2001 Field Investigation of the Vangorda Rock Dump, Faro Mine, Yukon

Prepared for
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1. Introduction

Deloitte and Touche Inc. commissioned Gartner Lee Limited (GLL) to conduct a field investigation at the Vangorda Rock Dump at the Faro Mine in the Yukon Territory. The Vangorda Rock Dump contains approximately 16 million tonnes of waste rock previously mined from the Vangorda open pit. All of the rock in the dump is confirmed to have some acid generation potential. The rock dump is currently generating high concentrations of acid rock drainage as evidenced by the poor quality of the water exiting at the toe drains. The mechanism for contaminant transport is unclear. Extremely low seepage volumes at the toe drains are lower than the volumes anticipated by water balance calculations. This observation suggests the following possible contaminant transport scenarios:

1. Evaporation of infiltrating water of the surfaces of the dump may be much greater than anticipated in the water balance and therefore less water is exiting the toe drains.
2. The storage capacity of the dump may not be fully utilized (i.e. infiltrating water will continue to be stored within the dump until the storage capacity is fully utilized.
3. Contaminated groundwater may be flowing along the bedrock contact below the dump and, thereby, escaping detection by the existing monitoring well network.

The purpose of the field study was to investigate the third scenario described above, that contaminated groundwater may be flowing along the bedrock contact below the dump and, thereby, escaping detection by the existing monitoring well network. This information may also enhance the environmental characterization of the dump for long term planning purposes.

2. Objective and Scope of Work

The 2001 field investigation was designed to investigate the possibility that deep groundwater flow at the bedrock/overburden contact is transporting contaminants from the dump into Vangorda Creek. The scope of work included the following:

1. conduct a surface geophysical survey around the perimeter of the dump to map the bedrock/overburden contact (seismic survey);
2. dependant on the information provided from the seismic survey, drill and install monitoring wells at the bedrock contact at strategic locations around the dump perimeter;
3. sample groundwater from the new wells and analyze samples for groundwater contaminants; and
4. prepare a project report that summarizes the findings of the investigation.

3. Background Information

The Vangorda rock dump contains approximately 16 million tonnes of waste rock mined from the Vangorda open pit. All of the rock contained in the dump is confirmed to have some acid generation potential ranging from weak (phyllites) to strong (sulphides). Construction of the rock dump began in 1989/90. Economic ore reserves in the Vangorda open pit were depleted by February 1998 at the start of the current mine shut down and construction of the dump was completed at that time.

In addition to the sulphide and phyllite rock types, approximately 225,000 tonnes of "oxidized fines" are located within the sulphide cell area. This material is the fine fraction of screening of the oxidized portion of the ore body and represents a significant source of readily available oxidation products.

A plan of the rock dump is provided in Figure 1. Figure 1 also displays the existing monitoring well network. Only one monitoring well (GW94-01; Figure 1) extends into the bedrock/overburden contact.

The southern edge of the rock dump generally overlies an area of no or thin soil cover. This topographic and bedrock "high" area represents a drainage divide (and possible recharge zone) between Vangorda Creek and Dixon Creek (Figure 1). The thickness of the soil layer that underlies the dump increases from the topographic and bedrock "high" towards the north (i.e. towards Vangorda Creek) and the soil layer was thought (prior to the 2001 field investigation) to be approximately 30 metres thick around the toe of most of the dump. The soil is predominantly a silty glacial till overlain by a relatively minor layer of organic soil.

In 1994, a series of ground water monitoring wells were installed around the perimeter of the dump (GW94-01 to GW94-05). One well (GW94-01) extends to bedrock in an area of shallow bedrock near the southern edge of the dump.

4. Methodology

4.1 Seismic Survey

The seismic refraction survey was conducted by Aurora Geosciences Ltd, Whitehorse, Yukon Territory. The instrument used to conduct the survey was a geomatrics S-24 with a phone spacing of 5 metres and a spread of 115 meters.

Seismic waves were generated using minor explosives. The propagation of seismic energy through subsurface layers were monitored. The refraction or angular deviation that a seismic pulse undergoes when passing from one material to another is expressed as a ratio of transmission velocities for the two materials.

The seismic survey line extended from the south end of the rock dump and generally followed the perimeter of the dump to the north and northeast as illustrated on Figure 1.

