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W.P. No. 152-65-02

CONT. No. 76-82

W. O. No.

STR. SITE No. 38S-63

HWY. No. 550

LOCATION Sharper Creek

No. of PAGES -

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS

MEMORANDUM

To: Mr. R. Morgenroth, (2)
Regional Materials Engineer,
Northwestern Region,
Thunder Bay, Ontario.

FROM: Foundations Office,
Design Services Branch,
West Bldg., Downsview.

ATTENTION:

DATE: October 13, 1972.

OUR FILE REF.

IN REPLY TO **OCT 17 1972**

SUBJECT:

FOUNDATION INVESTIGATION REPORT
For
Proposed Culvert
At Sharpe's Creek
On Highway 550
District No. 18 (Sault Ste. Marie)
W.O. 72-11091 -- W.P. ~~1502-71-01~~ CANCELLED
152-65-02

Attached we are forwarding to you our detailed foundation investigation report on the subsoil conditions existing at the above-mentioned site.

We believe that the factual data and recommendations contained therein will prove adequate for your design requirements. Should additional information be required, please do not hesitate to contact our Office.

AGS/ao
Attach.

cc: E. J. Orr
B. R. Davis
A. Rutka
W. L. Lees
G. R. Browning
B. J. Giroux
P. D. Lester
G. A. Wrong
B. A. Singh

A. G. Stermac
A. G. Stermac,
PRINCIPAL FOUNDATIONS ENGINEER.

Foundations Files
Documents ✓

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FOUNDATION INVESTIGATION REPORT
For
Proposed Culvert
At Sharpe's Creek
On Highway 550
District No. 18 (Sault Ste. Marie)
W.O. 72-11091 -- W.P. ~~1502-71-01~~ 152-65-02

1. INTRODUCTION:

A request for a foundation investigation where Hwy. 550 crosses Sharpe's Creek was received from Mr. R. Morgenroth, Regional Materials Engineer, in a memorandum dated July 21, 1972.

A field investigation was subsequently carried out by the Foundations Office to determine the subsoil conditions at this site. This report contains the results of that investigation and our recommendations pertaining to the design of the proposed culvert and embankment foundations.

2. SITE CONDITIONS:

The site is located on Hwy. 550 about 10 miles west of Hwy. 17 and Sault Ste. Marie. The surrounding area at this location is rolling and there are 150' high rock outcrops at 1000 ft. from the site.

The existing structure is a concrete culvert which is 12 ft. wide by 7 ft. high at 13 ft. left of centre-line and which widens to 21 ft. by 7 ft. at 13 ft. right of centre-line. Cracks occur in the culvert on the side walls and in some of the overhead beams. The side wall cracking occurs on both sides of the culvert at the south end. There is a horizontal crack 2 ft. below the top of the opening on both side walls. This crack is 18 ft. long on the east wall and 10 ft. long on the west side. Longitudinal

cracking occurs in three of the seven concrete beams about 2 inches from the bottom of each beam. The cracked beams are distributed throughout the length of the culvert.

There is no visible instability of the present embankment but road maintenance has been required at the culvert due to settlement of the embankment with respect to the culvert. The cracking of the culvert suggests that settlement of that structure has also occurred.

3. FIELD AND LABORATORY WORK:

The field work consisted of two sampled boreholes and three dynamic cone penetration tests. The boreholes were advanced using continuous flight augers and wash boring equipment mounted on a bombardier. Disturbed samples were obtained using a 2-inch O.D. split-spoon sampler driven according to specifications for the Standard Penetration Test. Undisturbed samples were taken using 2-inch I.D. Shelby tubes which were pushed into the soil manually. Field vane tests were carried out 18 inches below split spoon samples wherever possible.

Dynamic cone penetration tests were carried out adjacent to both boreholes and at one other location. Driving energy to advance the cone was 350 ft.-lbs. per blow.

The locations and elevations of the boreholes and cone tests are marked on Drawing #72-11091A accompanying this report.

