



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

OLD HIGHWAY 69 SOUTHBOUND OVERPASS

WP 5044-00-01, SITE 46-492S

HIGHWAY 69, DISTRICT 54

SUDBURY

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PML Ref.: 03TF012B-S
Index No.: 194FIR and 195FDR
Geocres No.: 41I-194
December 22, 2005



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FOUNDATION INVESTIGATION REPORT

for

Old Highway 69 Southbound Overpass
WP 5044-00-01, Site 46-492S
Highway 69, District 54
Sudbury

1. INTRODUCTION

This report summarises the results of the foundation investigation carried out for the proposed construction of an overpass to carry southbound traffic of Highway 69 on a new alignment over the old Highway 69 some 15 km south of Sudbury, Ontario. The investigation was conducted for Totten Sims Hubicki Associates (TSH) on behalf of the Ontario Ministry of Transportation.

The centreline of the overpass is at approximate Station 16+732, Highway 69 median chainage, in the Township of Burwash (ref. draft Drawing 1 'Hwy 69 (SBL) – Old Hwy 69 Overpass. General Arrangement' prepared by TSH in June 2004).

The report provides subsurface information pertaining to the proposed structure and approach embankments within about 20 m of the abutments.

2. SITE DESCRIPTION AND GEOLOGY

The site is situated on the new Highway 69 alignment at the crossing of the old Highway 69 approximately 15 km south of Sudbury. The proposed structure will carry Highway 69 southbound traffic over the old Highway 69. Highway 69 is designated as a south-north road. The alignment of the overpass is therefore considered to extend south-north even though the highway is actually oriented in the southwest-northeast direction at the structure location.

The site is situated in the area of the Precambrian Laurentian peneplane. The topography is irregular in detail and dotted with areas of wet ground separated by steep rock ridges. Pleistocene lacustrine/fluvial deposits and recent swamp sediments have been laid down in depressions and are probably associated with the Nipissing post-glacial stage of the Great Lakes. The native soils are typically represented by sand/silt and/or clay deposits.



Metasedimentary rocks of the Huronian Supergroup and granitic gneisses of the Grenville Province underlay the alignment. The area has undergone considerable folding, intrusive activity, regional metamorphism and faulting. The bedrock is at various depths ranging from surface to over 35 m, with the overburden/bedrock interface exhibiting sharp elevation differences along the alignment of Highway 69.

3. INVESTIGATION PROCEDURES

The field work for this study was carried out in two phases (December 8, 2004 to January 8, 2005 and February 2 to 4, 2005) and comprised 12 boreholes advanced to depths of 11.4 to 33.3 m at the locations shown on Drawing 492S-1, appended. Initially, the boreholes drilled at the piers identified the difference in the bedrock elevation over the length of the foundation element of up to 7 m. Hence, additional boreholes (492S-5 and 492S-9) were put down as close to the centre of each pier as possible to provide supplemental data on the bedrock inclination. Further details are given in the following table:

| LOCATION | BOREHOLE No. | DEPTH, m | | |
|--------------------------------|--------------|----------|-------------|-------|
| | | AUGER | ROCK CORE * | TOTAL |
| South Approach | 492S-1 | 11.4 | – | 11.4 |
| South Abutment, West End | 492S-2 | 17.7 | – | 17.7 |
| South Abutment, East End | 492S-3 | 16.3 | 3.4 | 19.7 |
| South Pier, West End | 492S-4 | 20.7 | – | 20.7 |
| 1 m West of South Pier Centre | 492S-5 | 26.7 | 2.8 | 29.5 |
| South Pier, East End | 492S-6 | 29.4 | 3.4 | 32.8 |
| North Pier, West End | 492S-7 | 30.2 | 3.1 | 33.3 |
| North Pier, East End | 492S-8 | 23.3 | – | 23.3 |
| 4 m North of North Pier Centre | 492S-9 | 26.1 | 2.8 | 28.9 |
| North Abutment, West End | 492S-10 | 23.2 | – | 23.2 |
| North Abutment, East End | 492S-11 | 24.1 | 4.0 | 28.1 |
| North Approach | 492S-12 | 14.3 | – | 14.3 |

* NQ diamond rock coring equipment



The new alignment of Highway 69 at the structure location was staked in the field by TSH. The positions of the boreholes along the staked alignment were selected by Peto MacCallum Ltd. The ground surface elevations at the borehole locations were provided by TSH.

The test holes were advanced using continuous flight hollow stem augers, powered by a track-mounted CME-55 drill rig, supplied and operated by a specialist drilling contractor, working under the full-time supervision of a member of our engineering staff. One or two boreholes were extended 3 to 4 m into bedrock at each foundation element using NQ diamond rock coring equipment supplemented by NW wash boring techniques.

Representative soil samples were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

The ground water conditions at the borehole locations were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open boreholes. Upon completion of drilling, the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO guidelines for borehole abandonment procedures.

All of the recovered samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determinations. In addition, one Atterberg limits test and fourteen grain size distribution analyses were carried out on selected soil samples, with the results presented in Figure PC-1 and Figures GS-1 to GS-4 respectively as well as on the corresponding Record of Borehole sheets.



4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, boundary elevations, standard penetration test data, ground water observations as well as the results of laboratory Atterberg limits testing, grain size distribution analyses and moisture content determinations.

The borehole locations and stratigraphic profiles prepared from the borehole data are shown on the appended Drawings 492S-1 to 492S-3.

The subsurface stratigraphy revealed in the boreholes drilled at the abutments, piers and approach embankments to the structure generally comprised a surficial fill and/or peat deposit underlain by a major stratum of sandy/silty soils containing a discontinuous layer of cohesive soils. Cobbles/boulders were encountered at both piers and the north abutment. Bedrock/probable bedrock was contacted at 11.4 to 29.4 m (elevation 205.5 to 221.2) and 23.2 to 30.2 m (elevation 206.7 to 214.1) south and north of Highway 69, respectively. The strata encountered are summarised below.

4.1 Fill

Fill (overlain by 200 mm of asphaltic concrete in borehole 492S-6) was present surficially at both piers and composed of sand in boreholes 492S-4 and 492S-8, sand and gravel over sand in boreholes 492S-6 and 492S-7. The thickness of the fill varied between 0.9 and 3.5 m.

4.2 Peat / Topsoil

A surficial deposit of peat was present in boreholes 492S-1 to 492S-3 and 492S-10 to 492S-12. This deposit underlay the fill at 3.5 m depth (elevation 233.4) in borehole 492S-7 and was not revealed at the south pier location. The peat was fine to coarse fibrous in texture (with decayed wood in boreholes 492S-3 and 492S-7) and had a thickness of 100 mm, locally 200 mm.



Directly beneath the fill at the east end of both piers was topsoil buried at 0.9 and 2.3 m (elevation 233.5 and 232.6) in boreholes 492S-8 and 492S-6 respectively. The topsoil was 300 and 900 mm thick.

4.3 Sand to Sand and Silt

Underlying the fill (and cohesive soils at the east end of the south pier) or peat/topsoil at 0.1 to 6.7 m (elevation 228.2 to 237.2) was a major stratum of cohesionless sandy soils represented by sand, silty sand, sand and silt. This stratum was 11.3 to 26.5 m thick and very loose to very dense (SPT-'N' values of 1 to over 93). The moisture content of the sandy soils was typically about 20%, ranging from 8 to 23%.

The results of nine grain size distribution analyses conducted on representative samples of the sand are presented in Figures GS-1 and GS-2. The sandy soils were penetrated at 11.4 to 30.2 m (elevation 206.7 to 221.2). The north approach borehole was terminated in the sand and silt at 14.3 m depth (elevation 221.8).

4.4 Silt / Sandy Silt

Silt was encountered at 10.2 to 20.4 m (elevation 216.5 to 225.9) in boreholes 492S-2, 492S-7, 492S-11 and 492S-12 (consisting of two layers at the east end of the north abutment). This unit was loose to dense, typically compact (SPT-'N' values of 8 to 33) and had a thickness of 1.5 to 5.1 m. The moisture content of the silt was about 21%.

The results of four grain size distribution analyses conducted on representative samples of this material are presented in Figure GS-3. Except for borehole 492S-7 where the sampling was terminated within the unit at 21.9 m depth (elevation 215.0), the silt was penetrated at 13.1 to 19.8 m (elevation 216.0 to 223.0).

An 800 mm thick layer of sandy silt was identified at 3.7 m (elevation 231.2) in borehole 492S-6. The sandy silt was compact in relative density (SPT-'N' value of 15) and had a moisture content of 20%.



4.5 Clayey Silt to Silty Clay

A discontinuous deposit of cohesive soils classified as low plastic clayey silt to medium plastic silty clay was revealed at 2.4 to 3.2 m (elevation 230.1 to 232.0) at both piers. The silty clay encountered within the sand in boreholes 492S-4 and 492S-8 was 1.3 and 0.5 m thick respectively. In borehole 492S-6, the cohesive soils were interlayered by the sandy silt. This deposit was very soft to stiff, typically soft to firm in consistency and had a moisture content varying between 19 and 31%.

The results of an Atterberg limits test and grain size distribution analysis conducted on the cohesive material are presented in Figures PC-1 and GS-4 respectively. The liquid and plastic limits of the silty clay containing occasional lenses of silty sand were 28 and 17 respectively, with a corresponding plasticity index of 11.

The cohesive soils were penetrated at 2.9 to 6.7 m (elevation 228.2 to 231.5).

4.6 Cobbles / Boulders

Cobbles and/or boulders were encountered at both piers and the north abutment – at 18.0 m (elevation 215.1) in borehole 492S-4, 26.3 m (elevation 207.7) in borehole 492S-5, 24.0 m (elevation 210.9) in borehole 492S-6, 20.4 m (elevation 216.5) in borehole 492S-7, 19.5 m (elevation 214.5) in borehole 492S-9 and 23.5 m (elevation 212.3) in borehole 492S-11.

The cobbly/boulder material within the sandy/silty strata ranged in thickness from 0.2 to 5.4 m.

4.7 Bedrock

Bedrock/probable bedrock was contacted below the native soils at 11.4 to 29.4 m (elevation 205.5 to 221.2) and 23.2 to 30.2 m (elevation 206.7 to 214.1) south and north of Highway 69, respectively. The bedrock predominantly comprises a light grey to pink granitic gneiss (reddish brown metasedimentary rock at the east end of the south pier), with a dark green to black amphibolite as well as a pink and dark green syenite that were identified in some rock cores from



the boreholes drilled to the north of Highway 69. A detailed description of the rock cores retrieved from boreholes 492S-3, 492S-5 to 492S-7, 492S-9 and 492S-11 is given in Table 1.

The measured core recovery varied between 88 and 100% but was only 54% in the last core run in borehole 492S-6. The RQD determined from the rock cores was in a typical range of 50 to 100%, thus indicating a fair to excellent quality rock. At the east end of the south pier, however, the metasedimentary rock exhibited fair becoming poor to very poor quality (RQD of 53% decreasing to 23%).

4.8 Ground Water

Ground water was observed in eight boreholes during drilling. Water was detected in the process of augering at 1.5 to 7.5 m (elevation 227.4 to 233.7) in boreholes 492S-1 to 492S-3, 492S-6, 492S-7, 492S-10 to 492S-12. No water was observed in boreholes 492S-4 and 492S-8 in the course of the field work.

Ground water levels may fluctuate subject to seasonal variations and precipitation patterns.

5. CLOSURE

The field work was carried out under the supervision of Mr. M. Rapsey, C.E.T., and direction of Mr. D.W. Kerr, MEng, P.Eng., Chief Foundation Engineer. The equipment was supplied by Marathon Drilling Co. Ltd. The laboratory tests were conducted in the Toronto laboratory of Peto MacCallum Ltd.



The report was prepared by Mr. Grigory O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. Dennis W. Kerr, MEng, P.Eng., Chief Foundation Engineer. Mr. Brian R. Gray, MEng, P.Eng., MTO Designated Contact, carried out an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in black ink, appearing to read "Grigory O. Degil", is positioned above the name and title.

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer



A handwritten signature in black ink, appearing to read "Dennis W. Kerr", is positioned above the name and title.

Dennis W. Kerr, MEng, P.Eng.
Chief Foundation Engineer



A handwritten signature in blue ink, appearing to read "Brian R. Gray", is positioned above the name and title.

Brian R. Gray, MEng, P.Eng.
MTO Designated Contact



GD/DWK/BRG:gd-mi



TABLE 1
ROCK CORE DESCRIPTION

| CORE RECOVERY | | | | | CORE DESCRIPTION | |
|---------------|----------|-------------|--------------|---------|------------------|---|
| HOLE NO. | CORE NO. | DEPTH (m) | RECOVERY (%) | RQD (%) | DEPTH (m) | DESCRIPTION |
| 492S-3 | 15 | 16.3 - 17.4 | 88 | 88 | 16.3 - 19.7 | GRANITIC GNEISS: Pink and grey, fine to medium crystalline, banded, high strength, unweathered, moderate to wide spaced dipping partings, rough planar, oxidized, good to excellent quality. |
| | 16 | 17.4 - 18.9 | 100 | 100 | | |
| | 17 | 18.9 - 19.7 | 100 | 100 | | |
| 492S-5 | 2 | 26.7 - 27.4 | 100 | 100 | 26.7 - 29.5 | GRANITIC GNEISS: Light grey to pink, medium crystalline, slight banding, garnetiferous, high strength, unweathered, close to moderate spaced flat to dipping partings, rough planar, tight, with occ. iron staining on partings, excellent quality. |
| | 3 | 27.4 - 28.9 | 100 | 100 | | |
| | 4 | 28.9 - 29.5 | 100 | 100 | | |
| 492S-6 | 18 | 29.4 - 30.6 | 96 | 53 | 29.4 - 32.8 | METASEDIMENTARY: Reddish brown fine grained matrix with light grey medium crystalline inclusions, with veins of iron / iron like material, medium to high strength, slightly weathered to unweathered, very close to close spaced flat to dipping partings, rough planar to slickensided planar, tight to oxidized, with occ. vertical partings, fair becoming poor to very poor quality. |
| | 19 | 30.6 - 32.1 | 100 | 32 | | |
| | 20 | 32.1 - 32.8 | 54 | 23 | | |

