THURBER ENGINEERING LTD.

July 31, 2019 File: 23705

McElhanney Consulting Services Ltd.
Suite 2300 Central City Tower
13450 - 102 Avenue
Surrey, B.C.
V3T 5X3

Attention: Michael Thiessen, P.Eng.

CITY OF SURREY DRAINAGE MAINTENANCE ACCESS UPGRADES GEOTECHNICAL RECOMMENDATIONS

Dear Mike:

Thurber has completed a desktop study and prepared preliminary geotechnical recommendations for access upgrades to drainage facilities along the Nikomekl, Serpentine, and Fraser Rivers. This letter provides the results of the desktop study, site specific comments regarding the Erikson and Cloverdale pump stations, and geotechnical recommendations for design and supercedes the April 9, 2019 preliminary report.

It is a condition of this letter that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1. BACKGROUND

The City of Surrey intends to improve maintenance access at 14 pump stations along the Nicomekl and Serpentine Rivers, and 2 pump stations along the Fraser River. The upgrades include constructing log booms, paths / roads, platforms, stairs, and improvements to existing facilities (e.g. railings for stairs / platforms).

Thurber visited Erickson and Cloverdale pump stations on March 11, 2019 at the request of McElhanney to review settlement distress features. The Thurber field review report is attached.

Thurber has been retained to prepare typical geotechnical recommendations for the various elements to be constructed at the various pump stations. Our recommendations are based on the results of a desktop study of the information contained in our files. Assessment of soil and groundwater contamination is not included in our scope of work.

2. DESKTOP STUDY

A review of Thurber's project database yielded a number of assignments completed near the pump stations. A summary of the available geotechnical information is provided in Table 1. Representative test hole logs are provided in Appendix A.

3. SUBSURFACE CONDITIONS

The pump stations located along the Serpentine, Nicomekl, and Fraser Rivers generally have a similar stratigraphic profile. A highly-simplified stratigraphy provided below is an aid to discussion.

- Fill
    - dike fill would be expected to comprise clay-silt mixtures or till-like soil
    - road or surfacing fill would probably comprise sand with varying minor silt content
- Peaty Silt
    - encountered in only about half of the test holes reviewed
    - generally less than 1 m thick, up to 4 m thick at Manson Canal
    - moisture contents generally less than 150%
- Clay-Silt
    - normally consolidated clay-silt mixtures with sand lenses or partings, occasional peat seams
- Sand
    - only present at 3 sites; Manson Canal at 15 m depth, Royal City at 8 m depth (inferred), and Panorama at 4 m depth
    - the sand layer should be at least 5 m thick at Manson Canal and Royal City, and 3 m to 4 m thick at Panorama
- Clay-Silt
    - artesian pressure in the underlying till-like soil can cause the effective stress to decrease with depth in the upper reaches of the Serpentine River, this reduces the strength of the soil

The available test hole information is provided in Appendix A. Table 1 shows which locations have test hole information, and if none is available which available log is inferred to be the most similar for that location.

The groundwater level would be expected to reflect the canal / river level and vary accordingly.

4. GEOTECHNICAL CONDITION ASSESSMENT

4.1 Erikson and Cloverdale Pump Stations

The distress features observed during the site visit are consistent with ongoing settlement of the compressible soils that underlie the sites. The distress features are most apparent around the pump stations because they are usually pile supported whereas the surrounding infrastructure is grade supported.

Stair extenders and locks blocks indicate that the dike was raised after the pump stations were constructed. Review of air photographs on COSMOS (City of Surrey GIS website) indicates that the dike near Erikson PS was raised in 2009/2010 and again in 2014, and the dike near Cloverdale PS in 2010 and 2012.

Raising the dike is the primary cause of the observed settlement distress features. Placing new dike fill would have re-initiated primary consolidation of the compressible soils which would have caused the grade supported infrastructure to settle relative to the pump station. Long-term secondary consolidation will still result in differential settlement between the grade and pile supported elements. However, the rate of secondary settlement is usually much slower (i.e. mm per year versus mm per week). Settlement of poorly compacted fill around the pump station could have contributed to the total settlement, but is unlikely a significant contributor.

5. SEISMIC ASSESSMENT

The pump station sites would generally be classified Site Class E, except for the Fraser River sites (Manson Canal, Royal City) and Panorama which would be Site Class F due to the presence of soils susceptible to seismic induced liquefaction.

All locations would be considered highly susceptible to lateral spreading for all but the smallest of earthquakes (i.e. 40% chance of exceedance in 50 years, or 1:100-year seismic event). Lateral movement of the dikes into the channels could be considerable depending on the magnitude and duration of the seismic event.

It is understood that design of drainage access upgrades will not consider seismic performance.

6. DISCUSSION AND PRELIMINARY RECOMMENDATIONS

6.1 General

Based on the subsurface conditions noted in our desktop study, it should be possible to construct works envisioned as part of the drainage access upgrades such as pile supported platforms, grade supported stairs, fall arrest anchors, and gravel paths. Preliminary geotechnical recommendations are provided in the subsequent sections for each type of structure.

6.2 Settlement

The light, grade-supported infrastructure described in the following sections would not be expected to initiate significant new primary consolidation. Long-term settlement of new infrastructure would be expected to reflect the regional rate of settlement which is probably in the order of a few millimetres per year. Differential settlement would be expected to develop where grade supported infrastructure is installed next to pile supported structures (e.g. pump stations) over a number of years.

Potentially significant settlement of grade supported infrastructure should be expected if the dike is raised. This will also increase the magnitude of differential settlement between grade- and pile-supported structures.

Consideration should be given to delaying access upgrades at locations where dike raising is likely to occur within a few years to reduce the early degradation of the improvements. Considerations should also be given to having infrastructure that can be shimmed or adjusted on their foundations to mitigate the effects of long-term settlement.

6.3 Piles

Platforms can be supported on close-ended, steel pipe piles driven to a minimum embedment length of 6 m for lateral restraint. Additional embedment would be required for axial resistance. The minimum embedment depth will need to be reviewed when the pile stick-up above ground level is known. Timber piles could be considered but compared to steel there would be a reduced service life and greater difficulty connecting to the metal platform.

The factored geotechnical axial compression resistance for several different pile diameters is provided in Appendix B (i.e. 276 mm, 324 mm, 356 mm, 406 mm). A factored resistance of 60 kN can be achieved with an embedment length of 10 m for a 406 mm diameter pile and 13 m for a 276 mm diameter. The minimum recommended wall thickness is 9.1 mm for a 276 mm diameter pile, 9.5 mm for a 324 mm diameter pile, 9.9 mm for a 356 mm diameter pile, and 10.4 mm for a 406 mm diameter pile.

It may be possible to support platforms on single piles if the lateral load demand and stick-up height is small enough. Preliminary calculations indicate that a lateral load of 4 kN would result in 25 mm deflection at the top of a single 324 mm diameter pile with a 5 m stick-up. If the stick-up was reduced to 2 m, the lateral load required to produce 25 mm of deflection would increase to 10 kN. To increase lateral resistance, piles could be installed in pairs and the deck/platform structurally connected to the pile cap to allow the structure to act as a frame. For structural assessment, a pile fixity depth of between 4 m and 6 m should be used. The fixity depth is greater than is usual at this site because of the very poor-quality soils. The proposed pile configurations are shown in Figures 1 and 2.

We do not anticipate any difficulties installing piles along the Nicomekl or Serpentine Rivers. Installation should be similarly feasible along the Fraser River although there is a greater risk of obstructions due to prior industrial use of the land. This could require relocating the piles or removing the obstruction.

Piles could be installed using impact hammers or vibratory methods. Vibratory methods would likely be superior insofar as it is easier to install the pile in the water as the vibratory unit is clamped onto the top of the pile making it easier to position than with an impact hammer. However, a vibratory hammer could require a larger crane than a drop hammer. For the conditions present, we anticipate that impact hammers will be better suited than hydraulic or diesel hammers due to their relative size and environmental considerations.

The pile compressive resistance was estimated using conservative assumptions. Accordingly, there is no ‘set-criteria’ for pile installation. The important geotechnical parameter for pile installation is the embedment depth (axial resistance).

6.4 Small Footings

Small footings will be required to support new stairs at a number of sites. The precast concrete proposed for the stairs are 0.9 m wide (into the slope) and 1 m long (along the slope). Larger footings may be used but 0.9 m x 1.0 m is the minimum probable size.

Footings should be embedded at least 500 mm below the adjacent grade for confinement and frost protection. The minimum dimension for individual footings should be 600 mm. The edge of the underside of footing should not be closer than 1 m to the surface of the slope at the same elevation. Settlement of foundations designed and constructed as described above would be expected to be less than 10 mm. This settlement estimate does not consider long-term regional settlement. This can be reviewed during detailed design when the slope geometry and stair layout is known.

The native soil or existing dike fill should be an acceptable subgrade. Deleterious materials such as debris, wood waste, soft, wet, or high-organic content soil should be removed and replaced with either competent dike fill or free draining granular fill with less than 5% passing a #200 sieve. The decision to use either dike fill or granular fill will depend on the amount of over-excavation.

All fill should be placed in loose lifts not exceeding 300 mm thickness and be compacted to 95% Standard Proctor Maximum Dry Density (SPMDD) with compaction equipment suitable to the task. The gradation and handling of the materials described above should conform to MMCD specifications. Dike fill should have at least 20% passing a #200 sieve, suitable materials could include clay-silt mixtures or silty till-like soils.

6.5 Dike Stability

We do not expect the stairs to adversely affect dike stability.

Fibreglass stairs are expected to be light. Using manufactures specifications for prefabricated steel stairs of similar dimensions the unit weight is about 1 kN per metre of length. This would correspond to a footing load of 1.5 kN for a 3 m stair, 3 kN for a 6 m stair, and 5 kN for a 10 m stair. For comparison, the footing would weigh about 14 kN.

The factor of safety was calculated assuming a 1.5H:1V and 2H:1V dike slope, with and without the stairs. Drained conditions were assumed for the dead load case and undrained conditions for the live load case. The dead load was assumed to be 5 kN (10 m stairs, most are less than 6 m) and the live load was assumed to be 4 times the dead load. For the various load and geometry conditions analysed, the calculated factor of safety dropped by about 3% for the undrained condition (transient load) and 1.5% in the drained condition (dead load). We consider the small reduction in factor of safety to be acceptable given typical factors of safety used for dike design. Furthermore, if poor performance were to become apparent it would be most likely via the drained condition which would involve shallow deformation around the footing which would not be expected to compromise the integrity of the dike.

6.6 Fall Arrest Anchors

Fall arrest anchors will be required for restraint of personnel and equipment. An efficient means of providing anchorage would be buried pre-cast concrete blocks with a stick-up pipe to provide a tie-off point. These anchorages could also be used to secure log booms.

Type B, C1, or E2 sign bases as described in the Master Municipal Construction Documents (MMCD) would be adequate to resist the lateral load specified by WorkSafe BC (22 kN). We assume that the backfill around the base is high-fines material suitable for use as dike fill.

A single lock block is inadequate to resist the design load. It would be necessary to bury and structurally connect two lock blocks to resist the design load. Thus, it is probably easier and cheaper to use MMCD standard sign bases as they also include pre-installed bolts that would allow the stick-up pipes to be bolted directly to the base.

6.7 Gravel Paths and Working Platforms

Gravel paths may be constructed at a number of sites to improve / allow access. No particular consideration is required if paths are located on a level surface or run directly up and down a dike slope (aside from the construction considerations arising due to sloping ground). However, gravel paths that cross slopes and working platforms will have to consider the alignment and cut / fill needed to establish a level surface.

Figures 3 through 7 provide typical details for path construction on a dike slope and for working platforms straddling the sluice gates. The figures are sketches and are intended to show the approximate arrangement in the field. Field modification during construction should be expected.

It is important to balance the cut and fill volumes as this will have the least overall effect on slope stability. Our preference is for planks or decks to be used to access the sluice gate crank (Figures 4 and 5). The large fill shown in Figures 6 and 7 would be difficult to construct without dewatering the ditch and would likely result in long term settlement which could degrade the performance of the discharge pipe.

