SUBSURFACE STUDY

FOR

THE PLANNED TOWNHOME BUILDINGS

5667 WEST 38TH AVENUE

WHEAT RIDGE, COLORADO

Job Number 21-228
April 28, 2021

PREPARED FOR

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0.1 Purpose and scope of work

This report presents the results of a subsurface study for the planned townhome buildings to be located at 5667 West 38th Avenue in Wheat Ridge, Colorado. The subsurface study was conducted for the purpose of developing foundation recommendations. The project site is shown on Fig. 1. The study was conducted in accordance with our proposal P21-149 dated April 2, 2021.

A field exploration program consisting of drilling three exploratory borings was conducted to obtain information on subsurface conditions. Material samples obtained during the field exploration were tested in the laboratory to determine the classification and engineering characteristics of the on-site soils. The results of the field exploration and laboratory testing were analyzed to develop foundation recommendations and allowable bearing pressures. The results of the field exploration and laboratory testing are presented herein.

This report has been prepared to summarize the data obtained during this study and to present our conclusions and recommendations based on the proposed construction and the subsurface conditions encountered. Design parameters and a discussion of geotechnical engineering considerations related to construction of the planned townhome buildings are included in the report.

0.2 Proposed construction

It is our understanding that (1) 4-unit townhome building and (1) 8-unit townhome building on crawlspaces or slabs are planned. Foundation loads are expected to be light as is typical for this type of construction. If the design varies from the project description above, the recommendations presented in this report should be reevaluated.

0.3 Site conditions

At the time of our field investigation, the site had an existing one-story house founded on a full basement. The site was fully landscaped with lawn, shrubs, and mature trees. The site was relatively flat.

0.4 Field exploration

The field exploration for the project was conducted on April 9, 2021. Three exploratory borings were drilled at the locations shown on Fig. 1 to explore the subsurface conditions. The locations of the exploratory borings were determined by Hollingsworth Associates personnel based on site access conditions.

The borings were advanced through the soils with a 4-inch diameter continuous flight auger. The borings were logged by a project engineer.

Samples of the subsurface materials were taken with a 2-inch I.D. spoon sampler. The sampler was driven into the various strata with blows from a 140-pound hammer falling 30 inches. This test is similar to the standard penetration test described by ASTM Method D-1586. Penetration resistance values, when properly evaluated, indicate the relative density or consistency of the soils and bedrock. Depths at which the samples were taken and the penetration resistance values are shown on the Logs of Exploratory Borings, Fig. 2 with a legend and notes shown on Fig. 3.

Measurement of the water level was made in the borings by lowering an M-scope into the open hole shortly after completion of drilling.

0.5 Laboratory testing

The samples obtained from the exploratory borings were examined and visually classified in the laboratory by the project engineer. Laboratory testing included standard property tests, such as natural moisture content (ASTM D-2216), dry unit weights, grain size analysis (ASTM D-422), and liquid and plastic limits (ASTM D-4318). Swell-consolidation tests (similar to ASTM D-2435) were conducted on five samples of the upper soils to determine the compressibility or swell characteristics under loading when submerged in water. The percentage of water soluble sulfates was determined in general accordance with "Standard Methods for the Examination of Water and Wastewater, 15th ed.", for one selected sample.

Results of the laboratory testing are shown on Figs. 4 through 9 and summarized in Table I. The laboratory testing was conducted in general accordance with applicable ASTM standards.

0.6 Subsurface conditions

The subsurface conditions at the site were quite uniform, as indicated by exploratory borings B-1 through B-3, and consisted of 12 inches of topsoil, 3 to 7 feet of loose to medium dense silty to clayey sand, and 3 feet to 11 feet of stiff to hard sandy clay overlying hard claystone/sandstone for the depth drilled, 21 feet. In exploratory boring B-1 the sandy clay was underlain by silty to clayey sand. Free water was encountered in exploratory borings B-1 at depth 13.5 feet and B-2 at depth of 18 feet at the time of drilling.

Gradations of typical samples of the sandy clay are shown on Figs. 4 and 6. The sandy clay possesses a low to high swell potential with a percent swell ranging from 0.3% to 4.7% and an uplift pressure ranging from 600 psf to 16,500 psf when wetted under constant load as indicated by the swell-consolidation test results shown on Figs. 7 and 9. A gradation of a typical sample of the clayey sand is shown on Fig. 4. The clayey sand possesses a high swell potential with a percent swell of 4.4% and an uplift pressure of 5,700 psf when wetted under constant load as indicated by the swell-consolidation test results shown on Fig. 7. Gradations of typical samples of the silty sand are shown on Fig. 5. The silty sand settled upon loading and when wetted under constant load as indicated by the swell-consolidation test results shown on Fig. 8. The laboratory test results are summarized in Table I.

0.7 Foundation recommendations

The proposed townhome buildings are to be founded on either a crawlspace or a slab. There are expansive soils present at or near the foundation bearing depth in the middle to north side of the site. Considering the subsurface conditions encountered in the exploratory borings and the nature of the proposed construction, we recommend the townhome buildings be founded on spread footings bearing on a minimum of 3 feet of properly compacted structural fill. This will require an overexcavation of 3 feet.

The design and construction criteria presented below should be observed for a spread footing foundation system. The construction details should be considered when preparing project documents.

1. Footings bearing on the properly compacted structural fill should be designed for an allowable soil bearing pressure of 3,000 psf. The footings

should also be designed for a minimum dead load pressure of 1,000 psf.

2. Based on one-dimensional consolidation theory, we estimate total settlement for footings designed and constructed as discussed in this section will be approximately 1 inch. Differential settlements across the buildings are estimated to be approximately $\frac{1}{2}$ inch.

3. Exterior footings and footings beneath unheated areas should be provided with adequate soil cover above their bearing elevation for frost protection. Placement of foundations at least 36 inches below the exterior grade is typically used in this area.

4. The lateral resistance of a spread footing bearing on properly compacted structural fill will be a combination of the sliding resistance of the footing on the foundation materials and passive earth pressure against the side of the footing. Resistance to sliding at the bottoms of the footings can be calculated based on a coefficient of friction of 0.40. Passive pressure against the sides of the footings can be calculated using an equivalent fluid unit weight of 250 pcf. The coefficient of friction and passive pressure values recommended above assume mobilization of the ultimate soil strength. Suitable factors of safety should be included in the design to limit the strain that will occur at the ultimate strength, particularly in the case of passive resistance.

5. Continuous foundation walls should be reinforced top and bottom to span an unsupported length of at least 12 feet.

6. Areas of loose material encountered within the foundation excavation should be removed and the footings extended to adequate natural bearing material. As an alternate, the loose material may be removed and replaced with non-expansive fill material compacted to 100% of the maximum standard Proctor (ASTM D-698) density within 2 percentage points of the optimum moisture content. New fill should extend down from the edges of the footings at a 1 horizontal to 1 vertical projection.

7. A representative of the soil engineer should observe all footing excavations prior to concrete placement.

0.8 Floor slabs

Floor slabs present a problem where expansive materials are present near floor slab elevation because sufficient dead load cannot be imposed on them to resist the uplift pressure generated when the materials are wetted and expand. Based on the moisture-volume change characteristics of the materials encountered, we believe slab-on-ground construction may be used, provided the risk of distress resulting from slab movement is accepted by the owner. The following measures should be taken to reduce damage which could result from movement should the underslab materials be subjected to moisture changes.

1. Floor slabs should be separated from all bearing walls and columns with expansion joints that allow unrestrained vertical movement.

2. Interior non-bearing partitions resting on floor slabs should be provided with slip joints at the bottoms so that, if the slabs move, the movement cannot be transmitted to the upper structure. This detail is also important for wallboards, stairways, and doorframes. Slip joints that will allow at least 4 inches of vertical movement are recommended.

3. Floor slab control joints should be used to reduce damage due to shrinkage cracking. We suggest joints be provided on the order of 15 feet on center. The requirements for slab reinforcement should be established by the designer based on experience and the intended slab use.