4.2 Borehole Drilling and Monitoring Well Installation

Drilling services were provided by Midnight Sun Drilling Co. Ltd. of Whitehorse, Yukon. Boreholes were drilled with a track mounted Maxi Drill 10 air rotary rig equipped with a pneumatic hammer and a carbide ODEX bit. Boreholes were advanced in 10 foot lengths using 10.2 cm diameter inner rods and 15.2 cm inner diameter casing. Boreholes were advanced to depths ranging from 29 to 62 metres depth. Drilling to depth was difficult duet to "squeezing" of the soils against the drill rods. Drilling to maximum depths was accomplished by discontinuing outer casing advancement and drilling deeper with the inner rod only. This method also required the use of a tricone bit.

Drill cuttings were blown up to surface via the centre rods and collected in a cyclone. Drill cuttings were collected from the cyclone every 5 feet of advanced depth. After being logged, some of the cuttings were placed in chip boxes for later observation.

Two of three boreholes drilled were completed as monitoring wells. One well was completed as a multi-level. Each monitoring well was completed with 2 inch diameter (5.04 cm) PVC pipes with slotted screens ranging from 1.5 to 3 meters in length. Screens were installed in a sand pack and the annulus space above the screen interval was sealed with bentonite pellets. Difficulties were encountered during the installation of MW2001-3. The open hole conditions (i.e. no outer casing advanced at greater depth) and the small diameter of this borehole (10.2 cm) caused bridging of the bentonite pellets when creating a seal. As a result, there are sections of the annular space that are open. These open sections may extend anywhere from 34 to 53 metres depth.

The following table (Table 1) provides monitoring well installation details. Figure 1 displays the location of the new monitoring wells and boreholes. A summary of borehole and monitoring well construction is provided on the drill logs in Appendix A.

Table 1 Monitoring Well Construction Details

Monitoring Well	*Top of Screen*	*Bottom of Screen*
2001-2B	12.3	13.9
2001-2A	25.8	27.3
2001-3	58.5	61.6

4.3 Groundwater Sampling

Groundwater samples were collected from monitoring wells 2001-2B (13.9 m depth) and 2001-3 (61.6 m depth). Groundwater was sampled using dedicated Waterra™ inertial lift pumps. Groundwater samples were placed in laboratory provided 250 ml bottles preserved with HCl. Monitoring wells were purged 5 x the well volume before samples were collected. Groundwater samples were stored in coolers with ice packs and were delivered to the laboratory within three to five days of sample collection.

Monitoring well 2001-2A was dry and was not sampled.

4.4 Analyses

Groundwater samples were analysed at ALS Analytical Laboratory located in Burnaby, British Columbia. ALS is certified and accredited by the Canadian Association of Environmental Analytical Laboratories (CAEAL). Samples were analyzed for dissolved metals, pH, total dissolved solids, sulphate, alkalinity and total cyanide.

5. Investigation Results

5.1 Seismic Survey

The results of the seismic survey are illustrated on Figure 2. The wave velocities were observed to range from 1610 m/s to 2014 m/s in the overburden and from 3298 m/s to 4500 m/s in the bedrock. The differences in velocity (velocity refraction) are interpreted to define a boundary contact between the overburden and bedrock. Results indicate that bedrock depressions are present at chainage lengths 840 metres and 930 metres.

Final locations for boreholes 2001-1, 2001-2 and 2001-3 were determined in the field to investigate the bedrock depressions.

5.2 Soil Geology

Borehole logs (Appendix A) indicate that the subsurface geology is mainly comprised of a silt and clay till. The till unit generally extends to bedrock. In borehole 2001-1 the clay till unit was observed to extend to the depth of the borehole completed at 38.1 metres below grade. In this borehole, the clay content increases at depths of 7.6 to 9.1 meters and silt content increases at 27.4 meters depth. This hole was dry.

Drill logs from borehole 2001-2 indicate that, in general, clay tills extend from surface to the depth of the borehole drilled (33.5 meters below grade). However a gravel unit was noted at 15.2 to 16.8 meters below grade. This gravel unit did contain some silts and clays. Water was noted at 12.2 meters below grade, however, no water was noted at greater depths.

Borehole 2001-3 was drilled to greatest depth (61.6 metres below grade). The clay till unit in this borehole is observed to extend to 50 metres depth. At greater depths gravel units are noted. Bedrock was encountered at 59.4 metres depth.

5.3 Hydrogeology

Water was encountered in wells 2001-2B (well screen at 12.3 – 13.8 metres depth). However, the deeper monitoring well (2001-2A at 26.7-27.2 metres depth) contained no water after purging. This indicates that water encountered at 12.3 meters is perched. Depth to the water table in this well was measured at 4.18 metres below casing top. The fact that no water was encountered in MW2001-1 and water was only observed in the shallow well MW2001-2B indicates that a perched water zone exists at the site. Other monitoring wells in this area (P94-3 and P94-2; Figure 1) may also intercept groundwater from this perched zone.