Originated: MR
 Compiled: JW
 Checked: GD

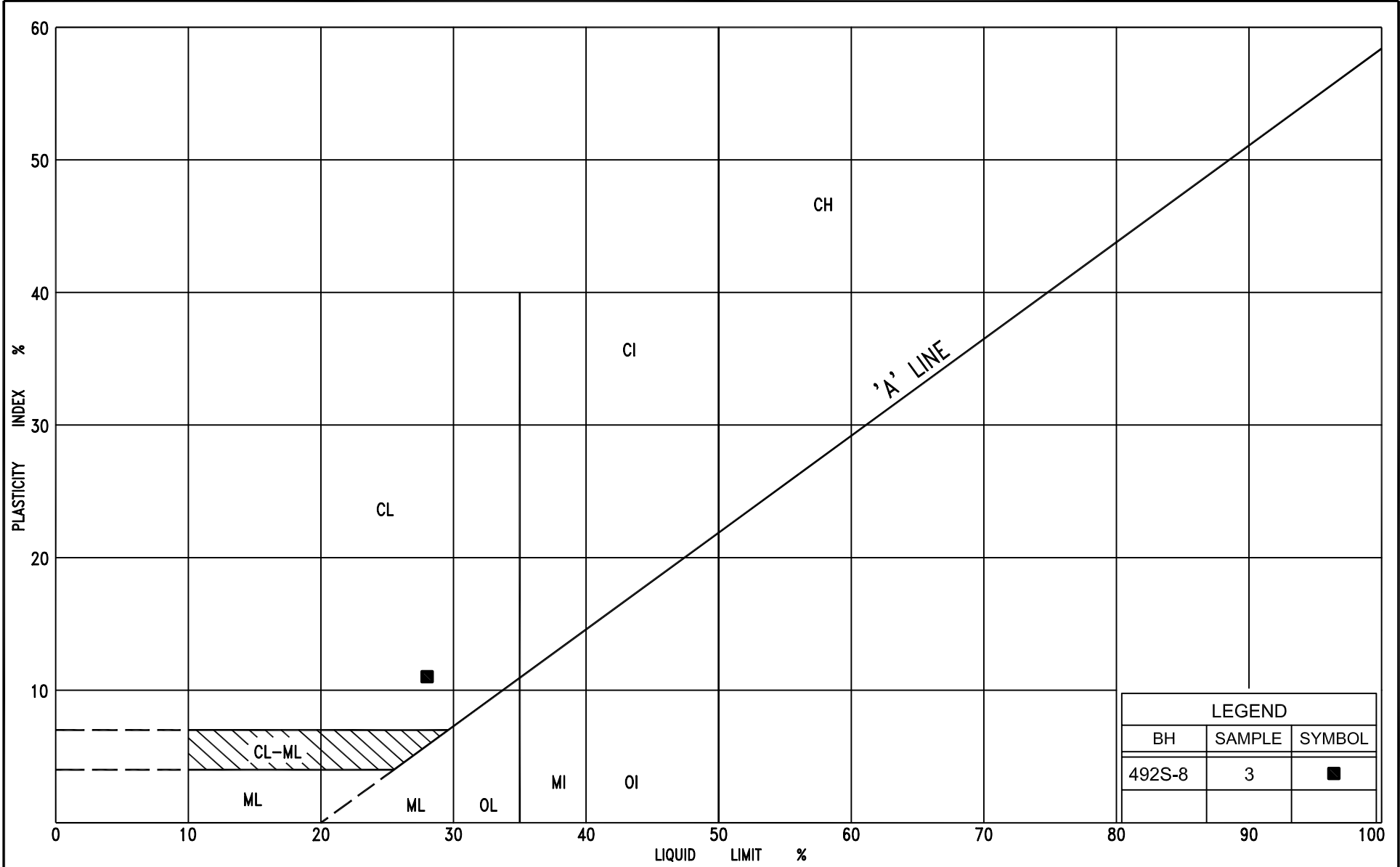


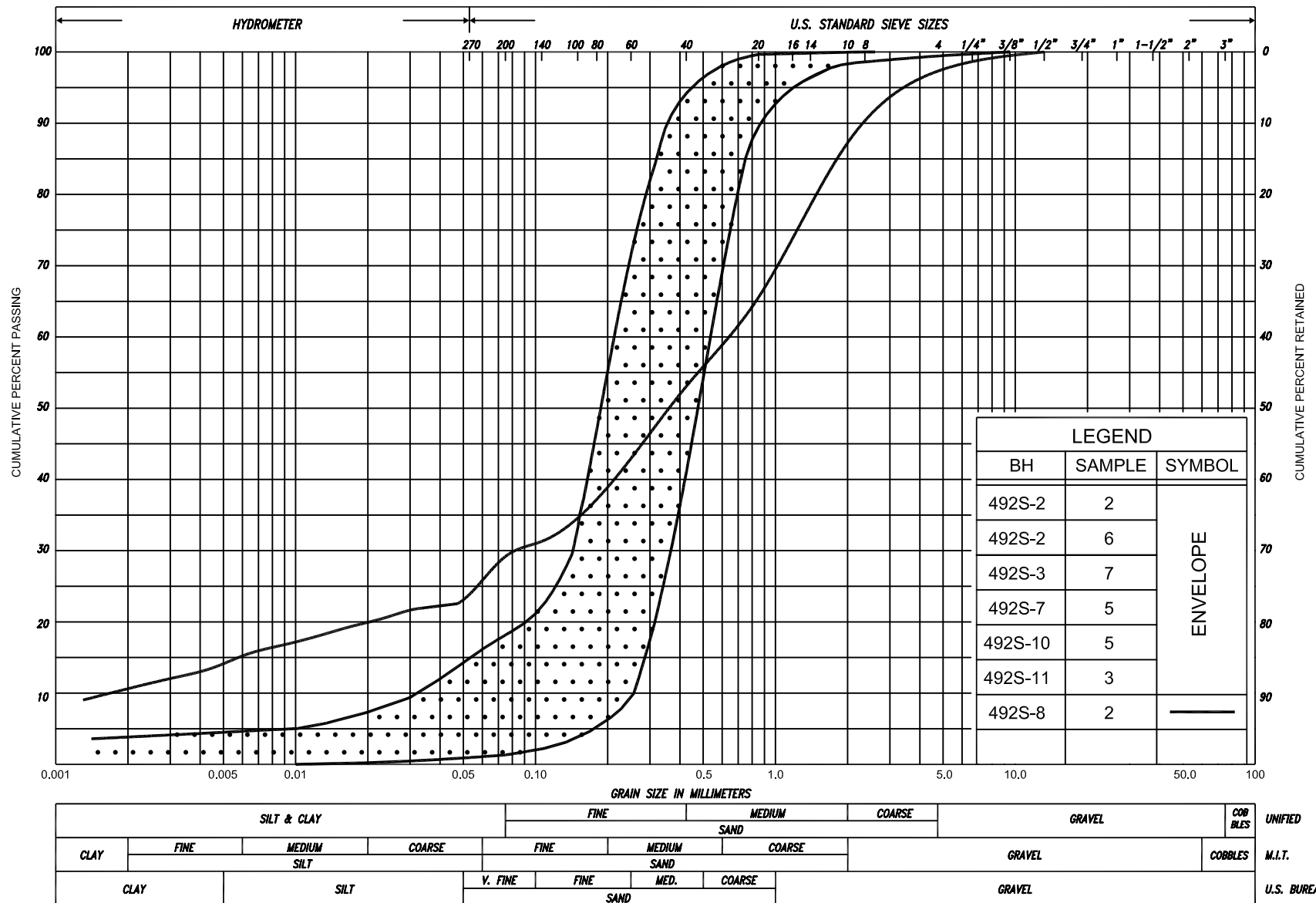
TABLE 1
ROCK CORE DESCRIPTION

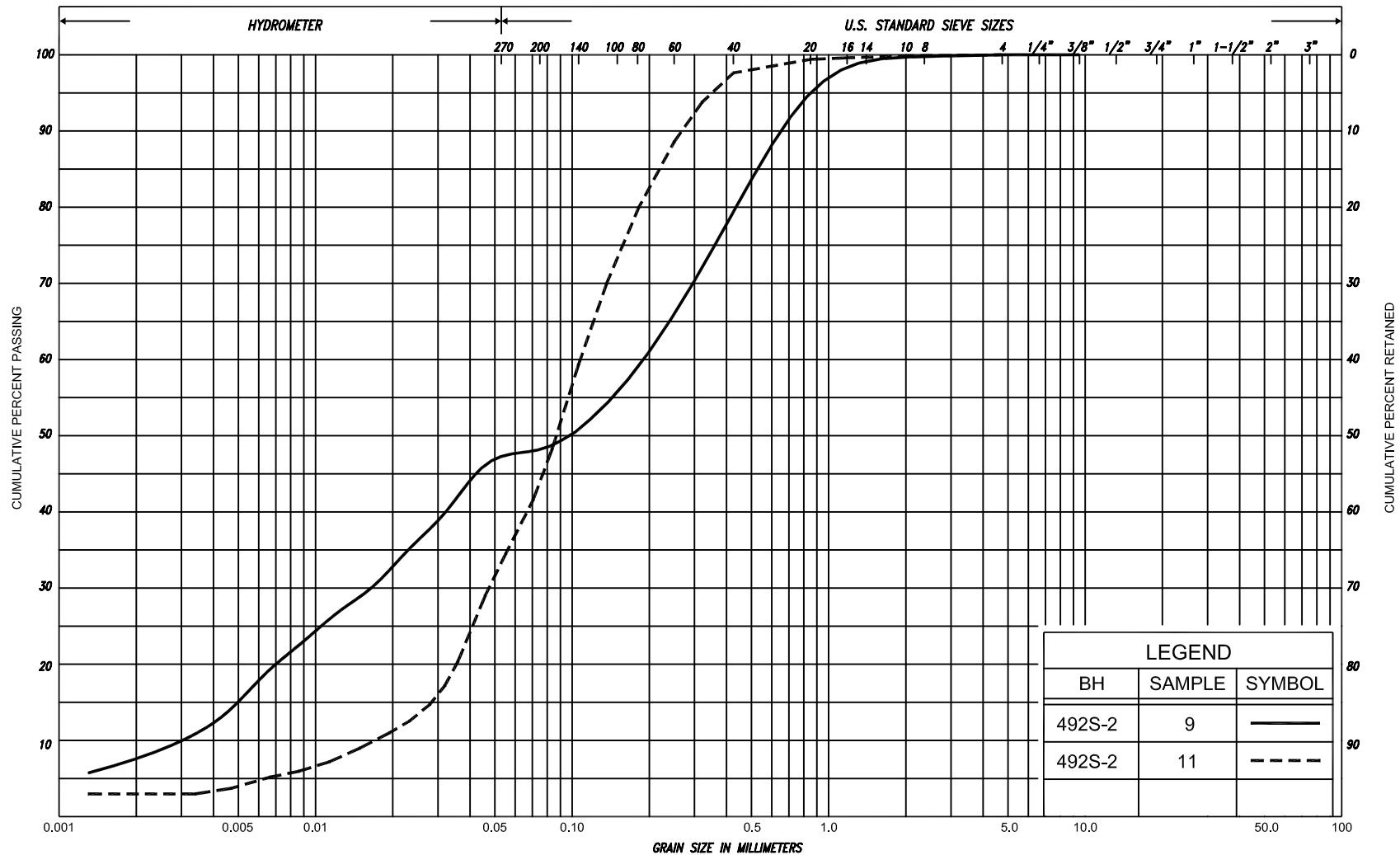
| CORE RECOVERY | | | | | CORE DESCRIPTION | |
|---------------|----------|-------------|--------------|---------|------------------|---|
| HOLE NO. | CORE NO. | DEPTH (m) | RECOVERY (%) | RQD (%) | DEPTH (m) | DESCRIPTION |
| 492S-7 | 16 | 30.2 - 31.0 | 100 | 94 | 30.2 - 32.8 | GRANITIC GNEISS: Pink and grey, medium to coarse crystalline, banded, high strength, unweathered, close to moderate spaced flat to dipping partings, rough planar, tight to oxidized with iron staining on partings, fair to excellent quality. SYENITE (?): Pink and dark green, fine to medium crystalline, high strength, unweathered, close to moderate spaced flat to dipping partings, rough planar, oxidized with iron staining on partings, with 50 mm thick clay layer at 33.1 m, fair quality. |
| | 17 | 31.0 - 31.5 | 100 | 50 | 32.8 - 33.3 | |
| | 18 | 31.5 - 32.4 | 100 | 100 | | |
| | 19 | 32.4 - 33.3 | 100 | 67 | | |
| 492S-9 | 2 | 26.1 - 27.3 | 100 | 78 | 26.1 - 28.9 | GRANITIC GNEISS: Pink and grey, medium crystalline, slight banding, high strength, unweathered, close to moderate spaced flat partings, rough planar to rough undulating, tight to oxidized with iron staining/scale on partings, good to excellent quality. |
| | 3 | 27.3 - 28.9 | 100 | 90 | | |
| 492S-11 | 15 | 24.1 - 24.7 | 100 | 63 | 24.1 - 24.7 | AMPHIBOLITE (?): Dark green to black, fine crystalline, high strength, unweathered, close spaced flat partings, rough planar, tight, fair quality. GRANITIC GNEISS: Pink, medium crystalline, banded, high strength, unweathered, very close to close becoming close to moderate spaced flat to dipping partings, rough planar, tight to oxidized, with white scale on partings, occ. vertical fissures, fair quality. SYENITE (?): Pink, medium to coarse crystalline with dark green bands, high strength, unweathered, close spaced flat to dipping partings, rough planar, tight to oxidized with red iron staining on partings, excellent quality. |
| | 16 | 24.7 - 25.3 | 100 | 52 | 24.7 - 26.8 | |
| | 17 | 25.3 - 26.8 | 98 | 63 | | |
| | 18 | 26.8 - 28.1 | 100 | 90 | 26.8 - 28.1 | |

