GEOTECHNICAL ENGINEERING REPORT
8-INCH SEWER LINE ARROYO CROSSING
FT. DEFIANCE, ARIZONA

Submitted To:

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Bohannan Huston
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Submitted By:

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February 23, 2022
GEOMAT Project 222-3930

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RE: Geotechnical Engineering Report
8-Inch Sewer Line Arroyo Crossing
Ft. Defiance, Arizona
GEOMAT Project No. 222-3930

GEOMAT Inc. (GEOMAT) has completed the geotechnical engineering exploration for the proposed 8-inch Sewer Line Arroyo Crossing Rehabilitation project to be located in Ft. Defiance, Arizona. This study was performed in general accordance with our Proposal No. 212-11-09, dated November 9, 2021.

The results of our engineering study, including the geotechnical recommendations, site plan, boring records, and laboratory test results are attached. Based on the geotechnical engineering analyses, subsurface exploration and laboratory test results, the proposed rehabilitated sewer line could be supported shallow spread footings bearing on compacted native soils. Other design and construction details, based upon geotechnical conditions, are presented in the report.

We have appreciated being of service to you in the geotechnical engineering phase of this project. If you have any questions concerning this report, please contact us.

Sincerely yours,
GEOMAT Inc.

Registered Professional Engineer (Civil)
CERTIFICATE NO.
52003
MATTHEW J.
CRAMER
Date Signed 2/23/22
ARIZONA U.S.A.
Expires 3/31/23

Douglas Hood
Staff Engineer

Matthew J. Cramer, P.E.
President, Principal

Copies to: Addressee (1)

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GEOTECHNICAL ENGINEERING REPORT
8-INCH SEWER LINE ARROYO CROSSING
FT. DEFIANCE, ARIZONAGEOMAT
PROJECT NO. 222-3940

INTRODUCTION

This report contains the results of our geotechnical engineering exploration for the proposed 8-inch Sewer Line Arroyo Crossing Rehabilitation project to be located in Ft. Defiance, Arizona., as shown on the Site Plan in Appendix A of this report.

The purpose of these services is to provide design information and geotechnical engineering recommendations about:

- subsurface soil conditions
- groundwater conditions
- lateral soil pressures
- earthwork
- foundation design and construction
- drainage

The opinions and recommendations contained in this report are based upon the results of field and laboratory testing, engineering analyses, and experience with similar soil conditions, structures, and our understanding of the proposed project as stated below.

PROPOSED CONSTRUCTION

We understand the project will consist of the replacement of the existing aerial line with a new 8-inch sewer line spanning approximately 180 feet. It is anticipated that the new line will be supported on concrete spread footings at approximately 30 feet on center. Supports will be located on either side of the existing arroyo. We understand that maximum allowable loads will be on the order of 5 kips. No significant cuts/fills are expected and no below grade structures are planned.

SITE EXPLORATION

Our scope of services performed for this project included a site reconnaissance by a staff engineer, a subsurface exploration program, laboratory testing and engineering analyses.

Field Exploration:

Subsurface conditions at the site were explored on February 3, 2022 by drilling three exploratory borings at the approximate locations shown on the Site Plan in Appendix A. All three borings were drilled to depths of approximately 15 feet below existing ground surface (bgs).

The borings were advanced using a CME-45 truck-mounted drill rig with continuous-flight, 7.25-inch O.D. hollow-stem auger. The borings were continuously monitored by a staff engineer from our office who examined and classified the subsurface materials encountered, obtained representative samples, observed groundwater conditions, and maintained a continuous log of each boring.

Soil samples were obtained from the borings using a combination of standard 2-inch O.D. split spoon and 3-inch O.D. ring-lined split-barrel samplers. The samplers were driven using a 140-pound hammer falling 30 inches. The standard penetration resistance was determined by recording the number of hammer blows required to advance the sampler in six-inch increments. Representative bulk samples of subsurface materials were also obtained.

Groundwater evaluations were made in each boring at the time of site exploration. Soils were classified in accordance with the Unified Soil Classification System described in Appendix A. Boring logs were prepared and are presented in Appendix A.

Laboratory Testing:

Samples retrieved during the field exploration were transported to our laboratory for further evaluation. At that time, the field descriptions were confirmed or modified as necessary, and laboratory tests were performed to evaluate the engineering properties of the subsurface materials.

SITE CONDITIONS

The site of the proposed Sewer Line replacement is located approximately 950 feet south and 875 feet west of the intersection of Kit Carson Drive and Indian Route 112 in Fort Defiance, Arizona. The arroyo crossing has residential buildings to the north and west, commercial and residential buildings to the east, and undeveloped land to the south. The ground surface on the west side of the site had a slight gradation toward the arroyo. The ground surface on the east side of the site had a slightly steeper gradation toward the arroyo. The east side of the site also contained berms made from soils and branches. The area was vegetated by a small trees and small to medium sized bushes at the time of our exploration. No evidence of prior structural development was noted at the site besides the current flume and irrigation ditch. The following photographs depict the site at the time of our exploration.

Near Boring B-1
View to the Southeast

Near Boring B-3
View to the North

SUBSURFACE CONDITIONS

Soil Conditions:

As presented on the Boring Logs in Appendix A, we encountered loose to medium dense sandy soils in all of the borings from the ground surface to varying depths. In borings, B-1 and B-3, the sandy soils extended from the ground surface to approximate depths of 10, and 5 feet bgs, respectively. Beneath the sandy soils in these borings, we encountered silty soils that extended to approximately 15 feet bgs, and then underlain by sandy soils to the remaining depth of exploration of 16½ feet bgs. In boring B-2, we encountered sandy soils through the entire depth of exploration of 16 feet bgs. The sandy soils encountered ranged in color from red/tan to red/dark brown with moistures of slightly damp to moist. The silty soils encountered were medium stiff to stiff and ranged in color from red/tan to brown with moistures of slightly damp to moist.

Groundwater Conditions:

Groundwater was not encountered in the borings to the depth explored. Groundwater elevations can fluctuate over time depending upon precipitation, irrigation, runoff and infiltration of surface water. We do not have any information regarding the historical fluctuation of the groundwater level in this vicinity.

