

GEOCREOS No:  
31F-117-1

**SUPPLEMENTARY FOUNDATION INVESTIGATION  
AND DESIGN REPORT  
MISSISSIPPI RIVER BRIDGES (EBL & WBL), SITE 3-594  
HIGHWAY 417, ARNPRIOR, ONTARIO  
DISTRICT 42, OTTAWA  
W.P. 451-90-03.04**

Report

to

**Ministry of Transportation, Ontario  
Pavements and Foundations Section**



Direction of fieldwork by:  
P.K. Chatterji, P.Eng.  
Project Engineer, Principal

Thurber Engineering Ltd.  
170 Evans Avenue, Suite 101  
Etobicoke, Ontario  
M8Z 5Y6  
Phone: (416) 503 3600  
Fax: (416) 503 3010



Engineering analysis and  
report reviewed by:  
Paulo J. Branco, P.Eng.  
Review Principal

November 2, 1999  
File: 15-64-7

## TABLE OF CONTENTS

1.	INTRODUCTION .....	1
2.	SITE DESCRIPTION .....	2
3.	SITE GEOLOGY .....	2
4.	INVESTIGATION PROCEDURES .....	3
4.1	Field Program .....	3
4.2	Laboratory Testing .....	4
5.0	SUBSURFACE CONDITIONS .....	5
5.1	General .....	5
5.2	Stratigraphic Units .....	6
5.2.1	Topsoil .....	6
5.2.2	Floodplain Deposits .....	6
5.2.3	Silty Clay to Clay .....	6
5.2.4	Lower Silty Clay .....	7
5.3	Groundwater Data .....	8
6.	ENGINEERING ANALYSIS AND RECOMMENDATIONS .....	9
6.1	Foundation Design Recommendations .....	9
6.1.1	General .....	9
6.1.2	End Bearing Steel H-Piles .....	9
6.2	Approach Embankments .....	10
6.2.1	General .....	10
6.2.2	Settlements due to Primary Consolidation .....	10
6.2.3	Settlements due to Secondary Consolidation .....	12
6.3.	Seismic Design .....	13
6.4	Embankment Design Alternatives .....	14
6.4.1	General .....	14
6.4.2	East Approach .....	15
6.4.3	West Approach .....	17
6.4.4	Embankment Design Recommendations .....	18

## **APPENDICES**

Appendix A	Borehole Logs
Appendix B	Laboratory Test Results
Appendix C	Non Standard Special Provisions - Granular Filter Blanket - Wick Drain
Appendix D	Non Standard Special Provisions - Monitoring Program

**SUPPLEMENTARY FOUNDATION INVESTIGATION  
AND DESIGN REPORT  
MISSISSIPPI RIVER BRIDGES (EBL & WBL), SITE 3-594  
HIGHWAY 417, ARNPRIOR, ONTARIO  
DISTRICT 42, OTTAWA  
W.P. 451-90-03.04**

**1. INTRODUCTION**

Thurber Engineering Ltd. (Thurber) has been awarded a Consultant Assignment by the Ministry of Transportation, Ontario (MTO), Pavements and Foundations Section, to produce a supplementary Foundation Investigation and Design Report for the twin structures to carry the proposed Highway 417 across the Mississippi River at Arnprior, Ontario.

A geotechnical investigation report on this site was prepared for MTO by Thurber in September 1995 under Thurber's file No: 15-64-1. The field investigation, analysis and reporting were based on the General Arrangement (GA) established for the bridges at that time. Since the submission of our previous report, the structures have been reconfigured to add one additional span at each end of each structure, thus lengthening the structures and moving the abutments from the valley floor onto the adjacent tableland. The maximum approach fill height has been reduced to approximately 4.5 m and 7.5 m at the West and East approaches, respectively.

The purpose of this supplementary investigation and analysis was to:

- explore the subsurface soil and groundwater conditions at the revised locations of the abutments and approach fills
- based on the data obtained provide borehole logs, soil profile and a model of the subsurface conditions
- analyze the data obtained during the investigation and provide geotechnical recommendations for the design and construction of the abutment foundations and associated earth works.
- provide geotechnical recommendations for the design of the foundations for

- new Pier 1 and new Pier 5
- review the geotechnical design recommendations previously provided with respect to embankment construction in light of the updated geotechnical model and modify if necessary

The contents of this report are applicable between approximate Stations 17+780 and 18+840 in the WBL and between Stations 17+760 and 18+215 in the EBL.

This report contains the results of the supplementary investigation carried out at the site and should only be read in conjunction with Thurber's previous report on the site dated September 18, 1995. Except as modified herein, all recommendations made in that previous report remain applicable to the reconfigured structures. In the interest of brevity, the background information such as site description and local geology have not been repeated in full in this report.

The field investigation, laboratory testing and engineering analysis presented herein have been completed in general conformance with Thurber's proposal letter to MTO dated July 19, 1999, and the terms of reference included with the MTO letter dated July 5, 1999.

## **2. SITE DESCRIPTION**

Refer to previous Thurber report, File No: 15-64-1, dated September 18, 1999.

## **3. SITE GEOLOGY**

Refer to previous Thurber report, File No: 15-64-1, dated September 18, 1999.

## **4. INVESTIGATION PROCEDURES**

### **4.1 Field Program**

Constraints imposed by permission to access parts of the site required the supplementary field investigation to be carried out in two stages between July 28 and August 5, 1999 and between August 24 and 28, 1999. A total of six sampled boreholes, numbered 99-1 through 99-6, were advanced at the approximate locations shown on the Borehole Location Plan, Drawing 45190- 03/04-A and summarized in the attached Table 1.

The drilling and sampling operations were carried out using a track-mounted CME 55 auger drill rig supplied and operated by Marathon Drilling Co. Ltd. of Gloucester, Ontario. The holes were advanced initially using 210 mm hollow stem augers and, at depths typically beyond 35 m, by casing and wash boring. Rock coring equipment was used to advance four of the six holes into bedrock. All drilling and sampling operations were carried out under the full time supervision of a member of Thurber's engineering staff. The supervisor identified and logged all soils samples recovered, recorded all insitu test data, preserved the samples and transported them to the laboratory in Toronto.

The sampled depths of the boreholes ranged from 15.9 m for the holes in the approach fill areas to 53.5 m for the holes at the abutments, the latter holes being terminated after approximately 3 m of coring into rock. Samples were obtained at intervals using a split spoon sampler or a thin wall tube sampler. Samples were generally recovered at intervals of 0.75 m in the upper 3.0 m and at increasing intervals, up to 6.0 m, at greater depth. The split spoon samples were obtained in conjunction with Standard Penetration Tests (SPT) following the test procedure outlined in ASTM D 1586. Thin wall sampling was carried out in accordance with ASTM D-1587.

The undrained shear strength of the clay soils was investigated insitu at intervals in each borehole using an MTO "N"-size vane and hand-held

spring balances. The vane shear testing was carried out in general conformance with ASTM D 2573. Both peak and remolded strengths were measured and the sensitivity of the clay was computed as the ratio of the peak to remolded strength.

A standpipe piezometer was installed in each borehole except BH 99-5. Details of the installations are shown on the individual borehole logs in Appendix A of this report and are summarized in Table 1. The piezometers consisted of 19 mm diameter, Schedule 40, PVC pipe, typically with a 1.5 m long slotted screen. Since the 1995 investigation encountered artesian groundwater conditions in the deep boreholes, the deep piezometers (BH 99-1, 99-2 and 99-4) installed as part of the current investigation were fitted with shut off valves at the top and fittings to allow the attachment of a pressure gauge. The two shallow piezometers (BH 99-3 and 99-6) were fitted with slip caps.

The borehole locations were established in the field, and the corresponding ground surface elevations were provided to Thurber by the MTO surveyor.

#### **4.2 Laboratory Testing**

All recovered soil samples were transported to Thurber's Toronto laboratory where they were subjected to detailed examination for visual identification in accordance with the methods set out in the MTC Soil Classification Manual and were all tested for natural moisture content. In addition, grain size analyses and Atterberg Limit determinations were carried out on selected samples to allow more detailed classification of the soils. The results of these laboratory tests are shown on the respective borehole logs and the grain size and Atterberg Limit results are presented in Appendix B.

In addition to the laboratory testing described above, a total of six one-dimensional consolidation tests were conducted on samples from thin wall tubes recovered from the east and west abutment areas. The consolidation tests were conducted by Golder Associates Ltd., Mississauga, Ontario, under contract to Thurber. The consolidation test

data is presented in Appendix C. A summary of the consolidation tests carried out in 1995 and in the current investigation is presented in Table C1, Appendix C.

## **5.0 SUBSURFACE CONDITIONS**

### **5.1 General**

The results of the geotechnical investigation carried out in 1999 confirm the subsurface stratigraphy described in the tableland boreholes in Thurber's 1995 investigation. An abbreviated description is provided in this report and for a detailed description the reader is referred to Thurber's 1995 report.

In general terms, the soils encountered in the boreholes drilled at the revised abutment locations in 1999 consisted of a thick deposit of cohesive soil overlying limestone bedrock. Based on the grain size distributions and plasticity limits obtained from laboratory tests on selected samples, the soils are described as a layer of high plasticity silty clay to clay, in the order of 12 to 34 m thick, overlying intermediate plasticity silty clay approximately 10 to 25 m thick. The deeper, intermediate plasticity clay is generally thicker, and the upper surface at a higher elevation at the east abutment than at the west. The upper silty clay to clay layer has a desiccated crust that is somewhat stronger than the underlying soil.

Limestone bedrock was encountered at depths of 50.1 to 50.6 m, corresponding to Elevation 37.4 to 41.7. The 1995 investigation program revealed the presence of a thin, discontinuous mantle of glacial till and/or sand on top of the bedrock.

With the exception of BH99-4, the piezometric head at the piezometer tip elevations was below ground surface. The piezometer installed in BH99-4 detected artesian piezometric head 1.1 m above ground surface. The discontinuous nature of piezometric head is consistent with the



discontinuous nature of the granular till overlying the bedrock and the possible localized fracturing and weathering of the bedrock.

A description of each soil unit and its key engineering properties is provided in the following sections. More detailed information is provided on the individual borehole logs in Appendix A, in the laboratory test data in Appendix B and in Drawing 451-90-03/04-A, Sheets 1 to 3.

## **5.2 Stratigraphic Units**

### **5.2.1 Topsoil**

Topsoil was found to be present at the ground surface at both the east and west abutments and approaches. The thicknesses encountered in the boreholes generally ranged from 100 to 200 mm.

### **5.2.2 Floodplain Deposits**

The 1999 boreholes were drilled on the tableland at the top of the valley slopes and did not encounter any floodplain deposits.

### **5.2.3 Silty Clay to Clay**

Boreholes 99-1 through 99-6 encountered a desiccated crust interpreted to be 4.0 to 7.0 m thick. Typically, the crust is very stiff just below the topsoil and has natural moisture content in the range of 10 to 20%. With increasing depth, the strength reduces to a stiff consistency and the natural moisture content increases to 50 to 70% about the base of the crust. Undrained shear strength measurements were carried out in the crust using insitu vane shear equipment and the measured peak values ranged from 50 kPa to greater than 215 kPa (the limit of the vane shear equipment). The soil in the crust is described as moist to wet and brown near the surface, becoming more grey with depth.

About the base of the crust, the peak undrained shear strength, as measured in-situ using the vane, reached minimum values in the order of 38 to 40 kPa. With increasing depth, the peak undrained shear strength generally increased, though some marked variation was observed. The maximum value of insitu, peak undrained shear strength measured in the silty clay to clay layer was 102 kPa, in Borehole 99-4. Below the base of the crust, the measured values of natural moisture content peaked at 88%, in Borehole 99-3. At greater depth, the moisture content values generally lay in the range of 50 to 80% and the soil was grey in colour.

Based on the measured values of peak and remoulded insitu shear strengths, the sensitivity of the lower silty clay soil ranges from 1 to 5, as shown on the individual borehole logs. These values are consistent with the 1995 findings of sensitivities ranging from 2 to 5.

The base of this soil unit lay at depths in the order of 12 to 34 m, corresponding to Elevation 57.5 to 75.5.

#### **5.2.4 Lower Silty Clay**

The lower silty clay is described as generally stiff to very stiff. The peak undrained shear strength values measured by the insitu vane lay in the range of 70 to 130 kPa, with the exception of the deepest measurement in each of Boreholes 99-1 and 99-2, where values of 247 and 236 kPa, respectively were obtained. These latter values indicate that the lower silty clay becomes hard below approximate Elevation 48 on the west side of the river. No in-situ shear strength tests were carried out at or below that elevation in the remaining boreholes, so there is the possibility that the soil also becomes hard with depth on the east side of the river.

The lower silty clay is grey in colour and the measured natural moisture contents range from 40 to 53%.

Based on the measured values of peak and remoulded insitu shear strengths, the sensitivity of the silty clay to clay soil ranges from 1 to 12, as

shown on the individual borehole logs. These values are consistent with the 1995 findings of sensitivities ranging from 1 to 13.

### 5.3 Groundwater Data

Groundwater levels were measured in the piezometers installed in five boreholes in the current investigation, plus two boreholes from the 1995 investigation which could be located. The data obtained is as follows:

Date	Depth to Groundwater (m) / Elevation of Groundwater						
	BH 99-1	BH 99-2	BH 99-3	BH 99-4	BH 99-6	BH 95-7	BH 95-14
Jul 29/99	-	-	4.0 / 88.50	-	-	-	-
Jul 30/99	-	-	3.97 / 88.53	-	-	-	-
Aug 3/99	-	-	2.60 / 89.9	-	-	-	-
Aug 4/99	-	0.94 / 90.06	2.48 / 90.02	-	-	-	-
Aug 5/99	1.40 / 90.40	0.96 / 90.04	2.51 / 88.99	-	-	-	-
Aug 27/99	1.44 / 90.36	-	3.53 / 88.97	-	-	-	-
Aug 28/99	-	-	-	+1.13 / 89.13*	dry	2.82 / 85.88	2.95 / 85.45

\* +1.13 indicates an artesian head of 1.13 m with respect to ground surface.

With the exception of Boreholes 99-4, all measured groundwater levels were below existing ground surface. At Borehole 99-4, the groundwater just overflowed from the piezometer tube at 1.13 m above ground surface. The pressure gauge was attached but did not record any excess pressure above the 1.13 m.

The 1999 groundwater levels must be regarded as short term and may change as they stabilize. In addition, seasonal fluctuations should be anticipated.

## **6. ENGINEERING ANALYSIS AND RECOMMENDATIONS**

### **6.1 Foundation Design Recommendations**

#### **6.1.1 General**

The previously proposed structures consisted of four spans, resting on the two abutments and three intermediate piers. The reconfigured design incorporates an additional span on each end and hence piers will now be required at the previous abutment locations and new abutment locations have been selected.

The data gathered in the current investigation has been analyzed together with the data from the 1995 investigation, particularly that from the previous abutment locations, to produce recommendations for the foundations for the outer sets of piers and the new abutments. The foundation recommendations for Piers 2 to 4, inclusive, have also been reviewed in light of current design practice.

Review of the site stratigraphy and the geotechnical properties of the soils confirms the conclusion reached in 1995 that the preferred foundation type is steel H-piles driven to bedrock. The issue of settlement is considered to preclude the use of friction piles and the installation of caissons to bedrock is not considered to be practical.

#### **6.1.2 End Bearing Steel H-Piles**

It is recommended that the foundations for the structure be supported on steel H-piles end bearing on the limestone bedrock.

It is recommended that HP 310X110 piles be used. Provided these piles are driven to practical refusal on the bedrock, they may be assumed to provide a factored, vertical, structural resistance of 1,600 kN at ULS. Downdrag forces due to long term settlements, acting above the neutral plane at 41m depth, associated with an average post-peak negative skin

adhesion of 20 kPa, have been included in the pile resistance and should not be subtracted further from the structural resistance given above.

For analysis at the SLS condition, the vertical movement at the pile head may be taken as equal to the elastic compression of the pile. In no case, however, should the SLS load exceed 1600 kN, the factored vertical pile resistance at ULS.

It is recommended that the piles be driven to practical refusal on the limestone bedrock. The Contractor should select a pile driving hammer that will not damage the pile during driving and delivering energy not exceeding 90 kJ.

## **6.2 Approach Embankments**

### **6.2.1 General**

Thurber's 1995 report indicated that the combination of high approach embankments and a thick compressible clay deposit, would result in large settlements of the approach embankments. Also of concern was the extended period of time that would be required for the settlements due to primary consolidation to stabilize. It was recommended to lengthen the bridges, in order to decrease the height of the approach embankments, and to accelerate settlements with a combination of fill surcharge and wick drains.

The following sections present the results of the settlement analysis for the new bridge general arrangement.

### **6.2.2 Settlements due to Primary Consolidation**

In view of the uniformity of the subsurface conditions in the tableland encountered in both, the 1995 and the current investigation program, the settlements due to primary consolidation at the approach embankments presented in our 1995 report are valid for the newly proposed approach

embankments. The results of that analysis are summarized in Table 2 for varying contact pressures at the underside of the embankment.

Also shown in the bottom portion of Table 2 is the contact pressure anticipated at the underside of the approach embankments at the abutment locations and approximately 50 m behind them. The contact pressures at the underside of the approach embankments have been calculated assuming that the embankment will be constructed with expanded pelletized blast furnace slag (unit weight of  $11.5 \text{ kN/m}^3$ ) and that the top 1 m of the embankment will consist of pavement structure.

Analysis of the Table 2 data shows that settlements due to primary consolidation up to 350mm and 120mm are anticipated for the East and West Approaches, respectively. These settlements are considered unacceptably high, unless the pile installation and pavement construction take place after most settlements have occurred. It is anticipated that construction time schedules will require acceleration of settlements through the use of fill surcharge and/or wick drains.

It is recommended that the design and construction of the embankment incorporate measures to reduce the potential for long term settlements due to secondary consolidation. This may be achieved through the following steps:

- overbuild the embankment to create a surcharge
- allow consolidation to continue under the surcharge pressure until the magnitude of consolidation equals at least 100% of the primary consolidation expected under a contact pressure of at least 20 kPa above the contact pressure due to the final embankment configuration
- remove the surcharge load and construct the pavement.

The effect of this procedure is to produce a small overconsolidation of the underlying, compressible clay, which reduces the potential for long term

settlements due to secondary consolidation .

The time required to produce the desired degree of overconsolidation depends on the magnitude of the surcharge pressure and on the length of the drainage path ( or the spacing between wick drains if they are installed). Analysis was carried out on combinations of surcharge pressure and wick drain spacing required to stabilize the settlement due to primary consolidation within certain selected time frames. The results of the analysis are presented in Tables 3 and 4 for the East and West Approaches, respectively.

Table 5 presents an example of the calculations and basic assumptions used for the assessment of the required wick drain spacing. The calculations have been carried out assuming that the wick drains will be installed to Elevation 60m, at approximately 30m depth. Below that depth the settlements due to primary consolidation are anticipated to be very small.

### 6.2.3 Settlements due to Secondary Consolidation

Despite of the surcharging of the clay during primary consolidation there is a potential for long term settlements of up to 70mm due secondary consolidation. This value was calculated based on the following assumptions:

$$\Delta T_{cs} = C\alpha\epsilon * T * \text{Log} (t_{sc}/t_p),$$

where:

$\Delta T_{cs}$  = settlement due to secondary consolidation

$C\alpha\epsilon$  = secondary compression ratio = 0.005

$T$  = initial thickness of compressible layer = 10m (\*)

(\*) only EL. 70m and EL. 80m, where the overconsolidation ratio of the clay is the lowest.

$t_{sc}$  = time over which secondary consolidation is to be calculated = 35years

$t_p$  = time to complete primary consolidation = 1.5 years

### 6.3. Seismic Design

The Mississippi River Bridge Site is located within Seismic Zone No. 2 which has a zonal acceleration ratio of 0.2 and zonal velocity ratio of 0.1.

The liquefaction potential of the foundation soils was analyzed based on a criteria used by the US Army Corps of Engineers (USACE). The analysis indicates that the foundation soils are not liquefiable. We anticipate, however, that in the event of an earthquake, the clay may suffer a partial loss of undrained shear strength and a decrease in stiffness. For design purposes we have estimated a loss of 10% and 25% in the undrained shear strength of the desiccated upper crust (top 4 m) and underlying clay, respectively, under seismic conditions.

The design issues associated with this loss of strength and cyclic loading are:

- Stability of the approach embankments and permanent deformation of the abutment piles
- Softening of the foundation soils under cyclic loads
- Possible loss of pile lateral support near ground surface due to formation of a gap between soil and pile

Our stability analysis indicates that the approach embankments are stable (at 2H:1V slope) under seismic loads. However, due to loss of shear strength in the foundation soils as discussed above, we anticipate that, during an earthquake, the approach embankment and foundation soils may undergo permanent lateral displacements in the order of 50mm to 100mm at the pile cap and displacements decreasing linearly to 0mm at 15 m depth. For the structural analysis of the abutment piles, one could carry out a numerical analysis (frame analysis) in which an uniform displacement field of 100mm is applied to the upper 5 m of the pile and the bottom portion of the pile, below 15m depth, is supported by springs. The spring constant values for this analysis (coefficient of horizontal subgrade reaction) are provided on Figure 1.



Figure 1 also provides spring constants for the analysis of piles located in the flood plain subjected to cyclic loads. It should be noted that, for the cyclic analysis, we have eliminated the springs in the upper 2.5 m of the pile to account for the possible formation of a gap between soil and pile. When carrying out an analysis of piles subjected to lateral loading by modelling the soil with linear elastic springs, it is critical to compare the load at each spring, which results from the numerical analysis, with the ultimate load ( $P_{ult} = p_u$  [given in Figure 1] x Length of finite element x Width of pile) calculated for each spring. If the spring load is larger than  $P_{ult}$ , the spring should be removed from the model and a second iteration should be carried out with a load equal to  $P_{ult}$  applied to the pile at that spring location.

## **6.4 Embankment Design Alternatives**

### **6.4.1 General**

It is our understanding that the approach embankments and bridges will be constructed over a 3 year period. Based on this schedule, it appears that a period of up to 24 months between a time approximately halfway through the construction of the approach embankments and the beginning of the installation of the abutment piles may be available for settlements due primary consolidation to take place and subsequent removal of the surcharge.

The following sections present construction alternatives that have been selected based on the assumption that a long term settlement due to primary consolidation of approximately 80mm at a location not closer than 100m to the abutment it is acceptable to MTO. This implies that embankment less than 2m high and not closer than 100m from the bridge will not require special measures for acceleration of settlements.

### 6.4.2 East Approach

The analysis of the data presented in Table 6 indicates that the following alternatives are feasible for the East Approach embankment construction:

Alternative 1: Construction without wicks - temporary embankment entirely constructed with earth fill

- Stage 1: Construct the embankment with earth fill to EL.96m between the following stations:  
EBL: Sta 18+163 (head slope) to Sta 18+370 (length:207m)  
WBL: Sta 18+185 (head slope) to Sta 18+430 (length: 245m)

This will result in a maximum embankment height of 9.5 m at the WBL approach embankment. The embankment side slopes should be sloped at 2H:1V for stability.

Beyond the eastern limit of the surcharged area above construct the embankment to 1 m above the finished pavement elevation.

- Stage 2: Wait until 80% (refer to Table 3) of the settlements due to primary consolidation have occurred (anticipated to take up to 24 months)
- Stage 3: Remove the embankment earth fill material entirely and replaced it with light weight fill and the pavement structure.

Alternative 2: Construction without wicks - embankment constructed with light weight fill to the underside of the pavement structure and with earth fill to the top of the surcharge

- Stage 1: Embankment constructed to Elevation 98m between the same stations as in Alternative 1.
- Stage 2: Wait until 80% (refer to Table 2) of the settlements due to primary consolidation have occurred (anticipated to take up to 24 months)
- Stage 3: Remove the earth fill above the light weight fill and construct the pavement structure.

Alternative 3: Construction with wick drains spaced at 4.5 m - embankment constructed with light weight fill to the elevation of the underside of the pavement structure and with earth fill to the top of the surcharge

- Stage 1: Installation of a sand blanket and wick drains in a triangular pattern, spaced at 4.5m, within the footprint of the embankments, between the following stations:  
EBL: Sta 18+163 (head slope) to Sta 18+370 (length:207m)  
WBL: Sta 18+185 (head slope) to Sta 18+430 (length: 245m)
- Stage 2: Between the stations above, embankment to be constructed using light weight fill to the elevation of the underside of the pavement structure and with earth fill to an elevation 1m above the finished pavement.
- Stage 3: Wait until most of the settlements due to primary consolidation have occurred (anticipated to occur within 16 months after the end of the embankment construction)
- Stage 4: Remove the earth fill material above the light weight fill and construct the pavement structure.

### 6.4.3 West Approach

The analysis of Table 5 indicates that the following alternatives are feasible for the West Approach embankment construction

Alternative 1: Construction without wicks - temporary embankment entirely constructed with earth fill

- Stage 1: Construct the embankment with earth fill to a height of 6.5m between the following stations:  
EBL: Sta 17+806 (head slope) to Sta 17+698 (length:108m)  
WBL: Sta 17+834 (head slope) to Sta 17+720 (length: 114m)
- Stage 2: Wait until 80% (refer to Table 4) of the settlements due to it primary consolidation have occurred (anticipated to take up to 18 months)
- Stage 3: Remove the embankment earth fill material and replaced with light weight fill and the pavement structure.

Alternative 2: Construction without wicks - embankment constructed with light weight fill to the underside of the pavement structure and with earth fill to the top of the surcharge

- Stage 1: Embankment constructed to with a height of 8m between the same stations as in Alternative 1.
- Stage 2: Wait until 80% (refer to Table 2) of the settlements due to primary consolidation have occurred (anticipated to take up to 24 months)
- Stage 3: Remove the earth fill material above the light weight fill and construct the pavement structure.

Alternative 3: Construction with wick drains spaced at 4.5 m - embankment constructed with light weight fill to the elevation of the underside of the pavement structure and with earth fill to the top of the surcharge

- Stage 1: Installation of a sand blanket and wick drains in a triangular pattern, spaced at 4.5m, within the footprint of the embankments, between the following stations:  
EBL: Sta 17+806 (head slope) to Sta 17+698 (length:108m)  
WBL: Sta 17+834 (head slope) to Sta 17+720 (length: 114m)
- Stage 2: Between the stations above, embankment to be constructed using light weight fill to the elevation of the underside of the pavement structure and with earth fill to an elevation 1m above the finished pavement.
- Stage 3: Wait until most of the settlements due to primary consolidation have occurred (anticipated to occur within 16 months after the end of the embankment construction)
- Stage 3: Remove the embankment earth fill material above the light weight fill and construct the pavement structure.

#### **6.4.4 Embankment Design Recommendations**

Recommended Alternative

Although all design alternatives discussed in the preceding section are technically equivalent, they present different degrees of uncertainty and risks with regards to the time required to complete a certain degree of primary consolidation.

The alternatives that include the use of wick drains represent the lowest risk since it allows a relatively good control over the length of the drainage path for dissipation of excess pore pressures within the clay deposit.

Therefore a combination of a surcharge of 2m above the finished pavement elevation and wick drains spaced at 3.0m is recommended. This will shorten the period required for dissipation of excess pore pressures from 16 to 7 months, therefore decreasing the risk of delays in construction schedule.

#### Light Weight Fill

In order to satisfy the design requirements for embankment loading, MTO should include in the Contract Documents a Special Provision for Pelletized Blast Furnace Slag (Structural Coarse #143 - Produced by Lafarge's Hamilton Slag Division - or equal), with unit weight not larger than 11.5 kN/m<sup>3</sup>.

Consideration should be given by MTO to include Special Provisions for treatment of the light weight fill side slopes with vegetation or rock.

The interface of the light weight fill with the earth fill at the locations beyond which lightweight fill is no longer required, should be inclined at 5H:1V, with the earth fill underlying the light weight fill.

#### Wick Drain Specification

In order to satisfy the design requirements for discharge capacity, soil retention, permeability and clogging criteria, and installation, the sand blanket and wick drains should be supplied and installed according to the NSSP included in Appendix C.

The sand blanket should be placed to an elevation at least 0.5m above the groundwater level and with minimum thickness of 0.5m.

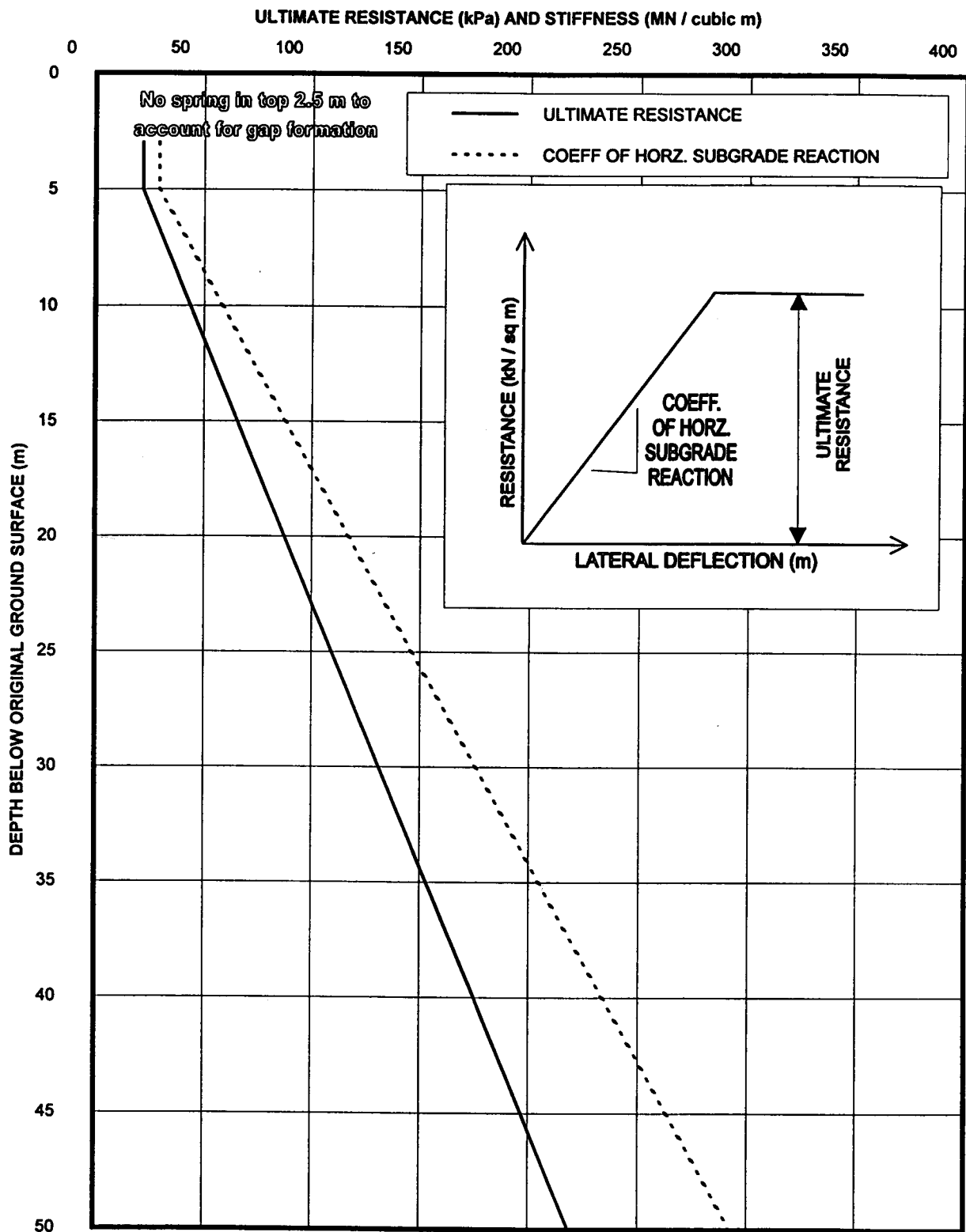
#### Monitoring Program

A monitoring program has been design for the monitoring of settlements of the embankment, horizontal displacements at depth in the foundation soils

at the abutment locations, and pore pressures in the foundation soils.

A NSSP included in Appendix D has been prepared for the monitoring program. It should be noted that, since stability of the embankment is not a governing factor in the embankment design, the monitoring program does not include excess pore pressure alert levels during construction.

Notwithstanding this fact, vibrating wire piezometers have been included in the program to aid in establishing the time for removal of the embankment surcharge.



