From: Virtue,Robyn-Lynne [CEAA] **On Behalf Of** DGR Review / Examen DFGP [CEAA]
Sent: March 25, 2013 11:31 AM
To: DGR Review / Examen DFGP [CEAA]
Subject: Request for OPG Techical Report

Hello Panel Members,

As per your request, I have attached Ontario Power Generation's Technical Report titled "Bedrock Formation's in DGR-7 and DGR-8" which is relevant in the assessment of Information Request Response EIS-08-314.

Thank you,
Robyn

Technical Report

Title: ***Bedrock Formations in DGR-7 and DGR-8***

Document ID: **TR-11-06**

Author: **Sean Sterling**

Revision: **0**

Date: **December 6, 2011**

DGR Shaft Investigation Document
Geofirma Engineering Project 11-206

Geofirma Engineering Ltd

Geofirma Engineering DGR Shaft Investigation Document		
Title:	Bedrock Formations in DGR-7 and DGR-8	
Document ID:	TR-11-06	
Revision Number:	0	Date: December 6, 2011
Author:	Sean Sterling	
Technical Review:	Kenneth Raven; Jim McLay, Dylan Luhowy (NWMO)	
QA Review:	John Avis	
Approved by:	<signature removed> Kenneth Raven	

Document Revision History		
Revision	Effective Date	Description of Changes
0	December 6, 2011	Initial release

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1 Introduction

Geofirma Engineering Ltd. (formerly Intera Engineering Ltd.) was contracted by the Nuclear Waste Management Organization (NWMO), on behalf of Ontario Power Generation, to implement geoscientific investigations of shaft locations of the proposed Deep Geologic Repository at the Bruce nuclear site located near Tiverton, Ontario. The Deep Geologic Repository (DGR) is proposed to store low-level and intermediate-level radioactive waste at a depth of about 680 metres below ground surface (mBGS) within the argillaceous limestone of the Cobourg Formation.

The activities described in this Technical Report (TR) constitute one component of the Geofirma Engineering Ltd. geoscientific investigations at the vent shaft and main shaft locations of the proposed DGR. As part of these geoscientific investigations Geofirma completed drilling and testing of two boreholes: DGR-7 near the proposed vent shaft location to a depth of 189.97 mBGS and DGR-8 at the proposed main shaft location to a depth of 723.81 mBGS.

This Technical Report summarizes the stratigraphy, geological contacts and nomenclature of bedrock formations encountered during drilling of the vent and main shaft investigation boreholes (DGR-7 and DGR-8). Bedrock stratigraphic data from DGR-1 to DGR-6 were previously reported in TR-09-11 (Geofirma Engineering Ltd., 2011a) and are reproduced as part of this report for reference purposes only with no changes.

Work described in this Technical Report (TR) was completed with data generated from Test Plan TP-11-03 – DGR-7 and DGR-8 Core Photography and Logging (Geofirma Engineering Ltd., 2011b) and Test Plan TP-11-05 – Borehole Geophysical Logging of DGR-7 and DGR-8 (Geofirma Engineering Ltd., 2011c), which were prepared following the general requirements of the Intera DGR Project Quality Plan (Geofirma Engineering Ltd., 2011d).

2 Background

Over the past five years Geofirma has completed a comprehensive Geoscientific Site Characterization Plan (GSCP) at the Bruce nuclear site. The GSCP activities completed to date include drilling borehole US-8 to a depth of 200.4 metres below ground surface (mBGS) to augment the existing US-series boreholes that create a shallow groundwater monitoring network on site. Six deep boreholes were also drilled at the site, DGR-1 through DGR-6. DGR-1 was drilled to a total vertical depth of 462.9 mBGS (into the Queenston Formation) and DGR-2 was drilled to a total vertical depth of 862.1 mBGS (into the Precambrian bedrock). DGR-3 and DGR-4 were drilled to total vertical depths of 869.2 and 857.0 mBGS, respectively (both into the Cambrian sandstone). These four boreholes (DGR-1 through DGR-4) were vertical. Bedrock stratigraphy at these four DGR borehole locations are described in Technical Report TR-07-05 – Bedrock Formations in DGR-1 and DGR-2 (Intera Engineering Ltd., 2010a) and Technical Report TR-08-12 – Bedrock Formations in DGR-1, DGR-2, DGR-3 and DGR-4 (Intera Engineering Ltd., 2010b). Figure 1 shows the location of US-series and DGR-series boreholes completed at the Bruce nuclear site.

Boreholes DGR-5 and DGR-6 were drilled at inclinations of approximately 65º and 60°, respectively, from horizontal. DGR-5 was drilled to a total vertical depth of 752.2 mBGS (into the Kirkfield Formation) and DGR-6 was completed at a total vertical depth of 785.5 mBGS (into the Gull River Formation). DGR-5 and DGR-6 were drilled to investigate the general characteristics of potential sub-vertical structure in the bedrock. Bedrock stratigraphy at these two DGR borehole locations is described in Technical Report TR-09-11 – Bedrock Formations in DGR-1 to DGR-6 (Geofirma Engineering Ltd., 2011a). Data collected from the US-series and DGR-series boreholes were used to create a Descriptive Geosphere Site Model of the Bruce nuclear site (Intera Engineering Ltd., 2011).

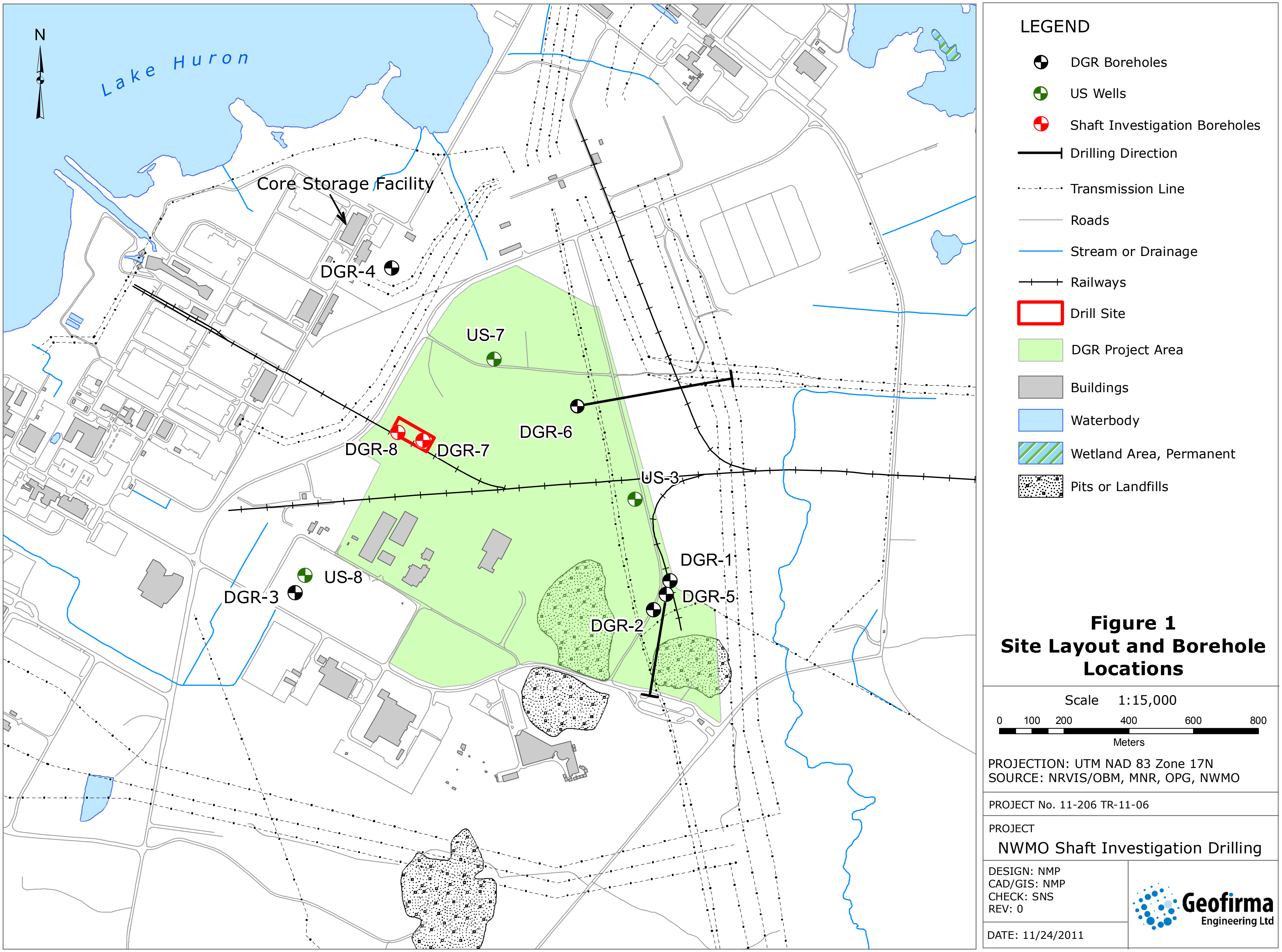


Figure 1
Site Layout and Borehole Locations

PROJECTION: UTM NAD 83 Zone 17N
SOURCE: NRVIS/OBM, MNR, OPG, NWMO

PROJECT No. 11-206 TR-11-06

PROJECT
NWMO Shaft Investigation Drilling

DESIGN: NMP
CAD/GIS: NMP
CHECK: SNS
REV: 0

DATE: 11/24/2011

Geofirma Engineering Ltd

P:\QMS_DGR\TR_WorkingFiles\TR-11-06 Bedrock Formations in DGR-7 and DGR-8\Figures\TR-11-06_Figure1_SiteLayoutRevised_R0.mxd

The DGR-7 and DGR-8 drilling program was completed by Layne Christensen Canada Ltd. (Layne), based in Capreol Ontario, in conjunction with International Directional Services (IDS), also based in Capreol Ontario. DGR-7 and DGR-8 were continuously cored from ground surface to total vertical depths of 189.97 mBGS (into the Salina Formation – F-Unit) and 723.81 mBGS (into the Kirkfield Formation), respectively. Layne completed the coring of DGR-7 and DGR-8 using an Atlas Copco skid-mounted drilling rig (model CS3001). The drilling rig was equipped with a top drive system capable of delivering a maximum torque of 3,500 ft-lb and a rotation speed up to 1,300 rpm. IDS was on-site when necessary to carryout borehole orientation surveys and to conduct borehole orientation corrections as outlined in TR-11-02 – Drilling, Logging and Sampling of DGR-7 and DGR-8 (Geofirma Engineering Ltd., 2011e).

