Geotechnical Report
For
Trailside Zoo Animal Enclosures
Bear Mountain, New York

File No. 3343

Prepared For:

Palisades Interstate Park Commission

Prepared By:

Daniel G Loucks, PE
NYSPE 068389

10 September 2018

INTRODUCTION:

The subsurface investigation for the proposed Animal Enclosures for Trailside Zoo, Bear Mountain, New York has been completed. Five (5) test pits have been excavated at the site. The logs of these test pits, along with a location diagram, have been included in the appendix of this report.

It is my understanding that the proposed construction will include two enclosures that will be constructed using steel mesh supported on steel poles/pipe. The enclosures will be located approximately as indicated on the test pit location diagram.

The maximum column loadings will range from 10 to 20 kips. The settlement tolerances are normal. Settlement tolerances are considered to include up to 1 inch of total settlement and 3/4 inch of differential settlement between column locations.

The floor of the enclosures will be established at between 0 and 10 feet above the existing grades at the site. I understand that where existing bedrock extends above the proposed floor level it will remain in place.

The purpose of this report is to describe the investigation conducted and the results obtained; to analyze and interpret the data obtained; and to make recommendations for the design and construction of the feasible foundation types and earthworks for the project. The recommendations contained in this report are based on the information that was provided up to the date the report was completed. Any changes in the design of the project or changes to the recommendations provided in this report should be brought to my attention to determine if there needs to be any revision of the geotechnical recommendations. I am not responsible for any changes in the recommendations provided in this report unless I have provided written approval of the changes.

The scope of my services has been limited to coordinating the test pit investigation, analyzing the soils information, and providing a geotechnical report with foundation recommendations, seismic site classifications as per NYS Building Code. Environmental aspects of the project as well as grading and site design should be performed by qualified others.

FIELD INVESTIGATION PROCEDURES:

The test pits were excavated with a track mounted mini excavator. The soil engineer observed the excavation of all the test pits.

All samples were examined in the field by the soil engineer and classified according to the Unified Soil Classification System. In this system, the soils are visually classified according to texture and plasticity. The appropriate group symbol is indicated on the test pit logs.

During the investigation, water level readings were obtained at various times where water accumulated in the test pit hole. The water level readings have been indicated on the test pit logs.

In association with the test pit investigation, the soil engineer visited the site to observe the surface conditions.

LABORATORY INVESTIGATION:

No formal laboratory tests were performed on the soil samples.

SITE CONDITIONS:

The ground surface at the proposed northeastern enclosure had exposed rock outcrops to the north and south side. In the center of the proposed enclosure the ground surface was lower and covered with soil.

The ground surface at the proposed southwestern enclosure had a large rock outcrop to the southwest and a smaller outcrop to the northeast. Between the outcrops the ground surface sloped down to the east as much as 8 to 12 feet lower than the ground surface at the western end of the proposed enclosure. Portions of this western center area appeared to have been filled in the past.

SUBSURFACE CONDITIONS:

The specific subsurface conditions encountered at each test pit location are indicated on the individual test pit logs. However, to aid in the evaluation of this data, I have prepared a generalized description of the soil conditions based on the test pit data.

Test pits were performed in locations where no bedrock was visible on the surface and where the excavator could access the sites. At the southwestern enclosure access was limited to only one location.

The test pits in general encountered an upper layer of clayey silt topsoil that extended to between approximately 0.5 and 1.0 feet below the existing ground surface. Beneath the topsoil is a mixture of clayey silt with varying amounts of cobbles, sand and gravel. This mixture extended to refusal at the bottom of the test pits at between approximately 1.2 and 4.5 feet below the existing ground surface.

The bedrock, where it was visible at the ground surface and where refusal was encountered was granitic gneiss. The bedrock was sound.

GROUNDWATER CONDITIONS:

Groundwater was observed in only in test pit TP#2 at a depth of 3.5 feet below the existing ground surface. I understand that at times of heavy precipitation and in the spring, water has been observed ponded at the lower ground surfaces.

Some fluctuation in hydrostatic groundwater levels and perched water conditions should be anticipated with variations in the seasonal rainfall and surface runoff.

It should be noted that the groundwater levels were obtained during the excavation of the test pits. Actual water levels may vary at the time of construction.

ANALYSIS AND RECOMMENDATIONS:

I understand that the proposed enclosure design include steel poles/pipe supporting steel mesh that extend into the existing bedrock or to reinforced concrete foundations. I understand that the vertical loads on the poles/pipe are light. The horizontal loading is not known at this time.