The topsoil horizon should be stripped from gravel path alignments to expose the subgrade. The native soil or existing dike fill should be an acceptable subgrade. Deleterious materials such as debris, wood waste, soft, wet, or high-organic soil will need to be removed and replaced with either competent dike fill or free draining granular fill with less than 5% passing a #200 sieve. The decision to use either dike fill or granular fill will depend on the location of the path (i.e. on dike or not) and the amount of over-excavation.

The minimum recommended gravel path structure is 150 mm of 19 mm Crushed Granular Base. The surface of the path should have a crossfall of 2% and should be slightly higher than the surrounding grade to provide drainage and keep the surface relatively dry. Consideration should also be given to sloping the subgrade to facilitate drainage of the granular base.

All fill should be placed in loose lifts not exceeding 300 mm thickness and be compacted to 95% SPMDD with compaction equipment suitable to the task. The gradation and handling of the materials described above should conform to MMCD specifications. As above, dike fill should have at least 20% passing a #200 sieve, suitable materials could include clay-silt mixtures or silty till-like soils.

7. CLOSURE

We trust that this information is sufficient for your needs. Should you require clarification of any item or additional information, please contact us at your convenience.

Yours truly,
Thurber Engineering Ltd.
David Tara, M.Sc.A., P.Eng.
Review Principal

Marc Bossé

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
M. C. BOSSE
36163
2019.07.31

Marc C. Bossé, M.Sc., P.Eng.
Project Engineer

Attachments	Statement of Limitations and Conditions FRR #1 – Settlement Review of Erikson and Cloverdale Pump Stations Appendix A – Test Hole Logs (8 sheets) Appendix B – Calculated Factored Pile Resistance (3 sheets)

Table 1 – Summary of Geotechnical Information

#	Location	Test Hole Available	Test Hole Type	Ground Conditions Similar to
1	Colebrook Road	Yes	CPT	
2	Panorama	Yes	CPT	
3	Logging Ditch	No		South Cloverdale / Hookbrook
4	Burrows I	No		
5	Nicomekl	Yes	AH	
6	South Cloverdale	Yes	AH	
7	Erickson Ditch	No		South Cloverdale / Hookbrook
8	Halls Prairie	No		
9	Hookbrook	Yes	CPT	
10	64 Avenue	No		Hookbrook
11	East Newton	No		
12	Fleetwood	No		
13	Coast Meridian	No		
14	Upper Serpentine	Yes	AH	
15	Manson Canal	Yes	AH	
16	Royal City	Yes	AH	

Note: AH = Auger Hole, CPT = Cone Penetration Test

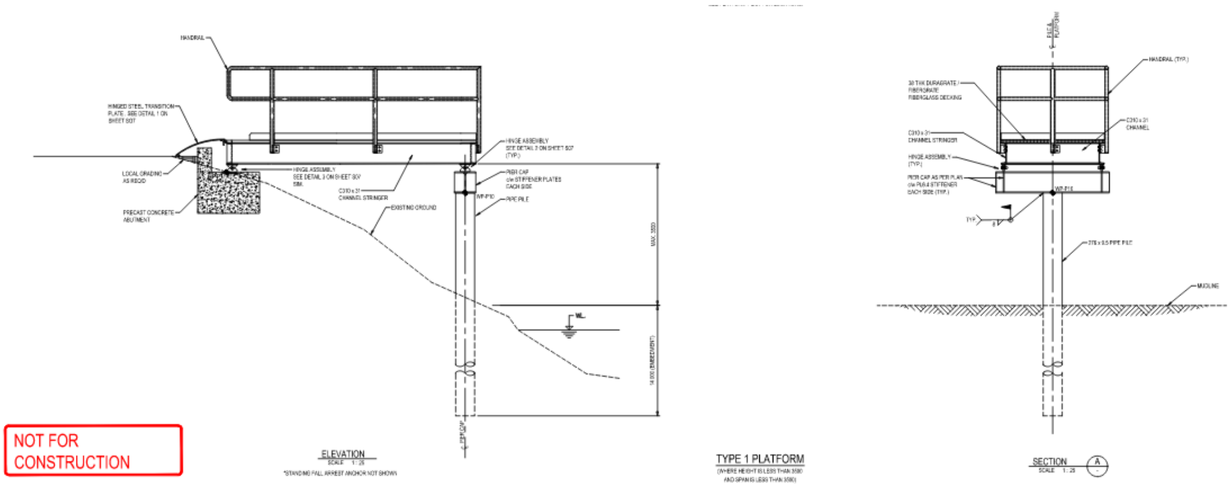


Figure 1 – Example of Type 1 platform from McElhanney drawings.

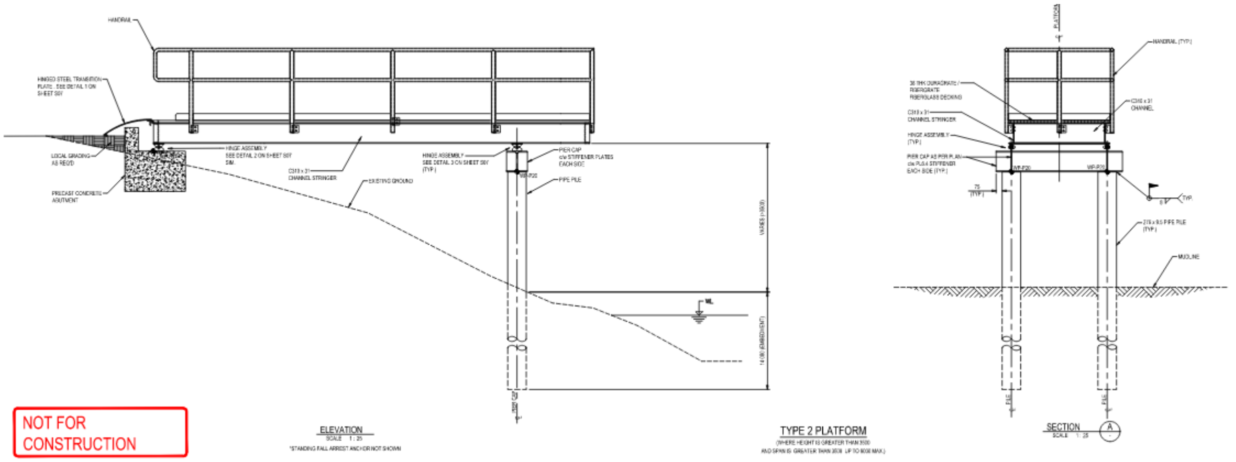
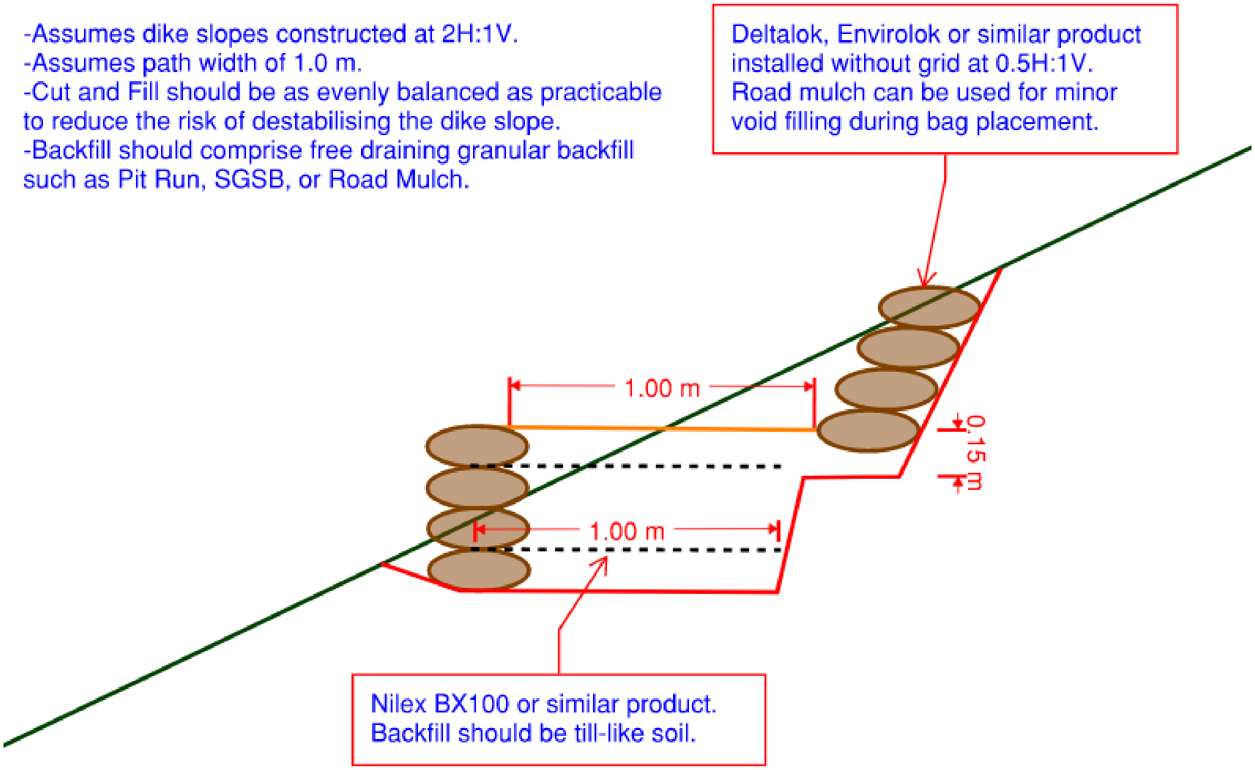


Figure 2 – Example of Type 2 platform from McElhanney drawings.



-Assumes dike slopes constructed at 2H:1V.
-Assumes path width of 1.0 m.
-Cut and Fill should be as evenly balanced as practicable to reduce the risk of destabilising the dike slope.
-Backfill should comprise free draining granular backfill such as Pit Run, SGSB, or Road Mulch.

Deltalok, Envirolok or similar product installed without grid at 0.5H:1V. Road mulch can be used for minor void filling during bag placement.

Nilex BX100 or similar product. Backfill should be till-like soil.

Figure 3 – Typical detail for constructing path or working platform on dike slope. Assumes that path is cut across the dike slope. A path running directly down the slope is just a matter of resurfacing.

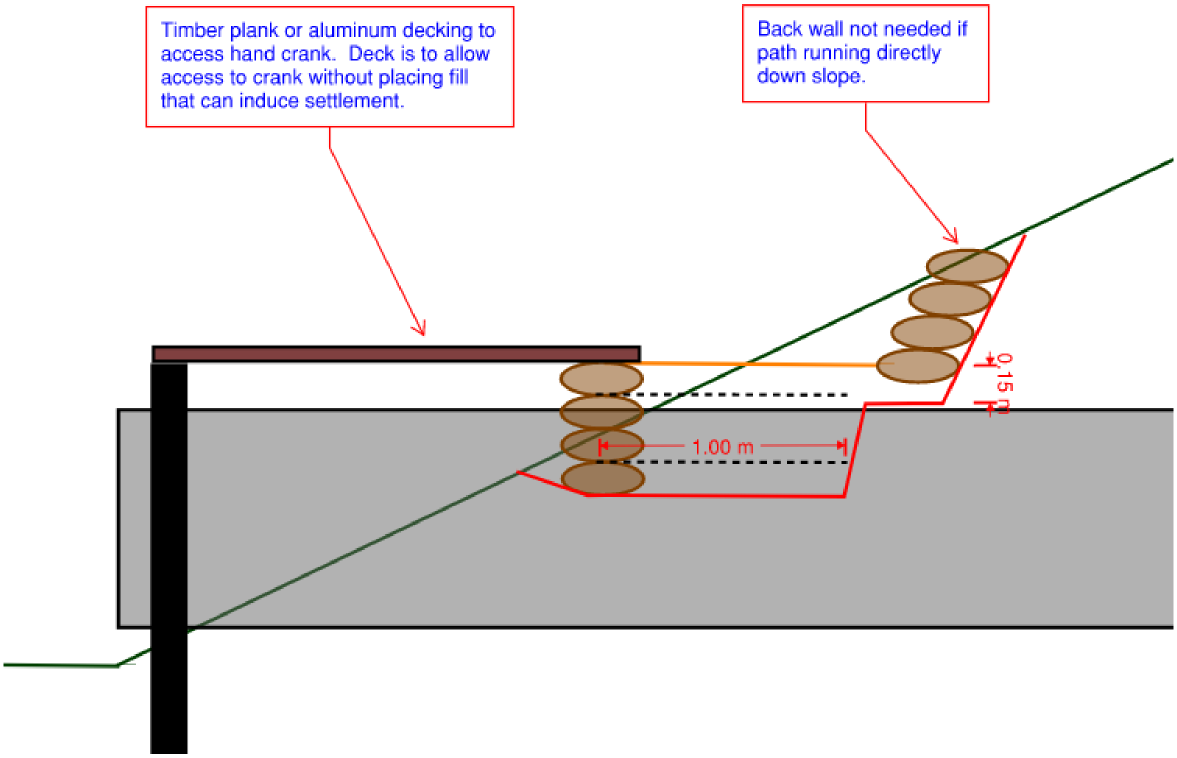


Figure 4 – Typical detail for constructing path or working platform at the outfall.

