REPORT S-05-1743 PRELIMINARY GEOTECHNICAL INVESTIGATION LNG TERMINAL – CACOUNA ENERGY GROS CACOUNA QUEBEC

NOVEMBER 28, 2005

for

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PRELIMINARY

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PRELIMINARY

EXECUTIVE SUMMARY

The preliminary investigation carried out in October 2005 involved geological mapping of the proposed construction site in an old abandoned quarry, a series of geophysical seismic traverse lines along the floor of the quarry and finally three (3) borings in the areas of reservoirs T-100 and T-101 to be constructed at elevation +5 m or about 1 metre above the floor of the quarry at elevation +4 m.

The geological mapping of the quarry face and shoreline identified massive, thick and resistant beds of well cemented sandstone formations with minor interbeds of softer more impure shaley zones.

The formations slope down (dip) at a low angle of about 12^{o} towards the south. A well defined near vertical dipping joint or fracture plane oriented in a northwest direction crosses the north perimeter of tank T-100. This fracture will not affect the foundation of the tank provided a small 15 to 20 metre adjustment directly southwest or a 25m adjustment directly south can be made for tank T-100. No significant faulting was identified in the exposed rock slopes or in the boreholes, and this is confirmed by geological mapping undertaken by Quebec Natural Resources in 1977.

The three (3) borings encountered solid (strong), massive sandstone formations to the 15-metre depth below the quarry floor, except for the surface blast fractured zone.

EXECUTIVE SUMMARY (cont'd)

During the detailed investigation, it is recommended to do at least one (1) borehole per tank perpendicular to the bedding orientation in order to give accurate bed thicknesses and obtain less fractured core at the contacts of the beds.

The preliminary investigation indicates that the quarry site offers an ideal location for the construction of the tank farm. The solid sandstone bedrock, located beneath about 2 to 3 metres of quarry fines and blast-fractured rock, offers a good bearing layer with an allowable design bearing value of 1,000 kPa (10 tons per square foot) with settlements limited to less than 10 mm.

No boreholes or geophysics were done in the vicinity of tank T-102 (future) as it was not part of the current mandate. However, based on available information of previous boreholes, test pits, and surveys, tank T-102 (future) is observed to be currently located on approximately 7m of fill near its north perimeter. A rock outcrop at approximate elevation 3m was observed 50m south of the northern perimeter of tank T-102 and approximately 1m below ground (elevation 2.5±) 25 metres south of the northern perimeter. Tank T-102 (future) should be moved at least one-third of a tank diameter (approximately 25 metres) directly to the south or parallel to the future pipe racks (approximately southeast) where rock is closer to the proposed foundation elevation of +4m. The exact location should be determined by future boreholes.

EXECUTIVE SUMMARY (cont'd)

Except for the quarry fines (less than 0.5 metres thick usually) and the fractured blast zone extending to a depth of about 2 to 3 metres, the rock formation below the quarry floor is solid; the result of the removal of more than 20 metres of rock during the quarry operation. The geophysical seismic lines confirm this condition in the vicinity of tank T-101. Based on the results of the seismic survey, no excessive fill exists under tank T-101 and the current placement of the tank does not require adjustment. During the detailed investigation, seismic cross-hole testing is to be done to determine if any soft zones occur at depth.

Geophysics were not done near tank T-100 due to the 10 to 20 metres of rock overburden to be excavated under the northwest half of the tank and the blast rock and road fill covering the southwest side. However, the borehole drilled on the southern perimeter of tank T-100 resulted in solid (strong) rock except for the thin layer (approx. 1 to 2m) blast affected surface rock.

Although these three (3) boreholes indicate good foundation support conditions on the floor of the quarry, a more detailed investigation is required around the full perimeter of the tanks to ensure that no local bedrock anomalies are present below the footprint of the tanks. A deeper large diameter hole (HQ size – 75 mm) is necessary at the centreline of each tank to investigate if any soft rock layer, which could be affected by freezing, is present at greater depth below the 80-metre diameter tanks.