3 Bruce Site Reference Stratigraphy

The nomenclature and stratigraphy developed for the Bruce nuclear site are consistent with the regional conceptual model developed by Armstrong and Carter (2006) and are consistent with the nomenclature and stratigraphy from other deep boreholes in the region.

The paperback Ontario Geological Survey open file report of Armstrong and Carter (2006) was released as an updated and reformatted hard cover Special Volume publication (Armstrong and Carter, 2010). The subsurface bedrock stratigraphic nomenclature is the same in both of these publications, although Armstrong and Carter (2010) include a modernized stratigraphic chart that removes the Middle Silurian and re-assigns the Middle Ordovician units to an expanded Upper Ordovician. The stratigraphic chart of Armstrong and Carter (2006) is used in this Technical Report to remain consistent with previously reported stratigraphic nomenclature associated with DGR-1 through DGR-6 boreholes.

Figure 2 shows the reference subsurface bedrock formation contact depths for the Bruce nuclear site based on the descriptions outlined in Armstrong and Carter (2006) and data from DGR-1 and DGR-2. The stratigraphic units referenced in Figure 2 are used throughout this Technical Report.

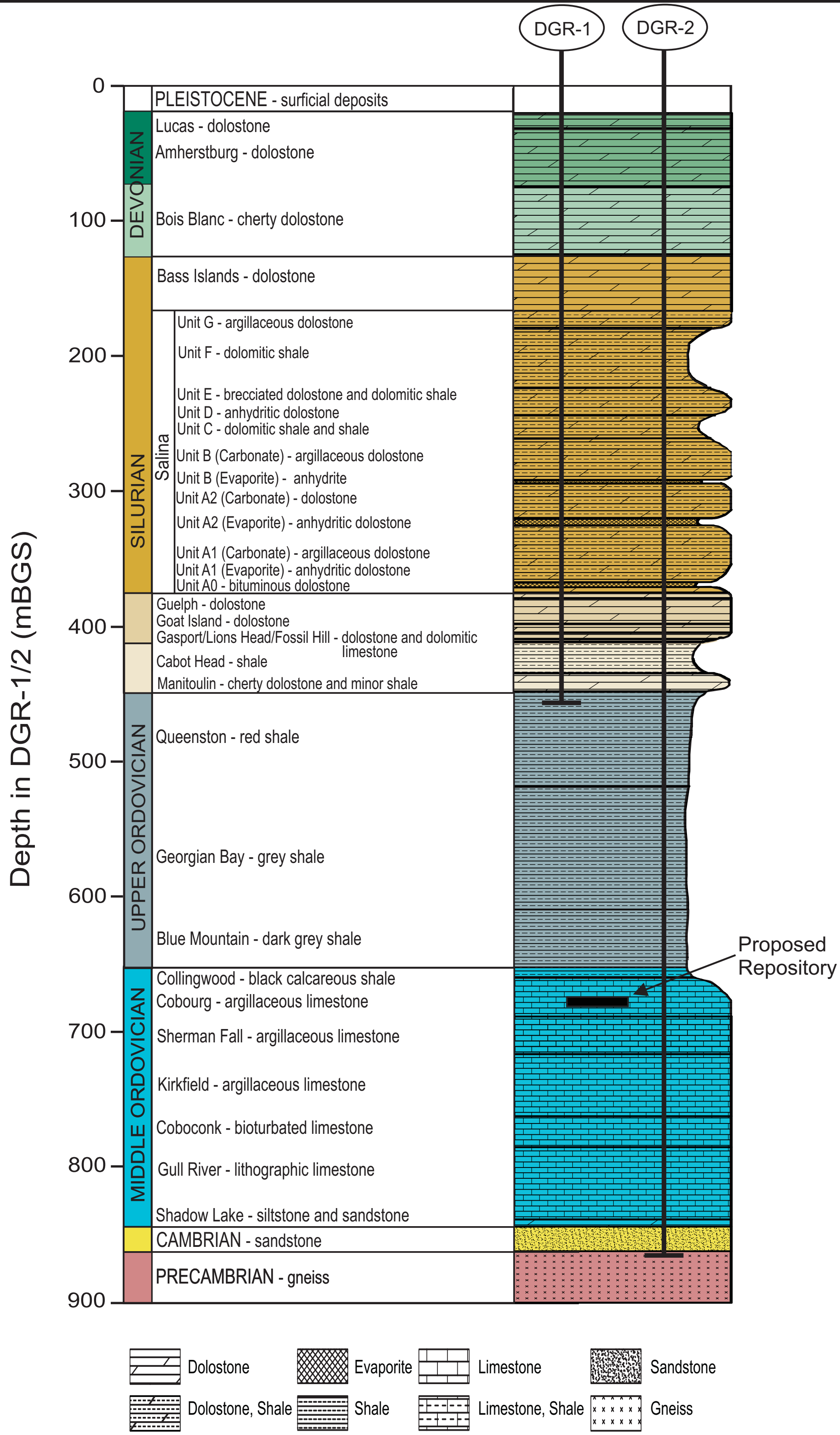
4 Core Workshop – November 30, 2011

A fourth Core Workshop was held on November 30, 2011 at the Core Storage Facility on the Bruce nuclear site following the completion of boreholes DGR-7 and DGR-8. The purpose of the fourth workshop was to obtain consensus regarding the formation contacts selected for DGR-7 and DGR-8 and was attended by the following groups participating in the NWMO DGR Program:

- Nuclear Waste Management Organization, and,
- Geofirma Engineering Ltd. (Shaft Investigation Contractor).

In addition, the following geology experts from the Ontario government [Ministry of Natural Resources (MNR), university (University of Western Ontario), and a private consultant attended the third workshop and assisted in reaching consensus on the identification of the top of bedrock formations:

- Terry Carter, Chief Geologist, MNR, Petroleum Resources Centre;
- Shelly Kilby and Stephanie Skoblenik, MNR;
- Fred Longstaffe and Joanne Potter, Professor and Post-Doctoral Fellow, respectively, Department of Earth Sciences, University of Western Ontario; and
- Mike Dorland, private oil and gas industry consultant.



Reference Stratigraphic Column at the Bruce Nuclear Site Based on DGR-1 and DGR-2 Data		Prepared by: SNG/ ADG Reviewed by: SNS Date: 11-Nov-11
FIGURE 2	Doc. No.: TR-11-06_Figure 2_R0.cdr	

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5 Bedrock Formation Pick Methodology

During drilling operations, continuous bedrock core was collected in 3.00 m core runs and logged by an on-site geologist. Core logging generally followed the guidelines of Armstrong and Carter (2006) for stratigraphic logging and nomenclature as described in TP-11-03 (Geofirma Engineering Ltd., 2011b). A summary of core logging results from DGR-7 and DGR-8 drilling operations is included in TR-11-02 (Geofirma Engineering Ltd., 2011e). Following drilling operations at each shaft investigation borehole, geophysical logging was completed by DGI Geoscience Inc. (DGI) based in Barrie, Ontario following TP-11-05 (Geofirma Engineering Ltd., 2011c). The results of borehole geophysical logging are summarized and presented as part of TR-11-04 – Borehole Geophysical Logging of DGR-7 and DGR-8 (Geofirma Engineering Ltd., 2011f).

The depths of each geologic formation, member or unit contact were selected based on a combination of information from rock core and borehole geophysical logs. The borehole geophysical logs that were most useful in identifying geological contacts in DGR-7 and DGR-8 were natural gamma and neutron. Following the methods of Armstrong and Carter (2006), final geophysics picks were primarily based on the natural gamma log where a distinguishable formation contact could be interpreted. In the case of large increases or large decreases in natural gamma response, the pick was selected as the mid-point of the inflection (increase or decrease).

6 Determination of True Vertical Depth (TVD)

All field data pertaining to drilling and borehole logging depths were recorded in units of metres along the borehole axis, and in the case of vertical boreholes such as DGR-7 and DGR-8, these data are recorded in units of metres below ground surface (mBGS). As described in TR-11-02 (Geofirma Engineering Ltd., 2011e) the borehole orientation of the vent and main shaft investigation boreholes was maintained within approximately 2 m of the surface well head location for the entire length of the borehole.

Although the strict adherence to these borehole orientation requirements results in a borehole that is conceptualized as being perfectly vertical, to remain consistent with data processing and reporting of bedrock formation depths in DGR-1 to DGR-6 and to better compare relative depths between boreholes, the depth data from DGR-7 and DGR-8 were converted to “true vertical depth” (TVD) in order to calculate formation top elevations and formation thicknesses.

The conversion from depth along borehole axis to TVD was applied to DGR-7 and DGR-8 depth data using the borehole orientation data collected with a gyroscopic tool. These tools provide a northing and easting coordinate along with a TVD for each measured point along the borehole axis. Borehole orientation data, along with other borehole geophysical data collected from DGR-7 and DGR-8, are further discussed in TR-11-04 (Geofirma Engineering Ltd., 2011f).

This conversion from depth along borehole axis to TVD for DGR-7 and DGR-8 data resulted in a negligible change in bedrock formation top elevations of 0.0 m (i.e. no change) in DGR-7 and approximately 0.1 m at the bottom of DGR-8.

7 Results

Consistent with DGR-1 through DGR-6, the drilling and testing of boreholes DGR-7 to DGR-8 resulted in the identification of 34 distinct Paleozoic bedrock formations, members or units at the Bruce nuclear site. These bedrock formations, members or units are logged in accordance with the stratigraphic nomenclature of Armstrong and Carter (2006). Formation geology was very consistent at the locations of the two shaft investigation boreholes compared to DGR-1 to DGR-6 borehole locations. No major lithofacies changes within individual formations, members or units were detected between DGR boreholes.

The final formation picks for DGR-1 to DGR-8 are summarized in Table 1 and Table 2. Data from DGR-1 to DGR-6 is presented in this report for reference purposes only and have not been changed compared to their original reporting in TR-09-11 (Geofirma Engineering Ltd., 2011a).

Table 1 contains a summary of the following data:

- lithologic description of each formation;
- primary evidence used to make each pick (core or geophysics data);
- type of contact (i.e. sharp or gradational);
- the rationale for each pick;
- the formation pick rationale used by Armstrong and Carter (2006); and
- an indication of the relative difficulty of each pick.

