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February 22, 2022

Project: 214510

Tetra Tech Canada Inc.
400 – 161 Portage Avenue East
Winnipeg, Manitoba R3B 0Y4

Attention: Indira Maharaj, P.Eng.

RE: City of Winnipeg WWD – D'Arcy Wastewater Pumping Station Load Shedding Upgrades
Winnipeg, Manitoba
Preliminary Geotechnical Investigation Report

As requested, Dyregrov Robinson Inc. (DRI) has undertaken a preliminary geotechnical investigation for the proposed load shedding upgrades to the D'Arcy Pumping Station. We understand a new load shedding forcemain from the D'Arcy Pumping Station to the Red River is being considered and there are two preferred options (1A and 1B). Option 1A would utilize an outfall chamber with a sluice gate at the downstream end of the forcemain and an outfall pipe that extends from the chamber to the river. The proposed outfall chamber would be located approximately 67 m away from the pumping station (i.e. approximately 9 m west of the active transportation path). Option 1B would utilize a forcemain to the river without a chamber, a flap gate and headwall structure would be provided at the discharge point. Refer to Tetra Tech's Proposed Forcemain Option 1 Plan/Profile Drawing in Appendix B.

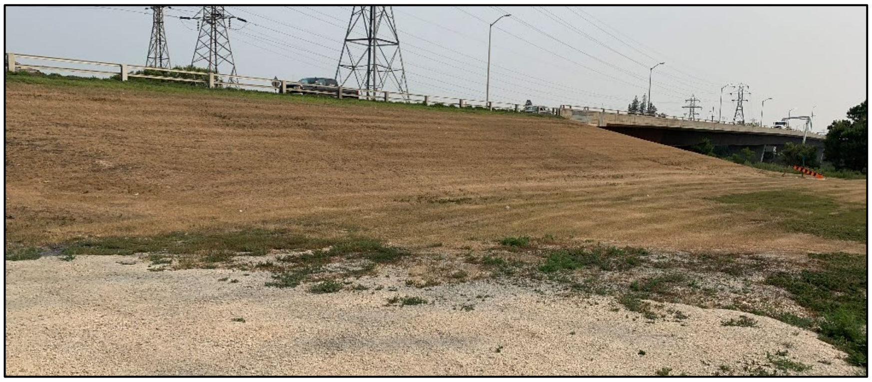
The purpose of the investigation was to evaluate the subsurface conditions to provide limit state design recommendations for foundations, to complete a riverbank stability assessment to determine if stabilization measures may be required for the new outfall and identify considerations for detailed design and construction. Authorization to proceed with the investigation was provided by Lin Watt of Tetra Tech Canada Inc. (Tetra Tech), via email, on July 26, 2021.

1) Site Conditions and Proposed Load Shedding Upgrades

We understand that the proposed load shedding upgrade infrastructure will be located on the west side of the Red River between the west bound and east bound lanes of Bishop Grandin Boulevard at the Fort Garry Bridge in Winnipeg, MB. The project site has existing City of Winnipeg water and waste infrastructure located east of the D'Arcy Pumping station building. The proposed load shedding upgrades will be installed north of the existing infrastructure. The project area is located between the two Fort Garry Bridge road embankments and the site is graded downward towards the Red River. Photograph 1 shows the general site conditions along the route of the proposed forcemain and outfall chamber (if used).

The proposed outfall will be located on the riverbank approximately 110 m east of the D'Arcy Pumping Station. The riverbank area is vegetated with weeds and brush and there are no signs of any active slope movements. Photograph 2 shows the general site conditions along the river near the location of the proposed outfall.

We understand that the proposed forcemain will be constructed with approximately 117 lineal metres of 750 mm diameter HDPE pipe. Trenchless installation of the forcemain pipe is preferred. The pipe will exit the existing pump station with an invert elevation of 225.31 m and the pipe invert at the outfall will be at elevation 224.74 m. Refer to Tetra Tech's Proposed Forcemain Option 1 Plan/Profile Drawing in Appendix B. If an outfall chamber is to be provided, the base slab will likely be installed at an elevation that is similar to the existing siphon / outfall chamber (i.e. elevation 224.45 m).



Photograph 1: Facing northeast from D'Arcy Pumping Station

Photograph 2: Facing south (upstream) along the Red River near proposed outfall location

2) Field Investigation

On August 17 and 18, 2021, four test holes were drilled along the route of the proposed forcemain at the approximate locations illustrated on Figure 1 and on the Proposed Forcemain Option 1 Plan/Profile Drawing in Appendix B. The test holes were drilled by Paddock Drilling Ltd. using a track-mounted CME 850 drill rig equipped with 125 mm solid stem augers. The test holes were drilled to auger refusal which occurred in Test Holes 1 to 4 at depths of 14.4 m, 14.6 m, 13.8 m and 12.5 m, respectively. Standpipe piezometers were installed at Test Holes 2 and 4 at depths of 14.6 m and 12.5 m below site grade. The piezometers are constructed of 25 mm diameter PVC pipe with a 300 mm long Cassagrande inlet tips. The top of piezometer pipes are 830 mm and 930 mm above grade in Test Holes 2 and 4, respectively, and they are protected with a padlocked steel above ground casing. The subsurface conditions were visually logged during drilling by DRI. Standard penetration testing (SPT) was performed in the glacial till by driving a split barrel sampler 450 mm into the base of the test hole using an automatic slide hammer weighing 63.5 kg and dropped from a height of 760 mm. The number of blows for every 150 mm of penetration was recorded.

Disturbed (auger cuttings, split spoon) and undisturbed (Shelby tube) soil samples were recovered from the test holes and taken to our Soils Testing Laboratory for additional visual classification and testing. The laboratory testing consisted of: determining moisture contents on all samples, measuring bulk unit weights and undrained shear strengths on the Shelby tube samples, three gradations and two Atterberg Limits. Two clay samples were submitted to Bureau Veritas Laboratories for soil chemistry testing. The test hole logs attached in Appendix A include a description of the subsurface conditions encountered, results of the laboratory testing, and notes regarding the observations made during drilling. UTM coordinates for the test hole locations and corresponding geodetic test hole elevations were provided by Tetra Tech.

3) Subsurface Conditions

The soil stratigraphy encountered in the test holes, from existing site grade, consists of clay fill, alluvium silty clay, lacustrine silty clay and glacial silt till. A general description of the main stratigraphic units is provided below and is based on the test hole logs in Appendix A. Refer to the test hole logs for additional information.

Clay Fill

A layer of clay fill was encountered at grade in Test Holes 1, 2 and 3 and it is around 2.5 m thick. The clay fill contains traces of sand, gravel and rootlets. It is brown to mottled brown and grey in color and dry to moist with a stiff consistency. Moisture content of the clay fill ranges from about 20 to 30 percent.

Alluvium Silty Clay

The main soil on the project site is an alluvium (alluvium is a general term for clay, silt, sand, gravel or similar unconsolidated detrital material, deposited during comparatively recent geologic time by a stream or other body of running water, as a sorted or semi-sorted sediment), which is a non-homogeneous combination fine grained soils including clay, silt and sand. The gradation of alluvium soil can vary significantly over short distances (horizontally and vertically) and localized, water bearing, layers of silt or sand may be present within the alluvium silty clay that was encountered in the test holes.

Alluvium silty clay was encountered at grade or beneath the fill materials in all test holes. It is 3 m thick in Test Hole 1 and 10.7 m to 11.8 m thick in Test Holes 2 to 4. The alluvium silty clay contains traces of sand and gravel and is generally brown in color becoming mottled brown and grey below 7 m and eventually turning grey below 9.5 m. It is generally moist with a stiff consistency however in Test Hole 4, the alluvium is dry to moist to a depth of around 4 m. The moisture content of the clay ranges from 20 to 35 percent with an average of around 30 percent. The alluvium silty clay has high plasticity based on two Atterberg limit tests (TH1 Sample T5 and TH3 Sample G41) yielding plastic limits of 22 and 23, liquid limits of 73 and 94 and plasticity indices of 51 and 71. Two particle size analyses were completed (TH1 Sample T5 and TH3 Sample G41) and the test results show the samples were comprised of approximately 73 to 95% clay, 5 to 25% silt and 1 to 2% sand.

The undrained shear strength of the alluvium silty clay was measured using Torvane, penetrometer and unconfined compressive strength tests. The clay has a stiff consistency with undrained shear strengths ranging from around 45 to 80 kPa. The average bulk unit weight of the alluvium silty clay is around 18.6 kN/m³.

Lacustrine Silty Clay

Lake Agassiz lacustrine silty clay was encountered in Test Hole 1 below the alluvium silty clay at a depth of 5.5 m. It is mottled brown and grey eventually becoming grey below 9 m. The clay has high plasticity and is moist becoming wet below 10.5 m and it has a stiff consistency becoming firm to stiff below 9 m. The moisture content of the clay generally ranges from about 30 to 53 percent with an average of 42 percent.

The undrained shear strength of the lacustrine clay was measured from one Shelby tube sample using Torvane, penetrometer and unconfined compressive strength tests. The clay has undrained shear strengths ranging 35 to 55 kPa and the bulk unit weight of the clay is 16.7 kN/m³.

Glacial Silt Till

Glacial silt till was encountered in Test Holes 2 to 4 below the alluvium silty clay layer at depths ranging from 11.6 m to 14.2 m below grade, which corresponds to a Geodetic elevation of approximately 217 m. The glacial silt till layer was not confirmed in Test Hole 1 prior to achieving auger refusal. The glacial till deposit in the Winnipeg area is typically a heterogeneous mixture of sand, gravel, cobble and boulder size materials within a predominantly silt matrix that has a low but variable clay content. The silt till encountered in the test holes contains some clay and traces of sand and gravel. No cobbles or boulders were recovered from the test holes due to the small diameter of augers used for drilling. It is brown in color and moist with a compact compactness condition. The moisture contents from six till samples ranged from approximately 10 to 19 percent with an average of around 12.5 percent. Three Standard Penetration Tests (SPT) were attempted after auger refusal in Test Holes 2 to 4, however, the SPTs were stopped after 25 to 300 mm of penetration when the split spoon sampler started to bounce with no penetration. Auger refusal occurred in Test Holes 1 to 4 at depths of 14.4 m, 14.6 m, 13.8 m and 12.5 m, respectively, which corresponds to a Geodetic elevation of approximately 216.5 m. The auger refusal conditions likely occurred on bedrock based on existing test hole information for the bridge abutments (Klohn Leonoff Consultants Ltd., Riverbank Stability, Site of Proposed Bridges, Fort Garry – St. Vital Corridor, August 19, 1976).

Soil Chemistry Test Results

One sample of the clay fill (Test Hole 3 – sample G38) and one sample of the alluvium silty clay (Test Hole 3 – G42) were submitted to Bureau Veritas Laboratories for testing to determine soil chemistry properties including; chloride content, conductivity / resistivity, pH and sulphate (SO4) content. The results are summarized in Table 3.1 and the laboratory test report is provided in Appendix A.

Table 3.1 – Soil Chemistry Test Results

Test Hole	Sample		Soluble Chloride (CL)	Soluble Conductivity	Resistivity @25C	Soluble pH	Soluble Sulphate (SO4)	
	ID#	Depth (m)	mg/L	dS/m	Ohm-m		mg/L	%
TH-3	G38	1.5 m	160	0.8	13	7.9	42	0.0036
TH-3	G42	6.0 m	770	3.5	2.9	7.6	450	0.045

Test Hole Stability and Groundwater Conditions

No sloughing was observed in the test holes during drilling, however, test hole squeezing was observed in Test Hole 1 below a depth of 12.2 m. Seepage was observed in Test Holes 2, 3 and 4 starting at depths below grade ranging from 12.2 to 13.7 m. Upon completion of drilling, the water levels in Test Holes 2 to 4 were measured at depths of 11.5 to 13.7 m, which corresponds to a Geodetic elevation of approximately 217.5 m.

Standpipe piezometers were installed in the glacial till layer at Test Holes 2 and 4. On the day of installation (August 17 and 18, 2021), the water levels were measured to be 9.5 m and 7.1 m below grade in Test Holes 2 and 4, respectively, which correspond to Geodetic elevations of approximately 221.5 m and 221.8 m. On September 17, 2021, the water levels had risen to 6.4 m and 4.4 m below grade in Test Holes 2 and 4, respectively, which correspond to a Geodetic elevation of approximately 224.5 m. The groundwater water levels in the glacial till and underlying bedrock may be influenced by the water level in the nearby Red River.

The groundwater conditions should be expected to vary seasonally, from year to year and possibly because of construction activities (e.g. from dewatering).