PRELIMINARY

1.0 INTRODUCTION

Within the scope of work for the construction of the new LNG storage tanks at the LNG Terminal in Gros Cacouna, Quebec, our firm was mandated to conduct a geotechnical investigation to determine the substrate stratigraphy and bearing capacity for the future tank sites.

This report contains the results of the October 19, 2005, geotechnical investigation, values of pertinent geotechnical parameters required for the design of foundations and our conclusions and recommendations.

2.0 GEOLOGY

2.1 Field Reconnaissance

Introduction

The Ile du Gros Cacouna is northwest of Cacouna on the east shore of the St. Lawrence River. The rocks in the region belong to the supergroup of Quebec in the Appalachian tectonic province. The rock age in the region is Cambrian (544 to 505 million years old) and Ordovician (505 to 440 million years old) but is constrained to the lower Cambrian on the Ile du Gros Cacouna where the tanks are to be located.

The former Ile du Gros Cacouna is approximately 2.5km long by 0.75km wide with elevations on the south west point of the island approaching 65m (Figure 1; Appendix 1).

2.0 GEOLOGY (cont'd)

2.1 Field Reconnaissance (cont'd)

The cliff face in the immediate vicinity of the tanks is approximately 35m to 40m in height and was formed by previous blasting activity for purposes of constructing the harbour. The southeastern side of the island has been joined to the mainland and is currently used as farmland.

The region surrounding Gros Cacouna has undergone a major deformation resulting in many rock layers (beds) that have been folded with axis of the fold crests running (striking) approximately parallel to the shoreline that is bearing north-east. These deformation features are commonly accompanied by slaty rock running parallel to the beach and cutting through the bedding (cleavage). This vertical to near vertical slaty rock was not seen inland near the tanks but was observed during the field reconnaissance on the beach just north west of the future site. Due to the steep downward sloping (dip) of the slate rock structures, the tanks located further inland will not be affected by this weaker rock material.

Vertical beds composed of weaker rock (as described above) are only a concern if they pass close (<10m) to or directly through the tank foundation. During the preliminary reconnaissance, none of these features were found to interfere with the tank placement.

2.0 GEOLOGY (cont'd)

2.1 Field Reconnaissance (cont'd)

The most prevalent rock type on the Ile du Gros Cacouna and at the future tank site is the “Grès de Cacouna” (Sandstone of Cacouna; Vallières, 1977). The lithology (rock type) as described by Vallières (1977) is massive grey feldspathic sandstone and microconglomerates with feldspar and quartz constituents. These types of rocks were confirmed during drilling and field reconnaissance and provide a good, solid foundation for the proposed tanks.

Vallières (1977) noted the rock layers (bedding) at the location of the site sloping down (dipping) at 20 degrees SE near the cement silos (south of the future tanks) and flattens to 12 degrees south-south-west near tank T-100 (figure 1; Appendix 1). He does not indicate any folded rock layers or slate on the island near tanks T-100 or T-101. It should be noted that the only potential weak layer was found near the surface of borehole BH-3 (refer to borehole BH-3, p.11) and has been determined to be sediment caused by grinding of rock in the core rather than a true mud seam. The rounded core pieces adjacent to the mud, warped core, lack of mud seams at similar depths in borehole BH-3 and geochemical tests done on the core and the nearby sediment (Appendix 6) all support this conclusion.

2.0 GEOLOGY (cont'd)

2.1 Field Reconnaissance (cont'd)

During detailed drilling and excavation, the rock should be further observed to ensure that potential low dipping seams are identified and assessed to determine their potential to cause differential tank settlement.

General Site overview

On October 22 and 23, preliminary field mapping was performed in order to ascertain the general structures of the rock in the region of tanks T-100 and T-101. The bedding (photos 1 to 3) is gently dipping 12 to 13 degrees towards the south-east in the proposed tank site location and becoming steeper (20 degrees) south of the tanks.