Table 2 shows the top of formation picks and also includes the following data:

- the depth of the top of formation, member, or unit expressed in units of metres length below ground surface along borehole axis (mLBGS);
- the corresponding core run number for future reference to archived core boxes and core photography;
- the corresponding "true vertical depth" (TVD) (i.e. depth along borehole axis corrected for borehole deviation) expressed as metres below ground surface (mBGS);
- the calculated formation top elevation;
- the calculated thickness of each formation; and,
- the pick rationale – core or geophysics.

DGR-7 and DGR-8 are located approximately along strike (slightly down-dip) compared to DGR-1/2 and DGR-4, therefore the bedrock formation contact depths reported for DGR-7 and DGR-8 are similar to these other DGR boreholes.

7.1 Formation Thicknesses

Intersection of bedrock formations by boreholes DGR-1 to DGR-8 allows assessment of the uniformity of bedrock formation thickness in the area of the proposed DGR. Table 2 shows that the formation thicknesses in DGR-7 and DGR-8 are remarkably similar with the other DGR boreholes (generally within two to three metres) with separation distances between other DGR drilling sites ranging from approximately 500 (between DGR-6 and DGR-7) to 1000 m (between DGR-1 and DGR-8). The thicknesses of formations are somewhat more variable above the Salina B Unit and more uniform below the B Unit.

7.2 Identification of Stratigraphic Marker Beds

During drilling of DGR-8, three of the five previously reported (from DGR-1 through DGR-6) laterally continuous and distinct marker beds or thin stratigraphic horizons were encountered. Due to the end depths of coring in DGR-7 none of the previously reported marker beds were encountered in DGR-7. Table 3 lists and describes the five previously reported marker beds and indicates the depth and elevation of the top of each bed in each borehole. Appendix A provides the core photographs illustrating the appearance of each of the marker beds in boreholes DGR-1 through DGR-8, where encountered.

Table 1. Summary of Bedrock Formation Picks in DGR-1 to DGR-8

Stratigraphic Nomenclature	Stratigraphic Description	Primary Evidence for Pick	Geological Contact Description	Core Pick Rationale	BH Geophysical Pick Rationale	Armstrong and Carter (2006)	Difficulty of Pick
Lucas Formation	Brownish grey, grey and brown, fine-grained, hard, argillaceous dolostone with abundant bituminous laminae (stromatolitic laminations). Formation is locally very vuggy with partial calcite infilling. Shaly layers with subordinate dolomite in few places. Formation has brecciated appearance in few spots due to light coloured dolostone fragments in matrix of grey calcite. Rock becomes cherty with depth. Rock also becomes fossiliferous near bottom of formation, including stromatoporoids, brachiopods and corals.	top of bedrock	top of bedrock	top of bedrock, known lithology	NA		NA
Amherstburg Formation	Light brown to grey, fine- to coarse-grained, hard, fossiliferous (stromatoporoids, corals, brachiopods), cherty dolostone with abundant bituminous shale laminae and zones. Locally vuggy with secondary calcite, pyrite and quartz mineralization in places and locally extensively fractured with fractures commonly infilled with calcite and pyrite.	core	sharp to gradational depending on colour change	first sharp change from tan coloured dolostone to dark brown bituminous dolostone	No distinguishing features	change from light brown, very fine-grained, evaporitic dolostones of the Lucas change to a dark brown, organic-looking (dolostone or limestone) with bituminous partings; does not appear possible to pick the contact consistently on geophysical logs	core = difficult geophysics = very difficult
Bois Blanc Formation	Light to dark grey to brown to tan, fine- to medium-grained, hard, fossiliferous (corals, brachiopods) cherty dolostone with some black bituminous shale laminae and zones. Chert is abundant and is found as light grey to white nodules and less commonly as up to 10-cm thick layers, some with dolostone clasts. Shale laminae are absent near the base of the formation. Slightly vuggy in places. Extensively fractured in few zones with calcite and, less commonly, pyrite found on fracture surfaces. Calcite stringers common throughout.	core	gradational	medium grained dolostone to fine grained limestone with abundant chert nodules. picked near 1st occurrence of chert nodule equal to core diameter (i.e. > 7 cm).	flat natural gamma ray response (no distinguishing features)	dominated by white chert	core = difficult geophysics = difficult
Bass Islands Formation	Light grey to brown to tan, very fine- to fine-grained dolostone with some to trace shale and bituminous laminae and intervals. Argillaceous-rich dolostones intervals are grey-blue with shale and dolostone intraclasts. Vuggy in very few places, with vugs in-filled with calcite. Trace evaporite mineral moulds. Trace amount of zones are fractured with calcite in-filling. Trace amount of anhydrite layers and in-filled fractures in bottom part of formation.	neutron log inflection (confirmed with core)	sharp	abrupt change from cherty-shaly dolostone to tan-grey very fine grained dolostone	increase in neutron log (inflection); flat natural gamma ray response (no distinguishing features)	oolitic beds in upper few m	core = easy geophysics = relatively easy
Salina Formation - G Unit	Grey-blue to grey-green, very-fine grained, soft, argillaceous dolostone with some to abundant white to pink-orange anhydrite/gypsum veins and layers throughout. Tan to brown, very-fine grained, hard, dolostone near middle of formation.	natural gamma log inflection usually below core pick (confirmed with core)	sharp	change to grey-green shaly dolostone with anhydrite/gypsum	first large increase in natural gamma after very low gamma of "cleaner" Bass Islands Fm; top of double gamma spike (inflection) corresponding to start of drop in neutron signature	average of 9 m above the more reliable F Unit top	core = easy but use approximate 9 m thickness to pick correct shale interval geophysics = easy
Salina Formation - F Unit	Dolomitic shale and suborindate dolostone. Dolomitic shale is grey-green to grey-blue with rusty brown-red mottling and diffuse staining with abundant cm-thick white and pink-orange anhydrite/gypsum veins and layers throughout; anhydrite/gypsum nodules are less common. Dolostone found near bottom of the formation and is light grey to light brown, very fine-grained, hard, and contains trace to some anhydrite/gypsum nodules and veins and locally contains dark grey to black bituminous laminae.	natural gamma log inflection usually below core contact (confirmed with core)	sharp	change from brown dolostone to green shale	sharp increase in natural gamma response (inflection) indicating higher shale content in F-Unit corresponding to start of drop in neutron signature	shale and gamma log	core = easy geophysics = extremely easy
Salina Formation - E Unit	Interbeded dolostone, dolomitic shale and argillaceous dolostone. Dolostone is grey tan to brown, very fine-grained, massive, and with dark grey to black bituminous laminae and trace anhydrite/gypsum veins. Dolomitic shale is grey to grey blue, soft, with abundant anhydrite/gypsum veins and layers. Argillaceous dolostone is tan-brown, very fine-grained, hard, massive, and contains trace amount of anhydrite/gypsum veins and layers. Formation is locally brecciated.	core (confirmed with natural gamma log, neutron log, drilling rate increases)	sharp	pick based on geophysics and is made either at abrupt change to grey-green shale from tan dolostone or beneath approximately 0.5 m of massive green shale which may coincide with top of a brecciated layer of grey-green shale with anhydrite/gypsum	increase in natural gamma response below low gamma signature of tan dolostone; base of neutron log that shows a drop after an interval approximately 5 m in length of elevated neutron reponse	increase in gamma in response to shale beds that mark top of E Unit	core = very easy to identify change from tan dolostone to grey-green shale geophysics = difficult with gamma alone; easier when combined with neutron
Salina Formation - D Unit	Light grey-blue, fine-grained anhydritic dolostone; locally slightly vuggy.	natural gamma log inflection (confirmed with core)	gradational	dolostone transitioning to anhydritic dolostone	top inflection of prominent "scoop dip" decrease in gamma log corresponding to anhydritic dolostone layer below dolostone	thin anhydritic dolostone layer where no Salina D Unit salt is present	core = easy if expecting a thin layer of anhydritic dolostone at that depth, otherwise difficult geophysics = difficult by itself, but aligns with core depths
Salina Formation - C Unit	Grey-blue, massive to laminated dolomitic shale with trace to some anhydrite and gypsum nodules, laminae and thin beds.	natural gamma log inflection (confirmed with core)	gradational	blue-grey and brown anhydritic dolostone transitioning to grey dolomitic shale	increased natural gamma corresponding to shale layer below anhydritic dolostone	increase in gamma response corresponding to transition from dolostones to shales	core = relatively easy geophysics = easy
Salina Formation - B Unit	Argillaceous dolostone grading downwards to dolostone near base of unit. Dolomitic shale is grey-green with abundant anhydrite/gypsum veins, layers and nodules. It is locally brecciated with dolostone clasts. Dolostone is tan-brown, very fine-grained with abundant white anhydrite/gypsum nodules and veins, and abundant dark brown-black laminae.	core (confirmed with natural gamma log)	sharp	top of thin, brown, anhydritic dolostone layer (B Unit Marker Bed) below red-green shale	start of long decrease in natural gamma log	decrease in gamma response	core = B Unit Marker Bed is easy to identify geophysics = difficult by itself, but aligns with core depths
B Unit Evaporite	Interbedded light to dark grey dolostone and bluish-grey anhydrite/gypsum, grading to mottled dolostone and anhydrite with depth.	natural gamma log inflection (confirmed with core)	gradational	gradational change from brown dolostone to interbedded brown dolostone and light grey anhydrite/gypsum	picked at lowest natural gamma response following gradual decline in gamma log	anhydrite-rich zone at bottom of B Unit	core = easy geophysics = relatively easy
Salina Formation - A2 Unit	Dolostone with subordinate argillaceous dolostone and dolomitic shale. Dolostone, argillaceous dolostone and dolomitic shale are locally interbeded. Dolostone is tan to grey, very fine- to fine-grained, laminated to massive, locally with dark brown to black bituminous laminae and less common anhydrite /gypsum layers; strong sulphur odour in places. Argillaceous dolostone is grey-brown with trace anhydrite/gypsum and pyrite flecks and has sulphurous odour when broken. Dolomitic shale is brown to dark grey, soft and friable and locally contains dolostone clasts and distorted bedding.	neutorn log inflection (confirmed with core and natural gamma log)	sharp to fairly sharp	laminated grey-brown dolostone with dark to black (organic-rich) thin layers	slight increase in natural gamma compared to gamma trough of B-Unit Evaporite; top inflection of neutron increase	sharp transition from anhydrite (B Unit) to carbonates (A2 Unit)	core = easy (immediately below anhydrite) geophysics = relatively easy
A2 Unit Evaporite	Mottled grey-blue, very fine-grained, laminated to massive anhydritic dolostone.	natural gamma log (below inflection) and neutron log (confirmed with core)	gradational	anhydrite/gypsum-rich dolostone (predominantly anhydrite); anydrite may be overlain by "A2 Shale Bed" as seen in DGR3 and DGR4	sharp decrease in neutron log, bottom of gamma spike (i.e. below inflection); very minor decrease in natural gamma log; gamma decrease more pronounced in DGR3 and DGR4 due to overlying "A2 Shale Bed".	below A2 Unit shale bed; anhydrite more prevalent at top and bottom of the A2 Unit Evaporite	core = easy to pick anhydrite rich zone (contact is where it is predominatly anhydrite - difficult to determine which unit it belongs to) geophysics = relatively easy with neutron and gamma; difficult by itself (gamma) on some logs

