ENGINEERING MATERIALS OFFICE
SOIL MECHANICS SECTION

WP 40-77-00 DIST 6

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Feasibility Study of Alignment C-2
Mid Ontario Tourist Highway
From Hwy. 400 to Jct. 7 & 12

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GEOCRES 31D-258

DATE MAY 01 1978

FOUNDATION INVESTIGATION REPORT

For

Feasibility Study of Alignment C-2
Mid Ontario Tourist Highway
From Hwy. 400 to Jct. 7 & 12
Hwy. 89, District 6, Toronto
W.P. 40-77-00

INTRODUCTION

The Soil Mechanics Section received an informal request from the Regional Structural Section to carry out a preliminary foundation investigation for the proposed Highway 89 extension crossing the Keswick Marsh and Holland River. Adequate preliminary subsoil information exists for the southerly alignments as presented in the September, 1968 report prepared by William Trow Associates, Ltd. for the Toronto and York Roads Commission (The Route Appraisal of the Schomberg River (Holland River) Crossing at York County Road No. 32). However, since that time one additional northerly route (C-2) has been identified as a result of requirements of the Ministry of Natural Resources and no subsoil information was available for that route. Because of the urgency of this project a meeting was held to discuss a means of obtaining the additional subsurface data. The meeting was held on February 16, 1978. Attending were representatives of Regional Planning and Design, Regional Geotechnical, Regional Structural, McCormick, Rankin and Associates Ltd. (the Planning and Design Consultant) and our office. It was decided that the Regional Geotechnical Office would carry out a field investigation for Route C-2 and that the Soil Mechanics Section would provide the necessary preliminary recommendations for the feasibility study of the alternative routes. The results of the fieldwork were contained in a memorandum dated 78 03 22 from Mr. R. Van Veen of the Regional Geotechnical Office.

The following is a brief description of the subsurface conditions encountered, together with our preliminary recommendation pertaining to the design and construction and also our comments related to the feasibility of the alternate routes.

SUBSURFACE CONDITIONS

The Trow investigation of 1968 for three southerly proposals included a total of 19 sampled boreholes advanced to depths of up to 43 feet below the ground surface. The recent Regional Geotechnical investigation for the most northerly alignment consists of a total of 7 auger holes, accompanied by field vane tests, advanced to depths of up to 32 feet below the ground surface. The investigations reveal that the subsurface conditions across the site are somewhat variable. The predominant surficial deposit is a stratum of soft peat extending to a depth of generally 10 to 15 feet below the ground surface, but extending to at least a depth of up to 43 feet west of and adjacent to the Holland River. Underlying this organic deposit, throughout most of the study area, is a firm to stiff stratum of clayey silt to silty clay which was not fully penetrated but was found to extend to a thickness of up to 25 feet. In some locations on alignments C3 and C5 within the vicinity of the Holland River, the surficial peat deposit is overlying up to 25 feet of compact to dense or hard silt or sandy silt. According to available geological information the depth of overburden to bedrock is in the order of 200 to 350 feet. The groundwater level in the area was found to be at or slightly below the existing ground level.

The specific description of the subsoil conditions for the various alignments are given in Table 1 of the Appendix. A plot of in-situ vane shear strength measurements vs. depth for the organic deposit and the cohesive clayey silt to silty clay deposits are shown on Figure 2 and 3 of the Appendix.

DISCUSSION AND RECOMMENDATIONS

It is proposed to construct a Mid Ontario Tourist Highway from Hwy. 400 to the intersection of Hwy. 7 and 12. The proposed corridor will cross the Keswick Marsh south of Cook Bay and three alternative alignments are considered for the crossing of the Holland River. (The southerly alignment as discussed in Trow's Report and shown as Line 'A', is no longer considered because of the extremely poor subsoil conditions and further, the long structure that is required at the widest portion of the Holland River Crossing) The alternative alignments and approximate limits of the Keswick Marsh are shown on Figure 1 of the Appendix.

The crossing of the Marsh will require profile grades in the order of 6 to 8 feet above the existing ground surface. However, at the Holland River Crossing the navigational clearance requires the profile grade to be at about elevation 751. The existing average ground surface is at about elevation 720.

