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investigation and
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WP 145-96-00 REGION Central
HWY 9 STR SITE

Embankment Stability, Hwy. 9 Reconstruction
Rolling Hills Drive to E of Mono 6th Line Road East

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GEOCRES 30M13-135

DATE NOV 18 1996

FOUNDATION INVESTIGATION REPORT

for

Embankment Stability, Highway 9 Reconstruction

Rolling Hills Drive to E of Mono 6th Line Road East

W.P. 145-96-00, Central Region

Introduction

This report summarizes the factual information obtained from a foundation investigation conducted for two high fill sections along the proposed widening of Highway 9, Rolling Hills Drive to east of Mono 6th Line Road East. The investigation was carried out at the request of Central Region, Geotechnical Section. The following areas were identified in the request:

Hwy 9: Sta 15+700 to 15+950

Hwy 9: Sta 17+950 to 18+200

Site Description

The fill sections are located along Highway 9 in the Mono Township, just east of Orangeville. The terrain is generally hilly with a number of low lying marshy areas and ponds. Land use is primarily agricultural and recreational.

The Mono Mills area lies within the physiographic region of the Oak Ridges Moraine. A glacial end moraine, it has a typical "knob and basin" relief" typified by "rugged sand hills and till knobs" (after Putnam and Chapman, 1984, The Physiography of Southern Ontario, 3rd Edition).

Field Investigation

The field investigation was carried out by the Foundations Unit on 96 08 26. Two boreholes were advanced, one at each section, using a track-mounted auger machine equipped with hollow stem augers.

Samples were recovered by means of a 50 mm O.D. split spoon sampler driven into the ground according to the specifications of the Standard Penetration Test (ASTM D 1586-8).

Groundwater elevations were obtained by measuring the water levels in the open boreholes prior to backfilling.

Subsurface Conditions

Fill Section Sta 15+700 to 15+950 (Borehole 1)

The subsurface data obtained from the borehole advanced at this location reveal a surficial fill deposit consisting of cohesive clayey silt extending for a depth of 2.9 m. The deposit contains occasional zones of silty sand, trace gravel and trace organics. N values ranging from 7 to 25 were measured within the deposit indicating a firm to very stiff consistency. The following soil properties were observed from laboratory testing:

| | |
|--------------------------|------------------------|
| Water Content (w) | 15.5% |
| Plastic Limit (w_p) | 16.0% |
| Liquid Limit (w_L) | 24.0% |
| Unit Weight (γ) | 21.8 kN/m ³ |

The fill is underlain by a non-cohesive silty sand stratum that is 2.3 m thick. Organics are present throughout imparting the deposit with its dark grey colour. N values range from 8 to 14, indicating that the deposit is in a loose to compact state of denseness. Laboratory testing revealed a water content of 13.5%.

A thin bed of homogeneous clayey silt, 0.7m thick, was present beneath the silty sand stratum. It contains a trace of sand and is light grey in colour. The silty clay is stiff in consistency as evidenced by a single N value of 12. The following soil properties were observed from laboratory testing:

| | |
|--------------------------|------------------------|
| Water Content (w) | 18.5% |
| Plastic Limit (w_p) | 16.0% |
| Liquid Limit (w_L) | 23.0% |
| Unit Weight (γ) | 21.7 kN/m ³ |

The borehole was terminated at El. 422.9, at a depth of 11.1 m, in a deposit consisting of a heterogeneous mixture of gravel, sand, silt and clay. The deposit is a non-cohesive glacial till. N values range from 36 to 73, indicating that the material is in a dense to very dense state. A water content of 8.0% was measured on a representative sample.

The groundwater level, measured in the open borehole following completion, was present at a depth of 2.9 m, or El. 431.1

Fill Section Sta 17+950 to 18+200 (Borehole 2)

The surficial deposit encountered at BH2 is a non-cohesive fill consisting of silty sand. The deposit is 1.4 m thick at the boring location and contains traces of gravel and organics. An N value of 5 indicates that the material is in a loose state of compaction.

The fill is underlain by a dark grey to black peat that is interspersed with silty sand zones. The organic deposit extends to El. 413.9 and is 1.2 m thick. Laboratory testing on the organic portion revealed a water content of 103.5% and an organic content of 28%. A water content of 42% was

observed on the silty sand portion of the deposit. The material is very soft/very loose as exhibited by N values of 2 and 1.