**FIGURE 1. Ultimate Resistance and Coefficient of Horizontal Subgrade Reactions for Lateral Pile Analysis Under Earthquake Loads**



**Table 1**

**Borehole Locations and Installation Details**

BH No:	Northing	Easting	Ground Elev.	Depth (m) (EOH* Elev)	Piezometer Installation Elevations					Stick up (m)
					Tip	Sand	Bentonite	Grout	Cuttings	
99-1	5026873	323472	91.8	53.3 (38.5)	41.8	44.5 - 38.5	50.6 - 44.5	90.9 - 50.6	91.8 - 90.9	1.02
99-2	5026845	323447	91.0	53.2 (37.9)	40.6	42.9 - 37.9	49.0 - 42.9	90.1 - 49.0	91.0 - 90.1	0.99
99-3	5026874	323445	92.5	15.9 (76.6)	87.9	90.2 - 87.9	91.4 - 90.2	none	92.5 - 91.4	0.91
99-4	5026596	323723	88.0	53.4 (34.60)	37.9	40.8 - 34.6	42.2 - 40.8	84.9 - 42.2	88.0 - 84.9	1.13
99-5	5026563	323698	87.8	53.5 (34.3)	No Piezometer					
99-6	5026568	323721	88.1	13.4 (74.7)	83.2	85.0 - 83.2	86.6 - 85.0	none	88.1 - 86.6	1.15

\* EOH = End of Hole

**Table 2**  
**Settlement due to Primary Consolidation**

Contact Pressure (kPa)	Settlement (mm)	
	East Approach	West Approach
10	25	26
20	46	48
40	81	84
60	113	115
80	184	144
100	340	190
120	547	412
160	1077	1096
200	1854	1833
240	2669	2606

Anticipated final contact pressures at the underside of the approach embankments:

East Approach Embankment:

At the Abutment: 74.8 kPa ( $1.0\text{m} \times 23\text{kN/m}^3 + 4.5\text{m} \times 11.5\text{ kN/m}^3$ )  
 50 m behind the Abutment: 97.8 kPa ( $1.0\text{m} \times 23\text{kN/m}^3 + 6.5\text{m} \times 11.5\text{ kN/m}^3$ )

West Approach Embankment:

At the Abutment: 61.0 kPa ( $1.0\text{m} \times 23\text{kN/m}^3 + 3.3\text{m} \times 11.5\text{ kN/m}^3$ )  
 50 m behind the Abutment: 40.3 kPa ( $1.0\text{m} \times 23\text{kN/m}^3 + 1.5\text{m} \times 11.5\text{ kN/m}^3$ )

**MISSISSIPPI RIVER - SURCHARGE AND WICK DRAIN ANALYSIS  
EAST APPROACH AND ABUTMENT - SUMMARY  
West and East Bound Lanes - Centreline**

Cv: 1.00E-06 m<sup>2</sup>/s  
Hd: 30 m

Final Contact Pressure (kPa)	Target Contact Pressure (kPa)	Target Settlement due to Primary Consolidation (mm)	Temporary Contact Pressure (kPa)	Anticipated Settlement due to Primary Consolidation (mm)	Percent Consolidation (U%) (target/anticip. settlements)	Tv time factor	Minimum Required Time (months)							
							Without Wicks	With Wicks Spaced at						
								1.50 m	2.00 m	2.50 m	3.00 m	3.50 m	4.00 m	4.50 m
40 kPa	60	113	60	113	99%	-	-	2	3	5	7	10	12	16
			80	184	61%	0.300851	104	1	2	2	2	3	4	
			100	340	33%	0.086754	30	1	1	1	1	2	2	
			120	547	21%	0.033518	12	1	1	1	1	1	1	
			140	812	14%	0.01521	5	1	1	1	1	1	1	
			160	1077	10%	0.008646	3	1	1	1	1	1	1	
50 kPa	70	148	70	148	99%	-	-	2	3	5	7	10	12	16
			80	184	80%	0.576045	200	1	2	2	3	3	4	5
			100	340	44%	0.148818	52	1	1	1	2	2	2	2
			120	547	27%	0.057496	20	1	1	1	1	1	1	1
			140	812	18%	0.026092	9	1	1	1	1	1	1	1
			160	1077	14%	0.014831	5	1	1	1	1	1	1	1
At Abutment 74.8 kPa (4.5m*11.5kN/m3 + 1.0m*23kN/m3)	90	262	90	262	99%	-	-	2	3	5	7	10	12	16
			100	340	77%	0.511546	178	1	2	2	3	3	4	5
			120	547	48%	0.180185	63	1	1	1	2	2	2	2
			140	812	32%	0.081767	28	1	1	1	1	1	2	2
			160	1077	24%	0.046479	16	1	1	1	1	1	1	1
			180	1465	18%	0.02512	9	1	1	1	1	1	1	1
~50m behind Abutment 97.7 kPa (6.5m*11.5kN/m3 + 1.0m*23kN/m3)	115	495	115	495	99%	-	-	2	3	5	7	10	12	16
			120	547	90%	0.868511	302	1	2	3	4	5	6	8
			140	812	61%	0.296127	103	1	2	2	2	2	3	4
			160	1077	46%	0.165909	58	1	1	1	2	2	2	2
			180	1465	34%	0.089665	31	1	1	1	1	1	2	2
			190	1655	30%	0.070259	24	1	1	1	1	1	1	1

**MISSISSIPPI RIVER - SURCHARGE AND WICK DRAIN ANALYSIS**  
**WEST APPROACH AND ABUTMENT - SUMMARY**  
**West and East Bound Lanes - Centreline**

Cv: 1.00E-06 m<sup>2</sup>/s  
Hd: 30 m

Final Contact Pressure (kPa)	Target Contact Pressure (kPa)	Target Settlement due to Primary Consolidation (mm)	Temporary Contact Pressure (kPa)	Anticipated Settlement due to Primary Consolidation (mm)	Percent Consolidation (U%) (target/anticip. settlements)	Tv time factor	Minimum Required Time (months)							
							Without Wicks	With Wicks Spaced at						
								1.50 m	2.00 m	2.50 m	3.00 m	3.50 m	4.00 m	4.50 m
20 kPa	40	84	40	84	99%	-	-	2	3	5	7	10	12	16
			60	115	73%	0.446191	155	1	1	2	2	3	4	5
			80	144	58%	0.269737	94	1	1	1	2	2	3	3
			100	190	44%	0.153512	53	1	1	1	1	2	2	2
			120	412	20%	0.032648	11	1	1	1	1	1	1	1
			140	754	11%	0.009748	3	1	1	1	1	1	1	1
~ 50 m behind Abutment 40.3 kPa (1.5m*11.5kN/m3 + 1.0m*23kN/m3)	60	115	60	115	99%	-	-	2	3	5	7	10	12	16
			70	129	89%	0.814843	283	1	2	3	4	5	6	7
			90	167	69%	0.387763	135	1	1	2	2	3	4	4
			110	301	38%	0.114644	40	1	1	1	1	2	2	2
			130	583	20%	0.03056	11	1	1	1	1	1	1	1
			150	925	12%	0.01214	4	1	1	1	1	1	1	1
At Abutment 61 kPa (3.3m*11.5kN/m3 + 1.0m*23kN/m3)	80	148	80	148	99%	-	-	2	3	5	7	10	12	16
			90	167	89%	0.795717	276	1	2	3	4	5	6	8
			110	301	49%	0.18988	66	1	1	1	2	2	2	3
			130	583	25%	0.050615	18	1	1	1	1	1	1	2
			150	925	16%	0.020106	7	1	1	1	1	1	1	1
			170	1280	12%	0.0105	4	1	1	1	1	1	1	1

**NEW HANSBO METHOD (combined with Lambe & Whitman's book) recommendations**  
**"Consolidation of Clay by Band-Shaped Prefabricated Drains"**  
**Ground Engineering, Vol.12 No.5, 1979**  
**Formulation according to Equation 1 - Including well resistance and smearing**

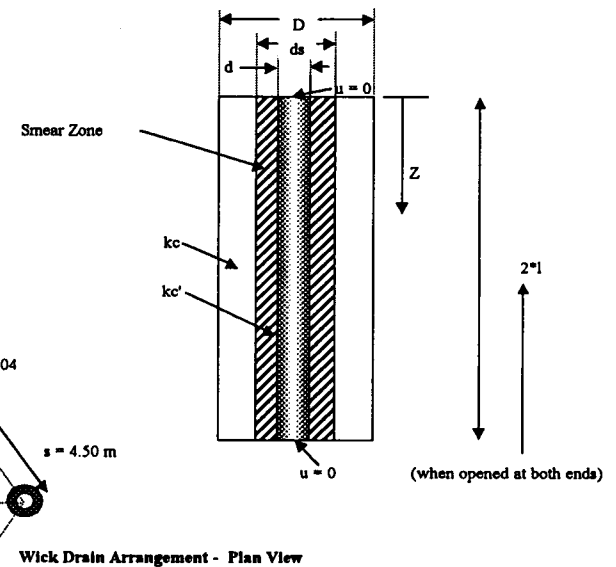
Job Number: 15-64-7  
 Title: Mississippi River Bridge  
 Case: East Abutment  
 Sub-case:

**INPUT PARAMETERS**

D	4.725	m	diameter of dewatered soil cylinder (Triangular Spacing equal to, $s =$	4.50	m)
d	0.07	m	equivalent diameter of band-shaped drain: $2(b+t)/\pi$ ; $n =$	67.5	
$C_H$	2.00E-06	$m^2/s$	consider reducing $C_H$ to account for smear; $C_H/C_v$ is often 2 to 5		
$C_v$	1.00E-06	$m^2/s$	determined by the oedometer test		
$\lambda$	1.00E-06	$m^2/s$	$=k_s/(\gamma_w \cdot m_v)$ ; or $\lambda = C_v$ obtained from the oedometer test (Hansbo 1979)		
$d_s$	0.21	m	diameter of the smear zone (typically equal to 1.5 to 3 times d); $s = ds/d =$	3	
$k_c$	5.00E-09	m/s	undisturbed soil permeability		
$k'_c$	1.67E-09	m/s	soil permeability within the smear zone; $k_c/k'_c =$	3.00	
$q_w$	1.00E-05	$m^3/s$	drain discharge capacity; $k_c/q_w =$	5.00E-04	; well resistance cannot be ignored if $k_c/q_w > 3.33E-04$
l	30.00	m	length of the drain when open at one end only		
Wick drainage (one end:1; two ends:2):	1		half length of the drain when open at both ends		
Layer	CI				
Surcharge (kPa)	100.00	kPa			
Drainage Path (m)	30.00	m			
Settlement due to Primary Consolidation	333	mm			
n	68		(D/d; should always be >12)		
$\alpha$	0.3828785		f(D/d); regression from Figure 3 of the paper)		

Time Increment for table below =  
 Resultant Maximum Time =

0.40 month  
 24.40 months



% Consolidation	Time required (months)	
	Uv and Uh	Uh only
16	0.80	0.80
25	1.20	1.20
49	2.40	2.40
89	7.20	8.00

## MISSISSIPPI RIVER BRIDGE - EMBANKMENT CONSTRUCTION ALTERNATIVES

### EAST APPROACH

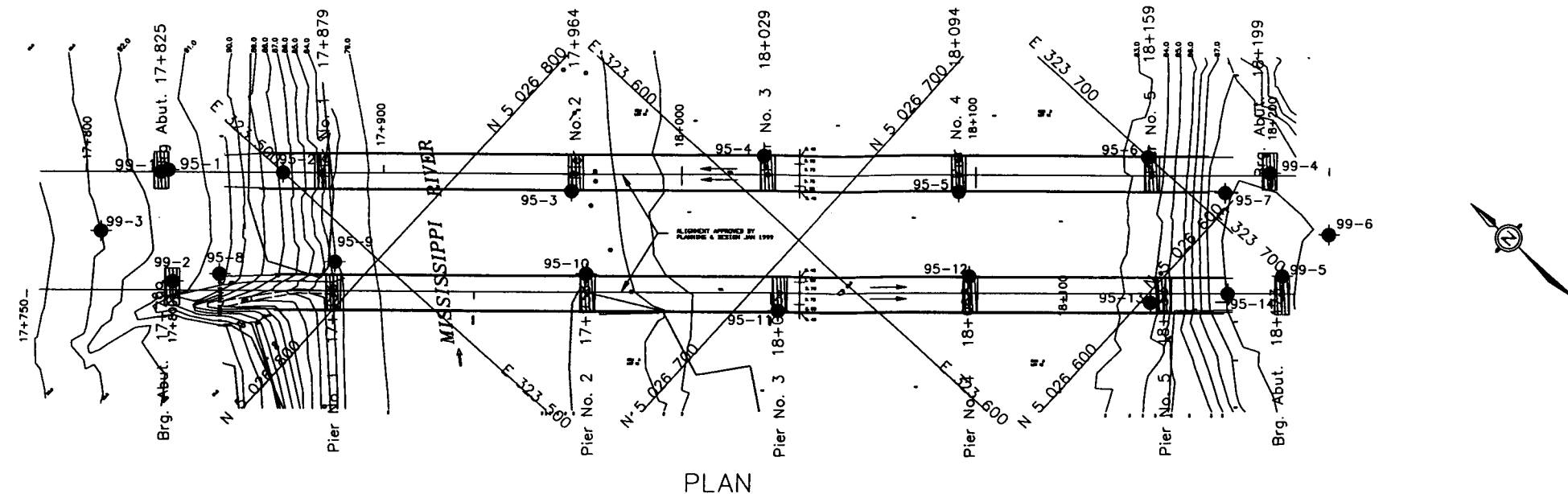
Location distance behind Abutment (m)	Final Configuration		Temporary Configuration							
	Embankment Height (m)	Contact Pressure (kPa)	No wick Drains				With wick drains spaced at 4.5 m			
			Temporary Contact Pressure (kPa)	Minimum Time prior to surcharge removal (month)	Height to top of Surcharge (m)		Temporary Contact Pressure (kPa)	Minimum Time prior to surcharge removal (month)	Height to top of Surcharge (m)	
					Regular Fill (*) ( $\gamma = 20 \text{ kN/m}^3$ )	Composite Fill (**)			Regular Fill (*) ( $\gamma = 20 \text{ kN/m}^3$ )	Composite Fill (**)
0 (at abutment)	5.5	74.8	160	16	8.0	9.8	90	16	4.5	6.3
50	7.5	97.7	190	24	9.5	12.1	115	16	5.8	8.4
140	3.5	50	120	20	6.0	7.0	70	16	3.5	4.5
210	2.7	40	120	12	6.0	6.7	60	16	3.0	3.7

### WEST APPROACH

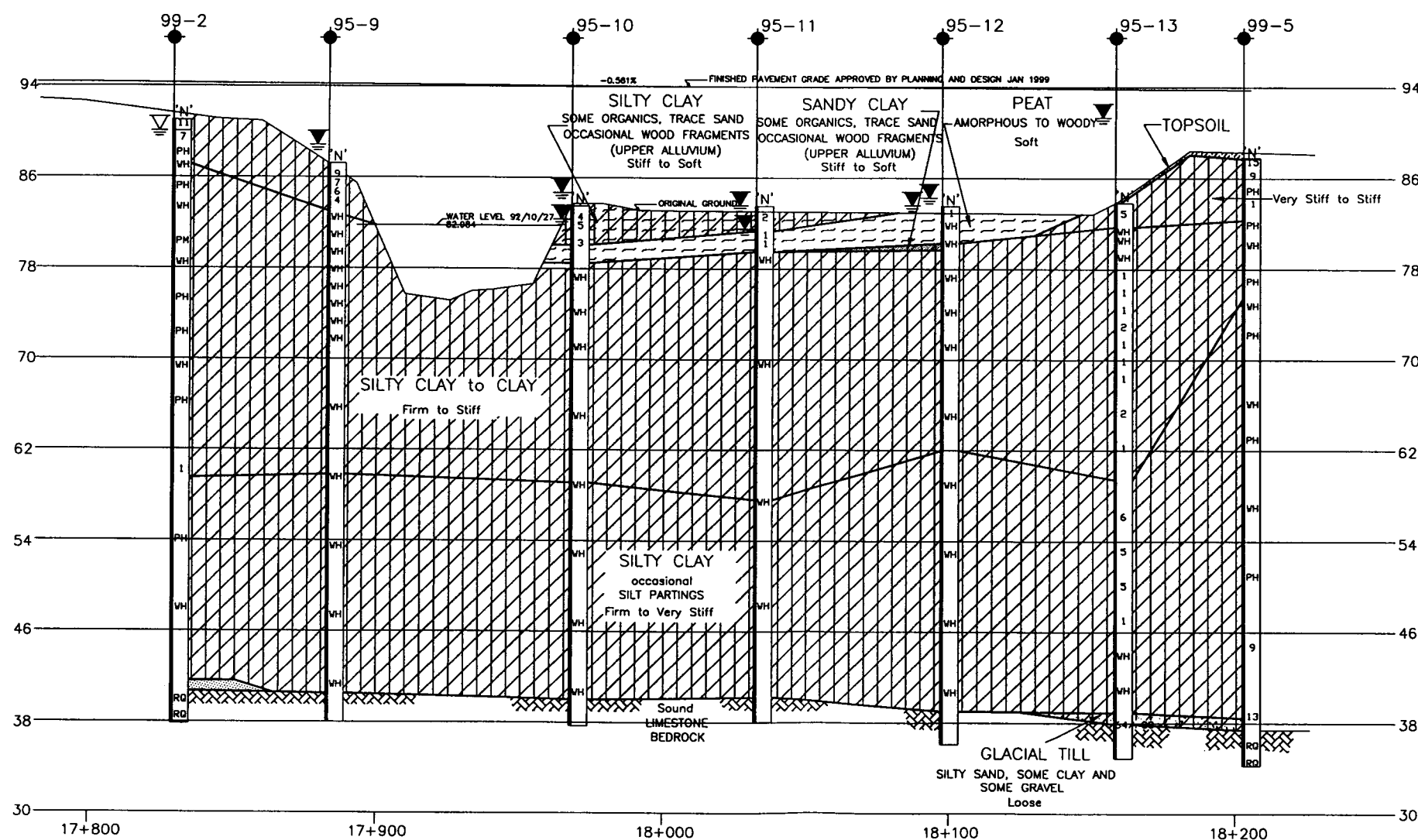
Location: distance behind Abutment (m)	Final Configuration		Temporary Configuration							
	Embankment Height (m)	Contact Pressure (kPa)	No wick Drains				With wick drains spaced at 4.5 m			
			Temporary Contact Pressure (kPa)	Minimum Time prior to surcharge removal (month)	Height to top of Surcharge (m)		Temporary Contact Pressure (kPa)	Minimum Time prior to surcharge removal (month)	Height to top of Surcharge (m)	
					Regular Fill (*) ( $\gamma = 20 \text{ kN/m}^3$ )	Composite Fill (**)			Regular Fill (*) ( $\gamma = 20 \text{ kN/m}^3$ )	Composite Fill (**)
0 (at abutment)	4.3	61	130	18	6.5	7.8	80	16	4.0	5.3
50	2.5	40.3	130	11	6.5	7.0	60	16	3.0	3.5
140	1.0	21	120	11	6.0	6.0	40	16	2.0	2.0

(\*): Regular fill: embankment constructed entirely with regular fill ( $\gamma=20 \text{ kN/m}^3$ )

(\*\*): Composite fill: embankment constructed with light weight fill ( $\gamma=11.5 \text{ kN/m}^3$ ) to the underside of the pavement structure and regular fill above that elevation



PLAN



C PROFILE EAST BOUND LANES

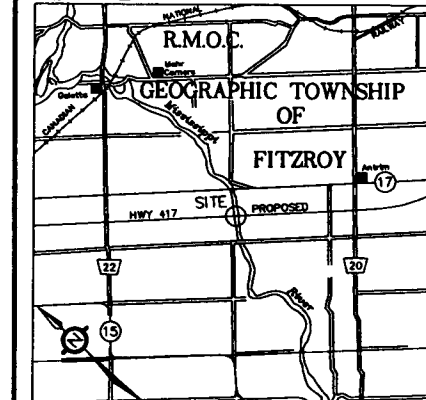
DIST 42 CR  
CONT No  
WP No 451-90-03/04

MISSISSIPPI RIVER BRIDGE  
HWY 417

SHEET  
1 of 3

THURBER ENGINEERING LTD.

# KEY PLAN



# LEGEND

- N Blows/0.3 (Std. Pen Test, 475 J/blow)
- BOREHOLE
- ⊕ BOREHOLE & CONE
- ▽ WL at time of investigation Apr. 1995
- ▽ WL at time of investigation Aug. 1999

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
95-1	91.5	5 026 872.5	323 474.5
95-2	86.9	5 026 844.1	323 500.1
95-3	84.3	5 026 768.0	323 560.5
95-4	83.0	5 026 727.7	323 612.9
95-5	83.0	5 026 671.4	323 647.5
95-6	83.4	5 026 631.1	323 699.9
95-7	88.1	5 026 603.7	323 708.3
95-8	91.1	5 026 836.3	323 460.5
95-9	87.2	5 026 810.4	323 489.6
95-10	83.4	5 026 745.3	323 542.8
95-11	83.1	5 026 689.0	323 577.4
95-12	83.1	5 026 648.7	323 629.8
95-13	83.5	5 026 597.4	323 663.9
95-14	88.4	5 026 580.1	323 683.5
99-1	91.8	5 026 873	323 472
99-2	91.0	5 026 845	323 447
99-3	92.5	5 026 874	323 445
99-4	88.0	5 026 596	323 723
99-5	87.8	5 026 563	323 698
99-6	88.1	5 026 568	323 721

# NOTES:

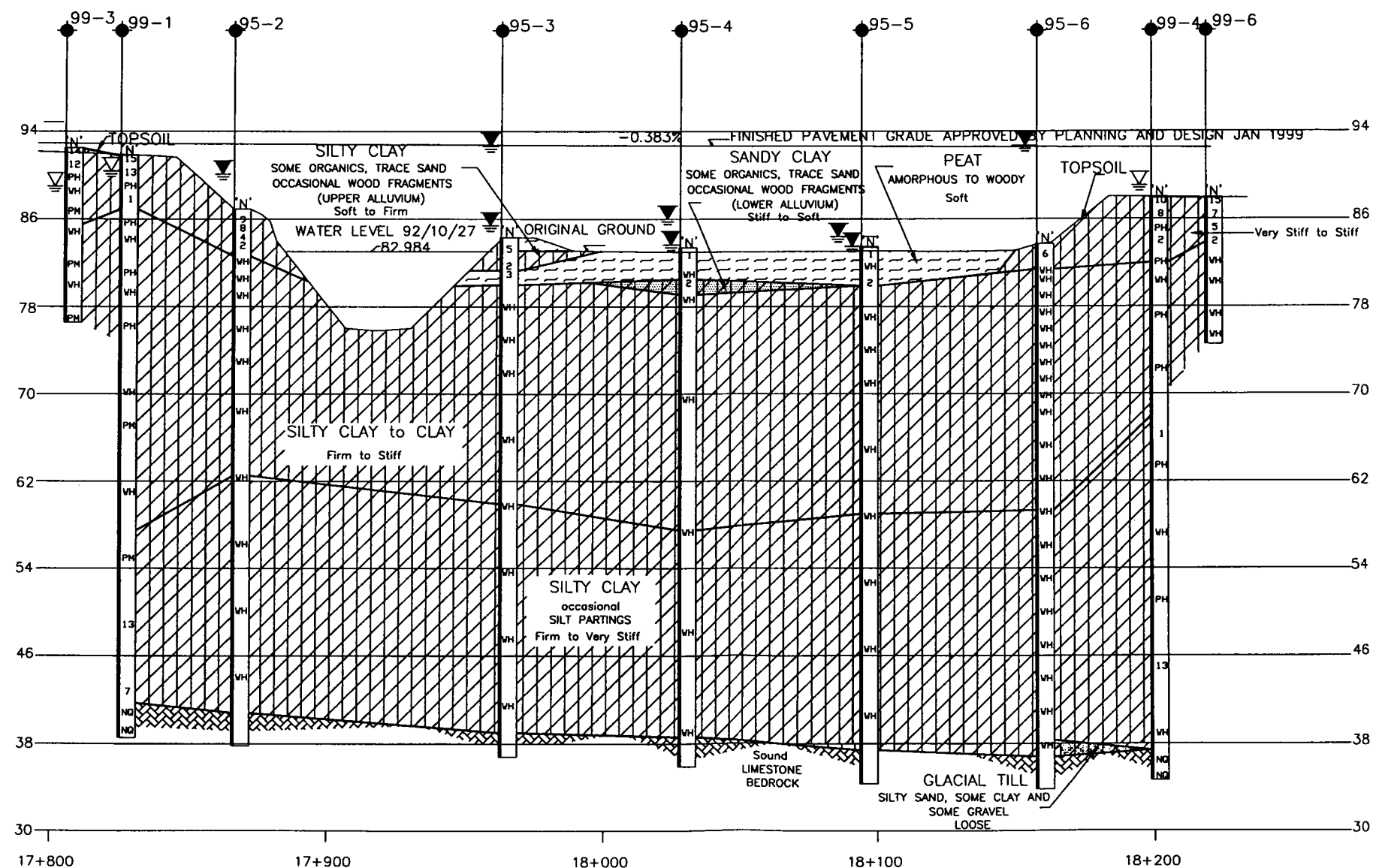
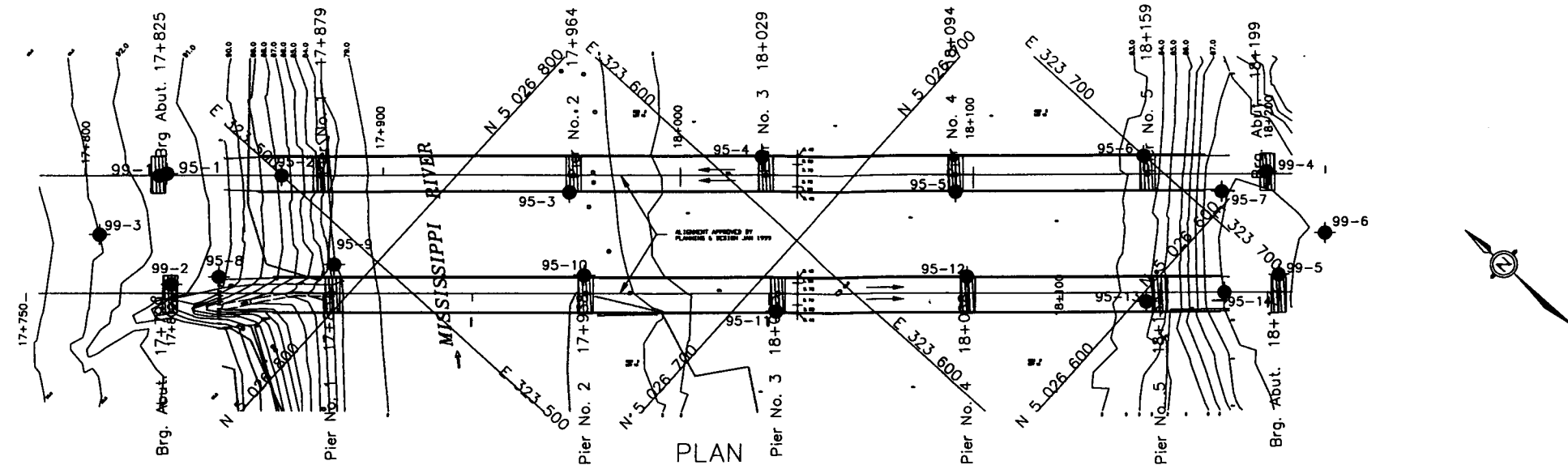
The boundaries between soil strata have been established only at borehole locations. Between boreholes, the boundaries are inferred.

The complete foundation investigation and design report for this project and other related documents may be examined at the Foundations and Pavements office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

DATE	BY	DESCRIPTION
DATE	BY	DESCRIPTION
DATE	BY	DESCRIPTION
DATE	BY	DESCRIPTION
DATE	BY	DESCRIPTION

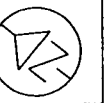
Geacres No 31F-117

HWY No	417	DIST	42
SUBM'D	CHECKED AG	DATE	OCT 15 1999
DRAWN	WM	CHECKED PK	BYG 45190 03/04-A



Q PROFILE WEST BOUND LANES

DIST 42 CR  
CONT No  
WP No 451-90-03/04

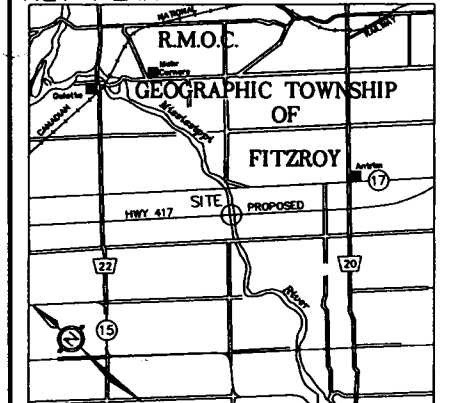


MISSISSIPPI RIVER BRIDGE  
HWY 417

SHEET  
2 of 3

THURBER ENGINEERING LTD.

# KEY PLAN



## LEGEND

- N Blows/0.3 (Std. Pen Test, 475 J/blow)
- BOREHOLE
- BOREHOLE & CONE
- WL at time of investigation Apr. 1995
- WL at time of investigation Aug. 1999

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
95-1	91.5	5 026 872.5	323 474.5
95-2	86.9	5 026 844.1	323 500.1
95-3	84.3	5 026 768.0	323 560.5
95-4	83.0	5 026 727.7	323 612.9
95-5	83.0	5 026 671.4	323 647.5
95-6	83.4	5 026 631.1	323 699.9
95-7	88.1	5 026 603.7	323 708.3
95-8	91.1	5 026 836.3	323 460.5
95-9	87.2	5 026 810.4	323 489.6
95-10	83.4	5 026 745.3	323 542.8
95-11	83.1	5 026 689.0	323 577.4
95-12	83.1	5 026 648.7	323 629.8
95-13	83.5	5 026 597.4	323 663.9
95-14	88.4	5 026 580.1	323 683.5
99-1	91.8	5 026 873	323 472
99-2	91.0	5 026 845	323 447
99-3	92.5	5 026 874	323 445
99-4	88.0	5 026 596	323 723
99-5	87.8	5 026 563	323 563
99-6	88.1	5 026 568	323 721

## NOTES:

The boundaries between soil strata have been established only at borehole locations. Between boreholes, the boundaries are inferred.

The complete foundation investigation and design report for this project and other related documents may be examined at the Foundations and Pavements office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

DATE	BY	DESCRIPTION
1999	31F-117	
HWY No	417	DIST 42
SUBM'D	CHECKED AG	DATE OCT 15 1999 SITE 3-594
DRAWN	WM	CHECKED PK

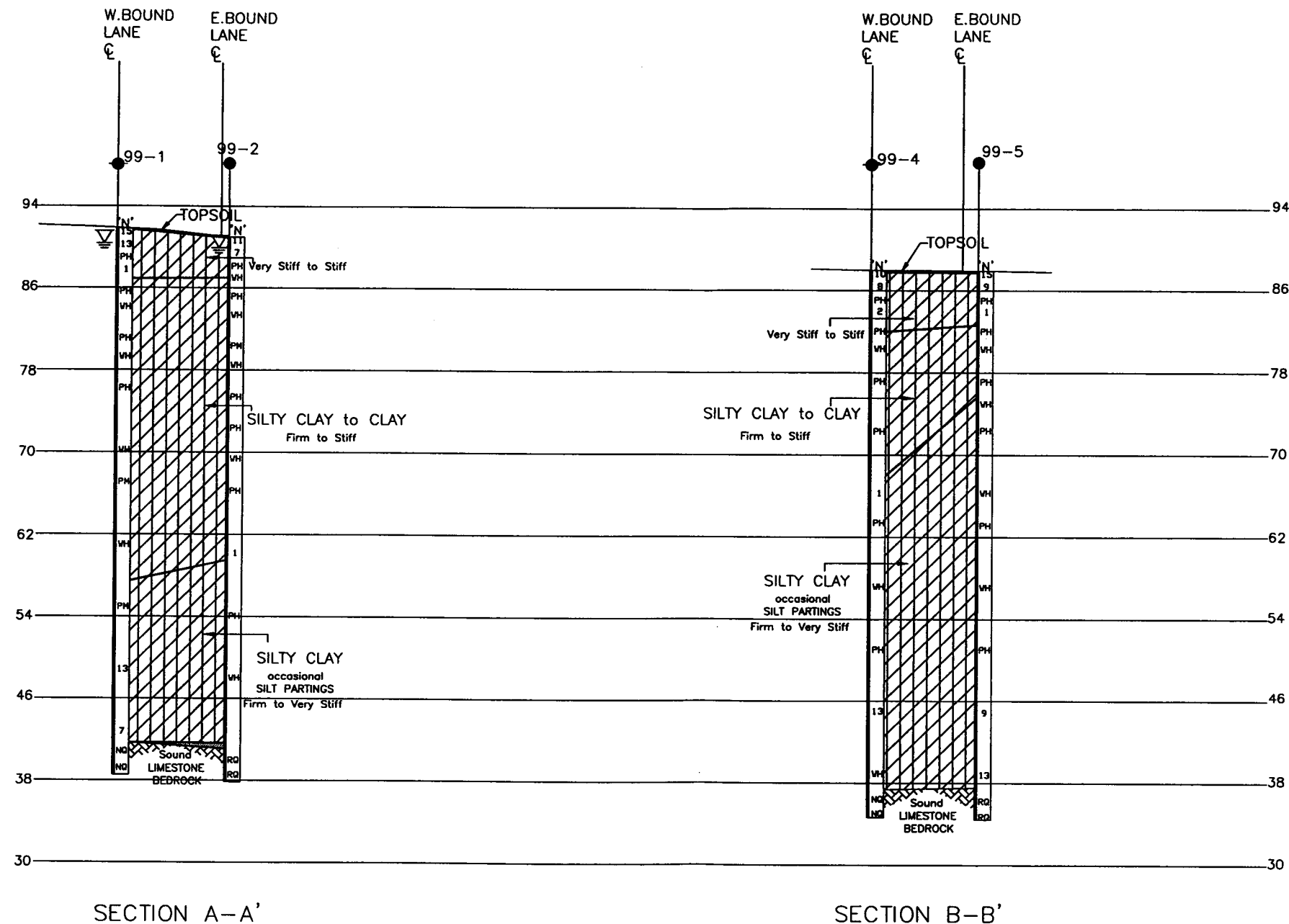


DIST 42 CR  
CONT No  
WP No 451-90-03/04

MISSISSIP RIVER BRIDGE  
HWY 417

SHEET  
3 of 3

THURBER ENGINEERING LTD.



#### LEGEND

- N Blows/0.3 (Std. Pen Test, 475 J/blow)
- BOREHOLE
- BOREHOLE & CONE
- WL at time of investigation Apr. 1995
- WL at time of investigation Aug. 1999

No.	ELEV.	CO-ORDINATES	
		NORTH	EAST
95-1	91.5	5 026 872.5	323 474.5
95-2	86.9	5 026 844.1	323 500.1
95-3	84.3	5 026 768.0	323 560.5
95-4	83.0	5 026 727.7	323 612.9
95-5	83.0	5 026 671.4	323 647.5
95-6	83.4	5 026 631.1	323 699.9
95-7	88.1	5 026 603.7	323 708.3
95-8	91.1	5 026 836.3	323 460.5
95-9	87.2	5 026 810.4	323 489.6
95-10	83.4	5 026 745.3	323 542.8
95-11	83.1	5 026 689.0	323 577.4
95-12	83.1	5 026 648.7	323 629.8
95-13	83.5	5 026 597.4	323 663.9
95-14	88.4	5 026 580.1	323 683.5
99-1	91.8	5 026 873	323 472
99-2	91.0	5 026 845	323 447
99-3	92.5	5 026 874	323 445
99-4	88.0	5 026 596	323 723
99-5	87.8	5 026 563	323 698
99-6	88.1	5 026 568	323 721

#### NOTES:

The boundaries between soil strata have been established only at borehole locations. Between boreholes, the boundaries are inferred.

The complete foundation investigation and design report for this project and other related documents may be examined at the Foundations and Pavements office, Downsview. Information contained in this report and related documents are specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

DATE	BY	DESCRIPTION
31F-117		
Geocres No	31F-117	
HWY No	417	DIST 42
SUBM'D	CHECKED AG	DATE OCT 15 1999 SITE 3-594
DRAWN	VM	CHECKED PK

## **APPENDIX A**

### **BOREHOLE LOGS**

- Symbols and Terms Used on Borehole Logs

- Unified Soil Classification

- Borehole Logs

## SYMBOLS AND TERMS USED ON TEST HOLE LOGS

### 1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	less than 0.002mm	Plastic particles, not visible to the naked eye

### 2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> *N* VALUE
Very Soft	Less than 10	Less than 2
Soft	10 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	greater than 200	Greater than 30






NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer

### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT *N* VALUE
Very Loose	less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

### 5. LEGEND FOR TEST HOLE LOGS

SYMBOLS FOR SAMPLE TYPE	 Shelby Tube	A - Casing
	 SPT	 Grab/Auger sample
	 No Recovery	 Core

- MC - Moisture Content (% by Weight) as determined by sample]

 Water Level

C<sub>vane</sub> Shear Strength Determination by Field Insitu Vane

C<sub>pen</sub> Shear Strength Determination by Pocket Penetrometer

C<sub>lab</sub> Shear Strength Determination using a Laboratory Vane Apparatus

C<sub>u</sub> Undrained Shear Strength determined by Unconfined Compression Test

- (1) SPT Standard Penetration Test - refers to the number the blows from a 63.5kg hammer falling through 0.76m to advance a 60 degree truncated cone 0.3m.

# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ( $W_L < 30\%$ ).
		CI	Inorganic clays of medium plasticity, silty clays. ( $30\% < W_L < 50\%$ ).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
		HIGHLY ORGANIC SOILS	Pt
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

# RECORD OF BOREHOLE No 99-1

1 OF 2

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 873 E 323 472 ORIGINATED BY GA  
 DIST 42 HWY 417 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY WM  
 DATUM Geodetic DATE 99.08.03 - 99.08.05 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT Y kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	
91.8	TOPSOIL		1	SS	15		91					
91.8 0.1	Silty CLAY to CLAY, occasional rootlets very stiff to stiff brown moist to wet becoming grey		2	SS	13		90					
			3	ST	PH		89					
			4	SS	1		88					
86.9							87	3				
4.9	firm, grey, wet		5	ST	PH		86					
			6	SS	WH		85	5				84.370
							84					82.820
							83	3				
			7	ST	PH		82					
							81					
			8	SS	WH		80	3				
							79					
							78	3				
							77					
			9	ST	PH		76					
							75	3				
							74					
							73	2				
							72					
							71					
			10	SS	WH		70					
							69	3				
							68					
			11	ST	PM		67					
							66	4				
							65					
							64					
							63					
							62					

Continued Next Page

+ 3, x 3: Numbers refer to 20  
Sensitivity 15 5  
10 (%) STRAIN AT FAILURE

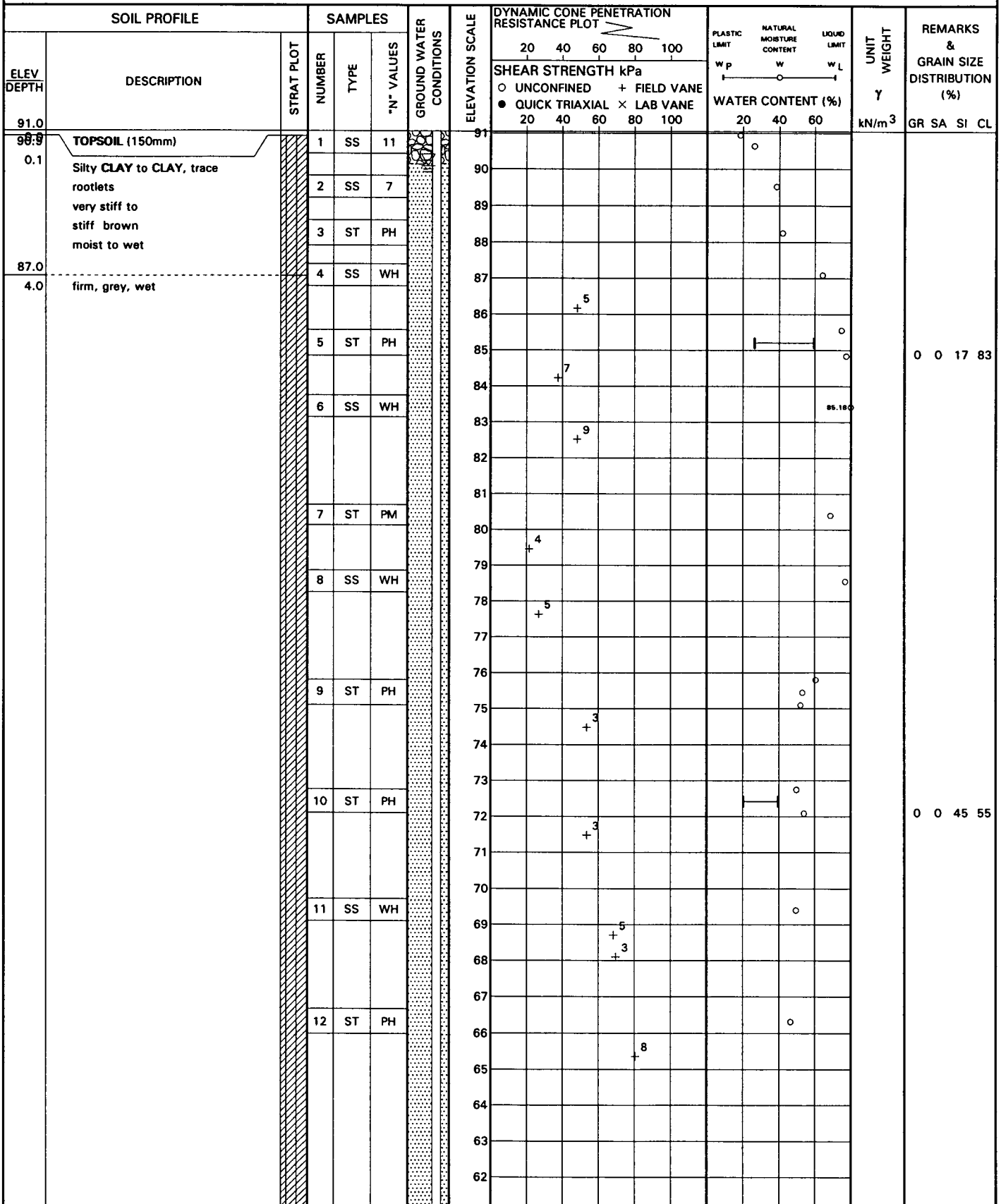


# RECORD OF BOREHOLE No 99-2

1 OF 2

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 845 E 323 447 ORIGINATED BY GA  
DIST 42 HWY 417 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY WM  
DATUM Geodetic DATE 99.07.28 - 99.07.29 CHECKED BY PJB



# RECORD OF BOREHOLE No 99-2

2 OF 2

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 845 E 323 447 ORIGINATED BY GA  
 DIST 42 HWY 417 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY WM  
 DATUM Geodetic DATE 99.07.28 - 99.07.29 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100							
59.5	Silty <b>CLAY</b> very stiff grey wet      becoming hard   occasional fine sand lenses		13	SS	1		61										
31.5							60										
							59				>>	2					
							58										
							57										
							56										
							55										
					14		ST	PH	54								
									53				>>			3	
									52								
						51											
						50											
						49											
			15	SS	WH	48											
						47				>>	3						
						46											
						45											
						44											
						43											
41.7						42											
49.4	Possible <b>SAND</b>					41											
40.7						40											
50.3	<b>LIMESTONE</b> , slightly weathered, grey		16	NQ	RQD	39											
			17	NQ	RQD	38											
37.9																	
53.2	END OF BOREHOLE AT 53.16m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH ELEVATION (m) (m) 04/08/99 0.94 90.06 27/08/99 0.96 90.04																

+ 3, x 3: Numbers refer to  
Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No 99-3

1 OF 1

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 874 E 323 445 ORIGINATED BY GA  
 DIST 42 HWY 417 BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY WM  
 DATUM Geodetic DATE 99.07.28 - 99.07.28 CHECKED BY PJB

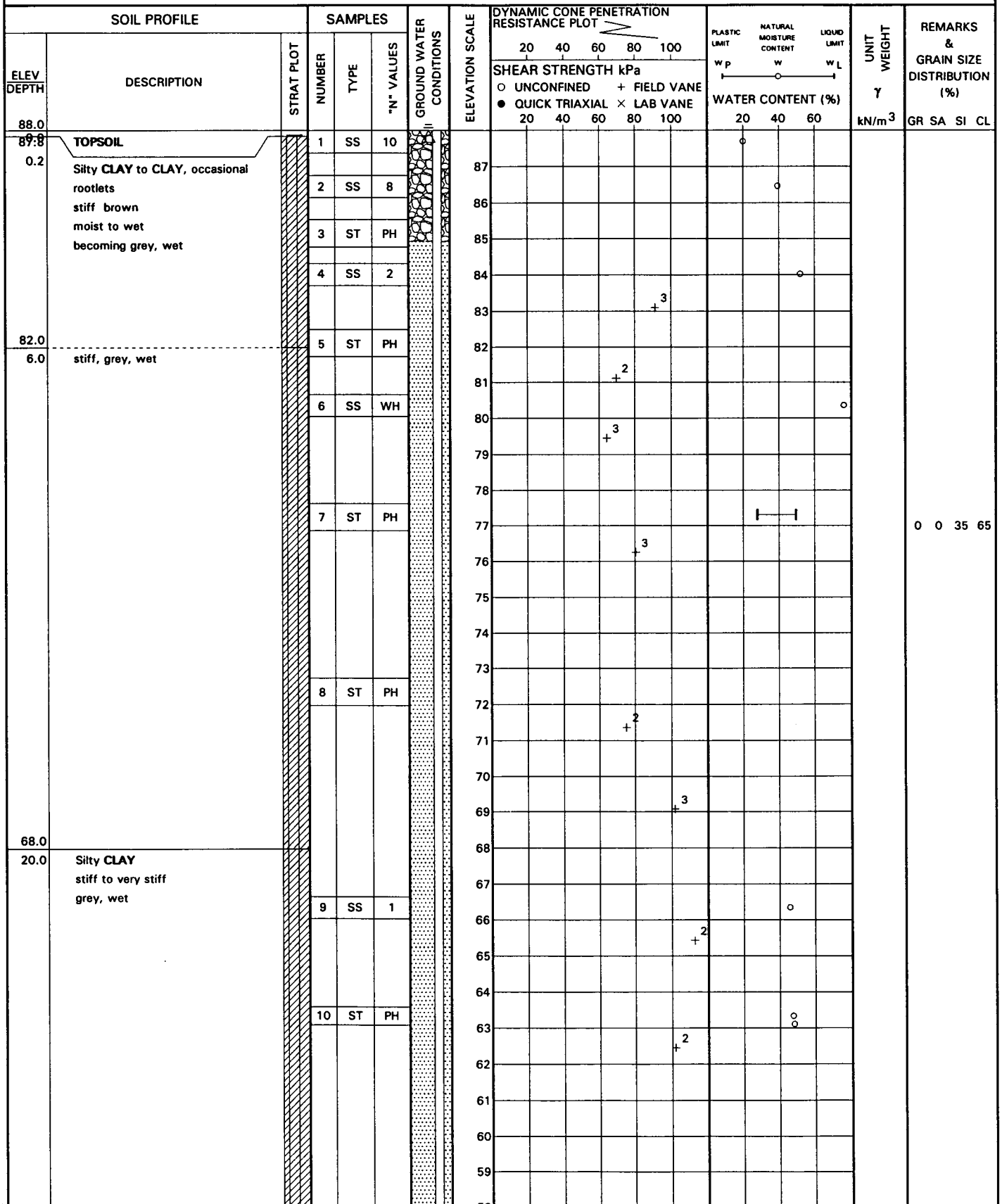
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
92.5	TOPSOIL		1	SS	14		92							
92.2														
0.1	Silty CLAY to CLAY, trace rootlets hard to stiff brown moist to wet		2	SS	12		91							
			3	ST	PH		90							
			4	SS	WH		89							
							88							
			5	ST	PM		87							
85.5							86							
7.0	firm, grey, wet		6	SS	WH		85							
							84							
			7	ST	PM		82							
							81							
			8	SS	WH		80							
							79							
							78							
			9	ST	PM		77							
76.6														
15.9	END OF BOREHOLE AT 15.93m. BOREHOLE OPEN TO 15.85m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH ELEVATION (m) (m) 29/07/99 4.00 88.50 30/07/99 3.97 88.53 03/08/99 2.60 89.90 04/08/99 2.48 90.02 05/08/99 2.51 89.99 27/08/99 3.53 88.97													

# RECORD OF BOREHOLE No 99-4

1 OF 2

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 596 E 323 723 ORIGINATED BY MTB  
 DIST 42 HWY 417 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY WM  
 DATUM Geodetic DATE 99.08.24 - 99.08.26 CHECKED BY PJB



Continued Next Page

+ 3, x 3: Numbers refer to Sensitivity 15 20 10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 99-4

2 OF 2

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 596 E 323 723 ORIGINATED BY MTB  
 DIST 42 HWY 417 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY WM  
 DATUM Geodetic DATE 99.08.24 - 99.08.26 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
			11	SS	WH		57							
							56							
							55							
							54							
							53							
							52							
			12	ST	PH		51							
							50							
							49							
							48							
							47							
							46							
			13	SS	13		45							
							44							
							43							
							42							
							41							
							40							
			14	SS			39							
							38							
37.4							37							
50.6	BEDROCK at 50.62m. Coring started at 50.75m. LIMESTONE, fresh, massive grey with dark grey and black laminations, strong, one sub-horizontal fracture (rough)		15	NQ	RQD		36							REC = 100% RQD = 100%
34.6			16	NQ	RQD		35							REC = 98% RQD = 98%
53.4	END OF BOREHOLE AT 53.36m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH ELEVATION (m) (m) 28/08/99 +1.13 89.13													

RECORD OF BOREHOLE No 99-5

1 OF 2

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 563 E 323 698 ORIGINATED BY MTB  
DIST 42 HWY 417 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY WM  
DATUM Geodetic DATE 99.08.26 - 99.08.27 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
87.8													
87.9	TOPSOIL		1	SS	15								
0.2	Silty CLAY, occasional rootlets very stiff to stiff brown moist to wet grey		2	SS	9								
			3	ST	PH								
			4	SS	1								
82.5													
5.3	firm to stiff grey wet		5	ST	PH								
			6	SS	WH								
			7	ST	PH								
75.5													
12.3	Silty CLAY stiff to very stiff grey wet		8	SS	WH								
			9	ST	PH								
			10	SS	WH								
			11	ST	PH								
	soft to firm around 25.8m												

Continued Next Page

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 99-5

2 OF 2

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 563 E 323 698 ORIGINATED BY MTB  
DIST 42 HWY 417 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY WM  
DATUM Geodetic DATE 99.08.26 - 99.08.27 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100					
			12	SS	WH		57							
							56							
							55							
							54							
							53							
							52							
			13	ST	PH		51							
							50							
							49							
							48							
							47							
							46							
			14	SS	9		45							
							44							
							43							
							42							
							41							
							40							
			15	SS	13		39							
37.5							38							
50.4	Bedrock at 50.39m. Coring Started at 50.47m. <b>LIMESTONE</b> , fresh, dark grey laminations, strong, fine sub-horizontal fractures, grey		16	NQ	RQD		37							REC = 93% RQD = 93%
			17	NQ	RQD		36							
34.3							35							REC = 100% RQD = 96%
53.5	END OF BOREHOLE AT 53.52m.													

# RECORD OF BOREHOLE No 99-6

1 OF 1

METRIC

W.P. 451-90-03/04 LOCATION N 5 026 568 E 323 721 ORIGINATED BY MTB  
 DIST 42 HWY 417 BOREHOLE TYPE 210mm HOLLOW STEM AUGERS COMPILED BY WM  
 DATUM Geodetic DATE 99.08.28 - 99.08.28 CHECKED BY PJB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
88.1														
88.8	TOPSOIL		1	SS	15									
0.1	Silty CLAY to CLAY, occasional rootlets hard to very stiff brown moist to wet becoming grey		2	SS	7									
			3	SS	5									
84.0			4	SS	2									
4.1	stiff, grey, wet													
	becoming stiff		5	SS	WH									
			6	SS	WH									
			7	SS	WH									
			8	SS	WH									
74.7														
13.4	END OF BOREHOLE AT 13.41m. BOREHOLE OPEN TO 13.41m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.													

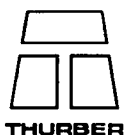
+ 3, x 3: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

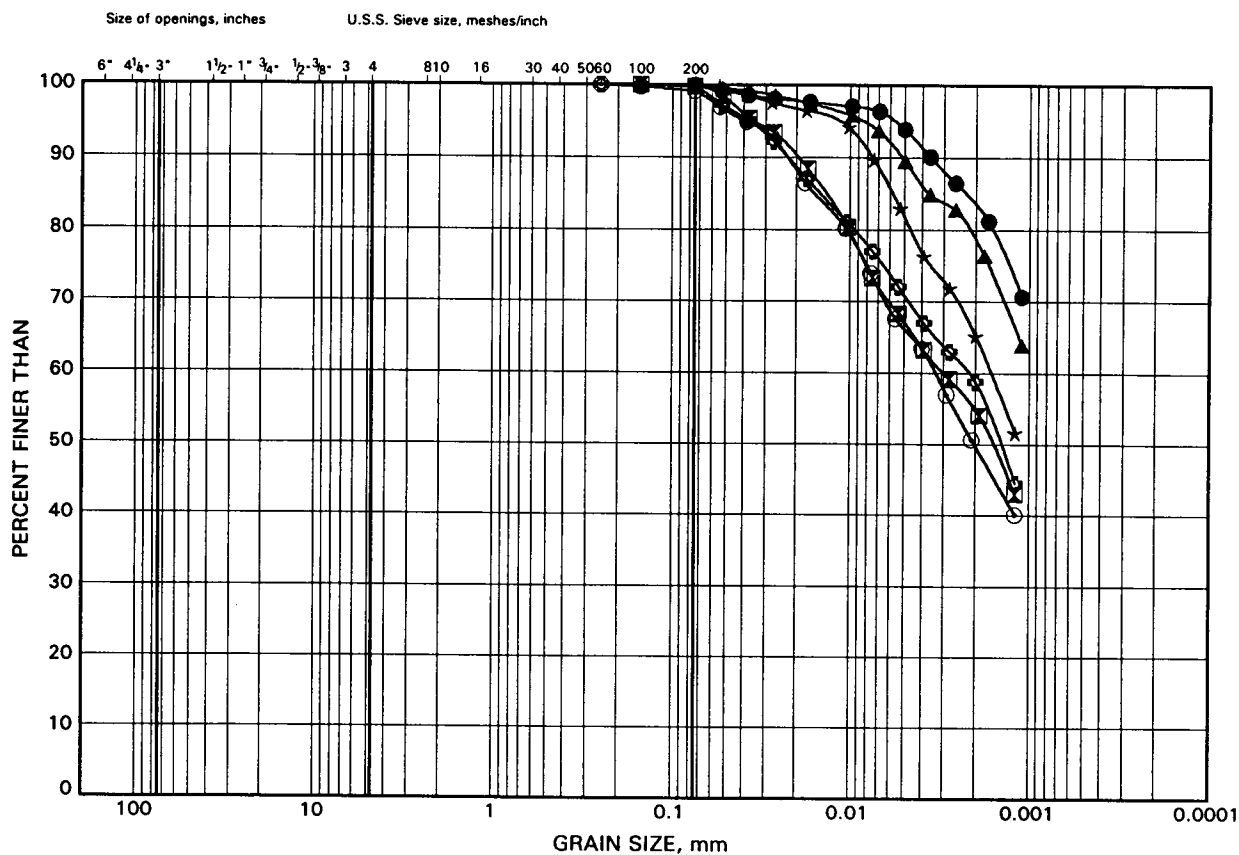
**APPENDIX B**

**LABORATORY TEST RESULTS**



# Mississippi River Bridge Supplementary Investigation GRAIN SIZE DISTRIBUTION

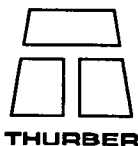
FIGURE B1



COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

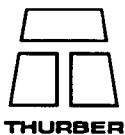
SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	99-2	5.84	85.20
⊠	99-2	18.62	72.42
▲	99-3	10.64	81.86
★	99-4	10.67	77.31
⊙	99-5	15.49	72.36
⊕	99-5	24.70	63.15

Date October 1999  
Project 451-90-03/04



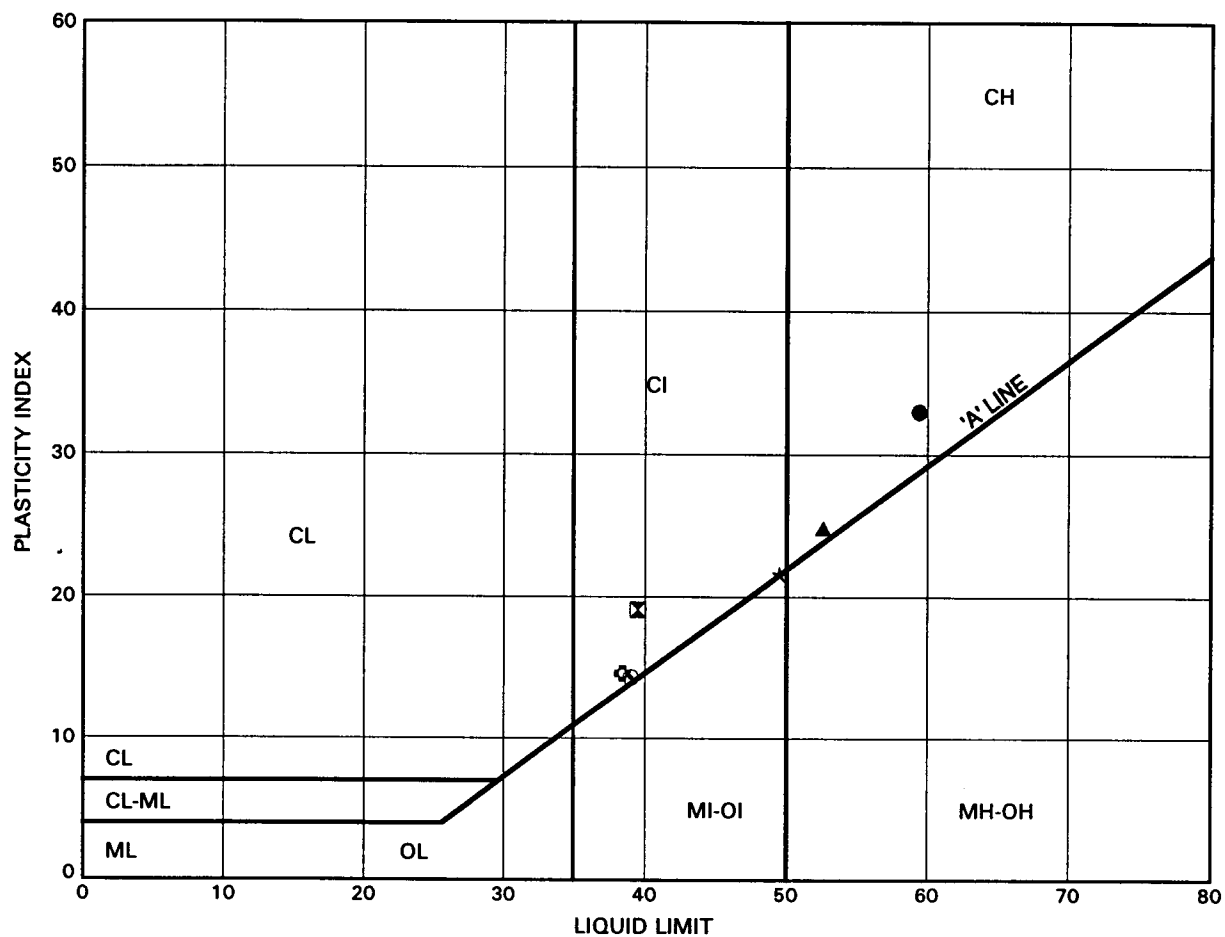
Prep'd WM  
Chkd. PJB





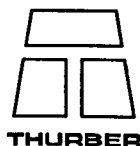
Mississippi River Bridge Supplementary Investigation  
**ATTERBERG LIMITS TEST RESULTS**

FIGURE B2



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	99-2	5.84	85.20
⊠	99-2	18.62	72.42
▲	99-3	10.64	81.86
★	99-4	10.67	77.31
⊙	99-5	15.49	72.36
⊕	99-5	24.70	63.15

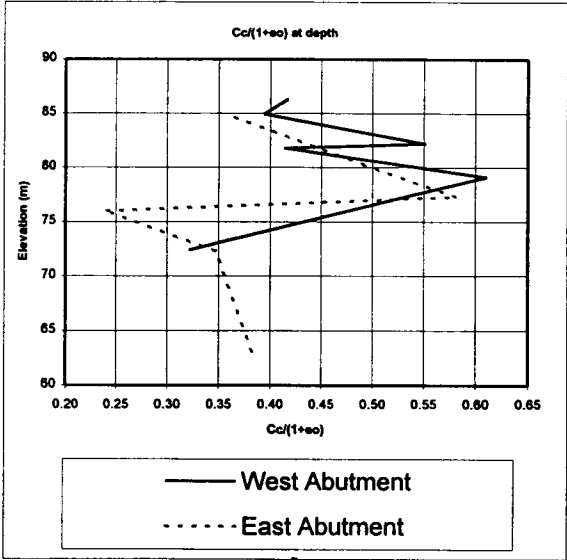
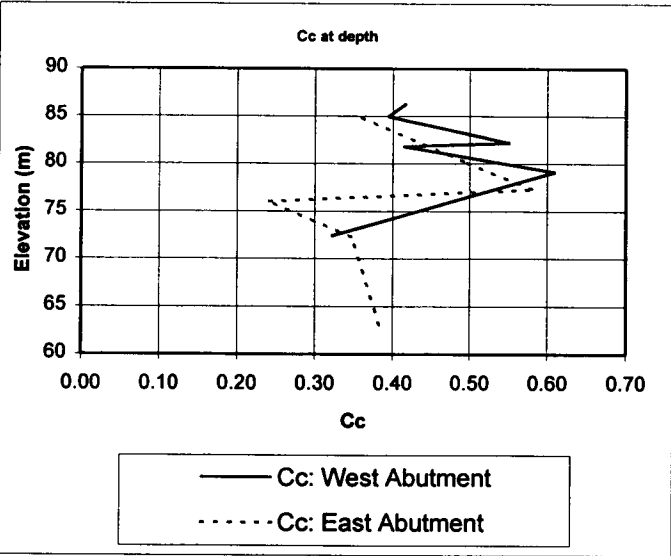
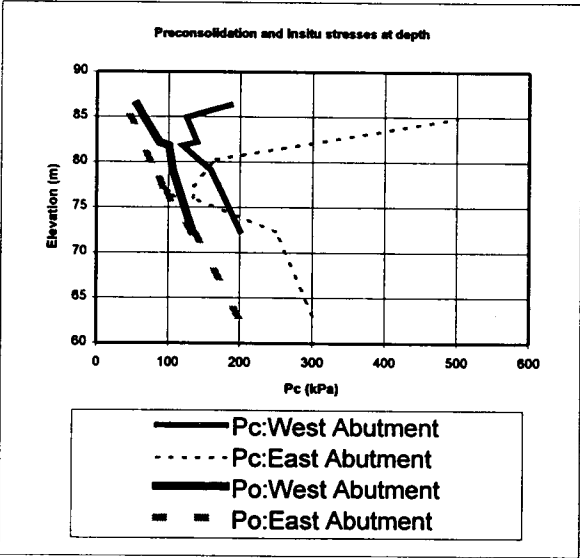
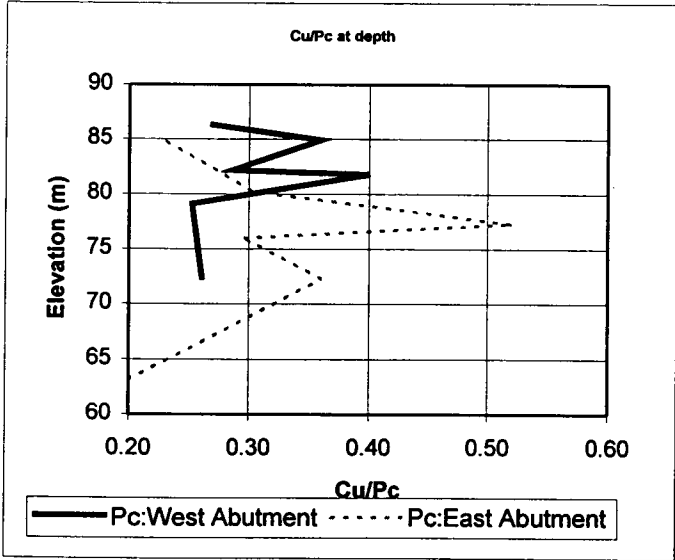
Date October 1999  
Project 451-90-03/04



Prep'd WM  
Chkd. PJB

MISSISSIPPI RIVER BRIDGE  
SUMMARY OF OEDOMETER TEST RESULTS

Layer Description	Location	Borehole	Sample #	Elevation (m)	Depth (m)	nit Weigh (kN/m³)	Wl (%)	Wp (%)	W (%)	eo	po (kPa)	pc (kPa)	Cc	Cc/(1+eo)	Cr	Cr/(1+eo)	Cu (kPa)	Cu/pc	OCR	Cv	
														0.451		0.024				10 <sup>-6</sup> m²/s	10 <sup>-7</sup> m²/s
														WEST ABUTMENT							
Upper Silty Clay	WA/EBL	99-2	5	72.38	18.62	16.8	39	20	54	1.461	133.6	200	0.79	0.321	0.04	0.016	52	0.26	1.50	p<pc	p>pc
	WA/WBL	95-1	9	79.1	12.42	15.6	59	25	65.6	1.82	106	159	1.72	0.610	0.055	0.020	40	0.25	1.50	1.48	3.79
	WA/CLditch	99-3	3	81.77	10.73	15.7	53	28	72.1	1.95	100.5	120	1.22	0.414	0.13	0.044	48	0.40	1.19		
	WA/WBL	95-1	7	82.15	9.37	15.1	64	28	77.3	2.1	87	140	1.71	0.552	0.07	0.023	40	0.29	1.61	1.59	1.94
	WA/EBL	99-2	2	84.91	6.09	15.1	59.4	26	81.2	2.226	65.7	125	1.27	0.394	0.08	0.025	45	0.36	1.90		
Crust	WA/EBL	95-8	4	86.3	4.8	15.7	61	28	68.9	1.83	55	186	1.18	0.417	0.053	0.019	50	0.27	3.38	1.19	5.18
EAST ABUTMENT																					
Upper Silty Clay	EA/EBL	99-5	5	63.1	24.7	17	38	23.8	49	1.328	198.8	300	0.89	0.382	0.06	0.026	60	0.20	1.51		
	EA/EBL	99-5	4	72.3	15.5	17	39	24.7	50.6	1.339	134.4	250	0.81	0.346	0.04	0.017	90	0.36	1.86	4.23	8.43
	EA/EBL	95-14	9	76	12.42	16.4	42	22	55	1.49	103	135	0.6	0.241	0.021	0.008	40	0.30	1.31	5.85	5.85
	EA/WBL	99-4	3	77.3	10.7	15.4	50	28	71.6	1.946	92.9	135	1.71	0.580	0.08	0.027	70	0.52	1.45		
	EA/WBL	95-7	6	80.25	7.85	15.3	56	26	75	2.03	76	166	1.49	0.492	0.074	0.024	50	0.30	2.18	2.28	2.93
Crust	EA/WBL	95-7	3	84.85	3.28	17.2	61	26	47.5	0.56	45	500	0.56	0.359	0.05	0.032	115	0.23	11.11		



**OEDOMETER CONSOLIDATION SUMMARY****SAMPLE IDENTIFICATION**

Project Number	991-101050	Sample Number	3
Borehole Number	99-4	Sample Depth, m	10.4-11.0

**TEST CONDITIONS**

Test Type	Standard	Load Duration, hours	24
Oedometer Number	6		
Date Started	99-09-01		
Date Completed	99-09-09		

**SAMPLE DIMENSIONS AND PROPERTIES - INITIAL**

Sample Height, cm	1.91	Unit Weight, kN/m <sup>3</sup>	15.42
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	8.99
Area, cm <sup>2</sup>	31.62	Specific Gravity, assumed	2.70
Volume, cm <sup>3</sup>	60.23	Solids Height, cm	0.65
Water Content, %	71.58	Volume of Solids, cm <sup>3</sup>	20.45
Wet Mass, g	94.73	Volume of Voids, cm <sup>3</sup>	39.79
Dry Mass, g	55.21	Degree of Saturation, %	99.3

**TEST COMPUTATIONS**

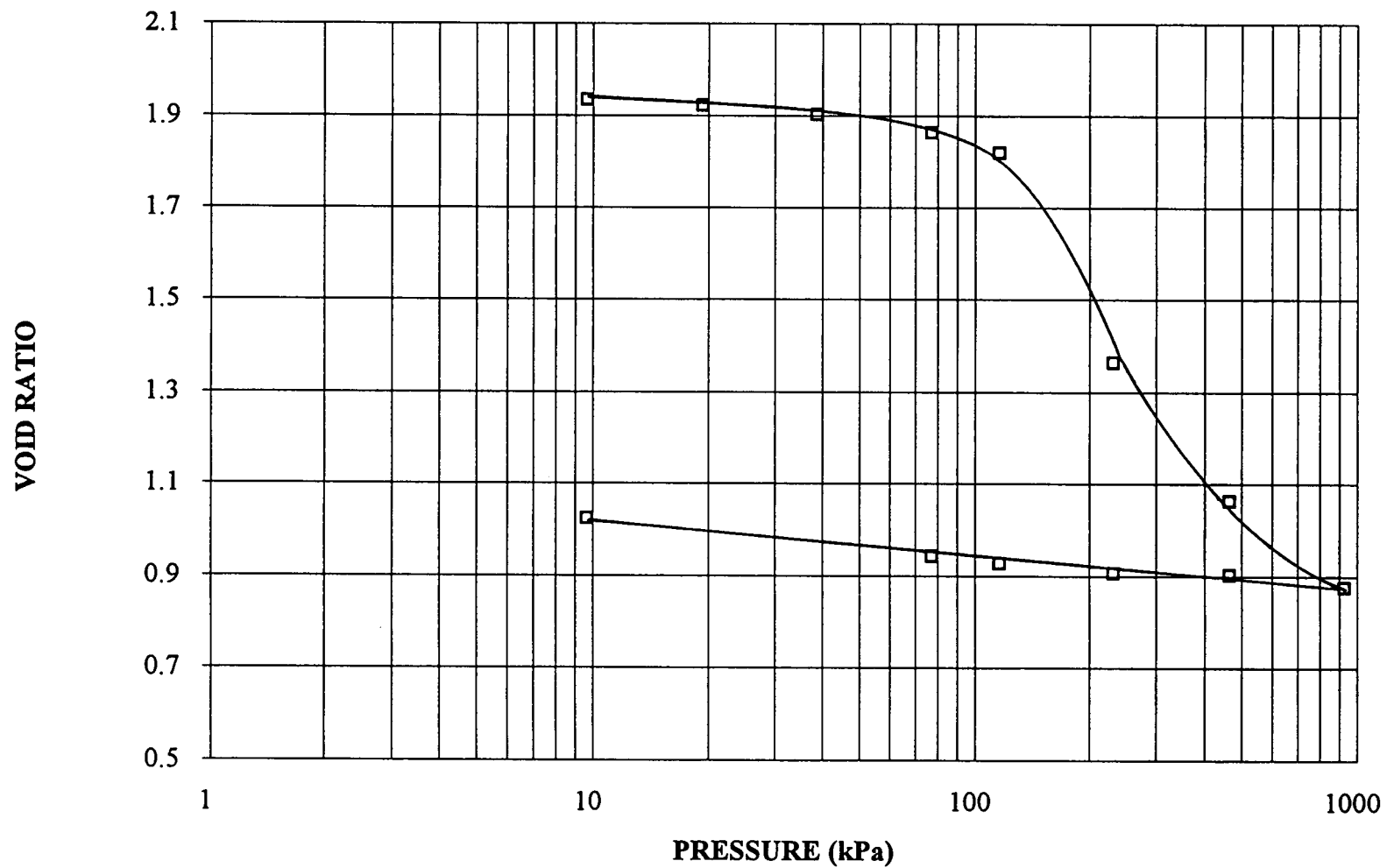
Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.905	1.946	1.905				
9.67	1.897	1.934	1.901	26	2.95E-02	4.29E-04	1.24E-06
19.34	1.890	1.922	1.893	49	1.55E-02	4.02E-04	6.10E-07
38.69	1.877	1.903	1.883	21	3.58E-02	3.42E-04	1.20E-06
77.37	1.852	1.863	1.864	32	2.30E-02	3.46E-04	7.81E-07
116.06	1.824	1.820	1.838	69	1.04E-02	3.80E-04	3.86E-07
232.11	1.528	1.363	1.676	128	4.65E-03	1.34E-03	6.09E-07
464.23	1.334	1.062	1.431	984	4.41E-04	4.39E-04	1.90E-08
928.46	1.213	0.876	1.273	93	3.70E-03	1.37E-04	4.95E-08
464.23	1.231	0.903	1.222				
232.11	1.233	0.906	1.232				
116.06	1.246	0.927	1.240				
77.37	1.256	0.942	1.251				
9.67	1.309	1.024	1.282				

Notes:

k calculated using cv based on t<sub>90</sub> values.**SAMPLE DIMENSIONS AND PROPERTIES - FINAL**

Sample Height, cm	1.31	Unit Weight, kN/m <sup>3</sup>	18.37
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	13.09
Area, cm <sup>2</sup>	31.62	Specific Gravity, assumed	2.70
Volume, cm <sup>3</sup>	41.38	Solids Height, cm	0.65
Water Content, %	40.37	Volume of Solids, cm <sup>3</sup>	20.45
Wet Mass, g	77.5	Volume of Voids, cm <sup>3</sup>	20.93
Dry Mass, g	55.21		

CONSOLIDATION TEST  
VOID RATIO vs LOG. PRESSURE  
BH 99-4 SA 3



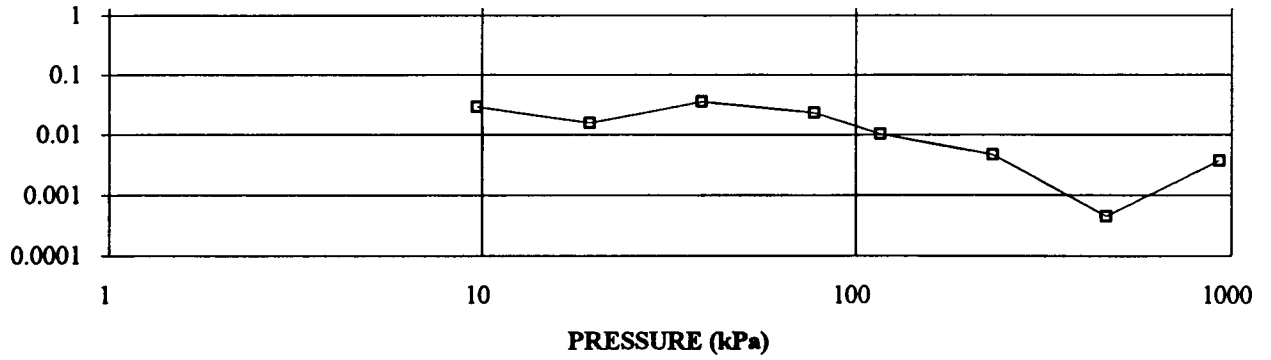
CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

FIGURE

# OEDOMETER CONSOLIDATION SUMMARY

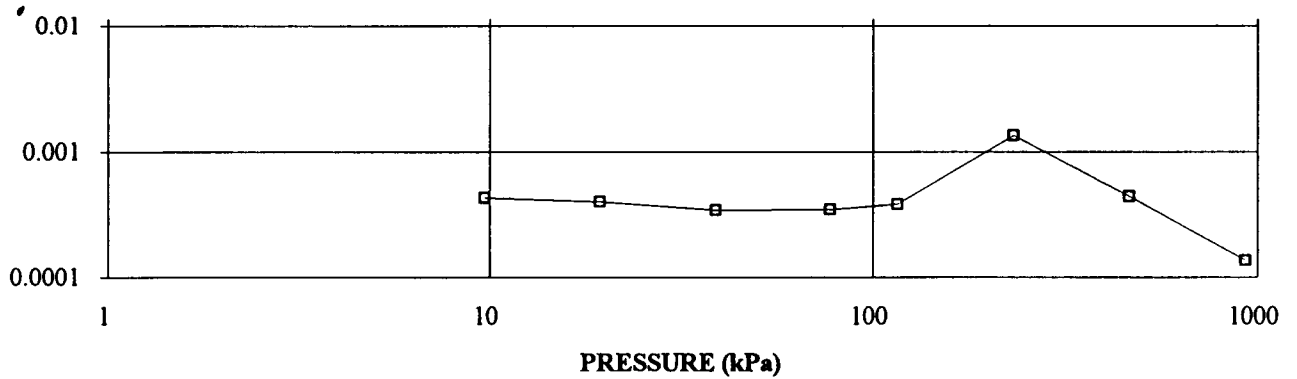
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $c_v$   $\text{cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
BH 99-4 SA 3



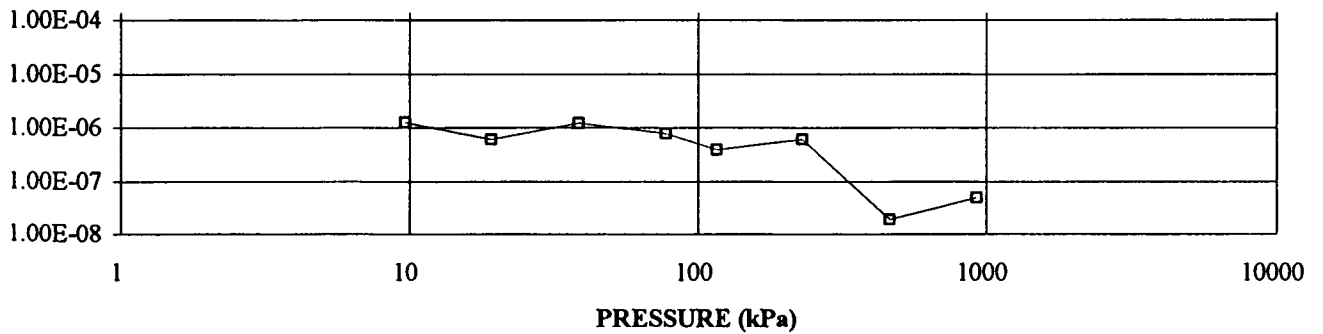
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $m_v$ ,  $\text{m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
BH 99-4 SA 3



HYDRAULIC  
CONDUCTIVITY,  $\text{cm/s}$

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
BH 99-4 SA 3



## OEDOMETER CONSOLIDATION SUMMARY

### SAMPLE IDENTIFICATION

Project Number	991-101050	Sample Number	5
Borehole Number	99-5	Sample Depth, m	24.4-25.0

### TEST CONDITIONS

Test Type	Standard	Load Duration, hours	24
Oedometer Number	7		
Date Started	99-09-01		
Date Completed	99-09-09		

### SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m <sup>3</sup>	16.95
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	11.38
Area, cm <sup>2</sup>	31.55	Specific Gravity, assumed	2.70
Volume, cm <sup>3</sup>	60.10	Solids Height, cm	0.82
Water Content, %	49.04	Volume of Solids, cm <sup>3</sup>	25.82
Wet Mass, g	103.91	Volume of Voids, cm <sup>3</sup>	34.28
Dry Mass, g	69.72	Degree of Saturation, %	99.7

### TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.905	1.328	1.905				
9.69	1.861	1.273	1.883	7	1.07E-01	2.41E-03	2.54E-05
19.39	1.855	1.266	1.858	19	3.85E-02	3.20E-04	1.21E-06
38.77	1.844	1.253	1.849	44	1.65E-02	2.84E-04	4.59E-07
77.54	1.825	1.229	1.834	19	3.75E-02	2.64E-04	9.71E-07
116.31	1.811	1.213	1.818	39	1.80E-02	1.81E-04	3.19E-07
232.63	1.766	1.158	1.789	151	4.49E-03	2.03E-04	8.94E-08
465.26	1.597	0.951	1.682	46	1.30E-02	3.81E-04	4.87E-07
930.51	1.450	0.771	1.524	63	7.81E-03	1.66E-04	1.27E-07
465.26	1.460	0.783	1.455				
232.63	1.471	0.797	1.465				
116.31	1.485	0.814	1.478				
77.54	1.493	0.824	1.489				
9.69	1.546	0.888	1.519				

Notes:

k calculated using cv based on t<sub>90</sub> values.

