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GEOCRES No. 31 C - 131

W.P. No. _____

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W. O. No. _____

STR. SITE No. _____

HWY. No. 401

LOCATION SALMON RIV. ,
BRIDGE #5

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. NONE

REMARKS: _____

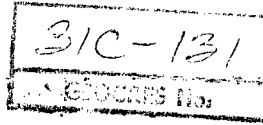
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YOUR REF.

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THE DEPARTMENT OF HIGHWAYS OF ONTARIO

THE KING'S HIGHWAY NO. 401

R E P O R T O N

TYENDINAGA TOWNSHIP BRIDGE NO. 5

SALMON RIVER CROSSING

T. O. LAZARIDES, LOUNT AND PARTNERS
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S U M M A R Y

The gentle slope, shallow depth and loose material of the river bed at the bridge site coupled with the presence of conditions leading to the easy formation of ice jams requires a relatively wide opening of 360 feet to accommodate anticipated flows. The geological conditions do not favour a re-location of the bridge without altering the center line of Highway No. 401 since the performance of a fill placed on the present river bottom would not be satisfactory without the use of sand drains. Even then there appears to be some doubt as to the satisfactory performance of fills over 10 feet high. Economic considerations show that a bridge 413 feet long located at the present site would not cost much more than a structure 360 feet long, plus a length of 52 feet of fill stabilized by sand drains. In our opinion there is no question but that the longer bridge will be more satisfactory and therefore is to be recommended.

TYENDINAGA TOWNSHIP BRIDGE NO. 5

HIGHWAY NO. 401

SALMON RIVER CROSSING

REPORT AND RECOMMENDATIONS

GENERAL

The recommendations contained in this report are based on a detailed study of the main factors having a bearing on the problem, that is:

Hydrological considerations inasmuch as they affect the function of the structure.

Geological considerations inasmuch as they affect the stability of the structure and the stability of the approach fill.

Economic considerations inasmuch as they affect the cost of the structure, cost of the approaches and the overall cost of the project.

The conclusions reached and the factual information on which these conclusions were based are contained in detail in the appendices listed hereunder. The above three factors are closely interrelated and should be considered simultaneously in making a decision. The main facts and conclusions are as follows.

A. HYDROLOGICAL CONSIDERATIONS

Computations and comparison of conditions on the Salmon River, the Humber River and the Moira River have led to the following figures on which our recommendations are based:

Average yearly flood over

a ten-year period - 7000 cfs

Maximum ten-year flood - 11400 cfs

Maximum twenty-five year flood - 19600 cfs

(This is comparable to the effects of Hurricane Hazel on the Humber River.)

Maximum all-time flood between 30,000 and 40,000 cfs.

Icing Conditions: Severe ice jams reported in the immediate vicinity of the bridge site.

Type of Flooding: The Salmon River frequently floods over the ice.

Computing the discharge capacities of structures of various sizes at this site it would appear that a water opening of approximately 260 feet would be sufficient to take care of the average yearly flood. To take care of the maximum ten-year flood without risk of damage to the structure and to make provisions for an emergency twenty-five year flood it is advisable to provide a water pening between 360 feet and 380 feet. Under these conditions the bottom

flanges of the girders at midspan would be approximately 4 feet 6 inches above the surface of the water and the bearings at the east abutment seats would be submerged by approximately 1 foot. As far as exceptional flood conditions are concerned the structure should be designed so that the flood in excess of 19,600 cfs would damage the approach fills rather than take out the structure. Finally, the icing conditions on the river make it appear inadvisable to undertake any major alterations of the angle of skew of the river with respect to the center line of the highway.

Note: See Appendix "A" for detailed hydrological computations.

B. GEOLOGICAL CONSIDERATIONS

These are discussed in the foundation report prepared by Kacey, MacCallum and Associates Limited, Consulting Engineers, Toronto. The nature of the surface deposits confirms the inadvisability of major alterations of the river channel, whereas the nature of the deeper deposits makes it desirable to ensure that the settlement of the approach fills at the two ends of the bridge due to delayed consolidation of the deep sub-strata remains within controllable limits and uniform without requiring excessive use of sand drains. The deepest point at which bedrock is found is approximately in the middle of the crossing at an approximate level of 210.00. The level of the center line of highway at this point is 278.90. The bedrock slopes on both sides, the slope being sharper on the west side than on the east.

In view of these considerations it seems advisable to increase the length of the structure beyond the 380 feet required for hydrological considerations to approximately 420 feet.

C. ECONOMIC CONSIDERATIONS

In view of the necessity of carrying the foundations down to bedrock the cost of abutments including the necessary retaining walls decreases sharply with a reduction of the total depth to bedrock. Consequently, once the ends of the structure are located over the sloping sides of the underground bedrock valley as they have to be in any case for hydrological considerations, the overall cost of the structure does not increase in direct proportion to its length. On the other hand, the saving in the cost of fill increases very rapidly.

Note: See Appendix "C"

D. CONCLUSION

In view of the above we recommend a structure with a total length of 412 feet 8 inches between center lines of extreme bearings as shown on our Drawing No. D-3572-P1 located athwart the deepest part of the underground bedrock valley as shown on our Drawing No. D-3572-P2.

Note: This choice is confirmed by a comparison with the C.N.R. Bridge located downstream from this site. Although the overall length of this structure is smaller the river channel is much deeper at this point, the depth of water under the bridge varying between 8 feet and 21 feet. At maximum flood level occurring with the flood of 19,600 cfs the calculated discharge capacity of the two structures is approximately the same.

APPENDIX "A"

HYDROLOGICAL CALCULATIONS

1. Estimated Flow from Watershed Area and
Estimated Run off Coefficients for Salmon River.

The calculations were based on the "Modified Rational Method of Estimating Flood Flows". *

The drainage basin area was determined from topographical maps to be equal to 350 square miles.

Rainfall factors

$$e = 0.83 \text{ (see fig. 115); } \frac{1}{e} = \frac{1}{0.83} = 1.20$$

$$x = 0.25 \text{ (see fig. 118)}$$

$$k = 35 \text{ (see fig. 117)}$$

Topographic factors

Area of drainage basin $A = 350 \text{ sq. miles} = 224,000 \text{ acres}$

Length of principal channel $L = 300,000 \text{ ft.}$

$$W = \frac{43,560 \times A}{L} = \frac{43,560 \times 224,000}{300,000} = 32,600 \text{ ft.}$$

$$\frac{L}{W} = \frac{300,000}{32,600} = 9.20$$

$$P = 0.00007 \text{ (see fig. 119)}$$

* For references see "Low Dams" by the National Resources Committee of the U.S.A. Washington, D.C. 1938.

Channel Factors

Assume side slopes 2:1

$$n = 0.040$$

$$\frac{\text{Bottom width}}{\text{Average depth}} = \frac{350}{6.5} = 54$$

channel factor $F = 17$ (see fig. 122)Slope Factors

Difference in elevation between headwaters and

$$\text{bridge site } E = 700 - 265 = 435 \text{ ft.}$$

$$D = \frac{1000 \times E}{L} = \frac{435 \times 1000}{300,000} = 1.45$$

Slope factor $S = 0.030$ (see fig. 124)Watershed Factor

$$J = \frac{1}{0.00007 \times 17 \times 0.03} = 28.000$$

Run off Factor

$$C_{\max} = 0.70$$

$$\text{Frequency factor } T = 10; \quad \left(\frac{T}{100}\right)^x = (0.10)^{0.25} = 0.5623$$

$$\text{" " } T = 25; \quad \text{"} = (0.25)^{0.25} = 0.7071$$

$$\text{" " } T = 50; \quad \text{"} = (0.50)^{0.25} = 0.8409$$

$$\text{" " } T = 100; \quad \text{"} = (1.00)^{0.25} = 1.0000$$

$$C = C_{\max} \left(\frac{T}{100}\right)^x$$

$$T_{10} \text{ --- } C_{10} = 0.70 \times 0.5623 = 0.394$$

$$T_{25} \text{ --- } C_{25} = 0.70 \times 0.7071 = 0.495$$

$$T_{50} \text{ --- } C_{50} = 0.70 \times 0.8409 = 0.588$$

$$T_{100} \text{ --- } C_{100} = 0.70 \times 1.0000 = 0.700$$

$$AK = 224,000 \times 35 = 7,840,000$$

$$T_{10} \text{ --- } CAK = 0.394 \times AK = 3,090,000$$

$$T_{25} \text{ --- } CAK = 0.495 \times AK = 3,880,000$$

$$T_{50} \text{ --- } CAK = 0.588 \times AK = 4,600,000$$

$$T_{100} \text{ --- } CAK = 0.700 \times AK = 5,470,000$$

$$g = \frac{1}{4-0.83} = \frac{1}{3.17} = 0.315; \quad gx = 0.07875$$

$$4g = 1.26 \text{ --- } 4gx = 1.26 \times 0.25 = 0.315$$

$$10 \text{ year flood; } (CAK)^{1.26} = 154,000,000; \quad T4gx = 2.065$$

$$25 \text{ " " ; " " } = 199,600,000; \quad " = 2.754$$

$$50 \text{ " " ; " " } = 247,800,000; \quad " = 3.429$$

$$100 \text{ " " ; " " } = 308,900,000; \quad " = 4.266$$

$$\text{Maximum Flood Discharge } Q = \frac{(CAK)^{4g} T^{4gx}}{J}$$

$$10 \text{ year flood: } Q = \frac{154 \times 10^6 \times 2.065}{28,000} = 11,400 \text{ cfs}$$

$$25 \text{ " " : } Q = \frac{199.6 \times 10^6 \times 2.727}{28,000} = 19,600 \text{ cfs}$$

$$50 \text{ " " : } Q = \frac{247.8 \times 10^6 \times 3.427}{28,000} = 30,300 \text{ cfs}$$

$$100 \text{ " " : } Q = \frac{308.9 \times 10^6 \times 4.266}{28,000} = 47,000 \text{ cfs}$$

Concentration Time

$$t_c = \frac{1}{J^g (CAK)^{gT} gx}$$

$$\begin{aligned}
 10 \text{ year flood : } t_c &= \frac{(28,000)^{1.21}}{(3,090,000)^{0.315} \times (10)^{0.07875}} = 1811 \text{ min.} \\
 &= 30 \text{ hours } 11 \text{ min.}
 \end{aligned}$$

$$\begin{aligned}
 25 \text{ year flood : } t_c &= \frac{(28,000)^{1.21}}{(3,880,000)^{0.315} \times (25)^{0.07875}} = 1568 \text{ min.} \\
 &= 26 \text{ hours } 8 \text{ min.}
 \end{aligned}$$

$$\begin{aligned}
 50 \text{ year flood : } t_c &= \frac{(28,000)^{1.21}}{(4,600,000)^{0.315} \times (50)^{0.07875}} = 1408 \text{ min.} \\
 &= 23 \text{ hours } 28 \text{ min.}
 \end{aligned}$$

$$\begin{aligned}
 100 \text{ year flood: } t_c &= \frac{(28,000)^{1.21}}{(5,470,000)^{0.315} \times (100)^{0.07875}} = 1262 \text{ min.} \\
 &= 21 \text{ hours } 2 \text{ min.}
 \end{aligned}$$

2. Estimated Flow from Watershed Area and
Estimated Run off Coefficients for Humber River.

Rainfall Factors

$$e = 0.88 \text{ (see fig. 115); } \frac{1}{e} = 1.135$$

$$x = 0.24 \text{ (see fig. 118)}$$

$$k = 46 \text{ (see fig. 117)}$$

Topographic Factors

$$A = 226,600 \text{ acres}$$

$$L = 255,000 \text{ feet}$$

$$W = 43,560 \times \frac{226.6}{255.0} = 38,800$$

$$\frac{L}{W} = \frac{255,000}{38,800} = 6.6$$

$$P = 0.000045 \text{ (see fig. 119)}$$

Channel Factors

$$\text{Slope } 1:1$$

$$n = 0.04$$

$$\frac{\text{Bottom width}}{\text{Average width}} = \frac{300}{7.5} = 40$$

$$F = 19 \text{ (see fig. 122)}$$

Slope Factors

$$E = 1000 \text{ ft.}$$

$$D = \frac{1000}{255} = 3.90 \text{ ft. per thousand}$$

$$S = 0.034 \text{ (see fig. 124)}$$

Watershed Factor

$$J = \frac{1}{0.000045 \times 19 \times 0.034} = 34,400$$

Run off Factor

$$C_{\max} = 0.7$$

$$\text{Frequency factor } T = 10 ; \left(\frac{T}{100} \right)^x = (0.10)^{0.24} = 0.575$$

$$\text{" " } T = 25 ; \text{" " } = (0.25)^{0.24} = 0.717$$

$$\text{" " } T = 50 ; \text{" " } = (0.50)^{0.24} = 0.847$$

$$\text{" " } T = 100 ; \text{" " } = (1.00)^{0.24} = 1.000$$

$$AK = 226,600 \times 46 = 10,400,000$$

$$T_{10} \text{ --- } CAK = 0.40 \times AK = 4,150,000$$

$$T_{25} \text{ --- } CAK = 0.51 \times AK = 5,300,000$$

$$T_{50} \text{ --- } CAK = 0.59 \times AK = 6,130,000$$

$$T_{100} \text{ --- } CAK = 0.70 \times AK = 7,270,000$$

$$g = \frac{1}{4-0.88} = \frac{1}{3.12} = 0.32 ; \quad 4g = 1.28$$

$$4gx = 1.28 \times 0.24 = 0.308 ; \quad gx = 0.0752$$

$$10 \text{ year flood } (CAK)^{1.28} = (4,150,000)^{1.28} = 295,900,000$$

$$25 \text{ " " " " } = (5,300,000)^{1.28} = 404,700,000$$

$$50 \text{ " " " " } = (6,130,000)^{1.28} = 487,500,000$$

$$100 \text{ " " " " } = (7,270,000)^{1.28} = 606,400,000$$

$$(T_{10})^{0.308} = 2.033$$

$$(T_{25})^{0.308} = 2.695$$

$$(T_{50})^{0.308} = 3.337$$

$$(T_{100})^{0.308} = 4.131$$

Max. Flood Discharge

$$10 \text{ year flood} \quad Q = \frac{295.9 \times 10^6 \times 2.033}{34,400} = 17,487 \text{ cfs}$$

$$25 \quad " \quad " \quad Q = \frac{404.7 \times 10^6 \times 2.695}{34,400} = 31,705 \text{ cfs}$$

$$50 \quad " \quad " \quad Q = \frac{487.5 \times 10^6 \times 3.337}{34,400} = 47,287 \text{ cfs}$$

$$100 \quad " \quad " \quad Q = \frac{606.4 \times 10^6 \times 4.131}{34,400} = 72,822 \text{ cfs}$$