Samples were examined visually in the field and again in the laboratory. Tests were performed on selected samples to determine the following physical properties:

- Grain-Size Distribution
- Atterberg Limits
- Natural Moisture Content
- Bulk Density
- Unconfined Shear Strength
- Consolidation Characteristics
- Triaxial Shear Strength

The results of the field and laboratory tests are given in the Record of Borehole sheets and in Figure 1 which are contained in the Appendix of this report.

4. SOIL CONDITIONS:

4.1) General:

The soil conditions were similar in both boreholes with the only difference in soil strata being due to the higher elevation of Borehole 1. The soil can be divided into five main strata which are listed from ground level downwards as follows.

4.2) Fill Material:

This 6-foot-thick stratum, found only in Borehole 1, is part of the present highway embankment. It is a very loose sand with silt and traces of gravel and organic material.

4.3) Topsoil and Sandy Clay:

This stratum varies between the boreholes. In Borehole 1 there is a 1-foot-thick layer of topsoil underlain by 3.5 feet of clay with some sand, firm. This clay is in the plastic state with a natural moisture content of 35%. The liquid and plastic limits are respectively 51% and 25%. In Borehole 2 the topsoil is 3.0 feet thick and there is no evidence of sandy clay. The topsoil is a silty sand with a trace of organics.

4.4) Silty Sand to Sandy Silt:

This stratum consists of a number of sand and silt layers having a total thickness of 21 to 23 feet. The soil constituents range from sand with some silt to silt with sand. A trace to some gravel is also present. The lower 3 to 4 feet of this stratum contain thin layers of clay and is very loose with a standard penetration 'N' value of 3. Above this lower layer the stratum is loose with 'N' values of 5 to 10. In Borehole 3, a trace of organic material is found in the upper half of the stratum. Moisture contents for this layer vary from 16 to 34% with an average value of about 26%.

4.5) Varved Clay:

This 11 to 15-foot-thick stratum consists of greyish-

brown clayey silt with grey silty clay and with brownish-grey silt seams. This material is soft to firm. The clayey silt varves were found to be approximately $1/8 - 3/4$ in. thick while the somewhat thinner silty clay varves were $1/8 - 1/2$ in. thick. The thin silt seams were $1/16 - 1/4$ inch thick with most of the seams being closer to the lesser thickness.

Undrained shear strengths determined by laboratory unconfined and quick triaxial compression tests yielded values approximately one half those obtained from field vane tests. Since the strain at failure of the laboratory tests did not indicate a great deal of disturbance of the samples, the strength values of these tests cannot be ruled out. A shear strength of 800 p.s.f. has been used as the design value.

Atterberg limit and moisture content tests were carried out on the clayey silt material and on a mixture of varve materials. The liquid limit of the clayey silt was 30% with a plasticity index of 13%. The corresponding values for the silty clay layers are estimated to be 45% or greater for liquid limit and 25% or greater for plasticity index. The moisture contents of the samples were found to be above the liquid limits with approximate liquidity indices of 1.3 for the clayey silt and 1.4 for the silty clay. These values indicate that the varved clay will behave as a viscous liquid without appreciable shear strength, when remoulded. Field vane tests indicate a sensitivity of approximately $S = 8$.

4.6) Silty Sand:

The deepest stratum is a dense to very dense sand with some to traces of silt. In Borehole 1 a 3-foot-thick layer of firm varved clay is present in the upper 7 feet of this layer.

5. GROUNDWATER CONDITIONS:

The groundwater level was found to be between 0.0 and 1.5 feet above the creek water level following the natural ground down to that level. The creek water level was at elevation 667.5 at the time of the investigation.

6. DISCUSSION AND RECOMMENDATIONS:

6.1) General:

It is proposed to replace the existing concrete culvert with a 9-foot-diameter multi-plate culvert. The new grade above the culvert will be about 11 feet higher than the existing grade necessitating an approximately 23-foot-high embankment at its highest point.

Subsoils consist of loose sands and silts and soft to firm clayey silts and silty clays.

6.2) Placing of Culvert:

The proposed culvert should be designed to the appropriate Ministry standard. A 2-foot-thick granular bedding should be adequate beneath the culvert. It is recommended that the culvert invert be placed at the level of the existing creek bed. It is recommended that the creek bed at both the upstream and the downstream end be protected by rip-rap. The size of the area to be covered by rip-rap should be determined by the hydrology section. The lack of such protective measures might cause serious washouts of the granular bedding, which in turn would endanger the stability of the embankment.

