FINAL

GEOTECHNICAL INVESTIGATIONS REPORT
2013 Field Investigations – North Spur
Muskrat Falls Hydroelectric Development
Lower Churchill Project

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IMPORTANT NOTICE

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1.0 INTRODUCTION

The Lower Churchill Hydroelectric Generation Project (Lower Churchill Project) consists of two (2) undeveloped hydroelectric sites and associated transmission systems: the Gull Island Hydroelectric Development, located 225 kilometers downstream from the existing Churchill Falls Generating Station; and the Muskrat Falls Hydroelectric Development, located 60 kilometers downstream from the proposed Gull Island Hydroelectric Development.

AMEC provided procurement, project management, field supervision and reporting services to execute the geotechnical investigation program at the North Spur of the Muskrat Falls site (the Site). The objective of the program was to gather geotechnical and geological data to assist with detailed engineering of the North Spur stabilization works. Associated field work was carried out between May and July, 2013. The investigation consisted of borehole drilling (both conventional and sonic), cone penetration testing, in-situ testing and laboratory testing. All work was completed in accordance with the "SM0713 – 2013 Field Investigations Technical Specification", Nalcor Doc. No. MFA-SN-CD-2800-GT-TS-0002-01, herein referred to as "the Specification" and subsequent requests/revisions.

The geotechnical investigation was carried out on the crest and on both the upstream and downstream sides of the North Spur at Muskrat Falls. The program consisted of:

a. The drilling of six (6) conventional boreholes ranging in depth from 19.0 to 69.0 meters. Two additional boreholes were advanced at NS-01-13 to facilitate the installation of two piezometers.

b. The drilling of five (5) sonic-drilled boreholes ranging in depth from 50.6 to 115.0 meters. One additional borehole was advanced at NS-03-13 to facilitate the installation of two piezometers.

c. The completion of twenty-seven (27) cone penetration tests using a static cone penetrometer (i.e. piezocone), advancing to depths ranging from 6.7 to 70.0 meters.

d. Execution of various in-situ testing including standard penetration tests (SPT), field vane shear tests (FVST), permeability tests and shear wave velocity testing.

e. The installation of standpipe piezometers in select borehole locations.

f. Sampling and geotechnical index testing of disturbed and undisturbed soils.

g. Thin wall sample extraction and logging, including specialized laboratory tests (triaxal, consolidation, direct shear) on select samples,

h. Site clearing for all test sites and trail construction to access the east and west shorelines.

2.0 PROJECT TERMS OF REFERENCE

As per the Request for Proposal (RFP) for the project, AMEC provided the following services:

a. Provision and management of a site specific Health and Safety Plan, including a dedicated full time Health, Safety & Environmental (HSE) Representative on site for the majority of the program;

b. Preparation and implementation of a Contract Specific Environmental Protection Plan (C-SEPP);

c. Mobilization, installation, operation and demobilization of all machinery, equipment, materials and personnel required for the investigation;

d. Accommodations for all AMEC and Subcontractor personnel;

e. Provision of an on-site laboratory and associated equipment, a site office, lunch room, sanitary facilities and communications;

f. Construction of access trails and clearing of testing sites;

g. Surveying and positional control work;

h. Execution of the drilling and testing program;

i. Execution of all specified in-situ testing, including Standard Penetration Tests (SPT), Cone Penetration Tests (CPT), Field Vane Shear Tests (FVST), and Permeability Tests;

j. Sampling of rock and soils as outlined in the RFP and as directed by the Engineer;

k. Execution of laboratory testing as outlined in the RFP and as directed by the Engineer;

l. Supply and installation of standpipe piezometers;

m. Completion of borehole logs and core logging;

n. Daily and weekly reporting to Nalcor of field activities; and

o. Preparation of the investigation report;

Nalcor were accountable for the following:

a. Interpretation of testing results and associated design recommendations;

b. Finalization and provision of key technical requirements. Such information included drill hole locations, depths, alignments, required angles of inclination, drill hole size(s) and required testing;

c. Provision of environmental monitoring services;

d. Acceptance of AMEC's Project Execution Plan;

e. Acceptance of AMEC's Health and Safety Plan; and

g. Acceptance of AMEC's Environmental Protection Plan.

3.0 PROGRAM MANAGEMENT

3.1 General

The investigation program was to provide procurement, supervision, laboratory testing and project management services to execute the geotechnical investigation program at the North Spur of the Muskrat Falls site.

AMEC provided the following personnel:

- A Campaign Manager with 15+ years of related geological and geotechnical engineering experience. The campaign manager ensured the quality of the work, coordinated all activities with subcontractors and acted as a liaison between the Engineer (SNC Lavalin Incorporated) and Nalcor. Calvin Miles, P.Geo., was assigned to this role.