The presence of the surficial deposits of soft organic material (peat) and underlying cohesive firm clayey silt to silty clay deposits are the governing factors from a foundation point of view, since it will be necessary to ensure that it is not overstressed by the embankment loading. The relevance of this will be discussed in the subsections to follow.

Highway Embankments and Approach Fills

The following are our recommendations pertaining to the feasibility study based on our preliminary assessment using the in-situ shear strengths measurements taken in the peat and clayey silt to silty clay deposits during the above mentioned investigations. Our recommendations pertain to two types of fill material: 1) regular granular fill ($\phi = 30^\circ$ and $\gamma = 130$ P.C.F.) and 2) an air cooled granulated lightweight blast furnace slag ($\phi = 35^\circ$ and $\gamma = 85$ P.C.F.). The following table summarizes our recommendations with the assumption that the fills will be constructed over the organic material without any subexcavation.

Type of Fill	Safe Fill Heights (With 2:1 Side Slopes)		
	Without Berm	With Mid Height Berm	
	Height of Fill	Height of Fill	Berm Length
Granular Material	5 ft.	8 ft.	20 ft.
Lightweight Slag	7 ft.	11 ft.	25 ft.

It is important to note that if fill heights exceed those mentioned in the above table, the underlying subsoil will be overstressed and settlements will be excessive. It should also be noted that even with the above recommended fill heights the underlying cohesive deposits will undergo consolidation settlements due to the imposed embankment loadings. In order to minimize the post construction settlements the embankments should be surcharged and left in place as long a period as possible if scheduling permits. The details for surcharge loading and time rate settlement calculations for the various fill heights will be provided once the alignment is finalized and further more detailed foundation investigations are carried out.

In order to minimize the differential settlements between the approach fills and the structure it is recommended that the peat be removed entirely below the embankment and to distance beyond the toe of the slope equal to the depth of the peat and backfilled with granular material. In addition, this excavation should be carried out to a minimum distance of 100 feet behind the abutments.

Furthermore, to facilitate construction on the organic layer and to prevent the fill material from puncturing the organics, a synthetic mat should be used to separate the fill material and organic layer. This mat would also permit water in the granular fill to drain.

Structure Over Holland River

The recommended height of approach fills on the Keswick Marsh and the profile grades at Holland River will dictate the required length of the structure. The approximate maximum and minimum structure lengths for Route C2 as governed by fill heights and geometrics are given below.

Governing Conditions		Structure Length (Feet)
Case A	Lightweight Slag With Mid Height Berms (H=11') Max. Grades 5%	1300 (min.)
Case B	Regular Granular Fill Without Berms (H=5') Min. V.C. 800'	2100 (max.)

The Holland River crossing will be a multi-span structure with a total structure length of 1300 to 2100 feet depending on geometric and fill material. The subsoil conditions are such that the structure can only be supported on friction piles driven into the firm clayey silt to silty clay deposit. The pile loading would depend on the type of pile chosen and the length. For example, a 45 foot long #14 timber pile would support a safe design load of 15 tons per pile. A minimum of 4 feet of earth cover should be provided above the base of the footing for frost protection purposes.

Culverts

Some alignments will also cross small streams, tributaries to the Holland River and to Cook Bay. The following are our comments pertaining to the design and construction of the culverts.

One or more corrugated steel or structural plate pipe or pipe arch could be used at the stream crossing locations. Due to the highly compressible nature of the subsurface soils,differential settlements can be anticipated within the length of the culverts. In order to articulate the performance provision should be made for joints or camber to accommodate for any differential settlements.

The culvert should be placed on granular 'A' bedding material to the full base width of the embankment and to a depth as specified according to current M.T.C. standards. A synthetic mat, as mentioned elsewhere, should also be used to prevent the bedding material from puncturing the organics and also to facilitate construction over the organic deposit. The culvert should be backfilled symmetrically. Compaction of the granular backfill material should be undertaken so as to avoid any damage to the culvert.

The culvert invert can be placed at the level of the existing stream bed. As a precuation against washout a three foot clay seal should be installed in the side slopes at the upstream end of the culvert.