RQD = Rock Quality Designation

Originated: MR
 Compiled: JW
 Checked: GD



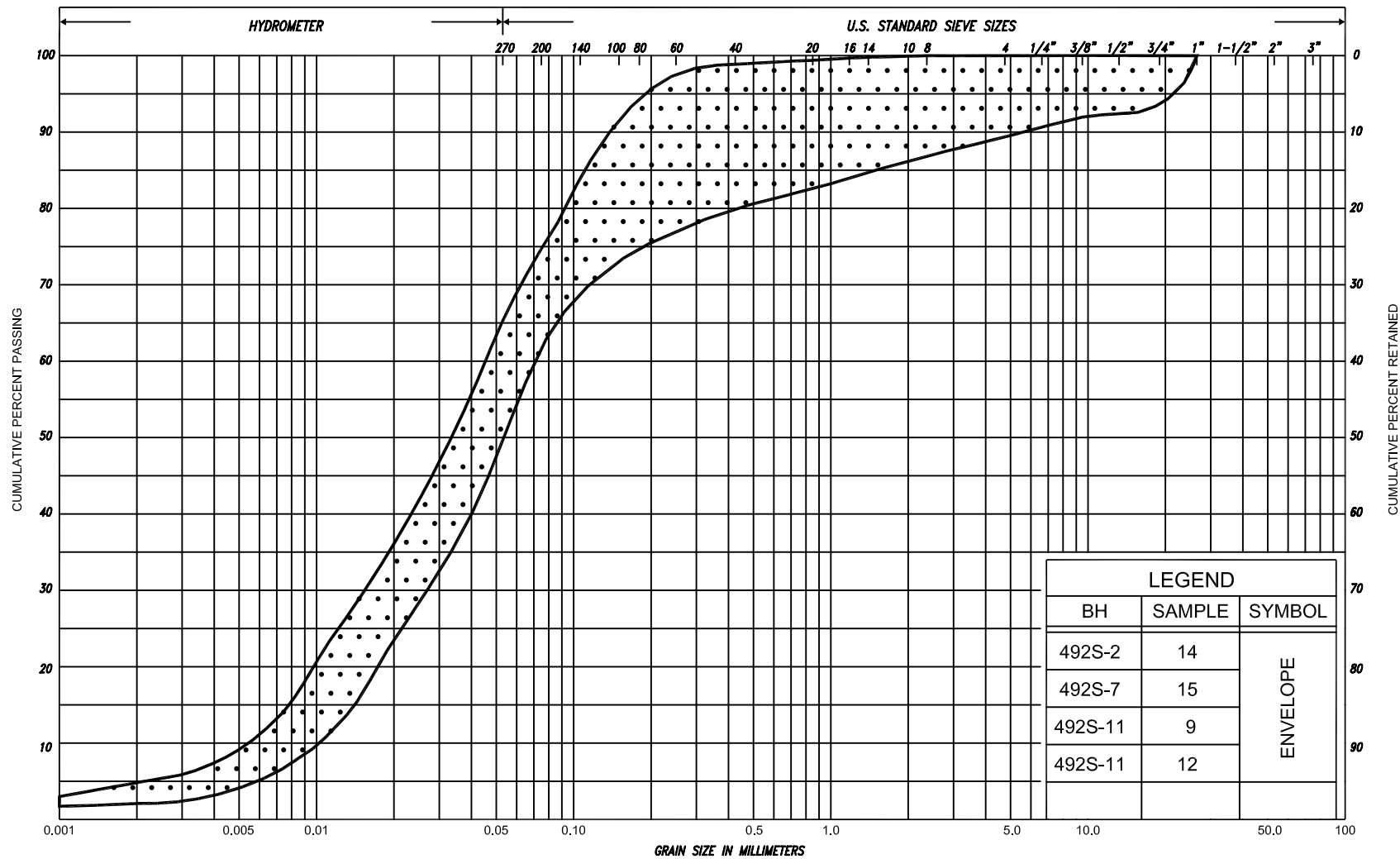




| | | | | | | | | | | | | | | | | | |
|-------------|------|------|--------|--|---------|------|--------|--------|--------|--|--------|--|--------|----------|---------|-------------|--------|
| SILT & CLAY | | | | | FINE | | MEDIUM | | COARSE | | GRAVEL | | | COB BLES | UNIFIED | | |
| | | | | | SAND | | | | | | | | | | | | |
| CLAY | FINE | | MEDIUM | | COARSE | | FINE | | MEDIUM | | COARSE | | GRAVEL | | | COBBLES | M.I.T. |
| | SILT | | | | | | | | | | | | | | | | |
| CLAY | | SILT | | | V. FINE | FINE | MED. | COARSE | GRAVEL | | | | | | | U.S. BUREAU | |
| | | | | | SAND | | | | | | | | | | | | |

GRAIN SIZE DISTRIBUTION

SAND, with layers of sandy silt



| | | | | | | | | | | | | | | |
|-------------|------|--------|--------|---------|------|--------|--------|--------|--------|--|--|---------|---------|-------------|
| SILT & CLAY | | | | FINE | | MEDIUM | | COARSE | GRAVEL | | | COBBLES | UNIFIED | |
| CLAY | FINE | MEDIUM | COARSE | FINE | | MEDIUM | | COARSE | GRAVEL | | | COBBLES | M.I.T. | |
| | SILT | | | SAND | | SAND | | | | | | | | |
| CLAY | | SILT | | V. FINE | FINE | MED. | COARSE | GRAVEL | | | | | | U.S. BUREAU |
| | | | | SAND | | | | | | | | | | |



| | | | | | | | | | | | | | |
|-------------|------|------|--------|---------|------|--------|--------|--------|--------|--------|---------|---------|-------------|
| SILT & CLAY | | | | FINE | | MEDIUM | | COARSE | GRAVEL | | COBBLES | UNIFIED | |
| | | | | SAND | | | | | | | | | |
| CLAY | FINE | | MEDIUM | COARSE | FINE | | MEDIUM | | COARSE | GRAVEL | | COBBLES | M.I.T. |
| | | SILT | | | | | | | | | | | |
| CLAY | | SILT | | V. FINE | FINE | MED. | COARSE | GRAVEL | | | | | U.S. BUREAU |
| | | | | SAND | | | | | | | | | |

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

| c_u (kPa) | 0 - 12 | 12 - 25 | 25 - 50 | 50 - 100 | 100 - 200 | > 200 |
|-------------|-----------|---------|---------|----------|------------|-------|
| | VERY SOFT | SOFT | FIRM | STIFF | VERY STIFF | HARD |

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

| N (BLOWS/0.3m) | 0 - 5 | 5 - 10 | 10 - 30 | 30 - 50 | > 50 |
|----------------|------------|--------|---------|---------|------------|
| | VERY LOOSE | LOOSE | COMPACT | DENSE | VERY DENSE |

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

| RQD (%) | 0 - 25 | 25 - 50 | 50 - 75 | 75 - 90 | 90 - 100 |
|---------|-----------|---------|---------|---------|-----------|
| | VERY POOR | POOR | FAIR | GOOD | EXCELLENT |

JOINTING AND BEDDING:

| SPACING | 50mm | 50 - 300mm | 0.3m - 1m | 1m - 3m | > 3m |
|----------|------------|------------|------------|---------|------------|
| JOINTING | VERY CLOSE | CLOSE | MOD. CLOSE | WIDE | VERY WIDE |
| BEDDING | VERY THIN | THIN | MEDIUM | THICK | VERY THICK |

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

| | | | |
|-----|---------------------|-----|----------------------------|
| S S | SPLIT SPOON | T P | THINWALL PISTON |
| W S | WASH SAMPLE | O S | OSTERBERG SAMPLE |
| S T | SLOTTED TUBE SAMPLE | R C | ROCK CORE |
| B S | BLOCK SAMPLE | P H | T W ADVANCED HYDRAULICALLY |
| C S | CHUNK SAMPLE | P M | T W ADVANCED MANUALLY |
| T W | THINWALL OPEN | F S | FOIL SAMPLE |
| F V | FIELD VANE | | |

STRESS AND STRAIN

| | | |
|--------------------------------------|-----|-------------------------------|
| u_w | kPa | PORE WATER PRESSURE |
| u | 1 | PORE PRESSURE RATIO |
| σ | kPa | TOTAL NORMAL STRESS |
| σ' | kPa | EFFECTIVE NORMAL STRESS |
| τ | kPa | SHEAR STRESS |
| $\sigma_1, \sigma_2, \sigma_3$ | kPa | PRINCIPAL STRESSES |
| ϵ | % | LINEAR STRAIN |
| $\epsilon_1, \epsilon_2, \epsilon_3$ | % | PRINCIPAL STRAINS |
| E | kPa | MODULUS OF LINEAR DEFORMATION |
| G | kPa | MODULUS OF SHEAR DEFORMATION |
| μ | 1 | COEFFICIENT OF FRICTION |

MECHANICAL PROPERTIES OF SOIL

| | | |
|----------------|-----------------------|--------------------------------------|
| m_v | kPa^{-1} | COEFFICIENT OF VOLUME CHANGE |
| C_c | 1 | COMPRESSION INDEX |
| C_s | 1 | SWELLING INDEX |
| C_α | 1 | RATE OF SECONDARY CONSOLIDATION |
| c_v | m^2/s | COEFFICIENT OF CONSOLIDATION |
| H | m | DRAINAGE PATH |
| T_v | 1 | TIME FACTOR |
| U | % | DEGREE OF CONSOLIDATION |
| σ'_{vo} | kPa | EFFECTIVE OVERBURDEN PRESSURE |
| σ'_p | kPa | PRECONSOLIDATION PRESSURE |
| τ_f | kPa | SHEAR STRENGTH |
| c' | kPa | EFFECTIVE COHESION INTERCEPT |
| ϕ' | -° | EFFECTIVE ANGLE OF INTERNAL FRICTION |
| c_u | kPa | APPARENT COHESION INTERCEPT |
| ϕ_u | -° | APPARENT ANGLE OF INTERNAL FRICTION |
| τ_R | kPa | RESIDUAL SHEAR STRENGTH |
| τ_r | kPa | REMOULDED SHEAR STRENGTH |
| S_t | 1 | SENSITIVITY = $\frac{c_u}{\tau_r}$ |

PHYSICAL PROPERTIES OF SOIL

| | | | | | | | | |
|-----------------------|------------------------|--------------------------------|-------|------|---|------------|------------------------|--|
| ρ_s | kg/m^3 | DENSITY OF SOLID PARTICLES | n | 1, % | POROSITY | e_{\max} | 1, % | VOID RATIO IN LOOSEST STATE |
| γ_s | kN/m^3 | UNIT WEIGHT OF SOLID PARTICLES | w | 1, % | WATER CONTENT | e_{\min} | 1, % | VOID RATIO IN DENSEST STATE |
| ρ_w | kg/m^3 | DENSITY OF WATER | S_r | % | DEGREE OF SATURATION | I_D | 1 | DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$ |
| γ_w | kN/m^3 | UNIT WEIGHT OF WATER | w_L | % | LIQUID LIMIT | D | mm | GRAIN DIAMETER |
| ρ | kg/m^3 | DENSITY OF SOIL | w_p | % | PLASTIC LIMIT | D_n | mm | n PERCENT - DIAMETER |
| γ | kN/m^3 | UNIT WEIGHT OF SOIL | w_s | % | SHRINKAGE LIMIT | C_u | 1 | UNIFORMITY COEFFICIENT |
| ρ_d | kg/m^3 | DENSITY OF DRY SOIL | I_p | % | PLASTICITY INDEX = $w_L - w_p$ | h | m | HYDRAULIC HEAD OR POTENTIAL |
| γ_d | kN/m^3 | UNIT WEIGHT OF DRY SOIL | I_L | 1 | LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$ | q | m^3/s | RATE OF DISCHARGE |
| ρ_{sat} | kg/m^3 | DENSITY OF SATURATED SOIL | I_C | 1 | CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$ | v | m/s | DISCHARGE VELOCITY |
| γ_{sat} | kN/m^3 | UNIT WEIGHT OF SATURATED SOIL | DTPL | | DRIER THAN PLASTIC LIMIT | i | 1 | HYDRAULIC GRADIENT |
| ρ' | kg/m^3 | DENSITY OF SUBMERGED SOIL | APL | | ABOUT PLASTIC LIMIT | k | m/s | HYDRAULIC CONDUCTIVITY |
| γ' | kN/m^3 | UNIT WEIGHT OF SUBMERGED SOIL | WTPL | | WETTER THAN PLASTIC LIMIT | j | kN/m^2 | SEEPAGE FORCE |
| e | 1, % | VOID RATIO | | | | | | |

RECORD OF BOREHOLE No 492S-1

1 of 1

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 337 N; 319 737 E ORIGINATED BY MR
 DIST 54 HWY 69 BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY GD
 DATUM Geodetic DATE December 13, 2004 CHECKED BY _____

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|-------------|----------------------------|-----------------|---|--------------|------------------|------------|--|---|---------------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | |
| | | | | | | | | ○ UNCONFINED | + FIELD VANE | ● QUICK TRIAXIAL | × LAB VANE | | | | | |
| | Ground Surface | | | | | | | | | | | | | | | |
| 0.1 | Peat, coarse fibrous Sand, with silt | | | | | 4 | 232 | | | | | | | | | |
| | Compact Brown Wet to very loose | | 1 | SS | 17 | | 231 | | | | | | | | | |
| | | | 2 | SS | 7 | | 230 | | | | | | | | | |
| | a layer of silty clay trace to some silt | | 3 | SS | 6 | | 229 | | | | | | | | | |
| | | | 4 | SS | 3 | | 228 | | | | | | | | | |
| | rust coloured layering, occ. small inclusions of clayey silt | | 5 | SS | 7 | | 227 | | | | | | | | | |
| | | | 6 | SS | 15 | | 226 | | | | | | | | | |
| | Dense | | 7 | SS | 30 | | 225 | | | | | | | | | |
| | | | 8 | SS | 50/ 13cm | | 224 | | | | | | | | | |
| | | | 9 | SS | 33 | | 223 | | | | | | | | | |
| | | | 10 | SS | 48 | 222 | | | | | | | | | | |
| 221.2 | End of borehole | | | | | | | | | | | | | | | |
| 11.4 | Refusal on probable bedrock | | | | | | | | | | | | | | | |
| | * 2004 12 13 ▽ Water level measured during drilling | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-2

1 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 358 N; 319 743 E
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring
DATUM Geodetic DATE December 11 & 12, 2004

ORIGINATED BY MR

COMPILED BY GD

CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | |
|---------------|--|------------|---------|------|-------------|----------------------------|--------------------|---|----|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|--|---|-----------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE | | | | | | | | | | |
| | | | | | | | | ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | | |
| | | | | | | | | WATER CONTENT (%) | | | | | | | | | | |
| | | | | | | | | 20 | 40 | 60 | 80 | 100 | 20 | 40 | 60 | | | |
| 232.7 | Ground Surface | | | | | | | | | | | | | | | | GR SA SI CL | |
| 0.1 | Peat, fibrous | | 1 | SS | 2 | ▽* | 232 | | | | | | | | | | 1 81 (18) | |
| | Dark brown | | | | | | | | | | | | | | | | | |
| | Sand, some silt, trace gravel, trace clay | | 2 | SS | 12 | | | | | | | | | | | | | |
| | Very loose Brown Moist loose mottled to rusty compact brown | | | | | | | | | | | | | | | | | |
| | with inclusions of clayey silt | | 3 | SS | 4 | | | | | | | | | | | | | |
| | Very loose to loose | | 4 | SS | 4 | | | | | | | | | | | | | |
| | | | 5 | SS | 7 | | | | | | | | | | | | | |
| | trace silt | | | | | | | 229 | | | | | | | | | | |
| | Wet | | 6 | SS | 2 | | | | | | | | | | | | | 1 94 (5) |
| | | | 7 | SS | 14 | | | 228 | | | | | | | | | | |
| | Compact to very dense | | | | | | | 227 | | | | | | | | | | |
| | | | 8 | SS | 30 | | | 226 | | | | | | | | | | |
| | | | | | | | | 225 | | | | | | | | | | 1 51 41 7 |
| | layers of sandy silt | | 9 | SS | 14 | | 224 | | | | | | | | | | | |
| | | | 10 | SS | 93/ 28cm | | 223 | | | | | | | | | | | |
| | | | | | | | 222 | | | | | | | | | 0 56 41 3 | | |
| | | | 11 | SS | 10 | | 221 | | | | | | | | | | | |
| | | | | | | | 220 | | | | | | | | | | | |
| | | | 12 | SS | 90/ 28cm | | 219 | | | | | | | | | | | |
| | occ. thin partings of silt | | 13 | SS | 28 | | 218 | | | | | | | | | | | |
| 217.7 | Cont'd | | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-2

