WILLIAM A. TROW AND ASSOCIATES LTD.

SITE INVESTIGATIONS
LABORATORY TESTING
SOIL MECHANICS CONSULTATION

W. A. TROW, M.A.Sc., M.E.I.C., P.ENG.

1850 JANE ST.,
WESTON, ONT.
[illegible]

Project: J2171 August 22, 1963

M.M. Dillon and Co. Ltd.,
Consulting Engineers,
P.O. Box 1026,
141 Maple Street, London, Ontario

Attention: Mr. A. Phillips, P.Eng.

Re: Preliminary Investigation - Foundation Conditions
Kilworth Bridge

Dear Sirs:

In conformance with your authorization, given by letter on July 10th, we have made a preliminary investigation of foundation conditions at this bridge crossing of the Thames River.

The purpose of this work was to provide sufficient information about the capacity of the foundation soil so that decisions can be made on the types of construction that are feasible for this bridge replacement and County road realignment scheme. If extremely dense incompressible soil exists, it is understood that an arch structure, having a span of approximately 250 feet, will receive serious consideration.

The field work involved in this preliminary survey consisted of four borings, two of which were made in the vicinity of the proposed bridge abutments and the remainder along the approaches to the bridge.

Although the presence of a dense boulder pavement at the various test locations has placed a temporary limit on the depth of the borings, sufficient information has been obtained to indicate that the soil along the entire length of this realignment route consists of fine-grained granular material which has an extremely high density below the thin surfacial covering of river alluvium and terrace deposits. The foundation conditions are tentatively considered to be excellent for the support of abutment foo[illegible] at quite shallow depths and the soil below footing level has a ve[illegible]igh capacity and low compressibility. Provided that scour protection is obtained, the footings along the west bank can be placed at any depth below El 724 feet, which is about 20 feet above river level. Along the east shoreline they can be placed at any depth below the present river surface. On the basis of present information, the safe net bearing pressure to apply at these levels is tentatively estimated to be at least equal to 5 tsf and the settlement associated with this loading will be elastic and it should not exceed ½ inch.

Since the alluvium, covering the east flood plain approach to the bridge, consists of sand underlain by extremely dense sandy silt till, there will be no instability of embankments placed on this material. The loose sand will adjust immediately to load application and the amount of settlement will be negligible. If the depth of the approach fill exceeds 4 feet, it is not necessary to remove the thin topsoil cover along this route.

The factual information and soil mechanics reasoning which form the bases for these statements will be considered more fully, together with the results of required additional borings, in our final report on this subject. The following sections will be limited to a brief outline of this initial program and to the indication of the additional field and laboratory testing required to confirm more completely that the foundation conditions are satisfactory.

FIELD WORK AND SUBSOIL

The borings of the investigation were made using continuous flight auger equipment. The holes were uncased to full depth. Although this machine can penetrate through very hard soil, great difficulty was experienced at this site because of the presence of buried boulder pavements which lie under the present flood plain and earlier higher terraces of the Thames River. The locations of the various attempts made to penetrate this boulder layer are indicated on Dwg. 1.

The subsoil conditions encountered at the various test locations are indicated in the borehole logs, Dwgs. 2 to 5, and in general form in the interpreted stratigraphical profile of Dwg. 1. It is noted that the boulder pavement, referred to above, lies at approximate El 728 feet under the ancient elevated river terrace beyond the west end of the proposed bridge, and it is encountered at approximate El 706 feet under the present flood plain, comprising the east approach to the bridge.

The soil beneath this pavement consists of extremely dense fine grained sandy silt or silt till which has a unit weight in the order of 143 pcf, a moisture content below the plastic limit in the cohesive sections of the soil, and a shear strength of approximately 8000 psf. This strength measurement was determined by an unconfined compression test on a partially disturbed split spoon sample recovered from a depth of 14 feet in hole 2 on the west bank.

The result is considered to be quite conservative, as is the measurement of the elastic modulus value E = 2000 ksf.

Although the foregoing physical properties apply for the more cohesive phases of the till encountered in hole 2, it is expected that the same high density and elasticity are applicable for the underlying sandy silt till as well. Although this extremely dense sandy till was very difficult to sample, attempts will be made in the final investigation to obtain a measurement of the density and elasticity.

Typical gradings for the till existing at and below footing level are indicated on Dwg. 6. Although there is very little clay in this material, its well graded character and high density are indicative of a very low permeability. Consequently, it should be possible to make the shallow excavations below the water table required for the bridge footings without too much difficulty, except for the anticipated high resistance to digging.

Gradings for the sandy silt alluvium overlying the boulder pavement and for the sand lying within the proposed cutting at the top of the west hillside are also indicated in Dwg. 6. The standard Proctor moisture density relationship for the sand in hole 1 is indicated on Dwg. 7. It is noted that the field moisture content for the sand is well below the optimum value. The water table in this cut section was found to be about 2 feet above the underlying till contact, or about 17 feet below the surface. This is below the limit of the excavation proposed for this hillside.

PRELIMINARY APPRAISAL OF SITE

According to the results of the two borings made near the ends of the proposed bridge a soil of high capacity and low compressibility exists at this site. On the basis of the very high undrained shear strength result obtained for the more cohesive portions of the soil in hole 2, and the extremely high penetration resistance measurements recorded in the underlying sandy silt till in both holes, the safe net bearing value of these materials is estimated to be at least equal to 5 tsf. Because of the very high density and granular nature of the soil, it is expected that any settlement under load will be of an elastic nature and of very small magnitude.