I recommend that the poles/pipe be extended into holes drilled in the bedrock at locations where there are bedrock outcrops and at locations where the bedrock is less 3 feet below grade. In my opinion this will provide consistent bearing and lateral support for the proposed structures. I recommend that the reinforced concrete foundations be extended to bedrock at the northeastern enclosure, due to the relatively shallow bedrock at this location.

I understand that for the eastern side of the southwestern enclosure up to approximately 10 feet of fill will be required. Based on the site plan the northern and southern end of this side will extend to bedrock outcrops. No test pit was able to be performed in this area due to access difficulties. In my opinion there would be two options for this area. The first would be to extend all the reinforced concrete foundations to bedrock and then extend them up to the proposed ground surface in the enclosure. This would be more expensive, but would limit differential settlements because all portions of the foundation would extend to bedrock. The other alternative would be to place the center portion of the foundation on controlled fill that in turn rests on virgin soils and each end would rest on bedrock. This would be less expensive but there will be greater differential settlements due to non-uniform bearing. I recommend that allowable bearing pressures be reduced to limit differential settlement and that the reinforced concrete foundations be designed with addition steel reinforcement to distribute the loading and reduce abrupt differential settlements. I have included recommendations for both alternatives to allow the owner to determine the value of each option. For the western portion of this enclosure and at the rock outcrops, the same procedure as above for the northeastern enclosure should be followed.

Site Work:

The proposed construction areas should be cleared and grubbed and all organic topsoil and vegetation along with any uncontrolled fill and debris. Excavations for the reinforced concrete foundations for northeastern enclosure and southwestern (where there is bedrock within 4 feet of existing grade or if the owner choses to place all foundations on bedrock) should extend to bedrock. If the owner choses to place the foundations for the eastern side of the southwestern enclosure on soils The stripped subgrade should be proof-rolled with a 10-ton roller. This proof rolling will compact the subgrade and reveal the presence of soft spots. If saturated subgrade conditions exist, I recommend that the subgrade be observed and probed by the soil engineer in place of proof rolling. Any soft spots should be excavated and backfilled with controlled fill material.

The removal of any uncontrolled fill should extend to a minimum horizontal distance past the edge of the footings equal to half the depth that the fill extends under the footing. This is equal to a 1:2 slope (H:V) down from the outer edge of the footing to the virgin soil.

A way to stabilize a spongy, but suitable, virgin, subgrade would be to spread a reinforcement or separation type of geo-textile (Mirafi 600X or approved equal) on the subgrade and follow with a lift of clean, granular fill or uniform crushed stone. The thickness of the controlled fill can range from 1.0 to 2.5 feet, as necessary, to achieve a working mat upon which to construct the remainder of the controlled fill or to place footings. If uniform crushed stone is used as controlled fill a layer of geotextile should be placed between the crushed stone and any sand/gravel controlled fill and virgin soil.

A third method for stabilizing spongy areas of the subgrade would be to improve the drainage by use of properly designed drain tiles or by using properly designed sump pit and pump dewatering systems. Using these methods, the local groundwater table maybe able to be lowered sufficiently to aid in stabilizing the subgrade surface. If large quantities of water are encountered vacuum well point dewatering maybe required. The need of a well point or any other type of dewatering program should be evaluated by the contractor before starting construction and be designed by a qualified dewatering contractor or hydrologist.

Controlled Fill:

Before any controlled fill is placed the site should be inspected to verify that the site has been prepared according to the recommendations contained in this report as required by the NYS Building Code Section 1704.7.1.

Controlled fill can consist of non-organic, imported soils free of debris and having a maximum particle size of 4 inches. A gradation and proctor should be performed on the proposed soil and submitted to me for approval. Approved, properly placed and compacted material can be used as controlled fill within the proposed enclosure footprint. Free draining controlled fill material should be placed as recommended in this report. Approved imported soils should not be used in these locations where free draining controlled fill is recommended unless approved by me.

Controlled, relatively clean, granular fill can be spread in lifts not exceeding 12 inches in loose thickness. These materials should be compacted to a minimum of 95 percent of the maximum ASTM Specification D 1557-91 density, modified proctor.

On-site, silty material may be difficult to compact during wet weather or poor drying conditions. Given good drying conditions, the on-site soils with more than 10 percent silt/clayey silt could be compacted using disc harrows and sheepsfoot rollers or rubber-tired rollers, as applicable. These types of soils are sensitive to moisture content and weather conditions. During freezing or wet weather conditions these materials may not be able to be adequately compacted for use as controlled fill inside the enclosures. On-site material should not be used as controlled fill under reinforced concrete foundations.