Laboratory Test Results:

Laboratory analyses of samples tested indicate the sandy soils have a fines content (silt- and/or clay-sized particles passing the U.S. No. 200 sieve) of approximately 23 percent and are non-plastic. In-place dry densities of the sandy soils ranged from approximately 98 to 110 pounds per cubic foot (pcf), with natural moisture contents between approximately 5 and 23 percent. The silty soils have a fines content of approximately 53 percent and are non-plastic. In-place dry densities of the silty soils ranged from approximately 87 to 97 pcf with natural moisture contents between approximately 6 and 33 percent.

Laboratory consolidation/expansion testing was performed on undisturbed ring samples of the subgrade soils beneath the proposed arroyo crossing. Results of these tests indicate that the sandy soils undergo slight to moderate compression when subjected to anticipated foundation stresses at the existing moisture contents. When subjected to increased moisture conditions at these stresses, they undergo slight to moderate additional compression.

Results of all laboratory tests are presented in Appendix B.

OPINIONS AND RECOMMENDATIONS

Geotechnical Considerations:

The site is considered suitable for the proposed aerial crossing based on the geotechnical conditions encountered and tested for this report. To reduce the potential for settlement and provide more uniform and higher allowable bearing pressures, the footings should bear on compacted native soils.

If there are any significant deviations from the assumed foundation type of concrete spread footings, structure locations and/or loads noted at the beginning of this report, the opinions and recommendations of this report should be reviewed and confirmed/modified as necessary to reflect the final planned design conditions.

Foundations:

Based on our understanding of the type of structures to be built and the results of our field subsurface exploration and laboratory testing, the aerial crossing supports could be founded on conventional shallow spread footings bearing on compacted native soils.

Due to the close proximity of the proposed footings to the adjacent arroyo, we anticipate that scour in the arroyo could impact the final footing depth if founded directly adjacent to the arroyo. Footings should be embedded as described below or lowest scour depth, whichever is greater.

Spread Footings Bearing on Compacted Native Soils:

The crossing supports could be supported on conventional shallow spread footings bearing on compacted native soils. Footings should bear a minimum of 30 inches below finished grade to provide protection against frost heaving.

Compacted native soils should be scarified to a minimum depth of twelve inches, conditioned to near optimum moisture content, and compacted to at least 95% of the maximum dry density as determined by the modified proctor (ASTM D1557). Spot/spread footings should have a minimum width of 2 feet.

The recommended design bearing capacities and footing depths are presented in the following table.

Footing Depth [1] (ft)	Allowable Bearing Pressure (psf)	Bearing Material
2.5 [2]	1,500	Compacted Native Soils

[1] Footing depth referenced below lowest adjacent finished grade. Finished grade is the lowest adjacent grade for perimeter footings and floor level for interior footings.
[2] Minimum footing depth for frost protection.

Total and differential settlements resulting from the assumed structural loads are estimated to be on the order of 1/2 inch or less. Proper drainage should be provided in the final design and during construction and areas adjacent to the structure should be designed to prevent water from ponding or accumulating next to the structure.

Total and differential settlements should not exceed predicted values, provided that:

1. Foundations are constructed as recommended, and
2. Essentially no changes occur in water contents of foundation soils.

For foundations adjacent to descending slopes, a minimum horizontal setback of five (5) feet should be maintained between the foundation base and slope face. In addition, the setback should be such that an imaginary line extending downward at 45 degrees from the nearest foundation edge does not intersect the slope.

Footings and foundations should be reinforced as necessary to reduce the potential for distress caused by differential foundation movement.

Foundation excavations should be observed by GEOMAT. If the soil conditions encountered differ significantly from those presented in this report, supplemental recommendations will be required.

Corrosion and Cement Type:

A representative sample of soil from the boring was tested to evaluate the potential for the on-site soils to corrode buried metal and/or concrete. The sample was tested for pH, electrical resistivity, and soluble sulfates and chlorides. Results of these tests are summarized in the following table.

Corrosivity Test Results						
Sample No.	**Boring No.**	**Sample Depth (ft)**	**pH**	**Resistivity (ohm-cm)**	**Sulfates (%)**	**Chlorides (%)**
7324	B-1	5	8.44	5920	0.003	ND

[1]ND = Not Detected

Corrosion of Concrete:

The soluble sulfate contents of the samples tested was less than 0.10 percent (by weight), which may be characterized as negligible potential for corrosion (IBC Table 1904.3). According to the American Concrete Institute Building Code 318, when the sulfate content is less than 0.10 percent by weight in soil, there shall be no restriction on the cement type and water/cement ratio.

Corrosion of Metals:

Corrosion of buried ferrous metals can occur when electrical current flows from the metal into the soil. As the resistivity of the soil decreases, the flow of electrical current increases, increasing the potential for corrosion. A commonly accepted correlation between soil resistivity and corrosion of ferrous metals is shown in the following table.

Resistivity (ohm-cm)	Corrosivity
0 to 1,000	Severely Corrosive
1,000 to 2,000	Corrosive
2,000 to 10,000	Moderately Corrosive
>10,000	Mildly Corrosive

The sample tested had a resistivity value of 5920 ohm-cm. Based on these laboratory results and the table above, the on-site soils would be characterized as moderately corrosive toward ferrous metals. The potential for corrosion should be taken into account during the design process.

Site Classification:

Based on the subsurface conditions encountered in the borings, we estimate that a Site Class D is appropriate for the site in accordance with the International Building Code. This parameter was estimated based on extrapolation of data beyond the deepest depth explored, using methods allowed by the code. Actual shear wave velocity testing/analysis and/or exploration to a depth of 100 feet were not performed as part of our scope of services for this project.

Lateral Earth Pressures:

For soils above any free water surface, recommended equivalent fluid pressures for unrestrained foundation elements are presented in the following table:

- **Active:**
  Granular soil backfill .... 35 psf/ft
  Undisturbed subsoil ....30 psf/ft

- **Passive:**
  Shallow foundation walls ....250 psf/ft
  Shallow column footings ....……….........350 psf/ft

- **Coefficient of base friction**: 0.40
  The coefficient of base friction should be reduced to 0.30 when used in conjunction with passive pressure.