- A Site Manager with 10+ years of relevant experience to assist in the management of all site personnel and activities. When required, the site manager performed the duties of the geotechnical engineer/geologist and of the campaign manager. Kevin Penney, MScEng, P.Eng. was assigned to this role.

- Two (2) geotechnical geologists with 5+ years of relevant experience. Both were responsible for the coordination of sampling, in-situ testing and drilling activities. Brad Walsh, P.Geo. and Ian Butt, P.Geo. were responsible for this work.

- Two (2) drill supervisors with 5+ years of experience in related work. They were responsible for sampling, supervision of drilling and in-situ testing.

- A HSE inspector with 5+ years of experience. She was responsible for assuring compliance with the health and safety, environmental protection and emergency response plans.

- A Job Clerk was provided to assist with: reporting, sample delivery / preparation and miscellaneous duties. When required, he assisted with laboratory testing and drill supervision.

- A laboratory technician was assigned to perform the required index testing (i.e. grain size analysis, moisture determination and Atterberg limits) at the temporary laboratory set up in Happy Valley-Goose Bay. In order to maintain the testing schedule, two (2) technicians were, at times, working concurrently in the laboratory.

In addition to AMEC personnel, AMEC was responsible for retaining and supervising subcontractors to carry out the work. Four subcontractors were retained. Personnel included supervisors with at least 5 years experience who overseen the activities of their crews. Additional information is presented in Section 3.8.

3.2 Permits and Approvals

All site work for the investigation was covered under Nalcor's site specific permits and approvals. No additional permits or approvals were required.

3.3 Health and Safety

All personnel working on the Site underwent the Nalcor project specific Drug & Alcohol and medical screening for approval to work on the project. In addition, a Nalcor site specific orientation was required to be completed by all workers. All AMEC employees and subcontractors were also required to complete an AMEC site specific orientation. Visitors to the Site were required to undergo a site visitor's orientation and had to be accompanied by an orientated worker.

Daily tool box and activity meetings were held by all employees prior to starting the daily activities. Absent employees who arrived later were required to review the minutes and given the opportunity to provide input. Each work crew also conducted an onsite (at the work location) meeting prior to the start of work where changes in tasks were identified. These meetings involved discussing the activities and their associated health & safety concerns. Nalcor "Step Back" cards and contractor specific check lists / forms were also completed.

A weekly health and safety meeting was conducted by AMEC for all personnel on site. Weekly health and safety statistics were submitted to Nalcor's on-site Health and Safety Department.

An Emergency Response Plan was required to be prepared and approved by Nalcor prior to commencing activities on the east and west shorelines. Emergency response measures were implemented and the plan reviewed with all personnel prior to starting the work.

No incidents or lost time occurrences were reported during the field program. One (1) near miss was recorded. Two (2) occurrences of property damage were reported.

3.4 Environmental

All personnel working on the Site were tasked to review AMEC's contract specific Environmental Protection Plan. Key items within the plan were addressed during AMEC's site orientation and discussed during the morning toolbox meetings. Environmental awareness and protection was also addressed during the Nalcor site orientation.

Job Environmental Assessments (JEA) were completed for each site and activity prior to commencing the work and reviewed daily. In addition, proposed drill locations and access trails were cleared for migratory song bird nests by the Nalcor Environmental Officer prior to the disturbance of any trees.

Due to mechanical breakdowns, two spills occurred which required clean up and were reported to Nalcor. One spill involved a hydraulic leak on a skid steer and the other a coolant leak on the CPT rig. Amounts spilled were minor and were easily addressed onsite utilizing spill kits. Impacted soil was shovelled into buckets and disposed of at a soil treatment facility in Happy Valley-Goose Bay.

3.5 Historic Archaeological Clearance

Due to the historical nature of the Site, many of the drill sites and access trails required archaeological clearance (provided by Nalcor) prior to commencing work. Some delays resulted due to waiting for this clearance and the uncovering of artefacts.

Due to the proximity of the east shoreline access trail to an historical portage trail, Nalcor requested that AMEC provide a plan to protect its natural state. This plan was approved by Nalcor and implemented prior to the construction of the east shoreline access trail. No issues were identified during trail construction and upon completion of the field program these protective measures were removed.

3.6 Surveying

Initial borehole and test site locations were first located in the field using a hand held GPS unit. Upon completion of drilling and testing, the sites were surveyed with a location accuracy of 100 mm and elevation accuracy of 20 mm. This service was provided by N.E. Parrott Surveys Limited. Two (2) visits were made to determine the test site locations and elevations, along with the locations of the access trails.

3.7 Progress Meetings / Reports

Daily progress meetings were held with Nalcor's and the Engineer's onsite personnel. Conference calls between onsite personnel and staff at the project office in St. John's were carried out on an as required basis.