Table 1. Summary of Bedrock Formation Picks in DGR-1 to DGR-8

Stratigraphic Nomenclature	Stratigraphic Description	Primary Evidence for Pick	Geological Contact Description	Core Pick Rationale	BH Geophysical Pick Rationale	Armstrong and Carter (2006)	Difficulty of Pick
Salina Formation - A1 Unit	Grey to tan-grey argillaceous dolostone with limestone and some to abundant dark grey, petroliferous shale laminae, beds and shale-rich intervals, and trace to some anhydrite/gypsum veins and layers. Dolostone and anhydrite/gypsum are locally brecciated. Upper 2-3 m is abundantly vuggy.	core (confirmed with density log, gamma, neutron)	gradational	start of vuggy brown dolostone (i.e. force vuggy dolostone associated with aquifer to be part of A1 Unit rather that in bottom of A2 Unit Evaporite); is coincident with bottom of lowermost anhydritic dolostone	bottom of last anhydrite/gypsum layers with densities ~ 3 g/cc as shown on density log; slight and gradual increase in natural gamma following low of A2 Unit Evaporite. Neutron log shows decline after peak.	sharp transition from anhydrite/gypsum (A2 Unit Evaporite) to carbonates (A1 Unit)	core = easy to pick start of vuggy zone geophysics = easy (density log) to see last high density spike
A1 Unit Evaporite	Interlaminated to interbedded to massive and mottled brown dolostone and bluish-grey anhydritic dolostone.	natural gamma log inflection (confirmed with core and density log)	gradational	start of light blue-grey anhydritic dolostone	sharp increase in density log, start of slight decrease in gamma log	sharp transition between dark brown-grey dolostones and lighter grey-blue anhydritic dolostone	core = easy geophysics = easy based on density log
Salina Formation - A0 Unit	Grey-brown to black, fine-grained, thinly laminated, petroliferous dolostone with abundant black bituminous laminae.	core (confirmed with density log, core	gradational	lower extent of anhydrite/gypsum nodules in dolostone and appearence of dark, thinly laminated bituminous dolostone	small but sharp decrease in density and natural gamma log; located in middle of neutron plateau	dark, thinly laminated bituminous dolostone	core = difficult on own, but aligns with geophysics (density log) geophysics = difficult on own, but aligns with core
Guelph Formation	Brown to grey-brown, very fine- to medium-grained (i.e. sucrosic) petroliferous dolostone with grey-brown bituminous shale laminae and beds. Formation grades downwards from very vuggy to non-vuggy. Trace anhydrite nodules within upper part of formation.	core (confirmed with neutron and density logs)	relatively sharp	start of brown sucrosic dolostone (upper limit of small vugs) following laminated brown dolostone of Salina A0	sharp decrease in neutron log and density log	sucrosic and fossiliferous dolostone	core = easy geophysics = easy based on density log and neutron log
Goat Island Formation	Light grey to brown, very-fine grained, massive, hard dolostone with stylolites and some dark grey irregular bituminous laminae.	natural gamma log inflection and core (confirmed with density log, neutron log)	gradational	change from brown porous and sucrosic dolostone (Guelph) to very fine grained, light grey to brown dolostone	picked at inflection point of increase in natural gamma log which is co-located on the neutron log prior to an increase; increase to a steady density value ~ 2.8 g/cc at same depth that neutron log values increase	elevated gamma response, change to finer grained, cleaner carbonates	core = easy geophysics = easy
Gasport Formation	Light to dark grey-brown, very fine- to coarse-grained dolomitic limestone with pits and vugs that are in-filled with pyrite and calcite. Also contains tan-grey mottled, diffuse shale laminae.	natural gamma log inflection (confirmed with core)	gradational	lighter grey, coarser grained, more porous dolostone compared to Goat Island	consistently low gamma response below higher response of Goat Island; decrease in gamma log is co-located at inflection point of increase in neutron to a plateau	drop in gamma response, transition from grey, fine grained dolostone to light grey-blue-white, coarser grained, more porous dolostone	core = difficult geophysics = difficult
Lions Head Formation	Mottled light grey to grey-brown, very fine to fine-grained dolostone with trace shale and siltstone clasts and laminae	natural gamma log inflection (confirmed with core)	gradational	increased brown-grey shale content (thin layers) and smaller grain size	slightly elevated gamma response below Gasport and above Fossil Hill; pick is located at at a slight increase in the natural gamma log which corresponds in the neutron log to a minor peak or plateau that precedes a significant decline	gradual upward decrease in gamma from Lions Head into overlying Gasport	core = difficult geophysics = difficult
Fossil Hill Formation	Mottled light grey to tan-grey, coarse-grained dolostone with few shale and siltstone clasts and laminae, stylolites, and medium- to coarse-grained interbeds.	natural gamma log inflection (confirmed with core)	gradational	lighter colour, finer grained, presence of numerous shale partings	small and gradual decrease (spoon shaped dip) in gamma log; corresponds to inflection point of large increase in neutron log	Lions Head has more elevated gamma response but lithologies are very similar although the Fossil Hill has a more brownish colour than the grey to white dolostone of the overlying Lions Head	core = moderately difficult due to gradational nature and ambiguity of formation names/descriptions geophysics = moderately difficult but directly above Cabot Head and aligns with core
Cabot Head Formation	Shale grading with depth to interbedded shale and limestone. Shale is diffusely banded or mottled red and maroon; in-filled mud cracks tentatively identified. Limestone is grey, coarse-grained (wacke- to packestone), dolomitic, with bituminous laminae and contains variable amounts of green shale.	natural gamma log inflection and core (confirmed with neutron log)	sharp	sharp change from dolostone to massive green shale	sharp increase in gamma response, sharp decrease in neutron log	massive grey shale and increase in gamma response	core = extremely easy geophysics = extremely easy
Manitoulin Formation	Dolostone, shale, limestone and argillaceous dolostone. Dolostone is mottled grey-blue to grey-tan, fine- to coarse-grained, fossiliferous, and contains variable amounts of limestone, grey-green calcareous shale laminae and beds, black organic-rich laminae, and stylolites. Argillaceous dolostone is mottled grey-green to grey-blue, medium- to coarse-grained, slightly fossiliferous (brachiopods), is variably argillaceous. Formation locally contains variable amount of light grey-tan cm-thick chert layers and nodules.	core (confirmed with neutron and natural gamma log inflection)	gradational	lowermost significant shale bed of Cabot Head Fm (> 10 cm); coincides with change from shale with carbonate interbeds in Cabot Head to dolomite	drop in gamma log and increase in neutron log to plateau; lighter colour in ATV	lowermost significant shale bed as indicated by drop in gamma response	core = moderately difficult geophysics = moderately difficult
Queenston Formation	Red to maroon shale. The red to maroon shale is calcareous to non-calcareous and contains subordinate amounts of grey-green shale and grey to brown dolostone, limestone and siltstone. Locally contains gypsum and anhydrite nodules and halite in-filled fractures. Green shale in middle of the formation is interbedded with cm- to tens of cm-thick grey to dark grey, fossiliferous (brachiopods) limestone beds.	core (confirmed with natural gamma and neutron log inflection)	sharp (but appears more gradational in DGR4)	sharp contact from coarse grained fossiliferous dolostone of overlying Manitoulin to predominantly red and green interbedded shale (near first evidence of red shale) of Queenston; contact appears much more gradational in core in DGR4 and DGR1 where overlying Manitoulin consists of interlayered green shale and grey dolostone; in DGR4, pick was made where there was a subtle change from interlaminated green shale and grey dolostone to massive green shale	sharp increase in natural gamma and sharp decrease in neutron; geophysical log signature not as sharp in DGR1	transition from tan to grey dolostones (Manitoulin) / red shales (Queenston), with elevated natural gamma in Queenston	core = easy (where colour and lithology change is sharp) geophysics = easy (where change in gamma and neutron is sharp)
Georgian Bay Formation	Shale with subordinate limestone interbeds. Green to blue-grey shale interbedded with light grey, fossiliferous (crinoids, brachiopods, shell fragments and trace fossils), hard limestone beds and grey, calcareous siltstone beds. Trace in-filled fractures, commonly with halite; pyrite mineralization on fractures surfaces less common. Trace anhydrite and gypsum nodules. Fossiliferous limestone beds decrease in abundance with depth from some to trace. Petroliferous and sulphurous odour noted with depth. Core disking common.	core	gradational	below lowest evidence of red shale which coincides with start of grey carbonate layers interlaminated with green shale	spikey gamma response due to elevated gamma in shale layers and decrease in gamma in limestone beds	highest negative limestone spike on gamma ray which coincides with downward transition from red to green shale	core = relatively easy geophysics = difficult
Blue Mountain Formation	Green-blue to grey-blue and transitioning to grey to dark grey with depth, fossiliferous (crinoids, brachiopods) shale interbedded over upper part of formation with cm-thick grey siltstone and fossiliferous limestone beds. Shale has a petroliferous and sulphurous odour. Locally contains calcite in-filled fractures with pryite mineralization on fracture surfaces. Pyritization of fossils locally common. Core disking common.	core	gradational	lowest significant thin calcareous limestone bed greater than 10 cm thick	last "significant" carbonate bed identified in natural gamma log as last "significant" dip in gamma preceding less variable gamma log in Blue Mountain that is due to thinner and less frequent limestone beds	most difficult pick that is not attempted, however it is arbitrarily defined as base of lowest "significant" limestone bed	core = relatively easy geophysics = extremely difficult