The elastic settlement to be expected under a bearing stress q = 5 tsf can be determined from the expression:

$$S_i = \mu \, \mu_o \, \frac{qB}{E} (1 - v^2)*$$

For a rectangular abutment footing having a length - breadth ratio equal to 5, shape factors μ and μ_o are approximately equal to 1.4 and 0.85 respectively, for the footing depth requirements applying here. Taking a footing B = 10 feet wide, and a value of E = 1000 tsf and Poisson's ratio v = 0.5, S_i is determined to be equal to ½ inch approximately. With a narrower footing, smaller settlements can be expected.

As indicated above, since the sandy silt till is so dense and well graded, it should have a very low permeability. Consequently, the footing beds in this material should remain relatively stable when carried to shallow depths below river level. Perimeter ditches may be required along the east bank to intercept water flowing in through the boulder pavement. It may be desirable, also, to place a working mat of concrete on the footing bed as soon as it is exposed, if this low plasticity material shows any tendency to become "quick". After the concrete has set, the excavation can be filled with water in order to balance the hydrostatic level.

* M.I.T. notes. Seminar, September, 1959.

Although it was not possible to penetrate through the boulder pavement at the hole 4 location, it is expected that dense conditions prevail under this part of the site as well. The soil above the pavement, although loose, consists of sand or sandy silt which will adjust immediately to embankment loadings.

The emergence of perched ground water above the silt till at approximate El 769 feet on the west hillside near hole 1, will require attention in the design of the roadbed. This water must be drained off, in a positive manner, to the lower land lying to the north of the cutting in this area. This drainage must ensure that the water table is always at least 4 feet below the road surface, and therefore that the road surface comes no closer than about 6 feet to the silt till.

ADDITIONAL WORK

Although the work performed to date was intended to provide preliminary information for the early planning stages of this bridge replacement scheme, it is apparent that no serious foundation problem exists at this site. Consequently, the main purpose of subsequent borings is to confirm that these satisfactory conditions continue for sufficient depth below river bed level. One boring, made on each side of the river to a depth of 40 feet below river bed level, should suffice for this additional survey.

If an arch structure is to be used, it is important also to obtain some measurement of the density, compressibility and angle of internal friction of the sandy silt till below footing level. The latter strength property is necessary for the determination of the ultimate capacity of the inclined abutment footings of the arch structure. An indication of the inclination of the resultant force on each footing will be required for this determination.

No additional work along the approaches to the bridge is considered to be warranted.

If you wish to discuss the results of this preliminary survey, we shall be pleased to hear from you.

Yours very truly,

REGISTERED PROFESSIONAL ENGINEER
CIVIL
W. A. TROW
PROVINCE OF ONTARIO

William A. Trow, P.Eng.

WAT/gc
Encls.

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SITE INVESTIGATIONS — SOIL MECHANICS CONSULTATION

DRAWING No. 2

PROJECT No. J1171

BOREHOLE No. 1

PROJECT Kilworth Bridge

LOCATION London, Ontario

HOLE LOCATION See Dwg. 1.

HOLE ELEVATION 786.0 ft.

DATUM See Dwg. 1.

LEGEND

PENETRATION RESISTANCE

- 2" O.D. SPLIT TUBE
- 2" I.D. SHELBY TUBE
- 2" DIA. CONE

SHEAR STRENGTH

- UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE
- UNCONFINED COMPRESSION
- VANE TEST AND SENSITIVITY (S)

NATURAL MOISTURE CONTENT AND LIQUIDITY INDEX

ATTERBERG LIMITS

- LIQUID LIMIT
- PLASTIC LIMIT

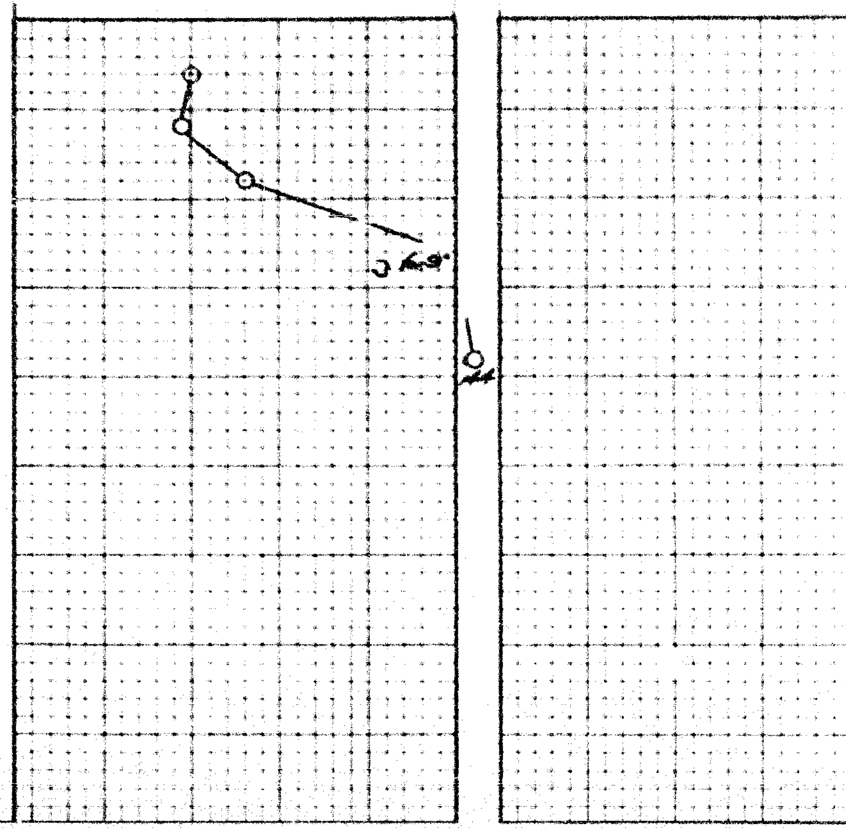
SAMPLE TYPE

- 2" O.D. SPLIT TUBE
- 2" I.D. SHELBY TUBE
- 3" O.D. SHELBY TUBE

SYMBOL	SOIL DESCRIPTION	ELEV. FEET	DEPTH FEET
		786.0	0
	SAND–dense to very dense, fine to med., brown, dry to moist, trace of clay, odd gravel. Becomes moist below 18'; occasional gravel or boulders encountered below 15 ft.		10
	▽	769.3	
	SILT TILL–v. dense, grey, dry, sandy, slightly cohesive, some moist to ~~dry sand~~ seams.	767.5 766.1	20
			30
			40

PENETRATION RESISTANCE 350 FT. LB. BLOWS/FT. — 20 40 60 80 — SHEAR STRENGTH P.S.F.

NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS % DRY WEIGHT — SAMPLE TYPE AND No. — NATURAL UNIT WEIGHT P.C.F.



Notes: 1) Two attempts were made to advance hole with continuous flight auger equipment. Hole uncased to full depth.

2) At completion, W.L. at 17.8', open to 18.2'
After 8 hrs., " " 16.7', " " 17 ft.

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SITE INVESTIGATIONS   SOIL MECHANICS CONSULTATION

DRAWING NO. 3

PROJECT NO. J1171

LEGEND

BOREHOLE NO. 2

PROJECT Lilworth Bridge

LOCATION London, Ontario

HOLE LOCATION See Dwg. 1.

HOLE ELEVATION 731.5 ft.

DATUM See Dwg. 1.

PENETRATION RESISTANCE
- 2" O.D. SPLIT TUBE
- 2" I.D. SHELBY TUBE
- 2" DIA. CONE

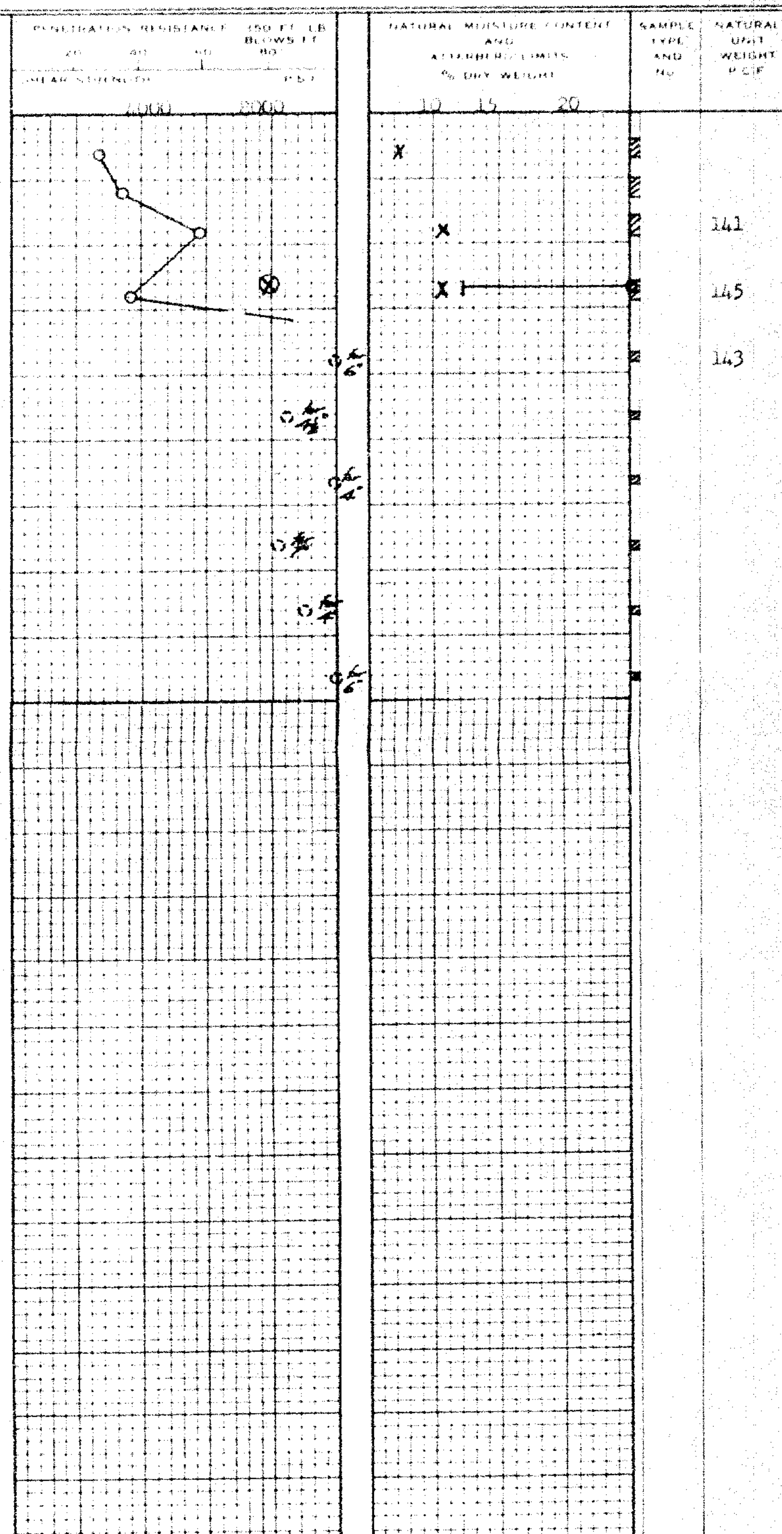
SHEAR STRENGTH
- UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE
- UNCONFINED COMPRESSION
- VANE TEST AND SENSITIVITY