4. A minimum 4-inch layer of free-draining gravel should be placed beneath the slabs. This material should consist of minus $1\frac{1}{2}$ inch aggregate with less than 10% passing the No. 4 sieve and less than 5% passing the No. 200 sieve. The granular layer will aid in drainage.

5. All plumbing lines should be tested before operation. Where plumbing lines enter through the floor, a positive bond break should be provided. Flexible connections should be provided for slab-bearing mechanical equipment.

0.9 Foundation walls

Foundation walls that are laterally supported and can be expected to undergo only a moderate amount of deflection should be designed for a lateral earth pressure computed based on an equivalent fluid unit weight of 50 pcf for backfill consisting of the on-site soils.

All foundation walls should be designed for appropriate hydrostatic pressures. The pressures recommended above assume drained conditions behind the walls and a horizontal backfill surface. The buildup of water behind a wall or an upward sloping backfill surface will increase the lateral pressure imposed on a foundation wall.

The lateral resistance of foundation wall footings placed on properly compacted structural fill will be a combination of the sliding resistance of the footing on the foundation materials and passive earth pressure against the side of the footing. Resistance to sliding at the bottoms of the footings can be calculated based on a coefficient of friction of 0.4. Passive pressure against the sides of the footings can be calculated an equivalent fluid unit weight of 250 pcf. The coefficient of friction and passive pressure values recommended above assume mobilization of the ultimate soil strength. Suitable factors of safety should be included in the design to limit the strain that will occur at the ultimate strength, particularly in the case of passive resistance.

Compacted fill placed against the sides of the footings to resist lateral loads should be a non-expansive material. Fill should be placed and compacted to at least 95% of the maximum standard Proctor (ASTM D-698) density at a moisture content near optimum.

0.10 Water soluble sulfates

The concentration of water soluble sulfates measured in a sample obtained from the exploratory boring was 0.02%. This concentration of water soluble sulfates represents a negligible degree of sulfate attack on concrete exposed to these materials. The degree of attack is based on a range of negligible, positive, severe, and very severe as presented in the U.S. Bureau of Reclamation Concrete Manual.

Based on this information, we believe special sulfate resistant cement will not be required for concrete exposed to the on-site soils.

0.11 Underdrain system

If the buildings are constructed with crawlspaces, the crawlspace level of the building should be protected by an underdrain system.

The underdrain system should consist of perimeter drains. Free-draining granular material used in the drain system should contain less than 5% passing the No. 200 sieve, less than 10% passing the No. 4 sieve and have a maximum size of $1\frac{1}{2}$ inch.

The drains should consist of drainpipe placed in the bottom of a trench and surrounded above the invert level with free-draining granular material. The free-draining material should extend 1 foot above the top of the footing for an exterior drain or to the interior grade for an interior drain. The perimeter drains should be at least 4 inches in diameter. The drain lines should be placed at least 1 foot below the interior grade and graded to sumps at a minimum slope of $\frac{1}{2}\%$. The underdrain system should be sloped to a sump where water can be removed by pumping or gravity drainage.

0.12 Surface drainage

The following drainage precautions should be observed during construction and maintained at all times after the buildings have been completed.

1. Excessive wetting or drying of the foundation excavations and under-slab areas should be avoided during construction.

2. Exterior backfill should be adjusted to near optimum moisture and compacted to at least 95% of the maximum standard Proctor (ASTM D-698) density in pavement areas and to at least 90% of the maximum standard Proctor (ASTM D-698) density in landscape areas.

3. The ground surface surrounding the exteriors of the buildings should be sloped to drain away from the foundation in all directions. We recommend a minimum slope of 6 inches in the first 10 feet in unpaved areas and a minimum slope of 3 inches in the first 10 feet in paved areas.

4. Roof downspouts and drains should discharge well beyond the limits of all backfill.

0.13 Limitations

This report has been prepared in accordance with generally accepted soil and foundation engineering practices in this area for use by the client for design purposes. The conclusions and recommendations submitted in this report are based upon the data obtained from the exploratory borings drilled at the locations on the exploratory boring plan and the proposed type of construction. The nature and extent of subsurface variations across the site may not become evident until excavation is performed. If during construction, fill, soil, rock, or water conditions appear to be different from those described herein, this office should be advised at once so reevaluation of the recommendations may be made. We recommend on-site observation of excavations and foundation bearing strata by a representative of the soil engineer.

Sincerely,
HOLLINGSWORTH ASSOCIATES, INC.

COLORADO REGISTERED PROFESSIONAL ENGINEER
THOMAS R. HOLLINGSWORTH
26360
4/28/21

Thomas R. Hollingsworth, P.E.
TRH: cm
Attachments

Thomas R Hollingsworth

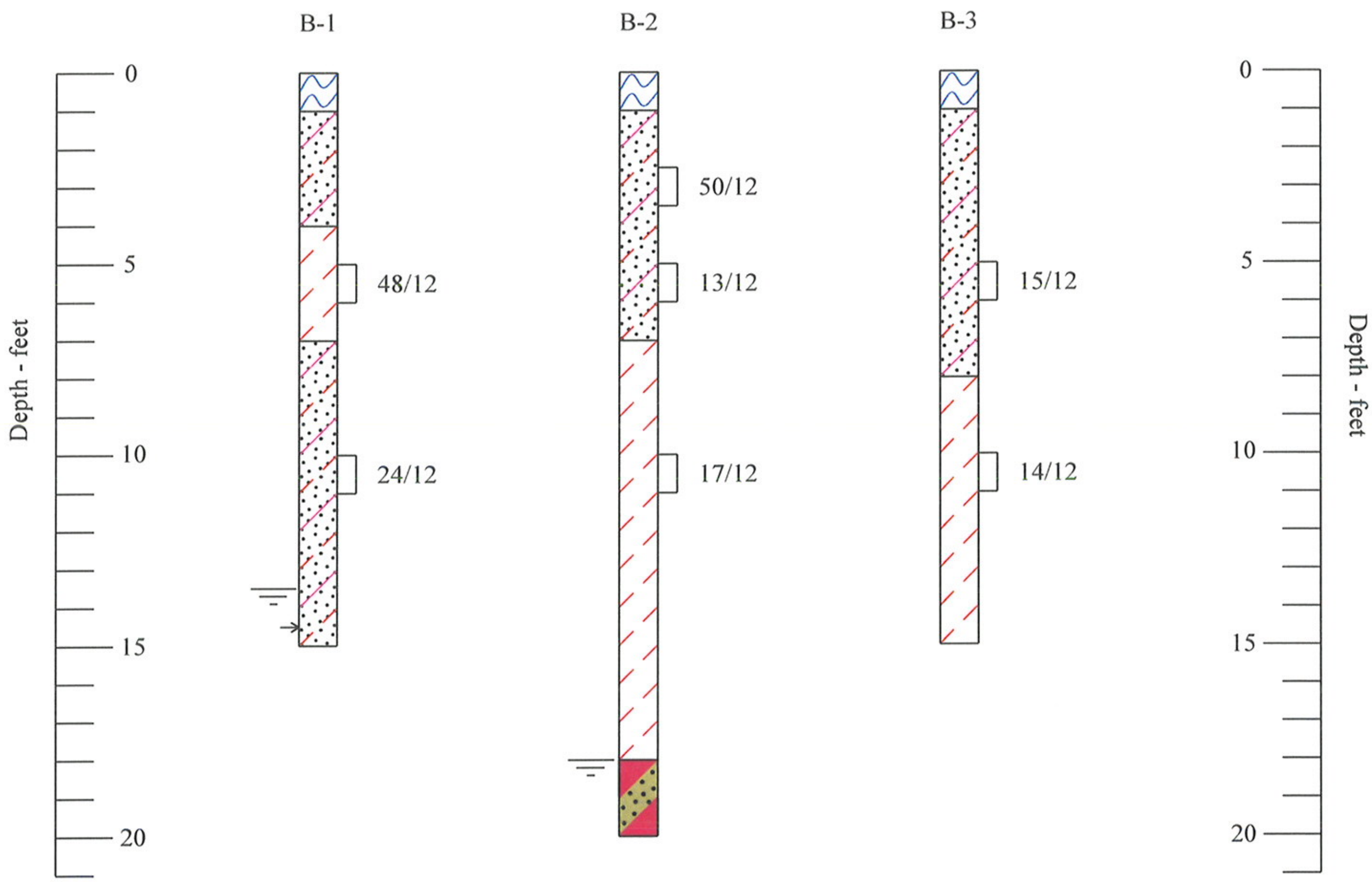
Digitally signed by Thomas R Hollingsworth
Date: 2021.04.28 15:10:06 -06'00'