Where the design includes restrained elements, the following equivalent fluid pressures are recommended:

- **At rest:**
  Granular soil backfill ....50 psf/ft
  Undisturbed subsoil..60 psf/ft

Fill against grade beams and retaining walls should be compacted to densities specified in **Earthwork**. Medium to high plasticity clay soils should not be used as backfill against retaining walls. Compaction of each lift adjacent to walls should be accomplished with hand-operated tampers or other lightweight compactors. Over compaction may cause excessive lateral earth pressures that could result in wall movement.

Slopes:

This recommendation is independent of the slope stability analysis for the existing embankment and applies to new, engineered construction. Assuming fill specifications, compaction requirements, and recommended setbacks provided in this report are followed, cut and fill slopes as steep as to 2.5:1 (horizontal:vertical) should be stable. Depending upon specific project conditions, adequate factors of safety against slope failure may be available for steeper configurations. However, such a determination would require additional analysis.

Earthwork:

General Considerations:

The opinions contained in this report for the proposed construction are contingent upon compliance with recommendations presented in this section. Although underground facilities such as foundations, septic tanks, cesspools, and irrigation systems were not encountered during site reconnaissance, such features could exist and might be encountered during construction.

Site Clearing:

1. Strip and remove all existing pavement, fill, debris and other deleterious materials from the proposed structure area. Any existing structures should be completely removed from below any structure, including foundation elements and any associated development such as underground utilities, etc. All exposed surfaces below footings and slabs should be free of mounds and depressions which could prevent uniform compaction.

2. If unexpected fills or underground facilities are encountered during site clearing, we should be contacted for further recommendations. All excavations should be observed by GEOMAT prior to backfill placement.

3. Stripped materials consisting of vegetation and organic materials should be removed from the site, or used to re-vegetate exposed slopes after completion of grading operations. If it is necessary to dispose of organic materials on-site, they should be placed in non-structural areas, and in fill sections not exceeding 5 feet in height.

4. Sloping areas steeper than 5:1 (horizontal:vertical) should be benched to reduce the potential for slippage between existing slopes and fills. Benches should be level and wide enough to accommodate compaction and earth moving equipment.

5. All exposed areas which will receive fill, once properly cleared and benched where necessary, should be scarified to a minimum depth of eight inches, conditioned to near optimum moisture content, and compacted to at least 95% of standard proctor (ASTM D1557).

Excavation:

1. We present the following general comments regarding our opinion of the excavation conditions for the designers' information with the understanding that they are opinions based on our boring data. More accurate information regarding the excavation conditions should be evaluated by contractors or other interested parties from test excavations using the equipment that will be used during construction. Based on our subsurface evaluation it appears that excavations in soils at the site will be possible using standard excavation equipment.

2. On-site soils may pump or become unstable or unworkable at high water contents, especially for excavations near the water table. Dewatering may be necessary to achieve a stable excavation. Workability may be improved by scarifying and drying. Over-

excavation of wet zones and replacement with granular materials may be necessary. Lightweight excavation equipment may be required to reduce subgrade pumping.

Foundation Preparation:

Footings should bear on compacted native soils as recommended in the **Foundations** section of this report. All loose and/or disturbed soils should either be compacted or removed from the bottoms of footing excavations prior to placement of reinforcing steel and/or concrete.

Fill Materials:

1. If required, native or imported soils with low expansive potentials could be used as fill material for the following:
   - general site grading
   - foundation areas
   - foundation backfill

2. Select granular materials should be used as backfill behind walls that retain earth.

3. On site or imported soils to be used in structural fills should conform to the following:

Gradation	Percent finer by weight (ASTM C136)
3"	100
No. 4 Sieve	50-100
No. 200 Sieve	50 Max

Maximum expansive potential (%)* 1.5

* Measured on a sample compacted to approximately 95 percent of the ASTM D1557 maximum dry density at about 3 percent below optimum water content. The sample is confined under a 144-psf surcharge and submerged.

4. Aggregate base should conform to Class I Aggregate Base as specified in Section 303 of the 2008 Arizona Department of Transportation (ADOT) *"Standard Specifications for Road and Bridge Construction."*

Placement and Compaction:

1. Place and compact fill in horizontal lifts, using equipment and procedures that will produce recommended moisture contents and densities throughout the lift.

2. Un-compacted fill lifts should not exceed 10 inches loose thickness.

3. Materials should be compacted to the following:

Material	Minimum Percent (ASTM D1557)
Subgrade soils beneath fill areas	95
On site or imported soil fills:	
Beneath footings, slabs on grade and pavements	95
Aggregate base beneath slabs and pavements	95
Miscellaneous backfill	90

4. On-site and imported soils should be compacted at moisture contents near optimum.

Compliance:

Recommendations for slabs-on-grade and foundation elements supported on compacted fills depend upon compliance with **Earthwork** recommendations. To assess compliance, observation and testing should be performed by GEOMAT.

Drainage:

Surface Drainage:

1. Positive drainage should be provided during construction and maintained throughout the life of the proposed project. Infiltration of water into utility or foundation excavations must be prevented during construction.

2. We recommend that protective slopes be provided with a minimum grade of approximately 5 percent for at least 10 feet from foundations.

Subsurface Drainage:

Free-draining, granular soils containing less than five percent fines (by weight) passing a No. 200 sieve should be placed adjacent to walls which retain earth. A drainage system consisting of either weep holes or perforated drain lines (placed near the base of the wall) should be used to intercept and discharge water which would tend to saturate the backfill. Where used, drain lines should be embedded in a uniformly graded filter material and provided with adequate clean-outs for periodic maintenance. An impervious soil should be used in the upper layer of backfill to reduce the potential for water infiltration.

GENERAL COMMENTS

It is recommended that GEOMAT be retained to provide a general review of final design plans and specifications in order to confirm that grading and foundation recommendations in this report have been interpreted and implemented. In the event that any changes of the proposed project are planned, the opinions and recommendations contained in this report should be reviewed and the report modified or supplemented as necessary.

GEOMAT should also be retained to provide services during excavation, grading, foundation, and construction phases of the work. Observation of footing excavations should be performed prior to placement of reinforcing and concrete to confirm that satisfactory bearing materials are present and is considered a necessary part of continuing geotechnical engineering services for the project. Construction testing, including field and laboratory evaluation of fill, backfill, pavement materials, concrete and steel should be performed to determine whether applicable project requirements have been met.