Table 1. Summary of Bedrock Formation Picks in DGR-1 to DGR-8

Stratigraphic Nomenclature	Stratigraphic Description	Primary Evidence for Pick	Geological Contact Description	Core Pick Rationale	BH Geophysical Pick Rationale	Armstrong and Carter (2006)	Difficulty of Pick
Blue Mountain Formation - Lower Member	Grey to dark grey shale with trace siltstone interlaminae and petroliferous odour. Core disking common. Interbedded with mottled grey, fine- to medium-grained, fossiliferous, hard limestone with depth.	core	gradational	subtle colour change from dark brown to black shale; upper member breaks into cm-thick pucks whereas lower member is more fissile and is prone to disking	no change in gamma log response		core = difficult geophysics = extremely difficult
Coburg Formation - Collingwood Member	Dark grey to black, organic-rich, calcareous shale interbedded with grey, very fine- to coarse-grained, fossiliferous (brachiopods, crinoids, shell fragments), locally bioturbated, hard limestone. Petroliferous odour. Limestone is locally mottled grey to dark brown-grey, very-fine grained, fossiliferous, argillaceous and seeps hydrocarbons.	core and natural gamma log inflection	sharp	top of grey-brown-black calcareous shale; a phosphatic lag that shows as a several mm to cm thick dark black irregular bed may separate the overlying Blue Mountain from the Cobourg	lower natural gamma log response compared to Blue Mountain	increase in carbonate and decrease in clay content, changes in colour from blue-grey to dark grey-black to grey-brown, slight decrease in gamma log	core = extremely easy (phosphatic tag), relatively easy if not using this marker geophysics = extremely easy
Cobourg Formation - Lower Member	Mottled light to dark grey to brownish grey, very fine- to coarse-grained (i.e. packstones and grainstones), very hard, fossiliferous (crinoids, brachiopods, shell fragments) argillaceous limestone. Petroliferous odour, and traces of hydrocarbons seep from rock in places. Irregular to wavy to diffuse shale interbeds found over bottom few metres.	core (confirmed with natural gamma log and neutron log)	relatively sharp	below lowest black calcareous shale bed and start of massive, non-disking brownish grey, argillaceous limestone	slight decrease in natural gamma and slight increase in neutron; gamma in the Lower Member is flatter compared to spikey gamma response of Collingwood	change to carbonates of Cobourg from calcareous shales of Collingwood, matched by slightly lower gamma response	core = easy geophysics = relatively easy
Sherman Fall Formation	Light grey to grey, medium- to coarse-grained, transitioning to fine- to medium-grained with depth, argillaceous limestone. Coarse-grained beds are bio- and intraclastic grainstones; fossils include brachiopods and other shell fragments. Grey-green, irregular shale laminae and beds are interbedded and interlaminated with the limestone and increase in abundance with depth to typically around 20% by volume. Formation is locally mottled with depth (nodular texture). Petroliferous odour over upper few metres.	core (confirmed with natural gamma log inflection)	gradational	gradational contact from grey-brown argillaceous limestone to grey argillaceous limestone (shaly interbeds more well defined); top picked at first grainstone bed and end of "spider vein" appearance.	picked at top of grainstone bed that presents in natural gamma as a trough that follows consistently higher gamma values of overlying Cobourg. Upper part of Sherman Fall has lower gamma values than Cobourg	transition from finer grain size of bluish grey Cobourg to tan or grey-brown of Sherman Fall	core = difficult, gradational geophysics = difficult (lower unit is similar to Cobourg)
Kirkfield Formation	Grey, fine- to medium-grained argillaceous, fossilliferous (brachiopods) limestone interbedded with dark grey-green irregular to planar bedded shale that locally constitutes up to 50% by volume of the rock. Some shale beds contain limestone clasts. Formation has petroliferous odour.	core (confirmed with natural gamma log inflection)	gradational	very difficult pick as lower part of Sherman Fall is very similar to upper part of Kirkfield; the upper Kirkfield is generally less shalier than the overlying lower part of the Sherman Fall	decrease in natural gamma (corresponding to less shalier limestone) that marks the top of a shallow broad trough approximately 6-7 m below the largest gamma peak in the Sherman Fall	decrease in gamma log	core = very difficult geophysics = difficult
Coboconk Formation	Grey to tan-grey, mostly fine-grained with subordinate medium- and coarse-grained beds, fossiliferous, bioturbated limestone with irregular mottled bituminous shale laminae. Locally contains horizons of brown and black chert nodules and rare calcite-filled vugs. Formation is petroliferous with trace amounts of hydrocarbons.	core and natural gamma log inflection	sharp	sharp transition from interbedded bluish-grey limestone and shale of Kirkfield to cleaner, light grey limestone of the Coboconk	base of plateau (elevated gamma of Kirkfield) and start of consistently low gamma values; located approximately 6 m above largest gamma peak in the Coboconk	decrease in gamma log and transition out of shaly limestones	core = easy geophysics = relatively easy
Gull River Formation	Light grey to grey, as well as tan-brown with depth, very fine-grained to medium-grained, locally bioturbated and fossiliferous limestone with brown to black bituminous shale laminae, beds and stringers. Limestone is locally arenaceous in middle of formation. Stylolites are locally common and the formation is commonly petroliferous with trace amounts of hydrocarbons.	core and natural gamma log inflection	sharp	change in character of shale from distorted shale beds and blebs in the overlying Coboconk to more regualr shale beds in the Gull River. Gull River underlies oolitic beds in Coboconk	elevated and spikey gamma log	first shaly spike below low gamma response of Coboconk coinciding with transition from fine-grained bioclastic limestones of the Coboconk to the very fine-grained lithographic lime mudstones of the Gull River	core = moderate geophysics = relatively easy
Shadow Lake Formation	Interbedded grey to light green-grey-brown pyritic and gluaconitic siltstone and sandstone with subordinate grey-green sandy shale.	core	relatively sharp	top of first grey-green silty sandstone	not collected due to bridge plug in borehole to prevent flowing artesian conditions from Cambrian	top of largest shift in gamma log coinciding with change from carbonates (Gull River) to argillaceous silt/sandstone (Shadow Lake)	core = easy geophysics = not collected due to bridge plug in bottom of DGR-2 to prevent flowing artesian conditions.
Cambrian Sandstone	Grey, tan, brown, white, pinkish-orange, medium-grained sandstone that is locally abundantly pyritic and glauconitic, and is interbedded with brown to light grey dolostone and sandy dolostone in places. Fractures in-filled with quartz, calcite and pyrite.	core	sharp	first dolostone bed below overlying sand of Shadow Lake; bottom of Shadow Lake may contain clasts of the Cambrian Formation (as in DGR2)	not collected due to bridge plug in borehole to prevent flowing artesian conditions	transition from greenish, shaly clastics to clean quartzose sandstones, dolomitic sandstones or sandy dolostones	core = extremely easy geophysics = not collected due to bridge plug in bottom of DGR-2 to prevent flowing artesian conditions.
Precambrian basement	Pink to black, fine- to medium-grained felsic gneiss.	core	sharp	sharp contact from overlying tan-grey sandstone to granitic gneiss	not collected due to bridge plug in borehole to prevent flowing artesian conditions	increase in gamma response coincident with sharp contact with granitic gneiss	core = easy geophysics = not collected due to bridge plug in bottom of DGR-2 to prevent flowing artesian conditions

TR-11-06 Table 2. Summary of Bedrock Formation Depths, Thicknesses and Elevations in DGR-1 to DGR-8