Progress was documented in both the daily and weekly reports prepared by the AMEC Site Manager. Activities and quantities presented in the reports were reviewed with the Nalcor onsite representative prior to submittal.

3.8 Supervision

AMEC supervised the activities of their subcontractors. These activities included: access clearing and construction, conventional drilling, sonic drilling, and CPT testing.

3.8.1 Access Clearing and Construction

AMEC retained the services of Shukun Enterprises for access trail clearing and construction. Direction and supervision of this work was the responsibility of the AMEC Site Manager. Personnel ranged from one operator to two operators and a foreman, depending on work load.

3.8.2 Conventional Drilling

AMEC retained the services of Cartwright Drilling Incorporated to execute the drilling, sampling, in-situ testing and piezometer installation for the conventional boreholes. Technical direction was the responsibility of AMEC's Drilling Geologist; daily supervision was provided by an AMEC Drilling Technologist. Personnel included a drill supervisor, driller, helper, and part time health and safety officer.

3.8.3 Sonic Drilling

AMEC retained the services of Boart Longyear Limited to execute the drilling, sampling and piezometer installation of the sonic boreholes. Technical direction was the responsibility of AMEC's Drilling Geologist; daily supervision was provided by an AMEC Drilling Technologist. Due to the quick advancement rate of the sonic drill, the Drilling Geologist assisted with the core logging. Upon occasion, the services of either the clerk or laboratory technologist were utilized. Personnel included a drill supervisor/driller and two helpers.

3.8.4 Cone Penetration Testing

AMEC retained Group Qualitas (Qualitas) to execute Cone Penetration Testing for this investigation. Direction and supervision was the responsibility of AMEC's Drilling Geologist. A technologist was provided by Qualitas to record the data. Analysis of the data was also performed by Qualitas. Personnel included a technologist and an operator.

3.9 Laboratory Services and Testing

AMEC obtained space within Happy Valley-Goose Bay for a field laboratory that was equipped to carry out gradation analysis, moisture determination and Atterberg limits. AMEC's laboratory technician was stationed here for the duration of the investigation to perform the requested testing. In order to maintain the testing schedule, two (2) technicians were, at times, working concurrently in the laboratory.

Select grab, SPT, and all Shelby Tube samples were sent to AMEC's laboratory in St. John's for further testing. Shelby Tube samples were extracted in the St. John's laboratory, logged and prepared for storage and/or shipment to AMEC's laboratory in Scarborough, Ontario for advanced geotechnical testing. On select samples, this testing included: consolidation, direct shear and triaxial CIU tests. Additional grain size and Atterberg limit testing was also conducted on these samples. All testing adhered to the applicable ASTM Standards.

Upon completion of the field program, all remaining unused samples and the sonic drill core were transported to a warehouse facility in Goose Bay and turned over to Nalcor.

4.0 PROJECT EXECUTION

The project was divided into four (4) phases: preparation, fieldwork, laboratory testing and reporting.

4.1 Preparation and Procurement

The program commenced with the preparation of the Health and Safety Plan (HASP), Contract Specific Environmental Protection Plan (C-SEPP) and Project Execution Plan (PEP). These plans were submitted to Nalcor for approval prior to mobilization. Preparation also included the procurement of qualified subcontractors to complete the drilling and in-situ testing procedures outlined in the Project RFP.

It was determined during the preparation phase that all permits currently in place by Nalcor were applicable for the project and no additional permits were required. A workshop was held at the project office on Torbay Road between AMEC, Nalcor and the Engineer to review the execution plan along with the project specific health and safety, environmental, quality and other relevant protocols.

4.2 Fieldwork

4.2.1 Mobilization / Demobilization

AMEC's staff travelled to Labrador via commercial airline. Pickup trucks equipped with buggy whips, beacon lights and fire extinguishers were used to travel between Happy Valley-Goose Bay and the Site. AMEC's sub-contractors used similar modes of transportation.

AMEC obtained space within Happy Valley-Goose Bay for a field laboratory that was equipped to carry out sieve analysis, moisture content and Atterberg limits. AMEC rented two on-site trailers: one served as office facilities for the Nalcor and Engineer staff; the second was utilized for AMEC's office facilities and lunch room. Three (3) "port-a-potties" were rented and serviced twice a week. Cellular communications worked over the majority of the Site and 2-way radios were utilized to communicate between onsite personnel. Internet service was provided using a wireless cellular router (Bell - Turbo Hub).

4.2.2 Site Preparation

Site preparation required the clearing of areas for rig setup (conventional, sonic and CPT) along with access trails to the sites. It was originally proposed to access borehole locations on the east and west shorelines via helicopter. However, alternate access by constructing access trails was evaluated by AMEC and proposed to Nalcor prior to the start of the field program.