The beds are composed of massive grey sandstones, silty sandstones and beds with laminations of grey and dark grey sandstone ranging from <1mm to 10 mm. Variable thickness conglomerate beds were observed with thicknesses as large as 2m near BH-2 and pinching out as one traverses the quarry wall towards the south. All three types of rock were measured for bearing capacity and had very high unconfined uniaxial strength, varying between 83.7 and 127.1 MPa, providing a solid foundation for the proposed tanks.

2.0 GEOLOGY (cont'd)

2.1 Field Reconnaissance (cont'd)

Several joint planes/fractures were observed in the vicinity of both tanks with the largest in the cliff face 45m southeast of tank T-100. This near vertical fracture does not show evidence of continuing through the tank foundation, but attention should be paid to this feature during blasting and excavation. In our opinion, this fracture does not continue into the footprint of tank T-100. However, in order to prevent any unexpected interference of this fissure with the reservoir foundation, a small 15m to 20m adjustment of tank T-100 to the southwest can be made.

Thin 30 to 40cm beds of green-grey flaggy (thin layered) to brown fissile (very thinly layered) sandstone (photos 4 and 5; Appendix 2) were observed approximately 150m southeast of BH-2 (100m southeast of tank T-101) and again in the face of the cliff near tank T-100 (photo 6, Appendix 2). The brown fissile rock is similar in colour to the brown mud observed near the surface of BH-3 (refer to BH-3; p.10) and may be the source material for the fines observed in the core. This material would have easily be ground up by the drill bit, resulting in the apparent mud seam found at a depth of 1.25m.

Lab testing (Appendix 6) on the rock and mud seam element and compounds gave practically identical results and confirms that the mud results from ground up rock material during drilling.

2.0 GEOLOGY (cont'd)

2.1 Field Reconnaissance (cont'd)

In our view, this is not an actual mud seam and will not cause problems for the tank foundation, but should be investigated further during the detailed investigation.

Fissures, Joints and Potential Faults

As rated in the general site overview, the most notable structural feature, in the vicinity of tank T-100, is a near vertical open fracture south of tank T-100 (figures 3 and 4; Appendix 1). A slaty sandstone layer has been truncated at the vertical fissure (photos 7, 8 and 9; Appendix 2) and a difference in grain size can be seen on either side of the fissure indicating that vertical movement has occurred in the past. However, no indications of current fault activity were observed (i.e., striations and chatter marks). The continuation of this fissure is difficult to find but does not appear to extend to the opposite cliff face where tank T-101 is to be situated (photo 10; Appendix 2). This is supported by the continuation of the shale layer three quarters of the way up the cliff face (photo 6; Appendix 2), which does not show any vertical offset that would indicate movement caused by faulting in the immediate vicinity of tank T-100.

2.0 GEOLOGY (cont'd)

2.1 Field Reconnaissance (cont'd)

In our view, there is no active fault movement occurring and the fissure does not pass through the foundation of tank T-100. However, this feature should be continuously observed and reassessed during future works.

About 250m southeast of tank T-101 and beyond our area of interest, a clearly defined fault with visible offset of approximately 2.5m (photo 13; Appendix 2) was noted on the rock cut. The projection of the fault direction (strike) is approximately 200m east of either of the proposed tanks (figure 3; Appendix 1) and dips steeply at 68 degrees to the east (away from the tanks). This fault is non-active and does not pass through or below the tanks according the measurements made during this field reconnaissance.

Closer to the tanks on the shoreline is an exposed joint plane with vertical striations (grooves) of unknown origin (figure 3, Appendix 1 and photo 20, Appendix 2). This feature is likely caused by differential erosion of softer rock from wave action, but observations should be made during blasting and excavations to ensure that it does not continue through tank 2-Future.