NATURAL MOISTURE CONTENT AND LIQUIDITY INDEX

ATTERBERG LIMITS
- LIQUID LIMIT
- PLASTIC LIMIT

SAMPLE TYPE
- 2" O.D. SPLIT TUBE
- 2" I.D. SHELBY TUBE
- 3" O.D. SHELBY TUBE

SYMBOL	SOIL DESCRIPTION	ELEV. FEET	DEPTH FEET
		731.5	0
	SAND WITH GRAVEL–dense, dry, silty, brown.		
		724.0	
	SILT TILL–very stiff to hard, sandy, dry; slightly cohesive, some gravel sizes; boulder at 18 ft.		10
		714	
	SANDY SILT TILL–very dense, very fine, brown-grey, odd small gravel; becomes moist to wet below 26 ft.; slightly cohesive below 37 ft.		20
			30
			40
	End of Hole	688.5	



Notes: 1) Seven attempts were made in a radius of 10 ft. from hole 2 to advance hole with continuous flight auger equipment before boulders at 3 to 5 ft. penetrated. Hole uncased to full depth.

2) At completion, hole open & wet at 27.8 ft. After 3 days, open & wet to 27.8 ft.

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SITE INVESTIGATIONS — SOIL MECHANICS CONSULTATION

DEFECTS IN NEGATIVE DUE TO CONDITION OF ORIGINAL DOCUMENT

DRAWING No 4

PROJECT No J1171

BOREHOLE No 3

PROJECT Kilworth Bridge

LOCATION London, Ontario

HOLE LOCATION See Dwg. 1.

HOLE ELEVATION 715.5 ft.

DATUM See Dwg. 1.

LEGEND

PENETRATION RESISTANCE
- 2" O.D. SPLIT TUBE
- 2" I.D. SHELBY TUBE
- 2" DIA. CONE

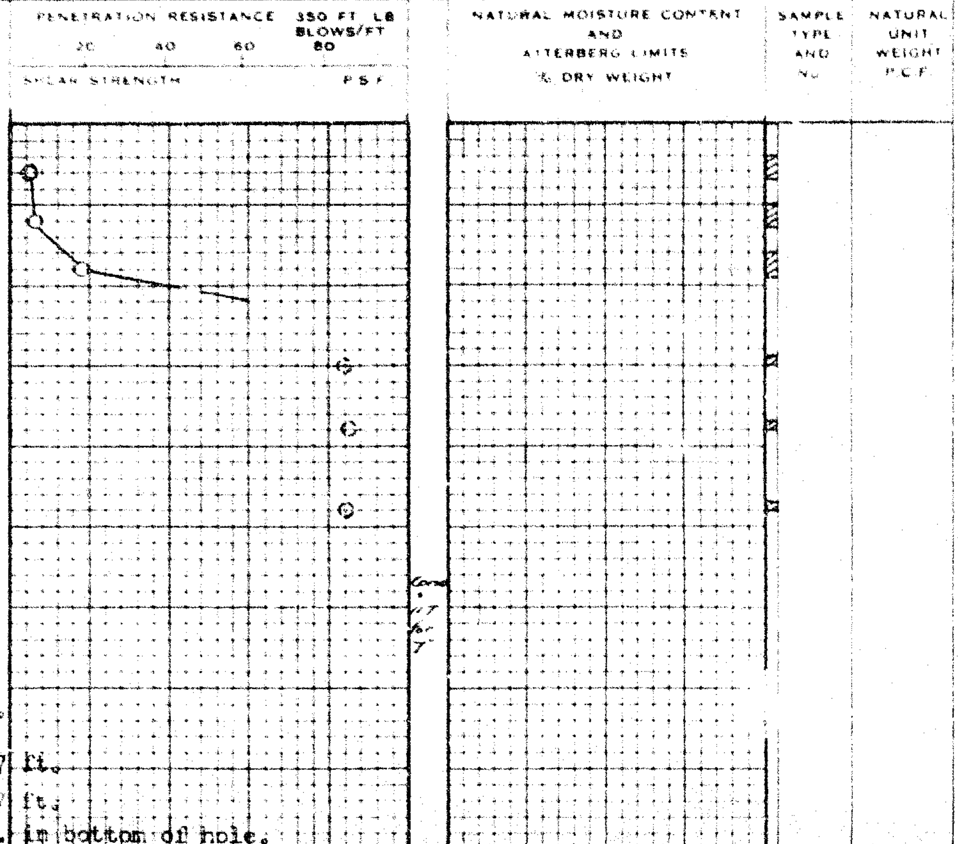
SHEAR STRENGTH
- UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE
- UNCONFINED COMPRESSION
- VANE TEST AND SENSITIVITY (S)

NATURAL MOISTURE CONTENT AND LIQUIDITY INDEX

ATTERBERG LIMITS
- LIQUID LIMIT
- PLASTIC LIMIT

SAMPLE TYPE
- 2" O.D. SPLIT TUBE
- 2" I.D. SHELBY TUBE
- 3" O.D. SHELBY TUBE

SYMBOL	SOIL DESCRIPTION	ELEV. FEET	DEPTH FEET
	3 - 4 ins. topsoil.	715.5	0
	SAND-loose to 8½ ft., fine, brown, becomes med. dense to dense below 8½ ft.; changing to grey below 9 ft.	706.5	
	MATRIX OF GRAVEL & BOULDERS-very dense. boulders (8 ins. to 2 ft.)	702.8	10
	SANDY SILT TILL-very dense, very fine wet, with occasional small gravel.	701.5	20
	End of Hole	686.8	30



Notes: 1) Nine attempts were made in a radius of 100 ft. from B.3 to advance hole through boulder pavement with continuous flight auger equipment. Hole uncased to full depth. Boulder pavement at approx. El 706 ft.