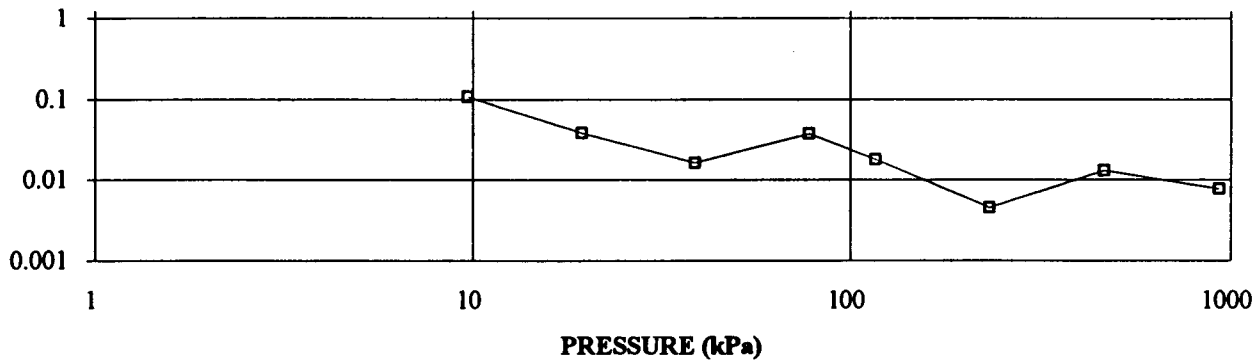
### SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.55	Unit Weight, kN/m <sup>3</sup>	19.22
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	14.02
Area, cm <sup>2</sup>	31.55	Specific Gravity, assumed	2.70
Volume, cm <sup>3</sup>	48.76	Solids Height, cm	0.82
Water Content, %	37.05	Volume of Solids, cm <sup>3</sup>	25.82
Wet Mass, g	95.55	Volume of Voids, cm <sup>3</sup>	22.94
Dry Mass, g	69.72		

# OEDOMETER CONSOLIDATION SUMMARY

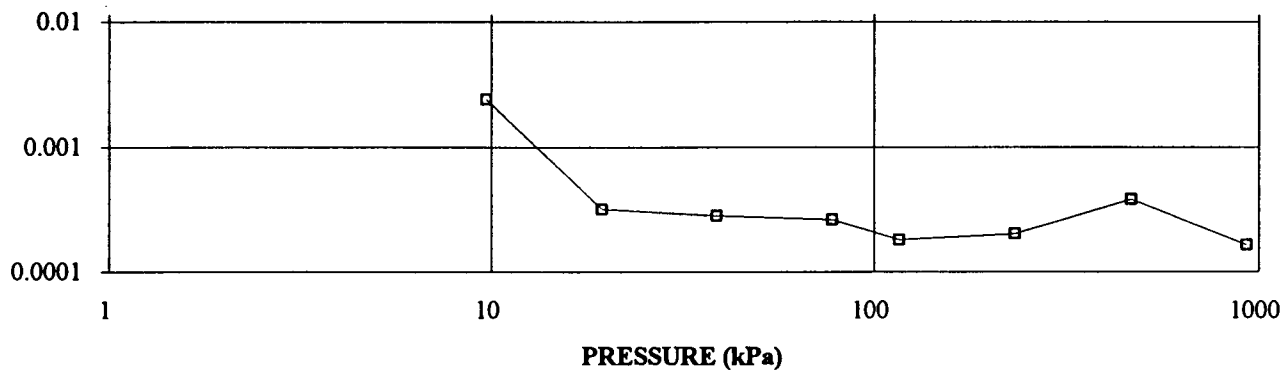
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $\text{cv}$   $\text{cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
BH 99-5 SA 5



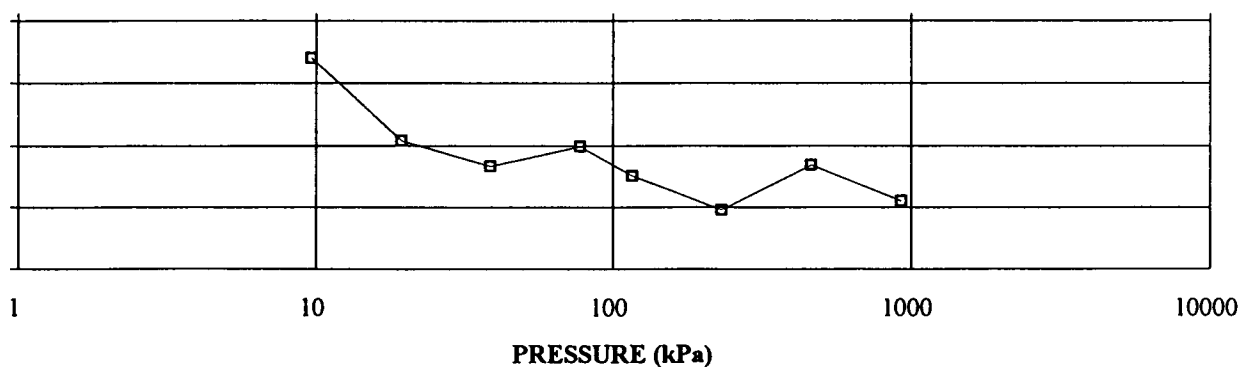
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $\text{mv}$ ,  $\text{m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
BH 99-5 SA 5

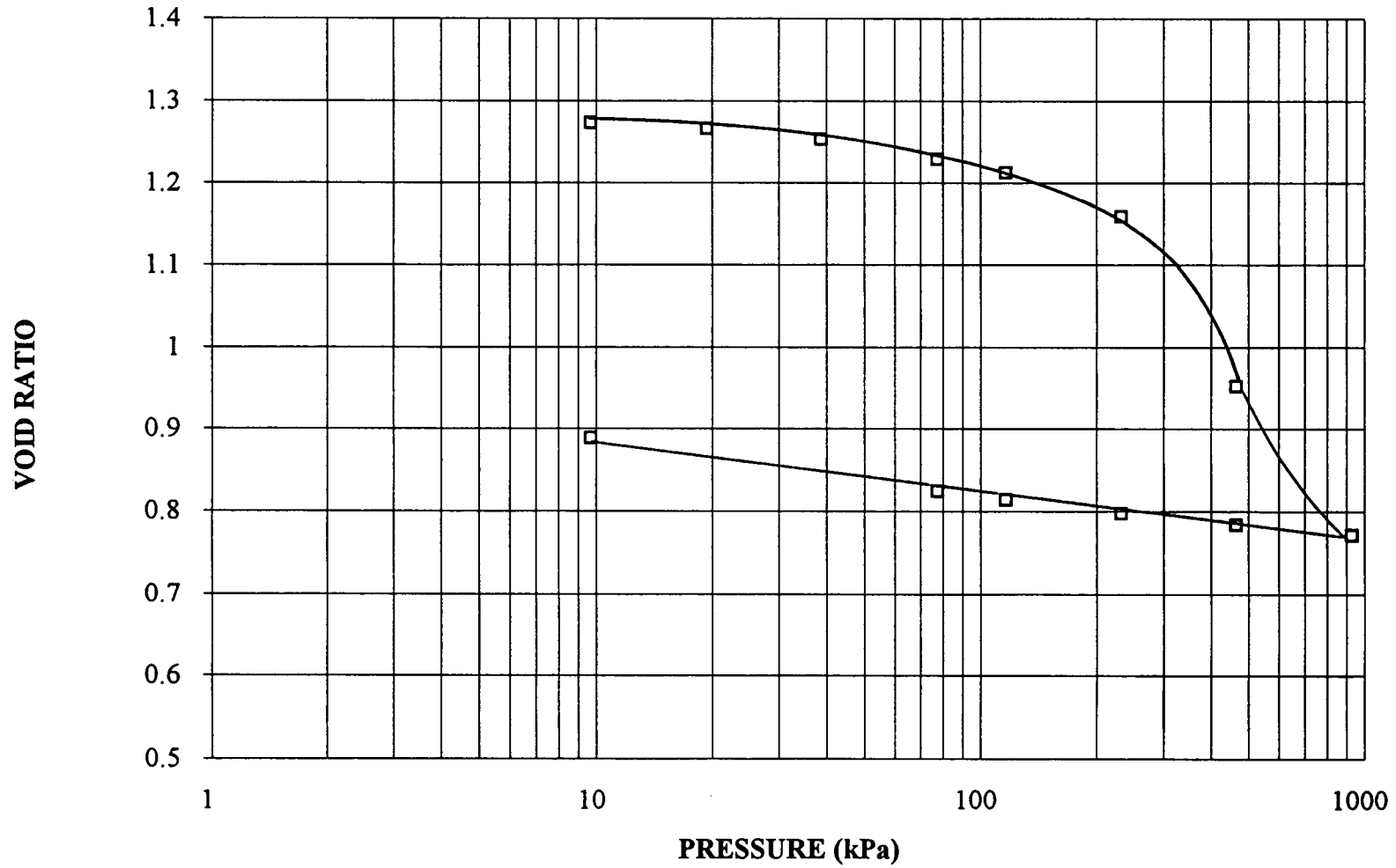


HYDRAULIC  
CONDUCTIVITY,  $\text{cm}/\text{s}$

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
BH 99-5 SA 5



CONSOLIDATION TEST  
VOID RATIO vs LOG. PRESSURE  
BH 99-5 SA 5



CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

FIGURE



## OEDOMETER CONSOLIDATION SUMMARY

### SAMPLE IDENTIFICATION

Project Number	991-101050	Sample Number	4
Borehole Number	99-5	Sample Depth, m	15.2-15.8

### TEST CONDITIONS

Test Type	Standard	Load Duration, hours	24
Oedometer Number	5		
Date Started	99-09-01		
Date Completed	99-09-09		

### SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m <sup>3</sup>	17.04
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m <sup>3</sup>	11.32
Area, cm <sup>2</sup>	31.50	Specific Gravity, assumed	2.70
Volume, cm <sup>3</sup>	59.98	Solids Height, cm	0.81
Water Content, %	50.57	Volume of Solids, cm <sup>3</sup>	25.64
Wet Mass, g	104.24	Volume of Voids, cm <sup>3</sup>	34.34
Dry Mass, g	69.23	Degree of Saturation, %	102.0

### TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.904	1.339	1.904				
9.71	1.807	1.220	1.856	3	2.43E-01	5.23E-03	1.25E-04
19.42	1.791	1.201	1.799	14	4.90E-02	8.71E-04	4.18E-06
38.83	1.778	1.184	1.785	37	1.82E-02	3.57E-04	6.39E-07
77.67	1.754	1.154	1.766	37	1.79E-02	3.30E-04	5.78E-07
116.50	1.733	1.129	1.744	46	1.40E-02	2.73E-04	3.75E-07
233.00	1.649	1.026	1.691	69	8.79E-03	3.81E-04	3.28E-07
465.99	1.477	0.815	1.563	212	2.44E-03	3.87E-04	9.27E-08
931.98	1.356	0.666	1.417	46	9.25E-03	1.36E-04	1.23E-07
465.99	1.362	0.673	1.359				
233.00	1.372	0.686	1.367				
116.50	1.383	0.699	1.378				
77.67	1.392	0.710	1.388				
9.71	1.425	0.750	1.408				

Notes:

k calculated using cv based on t<sub>90</sub> values.

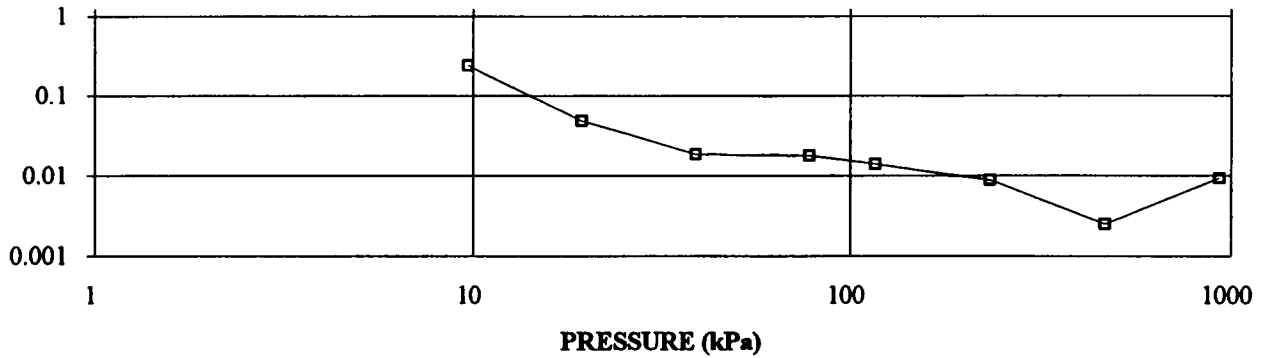
### SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.42	Unit Weight, kN/m <sup>3</sup>	20.44
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m <sup>3</sup>	15.13
Area, cm <sup>2</sup>	31.50	Specific Gravity, assumed	2.70
Volume, cm <sup>3</sup>	44.87	Solids Height, cm	0.81
Water Content, %	35.10	Volume of Solids, cm <sup>3</sup>	25.64
Wet Mass, g	93.53	Volume of Voids, cm <sup>3</sup>	19.23
Dry Mass, g	69.23		

# OEDOMETER CONSOLIDATION SUMMARY

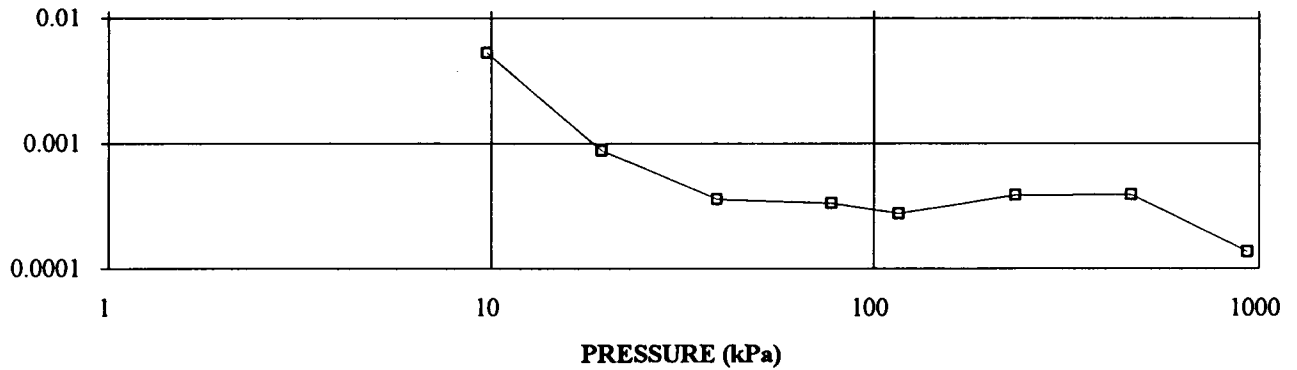
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $\text{cv cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
BH 99-5 SA 4



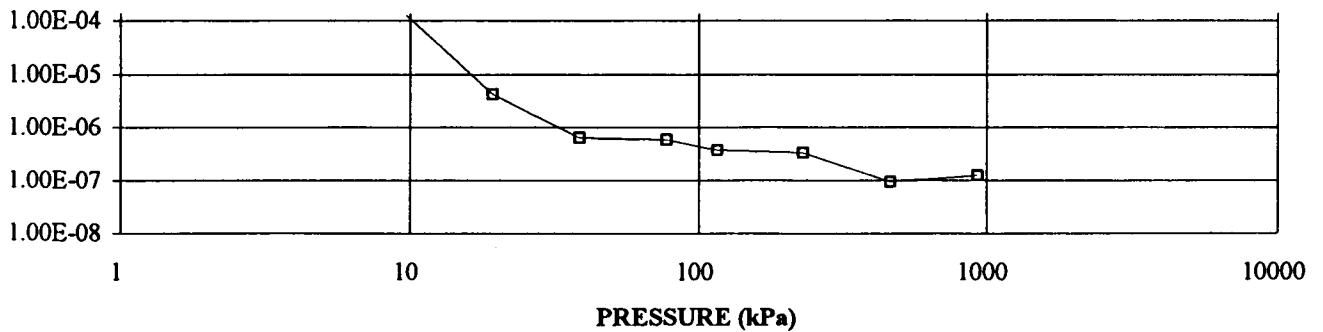
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $\text{mv, m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
BH 99-5 SA 4

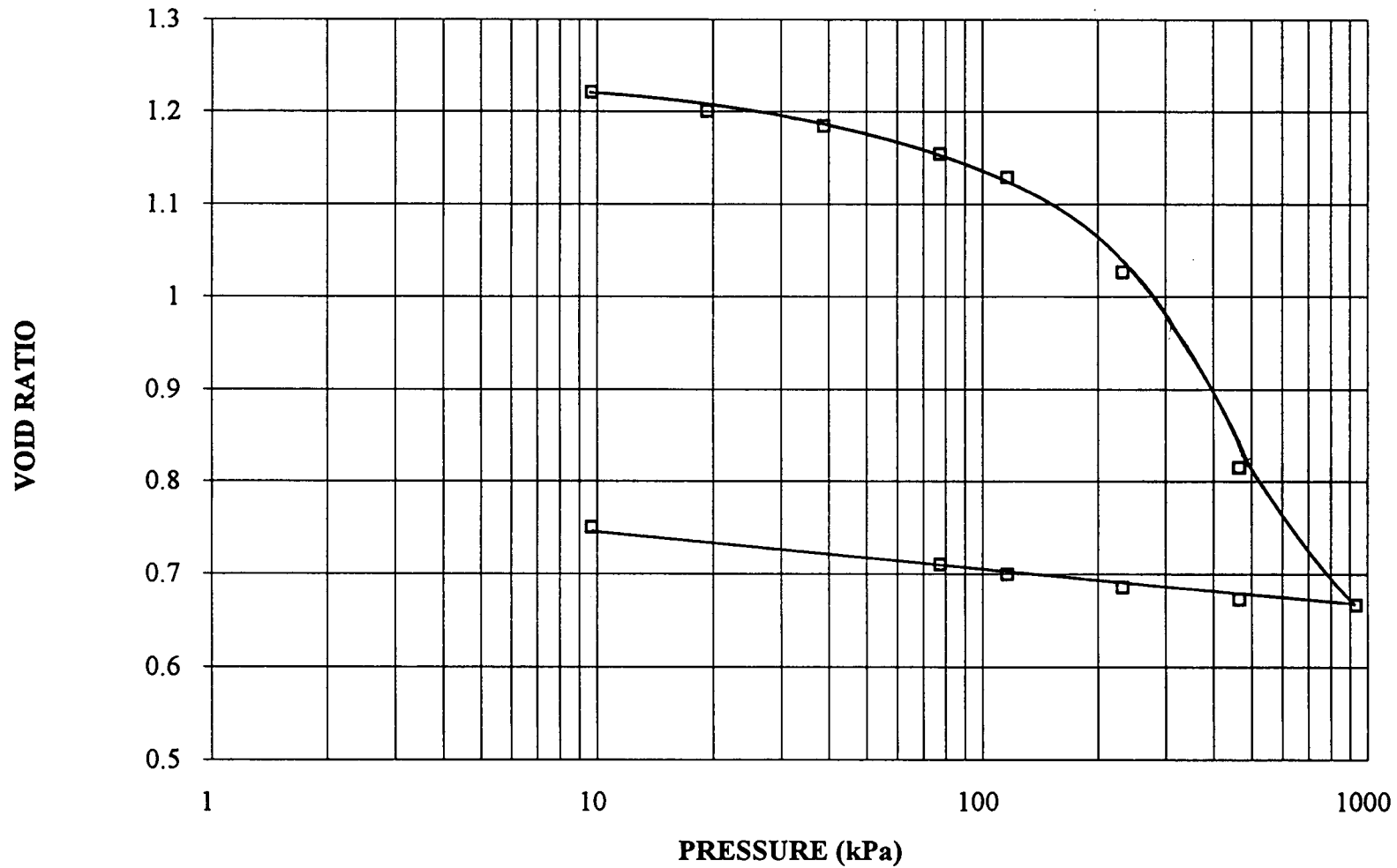


HYDRAULIC  
CONDUCTIVITY,  $\text{cm/s}$

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
BH 99-5 SA 4



**CONSOLIDATION TEST  
VOID RATIO vs LOG. PRESSURE  
BH 99-5 SA 4**



**CONSOLIDATION TEST  
VOID RATIO vs. LOG PRESSURE**

**FIGURE**

# OEDOMETER CONSOLIDATION SUMMARY

## SAMPLE IDENTIFICATION

Project Number	991-101050	Sample Number	99-2
Borehole Number	PH 2	Sample Depth, m	6.09

## TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	6		
Date Started	99-08-05		
Date Completed	99-08-13		

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m <sup>3</sup>	15.10
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	8.33
Area, cm <sup>2</sup>	31.62	Specific Gravity, assumed	2.74
Volume, cm <sup>3</sup>	60.23	Solids Height, cm	0.591
Water Content, %	81.20	Volume of Solids, cm <sup>3</sup>	18.67
Wet Mass, g	92.72	Volume of Voids, cm <sup>3</sup>	41.56
Dry Mass, g	51.16	Degree of Saturation, %	99.9

## TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv, cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.905	2.226	1.905				
9.67	1.896	2.211	1.901	63	1.22E-02	4.78E-04	5.69E-07
19.34	1.891	2.202	1.894	57	1.33E-02	2.82E-04	3.69E-07
38.69	1.881	2.185	1.886	74	1.02E-02	2.77E-04	2.76E-07
77.37	1.863	2.155	1.872	76	9.77E-03	2.42E-04	2.31E-07
116.06	1.843	2.121	1.853	66	1.10E-02	2.75E-04	2.98E-07
232.11	1.649	1.793	1.746	165	3.92E-03	8.75E-04	3.36E-07
464.23	1.380	1.337	1.515	1106	4.40E-04	6.09E-04	2.63E-08
928.46	1.232	1.085	1.306	480	7.53E-04	1.68E-04	1.24E-08
464.23	1.241	1.102	1.236				
232.11	1.252	1.120	1.247				
116.06	1.269	1.149	1.261				
58.03	1.286	1.177	1.278				
9.98	1.316	1.229	1.301				

Notes:

k calculated using cv based on t<sub>90</sub> values.

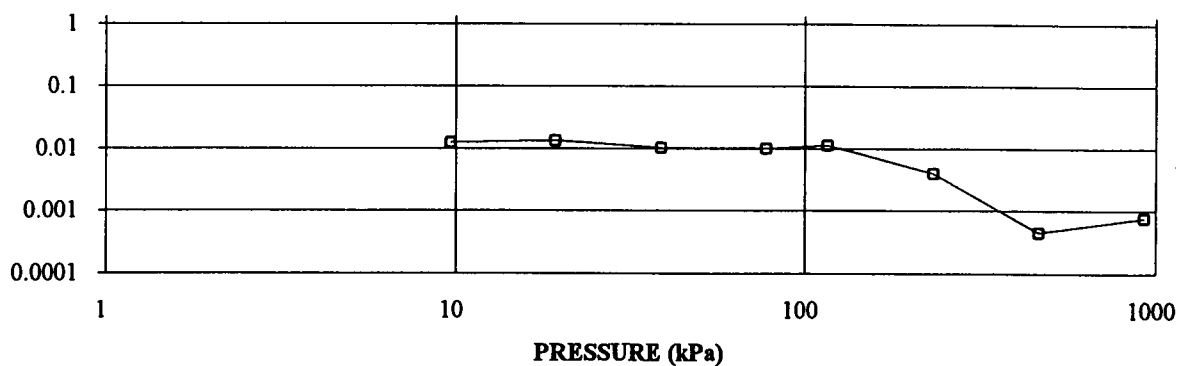
## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.32	Unit Weight, kN/m <sup>3</sup>	17.97
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	10.47
Area, cm <sup>2</sup>	31.62	Specific Gravity, assumed	2.74
Volume, cm <sup>3</sup>	41.61	Solids Height, cm	0.591
Water Content, %	71.7	Volume of Solids, cm <sup>3</sup>	18.67
Wet Mass, g	76.25	Volume of Voids, cm <sup>3</sup>	22.94
Dry Mass, g	51.16		

# OEDOMETER CONSOLIDATION SUMMARY

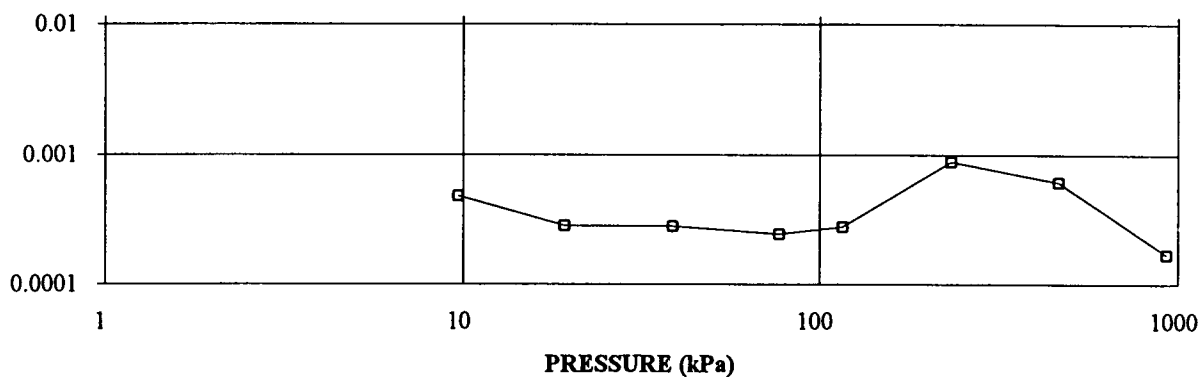
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $\text{cv cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
PH 2 SA 99-2



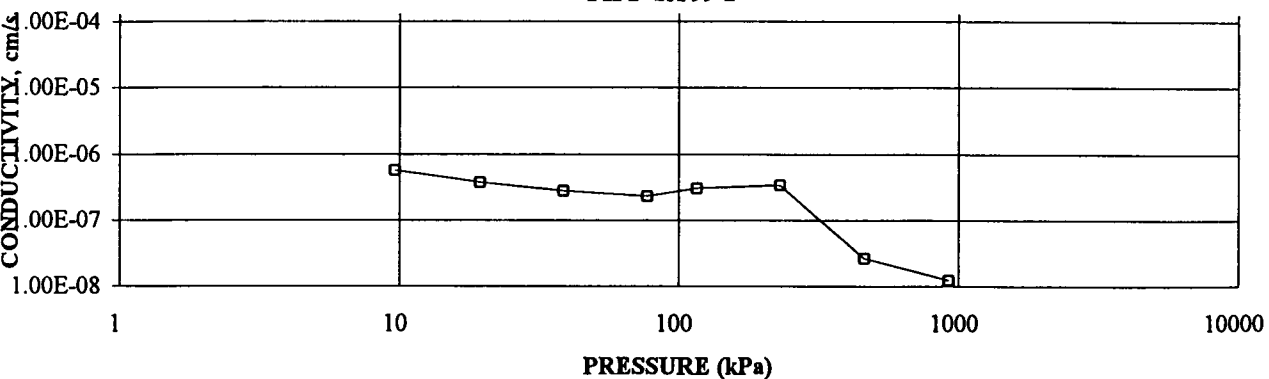
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $\text{mv, m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
PH 2 SA 99-2



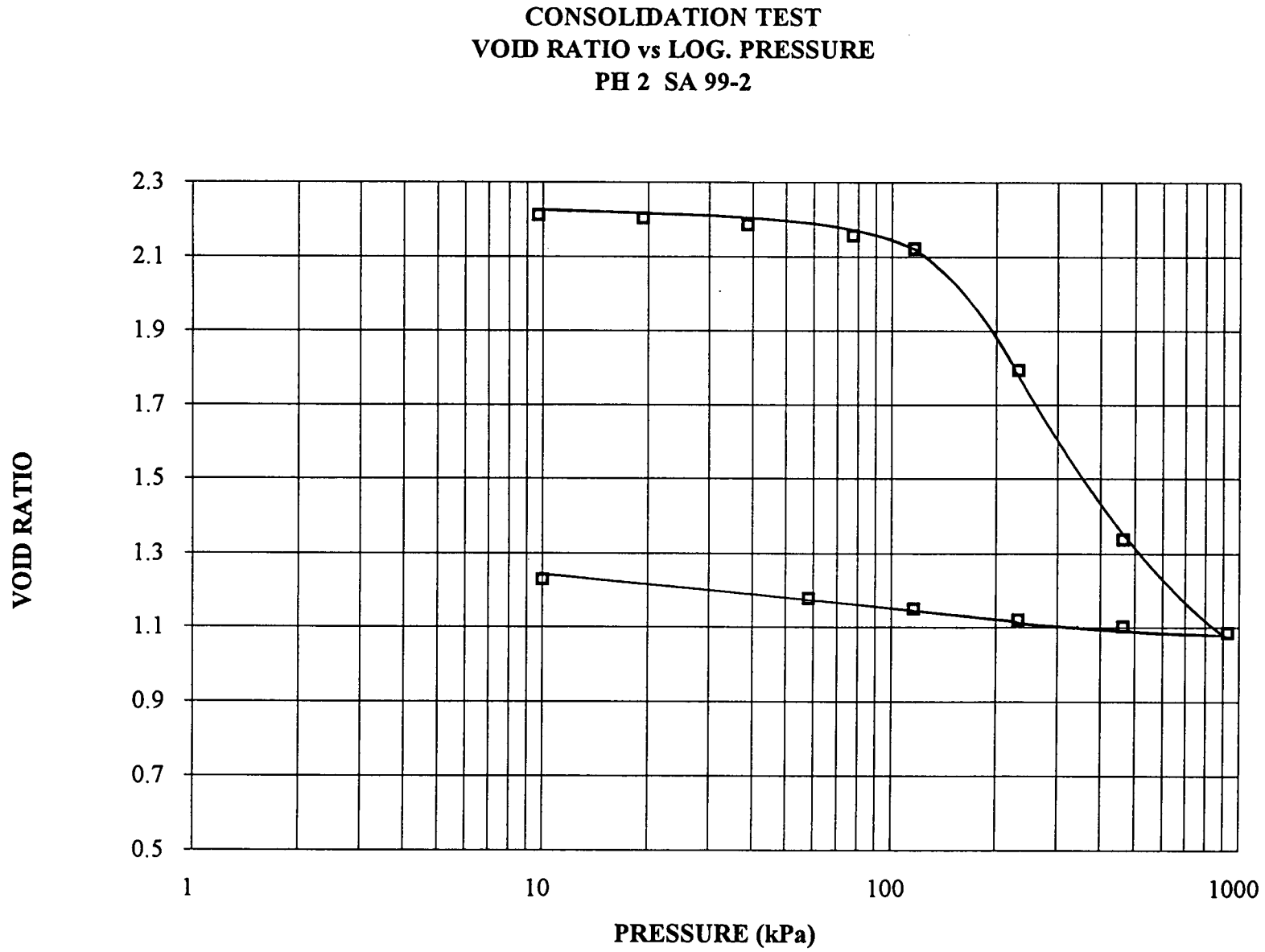
HYDRAULIC  
CONDUCTIVITY,  $\text{cm/s}$

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
PH 2 SA 99-2



CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

FIGURE



# OEDOMETER CONSOLIDATION SUMMARY

## SAMPLE IDENTIFICATION

Project Number	991-101050	Sample Number	99-3
Borehole Number	PH 3	Sample Depth, m	10.73

## TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	5		
Date Started	99-08-05		
Date Completed	99-08-13		

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m <sup>3</sup>	15.68
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m <sup>3</sup>	9.11
Area, cm <sup>2</sup>	31.50	Specific Gravity, measured	2.74
Volume, cm <sup>3</sup>	59.98	Solids Height, cm	0.645
Water Content, %	72.10	Volume of Solids, cm <sup>3</sup>	20.33
Wet Mass, g	95.89	Volume of Voids, cm <sup>3</sup>	39.64
Dry Mass, g	55.71	Degree of Saturation, %	101.3

## TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv, cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.904	1.950	1.904				
9.71	1.873	1.901	1.888	26	2.91E-02	1.70E-03	4.84E-06
19.42	1.865	1.889	1.869	32	2.31E-02	4.17E-04	9.45E-07
38.83	1.846	1.859	1.855	100	7.30E-03	5.19E-04	3.71E-07
77.67	1.814	1.810	1.830	170	4.17E-03	4.35E-04	1.78E-07
116.50	1.771	1.744	1.792	128	5.32E-03	5.75E-04	3.00E-07
233.00	1.537	1.381	1.654	2488	2.33E-04	1.06E-03	2.41E-08
465.99	1.366	1.116	1.451	631	7.08E-04	3.85E-04	2.67E-08
931.98	1.247	0.931	1.306	240	1.51E-03	1.34E-04	1.99E-08
465.99	1.257	0.948	1.252				
233.00	1.271	0.969	1.264				
116.50	1.293	1.003	1.282				
58.25	1.312	1.032	1.302				
9.71	1.345	1.084	1.329				

Notes:

k calculated using cv based on t<sub>90</sub> values.

