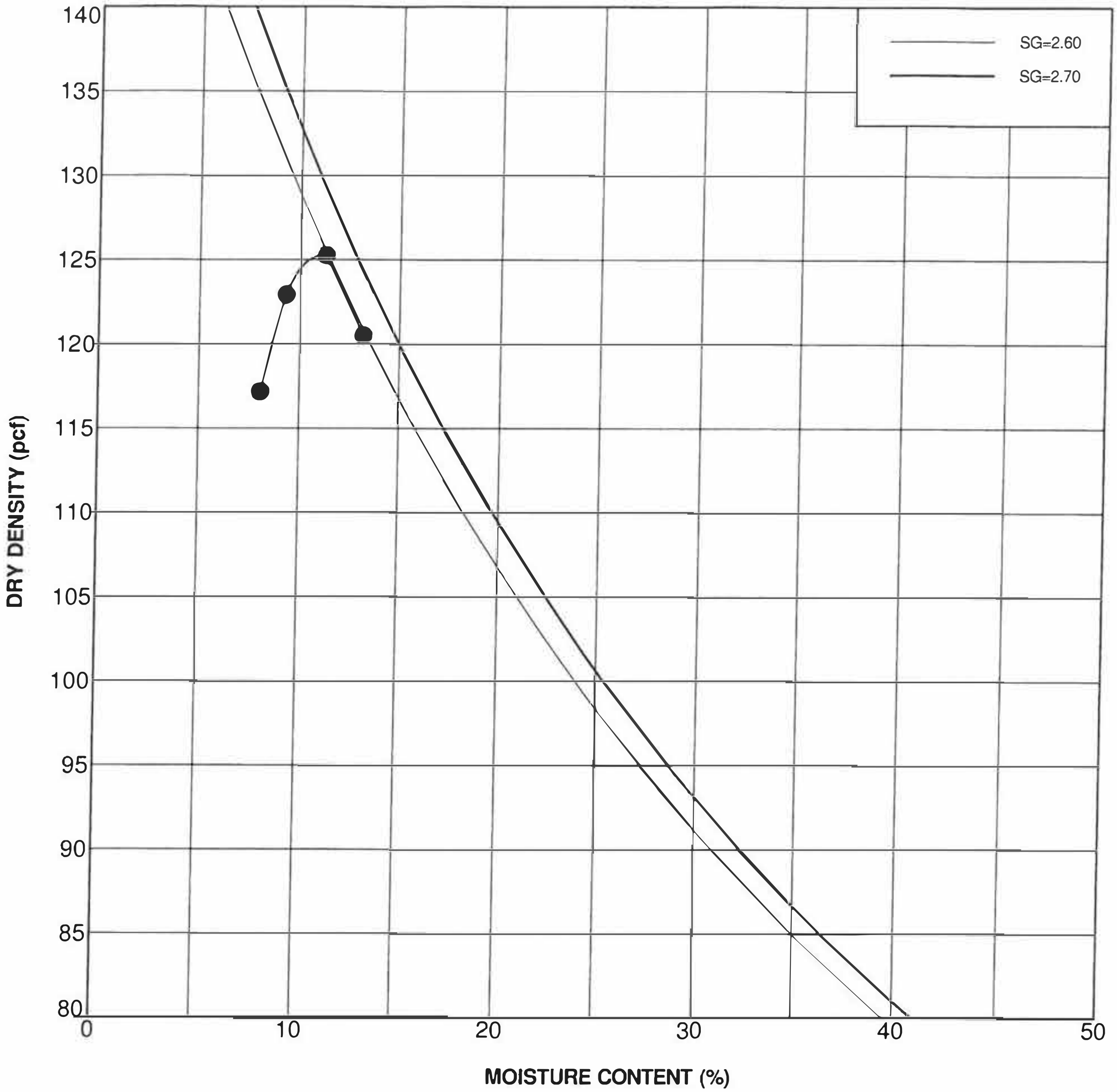



| Boring Number | Depth (feet) | Geologic Unit | Symbol | Maximum Dry Density, pcf | Optimum Moisture Content, % | Classification |
|---|---|---|---|---|---|---|
| DH-3 | 0.0 | | ● | 126 | 10.5 | CLAYEY SAND (SC) |
| | | | | | | |
| | | | | | | |
| | | | | | | |