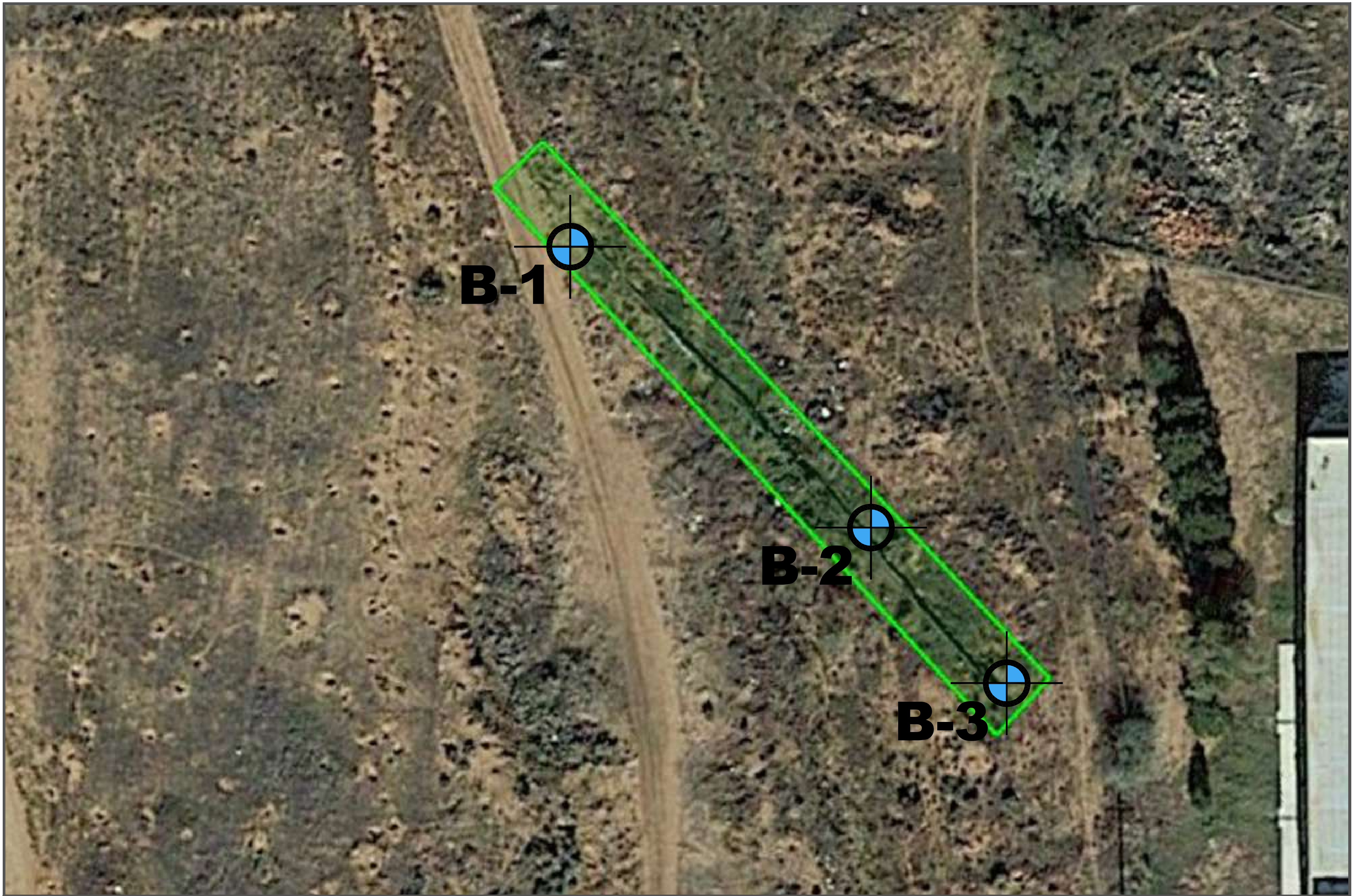
The analyses and recommendations in this report are based in part upon data obtained from the field exploration. The nature and extent of variations beyond the location of test borings may not become evident until construction. If variations then appear evident, it may be necessary to re-evaluate the recommendations of this report.

Our professional services were performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical engineers practicing in this or similar localities at the same time. No warranty, express or implied, is intended or made. We prepared the report as an aid in design of the proposed project. This report is not a bidding document. Any contractor reviewing this report must draw his own conclusions regarding site conditions and specific construction equipment and techniques to be used on this project.

This report is for the exclusive purpose of providing geotechnical engineering and/or testing information and recommendations. The scope of services for this project does not include, either specifically or by implication, any environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential for such contamination, other studies should be undertaken. This report has also not addressed any geologic hazards that may exist on or near the site.

This report may be used only by the Client and only for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both on and off site), or other factors may change over time and additional work may be required with the passage of time. Any party, other than the Client, who wishes to use this report, shall notify GEOMAT in writing of such intended use. Based on the intended use of the report, GEOMAT may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements, by the Client or anyone else, will release GEOMAT from any liability resulting from the use of this report by an unauthorized party.

Appendix A



Approximate

Not to Scale

SITE PLAN

Boring Locations (approximate)

GEOMAT Project No. 222-3930

Date of Exploration: February 3, 2022

PROJECT

Ft. Defiance Sewer Line

Arroyo Crossing

Ft. Defiance, Arizona

GEOMAT INC.