If crushed stone is used as controlled fill it should have a layer of geotextile (min. tensile strength of 200 lbs and min. burst strength of 400 psi) placed between the stone and existing soils. The stone should be placed in lifts not exceeding 12 inches in thickness and should be compacted with a minimum of 5 passes of a vibratory roller rated at 5 tons or larger. Weathered shale or crushed shale should not be used as controlled fill within the proposed enclosure area.

Free Draining Controlled Fill Material: Naturally or artificially graded mixture of sand, natural or crushed stone or gravel conforming to NYS DOT Item 304-2.03, Type 4 or 2 as follows:

U.S. Sieve No.	Percent Passing by Weight
2 inch	100
1/4 inch	30-65
No. 40	5-40
No. 200	0-10

NYS DOT Table 703-4, Size 2 crushed stone, clean, durable, angular, and of uniform quality throughout:

U.S. Sieve No.	Percent Passing by Weight
1 ½ inch	100
1 inch	90-100
1/4 inch	0-15

All controlled fill should be free of organic and/or frozen material.

Free-draining controlled fill should have less than 10 percent fines passing the #200 sieve.

I recommend performing one field density test for every 2,000 square feet of controlled fill placed, within the overlaying enclosure footprint, but in no case fewer than three tests per lift.

I recommend that for foundation wall and footing backfill that in each compacted backfill layer have at least one field in place density test for each 50 feet or less of wall or footing length, but not fewer than two tests along a wall face or footing be performed per lift.

Proper placement and compaction of backfill along exterior portions of foundation walls should be provided, especially in locations where there are sidewalks or enclosure entries. Proper placement of backfill materials can reduce possible settlements and the use of properly designed backfill and drainage can reduce possible frost heave movements.

Results of the field compaction test results should be sent to my office for review. Copies of the results of soil gradation tests should also be provided to me for review and approval.

Enclosure Foundations/Support:

I recommend that the proposed poles/pipes be extended into sound bedrock, if the bedrock is encountered within 3 feet of the proposed grades. Poles/pipes that extend into the sound bedrock a minimum of 1.5 feet can be designed with a maximum allowable rock bearing pressure of 25 tsf and a maximum side shear of 250 psi.

Portions of the structures/poles supported by spread footing foundations resting on sound bedrock can be designed for a maximum, net, allowable rock bearing pressure of 15 tsf. If the foundation is supported on controlled fill/virgin soils and bedrock then I recommend that the foundation be designed with a maximum allowable soil/rock bearing pressure of 1 tsf.

The soil engineer should observe the footing subgrade if foundations are placed on soils, to verify the allowable bearing pressure of the soil encountered. Any loose weathered bedrock should be removed from foundation subgrades.

Loads from adjacent footings or structures should be assumed to distribute based on the elastic theory. Typical Boussinesq charts can be used to approximate loads at various depths and locations due to adjacent structures.

A minimum footing width of 1.0 feet is recommended for foundations resting on bedrock and 2.0 feet for foundations resting of soil and bedrock. Any footings resting on soil and bedrock should have a minimum of two #5 bars placed in them, top and bottom, separated by a minimum of 12 inches vertically and a minimum of three #5 in foundation walls. This reinforcement is intended to resist possible negative as well as positive moments due to non-uniform bearing.

Exterior footings or footings in unheated areas should have a minimum of 4.0 feet of embedment for protection from frost action. If sound bedrock is encountered before 4 feet, foundations can be pinned into the existing bedrock.

All walls that retain soil on only one side should have a drain tile placed around the base of the wall. The drain tile should be a minimum of 4 inches in diameter, surrounded by a minimum of 6 inches of washed sand or crushed stone wrapped with a filter fabric (Amoco 4545 or equal). The drain tile should drain to a stormwater sewer, daylight, or a sump equipped with a pump.

The wall should then be backfilled with a controlled, well graded, free-draining granular material. The material should extend away from the wall a horizontal distance of two-thirds the height of the fill being placed. The upper 1 foot of material should be a fairly impermeable material to shed surface water and should be pitched away from the building to provide proper drainage.

If these procedures are used, a static lateral soil pressure of 42 psf per foot of retained soil can be used for design of the wall. This static, active lateral soil pressure is based on a moist unit weight of 135 pcf and an angle of internal friction of 32 degrees. A wall soil friction angle of 18 degrees and a coefficient of base sliding of 0.4 can also be used for design.