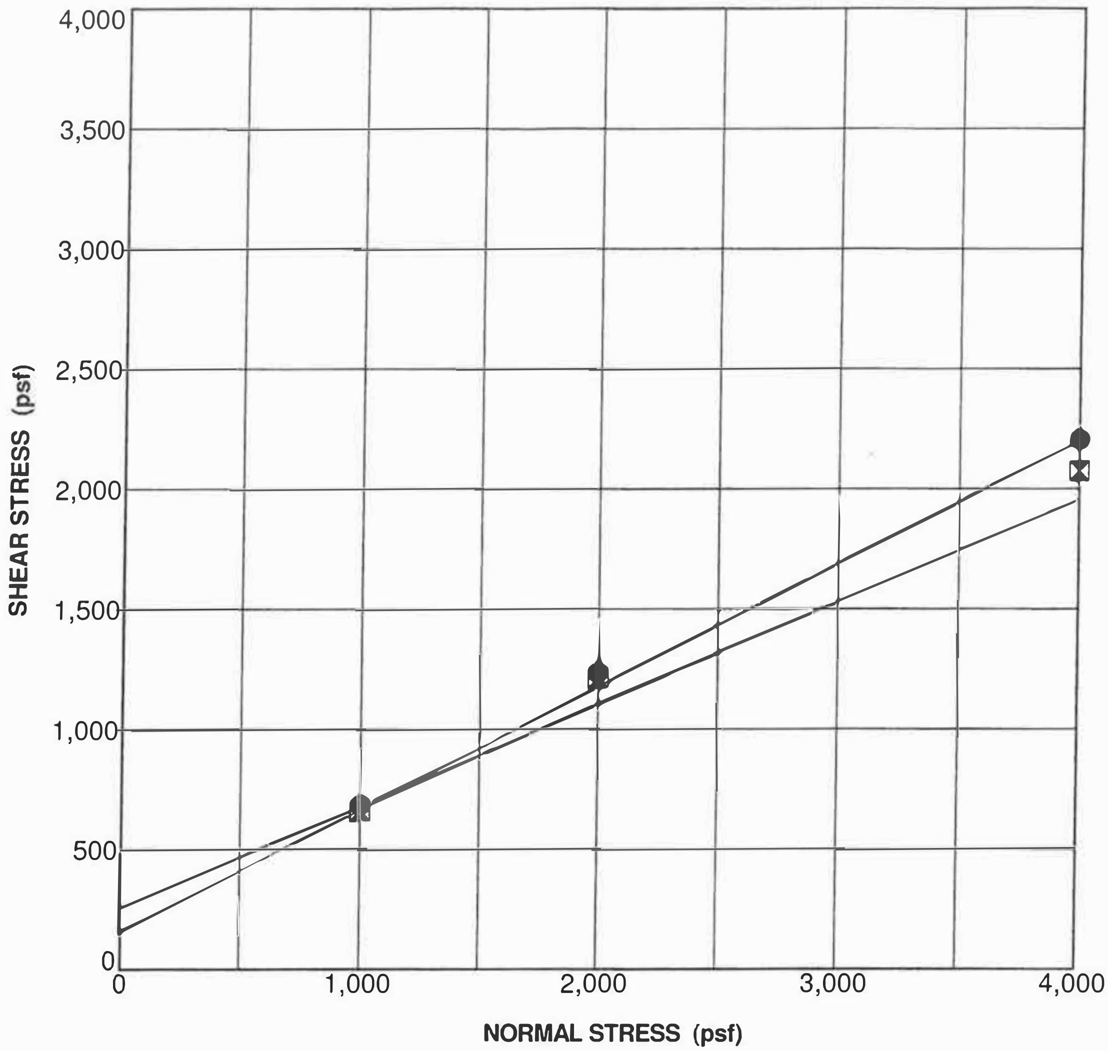
DVTCOMP 18-164-00.GPJ 9/19/18

# COMPACTION TEST DATA

Project: Bastanchury Road Widening

Project No. 18-164-00

GMU GEOTECHNICAL, INC.