4) Riverbank Stability Analysis

The objective of the analysis work was to evaluate the existing stability of the riverbank and see if any stabilization measures may be required at the proposed outfall and to assist with locating the outfall chamber (if used) on the riverbank. The stability model was prepared using a cross-section surveyed, and provided to DRI, by Tetra Tech (see Tetra Tech's Proposed Forcemain Option 1 Plan/Profile Drawing and Section A drawing in Appendix B) and the subsurface conditions encountered in the test holes. The stability analysis was performed using Geo-Slope International's Slope/W software program. All models were run using the Morgenstern-Price Method with a half-sine side function.

Existing Conditions

The total height of the riverbank from top of bank down to the normal summer water level is about 8 m and the average slope angle is about 8H:1V. The upper bank area (i.e. above elevation 228 m +/-) has a slope angle of approximately 13H:1V and the lower riverbank area (i.e. below elevation 228 m +/-) down to the normal summer water level has a slope angle of approximately 2.5H:1V. Below the normal summer water level (i.e. below elevation 223.7 m +/-) the slope of the river channel is around 7.5H:1V until it flattens out approximately 25 m into the river channel.

A site visit was made on July 13, 2021 to observe the conditions along the riverbank. The lower bank area near the water's edge is well vegetated with weeds and brush (see Photograph 2). No signs of riverbank movements, such as tension cracks or scarps, were observed on the riverbank down to the water's edge. Some rip rap material was visible along the water's edge at the bridge abutment areas (refer to Photograph 2).

Soil Properties

The soil properties used for the stability analysis work are provided in Table 4.1. The shear strength parameters are conventional effective shear strength parameters that were assigned to the clay fill, alluvial clay, lacustrine clay and glacial till. If a detailed slope stability assessment is required, higher cohesion (c') and friction angle (ϕ') values could be considered for the alluvial clay soil.

Table 4.1 – Soil Properties for Stability Analysis

Material	**Cohesion (c')** (kPa)	**Friction Angle (ϕ')** (degrees)	**Sat. Unit Weight** (kN/m^3)
Clay Fill	5	17	17.0
Alluvial Clay	5	17	18.0
Lacustrine Clay	5	17	17.0
Glacial Till	5	30	22.0

Groundwater and River Level Conditions

The groundwater level was assumed to vary from 2 to 3 m below site grade. The river levels used in the analyses were 223.7 m for the normal summer water level (NSL) and 221.8 m for the normal winter water level (NWL).

Stability Modeling Results

The stability model was analyzed for two ground water conditions (Case 1 and 2) with the river at NSL. The groundwater levels were set at 3 m below grade (Case 1) and 2 m below grade (Case 2). Case 1 is representative of a normal groundwater condition and Case 2 is a more extreme condition during wet weather. The riverbank stability was also analyzed with the river level at the NWL and the groundwater at 3 m and 2 m below grade (Cases 3 and 4). The D'Arcy Pumping Station serves as the reference point for the stability models and is located at the left hand side of the stability model output figures at a distance of zero.

The results of the stability modeling are summarized in Table 4.2. A global factor of safety of 1.5 was checked for the Case 1 condition and the slip surface was found to daylight around 85 m east of the existing D'Arcy Pumping station, which is a few metres east of the walking path under the Fort Garry Bridge. The same slip surface was checked for Cases 2 to 4 to see how the factor of safety at this location changes with groundwater and river levels. Figures 1 to 4 in Appendix B illustrate the stability modeling results for Cases 1 to 4, respectively.

The factor of safety at the lower bank area (i.e. the proposed outfall location) was checked for all four cases and the results are summarized in Table 4.2. Factors of safety at the toe of the slope near the outfall location range from about 1.2 to 1.3 and the slip surfaces daylight about 100 m east of the existing D'Arcy Pumping Station (i.e. about 3 m behind the lower bank area). Figures 1A to 4A in Appendix B illustrate the stability modeling results for Cases 1 to 4, respectively.

Table 4.2 – Summary of Stability Analysis Results

Case	Figure Reference (see App. B)	River Level Condition	Ground Water Level	Global Factor of Safety	Factor of Safety at Outfall Location
1	1 & 1A	NSL	-3 m	1.50	1.28
2	2 & 2A	NSL	-2 m	1.43	1.25
3	3 & 3A	NWL	-3 m	1.40	1.29
4	4 & 4A	NWL	-2 m	1.32	1.21

5) Discussion and Recommendations

5.1 Forcemain Pipe

It is our understanding that the forcemain pipe will be 750 mm in diameter and installed to depths ranging from 4 to 8 m below ground surface with invert elevations from approximately 224.7 to 225.3 m. Based on this information and the soil stratigraphy encountered in the test holes, the pipe will be installed in stiff silty clay soil about 6 to 8 m above the glacial till deposit.

Based on the subsurface conditions encountered during the geotechnical investigation, the subsurface conditions are suitable for trenchless pipe installation methods provided the pipe design, installation method and workmanship conform to good local practice. Conditions that could impact pipe installation procedures may include the presence of wet silt or sand layers, boulders and possibly zones of low strength clays. No significant seepage or sloughing conditions were observed in the clay soils during the field investigation however, these conditions may be encountered during construction particularly if wet silt and/or sand layers are encountered. Construction difficulties can include problems with roof and face stability and groundwater seepage. Areas of particular sensitivity to surface subsidence or expansion are expected to be where the pipe installation is near existing buried utilities and other surface facilities such as pavements.

5.2 Outfall Chamber

If used, we understand that the proposed outfall chamber will be located near Test Hole 3 (i.e. about 60 to 65 m east of the pumping station) with the underside of base slab at elevation 224.5 m (approx.). The outfall chamber could be supported on a footing (i.e. base slab bearing directly on clay soil).

The bearing soil for the base slab will be stiff silty clay (alluvium). The base slab can be sized with a service limit state (SLS) bearing pressure of 130 kPa and a factored ultimate limit state (ULS) bearing pressure of 200 kPa. A resistance factor of 0.5 was used to calculate the factored ULS bearing resistance. Settlements under the service loads are expected to be less than 25 mm. Inspection of the foundation bearing surface should be undertaken by experienced geotechnical personnel. The base slab should cast directly on undisturbed clay soil. During construction the bearing surfaces should be protected at all times from climatic conditions (i.e. freezing, wetting, drying etc.). The concrete should not be placed on frozen soil and the bearing surfaces should not be allowed to freeze after the footings have been installed. The footing excavation must be maintained in a dry condition at all times.

The outfall chamber should be designed to resist buoyancy assuming the structure is submerged to ground surface. The unfactored buoyant force is equal to the weight of water displaced by the structure. Uplift forces will be resisted by the self-weight of the structure and by the submerged unit weight of the backfill overlying the projected edges of the base slab. The submerged unit weight for sand backfill can be taken as 9 kN/m^3. The backfill soil contributing to the uplift resistance can be increased by projecting the base slab of the outfall chamber beyond the outside walls. The submerged weight of the backfill located within a vertical projection from the outer edges of the base slab can be used as a resisting force in the buoyancy calculations.

The backfill materials could be a free draining granular material such as a clean sand and gravel or crushed limestone gravel having a maximum particle size of 25 mm. Stabilized fill (i.e. lean mix concrete with a compressive strength of about 2 MPa) could also be considered. A clay cap (at least 1 m thick) should be provided around the walls to reduce the potential for water infiltration into the granular backfill, particularly during flood events on the Red River. The backfill materials should be compacted to 92 percent of the standard Proctor maximum dry density.

The outfall chamber and outfall pipe wing walls should be designed to resist lateral earth pressures that are derived on the basis of the following conventional relationship which produces a triangular pressure distribution:

$$P = Ko\ \gamma'\ D$$

where P = lateral earth pressure at depth D (kPa)
$Ko = 0.5$ (at-rest earth pressure coefficient)
$\gamma' = 10\ kN/m^3$ (submerged backfill unit weight)
$\gamma' = 20\ kN/m^3$ (bulk backfill unit weight above water level)
D = depth from surface to point of pressure calculation (m)

Hydrostatic water pressure should also be included in the design of the walls assuming the groundwater level is at original site grade (i.e. prairie level). The need for damp / waterproofing the walls of the outfall chamber should be evaluated but may not be necessary based on the type of structure being constructed.

5.3 Temporary Excavation and Shoring

It is understood that some temporary excavations will be required to install the forcemain, outfall pipe and chamber. Shoring will be required based on the anticipated excavation depths and proximity of nearby infrastructure (e.g. buried utility lines, roadways etc) . All temporary excavation work should be designed and completed by the Contractor in accordance with the current Manitoba Workplace Safety and Health

Regulations to suit the planned and expected construction activities and schedule. An excavation and shoring plan should be submitted by the Contractor for review.

The excavation and shoring system design must take into consideration the following:

- Existing buried utilities in the work area,
- Existing backfill and abandoned shoring at the pumping station,
- Excavation dewatering system,
- Installation and decommissioning of shoring and dewatering systems,
- Potential for water bearing sand layers within the clay deposit or water bearing backfill material
- Site access and work area constraints,
- Surcharge loading (q) from construction equipment should be considered in the design. The surcharge loading should be confirmed based on the equipment proposed for use by the contractor,
- Performance monitoring program,
- Duration the excavation will be open,
- Backfill type and placement,
- Along with the Manitoba Building Code requirements, Chapters 24 and 26 of the Canadian Foundation Engineering Manual (4th Edition) should be referred to for design of the shoring.
- Refer to the engineering properties for soil in Table 5.1

Other considerations will likely be required depending on the Contractors means and methods for installing their proposed excavation and shoring system.

Table 5.1: Engineering Properties For Soil

Material	**Undrained Shear Strength,** (kPa)	**Effective Cohesion** (kPa)	**Effective Friction Angle** (degrees)	**Saturated Unit Weight** (kN/m^3)	**Effective Unit Weight** (kN/m^3)	**Earth Pressure Coefficients (Rankine[1])** Ko	Ka	Kp
Clay	50	5	28	18.5	8.7	0.5	0.4	2.5
Silt Till	n/a	5	32	22.0	12.2	0.47	0.3	3.2
Sand	n/a	n/a	30	20.0	10.2	0.5	0.3	3.0

1) The effective stress earth pressure coefficients assume the magnitude of wall rotation is sufficient to develop the full earth pressure. The values should be reduced to suit the allowable wall rotation. Refer to Section 24.4 of the Canadian Foundation Engineering Manual.

5.4 Riverbank Stability

The results of the stability modeling indicate that the outfall chamber (if used) would be located approximately 20 metres behind the slip surface that corresponds with a typical target level of safety for design (i.e. factor of safety of 1.5). The results also showed that some local slip surfaces at the toe area of the riverbank had factors of safety around 1.2 to 1.3.

Local regrading of the lower riverbank area should be included in the final design to reduce the potential for localized failures to develop. A minimum slope angle of 3H:1V is recommended. A slip collar should be provided in the outfall pipe, it can be located approximately 9 m back from the toe of slope, that is located at an elevation of 223.7 m.

Some maintenance of the riverbank area upstream and downstream of the outfall zone may be required in the future should erosion related (localized) failures develop over time.

5.5 Other

Based on the soil chemistry test result for the two clay samples that were tested, the potential for sulphate attack is considered to be less than moderate (Exposure Class S-3). Sulphate resistant cement is commonly used in Winnipeg and is recommended that local practice be followed. The potential for sulphate attack in Winnipeg is considered to be severe (Exposure Class S-2). All concrete in contact with soil should be made with sulphate resistance cement (Type HS) in accordance with the Building Code and relevant CSA standards.

Positive drainage should be provided away from the structures at gradients of at least 2 percent.

6) Closure

This preliminary geotechnical report and its findings were prepared based on the subsurface conditions encountered in the random representative test holes drilled on August 17 and 18, 2021 for the sole purpose of this geotechnical investigation and our understanding of the proposed load shedding upgrades to the D’Arcy Pumping Station at the time of this report. Subsurface conditions are inherently variable and should be expected to vary across the site.

This report was prepared for the sole and exclusive use of Tetra Tech for the proposed load shedding upgrades to the D’Arcy Pumping Station located on the west side of the Red River in between the west bound and east bound lanes of Bishop Grandin Boulevard at the Fort Garry Bridge in Winnipeg, MB. The information and recommendations contained in this report are for the benefit of Tetra Tech only and no other party or entity shall have any claim against Dyregrov Robinson Inc., or the author, nor may this report be used for any other projects, including but not limited to changes in the proposed load shedding upgrade project without the consent of Dyregrov Robinson Inc. The findings and recommendations in this report have been prepared in accordance with generally accepted geotechnical engineering principles and practises. No other warranty, expressed or implied, is provided.

Please contact the undersigned if we can be of further assistance.

Sincerely,

DYREGROV ROBINSON INC.