To resist overturning and sliding a static lateral passive pressure of 250 psf per foot of embedment can be used. This static, passive pressure resistance value has been reduced from the calculated full passive pressure because of stress/strain characteristics of the soil. To develop the full, calculated resistance a certain amount of movement or deflection in the structure is required. The amount of movement required to generate this resistance generally greater then is acceptable for structures. I therefore recommend that the full passive pressure not be used.

The resistance of the upper two feet of soil, when determining the passive pressure resistance should be ignored due to surface effects of frost and moisture.

Any surcharge load should also be added to the above pressures as determined using Boussinesq charts.

Seismic Conditions:

The potential seismic conditions at the proposed site have been investigated using the information provided in the NYS Building Code Section 1618 and the test pit and laboratory information obtained during my investigation.

Based on the soils information it is my opinion that the Site Classification (Table 1615.1.1) could be assumed to be B. Using figures 1615 (1 and 2), and the data from the USGS Hazards Mapping and the 2012/2015 IBC Seismic Design Provisions, I estimate that the MCE spectral acceleration (S_{MS}) at short periods is 24.2 and the MCE spectral acceleration (S_{M1}) at 1 s period is 7.0.

The probabilistic ground motion values are expressed in %g for rock site class B. Peak ground accelerations in the upper soil profile may vary. If specific peak ground accelerations or shear wave velocities are required for the upper soil profile additional testing would be required. If it is determined by the structural engineer that the Seismic Design Category is D,E or F additional geotechnical recommendations can be provided.

A copy of the MCE Ground Motion Data has been included in the appendix of this report to provide additional information if required.

The field data and my analysis do not indicate any significant potential seismic hazards such as liquefaction, sensitive clays, weakly cemented soil or surface rupture.

CONSTRUCTION PROCEDURES AND PROBLEMS:

The NYS Building Code Section 17 requires special inspections and follow up reports. These inspections should be performed to verify compliance with the recommendations contained in this report.

Any test pit locations within the proposed enclosure areas should be over-excavated and the disturbed material should be removed and replaced with controlled fill.

All excavations of more than a few feet should be sheeted and braced or laid back to prevent sloughing in of the sides.

Excavations should not extend below adjacent footings or structures unless properly designed sheeting and bracing or underpinning is installed.

Footing subgrades should be tamped to compact any soil disturbed during the excavation process. If over excavation of subgrades are required to remove cobbles or possibly boulders, then the over excavated areas should be filled with controlled granular fill or lean concrete.

Sump-pit and sump-pump-type dewatering may be required in excavations or low areas during wet weather or if groundwater is encountered. If large quantities of groundwater are encountered vacuum wells maybe required to stabilize the subgrade soils. All dewatering programs should be designed to prevent bottom heave. All excavations should be dewatered to a minimum of 1 foot below the bottom of the excavation. Pumps should be properly filter protected to prevent loss of ground by pumping out fine soil particles.

As previously noted the on-site soils contain clayey silt which will make the soils sensitive to moisture content. If the material becomes wet or saturated, it will become spongy and easily disturbed. It will also be difficult to place as controlled fill if it becomes too wet. Imported well draining sand and gravel or possibly crushed stone may be required to prevent disturbance of the subgrade soils during construction.

Subgrades should be kept from freezing during construction.

Water, snow, and ice should not be allowed to collect and stand in excavations or low areas of the subgrade.

Some obstacles, including foundations and utilities and possibly cobbles/boulders and bedrock, will be encountered in excavations.

The use of pneumatic tools or drilling and blasting will be required to remove bedrock or large boulders if encountered.

Trailside Zoo Enclosures
Bear Mountain, New York
File No. 3343

CONTENTS OF APPENDIX:

GENERAL NOTES

DRILLING & SAMPLING SYMBOLS

SS	:	Split-Spoon — 1¾ " I.D., 2" O.D., except where noted
S	:	Shelby Tube — 2" O.D., except where noted
PA	:	Power Auger Sample
DB	:	Diamond Bit — NX: BX: AX:
CB	:	Carboloy Bit — NX: BX: AX:
OS	:	Osterberg Sampler — 3" Shelby Tube
HS	:	Housel Sampler
WS	:	Wash Sample
FT	:	Fish Tail
RB	:	Rock Bit
WO	:	Wash Out

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on a 2 inch OD split spoon, except where noted

WATER LEVEL MEASUREMENT SYMBOLS

WL	:	Water Level
WCI	:	Wet Cave In
DCI	:	Dry Cave In
WS	:	While Sampling
WD	:	While Drilling
BCR	:	Before Casing Removal
ACR	:	After Casing Removal
AB	:	After Boring

Water levels indicated on the boring logs are the levels measured in the boring at the times indicated. In pervious soils, the indicated elevations are considered reliable ground water levels. In impervious soils the accurate determination of ground water elevations is not possible in even several day's observation, and additional evidence on ground water elevations must be sought.