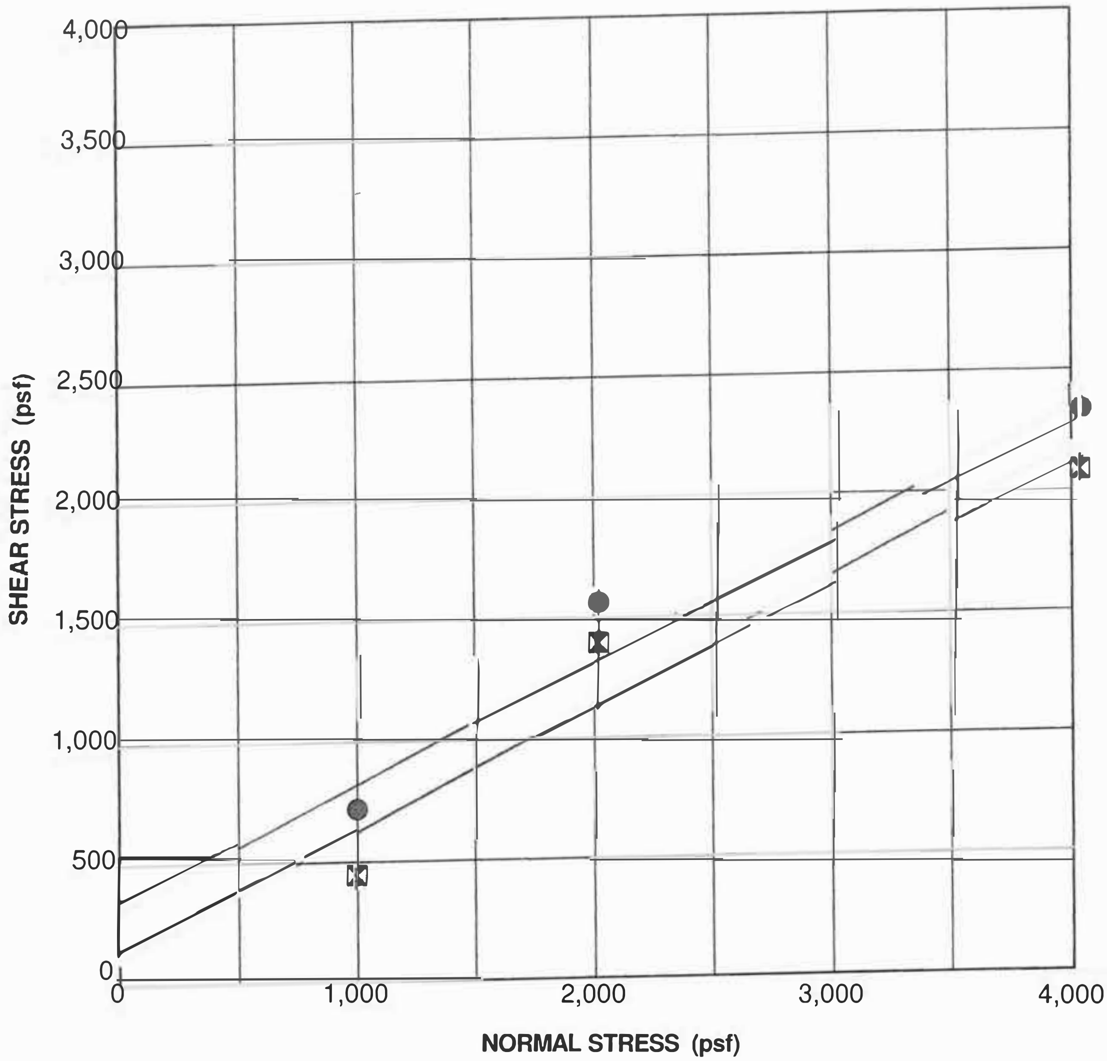

| SAMPLE AND TEST DESCRIPTION |
|---|
| **Sample Location:** DH-3 @ 5.0 ft **Geologic Unit:** **Classification:** SANDY CLAY (CL) |
| **Strain Rate (in/min):** 0.005 **Sample Preparation:** Undisturbed |
| **Notes:** Sample saturated prior and during shearing |

| STRENGTH PARAMETERS | | |
|---|---|---|
| STRENGTH TYPE | COHESION (psf) | FRICTION ANGLE (degrees) |
| ● Peak Strength | 198 | 27.0 |
| ⊠ Ultimate Strength | 228 | 25.0 |

# SHEAR TEST DATA

Project: Bastanchury Road Widening
Project No. 18-164-00

GMU GEOTECHNICAL, INC.




| SAMPLE AND TEST DESCRIPTION | | |
|---|---|---|
| **Sample Location:** DH-4 @ 5.0 ft | **Geologic Unit:** | **Classification:** SANDY CLAY (CL) |
| **Strain Rate (in/min):** 0.005 | **Sample Preparation:** Undisturbed | |
| **Notes:** Sample saturated prior and during shearing | | |