Concentration Time

$$t_c = \frac{J^{\frac{1}{E}}}{(CAK)^E T^{E_x}}$$

$$10 \text{ year flood: } t_c = \frac{(34,400)^{1.135}}{(4,150,000)^{0.32} \times (10)^{0.077}} = 902 \text{ min.}$$

$$= 15 \text{ hours } 2 \text{ min.}$$

$$25 \quad " \quad " : t_c = \frac{(34,400)^{1.135}}{(5,300,000)^{0.32} \times (25)^{0.077}} = 778 \text{ min.}$$

$$= 12 \text{ hours } 58 \text{ min.}$$

$$50 \text{ year flood: } t_c = \frac{(34,400)^{1.135}}{(6,130,000)^{0.32} \times (50)^{0.077}} = 703 \text{ min.}$$

$$= 11 \text{ hours } - 43 \text{ min.}$$

$$100 \text{ " " : } t_c = \frac{(34,400)^{1.135}}{(7,270,000)^{0.32} \times (100)^{0.077}} = 631 \text{ min.}$$

$$= 10 \text{ hours } 31 \text{ min.}$$

3. Estimated Flow of Salmon River at Bridge Site Using Manning's Formula.

The slope of Salmon River is determined from topographic maps, as shown in fig. 1, to be $S = 7.5 \times 10^{-4}$.

The roughness coefficient of the riverbed is estimated to be 0.04. Since the cross section of the channel is irregular the area is divided into five sections as shown in fig. 2. The limiting water level has been taken as El 268.50 or to the underside of the bottom flange of main girders at its lowest point.

$$\begin{aligned}\text{Manning's formula: } V &= \frac{1.486}{n} R^{2/3} S^{1/2} \\ &= C \sqrt{RS} \\ C^* &= \frac{1.486}{n} R^{1/6}\end{aligned}$$

$$S = \text{Slope} = 7.5 \times 10^{-4}$$

$$N = \text{Roughness Coefficient} = 0.04$$

$$A = \text{Cross-Sectional Area}$$

$$P = \text{Wetted Perimeter}$$

$$R = \text{Hydraulic Radius} = \frac{A}{P}$$

$$C = \text{Flow Factor}$$

$$V = \text{Velocity}$$

$$Q = \text{Discharge}$$

* See Table, Page 274 "Hydraulics" by G. E. Russell, N.York 1942

TABLE : FLOW PROPERTIES OF SALMON RIVER AT BRIDGE SITE

| SECTION | A in sq. ft. | P in ft. | R in ft. | C | V in ft/sec | Q in cfs |
|---------|--------------------|-------------|-------------|-------|-------------------|-------------|
| 1 | 338 | 82.0 | 4.35 | 48.00 | 2.74 | 926 |
| 2 | 790 | 75.4 | 10.50 | 55.25 | 4.90 | 3850 |
| 3 | 1375 | 111.0 | 12.40 | 56.40 | 5.44 | 7470 |
| 4 | 790 | 75.4 | 10.50 | 55.25 | 4.90 | 3850 |
| 5 | 638 | 83.5 | 7.65 | 52.48 | 4.00 | 2545 |

TOTAL Q = 18,641

4. Estimated Flow of Salmon River at the C. N. R. Bridge
Using Manning's Formula.

The average slope of the Salmon River at this bridge site is considered to be $S = 7.5 \times 10^{-4}$.

The cross section of the channel at the bridge site is divided into four sections as shown in fig. 3. The limiting water level has been taken at El 265.50

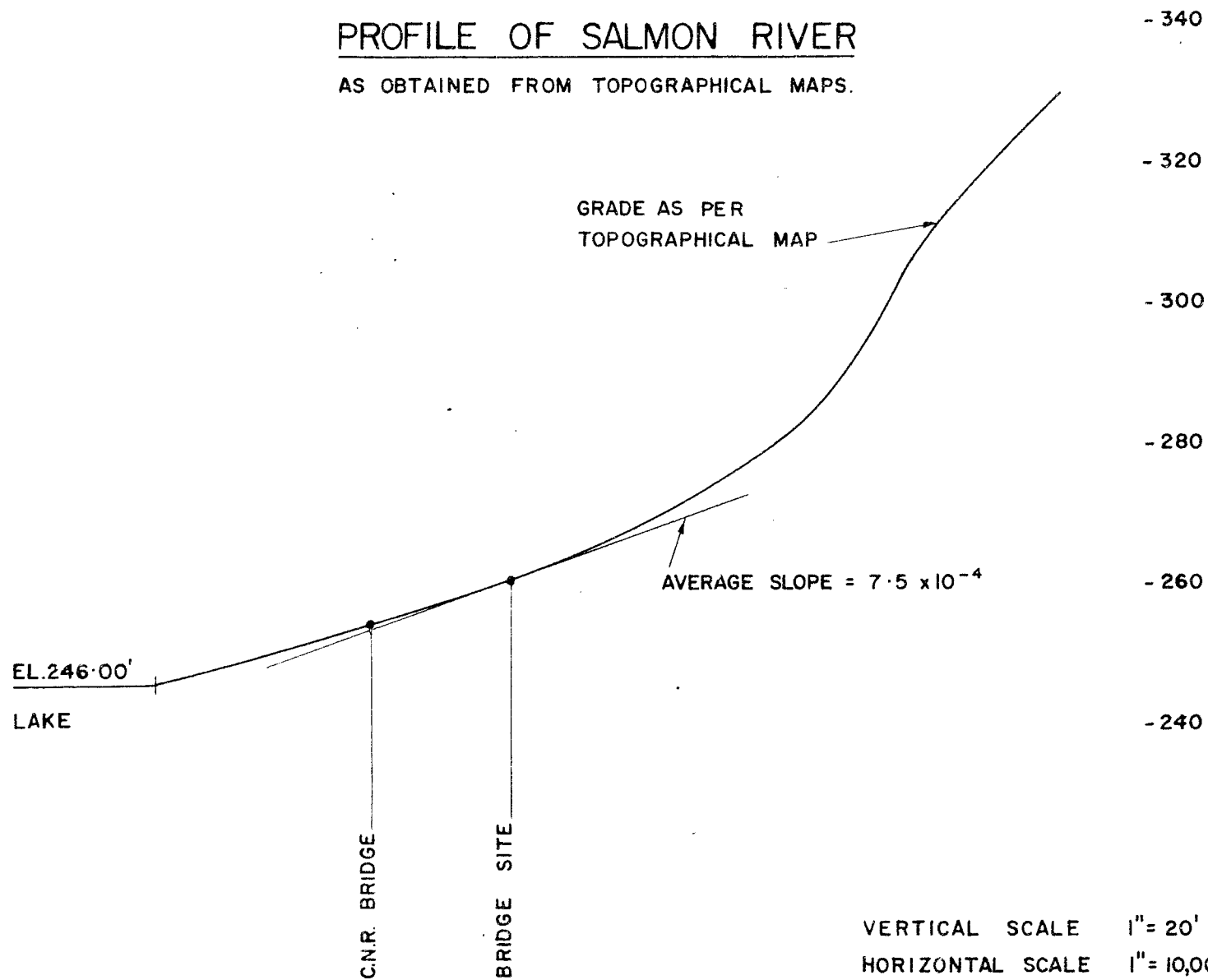
TABLE : FLOW PROPERTIES OF SALMON RIVER AT C.N.R. CROSSING

| SECTION | A in sq. ft. | P in ft. | R in ft. | C | V in ft/sec | Q in cfs |
|---------|--------------------|-------------|-------------|-------|-------------------|-------------|
| 1 | 795 | 59.9 | 13.30 | 57.30 | 5.72 | 4560 |
| 2 | 883 | 50.0 | 17.70 | 59.85 | 7.00 | 6200 |
| 3 | 671 | 48.0 | 14.00 | 58.00 | 5.98 | 4020 |
| 4 | 480 | 55.5 | 8.65 | 53.65 | 4.34 | 2080 |

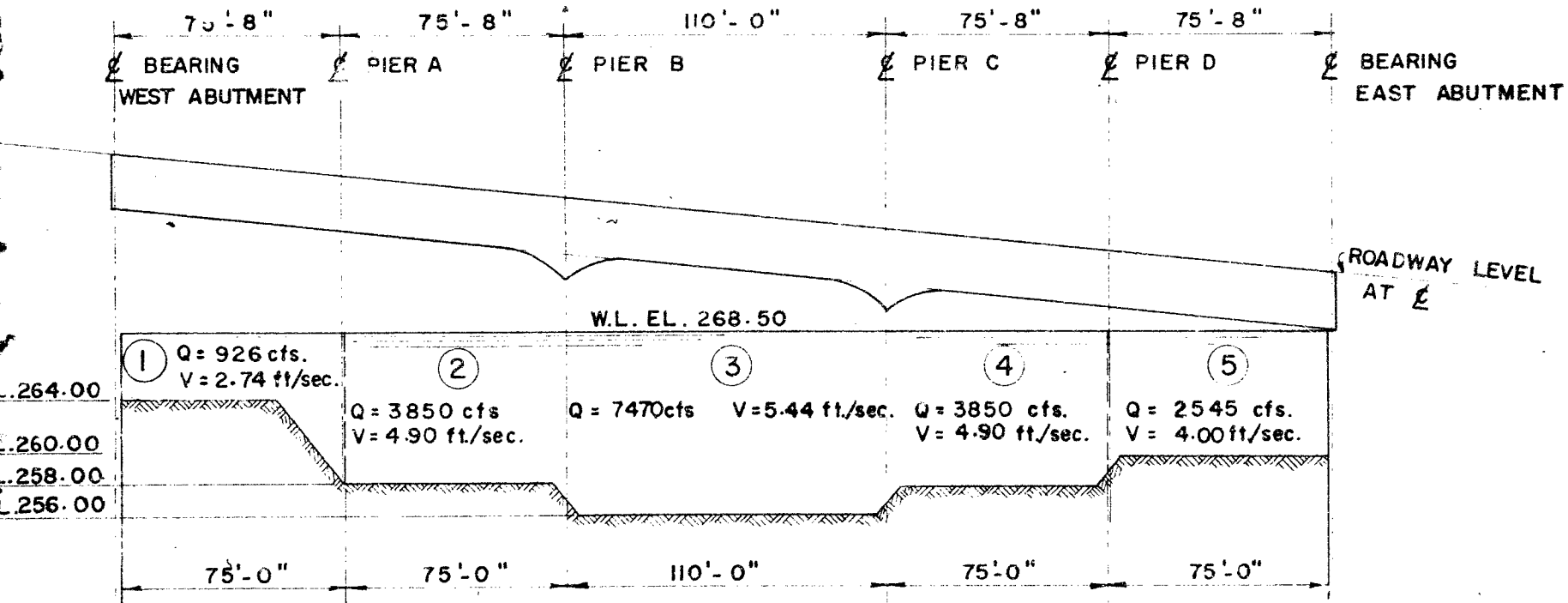
TOTAL Q = 16,860

PROFILE OF SALMON RIVER

AS OBTAINED FROM TOPOGRAPHICAL MAPS.