2.0 GEOLOGY (cont'd)

2.1 Field Reconnaissance (cont'd)

The rock face adjacent to BH-2, and near tank T-101, had minor vertical joints (cracks/seams) that were continuous through all the lower sandstone and conglomerate beds (photos 14, 15 and 16; Appendix 2). Evidence of movement, separation, or vertical displacement could not be found thus indicating that this feature will not affect the foundation of tank T-101.

Beach access north of the site was restricted due to high tide conditions and should be mapped more thoroughly to identify the surface expression of potential gently dipping beds that run under the tank locations. The only features that could be observed on the beach at this time were steeply dipping shale zones and joint planes running parallel to the beach (photos 18 and 19; Appendix 2) and a joint plane running approximately perpendicular to the beach (photo 20; Appendix 2). As discussed above, these features will not affect the foundation of the proposed tanks.

3.0 SUB-SURFACE EXPLORATION

On October 19 and 20, 2005, three boreholes were drilled (Appendix 4). Borehole BH-1 was drilled the first day in the vicinity of tank T-100 and encountered solid bedrock below the thin blast fractured upper zone.

3.0 SUB-SURFACE EXPLORATION (cont'd)

Borehole BH-2 was drilled the following day in the vicinity of tank T-101 and the rock encountered was generally solid. Borehole BH-2 was drilled to 14.96m depth and encountered two small fracture zones at 9m and 10.4m that appeared to be filled with grey sand and silt. A third borehole, BH-3, was drilled to a depth of 10.31m to confirm the presence of the silt and sand filled fractures observed in borehole BH-2. No grey sand and silt was observed. Instead, a distinct thin layer filled with brown sandy-silt was observed at 1.25m depth closer to the surface. Fine brown mud seams and two (2) grey seams were confirmed by laboratory chemical tests to be caused by grinding of thinly layered rock by the drill bit.

Water levels were taken two to three days after coring was completed.

3.1 Borehole BH-1

Borehole BH-1 was drilled near the SW perimeter of proposed tank T-100 at an approximate elevation of 4m. There is a small capture pond nearby that, at the time of drilling, contained standing water. Bedrock was encountered near the surface at 0.23m and cored to a depth of approximately 15m (see Appendix 4 – Borehole Logs). The bedrock was generally solid and will provide a good tank foundation except for the first 1.27 metres affected by blasting in the quarry.

3.0 SUB-SURFACE EXPLORATION (cont'd)

3.1 Borehole BH-1 (cont'd)

The rock type (lithology) alternated between thick beds of solid grey sandstone (2 to 3m) and thinner beds of solid conglomerate (0.9 to 1.8m). The sandstone layers become thinly laminated at the base of the bed. A layer of silty sandstone was encountered at 13.23m and continued to the end of the borehole at depth 14.96m. All three rock types have sufficient bearing capacities to provide a good tank foundation.

Fractures were generally steep (50 to 70 degrees) with tight fracture planes except at the blast affected surface where 30 degree fractures and calcite cemented joint were observed. Recoveries below the blast zone were 93% to 100%. The fractures in the silty sandstone core below 13m showed signs of weathering and had lower recoveries than the grey sandstone (63%). The lower recoveries at the bottom can be attributed to a known miss-latch problem with the drill, which resulted in the core being poorly recovered. Measurement of the unconfined uniaxial compressive strength for the silty sandstone resulted in a value of 127.1 MPa, which is the strongest of all three rock types measured.

Water was never lost during drilling in borehole BH-1. The water level was measured three days after drilling at 0.38m depth (approximate elevation: 3.6m).

3.0 SUB-SURFACE EXPLORATION (cont'd)

3.2 Borehole BH-2

Borehole BH-2 was drilled in the NW quadrant of tank T-101 at an approximate elevation of 3.5m. A thin layer (0.23m) of quarry fines was augured until bedrock was encountered. Bedrock was cored to a depth of approximately 15m (see Appendix 4 – Borehole Logs). The bedrock was generally solid, except for the first 2.5m affected by blasting in the quarry, and will provide a good foundation for the proposed tank.