**STRENGTH PARAMETERS**

| STRENGTH TYPE | COHESION (psf) | FRICTION ANGLE (degrees) |
|---|---|---|
| ● Peak Strength | 312 | 28.0 |
| ⊠ Ultimate Strength | 66 | 28.0 |

# SHEAR TEST DATA

Project: Bastanchury Road Widening

Project No. 18-164-00

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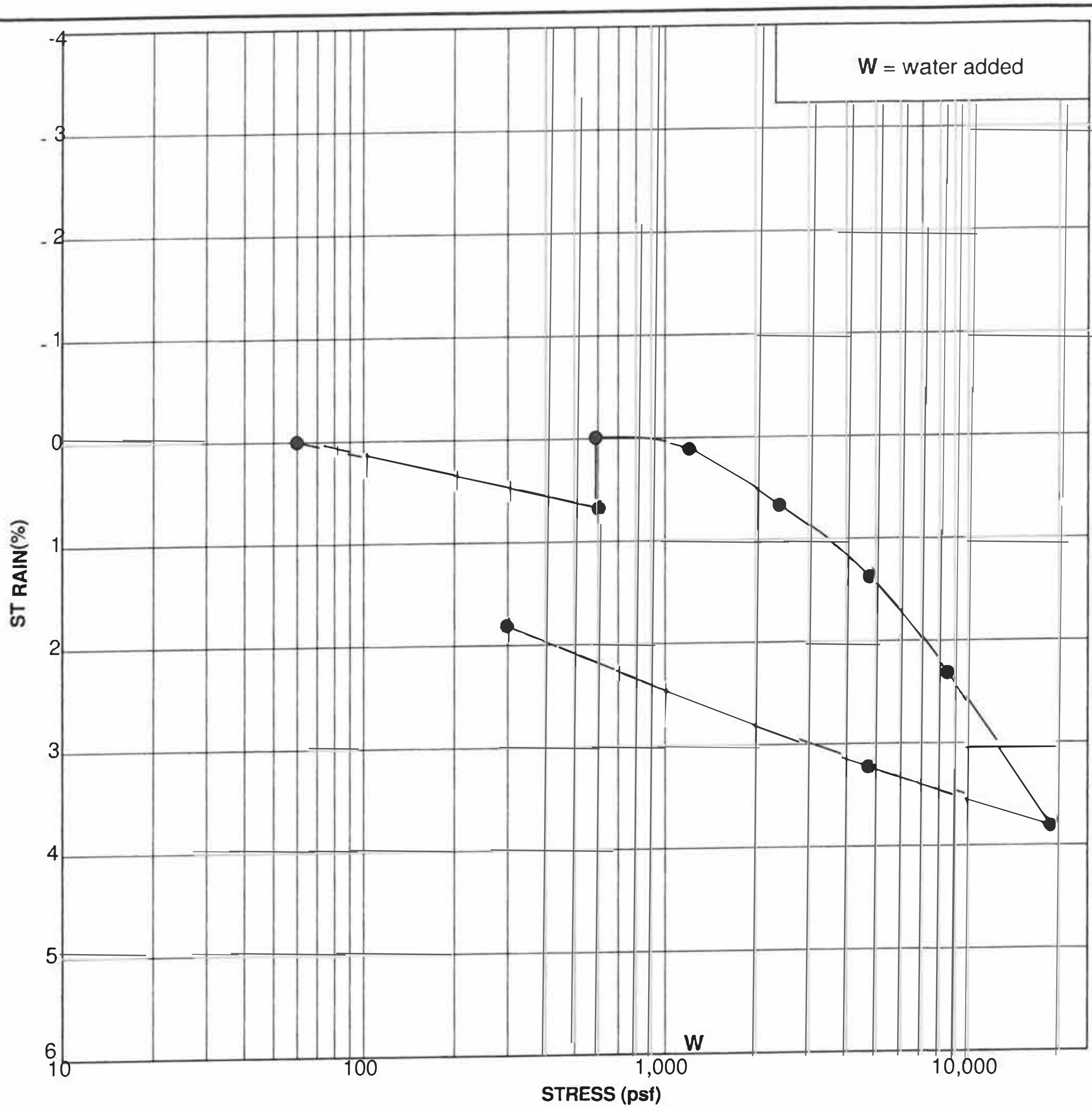
GMU_DIRECT_SHEAR 18-164-00.GPJ GM&U.GDT 9/19/18




| Boring Number | Depth (feet) | Geologic Unit | Symbol | In Situ or Remolded Sample | % Hydro-Collapse | Classification |
|---|---|---|---|---|---|---|
| DH-5 | 5.0 | | ● | In Situ | -0.68 | SANDY CLAY (CL) |
| | | | ⊠ | In Situ | | |
| | | | ▲ | In Situ | | |
| | | | ★ | In Situ | | |