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Boring B-1

Project Name:	Ft. Defiance Sewer Line Arroyo Crossing
Project Number:	222-3930
Client:	Bohannon Huston
Site Location:	Ft. Defiance, Arizona
Rig Type:	CME-45
Drilling Method:	7.25" O.D. Hollow Stem Auger
Sampling Method:	Bulk, Ring and Split spoon samples
Hammer Weight:	140 lbs
Hammer Fall:	30 inches
Date Drilled:	2/3/2022
Latitude:	Not Determined
Longitude:	Not Determined
Elevation:	Not Determined
Boring Location:	See Site Plan
Groundwater Depth:	None Encountered
Logged By:	DH
Remarks:	None

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Symbol	Material Type	Soil Symbol	Depth (ft)	Soil Description
							SM		0–10	Silty SAND, red/brown, fine- to coarse-grained, loose to medium dense, damp
101.6			5.4	8-11	R				3	
									4	gravel lense
				12-11-9	SS				5	
	23	NP			GRAB				8	
87.0			32.6	5-6	R		ML		10–15	Sandy SILT, red/brown/gray, medium stiff, damp to moist
				5-4-2	SS		SM		15–16½	Silty SAND, red/brown, fine- to coarse-grained, loose, moist
									16½	Total Depth 16½ feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample PP = Pocket Penetrometer

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Boring B-2

Project Name:	Ft. Defiance Sewer Line Arroyo Crossing	Date Drilled:	2/3/2022
Project Number:	222-3930	Latitude:	Not Determined
Client:	Bohannon Huston	Longitude:	Not Determined
Site Location:	Ft. Defiance, Arizona	Elevation:	Not Determined
Rig Type:	CME-45	Boring Location:	See Site Plan
Drilling Method:	7.25" O.D. Hollow Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Ring and Split spoon samples	Logged By:	DH
Hammer Weight:	140 lbs	Remarks:	None
Hammer Fall:	30 inches		

Laboratory Results										
Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Symbol	Material Type	Soil Symbol	Depth (ft)	Soil Description
									1	Silty SAND, red/brown, fine- to coarse-grained, loose to medium dense, damp
									2	
				4-4-3	SS				3	red/tan
									4	clayey sand lense
109.9			9.6	6-8	R				5	red/brown, fine- to medium- grained, slightly damp to damp
									6	
									7	
							SM		8	
									9	
				4-5-6	SS				10	red/orange/tan
									11	
									12	
									13	
									14	
98.8			23.3	7-5	R				15	damp to moist
									16	Total Depth 16 feet
									17	
									18	
									19	
									20	

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample PP = Pocket Penetrometer

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Boring B-3

Project Name: Ft. Defiance Sewer Line Arroyo Crossing
Project Number: 222-3930
Client: Bohannon Huston
Site Location: Ft. Defiance, Arizona
Rig Type: CME-45
Drilling Method: 7.25" O.D. Hollow Stem Auger
Sampling Method: Bulk, Ring and Split spoon samples
Hammer Weight: 140 lbs
Hammer Fall: 30 inches

Date Drilled: 2/3/2022
Latitude: Not Determined
Longitude: Not Determined
Elevation: Not Determined
Boring Location: See Site Plan
Groundwater Depth: None Encountered
Logged By: DH
Remarks: None

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Material Type	Depth (ft)	Soil Description
							0	Silty SAND, red/brown, fine- to coarse-grained, loose, damp
97.9			4.7	8-13	R	SM	3	
	53	NP		8-7-7	SS		5	Sandy SILT, red/brown, fine-grained, stiff, slightly damp to damp
							7.5	brown
							9.5	red/tan
					GRAB		10	
97.4			6.1	9-12	R	ML	10	
							15	red/brown
				2-3-3	SS	SM	15	Silty SAND, red/dark brown, fine- to coarse-grained, loose, damp
							16.5	Total Depth 16½ feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample PP = Pocket Penetrometer

UNIFIED SOIL CLASSIFICATION SYSTEM				
Major Divisions			Group Symbols	Typical Names
Coarse-Grained Soils More than 50% retained on No. 200 sieve	**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 passes No. 200 sieve	**Silts and Clays** Liquid Limit 50 or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			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 greater than 50		MH	Inorganic silts, micaceous or diatomaceous free sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, mucic & other highly organic soils

CONSISTENCY OR RELATIVE DENSITY CRITERIA

Standard Penetration Test
Density of Granular Soils

Penetration Resistance, N (blows/ft.)	Relative Density
0-4	Very Loose
5-10	Loose
11-30	Medium Dense
31-50	Dense
>50	Very Dense

Standard Penetration Test
Density of Fine-Grained Soils

Penetration Resistance, N (blows/ft.)	Consistency	Unconfined Compressive Strength (Tons/ft2)
<2	Very Soft	<0.25
2-4	Soft	0.25-0.50
4-8	Firm	0.50-1.00
8-15	Stiff	1.00-2.00
15-30	Very Stiff	2.00-4.00
>30	Hard	>4.0

U.S. Standard Sieve Sizes

>12"	12"	3"	3/4"	#4	#10	#40	#200
Boulders	Cobbles	Gravel		Sand			Silt or Clay
		coarse	fine	coarse	medium	fine	

MOISTURE CONDITIONS

Dry	Absence of moist, dusty, dry to the touch
Slightly Damp	Below optimum moisture content for compaction
Moist	Near optimum moisture content, will moisten the hand
Very Moist	Above optimum moisture content
Wet	Visible free water, below water table

MATERIAL QUANTITY

trace	0-5%
few	5-10%
little	10-25%
some	25-45%
mostly	50-100%

OTHER SYMBOLS

R Ring Sample
S SPT Sample
B Bulk Sample
▼ Ground Water

BASIC LOG FORMAT:
Group name, Group symbol, (grain size), color, moisture, consistency or relative density. Additional comments: odor, presence of roots, mica, gypsum, coarse particles, etc.

EXAMPLE:
SILTY SAND w/trace silt (SM-SP), Brown, loose to med. Dense, fine to medium grained, damp

UNIFIED SOIL CLASSIFICATION SYSTEM

TEST DRILLING EQUIPMENT & PROCEDURES

Description of Subsurface Exploration Methods

Drilling Equipment – Truck-mounted drill rigs powered with gasoline or diesel engines are used in advancing test borings. Drilling through soil or softer rock is performed with hollow-stem auger or continuous flight auger. Carbide insert teeth are normally used on bits to penetrate soft rock or very strongly cemented soils which require blasting or very heavy equipment for excavation. Where refusal is experienced in auger drilling, the holes are sometimes advanced with tricone gear bits and NX rods using water or air as a drilling fluid.

Coring Equipment – Portable electric core drills are used when recovery of asphalt or concrete cores is necessary. The core drill is equipped with either a 4" or 6" diameter diamond core barrel. Water is generally used as a drilling fluid to facilitate cooling and removal of cuttings from the annulus.