A fractured grey sandstone was encountered at 0.97m depth and continued to 2.77m. Water was lost during drilling at approximately 1.7m depth. This blast-affected sandstone is followed by solid grey sandstone with fractures of 15 and 20 degrees to a depth of 8.5 metres. Between 8.5 and 9m, fractures of 5 and 70 degrees were encountered. Recoveries ranged from 97 to 100%. The grey sandstone bedrock is underlain by a laminated rock with fine interbeds of grey and dark grey sandstone. Fracturing occurs at angles of 40, 60, and 80 throughout with a 60-degree fracture filled with calcite at 12.5m (photo 2; Appendix 3). Gentle 12-degree fractures are observed at 13 to 14.5 metres. This is concordant with the slope of the bedding adjacent to borehole BH-2. A thin 25mm conglomerate layer was encountered at 14.5m followed by a return of the laminated sandstone.

3.0 SUB-SURFACE EXPLORATION (cont'd)

3.2 BH-2 (cont'd)

Two (2) thin layers of grey silt and sand (10 mm to 20 mm) were observed in the core at 8.9 and 10.4m depth but in our view can be attributed to grinding by the drill due to the rounded core pieces adjacent to the mud, warped core, lack of mud seams at similar depths in borehole BH-3 and geochemical tests done on the core and the nearby sediment (Appendix 6).

It should be noted that the core logged by Golder Associates for monitoring well MW-04-01 showed grey silt and sand filled fractures at approximately the same depth (6.6m, 6.8m, and 8.25) but cannot be correlated to borehole BH-2 due to the slope of the bedding.

It is also apparent that the sandstone shows more fracturing the further south one goes from tank T-101 (figure 7; Appendix 1; Golder monitoring well MW-04-01). However, the rock cores in the vicinity of tank T-101 are solid and will provide a good foundation for the proposed tank.

The water level in borehole BH-2 was measured two days after drilling at 0.94m depth (approximate elevation: 2.5m).

3.0 SUB-SURFACE EXPLORATION (cont'd)

3.3 Borehole BH-3

Borehole BH-3 was drilled near the NW perimeter of tank T-101 at an approximate elevation of 3.4m. A thin layer (0.3m) of quarry fines was augured until bedrock was encountered. Bedrock was cored to a depth of 10.3m (see Appendix 4 – Borehole Logs). The bedrock was generally solid and will provide a good foundation for tank T-101 (except for the first 1.5m affected by blasting in the quarry).

Borehole BH-3 is composed of alternating beds of solid grey sandstone and solid conglomerate. A laminated sandstone bed was encountered between 4.1m and 5.8m and again at 7.85m to the end of the borehole. Recoveries ranged from 94 to 100% except between 2.5 and 4 metres where a core latch problem with the drill resulted in 43% recovery.

A 75mm reddish brown seam was observed in the core at 1.25m but in our view can be attributed to grinding by the drill due to the rounded core pieces adjacent to the mud, warped core, lack of mud seams at similar depths in borehole BH-2 and geochemical tests done on the core and the nearby sediment (Appendix 6). The water level was measured two days after drilling at 1.12m depth (approximate elevation: 2.3m).

3.0 SUB-SURFACE EXPLORATION (cont'd)

3.4 Ground Water Observations Summary

Ground water levels measured 2 to 3 days after drilling are summarised in the following table.

WATER LEVELS MEASURED IN THE BOREHOLES 2 DAYS AFTER DRILLING (NOVEMBER 22, 2005)		
BOREHOLE	**WATER DEPTH (m)**	**APPROXIMATE WATER ELEVATION (m)**
BH-1	0.38	3.6
BH-2	0.94	2.5
BH-3	1.12	2.2

3.5 Test Pits

The results of nine (9) test pits provided by Sandwell are summarised in the following table and located on figure 5 (Appendix 1).