The peat diminishes into a silty sand deposit that contains trace organics throughout, as well as a trace of clay. The deposit is dark grey in colour and is 1.8 m thick. N values of 2 and 9 indicate that the deposit ranges from a very loose to loose state of compaction.

A heterogeneous mixture of clayey silt, sand and gravel was encountered beneath the silty sand stratum at a depth of 4.4 m. The material is cohesive and is glacial in origin. The deposit exhibits a consistency of very stiff to hard as shown from measured N values ranging from 23 to 47. A single lab test revealed a water content of 7.5%. The borehole was terminated in the glacial till deposit. Auger refusal was encountered at a depth of 8.2 m (El. 408.3) on a possible boulder.

The groundwater level was measured in the open borehole and was present at a depth of 2.4 m, or El. 414.0.

For the boundaries of the various subsoil types, field and laboratory test results and groundwater levels refer to the appended Record of Borehole Sheets. The locations of the borings in plan are shown on the appended drawings, Drawing Nos. 1459600-A and 1459600-B.

DISCUSSION

The proposed fills are extensions of existing fill slopes required to accommodate the Highway 9 widening. The existing fill embankments are as much as 12 m high between Sta 15+700 and Sta 15+950, and 8 m high between Sta 17+950 and Sta 18+200.

Visual inspection of the fill areas revealed that the section between Sta 15+700 and Sta 15+950 has experienced considerable surficial movement. Stakes present on the slope are evidence that an attempt was made in the past to maintain the vegetation and minimize the surficial creep of the slope. A section of guard rail along the crest of the slope has moved out of alignment towards a large depression created as a result of ground movement.

In the event that the project construction is delayed beyond 1997, consideration should be given to rehabilitate the slope (Sta 15+700 to Sta 15+950) during the 1998 construction season. Although no global failure is anticipated, the surficial erosion due to run off along the shoulder of this section may cause damage to the pavement structure and patching may be required. Seasonal monitoring of the slope may be prudent during the interim period.

The existing slope between Sta 17+950 and 18+200 are stable, both surficially and globally.

RECOMMENDATIONS

Recommendations consisting of slope stability, slope geometry, and slope treatment are provided for the high fill sections proposed along the Highway 9 widening. They are based on the premise that no additional property will be acquired and that, for the most part, the location of the toe of slope will not change.

For both fill sections, slopes steeper than 2H:1V will be unstable. It is recommended that a retained soil system be applied at each of the slopes to accommodate the widening of Highway 9 and to minimize surficial instability. They should extend for a minimum height that will accommodate a 2H:1V slope and berm, if required. It is recommended that a retaining system at the fill section Sta 15+700 to 15+950 be constructed at the base of the slope as shown in Figure 1. At fill section Sta 17+950 to 18+200 a retaining system at the crown of the slope is preferred because the presence of 2.6 m of peat at the base of the slope would require considerable subexcavation.

The designer is referred to DSM Item 9.70.55 Retained Soil Systems (RSS) which lists the approved proprietary systems. For this project, a reinforced vertical/terraced wall meeting the minimum requirements for performance and appearance is the preferred geometry.

Where the fill embankment heights are greater than or equal to 8.0 m, a 2.0m berm is recommended. The berms may be run out as quickly as is feasible in the area beyond which they are required for stability. There should be a slight grade in the berm towards the slope to prevent the ponding of water.

Prior to placement of the fill, all surficial organic material should be removed. Any necessary proof-rolling or foundation preparation should be carried out prior to placement of retaining system elements. Any soft areas identified by proof-rolling should be sub-excavated and replaced with suitable backfill. Suitable backfill does not include silt. Temporary excavations should be inclined at 1.5H:1V or flatter.

Excavation for the installation of reinforcing elements at the fill section from Sta 17+950 to 18+200 may require temporary shoring for roadway protection, depending on the final height of the system. If so, the designer is referred to OPSS 538 Shoring and Bracing.

Fill placed on existing embankments should be keyed into the existing fill. Topsoil and slope vegetation should be established as soon as possible after filling and grading to control surficial erosion. The use of straw mats is also recommended. The RSS must maintain the integrity of the slope and vegetative growth must be ensured.