2 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 358 N; 319 743 E South Abutment, West End ORIGINATED BY MR
 DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
 DATUM Geodetic DATE December 11 & 12, 2004 CHECKED BY

| SOIL PROFILE | | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | | PLASTIC LIMIT | NATURAL MOISTURE CONTENT | LIQUID LIMIT | UNIT WEIGHT γ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | |
|-------------------|---|------------|--------|---------|------------|--|----------------------------|-----------------|---|--|--|----------------|---|----------------|------------------|--------------------------------|-----------------|-------------------------|---|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | SHEAR STRENGTH kPa | | | | | | w _p | w | w _L | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | | | | | | | |
| WATER CONTENT (%) | | | | | | 20 40 60 80 100 | | | | | | 20 40 60 | | | | | | | | | |
| 217.7 15.0 | Silt, some sand, trace gravel, trace clay Compact Grey Wet | | | | | | 217 | | | | | | | | | | | 7 18 72 3 | | | |
| | | | 14 | SS | 13 | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | |
| 216.2 16.5 | Silty sand Compact Grey Wet | | | | | | 216 | | | | | | | | | | | | | | |
| | | | 15 | SS | 22 | | | | | | | | | | | | | | | | |
| 215.0 17.7 | End of borehole Refusal on probable bedrock | | | | | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-3

1 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 349 N; 319 755 E
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring
DATUM Geodetic DATE December 12, 2004

ORIGINATED BY MR

COMPILED BY GD

CHECKED BY




| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|-------------|----------------------------|--------------------|--|----|----|-----|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | |
| 232.4 | Ground Surface | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | |
| 0.1 | Peat, coarse fibrous with decayed wood Dark brown | | 1 | SS | 3 | | | | | | | | | | | | |
| | Sand, with silt with incl. of clayey silt | | | | | | | | | | | | | | | | |
| | Very loose Brown Moist loose mottled to compact rusty brown | | 2 | SS | 16 | | | | | | | | | | | | |
| | Wet | | 3 | SS | 3 | | | | | | | | | | | | |
| | | | 4 | SS | 3 | | | | | | | | | | | | |
| | layers of silt and silty clay | | 5 | SS | 1 | | | | | | | | | | | | |
| | Grey | | 6 | SS | 1 | | | | | | | | | | | | |
| | Brown | | 7 | SS | 13 | | | | | | | | | | | | |
| | some to trace silt | | | | | | | | | | | | | | | | |
| | Grey | | 8 | SS | 29 | | | | | | | | | | | | |
| | Dense to very dense | | 9 | SS | 46 | | | | | | | | | | | | |
| | Brown mottled rusty brown | | | | | | | | | | | | | | | | |
| | | | 10 | SS | 58 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 11 | SS | 50/ 15cm | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 12 | SS | 50/ 13cm | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | with silt | | | | | | | | | | | | | | | | |
| | Compact Brown | | 13 | SS | 10 | | | | | | | | | | | | |
| 217.4 | Cont'd | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-3

2 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 349 N; 319 755 E ORIGINATED BY MR
 DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
 DATUM Geodetic DATE December 12, 2004 CHECKED BY _____

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | | |
|---------------|---|---|---------|----------|-------------|----------------------------|-----------------|---|--|--|--|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|--|----------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | | | |
| 217.4 15.0 | Grey |  | | | | | 217 | | | | | | | | | | | | |
| | | | 14 | SS | 28 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| 216.1 16.3 | Bedrock Granitic gneiss High strength Good to excellent quality |  | 15 | RC NQ | REC 88% | | 216 | | | | | | | | | | RQD 88% | | |
| | | | 16 | RC NQ | REC 100% | | | | | | | | | | | | | | |
| | | | 17 | RC NQ | REC 100% | | | | | | | | | | | | | | RQD 100% |
| | | | | | | | | | | | | | | | | | | | |
| 212.7 19.7 | End of borehole | | | | | | 213 | | | | | | | | | | RQD 100% | | |
| | <div>* 2004 12 12</div> <div> Water level observed during drilling</div> | | | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-4

1 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 382 N; 319 761 E
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring
DATUM Geodetic DATE December 9 & 10, 2004

ORIGINATED BY MR
COMPILED BY GD
CHECKED BY


| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS * | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|-------------|---------------------------------|-----------------|---|----|----|-----|--|--|---|---------------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE | | | | | | | | | |
| | | | | | | | | ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | |
| 233.1 | Ground Surface | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | |
| 0.0 | Sand, some silt Mottled brown Wet (FILL) | | | | | | | | | | | | | | | | |
| 231.6 | | | 1 | SS | 24 | | | | | | | | | | | | |
| 1.5 | Sand, with silt Loose Grey Wet to very loose | | 2 | SS | 9 | | | | | | | | | | | | |
| | | | 3 | SS | 3 | | | | | | | | | | | | |
| 230.1 | | | | | | | | | | | | | | | | | |
| 3.0 | Silty clay, trace sand with layers of silt Very soft Grey Wet | | 4 | SS | WH** | | | | | | | | | | | | |
| | | | 5 | SS | WH | | | | | | | | | | | | |
| 228.8 | | | | | | | | | | | | | | | | | |
| 4.3 | Sand, trace to some silt Compact Brown Wet | | 6 | SS | 16 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 7 | SS | 14 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 8 | SS | 18 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | Very dense | | 9 | SS | 50/ 15cm | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | trace gravel | | 10 | SS | 75/ 25cm | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 11 | SS | 58 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 12 | SS | 65 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| 218.1 | Cont'd | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-4

2 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 382 N; 319 761 E ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring COMPILED BY GD
DATUM Geodetic DATE December 9 & 10, 2004 CHECKED BY _____

| SOIL PROFILE | | | | SAMPLES | | | GROUND WATER * CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | |
|---------------|--|--|--|--|--------|------|---------------------------------|-----------------|---|--|--|--|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|--|
| ELEV DEPTH | DESCRIPTION | | | STRAT PLOT | NUMBER | TYPE | | | "N" VALUES | SHEAR STRENGTH kPa | | | | | | | | | |
| | | | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | |
| | | | | | | | | | | WATER CONTENT (%) | | | | | | | | | |
| 218.1 15.0 | Sand and silt Very dense Light brown Wet | | |  | 13 | SS | 64 | | 218 | | | | | | | | | | |
| 216.8 16.3 | Sand, with silt Very dense Brown Wet | | | | | | | | 217 | | | | | | | | | | |
| | with gravel and cobbles | | | | 14 | SS | 81 | | 216 | | | | | | | | | | |
| | | | | | | | | | 215 | | | | | | | | | | |
| | | | | | 15 | SS | 37 | | 214 | | | | | | | | | | |
| | | | | | | | | | 213 | | | | | | | | | | |
| 212.4 20.7 | End of borehole Refusal on probable bedrock | | | | | | | | | | | | | | | | | | |

1 of 3

METRIC

Foundation Design

[illegible]

2 of 3

METRIC

Foundation Design

[illegible][illegible]

METRIC

ON MOT VER 3A 03TF012B SBL GPJ ON MOT GDT 22/12/05 3:21:18 PM

20
15 — 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 492S-6

1 of 3

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 374 N; 319 772 E
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring
DATUM Geodetic DATE December 08, 2004

ORIGINATED BY MR

COMPILED BY GD

CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | | |
|---------------|--|------------|---------|------|-------------------|----------------------------|-----------------|---|--|----------|--|--|--|---|---------------------------------------|--|--|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE | | | | | | | | | | | |
| | | | | | | | | ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | | | |
| | | | | | WATER CONTENT (%) | | | | | | | | | | | | | | |
| | | | | | 20 40 60 80 100 | | | | | 20 40 60 | | | | | | | | | |
| 234.9 | Ground Surface | | | | | | | | | | | | | | | | | | |
| 0.0 | Asphaltic concrete | | | | | | | | | | | | | | | | | | |
| 0.2 | Sand and gravel, some silt | | | | | | | | | | | | | | | | | | |
| 234.4 | Dark brown (FILL) | | | | | | | | | | | | | | | | | | |
| 0.5 | Sand, trace silt with layers of clayey silty sand | | 1 | SS | 11 | | 234 | | | | | | | | | | | | |
| | Brown Damp | | 2 | SS | 5 | | 233 | | | | | | | | | | | | |
| 232.6 | Topsoil | | 3 | SS | 3 | | 232 | | | | | | | | | | | | |
| 231.7 | Clayey silt, with sand with partings of sand | | 4 | SS | 9 | | 231 | | | | | | | | | | | | |
| 3.2 | Firm to stiff Dark brown (ALLUVIUM) Moist to wet | | 5 | SS | 15 | | 230 | | | | | | | | | | | | |
| 231.2 | Sandy silt, trace clay | | 6 | SS | 5 | | 229 | | | | | | | | | | | | |
| 3.7 | Compact Grey Wet Layered silt, sand and silty clay | | 7 | SS | 1 | | 228 | | | | | | | | | | | | |
| 230.4 | Loose/ Grey Wet firm | | 8 | SS | 1 | | 227 | | | | | | | | | | | | |
| 4.5 | Clayey silt, with sand | | 9 | SS | 38 | | 226 | | | | | | | | | | | | |
| 229.3 | Soft Grey Wet | | 10 | SS | 50/15cm | | 225 | | | | | | | | | | | | |
| 5.6 | Sand, trace silt | | 11 | SS | 43 | | 224 | | | | | | | | | | | | |
| 228.2 | Very loose Grey Wet to dense | | 12 | SS | 58 | | 223 | | | | | | | | | | | | |
| 6.7 | a thin layer of gravel | | | | | | 222 | | | | | | | | | | | | |
| | Very dense Rusty brown to dense | | | | | | 221 | | | | | | | | | | | | |
| | Grey | | | | | | 220 | | | | | | | | | | | | |
| 219.9 | Cont'd | | | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-6

2 of 3

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 374 N; 319 772 E ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
DATUM Geodetic DATE December 08, 2004 CHECKED BY _____

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|--|------------|---------|------|-------------|----------------------------|-----------------|---|---------------------------------|-------------------------------------|--------------------------------|---|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 40 60 80 100 | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | | |
| 219.9 | | | | | | | | | | | | | |
| 15.0 | Sand, some silt | | | | | | | | | | | | |
| | Very dense Brown mottled to rusty brown Wet | | 13 | SS | 50/ 15cm | | 219 | | | | | | |
| | | | | | | | 218 | | | | | | |
| | | | | | | | 217 | | | | | | |
| | | | 14 | SS | 49 | | 216 | | | | | | |
| 214.8 | | | | | | | 215 | | | | | | |
| 20.1 | Sand and silt | | | | | | 214 | | | | | | |
| | Dense Brown Wet | | | | | | 213 | | | | | | |
| | | | 15 | SS | 37 | | 212 | | | | | | |
| | | | | | | | 211 | | | | | | |
| 210.9 | | | | | | | 210 | | | | | | |
| 24.0 | Gravel to cobbles, up to 25 mm diameter broken particles in a sand matrix | | 16 | SS | 38 | | 209 | | | | | | |
| | Dense to very dense | | | | | | 208 | | | | | | |
| | | | | | | | 207 | | | | | | |
| | | | 17 | SS | 64 | | 206 | | | | | | |
| 205.5 | | | | | | | 205 | | | | | | |
| 29.4 | Bedrock | | | | | | | | | | | | |
| 204.9 | Cont'd | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-6

3 of 3

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 374 N; 319 772 E ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
DATUM Geodetic DATE December 08, 2004 CHECKED BY _____

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | | | |
|---------------|---|------------|-----------------|----------|-------------|----------------------------|-----------------|---|------------------|---|---|------------|----------|---|---|----------------|--------------------------------------|---|---------|----|---------|-------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | w _p | w | w _L | | GR | SA | SI | CL | |
| | | | | | | | | ○ UNCONFINED | ● QUICK TRIAXIAL | + | × | FIELD VANE | LAB VANE | | | | | | | | | WATER CONTENT (%) |
| 204.9 30.0 | Metasedimentary Medium to high strength Fair becoming poor to very poor quality | | 18 | RC NQ | REC 96% | | 204 | | | | | | | | | | | | RQD 53% | | | |
| | | | 19 | RC NQ | REC 100% | | | 203 | | | | | | | | | | | | | RQD 32% | |
| | | | 20 | RC NQ | REC 54% | | | | | | | | | | | | | | | | | RQD 23% |
| 202.1 32.8 | | | End of borehole | | | | | | | | | | | | | | | | | | | |
| | * 2004 12 08 ▽ Water level observed during drilling | | | | | | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-7

1 of 3

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 416 N; 319 784 E North Pier, West End ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
DATUM Geodetic DATE December 18, 2004, January 24 and 25, 2005 CHECKED BY



| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------------------|---|--|--|--|----------------|------------------------------------|-------------------------------------|-----------------------------------|--|---|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE | | | | | | | | | |
| | | | | | | | | ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | |
| | | | | | | | WATER CONTENT (%) | | | | | | | | | | |
| | | | | | | | 20 40 60 80 100 | | | | | 20 40 60 | | | | | |
| 236.9 | Ground Surface | | | | | | | | | | | | | | | | |
| 0.0 | Sand and gravel, some silt | | | | | | | | | | | | | | | | |
| | _____ (FILL) _____ Sand, trace silt, trace gravel | | | | | | | | | | | | | | | | |
| | Brown Dry | | 1 | SS | 18 | | 236 | | | | | | | | | | |
| | | | 2 | SS | 17 | | 235 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | some silt | | 3 | SS | 16 | | 234 | | | | | | | | | | |
| | Mottled rusty brown | | | | | | | | | | | | | | | | |
| 233.4 | | | 4 | SS | 5 | | | | | | | | | | | | |
| 233.2 | Peat, fine fibrous with decayed wood | | | | | | | | | | | | | | | | |
| 3.7 | Dark brown | | | | | | 233 | | | | | | | | | | |
| | Sand, trace to some silt | | 5 | SS | 18 | | | | | | | | | | | | |
| | Compact Grey Wet to very mottled loose rusty brown | | 6 | SS | 10 | | 232 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | Brown | | 7 | SS | 4 | | 231 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | 230 | | | | | | | | | | |
| | Compact | | 8 | SS | 13 | | 229 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | 9 | SS | 10 | | 228 | | | | | | | | | | |
| | | | | | | | 227 | | | | | | | | | | |
| | | | | | | | 226 | | | | | | | | | | |
| 225.3 | | | 10 | SS | 15 | | | | | | | | | | | | |
| 11.6 | Layered sand, trace silt, and silt, some sand | | | | | | 225 | | | | | | | | | | |
| | Compact Brown Wet | | 11 | SS | 15 | | 224 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| 223.2 | | | | | | | | | | | | | | | | | |
| 13.7 | Sand, trace silt | | | | | | 223 | | | | | | | | | | |
| | Compact Brown Wet mottled rusty brown | | 12 | SS | 18 | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| 221.9 | Cont'd | | | | | | 222 | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-7