CLASSIFICATION

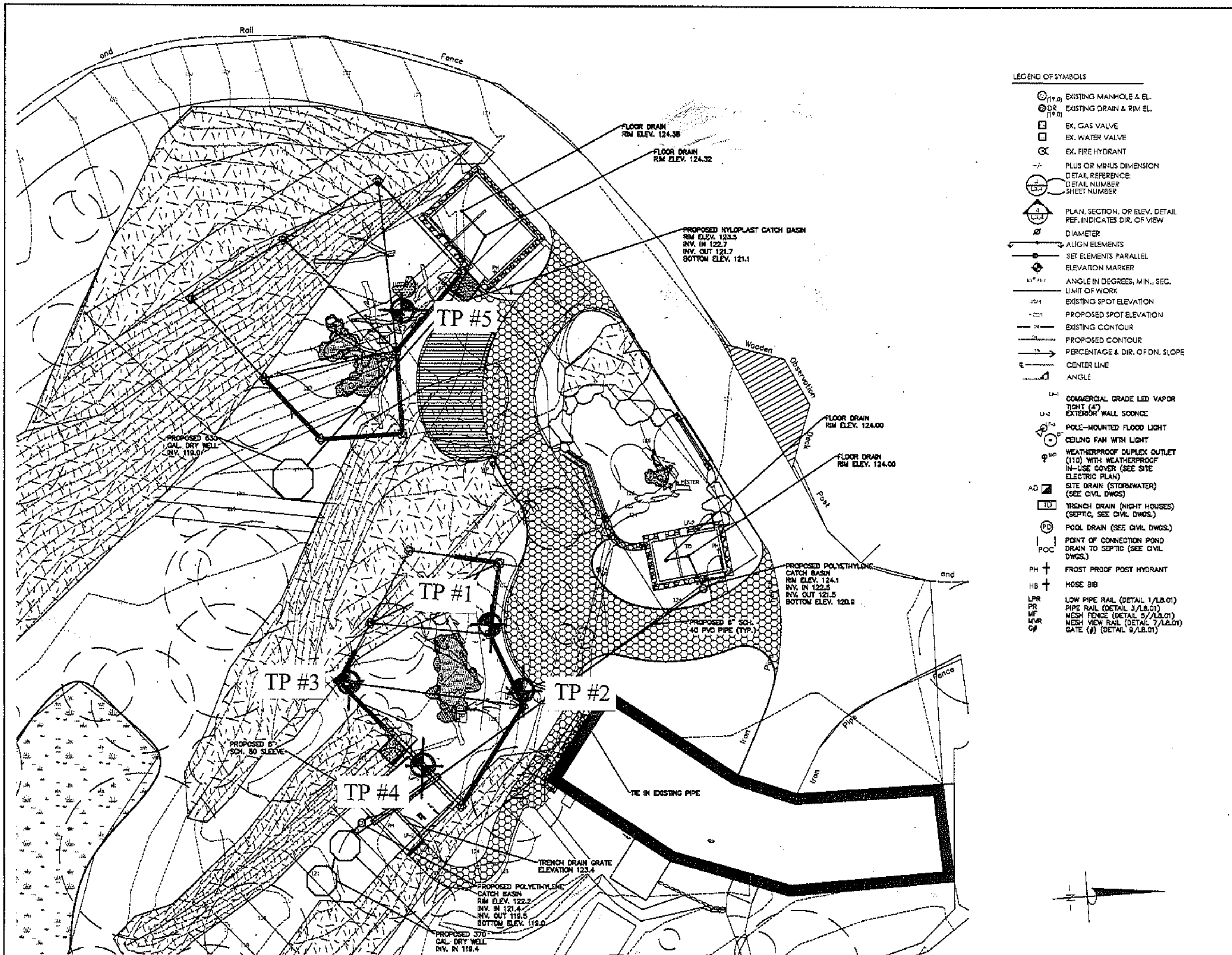
COHESIONLESS SOILS

"Trace"	:	1% to 10%	
"Trace to some"	:	10% to 20%	
"Some"	:	20% to 35%	
"And"	:	35% to 50%	
Loose	:	0 to 9 Blows	or equivalent
Medium Dense	:	10 to 29 Blows	
Dense	:	30 to 59 Blows	
Very Dense	:	≥60 Blows	

COHESIVE SOILS

If clay content is sufficient so that clay dominates soil properties, then clay becomes the principle noun with the other major soil constituent as modifiers: i.e., silty clay. Other minor soil constituents may be added according to classification breakdown for cohesionless soils; i.e., silty clay, trace to some sand, trace gravel.