Report Prepared By:

Alessandro Augellone, EIT
Geotechnical Engineering Intern

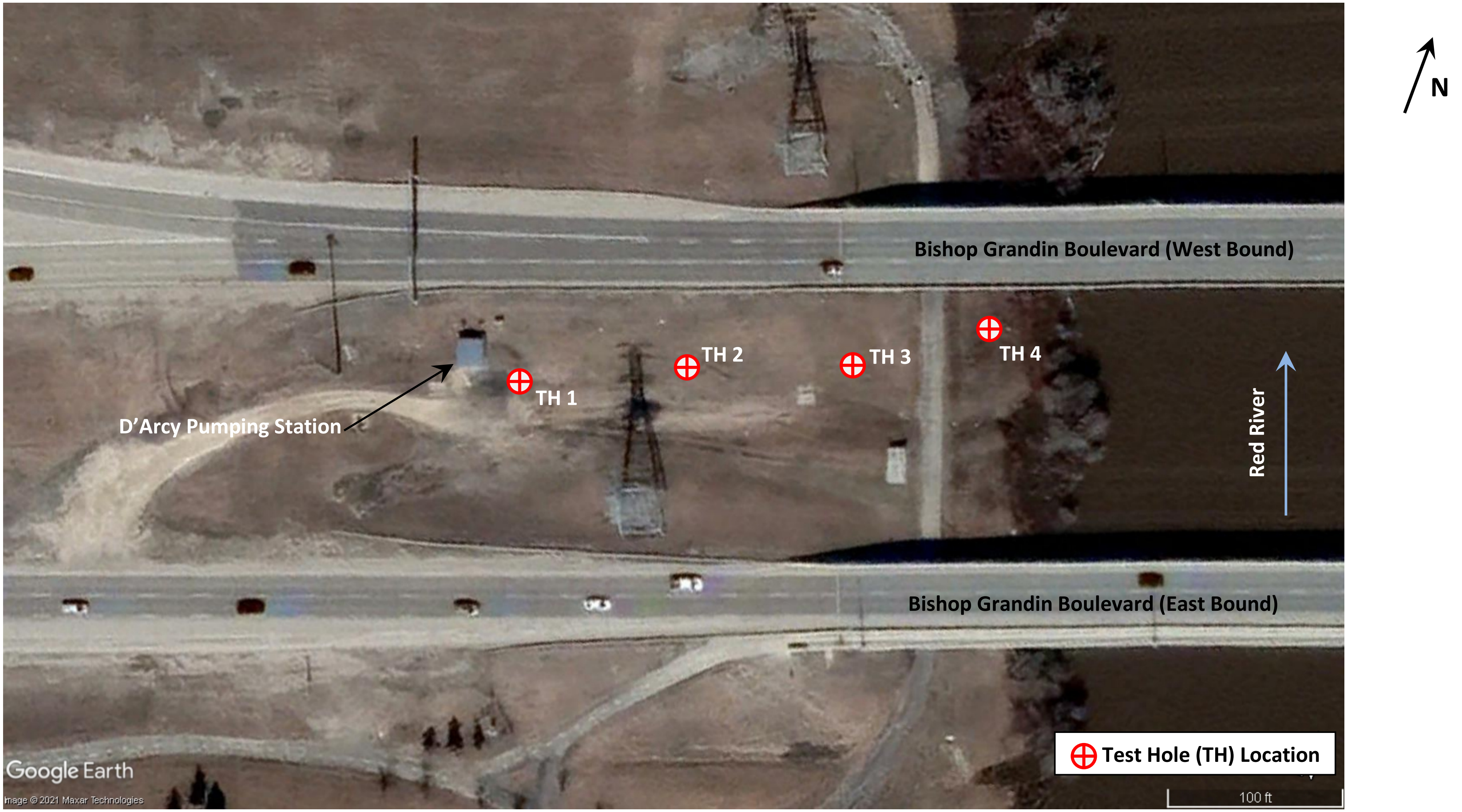
Report Reviewed By:

per Gil Robinson

Gil Robinson, M.Sc., P.Eng.
Senior Geotechnical Engineer

APEGM
Certificate of Authorization
Dyregrov Robinson Inc.
No. 86 **Date:** 22 Feb 2022

PROVINCE OF MANITOBA
GR
G.G.B.
ROBINSON
22 Feb 2022
REGISTERED PROFESSIONAL ENGINEER



DYREGROV ROBINSON INC.
CONSULTING GEOTECHNICAL ENGINEERS

D'Arcy Pumping Station - Winnipeg, MB
Test Hole Location Plan

SCALE:	MADE BY:	CHKD BY:	PROJECT NO.	DATE:	
NTS	JW	AA	214510	September 2021	**Figure 1**

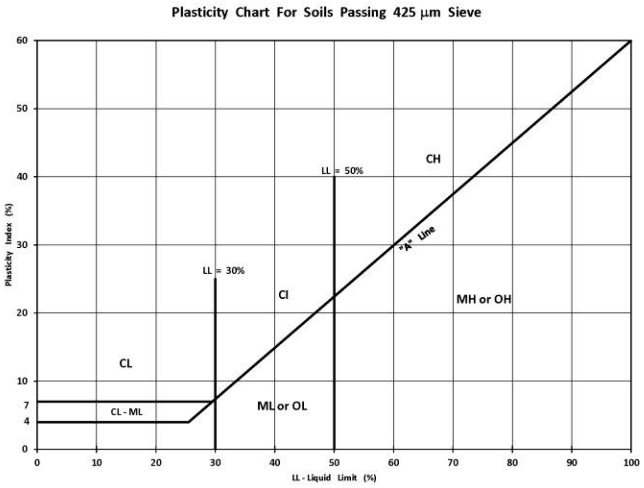
APPENDIX A

Test Hole Logs
&
Soil Chemistry Lab Testing Results

EXPLANATION OF TERMS & SYMBOLS

Description				TH Log Symbols	USCS Classification	Laboratory Classification Criteria			
						Fines (%)	Grading	Plasticity	Notes
COARSE GRAINED SOILS	GRAVELS (More than 50% of coarse fraction of gravel size)	CLEAN GRAVELS (Little or no fines)	Well graded gravels, sandy gravels, with little or no fines	△	GW	0-5	$C_U > 4$ $1 < C_C < 3$		Dual symbols if 5-12% fines. Dual symbols if above “A” line and $4<W_P<7$ $C_U = \frac{D_{60}}{D_{10}}$ $C_C = \frac{(D_{30})^2}{D_{10} x D_{60}}$
			Poorly graded gravels, sandy gravels, with little or no fines	▲	GP	0-5	Not satisfying GW requirements		
		DIRTY GRAVELS (With some fines)	Silty gravels, silty sandy gravels	▥	GM	> 12		Atterberg limits below “A” line or $W_P<4$	
			Clayey gravels, clayey sandy gravels	▨	GC	> 12		Atterberg limits above “A” line or $W_P<7$	
	SANDS (More than 50% of coarse fraction of sand size)	CLEAN SANDS (Little or no fines)	Well graded sands, gravelly sands, with little or no fines	◌	SW	0-5	$C_U > 6$ $1 < C_C < 3$		
			Poorly graded sands, gravelly sands, with little or no fines	○	SP	0-5	Not satisfying SW requirements		
		DIRTY SANDS (With some fines)	Silty sands, sand-silt mixtures	▥	SM	> 12		Atterberg limits below “A” line or $W_P<4$	
			Clayey sands, sand-clay mixtures	▨	SC	> 12		Atterberg limits above “A” line or $W_P<7$	
FINE GRAINED SOILS	SILTS (Below ‘A’ line negligible organic content)	$W_L<50$	Inorganic silts, silty or clayey fine sands, with slight plasticity	▥	ML			Classification is Based upon Plasticity Chart	
		$W_L>50$	Inorganic silts of high plasticity	▥	MH				
	CLAYS (Above ‘A’ line negligible organic content)	$W_L<30$	Inorganic clays, silty clays, sandy clays of low plasticity, lean clays	▨	CL				
		$30<W_L<50$	Inorganic clays and silty clays of medium plasticity	▨	CI				
		$W_L>50$	Inorganic clays of high plasticity, fat clays	▨	CH				
	ORGANIC SILTS & CLAYS (Below ‘A’ line)	$W_L<50$	Organic silts and organic silty clays of low plasticity	▥	OL				
		$W_L>50$	Organic clays of high plasticity	▨	OH				
HIGHLY ORGANIC SOILS			Peat and other highly organic soils	〰	Pt	Von Post Classification Limit		Strong colour or odour, and often fibrous texture	

■	Asphalt	▦	Glacial Till	^	Bedrock (Igneous)	
■	Concrete	▤	Clay Shale	▦	Bedrock (Limestone)	**DYREGROV ROBINSON INC.** CONSULTING GEOTECHNICAL ENGINEERS
▩	Fill			▩	Bedrock (Undifferentiated)	



FRACTION		PARTICLE SIZE (mm)	
		Min.	Max.
Boulders		>300	
Cobbles		75	300
Gravel	Coarse	19	75
	Fine	4.75	19
Sand	Coarse	2.0	4.75
	Medium	0.425	2.0
	Fine	0.075	0.425
Silt (non-plastic) or Clay (plastic)		< 0.075 mm	

RELATIVE PROPORTIONS (by weight)	
Percent	Descriptor
>35%	main fraction
35 - 50	"and"
20 – 35	Adjective e.g. silty, clayey
10 – 20	"some"
1 - 10	"trace"

Soil Classification Example

Clay 50% (main fraction), Silt 25%, Sand 17%, Gravel 8%

Clay – silty, some sand, trace gravel

TERMS and SYMBOLS

Laboratory and field tests are identified as follows:

Unconfined Comp.: undrained shear strength (kPa or psf) derived from unconfined compression testing.

Torvane: undrained shear strength (kPa or psf) measured using a Torvane

Pocket Pen.: undrained shear strength (kPa or psf) measured using a pocket penetrometer.

Unit Weight bulk unit weight of soil or rock (kN/m^3 or pcf).

SPT – N Standard Penetration Test: The number of blows (N) required to drive a 51 mm O.D. split barrel sampler 300 mm into the soil using a 63.5 kg hammer with a free fall drop height of 760 mm.

DCPT Dynamic Cone Penetration Test. The number of blows (N) required to drive a 50 mm diameter cone 300 mm into the soil using a 63.5 kg hammer with a free fall drop height of 760 mm.

M/C insitu soil moisture content in percent

PL Plastic limit, moisture content in percent

LL Liquid limit, moisture content in percent

The undrained shear strength (Su) of cohesive soil is related to its consistency as follows:

Su (kPa)	Su (psf)	CONSISTENCY
<12	250	very soft
12 – 25	250 – 525	soft
25 – 50	525 – 1050	firm
50 – 100	1050 – 2100	stiff
100 – 200	2100 – 4200	very stiff
200	4200	hard

The SPT - N of non-cohesive soil is related to compactness condition as follows:

N – Blows / 300 mm	COMPACTNESS
0 - 4	very loose
4 - 10	loose
10 - 30	compact
30 - 50	dense
50 +	very dense