2 of 3

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 416 N; 319 784 E ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
DATUM Geodetic DATE December 18, 2004, January 24 and 25, 2005 CHECKED BY _____

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | | | |
|---------------|--|---|---------|------|------------|----------------------------|-------------------|---|----|----|-----|----|------------------------------------|-------------------------------------|-----------------------------------|--|--|--|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE | | | | | | | | | | | | |
| | | | | | | | | ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | | | | |
| | | | | | | | WATER CONTENT (%) | | | | | | | | | | | | | |
| 221.9 | | | | | | | 20 | 40 | 60 | 80 | 100 | 20 | 40 | 60 | | | | | | |
| 15.0 | Sand, some silt Compact Brown Wet |  | 13 | SS | 27 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| | layers of silt, trace sand | | | | | | | | | | | | | | | | | | | |
| | | | 14 | SS | 16 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| 216.5 | | | | | | | | | | | | | | | | | | | | |
| 20.4 | Silt, some sand, trace clay with occ. cobbles and layers of sand Compact Brown Wet |  | 15 | SS | 24 | | | | | | | | | | | | | | | |
| 215.0 | Unsampled | | | | | | | | | | | | | | | | | | | |
| 21.9 | Probable silty/sandy soils | | | | | | | | | | | | | | | | | | | |
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RECORD OF BOREHOLE No 492S-7

3 of 3

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 416 N; 319 784 E North Pier, West End ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
DATUM Geodetic DATE December 18, 2004, January 24 and 25, 2005 CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT W _p | NATURAL MOISTURE CONTENT W | LIQUID LIMIT W _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|--------------------------------------|------------|---------|----------|-------------|----------------------------|-----------------|---|----|----|----|-----|------------------------------------|-------------------------------------|-----------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | 20 | 40 | 60 | 80 | 100 | | | | | |
| 206.9 | | | | | | | | | | | | | | | | | |
| 206.9 | Bedrock | | 16 | RC NQ | REC 100% | | 206 | | | | | | | | | | RQD 94% |
| 30.2 | Granitic gneiss | | 17 | RC NQ | REC 100% | | | | | | | | | | | | RQD 50% |
| | High strength | | 18 | RC NQ | REC 100% | | 205 | | | | | | | | | | RQD 100% |
| | Fair to excellent quality | | 19 | RC NQ | REC 100% | | 204 | | | | | | | | | | RQD 67% |
| 203.6 | Probable syenite | | | | | | | | | | | | | | | | |
| 33.3 | High strength | | | | | | | | | | | | | | | | |
| | Fair quality | | | | | | | | | | | | | | | | |
| | End of borehole | | | | | | | | | | | | | | | | |
| | * 2004 12 18 | | | | | | | | | | | | | | | | |
| | Water level observed during drilling | | | | | | | | | | | | | | | | |
| | Borehole charged with drilling water | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-8

1 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 408 N; 319 796 E North Pier, East End ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring COMPILED BY GD
DATUM Geodetic DATE January 7 & 8, 2005 CHECKED BY

| SOIL PROFILE | | | | SAMPLES | | GROUND WATER CONDITIONS * | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | | | |
|---------------|---|------------|--------|---------|------------|---------------------------------|-----------------|---|----|--------------|-----|----|--|---|---------------------------------------|--|--|-------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | | WATER CONTENT (%) | | |
| | | | | | | | | ○ UNCONFINED | | + FIELD VANE | | | | | | | | ● QUICK TRIAXIAL | | |
| 234.4 | Ground Surface | | | | | | 20 | 40 | 60 | 80 | 100 | 20 | 40 | 60 | | | | | | |
| 0.0 | Fine to coarse sand, trace silt, trace cobbles | | | | | | | | | | | | | | | | | | | |
| 233.5 | Brown Wet (FILL) | | | | | | | | | | | | | | | | | | | |
| 0.9 | Topsoil | | 1 | SS | 3 | | | | | | | | | | | | | | | |
| 233.2 | Sand, some silt, some clay, trace gravel | | | | | | | | | | | | | | | | | | | |
| 1.2 | Loose Grey Moist to Brown | | 2 | SS | 8 | | | | | | | | | | | 3 68 18 11 | | | | |
| 232.0 | Silty clay, trace sand with occ. lenses of silty sand, trace gravel | | 3 | SS | 4 | | | | | | | | | | | 1 32 42 25 | | | | |
| 2.4 | Soft Brown Wet to firm | | | | | | | | | | | | | | | | | | | |
| 231.5 | Sand, with silt with occ. thin layers of silty clay and silt | | 4 | SS | 12 | | | | | | | | | | | | | | | |
| 2.9 | Compact Brown Wet | | | | | | | | | | | | | | | | | | | |
| | trace silt | | | | | | | | | | | | | | | | | | | |
| 229.2 | Unsampled | | 5 | SS | 26 | | | | | | | | | | | | | | | |
| 5.2 | Probable sandy soils | | | | | | | | | | | | | | | | | | | |
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RECORD OF BOREHOLE No 492S-8

2 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 408 N; 319 796 E ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring COMPILED BY GD
DATUM Geodetic DATE January 7 & 8, 2005 CHECKED BY _____

| SOIL PROFILE | | | | SAMPLES | | | GROUND WATER * CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | | |
|---------------|---|------------|--------|---------|------------|--|---------------------------------|-----------------|---|--|-------------------|--|--|--|---|---------------------------------------|--|--|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | SHEAR STRENGTH kPa | | | | | WATER CONTENT (%) | | | | | | | | | |
| | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | | | | | | |
| 219.4 15.0 | (Cont'd) Unsampled Probable sandy soils | | | | | | | 219 | | | | | | | | | | | | |
| | | | | | | | | 218 | | | | | | | | | | | | |
| | | | | | | | | 217 | | | | | | | | | | | | |
| | | | | | | | | 216 | | | | | | | | | | | | |
| | | | | | | | | 215 | | | | | | | | | | | | |
| | | | | | | | | 214 | | | | | | | | | | | | |
| | | | | | | | | 213 | | | | | | | | | | | | |
| | | | | | | | | 212 | | | | | | | | | | | | |
| 211.1 23.3 | End of borehole Refusal on probable bedrock * Borehole dry on completion of drilling | | | | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-9

1 of 2

METRIC

| | | | | | |
|-------|-------------------|----------|--|---------------|--|
| W.P. | <u>5044-00-01</u> | LOCATION | <u>Co-ords: 5 132 415 N; 319 792 E 4 m North of North Pier, CL</u> | ORIGINATED BY | <u>MR</u> |
| DIST | <u>54</u> | HWY | <u>69</u> | BOREHOLE TYPE | <u>C.F.H.S.A. + NW Washboring + NQ Rock Coring</u> |
| DATUM | <u>Geodetic</u> | DATE | <u>February 02, 2005</u> | CHECKED BY | |


[illegible]

RECORD OF BOREHOLE No 492S-9

2 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 415 N; 319 792 E 4 m North of North Pier, CL ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
DATUM Geodetic DATE February 02, 2005 CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER * CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | | | | | | |
|---------------|----------------------------|--|---------|----------|------------|---------------------------------|-----------------|---|----|----|-----|----|---|----|----------------|--------------------------------------|--|--|--|--|--|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | w _p | w | w _L | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | |
| 219.0 15.0 | Probable sandy/silty soils | | | | | | 20 | 40 | 60 | 80 | 100 | 20 | 40 | 60 | | | | | | | | | |
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| 214.5 19.5 | Boulder |  | 1 | RC NQ | | | | | | | | | | | | | | | | | | | |
| 213.6 20.4 | Probable sandy/silty soils | | | | | | | | | | | | | | | | | | | | | | |
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RECORD OF BOREHOLE No 492S-10

1 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 432 N; 319 795 E ORIGINATED BY MR
 DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring COMPILED BY GD
 DATUM Geodetic DATE January 03, 2005 CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---------------------------------|------------|---------|------|------------|----------------------------|-----------------|--|-------------------|--|--|--|--|---|---------------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | WATER CONTENT (%) | | | | | | | | |
| | Ground Surface | | | | | | | | | | | | | | | | |
| 0.1 | Peat, fine fibrous Brown | | | | | | 237 | | | | | | | | | | |
| | Sand, some gravel, some silt | | | | | | | | | | | | | | | | |
| | Loose Brown Dry to compact | | 1 | SS | 7 | | 236 | | | | | | | | | | |
| | | | 2 | SS | 5 | | | | | | | | | | | | |
| | a layer of silt | | | | | | 235 | | | | | | | | | | |
| | trace silt | | 3 | SS | 25 | | | | | | | | | | | | |
| | | | 4 | SS | 7 | | 234 | | | | | | | | | | |
| | trace clay | | | | | | 233 | | | | | | | | | | |
| | Very loose Wet | | 5 | SS | 4 | | 232 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | Grey | | 6 | SS | 3 | | 231 | | | | | | | | | | |
| 230.6 | Unsampled | | | | | | 230 | | | | | | | | | | |
| 6.7 | Probable sandy/silty soils | | | | | | 229 | | | | | | | | | | |
| | | | | | | | 228 | | | | | | | | | | |
| | | | | | | | 227 | | | | | | | | | | |
| | | | | | | | 226 | | | | | | | | | | |
| | | | | | | | 225 | | | | | | | | | | |
| | | | | | | | 224 | | | | | | | | | | |
| | | | | | | | 223 | | | | | | | | | | |
| 222.3 | Cont'd | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-10

2 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 432 N; 319 795 E ORIGINATED BY MR
 DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring COMPILED BY GD
 DATUM Geodetic DATE January 03, 2005 CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---|------------|---------|------|------------|----------------------------|-----------------|--|--|--|--|--|---|---------------------------------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | | | |
| 15.0 | (Cont'd) Unsampled Probable sandy/silty soils | | | | | | 222 | | | | | | | | | |
| | | | | | | | 221 | | | | | | | | | |
| | | | | | | | 220 | | | | | | | | | |
| | | | | | | | 219 | | | | | | | | | |
| | | | | | | | 218 | | | | | | | | | |
| | | | | | | | 217 | | | | | | | | | |
| | | | | | | | 216 | | | | | | | | | |
| | | | | | | | 215 | | | | | | | | | |
| 214.1 | | | | | | | | | | | | | | | | |
| 23.2 | End of borehole Refusal on probable bedrock | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 492S-11

1 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 424 N; 319 807 E North Abutment, East End ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
DATUM Geodetic DATE January 4 to 6, 2005 CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT w _p | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w _L | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | | |
|---------------|--------------------|------------|---------|------|-------------------|----------------------------|--------------------|---|--|----------|--|--|------------------------------------|-------------------------------------|-----------------------------------|--|--|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE | | | | | | | | | | | |
| | | | | | | | | ● QUICK TRIAXIAL × LAB VANE | | | | | | | | | | | |
| | | | | | WATER CONTENT (%) | | | | | | | | | | | | | | |
| | | | | | 20 40 60 80 100 | | | | | 20 40 60 | | | | | | | | | |
| 235.8 | Ground Surface | | | | | ▽* | 235 | | | | | | | | | 0 98 (2) | | | |
| 0.0 | Peat, fine fibrous | | | | | | 234 | | | | | | | | | | | | |
| 0.1 | Dark brown | | | | | | 233 | | | | | | | | | | | | |
| | Sand, trace silt | | | | | | 232 | | | | | | | | | | | | |
| | Loose Brown Dry | | 1 | SS | 7 | | 231 | | | | | | | | | | | | |
| | | | 2 | SS | 7 | | 230 | | | | | | | | | | | | |
| | | | | | | | 229 | | | | | | | | | | | | |
| | | | 3 | SS | 6 | | 228 | | | | | | | | | | | | |
| | | | | | | | 227 | | | | | | | | | | | | |
| | | | 4 | SS | 7 | | 226 | | | | | | | | | | | | |
| | | | | | | | 225 | | | | | | | | | | | | |
| | | | | | | 224 | | | | | | | | | | | | | |
| | | | | | | 223 | | | | | | | | | | | | | |
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RECORD OF BOREHOLE No 492S-11

2 of 2

METRIC

W.P. 5044-00-01 LOCATION Co-ords: 5 132 424 N; 319 807 E North Abutment, East End ORIGINATED BY MR
DIST 54 HWY 69 BOREHOLE TYPE C.F.H.S.A. + NW Washboring + NQ Rock Coring COMPILED BY GD
DATUM Geodetic DATE January 4 to 6, 2005 CHECKED BY

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) | | | | | |
|---------------|---|------------|---------|----------|-------------|----------------------------|-----------------|---|----|----|----|-----|---|---|----------------|--------------------------------------|---|----|----|----|----|---------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | w _p | w | w _L | | WATER CONTENT (%) | GR | SA | SI | CL | |
| | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| 220.8 | | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | | | | | |
| 15.0 | Silt, with sand, trace clay Loose Brown Wet to compact | | 12 | SS | 9 | | 220 | | | | | | | | | | | | 0 | 26 | 72 | 2 |
| | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | 219 | | | | | | | | | | | | | | | |
| | | | | | | | 218 | | | | | | | | | | | | | | | |
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| | | | 13 | SS | 13 | | 217 | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| 216.0 | | | | | | | 216 | | | | | | | | | | | | | | | |
| 19.8 | Sand, some silt, trace gravel Dense Brown Wet | | | | | | | | | | | | | | | | | | | | | |
| | | | 14 | SS | 47 | | 215 | | | | | | | | | | | | | | | |
| | | | | | | | 214 | | | | | | | | | | | | | | | |
| | | | | | | | 213 | | | | | | | | | | | | | | | |
| | with cobbles | | | | | | 212 | | | | | | | | | | | | | | | |
| 211.7 | | | | | | | | | | | | | | | | | | | | | | |
| 24.1 | Bedrock Probable amphibolite High strength Fair quality | | 15 | RC NQ | REC 100% | | 211 | | | | | | | | | | | | | | | RQD 63% |
| | Granitic gneiss High strength Fair quality | | 16 | RC NQ | REC 100% | | 210 | | | | | | | | | | | | | | | RQD 52% |
| | | | 17 | RC NQ | REC 98% | | 209 | | | | | | | | | | | | | | | RQD 63% |
| | Probable syenite High strength Excellent quality | | 18 | RC NQ | REC 100% | | 208 | | | | | | | | | | | | | | | RQD 90% |
| 207.7 | | | | | | | | | | | | | | | | | | | | | | |
| 28.1 | End of borehole | | | | | | | | | | | | | | | | | | | | | |
| | * 2005 01 04 ▽ Water level observed during drilling | | | | | | | | | | | | | | | | | | | | | |