	Stratigraphic Nomenclature	Top of Formation Length Along Borehole Axis (mLBGS)							Core Run Containing Contact							Top of Formation True Vertical Depth (mBGS)							Top of Formation Elevation (mASL)							Interpreted Thickness (m)							Primary Formation Pick
		DGR-1/2*	DGR-3	DGR-4	DGR-5	DGR-6	DGR-7	DGR-8	DGR-1/2*	DGR-3	DGR-4	DGR-5	DGR-6	DGR-7	DGR-8	DGR-1/2*	DGR-3	DGR-4	DGR-5	DGR-6	DGR-7	DGR-8	DGR-1/2*	DGR-3	DGR-4	DGR-5	DGR-6	DGR-7	DGR-8	DGR-1/2*	DGR-3	DGR-4	DGR-5	DGR-6	DGR-7	DGR-8	Core or Geophysics
Late Devonian	Lucas Formation	20	7.9	7.5	22.2	16.9	12.8	11.9	--	--	--	--	--	6	5	20.0	7.9	7.5	20.0	14.4	12.8	11.9	165.7	179.5	174.1	165.7	169.1	173.5	174.4	10.4	46.6	30.1	10.4	16.9	34.5	35.2	Core
	Amherstburg Formation	30.4	54.5	37.6	33.8	37.0	47.3	47.1	3	11	3	--	--	21	18	30.4	54.5	37.6	30.4	31.3	47.3	47.1	155.3	132.9	144.0	155.3	152.2	138.9	139.2	44.6	39.4	38.6	44.6	42.5	38.0	38.4	Core
Early Devonian	Bois Blanc Formation	75	93.9	76.2	83.2	87.1	85.3	85.5	20	26	17	--	--	33	30	75.0	93.8	76.2	75.0	73.9	85.3	85.4	110.7	93.5	105.4	110.7	109.6	100.9	100.8	49.0	49.3	49.8	47.3	48.0	49.8	50.1	Core
Upper Silurian	Bass Islands Formation	124	143.3	126	134.8	142.3	135.1	135.6	39	44	33	--	--	51	48	124.0	143.1	126.0	122.2	121.9	135.1	135.6	61.7	44.2	55.6	63.5	61.6	51.1	50.7	45.3	44.0	44.1	44.6	44.2	43.6	43.8	Core and Geophysics
	Salina Formation - G Unit	169.3	187.3	170.1	184.0	193.0	178.7	179.5	62	59	48	--	--	68	63	169.3	187.1	170.1	166.8	166.1	178.7	179.4	16.4	0.2	11.5	18.9	17.4	7.5	6.8	9.3	9.2	7.3	7.6	8.6	8.5	7.6	Core and Geophysics
	Salina Formation - F Unit	178.6	196.5	177.4	192.5	203.0	187.2	187.0	66	62	51	--	--	71	65	178.6	196.3	177.4	174.3	174.7	187.2	187.0	7.1	-8.9	4.2	11.4	8.8	-1.0	-0.7	44.4	43.0	43.6	38.7	40.0	--	42.7	Geophysics
	Salina Formation - E Unit	223	239.6	221	235.2	249.1	--	229.7	82	78	65	10	14	--	90	223.0	239.3	220.9	213.1	214.7	--	229.7	-37.2	-51.9	-39.3	-27.4	-31.2	--	-43.4	20.0	23.8	24.4	19.4	17.2	--	25.7	Core and Geophysics
	Salina Formation - D Unit	243	263.4	245.5	256.2	268.9	--	255.4	88	86	73	16	21	--	96	243.0	263.1	245.4	232.4	231.9	--	255.4	-57.2	-75.7	-63.8	-46.7	-48.4	--	-69.1	1.6	2.6	1.8	1.0	1.0	--	1.1	Geophysics
	Salina Formation - C Unit	244.6	266	247.3	257.3	270.0	--	256.5	89	87	74	17	21	--	97	244.6	265.6	247.2	233.5	232.8	--	256.5	-58.8	-78.3	-65.6	-47.8	-49.3	--	-70.2	15.7	11.9	14.7	12.8	33.3	--	15.7	Geophysics
	Salina Formation - B Unit	260.3	277.9	262	271.2	308.5	--	272.3	94	91	78	21	34	--	102	260.3	277.5	261.9	246.3	266.2	--	272.2	-74.5	-90.2	-80.3	-60.6	-82.7	--	-86.0	30.9	25.1	28.8	40.8	21.2	--	25.9	Core
	B Unit Evaporite	291.2	303.0	290.8	315.5	333.0	--	298.2	104	99	88	38	42	--	111	291.2	302.6	290.7	287.1	287.4	--	298.1	-105.4	-115.2	-109.1	-101.4	-103.9	--	-111.9	1.9	1.6	1.7	3.2	4.0	--	1.5	Geophysics
	Salina Formation - A2 Unit	293.1	304.6	292.5	319.0	337.7	--	299.7	105	99	88	39	43	--	111	293.1	304.2	292.4	290.3	291.4	--	299.6	-107.3	-116.8	-110.8	-104.6	-107.9	--	-113.4	26.6	28.8	28.4	27.9	25.8	--	26.8	Core and Geophysics
	A2 Unit Evaporite	319.7	333.5	320.9	349.4	367.5	--	326.5	113	109	98	49	55	--	120	319.7	333.0	320.8	318.2	317.2	--	326.4	-133.9	-145.7	-139.2	-132.5	-133.7	--	-140.2	5.8	5.1	5.2	5.6	3.7	--	4.7	Geophysics
	Salina Formation - A1 Unit	325.5	338.6	326.1	355.5	371.8	--	331.2	115	111	99	51	56	--	122	325.5	338.1	326.0	323.7	320.9	--	331.2	-139.7	-150.7	-144.4	-138.0	-137.4	--	-144.9	41.5	41.1	40.7	41.5	40.4	--	40.8	Core
	A1 Unit Evaporite	367	379.8	366.8	400.4	418.0	--	372.0	129	125	113	66	74	--	135	367.0	379.2	366.7	365.2	361.2	--	372.0	-181.2	-191.9	-185.1	-179.5	-177.7	--	-185.7	3.5	4.4	5.0	4.4	4.4	--	4.7	Geophysics
	Salina Formation - A0 Unit	370.5	384.2	371.8	405.0	423.0	--	376.7	130	126	114	68	75	--	137	370.5	383.6	371.7	369.6	365.7	--	376.7	-184.7	-196.3	-190.1	-183.9	-182.2	--	-190.4	4.0	2.6	3.8	2.8	3.9	--	3.3	Core and Geophysics
Middle Silurian	Guelph Formation	374.5	386.8	375.6	408.0	427.3	--	380.0	132	127	116	69	77	--	138	374.5	386.2	375.5	372.3	369.6	--	379.9	-188.7	-198.9	-193.9	-186.6	-186.1	--	-193.7	4.1	5.4	4.9	5.4	3.7	--	5.4	Core
	Goat Island Formation	378.6	392.2	380.5	413.7	431.5	--	385.4	133	129	117	71	78	--	140	378.6	391.6	380.4	377.7	373.3	--	385.4	-192.8	-204.3	-198.8	-192.0	-189.8	--	-199.1	18.8	18.3	18.6	18.1	18.5	--	18.7	Core and Geophysics
	Gasport Formation	397.4	410.5	399.1	433.0	452.2	--	404.1	139	135	123	77	85	--	146	397.4	409.9	399.0	395.8	391.8	--	404.0	-211.6	-222.6	-217.4	-210.1	-208.3	--	-217.8	6.8	6.5	6.5	9.2	7.9	--	7.0	Geophysics
Lower Silurian	Lions Head Formation	404.25	417	405.6	442.8	461.0	--	411.1	141	137	126	80	88	--	148	404.2	416.4	405.5	405.0	399.7	--	411.0	-218.5	-229.1	-223.9	-219.3	-216.2	--	-224.8	4.4	4.5	4.4	2.3	3.6	--	3.9	Geophysics
	Fossil Hill Formation	408.7	421.5	410	445.3	465.0	--	415.0	143	139	127	81	89	--	149	408.7	420.9	409.9	407.3	403.3	--	415.0	-222.9	-233.6	-228.3	-221.6	-219.8	--	-228.7	2.3	1.3	1.5	2.4	2.6	--	2.2	Geophysics
	Cabot Head Formation	411	422.8	411.5	447.8	467.9	--	417.2	143	139	127	82	90	--	150	411.0	422.2	411.4	409.7	405.9	--	417.1	-225.2	-234.8	-229.8	-224.0	-222.4	--	-230.9	23.8	24.7	24.2	23.7	23.4	--	23.5	Core and Geophysics
	Manitoulin Formation	434.8	447.5	435.7	473.0	493.6	--	440.7	151	147	136	92	100	--	158	434.8	446.9	435.6	433.4	429.3	--	440.7	-249.0	-259.5	-254.0	-247.7	-245.8	--	-254.4	12.8	9.5	10.6	12.9	13.2	--	10.9	Core and Geophysics
Upper Ordovician	Queenston Formation	447.65	457	446.3	486.6	507.9	--	451.6	156	150	140	96	105	--	162	447.6	456.4	446.2	446.2	442.6	--	451.6	-261.9	-269.0	-264.6	-260.5	-259.1	--	-265.3	70.3	74.4	73.0	70.3	69.3	--	72.6	Core
	Georgian Bay Formation	518	531.4	519.3	560.6	583.1	--	524.2	DGR-2 23	175	164	121	133	--	191	518.0	530.7	519.2	516.6	511.9	--	524.2	-332.1	-343.4	-337.6	-330.9	-328.4	--	-337.9	90.9	88.7	88.7	88.6	88.2	--	89.5	Core
	Blue Mountain Formation	608.9	620.1	608	653.3	684.7	--	613.7	52	205	195	151	172	--	223	608.9	619.4	607.9	605.2	600.1	--	613.6	-423.0	-432.1	-426.3	-419.5	-416.6	--	-427.4	38.1	40.0	41.1	45.1	45.0	--	39.8	Core
	Blue Mountain Formation - Lower Member	647	660.2	649.1	--	--	--	653.4	65	218	209	--	--	--	237	647.0	659.5	649.0	--	--	--	653.4	-461.1	-472.1	-467.4	--	--	--	-467.1	4.6	4.1	4.0	--	--	--	4.5	Core
Middle Ordivician	Cobourg Formation - Collingwood Member	651.6	664.3	653.1	699.9	738.3	--	658.0	67	219	211	167	190	--	239	651.6	663.6	653.0	650.3	645.1	--	657.9	-465.7	-476.3	-471.4	-464.6	-461.6	--	-471.7	7.9	8.7	8.4	8.6	6.5	--	7.9	Core and Geophysics
	Cobourg Formation - Lower Member	659.5	673	661.5	708.7	746.1	--	665.8	70	222	214	170	192	--	241	659.5	672.3	661.4	658.9	651.6	--	665.8	-473.6	-485.0	-479.8	-473.2	-468.1	--	-479.5	28.6	27.8	27.5	27.1	28.5	--	27.9	Core
	Sherman Fall Formation	688.1	700.8	689	736.5	780.2	--	693.7	79	232	223	179	203	--	250	688.1	700.1	688.8	686.0	680.2	--	693.6	-502.2	-512.7	-507.2	-500.3	-496.7	--	-507.4	28.0	28.9	28.3	29.3	28.8	--	29.2	Core
	Kirkfield Formation	716.1	729.8	717.3	766.5	814.7	--	722.9	89	243	233	189	215	--	262	716.1	729.0	717.1	715.3	709.0	--	722.9	-530.2	-541.7	-535.5	-529.6	-525.5	--	-536.6	45.9	45.8	45.7	--	46.8	--	--	Core
	Coboconk Formation	762	775.6	763	--	870.5	--	--	105	258	248	--	234	--	--	762.0	774.9	762.8	-	755.8	--	--	-576.1	-587.5	-581.2	--	-572.3	--	--	23.0	23.7	23.8	--	22.4	--	--	Core and Geophysics
	Gull River Formation	785	799.3	786.8	--	897.2	--	--	114	266	256	--	243	--	--	785.0	798.6	786.6	-	778.1	--	--	-599.1	-611.2	-605.0	--	-594.6	--	--	53.6	51.7	52.2	--	--	--	--	Core and Geophysics
	Shadow Lake Formation	838.6	851	839	--	--	--	--	132	283	273	--	--	--	--	838.6	850.3	838.8	-	-	--	-	-652.7	-662.9	-657.2	--	--	--	--	5.2	4.5	5.1	--	--	--	--	Core
	Cambrian Sandstone	843.8	855.5	844.1	--	--	--	--	133	284	274	--	--	--	--	843.8	854.8	843.9	-	-	--	-	-657.9	-667.4	-662.3	--	--	--	--	16.9	--	--	--	--	--	--	Core
	Precambrian basement	860.7	--	--	--	--	--	--	146	--	--	--	--	--	--	860.7	-	-	-	-	--	-	-674.8	--	--	--	--	--	--	--	--	--	--	--	--	--	Core

DGR Borehole	DGR-1*	DGR-2*	DGR-3	DGR-4	DGR-5	DGR-6	DGR-7	DGR-8
Ground Surface Elevation (mASL)	185.71	185.84	187.35	181.6	185.70	183.50	186.20	186.25
Total Drilled Depth (m)	462.87	862.12	869.17	856.98	807.15	903.16	189.97	723.81

Note: * DGR-1 and DGR-2 are both vertically cored boreholes situated approximately 50 m apart and therefore are considered to represent 1 stratigraphic borehole.
As such, all top of formation depth information for bedrock units above and including the Queenston Formation are referenced to DGR-1

and all formation top information for bedrock units below and including the Georgian Bay Formation are referenced to DGR-2.