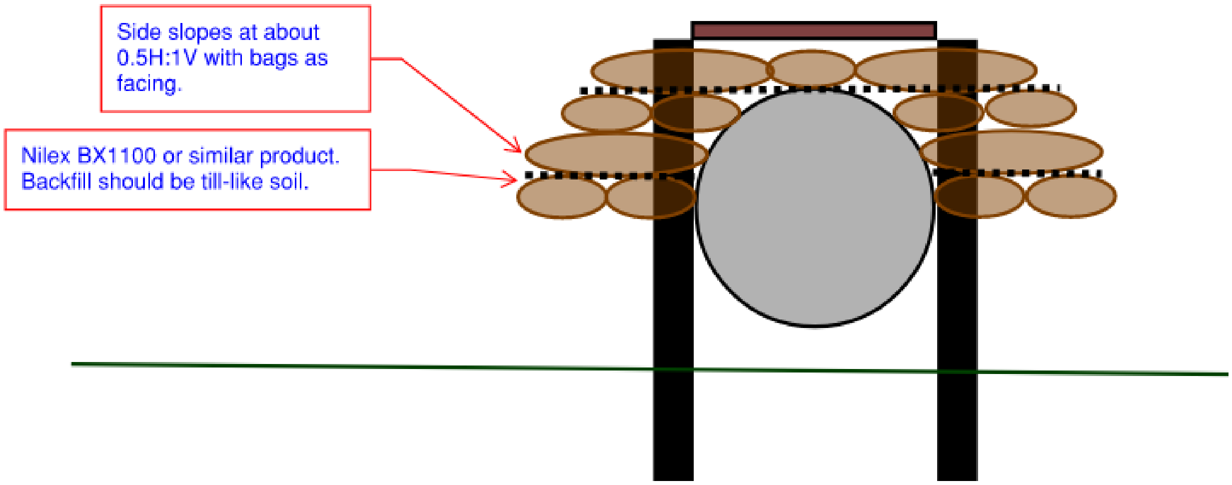


Figure 5 – Typical detail for constructing path or working platform at the outfall

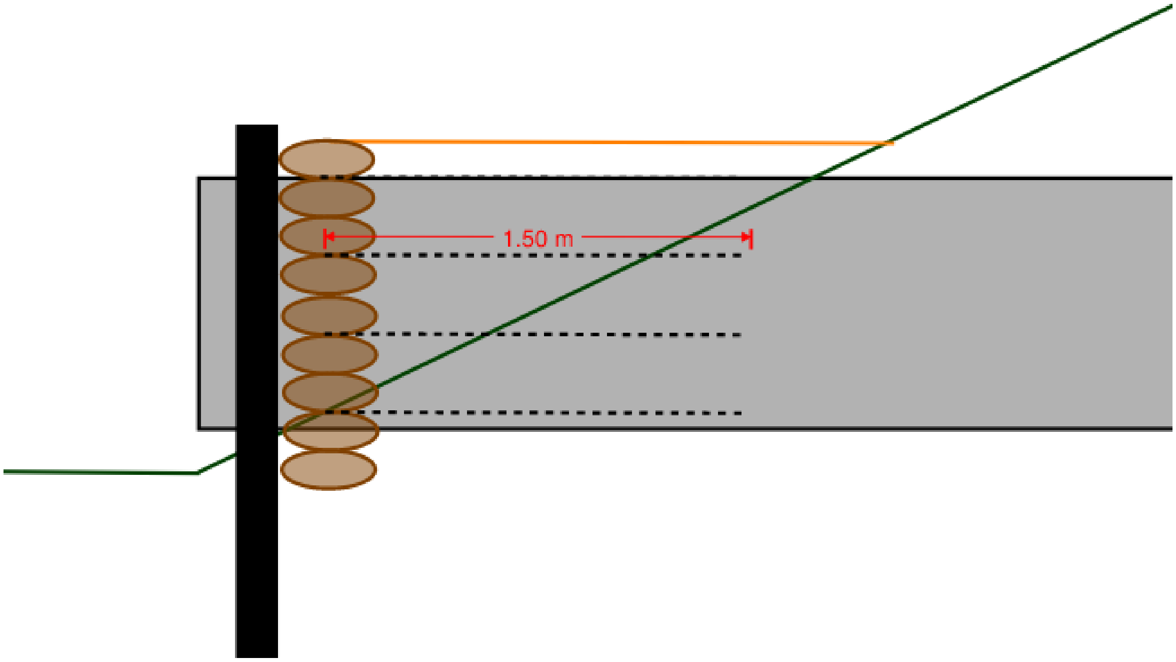


Figure 6 – Typical detail for constructing path or working platform at the outfall.

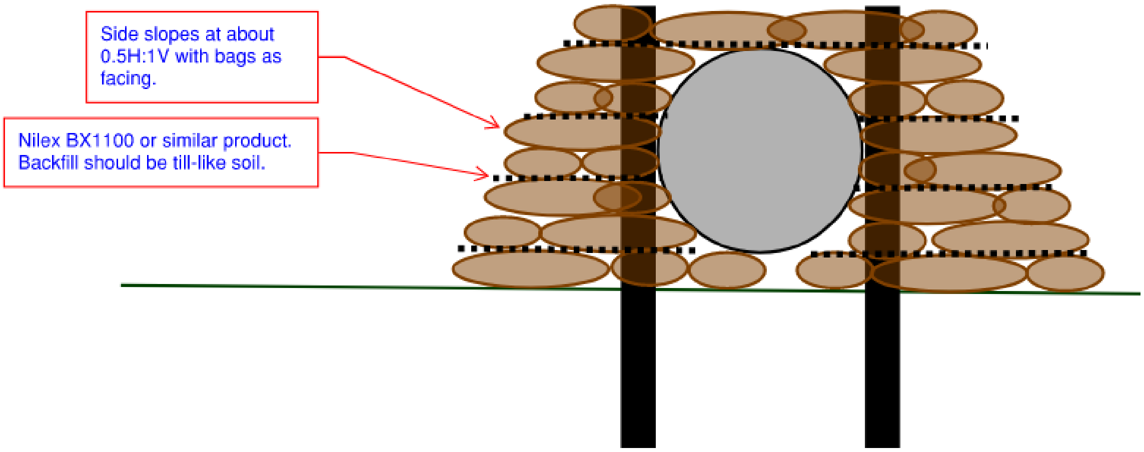


Figure 7 – Typical detail for constructing path or working platform at the outfall.

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

THURBER ENGINEERING LTD.

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FIELD REVIEW REPORT NO.: 1

THURBER FILE NO.: 23705

FIELD REVIEW REPORT	DATE: March 11, 2019
TO: McElhanney Consulting Services	ATTENTION: Mike Thiessen EMAIL: mthiessen@mcelhanney.com

PROJECT NAME: Surrey Pump Stations
CONTRACTOR(S):

PURPOSE OF SITE VISIT: Settlement Review
REFERENCE DRAWING / DOCUMENTS: McElhanney Surrey Pump Station Structural Inspections

THURBER PERSONNEL ON SITE: Amy Russell (ANR)	CLIENT/CONTRATOR PERSONNEL ON SITE: Amun, City of Surrey	TIME ON SITE: 1300 to 1445, Overcast

ACTIVITIES/OBSERVATIONS:

Erikson Pump Station

- The concrete stairs and retaining wall on the north side of the pump station showed signs of settlement.
- The stair stringer had a crack approximately 150 mm wide (see Photo 1). Rebar was visible in the crack. The stairs and stringers do not look like they have significantly settled. The stairs were at an angle of 0° to horizontal.
- The retaining wall adjacent to the stairs appears to have settled (see Photo 2). The top of the retaining wall was at an angle of 3° from horizontal. There is a gap of approximately 25 mm between the edge of the stairs and the retaining wall (see Photo 3). The railing at the top of the retaining wall is at an angle of 5° from horizontal.
- The wooden platform at the top of the retaining wall is in line with the top of the wall (see Photo 4). There is an approximately 150 mm void below the wooden platform.
- Surficial soil comprised gravelly, silty sand fill.
- The wooden stairs on the south side of the pump station shows signs of settlement. Thurber has been informed that these stairs are to be replaced. The stair surfaces are at angle of 5° to horizontal (see Photo 5).
- There was a 3 mm crack in the concrete pathway near the pump station door.
- Mud cracking was visible at the top of the dike. No evidence of slope instability was observed.
- The inlet and outlet structures have sheet pile walls. The outlet structure pile cap has an approximately 50 to 80 mm gap between the underside of the pile cap and the fill.

Cloverdale Pump Station

- The south stairs consisted of 5 wooden stairs above 8 concrete stairs and showed signs of settlement.
- The bottom stair is approximately 80 mm below the outlet structure (see Photo 6). The concrete stairs are sloping at an angle of 5° from horizontal towards the water (see Photo 7). The upper slope is at approximately a 1H:1V slope.
- Mud cracking was visible at the top of the dike. No evidence of slope instability was observed.
- The north stairs consisted of concrete stairs on the west side on the pump station (see Photo 8).
- The bottom step was only 90 mm above the ground surface. The steps sloped 3° from horizontal towards the west.
- There is an approximately 50 mm gap between the edge of the staircase and the wall of the pump station (see Photo 9).

PHOTOS/FIGURES:

Photo 1 – Failure in north stair stringer for Erikson Pump Station.

Photo 2 – Sloping of retaining wall for Erikson Pump Station.

Photo 3 – Gap between the stairs and retaining wall for Erikson Pump Station.

Photo 4 – Wooden platform at the top of the retaining wall for Erikson Pump Station.

Photo 5 – South Stairs for Erikson Pump Station.

Photo 6 – Cloverdale pump station south stairs.

Photo 7 – South Stairs for Cloverdale Pump Station.

Photo 8 – North Stairs for Cloverdale Pump Station.