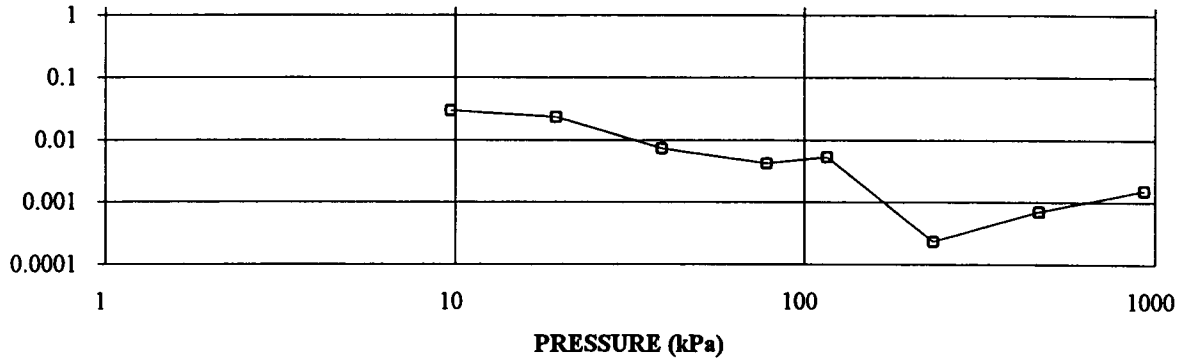
## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.35	Unit Weight, kN/m <sup>3</sup>	18.96
Sample Diameter, cm	6.33	Dry Unit Weight, kN/m <sup>3</sup>	12.90
Area, cm <sup>2</sup>	31.50	Specific Gravity, measured	2.74
Volume, cm <sup>3</sup>	42.37	Solids Height, cm	0.645
Water Content, %	47.0	Volume of Solids, cm <sup>3</sup>	20.33
Wet Mass, g	81.92	Volume of Voids, cm <sup>3</sup>	22.04
Dry Mass, g	55.71		

# OEDOMETER CONSOLIDATION SUMMARY

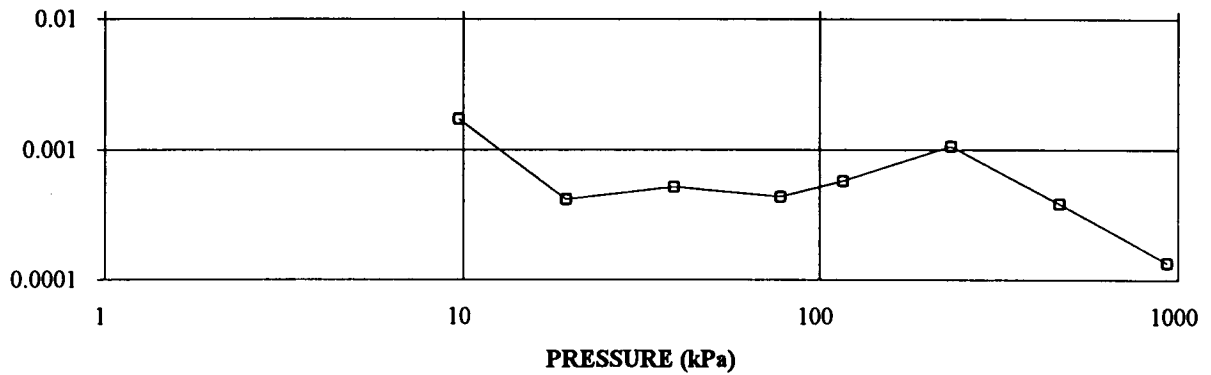
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $c_v$   $\text{cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
PH 3 SA 99-3



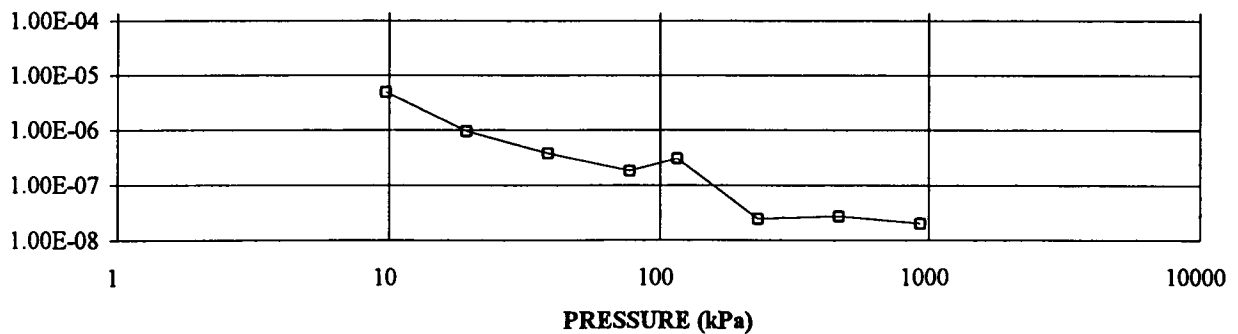
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $m_v$ ,  $\text{m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
PH 3 SA 99-3



HYDRAULIC  
CONDUCTIVITY,  $\text{cm/s}$

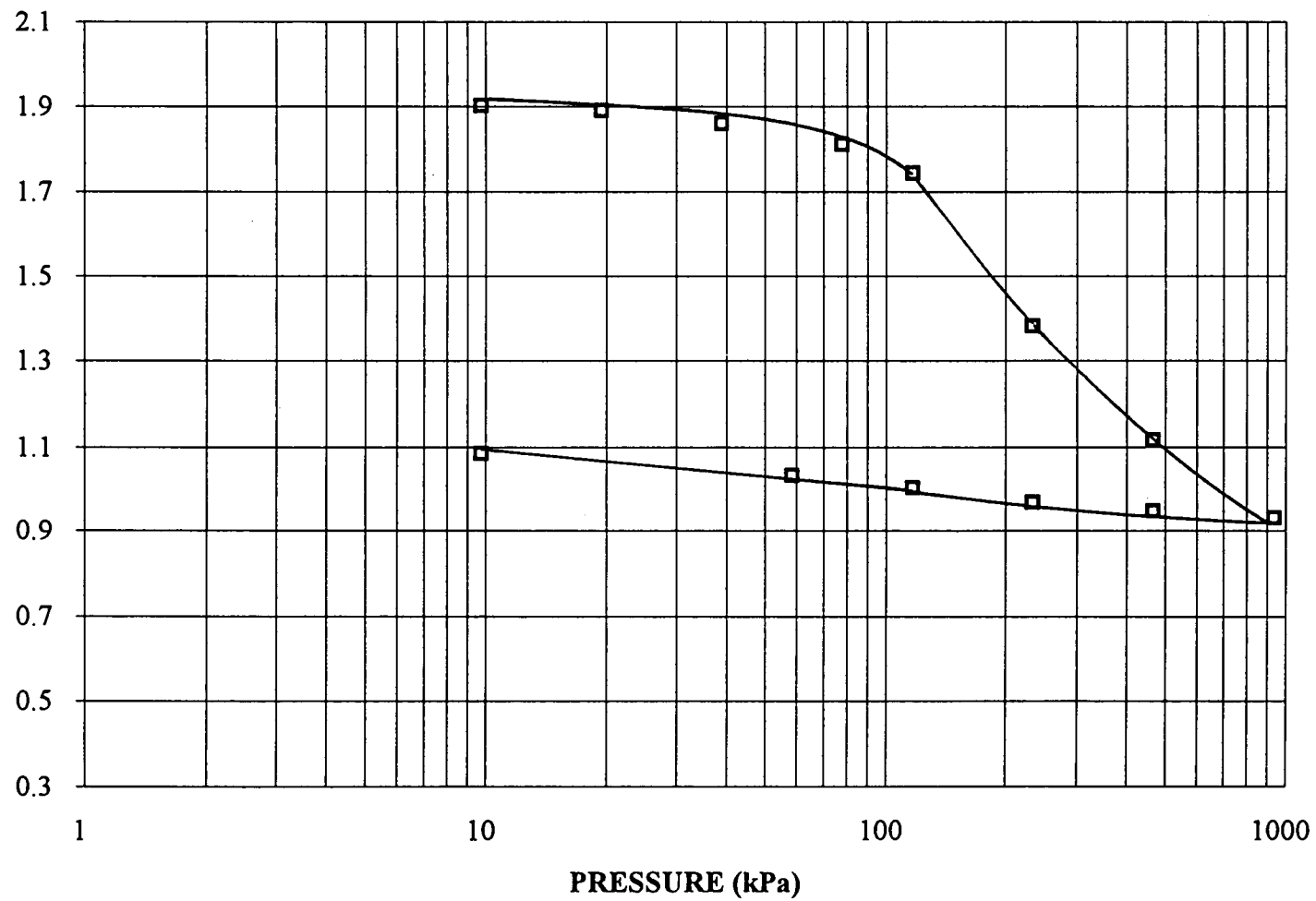
CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
PH 3 SA 99-3





## VOID RATIO

CONSOLIDATION TEST  
VOID RATIO vs LOG. PRESSURE  
PH 3 SA 99-3



CONSOLIDATION TEST  
VOID RATIO vs. LOG PRESSURE

FIGURE

# OEDOMETER CONSOLIDATION SUMMARY

## SAMPLE IDENTIFICATION

Project Number	991-101050	Sample Number	99-2
Borehole Number	PH 5	Sample Depth, m	18.62

## TEST CONDITIONS

Test Type	Standard	Load Duration, hr	24
Oedometer Number	7		
Date Started	99-08-05		
Date Completed	99-08-13		

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m <sup>3</sup>	16.81
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	10.92
Area, cm <sup>2</sup>	31.55	Specific Gravity, assumed	2.74
Volume, cm <sup>3</sup>	60.10	Solids Height, cm	0.774
Water Content, %	54.00	Volume of Solids, cm <sup>3</sup>	24.42
Wet Mass, g	103.05	Volume of Voids, cm <sup>3</sup>	35.68
Dry Mass, g	66.91	Degree of Saturation, %	101.3

## TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv, cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.905	1.461	1.905				
9.69	1.876	1.423	1.890	28	2.71E-02	1.58E-03	4.19E-06
19.39	1.868	1.413	1.872	69	1.08E-02	4.44E-04	4.68E-07
38.77	1.855	1.396	1.861	52	1.41E-02	3.52E-04	4.87E-07
77.54	1.833	1.368	1.844	52	1.39E-02	2.91E-04	3.95E-07
116.31	1.814	1.343	1.823	89	7.92E-03	2.61E-04	2.03E-07
232.63	1.734	1.241	1.774	89	7.50E-03	3.59E-04	2.64E-07
465.26	1.551	1.004	1.643	432	1.32E-03	4.13E-04	5.36E-08
930.51	1.430	0.848	1.491	185	2.55E-03	1.37E-04	3.41E-08
465.26	1.436	0.855	1.433				
232.63	1.440	0.860	1.438				
116.31	1.455	0.879	1.447				
58.16	1.464	0.892	1.459				
9.69	1.488	0.922	1.476				

Notes:

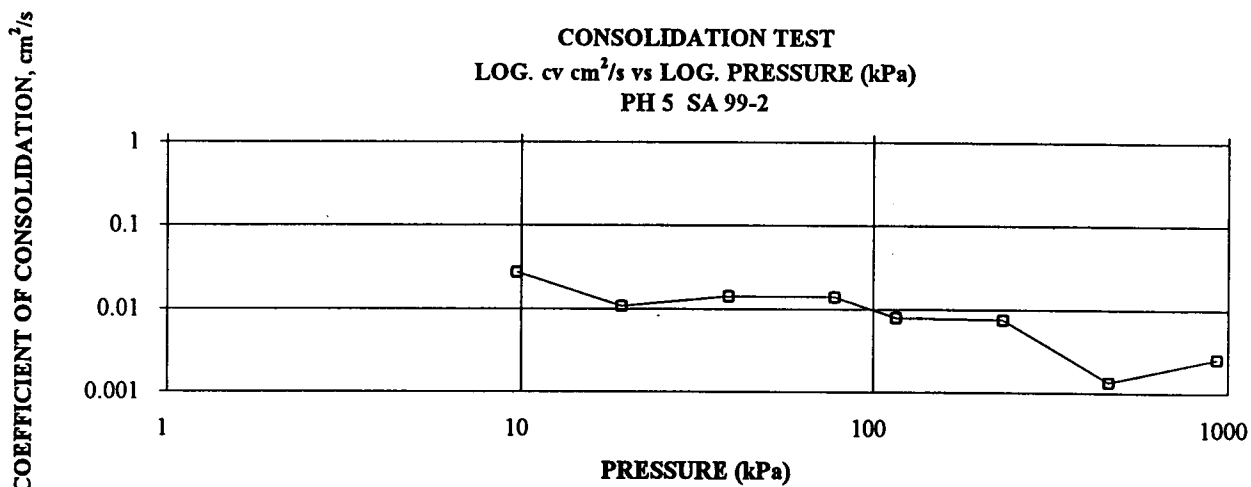
k calculated using cv based on t<sub>90</sub> values.

## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

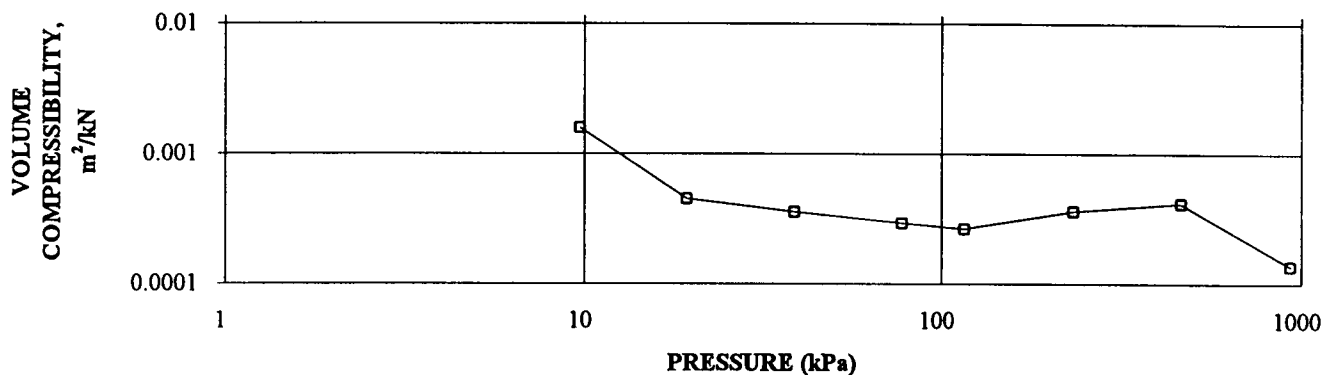
Sample Height, cm	1.49	Unit Weight, kN/m <sup>3</sup>	19.20
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	13.98
Area, cm <sup>2</sup>	31.55	Specific Gravity, assumed	2.74
Volume, cm <sup>3</sup>	46.95	Solids Height, cm	0.774
Water Content, %	37.4	Volume of Solids, cm <sup>3</sup>	24.42
Wet Mass, g	91.93	Volume of Voids, cm <sup>3</sup>	22.53
Dry Mass, g	66.91		

# OEDOMETER CONSOLIDATION SUMMARY

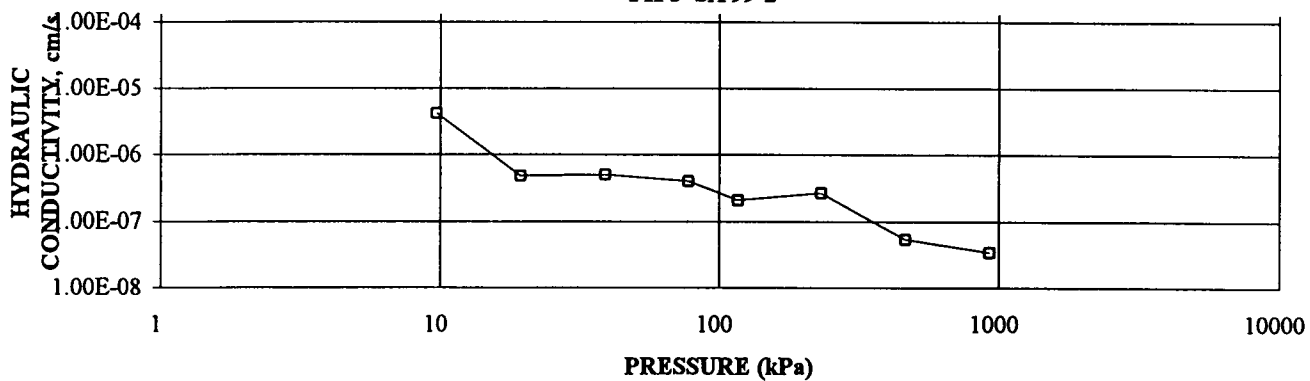
CONSOLIDATION TEST  
LOG.  $cv$   $cm^2/s$  vs LOG. PRESSURE (kPa)  
PH 5 SA 99-2



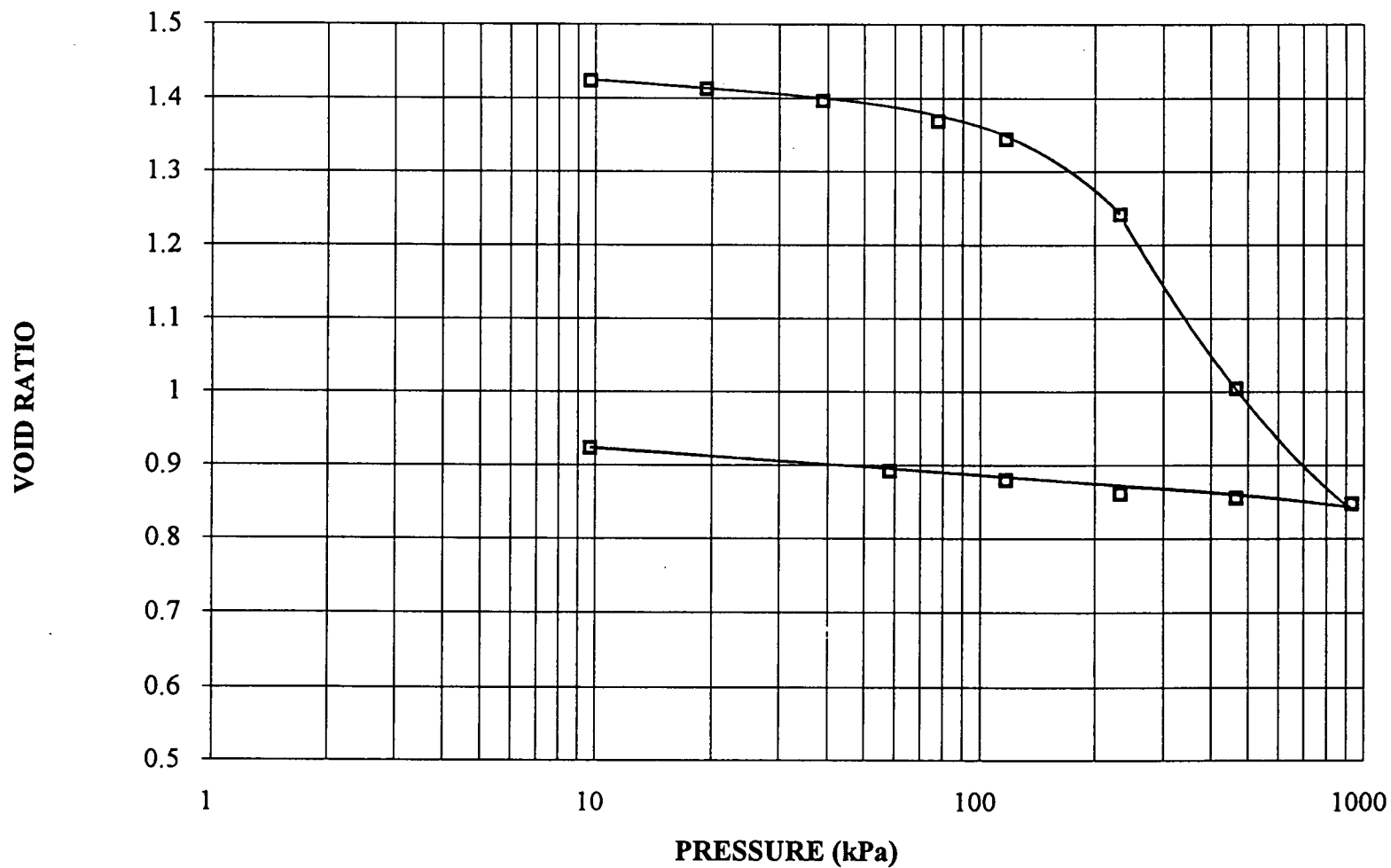
CONSOLIDATION TEST  
LOG.  $mv$ ,  $m^2/kN$  vs LOG. PRESSURE (kPa)  
PH 5 SA 99-2



CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
PH 5 SA 99-2



CONSOLIDATION TEST  
VOID RATIO vs LOG. PRESSURE  
PH 5 SA 99-2



CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

FIGURE

**APPENDIX C**

**NON STANDARD SPECIAL PROVISIONS**

Granular Filter Blanket

Wick Drains

**Non Standard Special Provision****1.0 SCOPE**

This non-standard special provision specifies the requirements for the surface preparation, supply, placement and compaction of the Granular Filter blanket in connection with the installation of the prefabricated vertical drains.

**2.0 MATERIALS**

The Granular Filter Blanket shall be Granular 'A' material and shall satisfy the physical and gradation requirements as specified in OPSS 1010.

**3.0 CONSTRUCTION**

3.1 The Granular 'A' blanket shall be placed and compacted to the limits and, grades shown on the plans or as directed by the Contract Administrator.

3.2 The Granular 'A' blanket shall be placed subsequent to the required subexcavation.

3.3 The Granular 'A' blanket shall be placed and compacted in lift thicknesses not exceeding 250 mm.

3.4 The Granular 'A' blanket shall be compacted to 90%  $\pm$  2% of its standard proctor density.

**4.0 PAYMENT****4.1 Measurement of Payment**

Measurement of payment shall be by the tonne. The method of determining the mass of materials for payment shall conform to

OPSS 102.

#### 4.2 Basis of Payment

Granular 'A' Blanket - Item

Payment at the contract price for the above item shall be full compensation for all labour, equipment and material required to do the, work.

---

**WICK DRAINS**

---

**ITEM NO. \_\_\_\_****Non Standard Special Provision****1.0 GENERAL****1.1 Scope**

This non-standard special provision specifies the requirements for the supply and installation of wick drains in accordance with the details shown on the plans and with the requirements of these specifications.

**1.2 Qualifications**

This work shall be undertaken by a recognized specialist subcontractor which has proven satisfactory experience in work of this type and magnitude and have completed a minimum of five wick drain installation projects in the last five years, each project with the following characteristics:

- Maximum installation depth: not less than 15m
- Total length of wick drains: not less than 40,000m

**2.0 SITE CONDITIONS**

The Contractor shall refer to the following reports in the Contract Documents for a description of subsurface conditions at this site:

- Foundation Investigation Report for Mississippi River Bridges (EBL/WBL), WP 451-90-03/04, Site 3-594, Hwy 417, District 42, Ottawa. Prepared by Thurber Engineering Ltd., September 18, 1995
- Supplementary Foundation Investigation Design Report - Mississippi River Bridges (EBL & WBL), Site 3-594, Hwy 417, Arnprior, Ontario, District 42, Ottawa, WP 451-90-03/04. Prepared by Thurber Engineering Ltd., October 1999



The Record of Borehole sheets are not represented as a complete description of the subsurface conditions, but only present what was found in borings at the indicated locations on the date boreholes were drilled. The subsurface conditions may be variable between the borehole locations. The Contractor should verify existing surface conditions.

### **3.0 MATERIALS**

- 3.1 The prefabricated drain shall consist of a continuous plastic drainage core wrapped in a non-woven geotextile material. The core configuration should be 'Studded' or 'Grooved' ('Filament ' or 'Cuspated' are not acceptable).

The Contractor shall submit samples of the prefabricated drain for evaluation and approval to the Contract Administrator at least one month prior to commencement of work under this item.

Fabricated wick drain material shall meet the minimum Specifications included in the table attached at the end of this text.

- 3.3 The Contractor shall submit a 1 m sample of the vertical drain material to the Contract Administrator prior to usage and shall allow two weeks for the Contract Administrator to evaluate the material. The sample shall be stamped or labelled by the manufacturer as being representative of the drain material having the specified trade name. Documentation indicating the source of the drain shall be provided. Approval of the sample by the Contract Administrator shall be required prior to site delivery of the vertical drain material.
- 3.4 Manufacturer certification shall be provided for all drain material delivered to the project.
- 3.5 All drains supplied shall be free of defects, rips, holes or flaws. During shipment the drain shall be protected from damage. During on-site storage the storage area shall be such that the drain is protected from

sunlight, dirt, dust, mud, debris and any other detrimental substances.

#### **4.0 EQUIPMENT**

4.1 Vertical drains shall be installed with equipment which will minimise disturbance to the granular 'A' blanket or the native subsoil during the installation operation. Static or vibratory methods are considered acceptable. Falling weight impact hammers will not be allowed.

4.2 The Contractor is advised that the site is considered as an environmentally sensitive area and therefore the control of any water effluent needs to be carefully planned and organized. Jetting techniques, therefore, shall be subjected to the approval of the Contract Administrator.

4.3 The Contractor shall be permitted to use augering equipment to predrill or to loosen the native soils and the granular 'A' blanket if required to facilitate the installation of the wick drains.

4.4 Each prefabricated wick drain shall be installed using a mandrel or sleeve which shall be advanced through the underlying soil and the granular blanket. The mandrel shall protect the prefabricated drain material from tears, cuts and abrasions during installation and shall be withdrawn after the installation on the drain. The mandrel shall be provided with an "anchor" rod or plate at the bottom to prevent the soil from entering the bottom of the mandrel during installation of the drain and to anchor the bottom of the drain at the required depth at the time of mandrel removal. The projected cross-sectional area of the mandrel and anchor combination shall not exceed 7700 mm<sup>2</sup>.

#### **5.0 INSTALLATION**

##### **5.1 Installation Method Proposal Submission**

At least three weeks prior to the installation of the drainage strips, the Contractor shall submit to the Contract Administrator, for review and approval, details of the sequence and method of installation. The submittals shall satisfy the specifications and at a minimum contain the

following specific information:

- Size, type, weight, maximum pushing force, and configuration of the installation rig.
- Dimensions and length of mandrel.
- Details of drain anchorage.
- Detailed description of proposed installation procedures.
- Proposed methods for overcoming obstructions.
- Proposed methods for splicing drains.

Approval by the Engineer will not relieve the Contractor of his responsibilities to install vertical drain strips in accordance with the plans and specifications.

## 5.2 Construction Sequence

Vertical drains shall be installed subsequent to the construction of the granular 'A' blanket and prior to installation of monitoring instruments and placement of the embankment material.

## 5.3 Trial Drains

Prior to the installation of prefabricated drains within the areas designated on the plans, the Contractor shall demonstrate that the proposed materials, equipment and installation method produces a satisfactory drain installation in accordance with these specifications. The Contractor will be required to install a total of ten trial drains at locations within the work area as designated by the Contractor Administrator.

Should the ten trial drains be installed to the satisfaction of the Contract Administrator, the trial drains can be incorporated as part of the permanent installation. The Contractor will be compensated for each trial drain if the

installation satisfies the requirements of this specification, at the same unit price as the production drains. The Contractor shall not be compensated for unsatisfactory trial drains.

Approval by the Contract Administrator of the method and equipment used to install the trial drains shall not constitute, necessarily, acceptance of the method for the remainder of the project. If, at any time, the Contractor Administrator installation considers that the method of installation does not produce a drain which satisfies the project requirements, the Contractor shall alter his method and/or equipment as necessary to comply with these specifications.

#### 5.4 Layout

Prefabricated drains shall be located and staked out by the Contractor. The location of the drains shall not vary by more than 150 mm from the locations indicated on the drawings.

#### 5.5 Plumbness

Drains shall be installed vertically, within a tolerance of not more than 10 mm per 500 mm. The equipment shall be carefully checked for plumbness, and the Contractor shall provide the Contract Administrator with a suitable means of verifying the plumbness of the mandrel and of determining the depth of the drain at any time.

#### 5.6 Splices

Splices or connections in the vertical drain material shall be done in a professional manner so as to ensure continuity and to avoid any reduction of the flow characteristics of the wick material. Splices shall be a minimum of 150 mm in length.

#### 5.7 Cut-off

The prefabricated drain shall be cut at the surface such that at least a 150 mm length protrudes above the top of the granular blanket at each

drain location.

5.8 Obstructions

Where obstructions are encountered below the working surface which cannot be penetrated by the drain installation equipment, the Contractor shall complete the drain from the elevation of the obstruction to the working surface and notify the Contract Administrator. At the direction of the Contract Administrator, the Contractor shall attempt to install a new drain within a 500 mm radius of the obstructed drain. A maximum of two attempts shall be made as directed by the Contract Administrator. The Contractor will be compensated for each obstructed drain unless the drain is improperly completed, in which case no compensation will be allowed.

5.9 Preaugering

Preaugering will likely not be required at this site. If however, the Contractor judges that preaugering is required, the drilling shall not extend below the design elevation of the wick drain tips. Any additional cost for preaugering, shall be incorporated into the unit price.

5.10 Rejected Drains

Prefabricated drains that are installed beyond the plan location by more than 150 mm, or that are damaged or are not installed in accordance with the specifications described above shall be rejected. Rejected drains may be removed at the Contractor's own expense and time. The Contractor shall not be compensated for the materials and work associated with rejected drains.

Replacement drains shall be installed within a 50 cm radius from the location of the rejected drain as directed by the Contract Administrator.

5.11 Geotechnical Instrumentation

Installation of the drains should be coordinated with the placement of geotechnical instrumentation as shown on the drawings. Special care

should be taken to install drains in such a manner so as not to disturb instrumentation already in place. The replacement of instrumentation damaged as a result of the Contractor's activities will be the responsibility of the Contractor.

## **6.0 PAYMENT**

### **6.1 Measurement of Payment**

Measurement of the item "WICK DRAINS" is by Plan Quantity, as may be revised by Adjusted Plan Quantity shall be by the linear metre for all accepted drains installed including the protruding portion. Properly completed obstructed wick drains and properly installed replacement wick drains and trial drains will be measured for payment.

### **6.2 Basis for Payment**

Item - Wick Drains

Payment at the contract unit price per linear metre for the above item shall be full compensation for all labour, materials and equipment to complete the work in accordance with the Plans and Specifications.

No payment shall be made for unacceptable drains or delays or expenses incurred by the Contractor as a result of improper or unacceptable material or installation.

PRODUCT SPECIFICATIONS			
	Test Method	Units	Value
PHYSICAL PROPERTIES			
Drain Body Material		Studded or Groved	Polypropylene
Filter Material		Non-Woven	Polypropylene
Weight	ASTM-D-1777	g/m	75
Width		mm	not less than 100
Thickness	ASTM-D-5199	mm	not less than 3
Mass of Filter	ASTM-D-1777	g/m <sup>2</sup>	154
MECHANICAL PROPERTIES			
Drain composite Tensile Strength	ASTM D-4595	kN	0.375 @ 10%
Filter Puncture Strength	ASTM-D-751-68	kN	0.335
Filter Grab Strength	ASTM-D-1682	kN	0.8
Filter Trapezoidal Tear	ASTM-D-1117	kN	0.22
Filter Burst Strength	ASTM-D-751-68	kPa	2000
Discharge Capacity @ 70 kPa	ASTM-D4716	m <sup>3</sup> /s	100x10 <sup>-6</sup>
FOS	CAN/CGSB-148.1 No. 10.2	μm	15 to 100
Minimum elongation at break (%)	CAN/CGSB-148.1 No. 7.3	%	15
Water Permeability	ASTM D-4491	m/s	0.000005

**APPENDIX D**  
**NON STANDARD SPECIAL PROVISIONS**  
Monitoring Program



---

## **GENERAL**

---

### **1.0 GENERAL**

The Contractor shall retain a Geotechnical Consultant with MTO classification of 'Geotechnical (Structures and Embankments) - High Complexity', to undertake the supply and installation of geotechnical instruments.

'The Contractor' shall be understood to refer to the Contractor and their Geotechnical Consultant.

### **1.1 Scope**

These non-standard special provisions contain the requirements for the supply, installation and monitoring of the following geotechnical instruments:

- ▶ Inclinometers (SI);
- ▶ Vibrating Wire Settlement Cells with Pressurized Reservoirs (SC);
- ▶ Settlement Rods (SR);
- ▶ Settlement Pins (SP);
- ▶ Vibrating Wire Piezometers (VWP);
- ▶ Standpipes (SSP).

### **1.2 Purpose**

1.2.1 The purpose of these instruments is to monitor the progress of settlement, lateral displacement and dissipation of excess pore water pressure in the foundation soils. These predicted responses are due to the construction of the approach embankments with wick drains and surcharge loading.

1.2.2 The rate of fill construction, staging of fill construction, removal of surcharge and the timing for driving abutment piles will be controlled by the instrumentation readings.

### **1.3 Or equal**

The term, 'or equal' shall be understood to indicate that the equal product is the same or better than the specified product in function, performance, reliability, quality and general configuration.

### **1.4 Notification**

The Contract Administrator shall be notified a minimum of 15 working days in advance of commencing the installation of instruments.

### 1.5 Submission Requirements

The Contractor shall submit details of proposed installation methods and installation schedule to the Contract Administrator, a minimum of 15 days before the start of instrument installation.

### 2.0 DRAWINGS

Reference shall be made to the following drawings :

▶	Drawing 15-64-7-1A	Monitoring Section Location Plan
▶	Drawing 15-64-7-2A	Typical Monitoring Section Type A
▶	Drawing 15-64-7-2B	Typical Monitoring Section Type B
▶	Drawing 15-64-7-2C	Typical Monitoring Section Type C
▶	Drawing 15-64-7-3A	Typical Instrument Installation Details
▶	Drawing 15-64-7-3B	Typical Instrument Installation Details

### 3.0 SITE CONDITIONS

#### 3.1 Subsurface Conditions

The subsurface conditions at the site are described in the reports:

- ▶ Supplementary Foundation Design Report  
Mississippi River Bridges, (EBL & WBL) Site 3-594  
Highway 417, Arnprior, Ontario  
WP 451-90-03.04  
*Thurber Engineering Ltd. October, 1999*
- ▶ Geotechnical Investigation Report  
Mississippi River Bridges, (EBL & WBL) Site 3-594  
Highway 417, Arnprior, Ontario  
WP 451-90-03.04  
*Thurber Engineering Ltd. September 18, 1995*

#### 3.2 Equipment Operation and Weather Conditions

All monitoring equipment and associated materials shall be capable of withstanding the range of temperatures possible for their location within the ground or on the surface. Monitoring shall be conducted year round.

#### 4.0 INSTALLATIONS

##### 4.1 Quantities and Locations of Instruments

Table 1a - Instrument Quantities and Locations

TYPE	MONITORING SECTION LOCATION			NUMBER OF :					
	APPROACH	LANE	STATION	SI	SC	SR	SP	VWP	SSP
A  (Dwg 15-64-7-2A)	west	WBL	17+822 (3 m behind west abutment)	1	2	2	3	7	1
		EBL	17+796 (3 m behind west abutment)	1	2	2	3	7	1
	east	WBL	18+202 (3 m behind east abutment)	1	2	2	3	7	1
		EBL	18+176 (3 m behind east abutment)	1	2	2	3	7	1
B  (Dwg 15-64-7-2B)	west	WBL	17+775 (~50 m behind west abutment)	0	0	1	3	7	1
		EBL	17+750 (~50 m behind west abutment)	0	0	1	3	7	1
	east	WBL	18+250 (~50 m behind east abutment)	0	0	1	3	7	1
		EBL	18+225 (~50 m behind east abutment)	0	0	1	3	7	1
C  (Dwg 15-64-7-2C)	east	WBL	18+300 (~100 m behind east abutment)	0	0	1	3	0	0
			18+350 (~150 m behind east abutment)	0	0	1	3	0	0
			18+400 (~200 m behind east abutment)	0	0	1	3	0	0
		EBL	18+275 (~100 m behind east abutment)	0	0	1	3	0	0
			18+325 (~150 m behind east abutment)	0	0	1	3	0	0
TOTALS				4	8	18	39	56	8

##### 4.2 Survey Bench Marks

4.2.1 The Contractor shall provide non-yielding deep seated survey bench marks.

4.2.2 The number and locations of bench marks shall be such that direct sighting is possible from all settlement pins (SP) and settlement rods (SR) to at least one bench mark.