Comparison of Alternate Routes

A comparison of alternate routes from a geotechnical point of view are included in Table 2. of the Appendix. The geotechnical considerations for the Keswick Marsh and Holland River Crossing lead to the following order of preference.

Route	C5 & C6	Most Desirable
Route	C3 & C4 & C7	Mediocre
Route	C2	Least Desirable

If you have any further questions on this subject please do not hesitate to call this office.

M MacLean

M. MacLean, P. Eng.
Project Engineer

M. Devata

M. Devata, P. Eng.
Supervising Engineer

April, 1978

APPENDIX

TABLE I

Summary of Subsoil Conditions in Keswick Marsh at Proposed Alignments

Line	General Subsoil Conditions: Surficial Deposits	General Subsoil Conditions: Underlying the Surficial Deposits	Location of Organic Deposits Deeper than 15'	Approximate Width of Holland River at This Location
C2	7'-13' of soft peat	Firm Clayey Silt	1) 30' of peat from Holland River to 2000' West of River 2) 30' of peat at intersection of Line C2 and C4	470'
C3, C4 & C7	5'-9' of soft peat	Firm to Stiff Clayey Silt and/or Dense Silt	35' of peat from Holland River to 800' West of River	500'
C5 & C6	5'-15' of soft peat	Firm to Stiff Clayey Silt to Silty Clay and/or Dense Granular Silt or Sandy Silt and/or Firm to Hard Silt	35' of peat from 1500' to 1000' West of Holland River	350'
Southerly Alignment Trow Line 'A'	5-20' of soft peat	Firm to Stiff Clayey Silt	40' of peat from 500' West of Holland River to East of River	1500'

TABLE II

Comparison of Alternate Alignments
Geotechnical Considerations

Line	Approximate Width of Holland River at Crossing	Advantages	Disadvantages
C2	470'		1) Deep Peat Deposit Under West Structure Approach 2) Requires 1 additional major stream crossing West of River 3) Greatest length of Highway on peat deposits
C3, C4 & C7	500'		Deep Peat Deposit Under West Structur Approach
C5 & C6	350'	1) Shortest Structure length required 2) Only moderately deep peat deposit under structure approaches 3) Existing County Road East of River. Therefore expect reduced settlements for this section & therefore reduced maintenance costs	