Soft	:	0.00 — 0.59 tons/ft²
Medium	:	0.60 — 0.99 tons/ft²
Stiff	:	1.00 — 1.99 tons/ft²
Very Stiff	:	2.00 — 3.99 tons/ft²
Hard	:	≥ 4.00 tons/ft²



TRAILSIDE MUSEUMS AND ZOO

Palisades Parks Conservancy

Bear Mountain State Park
Bear Mountain, New York 10911

LEHMAN & GETZ, P.C.
CONSULTING ENGINEERS
17 RIVER STREET WARWICK, NEW YORK 10990

DAVID A. GETZ, P.E.
N.Y.S. LIC. No. 51265

BLAKE ENGINEERING PLLC

100% CONSTRUCTION DOCUMENTS

Coyle & Caron Inc.
833 HIGHLAND AVE., SUITE 200
ORLANDO, FL 32803

0191

ANIMAL HABITAT IMPROVEMENTS

JV DG

March 22, 2018

$\frac{1}{8}" = 1'$

SUBSURFACE SEWAGE DISPOSAL SYSTEM

C1

Test Pit Logs

Trailside Zoo Enclosures
Baer Mountain, New York
27 August 2018

Test Pit # 1
0.0 – 1.0 ft Dark Brown Clayey Silt, some Sand, trace Roots (ML) Topsoil
1.0 – 1.8 ft Brown/Gray Clayey Silt, trace to some Sand, trace Gravel (ML)
Refusal on Granitic Gneiss Bedrock
No Water Observed

Test Pit # 2
0.0 – 4.0 ft Dark Brown Cobbles and Clayey Silt, trace to some Sand, trace Roots (GM-ML)
4.0 – 4.5 ft Brown/Gray Cobbles, trace to some Clayey Silt (GM-GP)
Refusal on Granitic Gneiss Bedrock
Water Observed at 3.5 feet

Test Pit # 3
0.0 – 0.5 ft Dark Brown Clayey Silt, some Sand, trace Roots (ML) Topsoil
0.5 – 1.2 ft Brown/Gray Clayey Silt, trace to some Sand, Gravel (ML)
Refusal on Granitic Gneiss Bedrock
No Water Observed

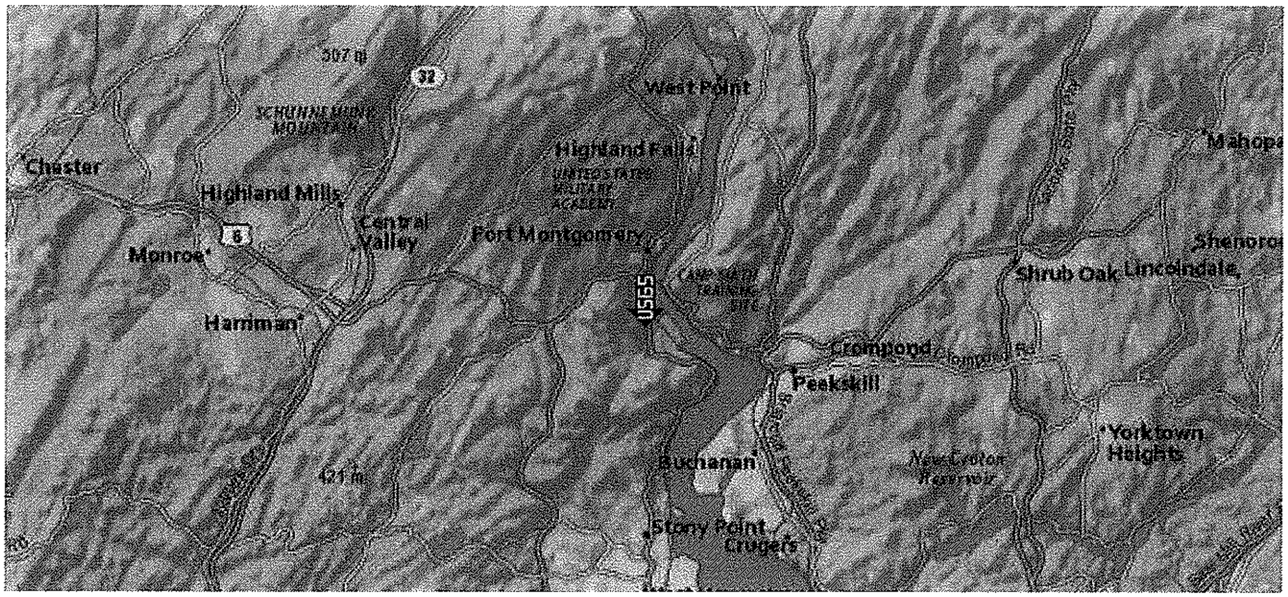
Test Pit # 4
0.0 – 0.5 ft Dark Brown Clayey Silt, some Sand, trace Roots (ML) Topsoil
0.5 – 2.5 ft Brown/Gray Clayey Silt, some Cobbles, trace to some Sand (ML)
Refusal on Granitic Gneiss Bedrock
No Water Observed