Sampling Procedures - Dynamically driven tube samples are usually obtained at selected intervals in the borings by the ASTM D1586 test procedure. In most cases, 2" outside diameter, 1 3/8" inside diameter, samplers are used to obtain the standard penetration resistance. "Undisturbed" samples of firmer soils are often obtained with 3" outside diameter samplers lined with 2.42" inside diameter brass rings. The driving energy is generally recorded as the number of blows of a 140-pound, 30-inch free fall drop hammer required to advance the samplers in 6-inch increments. These values are expressed in blows per foot on the boring logs. However, in stratified soils, driving resistance is sometimes recorded in 2- or 3-inch increments so that soil changes and the presence of scattered gravel or cemented layers can be readily detected and the realistic penetration values obtained for consideration in design. "Undisturbed" sampling of softer soils is sometimes performed with thin-walled Shelby tubes (ASTM D1587). Tube samples are labeled and placed in watertight containers to maintain field moisture contents for testing. When necessary for testing, larger bulk samples are taken from auger cuttings. Where samples of rock are required, they are obtained by NX diamond core drilling (ASTM D2113).

Boring Records - Drilling operations are directed by our field engineer or geologist who examines soil recovery and prepares boring logs. Soils are visually classified in accordance with the Unified Soil Classification System (ASTM D2487), with appropriate group symbols being shown on the logs.

Appendix B

LAB NO.	BORING NO.	SAMPLE DEPTH (ft)	MOISTURE CONT. (%)	DENSITY		ATTERBERG LIMITS			% PASS # 200 SIEVE	CONSOL TEST	CLASSIFICATION
				WET (pcf)	DRY (pcf)	LL	PL	PI			
7323	B-1	2.5	5.4	107.0	101.6	-	-	-	-	-	Silty **SAND** (SM)
7324*	B-1	5	-	-	-	-	-	-	-	-	Silty **SAND** (SM)
7325	B-1	7.5	-	-	-	NLL	NPL	NP	23	-	Silty **SAND** (SM)
7326	B-1	10	32.6	115.4	87.0	-	-	-	-	-	Sandy **SILT** (ML)
7327	B-2	5	9.6	120.5	109.9	-	-	-	-	Attached	Silty **SAND** (SM)
7328	B-2	15	23.3	121.8	98.8	-	-	-	-	-	Silty **SAND** (SM)
7330	B-3	2.5	4.7	102.5	97.9	-	-	-	-	Attached	Silty **SAND** (SM)
7331	B-3	5.0	-	-	-	NLL	NPL	NP	53	-	Sandy **SILT** (ML)
7332	B-3	10.0	6.1	103.4	97.4	-	-	-	-	-	Sandy **SILT** ()ML)
											NLL = No Liquid Limit NPL = No Plastic Limit NP = Non-Plastic * = Corrosivity Sample

GEOMAT INC.

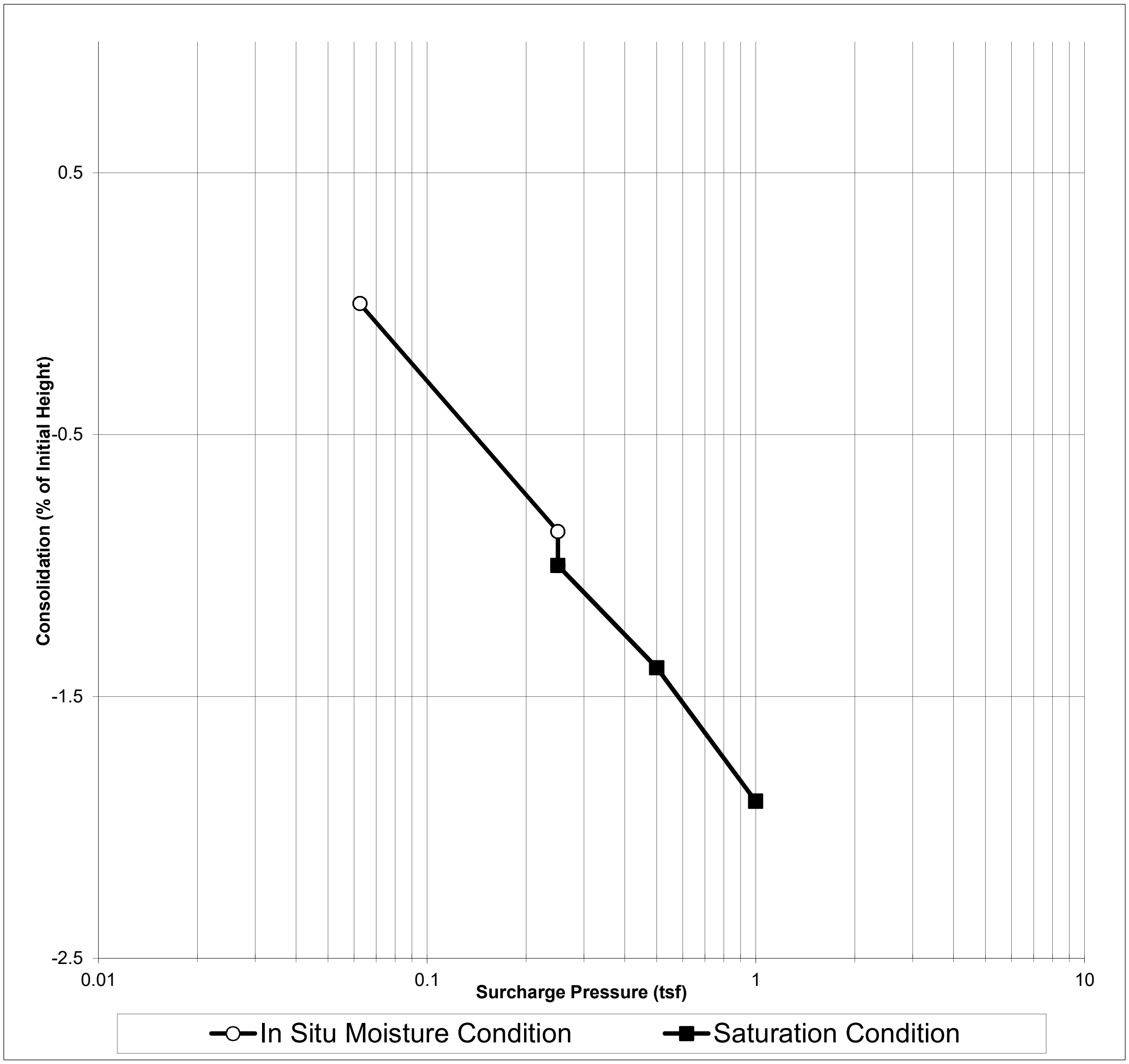
SUMMARY OF SOIL TESTS

Project	Ft. Defiance Sewer Line Arroyo Crossing
Job No.	222-3930
Location	Ft. Defiance, Arizona
Date of Exploration	February 3, 2022