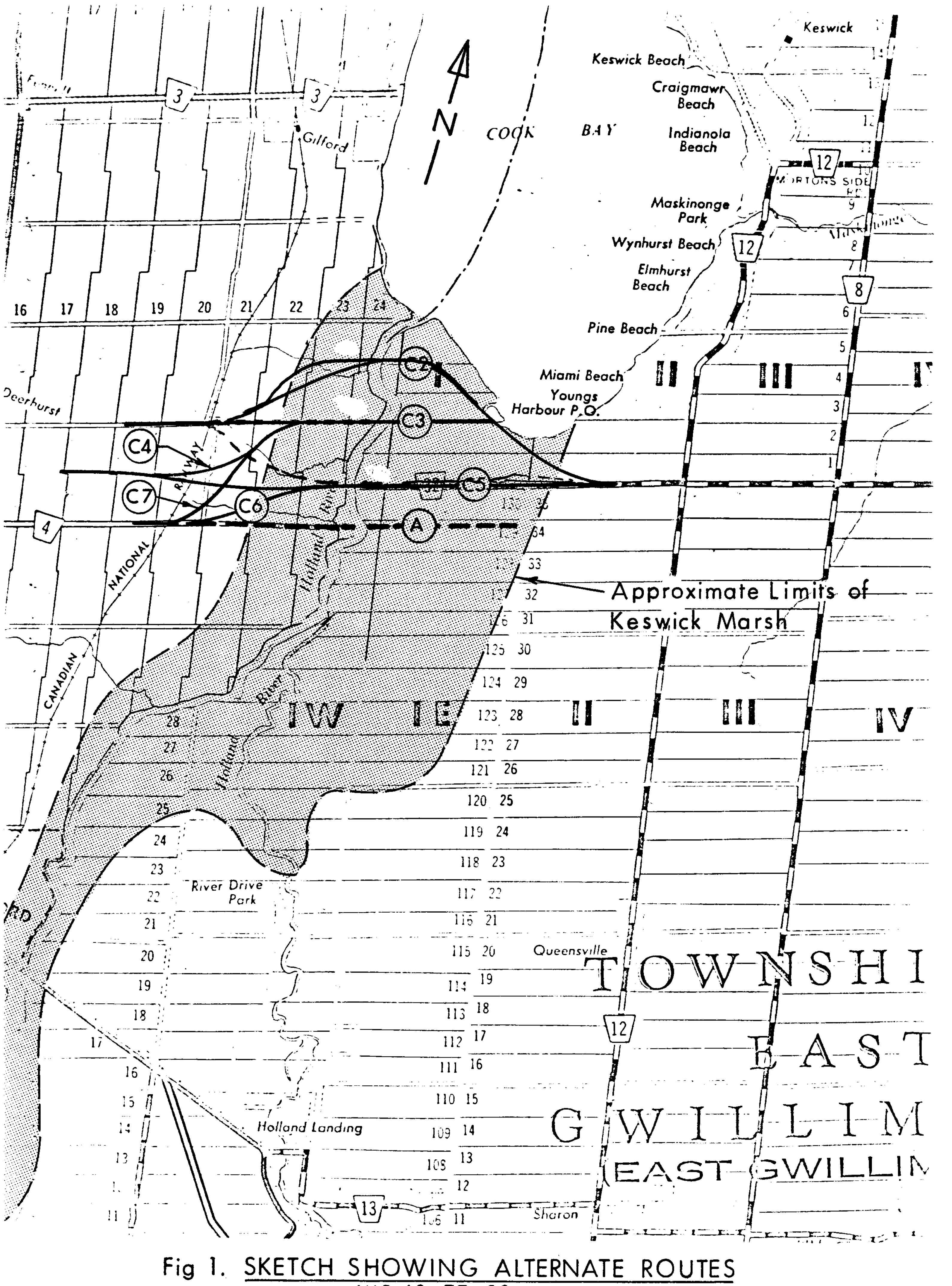

Fig 1. SKETCH SHOWING ALTERNATE ROUTES