Because the culvert will be placed in the stratum consisting of predominantly sand and silt layers, a dewatering scheme is essential to prevent boiling of the bottom of the excavation. If sheet piling is used, the sheet piles should be driven to a depth measured from the creek water level which is double the depth to the bottom of the excavation from the creek water level. At the time of this investigation the creek was about 1 foot deep; thus a 2-foot-deep excavation would necessitate driving sheet piling a distance of 3 feet below the bottom of the excavation.

6.3) Embankment Stability:

The stability of the proposed embankment has been checked in the lateral direction. Stability analyses were carried out by means of an electronic computer assuming that failure

occurs along a circular arc immediately after construction. Such computations are based on shear stress parameters in terms of total stresses.

The results of the stability analyses indicate that the proposed embankment height will be stable with a slope of 1.5 horizontal to 1 vertical. The fill around the culvert should be placed according to the appropriate Ministry standard.

6.4) Settlements:

Computation of settlements due to compression of the varved clay stratum were performed using laboratory consolidation curves. Stresses induced by the embankment were calculated by the Boussinesq theory. The results of these calculations indicated that a 1 in. - 2 in. consolidation of the varved clay stratum will occur. Because of the looseness of the silty sand to sandy silt stratum, a 1 in. - 2 in. settlement of this layer will occur.

It is recommended that a flexible culvert be used at this crossing to withstand these small settlements.

7. MISCELLANEOUS:

The field investigation, carried out during the period of August 11 - 17, 1972, was supervised by Mr. E. A. Wood, Project Foundations Engineer.

The equipment was owned and operated by Canadian Longyear Ltd.

This report was written by Mr. E. A. Wood and reviewed by Mr. K. G. Selby, Supervising Foundations Engineer.

E A Wood

E. A. Wood

K G Selby

K. G. Selby, P. Eng.

APPENDIX I

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

Dist 18 Hwy 550 Line C RECORD OF BOREHOLE NO 1
273+70 11' LT. E Hwy 550 Line C

JOB 72-11091LOCATION Sta. 135+76, 10' Rt. 0 (new alignment)ORIGINATED BY EWW.P. 1502-71-01 152-65-02BORING DATE August 15, 1972COMPILED BY EWDATUM GeodeticBOREHOLE TYPE Washboring & Cone TestCHECKED BY EW

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT W_L PLASTIC LIMIT W_P WATER CONTENT W			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		20	40	60	80	100	W_P	W	W_L		
678.4	Ground Level															
0.0	Silty sand Very Loose															
672.4	Fill Material		1	SS	3											1 69 (30)
671.4	Topsoil		2	SS	6											
7.0	Sandy Clay. Firm		3	SS	5											
667.9			4	SS	6											
10.5	Sand, some gravel and silt. Loose		5	SS	10											29 65 (6)
661.9			6	WS	-											13 29 (58)
16.5	Silt with sand, some gravel. Loose		7	SS	8											
657.9			8	WS	-											
20.5	Silty sand, trace of gravel. Loose		9	SS	4											
651.4			10	SS	3											
27.0	Sandy Silt. Very Loose		11	TW	PM											
648.4			12	SS	4											
30.0	Clayey silt with silty clay and silt seams. Firm varved clay		13	SS	46											1 81 (18)
634.1			14	SS	16											0 90 (10)
644.3	Silty sand. Dense		15	SS	37											
630.4	Varved Clay. Firm		16	SS	41											0 88 (12)
48.0																
626.9																
51.5	Sand, trace to some silt. Dense															
616.4																
62.0	End of Borehole															

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 2

JOB 72-11091

LOCATION Sta. 136 + 32 6' Rt. 0 (new alignment)

ORIGINATED BY EW

W.P. 1502-71-01 152-65-02

BORING DATE August 11, 1972

COMPILED BY EW

DATUM Geodetic

BOREHOLE TYPE Cone Test

CHECKED BY SR

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100	SHEAR STRENGTH P.S.F. ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	LIQUID LIMIT w_L PLASTIC LIMIT w_p WATER CONTENT w w_p w w_L WATER CONTENT %	BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT						
678.7	Ground Level										
0.0											
						670					
						660					
						650					
						640					
						630					
625.7											
53.0	End of Cone Test										