N

Not to scale

● B-1 --Exploratory boring

21-228	HOLLINGSWORTH ASSOCIATES Geotechnical/Environmental Engineers	Locations of Exploratory Borings	Fig. 1



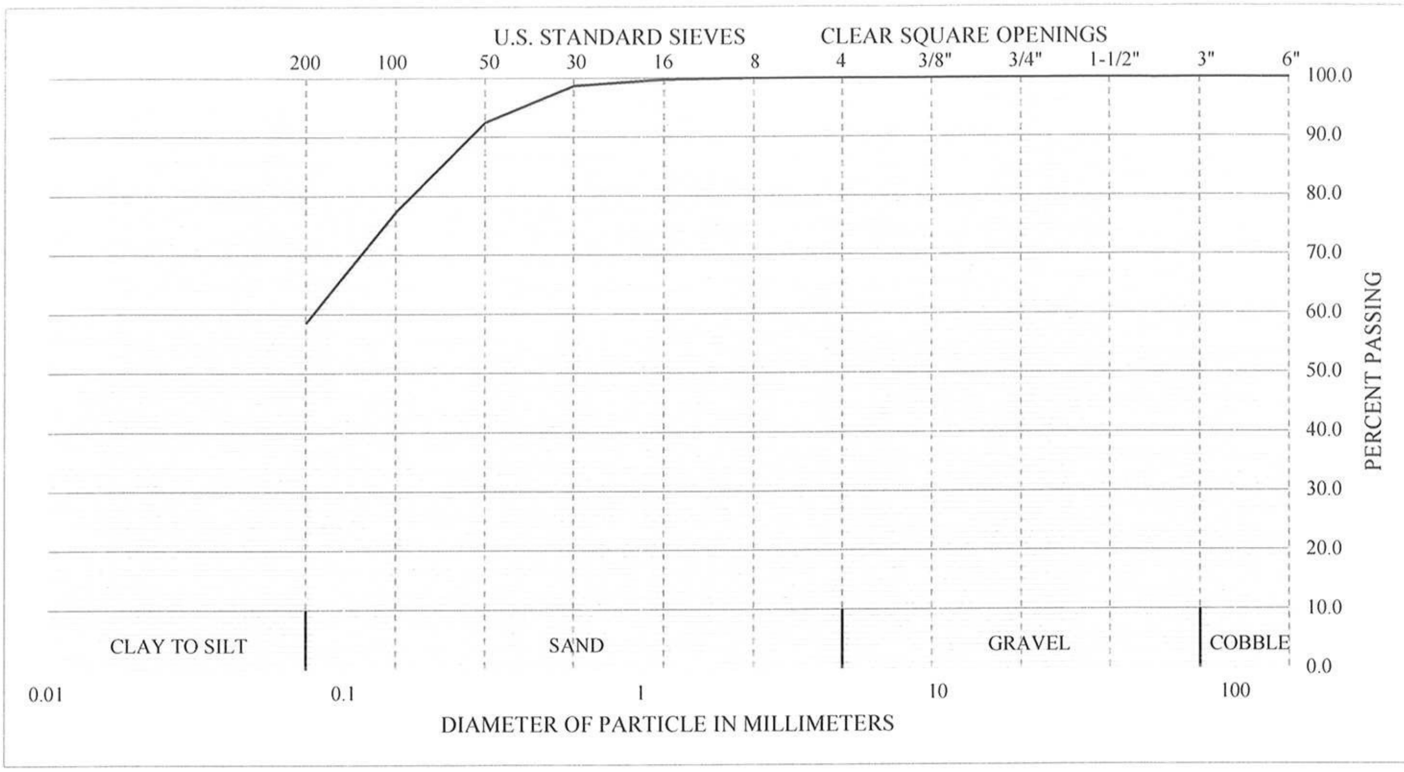
21-228	HOLLINGSWORTH ASSOCIATES Geotechnical/Environmental Engineers	Logs of Exploratory Borings	Fig. 2

LEGEND

	Topsoil.
	Sand (SM-SC), clayey to silty, loose to medium dense, light brown, moist.
	Clay (CL), sandy, stiff to hard, gray, moist.
	Claystone/sandstone, interlayered and intergraded, hard, gray, moist.
	Drive sample, 2-inch I.D., California liner sample.
48/12	Drive sample blow count. Indicates that 48 blows of a 140-pound hammer falling 30 inches were required to drive the California sampler 12 inches.
	Depth to water level at the time of drilling.
	Depth at which boring caved.

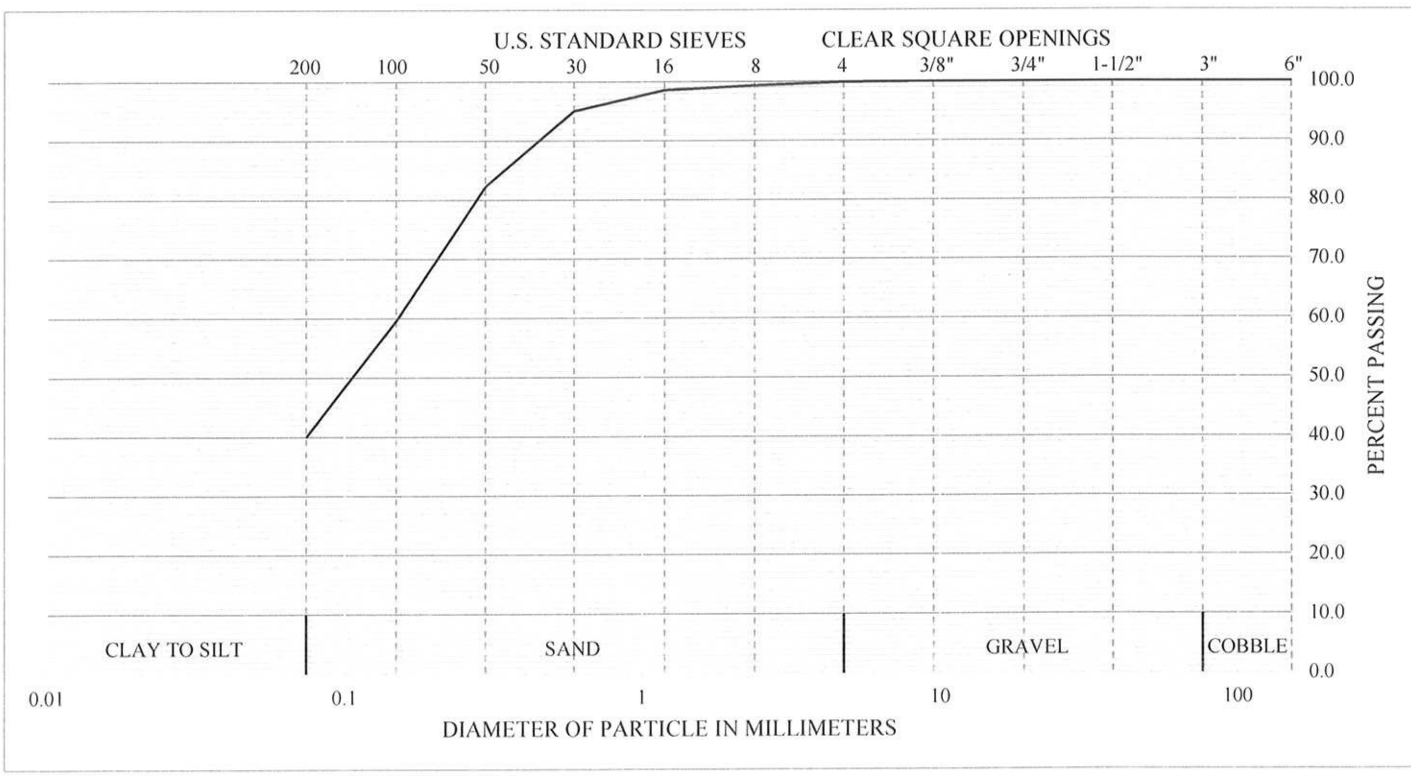
NOTES

1. The exploratory borings were drilled on April 9, 2021, with a 4-inch diameter continuous flight auger.
2. The exploratory borings were located in the field by HA personnel based on site access conditions.
3. Logs are drawn to depth.
4. The lines between materials shown in the borings represent the approximate boundaries between material types and the transitions may be gradual.
5. Water level readings shown on the logs were made at the time and under conditions indicated. Fluctuations in the water levels may occur with time.