PROJECT:	Ft. Defiance Sewer Line Arroyo Crossing	**JOB NO:**	222-3930
CLIENT:	Bohannon Hustion	**WORK ORDER NO:**	NA
MATERIAL:	Silty SAND (SM)	**LAB NO:**	7327
SAMPLE SOURCE:	B-2 @ 5'	**DATE SAMPLED:**	2/3/2022
SAMPLE PREP.:	In Situ	**SAMPLED BY:**	DH

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (ASTM D2435)

INITIAL VOLUME (cu.in)	4.60	FINAL VOLUME (cu.in)	4.52
INITIAL MOISTURE CONTENT	9.6%	FINAL MOISTURE CONTENT	15.4%
INITIAL DRY DENSITY(pcf)	109.9	FINAL DRY DENSITY(pcf)	111.5
INITIAL DEGREE OF SATURATION	36%	FINAL DEGREE OF SATURATION	59%
INITIAL VOID RATIO	0.51	FINAL VOID RATIO	0.48
ESTIMATED SPECIFIC GRAVITY	2.651	SATURATED AT	0.25 tsf

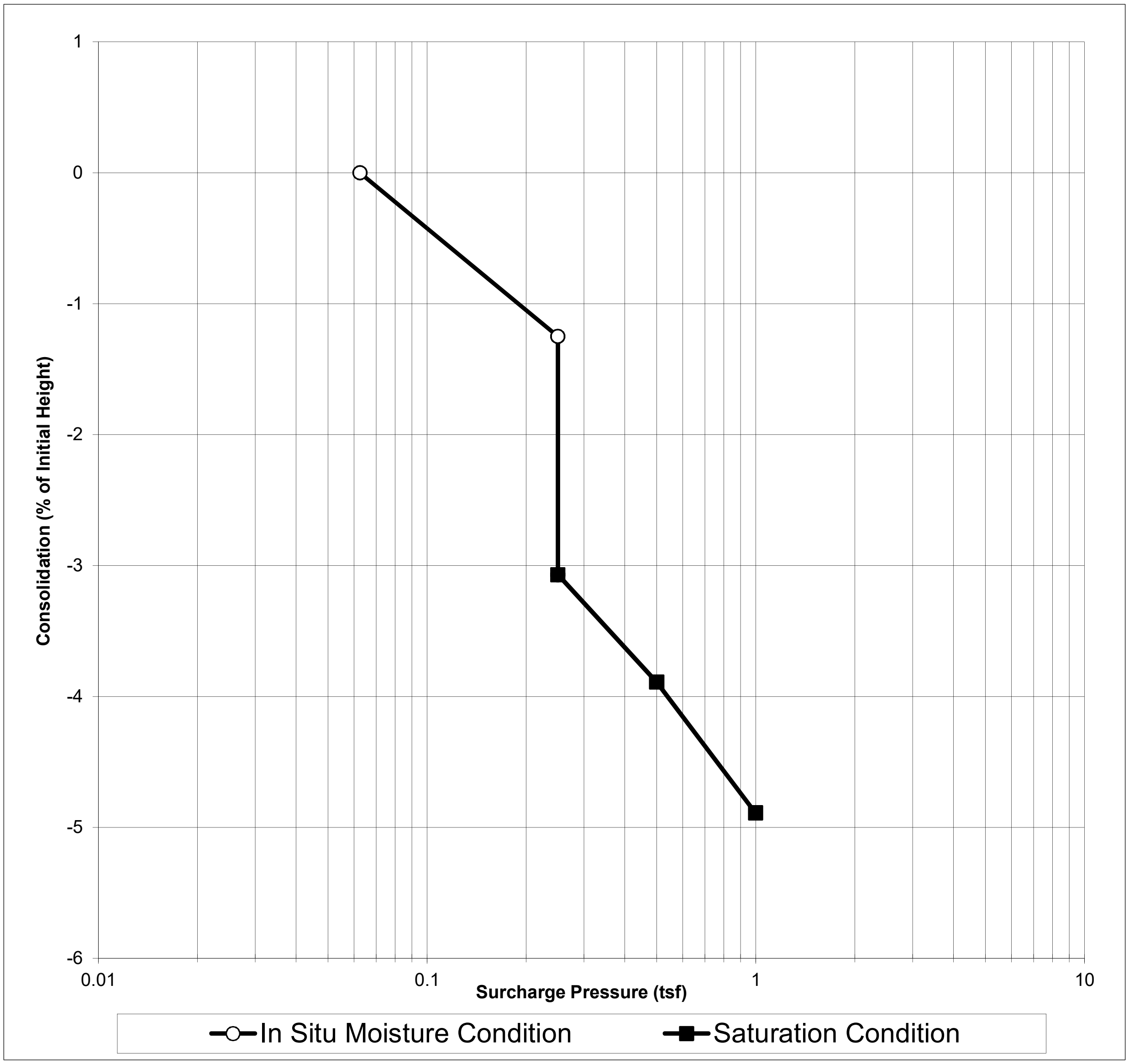


GEOMAT INC.

PROJECT:	Ft. Defiance Sewer Line Arroyo Crossing	**JOB NO:**	222-3930
CLIENT:	Bohannon Hustion	**WORK ORDER NO:**	NA
MATERIAL:	Silty SAND (SM)	**LAB NO:**	7330
SAMPLE SOURCE:	B-3 @ 2.5'	**DATE SAMPLED:**	2/3/2022
SAMPLE PREP.:	In Situ	**SAMPLED BY:**	DH

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (ASTM D2435)

INITIAL VOLUME (cu.in)	4.60	FINAL VOLUME (cu.in)	4.38
INITIAL MOISTURE CONTENT	4.7%	FINAL MOISTURE CONTENT	21.7%
INITIAL DRY DENSITY(pcf)	97.9	FINAL DRY DENSITY(pcf)	102.4
INITIAL DEGREE OF SATURATION	14%	FINAL DEGREE OF SATURATION	70%
INITIAL VOID RATIO	0.70	FINAL VOID RATIO	0.61
ESTIMATED SPECIFIC GRAVITY	2.651	SATURATED AT	0.25 tsf



GEOMAT INC.