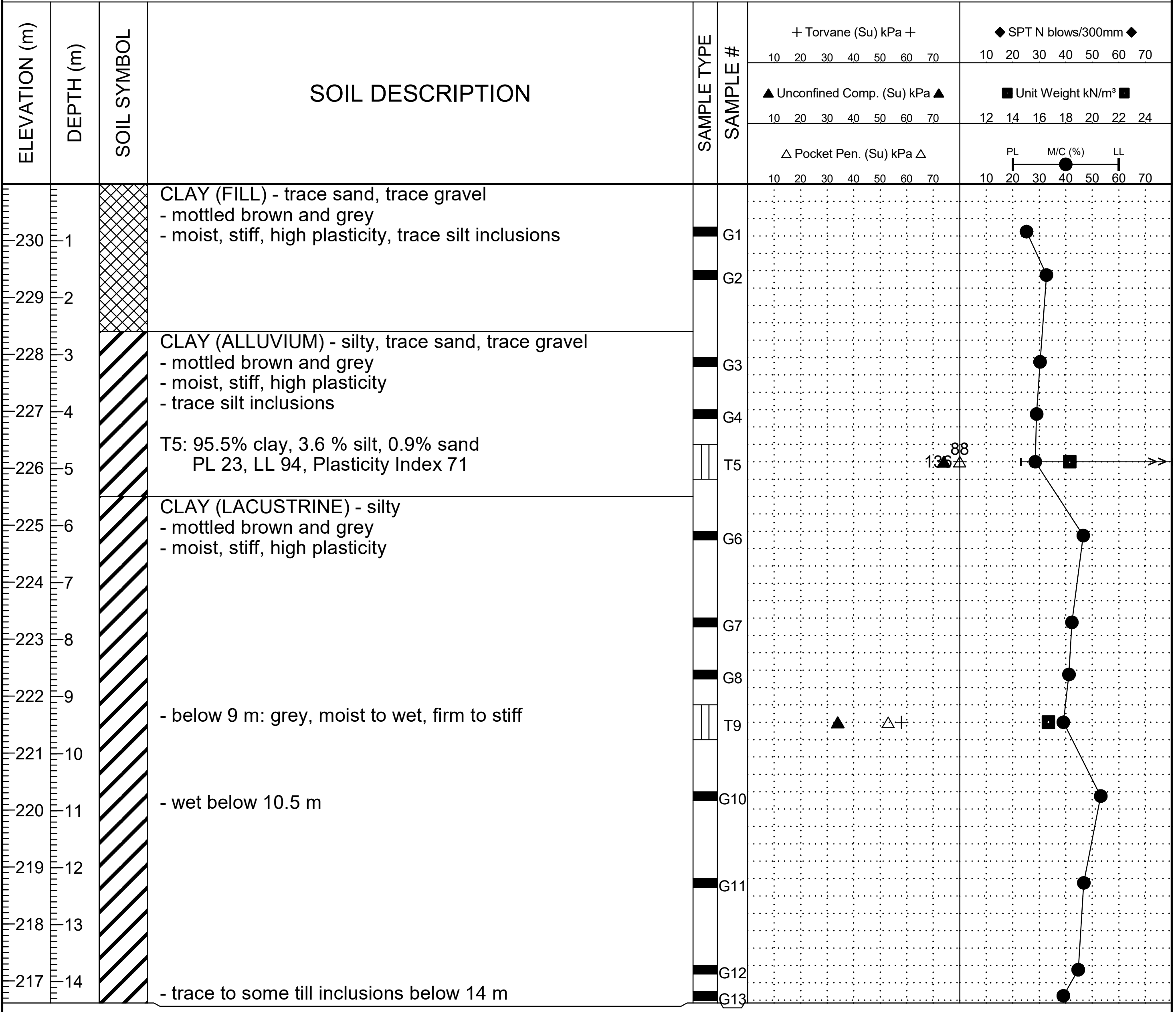
References:

ASTM D2487 – Classification of Soils For Engineering Purposes (Unified Soil Classification System)

Canadian Foundation Engineering Manual, 4th Edition, Canadian Geotechnical Society, 2006

PROJECT: COW-WWD: D'Arcy Pumping Station
CLIENT: Tetra Tech Canada Inc.
TEST HOLE NO: 1
LOCATION: UTM 14U: 633,408 m E, 5,520,409 m N
PROJECT NO.: 214510
CONTRACTOR: Paddock Drilling Ltd.
METHOD: CME 850 Drill Rig w/ 125 mm SS Augers
ELEVATION (m): 231

SAMPLE TYPE ■ GRAB ▥ SHELBY TUBE ☒ SPLIT SPOON ☰ BULK ▱ NO RECOVERY ▮ CORE
BACKFILL TYPE ■ BENTONITE ⁘ GRAVEL ▥ SLOUGH ⁘ GROUT ▨ CUTTINGS ⁘ SAND



CLAY (FILL) - trace sand, trace gravel
- mottled brown and grey
- moist, stiff, high plasticity, trace silt inclusions

CLAY (ALLUVIUM) - silty, trace sand, trace gravel
- mottled brown and grey
- moist, stiff, high plasticity
- trace silt inclusions

T5: 95.5% clay, 3.6 % silt, 0.9% sand
PL 23, LL 94, Plasticity Index 71

CLAY (LACUSTRINE) - silty
- mottled brown and grey
- moist, stiff, high plasticity

- below 9 m: grey, moist to wet, firm to stiff

- wet below 10.5 m

- trace to some till inclusions below 14 m

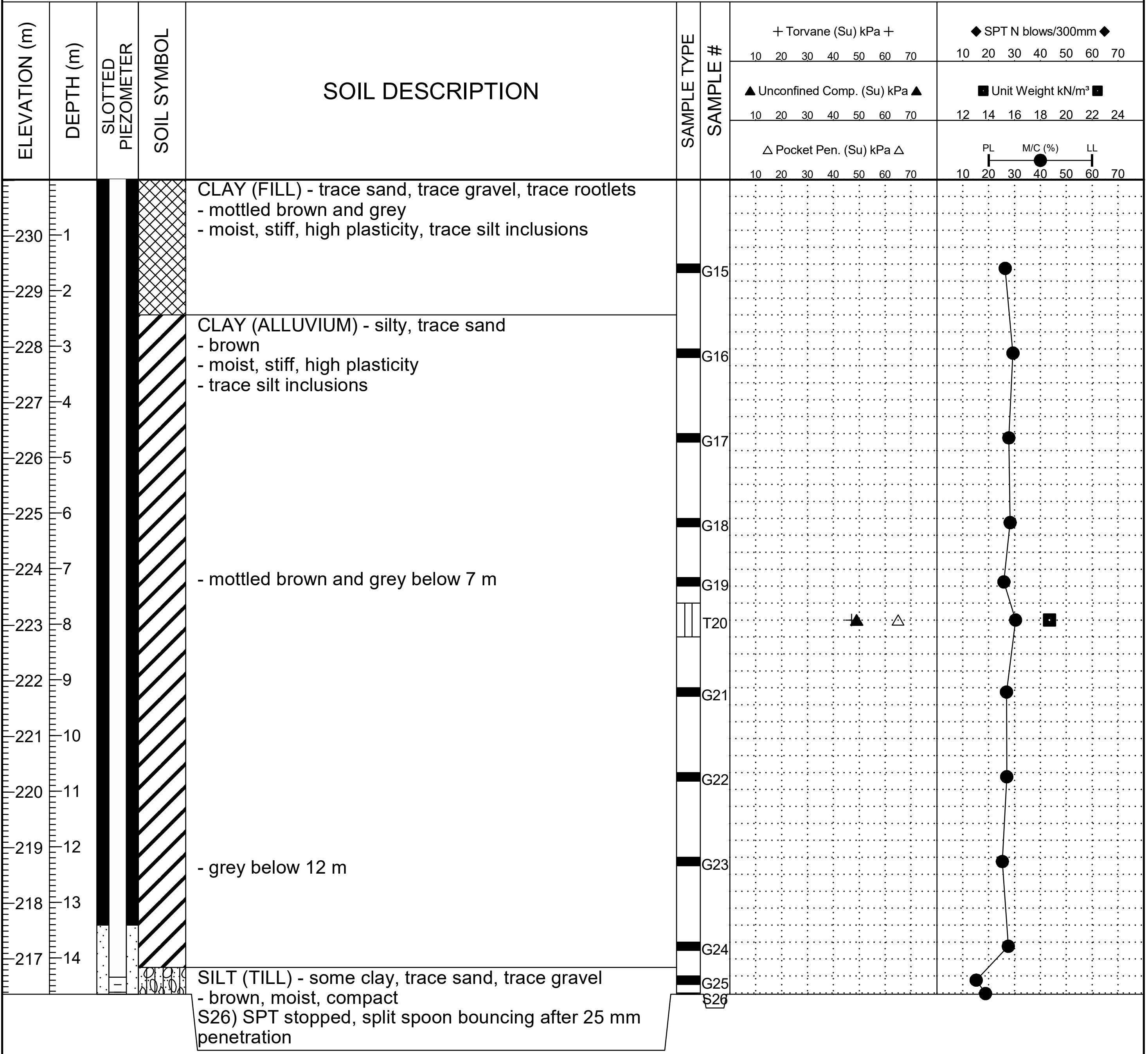
END OF TEST HOLE AT 14.4 m in CLAY (AUGER REFUSAL)
Notes:
1. SPT attempted after auger refusal, sampler bouncing with no penetration.
2. No seepage observed during drilling.
3. Test hole squeezing observed below 12.2 m during drilling.
4. Upon completion of drilling, test hole open to 14.3 m and dry.
5. Test hole backfilled with auger cuttings and bentonite chips.

DYREGROV ROBINSON INC.
Consulting Geotechnical Engineers

LOGGED BY: JW
REVIEWED BY: GR
PROJECT ENGINEER: Gil Robinson
COMPLETION DEPTH: 14.38 m
COMPLETION DATE: 17/8/21

PROJECT: COW-WWD: D'Arcy Pumping Station	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **2**
LOCATION: UTM 14U: 633,430 m E, 5,520,421 m N		PROJECT NO.: 214510
CONTRACTOR: Paddock Drilling Ltd.	METHOD: CME 850 Drill Rig w/ 125 mm SS Augers	ELEVATION (m): 231.03

SAMPLE TYPE	■ GRAB	▥ SHELBY TUBE	☒ SPLIT SPOON	☰ BULK	▨ NO RECOVERY	▌ CORE
BACKFILL TYPE	■ BENTONITE	⁘ GRAVEL	▥ SLOUGH	⁘ GROUT	▨ CUTTINGS	⁘ SAND



CLAY (FILL) - trace sand, trace gravel, trace rootlets
- mottled brown and grey
- moist, stiff, high plasticity, trace silt inclusions

CLAY (ALLUVIUM) - silty, trace sand
- brown
- moist, stiff, high plasticity
- trace silt inclusions

- mottled brown and grey below 7 m

- grey below 12 m

SILT (TILL) - some clay, trace sand, trace gravel
- brown, moist, compact
S26) SPT stopped, split spoon bouncing after 25 mm penetration

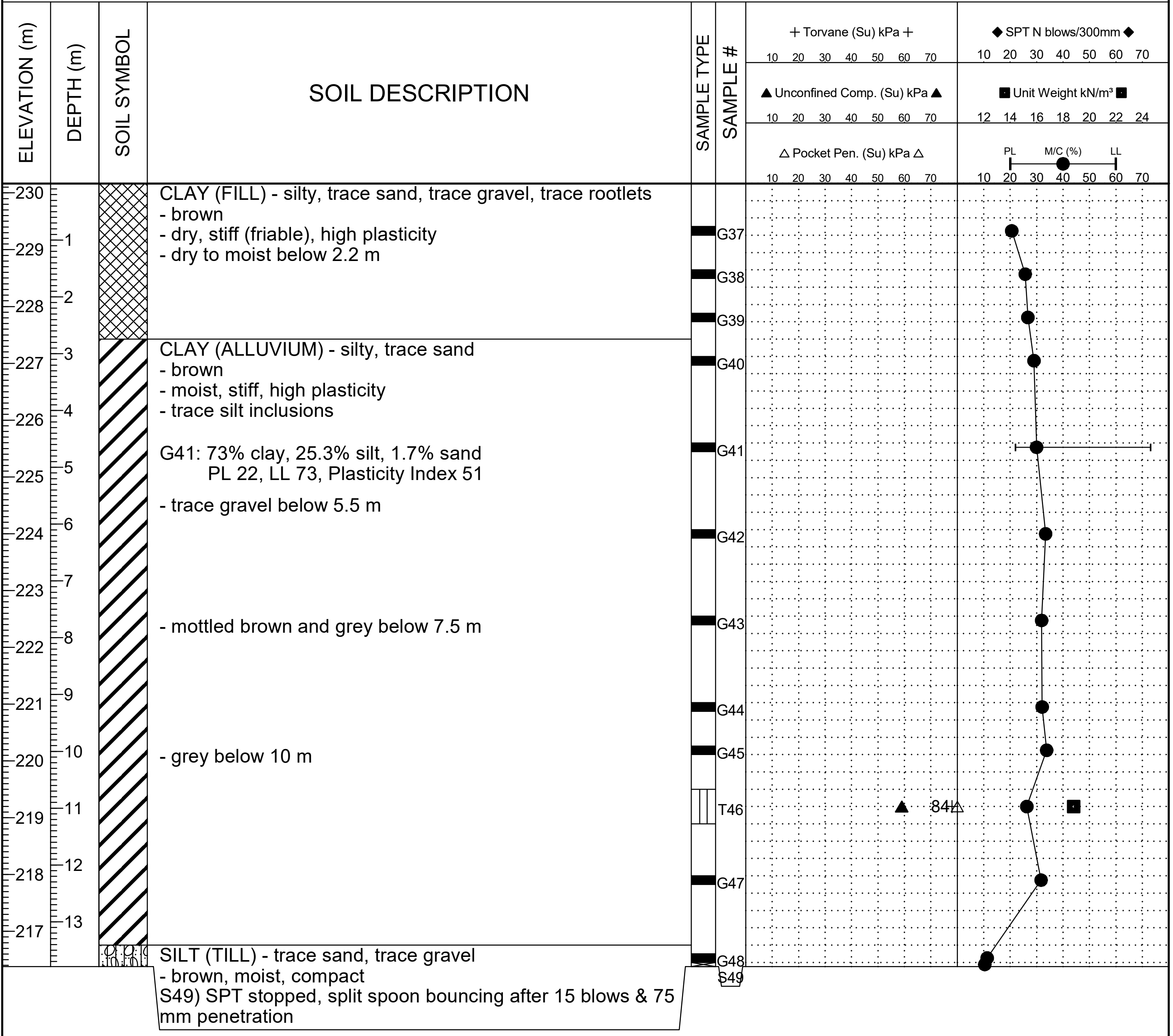
END OF TEST HOLE AT 14.6 m in SILT TILL (AUGER REFUSAL)
Notes:
1. Minor seepage observed below 12 m during drilling.
2. No sloughing was observed during drilling.
3. Upon completion of drilling, test hole open to 14.6 m and water level 13.7 m b/l grade.
4. 25 mm PVC Standpipe piezometer w/ Cassagrande tip installed 14.6 m b/l grade.
Top of pipe (T.O.P) 830 mm above grade.
Water levels:
August 17, 2021: Water level 9.5 m b/l grade
August 18, 2021: Water level 6.7 m b/l grade
September 17, 2021: Water level 6.4 m b/l grade

