Bedrock in the area, as mapped on the Geologic Map of New York State, Hudson-Mohawk Sheet (State Education Department, 1970), is described as shale and sandstone conglomerate of the lower Walton formation. All rock types exhibit a broad range of compressive strengths reflecting their heterogeneity in composition and structure; it is estimated that compressive strengths associated with the sandstone recovered in this investigation range from about 1,000 pounds per square inch (psi) to 15,000 psi or more, depending on the extent of weathering and other factors affecting its structural integrity.

Groundwater Conditions:

Groundwater was not encountered in significant quantity in the test borings. Recovered soil samples were for the most part damp or moist, and wet soils were not recovered. At most locations, water was introduced into the borehole for either permeability tests or rock coring, and some measurable residual water was therefore present in the borehole upon completion of sampling at these locations. No groundwater was noted in the test pits.

Field and Laboratory Testing:

Permeability testing indicates that the upper sand and gravel soils exhibit hydraulic conductivity on the order of 10^{-4} to10^{-5} centimeters per second (cm/sec), while that of the deeper basal till soils is on the order of 10^{-6} cm/sec. These values represent relative permeabilities in the range of semi-pervious to impervious (Bear, 1972).

Natural water contents of the individual test pit samples ranged from 4.6 to 7.6 percent. Testing of the test pit composite sample indicates its maximum dry density is 129.0 pounds per cubic foot (pcf) at an optimum moisture content of 9.2 percent. Based on mechanical analysis of the sample, its USCS classification is SM, and its uniformity coefficient (D_{60}/D_{10}) is 466. The direct shear test indicates a peak friction angle of 35 degrees, and peak cohesion of 0.1 pounds per square inch (psi). Published reference material indicates the reported angle of internal friction is within the range of expected values for this type of material (NAVFAC DM 7.01). Note that the laboratory permeability and direct shear results were obtained on samples compacted to a target dry density of 122.6 pcf, approximately 95 percent of maximum dry density.

CONCLUSIONS AND RECOMMENDATIONS

Soil Properties and Design Parameters:

It appears that cuts up to 25 feet and fills upwards of 28 feet will be necessary to establish the proposed grades. Where cuts are required, the displaced material should generally consist of silty sands and gravels (as represented by the composite laboratory sample) which are suitable for re-use as embankment fill, with some limitations. Most notably, re-use of the prevalent cobbles and boulders in this material should be avoided. In order to achieve proper compaction of the embankment materials as they are placed, oversize material (larger in any dimension than the specified compacted lift thickness) must be removed. We would recommend that lift thickness does not exceed 12 inches; depending on the size and effectiveness of the compaction equipment used,

smaller lift thickness may be necessary. The natural moisture content of excavated materials should allow them to be adequately compacted as they are placed, although some adjustment to moisture content may be necessary depending on prevailing weather conditions at the time of construction.

Deeper cuts (in excess of 20 feet or so) will likely encounter basal till materials, to some extent. These soils, while quite dense in their natural condition, may prove more difficult to work with in their re-use as embankment fill, as they consist of a greater fractional component of fines as compared with the upper soils. As such, they will likely exhibit greater moisture sensitivity, thereby limiting the ease in which proper compaction can be achieved. Additionally, the parameters derived from the laboratory testing program are not necessarily representative of this material. If these till soils are encountered in significant quantity, and if their re-use as embankment fill is intended, additional laboratory testing should be performed to establish parameters specific to this material. Such testing should include ASTM D-422, Particle Size Analysis of Soils and ASTM D-698-02, Laboratory Compaction Characteristics of Soil Using Method C Standard Effort, at a minimum.

At location B-6, it is noted that the planned finished grade is near in elevation to where the bedrock surface was found, at elevation 1906.8 feet. While the need for extensive rock excavation across the site is not anticipated, the preceding example demonstrates that bedrock may be encountered near or above planned grades in places. The publication *Guidelines for Design of Dams* (NYSDEC, 1985; revised 1989) cautions against exposing pervious soils or fissured rock at borrow areas within proposed reservoir areas, and recommends that any such areas encountered be sealed with at least two feet of compacted impervious material.

Based on our findings, the following soil parameters can be used for design of the earthen embankment dam, cognizant of the limitations described above:

<u>Recommended Soil Parameters for Earthen Embankment Dam:</u>

- Angle of Internal Friction – 35 degrees
- Cohesion – 0.1 psi (negligible)
- Permeability – 1.0×10^{-4} cm/sec
- Uniformity Coefficient – 466
- Bearing Capacity – 10,000 psf*
- Coefficient of Friction – 0.7

* Nominal bearing capacity for generalized embankment foundation (min. 20 feet width)

The calculated uniformity coefficient of 466 indicates the silty sand and gravel overburden soils are well-graded. With respect to embankment construction, well-graded soils are preferable to soils having relatively uniform particle size, as the former are usually stronger, less susceptible to piping, erosion and liquefaction, and less compressible, other factors being equal (U.S. Army Corps of Engineers, 2004, publication EM 1110-2-2300).

Embankment Construction Considerations:

It should be noted that excavation of the coarse materials revealed in the subsurface investigation may be relatively difficult. Frequent boulders and cobbles were noted throughout the test borings and test pits. It is estimated that one-quarter to one-third of the excavated materials may be oversize and therefore not suitable for re-use as embankment fill. Plans should include a suitable borrow material/source if a net deficit is anticipated with respect to cuts and fills.

As embankment fill materials are placed, compacted layers should be firm, stable, and free of any oversize material, loose soil, mud, water or frost. It is not expected that generalized groundwater conditions will be encountered in excavations, although it is possible some localized perched or trapped seepage could be present depending on precipitation and seasonal conditions at the time of construction. Such conditions, if encountered, should be handled with conventional sump and pump methods to maintain construction in the dry.

CLOSURE

This report was prepared to assist in planning for design and construction of a water storage pond for the Belleayre Mountain ski area in the town of Shandaken, New York. The design parameters and recommendations were developed based on Empire's understanding of the project, as described herein, and through the application of generally accepted soils and foundation engineering practice. No other warranties, expressed or implied, are made. Should there be any changes in the planned construction, Empire should be notified to determine if revisions to the recommendations contained herein are required. Important information regarding the use and interpretation of this report is attached.

Sincerely,
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