DESIGN SERVICES BRANCH

FOUNDATIONS OFFICE

RECORD OF BOREHOLE NO 3

273+22 RT. 40' RT. & HWY 550 LINE 'C'

JOB 72-11091

LOCATION Sta. 136 +09 40' Lt. 0 (new alignment)

ORIGINATED BY EW

W.P. 1502-71-01 152-65-02 BORING DATE August 12, 1972

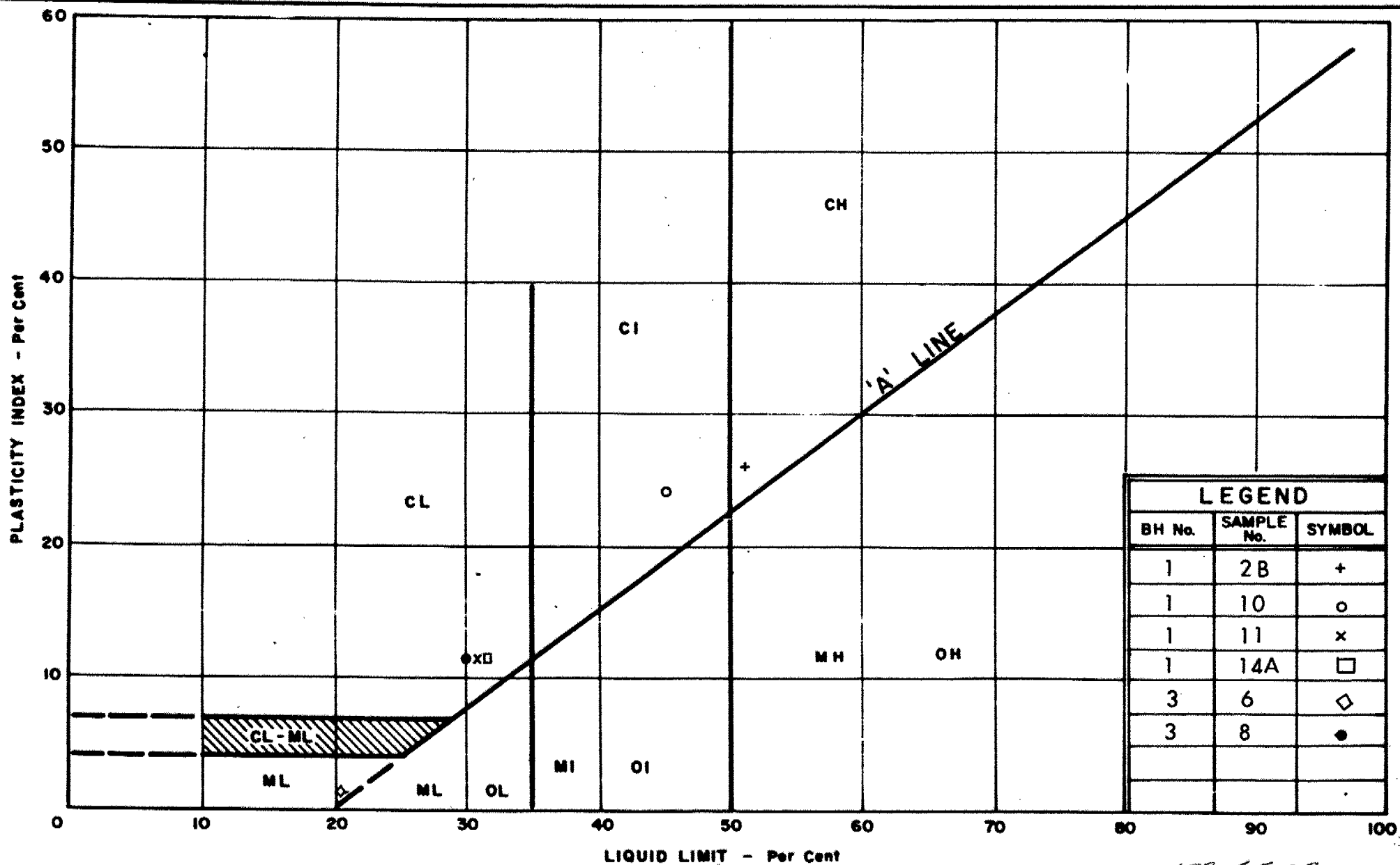
COMPILED BY EW

DATUM Geodetic

BOREHOLE TYPE Washboring & Cone Test

CHECKED BY *OK*

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT					LIQUID LIMIT — W _L PLASTIC LIMIT — W _P WATER CONTENT — W			BULK DENSITY γ P.C.F.	REMARKS
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS/FOOT		20	40	60	80	100	W _P	W	W _L		
670.0	Ground Level															
0.0 667.0	Topsoil	{ { {														
3.0	Sand, some silt to silty sand, traces of gravel & organics.	{ { {	1	SS	5											0 87 (13)
		{ { {	2	SS	10											
		{ { {	3	SS	3											1 52 (47)
	Loose	{ { {	4	SS	7											
		{ { {	5	SS	10											
650.0																
20.0 646.0	Sandy silt. Very Loose	{ { {	6	SS	3											
24.0	Clayey silt with silty clay & silt seams Firm varved clay	{ { {	7	SS	5											
		{ { {	8	SS	5											
635.0																
35.0	Sand, some silt. Dense to Very Dense	{ { {	9	SS	48											0 75 (25)
		{ { {	10	SS	30											
		{ { {	11	SS	42											0 73 (27)
		{ { {	12	SS	100/2"	620										
		{ { {	13	WS	-											
		{ { {	14	SS	39											