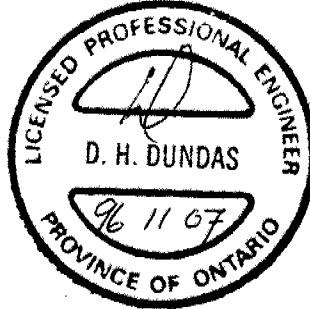
Drainage by means of interceptor ditches, catch basins, or curb and gutter at the top of the slope is recommended to control surface runoff. Directing runoff to armoured spillways on the slopes should also be considered to minimize surficial erosion. Ditches placed at the base of the lower slopes with provisions for positive drainage should be incorporated to prevent ponding of water.

Miscellaneous

The fieldwork for this investigation was carried out on August 26, 1996 under the supervision of J. Werner, Engineer in Training . The report was prepared by B. Bennett, Foundation Engineer and was reviewed by D. Dundas, Senior Foundation Engineer.



B. Bennett
Betty Bennett, P.Eng.
Foundation Engineer



D. Dundas
David Dundas, P.Eng.
Sr. Foundation Engineer

APPENDIX

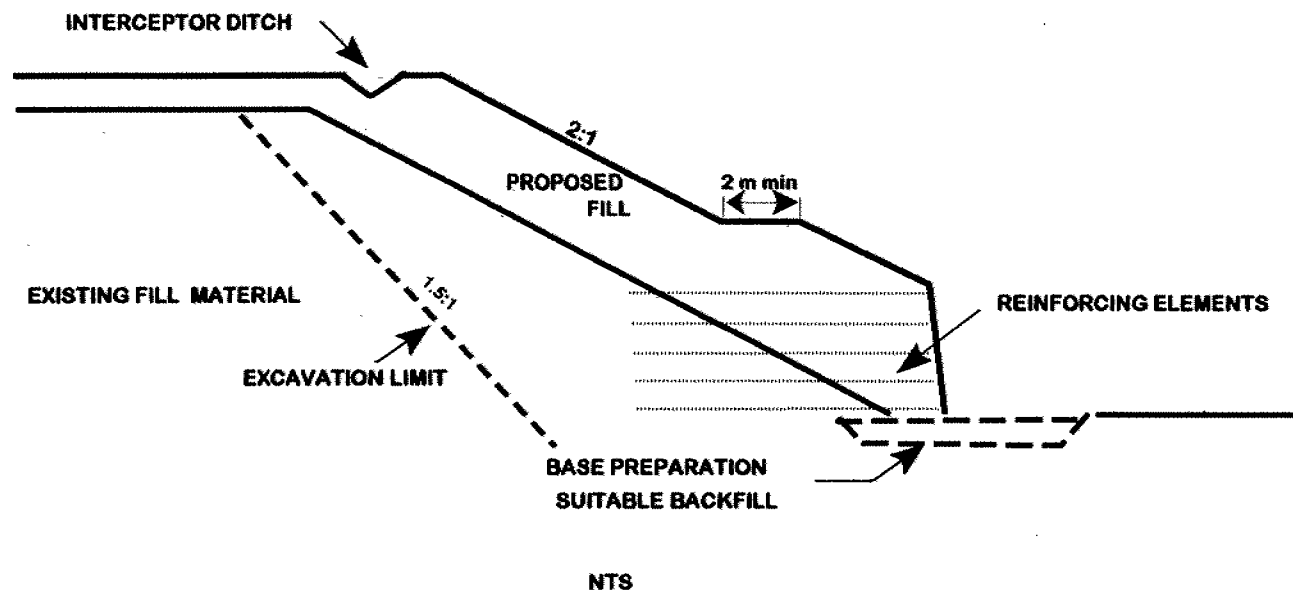


Figure 1 - GEOMETRY AND TREATMENT FOR HIGH FILL SECTION - Sta 15 + 700 to 15 + 950

RECORD OF BOREHOLE No 1

1 OF 1

METRIC

W.P. 145-96-00 LOCATION Coords: N 4 866 407.5 E 263 713.1 ORIGINATED BY JW
DIST CR HWY 9 BOREHOLE TYPE HS Auger COMPILED BY JW/BB
DATUM Geodetic DATE 96/08/26 CHECKED BY BB/DD