Water was encountered in monitoring well MW 2001-3 at 36.68 metres below the casing top. This well is screened at the overburden/bedrock contact. The water sampled from this zone is likely water that travels along this contact.

5.4 Analytical Results

The following table (Table 2) provides the analytical results from the groundwater samples collected in MW2001-2B and MW 2001-3.

Detectable zinc concentrations were observed in both wells. Sulphate concentrations were observed to be elevated (199 mg/L) in groundwater sample MW2001-2B when compared to sulphate concentrations (89 mg/L) in MW2001-3 that screens the bedrock/overburden contact.

Table 2 Groundwater Analytical Results

			Monitoring Well:	2001-2B	2001-3
			Sample ID:		
			Date sampled:	9/13/01	9/13/01
Parameter		**Units**	**Lab MDL**		
PHYSICAL TESTS					
pH		pH units	0.01	8.09	8.05
Hardness ($CaCO_3$)		mg/L	0.7	511	389
Dissolved Solids			10	690	583
METALS DISSOLVED					
Aluminum Dissolved		mg/L	0.005	0.01	0.013
Antimony Dissolved		mg/L	0.0005	0.017	0.0262
Arsenic Dissolved		mg/L	0.0005	0.01	0.0026
Barium Dissolved		mg/L	0.02	0.05	0.04
Beryllium Dissolved		mg/L	0.001	<0.002	<0.01
Boron Dissolved		mg/L	0.1	<0.1	<0.1
Cadmium Dissolved		mg/L	0.00005	0.0002	0.00062
Calcium Dissolved		mg/L	0.1	89.9	68.3
Chromium Dissolved		mg/L	0.001	<0.002	<0.001
Cobalt Dissolved		mg/L	0.0003	0.0015	0.0013
Copper Dissolved		mg/L	0.001	<0.002	0.001
Iron Dissolved		mg/L	0.03	<0.08	0.34
Lead Dissolved		mg/L	0.001	0.002	<0.0005
Magnesium Dissolved		mg/L	0.1	69.6	53
Manganese Dissolved		mg/L	0.0006	0.213	1.26
Mercury Dissolved		mg/L	0.00005	<0.00005	<0.00005
Molybdenum Dissolved		mg/L	0.002	0.028	0.007
Nickel Dissolved		mg/L	0.002	0.009	0.003
Potassium Dissolved		mg/L	2	11	3
Selenium Dissolved		mg/L	0.002	<0.002	<0.001
Silver Dissolved		mg/L	0.001	<0.001	<0.0005
Sodium Dissolved		mg/L	2	52	24
Thallium Dissolved		mg/L	0.0004	<0.0004	<0.0002
Tin Dissolved		mg/L	0.001	<0.001	<0.0005
Titanium Dissolved		mg/L	0.01	<0.01	<0.01
Vanadium Dissolved		mg/L	0.03	<0.03	<0.03
Zinc Dissolved		mg/L	0.05	0.007	0.014
ANIONS					
Alkalinity (CaCO3)			-	476	473
Sulphate			-	199	89
Total Cyanide			-	0.022	<0.005