1 of 1

METRIC

Foundation Design

| | | | | | |
|-------|------------|----------|---|---------------|--------------------------------------|
| W.P. | 5044-00-01 | LOCATION | CO-ORDS: 5 132 445 N; 519 612 E North Approach | ORIGINATED BY | MR |
| DIST | 54 | HWY | 69 | BOREHOLE TYPE | Continuous Flight Hollow Stem Augers |
| DATUM | Geodetic | DATE | January 07, 20065 | CHECKED BY | |

ON MOT VER 3A 03TF012B SBL GPJ ON MOT GDT 22/12/05 3:23:18 PM

+⁷, ×⁵: Numbers refer to Sensitivity

20
15 — 5 (%) STRAIN AT FAILURE
10

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES

OLD HIGHWAY 69 OVERPASS
HIGHWAY 69 SBL
 HIGHWAY 69 FOUR-LANING FOR 12 km
 From 4 km South of Estaire to 1 km North of Hwy 537
BOREHOLE LOCATIONS



KEY PLAN
SCALE

1 0 1 2 3km

The diagram shows a vertical borehole with several instruments and logs. From top to bottom, the components are:

- Borehole**: Indicated by a solid black circle at the top.
- Dynamic Cone Penetration Test (Cone)**: Indicated by a circle with a crosshair.
- Borehole & Cone**: Indicated by a circle with a crosshair and a solid black circle below it.
- Blows/0.3m (Std. Pen Test, 475 J / blow)**: A log entry corresponding to the Borehole & Cone instrument.
- CONE**: Indicated by a circle with a crosshair.
- Blows/0.3m (60° Cone, 475 J / blow)**: A log entry corresponding to the CONE instrument.
- W.L. at time of investigation Dec 2004 to Feb 2005**: A log entry corresponding to the water level measurement.
- Head**: Indicated by a downward-pointing triangle.
- ARTESIAN WATER**: Indicated by a downward-pointing triangle.
- Encountered**: Indicated by a downward-pointing triangle.
- PIEZOMETER**: Indicated by a solid black circle at the bottom.

| BH No | ELEVATION | CO-ORDINATES | |
|---------|-----------|--------------|-----------|
| | | NORTH | EAST |
| 492S-10 | 237.3 | 5 132 432 | 319 795 |
| 492S-11 | 235.8 | 5 132 424 | 319 807 |
| 492S-12 | 236.1 | 5 132 445 | 319 812 |
| BH No | ELEVATION | STATION | o/s CL ME |
| 608-9M | 236.2 | 16+787.5 | CL |
| 608-9MA | 234.3 | 16+760 | CL |
| 608-22S | 233.7 | 16+650 | 19m Lt |
| 608-23S | 235.0 | 16+662.5 | 41.5m Lt |
| 608-24S | 237.4 | 16+800 | 19m Lt |

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

| | | | |
|-----------|----|-------------|--|
| REVISIONS | | | |
| | | | |
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| | | | |
| | | | |
| DATE | BY | DESCRIPTION | |

| | | | | | |
|-----------|----|---------|-----|--------------------|--------------|
| HWY No 69 | | | | DIST 54 | |
| SUBM'D | GD | CHECKED | GD | DATE DEC. 22, 2005 | SITE 46-492S |
| DRAWN | NA | CHECKED | DWK | APPROVED BRG | DWG 492S-1 |









REFER TO DRAWINGS 492S-2 AND 492S-3 FOR SECTIONS A-A, B-B, C-C, D-D AND E-E.

REF No E-OLD-HWY69-GA-SBL.pdf; June 2004

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES

OLD HIGHWAY 69 OVERPASS
HIGHWAY 69 SBL
HIGHWAY 69 FOUR-LANING FOR 12 km
From 4 km South of Estaire to 1 km North of Hwy 537
SOIL STRATA



| | |
|---|--|
|  | Borehole |
|  | Dynamic Cone Penetration Test (Cone) |
|  | Borehole & Cone |
| N | Blows/0.3m (Std. Pen Test, 475 J / blow) |
| CONE | Blows/0.3m (60° Cone, 475 J / blow) |
|  | W L at time of investigation Dec 2004 to Feb 2005 |
|  | Head |
|  | ARTESIAN WATER |
|  | Encountered |
|  | PIEZOMETER |

- NOTE -

The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

Geocres No. 411 - 194

| | | | | | |
|-----------|----|-------------|--------------------|---------|--------------|
| HWY No 69 | | | | DIST 54 | |
| SUBM'D | GD | CHECKED GD | DATE DEC. 22, 2005 | | SITE 46-492S |
| DRAWN | NA | CHECKED DWK | APPROVED BRG | | DWG 492S-2 |

NOTES:

1. REFER TO DRAWING 492S-1 FOR PLAN; DRAWING 492S-3 FOR SECTIONS B-B, C-C, D-D AND E-E.
2. *SECTIONS ARE PROVIDED SOLELY FOR ILLUSTRATIVE PURPOSES. REFER TO RECORD OF BOREHOLES FOR DETAILED DESCRIPTION OF SUBSURFACE CONDITIONS, IN-SITU TEST DATA AND LABORATORY TEST RESULTS.*

A horizontal number line with tick marks. Above the line, the numbers 5, 0, 5, and 10m are labeled. The segment between the first 5 and 0 is divided into 10 equal sub-segments by small tick marks, indicating a scale of 0.5m per sub-segment.

REF No E-OLD-HWY69-GA-SBL.pdf; June 2004



FOUNDATION DESIGN REPORT

for

OLD HIGHWAY 69 SOUTHBOUND OVERPASS

WP 5044-00-01, SITE 46-492S

HIGHWAY 69, DISTRICT 54

SUDBURY

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December 22, 2005



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Close to Excavation

FOUNDATION DESIGN REPORT
for
Old Highway 69 Southbound Overpass
WP 5044-00-01, Site 46-492S
Highway 69, District 54
Sudbury

1. INTRODUCTION

This report provides foundation engineering comments and recommendations regarding design and construction of the foundations, abutments and approach embankments for the proposed construction of an overpass to carry southbound traffic of Highway 69 on a new alignment over the old Highway 69 some 15 km south of Sudbury, Ontario. The investigation was conducted for Totten Sims Hubicki Associates (TSH) on behalf of the Ontario Ministry of Transportation (MTO).

The centreline of the overpass is at approximate Station 16+732, Highway 69 median chainage. The overpass is proposed to be a three span structure with a total length of 91.5 m (span lengths of 20.5, 30.0 and 41.0 m) and width of 14.1 m (ref. draft Drawing 1 'Hwy 69 (SBL) – Old Hwy 69 Overpass. General Arrangement' prepared by TSH in October 2004).

The road grade on Highway 69 at the overpass location is planned to be at elevation 245.3 at the south abutment and elevation 247.0 at the north abutment. The approach embankments to the structure are envisaged to be about 12.6 m high at the south abutment and 11.0 m high at the north abutment (interpolated from ground surface elevations at the borehole locations and the road grade shown on the TSH drawing referred to above).

The subsurface stratigraphy revealed in the boreholes drilled at the abutments, piers and approach embankments to the structure generally comprised a surficial fill and/or peat deposit underlain by a major stratum of sandy/silty soils containing a discontinuous layer of cohesive soils. Cobbles/boulders were encountered at both piers and the north abutment. Bedrock/probable bedrock was contacted at depths of 11.4 to 29.4 m south and 23.2 to 30.2 m north of Highway 69, respectively.



The depth to and surface elevation of the bedrock identified in the boreholes drilled at this site are summarised in the following table:

| Location | Borehole No. | Depth to Rock (m) | Bedrock Elevation |
|--------------------------------|--------------|-------------------|-------------------|
| South Approach | 492S-1 | 11.4 | 221.2 |
| South Abutment, West End | 492S-2 | 17.7 | 215.0 |
| South Abutment, East End | 492S-3 | 16.3* | 216.1* |
| South Pier, West End | 492S-4 | 20.7 | 212.4 |
| 1 m West of South Pier Centre | 492S-5 | 26.7* | 207.3* |
| South Pier, East End | 492S-6 | 29.4* | 205.5* |
| North Pier, West End | 492S-7 | 30.2* | 206.7* |
| North Pier, East End | 492S-8 | 23.3 | 211.1 |
| 4 m North of North Pier Centre | 492S-9 | 26.1* | 207.9* |
| North Abutment, West End | 492S-10 | 23.2 | 214.1 |
| North Abutment, East End | 492S-11 | 24.1* | 211.7* |
| North Approach | 492S-12 | >14.3 | <221.8 |

* confirmed by rock coring

2. **FOUNDATIONS**

2.1 **General**

The design calls for the approach embankments to the structure to be about 12.6 m high at the south abutment and 11.0 m high at the north abutment, with the road grade 30 to 40 m above bedrock. Consequently, use of end-bearing piles driven to bedrock is considered to be the preferred means of supporting the abutment and pier foundation loads from a foundation engineering perspective. Further, construction of integral abutments supported on steel H-piles is considered to be feasible.

Cognizant of the proximity to the existing Highway 69 embankment, the relatively previous sandy soils at this site along with the ground water level and the depth to a competent bearing material,



it is considered that spread footings founded on a pad of engineered fill or the compact native sand to support the foundation loads are not suitable at this site.

Further comments and recommendations for design of the foundations are provided in the following sections. A summary of the advantages, disadvantages and the preferred foundation scheme from a foundation engineering perspective is provided in Table 1.

A list of MTO documents used in subsequent sections of the report is given in Table 2 for ease of reference.

2.2 Seismic Analysis and Liquefaction Potential

The seismic site coefficient for the conditions at the site is 1.0 (Type I soil profile as per clause 4.4.6 of the Canadian Highway Bridge Design Code (CHBDC), CAN/CSA-S6-00). The zonal acceleration ratio is 0.05.

The site is located in Seismic Performance Zone 1. The liquefaction potential of the sandy/silty soils at the site was evaluated using the procedure suggested by Seed and Idriss (1971) and, on this basis, it is considered that liquefaction of the cohesionless soils is unlikely to occur (clause 4.6.2 of the CHBDC).

2.3 Piles

The steel H-piles should be driven to refusal on bedrock anticipated at depths of 16.3 to 24.1 m below existing grade (elevation 211.7 to 216.1) at the abutments and 20.7 to 30.2 m (elevation 205.5 to 212.4) at the piers.

Cobbles/boulders were encountered in a dense to very dense granular deposit below elevation 216 at both piers and the north abutment. Refusal to augering was met in boreholes 492S-5 and 492S-9 (piers); coring revealed that refusal was met on a boulder. The presence of the cobbles/boulders could damage the piles during installation and/or impede the progress of installation. It is recommended therefore, that an NSSP specific to this project be prepared to



advise the contractor of the need for more comprehensive engineering supervision than is called for in SP 903S01 due to the presence of cobbles/boulders identified within the sandy soil.

The NSSP should include specific direction for the contractor to provide experienced full time foundation engineering supervision to monitor the driving operations over the complete length of the pile during driving below elevation 216. This should involve assessment of the performance of the hammer, recording of the number of blows required to advance the pile during each 25 mm of penetration over the total length of the pile below elevation 216, interpretation of the penetration data as the pile is driven for evidence of unusual conditions that could be indicative of damage, ensuring the driving of piles to refusal on bedrock and the need to drive replacement piles if evidence of damage is detected.

Subject to preparation of the NSSP, the factored axial resistance at ultimate limit states (ULS) recommended for selected pile sections is as follows (refer to notes 5 and 6 in Section 3.3.3 of the Pile Driving Notes in the Structural Manual, June 2002):

| Pile Section | Factored Axial Resistance at ULS (kN) | |
|-----------------------|---------------------------------------|-----------|
| | Piers ⁽¹⁾ | Abutments |
| HP 310x110/HP 360x108 | 1600 | 2000 |
| HP 310x132 | 2000 | 2400 |
| HP 310x152/HP 360x152 | 2500 | 2800 |

1. Reduction factors of 0.8 to 0.9 have been applied to the normal resistance of the HP 310x110 / 360x108, HP 310x132 and HP 310x152 / 360x152 pile sections to account for potential damage when driving through the boulders identified in boreholes 492S-5 and 492S-9 drilled at both piers. A prorated reduction factor is deemed to be appropriate to take into account the reduced potential for damage of the heavier pile sections.

The resistance at serviceability limit states (SLS) normally allows for 25 mm compression of the pile and founding medium. Considering the bedrock to be non-yielding and the pile length required, the design is not expected to be governed by settlement criteria since the loading necessary to produce 25 mm axial deformation of the pile and bedrock would be larger than the factored resistance at ULS.

The approach fill embankments within the limits of the pile foundation should comprise Granular A to enable driving and minimise the potential for damage during pile installation.



To accommodate movement of the integral abutment system, two concentric CSPs that extend at least 3 m below the bottom of the abutment should be placed around the pile to create an annular space. The inner CSP should be filled with granular material meeting the gradation requirements of Granular B Type I. Alternatively, a single CSP or auger hole filled with loose uniform sand meeting the requirements shown in the attached Table 3 may be used. Refer to MTO Report SO-96-01 for further details.

The piles are assessed to be 20 to 29 m long at the foundation elements. The piles will be driven through compacted granular fill at the abutments and the underlying native soils that comprise very loose to very dense cohesionless sandy/silty strata containing a discontinuous deposit of soft to firm cohesive soils and an approximately 5 m thick layer of cobbly material. It is considered, based on our extensive experience with pile driving under similar conditions, that a hammer transferring at least 40 kJ of energy to the pile should be employed to drive the piles. The rated energy of the hammer should therefore be 50 to 55 kJ depending on the type of equipment employed. Since the piles will be driven to bedrock, a specific set is not provided.