TOTAL Q = 18,641 cfs



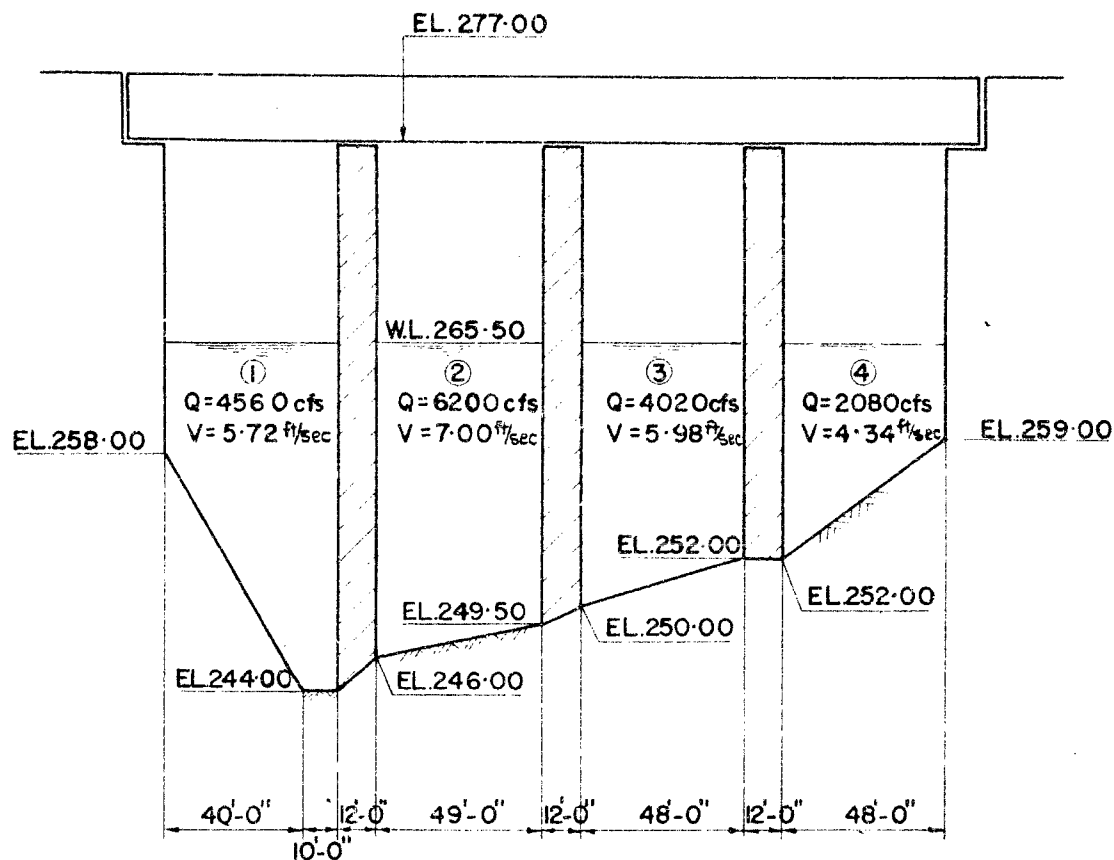
DIAGRAMMATIC SECTION.

SHOWING FLOW PROPERTIES OF SALMON RIVER AT BRIDGE SITE

SCALES: VERTICAL 1"=10'-0"

HORIZONTAL 1"=50'-0"

TOTAL Q = 16,860 cfs



DIAGRAMMATIC SECTION

SHOWING FLOW PROPERTIES OF SALMON RIVER AT C.N.R. CROSSING.

APPENDIX "C" SALMON RIVER COMPARISON OF COSTS



EMBANKMENT WITH SAND DRAINS



" WITHOUT " "



BRIDGE

A



450' @ \$ 425
\$ 191,250



360' @ \$ 900
\$ 324,000

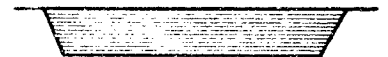
= \$ 515,250

B



37' @ \$ 480
\$ 17,360

413' @ \$ 1000
\$ 413,000



360' @ \$ 150
\$ 54,000

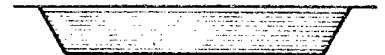
= \$ 484,360

C



90' @ \$ 450
\$ 40,500

360' @ \$ 1100
\$ 396,000



360' @ \$ 150
\$ 54,000

= \$ 490,500

RACEY, MACCALLUM AND ASSOCIATES LIMITED

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REPORT NO.
S-500-501/55/T-66-1

Toronto, Ontario,
May 16th, 1955.
(Dictated May 14th)

Ontario Department of Highways,
c/o Lazarides, Lount and Partners,
79 Scollard Street,
TORONTO, Ontario.

RE: FOUNDATION INVESTIGATION -
TYENDINAGA BRIDGE NO. 5
CROSSING THE SALMON RIVER

Dear Sirs:

The soil investigations for the proposed Tyendinaga Bridge No. 5 crossing the Salmon River are now at a stage that requires a summary report on our findings before the final decision on the location of abutments, piers and approaches can be taken. We, therefore, wish to report as follows.

LOCATION OF THE SITE AND OF THE BOREHOLES:

The proposed bridge site is located about 12 miles E.N.E. of the Town of Belleville, Ontario, and 0.6 miles N. of Highway No. 2. where the Salmon River locally forms two arms, thus creating a little island, 400' by 500' across (see topographical sketch plan, enclosure No. 1).

The location of the boreholes and soundings is marked on a sketch attached to this report as enclosure No. 1. The boreholes were spotted by our engineer in the field as shown on sketches handed over to us by the client successively as the field work proceeded.

REPORT NO. S-500-501/55/T-66-1 Cont'd

THE DRILLING WORK:

The performance of this work was influenced by most inconvenient weather conditions and had to be discontinued several times. The drilling equipment, consisting of a Longyear Straitline Diamond drill and since April 6th, 1955, a lighter Boyles Bros. drill type for drilling from a raft, completely equipped with the required tools for sampling and driving of 3" extra heavy duty steel pipe, was moved to the site for the first time on February 28th, 1955. Until March 16th the drilling of boreholes Nos. 6, 8, 9, 12 and 3 was completed. Until March 10th the river was still frozen, though the ice cover was already unreliable. Breaking up of the ice and flooding of the site started on March 10th, when the weather conditions turned definitely to the changeover to spring. Ice floats and floods promised to prohibit the continuation of the investigations for some time. The equipment was moved to a farm-yard near the western embankment for later resumption of the work.

As the client was seriously delayed with the design work due to the impossibility to resume the drilling work, the proposal was made to determine the depth of bedrock by probing with a sounding bar. This work was prepared and carried out from March 24th to 28th. The sounding procedure was supplemented by jetting down to rock with open drill rods and water pressure as the depth to rock proved to be deeper than expected. Weather conditions were very unfavourable during these days. Heavy snowfall and the rising water level did not permit to complete the anticipated sounding programme. However, valuable further data were obtained.

EXPORT NO. S-500-501/55/T-66-1 Cont'd

THE DRILLING WORK Cont'd

Finally, it was decided to enforce a certain completion of the investigation in order to determine the soil conditions below the river bed. A raft was built from April 3rd to 5th and floated into position for borehole No. 12, under difficult flood conditions and against fairly strong current. This procedure was completed on April 7th. Drilling was carried out on the raft for boreholes Nos. 12, 13 and 14 from April 11th until April 22nd. From April 22nd until April 24th the drilling on borehole No. 15 located on the centre line on the western embankment was done and the equipment subsequently moved from the site. Further drilling work has been postponed until the final decision regarding the location of the abutments and piers will be taken.

With the exception of borehole No. 6, where sampling was done with the 2" split spoon sampler every 2.5 feet to 25 feet depth and every 5 feet thereafter, soil samples were generally taken at 5 foot intervals. When refusal on rock was met, core drilling was carried 10 feet into rock. Solely in borehole No. 9 only 5 feet of core were drilled this being considered satisfactory for this hole.

The drilling equipment subsequently was returned to Toronto for use on other projects.

The soil and rock samples will be kept for reference purposes in our storage room for six months from now and will be destroyed thereafter if no other instructions are received.

LABORATORY WORK:

Laboratory tests for identification purposes, such as the determination of Atterberg limits and water contents were carried out on samples of boreholes Nos. 6 and 12.

Consolidation tests on three representative undisturbed samples of borehole No. 12 were carried out to obtain data of the possible settlement

REPORT NO. S-500-501/55/T-66-1 Cont'dLABORATORY WORK: Cont'd

in the river bed deposits when loaded with fill. These tests which take considerable time had been completed only a short time before this report was given, and our computations are based on data received from the laboratory prior to the final test report.

DISCUSSION OF THE RESULTS:

The soil profiles as revealed by the borings are shown on the attached Engineering Data Sheets. These data sheets, furthermore, give penetration diagrams plotted from the number of blows per foot of penetration of the standard 2" split spoon sampler (solid line in diagram) driven by a 350 lb. hammer with 12 inches drop. The penetration of the drive pipe is also entered (dotted line) for correlation purposes. Atterberg test results and water contents are shown additionally.

A topmost soil layer consisting of loose muddy silt and sand with plenty of organic matter, shells, etc., covers to a depth of about 7' the underlying strata on the eastern, frequently flooded, swampy embankment in all boreholes, with the exception of boreholes Nos. 9 and 14 where the loose soil extends to ten and seven feet depth respectively. In borehole No. 15 on the western embankment only 3 feet of this type of soil occurred. Similarly composed loose soil was met in the riverbed: about 3.5 feet in the centre of the river in borehole No. 12, and 4.5 feet in the centre of the river in borehole No. 13. This soil is a very recent river deposit and subject to change in thickness and composition with varying velocity of the water flow.

Post glacial marine clay deposits form the main volume of the soils body underneath the described surface layer. The clay was encountered in all but the shallow boreholes Nos. 1, 3, 7 and 8. As revealed by our consolidation tests these clays are preconsolidated and once filled the whole valley apparently to approximately 252' + 75' or roughly 325' (M.S.L.). (See contour

REPORT NO. S-500-501/55/T-66-1 Cont'dDISCUSSION OF RESULTS Cont'd

line 325 on topographical sketch plan, enclosure No. 1). The clay soils agriculturally utilised on the farmfields, therefore, are considered to be representatives of the former valley fill. It appears to us that this is in fairly good accordance with the observation of the exposed rock on the plateau where dairy farming is practised while the farm fields do not exceed the above given elevation.

The clay, encountered in the boreholes, is stiff and medium and of medium to high plasticity, down to approximately El. 235. Below this elevation soft silt clay of low plasticity and pure fine to medium silt layers occur with water contents above the liquid limit.

The consolidation tests carried out on three samples from borehole No. 12 taken from 17' to 18' (El. 245) from 25' to 26' (El. 237) and from 35' to 36' (El. 227) show preconsolidation of the clay (including the present overburden) of 2.6 t/sq. ft., 2.7t/sq. ft. and 2.85 t/sq. ft. respectively.

The clay strata contain gravel only in boreholes Nos. 9 (El. 243 to El. 237), and 13 (El. 225 to 215), these layers are underlain by bedrock.

Bedrock consists of solid limestone, generally of grey colour, some beds of argillaceous limestone being dark grey. The thickness of the beds amounts to only several inches. Bedding appears to be fairly horizontal. Borehole No. 15 shows lower resistance, than observed in the other boreholes, for the upper 4 feet of bedrock. It was noticed in the field that some softer beds occurred in the harder strata. No indication of a fault was observed in the rock.

REPORT NO. S-500-501/55/T-66-1 Cont'dDISCUSSION OF RESULTS Cont'd

The shape of the cross-profile of the valley is asymmetric. This applies even to a farther reaching extent to the cross-profile of the rock surface of the valley which is shown by contour lines on enclosure No. 2. The lowest elevation of the rock surface was encountered in borehole No. 12 at El. 211.5. Borehole No. 6 reveals bedrock at 214.5. The slope of rock on the southeast side of the valley appears to be 8° to 9° . On the northwest side of the valley the slope is of the order of 20° to 25° . The flat zone in the rock cross-section between the contour lines 220, measured along the centre line of the proposed highway, is 300 feet wide. The contour lines show a fairly good parallelity between both sides of the valley, the average angle between the contour lines and the centre line of the proposed highway is about 40° .

CONCLUSIONS FOR THE PROPOSED STRUCTURE:

The abutments and piers of any proposal for the subject bridge project will have to be carried by piles driven to bedrock. The overlying clay strata, though preconsolidated, would settle non-uniformly if subjected to foundation loads.

The elevation of the surface of bedrock as shown on enclosure No. 2 will be sufficiently accurate for design purposes. Once the location of the foundation structures will be determined, it may be advisable to obtain pertinent rock elevation data by soundings. A raft, however, may be needed if soundings in the riverbed are required.

The design of the approaches raises the question of the approximate settlement of the clay strata if loaded with fill. The results of the consolidation tests on the above-mentioned three clay samples (enclosure No. 3) permit a computation of the total settlement which may occur if the clay in borehole No. 12 would be loaded with 28' of rock or granular fill, 3' of which would be submerged in water below the water level

REPORT NO. 3-500-501/55/T-66-1 Cont'dCONCLUSIONS FOR THE PROPOSED STRUCTURE Cont'd

of the river. The computation is based on the final settlement of the approximately $3/8$ " thick specimens of 1.9" diameter in the laboratory which occurred for the same load increment that would be produced by adding the load of the fill to the present overburden of the samples in the ground.

A total settlement of 13" was found for borehole No. 12 (see enclosure No. 2, figures shown in squares). The values given for the other boreholes were estimated from the appearance of the log and the respective thickness of the clay layers in correlation with borehole No. 12.

As the amount of settlement depends on the physical properties of the strata and their thickness, the local settlement values decrease as we approach the banks of the solid rock bed of the clay.

The time-settlement relationship being of considerable interest for the judgment of the permissible settlement of the earth structures, another computation was made utilising the coefficients of consolidation of the specimens for the pertinent load interval (enclosure No. 3). On enclosure No. 4 the application of the load and the obtained degree of consolidation expressed in percent. The amount of settlement reached after a certain time can easily be determined as a percentage of the approximate total settlement. Fifty percent settlement, or 6.5" at borehole No. 12, would be reached in about 15 years accordingly.

The settlement will be non-uniform in the direction of the centre line of the highway and as well across the roadway, this applying especially to the banks of the existing river, where the thickness of the consolidating layers decreases rapidly in a direction deviating 40° from the centre line.

A considerable acceleration of the settlement can be achieved by installation of vertical sand drains. If their spacing will be chosen to be 10 feet and their diameter be 2 feet or 1 foot, the dashed curves in enclosure No. 4 show that the settlement may be practically terminated after

REPORT NO. S-500-501/55/T-66-1 Cont'dCONCLUSIONS FOR THE PROPOSED STRUCTURE Cont'd

one month. Whether driving of sand drains is preferable will be mainly depending on economical considerations. Inquiries we have made on the cost of sand piles permit us to give the following information. The site must be made accessible by roads for the transportation of heavy pile driving equipment. The area to be drained, which is located in the river bed, is to be filled well above the water table with such granular fill material that the sand-drain rig can travel over it and that the mandrel can penetrate it easily. This fill, at the same time, serves the purpose of keeping the top ends of the sand drains open for drainage at all times. For the same reason the area to be drained off the river has to be covered with an adequate layer of granular fill, i.e. of 1.5 to 2 foot thickness.