TEST PITS		
BOREHOLE	**BEDROCK DEPTH**	**WATER DEPTH**
PT-1	1.2m	No data
PT-2	2.25m	No data
PT-3	2.7m	No data
PT-4	>4m	2.9m
PT-5	>4m	3m
PT-6	2.7m	No data
PT-7	1 to 1.1m	No data
PT-8	>4m	3.2m
PT-9	4.1m	No data

3.0 SUB-SURFACE EXPLORATION (cont'd)

3.6 Strength of the Rock Formation

Three (3) rock samples were tested for unconfined uniaxial compression strength, i.e. one (1) from each borehole. The rock samples were representative of the lithology variation of the sandstone. The unconfined uniaxial strength of the bedrock varied between 83.7 and 127.1 MPa, as summarised in the table below.

UNCONFINED UNIAXIAL COMPRESSIVE STRENGTH OF THE SANDSTONE BEDROCK				
SAMPLE NO.	**BOREHOLE**	**DEPTH (m)**	**UNCONFINED UNIAXIAL COMPRESSIVE STRENGTH (MPa)**	**LITHOLOGY**
1	BH-1	13.4	127.1	Silty sandstone
2	BH-2	4.4	104.3	Sandstone
3	BH-3	4.6	83.7	Conglomerate

The compressive strength tests done on four (4) samples in May 2005 had a similar range of 66MPa to 114MPa indicating a good quality rock. The absorption values were usually less than 0.5% for the cemented sandstone fragments but increasing to 1 to 1.5% for the softer sandstones.

4.0 GEOPHYSICS

On October 21, 2005, a geophysical survey using seismic refraction was carried out on the future tank T-101 site.

4.0 GEOPHYSICS (cont'd)

Three (3) lines were completed. Each line was 115m in length and orientated northwest to southeast (parallel to the nearby cliff face) through the centre of the tank and through the northeast and southwest perimeters (figure 8; Appendix 1). Seven (7) explosive charges were detonated along each seismic line and measurements taken using 24 geophones spaced approximately 5m apart. This method is able to determine the overburden thickness to within 1.5m of the actual thickness.

Results showed velocities in the overburden to be 600m/sec. The maximum overburden and fractured rock thickness was 1.5m in the seismic line closest to the cliff face (SL-01-05) and 2.4m in the seismic line on the southwest perimeter of the tank and farthest from the cliff face (SL-03-05). This generally agrees with depths established at the borehole locations.

The velocities in the bedrock range from 5200m/sec along SL-01-05 to 4800m/sec along SL-03-05 and are representative of solid rock suitable for the proposed foundations. The velocities measured are within the expected range for sandstone. No significant velocity variations were measured along the lengths of the seismic lines indicating that the rock is of the same type and quality when one traverses northwest to southeast along the length of the line. This will not affect the foundation of the tanks.

4.0 GEOPHYSICS (cont'd)

The relatively consistent velocities and absence of bedrock surface depressions confirm that the bedrock is solid and major fractures, faults, or shear zones were not detected in any of the three seismic lines.

No other rock contacts were encountered at depth by the geophysical survey. The seismic cross-hole survey to be done during the detailed investigation will be able to identify deviations from the solid (strong) rock encountered at approximately 2m depth during the seismic survey and the solid rock below the 1-2 metre surface fracture zone identified in the boreholes. No excessive overburden was detected by the seismic survey and the placement of tank T-101 does not require any adjustments based on these results.

5.0 DESIGN OF FOUNDATIONS, DISCUSSIONS AND RECOMMENDATIONS

The final site elevation or top of tanks foundation is planned to be at 5 metres geodetic. The concrete ring foundation mat is planned to be 5 metres wide and will be carried below frost depth and in solid rock. This foundation will support the double walled tank consisting of a 1 metre thick prestressed concrete shell 40 metres high applying a loading of about 150 kPa. The bottom of the tank will be 1 metre thick and will be carried on engineered fill.