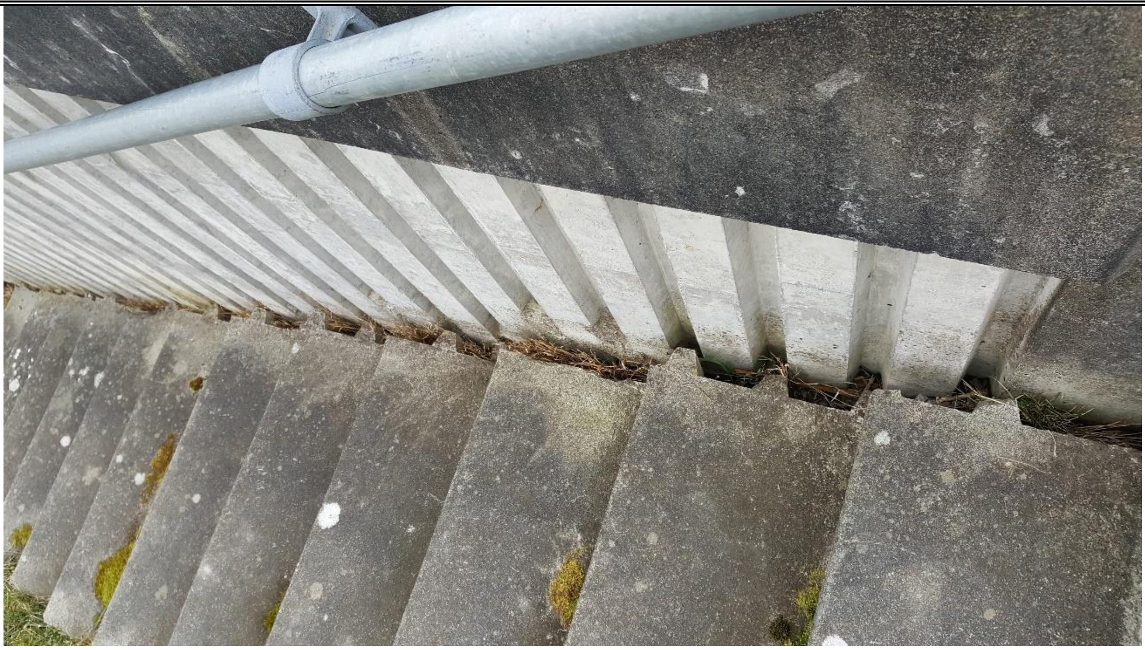


Photo 9 – North Stairs for Cloverdale Pump Station.

INSTRUCTIONS / RECOMMENDATIONS / REMARKS:

- The distress features appear consistent with the effects of long term settlement. No features suggest an obvious stability concern about the dike.

FURTHER EXAMINATION REQUIRED: ☐ YES ☐ NO ☐ NOT APPLICABLE

COPIES TO:	REPORT BY: Amy Russell, EIT EMAIL: arussell@thurber.ca	REVIEWED BY: Marc Bossé, P.Eng.

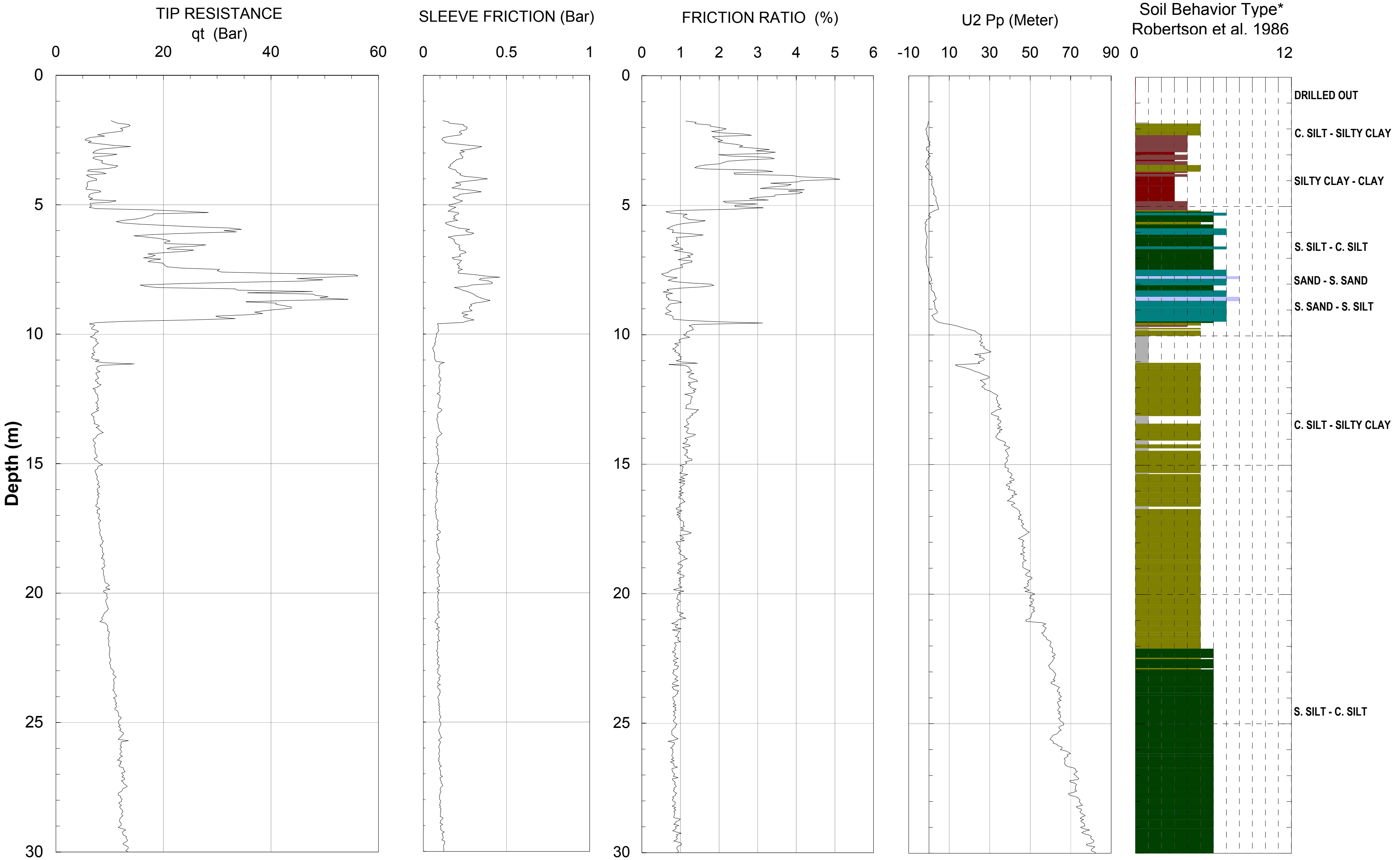
Appendix A – Test Hole Logs

Thurber Engineering

COLEBROOK

Operator: Schwartz Soil Technical
Sounding: CPT15 - 01
Cone ID: DPG1236 10 Ton

Date: July 31, 2015
Site: Colebrook Pump Station
Thurber project no: 19 - 708 - 18



Maximum Depth = 30.00 meters

Depth Increment = 0.05 meters

⬜ 1 sensitive fine grained
⬛ 2 organic material
🟥 3 clay
🟫 4 silty clay to clay
🟨 5 clayey silt to silty clay
🟩 6 sandy silt to clayey silt
🟦 7 silty sand to sandy silt
🟪 8 sand to silty sand
🟧 9 sand
🟥 10 gravelly sand to sand
🟪 11 very stiff fine grained (*)
🟦 12 sand to clayey sand (*)

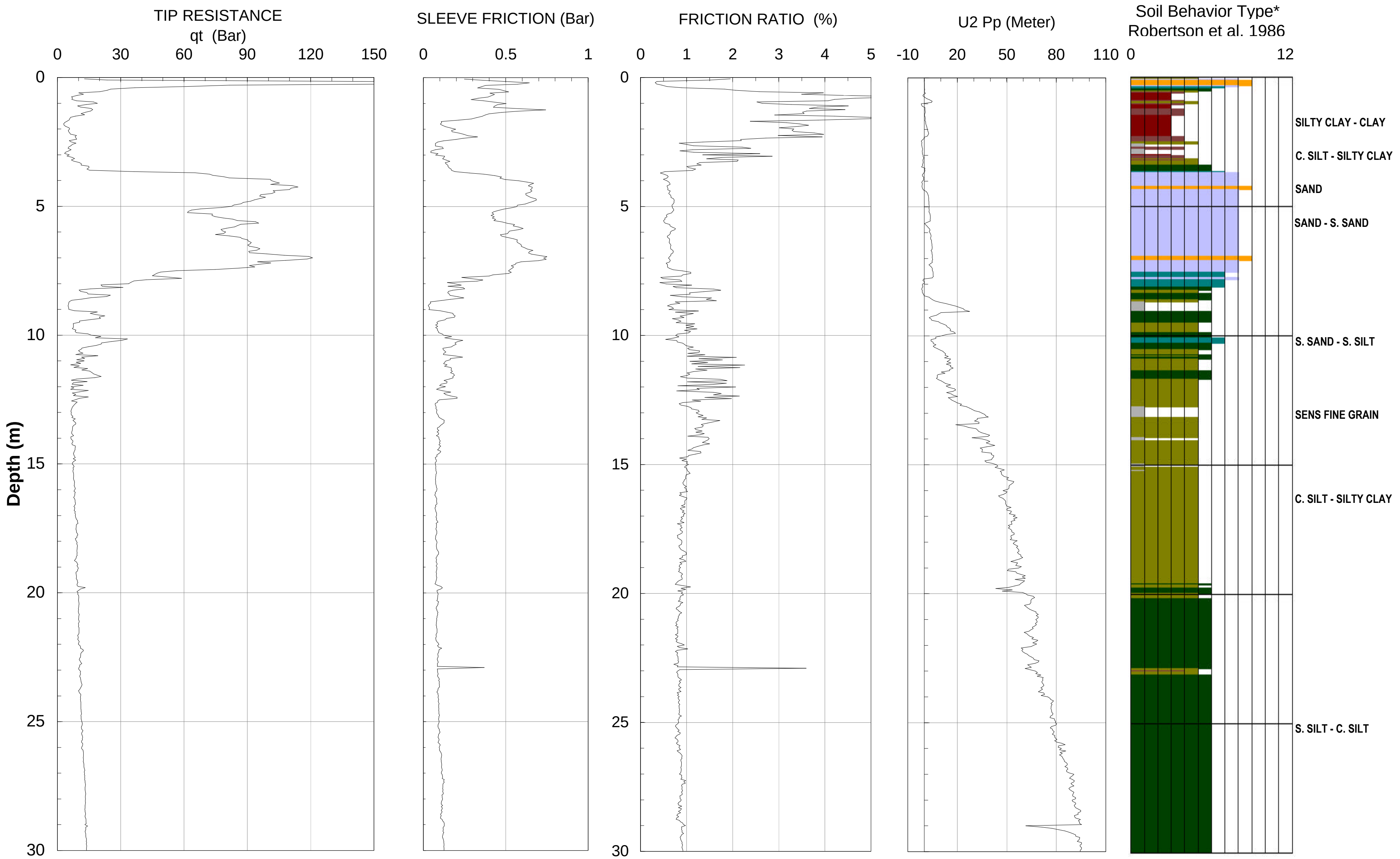
LEVELTON

PANORAMA

Operator: Schwartz Soil Technical
Sounding: CPT15 - 01
Cone ID: DPG1236 10 Ton

Date: March 09, 2015
Site: Panorama Pump Station
Levelton Project No: R714 - 1751 - 00

Schwartz
SOIL TECH



Maximum Depth = 30.00 meters

Depth Increment = 0.05 meters

- ■ 1 sensitive fine grained
- ■ 2 organic material
- ■ 3 clay
- ■ 4 silty clay to clay
- ■ 5 clayey silt to silty clay
- ■ 6 sandy silt to clayey silt
- ■ 7 silty sand to sandy silt
- ■ 8 sand to silty sand
- ■ 9 sand
- ■ 10 gravelly sand to sand
- ■ 11 very stiff fine grained (*)
- ■ 12 sand to clayey sand (*)

Sheet 1 of 1

NICOMEKL

LOG OF TEST HOLE

TEST HOLE NO. 13-3

THURBER

LOCATION: See Dwg. 17-610-181-1

CLIENT: Urban Systems Ltd.

PROJECT: Cloverdale Canal Upgrade

TOP OF HOLE ELEV:

METHOD: Solid Stem Auger

DRILLING CO.: Uniwide Drilling Co. Ltd.