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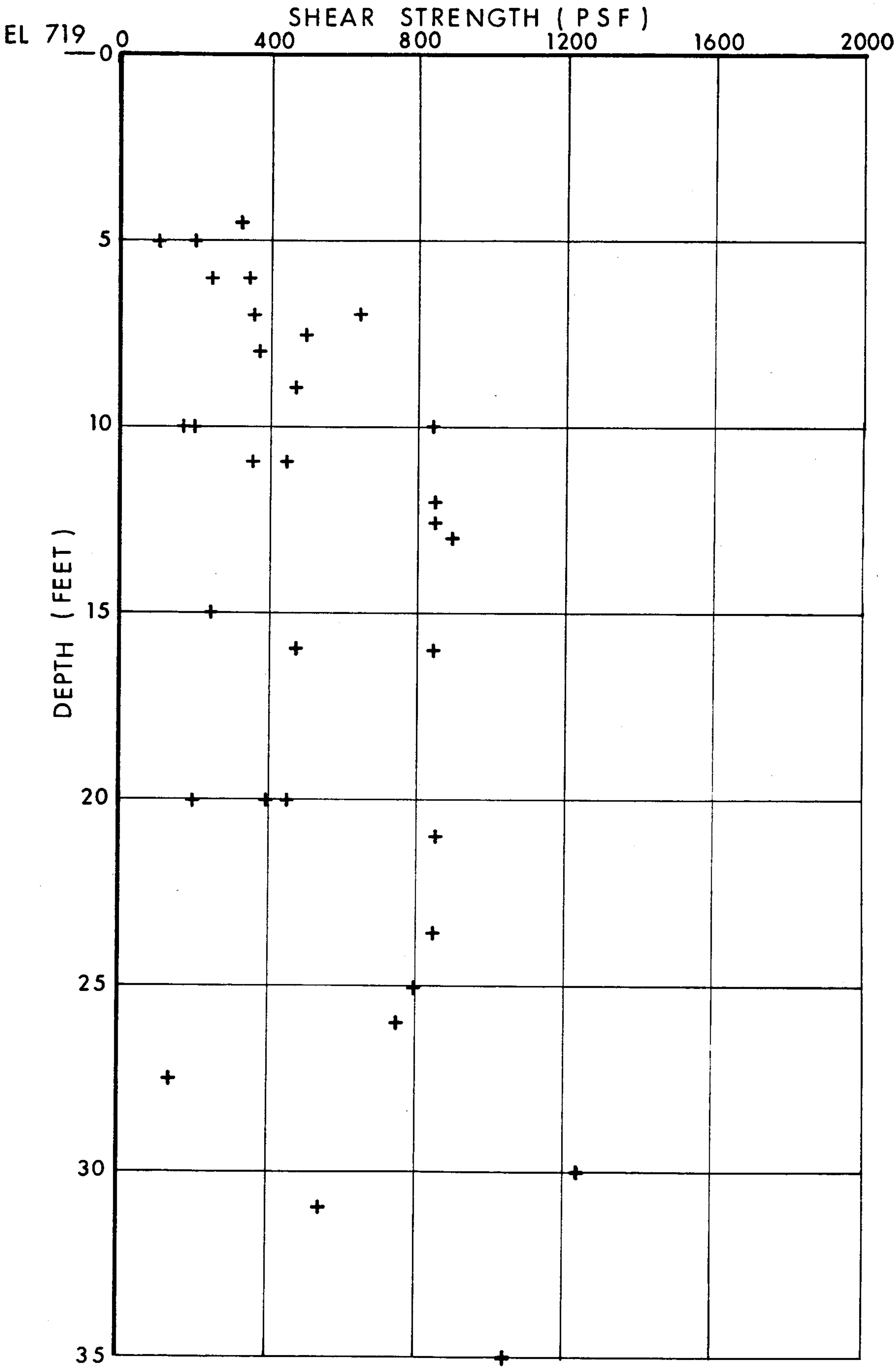