##### 4.3 Personnel

Instrument installation shall be undertaken under the full time supervision of the Contractor.

#### 4.4 Materials and Equipment

The Contractor shall supply all materials and equipment required for the installation of equipment unless otherwise noted.

#### 4.5 Instrument Location

Prior to the installation of instruments, the Contractor shall accurately survey and stake the location of each instrument and obtain a ground elevation at each instrument location.

#### 4.6 Underground Utilities

The Contractor shall be responsible for locating and protecting all underground utilities prior to drilling boreholes for installing instruments. Any damage to underground utilities caused by the Contractors work shall be repaired by the Contractor at no cost to the Contract Administrator.

#### 4.7 Marking and Labelling

4.7.1 The location of any above ground monitoring fixture shall be made clearly visible to nearby traffic before, during and after embankment construction. Marking shall be of sufficient size to be visible from a reversing vehicle and after heavy snow falls.

4.7.2 Instruments or their data cables shall be clearly labelled in the field, each instrument having a unique identifier. The labelling shall remain legible for the entire period of monitoring.

#### 4.8 Protection of Instruments

All instruments shall be adequately protected by the Contractor such that they are not damaged during construction. Any instrument damaged by the Contractors work shall be immediately replaced at the Contractors cost.

#### 4.9 Accuracy of Surveying for Settlement Rods / Pins / Cells

The elevations of settlement cells, settlement rods and settlement pins shall be surveyed to an accuracy of plus/minus 2 mm or better.

#### 4.10 Survey Personnel

Surveying for settlement monitoring shall be conducted by a registered surveyor with appropriate equipment and experience. The surveyor shall be retained by the Contractor.

#### 4.11 Boreholes

- 4.11.1 The Contractor shall make a basic stratigraphic log of boreholes as they are being drilled. In-situ or laboratory testing is not required.
- 4.11.2 Borehole drilling shall be conducted by a recognized drilling subcontractor with eligibility defined by the current MTO Boring Contractor supply list.
- 4.11.3 Boreholes shall be advanced using conventional drilling methods and shall be as straight and vertical as practical.

#### 4.12 Installation Program

Instrument installation shall commence immediately after wick drain installation and construction of the drainage blanket. Table 1b gives a summary of the installation schedule requirements.

Table 1b - Installation Program

TYPE	START INSTALLATION	FINISH INSTALLATION
SI	After wick drain installation	at completion of embankment construction
SC	After wick drain installation	before embankment construction
SR	After wick drain installation	at completion of embankment construction
SP	After embankment construction	within 2 days of embankment completion
VWP	After wick drain installation	before embankment construction
SSP	After wick drain installation	before embankment construction

#### 5.0 MONITORING

##### 5.1 Personnel

Data collection, interpretation and reporting shall be conducted by the Contractor.

##### 5.2 Materials and Equipment

The Contractor shall supply all materials and equipment that are required for monitoring.

### 5.3 Monitoring Program

5.3.1 Monitoring shall commence immediately after the installation of an instrument.

5.3.2 Monitoring will continue for a period of approximately one year following the installation of the abutment piles.

### 5.4 Monitoring Frequency

The monitoring frequency for individual instruments is given in the relevant sections. These are minimum frequencies. Instruments shall be read more frequently if judged to be required by the Contract Administrator. Such circumstances are, but are not limited to:

- ▶ Unusually high rate of foundation movement or pore pressure change;
- ▶ Erroneous data;
- ▶ Change in equipment, (especially inclinometer probe and cable);
- ▶ Anomalous data from other monitoring installations or observations.

### 5.5 Raw Data

The Contractor shall save and archive raw data in electronic and hard copy format.

### 5.6 Reporting

5.6.1 An updated processed copy of monitoring data accompanied by a brief interpretation, shall be provided to the Contract Administrator the day after each set of readings are obtained. The data shall be presented in tabular and graphical form.

5.6.2 At the completion of the monitoring program, a final monitoring report shall be issued to the Contract Administrator. The monitoring results shall be presented in tabular and graphical form.

## 6.0 PAYMENT

### 6.1 Measurement of Payment

The measurement of payment is outlined in each of the attached relevant sections.

### 6.2 Basis of Payment

The basis of payment is outlined in each of the attached relevant sections.

---

**INCLINOMETERS (SI) - SUPPLY & INSTALLATION**

---

**1.0    GENERAL****1.1    Scope**

- 1.1.1        This non-standard special provision contains the requirements for the supply and installation of inclinometer casing and accessories.
- 1.1.2        The purpose of the inclinometers is to monitor horizontal displacements at depth at the abutment locations.
- 1.1.3        The location and approximate installation depths of the inclinometers are given in Table 2a :

**Table 2a - Inclinometer Locations and Approximate Installation Depths**

<b>Station / Offset</b>	<b>Lane</b>	<b>Approximate Elevation of Bottom of Inclinometer*</b>	<b>Estimated Final Inclinometer Length (m)**</b>
17+822 / 0 m	WBL	39	57
17+796 / 0 m	EBL	39	57
18+202 / 0 m	WBL	35	59
18+176 / 0 m	EBL	36	58

NOTE:        \*        The actual elevation of the bottom of the inclinometer shall be determined by the Contractor during drilling of the borehole.

              \*\*        The Contractor shall provide an additional 6 m of inclinometer casing per inclinometer to allow for a deeper installation than anticipated .

**1.2    General Procedure**

- 1.2.1        The inclinometers shall be installed to the ground surface elevations after wick drain installation but prior to embankment construction. This shall provide baseline data. As the embankment height increases in lifts, the inclinometer casing shall be extended upward through the embankment fill.
- 1.2.2        The installation phase shall be complete when the surrounding embankment is at final design surcharge height for pre loading, and extension of the inclinometer casing is no longer required.

## 2.0 MATERIALS

### 2.1 General

The Contractor shall supply inclinometer QC casing, manufactured by Slope Indicator Company - or equal. Fittings for the casing shall be consistent in manufacturer and system, (e.g. QC casing system and fittings by Slope Indicator).

### 2.2 Casing

Casing shall be 70 mm OD, (Slope Indicator model 51150210 or 51150211 - or equal).

### 2.3 Telescopic Casing Sections

Telescopic casing shall be Slope Indicator model 51150220 - or equal.

### 2.4 Splices

If required, splice kits shall be Slope Indicator model 51150250 (male) or 51150251 (female) - or equal.

### 2.5 Bottom Caps

Bottom caps shall be Slope Indicator model 51150230 - or equal.

### 2.6 Top Caps

Top caps shall be Slope Indicator model 51101500 - or equal.

### 2.7 Protective Surround - during embankment construction

The Contractor shall supply a protective surround for the portion of the inclinometer casing in the embankment. The surround shall consist of 300 mm diameter corrugated metal pipe (CMP) filled with compacted sand.

### 2.8 Grout

2.8.1 The annular space between the inclinometer casing and the borehole shall be filled with grout that has similar strength as the surrounding soil. The grout mix shall have a low drying shrinkage.

2.8.2 The Contractor shall submit a grout mix design for approval by the Contract Administrator, no



later than 15 days before the start of installation.

### 3.0 INSTALLATION

#### 3.1 General

- 3.1.1 Installation of the inclinometer casing shall be as per the manufacturers recommendations in addition to what is stated or emphasised below. Standard inclinometer casing lengths shall be used.
- 3.1.2 Boreholes for inclinometers shall be  $\pm 2\%$  of vertical. The boreholes shall be of sufficient diameter to enable installation of the inclinometer casing and grouting of the annular space between the inclinometer casing and borehole.
- 3.1.3 The A+ inclinometer groove shall be aligned parallel to the road centerline, towards the head slope.
- 3.1.4 The B+ inclinometer groove shall be aligned perpendicular to the road centerline, in the direction away from the median centerline.
- 3.1.5 A+ and B+ direction grooves shall be permanently marked and identified on each casing.
- 3.1.6 Care shall be taken not to apply torsion to the inclinometer casing during installation.
- 3.1.7 The inclinometer socket length, (in bedrock) shall be a minimum of 1.5 m and shall be confirmed by the Contractor during drilling of the borehole.

#### 3.2 Telescopic Couplings

- 3.2.1 Three telescopic couplings shall be included per inclinometer. The couplings shall each accommodate up to 0.15 m of contraction.
- 3.2.2 The telescopic couplings shall be installed at 5 m, 10 m and 15 m depths below existing ground level.
- 3.2.3 Telescopic sections are not required within the embankment fill or below 15 m depth, (from existing ground level).

#### 3.3 Grouting

- 3.3.1 Prior to grouting, the Contractor shall lower a dummy probe to confirm that all grooves are properly aligned and that the probe can reach the bottom of the casing.
- 3.3.2 The annulus between the borehole and casing shall be grouted up to the existing ground level. All drilling slurry shall be flushed out of the borehole. Grout shall displace any water from the borehole.

3.3.3 When grouting around the inclinometer casing, the buoyancy force acting on the casing must be opposed. Clean water can be added inside the inclinometer casing but additional force may be required. If so, the force shall be applied below the lowest telescopic section and is ideally applied at the base of the inclinometer casing. The casing shall not be pushed down from the top as this will cause telescopic sections to prematurely contract or collapse and thus render the telescopic sections unusable.

3.3.4 Once grouting is completed, the Contractor shall lower the dummy probe to the bottom of the inclinometer casing to confirm that it has been correctly installed.

3.3.5 Once the grout has set, the water level inside the casing shall be lowered to approximately 6 m below the ground to prevent freezing.

#### 3.4 Protective Surround

3.4.1 A protective surround, consisting of a CMP pipe and sand backfill, shall be placed around the portion of inclinometer casing that is above ground.

3.4.2 The above ground portion of inclinometer casing shall be greater than 0.3 m in length.

3.4.3 A PVC pipe shall be placed around the inclinometer casing to a slightly lower height. The internal diameter of the pipe and its couplings shall be such that the inclinometer casing is free to slide inside but without excessive play. (Note that the outside diameter of Slope Indicator QC casing is larger than 70 mm due to coupling alignment pins).

#### 3.5 Extension of Inclinometer

As embankment construction proceeds, the inclinometer casing, PVC pipe sleeve and the protective surround shall be extended so that they are always above the current ground level.

#### 3.6 Baseline Set of Readings

3.6.1 The Contractor shall take at least three sets of baseline readings of each inclinometer, on three consecutive days, no sooner than 7 days after grouting.

3.6.2 The rigidity of the inclinometer casing within the borehole shall be checked during baseline reading and the upper portion shall be re-grouted if grout settlement occurs.

3.6.3 A spiral survey of the inclinometer casing grooves shall be conducted once for each inclinometer at the time of baseline readings.

3.6.4 Refer to Monitoring section for reading details.

#### 4.0 REPORTING

The Contractor shall record and report relevant inclinometer installation details to the Contract Administrator. These include, but are not limited to :

- ▶ Inclinometer location, easting, northing;
- ▶ Elevation of ground levels and top of casing;
- ▶ Magnetic and grid bearings of A+ and B+ groove directions;
- ▶ Spiral survey details;
- ▶ Difference between A-axis bearing and line parallel to centerline;
- ▶ Stratigraphic log of subsurface conditions at the inclinometer, including drilling method notes;
- ▶ Socket details;
- ▶ Dates of installation and datum readings;
- ▶ Depths of casing, stick up and telescopic sections;
- ▶ Installation notes / grouting notes;
- ▶ Model, make and serial numbers of inclinometer probe, readout unit and control cable.

#### 5.0 PAYMENT

##### 5.1 Measurement of Payment

Inclinometer Supply, Installation, Extension Through Fill, Reporting

all Measurement of the item, 'Inclinometer Supply and Installation' is by plan quantity, including appurtenances. The unit of measurement is each.

##### 5.2 Basis of Payment

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## INCLINOMETERS (SI) - MONITORING

---

### 1.0 GENERAL

#### 1.1 Scope

This non-standard special provision contains the requirements for the monitoring of inclinometers including data reduction, interpretation and reporting. The monitoring shall be carried out by the Contractor.

#### 1.2 Equipment

- 1.2.1 Inclinometers shall be read with a bi-axial inclinometer probe, (force balanced servo accelerometer type) that is compatible with the casing installed. For example: Digitilt Inclinometer Probe model 50302510 (metric) or 50302500 (imperial) - or equal.
- 1.2.2 A Digitilt DataMate, Slope Indicator model 50310900 - or equal, shall be used as a readout unit. Appropriate software, (DigiPro for windows, Slope Indicator model 50310035) - or equal shall be available along with a suitable laptop computer to process, store and view the cumulative and incremental deflected plots on site.
- 1.2.3 The probe control cable shall be Slope Indicator model 50601010 (metric) or 50601000 (imperial) - or equal. The control cable shall be of sufficient length for reading the inclinometers and have connectors for the readout unit and probe.
- 1.2.4 It is desirable to use one inclinometer probe, one control cable and one readout unit exclusively. If any of this equipment is exchanged for another, two data sets shall be taken one after the other. The first with the old equipment and a second with the new equipment. Comparison and corrections shall then be made if required.
- 1.2.5 The probe, cable and readout unit shall be calibrated prior to taking baseline readings and every 3 months thereafter. Calibration records shall be supplied to the Contract Administrator.
- 1.2.6 Inclinometer casing groove spiral survey shall be conducted with a Slope Indicator spiral sensor, model 50900115 (metric) or 50900100 (imperial) - or equal. The spiral sensor used shall be compatible with the data cable, readout unit, inclinometer casing, software and inclinometer sensor.
- 1.2.7 Inclinometer readings and spiral surveys shall be consistently in either metric or imperial units, never a mixture.

### 2.0 DATA COLLECTION

#### 2.1 General

- 2.1.1 Data collection shall be done in accordance with the inclinometer probe manufacturers recommendations and instructions.

- 2.1.2 Care shall be taken not to take readings with the probe wheels in a casing joint.
- 2.1.3 One complete data set shall consists of two runs:  
 Run 1 - in the A+ direction, with the upper most wheel in the A+ groove.  
 Run 2 - rotate probe 180°, with the upper most wheel in the groove opposite the A+ groove.
- 2.1.4 The readings shall be taken from the bottom of the casing up.
- 2.1.5 Spiral survey corrections shall be made to all data, resolving A and B axis to give deflection in the desired direction.

## 2.2 Monitoring Frequency

- 2.2.1 As a minimum, inclinometers shall be read with the frequencies given in Table 2b.

Table 2b - Minimum Inclinometer Monitoring Frequency

STAGE	FREQUENCY (spread over given time)
Baseline Reading	3 readings on 3 consecutive days, no sooner than 7 days following installation.
Just prior to start of embankment construction	once
during embankment construction	once every 0.5m fill lift within 20m of the monitoring section
after end of embankment construction to top of surcharge and prior to surcharge removal	weekly
prior to paving	monthly

- 2.2.2 During embankment construction, the elevation of the top of the casing will increase. Shifts in the data shall be performed to accommodate the change in reference point (top of casing) such that readings are taken at the same elevations for each data set.

## 3.0 REPORTING

- 3.1 As a minimum the following shall be reported to the Contract Administrator within 24 hours of obtaining a set of readings from each inclinometer:
- cumulative and incremental lateral displacement versus depth plots for both A and B directions.
  - cumulative and incremental lateral displacement versus time plots at the elevation of maximum lateral displacement, for both A and B directions.

- fill height versus time
- plan view, cross section and profile sketches showing the top of fill location while the inclinometer readings were being taken
- A brief interpretation of recorded displacements shall be provided

3.2 Plots shall clearly show and identify each data set.

3.3 A sign convention of + lateral displacement = towards the head slope in A+ direction shall be employed.

#### 4.0 PAYMENT

##### 4.1 Measurement of Payment

###### **Inclinometer Monitoring and Reporting**

Measurement of the item, 'Inclinometer Monitoring and Reporting' is for supply of services to collect, process and interpret the inclinometer data. This is a lump sum item. Unit rates shall be supplied for each additional set of readings over and above the specified quantity.

##### 4.2 Basis of Payment

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## **VIBRATING WIRE SETTLEMENT CELLS (SC) - SUPPLY & INSTALLATION**

---

### **1.0 GENERAL**

#### **1.1 Scope**

- 1.1.1 This non-standard special provision contains the requirements for the supply and installation of vibrating wire settlement cells with pressurized reservoirs.
- 1.1.2 The purpose of the settlement cells is to remotely monitor settlements of the embankment base at the abutment locations.

#### **1.2 General Procedure**

- 1.2.1 The settlement cells will be installed just below the existing ground level after installation of wick drains but before construction of the embankment begins.
- 1.2.2 The total number of settlement cells and their location are given in Table 3a.

**Table 3a - Approximate Settlement Cell Locations**

Station	Offset (m)	Lane
17+819	3.75 Rt	WBL
	3.75 Lt	
17+793	3.75 Rt	EBL
	3.75 Lt	
18+205	3.75 Rt	WBL
	3.75 Lt	
18+179	3.75 Rt	EBL
	3.75 Lt	

### **2.0 MATERIALS**

#### **2.1 General**

The Contractor shall supply all materials and equipment required for the installation of the settlement cells. The lengths of tubing and signal cables shall be carefully estimated from the drawings supplied, prior to ordering the instruments.

## 2.2 Settlement Cells

2.2.1 Settlement cells shall be calibrated prior to installation.

2.2.2 Settlement cells shall be 20 psi vibrating wire type , Slope Indicator model 52630502 - or equal.

## 2.3 Tubing and Tubing Adaptors

Tubing shall be Slope Indicator model 51416950 - or equal. Tubing adaptors shall be Slope Indicator model 51419530 - or equal. The fluid filled tube shall extend from the reservoir at the readout location to the sensor.

## 2.4 Signal Cable and Connectors

Signal cable shall be Slope Indicator model 50613524 - or equal. Universal connectors to match.

## 2.5 Pressurized Reservoir, Reference Transducer

Pressurized reservoir shall be Slope Indicator model 51419520 - or equal. The reference transducer shall be Slope Indicator model 51419526 (20 psi) - or equal. They shall be calibrated prior to installation.

## 2.6 Hand Pump

Slope Indicator model 51419540 - or equal, to pressurize the reservoirs.

## 2.7 Protective Enclosure

A protective enclosure is required for the reservoir. Slope Indicator model 51419534 - or similar. The enclosure shall be attached to a secure post.

## 2.8 Terminal Box

The signal cables from the settlement cells and reference transducer shall be connected to the nearest universal terminal box, Slope Indicator model 57711600 - or equal, as specified for the vibrating wire piezometers.

## 2.9 Trench Burial and Metal Conduit

2.9.1 The signal cable and liquid filled tubing shall be buried in a shallow trench as shown in Dwg. 15-64-7-3A and taken out of the embankment footprint area and offset at an appropriate distance



beyond the toe of the embankment where they cannot be damaged by construction activities and are readily accessible for monitoring.

- 2.9.2 The Contractor shall supply suitable metal conduits to protect cables and tubing in the trenches and above ground surface. If appropriate, several cables and tubing may be housed in a single metal conduit.

2.10 De-Aired Liquid

The Contractor shall supply a de-aired liquid mixture of water and glycol. The liquid shall not freeze within the operating temperature range anticipated. De-aired liquid shall be Slope Indicator model 51419552 - or equal.

2.11 Readout Box

The Contractor shall supply VS DataMate model 52620900 - or equal, (as specified for the vibrating wire piezometers) to read and store the settlement cell readings.

3.0 INSTALLATION

3.1 General

Installation of settlement cells shall be as per the manufacturers recommendations in addition to what is stated or emphasised below.

3.2 Vibrating Wire Sensor

The sensors shall be located as shown on the attached Dwg. 15-64-7-3A The sensors shall be installed in a trench excavated large enough to accommodate the cell, (63 mm diameter x 91 mm high).

3.3 Liquid Filled Tubes and Cables

- 3.3.1 Liquid filled tubes and cables shall be placed in a 0.5 m deep trench and backfilled, (see Dwg. 15-64-7-3A).

- 3.3.2 Tubes and cable shall be protected by a metal conduit both in the trench and above ground.

- 3.3.3 Tubes shall be filled with a de-aired water / glycol mix.

### 3.4 Pressurized Reservoir

- 3.4.1 The reservoir shall be placed at least 5 m from the toe of the embankment.
- 3.4.2 The elevation of the reservoir shall be surveyed immediately after installation and at the same frequency of reading of settlement pins and settlement rods.
- 3.4.3 The liquid level of the reservoir shall be checked regularly and topped up as required.
- 3.4.4 The reservoir shall initially be between 0.5 m and 1.5 m higher than the settlement cells.

### 3.5 Protective Housing and Readout Box

- 3.5.1 The reservoir shall be locked in a housing on stable supports. The supports shall have a minimum embedment of 2 m.
- 3.5.2 The readout box shall be attached to a secure support.
- 3.5.3 The Contractor shall ensure access to the readout location at all times.

### 3.6 System Test and Initial Readings

- 3.6.1 Before trenches are backfilled the system shall be connected and tested.
- 3.6.2 The initial elevation of the settlement cell shall be accurately determined by survey.

## 4.0 REPORTING

The Contractor shall record and report relevant installation details to the Contract Administrator. These include, but are not limited to :

- ▶ Settlement Cell location, easting, northing;
- ▶ Elevation of cells and reservoir;
- ▶ Calibration test results for cells and transducers;
- ▶ Dates of installation and datum readings;
- ▶ Installation notes / sketches;
- ▶ Description of settlement cells, reservoir, tubing, cables and liquid in tubes.

5.0 PAYMENT

5.1 Measurement of Payment

Vibrating Wire Settlement Cell System

Measurement for the supply and installation of the item, 'vibrating wire settlement cell system' including all appurtenances shall be on a per unit basis.

5.2 Basis of Payment

Vibrating Wire Settlement Cell System - Item

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## **VIBRATING WIRE SETTLEMENT CELLS (SC) - MONITORING**

---

### **1.0 GENERAL**

#### **1.1 Scope**

This non-standard special provision contains the requirements for the monitoring of vibrating wire settlement cells including data reduction, interpretation and reporting. The monitoring shall be conducted by the Contractor.

#### **1.2 Monitoring Frequency**

1.2.1 Settlement cells shall be read with the frequencies given in Table 3b.

**Table 3b - Settlement Cell Monitoring Frequency**

<b>STAGE</b>	<b>FREQUENCY (spread over given time)</b>
Baseline Reading	3 readings on 3 consecutive days, no sooner than 7 days following installation.
Just prior to start of embankment construction	once
during embankment construction	once every 0.5m fill lift within 20m of the monitoring section
after end of embankment construction to top of surcharge and prior to surcharge removal	weekly
prior to paving	monthly

### **2.0 REPORTING**

2.1 An updated processed copy of monitoring data accompanied by a brief interpretation, shall be provided to the Contract Administrator the day after each set of readings are obtained. The data shall be presented in tabular and graphical form.

2.2 As a minimum the following shall be reported to the Contract Administrator within 24 hours of obtaining a set of readings from SC instruments:

- a plot of settlement of the base of the embankment versus time
- fill height versus time
- plan view, cross section and profile sketches showing the top of fill location while the SC readings were being taken and Pressurized Reservoir being surveyed

### 3.0 PAYMENT

#### 3.1 Measurement of Payment

##### Vibrating Wire Settlement Cell Monitoring

Measurement of the item, 'Vibrating Wire Settlement Cell Monitoring' is for the supply of services to collect, process and interpret the vibrating wire settlement cell data. This is a lump sum item. A unit rate shall be provided for each additional set of readings over and above the specified quantity.

#### 3.2 Basis of Payment

##### Vibrating Wire Settlement Cell Monitoring - Item

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## **SETTLEMENT RODS (SR) - SUPPLY & INSTALLATION**

---

### **1.0     GENERAL**

#### **1.1     Scope**

- 1.1.1        This non-standard special provision contains the requirements for the supply and installation of settlement rods.**
- 1.1.2        The purpose of the settlement rods is to directly monitor settlements of the embankment base. Settlement is measured by survey of the top of the rod with reference to stable, non-settling benchmarks.**

#### **1.2     General Procedure**

- 1.2.1        The settlement rods shall be attached to a plate at existing ground level. As embankment construction proceeds the rods shall be extended above the new ground level.**
- 1.2.2        Sleeves around the rods shall be installed to reduce friction and allow uninhibited movement of the rod with the plate.**
- 1.2.3        A protective surround shall be extended with the rods as embankment construction proceeds.**

#### **1.3     Location**

**The locations of the settlement rods are shown on Dwg. 15-64-7-1A and Dwgs. 15-64-7-2A,B,C and are given in Table 4a. A typical installation detail is shown in Dwg. 15-64-7-3A.**

Table 4a - Approximate Settlement Rod Locations

Station	Offset (m)	Lane	Approximate elevation of existing ground	Estimated thickness of embankment with no surcharge (m)
17+819	0	WBL	92	4.0
17+814.5	0			
17+793	0	EBL	90	5.0
17+788.5	0			
18+205	0	WBL	88	6.0
18+209.5	0			
18+179	0	EBL	88	5.0
18+183.5	0			
17+778	0	WBL	93	3.0
17+753	0	EBL	93	1.8
18+247	0	WBL	86	7.5
18+222	0	EBL	89	4.2
18+298.5	0	WBL	89	4.2
18+348.5	0		90	3.2
18+398.5	0		92	2.6
18+273.5	0	EBL	88	4.6
18+323.5	0		89	2.8

## 2.0 MATERIALS

### 2.1 General

The Contractor shall supply all materials and equipment required for the installation of the settlement rods.

### 2.2 Plate

The Contractor shall supply a steel plate with thickness of at least 6.35 mm. It shall be at least 0.5 m by 0.5 m.

### 2.3 Rod

2.3.1 The Contractor shall supply a steel pipe with an outside diameter of at least 25 mm.

2.3.2 The top of the rod shall be copped in such a way that a single survey point can be clearly identified and returned to.

### 2.4 Friction Reducing Sleeve

The Contractor shall supply a PVC pipe, friction reducing sleeve with an internal diameter slightly larger than the rod diameter.

### 2.5 Protective Surround

The Contractor shall supply a protective surround for the portion of the rod within the embankment. The surround shall consist of a 300 mm diameter corrugated metal pipe (CMP) filled with compacted sand.

### 2.6 Monitoring Equipment

The elevation of the top of the settlement rod shall be surveyed by an experienced surveyor, retained by the Contractor. The surveyor shall provide suitable equipment capable of surveying settlement rod elevation to an accuracy of  $\pm 2$  mm or better.

## 3.0 INSTALLATION

### 3.1 General

The Contractor shall install settlement rods as per the drawings provided in addition to what is stated or emphasized below.

### 3.2 Settlement Plate

3.2.1 The settlement plate shall be installed horizontally on undisturbed native soil, just below the existing ground.

3.2.2 The elevation of the base of the plate shall be surveyed before backfilling.

### 3.3 Rod

3.3.1 The rod shall be fixed to the centre of the plate and perpendicular to the plate.

3.3.2 The rod will be extended in 3 m increments as the embankment increases in height



- 3.3.3 The coupling of the rods shall be such that all sections have the same axis and no separation or contraction will occur at the couplings.

3.4 Friction Reducing Sleeve

The friction reducing sleeve shall be over the entire length of the rod that is below ground and within the embankment fill.

3.5 Protective Surround

- 3.5.1 The CMP protective surround shall be extended in 3 m increments with the rods.
- 3.5.2 The settlement rod shall be in the centre of the CMP.
- 3.5.3 The annulus between the CMP and the friction reducing sleeve shall be filled with compacted sand to a level no higher than the top of the sleeve.

3.6 Installation Details

- 3.6.1 The elevation, easting and northing of the centre of the base of the plate shall be surveyed.
- 3.6.2 The elevation, easting and northing of the top of the rod shall be surveyed.
- 3.6.3 The total distance from the base of the plate to the top of the rod shall be measured to an accuracy of  $\pm 2$  mm or better.

4.0 REPORTING

The Contractor shall record and report relevant installation details to the Contract Administrator. These include, but are not limited to :

- ▶ Settlement rod and plate location, easting, northing;
- ▶ Elevation of plate and rod;
- ▶ Distance between base of plate and top of rod;
- ▶ Dates of installation and datum readings;
- ▶ Installation notes / sketches;
- ▶ Description of settlement rods, sleeve, plate.

5.0 PAYMENT

5.1 Measurement of Payment

Settlement Rods Supply and Installation including benchmarks

Measurement for the item 'Supply and Installation of Settlement Rods and Benchmarks' is for the supply and installation of settlement rods including all appurtenances by plan quantity. The unit of measurement is each.

5.2 Basis of Payment

Settlement Rods Supply, Installation and Reporting - Item

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## SETTLEMENT RODS (SR) - MONITORING

---

### 1.0 GENERAL

#### Scope

This non-standard special provision contains the requirements for the monitoring of settlement rods including data reduction, interpretation and reporting. The monitoring shall be carried out by an experienced surveyor retained by the Contractor.

### 2.0 DATA COLLECTION

#### 2.1 General

The Contractor shall coordinate the collection of data by survey.

#### 2.2 Monitoring Frequency

2.2.1 As a minimum, settlement rods shall be read with the frequencies given in Table 4b.

Table 4b - Minimum Settlement Rod Monitoring Frequency

STAGE	FREQUENCY (spread over given time)
Baseline Reading	3 readings on 3 consecutive days, no sooner than 7 days following installation.
just prior to start of embankment construction	once
during embankment construction	once every 0.5m fill lift within 20m of the monitoring section
after end of embankment construction to top of surcharge and prior to surcharge removal	weekly
prior to paving	monthly

### 3.0 REPORTING

3.1 An updated processed copy of monitoring data accompanied by a brief interpretation, shall be provided to the Contact Administrator the day after each set of readings are obtained. The data shall be presented in tabular and graphical form.

3.2 As a minimum the following shall be reported to the Contract Administrator within 24 hours of obtaining a set of level survey data from SR instruments:

- a plot of settlement of the base of the embankment versus time
- fill height versus time
- plan view, cross section and profile sketches showing the top of fill location while the SRs were being surveyed

#### 4.0 PAYMENT

##### 4.1 Measurement of Payment

Settlement Rod Monitoring

Measurement of the item, 'Settlement Rod Monitoring' is for the supply of services to collect, process and interpret the settlement rod data. This is a lump sum item. A unit rate shall be provided for each additional set of readings over and above the specified quantity.

##### 4.2 Basis of Payment

Settlement Rod Monitoring - Item

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## **SETTLEMENT PINS (SP) - SUPPLY & INSTALLATION**

---

### **1.0     GENERAL**

#### **1.1     Scope**

- 1.1.1        This non-standard special provision contains the requirements for the supply and installation of settlement pins.
- 1.1.2        The purpose of the settlement pin is to directly monitor settlement of the top of the embankment. Settlement is measured by survey of the top of the pin with reference to stable non-settling benchmarks.

#### **1.2     General Procedure**

- 1.2.1        The settlement pins shall be cast into concrete at the top of the surcharge when it has reached full height.
- 1.2.2        The concrete will be cast in-situ in a hole dug in the top of the surcharge.

#### **1.3     Location**

The locations of the settlement pins are shown on Dwg. 15-64-7-1A and Dwgs. 15-64-7-2A,B,C and are given in Table 5a. A typical installation detail is shown in Dwg. 15-64-7-3A.

Table 5a - Approximate Settlement Pin Locations

Station	Lane	Number of Pins	Offsets (m)		
17+819	WBL	3	3.75 Lt	0	3.75 Rt
17+793	EBL	3	3.75 Lt	0	3.75 Rt
18+205	WBL	3	3.75 Lt	0	3.75 Rt
18+179	EBL	3	3.75 Lt	0	3.75 Rt
17+775	WBL	3	3.75 Lt	0	3.75 Rt
17+750	EBL	3	3.75 Lt	0	3.75 Rt
18+250	WBL	3	3.75 Lt	0	3.75 Rt
18+225	EBL	3	3.75 Lt	0	3.75 Rt
18+300	WBL	3	3.75 Lt	0	3.75 Rt
18+350		3	3.75 Lt	0	3.75 Rt
18+400		3	3.75 Lt	0	3.75 Rt
18+275	EBL	3	3.75 Lt	0	3.75 Rt
18+325		3	3.75 Lt	0	3.75 Rt

## 2.0 MATERIALS

### 2.1 General

The Contractor shall supply all materials and equipment required for the installation of the settlement pins.

### 2.2 Concrete

The Contractor shall supply rapid set concrete.

### 2.3 Pin

2.3.1 The Contractor shall supply a steel pin with a diameter of at least 25 mm.

2.3.2 The top of the pin shall be angled or rounded in such a way that a single survey point can be clearly identified and repeated.

2.3.3 The pin shall not be coated and shall have surface roughness to assist in bonding to the concrete.

## 2.4 Monitoring Equipment

The elevation of the top of the settlement pin shall be surveyed by an experienced surveyor, retained by the Contractor. The surveyor shall provide suitable equipment capable of surveying pin elevation to an accuracy of  $\pm 2$  mm or better.

## 3.0 INSTALLATION

### 3.1 General

The Contractor shall install settlement pins as per the drawings provided in addition to what is stated or emphasized below.

### 3.2 Installation Details

The elevation, easting and northing of the top of the pin shall be surveyed, after installation when the concrete has set and the pin is firmly secured in the concrete.

## 4.0 REPORTING

The Contractor shall record and report relevant installation details to the Contract Administrator. These include, but are not limited to :

- ▶ Settlement pin location, easting, northing;
- ▶ Elevation of pin;
- ▶ Dates of installation and datum readings;
- ▶ Installation notes / sketches;
- ▶ Description of settlement pin.

## 5.0 PAYMENT

### 5.1 Measurement of Payment

Settlement Pins Supply and Installation

Measurement for the item 'Supply and Installation of Settlement Pins' is for the supply and installation of settlement pins including all appurtenances by plan quantity. The unit of measurement is each.

### 5.2 Basis of Payment

Settlement Pins Supply, Installation and Reporting - Item  
Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## **SETTLEMENT PINS (SP) - MONITORING**

---

### **1.0 GENERAL**

#### **1.1 Scope**

This non-standard special provision contains the requirements for the monitoring of settlement pins including data reduction, interpretation and reporting. The monitoring shall be carried out by an experienced surveyor retained by the Contractor.

#### **1.2 Monitoring Frequency**

1.2.1 As a minimum, settlement pins shall be read with the frequencies given in Table 5b :

**Table 5b - Minimum Settlement Pin Monitoring Frequency**

STAGE	FREQUENCY (spread over given time)
Baseline Reading	3 readings on 3 consecutive days, no sooner than 7 days following installation.
Just prior to start of embankment construction	once
during embankment construction	once every 0.5m fill lift within 20m of the monitoring section
after end of embankment construction to top of surcharge and prior to surcharge removal	weekly
prior to paving	monthly

### **2.0 REPORTING**

2.1 An updated processed copy of monitoring data accompanied by a brief interpretation, shall be provided to the Contract Administrator the day after each set of readings are obtained. The data shall be presented in tabular and graphical form.

2.2 As a minimum the following shall be reported to the Contract Administrator within 24 hours of obtaining a set of level survey data from SPs:

- a plot of settlement of the embankment top (SP only) versus time
- fill height versus time
- plan view, cross section and profile sketches showing the top of fill location while the SPs were being surveyed



3.0 PAYMENT

3.1 Measurement of Payment

Settlement Pin Monitoring

Measurement of the item, 'Settlement Pin Monitoring' is for the supply of services to collect, process and interpret the settlement pin data. This is a lump sum item. A unit rate shall be provided for each additional set of readings over and above the specified quantity.

3.2 Basis of Payment

Settlement Pin Monitoring - Item

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## VIBRATING WIRE PIEZOMETER (VWP) - SUPPLY & INSTALLATION

---

### 1.0 GENERAL

#### 1.1 Scope

- 1.1.1 This non-standard special provision contains the requirements for the supply and installation of vibrating wire (VW) piezometers. The installation shall be carried out by the Contractor.
- 1.1.2 The purpose of the piezometers is to monitor pore water pressure at depths within the foundation soil. The piezometer readings shall help to establish the timing for the removal of surcharge and driving of abutment piles.