Test Pit # 5
0.0 – 2.0 ft Dark Brown Clayey Silt and Cobbles, some Sand (GM-ML) Topsoil FILL
Refusal on Granitic Gneiss Bedrock
No Water Observed

USGS Design Maps Summary Report

User–Specified Input

Report Title	Parkside Zoo Enclosures Mon September 10, 2018 14:56:30 UTC
Building Code Reference Document	2012/2015 International Building Code (which utilizes USGS hazard data available in 2008)
Site Coordinates	41.31454°N, 73.98846°W
Site Soil Classification	Site Class B – "Rock"
Risk Category	I/II/III



USGS–Provided Output

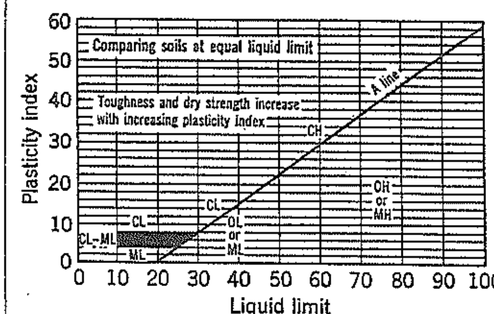
$S_S =$	0.242 g	$S_{MS} =$	0.242 g	$S_{DS} =$	0.161 g
$S_1 =$	0.070 g	$S_{M1} =$	0.070 g	$S_{D1} =$	0.046 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the "2009 NEHRP" building code reference document.

Table 3.5 Unified Soil Classification

Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)						Group Symbols[a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils: More than half of material is *larger* than No. 200 sieve size[b] (The No. 200 sieve size is about the smallest particle visible to naked eye)	Gravels: More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing			*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)			*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures		Atterberg limits below "A" line, or *PI* less than 4 / Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics	Atterberg limits above "A" line, with *PI* greater than 7
	Sands: More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			*SW*	Well graded sands, gravelly sands, little or no fines	Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing			*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)			*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5 / Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7
	Identification Procedures on Fraction Smaller than No. 40 Sieve Size		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)				
Fine-grained soils: More than half of material is *smaller* than No. 200 sieve size (The No. 200 sieve size is about the smallest particle visible to naked eye)	Silts and clays liquid limit less than 50		None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses	
			Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions	
	Silts and clays liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)	
			Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity		
Highly Organic Soils			Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils		

Laboratory classification criteria (coarse-grained soils), printed vertically: Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of dual symbols



Plasticity chart for laboratory classification of fine grained soils

From Wagner, 1957.

[a] *Boundary classifications.* Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW–GC*, well graded gravel-sand mixture with clay binder.

[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking):
After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.
Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.
Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):
After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.
High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):
After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eight inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.
After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.
The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.
Highly organic clays have a very weak and spongy feel at the plastic limit.