BH GEOTECH PLOTS-AUGUST 2013 214510_D'ARCY PUMPING STATION_GINT.GPJ DATA TEMPLATE - AUGUST 2, 2013.GDT 4/1/22

DYREGROV ROBINSON INC. Consulting Geotechnical Engineers	LOGGED BY: JW	COMPLETION DEPTH: 14.65 m
	REVIEWED BY: GR	COMPLETION DATE: 17/8/21
	PROJECT ENGINEER: Gil Robinson	Page 1 of 1

PROJECT: COW-WWD: D'Arcy Pumping Station	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **3**
LOCATION: UTM 14U: 633,461 m E, 5,520,433 m N		PROJECT NO.: 214510
CONTRACTOR: Paddock Drilling Ltd.	METHOD: CME 850 Drill Rig w/ 125 mm SS Augers	ELEVATION (m): 230.18

SAMPLE TYPE	■ GRAB	▥ SHELBY TUBE	☒ SPLIT SPOON	☰ BULK	▨ NO RECOVERY	▌ CORE
BACKFILL TYPE	■ BENTONITE	⁘ GRAVEL	▥ SLOUGH	⁘ GROUT	▨ CUTTINGS	⁘ SAND



CLAY (FILL) - silty, trace sand, trace gravel, trace rootlets
- brown
- dry, stiff (friable), high plasticity
- dry to moist below 2.2 m

CLAY (ALLUVIUM) - silty, trace sand
- brown
- moist, stiff, high plasticity
- trace silt inclusions

G41: 73% clay, 25.3% silt, 1.7% sand
PL 22, LL 73, Plasticity Index 51

- trace gravel below 5.5 m

- mottled brown and grey below 7.5 m

- grey below 10 m

SILT (TILL) - trace sand, trace gravel
- brown, moist, compact
S49) SPT stopped, split spoon bouncing after 15 blows & 75 mm penetration

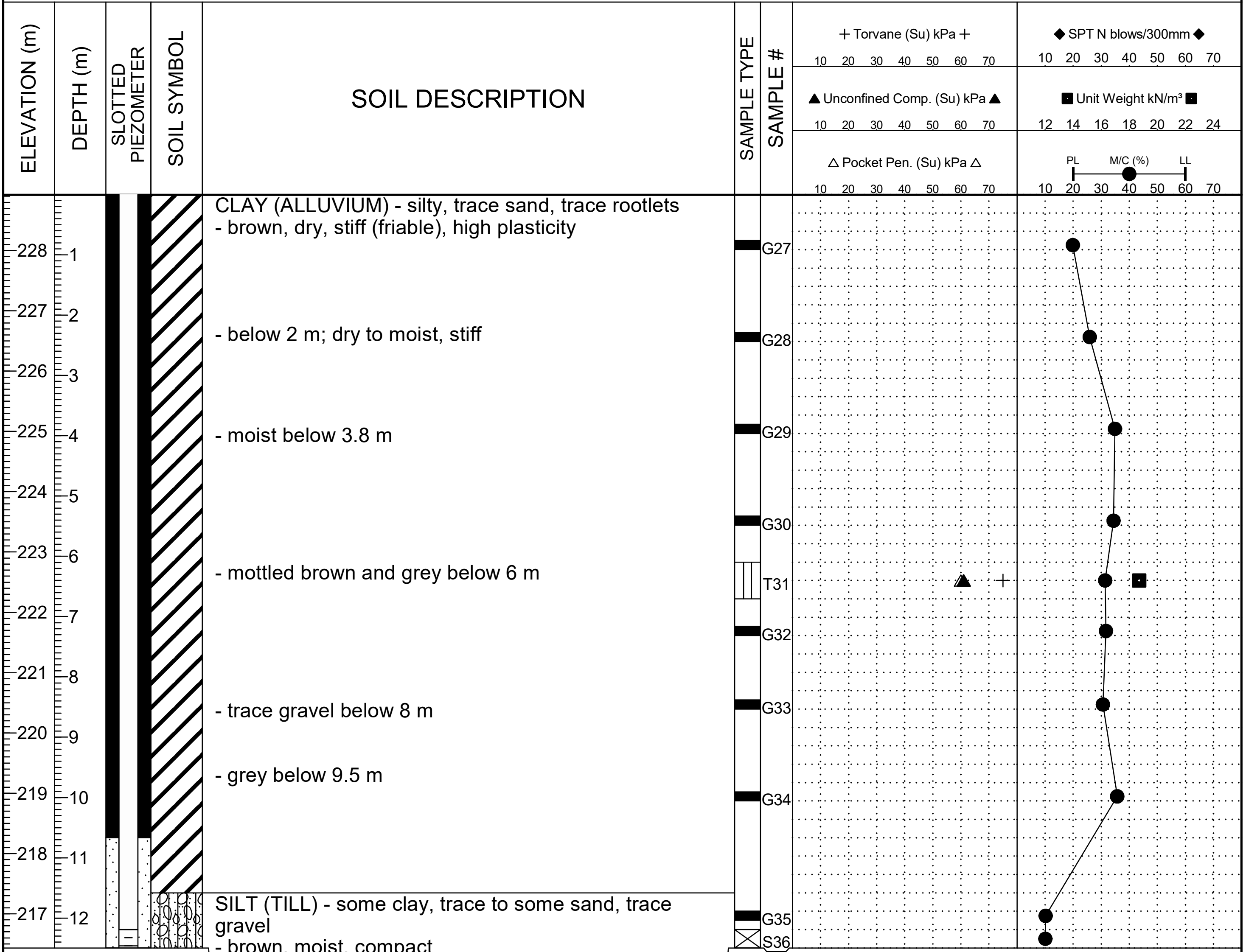
END OF TEST HOLE AT 13.8 m in SILT TILL (AUGER REFUSAL)
Notes:
1. Minor seepage observed below 13.7 m during drilling.
2. No sloughing was observed during drilling.
3. Upon completion of drilling, test hole open to 13.7 m and water level 12.5 m b/l grade.
4. Test hole backfilled with auger cuttings and bentonite chips.

DYREGROV ROBINSON INC.
Consulting Geotechnical Engineers

LOGGED BY: JW	COMPLETION DEPTH: 13.79 m
REVIEWED BY: GR	COMPLETION DATE: 18/8/21
PROJECT ENGINEER: Gil Robinson	Page 1 of 1

PROJECT: COW-WWD: D'Arcy Pumping Station	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: 4
LOCATION: UTM 14U: 633,482 m E, 5,520,447 m N		PROJECT NO.: 214510
CONTRACTOR: Paddock Drilling Ltd.	METHOD: CME 850 Drill Rig w/ 125 mm SS Augers	ELEVATION (m): 228.94

SAMPLE TYPE	■ GRAB	▥ SHELBY TUBE	☒ SPLIT SPOON	☰ BULK	▱ NO RECOVERY	▮ CORE
BACKFILL TYPE	■ BENTONITE	⁚ GRAVEL	▥ SLOUGH	▩ GROUT	▨ CUTTINGS	⁚ SAND



CLAY (ALLUVIUM) - silty, trace sand, trace rootlets
- brown, dry, stiff (friable), high plasticity

- below 2 m; dry to moist, stiff

- moist below 3.8 m

- mottled brown and grey below 6 m

- trace gravel below 8 m

- grey below 9.5 m

SILT (TILL) - some clay, trace to some sand, trace gravel
- brown, moist, compact
G35: 38.9% clay, 31.2% silt, 29.9% sand
S36) SPT stopped, split spoon bouncing after 30 blows & 75 mm penetration

END OF TEST HOLE AT 12.5 m in SILT TILL (AUGER REFUSAL)
Notes:
1. Minor seepage observed below 12.2 m during drilling.
2. No sloughing was observed during drilling.
3. Upon completion of drilling, test hole open to 12.5 m and water level 11.5 m b/l grade.
4. 25 mm PVC Standpipe piezometer w/ Cassagrande tip installed 12.5 m b/l grade.
Top of pipe (T.O.P) 930 mm above grade.
Water levels:
August 18, 2021: Water level 7.1 m b/l grade
September 17, 2021: Water level 4.4 m b/l grade

DYREGROV ROBINSON INC. Consulting Geotechnical Engineers	LOGGED BY: JW	COMPLETION DEPTH: 12.50 m
	REVIEWED BY: GR	COMPLETION DATE: 18/8/21
	PROJECT ENGINEER: Gil Robinson	Page 1 of 1

Your Project #: 214510
Site#: WINNIPEG
Site Location: DARCY PUMP STATION
Your C.O.C. #: N018381

Attention: GIL ROBINSON

DYREGROV ROBINSON INC
UNIT 1, 1692 DUBLIN AVENUE
WINNIPEG, MB
CANADA R3H 1A8

Report Date: 2021/09/21
Report #: R3074291
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C167515
Received: 2021/09/10, 15:58

Sample Matrix: Soil
Samples Received: 2

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (Soluble) (1)	2	2021/09/20	2021/09/20	AB SOP-00033 / AB SOP-00020	SM 23-4500-Cl-E m
Resistivity (1)	2	N/A	2021/09/19		Auto Calc
Conductivity @25C (Soluble) (1)	2	2021/09/18	2021/09/19	AB SOP-00033 / AB SOP-00004	SM 23 2510 B m
pH @25C (Soluble) (1)	2	2021/09/18	2021/09/18	AB SOP-00033 / AB SOP-00006	SM 23 4500 H+B m
Soluble Ions (1)	2	2021/09/18	2021/09/18	AB SOP-00033 / AB SOP-00042	EPA 6010d R5 m
Soluble Ions Calculation (1)	2	2021/09/13	2021/09/18		Auto Calc
Soluble Paste (1)	2	2021/09/18	2021/09/18	AB SOP-00033	Carter 2nd ed 15.2 m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested. When sampling is not conducted by Bureau Veritas, results relate to the supplied samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix “m” indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Bureau Veritas Calgary, 4000 - 19 St. , Calgary, AB, T2E 6P8

Your Project #: 214510
Site#: WINNIPEG
Site Location: DARCY PUMP STATION
Your C.O.C. #: N018381

Attention: GIL ROBINSON

DYREGROV ROBINSON INC
UNIT 1, 1692 DUBLIN AVENUE
WINNIPEG, MB
CANADA R3H 1A8

Report Date: 2021/09/21
Report #: R3074291
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C167515
Received: 2021/09/10, 15:58

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Customer Solutions, Western Canada Customer Experience Team
Email: customersolutionswest@bureauveritas.com
Phone# (204) 772-7276
==

Total Cover Pages : 2

RESULTS OF CHEMICAL ANALYSES OF SOIL

BV Labs ID		AFR478		AFR479		
Sampling Date		2021/08/18		2021/08/18		
COC Number		N018381		N018381		
	UNITS	**TH3-G38-5'**	**RDL**	**TH3-G42-20'**	**RDL**	**QC Batch**
Calculated Parameters						
Resistivity @ 25 °C	ohm-m	13	0.050	2.9	0.050	A349703
Calculated Sulphate (SO4)	%	0.0036	0.00013	0.045	0.00013	A349711
Soluble Parameters						
Soluble Chloride (Cl)	mg/L	160	10	770	50	A358778
Soluble Conductivity	dS/m	0.80	0.020	3.5	0.020	A357962
Soluble pH	pH	7.90	N/A	7.60	N/A	A357576
Saturation %	%	85	N/A	100	N/A	A356630
Soluble Sulphate (SO4)	mg/L	42	5.0	450	5.0	A357687