#### 1.2 General Procedure

- 1.2.1 The piezometers shall be installed in boreholes after wick drain installation but prior to embankment construction. The boreholes shall be of sufficient diameter to accommodate installation of two VW sensors, filter sand and grout.
- 1.2.2 No more than two VW sensors shall be installed in a borehole. See Dwg. 15-64-7-3B for installation details.
- 1.2.3 The VW signal cables shall be extended out of the embankment footprint area through metal conduit, buried in trenches, as shown in Dwg. 15-64-7-3A.
- 1.2.4 Boreholes containing VW sensors shall be at least 3 m from other boreholes.
- 1.2.5 Boreholes containing VW sensors shall be equidistant from nearby wick drains.

#### 1.3 Locations

- 1.3.1 The Contractor shall install VW sensors at the locations and depths given in Table 6a.

Table 6a - VW Piezometer Locations

Lane	Station	Offset (m)	Number of VW Sensors in Borehole	Approximate Ground Elevation (m)	Tip Elevations (m)	
WBL A 17+822	17+816	0	2	92	86	78
	17+813	0	2		82	72
	17+810	0	2		66	58
	17+807	0	1		44	
WBL A 18+202	18+208	0	2	88	84	76
	18+211	0	2		80	70
	18+214	0	2		64	50
	18+217	0	1		44	
EBL A 17+796	17+790	0	2	91	84	76
	17+787	0	2		80	70
	17+784	0	2		64	50
	17+781	0	1		44	
EBL A 18+176	18+182	0	2	87	84	76
	18+185	0	2		80	70
	18+188	0	2		64	50
	18+191	0	1		44	
WBL B 17+775	17+775	0	2	93	86	78
	17+772	0	2		82	72
	17+769	0	2		66	58
	17+766	0	1		44	
WBL B 18+250	18+250	0	2	87	84	76
	18+253	0	2		80	70
	18+256	0	2		64	50
	18+259	0	1		44	
EBL B 17+750	17+750	0	2	93	86	78
	17+747	0	2		82	72
	17+744	0	2		66	58
	17+741	0	1		44	
EBL B 18+225	18+225	0	2	89	84	76
	18+228	0	2		80	70
	18+231	0	2		64	50
	18+234	0	1		44	

## 2.0 MATERIALS

### 2.1 VW Piezometers

- 2.1.1 The Contractor shall supply VW borehole piezometers by Slope Indicator model 52611020 (-5 to 50 psi) and model 52611030 (-5 to 100 psi) - or equal, compatible with the Slope Indicator VS DataMate model 52620900 - or equal. All piezometers shall be of the same make.
- 2.1.2 Piezometers installed at depths less than 15 m shall have a range of -5 to 50 psi. Piezometers installed at depths greater than 15 m shall have a range of -5 to 100 psi.
- 2.1.3 All piezometers shall be calibrated prior to installation and the calibration data for each piezometers shall be provided for the Contract Administrator.

### 2.2 Signal Cable

The Contractor shall supply Slope Indicator model 50613524 cable - or equal. The length of cable for each piezometer shall be carefully estimated from the construction drawings to ensure that there is enough signal cable for each piezometer to provide enough slack in the borehole and along the trenches until each cable is out of the embankment footprint area where they shall be protected from earthmoving equipment.

### 2.3 Bentonite

- 2.3.1 The Contractor shall supply bentonite in pellet form in sufficient quantity to form borehole plugs as required.
- 2.3.2 The Contractor shall supply bentonite in powder form in sufficient quantity for the bentonite-cement grout mix for general borehole backfilling.

### 2.4 Filter Sand

The Contractor shall supply clean washed sand for filter around VW sensors. The sand shall be Sakcrete washed general purpose sand - or equal.

### 2.5 Grout

The Contractor shall supply cement-bentonite grout. A suitable grout mix design shall be submitted by the Contractor.

### 2.6 Readout Unit

The Contractor shall supply VS DataMate model 52620900 - or equal, to read and store the

piezometer readings. Slope Indicator IDAgraph software model 58710030 - or equal, shall be used to generate plots of pore pressures with time.

## 2.7 Trench Burial and Metal Conduit

The signal cable for each piezometer shall be buried in a shallow trench as shown in Dwg. 15-64-7-3A and taken out of the embankment footprint area. The Contractor shall supply suitable metal conduits to protect the signal cables in the trenches and above ground surface. If appropriate, several signal cables may be housed in a single metal conduit and laid in a common trench.

## 2.8 Universal Terminal Box

2.8.1 The cable and the 'quick connect' at the reading end of all the piezometers for a monitoring section shall be connected to a universal terminal box, Slope Indicator model 57711600 - or equal, equipped with a universal connector, Slope Indicator model 577 05001 - or equal.

2.8.2 For the monitoring sections specified in the Contract, 8 such terminal boxes will be required, 4 for the EBL and 4 for the WBL.

2.8.3 The terminal boxes shall be locking and waterproof and securely attached to posts.

## 3.0 INSTALLATION

### 3.1 General

Installation of the VW piezometers shall be as per the manufacturers recommendations in addition to what is stated or emphasised below.

### 3.2 Borehole Installation

3.2.1 The borehole shall be advanced to 300 mm below the lowest tip elevation using suitable drilling technique. The sides of the borehole shall be stable and the borehole shall be free of drilling mud and debris.

3.2.2 The piezometer shall be installed as shown in Dwg. 15-64-7-3B.

## 4.0 REPORTING

The Contractor shall record and report relevant installation details to the Contract Administrator. These include, but are not limited to :

- ▶ VW piezometer location, easting, northing;
- ▶ Elevations of VW sensors;
- ▶ Stratigraphic log of subsurface conditions, including drilling method notes;
- ▶ Dates of installation and datum readings;
- ▶ Installation notes / sketches;

- ▶ Model, make and serial numbers of VW sensors, readout unit and signal cable;
- ▶ Calibration details of VW sensors.

## 5.0 PAYMENT

### 5.1 Measurement of Payment

Vibrating Wire Piezometer Supply, Installation, Reporting

Measurement for the supply and installation of the vibrating wire piezometers, including all appurtenances is by plan quantity. The unit of measurement is each.

### 5.2 Basis of Payment

Vibrating Wire Piezometer Supply, Installation, Reporting

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## **VIBRATING WIRE PIEZOMETERS (VWP) - MONITORING**

---

### **1.0 GENERAL**

#### **1.1 Scope**

This non-standard special provision contains the requirements for the monitoring of VW piezometers including data reduction, interpretation and reporting. The monitoring shall be carried out by the Contractor.

#### **1.2 Monitoring Frequency**

- 1.2.1 As a minimum, piezometers shall be read with the frequencies given in Table 6b. The fill height at each piezometer location shall be recorded and reported for each piezometer reading.

**Table 6b - Minimum VW Piezometer Monitoring Frequency**

<b>STAGE</b>	<b>FREQUENCY (spread over given time)</b>
Baseline Reading	3 readings on 3 consecutive days, no sooner than 7 days following installation.
Just prior to start of embankment construction	once
during embankment construction	once every 0.5m fill lift within 20m of the monitoring section
after end of embankment construction to top of surcharge and prior to surcharge removal	weekly
prior to paving	monthly

### **2.0 COORDINATION OF READINGS**

- 2.1 The VWP data reduction (calculation of excess pore pressure - EPP: pore pressure in excess of hydrostatic) requires the groundwater level elevation at the time the VWPs were read. Therefore, the elevation of the standpipes (SSP) should be obtained by surveying on the same day the VWPs and groundwater depth in the SSPs are monitored.

### **3.0 SURVEYING**

- 3.1 The elevations of the top of the SSPs shall be surveyed to an accuracy of plus/minus 2mm or better.

3.2 Surveying shall be conducted by a registered surveyor with appropriate equipment and experience. The surveyor shall be retained by the Contractor.

#### 4.0 REPORTING

4.1 An updated processed copy of monitoring data accompanied by a brief interpretation, shall be provided to the Contract Administrator the day after each set of readings are obtained. The data shall be presented in tabular and graphical form.

4.2 As a minimum the following shall be reported to the Contract Administrator within 24 hours of obtaining a set of readings from VWP instruments:

- plots of piezometric elevation versus time for VWPs located in the same monitoring section and at the same approximate relative position with respect to the embankment centreline;
- same as above for excess pore pressure
- plots of EPP versus embankment height, for VWPs located in the same monitoring section and at the same approximate relative position with respect to the embankment centreline;
- plot of groundwater elevation versus time for each monitoring section
- fill height versus time
- plan view, cross section and profile sketches showing the top of fill location while the VWPs readings were being taken.

#### 5.0 PAYMENT

##### 5.1 Measurement of Payment

Vibrating Wire Piezometer Monitoring

Measurement of the item, 'Vibrating Wire Piezometers Monitoring' is for the supply of services to collect, process and interpret the vibrating wire piezometer data. This is a lump sum item. A unit rate shall be provided for each additional set of readings over and above the specified quantity.

##### 5.2 Basis of Payment

Vibrating Wire Piezometer Monitoring - Item

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.



---

## STANDPIPE (SSP) - SUPPLY & INSTALLATION

---

### 1.0 GENERAL

#### 1.1 Scope

1.1.1 This non-standard special provision contains the requirements for the supply and installation of standpipes.

1.1.2 The purpose of the standpipe is to monitor the level of the near surface groundwater table.

#### 1.2 General Procedure

1.2.1 The standpipes shall be installed after the installation of wick drains but prior to embankment construction.

1.2.2 Standpipes will be installed in vertical boreholes.

#### 1.3 Location

The locations of the standpipes are shown on Dwg. 15-64-7-1A and Dwgs. 15-64-7-2A,B and are given in Table 7a. A typical installation detail is shown in Dwg. 15-64-7-3B.

Table 7a - Standpipe Locations

Station	Offset (m)	Lane
17+822	19 Lt	WBL
17+796	19 Rt	EBL
18+202	25 Lt	WBL
18+176	21 Rt	EBL

### 2.0 MATERIALS

#### 2.1 General

The Contractor shall supply material and equipment, including drill rigs, required for installation of the standpipes.

## 2.2 Pipe and Couplings

The Contractor shall supply PVC pipe and couplings. The pipe internal diameter shall be no smaller than 19 mm.

## 2.3 Perforated Section

2.3.1 The Contractor shall supply a perforated section of the pipe that is 1.5 m long.

2.3.2 The perforations shall be frequent and large enough to allow rapid ingress of water along the length of the perforated section.

## 2.4 Bottom Cap

The Contractor shall supply bottom caps to fit the perforated section.

## 2.5 Top Caps

The Contractor shall supply vented top caps to fit the pipe.

## 2.6 Filter Sand

The Contractor shall supply clean washed sand for backfilling around perforated section.

## 2.7 Bentonite

The Contractor shall supply bentonite pellets for backfilling above the filter sand.

## 2.8 Grout

The Contractor shall supply grout for general backfilling.

## 2.9 Protective Housing

The Contractor shall supply a protective housing similar to that specified for inclinometers.

## 2.10 Monitoring Equipment

The Contractor shall supply an appropriate water level indicator with sufficient cable or tape length to read the water levels.

### 3.0 INSTALLATION

#### 3.1 General

- 3.1.1 Installation of the standpipe shall be as per the drawings provided in addition to what is stated or emphasised below.
- 3.1.2 The standpipe location shall be at sections indicated by the drawings provided.

### 4.0 REPORTING

The Contractor shall record and report relevant standpipe installation details to the Contract Administrator. These include, but are not limited to :

- ▶ Standpipe location, easting, northing;
- ▶ Elevation of ground level;
- ▶ Stratigraphic log of subsurface conditions at the standpipe;
- ▶ Dates of installation;
- ▶ Depth of pipe, stick up;
- ▶ Installation notes / backfilling notes;

### 5.0 PAYMENT

#### 5.1 Measurement of Payment

Standpipe Supply and Installation

Measurement for the item 'Standpipe Supply and Installation' is for the supply and installation of standpipes including all appurtenances by plan quantity. The unit of measurement is each.

#### 5.2 Basis of Payment

Standpipe Supply and Installation and Reporting - Item

Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.

---

## STANDPIPE (SSP) - MONITORING

---

### 1.0 GENERAL

#### 1.1 Scope

This non-standard special provision contains the requirements for the monitoring of standpipes including data reduction, interpretation and reporting. The monitoring shall be carried out by the Contractor.

#### 1.2 Monitoring Frequency

As a minimum, standpipes shall be read with the frequencies given in Table 7b.

Table 7b - Minimum Standpipe Monitoring Frequency

STAGE	FREQUENCY (spread over given time)
Baseline Reading	3 readings on 3 consecutive days, no sooner than 7 days following installation.
Just prior to start of embankment construction	once
during embankment construction	once every 0.5m fill lift within 20m of the monitoring section
after end of embankment construction to top of surcharge and prior to surcharge removal	weekly
prior to paving	monthly

### 2.0 REPORTING

Groundwater level data shall be presented in conjunction with the VWP's.

### 3.0 PAYMENT

#### 3.1 Measurement of Payment

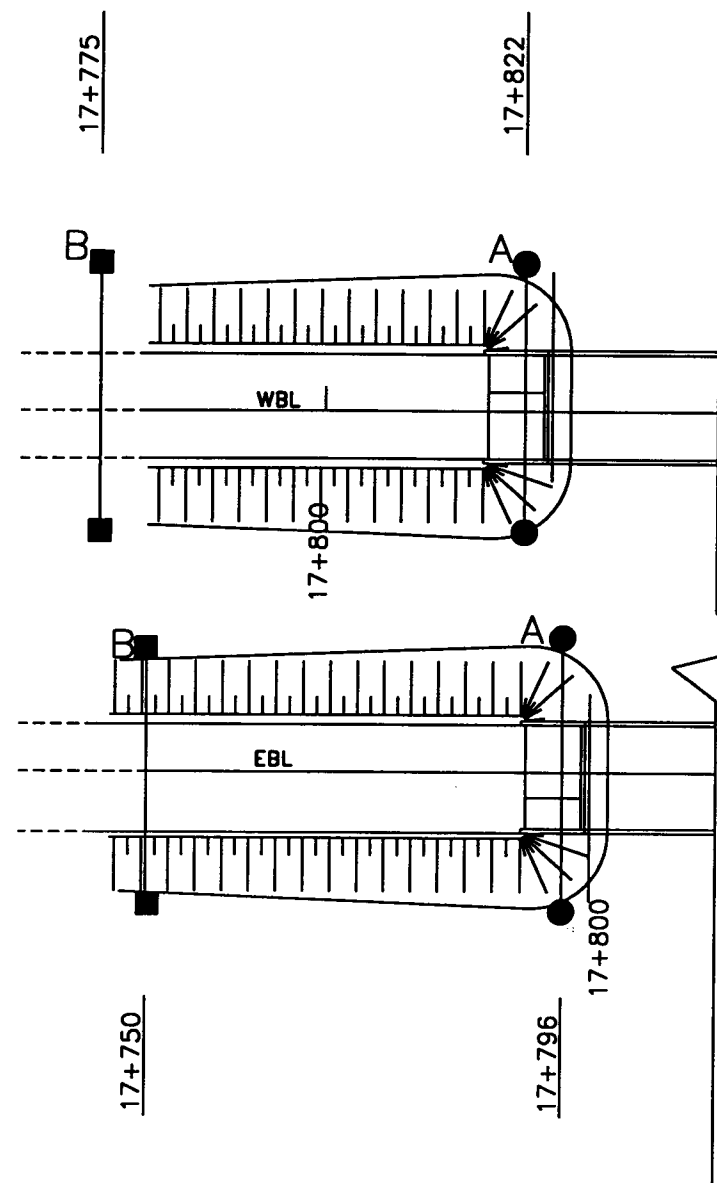
Standpipe Monitoring

Measurement of the item, 'Standpipe Monitoring' is for the supply of services to collect, process and interpret the standpipe data. This is a lump sum item. A unit rate shall be provided for each additional set of readings over and above the specified quantity.

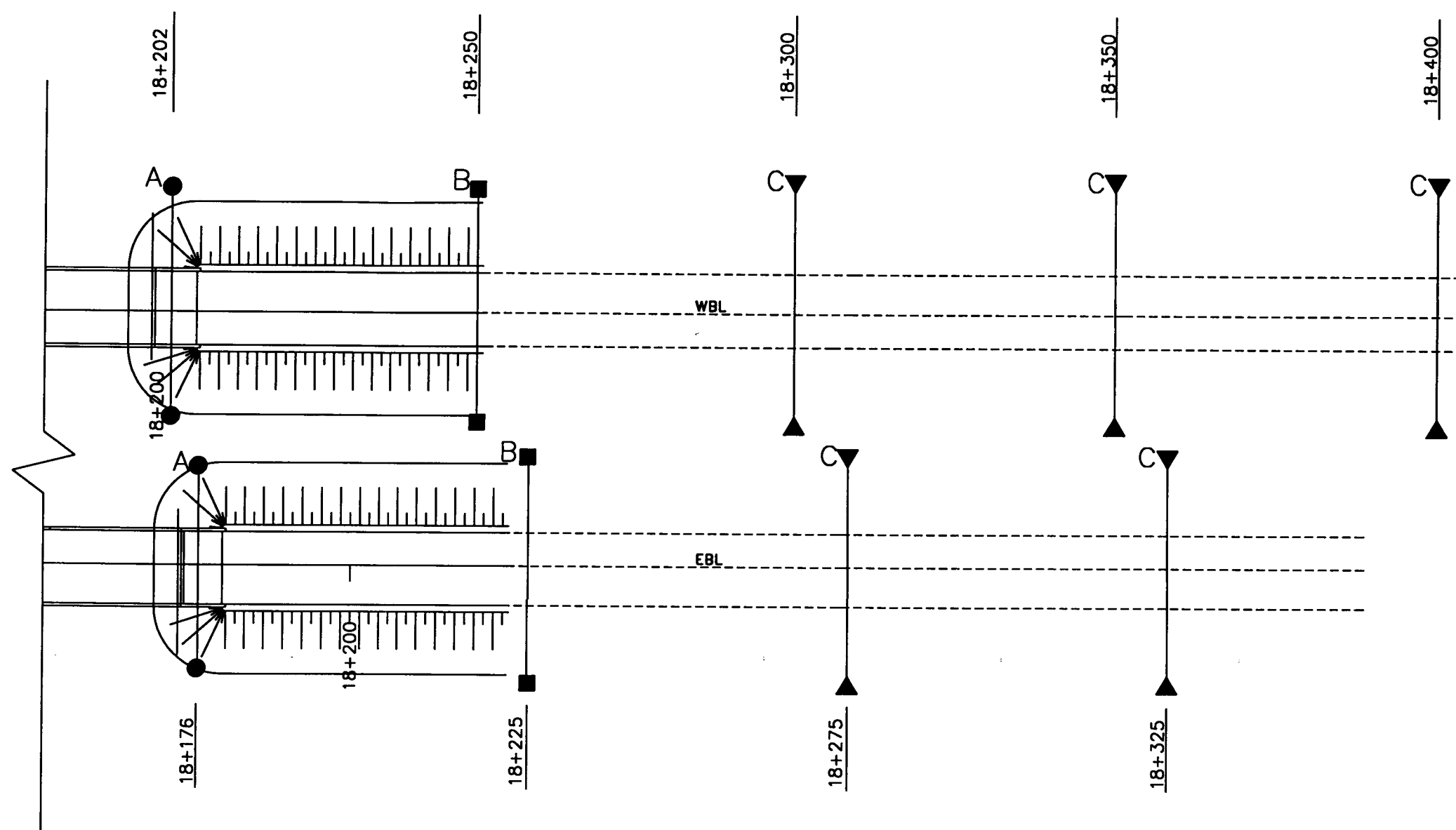
3.2 Basis of Payment

Standpipe Monitoring - Item

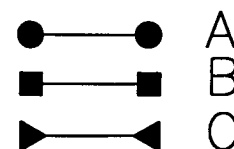
Payment at the contract price for the above item shall be full compensation for all labour, monitoring equipment and material to do the work.



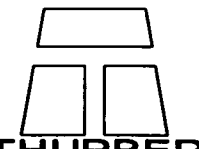
WEST APPROACH  
AND ABUTMENTS

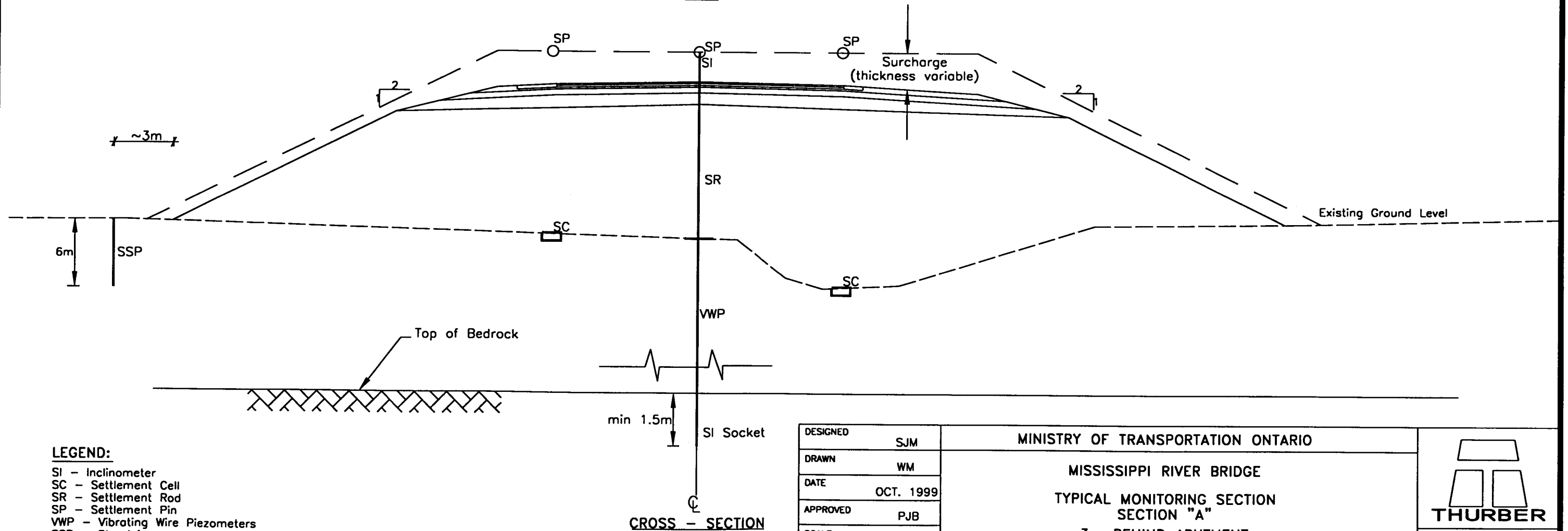
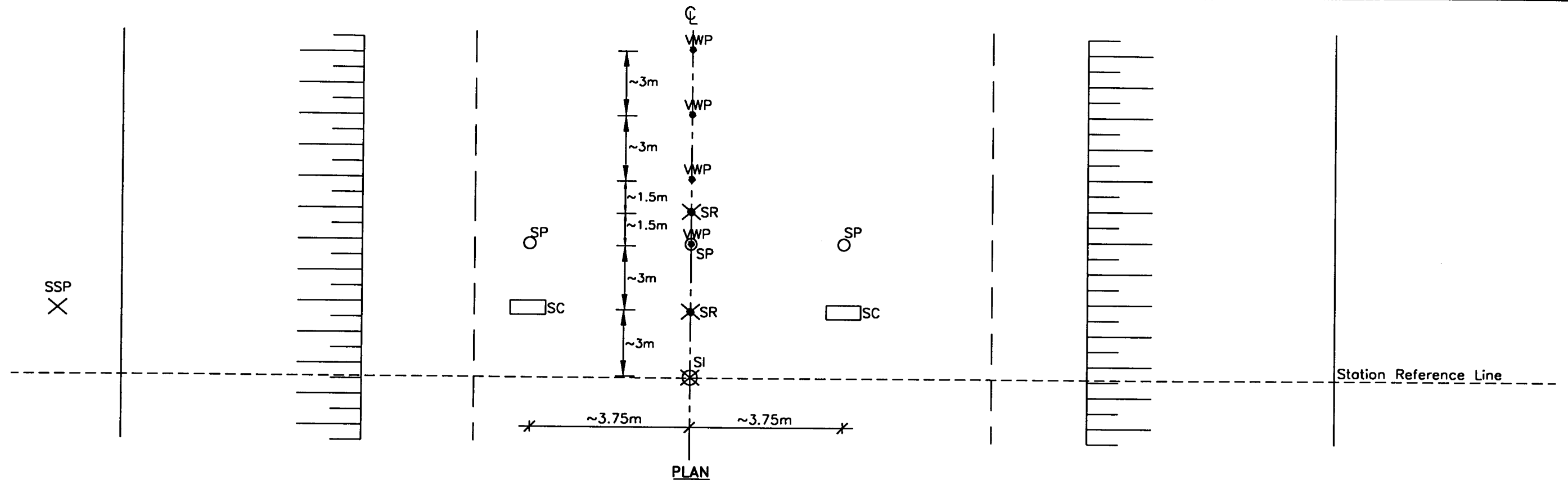


EAST APPROACH AND ABUTMENTS



NOTE: DRAWING MODIFIED FROM GENERAL ARRANGEMENT  
BY MTO JULY, MAY 1999.

DESIGNED	SJM	MINISTRY OF TRANSPORTATION ONTARIO	
DRAWN	WM	<div>MISSISSIPPI RIVER BRIDGE MONITORING SECTIONS-PLAN</div>	
DATE	OCT. 1999		
APPROVED	PJB		
SCALE	NTS		
		 THURBER DRAWING No. 15-64-7-1A	



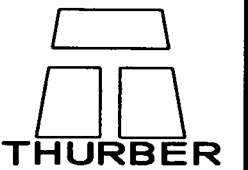
**LEGEND:**

SI - Inclinometer  
 SC - Settlement Cell  
 SR - Settlement Rod  
 SP - Settlement Pin  
 VWP - Vibrating Wire Piezometers  
 SSP - Standpipe

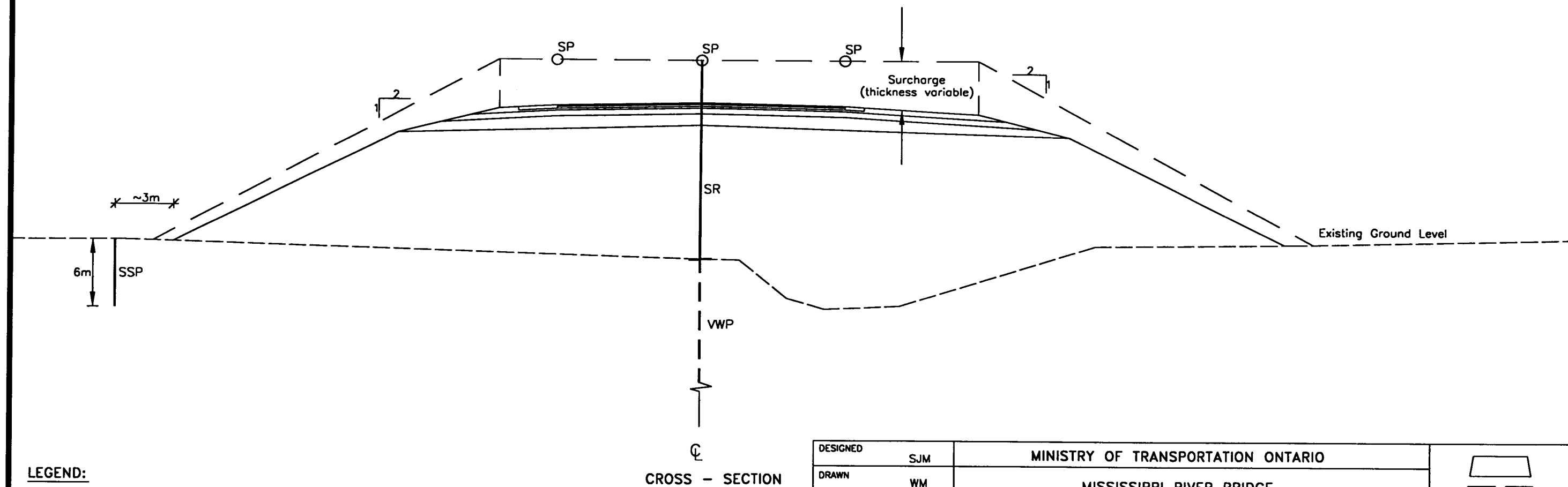
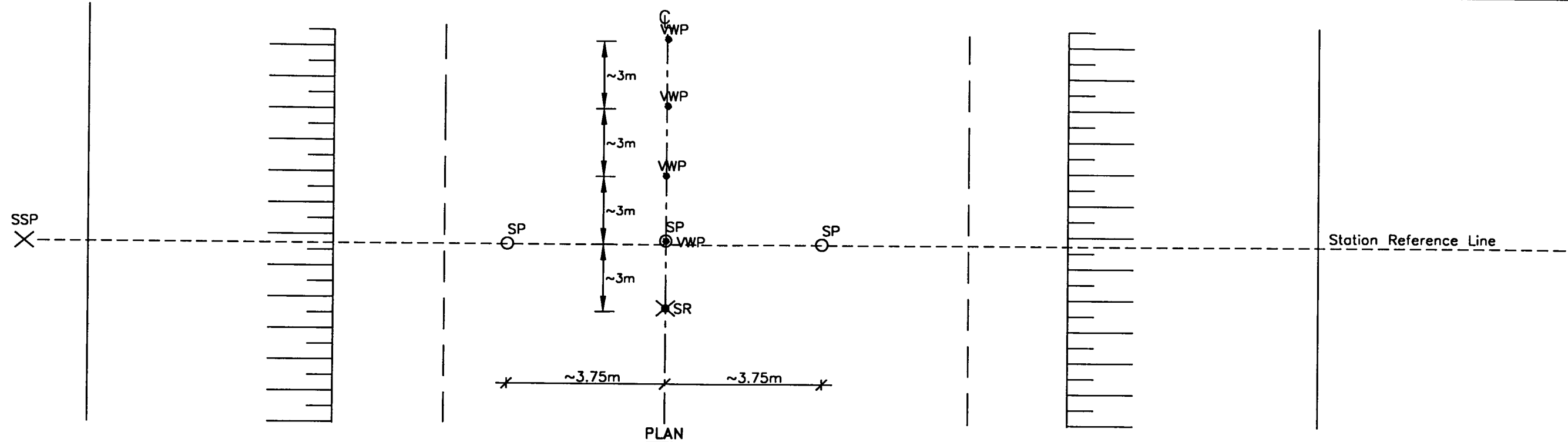
DESIGNED	SJM
DRAWN	WM
DATE	OCT. 1999
APPROVED	PJB
SCALE	N.T.S.

MINISTRY OF TRANSPORTATION ONTARIO

MISSISSIPPI RIVER BRIDGE  
 TYPICAL MONITORING SECTION  
 SECTION "A"  
 3m BEHIND ABUTMENT



DRAWING No. 15-64-7-2A



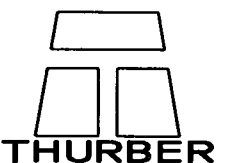
**LEGEND:**

SR - Settlement Rod  
 SP - Settlement Pin  
 VWP - Vibrating Wire Piezometers  
 SSP - Shallow Standpipe

DESIGNED	SJM
DRAWN	WM
DATE	OCT. 1999
APPROVED	PJB
SCALE	N.T.S.

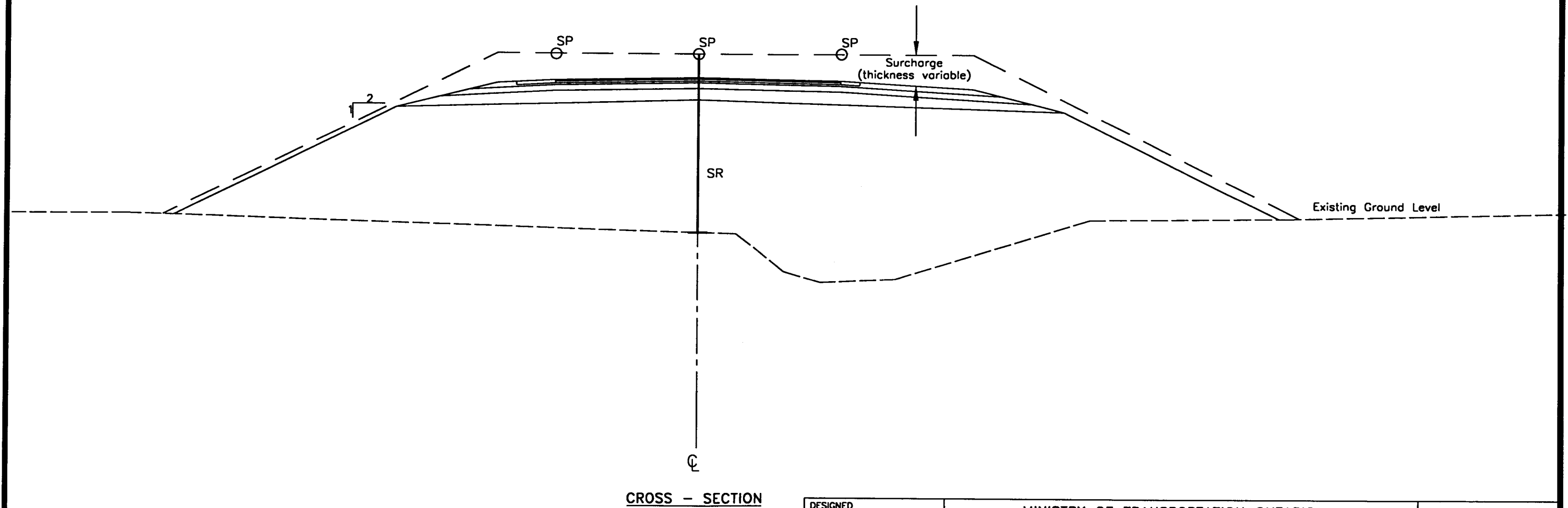
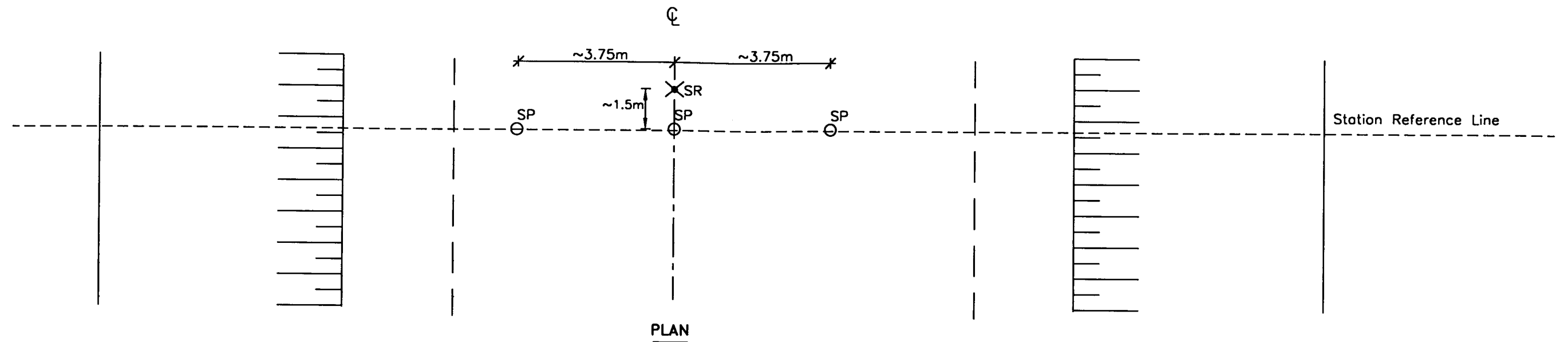
MINISTRY OF TRANSPORTATION ONTARIO

MISSISSIPPI RIVER BRIDGE  
 TYPICAL MONITORING SECTION  
 SECTION "B"  
 50m BEHIND ABUTMENT



DRAWING No. 15-64-7-28





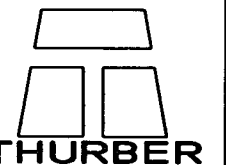
**LEGEND:**

SR - Settlement Rod  
SP - Settlement Pin

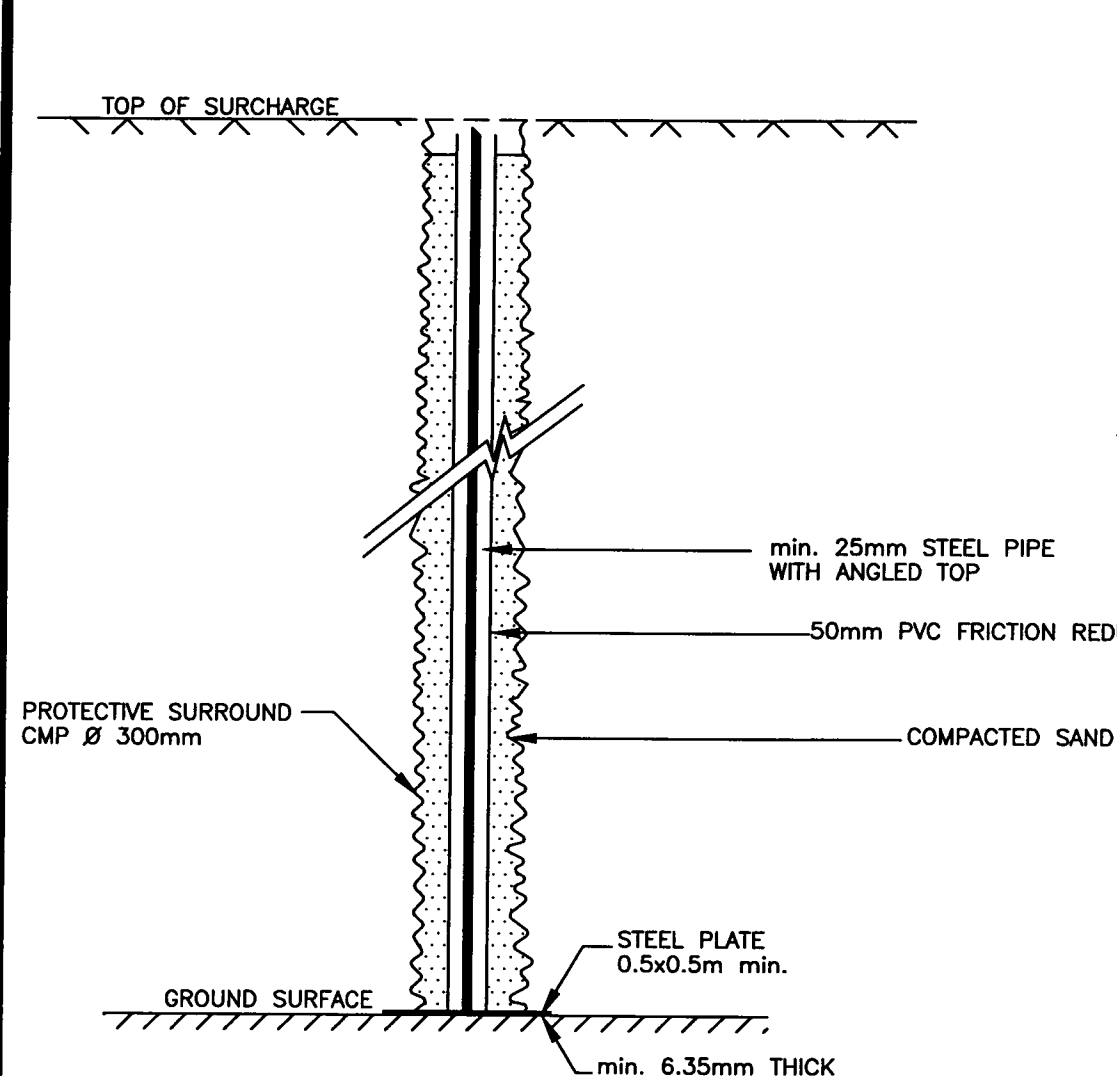
DESIGNED	SJM
DRAWN	WM
DATE	OCT. 1999
APPROVED	PJB
SCALE	N.T.S.