Fig 2. FIELD VANE SHEAR STRENGTH FOR PEAT

WP 40 - 77 - 00

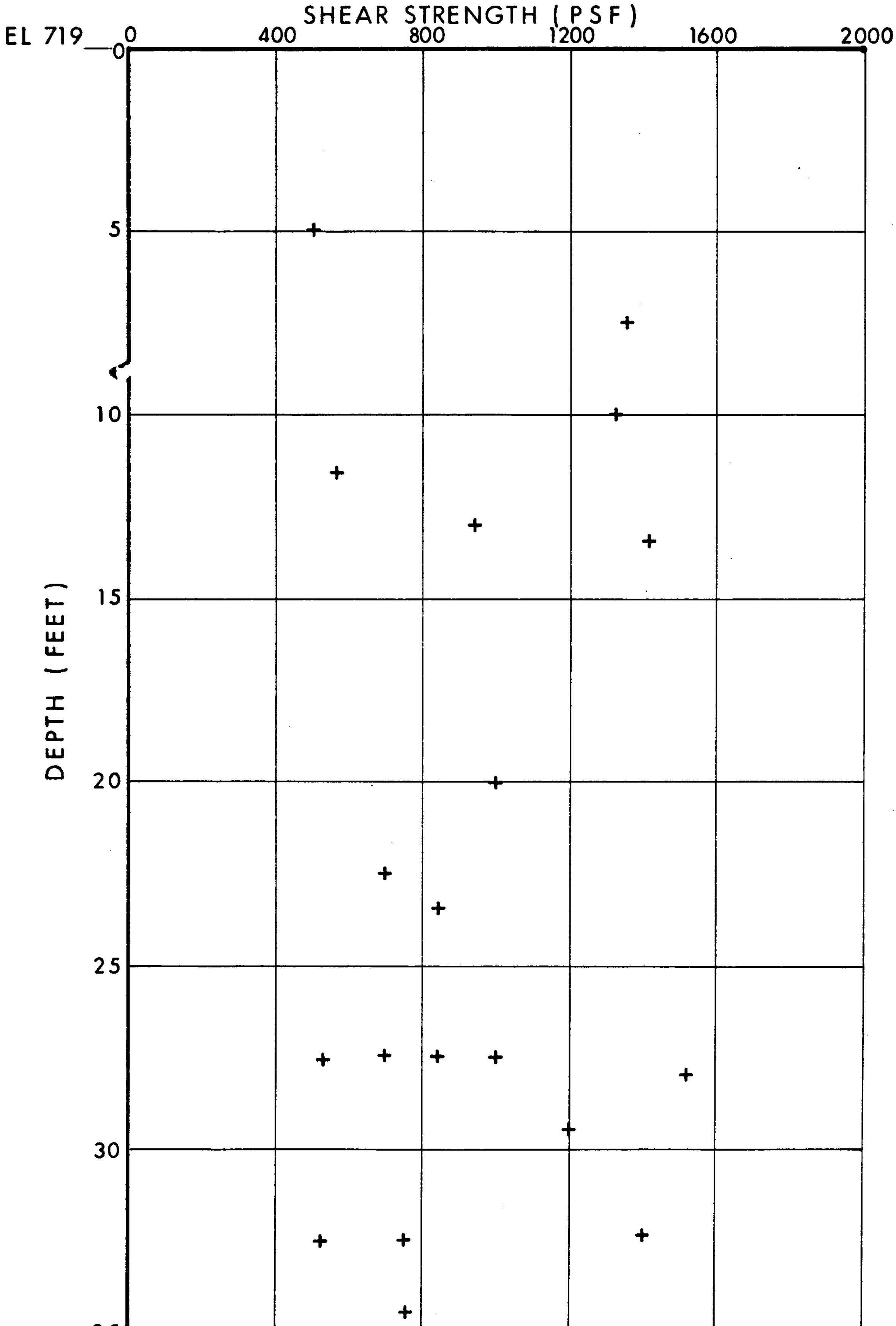

Fig 3. FIELD VANE SHEAR STRENGTH FOR CLAYEY SILT TO SILTY CLAY

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EXPLANATION OF TERMS USED IN REPORT

'N' VALUE: AN INDICATOR OF SUBSOIL QUALITY. IT IS OBTAINED FROM THE STANDARD PENETRATION TEST (CSA STD. A119.1). SPT 'N' VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 2 INCH O.D. SPLIT-BARREL SAMPLER TO PENETRATE 12 INCHES INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WEIGHING 140 POUNDS, FALLING FREELY A DISTANCE OF 30 INCHES. FOR PENETRATIONS OF LESS THAN 12 INCHES 'N' VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. 'N' VALUES CORRECTED FOR OVERBURDEN PRESSURE ARE DENOTED THUS $\overline{N}$.

DYNAMIC CONE PENETRATION TEST (CSA STD. A119.3): CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (2" O.D. 60 CONE ANGLE) DRIVEN BY 350 FT-LB IMPACTS ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 12 INCH ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOIL QUALITY: SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSITY.

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

S_u (PSF)	0 - 250	250 - 500	500 - 1000	1000 - 2000	2000 - 4000	> 4000
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

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

'N' (BLOW/FT)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCK QUALITY: 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 DRILLED IN THAT CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE NATURALLY FRACTURED CORE PIECES, 4"+ 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	2"	2" - 12"	1' - 3'	3' - 10'	> 10'
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS & SYMBOLS

LABORATORY TESTING

TRIAXIAL TESTS ARE DESCRIBED IN TERMS OF WHETHER THEY ARE CONSOLIDATED (C) OR NOT (U) ISOTROPICALLY (I) OR NOT (A) AND SHEARED DRAINED (D) OR UNDRAINED (U) WITH PORE PRESSURE MEASUREMENTS (BAR OVER SYMBOLS)

EG. $\overline{CIU}$ = CONSOLIDATED ISOTROPIC UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENT

UNLESS OTHERWISE SPECIFIED IN REPORT ALL TESTS ARE IN COMPRESSION

FIELD SAMPLING

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

EARTH PRESSURE TERMS

- μ — COEFFICIENT OF FRICTION
- δ — ANGLE OF WALL FRICTION
- k_o — COEFFICIENT OF EARTH PRESSURE AT REST
- k_A — COEFFICIENT OF ACTIVE EARTH PRESSURE
- k_P — COEFFICIENT OF PASSIVE EARTH PRESSURE
- i — ANGLE OF INCLINATION OF SURCHARGE
- ω — SLOPE ANGLE-BACKFACE OF WALL
- β — ANGLE OF SLOPE
- N_γ, N_q, N_c — BEARING CAPACITY FACTORS
- D_f — DEPTH OF FOOTING
- B,L — FOOTING DIMENSIONS

INDEX PROPERTIES

- γ — UNIT WEIGHT OF SOIL (BULK DENSITY)
- γ_w — UNIT WEIGHT OF WATER
- γ_d — UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
- γ' — UNIT WEIGHT OF SUBMERGED SOIL
- G_s — SPECIFIC GRAVITY OF SOLIDS
- e — VOIDS RATIO
- e_o — INITIAL VOIDS RATIO
- e_{max} — e IN LOOSEST STATE
- e_{min} — e IN DENSEST STATE
- D_r — RELATIVE DENSITY = $\frac{e_{max} - e}{e_{max} - e_{min}}$
- n — POROSITY
- w — WATER CONTENT
- w_L — LIQUID LIMIT
- w_p — PLASTIC LIMIT
- w_S — SHRINKAGE LIMIT
- I_p — PLASTICITY INDEX = $w_L - w_p$
- I_L — LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
- I_c — CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
- A_c — ACTIVITY = $\frac{I_p \text{ of soil}}{\% < 2\mu m \text{ Soil Fraction}}$
- Om — ORGANIC MATTER CONTENT
- S_r — DEGREE OF SATURATION
- S — SENSITIVITY = $\frac{S_u \text{ (undisturbed)}}{S_u \text{ (remoulded)}}$

STRENGTH PARAMETERS

- ϕ — ANGLE OF SHEARING RESISTANCE
- τ_f — PEAK SHEAR STRENGTH
- τ_R — RESIDUAL SHEAR STRENGTH
- c — COHESION INTERCEPT
- $\sigma_1, \sigma_2, \sigma_3$ — NORMAL PRINCIPAL STRESSES
- u — PORE WATER PRESSURE
- u_e — EXCESS u
- r_u — PORE PRESSURE RATIO
- q_u — UNCONFINED COMPRESSIVE STRENGTH
- s_u — UNDRAINED SHEAR STRENGTH
- ϵ — LINEAR STRAIN
- γ — SHEAR STRAIN
- ν — POISSON'S RATIO
- E — MODULUS OF ELASTICITY
- G — MODULUS OF SHEAR DEFORMATION
- k_s — MODULUS OF SUBGRADE REACTION
- m,n — STABILITY COEFFICIENTS
- A,B — PORE PRESSURE COEFFICIENTS

NOTE: EFFECTIVE STRESS PARAMETERS ARE DENOTED BY USE OF APOSTROPHE ABOVE THE SYMBOL, THUS:
ϕ' = EFFECTIVE ANGLE OF SHEARING RESISTANCE;
σ' = EFFECTIVE NORMAL STRESS

HYDRAULIC TERMS

- h — HYDRAULIC HEAD OR POTENTIAL
- q — RATE OF DISCHARGE
- v — VELOCITY OF FLOW
- i — HYDRAULIC GRADIENT
- j — SEEPAGE FORCE PER UNIT VOLUME
- η — COEFFICIENT OF VISCOSITY
- k — COEFFICIENT OF HYDRAULIC CONDUCTIVITY
- k_h — k IN HORIZONTAL DIRECTION
- k_v — k IN VERTICAL DIRECTION
- m_v — COEFFICIENT OF VOLUME CHANGE
- c_v — COEFFICIENT OF CONSOLIDATION
- C_c — COMPRESSION INDEX
- C_r — RECOMPRESSION INDEX
- d — DRAINAGE PATH DISTANCE
- T_v — TIME FACTOR
- U — DEGREE OF CONSOLIDATION
- O_r — OVERCONSOLIDATION RATIO (OCR)