The price for 2 foot diameter sand drains practically only differs from one foot diameter sand drains by the cost of the additional quantity of sand needed. The price per linear foot of sand-drain will be of the order of \$1.50 if a large area, e.g., the subsoil of the complete river bed were to be drained. For smaller areas, e.g., approaches on both banks of the river the price per linear foot may be as high as \$2.00. Dumping of granular fill as required above is considered part of the general earth structure and is not included in the price for the sand drains.

We trust that this information is satisfactory and shall be pleased to clarify matters further if you so desire.

Yours very truly,

RACEY, MACCALLUM AND ASSOCIATES LIMITED



KT/PW

K. Tubbesing, P. Eng.

Original and

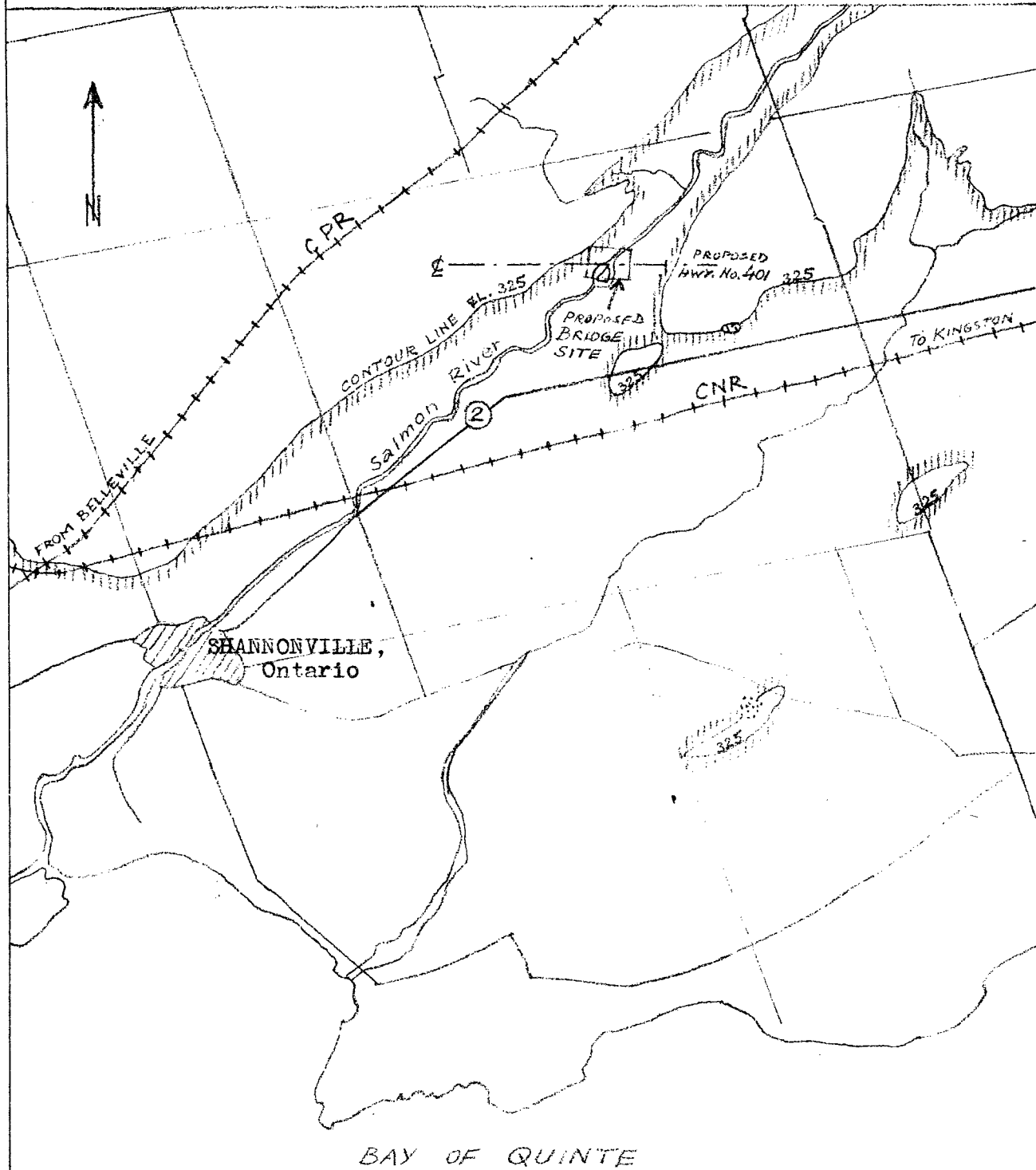
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2 - Mr. K. Tubbesing

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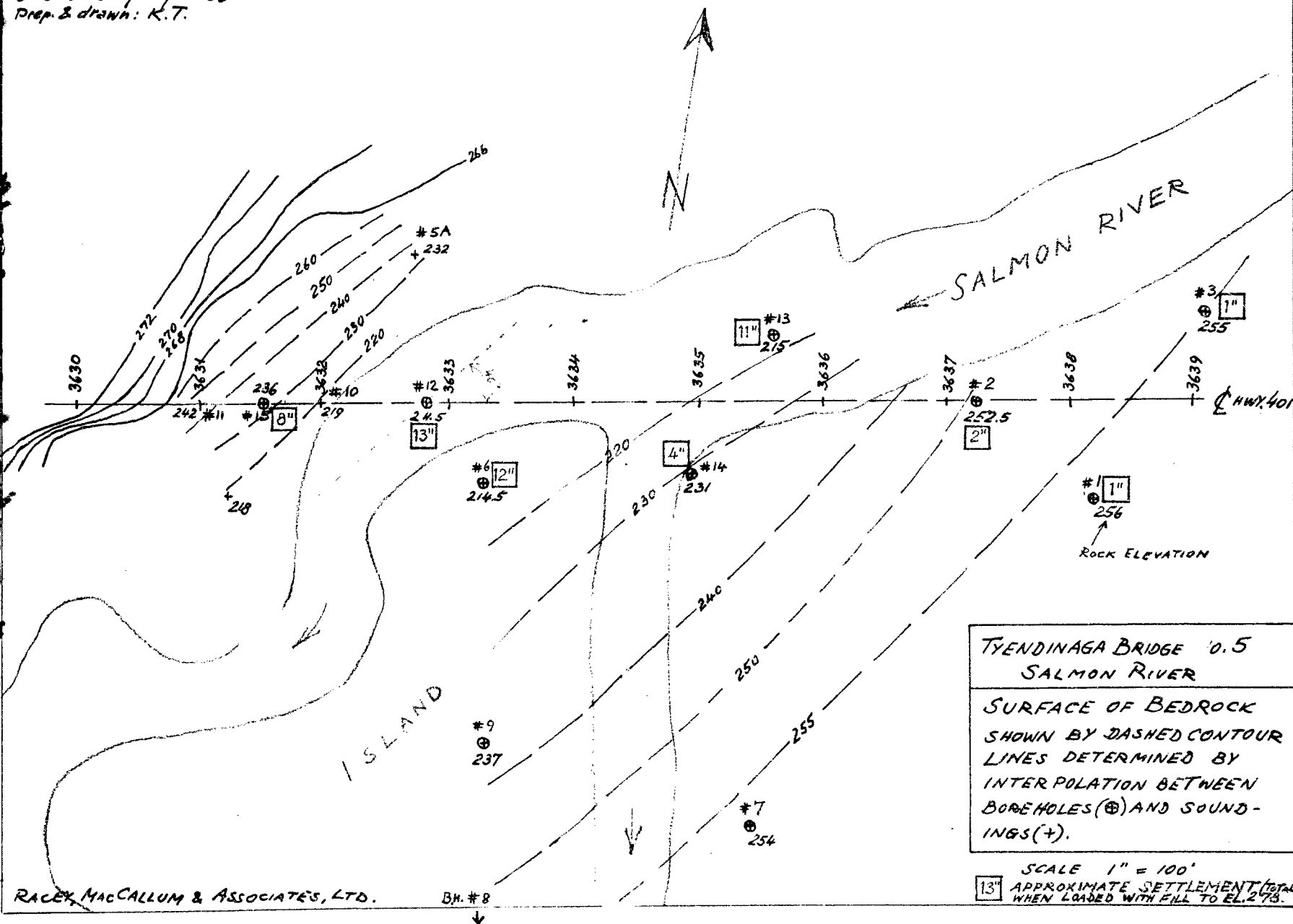
Order No. S-500-501/55/T-66

Tyendinaga Township Bridge No. 5
Location of the Site at Crossing
of Proposed Highway No. 401 over
the Salmon River

SCALE 1 : 50,000



S-500-501/55/T-66
 Prep. & drawn: K.T.



TYENDINAGA BRIDGE 0.5
 SALMON RIVER

SURFACE OF BEDROCK
 SHOWN BY DASHED CONTOUR
 LINES DETERMINED BY
 INTERPOLATION BETWEEN
 BOREHOLES (⊕) AND SOUND-
 INGS (+).

SCALE 1" = 100'
 13" APPROXIMATE SETTLEMENT (TOTAL)
 WHEN LOADED WITH FILL TO EL. 273.