GMU_CONSOL 1 8-164-00.GPJ GM&U.GDT 9/19/18

# CONSOLIDATION TEST DATA

Project: Bastanchury Road Widening

Project No. 18-164-00

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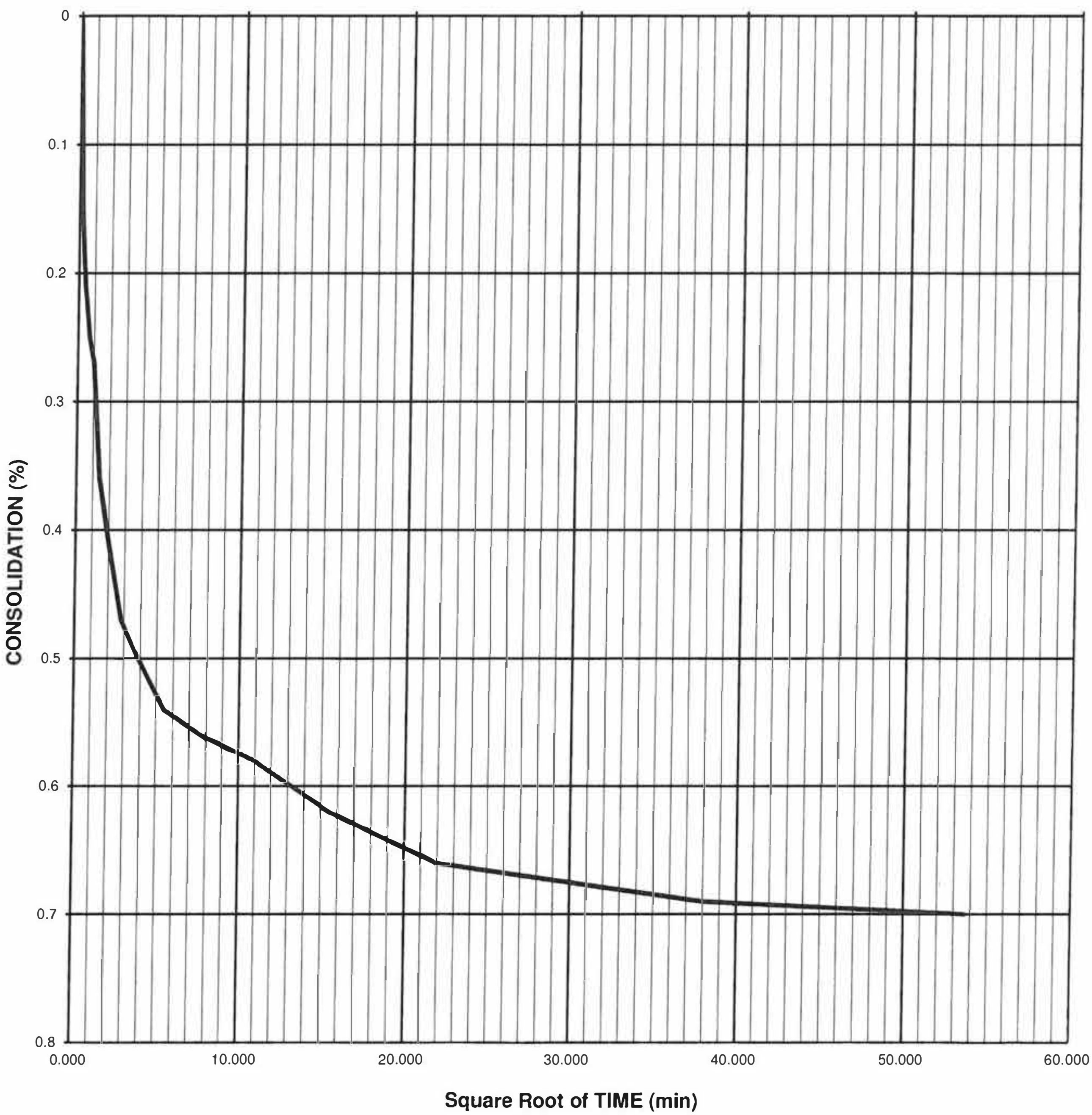
# TIME RATE CONSOLIDATION RESULTS

| | | | |
|---|---|---|---|
| PROJECT NAME: | Bastanchury Road Widening | PROJECT NUMBER: | 18-164-00 |
| SAMPLE LOCATION: | DH-5 | SAMPLE DEPTH: | 5 |
| SAMPLE DESCRIPTION: | Sandy Clay (CL) | LOAD (PSF) | 2360 |