5.0 DESIGN OF FOUNDATIONS, DISCUSSIONS AND RECOMMENDATIONS (cont'd)

The rock cliff on the north half of tank T-100 (Elev. 35 m) will require excavation of the rock (blasting) to a depth of between 20 and 32 metres to reach the current quarry floor. At this level, the solid rock has an allowable design bearing value of 1,000 kPa.

The LNG concrete mat foundation should be placed on solid rock or lean concrete.

Dewatering will be required as the bottom of the foundation about one metre below the water table. This can be achieved by pumping from sumps installed below the footing level.

At the time of drilling, a small waterfall was observed at a location in between the future construction sites of the LNG tanks. Should this water interfere with construction, it should be diverted away through drainage ditches.

5.1 Foundation design parameters

Table 5.1 summarises foundations design parameters pertinent to the site conditions.

5.0 DESIGN OF FOUNDATIONS, DICUSSIONS AND RECOMMENDATIONS (cont'd)

5.1 Foundation design parameters (cont'd)

TABLE 5.1 GEOTECHNICAL DESIGN PARAMETERS		
Parameter	**Units**	**Rock**
Allowable bearing capacity	kPa (tsf)	1000 (10) *
Density	kN/m^3	25.5 to 27
Design of foundation walls (triangular pressure distribution with depth)		
Modulus of vertical subgrade reaction	tonnes / m^3	14,000
Allowable rock anchor bond stress	kg / cm^2	11.00
Seismic design foundation factors		
Seismic coefficient, k	----	0.05 (for intensity 5 to 6 on Richter scale)
Horizontal design acceleration	g	0.20 (for intensity 6 on Richter scale)
Vertical design acceleration	g	0.13 (for intensity 6 on Richter scale)
Shear wave velocity, V	m / s	~ 2100
Dynamic shear modulus, G	kg / cm^2	~ 120,000
Dynamic Poisson's ratio, ν'	----	0.33
Poisson's ratio, ν	----	0.30
Modulus of elasticity, E	kg / cm^2	6×10^5
* *Expected settlement < 10mm*		

Chemical tests on ground water are summarized in Table 5.2. These tests confirm the following:

- The pH has a low corrosion effect on exposed steel
- Chloride concentration in the water is very low to moderate
- Sulphates concentration in the water is very low and is not aggressive to concrete.

5.0 DESIGN OF FOUNDATIONS, DICUSSIONS AND RECOMMENDATIONS (cont'd)

5.1 Foundation design parameters (cont'd)

TABLE 5.2 CORROSION CONSIDERATIONS				
Parameter	**Units**	**Ground water***	**DRINKING WATER LIMITS**	**Rock**
Resistivity	Ohm – m	----	---	~ 5000
Ph	pH	MW-04-1 7.3 MW-04-5 8.2	6.5 – 8.5	----
Chloride (Cl)	mg/kg or ppm	MW-04-1 54 MW-04-5 490	250	----
Sulphates (SO_4)	mg/kg or ppm	MW-04-1 12 MW-04-5 46	500	----

* Golder & Assoc., 2005, Environmental Impact Statement (EIS)

5.2 Foundation construction recommendations

- Frost depth is 1.8m in this area
- All foundations on rock must be anchored to prevent uplift due to freezing unless insulation is used.
- Rock anchors bond strength must be confirmed by pullout tests. Galvanised anchors should be used for corrosion resistance.
- Make a working platform for the foundations on rock by levelling the rock surface with lean concrete.
- For foundations or slabs on grade, remove quarry fines and replace with compacted engineered granular 20 – 00 mm crushed stone fill. If more than 300 mm of engineered fill or MG20 is required, compact in 150 mm lifts to 95% of the modified proctor density.
- Backfill around the foundation to ground level with clean coarse granular material (<5% minus 80µm) to eliminate heaving due to soil freezing.