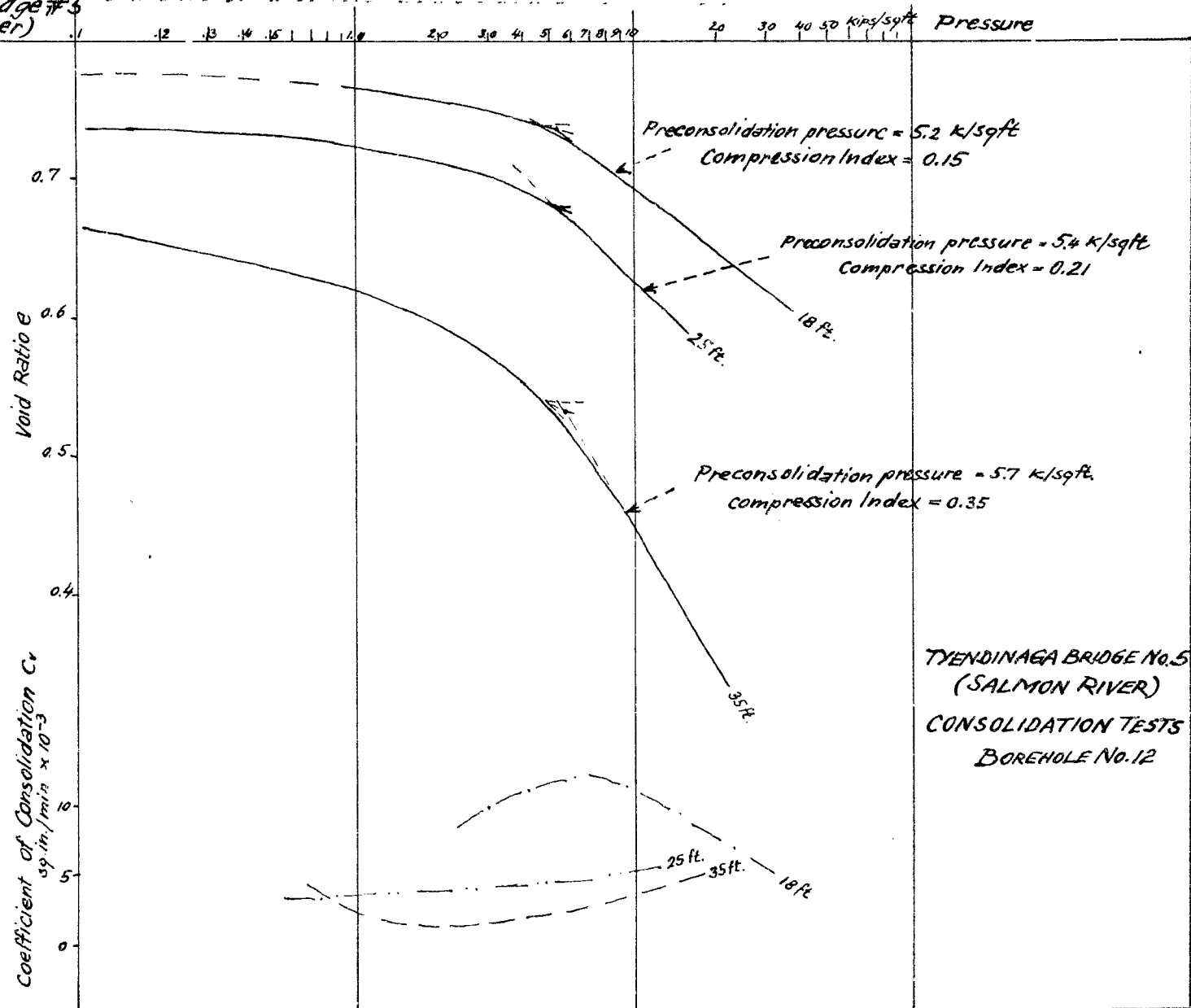
ENCLOSURE NO. 2

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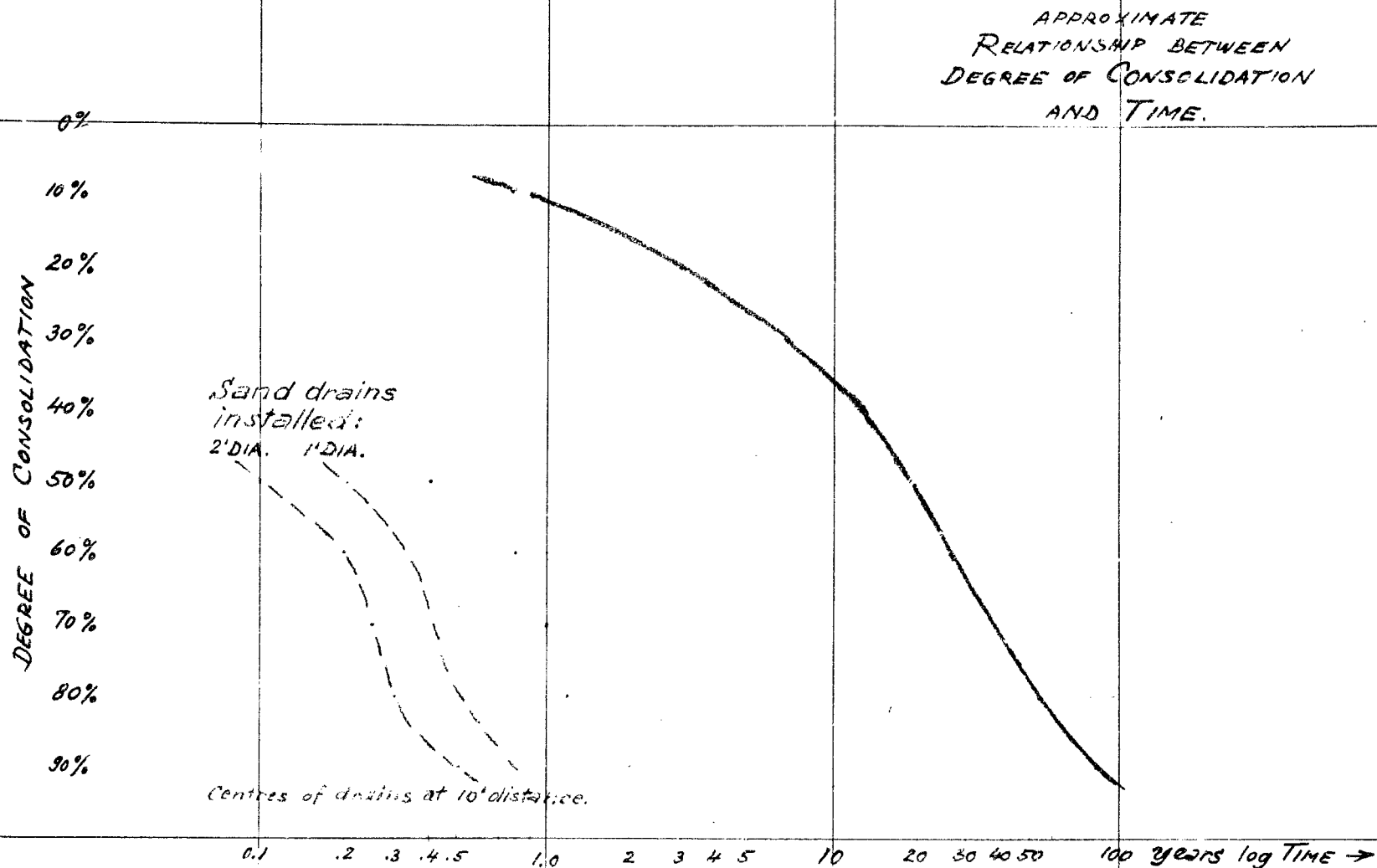
B.M. #8

S-500-501/55/T-66

Tyendinaga Bridge #5
(Salmon River)



S-500 01/55/T-55
PREP & DRAWN: K.T.



RACEY, MACCALLUM & ASSOCIATES, LTD.

TYNDINAGA BRIDGE No. 5
SALMON RIVER

ENCLOSURE No. 4

Geological Survey S-500-501/55/T-66

10/4/55

10/13/55

11/10/55

F. LUSK

Printer

W. LINTON

Editor

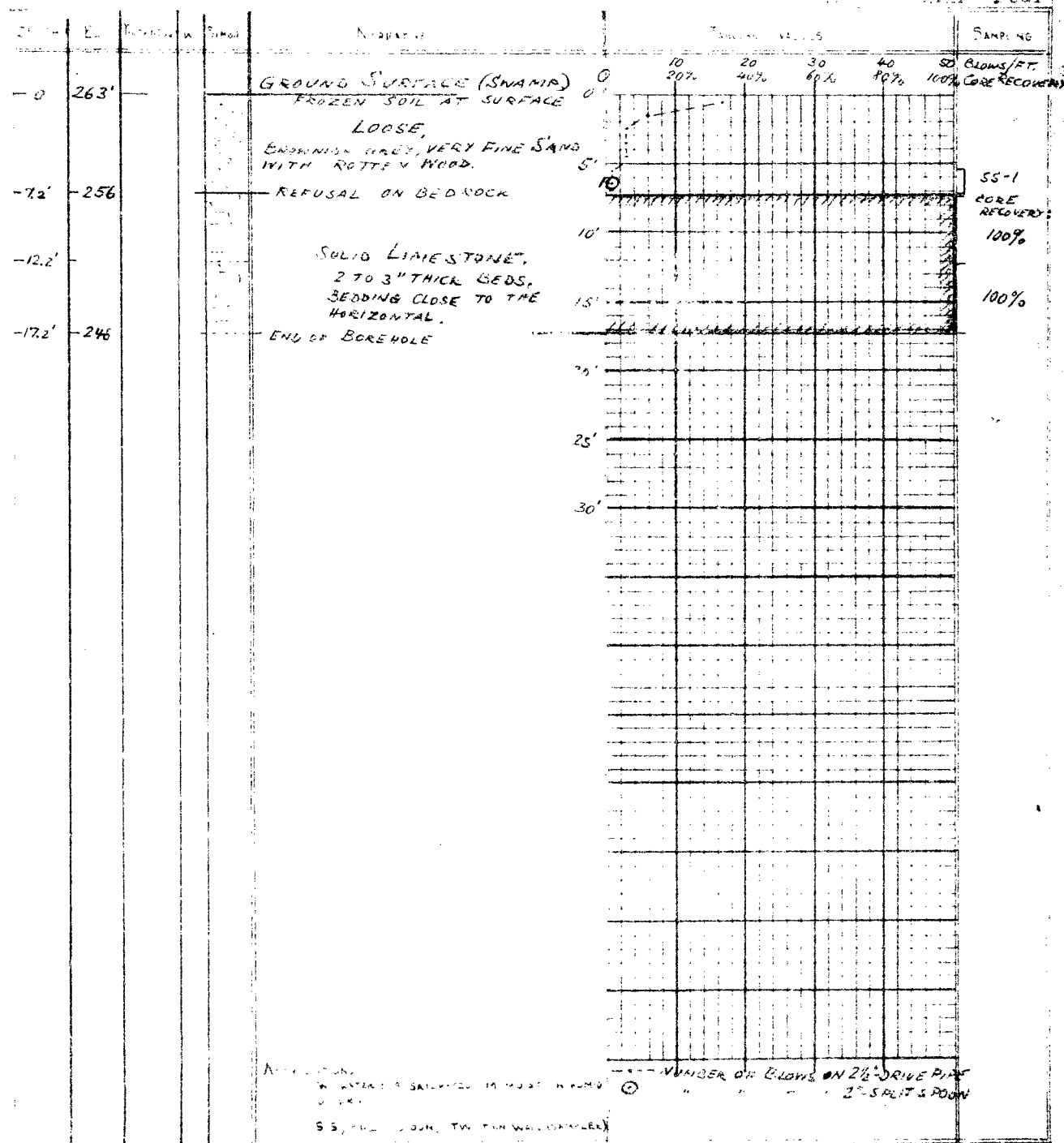
TYENDINAGATWP. BRIDGE NO. 5 - SALMON RIVER

K. TUBESING

CROSSING SALMON RIVER, 12 MILES ENE. OF BELLEVILLE, ONT. AS SHOWN ON ATTACHED SKETCH PLAN

283' T.D. M.S.L.

23/3/55



① NUMBER OF BLOWS ON 2" SPLIT SPOON SAMPLE
" " " " 2 1/2" DRIVE PIPE

| DEPTH | EL | THICKNESS | W | SYMBOL | NARRATIVE | TANGULAR VALUES | SAMPLING |
|-------|-------|-----------|---|--------|---|--|------------------------------------|
| 0 | 262.5 | | | | GROUND SURFACE FROZEN SOIL | 10 20 30 40 50 20% 40% 60% 80% 100% | 50 BLOWS/FT. 100% CORE RECOVERY |
| 7.3' | 255 | | | | VERY LOOSE, BROWNISH SAND WITH SILT REFUSAL ON BEDROCK | | SS-1 CORE RECOVERY |
| 12.3' | | | | | SOLID LIMESTONE | | 100% |
| 17.3' | 245 | | | | END OF BOREHOLE | | 100% |

ABBREVIATIONS
 W WATER, S SATURATED, M MUD, H HUMID, D DRY
 5 3, 5 1/2, 6 1/2, 7 1/2, 8 1/2, 9 1/2, 10 1/2, 11 1/2, 12 1/2, 13 1/2, 14 1/2, 15 1/2, 16 1/2, 17 1/2, 18 1/2, 19 1/2, 20 1/2, 21 1/2, 22 1/2, 23 1/2, 24 1/2, 25 1/2, 26 1/2, 27 1/2, 28 1/2, 29 1/2, 30 1/2, 31 1/2, 32 1/2, 33 1/2, 34 1/2, 35 1/2, 36 1/2, 37 1/2, 38 1/2, 39 1/2, 40 1/2, 41 1/2, 42 1/2, 43 1/2, 44 1/2, 45 1/2, 46 1/2, 47 1/2, 48 1/2, 49 1/2, 50 1/2, 51 1/2, 52 1/2, 53 1/2, 54 1/2, 55 1/2, 56 1/2, 57 1/2, 58 1/2, 59 1/2, 60 1/2, 61 1/2, 62 1/2, 63 1/2, 64 1/2, 65 1/2, 66 1/2, 67 1/2, 68 1/2, 69 1/2, 70 1/2, 71 1/2, 72 1/2, 73 1/2, 74 1/2, 75 1/2, 76 1/2, 77 1/2, 78 1/2, 79 1/2, 80 1/2, 81 1/2, 82 1/2, 83 1/2, 84 1/2, 85 1/2, 86 1/2, 87 1/2, 88 1/2, 89 1/2, 90 1/2, 91 1/2, 92 1/2, 93 1/2, 94 1/2, 95 1/2, 96 1/2, 97 1/2, 98 1/2, 99 1/2, 100 1/2, 101 1/2, 102 1/2, 103 1/2, 104 1/2, 105 1/2, 106 1/2, 107 1/2, 108 1/2, 109 1/2, 110 1/2, 111 1/2, 112 1/2, 113 1/2, 114 1/2, 115 1/2, 116 1/2, 117 1/2, 118 1/2, 119 1/2, 120 1/2, 121 1/2, 122 1/2, 123 1/2, 124 1/2, 125 1/2, 126 1/2, 127 1/2, 128 1/2, 129 1/2, 130 1/2, 131 1/2, 132 1/2, 133 1/2, 134 1/2, 135 1/2, 136 1/2, 137 1/2, 138 1/2, 139 1/2, 140 1/2, 141 1/2, 142 1/2, 143 1/2, 144 1/2, 145 1/2, 146 1/2, 147 1/2, 148 1/2, 149 1/2, 150 1/2, 151 1/2, 152 1/2, 153 1/2, 154 1/2, 155 1/2, 156 1/2, 157 1/2, 158 1/2, 159 1/2, 160 1/2, 161 1/2, 162 1/2, 163 1/2, 164 1/2, 165 1/2, 166 1/2, 167 1/2, 168 1/2, 169 1/2, 170 1/2, 171 1/2, 172 1/2, 173 1/2, 174 1/2, 175 1/2, 176 1/2, 177 1/2, 178 1/2, 179 1/2, 180 1/2, 181 1/2, 182 1/2, 183 1/2, 184 1/2, 185 1/2, 186 1/2, 187 1/2, 188 1/2, 189 1/2, 190 1/2, 191 1/2, 192 1/2, 193 1/2, 194 1/2, 195 1/2, 196 1/2, 197 1/2, 198 1/2, 199 1/2, 200 1/2, 201 1/2, 202 1/2, 203 1/2, 204 1/2, 205 1/2, 206 1/2, 207 1/2, 208 1/2, 209 1/2, 210 1/2, 211 1/2, 212 1/2, 213 1/2, 214 1/2, 215 1/2, 216 1/2, 217 1/2, 218 1/2, 219 1/2, 220 1/2, 221 1/2, 222 1/2, 223 1/2, 224 1/2, 225 1/2, 226 1/2, 227 1/2, 228 1/2, 229 1/2, 230 1/2, 231 1/2, 232 1/2, 233 1/2, 234 1/2, 235 1/2, 236 1/2, 237 1/2, 238 1/2, 239 1/2, 240 1/2, 241 1/2, 242 1/2, 243 1/2, 244 1/2, 245 1/2, 246 1/2, 247 1/2, 248 1/2, 249 1/2, 250 1/2, 251 1/2, 252 1/2, 253 1/2, 254 1/2, 255 1/2, 256 1/2, 257 1/2, 258 1/2, 259 1/2, 260 1/2, 261 1/2, 262 1/2, 263 1/2, 264 1/2, 265 1/2, 266 1/2, 267 1/2, 268 1/2, 269 1/2, 270 1/2, 271 1/2, 272 1/2, 273 1/2, 274 1/2, 275 1/2, 276 1/2, 277 1/2, 278 1/2, 279 1/2, 280 1/2, 281 1/2, 282 1/2, 283 1/2, 284 1/2, 285 1/2, 286 1/2, 287 1/2, 288 1/2, 289 1/2, 290 1/2, 291 1/2, 292 1/2, 293 1/2, 294 1/2, 295 1/2, 296 1/2, 297 1/2, 298 1/2, 299 1/2, 300 1/2, 301 1/2, 302 1/2, 303 1/2, 304 1/2, 305 1/2, 306 1/2, 307 1/2, 308 1/2, 309 1/2, 310 1/2, 311 1/2, 312 1/2, 313 1/2, 314 1/2, 315 1/2, 316 1/2, 317 1/2, 318 1/2, 319 1/2, 320 1/2, 321 1/2, 322 1/2, 323 1/2, 324 1/2, 325 1/2, 326 1/2, 327 1/2, 328 1/2, 329 1/2, 330 1/2, 331 1/2, 332 1/2, 333 1/2, 334 1/2, 335 1/2, 336 1/2, 337 1/2, 338 1/2, 339 1/2, 340 1/2, 341 1/2, 342 1/2, 343 1/2, 344 1/2, 345 1/2, 346 1/2, 347 1/2, 348 1/2, 349 1/2, 350 1/2, 351 1/2, 352 1/2, 353 1/2, 354 1/2, 355 1/2, 356 1/2, 357 1/2, 358 1/2, 359 1/2, 360 1/2, 361 1/2, 362 1/2, 363 1/2, 364 1/2, 365 1/2, 366 1/2, 367 1/2, 368 1/2, 369 1/2, 370 1/2, 371 1/2, 372 1/2, 373 1/2, 374 1/2, 375 1/2, 376 1/2, 377 1/2, 378 1/2, 379 1/2, 380 1/2, 381 1/2, 382 1/2, 383 1/2, 384 1/2, 385 1/2, 386 1/2, 387 1/2, 388 1/2, 389 1/2, 390 1/2, 391 1/2, 392 1/2, 393 1/2, 394 1/2, 395 1/2, 396 1/2, 397 1/2, 398 1/2, 399 1/2, 400 1/2, 401 1/2, 402 1/2, 403 1/2, 404 1/2, 405 1/2, 406 1/2, 407 1/2, 408 1/2, 409 1/2, 410 1/2, 411 1/2, 412 1/2, 413 1/2, 414 1/2, 415 1/2, 416 1/2, 417 1/2, 418 1/2, 4