The objective of the access trails were to remove the requirement for helicopter support and to utilize the self propelled, all terrain CPT rig. Removal of the helicopter limited the effects it may have had on scheduling and overall project expense. In addition, the trails allowed for easier access to alternate and additional test sites. Due to access restrictions (close proximity to archeological interests and steep slopes) some of the proposed locations were inaccessible and alternate locations were chosen in consultation with the Engineer.

Two (2) excavators, one with a mulcher attachment, were utilized for access trail construction. Due to the steep terrain and the predominance of unmerchantable timber, trees within the access trails were either mulched or fell and used for trail stabilization and to assist with erosion protection. Geofabric was used in select areas for further stabilize and erosion protection. Where required, silt fencing was placed accordingly.

Each drill site and access trail was assessed for health and safety and environmental concerns prior to construction. These areas also required clearance from Nalcor for migratory song bird nests, as well as clearance from the archeologist for historic resources.

An onsite assessment and meeting was held between AMEC and various Nalcor representatives to evaluate potential alternate routes for the east access. It was concluded from this activity that the original proposed route was the preferred route.

Upon completion of drilling, each site was cleaned of debris and disturbed areas were remediated to reduce erosion and promote re-vegetation. Access trails were left for future use, with surface water flow paths reestablished and access to the trails barricaded using a windrow of soil.

4.2.3 Conventional Drilling Program

From May 31 to July 3, 2013, a total of six (6) conventional boreholes were advanced with a Duralite 1000 fly drilling rig owned and operated by Cartwright Drilling Incorporated. Borehole details such as termination depth, location and frequency of in-situ testing were at the discretion of the Engineer. Since the drill rig was a modified fly exploration rig, it was equipped with a safety hammer and wire line winch in place of an automatic hammer (typically found on geotechnical rigs). Standard Penetration Testing (SPT) results had to be adjusted accordingly.

Completed conventional boreholes include: NS-1-13, NS-1B-13, NS-1C-13, NS-4-13, NS-9-13 and NS-11-13. Refer to the site drawing in Appendix A for their relative locations. Borehole logs are provided in Appendix B1. Termination depths ranged from 19.0 meters below ground surface (mbgs) (NS-9-13) to 69.0 mbgs (NS-1-13). Bedrock was not encountered in any of the conventional borehole locations.

Due to piezometer installation difficulties in NS-1-13, the piezometer install was abandoned and a second borehole (NS-1B-13) advanced for the piezometer installation. Due to difficulties with installation of the upper piezometer in NS-1B-13, a third borehole (NS-1C-13) was required.

At the request of the Engineer, boreholes NS-8-13, NS-10-13 and NS-12-13 were replaced with cone penetration testing. Additionally, borehole NS-4-13, originally proposed as a sonic borehole, was advanced with the conventional drill for the purposes of piezometer installation. Refer to Table 1 for a summary of the conventional drilling program.

Table 1: Summary of Conventional Boreholes

Borehole ID	Start Date	Finish Date	UTM Coordinates[1]		Surface Elevation	Depth	Comments
			Northing (m)	Easting (m)	(masl[2])	(mbgs)[3]	
NS-1-13	31-May-13	13-Jun-13	5903188	648558	55.3	69.0	Initial piezometer installation attempt abandoned.
NS-1B-13	17-Jun-13	19-Jun-13	5903172	648568	55.6	45.1	Advanced adjacent to NS-1-13 for lower piezometer installation.
NS-1C-13	20-Jun-13	21-Jun-13	5903172	648569	55.6	25.6	Advanced adjacent to NS-1B-13 for upper piezometer installation.
NS-4-13	28-Jun-13	01-Jul-13	5903041	647997	58.6	41.3	Initially proposed to be a sonic borehole. Drilled as a conventional borehole for piezometer installation.
NS-9-13	03-Jul-13	03-Jul-13	5902953	648584	16.3	19.0	No piezometer installation requested at this location.
NS-11-13	23-Jun-13	25-Jun-13	5902685	648098	20.5	33.1	No piezometer installation requested at this location.

Notes: 1. NAD83, Zone 20
2. masl – meters above sea level
3. mbgs – meters below ground surface

All conventional boreholes were advanced using standard wash boring methods with HW sized casing. Overburden soils were sampled, logged and tested for relative density by SPT results at intervals and locations determined by the Engineer. These disturbed soil samples were sealed in watertight plastic bags and transported to the temporary AMEC laboratory for directed gradation analysis, moisture determination and Atterberg limits.