		{ { {	15	WS	-											
608.0																
		{ { {	16	SS	37											
62.0	End of Borehole															



152-65-02



DEPARTMENT OF HIGHWAYS
**MATERIALS and
TESTING
DIVISION**

PLASTICITY CHART **VARVED CLAY**

WP. No. 1502-71-01

JOB No. 72-11091

FIG. No. 1

ABBREVIATIONS USED IN THIS REPORT

PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE 'N' :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE :- THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

<u>CONSISTENCY</u>	<u>'N' BLOWS / FT.</u>	<u>c LB. / SQ. FT.</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
VERY SOFT	0 - 2	0 - 250	VERY LOOSE	0 - 4
SOFT	2 - 4	250 - 500	LOOSE	4 - 10
FIRM	4 - 8	500 - 1000	COMPACT	10 - 30
STIFF	8 - 15	1000 - 2000	DENSE	30 - 50
VERY STIFF	15 - 30	2000 - 4000	VERY DENSE	> 50
HARD	> 30	> 4000		

TYPE OF SAMPLE

S.S.	SPLIT SPOON	T.W.	THINWALL OPEN
W.S.	WASHED SAMPLE	T.P.	THINWALL PISTON
S.B.	SCRAPER BUCKET SAMPLE	O.S.	OESTERBERG SAMPLE
A.S.	AUGER SAMPLE	F.S.	FOIL SAMPLE
C.S.	CHUNK SAMPLE	R.C.	ROCK CORE
S.T.	SLOTTED TUBE SAMPLE		
	P.H. SAMPLE ADVANCED HYDRAULICALLY		
	P.M. SAMPLE ADVANCED MANUALLY		

SOIL TESTS

Qu	UNCONFINED COMPRESSION	L.V.	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F.V.	FIELD VANE
Qcu	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Qd	DRAINED TRIAXIAL	S	SENSITIVITY