Order No.: S-500-501/55, T-60 RACEY, MacCALLUM AND ASSOCIATES

Dated 16/2/55

Limited

F. LUSK
Driller

Day Month Year

Foundation Engineering Division

Hole Begun 28/2/55

Hole Ended 4/3/55

Engineering Data Sheet for Borehole: 6

W. LINTON
Helper

Job Name: TYENDINAGA TWP. BRIDGE NO. 5 - SALMON RIVER

K. TUBBESING

Job Location: PROP. HWY. NO. 401 CROSSING SALMON RIVER, 1/2 MILES E.N.E. OF BELLEVILLE, ONT.

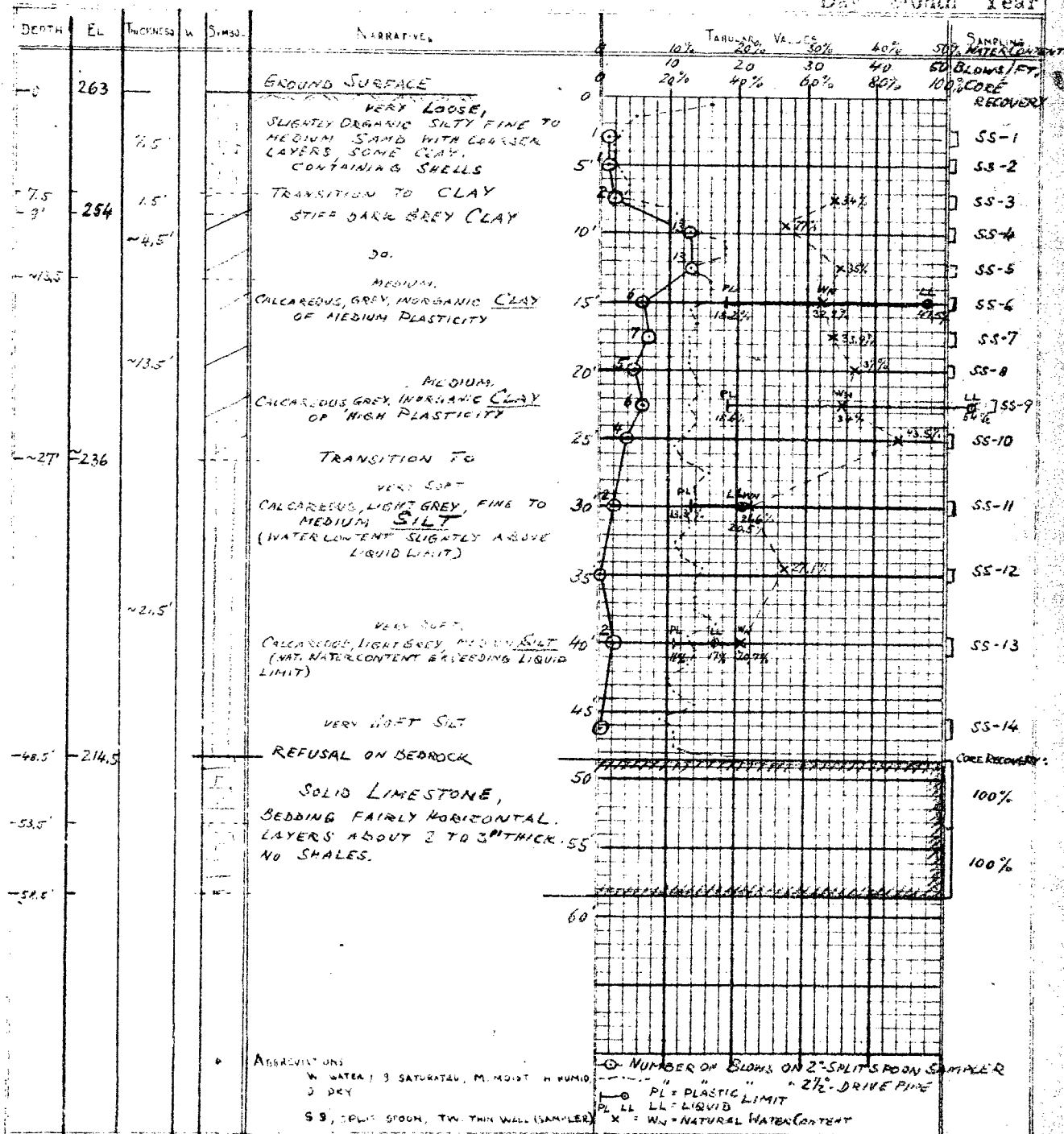
Checked by

Hole Location: AT NORTH END OF ISLAND IN SALMON RIVER; SEE ATTACHED SKETCH PLAN.

Hole Elevation: 263 Datum: M.S.L.

23/3/55

Day Month Year



F. Lusk

Dated 16/2/55

Limited

Driller

May North 22

Foundation Engineering Division

Hole No. 8/3/55

W. LINTON

Hold. Ended 8/3/55

Engineering Data Sheet for Porch: 7

Helper

300 1000: TYENDINGAGA TWP. BRIDGE NO. 5 - SALMON RIVER

K. TUBBESING

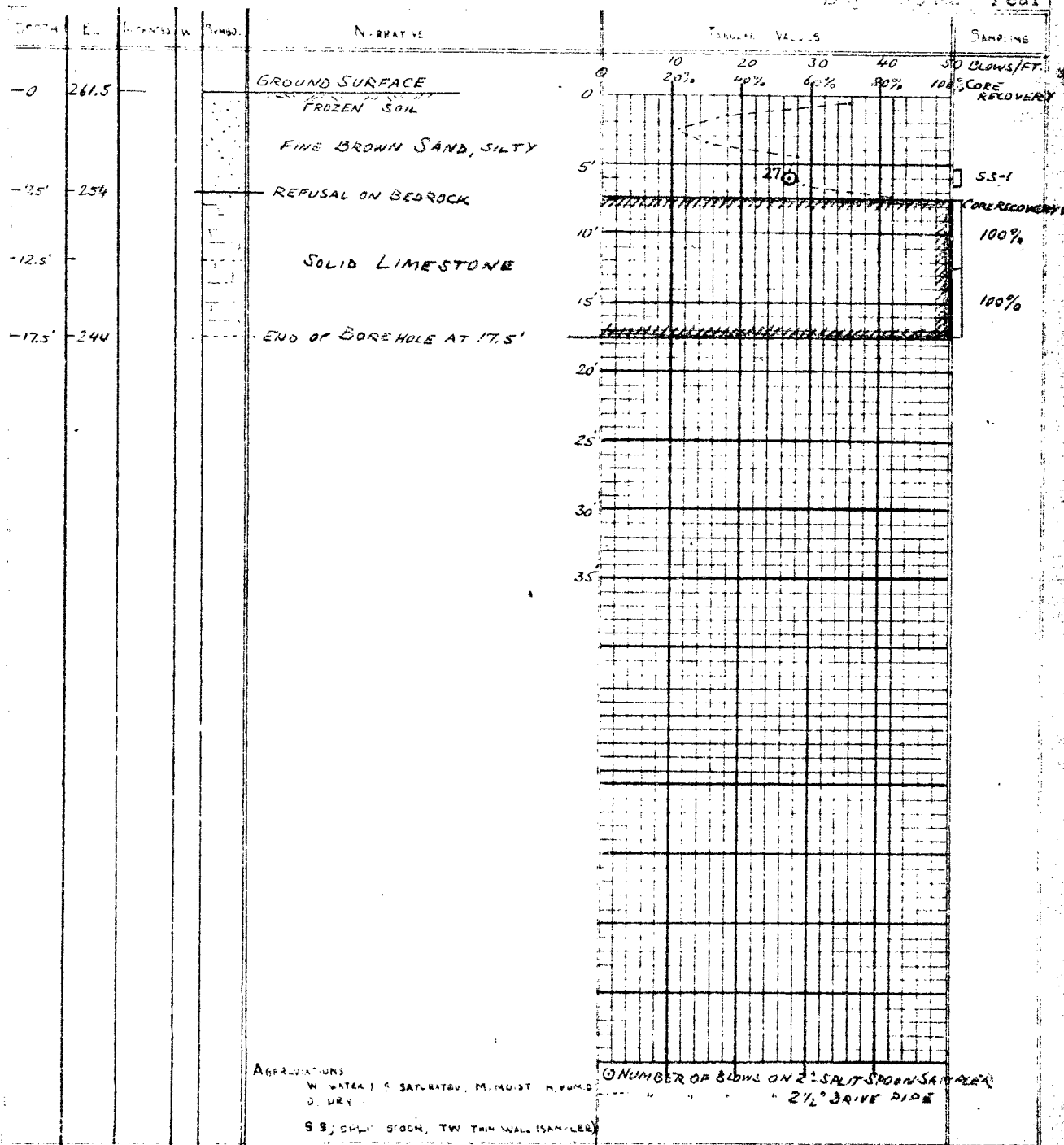
195 1-044-G: PROP. HWY. NO. 401 CROSSING SALMON RIVER; ~12 MILES E.N.E. OF BELLEVILLE, ONT. checked by

NEAR EDGE OF E. BRANCH OF RIVER, OPPOSITE ISLAND; SEE ATTACHED SKETCH PLAN

Re: Mr. Galt: 261.5 Datum: M.S.C.

23/3/55

Do Month Year



Order No. S-500-501/55/T-66 RACEY, MacCALLUM AND ASSOCIATES

Dated 16/2/55

Limited

F. Lusk

Driller

May 1955

Foundation Engineering Division

Bore Log No. 5/3/55

Bore Bored 5/3/55

Engineering Data Sheet for Borehole: 8

W. LINTON

Helper

Job Name: TYENDINAGA TWP. BRIDGE NO. 5 - SALMON RIVER

K. TUBBESING

Job Location: PROP HWY. NO. 401 CROSSING SALMON RIVER; ~12 MILES ENE. OF BELLEVILLE, ONT. Checked by

Bore Located: NEAR SCORNER OF ISLAND IN SALMON RIVER; STA. 3633+25, 490' SOUTHEAST WARD.

Bore Elevation: 262 Datum: M.S.L.

23/3/55

Day Month Year

| DEPTH | E.L. | THICKNESS | W. | SYMBOL | NARRATIVE | TARGET VALUES | SAMPLING |
|--------|------|-----------|----|--------|---|--|------------------------------------|
| | | | | | | 10 20 30 40 50 20% 40% 60% 80% 100% | 50 BLOWS/FT. 100% CORE RECOVERY |
| 0 | 262 | | | | GROUND SURFACE | | |
| | | | | | FROZEN GROUND | | |
| | | | | | VERY LOOSE, GREY FINE SAND WITH WOOD | | SS-1 |
| -7.8' | 254 | | | | REFUSAL ON BEDROCK | | CORE RECOVERY: |
| | | | | | SOLID LIMESTONE | | 100% |
| -12.8' | | | | | | | 100% |
| -17.8' | 244 | | | | END OF BOREHOLE AT 17.8' | | |

ABBREVIATIONS

W. WATER; S. SATURATED; M. MOIST; H. HUMID; D. DRY

SS, SPLIT SPOON, TW. THIN WALL SAMPLER

① NUMBER OF BLOWS ON SPLIT SPOON SAMPLER
DRIVE PIPE

Order No.: S-500-501/55/T-66 RACET, MacCALLUM AND ASSOCIATES

Dated 16/2/55

Limited

FLUSK

Driller

Day Month Year

Foundation Engineering Division

Hole Log No. 7/3/55

W. LINTON

Hole Ended 7/3/55

Engineering Data Sheet for Borehole: 9

Helper

Job Name: TENDINAGA BRIDGE NO. 5 - SALMON RIVER

K. TUBBESING

Job Located: PROP. HWY. NO. 401 CROSSING SALMON RIVER; ~12 MILES E.N.E. OF BELLEVILLE, ONT.