INSPECTOR: HW

DATE: August 16, 2013

FILE NO.: 17-610-181

DEPTH (m)

PENETRATION (blows/300 mm)

WATER CONTENT (%)
○ Disturbed
● Undisturbed
Plastic Limit ├──┤ Liquid Limit

WATER LEVEL

SAMPLES
◧ Disturbed
■ Undisturbed
☒ No Recovery

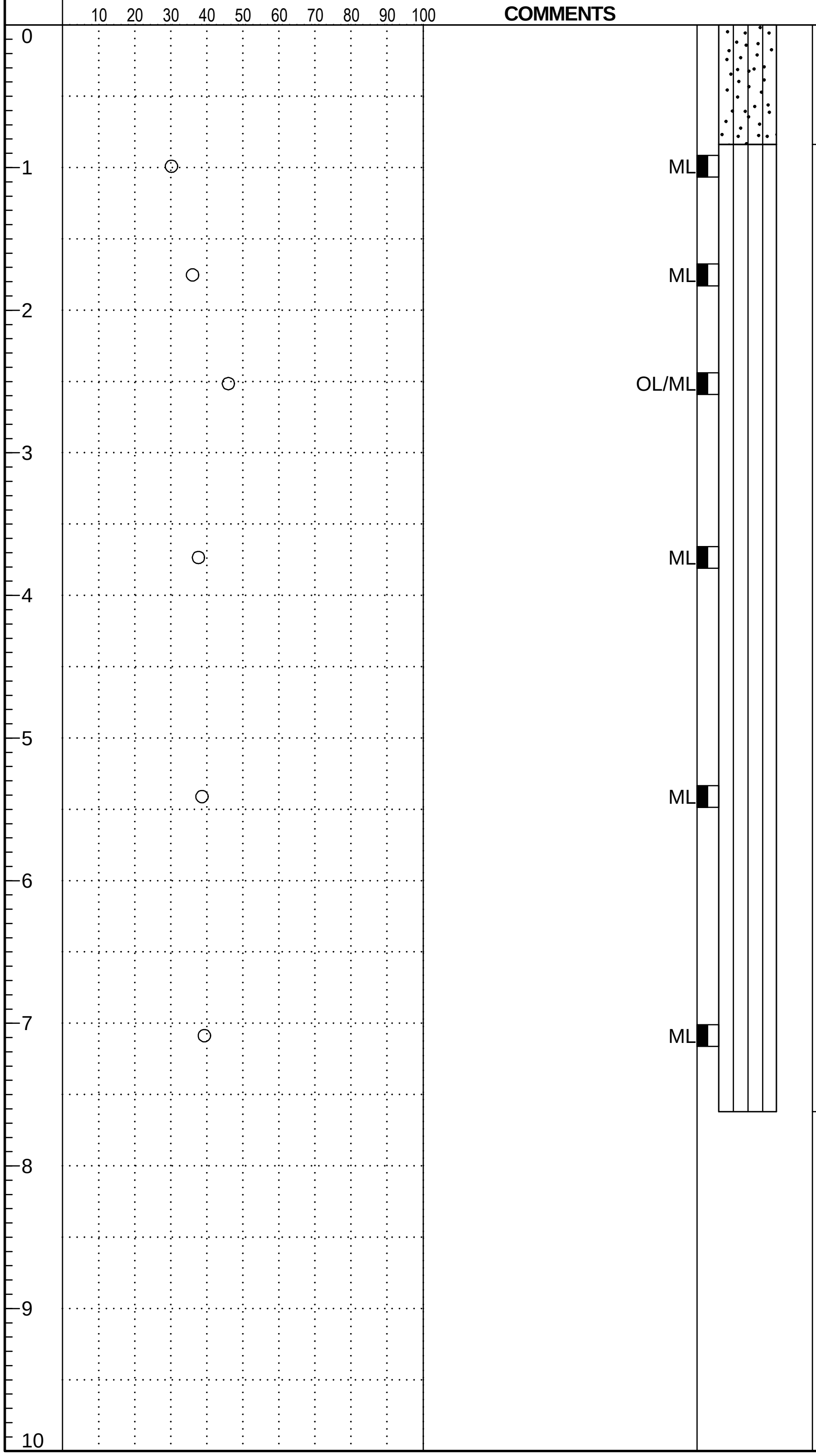
UNDRAINED SHEAR STRENGTH (kPa)
◆ Peak
◇ Residual
◆ Remolded

GRAIN SIZE (%)
▲ Passing #200 sieve
△ Passing #4 sieve

SOIL HEADSPACE READING (ppm)
GASTECH reading
PID reading

COMMENTS

SOILS DESCRIPTION



DEPTH (m)	SOILS DESCRIPTION
0	Compact, brown SILT and SAND with a trace of organics (Fill).
0.8	Stiff, brown SILT with a trace to some clay and traces of organics and sand. - firm with a trace of clay below 1.6 m - soft and grey-brown below 2.1 m - dark grey below 2.7 m - some fine sand between 4.0 and 4.6 m - some fine sand below 7.0 m
7.6	End of hole at required depth. Hole open to 1.8 m and dry upon completion.

Sheet 1 of 1

SOUTH CLOVERDALE

LOG OF TEST HOLE

TEST HOLE NO. **13-2**

THURBER

LOCATION: See Dwg. 17-610-181-1

CLIENT: Urban Systems Ltd.

PROJECT: Cloverdale Canal Upgrade

TOP OF HOLE ELEV:

METHOD: Solid Stem Auger

DRILLING CO.: Uniwide Drilling Co. Ltd.

INSPECTOR: HW

DATE: August 16, 2013

FILE NO.: 17-610-181

PENETRATION (blows/300 mm)

WATER CONTENT (%): ○ Disturbed ● Undisturbed

WATER LEVEL

Plastic Limit, Liquid Limit

SAMPLES: ◧ Disturbed ■ Undisturbed ☒ No Recovery

UNDRAINED SHEAR STRENGTH (kPa): ◆ Peak ◇ Residual ⬖ Remolded

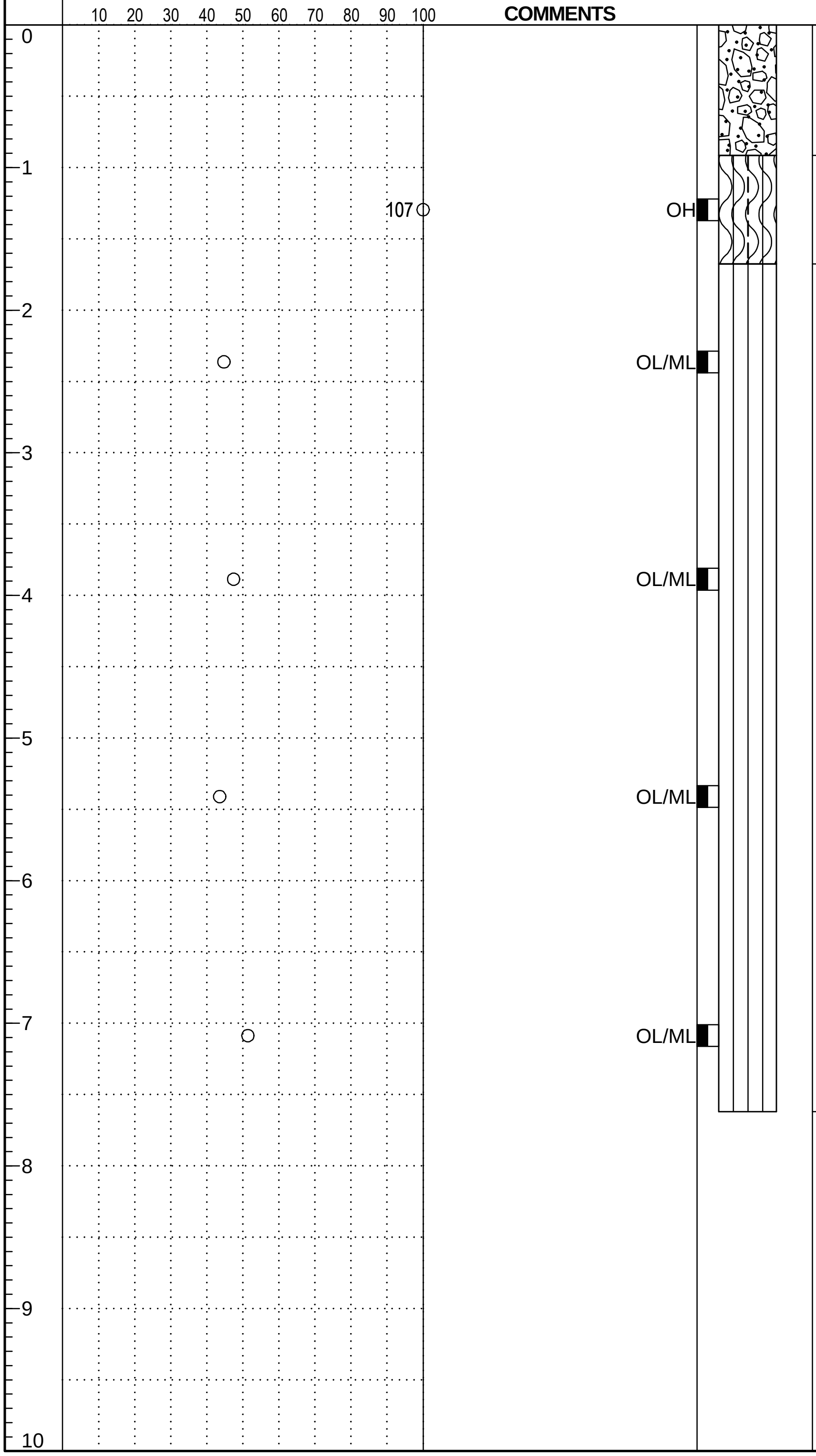
GRAIN SIZE (%): ▲ Passing #200 sieve △ Passing #4 sieve

SOIL HEADSPACE READING (ppm): ✱ GASTECH reading ✲ PID reading

DEPTH (m)