Soil Characteristics Pertinent to Roads and Airfields

Major Divisions		Letter (1)		Name	Value as Subgrade When Not Subject to Frost Action	Value as Subbase When Not Subject to Frost Action	Value as Base When Not Subject to Frost Action	Potential Frost Action	Compressibility and Expansion	Drainage Characteristics	Compaction Equipment	Unit Dry Weight lb. per cu. ft.	Typical Design Values CBR (2)	Typical Design Values Subgrade Modulus k lb. per cu. in.
Coarse-Grained Soils	Gravel and Gravelly Soils	GW		Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Excellent	Good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	125-140	40-80	300-500
		GP		Poorly graded gravels or gravel-sand mixtures, little or no fines	Good to excellent	Good	Fair to good	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller, steel-wheeled roller	110-140	30-60	300-500
		GM	d	Silty gravels, gravel-sand-silt mixtures	Good to excellent	Good	Fair to good	Slight to medium	Very slight	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	125-145	40-60	300-500
			u		Good	Fair	Poor to not suitable	Slight to medium	Slight	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	115-135	20-30	200-500
		GC		Clayey gravels, gravel-sand-clay mixtures	Good	Fair	Poor to not suitable	Slight to medium	Slight	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	130-145	20-40	200-500
	Sand and Sandy Soils	SW		Well-graded sands or gravelly sands, little or no fines	Good	Fair to good	Poor	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller	110-130	20-40	200-400
		SP		Poorly graded sands or gravelly sands, little or no fines	Fair to good	Fair	Poor to not suitable	None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired roller	105-135	10-40	150-400
		SM	d	Silty sands, sand-silt mixtures	Fair to good	Fair to good	Poor	Slight to high	Very slight	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	120-135	15-40	150-400
			u		Fair	Poor to fair	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-130	10-20	100-300
		SC		Clayey sands, sand-clay mixtures	Poor to fair	Poor	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired roller, sheepsfoot roller	100-135	5-20	100-300
Fine-Grained Soils	Silts and Clays LL is less than 50	ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor to fair	Not suitable	Not suitable	Medium to very high	Slight to medium	Fair to poor	Rubber-tired roller, sheepsfoot roller; close control of moisture	90-130	15 or less	100-200
		CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Poor to fair	Not suitable	Not suitable	Medium to high	Medium	Practically impervious	Rubber-tired roller, sheepsfoot roller	90-130	15 or less	50-150
		OL		Organic silts and organic silt-clays of low plasticity	Poor	Not suitable	Not suitable	Medium to high	Medium to high	Poor	Rubber-tired roller, sheepsfoot roller	90-105	5 or less	50-100
	Silts and Clays LL is greater than 50	MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Not suitable	Not suitable	Medium to very high	High	Fair to poor	Sheepsfoot roller, rubber-tired roller	80-105	10 or less	50-100
		CH		Inorganic clays of medium to high plasticity, organic silts	Poor to fair	Not suitable	Not suitable	Medium	High	Practically impervious	Sheepsfoot roller, rubber-tired roller	90-115	15 or less	50-150
		OH		Organic clays of high plasticity, fat clays	Poor to very poor	Not suitable	Not suitable	Medium	High	Practically impervious	Sheepsfoot roller, rubber-tired roller	80-110	5 or less	25-100
Highly Organic Soils		Pt		Peat and other highly organic soils	Not suitable	Not suitable	Not suitable	Slight	Very high	Fair to poor	Compaction not practical	—	—	—

Note:

(1) Unit Dry Weights are for compacted soil at optimum moisture content for modified AASHO compaction effort. Division of GM and SM groups into subdivision of d and u are for roads and airfields only. Subdivision is basis of Atterberg limits; suffix d (e.g., GMd) will be used when the liquid limit (LL) is 25 or less and the plasticity index is 6 or less; the suffix u will be used otherwise.

(2) The maximum value that can be used in design of airfields is, in some cases, limited by gradation and plasticity requirements.

GENERAL QUALIFICATIONS

This report has been prepared in order to aid in the evaluation of this property and to assist the architect and/or engineer in the design of this project. The scope of the project and location described herein, and my description of the project represents my understanding of the significant aspects relevant to soil and foundation characteristics. In the event that any changes in the design or location of the proposed facilities, as outlined in this report, are planned, I should be informed so the changes can be reviewed and the conclusions of this report modified or approved in writing by myself.

It is recommended that all construction operations dealing with earthwork and foundations be inspected by an experienced soil engineer to assure that the design requirements are fulfilled in the actual construction. If you wish, I would welcome the opportunity to review the plans and specifications when they have been prepared so that I may have the opportunity of commenting on the effect of soil conditions on the design and specifications.

The analysis and recommendations submitted in this report are based upon the data obtained from the soil borings and/or test pits performed at the locations indicated on the location diagram and from any other information discussed in the report. This report does not reflect any variations which may occur between these boring and/or test pits. In the performance of subsurface investigations, specific information is obtained at specific locations at specific times. However, it is a well-known fact that variations in soil and rock conditions exist on most sites between boring locations and also such situations as groundwater conditions vary from time to time. The nature and extent of variations may may not become evident until the course of construction. If variations then appear evident, it will be necessary for a reevaluation of the recommendations of this report after performing on-site observations during the construction period and noting the characteristics of any variations.