| 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 | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | | |
| 434.0 | Ground Surface | | | | | | | | | | | | | |
| 0.0 | | | | | | | | | | | | | | |
| | CLAYEY SILT Trace Organics | | 1 | SS | 7 | | 433 | | | | | | 21.8 | 3 42 (55) |
| | With Sand Trace Gravel Occasional Silty Sand zones | | 2 | SS | 25 | | 432 | | | | | | | |
| | Brown Firm to Very Stiff | | 3 | SS | 11 | | 431 | | | | | | | |
| 431.1 | (Fill Material) | | | | | | | | | | | | | |
| 2.9 | SILTY SAND | | 4 | SS | 14 | | 430 | | | | | | | 1 48 44 7 |
| | Trace to Some Gravel Trace Clay Trace Organics | | 5 | SS | 8 | | | | | | | | | |
| | Dark Grey Loose to Compact | | 6 | SS | 12 | | 429 | | | | | | | |
| 428.8 | | | | | | | | | | | | | | |
| 5.2 | CLAYEY SILT | | 7 | SS | 12 | | 428 | | | | | | 21.7 | 0 5 (95) |
| 428.1 | Trace Sand Grey Stiff | | | | | | | | | | | | | |
| 5.9 | | | 8 | SS | 32 | | 427 | | | | | | | 28 41 (31) |
| | Heterogeneous Mixture of GRAVEL, SAND, SILT and CLAY | | | | | | | | | | | | | |
| | Occasional wet Sand Seams Red Brown Dense to Very Dense | | 9 | SS | 73 | | 426 | | | | | | | |
| | (Glacial Till) | | 10 | SS | 41 | | 425 | | | | | | | |
| | | | | | | | 424 | | | | | | | |
| 422.9 | | | 11 | SS | 57 | | 423 | | | | | | | |
| 11.1 | End of Borehole | | | | | | | | | | | | | |
| | + 96/08/26 | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 2

1 OF 1

METRIC

W.P. 145-96-00 LOCATION Coords: N 4 867 045.1 E 265 811.3 ORIGINATED BY JW
DIST CR HWY 9 BOREHOLE TYPE HS Auger COMPILED BY JW/BB
DATUM Geodetic DATE 96/08/26 CHECKED BY BB/DD

| 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 | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | 20 40 60 80 100 | | |
| 416.5 | Ground Surface | | | | | | | | | | | | | |
| 0.0 | SILTY SAND Trace Gravel Trace Organics Brown Loose (Fill Material) | | 1 | SS | 5 | | 416 | | | | | | | |
| 415.1 | | | | | | | 415 | | | | | | | |
| 1.4 | PEAT Interspersed with Silty Sand Trace Clay Black Very Soft/Very Loose | | 2 | SS | 2 | | | | | | | w=103.5 | 28% org | 0 48 (52) |
| 413.9 | | | 3 | SS | 1 | | 414 | | | | | w=42 | | 0 63 34 3 |
| 2.6 | SILTY SAND Trace Gravel Trace Organics Trace Clay Dark Grey Very Loose to Loose | | 4 | SS | 2 | | 413 | | | | | | | |
| 412.1 | | | 5 | SS | 9 | | 412 | | | | | | | |
| 4.4 | Heterogeneous Mixture of CLAYEY SILT, GRAVEL AND SAND Grey Very Stiff to Hard (Glacial Till) | | 6 | SS | 23 | | 411 | | | | | | | 30 32 (38) |
| | | | 7 | SS | 29 | | 410 | | | | | | | |
| | | | 8 | SS | 47 | | 409 | | | | | | | |
| 408.3 | | | 9 | SS | 60 | /6cm | | | | | | | | |
| 8.2 | End of Borehole + 96/08/26 | | | | | | | | | | | | | |

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 |

MECHANICAL PROPERTIES OF SOIL

| | | |
|----------------|-----------------------|--------------------------------------|
| m_v | kPa^{-1} | COEFFICIENT OF VOLUME CHANGE |
| C_c | 1 | COMPRESSION INDEX |
| C_s | 1 | SWELLING INDEX |
| C_a | 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 = $\frac{c_u}{\tau_r}$ |

STRESS AND STRAIN

| | | |
|--------------------------------------|-----|-------------------------------|
| u_w | kPa | PORE WATER PRESSURE |
| r_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 |

PHYSICAL PROPERTIES OF SOIL

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

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS DRAWING NO. 145-96-00

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AND/OR MILLIMETRES
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WP No 145-96-00