COMMENTS

SOILS DESCRIPTION



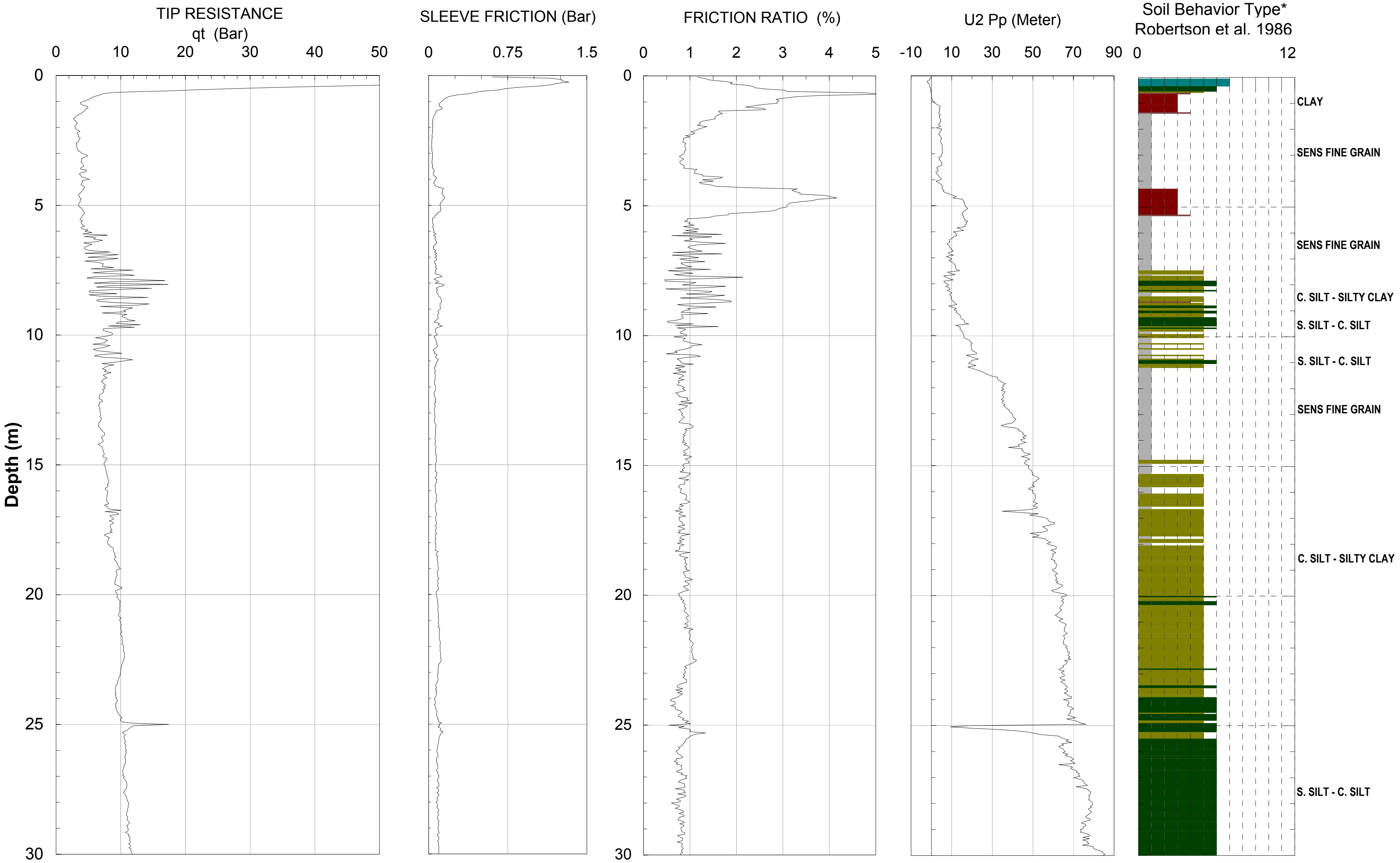
DEPTH (m)	SOILS DESCRIPTION
0	Compact, brown GRAVEL and SAND with a trace of silt (Fill). - some gravel below 0.3 m
1	Stiff to firm, dark brown PEAT and ORGANIC SILT with a trace of sand. - ORGANIC SILT below 1.2 m
1.7	Soft, dark grey SILT with a trace to some clay and organics and a trace of fine sand. - a trace to some fine sand below 5.3 m - some shell fragments below 7.0 m
7.6	End of hole at required depth. Hole open to 1.2 m and dry upon completion.

Thurber Engineering

HOOKBROOK

Operator: Schwartz Soil Technical
Sounding: CPT15 - 01
Cone ID: DPG1236 10 Ton

Date: July 22, 2015
Site: Hook Brook Pump Stn 2
Thurber project no: 17 - 610 - 212



Maximum Depth = 30.00 meters

Depth Increment = 0.05 meters

⬜ 1 sensitive fine grained
⬛ 2 organic material
🟥 3 clay

🟫 4 silty clay to clay
🟨 5 clayey silt to silty clay
🟩 6 sandy silt to clayey silt

🟦 7 silty sand to sandy silt
🟪 8 sand to silty sand
🟧 9 sand

🟥 10 gravelly sand to sand
🟪 11 very stiff fine grained (*)
🟦 12 sand to clayey sand (*)

PROJECT: 972-1149

RECORD OF BOREHOLE BH97-3

SHEET 1 OF 1

LOCATION: East of 176th St., North of Serpentine River

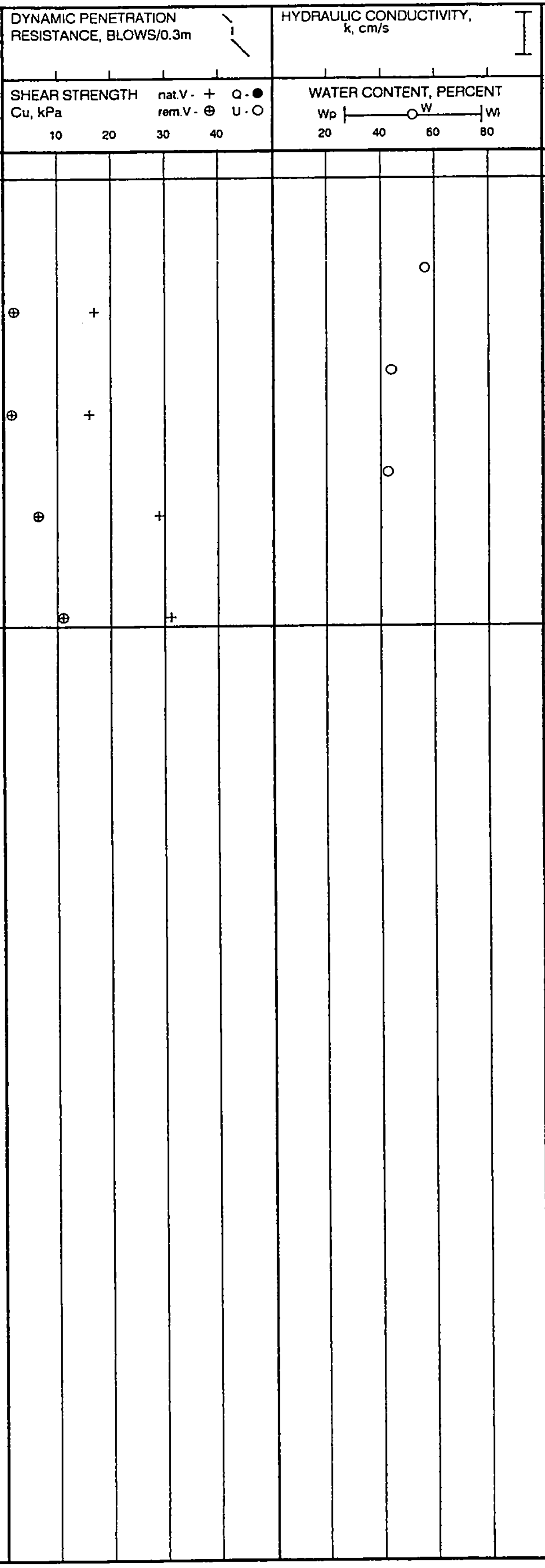
BORING DATE: October 9,1997

DATUM: G.S.

UPPER SERPENTINE

BORING METHOD: MARL M-5 Track-Mounted Rig, Hollow-Stem Auger

DESCRIPTION	ELEV. DEPTH (m)	NUMBER	TYPE	BLOWS/0.3m	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION
Ground Surface						
Topsoil.	0.00					
Firm to stiff, moist, light grey, clayey SILT, some organics (FILL).	0.15	1	AS			
Soft, wet, dark brown, fibrous to amorphous PEAT.	0.60	2	AS		Org	
Very soft to soft, wet, light grey to grey, organic clayey SILT, becoming silt, some clay, trace organics below 1.8m, trace fine sand.	1.06	3 4	AS AS			
Firm, wet, grey, SILT, some clay, trace fine sand, with seams of silt, some fine sand, trace clay.	3.96	5 6	AS AS			
End of Borehole.	6.70					



DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

DATA INPUT: S.S. Oct./97

DEPTH SCALE

1 to 100

Golder Associates

LOGGED: C.W.

CHECKED: N.W.

CRIPPEN CONSULTANTS
VANCOUVER, B.C.

LOG OF DRILL HOLE

HOLE NO. 86-1
SHEET 1 OF 2

PROJECT Manson Road Pumphouse
LOCATION OF HOLE –

ELEVATION tEl +2.5
CONTRACTOR Pentest
TYPE OF DRILL Mayhew 1000
DATE OF DRILLING 21 May 1986

MANSON CANAL

LEGEND

- ▨ SPLIT SPOON
- ☒ WASH SAMPLE
- ■ SHELBY TUBE
- ◫ CORE SAMPLE

SHEAR STRENGTH

- ⌖ UNCONFINED COMPRESSION
- + LAB. VANE

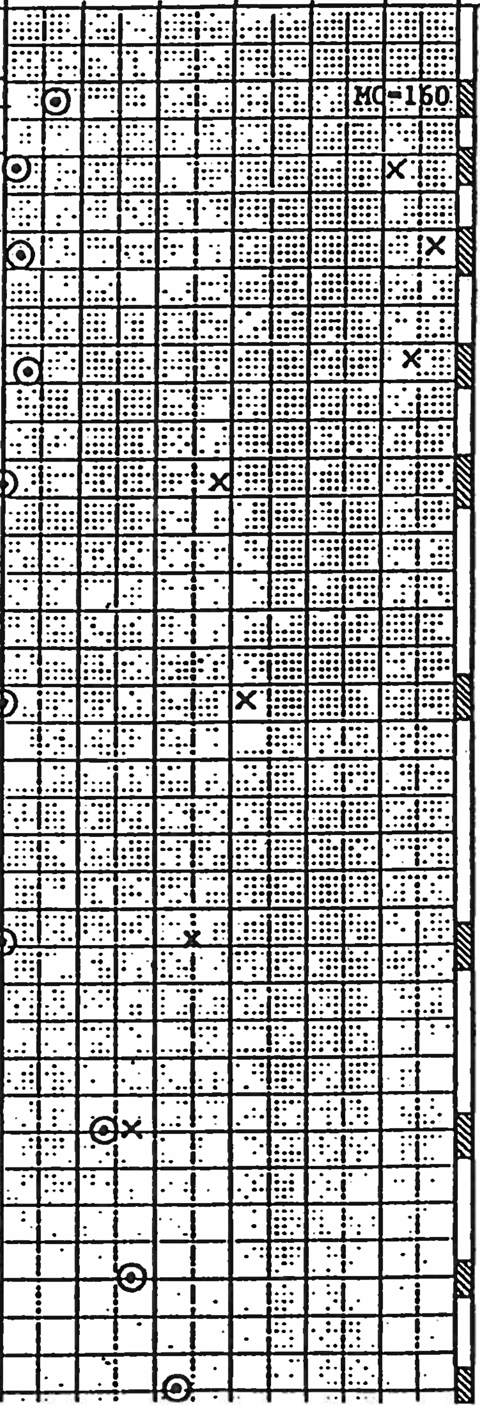
PENETRATION RESISTANCE

- ⊙ STANDARD N-VALUE

ATTERBERG LIMITS

P.L. ——×—— L.L.
MOISTURE CONTENT

SYMBOL	DESCRIPTION	DEPTH METRES	ELEV. METRES	TEST RESULTS	SAMPLE NO.	RECOVERY cm
		0.0	+2.5	200 400 600 800 1000 kN/m² 20 40 60 80 100 BLOWS/FT. (0.3 m)		
	FILL (sand and gravel with some asphalt)	1.1	+1.4			
	PEAT and TOPSOIL				1	40/45
	Loose grey fine SAND with a trace of silt	1.7	+0.8		2	10/45
	Very soft grey or grey brown peaty clayey SILT. Very peaty above about 6 m depth. Occasional thin (±75 mm) sand layers at 11 m depth				3	30/45
					4	45/60
					5	50/60
					6	7.5/60
					7	50/60
	48	14.7	-12.2			
	Compact to dense grey fine to medium SAND with traces of silt and mica.				8	55/60
					9	45/45
					10	35/45



CRIPPEN CONSULTANTS
VANCOUVER, B.C.