ABBREVIATIONS USED IN THIS REPORT

SOIL PROPERTIES

γ	UNIT WEIGHT OF SOIL (BULK DENSITY)
γ_s	UNIT WEIGHT OF SOLID PARTICLES
γ_w	UNIT WEIGHT OF WATER
γ_d	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
γ'	UNIT WEIGHT OF SUBMERGED SOIL
G	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
S_r	DEGREE OF SATURATION
w_L	LIQUID LIMIT
w_p	PLASTIC LIMIT
I_p	PLASTICITY INDEX
s	SHRINKAGE LIMIT
I_L	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$
I_c	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$
e_{max}	VOID RATIO IN LOOSEST STATE
e_{min}	VOID RATIO IN DENSEST STATE
I_D	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY D_r IS ALSO USED
h	HYDRAULIC HEAD OR POTENTIAL
q	RATE OF DISCHARGE
v	VELOCITY OF FLOW
i	HYDRAULIC GRADIENT
k	COEFFICIENT OF PERMEABILITY
j	SEEPAGE FORCE PER UNIT VOLUME
m_v	COEFFICIENT OF VOLUME CHANGE = $\frac{-\Delta e}{(1+e)\Delta\sigma}$
c_v	COEFFICIENT OF CONSOLIDATION
C_c	COMPRESSION INDEX = $\frac{\Delta e}{\Delta \log_{10} \sigma}$
T_v	TIME FACTOR = $\frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
τ_f	SHEAR STRENGTH
c'	EFFECTIVE COHESION INTERCEPT
ϕ'	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
c_u	APPARENT COHESION
ϕ_u	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
μ	COEFFICIENT OF FRICTION
S_t	SENSITIVITY

GENERAL

π	= 3.1416
e	BASE OF NATURAL LOGARITHMS 2.7183
$\log_e a$ OR $\ln a$	NATURAL LOGARITHM OF a
$\log_{10} a$ OR $\log a$	LOGARITHM OF a TO BASE 10
t	TIME
g	ACCELERATION DUE TO GRAVITY
V	VOLUME
W	WEIGHT
M	MOMENT
F	FACTOR OF SAFETY

STRESS AND STRAIN

u	PORE PRESSURE
σ	NORMAL STRESS
σ'	NORMAL EFFECTIVE STRESS ($\bar{\sigma}$ IS ALSO USED)
τ	SHEAR STRESS
ϵ	LINEAR STRAIN
γ	SHEAR STRAIN
ν	POISSON'S RATIO (μ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
η	COEFFICIENT OF VISCOSITY

EARTH PRESSURE

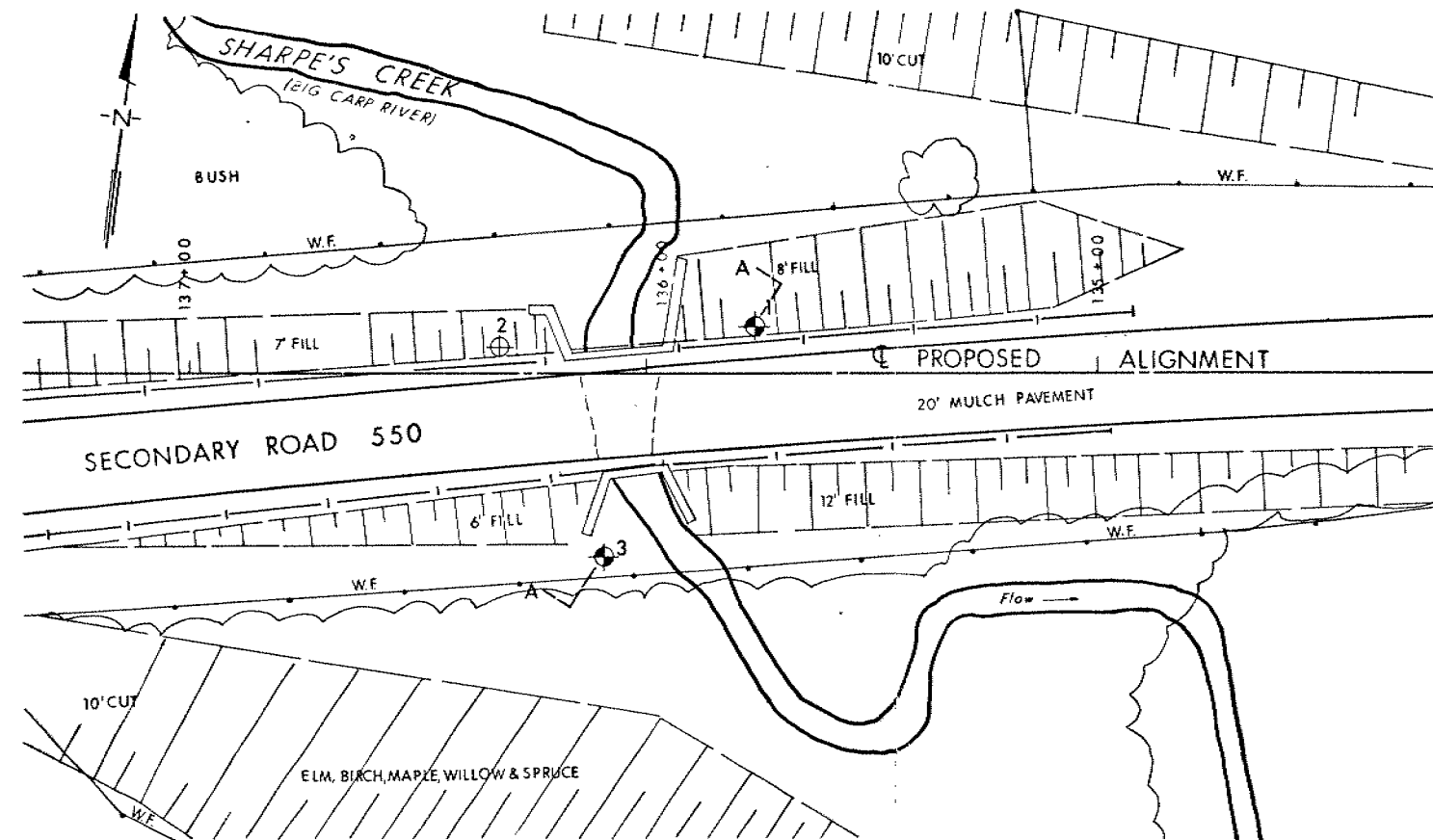
d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
δ	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
K_0	COEFFICIENT OF EARTH PRESSURE AT REST