LABORATORY TESTING PROCEDURES

Laboratory testing is performed by trained personnel in our accredited laboratory or may be subcontracted by GEOMAT through a qualified outside laboratory if necessary. Actual types and quantities of tests performed for any project will be dependent upon subsurface conditions encountered and specific design requirements.

The following is an abbreviated table of laboratory testing that may be performed by GEOMAT with the applicable standards listed. Testing for a specific project may include all or a selected subset of the laboratory work listed. Laboratory testing beyond those listed may be available and could be incorporated into the project scope at the discretion of GEOMAT.

PROCEDURE	ASTM	AASHTO
Moisture Content	ASTM D2216	AASHTO T 265
Sieve Analysis	ASTM C136	AASHTO T 27
Fines Content	ASTM D1140	T 11
Hydrometer	ASTM D422	T 88
Atterberg Limits	ASTM D4318	AASHTO T 89/T 90
Soil Compression/Expansion	ASTM D2435	T 216
Soil Classification	ASTM D2487	M 145
Direct Shear	ASTM D3080	T 236
Unconfined Compressive Strength of Soils	ASTM D2166	T 208
Unconfined Compressive Strength of Rock Cores	ASTM D4543	-

Appendix C

Important Information about This

Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, you can benefit from a lowered exposure to problems associated with subsurface conditions at project sites and development of them that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed herein, contact your GBA-member geotechnical engineer. Active engagement in GBA exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project.

Understand the Geotechnical-Engineering Services Provided for this Report

Geotechnical-engineering services typically include the planning, collection, interpretation, and analysis of exploratory data from widely spaced borings and/or test pits. Field data are combined with results from laboratory tests of soil and rock samples obtained from field exploration (if applicable), observations made during site reconnaissance, and historical information to form one or more models of the expected subsurface conditions beneath the site. Local geology and alterations of the site surface and subsurface by previous and proposed construction are also important considerations. Geotechnical engineers apply their engineering training, experience, and judgment to adapt the requirements of the prospective project to the subsurface model(s). Estimates are made of the subsurface conditions that will likely be exposed during construction as well as the expected performance of foundations and other structures being planned and/or affected by construction activities.

The culmination of these geotechnical-engineering services is typically a geotechnical-engineering report providing the data obtained, a discussion of the subsurface model(s), the engineering and geologic engineering assessments and analyses made, and the recommendations developed to satisfy the given requirements of the project. These reports may be titled investigations, explorations, studies, assessments, or evaluations. Regardless of the title used, the geotechnical-engineering report is an engineering interpretation of the subsurface conditions within the context of the project and does not represent a close examination, systematic inquiry, or thorough investigation of all site and subsurface conditions.

Geotechnical-Engineering Services are Performed for Specific Purposes, Persons, and Projects, and At Specific Times

Geotechnical engineers structure their services to meet the specific needs, goals, and risk management preferences of their clients. A geotechnical-engineering study conducted for a given civil engineer will not likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client.

Likewise, geotechnical-engineering services are performed for a specific project and purpose. For example, it is unlikely that a geotechnical-engineering study for a refrigerated warehouse will be the same as one prepared for a parking garage; and a few borings drilled during a preliminary study to evaluate site feasibility will not be adequate to develop geotechnical design recommendations for the project.

Do not rely on this report if your geotechnical engineer prepared it:
- for a different client;
- for a different project or purpose;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it; e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, the reliability of a geotechnical-engineering report can be affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. *If you are the least bit uncertain* about the continued reliability of this report, contact your geotechnical engineer before applying the recommendations in it. A minor amount of additional testing or analysis after the passage of time – if any is required at all – could prevent major problems.

Read this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read the report in its entirety. Do not rely on an executive summary. Do not read selective elements only. *Read and refer to the report in full.*

You Need to Inform Your Geotechnical Engineer About Change

Your geotechnical engineer considered unique, project-specific factors when developing the scope of study behind this report and developing the confirmation-dependent recommendations the report conveys. Typical changes that could erode the reliability of this report include those that affect:
- the site's size or shape;
- the elevation, configuration, location, orientation, function or weight of the proposed structure and the desired performance criteria;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project or site changes – even minor ones – and request an assessment of their impact. *The geotechnical engineer who prepared this report cannot accept* *responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.*

Most of the "Findings" Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site's subsurface using various sampling and testing procedures. *Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing is performed.* The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgement to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team through project completion to obtain informed guidance quickly, whenever needed.

This Report's Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, they are not final, because the geotechnical engineer who developed them relied heavily on judgement and opinion to do so. Your geotechnical engineer can finalize the recommendations *only after observing actual subsurface conditions* exposed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. *The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation.*

This Report Could Be Misinterpreted

Other design professionals' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a continuing member of the design team, to:

- confer with other design-team members;
- help develop specifications;
- review pertinent elements of other design professionals' plans and specifications; and
- be available whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction-phase observations.

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, *but be certain to note conspicuously that you've included the material for information purposes only.* To avoid misunderstanding, you may also want to note that "informational purposes" means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, *only* from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and *be sure to allow enough time* to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. This happens in part because soil and rock on project sites are typically heterogeneous and not manufactured materials with well-defined engineering properties like steel and concrete. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a "phase-one" or "phase-two" environmental site assessment – differ significantly from those used to perform a geotechnical-engineering study. For that reason, a geotechnical-engineering report does not usually provide environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated subsurface environmental problems have led to project failures.* If you have not obtained your own environmental information about the project site, ask your geotechnical consultant for a recommendation on how to find environmental risk-management guidance.

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, the engineer's services were not designed, conducted, or intended to prevent migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, ***proper implementation of the geotechnical engineer's recommendations will not of itself be sufficient to prevent moisture infiltration. Confront the risk of moisture infiltration*** by including building-envelope or mold specialists on the design team. ***Geotechnical engineers are not building-envelope or mold specialists.***

GEOPROFESSIONAL BUSINESS ASSOCIATION

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