# APPENDIX C

## Slope Stability Analysis

GMU
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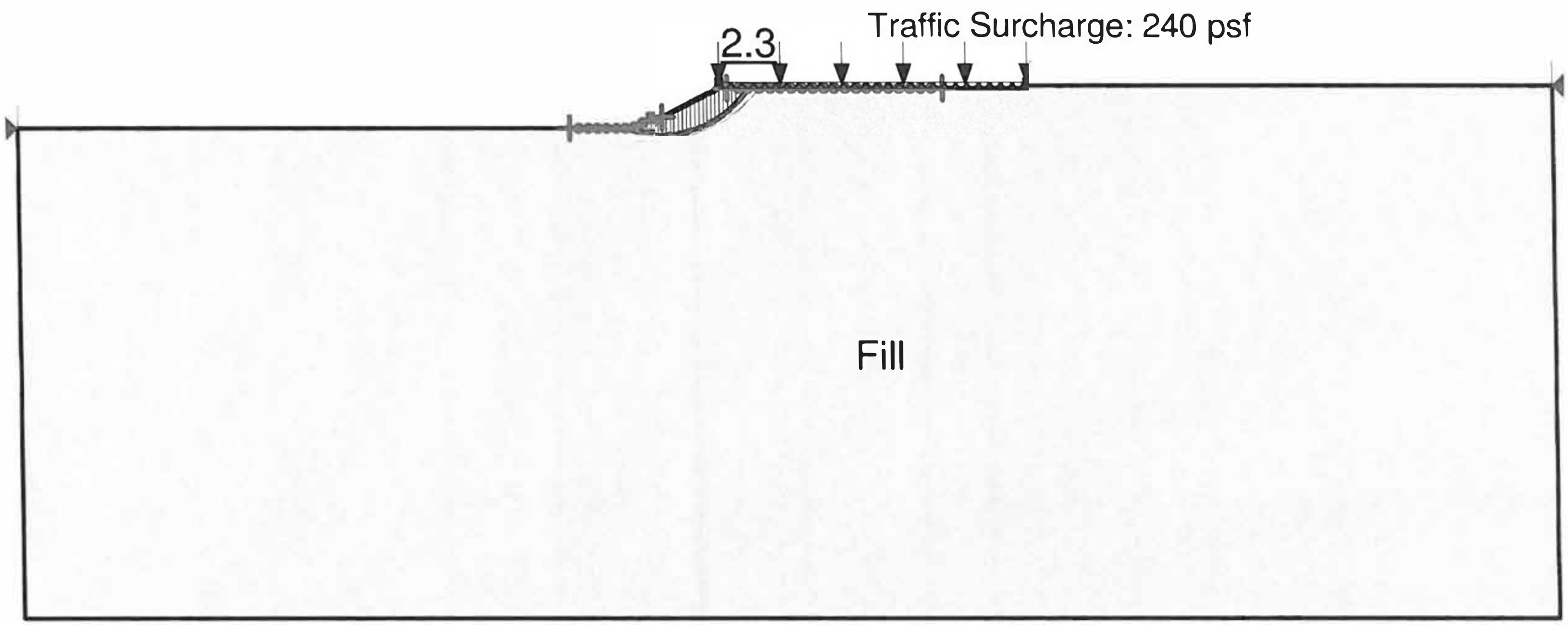
Project No. 18-164-00
STATIC STABILITY ANALYSIS
7-Foot High 2H:1V Road Embankment

Horz Seismic Coef.: 0

Name: Fill
Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion': 150 psf
Phi': 26 °



Project No. 18-164-00
PSEUDOSTATIC STABILITY ANALYSIS
7-Foot High 2H:1V Road Embankment

Horz Seismic Coef.: 0.19

Name: Fill
Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion': 150 psf
Phi': 26 °