RDL = Reportable Detection Limit
N/A = Not Applicable

GENERAL COMMENTS

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
A356630	LZ3	QC Standard	Saturation %	2021/09/18		103	%	75 - 125
A356630	LZ3	RPD	Saturation %	2021/09/18	0.98		%	12
A357576	JHC	QC Standard	Soluble pH	2021/09/18		99	%	98 - 102
A357576	JHC	Spiked Blank	Soluble pH	2021/09/18		99	%	97 - 103
A357576	JHC	RPD	Soluble pH	2021/09/18	0		%	N/A
A357687	JAB	QC Standard	Soluble Sulphate (SO4)	2021/09/18		124	%	75 - 125
A357687	JAB	Method Blank	Soluble Sulphate (SO4)	2021/09/18	ND, RDL=5.0		mg/L	
A357687	JAB	RPD	Soluble Sulphate (SO4)	2021/09/18	15		%	30
A357962	STB	QC Standard	Soluble Conductivity	2021/09/19		109	%	75 - 125
A357962	STB	Spiked Blank	Soluble Conductivity	2021/09/19		99	%	90 - 110
A357962	STB	Method Blank	Soluble Conductivity	2021/09/19	ND, RDL=0.020		dS/m	
A357962	STB	RPD	Soluble Conductivity	2021/09/19	3.4		%	20
A358778	KWE	Matrix Spike	Soluble Chloride (Cl)	2021/09/20		NC	%	75 - 125
A358778	KWE	QC Standard	Soluble Chloride (Cl)	2021/09/20		122	%	75 - 125
A358778	KWE	Spiked Blank	Soluble Chloride (Cl)	2021/09/20		111	%	80 - 120
A358778	KWE	Method Blank	Soluble Chloride (Cl)	2021/09/20	ND, RDL=10		mg/L	
A358778	KWE	RPD	Soluble Chloride (Cl)	2021/09/20	4.5		%	30

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

Maria Magdalena Florescu, Ph.D., P.Chem., QP, Inorganics Manager

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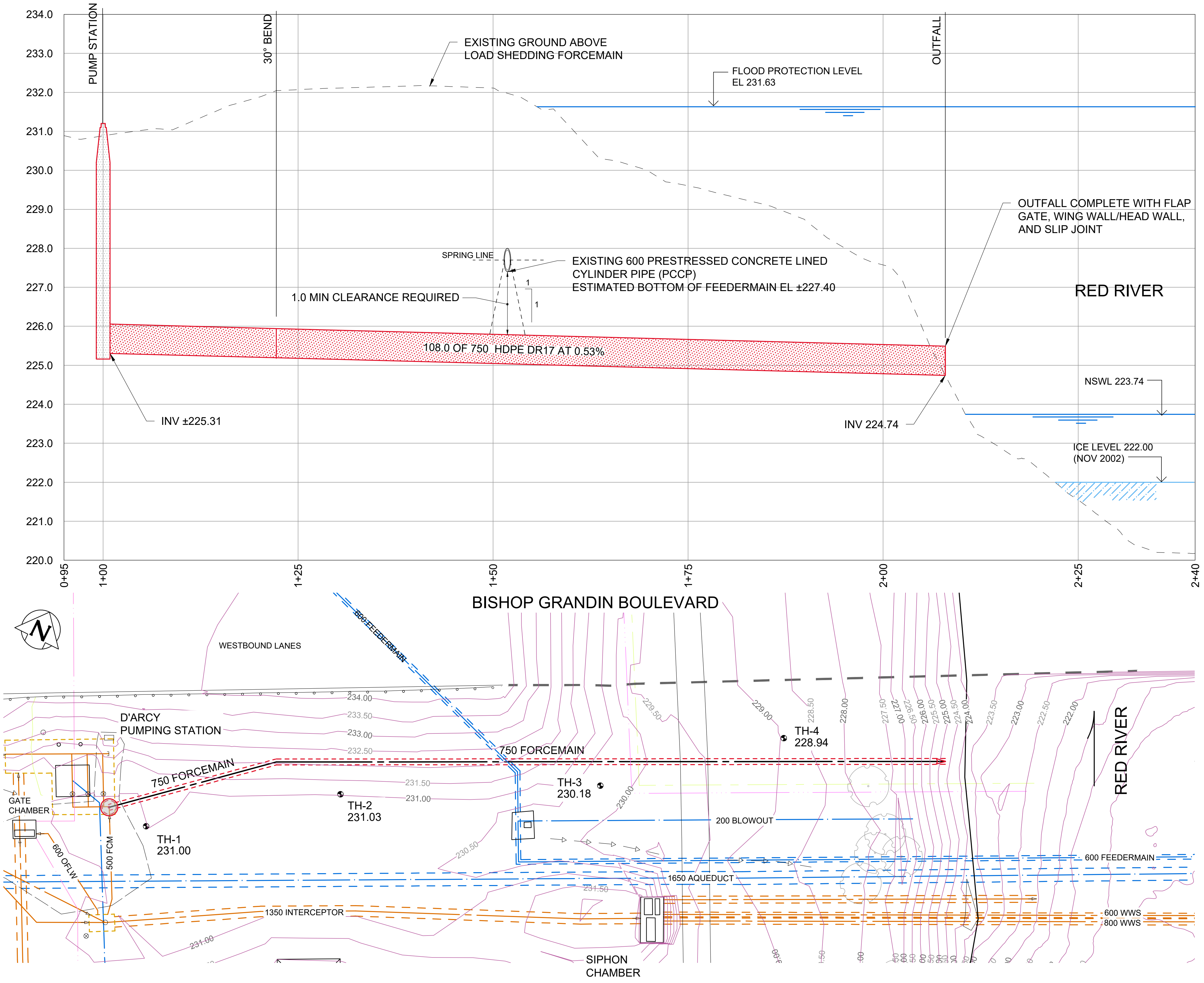
BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

APPENDIX B

Proposed Forcemain Option 1 Plan/Profile Drawing
& Section - A Drawing (provided by Tetra Tech)
&
Riverbank Stability Results
(Figures 1 to 4 and Figures 1A to 4A)



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10 0 10 20m

PROJECT:

D'ARCY WASTEWATER PUMPING STATION
LOAD SHEDDING UPGRADE

DESCRIPTION:

PROPOSED FORCEMAIN
OPTION 1 PLAN/PROFILE

FIGURE 4.1

Winnipeg

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT
ENGINEERING DIVISION

TETRA TECH

B.M.
ELEV.

NO.	REVISIONS	DATE	BY

TETRA TECH

DESIGNED BY
CHECKED BY
DRAWN BY GMD
APPROVED BY
SCALE:
HORIZONTAL 1:250
VERTICAL 1:50
RELEASED FOR CONSTRUCTION
DATE
DATE
PLOT DATE:

ENGINEER'S SEAL

CONSULTANT DRAWING NUMBER

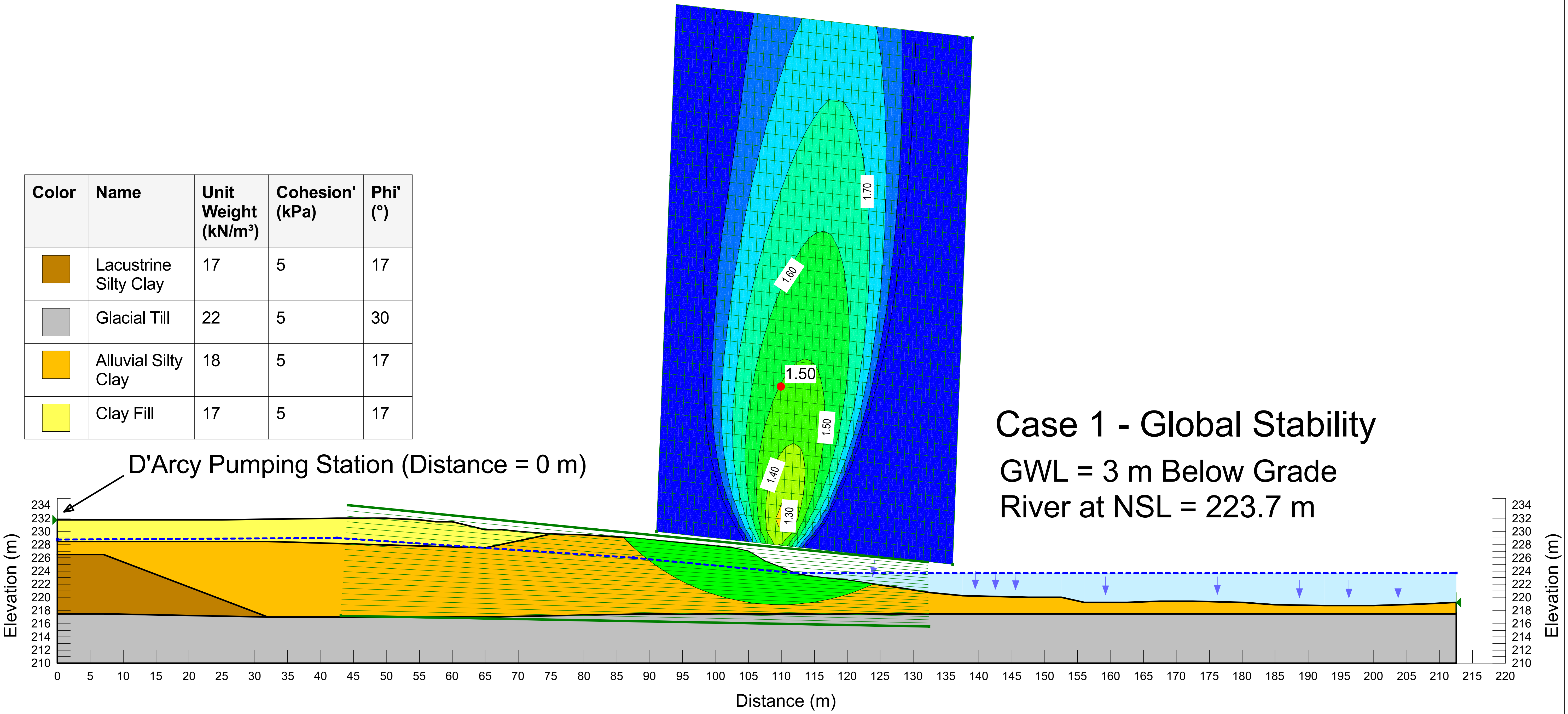
Winnipeg

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT
ENGINEERING DIVISION

D'ARCY WASTEWATER PUMPING STATION
LOAD SHEDDING UPGRADE
SECTION A

SHEET OF
CITY DRAWING NUMBER

FILE PATH: \\TTS293FS2.TT.LOCAL\Projects\A-G\City of Winnipeg-Water&Waste Department-0012\734-20001204.00-2020 Water Main Renewals - C3\CAD\Civil\Production Drawings\
FILE NAME: C0001 Darcy Overall Plan.dwg



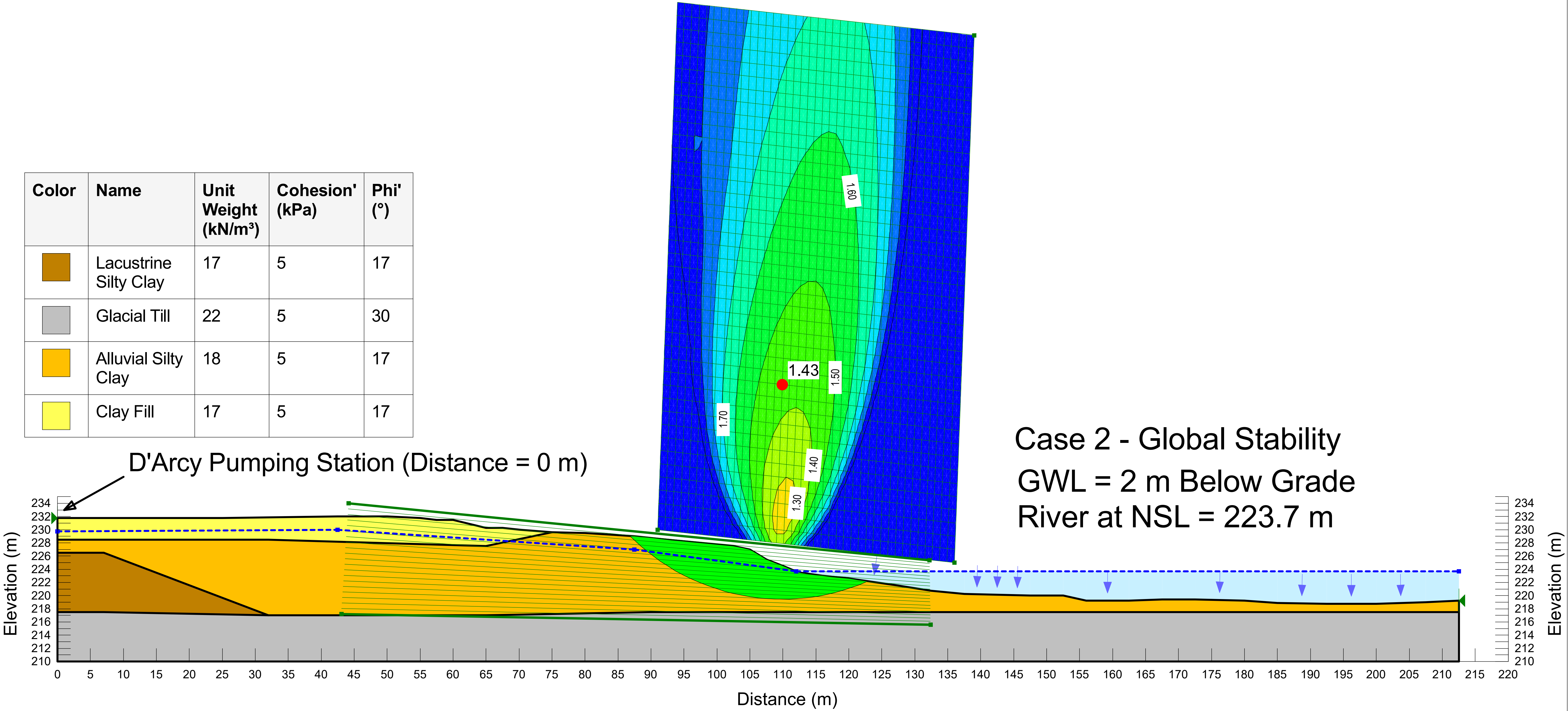
Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Lacustrine Silty Clay	17	5	17
⬜	Glacial Till	22	5	30
🟧	Alluvial Silty Clay	18	5	17
🟨	Clay Fill	17	5	17