In cohesive soils, attempts were made to collect thin-walled tube samples at depths determined by the Engineer. The samples were properly labeled, sealed with paraffin wax and were transported to AMEC laboratories in St. John's and Scarborough. Select samples, under the discretion of the Engineer, underwent direct shear, triaxial and consolidation testing. All testing adhered to the applicable ASTM standards. In boreholes where piezometer installation was not requested, a cement-bentonite-water mixture was utilized to backfill to surface upon completion of drilling.

4.2.4 Sonic Drilling Program

From May 31 to June 21, 2013, a total of five (5) sonic boreholes were advanced with a track-mounted sonic drilling rig owned and operated by Boart Longyear Limited. Borehole details such as termination depth, location and frequency of sampling were at the discretion of the Engineer.

Completed sonic boreholes include: NS-2-13, NS-3-13, NS-3B-13, NS-5-13 and NS-6-13. Refer to the drawing in Appendix A for their relative locations. Borehole logs are provided in Appendix B1. Termination depths ranged from 50.6 mbgs (NS-6-13) to 115.0 mbgs (NS-2-13). Bedrock was not encountered in any of the sonic borehole locations.

Due to piezometer installation difficulties in NS-3-13, its installation was abandoned and a second borehole (NS-3B-13) was advanced to complete the lower and upper piezometer installations. At the request of the Engineer, borehole NS-7-13 was replaced with cone penetration testing. Additionally, borehole NS-4-13 was removed from the sonic drill program and later advanced with the conventional drill for the purposes of piezometer installation only. Refer to Table 2 for a summary of the sonic drilling program.

Table 2: Summary of Sonic Boreholes

Borehole ID	Start Date	Finish Date	UTM Coordinates[1]		Surface Elevation	Depth	Comments
			Northing (m)	Easting (m)	(masl[2])	(mbgs[3])	
NS-2-13	15-Jun-13	21-Jun-13	5902661	648315	61.4	115.0	
NS-3-13	07-Jun-13	09-Jun-13	5903199	648041	59.1	59.7	Initial piezometer installation abandoned.
NS-3B-13	13-Jun-13	14-Jun-13	n/d[4]	n/d	59.1	54.3	Advanced 10 m west of NS-3-13 for piezometer installation.
NS-5-13	31-May-13	02-Jun-13	5903164	647932	59.1	68.9	No installation requested at this location.
NS-6-13	03-Jun-13	06-Jun-13	5903306	647983	58.9	50.6	

Notes:
1. NAD83, Zone 20
2. masl – meters above sea level
3. mbgs – meters below ground surface
4. n/d – not determined

All sonic boreholes were advanced using high frequency vibration generated by the drill head using 152 mm (6") sized casing and a 3 m core sampler. Overburden soils were continuously logged and sampled at approximate 1.5 m intervals, or at each stratum change. It should be noted that there were some difficulties in retaining the upper silts and clays. Various methods were utilized in an attempt to maximize recovery. These included the implementation of core catchers, the shortening of runs to 1.5 m and 0.75 m and only using vibration and drill water in stiffer soils. Shorter 1.5 m runs proved to be the most successful method.

Collected soil samples were sealed in watertight plastic bags and transported to the temporary AMEC laboratory for directed gradation analysis, moisture determination and Atterberg limits. All remaining core was boxed, labeled and stored at Nalcor's storage facility located in Goose Bay. In boreholes where piezometer installation was not requested, a cement-bentonite-water mixture was utilized to backfill to surface upon completion of drilling.

4.2.5 Cone Penetration Testing

A total of 27 Cone Penetration Tests (CPT) were completed between May 25, 2013 and July 5, 2013. Originally 12 CPT holes were proposed. At the direction of the Engineer, additional CPT holes were completed to either provide supplementary information or to replace proposed conventional or sonic boreholes. A summary of the testing is presented in Table 3.

Table 3. Summary of CPT Testing

CPT ID	Date	UTM Coordinates[1]		Surface Elevation	Depth	Comments
		Northing (m)	Easting (m)	(m)	(mbgs)[2]	
NS-CPT-1A-13	08-Jun-13	5902416	648158	20.6	6.7	Moved ~5 m N to new location referred to as NS-1B-13 to confirm refusal on probable bedrock.
NS-CPT-1B-13	08-Jun-13	5902421	648159	20.8	7.5	Refusal on probable bedrock.
NS-CPT-2A-13	12-Jun-13	5902518	648217	33.6	36.7	Moved 22 m WSW to new location referred to as NS-CPT-02B-13 to confirm refusal at same elevation.
NS-CPT-2B-13	12-Jun-13	5902509	648197	29.8	32.0	Refusal at 32.0 m depth.
NS-CPT-3-13	09-Jun-13	5902527	648150	21.0	30.0	Coordinates obtained using hand-held GPS unit. Elevation taken from topographic map.
NS-CPT-4-13	09-Jun-13	5902974	647856	19.2	30.0	
NS-CPT-5-13	26-May-13	5903035	647972	58.6	70.0	
NS-CPT-6-13	04-Jul-13	5902775	648528	16.1	30.0	Moved 140 m NE from proposed location.
NS-CPT-7-13	01-Jul-13	5902667	648606	5.3	20.0	
NS-CPT-8-13	02-Jul-13	5902954	648591	16.0	40.0	Moved 50 m NW from proposed