MINISTRY OF TRANSPORTATION ONTARIO

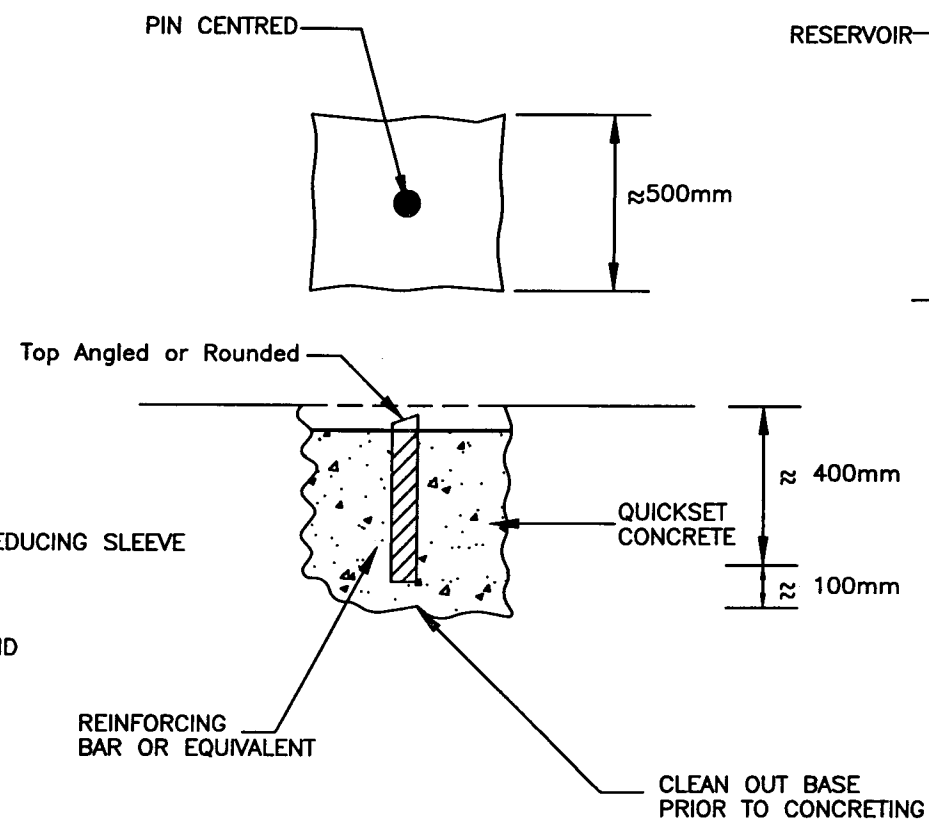
MISSISSIPPI RIVER BRIDGE  
TYPICAL MONITORING SECTION  
SECTION "C"



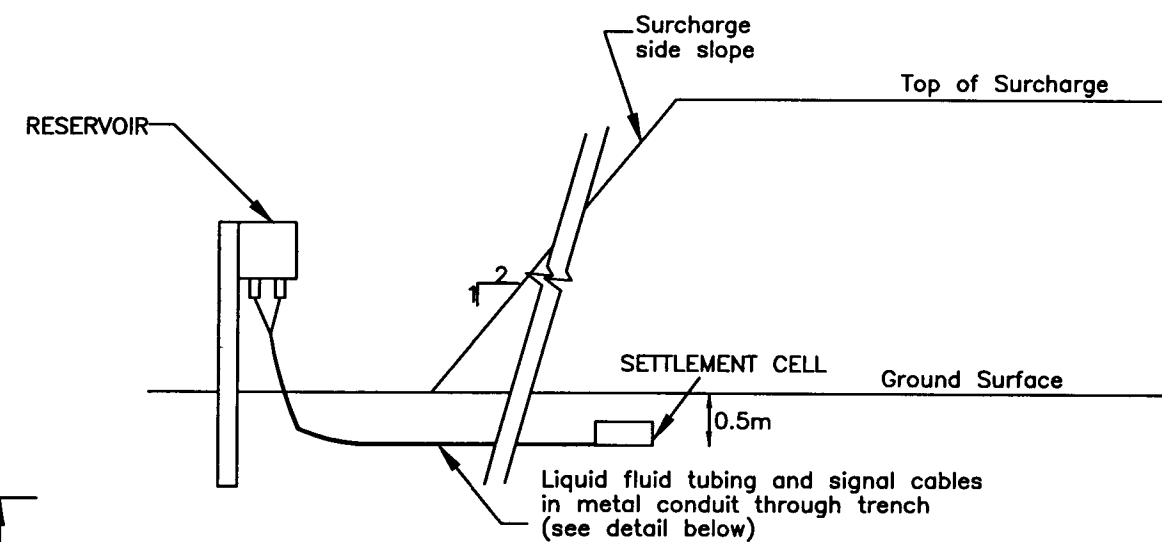
DRAWING No. 15-64-7-2C



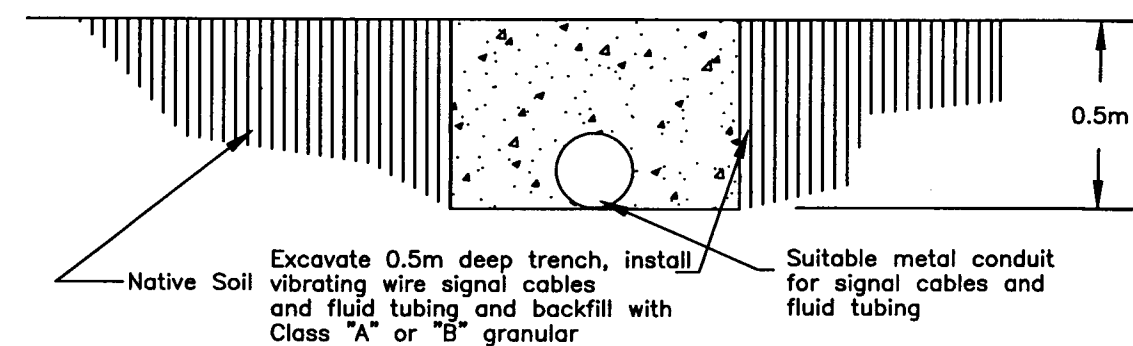
SETTLEMENT ROD (SR)



SETTLEMENT PIN (SP)



VIBRATING WIRE SETTLEMENT CELLS WITH PRESSURIZED RESERVOIR (SC)

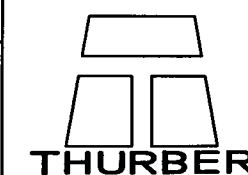


MONITORING TRENCH

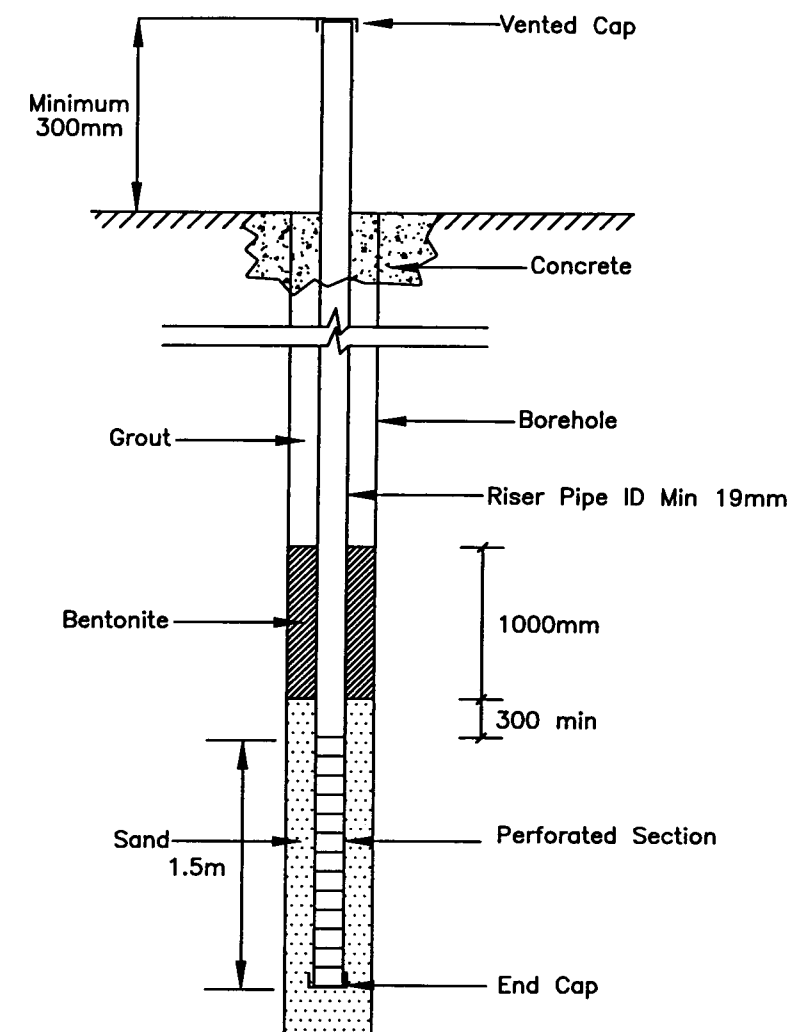
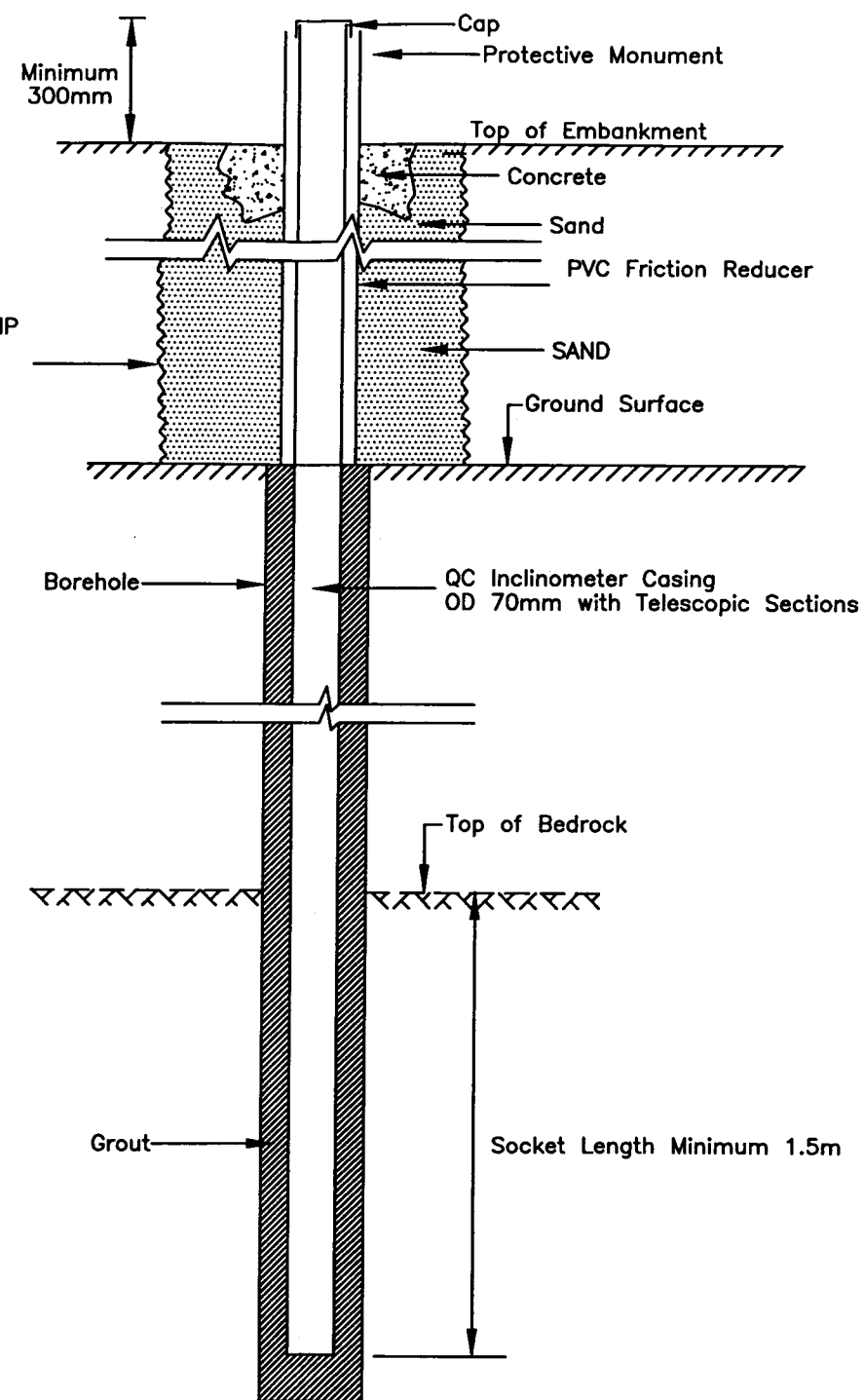
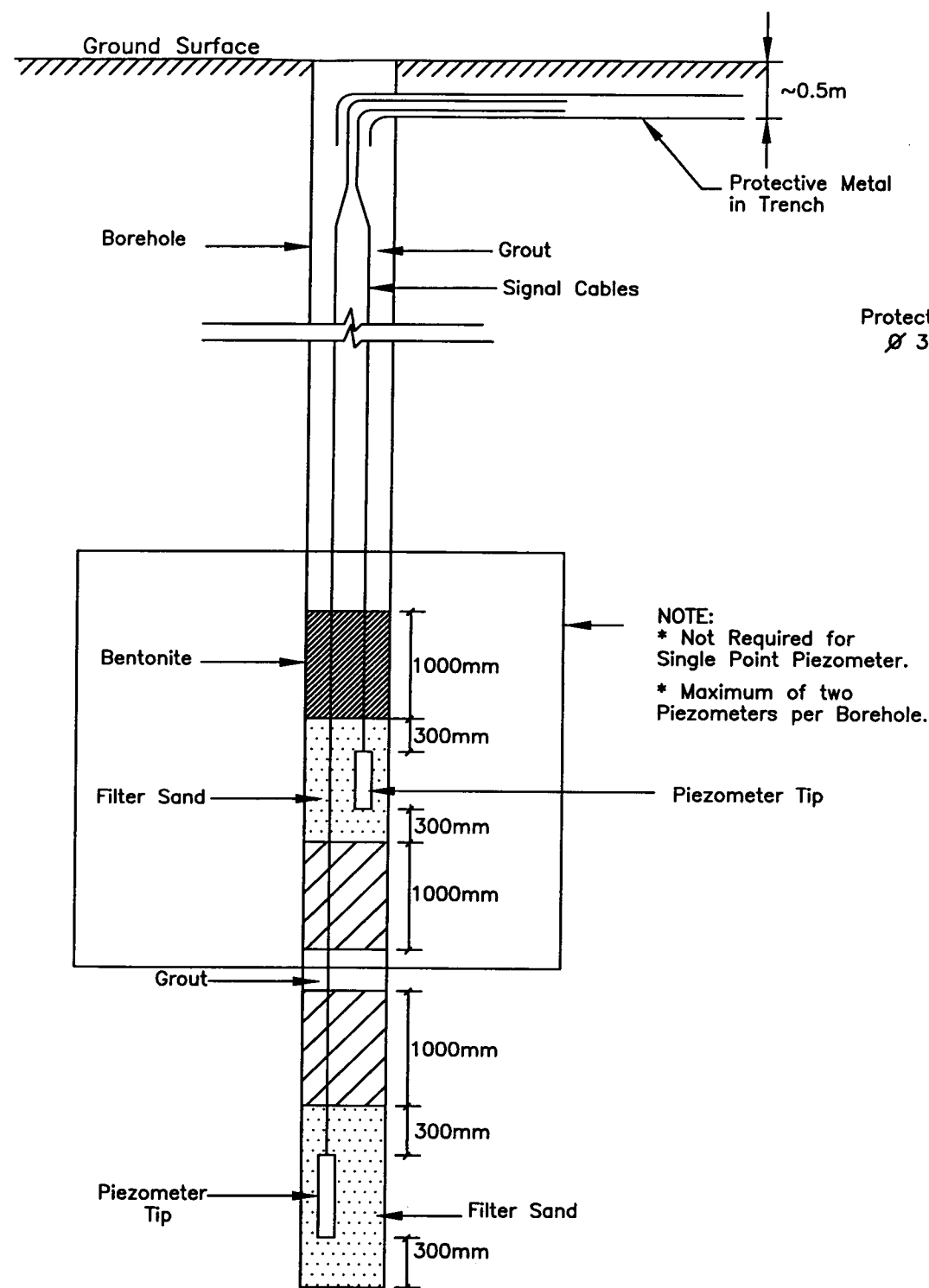
DESIGNED	SJM
DRAWN	WM
DATE	OCT. 1999
APPROVED	PJB
SCALE	NTS

MINISTRY OF TRANSPORTATION ONTARIO

MISSISSIPPI RIVER BRIDGE  
MONITORING INSTRUMENT DETAILS



DRAWING No. 15-64-7-3A



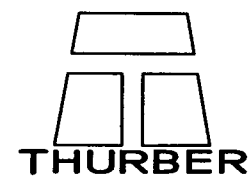
DESIGNED	SJM
DRAWN	WM
DATE	OCT. 1999
APPROVED	PJB
SCALE	NTS

MINISTRY TRANSPORTATION ONTARIO

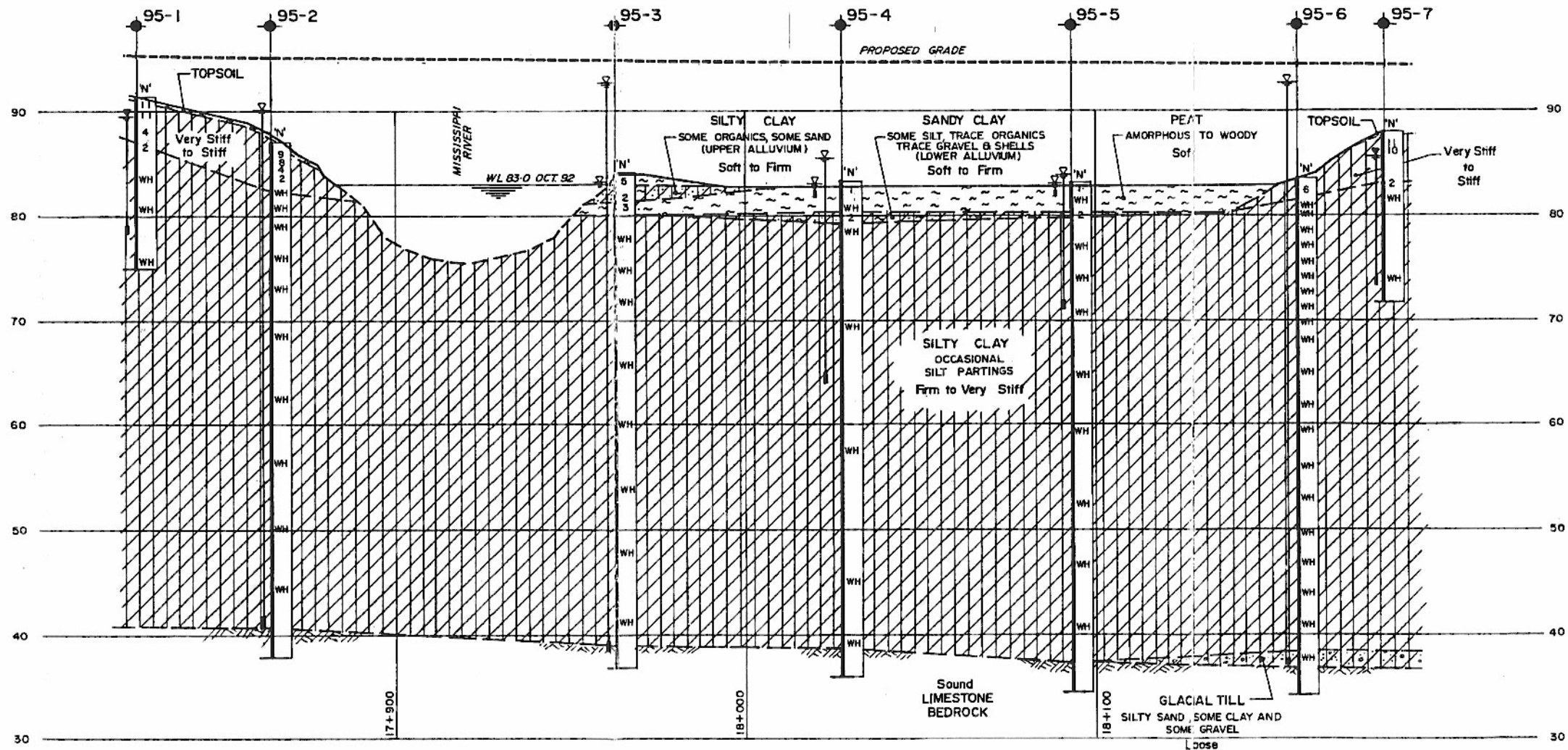
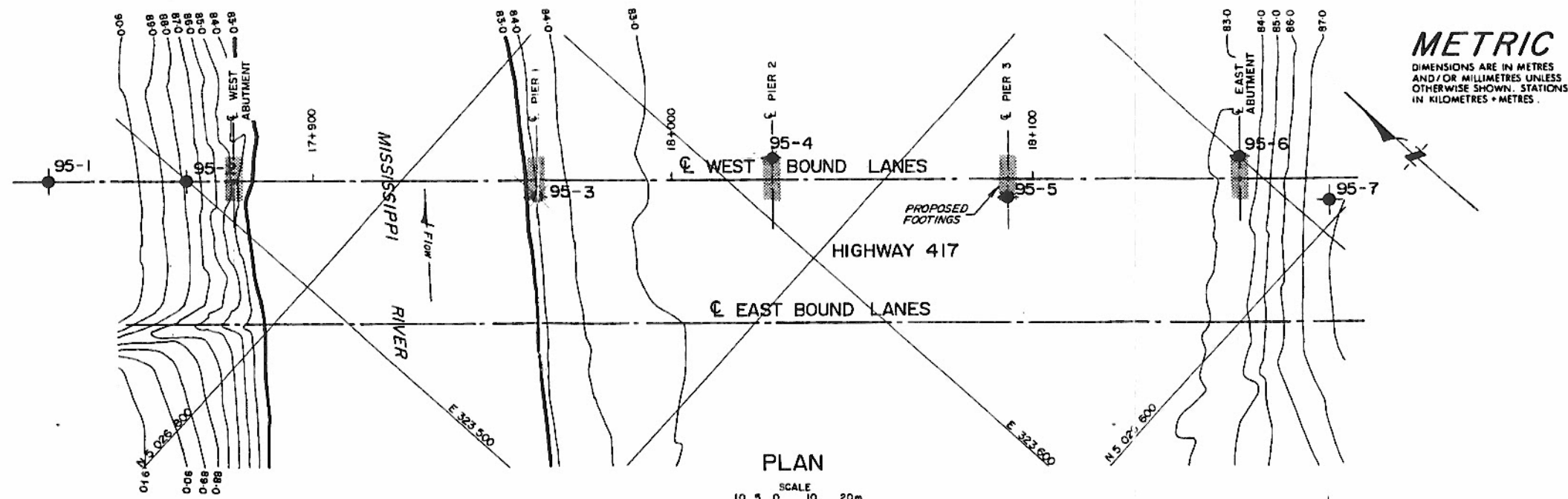
# MISSISSIPPI RIVER BRIDGE

## MONITORING INSTRUMENT DETAILS

## MONITORING INSTRUMENT DETAILS



**DRAWING No.** 15-64-7-3B



**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METRES.

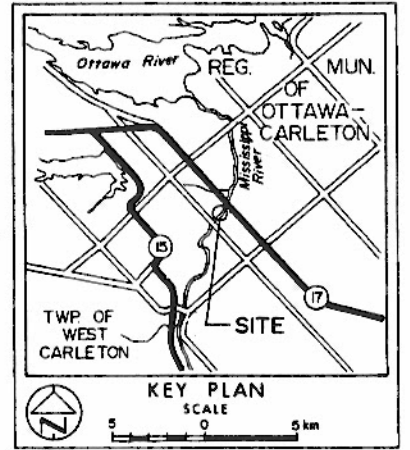
CONT No  
WP No451-90-03/04

MISSISSIPPI RIVER BRIDGE  
HWY 417  
BORE HOLE LOCATIONS & SOIL STRATA



SHEET

THURBER ENGINEERING LTD.



**LEGEND**

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- WH Weight of Hammer
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W.L. at time of investigation Apr. 1995
- PIEZOMETER
- ARTESIAN WATER

No	ELEVATION	CO ORDINATES NORTH	EAST
95-1	91.5	5 026 872.5	323 474.5
95-2	86.9	5 026 844.1	323 500.1
95-3	84.3	5 026 768.0	323 560.5
95-4	83.0	5 026 727.7	323 612.9
95-5	83.0	5 026 671.4	323 647.5
95-6	83.4	5 026 631.1	323 699.9
95-7	88.1	5 026 603.7	323 708.3

**NOTE**

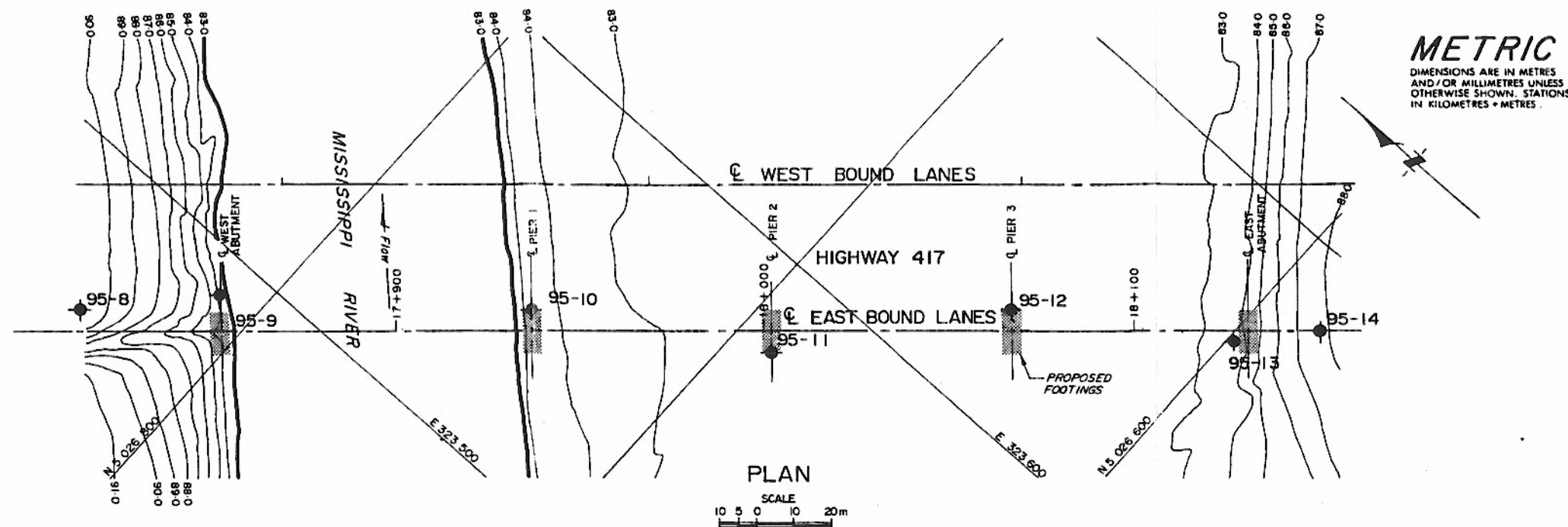
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REV	DATE	BY	DESCRIPTION

Geocres No 31F-117

HWY No 417	DIST 42
SUBMD	CHECKED CB DATE May 15 1995 SITE 3-594
DRAWN DW	CHECKED IC APPROVED DWG 45190 03/04-4



**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METRES.

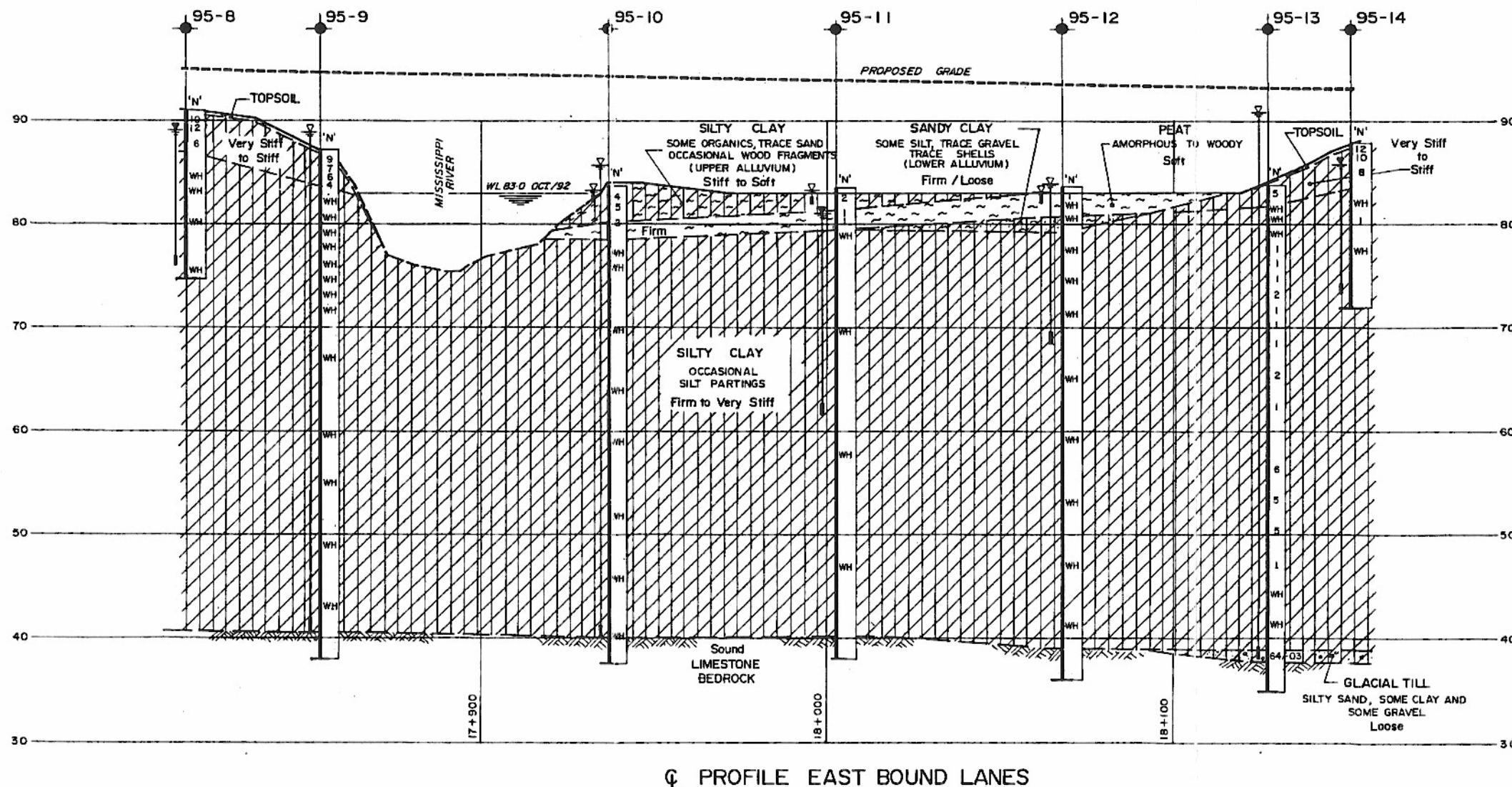
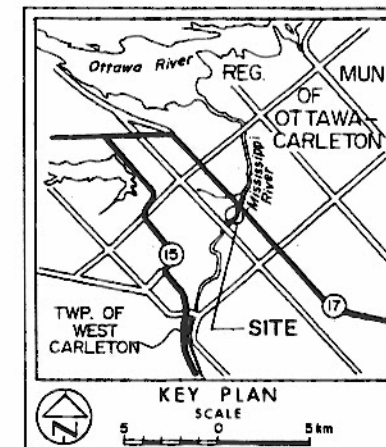
CONT No  
WP No.451-90-03/04

MISSISSIPPI RIVER BRIDGE  
HWY 417  
BORE HOLE LOCATIONS & SOIL STRATA



SHEET

THURBER ENGINEERING LTD.



**LEGEND**

- Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ⊕ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- WH Weight of Hammer
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- WL at time of investigation Apr. 1995
- PIEZOMETER
- ARTESIAN WATER

No	ELEVATION	CO-ORDINATES NORTH	EAST
95-8	91.1	5 026 836.3	323 460.5
95-9	87.2	5 026 810.4	323 489.6
95-10	83.4	5 026 748.3	323 542.8
95-11	83.1	5 026 689.0	323 577.4
95-12	83.1	5 026 648.7	323 629.8
95-13	83.5	5 026 597.4	323 663.9
95-14	88.4	5 026 580.1	323 683.5

**NOTE**

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

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REV.	DATE	BY	DESCRIPTION
1			

Geocres No 31F-117

HWY No	417	DIST	42
SUBMD	CHECKED CB	DATE	May 15 1995
DRAWN	DW	CHECKED	IC

REF No. E-66-417-1