D'Arcy Pumping Station (Distance = 0 m)

Case 1 - Global Stability

GWL = 3 m Below Grade
River at NSL = 223.7 m

Figure 1

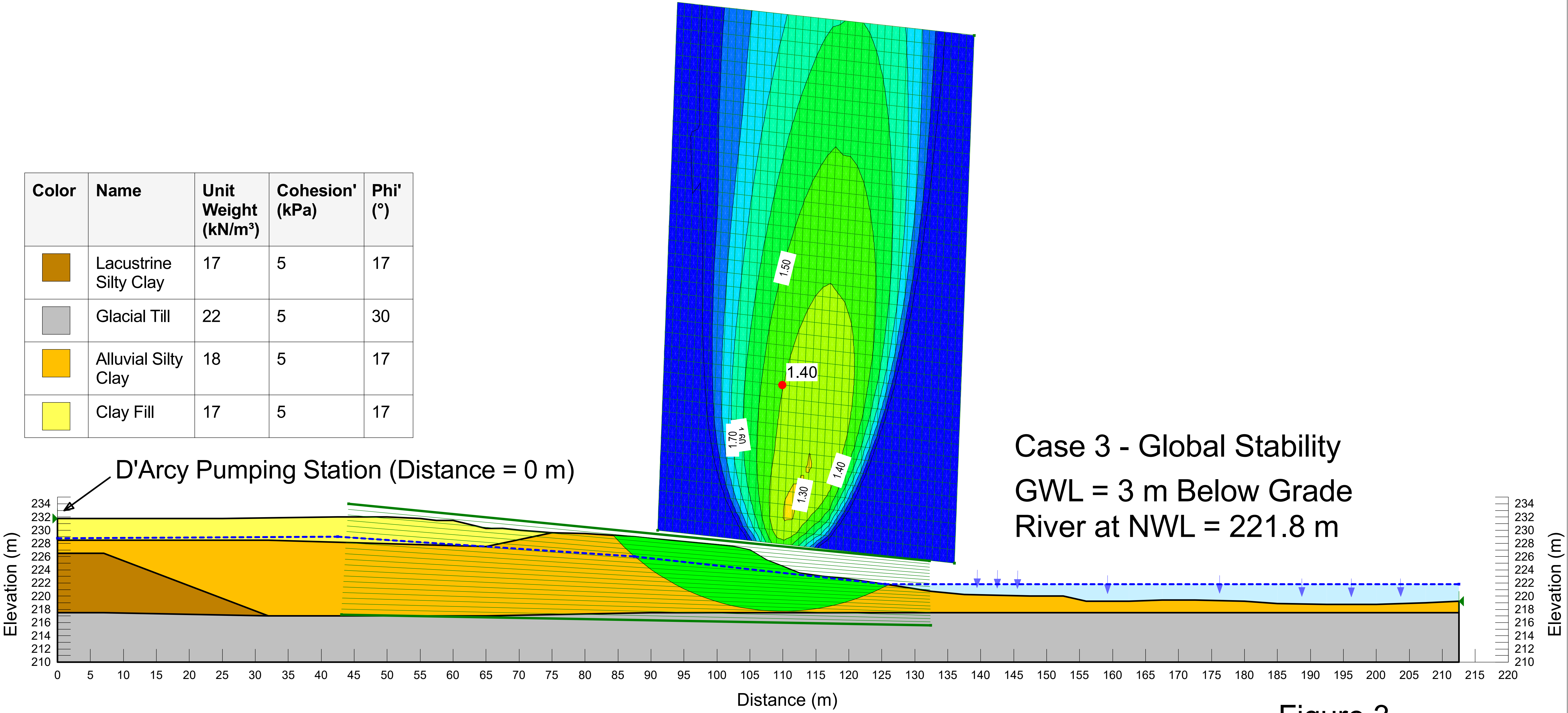


Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Lacustrine Silty Clay	17	5	17
⬜	Glacial Till	22	5	30
🟧	Alluvial Silty Clay	18	5	17
🟨	Clay Fill	17	5	17

D'Arcy Pumping Station (Distance = 0 m)

Case 2 - Global Stability
GWL = 2 m Below Grade
River at NSL = 223.7 m

Figure 2



Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Lacustrine Silty Clay	17	5	17
⬜	Glacial Till	22	5	30
🟧	Alluvial Silty Clay	18	5	17
🟨	Clay Fill	17	5	17

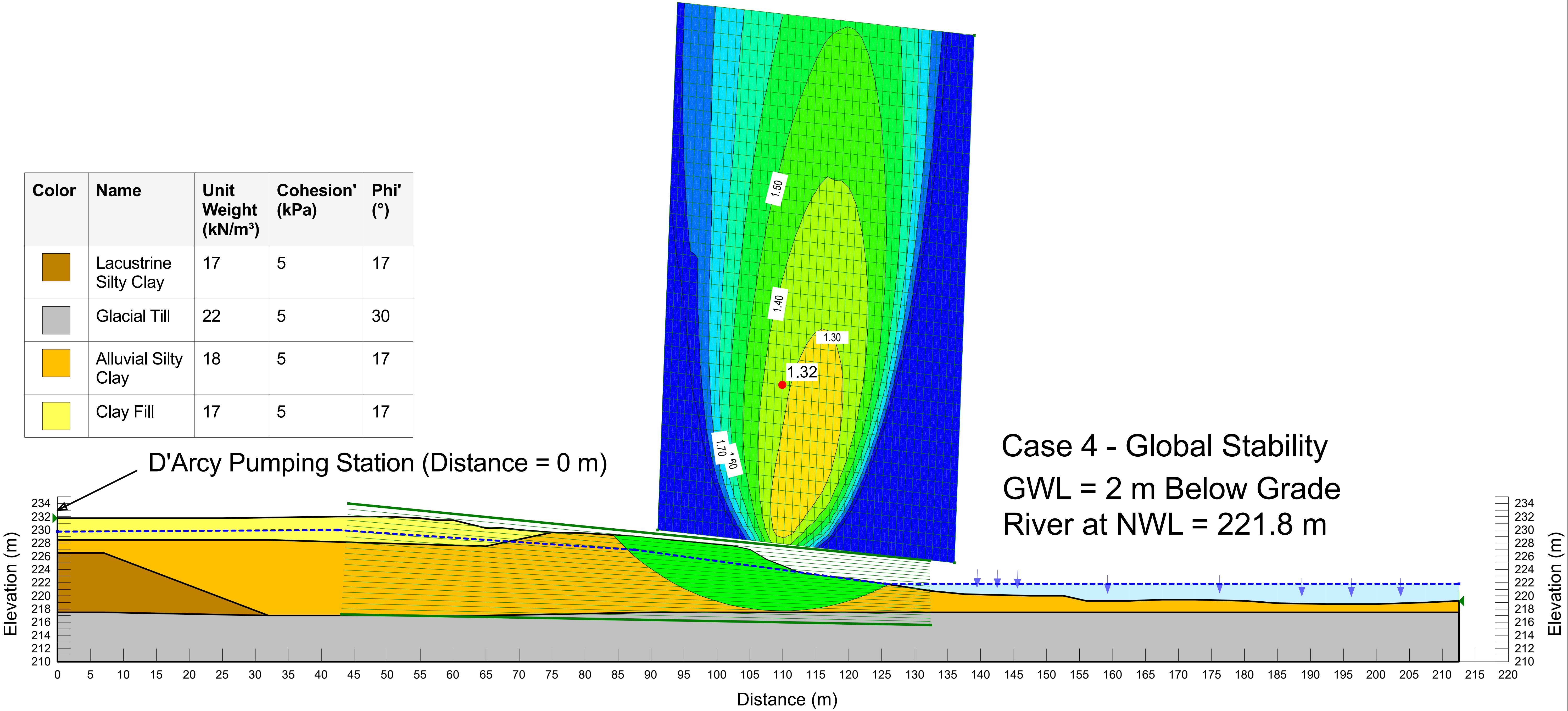
Case 3 - Global Stability

GWL = 3 m Below Grade

River at NWL = 221.8 m

Figure 3

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Lacustrine Silty Clay	17	5	17
⬜	Glacial Till	22	5	30
🟧	Alluvial Silty Clay	18	5	17
🟨	Clay Fill	17	5	17