CPT ID	Date	UTM Coordinates[1]		Surface Elevation	Depth	Comments
		Northing (m)	Easting (m)	(m)	(mbgs)[2]	
						location to avoid east shoreline.
NS-CPT-9-13	29-May-13	5903161	648588	54.6	65.0	Shear wave velocity (Vs) was performed.
NS-CPT-10A-13	02-Jun-13	5903228	648661	47.9	38.5	Site was originally planned along east shoreline but for safety concerns it was moved to top of slope. Refusal at 38.5 m depth. Ran in hole with dummy cone to try and push past area of refusal. Able to push cone to 40 m depth. Decided to run back in hole with tool but hit refusal at 39 m depth. Test was referred to as NS-CPT-10B-13. Moved 20 m NW to new location referred to as NS-CPT-10C-13 to confirm refusal.
NS-CPT-10C-13	04-Jun-13	5903235	648643	49.1	48.9	Refusal at 48.9 m depth.
NS-CPT-11-13	31-May-13	5902654	648291	61.5	70.0	Shear wave velocity (Vs) was performed.
NS-CPT-12-13	25-May-13	5903272	648005	58.7	70.0	
NS-CPT-13-13	11-Jun-13	5902745	648066	21.0	40.0	Supplementary information. Coordinates obtained using hand-held GPS unit. Elevation taken from topographic map.
NS-CPT-14-13	10-Jun-13	5902933	647916	20.0	30.0	Supplementary information.
NS-CPT-15-13	06-Jun-13	5903115	647882	58.7	48.5	Supplementary information.
NS-CPT-16-13	01-Jun-13	5902926	648409	61.8	65.0	Supplementary information.
NS-CPT-17-13	05-Jun-13	5903343	648081	56.9	52.5	Replaced sonic borehole NS-07-13.
NS-CPT-18-13	10-Jun-13	5902814	648018	20.1	30.0	Replaced NS-12-13.
NS-CPT-19-13	11-Jun-13	5902636	648118	20.8	30.0	Supplementary information.
NS-CPT-20-13	05-Jul-13	5902586	648133	21.4	12.0	Supplementary information.
NS-CPT-21-13	05-Jul-13	5902900	647955	19.9	10.0	Supplementary information.
NS-CPT-22-13	04-Jul-13	5903016	647827	19.3	13.0	Supplementary information.
NS-CPT-23-13	03-Jul-13	5902790	648599	8.5	25.0	Replaced NS-10-13.
NS-CPT-24-13	03-Jul-13	5903062	648665	2.8	21.0	Replaced NS-08-13.

Notes: 1. NAD83, Zone 20
2. mbgs – meters below ground surface

The testing was conducted using a Standard 15 cm^2 Type 2 Piezocone (Plate 1) and 38 mm push rods. The CPT assembly was advanced using hydraulic cylinders with a thrusting capacity of 20 tons mounted on a modified rubber-tire forwarder (Plate 2) weighing 25 tons. Measurements were collected every 10 mm as the piezocone was advanced one meter at a constant rate of 600 mm per minute. The data was collected using an acquisition system supplied by ConeTec.

Plate 1. Piezocone

Plate 2. Modified rubber-tire forwarder

Each hole was advanced to the depth directed by the Engineer, or to refusal. All test holes were backfilled to surface using a cement-bentonite-water slurry upon completion. Shear wave velocity measurements were conducted in holes NS-CPT-09-13 and NS-CPT-11-13 at 1.0 m intervals. Test results are provided in Appendix C.

4.2.6 Piezometer Installation

Casagrande-type piezometers (25 mm diameter; 0.41 m length) were installed in the following conventional borehole locations: NS-1B-13, NS-1C-13 and NS-4-13. Each piezometer was placed in a lantern of No.2 silica sand and sealed using coated bentonite pellets. Refer to Table 4 for a summary of piezometer installations in the conventional boreholes.

Piezometers were installed in the following sonic borehole locations: NS-2-13, NS-3B-13 and NS-6-13. In each, the lower piezometers were pre-packed with sand. The pre-packed piezometers were 0.9 m in length with a 0.3 m interior slotted section. Standard 25 mm slotted PVC pipe was utilized for the upper piezometers with lengths ranging from 0.9 m to 1.5 m (upper piezometer lengths determined in consultation with the Engineer). All were placed in a lantern of No.2 silica sand and sealed using coated bentonite chips. Refer to Table 4 for a summary of the piezometer installations in the sonic boreholes.