2) At completion, W.L. at 12.7 ft., open to 13.7 ft.
After 3 hrs. " " 12.7 ft., " " 12.7 ft.

3) Cone driven to virtual refusal at El 686 ft. in bottom of hole.

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SITE INVESTIGATIONS   SOIL MECHANICS CONSULTATION

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DRAWING NO. 5

PROJECT NO. 11171

BOREHOLE NO. 4

PROJECT Kilworth Bridge

LOCATION London, Ontario

HOLE LOCATION See Dwg. 1.

HOLE ELEVATION 716.5 Ft.

DATUM See Dwg. 1.

LEGEND

PENETRATION RESISTANCE

2" O.D. SPLIT TUBE —o—o—o—

2" I.D. SHELBY TUBE —+—+—+—

2" DIA. CONE ————

SHEAR STRENGTH

UNDRAINED TRIAXIAL AT OVERBURDEN PRESSURE ⊕

UNCONFINED COMPRESSION ⊗

VANE TEST AND SENSITIVITY (S) +S

NATURAL MOISTURE CONTENT AND LIQUIDITY INDEX x

ATTERBERG LIMITS

LIQUID LIMIT —o

PLASTIC LIMIT —

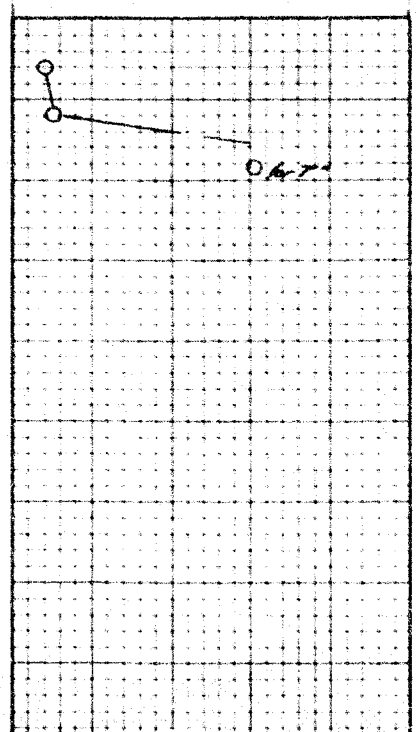
SAMPLE TYPE

2" O.D. SPLIT TUBE

2" I.D. SHELBY TUBE

3" O.D. SHELBY TUBE

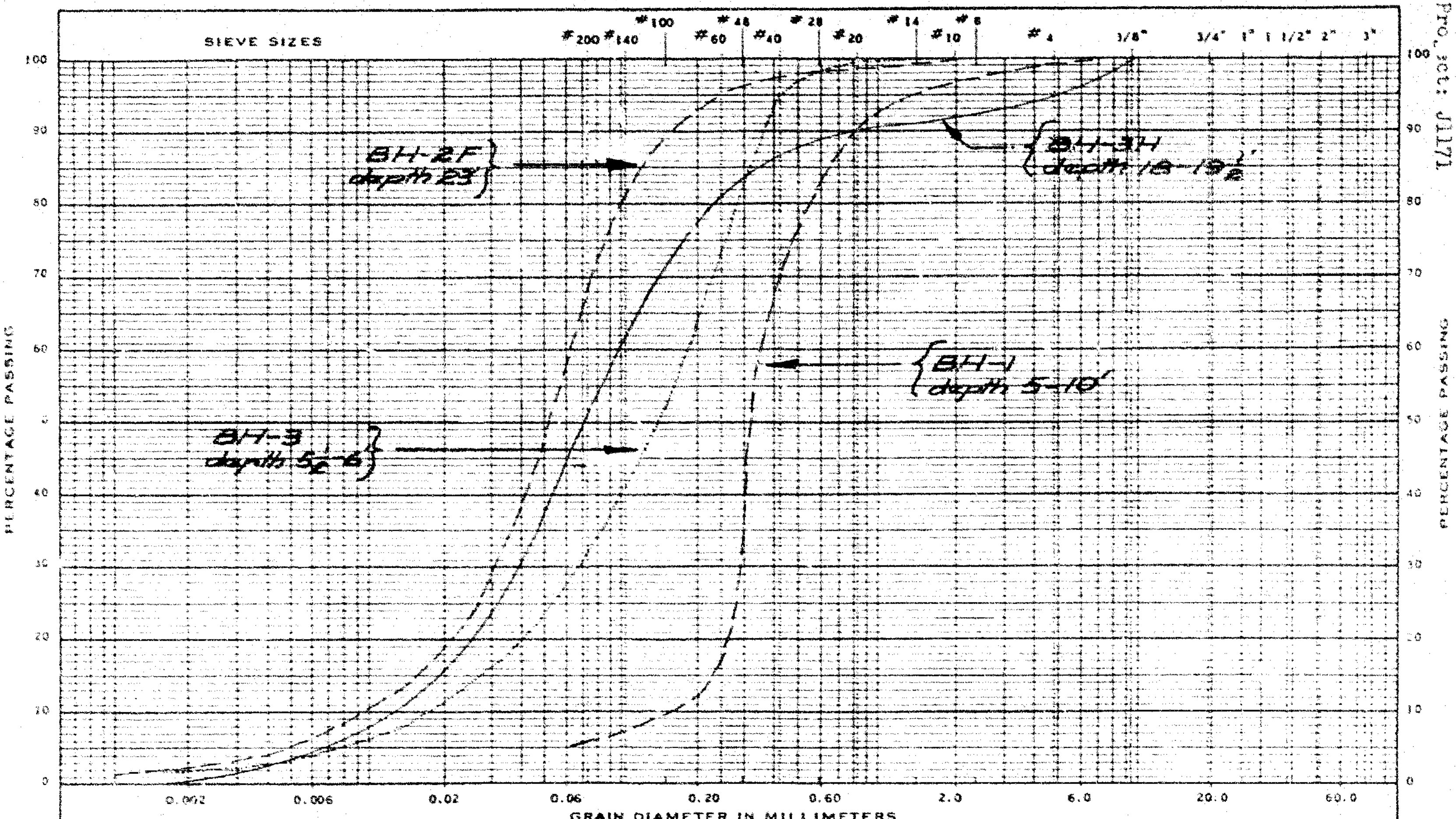
SYMBOL	SOIL DESCRIPTION	ELEV FEET	DEPTH FEET	PENETRATION RESISTANCE 350 FT. LB. BLOWS/FT. 20 40 60 80 / SHEAR STRENGTH P.S.F.	NATURAL MOISTURE CONTENT AND ATTERBERG LIMITS % DRY WEIGHT	SAMPLE TYPE AND No.	NATURAL UNIT WEIGHT P.C.F.
	3 - 4 ins. topsoil	716.5	0				
	SAND-loose to med. dense, fine, brown, dry, stained and with roots to 8½ ft. Gravel & boulders encountered at 10 ft.						
	End of Hole	706.3	10				
			20				
			30				
			40				