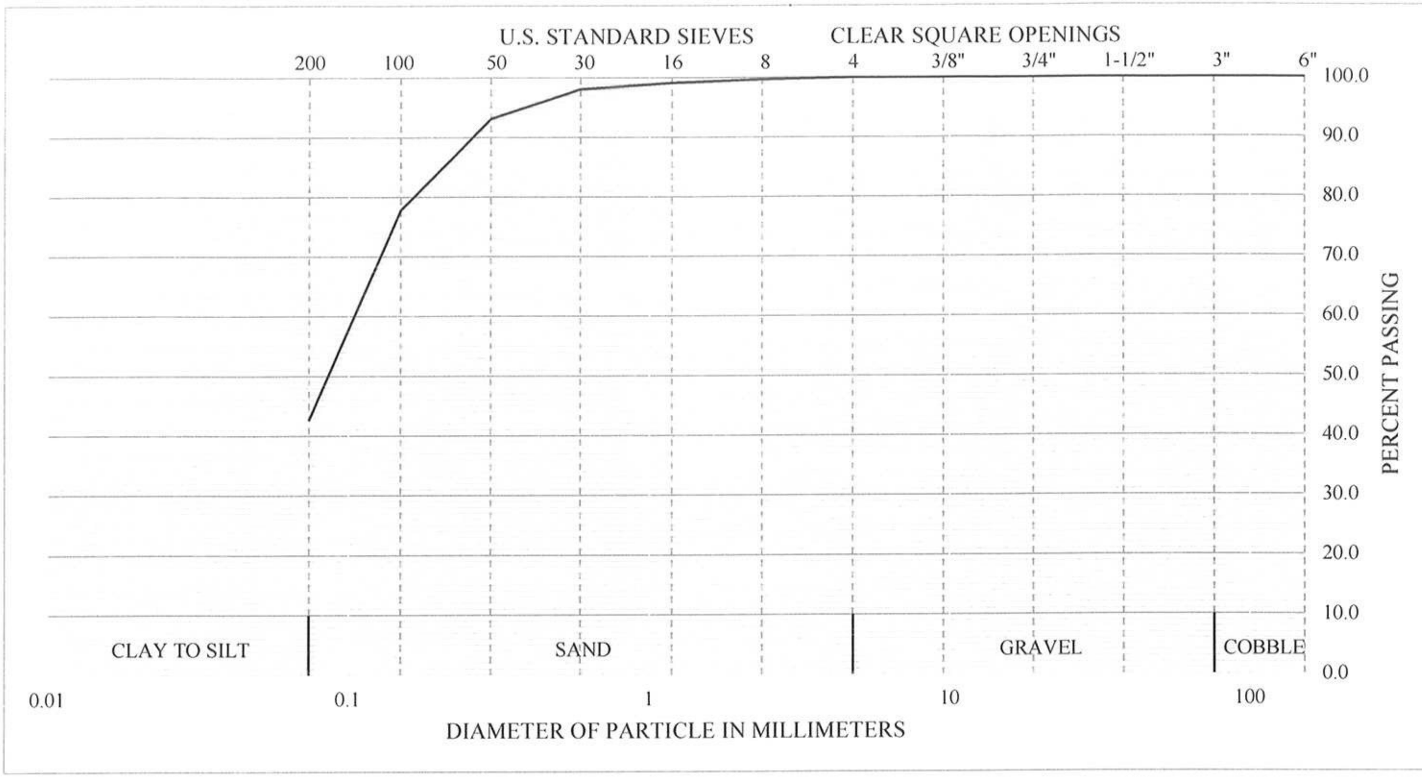
Gravel:	0 %	Sand:	41 %	Silt and Clay:	59 %
Liquid Limit:	30 %	Plasticity Index:	17 %		

Sample of: Sandy clay From: Boring B-1 at 5-0"



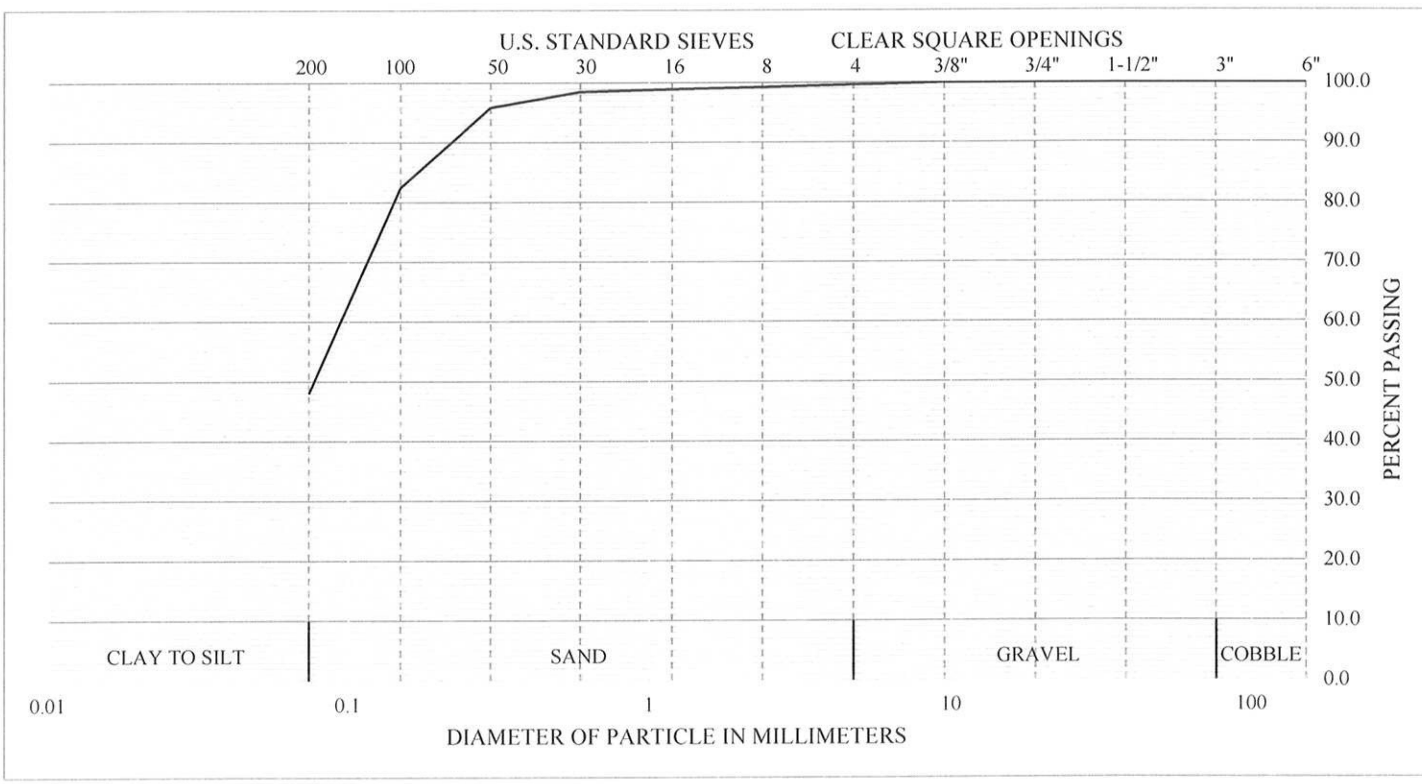
Gravel:	0 %	Sand:	60 %	Silt and Clay:	40 %
Liquid Limit:	33 %	Plasticity Index:	20 %		