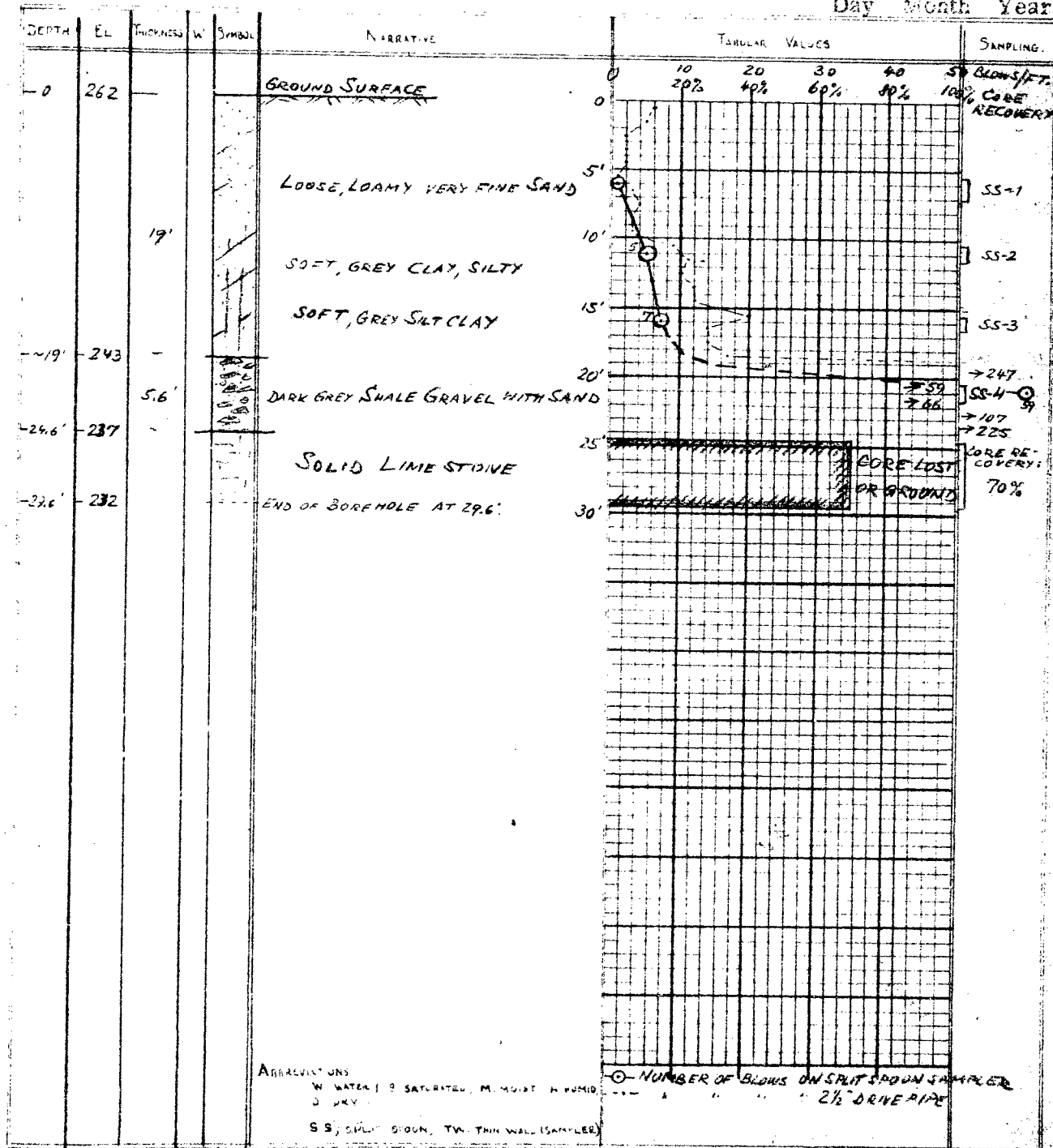
Checked by

Hole Located: BETWEEN BOREHOLES NOS. 6 AND 8; SEE ATTACHED SKETCH PLAN

Hole Elevation: 262 Datum:

23/3/55

Day Month Year



Order No. S-500-501/55/T-66 RACEY, MacCALLUM AND ASSOCIATESDated 16/2/55

Limited

A. McCADDEN

Driller

Day Month Year

Foundation Engineering Division

Bore Log No. 6/4/55

D. McCURDY

Bore Bored 16/4/55Engineering Data Sheet for Borehole: 12

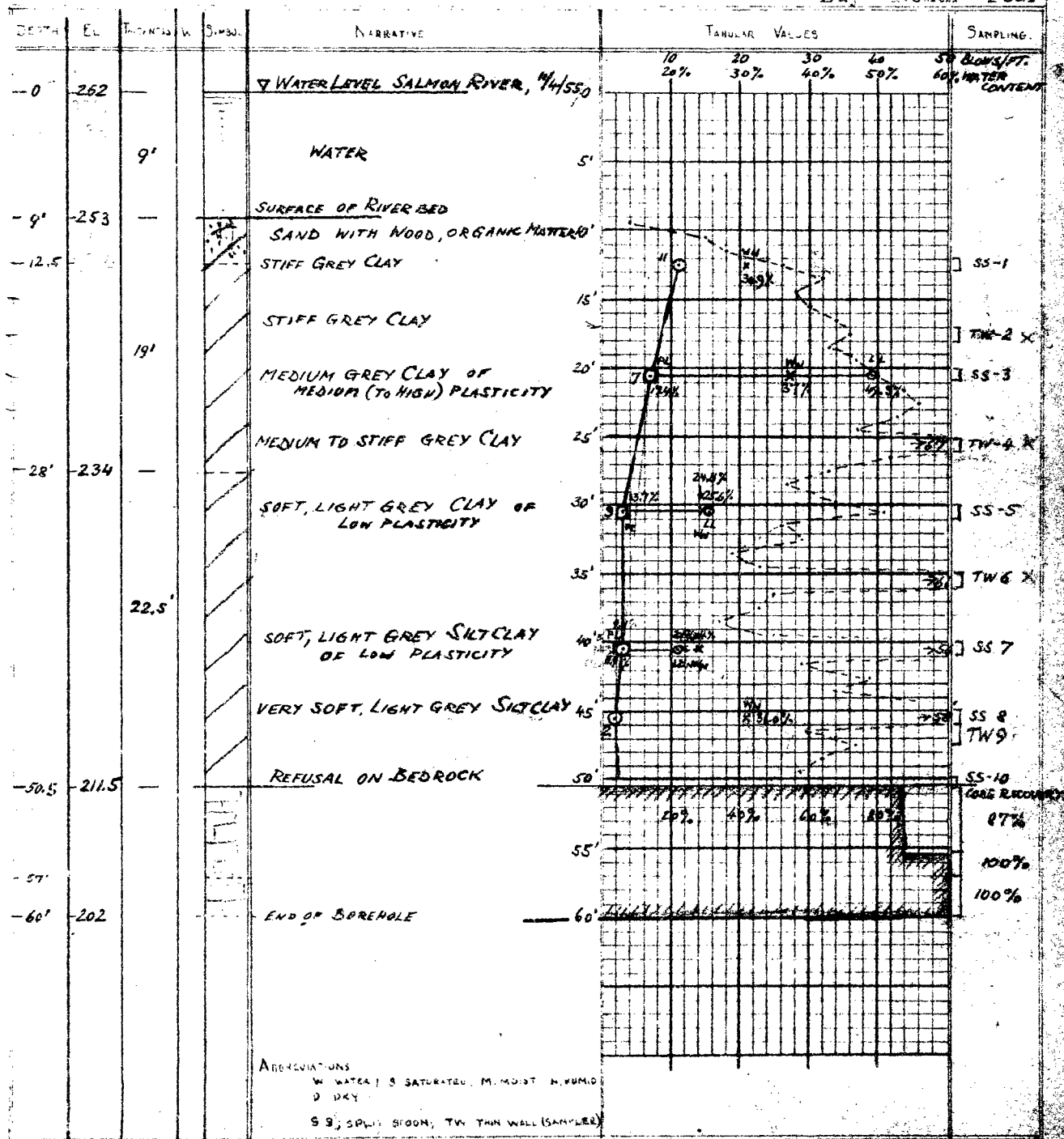
Helper

Job Name: TYNDINAGA TWP. BRIDGE NO. 5 - SALMON RIVER

K. TUBBESING

Job Located: PROP. HWY. NO. 401 CROSSING OVER SALMON RIVER, ~12 MILES E.N.E. OF BELLEVILLE, Checked byBore Located: ON CENTRE LINE OF HWY., CENTRE OF MAIN BRANCH OF RIVER (ON RAFT), STA. 3632+75Bore Elevation: ~262' (W.L.) Datum: M.S.L.13/4/55

Day Month Year



Hole Begun 18/4/55

Foundation Engineering Division

Hole Ended 20/4/55

Engineering Data Sheet for Borehole: 13

D. McCURDY

Helper

Job Name: TYENDINGA BRIDGE NO 5

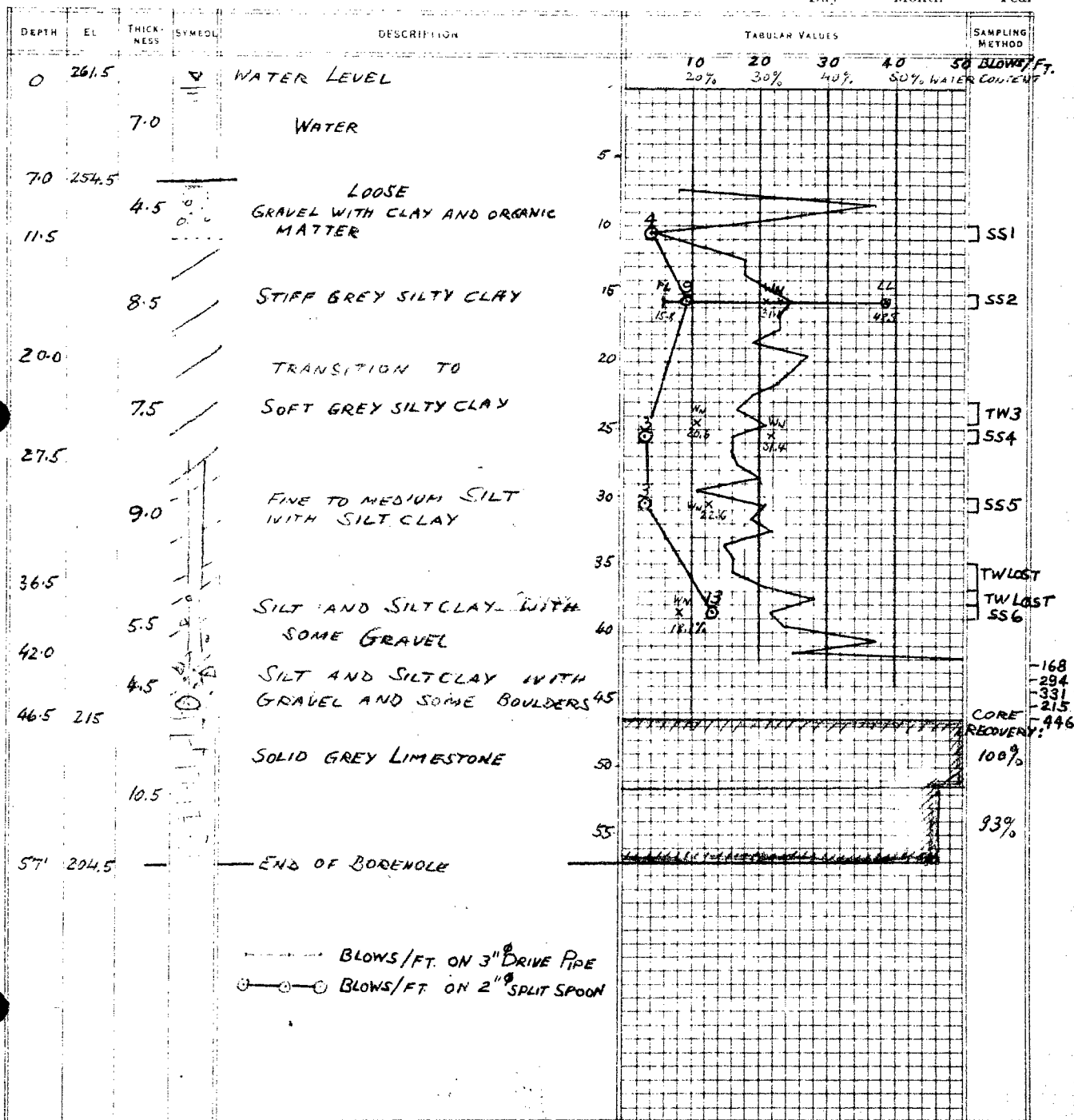
Job Located: SALMON RIVER EAST OF BELLEVILLE

Hole Located: AS SHOWN ON ATTACHED SKETCH PLAN

Hole Elevation: 261.5 (M.L.) Datum: M.S.L.