Notes: 1) Four attempts were made in a radius of 15 ft. from B.H. to advance hole past 10 ft. with continuous flight auger equipment. Hole uncased to full depth.

2) At completion, hole open and dry to 10 ft.

MECHANICAL ANALYSIS



← CLAY	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE
	SILT			SAND			GRAVEL		

MODIFIED M.I.T. CLASSIFICATION

GRAIN SIZE CURVES – KILWORTH BRIDGE

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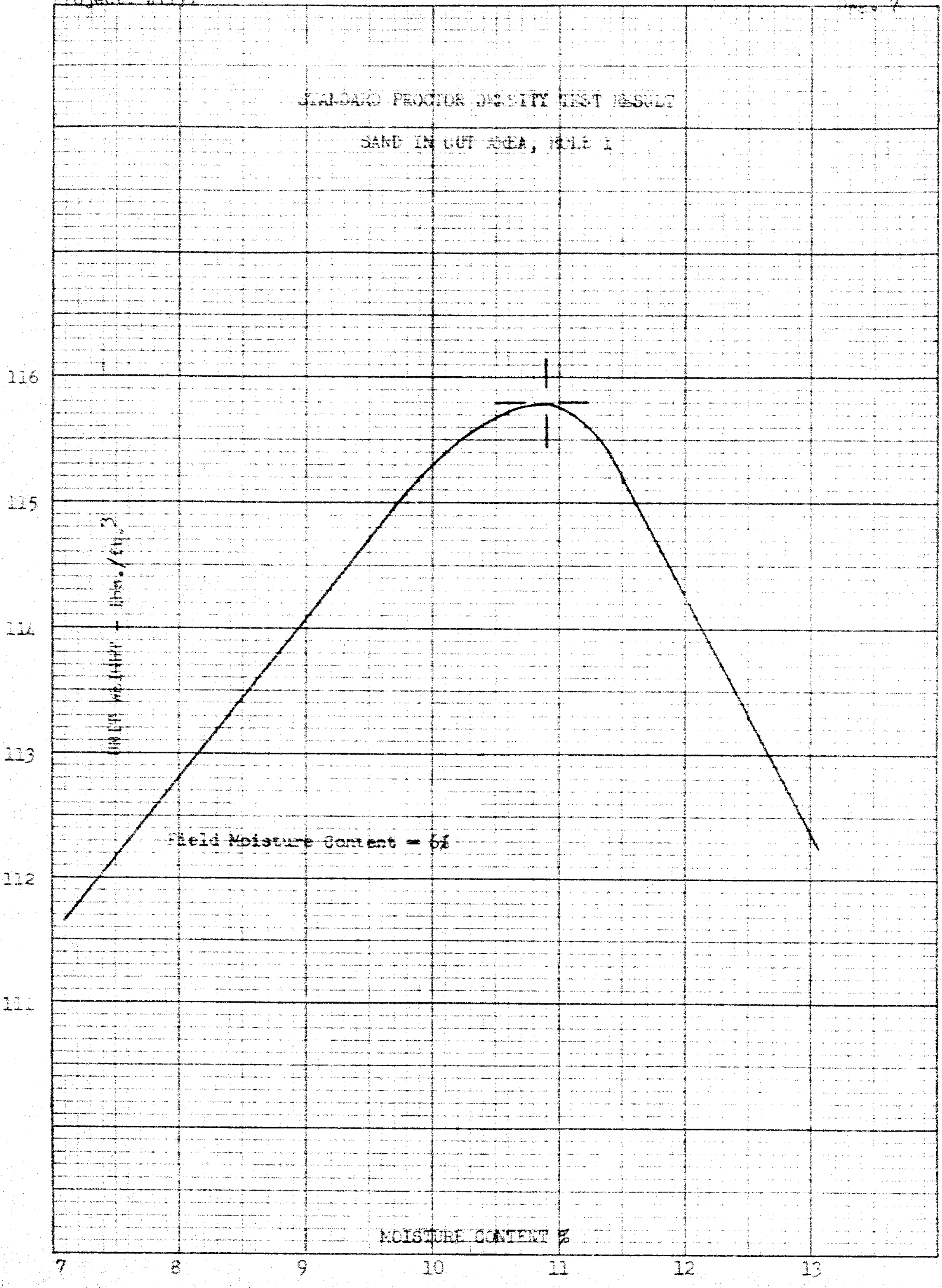
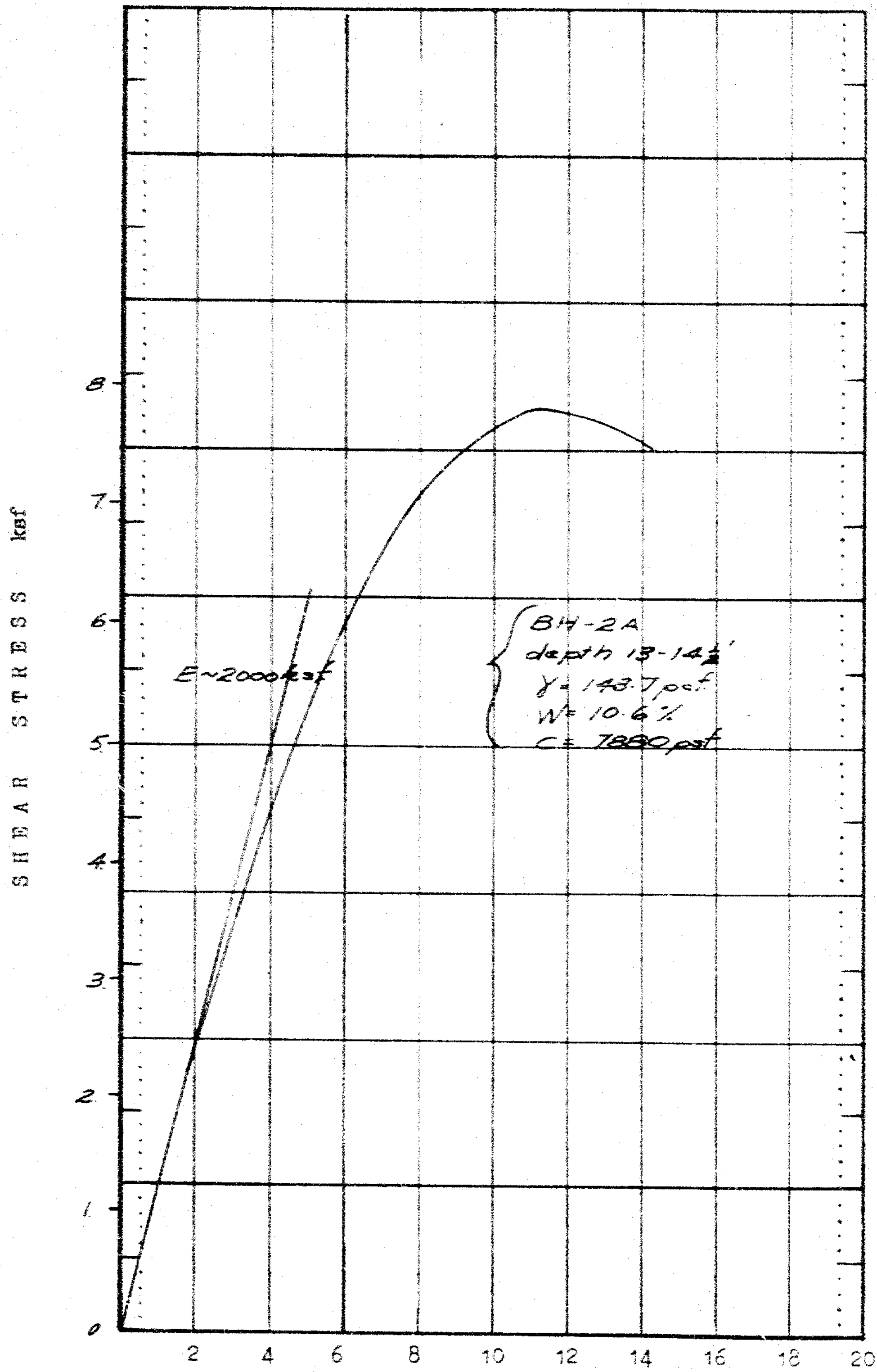
Project: J1171

Dwg. 6


STANDARD PROCTOR DENSITY TEST RESULT
SAND IN CUT AREA, HOLE 1
116
115
114
113
112
111
Field Moisture Content = 6%
MOISTURE CONTENT %
7
8
9
10
11
12
13