Sample of: Clayey sand From: Boring B-2 at 3'-0"



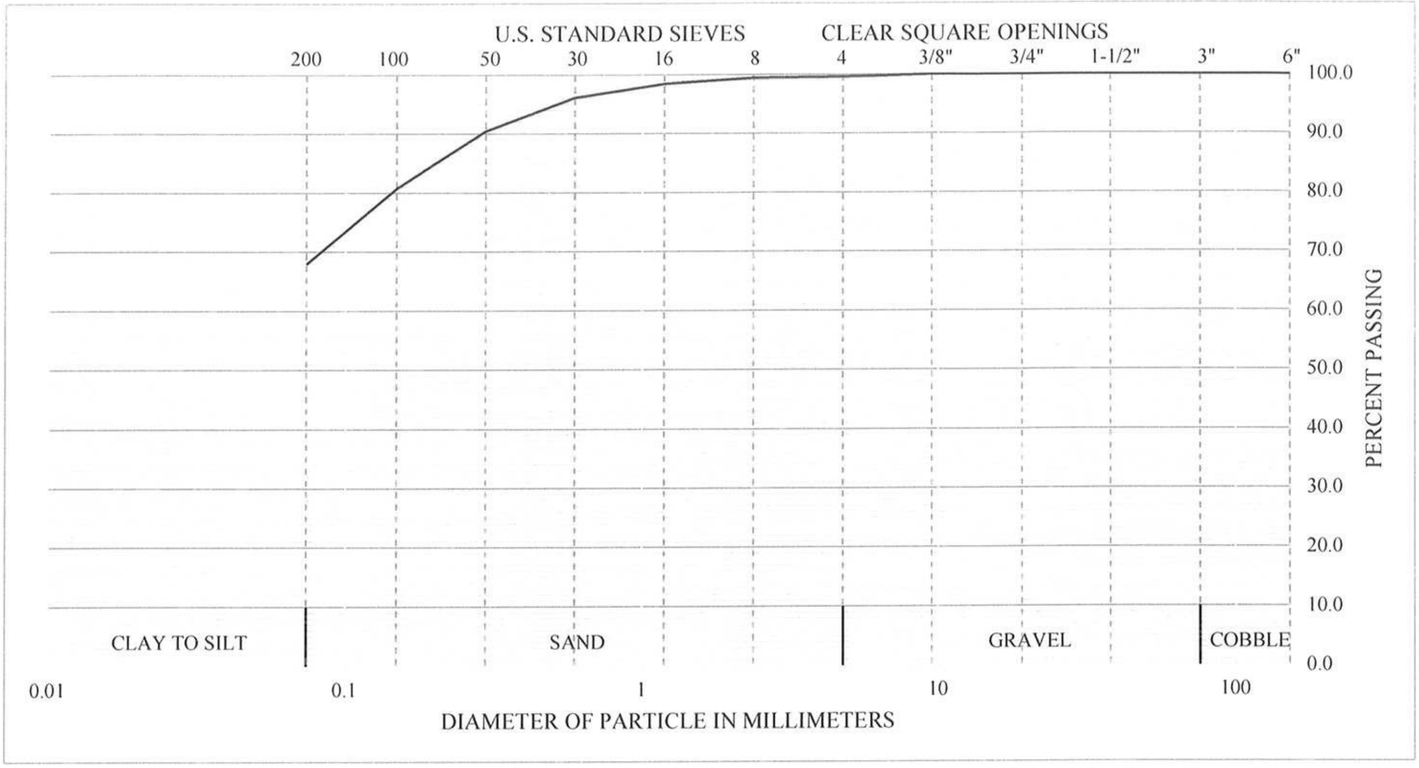
Gravel:	0 %	Sand:	57 %	Silt and Clay:	43 %
Liquid Limit:	%	Plasticity Index:	NP %		

Sample of: Silty sand — From: Boring B-2 at 5'-0"



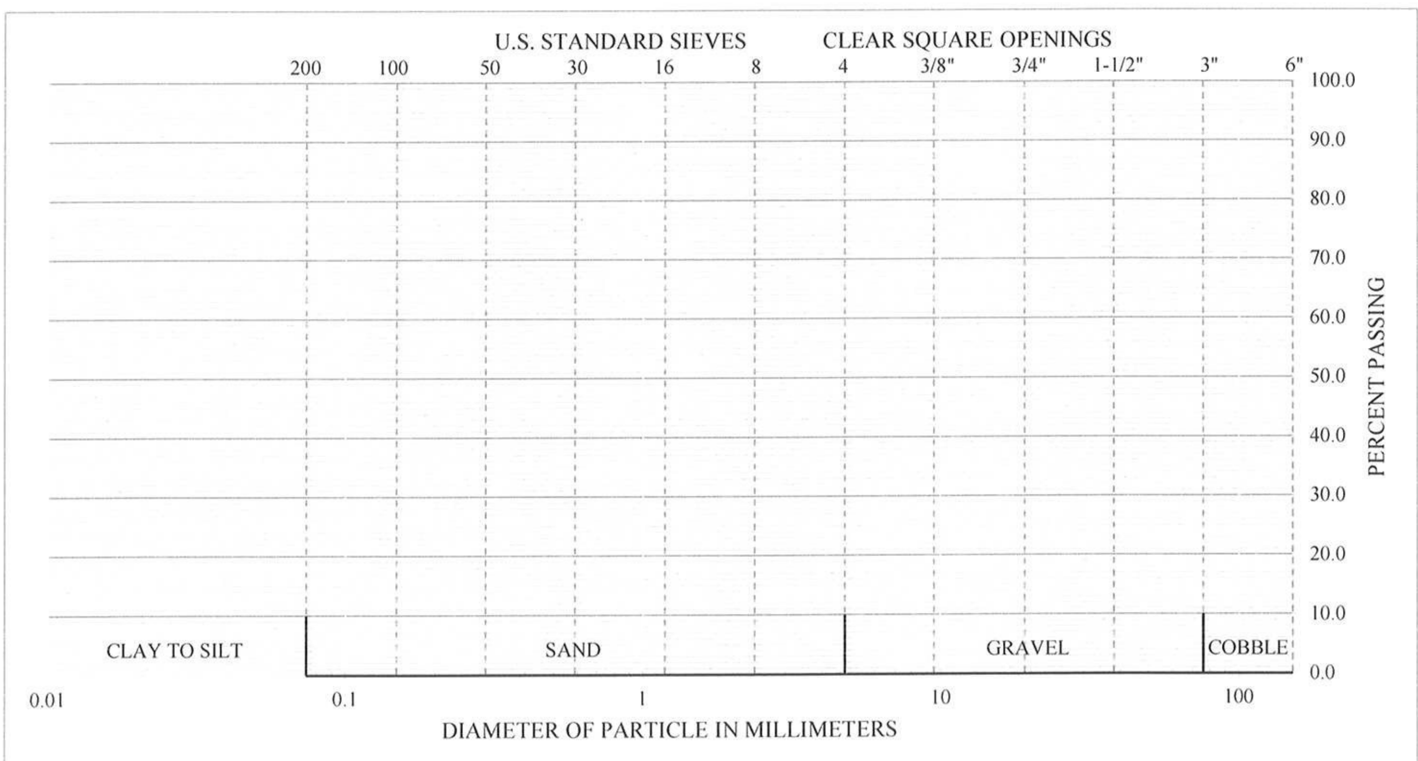
Gravel:	0 %	Sand:	52 %	Silt and Clay:	48 %
Liquid Limit:	%	Plasticity Index:	NP %		

Sample of: Silty sand — From: Boring B-3 at 5-0"