The bedrock surface elevation revealed in the boreholes drilled at the site varies significantly in both the longitudinal and lateral direction along the structure. Overall, it dips in the southwest-northeast direction towards the old Highway 69 alignment. However, significant differences in the bedrock surface elevation were measured between foundation units as well as along individual foundation units. The maximum measured inclination is nearly 1H:1V between boreholes 492S-4 and 492S-5 at the south pier. Along the axis of each foundation element, the bedrock surface slopes down alternately to the west and east at the piers and north abutment at an angle of 10 to 26°.

The piles will be driven through cobbly material and set on or into bedrock. Therefore, they should be equipped with Titus 'H' Bearing Pile Points, Rock Injector model, or equivalent (SP 903S01, clause 903.05.03; clauses 3.1.2 and 3.3.1-6 of the Structural Manual (Division 1 – Exceptions to the CHBDC) dated June 2002) to minimise potential damage to the pile tip.



Pile caps should be provided with at least 1.7 m of earth cover or equivalent thermal insulation as protection against frost action. A 25 mm thick layer of polystyrene insulation is thermally equivalent to 600 mm of soil cover.

Resistance to lateral loads may be provided in part by mobilisation of passive resistance along the pile below the annular space created by the concentric CSPs. The recommended lateral resistance is as follows:

| | <u>Native Sand/Silt</u> | | <u>Granular Backfill</u> | |
|--------------------------------|-------------------------|-----|--------------------------|-----|
| Pile Section | 310 | 360 | 310 | 360 |
| Factored Resistance at ULS, kN | 100 | 130 | 120 | 170 |
| Resistance at SLS, kN | 25 | 40 | 50 | 70 |

If greater resistance is required, batter piles should be installed. Considering the inclination of the bedrock surface, the batter should not exceed 1H:6V.

The coefficient of horizontal subgrade reaction k_s (MN/m^3) should be computed using the following equation to evaluate the point of contraflexure:

$$k_s = n_h z/b$$

where n_h = coefficient related to soil density

= $10 \text{ MN}/\text{m}^3$ for granular backfill

= $2 \text{ MN}/\text{m}^3$ for native sandy/silty soils above the ground water level (elevation 234.0)

= $1 \text{ MN}/\text{m}^3$ for native sandy/silt soils below the ground water level

z = depth, m

b = pile width, m



3. ABUTMENT WALLS

3.1 General

The abutment walls should be designed to resist the unbalanced lateral earth pressure imposed by the backfill adjacent to the wall. The lateral earth pressure may be computed using the equivalent fluid pressure diagrams presented in Section 6.9 of the CHBDC or employing the following equation, assuming a triangular pressure distribution.

$$p = K (\gamma h + q) + C_p + C_s$$

where K = coefficient of lateral earth pressure (dimensionless)

γ = unit weight of free-draining granular material, kN/m^3

h = depth below final grade, m

q = surcharge load, kPa, if present

C_p = compaction pressure, kPa (refer to clause 6.9.3 of CHBDC)

C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.4 of CHBDC)

where \emptyset = angle of internal friction of retained soil (35° for Granular A or B Type II)

δ = angle of friction between soil and wall (23° for Granular A or B Type II)

The seismic site coefficient and zonal acceleration ratio for the conditions at this site were provided in Section 2.2.

Free-draining granular material or rock fill should be used as backfill behind the walls. The following parameters are recommended for design:

| Parameters | Granular A | Granular B Type II | Rock Fill |
|---|------------|--------------------|-----------|
| Angle of Internal Friction, degrees | 35 | 35 | 42 |
| Unit Weight, kN/m^3 | 22.8 | 22.8 | 18.0 |
| Coefficient of Active Earth Pressure K_a | 0.27 | 0.27 | 0.20 |
| Coefficient of Earth Pressure At-Rest K_o | 0.43 | 0.43 | 0.33 |
| Coefficient of Passive Earth Pressure K_p | 3.69 | 3.69 | 5.04 |



Refer to MTO Report SO-96-01 for procedures to determine the earth pressure coefficient to be employed in design of integral abutments. The coefficient of earth pressure at-rest should be used for design of rigid and unyielding walls, the active earth pressure coefficient for unrestrained structures. The earth pressure coefficients should be reviewed if the slope of the backfill exceeds 10° to the horizontal. Alternatively, the material above the top of the wall could be treated as a surcharge load (q in the preceding equation).

A weeping tile system and/or weep holes should be installed to minimise the build-up of hydrostatic pressure behind the walls. The weeping tiles should be surrounded by a properly designed granular filter or geotextile to prevent migration of fines into the system. The drainage pipe should be placed on a positive grade and lead to a frost-free outlet.

Backfilling adjacent to the structure should be performed in conformance with Ontario Provincial Standards specifications for granular or rock backfill at abutments (OPSD 3501 or 3505). As noted earlier, Granular A should be employed within the limits of driven piles.

Operation of compaction equipment adjacent to retaining structures should be restricted to limit the compaction pressure noted in clause 6.9.3 of the CHBDC. Refer to OPSS 501.06 and SP 105S10 for additional information in this regard.

3.2 Retained Soil System

Since the native sandy soils are very loose to loose to depths of about 5 m (elevation 228) at the south abutment and 10 m (elevation 226) at the north abutment, it is considered that construction of a retained soil system (RSS) is not suitable at this site.



4. APPROACH EMBANKMENTS

It is anticipated that the approach embankments will be constructed with earth borrow, granular material or rock fill. The approach fill embankments will be about 12.6 m high at the south abutment and 11.0 m high at the north abutment. Construction of the fill on the very loose to very dense sandy/silty soils is considered to be feasible, subject to the comments provided in the following paragraphs.

The peat identified at the abutment locations and along the alignment of the approach fills within 20 m of the abutments should be stripped and the exposed sandy/silty soils within 10 m of the abutments proof rolled with at least six passes of a heavy roller to improve the density of the subgrade soil prior to placement of the embankment fill.

The embankments should be constructed in accordance with OPSD 201.010, 201.020, 202.010, 203.010, 208.010 and SP 206S03. The side slopes of the approach embankments should be inclined no steeper than 2H:1V for earth fill and 1.25H:1V for rock fill. For erosion control and slope maintenance purposes, a 2 m wide mid-height berm should be provided on the sides of the embankment so that no uninterrupted slope is greater than 10 m high as specified in the Northeastern Region Pavement Design Practices and Guidelines.

Where slope flattening is proposed, a drainage gap should be provided in accordance with OPSD 202.020. Where slopes are flattened to eliminate the need for a guide rail, a granular infilled drainage gap should be provided in accordance with the Northeastern Region Pavement Design Practices and Guidelines as shown in Figure 1, appended. OPSS Granular B Type II should be used for the drainage gaps.

It is considered that the approach embankments constructed according to these recommendations will be stable (factor of safety against failure of at least 1.3 in the short term and 1.5 in the long term).



Some settlement of the road surface should be expected, however, resulting from two mechanisms – consolidation of the soil below the recently placed fill and self-compaction of the new fill (rockfill remote from the abutments and backfill adjacent to the abutments).

- Settlement of the embankment surface due to consolidation of the subgrade soil is expected to be less than 40 mm and completed within two months following placement of the rockfill to the design height.
- The backfill placed adjacent to the abutments will be 11.0 to 12.6 m high. Settlement of the embankment surface due to self-compaction of the backfill is computed to be 30 to 40 mm.

Consequently, the total settlement of the approach fill surface near the abutments should be in the order of 75 mm and be essentially complete within two months after placement of the fill.

The embankments remote from the abutments will be of similar height. Settlement of the rockfill embankments is computed to be 30 to 40 mm in the first year and about 30 mm in the following 10-year period.

The settlement assessment for the granular backfill and the rockfill was based on the following criteria/considerations:

Self-Compaction of the Granular Backfill Placed Adjacent to the Abutments

Settlement of the road surface due to self-compaction of the granular backfill placed adjacent to the abutments is primarily dictated by the height of the embankment, the quality of workmanship employed by the contractor and the diligence of the quality control program (to ensure that the material is placed in accordance with the requirements of SP 902S01 and SP 105S10) and is considered to be about 0.25% of the embankment height.



Self-Compaction of the Rockfill

Assessment of the magnitude of settlement resulting from consolidation of the rockfill was based on the following criteria established from review of research documents prepared by MTO (RR229 dated March 1983) and discussions with the Pavement and Foundation Section of MTO.

- **Rockfill Above Grade**

Total settlement is about 0.5% of the rockfill height considering that it will be placed in accordance with SP 206S03.

- **Rockfill Below Grade**

Total settlement is up to 2% of the rockfill thickness since it will be end dumped and placed with minimal compactive effort.

- **Rate of Settlement**

About 50% of the total settlement occurs during the first year following placement of the rockfill and the remainder at a progressively decreasing rate during the following 10-year period.

Total settlement of the road surface is computed to be about 75 mm; the minimum widening of 2.0 m on each side for embankments constructed on earth in accordance with the requirements of the Northeastern Region Engineering Directive (NRE 98-200) dated October 28, 1998 is considered to be sufficient.

Fill slopes should be protected against surface erosion by sodding and suitable vegetation. Refer to OPSS 571 or 572 for time constraints and the type of seed and mulch required.

5. EXCAVATION AND GROUND WATER CONTROL

The bottom of both abutments is envisaged to be constructed on a compacted granular pad some 5 m above existing grade, near elevation 238 and 240 at the south and north abutments respectively. From a foundation engineering perspective, the granular pad should be completed at least two months before the piles are driven to support the abutments.



Excavation for construction of the pile cap at the south pier will extend to near elevation 231, about 2 m (the west end remote from existing embankment) to 4 m (the east end adjacent to existing embankment) below existing grade and about 3 m below the high water level observed during the field investigation.

Excavation for construction of the pile cap at the north pier will extend to near elevation 232, about 2 m (the east end of pier remote from existing embankment) to 5 m (the west end of pier adjacent to existing embankment) below existing grade and about 2 m below the high water level observed during the field investigation.

The material to be excavated primarily consists of very loose sand/silt and soft clay. The very loose sand/silt and soft to very soft clayey soils are classified as Type 4 soil according to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria. Temporary cut slopes over the full depth of excavation should therefore be inclined at 3H:1V.

It is anticipated that shoring will be required to support the walls of the excavation and adjacent traffic lanes during construction where adequate space for inclined slopes is not available.

The magnitude and distribution of the lateral earth pressures acting on a braced excavation wall is dependent upon the support system used, the number of supports, the allowable movements and the construction sequence. The recommended design earth pressure distribution for singly and multi-braced walls, for the conditions that exist at the site, are presented in Figures 2 and 3 respectively. Recommendations concerning design and construction of the braced excavation support systems are provided in the figures.

Considering the depth of excavation, ground water level and the relatively pervious soils at the site, we believe that steel sheeting should be installed to support the walls of the excavation and control ground water seepage.



The following geotechnical parameters should be employed to design the wall:

| <u>Parameters</u> | <u>Native Sand/Silt</u> |
|---|--------------------------------|
| Angle of Internal Friction, degrees | 30 |
| Unit Weight, kN/m ³ | 20.0 |
| Coefficient of Active Earth Pressure K_a | 0.33 |
| Coefficient of Earth Pressure At-Rest K_o | 0.50 |
| Coefficient of Passive Earth Pressure K_p | 3.00 |

Additional lateral resistance could be provided by installing tiebacks anchored in the compact sand. The unfactored pull-out resistance (R) of anchors grouted in cohesionless material can be estimated using the following equation:

$$R = K_f \sigma'_z L_s A_s$$

where

$$K_f = \text{anchorage coefficient}$$

$$= 0.8 \text{ for compact sand/silt}$$

$$\sigma'_z = \text{effective vertical stress at mid-point of anchor}$$

$$= \gamma' z$$

$$\gamma' = \text{effective unit weight of soil}$$

$$= 20 \text{ kN/m}^3 \text{ above ground water level}$$

$$= 10.2 \text{ kN/m}^3 \text{ below ground water level}$$

$$z = \text{depth to mid-point of anchor, m}$$

$$L_s = \text{fixed length of anchor, m}$$

$$A_s = \text{circumference of cross-section of fixed length of anchor, m}^2/\text{m}$$

A resistance factor of 0.4 should be applied to the computed anchor capacity to determine the ULS resistance.



The ground surface adjacent to the excavation is expected to experience some inward movement and vertical settlement. The magnitude of movements adjacent to a braced cut can be limited by selection of an appropriate lateral earth pressure coefficient (see Figures 2 and 3) provided good quality workmanship and construction practice is employed. The anticipated magnitude of movements is as follows:

| | <u>Movement (% of Excavation Depth)</u> |
|-------------------|--|
| Lateral Movement | |
| Braced Excavation | 0.2 |
| Anchored Wall | 0.1 |
| Vertical Movement | 0.05 |

Construction procedures should be specifically suited to limit any consequent settlement of the pavement subgrade behind the excavation face.

Foundations of heavily loaded/settlement sensitive structures and/or utilities, if located within close proximity to the excavation, may require underpinning to preserve the integrity of these structures. Further comments and general recommendations in this regard are provided in Figure 4.

During drilling, water was detected at depths of 1.5 to 7.5 m (elevation 227.4 to 233.7) in boreholes 492S-1 to 492S-3, 492S-6, 492S-7, 492S-10 to 492S-12. Positive ground water control measures such as steel sheeting and/or well points will be required to ensure the integrity of the existing embankment and maintain basal stability. Ground water levels are subject to seasonal fluctuations and precipitation patterns.

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.



6. CLOSURE

The report was prepared by Mr. Grigory O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. Dennis W. Kerr, MEng, P.Eng., Chief Foundation Engineer. Mr. Brian R. Gray, MEng, P.Eng., MTO Designated Contact, carried out an independent review of the report.

Yours very truly

Peto MacCallum Ltd.

A handwritten signature in blue ink, appearing to read "Grigory O. Degil".

Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer



A handwritten signature in blue ink, appearing to read "Dennis W. Kerr".

Dennis W. Kerr, MEng, P.Eng.
Chief Foundation Engineer



A handwritten signature in blue ink, appearing to read "Brian R. Gray".