5.0 DESIGN OF FOUNDATIONS, DICUSSIONS AND RECOMMENDATIONS (cont'd)

5.2 Foundation construction recommendations (cont'd)

- The soil surface surrounding a building should be sloped away from the building for better drainage. The exterior walls of basements, if there are any, should be made impervious using a liner and a perimetric drain.

- Foundation excavations should follow standard specifications (CSST, Quebec) – minimum side slopes 7V:1H (or flatter) more than 2.5 metres deep.

- High rock cut slope should be cut at 7V:1H using preshearing blast methods.

- Backfill behind retaining walls with compacted crushed stone or clean sand and gravel for drainage. Place a longitudinal drain pipe along the base of the wall.

5.3 Asphalt and granular pavements

Light duty asphalt pavement

Suggested cross section for light duty asphalt pavements is:

50 mm asphalt (EB-14)
200 mm 0-35mm crushed stone
100 mm sand-gravel filter or suitable geotextile

Heavy-duty asphalt pavement

Suggested cross section for heavy-duty asphalt pavements is:

75 mm asphalt (EB-14)
400 mm 0-35mm crushed stone
100 mm sand-gravel filter or suitable geotextile

5.0 DESIGN OF FOUNDATIONS, DICUSSIONS AND RECOMMENDATIONS (cont'd)

5.3 Asphalt and granular pavements (cont'd)

Granular pavement

Suggested cross section for granular pavements is:

50 mm 19mm crusher run
400 mm 0-35mm crushed stone
100 mm sand-gravel filter

It is suggested to raise roads a minimum of 300 mm above the current ground level to avoid road drainage ditches excavation.

The gradations, placement and compaction specifications for the granular bases of the pavements are summarised in Table 5.3.

TABLE 5.3 SPECIFICATIONS FOR PAVEMENT GRANULAR BASES COMPACTED TO 95% OF THE STANDARD PROCTOR IN 150 mm LAYERS USING LIGHT COMPACTION EQUIPMENT

Sieve size	0 – 35 mm crushed stone	Sand-gravel filter
112 mm	----	100 %
35 mm	100 %	----
31.5 mm	90 % - 100%	----
14 mm	68 % - 93 %	----
5 mm	35 % - 60 %	35% min.
1.25 mm	19 % - 38 %	----
0.315 mm	9 % - 17 %	----
0.080 mm	2 % - 7 %	0 – 10 %

6.0 CONCLUSIONS

Based on the sub-surface exploration (drilling of boreholes, geophysical (seismic) surveys and geological mapping) of the area proposed for the installation of LNG tanks and lighter structures at the LNG Gros Cacouna Terminal, it is concluded that:

- The bedrock observed on site and in boreholes BH-1 to BH-3 consists of solid sandstone and conglomerate adequate for supporting the proposed LNG tanks and smaller structures.
- The structural features of the rock indicate no current tectonic activity.
- An allowable bearing pressure of 1,000 kPa (10 tsf) may be used in design of foundations on the rock.
- Mud seams found in boreholes BH-2 and BH-3 are a result of surrounding rock ground up by the drill and do not pose a problem for the tank foundation.
- Dewatering during foundation construction will be minimal, if required.
- Basic chemical analysis of the ground water in the area proposed for the tank construction indicates no immediate concerns. However, the water will be more corrosive to exposed steel and detrimental to concrete in the long term as we advance towards the beach zone.
- Seismic (geophysical) surveys did not detect excessive overburden or major faults, factures or shear zones in the rock along the three seismic lines under tank T-102.
- Due to the shallow depth of rock at the proposed location, it is recommended that buildings be founded on the rock after complete removal of the fill material over the footprint of the structure.
- Since we do not have details of the insulation of the tank foundations and the water table is at the foundation level, we cannot presently comment on the effects of frost heave on the tank foundation. When this information becomes available, this item can be addressed.

6.0 CONCLUSIONS (cont'd)

Also included in appendix 5 are the results for the geophysical seismic survey.

We trust that this report answers all your questions. Please do not hesitate to contact us if any further information is required.

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