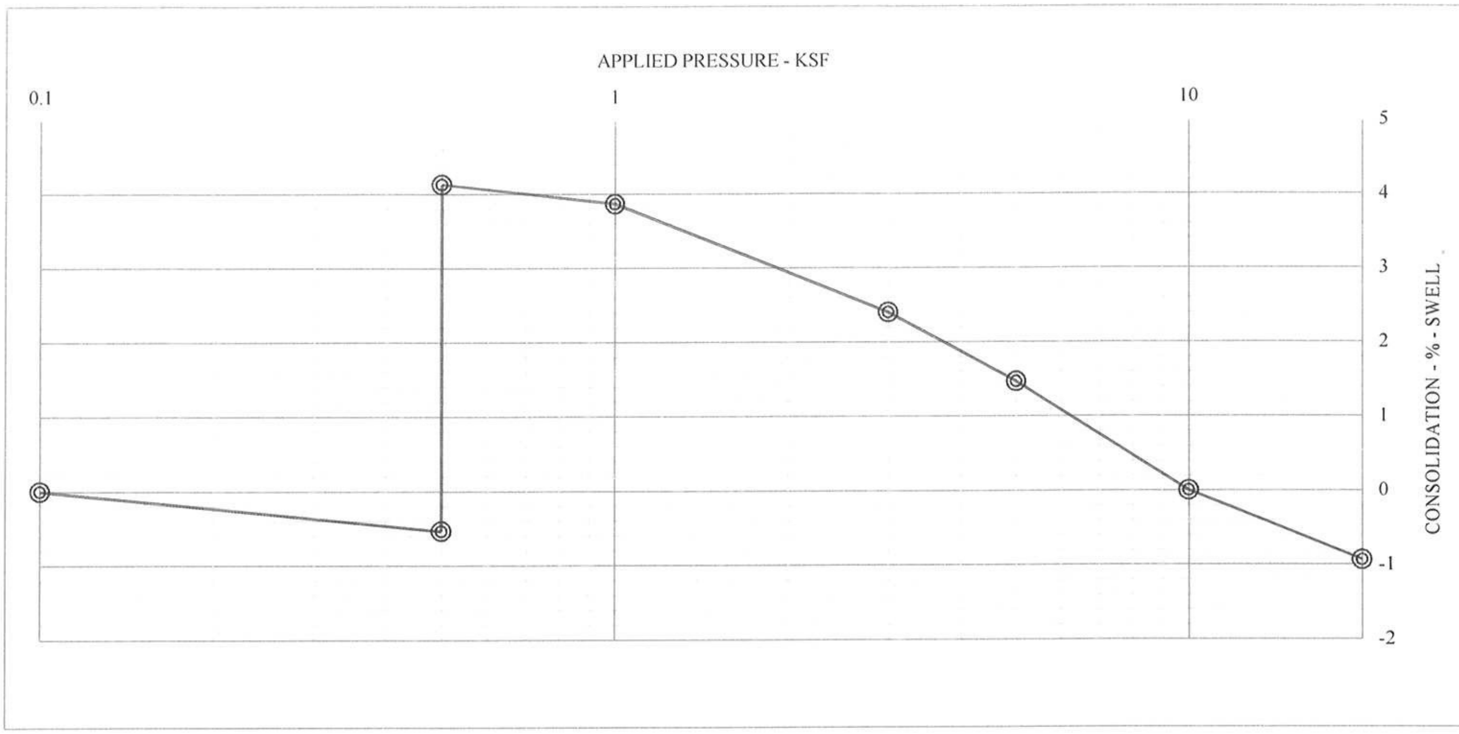
Gravel:	0 %	Sand:	32 %	Silt and Clay:	68 %
Liquid Limit:	40 %	Plasticity Index:	27 %		

Sample of: Sandy clay From: Boring B-3 at 10-0"