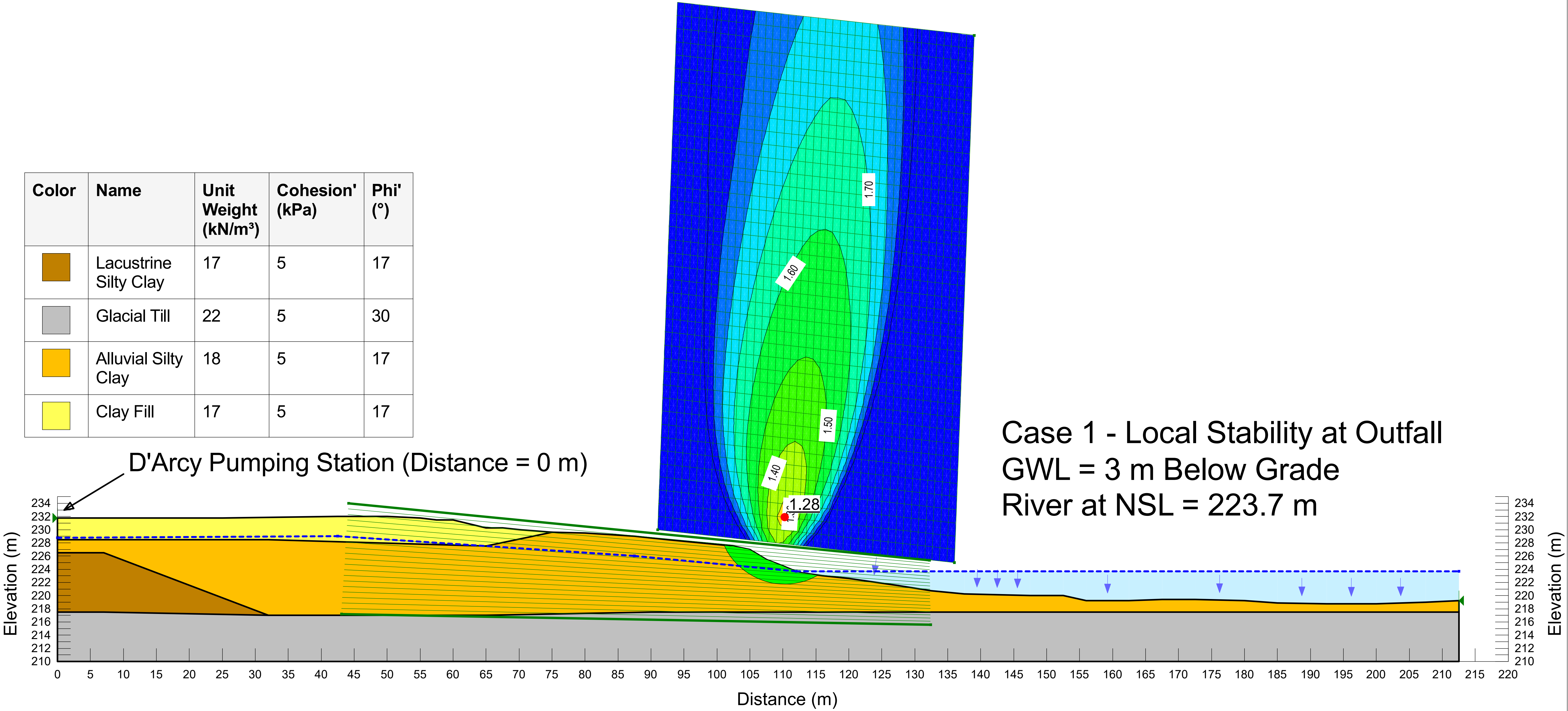
Case 4 - Global Stability

GWL = 2 m Below Grade

River at NWL = 221.8 m

Figure 4

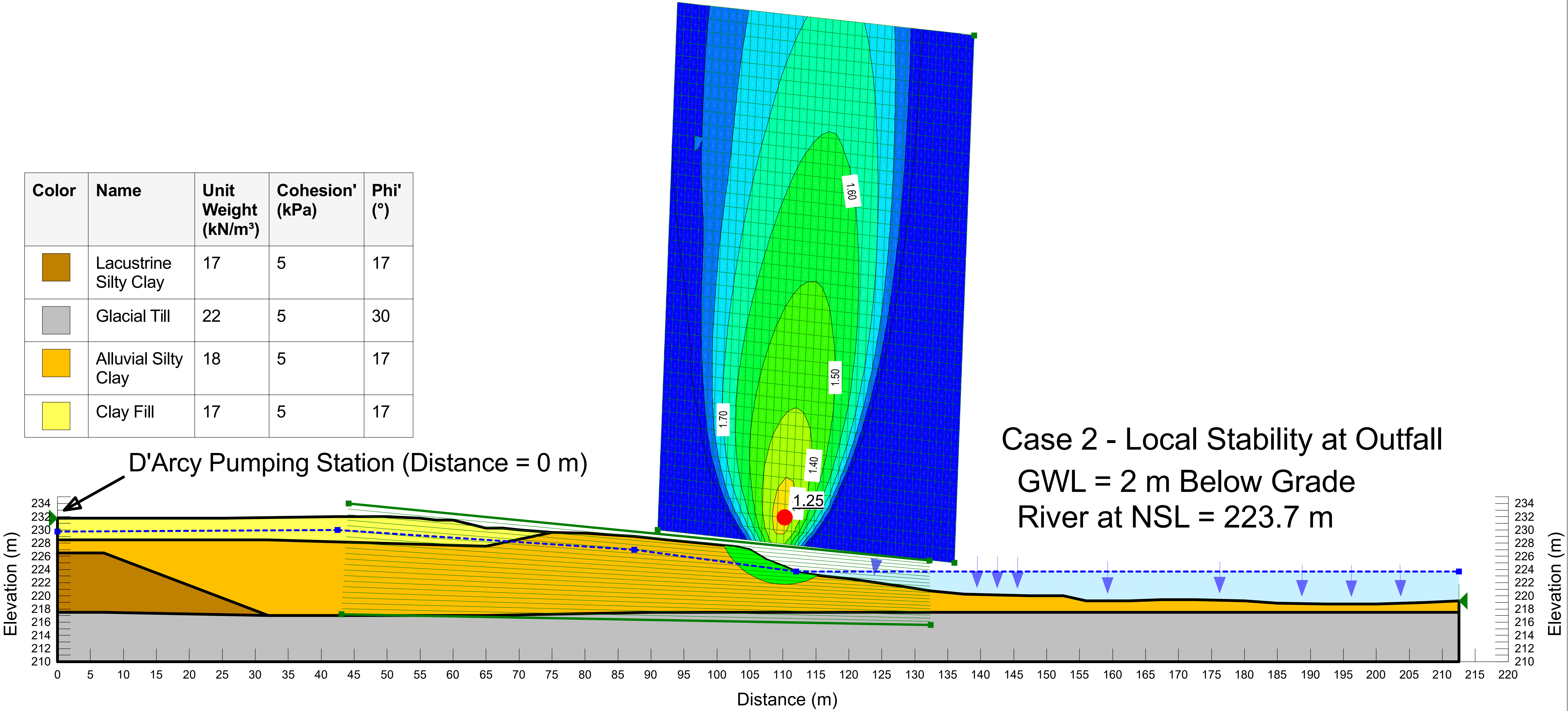
Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Lacustrine Silty Clay	17	5	17
⬜	Glacial Till	22	5	30
🟧	Alluvial Silty Clay	18	5	17
🟨	Clay Fill	17	5	17



Case 1 - Local Stability at Outfall
GWL = 3 m Below Grade
River at NSL = 223.7 m

Figure 1A

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Lacustrine Silty Clay	17	5	17
⬜	Glacial Till	22	5	30
🟧	Alluvial Silty Clay	18	5	17
🟨	Clay Fill	17	5	17



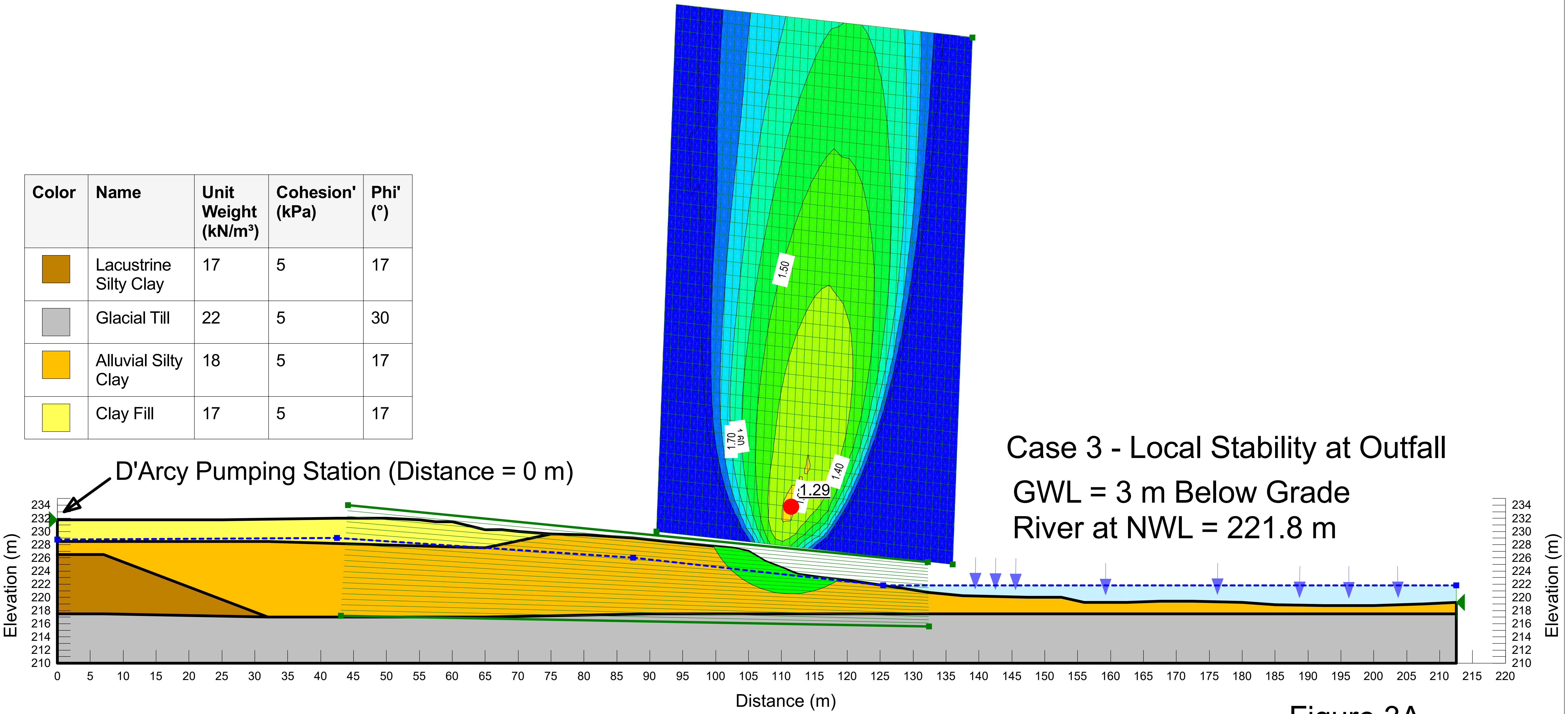
Case 2 - Local Stability at Outfall

GWL = 2 m Below Grade

River at NSL = 223.7 m

Figure 2A

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Lacustrine Silty Clay	17	5	17
⬜	Glacial Till	22	5	30
🟧	Alluvial Silty Clay	18	5	17
🟨	Clay Fill	17	5	17



D'Arcy Pumping Station (Distance = 0 m)

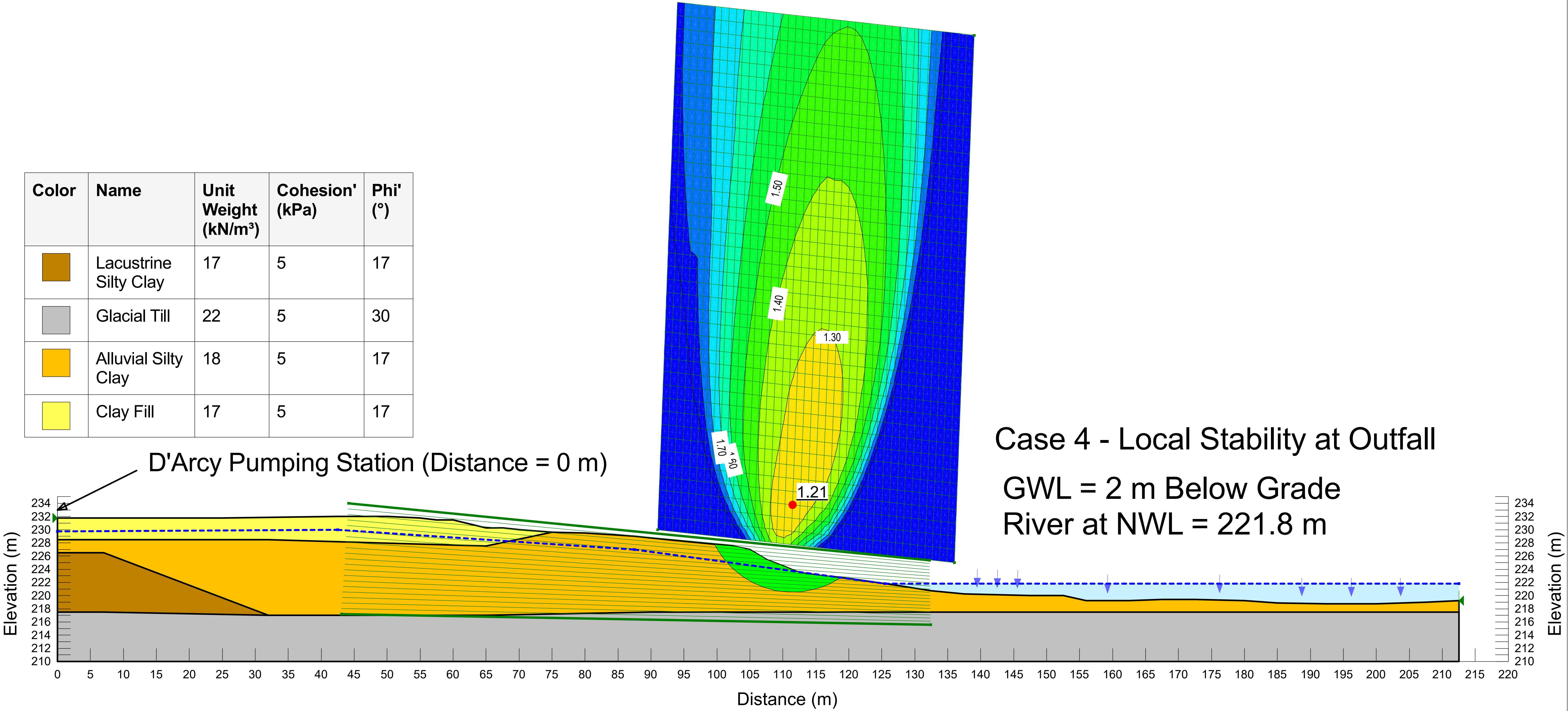
Case 3 - Local Stability at Outfall

GWL = 3 m Below Grade

River at NWL = 221.8 m

Figure 3A

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
🟫	Lacustrine Silty Clay	17	5	17
⬜	Glacial Till	22	5	30
🟧	Alluvial Silty Clay	18	5	17
🟨	Clay Fill	17	5	17



Case 4 - Local Stability at Outfall

GWL = 2 m Below Grade

River at NWL = 221.8 m

Figure 4A