LOG OF DRILL HOLE

HOLE NO. 86-1
SHEET 2 OF 2

PROJECT Manson Road Pumphouse
LOCATION OF HOLE –
ELEVATION ±El +2.5
CONTRACTOR Pentest
TYPE OF DRILL Mayhew 1000
DATE OF DRILLING 21 May 1986

LEGEND

- ▧ SPLIT SPOON
- ☒ WASH SAMPLE
- ■ SHELBY TUBE
- ◫ CORE SAMPLE

MANSON CANAL

SHEAR STRENGTH

- ⊕ UNCONFINED COMPRESSION
- + LAB. VANE

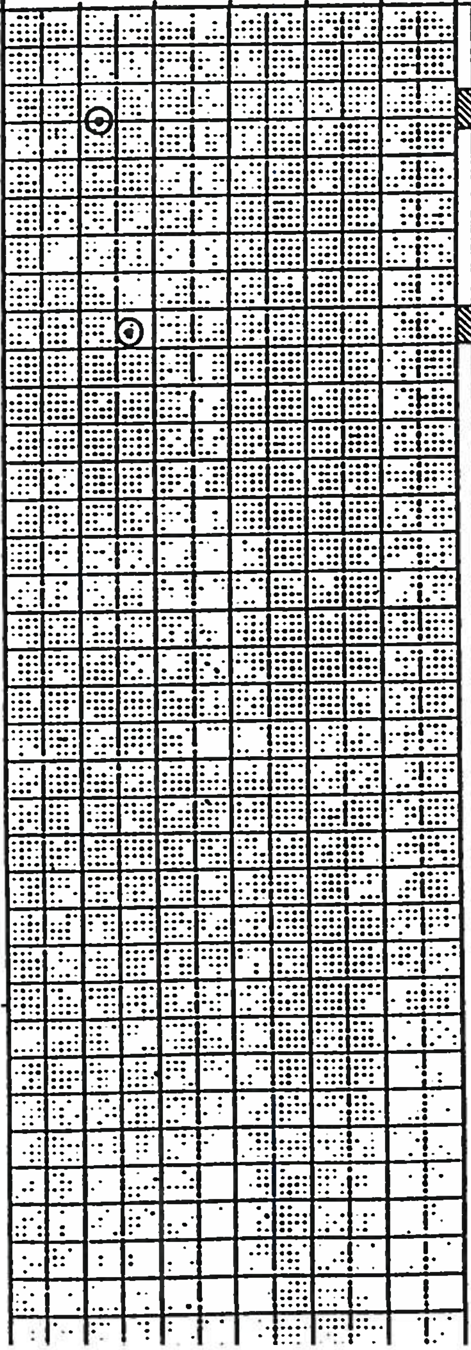
PENETRATION RESISTANCE

- ⊙ STANDARD N-VALUE

ATTERBERG LIMITS

P.L. ——×—— L.L.
MOISTURE CONTENT

SYMBOL	DESCRIPTION	DEPTH METRES	ELEV. METRES	TEST RESULTS 200 400 600 800 1000 kN/m² 20 40 60 80 100 BLOWS/FT. (0.3 m)	SAMPLE NO.	RECOVERY cm
		19.0				
	Compact to dense grey fine to medium SAND with traces of silt and mica			⊙	11	40/45
				⊙	12	37.5/45
		25.0	-22.5			



Sheet 1 of 1

ROYAL CITY

LOG OF TEST HOLE

TEST HOLE NO.
TH09-23

THURBER

LOCATION: N 509344, E 453421

TOP OF HOLE ELEV: 0.3 m
METHOD: Solid Stem Auger
DRILLING CO.: Dynamic Drilling Ltd.
INSPECTOR: HMW

CLIENT: Delcan
PROJECT: Surrey Flood Protection Dyke

DATE: June 16, 2009
FILE NO.: 17-454-91

DEPTH (m)

PENETRATION (blows/300 mm)

WATER CONTENT (%)
○ Disturbed
● Undisturbed

WATER LEVEL
Plastic Limit ⊢—⊣ Liquid Limit

SAMPLES
◧ Disturbed
■ Undisturbed
☒ No Recovery

UNDRAINED SHEAR STRENGTH (kPa)
◆ Peak
◇ Residual

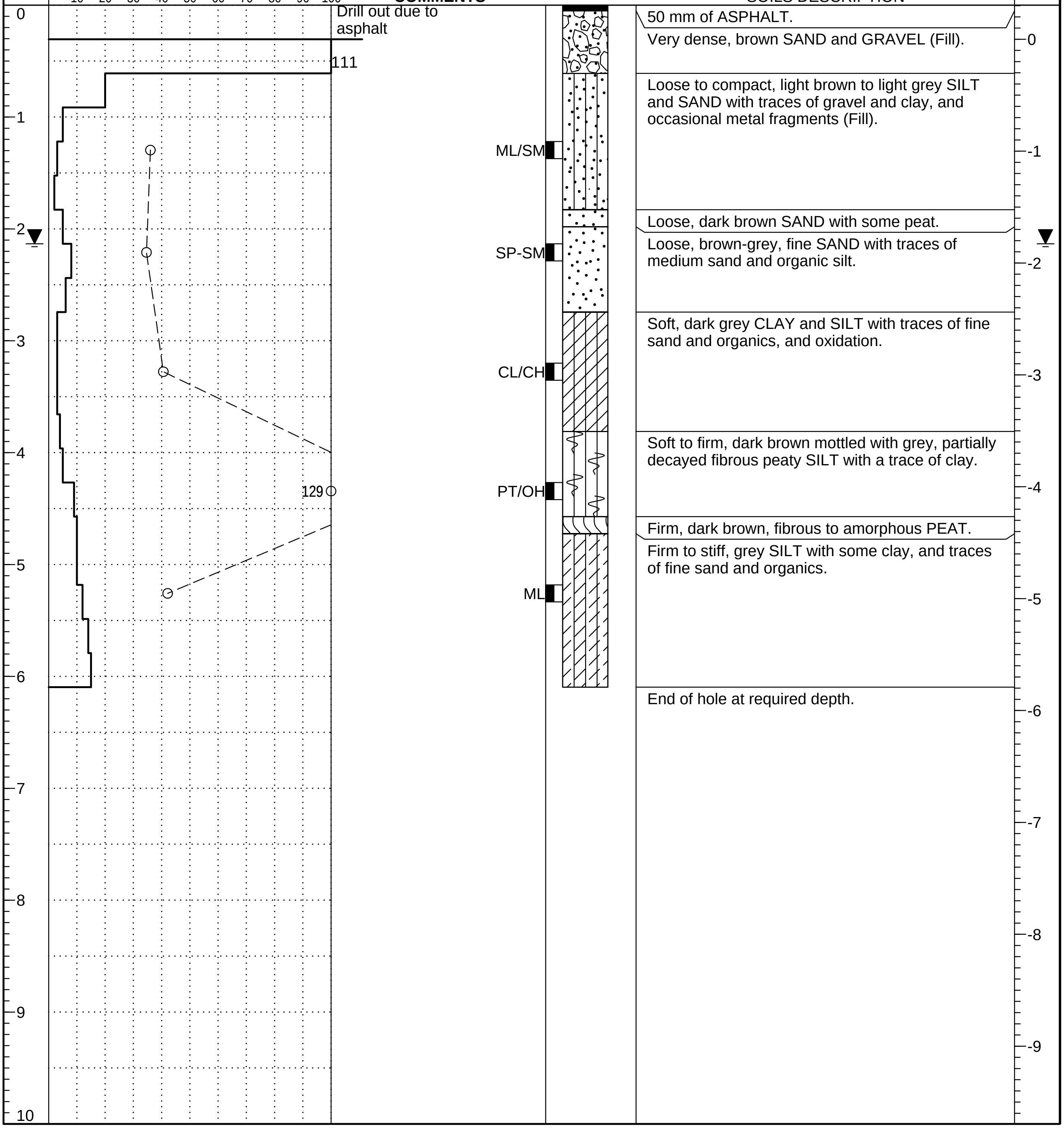
GRAIN SIZE (%)
▲ Passing #200 sieve
△ Passing #4 sieve

SOIL HEADSPACE READING (ppm)
✖ GASTECH reading
✖ PID reading

ELEVATION (m)

COMMENTS

SOILS DESCRIPTION



50 mm of ASPHALT.

Very dense, brown SAND and GRAVEL (Fill).

Loose to compact, light brown to light grey SILT and SAND with traces of gravel and clay, and occasional metal fragments (Fill).

Loose, dark brown SAND with some peat.

Loose, brown-grey, fine SAND with traces of medium sand and organic silt.

Soft, dark grey CLAY and SILT with traces of fine sand and organics, and oxidation.

Soft to firm, dark brown mottled with grey, partially decayed fibrous peaty SILT with a trace of clay.

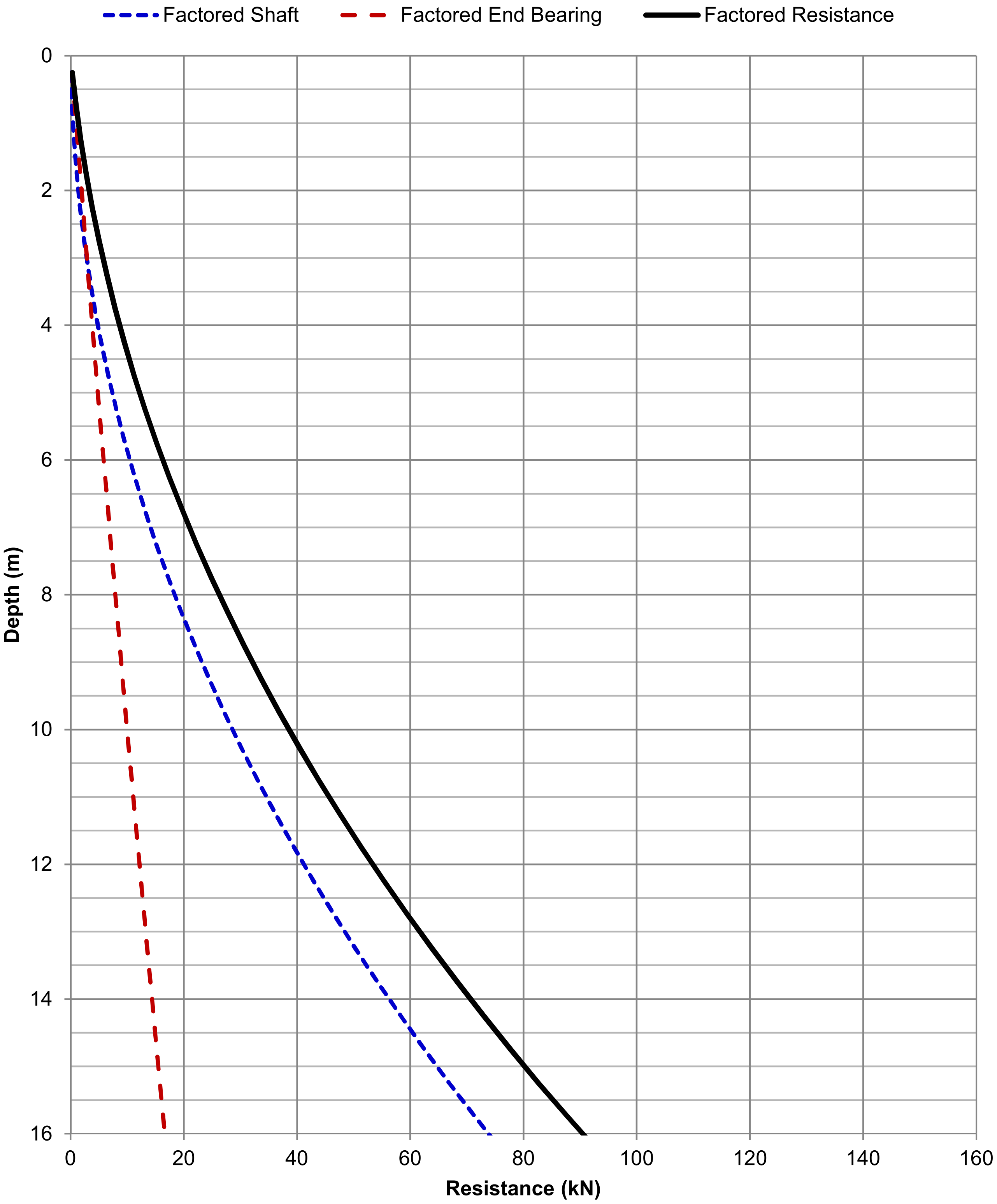
Firm, dark brown, fibrous to amorphous PEAT.

Firm to stiff, grey SILT with some clay, and traces of fine sand and organics.

End of hole at required depth.