B. F. WELSH & K. T.

Checked by

20 4 55
Day Month Year

Hole Begun 20/4/55 Foundation Engineering Division

Hole Ended 21/4/55 Engineering Data Sheet for Borehole: 14

D. McCurdy
Helper

Job Name: TYENDINAGA BRIDGE No. 5

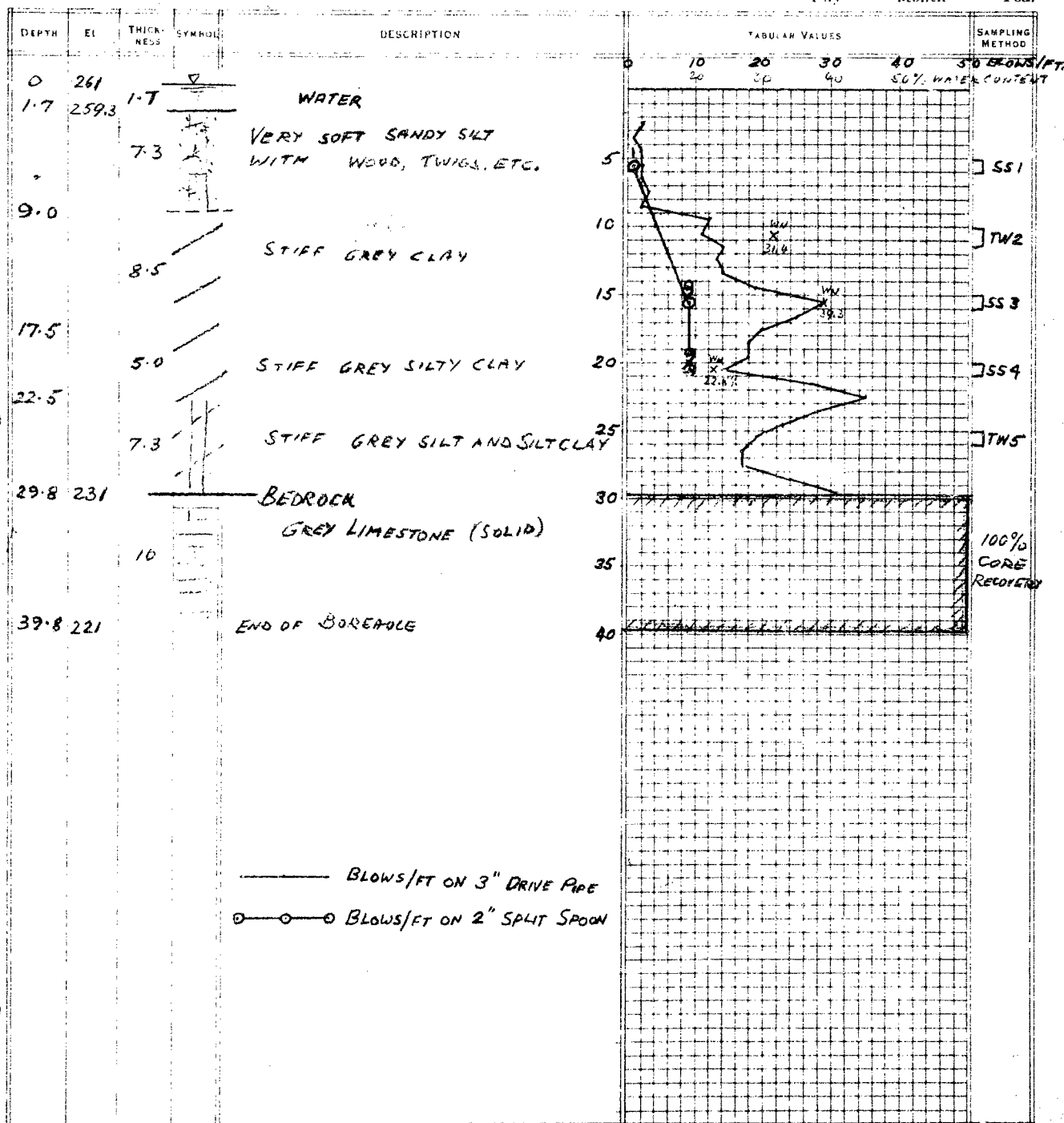
B.F. WELSH & K.T.
Checked by

Job Located: SALMON RIVER E OF BELLEVILLE

Hole Located: AS SHOWN ON ATTACHED SKETCH PLAN

Hole Elevation: 261 Datum: M.S.L.

22 4 55
Day Month Year



Order No.: 5500-501/55/7-66 RACEY, MACCALLUM AND ASSOCIATES

LIMITED

A. McCadden

Driller

Hole Begun 22/4/55

Foundation Engineering Division

Hole Ended 23/4/55Engineering Data Sheet for Borehole: 15D. McCurdy

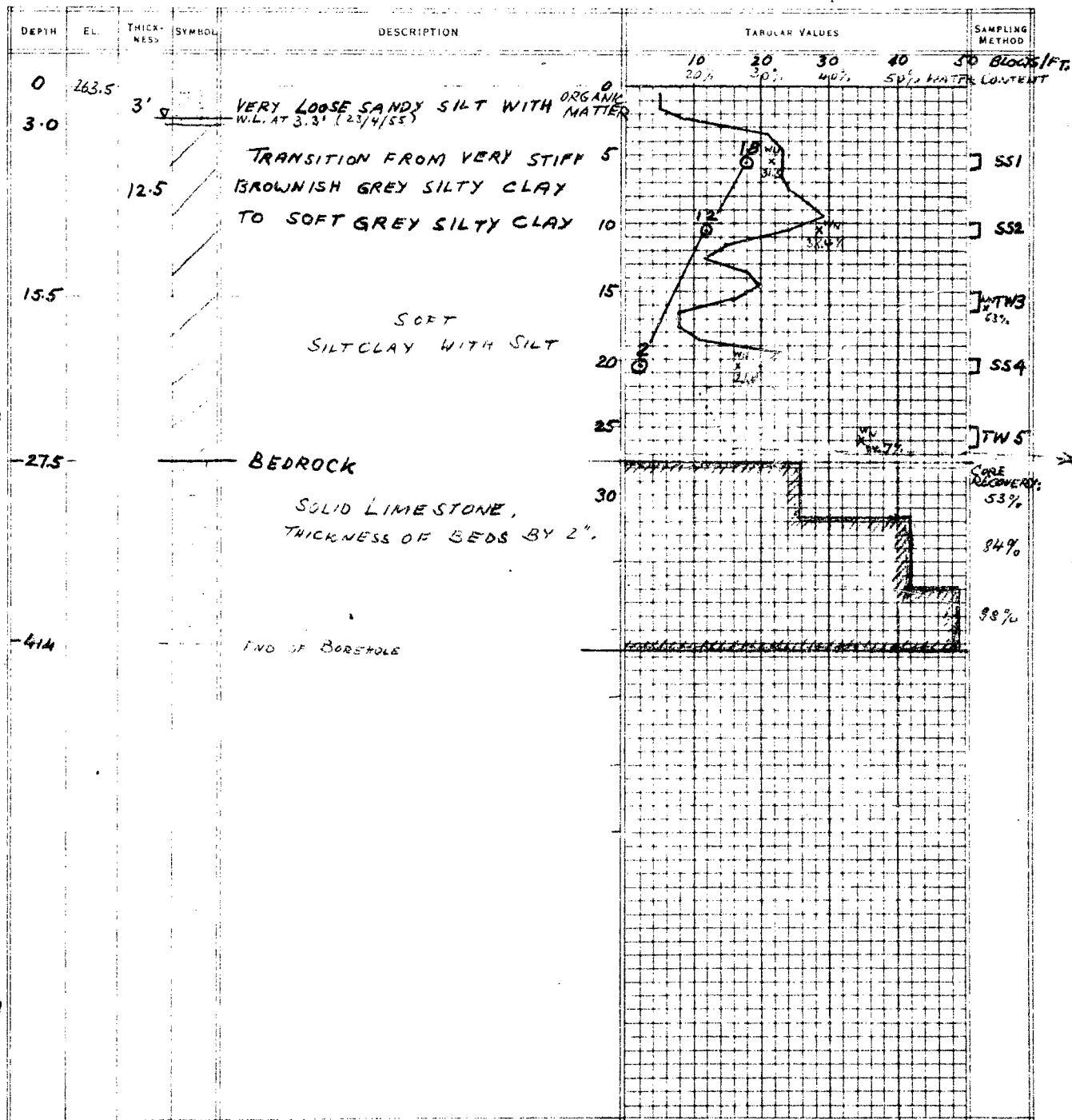
Helper

Job Name: TENDINAGA TWP. BRIDGE NO. 5 - SALMON RIVERB. F. Welsh B.K.T.

Checked by

Job Located: PROP. HWY. # 401 CROSSING OVER SALMON RIVER, EAST OF BELLEVILLE, ONT.Hole Located: STA. 36 31 + 50'Hole Elevation: 263.5 Datum: M.S.L.25/4/55

Day Month Year



RACEY, MacCALLUM AND ASSOCIATES LIMITED

Directors:

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THE VIBRATION ENGINEERING COMPANY

RE: FILE NO. 501

Toronto, Ontario,
May 24th, 1955.

Messrs. Lazarides, Lount and Partners,
79 Scollard Street,
TORONTO, Ontario.

Attention: Dr. T. C. Lazarides

RE: SALMON RIVER BRIDGE

Dear Sirs:

Following your enquiry on the advisability of replacing a substantial part of the bridgework by a causeway or an embankment, we have made some comparative studies which we desire to digest for you as follows:-

We have assumed a 100' wide bridge at a cost of \$10.00 per square foot to which should be added some \$0.50 per square foot for an assumed 6-pile bent every 50 feet. The cost per linear foot of causeway will be \$1,050.00. From this must be immediately deducted the cost of the roadway over the embankment which is a relatively minor figure, averaging about \$75.00 per foot.

The substitute embankment being partly submerged should be, from the point of view of soil mechanics, built with slopes of 1:2 to 1:3. Assuming 20 foot high embankment, 100 feet wide from shoulder to shoulder, the volume of embankment should be:-

$$100 \times 20 + \left(\frac{(20 \times 2) + (20 \times 3)}{2} \right) \times \frac{20}{2} \times 2 \times 1 = 111 \text{ c.y. per lin. ft.}$$

The cost of the embankment is based on unit cost of \$0.65 per cubic yard for the material including hauling. Per linear foot of causeway this comes to \$74.00 per linear foot.

In view of the poor nature of the sub-soil, it is felt that substantial settlement is bound to take place unless it is wished to repair the road at frequent intervals until full settlement has been

reached. It is felt that sand drains will be required.

In certain instances, such as for urban N. Y. State highways, a flexible pavement, expendable after a relatively short life, has been used. When it is desired to use a more permanent finish, the drains are used to permit full consolidation by the time grading is reached. When a very large number of such drains is used and the driving conditions are ideal, the cost may be as low as \$1.00 per linear foot. Generally the cost is more in the range of \$5.00 per linear foot.

In the present project, some of the work is off shore. Rather than build an expensive trestle for this phase of the work, it is suggested that part of the gravel be placed to bring the grade above normal water and the drains then placed. This will increase the necessary length and possibly the cost of driving at least for the first 10 to 20 feet. Even though without considering this contingency, it is felt that the drainage and consolidation work will be of the order of \$250.00 per pile or \$2.50 per square foot. If some extra driving has to be done in the top gravel layer, say the topmost 15 feet, a cost of \$7.00 per foot is not out of reason, bringing the unit price to \$3.20 per square foot over the whole project. It should be noted that this remedial work must be done on a width intermediate between the width at the shoulders and that at the toe of the embankment, say, as a first estimate, on 150 feet. The cost per linear foot of artery is thus at least \$375.00, possibly as much as \$480.00 say on the average \$425.00 for the consolidating devices.

The total estimated cost per linear foot is \$425.00 + \$74.00 = \$500.00.

The above are all estimated values rather than firm bids and thus subject to modification one way or the other. When comparing the cost of the bridge to that of the embankment is changed appreciably. We feel, therefore, that the decision should be based also on technical considerations as follows:-

In Favour of Embankment:

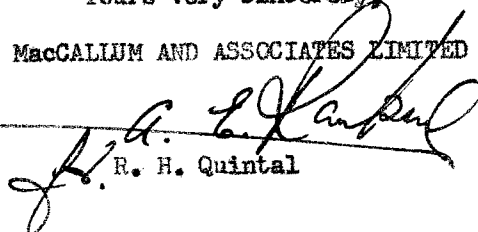
1. Except for the question of the sand drains this may be erected by a larger number of contractors thus may allow a greater freedom of choice.
2. It may be erected faster.
3. In case of catastrophe it may be repaired more rapidly.
4. For scenic routes it may possibly lend itself better to landscaping..

Against Embankment:

1. Secondary consolidation may occur: this phenomenon is not yet completely classified but has been known to cause settlement well in excess of the estimates and for long periods.
2. It requires a higher bridge to offer the same cross-sectional area during flood stages.
3. The construction of the same drains may be difficult and may require calling in outside specialists with resultant contractual difficulties.
4. On the basis of our experience and that of specialists we have discussed the problem with, we favour the construction of an embankment only to that point at which the economical height of same will clearly indicate a financial advantage. We believe that the critical height of this embankment will be less than 10 feet. This value, however, can not be obtained accurately unless a very serious study were to be made as regards unit prices in the subject region which is outside the scope of the present research.

Yours very sincerely,

RACEY, MacCALLUM AND ASSOCIATES LIMITED


R. H. Quintal

RHQ/PW

In duplicate