7.3 Prediction of Formations in DGR-7 and DGR-8

Borehole coordinates and relative distances are listed in Table 4. True strike and dip values were calculated and reported in TR-09-11 (Geofirma Engineering Ltd., 2011a) using the TVD elevation data for the tops of formations and marker beds in the three vertical borehole locations (DGR-1/2, DGR-3, and DGR-4). Table 5 shows these previously calculated true strike and dip values along with the dip direction in azimuth degrees for each bedrock formation. These calculations assume that the top surface of each bedrock formation is a linear plane and although geologically this is inaccurate, this assumption is sufficient for the purpose of this exercise when discussing boreholes separated by less than 1500 metres. Strike values are reported in azimuth degrees using the right-hand rule convention in which the direction of dip is 90° in a clockwise direction from the strike.

Table 3 Stratigraphic Marker Beds in Boreholes DGR-1 to DGR-8

Formation	***Marker Bed or Horizon***	***Depth (mLBGS) [Elevation (mASL)]***						
		DGR-1/2	***DGR-3***	***DGR-4***	***DGR-5***	***DGR-6***	***DGR-7***	***DGR-8***
Salina F Unit	brown dolostone bed in grey shale	182.0 [3.7]	200.7 [-13.1]	181.5 [0.1]	--	--	--	190.3 [-4.1]
Queenston	limestone bed in shale	504.3 [-318.5]	517.7 [-330.4]	505.6 [-324.0]	546.0 [-360.3]	568.6 [-385.1]	--	511.7 [-325.4]
Georgian Bay	fossiliferous limestone bed in shale	576.5 [-390.7]	589.2 [-401.9]	577.9 [-396.3]	622.3 [-436.6]	649.6 [-466.1]	--	583.3 [-397.0]
Coboconk	volcanic ash bed in limestone	768.8 [-583.0]	781.0 [-593.7]	769.0 [-587.4	--	876.7 [-693.2]	--	--
Coboconk	tan dolostone bed in grey limestone	778.7 [-592.9]	790.5 [-603.2]	778.3 [-596.7]	--	888.0 [-704.5]	--	--

As previously discussed in TR-09-11 and shown in Table 5, the dip direction of all formation tops and marker beds, with the exception of the Lucas Formation, were to the southwest and ranged between 235° (Salina Formation – E Unit) and 257° (Cobourg Formation) azimuth degrees, although the majority were between 243° and 258°. The Lucas Formation dip direction was 81° which reflects the attitude of the erosional surface. Dip angles were between 0.41° (Queenston Formation) and 1.15° (Amherstburg Formation) (7 to 20 m/km, respectively).

The top elevation of bedrock formations encountered in DGR-7 and DGR-8, as presented in Table 2, were compared to the predicted formation top elevations based on the equation of a plane using data from DGR-1/2, DGR-3, and DGR-4 as described in TR-09-11 (Geofirma Engineering Ltd., 2011a). This comparison provides an assessment of the predictability of formation occurrence at the Bruce DGR site. Table 5 lists the measured top of bedrock formation elevations based on core data, the predicted elevations, and the difference between measured and predicted values for each bedrock formation in DGR-7 and DGR-8.

Table 4 Borehole Coordinates and Distances Between DGR Boreholes

Borehole	*UTM Coordinates (NAD83, Zone 17N)*		*Horizontal Distance Between Borehole Collar Locations (m)*						
	Easting	***Northing***	***DGR-2***	***DGR-3***	***DGR-4***	***DGR-5***	***DGR-6***	***DGR-7***	***DGR-8***
DGR-1	454240	4907755	47	1159	1312	22	631	890	970
DGR-2	454209	4907720	-	1128	1319	26	650	883	962
DGR-3	453081	4907740	-	-	1047	1141	1046	613	587
DGR-4	453378	4908744	-	-	-	1310	716	543	509
DGR-5	454222	4907742	-	-			635	881	961
DGR-6	453953	4908317						490	562
DGR7	453475	4908210							82
DGR8	453397	4908235	--	--	--	--	--	--	--

DGR-8 is located slightly down-dip compared to DGR-7 and therefore the predicted bedrock formation top elevations for DGR-8 are between 0.8 (Salina F Unit) and 1.4 m (Amherstburg Formation) deeper compared to those for DGR-7. Table 5 shows measured bedrock formation top elevations in DGR-7 and DGR-8 are generally above their predicted elevations for formations above, and including, the Salina A2 Unit and below their predicted elevations for formations below and including the Salina A2 Evaporite Unit.

Above, and including, the Salina A2 Unit, the offsets or differences between observed and predicted formation depths are within the range of 0.6 m (Salina F Unit in DGR-8) to 4 m (Amherstburg Formation in DGR-7). The Salina Formations above the A2 Unit are subject to salt dissolution and structural collapse, therefore the predictability and uniformity of formation thicknesses and elevations is considered to be lower for these bedrock units. In addition the variable offsets for formations above the Salina A2 Unit are also partially due to the difficulty in making formation picks where the change in lithology is gradational in nature and brecciation is evident.

Below the Salina A2 Unit, these offsets range from 0.1 m (Cabot Head Formation in DGR-8) to 1.3 m (Salina A1 Evaporite Unit). The minor differences in predicted versus measured elevation of formations in DGR-7 and DGR-8 appear to be in the range of expected values given uncertainty in the strike and dip measured based on DGR-1 to DGR-4 data, formation picks and the formation planarity. Consequently, these data do not indicate any significant formation offsets in the vicinity of DGR-7 or DGR-8.

8 Data Quality and Use

Data on bedrock formation nomenclature and identification in this Technical Report are based on expert geological review of the geology and geophysical properties observed in boreholes DGR-1 to DGR-8 at the Bruce nuclear site. Many contacts between individual bedrock formations are gradational and the selected contacts reflect the consensus opinion of the geological experts.

Table 5. Summary of True Strike and Dip Values for Bedrock Formations/Marker Beds and Differences Between Measured and Predicted Bedrock Elevations in DGR-7 and DGR-8

	Stratigraphic Nomenclature	True Strike and Dip (DGR-1/2, DGR-3 & DGR-4)				DGR-7			DGR-8		
		Strike (Azimuth Degrees)	Dip Gradient (m/km)	True Dip (Degrees from Horizontal)	Dip Direction (Azimuth Degrees)	Predicted Elevation from Plane (mASL)	Table 2 Measured Elevation in Core (mASL)	Vertical Offset (m)	Predicted Elevation from Plane (mASL)	Table 2 Measured Elevation in Core (mASL)	Vertical Offset (m)
Late Devonian	Lucas Formation	351.1	12.0	0.7	81.1	173.9	173.5	0.5	174.8	174.4	0.5
	Amherstburg Formation	164.4	20.0	1.1	254.4	143.0	138.9	4.1	141.6	139.2	2.5
Early Devonian	Bois Blanc Formation	153.1	16.6	1.0	243.1	102.8	100.9	2.0	101.9	100.8	1.1
Upper Silurian	Bass Islands Formation	155.2	16.6	1.0	245.2	53.4	51.1	2.3	52.4	50.7	1.7
	Salina Formation - G Unit	152.7	15.8	0.9	242.7	9.1	7.5	1.6	8.2	6.8	1.4
	Salina Formation - F Unit	146.6	16.7	1.0	236.6	0.7	-1.0	1.7	-0.1	-0.7	0.6
	Salina Formation - E Unit	144.8	15.6	0.9	234.8	--	--	--	-43.6	-43.4	-0.2
	Salina Formation - D Unit	155.4	17.7	1.0	245.4	--	--	--	-67.1	-69.1	2.0
	Salina Formation - C Unit	155.1	18.7	1.1	245.1	--	--	--	-69.2	-70.2	1.0
	Salina Formation - B Unit	156.2	15.0	0.9	246.2	--	--	--	-83.0	-86.0	2.9
	B Unit Evaporite	156.2	9.5	0.5	246.2	--	--	--	-110.8	-111.9	1.1
	Salina Formation - A2 Unit	155.6	9.3	0.5	245.6	--	--	--	-112.5	-113.4	0.9
	A2 Unit Evaporite	160.4	11.1	0.6	250.4	--	--	--	-140.8	-140.2	-0.6
	Salina Formation - A1 Unit	158.8	10.5	0.6	248.8	--	--	--	-146.0	-144.9	-1.1
	A1 Unit Evaporite	155.4	10.5	0.6	245.4	--	--	--	-187.0	-185.7	-1.3
	Salina Formation - A0 Unit	161.1	10.9	0.6	251.1	--	--	--	-191.6	-190.4	-1.2
Middle Silurian	Guelph Formation	163.6	9.5	0.5	253.6	--	--	--	-195.0	-193.7	-1.3
	Goat Island Formation	164.4	10.7	0.6	254.4	--	--	--	-199.9	-199.1	-0.8
	Gasport Formation	164.6	10.2	0.6	254.6	--	--	--	-218.5	-217.8	-0.7
Lower Silurian	Lions Head Formation	163.7	9.9	0.6	253.7	--	--	--	-225.0	-224.8	-0.2
	Fossil Hill Formation	163.3	10.0	0.6	253.3	--	--	--	-229.4	-228.7	-0.7
	Cabot Head Formation	161.4	9.2	0.5	251.4	--	--	--	-231.0	-230.9	-0.1
	Manitoulin Formation	161.3	10.0	0.6	251.3	--	--	--	-255.3	-254.4	-0.9
Upper Ordovician	Queenston Formation	155.8	7.2	0.4	245.8	--	--	--	-265.8	-265.3	-0.5
	Georgian Bay Formation	163.3	11.1	0.6	253.3	--	--	--	-338.9	-337.9	-1.0
	Blue Mountain Formation	156.5	9.4	0.5	246.5	--	--	--	-427.9	-427.4	-0.5
	Blue Mountain Formation - Lower Member	168.0	10.6	0.6	258.0	--	--	--	--	-467.1	--
Middle Ordivician	Cobourg Formation - Collingwood Member	166.0	10.3	0.6	256.0	--	--	--	-472.3	-471.7	-0.7
	Cobourg Formation - Lower Member	166.5	11.0	0.6	256.5	--	--	--	-480.8	-479.5	-1.2
	Sherman Fall Formation	162.9	10.4	0.6	252.9	--	--	--	-508.5	-507.4	-1.1
	Kirkfield Formation	162.2	11.4	0.7	252.2	--	--	--	-537.0	-536.6	-0.4
	Coboconk Formation	161.4	11.4	0.7	251.4	--	--	--	--	--	--
	Gull River Formation	163.6	11.9	0.7	253.6	--	--	--	--	--	
	Shadow Lake Formation	161.0	10.3	0.6	251.0	--	--	--	--	--	--
	Cambrian Sandstone	162.1	9.5	0.5	252.1	--	--	--	--	--	--
	Precambrian basement	--	--	--	--	--	--	--	--	--	--
Marker Beds	Salina F Unit (brown dolostone bed in shale)	149.9	17.7	1.0	239.9	--	--	--	-4.1	-4.1	-0.1
	Queenston Formation (limestone bed below shale)	163.6	11.1	0.6	253.6	--	--	--	-325.2	-325.4	0.2
	Georgian Bay Formation (6 cm fossiliferous limestone bed)	165.5	10.3	0.6	255.5	--	--	--	-397.2	-397.0	-0.2
	Coboconk (ash bed in limestone)	160.4	10.1	0.6	250.4	--	--	--	--	--	--
	Coboconk (tan bed in grey limestone)	158.8	9.8	0.6	248.8	--	--	--	--	--	--

The data presented in this Technical Report are suitable for assessing the bedrock formation elevations and thicknesses near the proposed vent and main shaft locations compared to geological, hydrogeological and geomechanical descriptive site models of the Bruce DGR site as reported in the Descriptive Geosphere Site Model of the Bruce nuclear site (Intera Engineering Ltd., 2011).