Appendix B – Calculated Factored Pile Resistance for 276 mm, 324 mm, 356 mm, and 406 mm diameter Piles

23703 - Surrey Drainage Access Upgrades
Calculated Factored Pile Resistance
Resistance Factor = 0.4
276 mm Diameter Pile



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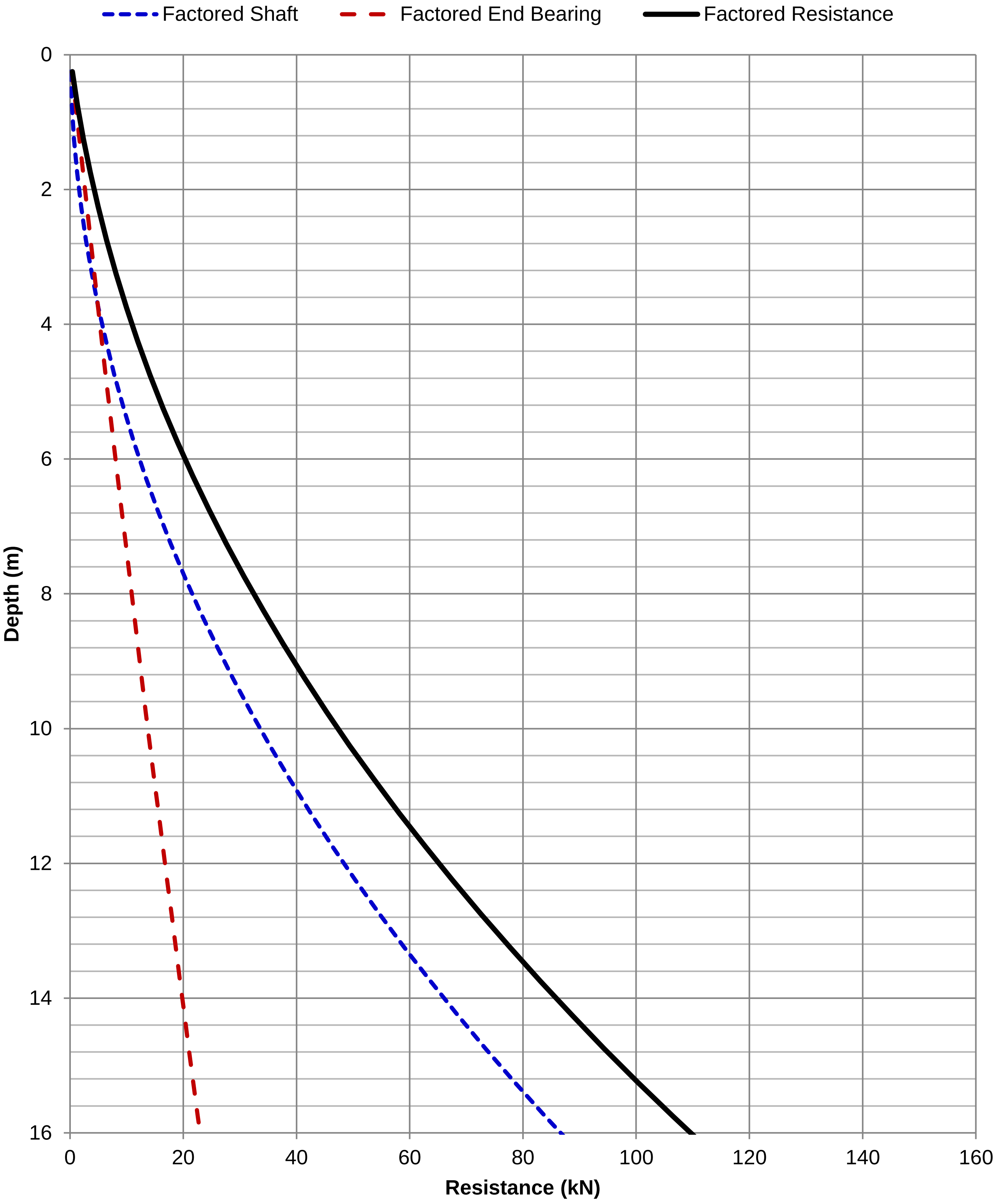
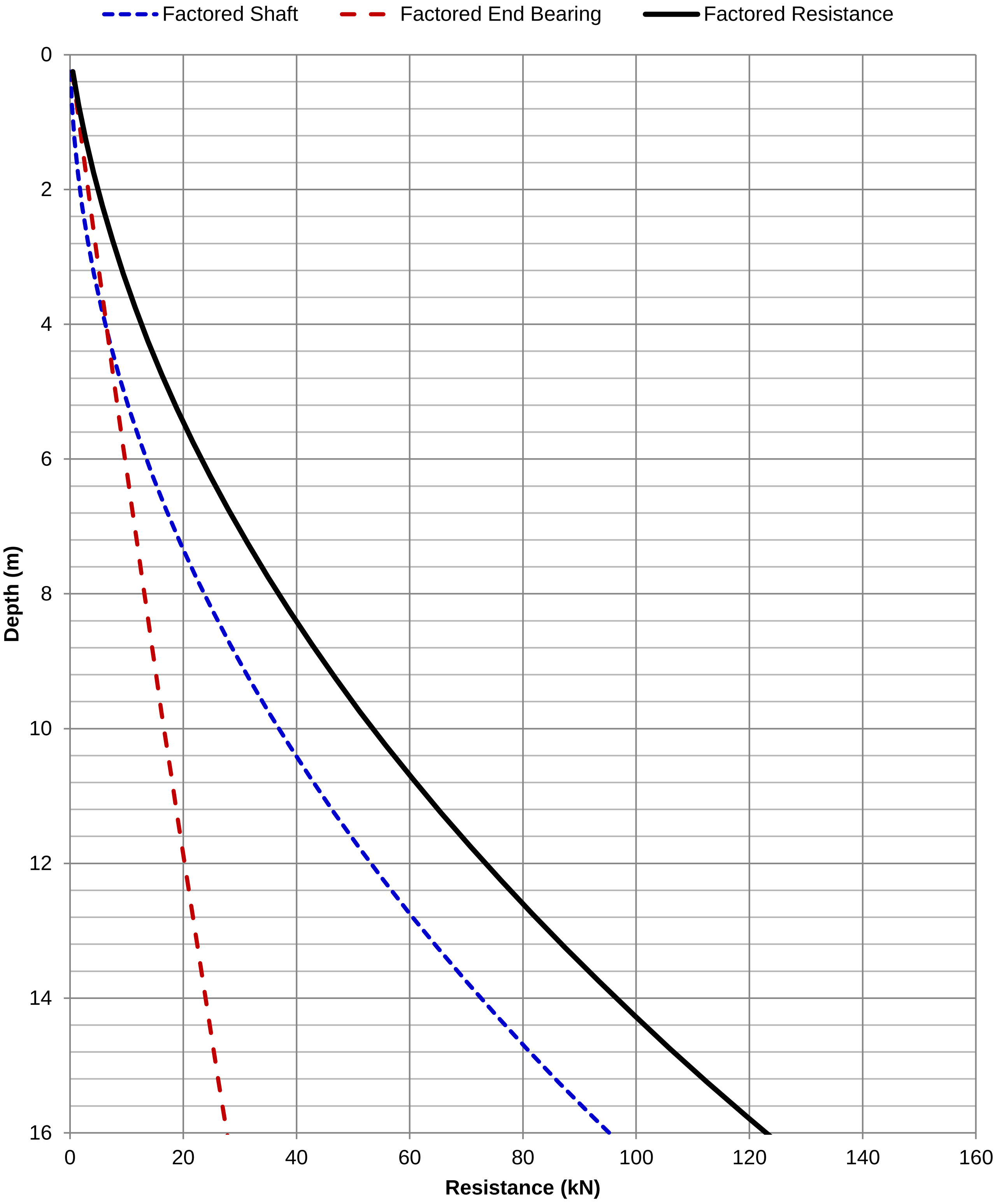
2019-07-02

23705 - Surrey Drainage Access Upgrades
Calculated Factored Pile Resistance
Resistance Factor = 0.4
324 mm Diameter Pile



23705 - Surrey Drainage Access Upgrades
Calculated Factored Pile Resistance
Resistance Factor = 0.4
356 mm Diameter Pile



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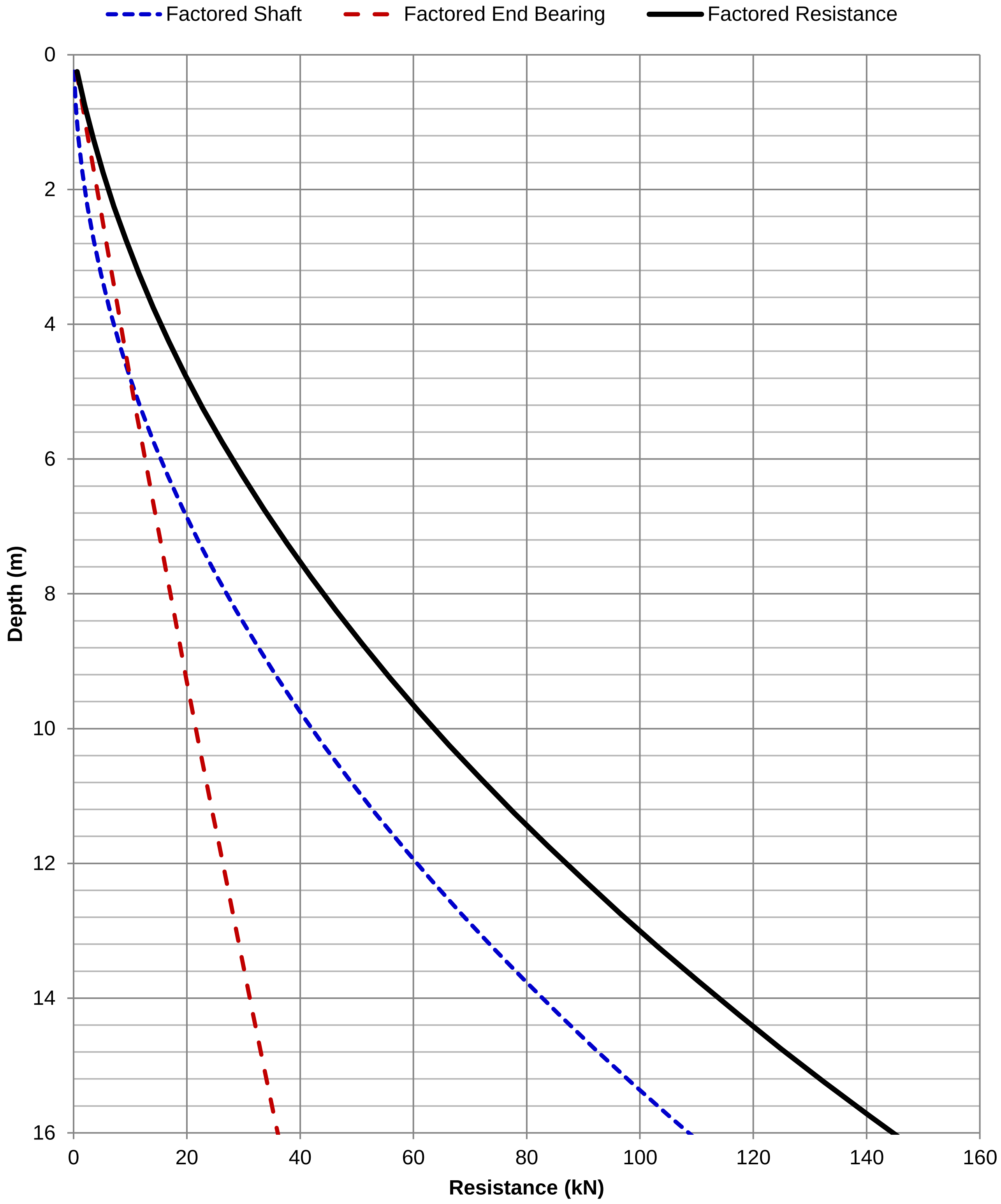
2018-12-06

THURBER

23703 - Surrey Drainage Access Upgrades
Calculated Factored Pile Resistance
Resistance Factor = 0.4
406 mm Diameter Pile



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2018-12-06