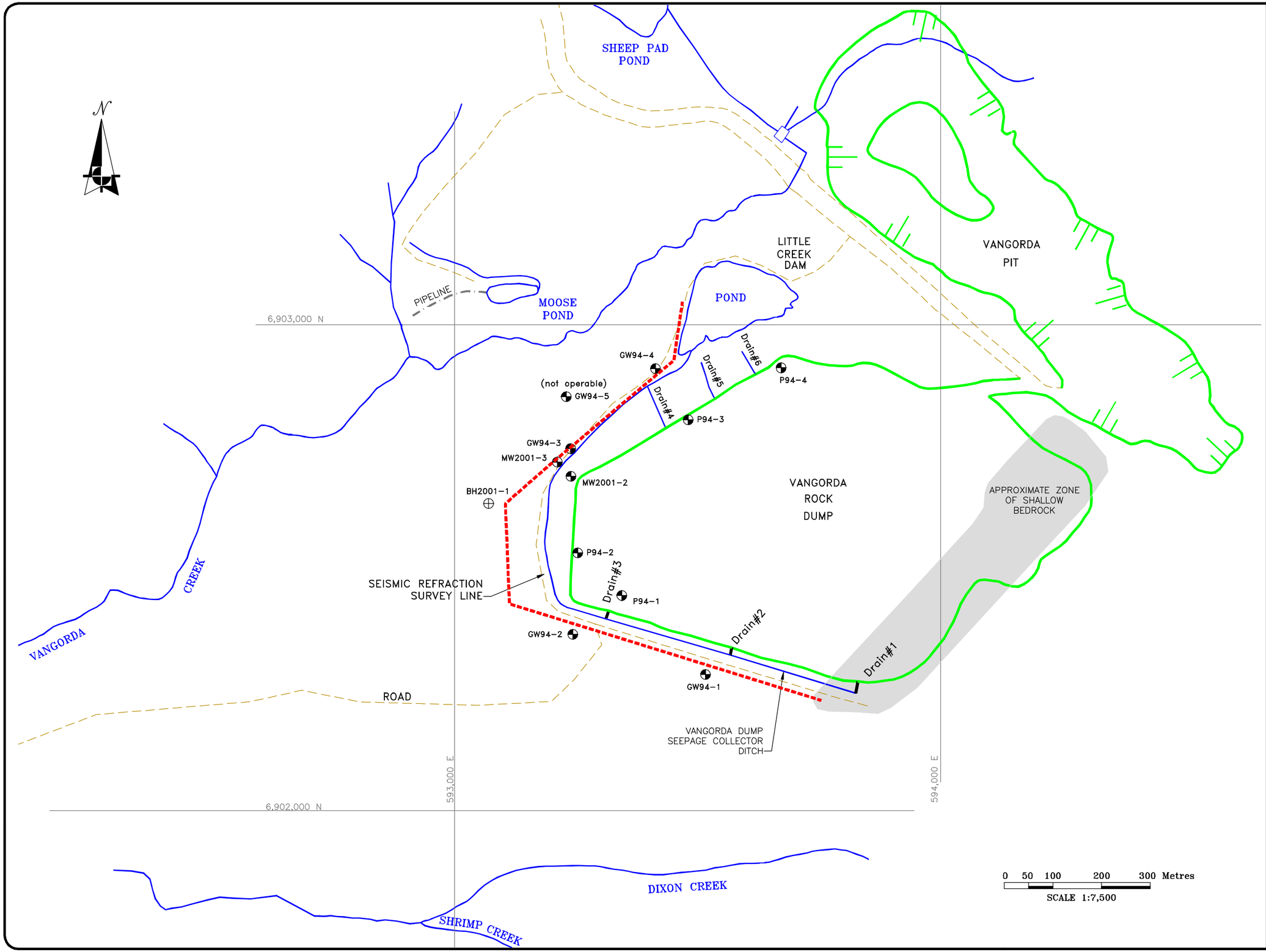
6. Summary and Recommendations

The following provides a summary of the 2001 field investigation at the Vangorda Rock Dump:

- A geophysical (seismic) survey was conducted around the perimeter of the dump to map the bedrock/overburden contact. The results of the survey indicated depressions in the bedrock surface with depths of approximately 60 m below ground surface at locations near the western "nose" of the dump.
- A borehole drilling and monitoring well installation program was conducted at the site. Difficulties were encountered using the air rotary drilling method to drill to depths greater than approximately 35 meters below grade in the clay till overburden. MW2001-3 could only be completed at greater depth by advancing the smaller diameter inner rods only. The smaller diameter borehole and open hole conditions presented well bridging problems during well construction.
- The site geology indicates that a clay till extends from ground surface to the bedrock contact. Gravel layers/seams were noted at depths of 15 m and greater than 50 metres below grade.
- Groundwater was encountered in monitoring wells MW2001-2B (well screen placed at 12.3 – 13.8 metres depth) and in well MW2001-3 (well screen placed at 58.6 –61.6 metres depth). However, groundwater was not encountered in monitoring well MW2001-2A (well screen at 26.7 – 27.2 m depth). This suggests that MW2001-2B and other existing wells in the area are screened in a perched water bearing zone and not the true water table.
- Detectable zinc concentrations were observed in groundwater sampled from wells MW2001-2B (0.007 mg/L) and MW2001-3 (0.014 mg/L). Sulphate concentrations were observed to be 199 mg/L and 89 mg/L in monitoring wells MW2001-2B and MW2001-3 respectively.

Based on the results of the 2001 field investigation, the following recommendations are made:

- Monitoring Wells MW2001-2B and MW2001-3 should be sampled on the same twice per year schedule as is established for other monitoring wells in the area.
- Future deep drill projects in the area should consider alternate drilling techniques such as sonic or mud rotary.
- Future drill investigations should consider the installation of additional monitoring wells at the bedrock interface that would increase the sampling of subsurface flow along this contact. Further, future drill investigations should consider the installation of a monitoring well upgradient of the rock dump in the zone of shallow bedrock that would enhance the measurement of local flow gradients.