Brian R. Gray, MEng, P.Eng.
MTO Designated Contact



GD/DWK/BRG:gd-mi



TABLE 1
SUMMARY OF ADVANTAGES, DISADVANTAGES AND
RECOMMENDED FOUNDATIONS

| FOUNDATION TYPE | ADVANTAGES | DISADVANTAGES | RECOMMENDED FOUNDATION SCHEME |
|--|---|---|-------------------------------|
| Abutments | | | |
| Spread footings on rock | Not appropriate | | Driven piles |
| Spread footings on engineered fill pad | Not appropriate | | |
| Driven piles | <ul style="list-style-type: none">• High bearing resistance• Construction of integral abutments possible | <ul style="list-style-type: none">• Difficult access | |
| Caissons | <ul style="list-style-type: none">• High bearing resistance | <ul style="list-style-type: none">• High cost relative to driven piles• Difficult access | |
| Piers | | | |
| Spread footings on rock | Not appropriate | | Driven piles |
| Spread footings on engineered fill pad | Not appropriate | | |
| Driven piles | <ul style="list-style-type: none">• High bearing resistance | <ul style="list-style-type: none">• Difficult access | |
| Caissons | <ul style="list-style-type: none">• High bearing resistance | <ul style="list-style-type: none">• High cost relative to driven piles• Difficult access | |



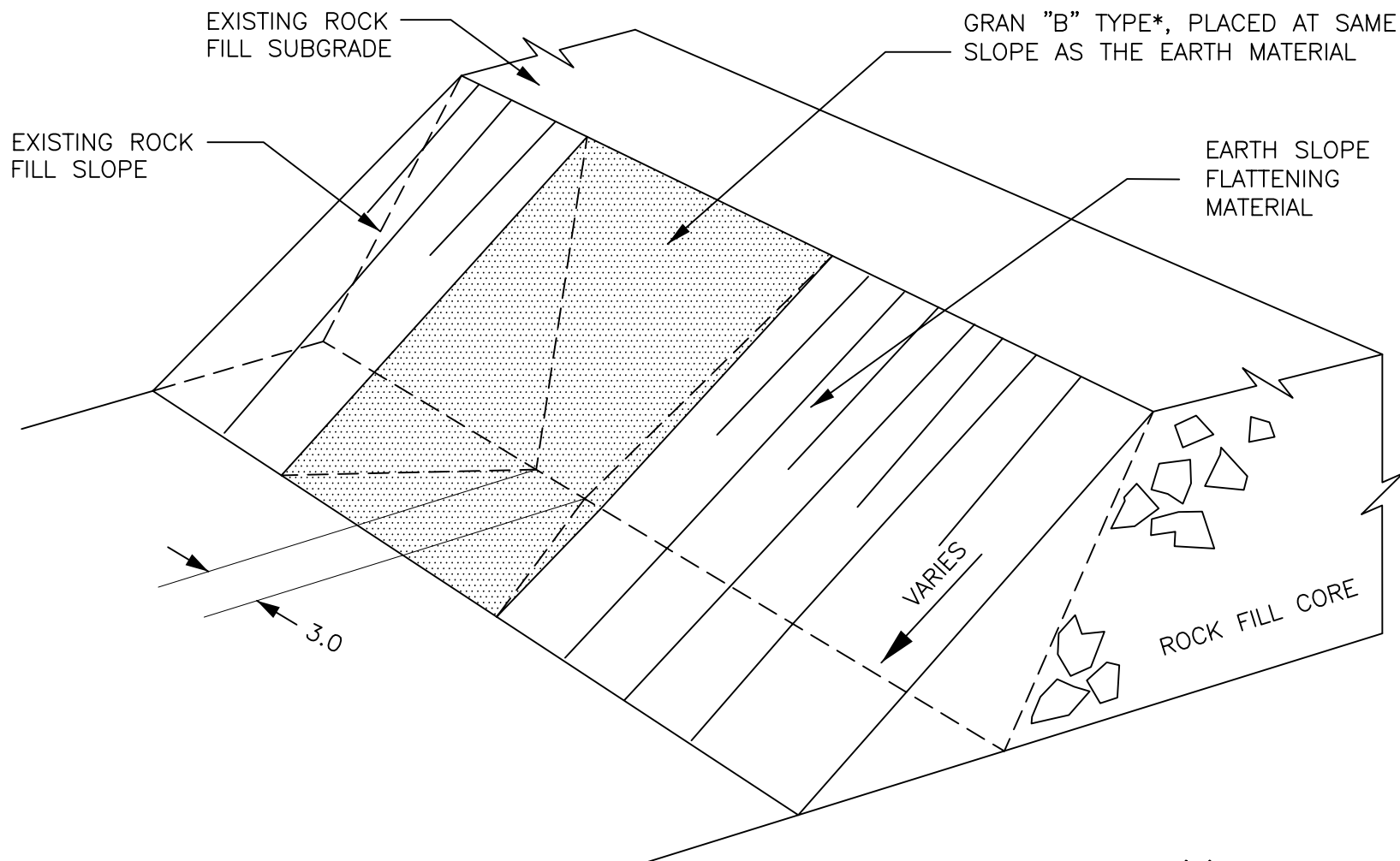
TABLE 2
LIST OF MTO DOCUMENTS USED IN REPORT

| NO. | TITLE | DATE |
|---------------|---|------------------|
| OPSD 201.010 | Rock Grading. Undivided Highway | April 1999 |
| OPSD 201.020 | Rock Grading. Divided Highway | April 1999 |
| OPSD 202.010 | Embankment Construction Using Excess Material Outside of Earth or Rock Fill | March 1, 1998 |
| OPSD 202.020 | Drainage Gap for Slope Flattening on Rock or Granular Embankment | March 1, 1998 |
| OPSD 203.010 | Embankments over Swamp. New Construction | November 2004 |
| OPSD 208.010 | Benching of Earth Slopes | November 2003 |
| OPSD 3501.000 | Minimum Granular Backfill Requirements. Abutments | April 1999 |
| OPSD 3505.000 | Rock Backfill Requirements. Abutments | November 2001 |
| OPSS 501 | Construction Specification for Compaction | February 1996 |
| OPSS 571 | Construction Specification for Sodding | November 2001 |
| OPSS 572 | Construction Specification for Seed and Cover | November 2003 |
| SP 105S10 | Soils Compaction - Quality Assurance and Quality Control | November 2004 |
| SP 206S03 | Earth and Rock Excavation | January 2004 |
| SP 902S01 | Earth and Rock Excavation for Structure | September 2003 |
| SP 903S01 | Piling | September 2004 |
| SO-96-01 | Integral Abutment Bridges | July 1996 |
| NRE 98-200 | Embankment Platform Widening | October 28, 1998 |



TABLE 3
GRADATION SPECIFICATION FOR SAND FILL IN
PRE-AUGERED HOLES AT INTEGRAL ABUTMENTS

| MTO SIEVE DESIGNATION | | PERCENTAGE PASSING BY MASS |
|------------------------------|------|-----------------------------------|
| 2 mm | #10 | 100 |
| 600 µm | #30 | 80 – 100 |
| 425 µm | #40 | 40 – 80 |
| 250 µm | #60 | 5 – 25 |
| 150 µm | #100 | 0 – 6 |



* GRAN 'B' TYPE I OR TYPE II AS RECOMMENDED FOR PROJECT.

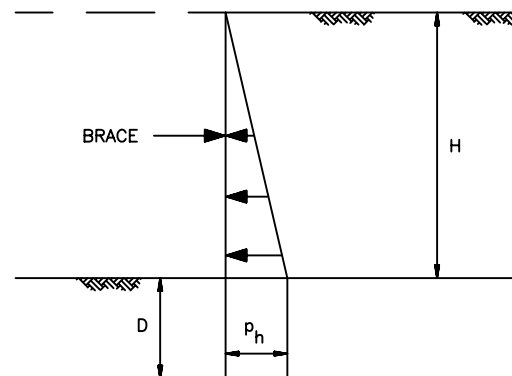
FIGURE 1: ROCK FILL DRAINAGE IN SLOPE FLATTENED AREAS

NOT TO SCALE

NOTES

1. The actual magnitude and distribution of the horizontal earth pressures which will act on the bracing system are dependent upon the permissible lateral/vertical movements adjacent to the excavation, the soil type, groundwater conditions, drainage provisions, temporary/permanent surcharge loads, the type of bracing system adopted, weather conditions, quality of workmanship and length of time the excavation will be supported. Hence, the recommended pressure diagram and design parameters should be reviewed when construction details, schedule and type of support system are established.
2. Stability of base of excavation must be confirmed when bracing system design, excavation geometry and surcharge loads are established. If groundwater table is well above base of excavation and/or artesian conditions exist, local lowering of the groundwater level will be necessary to prevent bottom heave/piping of the base of the excavation.
3. Earth pressure diagram is applicable to maximum depth of cut of 12m (40 ft.).
4. Structural components of bracing system should be confirmed adequate for each level of excavation.
5. If sheeting will not permit drainage, bracing system must be designed to resist water pressure.
6. Surcharge loads such as street/construction traffic, supported utilities, adjacent foundations, temporary stockpiles and other loads carried by bracing system are not included in earth pressure diagram.
7. Temporary surcharge loading should not be closer to the face of the excavation than half the depth of excavation unless accounted for in bracing design.
8. If settlement sensitive structures are located near the excavation, special measures should be undertaken to control settlements. A condition survey should be conducted prior to construction and appropriate monitoring (surface and insitu) carried out during construction.
9. Earth pressure diagram is applicable for relatively short construction periods. If excavation is to be open for long periods, monitoring of deformation is essential, the earth pressure diagram must be reviewed, and remedial works may be required.
10. Earth pressure diagram does not account for extended periods of exposure of the excavation to freezing temperatures.
11. Bracing system should be regularly examined for signs of distress.
12. All work should be carried out in accordance with the Occupational Health and Safety Act and local regulations. Good quality workmanship and construction practices are to be employed.
13. This sheet should be read in conjunction with text of report for this project. Additional comments and recommendations concerning these general guidelines will be provided if required.

EARTH PRESSURE DIAGRAM



$$p_h = \text{design lateral earth pressure} \\ = K\gamma H$$

$$K = \text{lateral earth pressure coefficient}$$

$$\gamma = \text{unit weight of soil}$$

$$H = \text{depth of excavation}$$

$$D = \text{depth of embedment of soldier piles (if used).}$$

RECOMMENDED DESIGN PARAMETERS

$$\gamma = 20.0 \text{ kN/m}^3$$

$$K = 0.33 \text{ (movement of retained soil acceptable)}$$

$$= 0.50 \text{ (movement of adjacent structures/facilities unacceptable)}$$

LATERAL EARTH PRESSURE DISTRIBUTION

SINGLY-BRACED CUTS IN COHESIONLESS SOILS



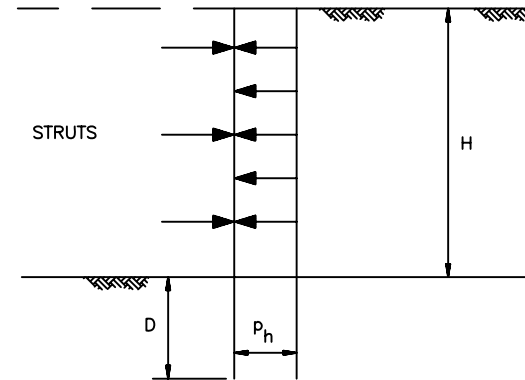
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|-----------|-----|-----------|--------|------------|------------|
| DRAWN: | NA | DATE | SCALE | JOB NO. | FIGURE NO. |
| CHECKED: | GD | DEC. 2005 | N.T.S. | 03TF012B-S | 2 |
| APPROVED: | BRG | | | | |

NOTES

1. The actual magnitude and distribution of the horizontal earth pressures which will act on the bracing system are dependent upon the permissible lateral/vertical movements adjacent to the excavation, the soil type, groundwater conditions, drainage provisions, temporary/permanent surcharge loads, the type of bracing system adopted, weather conditions, quality of workmanship and length of time the excavation will be supported. Hence, the recommended pressure diagram and design parameters should be reviewed when construction details, schedule and type of support system are established.
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RECOMMENDED DESIGN PARAMETERS

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$$K = 0.33 \text{ (movement of retained soil acceptable)} \\ 0.50 \text{ (movement of adjacent structures/facilities unacceptable)}$$

LATERAL EARTH PRESSURE DISTRIBUTION

MULTI-BRACED CUTS IN COHESIONLESS SOILS



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| DRAWN: | NA | DATE | SCALE | JOB NO. | FIGURE NO. |
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NOTES

1. The need to underpin existing footings/utilities is dependent upon soil type, proximity of the existing facility to the face of the excavation, loads imposed on the foundation and permissible movements.

ZONE A:

Foundations of relatively heavy and/or settlement sensitive structures/utilities located in Zone A generally require underpinning.

ZONE B:

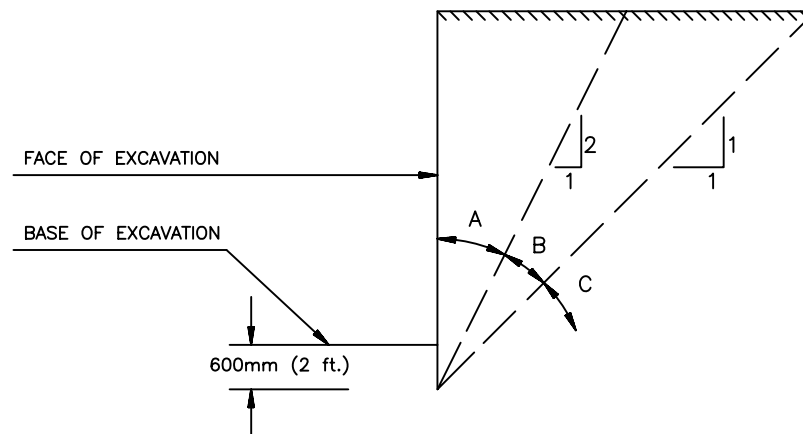
Foundations of structures located within Zone B generally do not require underpinning. Consideration should be given to underpinning of settlement sensitive utilities or heavy foundation units located in this zone.

ZONE C:

Utilities and foundations located within Zone C do not normally require underpinning.

Underpinning of foundations located in Zones A and B should extend at least into Zone C.

2. As an alternative to underpinning, it may be possible to control movement of existing utilities and foundations by supporting the face of the excavation with bracing/tiebacks or a rigid (caisson) wall. Horizontal and vertical earth pressures imposed on the excavation wall by non-underpinned foundations must be considered in the design of the support system.
3. A condition survey should be conducted prior to construction and appropriate monitoring (surface and insitu) carried out during construction to monitor any movement which may occur.
4. All work should be carried out in accordance with the Occupational Health and Safety Act and local regulations. Good quality workmanship and construction practices are to be employed.
5. This sheet is to be read in conjunction with text of report for this project. Additional comments and recommendations concerning these general guidelines will be provided if required.



STANDARD DRAWING

GENERAL RECOMMENDATIONS REGARDING UNDERPINNING OF FOUNDATIONS/UTILITIES
LOCATED CLOSE TO EXCAVATION



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|---------------|-----------|--------|------------|------------|
| DRAWN: NA | DATE | SCALE | JOB NO. | FIGURE NO. |
| CHECKED: GD | DEC. 2005 | N.T.S. | 03TF012B-S | 4 |
| APPROVED: BRG | | | | |