FOUNDATIONS

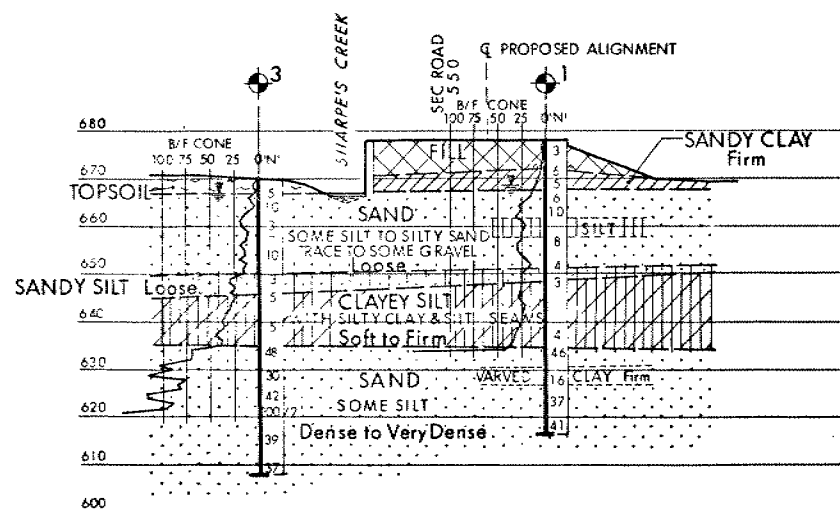
B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY
k_s	MODULUS OF SUBGRADE REACTION

SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
β	ANGLE OF SLOPE TO HORIZONTAL