LEGEND

- ROAD
- CREEK, DITCH, POND
- PIT AND ROCK DUMP
- SEISMIC REFRACTION SURVEY LINE
- P94-2 — MONITORING WELL INSTALLED BEFORE 2001
- MW2001-1 — MONITORING WELL INSTALLED IN SUMMER 2001
- BH2001-1 — BOREHOLE INSTALLED IN SUMMER 2001

SOURCE OF DRAWING:

FILE VGDUMP.DWG DATED OCTOBER 1995 BY ANVIL RANGE MINING CORPORATION

SEISMIC DATA PROVIDED BY AURORA GEOSCIENCES LIMITED. SUMMER 2001

DRAWING INFORMATION:	
REVIEWED BY:	LZ
DRAWN BY:	CPW
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PROJECT NUMBER:	21-906
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REVISION:	0

SITE PLAN OF VANGORDA ROCK DUMP

2001 FIELD INVESTIGATION
VANGORDA ROCK DUMP SITE
FARO, YUKON
DELOITTE & TOUCHE

Gartner Lee Limited

Figure No. 1

593, 667E
6, 902, 417N
593, 036E
6, 902, 606N
593, 063E
6, 902, 832N
593, 122E
6, 902, 928N
593, 382E
6, 903, 144N
593, 488E
6, 903, 179N

LINE 1 | LINE 2 | LINE 3 | LINE 4 | LINE 5

SPREAD 1 | SPREAD 2 | SPREAD 3 | SPREAD 4 | SPREAD 5 | SPREAD 6 | SPREAD 1 | SPREAD 2 | SPREAD 1 | SPREAD 1 | SPREAD 2 | SPREAD 3 | SPREAD 1

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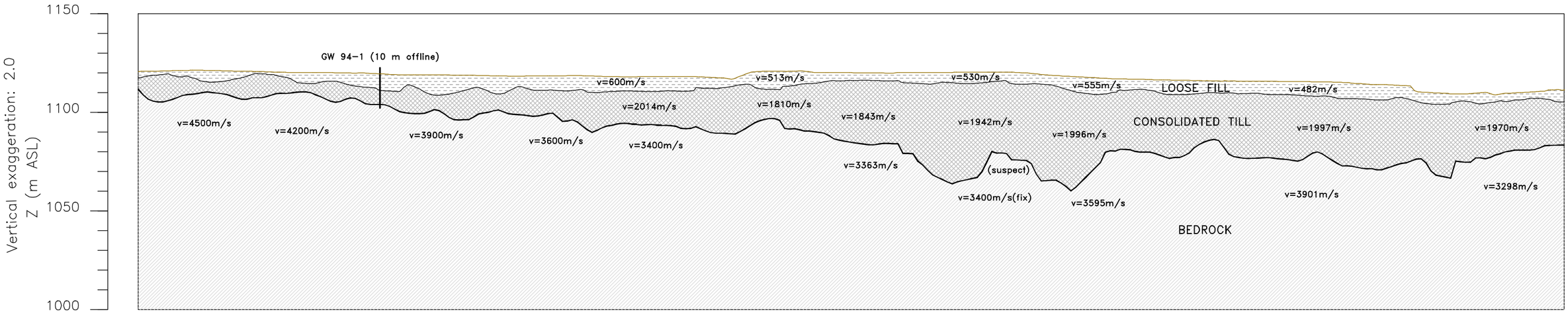

SEISMIC REFRACTION SURVEY

Instrument: Geometrics S-24
Phone spacing: 5 m
Spread: 115 m (24 channels)
Shots: 60 m off-end, 5 m off-end, midspread
Record: 250 microsecond sampling / 512 ms record
Analog pre-acquisition filter: 500 Hz high cut

0 100 200 Metres
SCALE 1:4000
HORIZONTAL SCALE

500, 000E
6, 600, 000N - UTM registration point

SOURCE OF DRAWING:

SEISMIC DATA PROVIDED BY AURORA GEOSCIENCES LIMITED. SUMMER 2001

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RESULTS OF SEISMIC SURVEY - VANGORDA ROCK DUMP

2001 FIELD INVESTIGATION
VANGORDA ROCK DUMP SITE
FARO, YUKON
DELOITTE & TOUCHE

Gartner Lee Limited

Figure No. 2

Appendices

Appendix A

Borehole Logs