PROJECT NO. J1171 DRAWING NO. 8



UNCONFINED COMPRESSION TEST
B.H. 2A

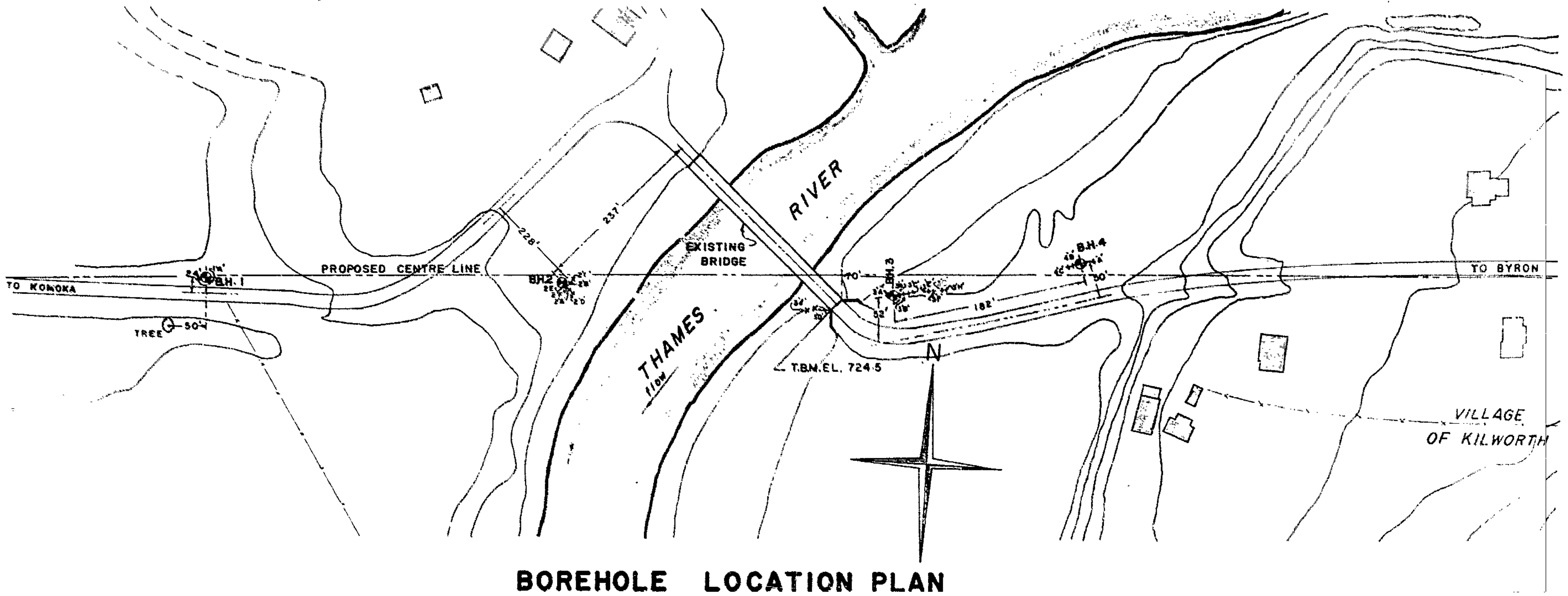
WILLIAM A. TROW AND ASSOCIATES

#63-F-251 M

KILWORTH BRIDGE

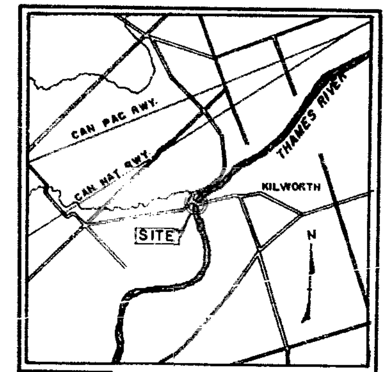
OVER

THAMES RIVER

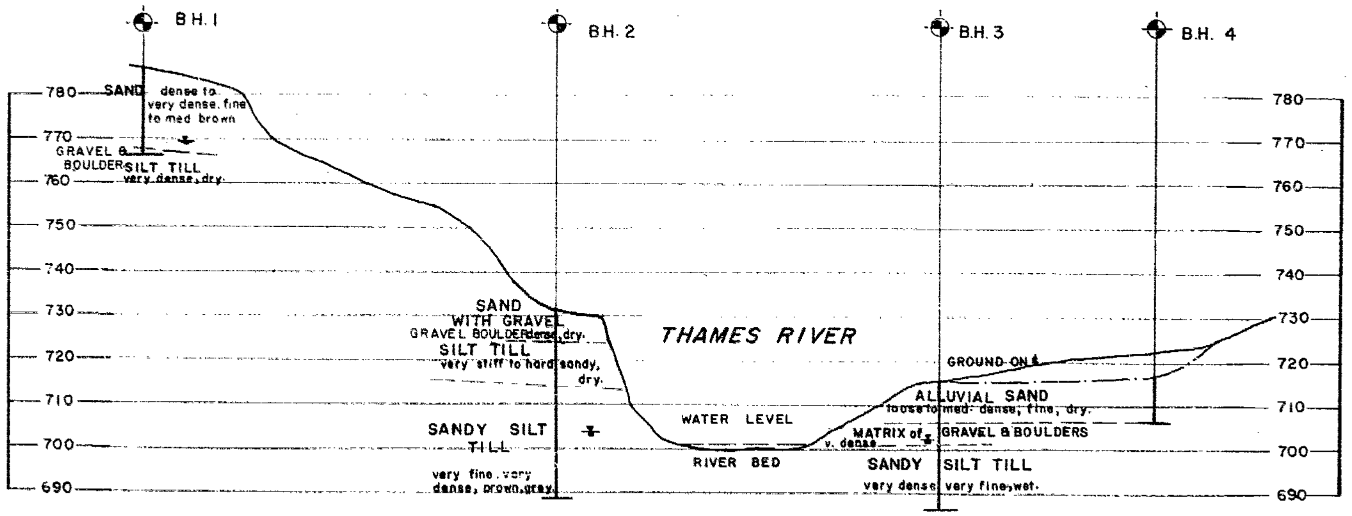


BOREHOLE LOCATION PLAN

SCALE: 1 IN = 100 FT.



SITE PLAN
SCALE 1 IN = 0.8 MI.



INTERPRETED SUBSOIL STRATIGRAPHY

SCALE: HOR. 1 IN. = 100 FT.
VERT. 1 IN. = 20 FT.

LEGEND

- BOREHOLE
- ATTEMPTS AT DRILLING.

NOTE

Ground levels referred to elevations of river level, assumed from contoured site plan.
T.B.M. TOP OF CONCRETE ABUTMENT S.E. CORNER OF BRIDGE ELEV. 724.5 ft.

W A TROW & ASSOCIATES LIMITED		
FOUNDATION INVESTIGATION		
KILWORTH BRIDGE OVER THAMES RIVER		
LONDON		ONTARIO
PROJ. 1171	DATE AUG. 1963	DWG. Nº 1