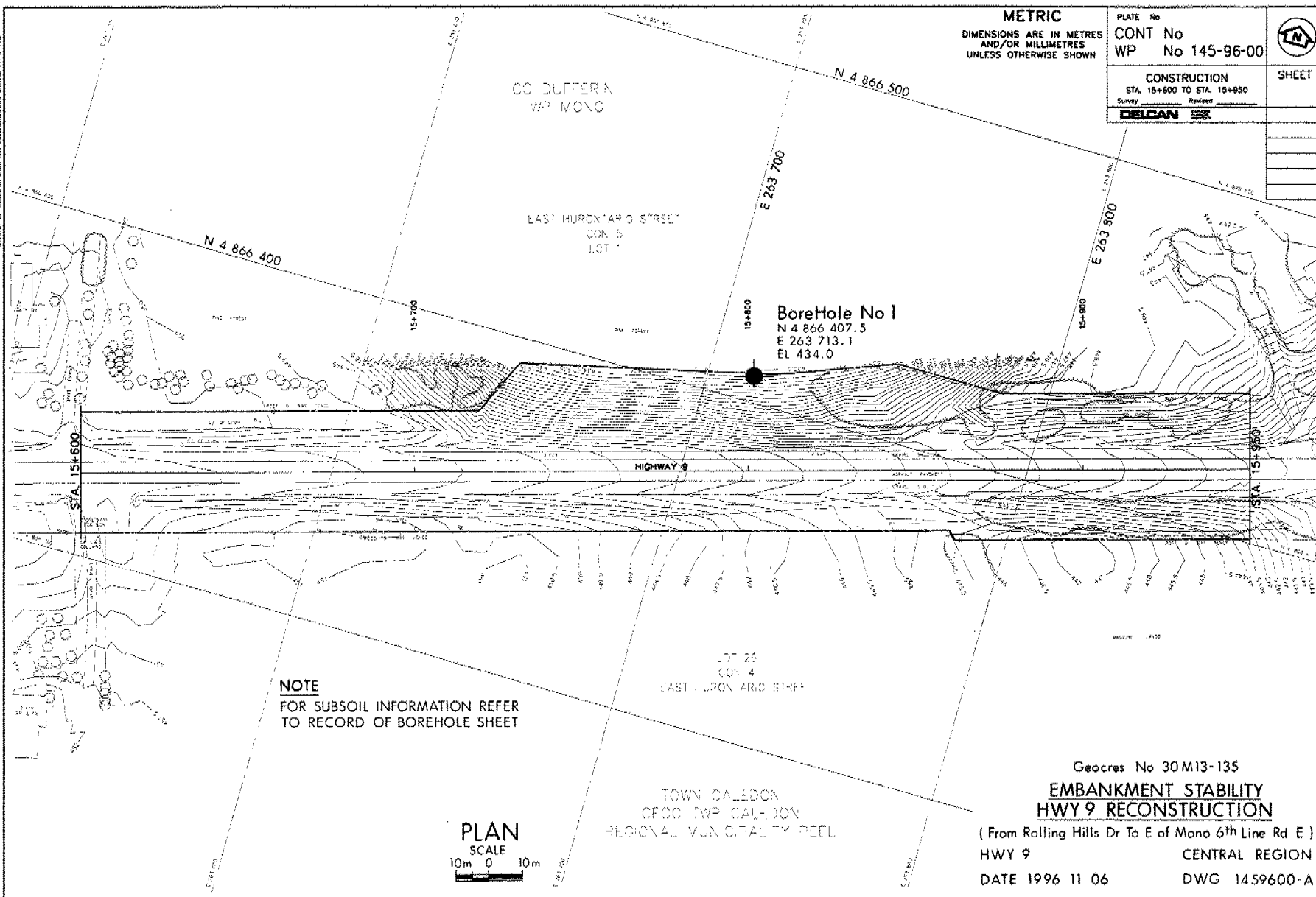


CONSTRUCTION
STA. 15+600 TO STA. 15+950

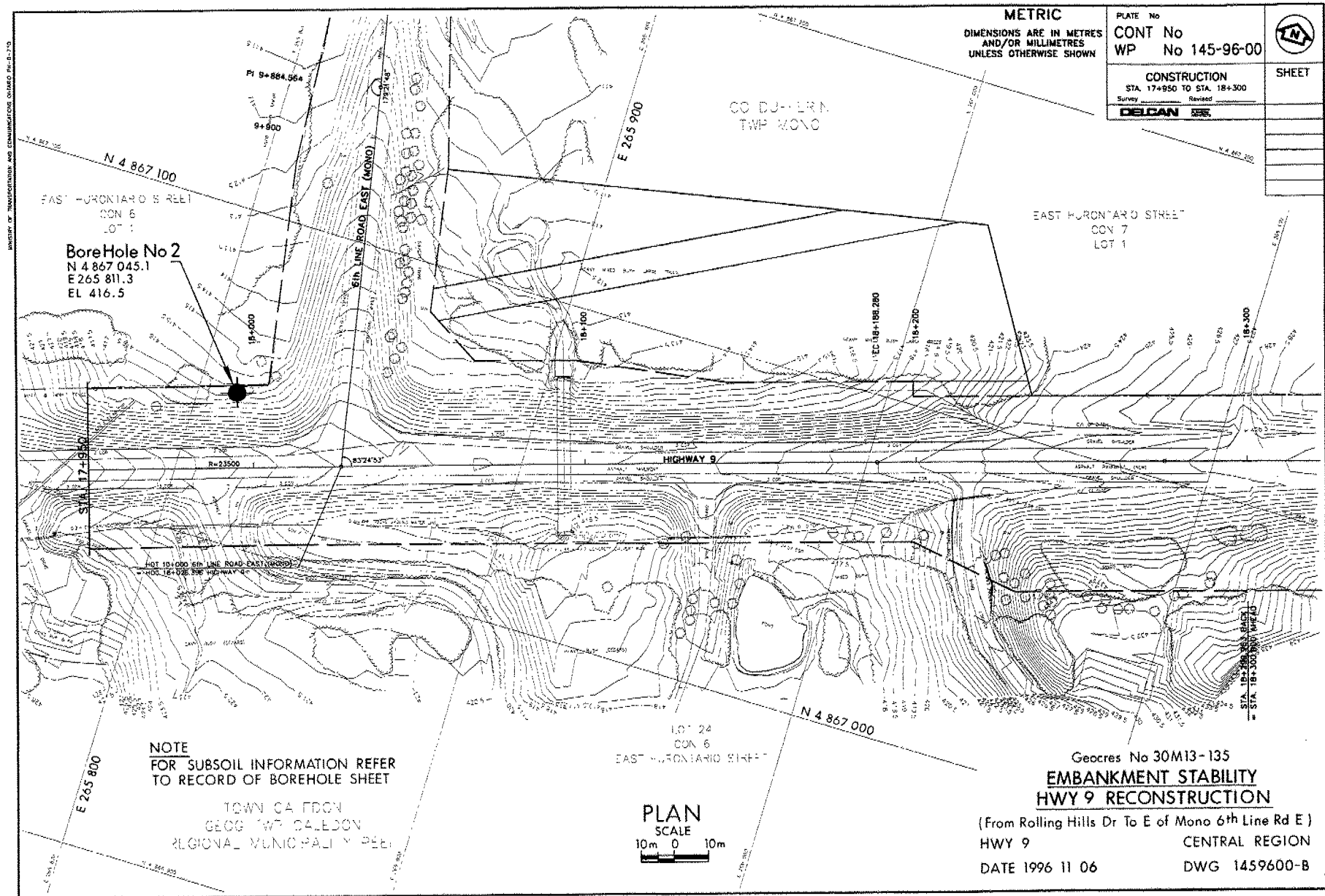
SHEET

Survey
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Revised



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| WP | No 145-96-00 |
| CONSTRUCTION | |
| STA. 17+950 TO STA. 18+300 | |
| Survey | Revised |
| DELCAN | DES |



SHEET

BoreHole No 2
N 4 867 045.1
E 265 811.3
EL 416.5

NOTE
FOR SUBSOIL INFORMATION REFER
TO RECORD OF BOREHOLE SHEET

TOWN OF CALEDON
GEOG. TWP. CALEDON
REGIONAL MUNICIPALITY OF

LOT 24
CON 6
EAST HURONTARIO STREET



Geocres No 30M13-135
**EMBANKMENT STABILITY
HWY 9 RECONSTRUCTION**

(From Rolling Hills Dr To E of Mono 6th Line Rd E)
HWY 9 CENTRAL REGION
DATE 1996 11 06 DWG 1459600-B