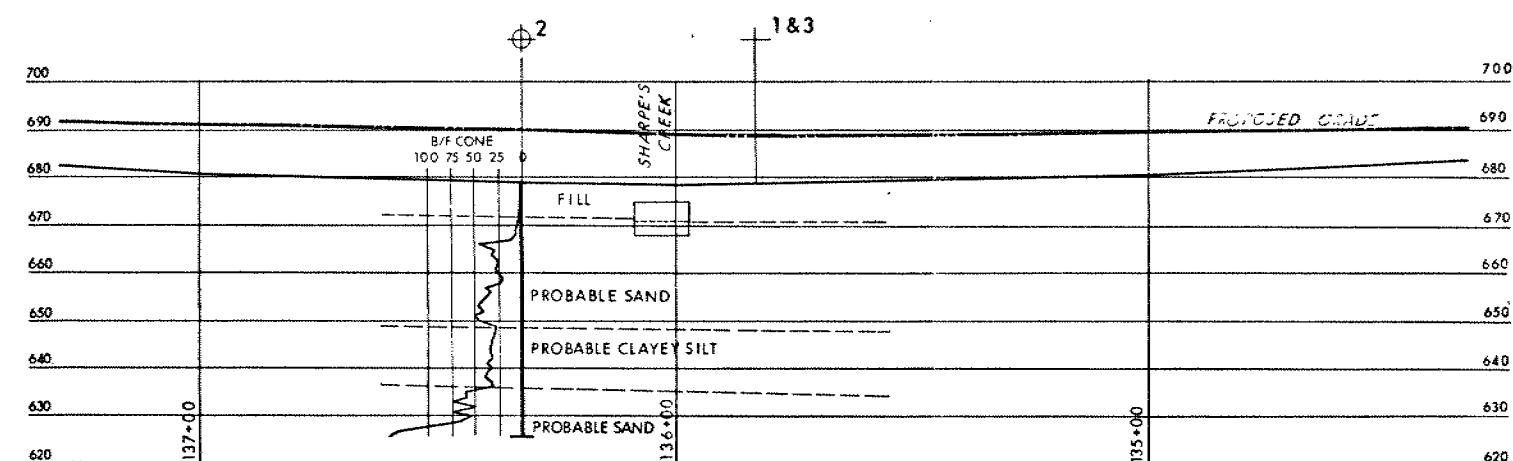


PLAN
20 10 0 SCALE 20 40 FT.



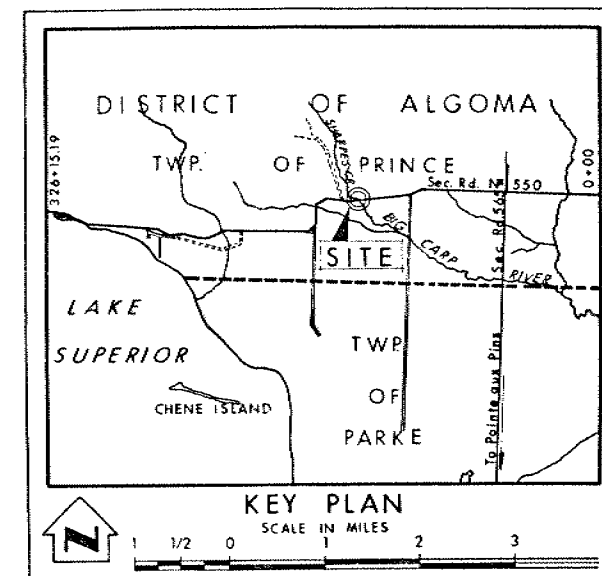
SECTION A-A

20 10 0 SCALE 20 40



PROFILE

20 10 0 SCALE 20 40 FT.



LEGEND

- Bore Hole
- ⊕ Cone Penetration Test
- ⊕ Bore Hole & Cone Test
- W.F. Water Levels established at time of field investigation AUGUST, 1972

NO.	ELEVATION	STATION	OFFSET
1	678.4	135+76	10' RT.
2	678.7	136+32	6' RT.
3	670.0	136+09	40' LT.

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS—ONTARIO
DESIGN SERVICES BRANCH—FOUNDATIONS OFFICE

SHARPE'S CREEK

HIGHWAY NO. SEC. RD. 550 PROP. ALIGNMENT DIST. NO. 18

DIST. OF ALGOMA

TWP. PRINCE LOT CON.

BORE HOLE LOCATIONS & SOIL STRATA

SUBMITT. W.	CHECKED	W.P. NO. 1502-71-01	DRAWING NO.
DRAWN F.L.	CHECKED	W.O. NO. 72-11091	72-11091A
DATE	SEPT 15, 1972	SITE NO.	BRIDGE DRAWING NO.
APPROVED	PRINCIPAL FOUNDATION ENGINEER	CONT. NO.	

REF. No. 1B595