Future research may result in changes to the stratigraphic nomenclature used to describe the rock record of the DGR boreholes; however, hydrogeological and geomechanical descriptive site models are based on the properties of the bedrock, irrespective of their nomenclature, and therefore, it is not anticipated that changes in nomenclature will affect these models.

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APPENDIX A

Core Photographs of Selected Marker Beds

Salina Formation - F Unit Tan Dolostone Marker Bed in DGR-1, DGR-3, DGR-4, and DGR-8		Prepared by: SNS Reviewed by: KGR Date: 11-Nov-11
FIGURE A.1	TR-11-06_Fig A.1 Salina F Unit_R0.doc	

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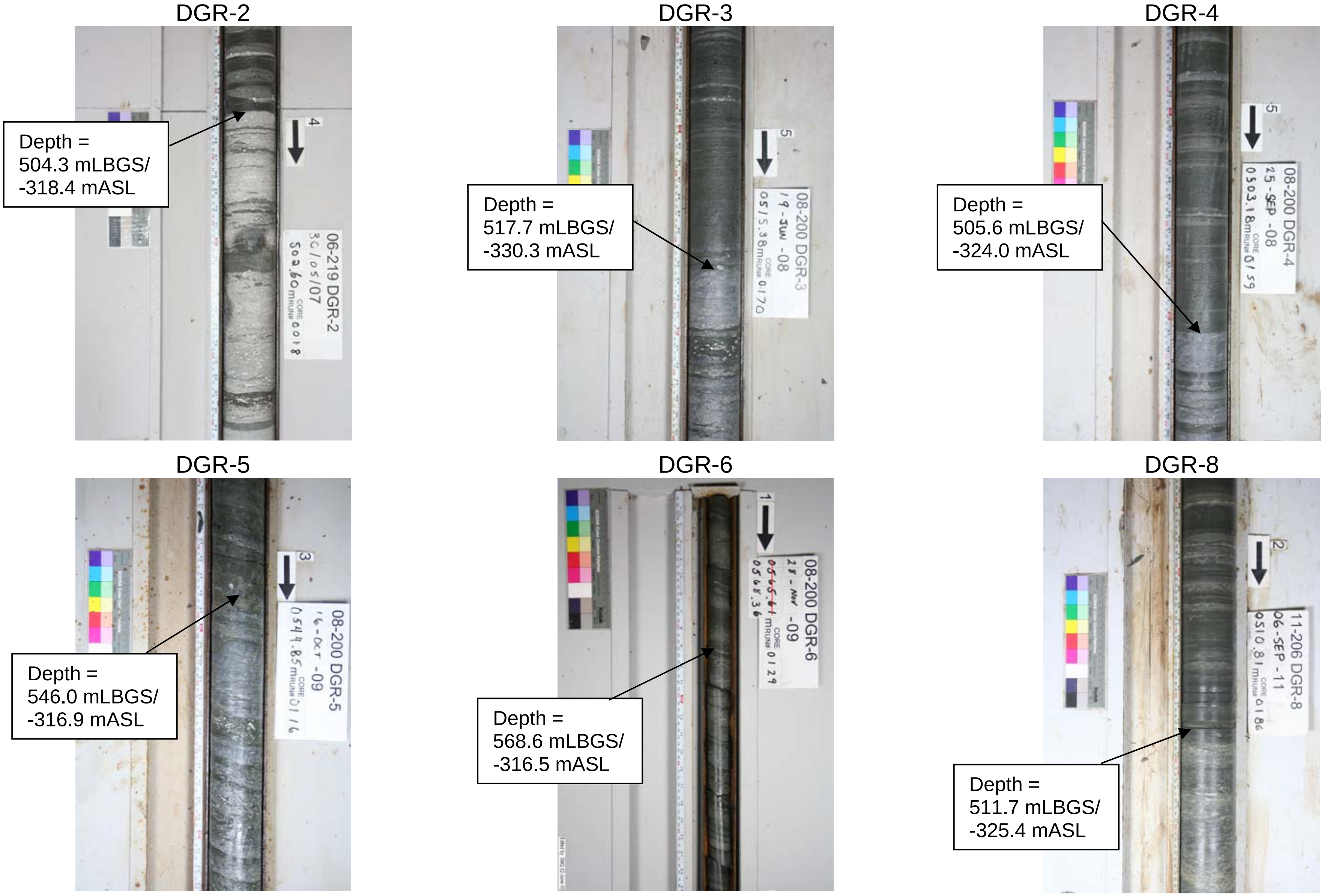


Queenston Formation - Limestone Marker Bed in DGR-2, DGR-3, DGR-4, DGR-5, DGR-6, and DGR-8

FIGURE A.2

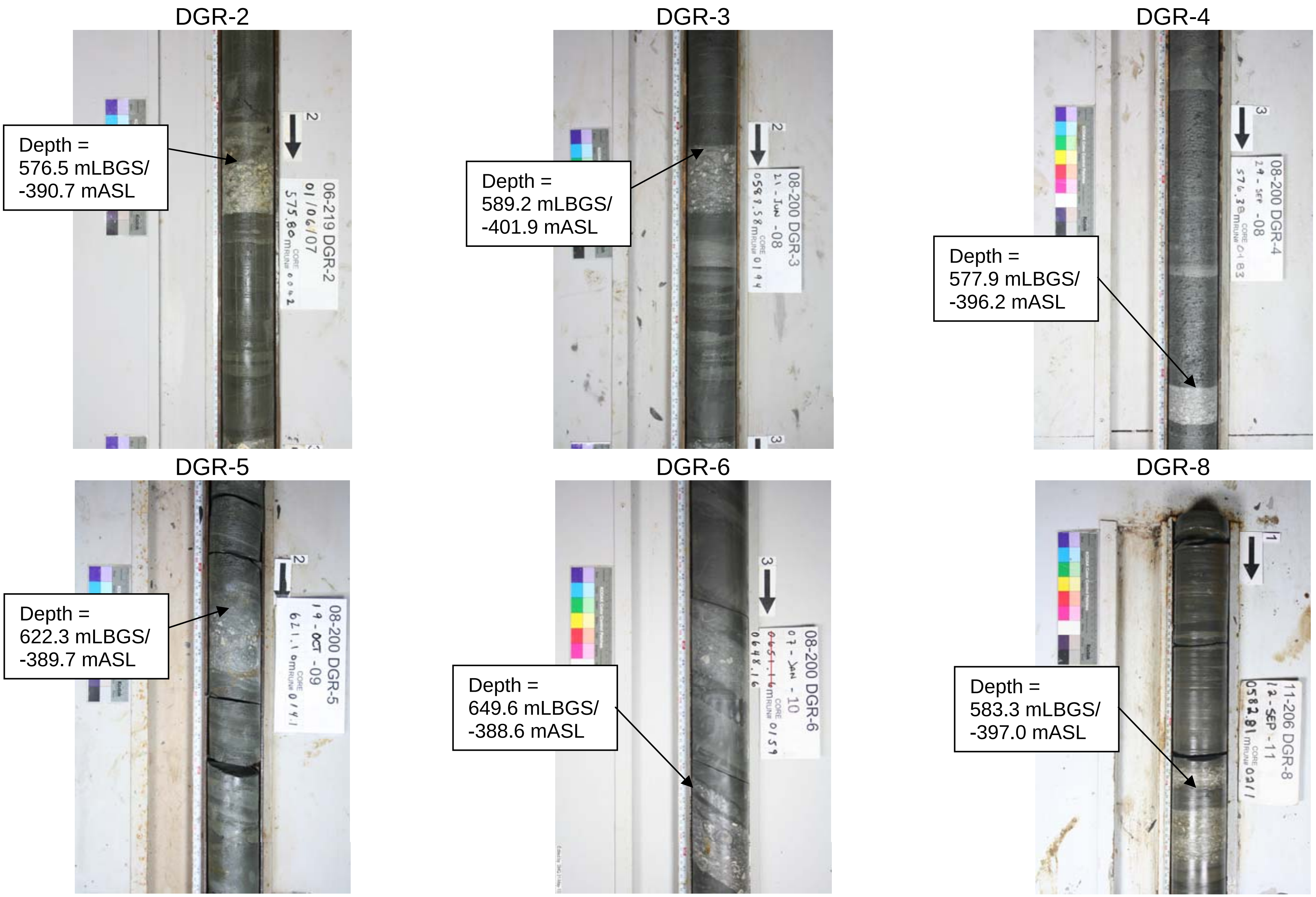
TR-11-06_Fig A.2 Queenston_R0.doc

Prepared by: SNS

Reviewed by: KGR

Date: 11-Nov-11

Geofirma Engineering Ltd



Georgian Bay Formation - Limestone Marker Bed in DGR-2, DGR-3, DGR-4, DGR-5, DGR-6, and DGR-8	Prepared by: SNS Reviewed by: KGR Date: 11-Nov-11
FIGURE A.3	TR-11-06_Fig A.3 Georgian Bay_R0.doc

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