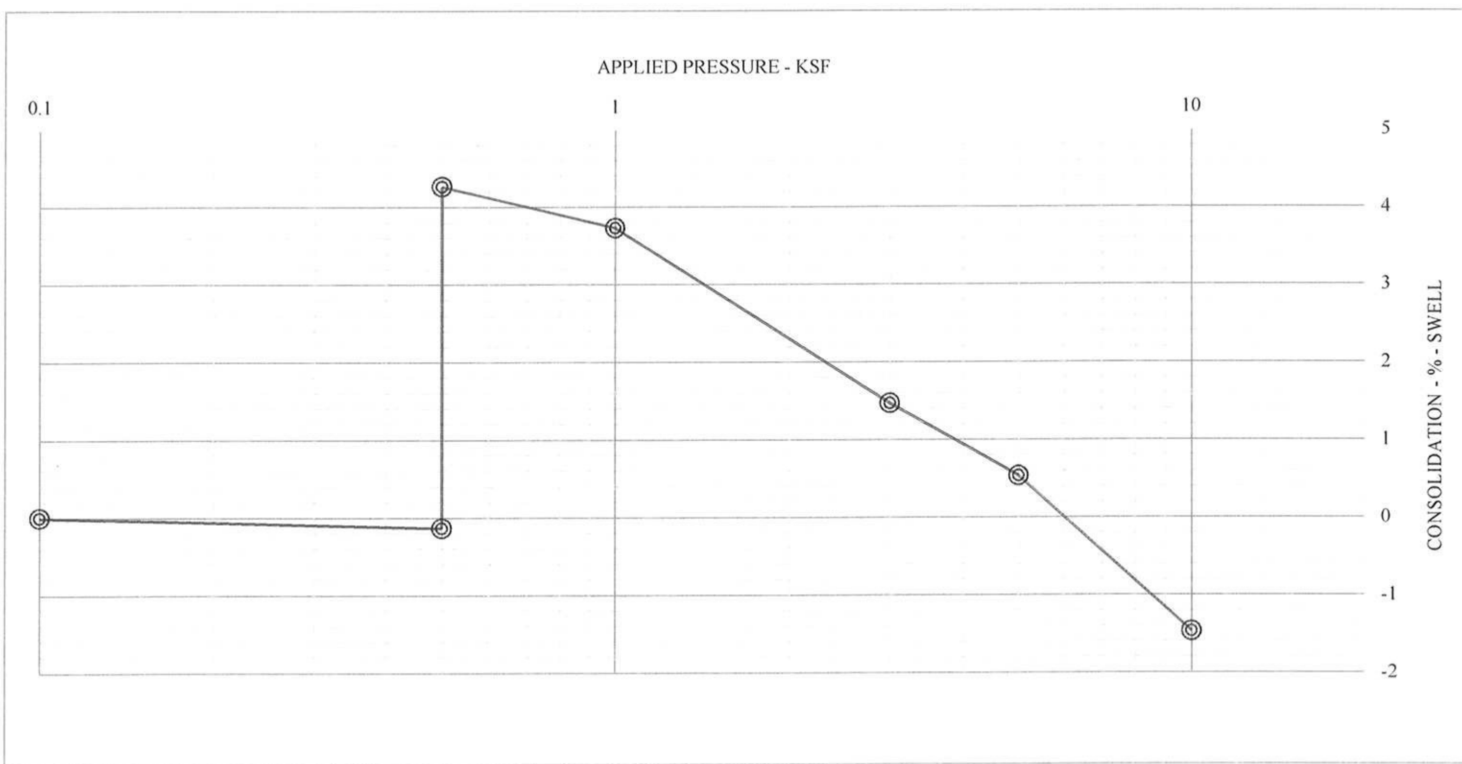


Gravel:	%	Sand:	%	Silt and Clay:	%
Liquid Limit:	%	Plasticity Index:	%		

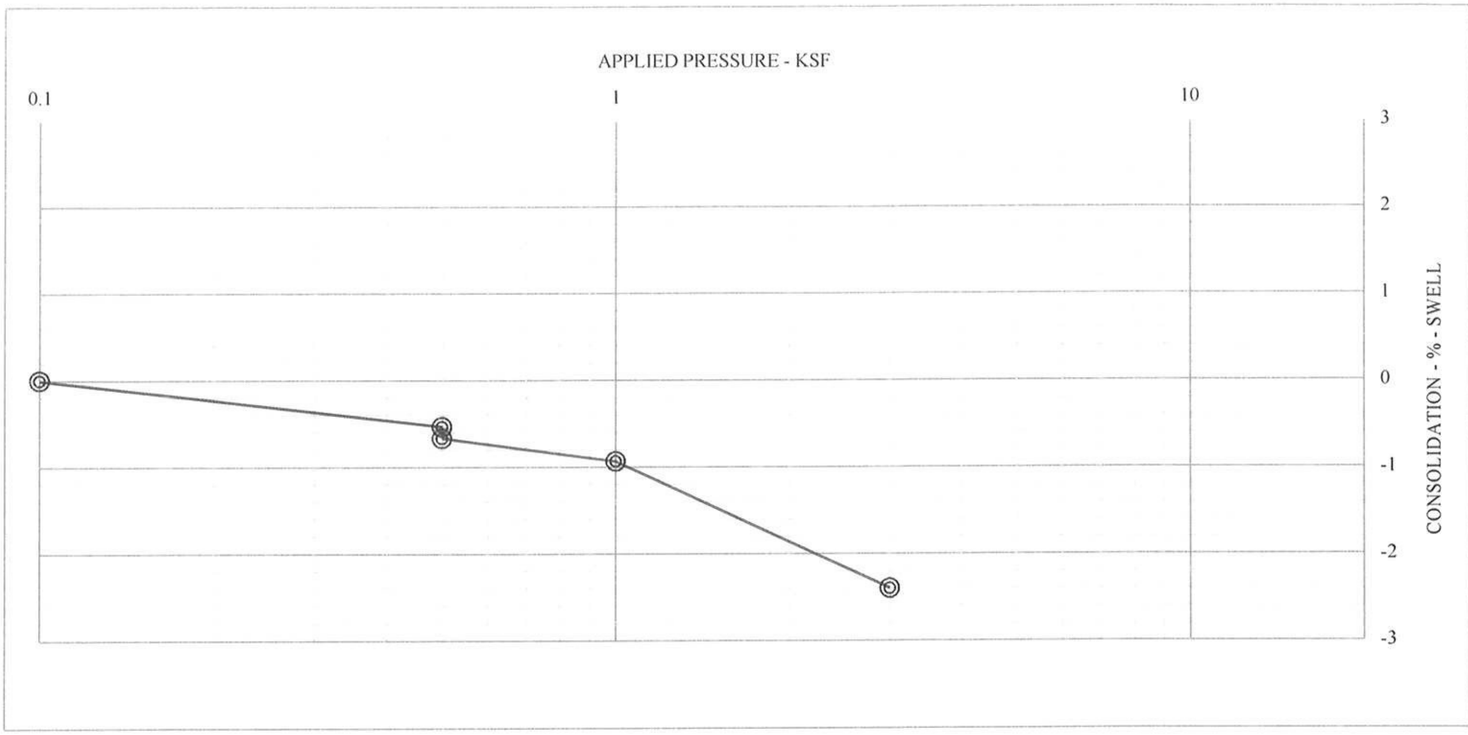
Sample of: From:



Expansion under constant pressure upon wetting		Percent Swell:	4.7 %
Moisture Content:	9.2 %	Sample of:	Sandy clay
Dry Unit Weight:	125.4 pcf	From:	Boring B-1 at 5'-0"



Expansion under constant pressure upon wetting		Percent Swell:	4.4 %
Moisture Content:	7.5 %	Sample of:	Clayey sand
Dry Unit Weight:	121.4 pcf	From:	Boring B-2 at 3'-0"



Additional movement under constant pressure upon wetting

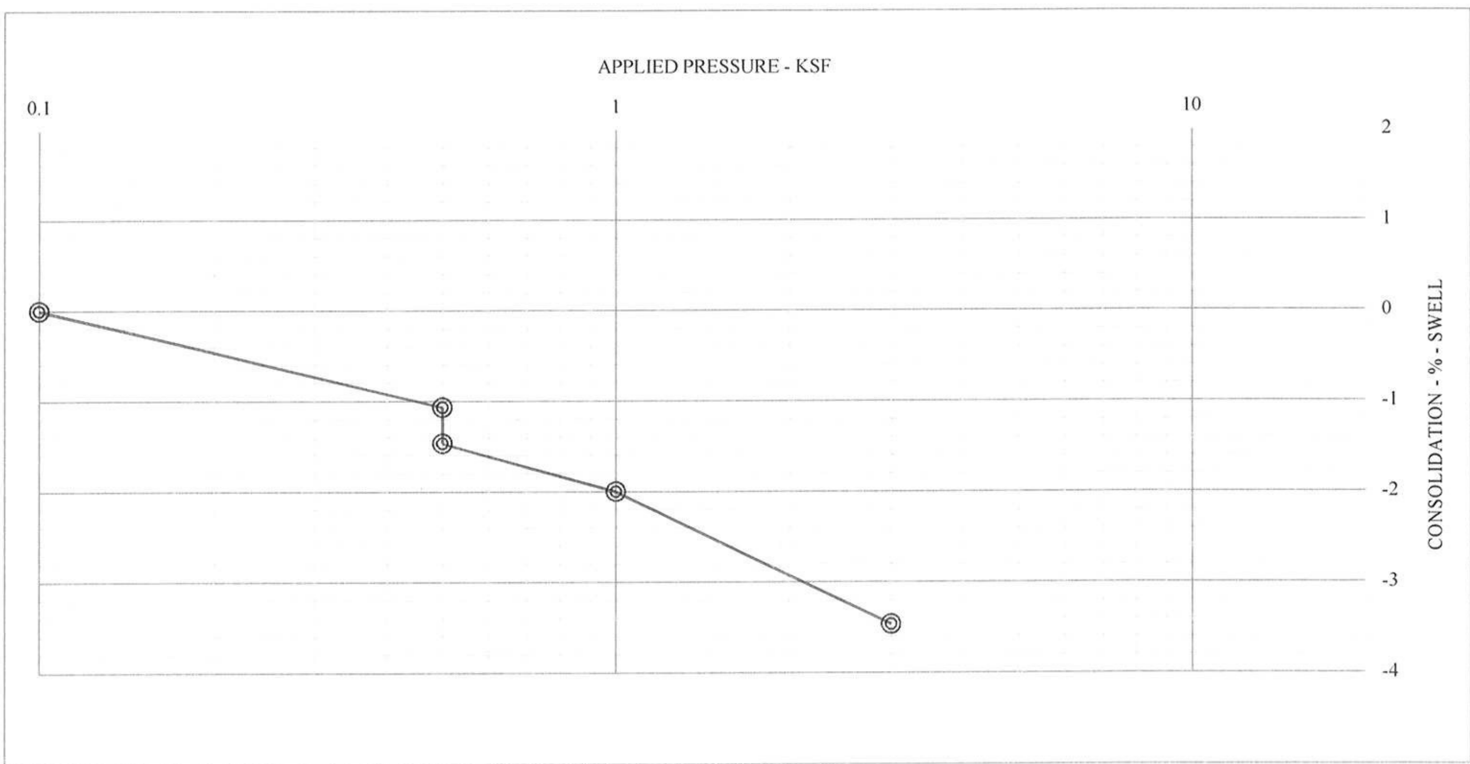
Percent Consolidation: -0.1 %

Moisture Content: 7.3 %

Sample of: Silty sand

Dry Unit Weight: 107.1 pcf

From: Boring B-2 at 5'-0"