Final installation designs were developed in consultation with the Engineer. Detailed installation design is provided in Appendix B2.

Table 4. Summary of piezometer installations

Piezometer ID	Piezometer Type	Date Installed	Piezometer Elevation (masl)		Sand Lantern Elevation (masl)		Stick-up Elevation (masl)
			Top	Bottom	Top	Bottom	
NS-1B-13	Casagrande	19-Jun-13	11.5	11.1	13.6	10.5	56.5
NS-1C-13	Casagrande	21-Jun-13	30.5	30.1	31.9	30.0	56.3
NS-2-13 (Upper)	Slotted Pipe	23-Jun-13	36.4	34.9	37.6	34.4	62.3
NS-2-13 (Lower)	Pre-packed	22-Jun-13	-52.6	-53.5	-46.4	-53.6	62.3
NS-3B-13 (Upper)	Slotted Pipe	14-Jun-13	21.3	19.8	23.1	19.2	60.4
NS-3B-13 (Lower)	Pre-packed	14-Jun-13	6.2	5.3	7.1	4.8	60.4
NS-4-13 (Upper)	Casagrande	01-Jul-13	27.0	26.6	28.2	26.1	59.1
NS-4-13 (Lower)	Casagrande	30-Jun-31	18.2	17.8	18.7	17.1	59.1
NS-6-13 (Upper)	Slotted Pipe	05-Jun-13	27.1	26.2	28.6	26.0	60.1
NS-6-13 (Lower)	Pre-packed	05-Jun-13	16.9	16.0	17.2	14.8	60.1

Notes: 1. masl – meters above sea level

4.2.7 Permeability Testing

The RFP had originally proposed performing falling head tests during drilling operations by the LeFranc Method. At the request of the Engineer, these tests were replaced by standard falling head (slug) tests in the installed piezometers after completion of the drilling activities and stabilization of the groundwater table. This was performed at:

- NS-2-13 (Lower)
- NS-3B-13 (Upper)
- NS-3B-13 (Lower)
- NS-4-13 (Lower)
- NS-6-13 (Upper)
- NS-6-13 (Lower)

Permeability testing could not be performed at:

- NS-1B-13 – reported as dry
- NS-1C-13 – blockage reported during field program that has since been cleared.
- NS-4-13 (upper piezometer) – did not return to static water level after flushing during the time of the field program

Slug tests were completed by filling the well to the top of the stick-up with water and collecting water level data at select time intervals as the well returned to equilibrium conditions (i.e. static water level). Slug test results were analysed using the Bouwer and Rice (1976) method using the AQTESOLV PRO 4.0 software package. Hydraulic conductivity (K) results are shown in Table 5 and range from 3.1×10^{-9} m/s to 4.9×10^{-8} m/s. It should be noted that hydraulic conductivity values are representative of the aquifer material from the bottom of the screened interval to the bottom of the overlying impermeable layer and may represent several different geologic layers of differing hydraulic conductivities values. Results should be considered an average value over the thickness of the representative layer, though thinner layers of higher and lower permeability layers will exist within the representative layer.

Table 5. Summary of permeability testing

Piezometer ID	K (m/s)
NS-2-13 (Lower)	4.9×10^{-8}
NS-3B-13 (Upper)	5.7×10^{-9}
NS-3B-13 (Lower)	8.1×10^{-9}
NS-4-13 (Lower)	3.1×10^{-8}
NS-6-13 (Upper)	5.6×10^{-9}
NS-6-13 (Lower)	3.1×10^{-9}

Refer to Appendix E for the permeability testing results.

4.2.8 Field Vane Shear Testing

Field vane shear testing (FVST) was completed at locations NS-09V-13 and NS-13-13 for the purpose of determining the undisturbed and remoulded shear strength of the underlying clay strata. Refer to the drawing in Appendix A for the relative locations of NS-09V-13 and NS-13-13. A M-1000 Vane Borer system supplied by Omnimetrix, a company based in Ville St-Laurent, QC, was utilized for this work.

During the advancement of NS-1-13, FVST were attempted at select locations but were unsuccessful due to apparent compact silty sand seams within the clay layers. At test locations NS-09V-13 and NS-13-13, the vane assembly was continuously pushed with the rigs hydraulic head and tests conducted at 1.0 m intervals until refusal, or until the maximum torque was reached. The testing was conducted in accordance with ASTM D 2573-08. Results are presented in Appendix D.

4.3 Laboratory Results

A sampling program was provided by the Engineer which identified the sampling frequency and testing required for each of the borehole. All samples were collected into either re-sealable plastic bags (SPT and grab samples) or thin-walled Shelby tubes.

The following testing was conducted at AMEC's laboratories Goose Bay and St. John's:

- Particle-size Analyses: ASTM D422 – "Standard Test Method for Particle Size Analysis of Soils";

- Atterberg Limit Testing: ASTM D4318 – "Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils"; and

- Natural Moisture Determination: ASTM D2216 – "Standard Test Method for Laboratory determination of Moisture Content of Soils and Rock by Mass".

A total of 123 sieve analyses were carried out; 20 of which were coupled with hydrometers. A total of 125 samples underwent Atterberg limit testing and determination natural moisture content. Results are presented in appendices F1, F2 and F3 respectively.

Select Shelby tube samples were transported to the AMEC laboratory in St. John's where they were extruded, logged (see Appendix B3 for detailed logs) and select samples shipped to Scarborough, Ontario to undergo the following analysis:

- Direct Shear Testing: ASTM D3080.D3080M – "Standard Test Method for Direct Shear Test of Soils under Consolidated Drained Soils";

- Undrained Triaxial Compression Testing: ASTM D4767 – "Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soils"; and

- Consolidation Testing: ASTM D2435/2435M – "Standard Test Method for One-Dimensional Consolidation Properties of Soils Using Incremental Loading".

A total of 21 direct shear, 11 triaxial and 8 consolidation tests were requested. Results are shown in appendices F4, F5 and F6 and summarized in Tables 6, 7 and 8, respectively.

Table 6. Summary of Direct Shear testing results

Sample ID	Normal Stress (kPa)	Peak Shear Stress (kPa)	Residual Shear Stress (kPa)
NS-01-13 SS-08,09,10	100	74	71
	200	142	133
	400	275	269
NS-01-13 SS-18,19,20	200	141	151
	400	300	310
	800	562	565
NS-01-13 ST-02	150	129	98
	300	213	192
	600	387	378

Sample ID	Normal Stress (kPa)	Peak Shear Stress (kPa)	Residual Shear Stress (kPa)
NS-01-13 ST-07	200	127	116
	400	233	246
	800	433	407
NS-01-13 ST-11	200	136	119
	400	241	240
	800	431	464
NS-09-13 ST-04	100	62	59
	200	111	112
	400	215	219
NS-11-13 ST-04	200	112	114
	400	208	235
	800	413	457

Table 7. Summary of Triaxial testing results

Sample ID	STRESS				FAILURE CRITERIA MOHR CIRCLE			
	σ_1 (kPa)	σ_3 (kPa)	σ_1 (kPa)	σ_3 (kPa)	C (kPa)	Φ (degrees)	C' (kPa)	Φ' (degrees)
	Total Stress	Total Stress	Effective Stress	Effective Stress	Total Stress	Total Stress	Effectiv e Stress	Effective Stress
NS-01-13 ST-08	157	50	145	38	25	19	0	35
	277	100	243	66				
	669	300	496	127				
	1010	500	706	196				
NS-09-13 ST-05	142	50	118	26	24	18	0	30
	272	100	244	72				
	569	300	386	117				
	1022	500	794	273				
NS-11-13 ST-03	-	-	-	-	54	11	15	32
	279	100	232	53				
	612	300	421	108				
	865	500	503	138				

Table 8. Summary of Consolidation testing results

Sample ID	Depth (m)	Coefficient of Consolidation (c_v) (m^2/day)
NS-1-13 ST-8	54.98 - 55.03	0.01
NS-1-13 ST-11	68.70 - 68.75	0.03
NS-9-13 ST-4	12.57 - 12.62	0.02
NS-9-13 ST-5	15.72 - 15.77	0.02
NS-9-13 ST-6	18.67 - 18.72	0.02
NS-11-13 ST-2	21.56 - 21.66	0.02
NS-11-13 ST-3	24.76 - 24.81	0.03
NS-11-13 ST-4	27.72 - 27.82	0.02

4.4 Reporting

Reporting ran concurrently with the geotechnical investigation. Daily reports were compiled by each drill supervisor and submitted to the Site Manager and Engineer. The Site Manager prepared daily reports that included all relevant information: daily production, crew members on site, working/standby time, health & safety and environmental activities and a description of the work. The Site Manager also produced weekly reports that included a summary of the work for the particular week. Additional site specific health & safety and environmental reporting and forms were submitted as required.

Upon completion of the field program a geotechnical report was prepared (this report) which includes methodology, all relevant geotechnical data, equipment and instruments used, survey information, laboratory and in-situ testing results. No geotechnical recommendations are made.

5.0 CLOSURE

This report was prepared for the exclusive use of Nalcor Energy for specific application to the project site. The work was conducted in accordance with the work plan developed for this site and verbal requests from Nalcor Energy. The work was performed using generally accepted construction practices and procedures commonly used in the industry.