Additional movement under constant pressure upon wetting

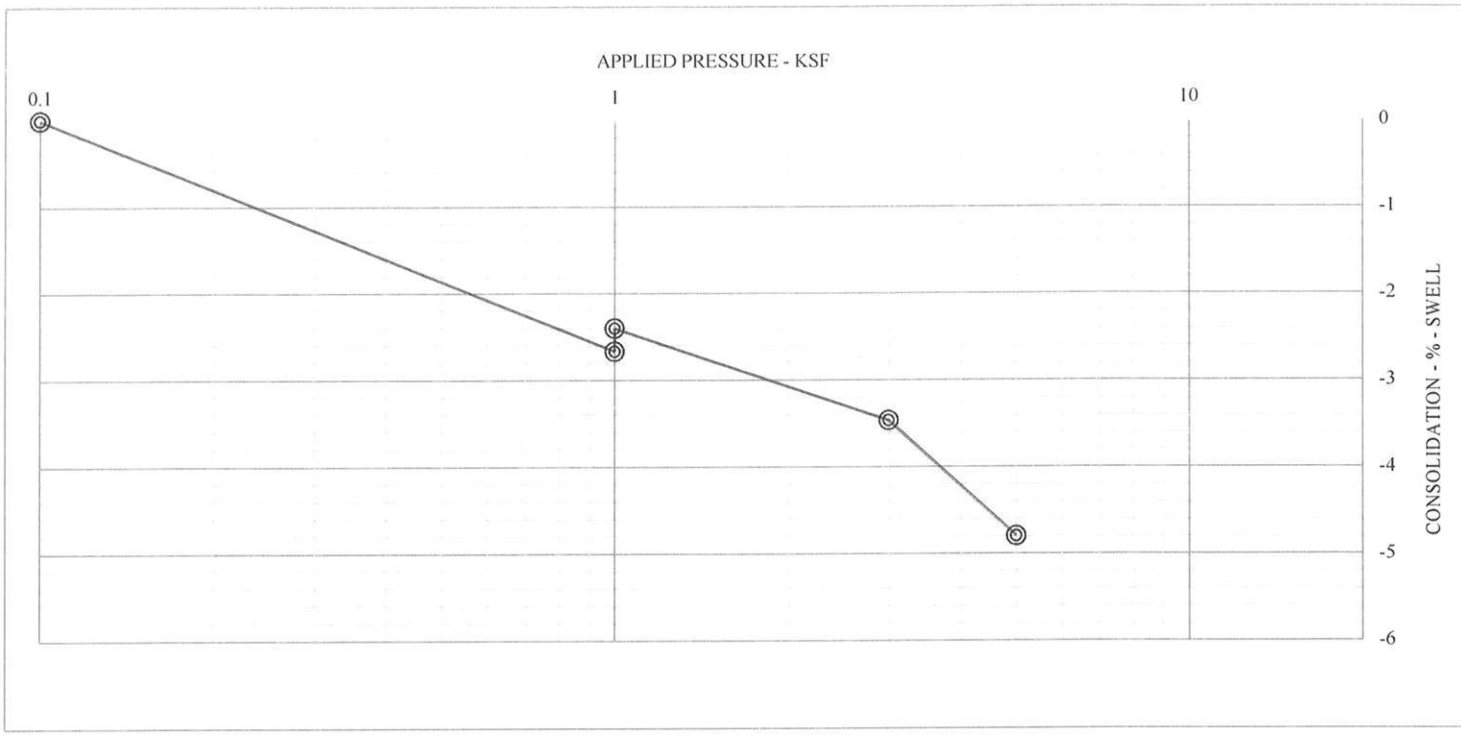
Percent Consolidation: -0.4 %

Moisture Content: 9.7 %

Sample of: Silty sand

Dry Unit Weight: 109.9 pcf

From: Boring B-3 at 5'-0"



Expansion under constant pressure upon wetting

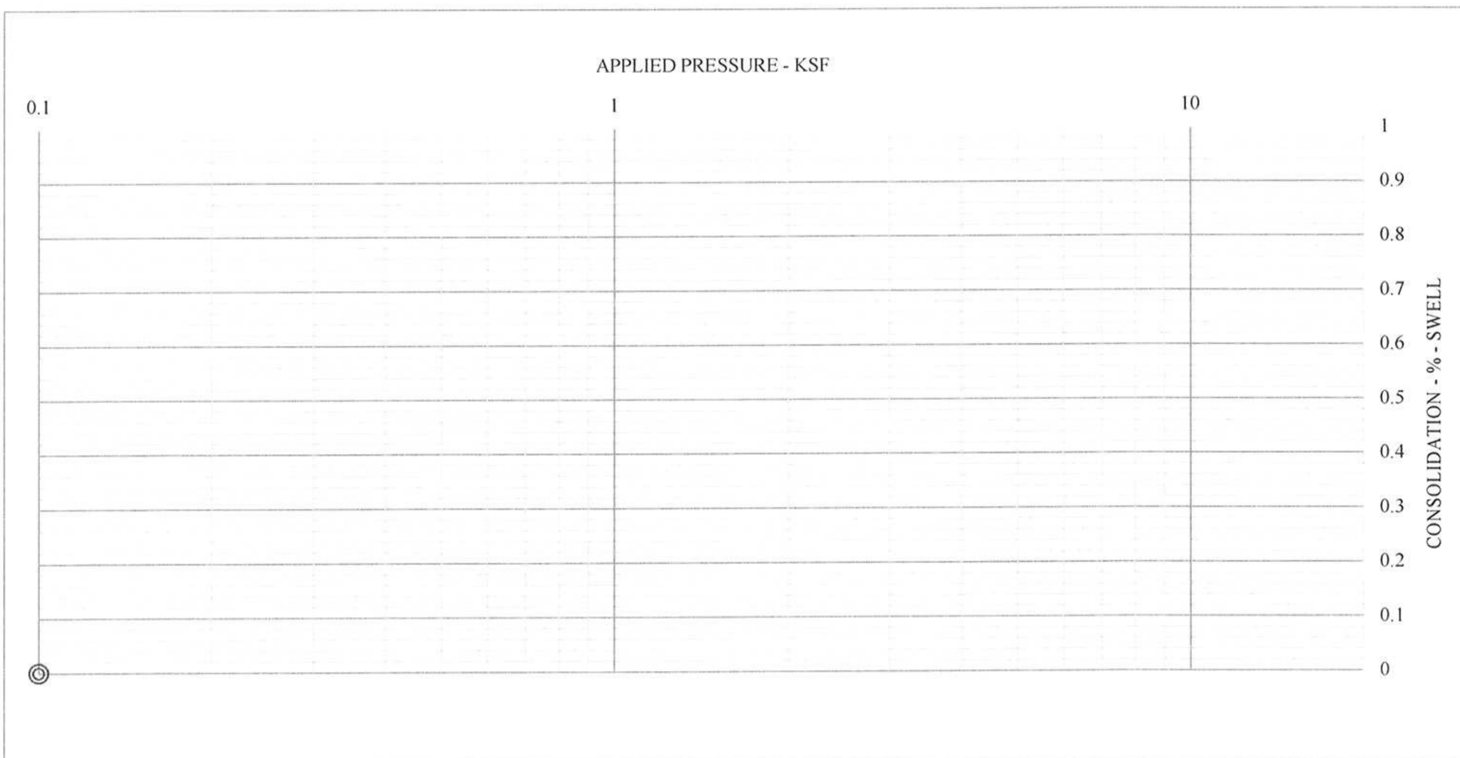
Percent Swell: 0.3 %

Moisture Content: 22.5 %

Sample of: Sandy clay

Dry Unit Weight: 102.9 pcf

From: Boring B-3 at 10'-0"



Percent Swell: %

Moisture Content: %

Sample of:

Dry Unit Weight: pcf

From:

Hollingsworth Associates, Inc.

Job No.: 21-228

TABLE I
SUMMARY OF LABORATORY TEST RESULTS

Sample Location		Natural Moisture Content	Natural Dry Density	Gradation			Atterberg Limits		Water Soluble Sulfate Content	Soil Type
Boring	Depth (feet)	(%)	(pcf)	Gravel + No. 4 (%)	Sand - No. 4 + No. 200 (%)	Minus No. 200 Sieve (%)	Liquid Limit (%)	Plasticity Index (%)	(%)	
1	5	9.2	125.4	0	41	59	30	17	0.02	Sandy clay
2	3	7.5	121.4	0	60	40	33	20		Clayey sand
	5	7.3	107.1	0	57	43		NP		Silty sand
3	5	9.7	109.9	0	52	48		NP		Silty sand
	10	22.5	102.9	0	32	68	40	27		Sandy clay