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DELTA (E.M.D.) (PROPRIETARY) LIMITED

Excavatability Assessment at the Delta site in Nelspruit

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REPORT

Report Number: 1401660-13038-5

Distribution:

1 x copy to Delta (E.M.D.) (Proprietary) Limited
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Golder Associates

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1.0 BACKGROUND

Delta (E.M.D.) (Proprietary) Limited (hereafter referred to as Delta) is a manufacturing facility located in Nelspruit, Mpumalanga, produces electrolytic manganese dioxide (MnO2; EMD), which is an inorganic compound used for dry-cell batteries such as alkaline and zinc-carbon batteries. Manganese ore is obtained from Black Rock (in the Northern Cape), where the ore is calcined, milled and classified before being transferred to Delta for further processing.

The site is located within the industrial area of Nelspruit, Mpumalanga, which falls within the ambit of the Mbombela Local Municipality, a substructure of the Ehlanzeni District Council. The Crocodile River is located approximately 200 m from the northern site boundary. The area between Delta and the Crocodile River is undeveloped land apart from the R2296, Kanyamazane road. Delta is bordered by a canal to the south-west.

As part of the environmental assessment required for the decommissioning of the Delta site, Golder Associates (Pty) Ltd (Golder) proposed to undertake a geotechnical investigation to determine the nature of the underlying strata for potential excavation. At the time of the investigation it was considered that a trench may be required to up to 2m deep along a length of approximately 200m to 300m; however such would be confirmed during any subsequent rehabilitation planning works.

2.0 OBJECTIVES

These works were required in order to inform a remediation solution under consideration which would involve potential excavation of a shallow trench either on-site along the northern boundary road or outside of the site boundary along the road to the north of the site.

Therefore, the specific objectives of the exercise were to:

- Determine the excavatability of the underlying strata along the northern boundary of the site; and
- Determine the excavatability of the underlying strata along the road to the north of the site.

3.0 STUDY APPROACH

The works represented a multi-phased investigation utilising both non-intrusive and intrusive site investigation and sampling techniques. Specifically the investigation included the following key components:

- Desktop study to determine probable ground conditions;
- Geophysical survey to determine depth of weathering across the site;
- Borehole drilling and core logging;
- Point load testing to determine rock strength; and
- Excavatability assessment and reporting.

4.0 DESK TOP STUDY

4.1 Site Location

The site is located within the industrial area of Nelspruit, within the Mbombela (MP322) Local Municipality, a sub-structure of the Ehlanzeni District Council (DC32). A site location drawing is provided as Figure 1. The Delta site is located immediately adjacent to the Manganese Metal Company (MMC) in Heyneke Street, Extension 12. The land and buildings belong to Delta and MMC.

4.2 Topography

The surface elevation in the study area varies from 640 mamsl in the southwest and 570 mamsl in the northeast. The site is terraced and slopes towards the Crocodile River.

4.3 Geological Setting

The regional geology comprises Archaean granite of the Nelspruit Suite in the west and the biotite gneiss and migmatite in the east. Two regional faults running NW-SE are located more than 1km NE of the site. It is capped to the south by the granite of the Nelspruit granite suite which is characterised by basic dykes and sill's intrusion.

The local area is underlain by medium- to very coarse-grained granite which has been intruded by numerous basic dykes and sills. The granite is highly weathered from 0 to +/-15m. North-south trending geological structures e.g. dykes or fractured zones are suspected to be present across the site. Additional information relating to ground conditions identified at the site can be found in the Groundwater Assessment (Report number 1401660-13021-3).

4.4 Hydrogeological Setting

The site lies within the Crocodile catchment. General drainage in the area is towards a tributary of the Crocodile River to the northwest and directly to the Crocodile River to the north. The highly weathered granite and granitic gneiss is associated with a shallow perched aquifer with weathered zones and the water table is shallow, at some places less than 1 m below ground level. Aquifers identified in this geology type are usually poorly developed (low yielding) and controlled mainly by the presence of weathering in the upper horizons.

4.4.1 Groundwater Flow Direction

Groundwater elevations obtained during site visits in March 2014 and August 2014 indicated that groundwater flow across the site is generally in a northerly direction. However, an easterly groundwater flow direction is evident towards the eastern side of the Delta site.

5.0 GEOPHYSICAL INVESTIGATION

5.1 Introduction

In order to assess the possible depth of weathering and/or extensive fracturing and provide an indication of variations in rock strength with increasing depth, geophysical surveying using electrical resistivity methods was utilised along sections of the site where it was proposed that trenches could potentially be constructed i.e. along the internal northern boundary road of the site and along the road to the north of the site.

5.2 Description of Technique Employed

Resistivity surveying allows the mapping of variations in ground resistance (or its inverse conductance) both laterally and with depth. Ground resistance depends on electronic conductance that takes place as a result of the physical and chemical properties of the subsurface material. In this case, the conductance of water contained in the pores, fractures and weathered zones on site was interpreted to spatially determine the areas potentially subject to elevated concentrations of contamination.

This interpretation is based on the simple chemical principle that ions in the water allow ionic current flow to take place. Effectively then the resistance of a rock formation or structure depends on the percentage of pore or fracture space (filled with water) in the rock and the conductivity of the water, which itself depends on the dissolved solids content.

The resistivity imaging survey was conducted using the Wenner survey protocol with 5m electrode spacing and a total cable length of 200m, to achieve an investigation depth of 30m. A 2D resistivity image is generated from the survey data showing the apparent resistivity of the sub-surface. Zones with lower resistivity may represent increased salinity or increase in clay content in the weathered profile of rocks.

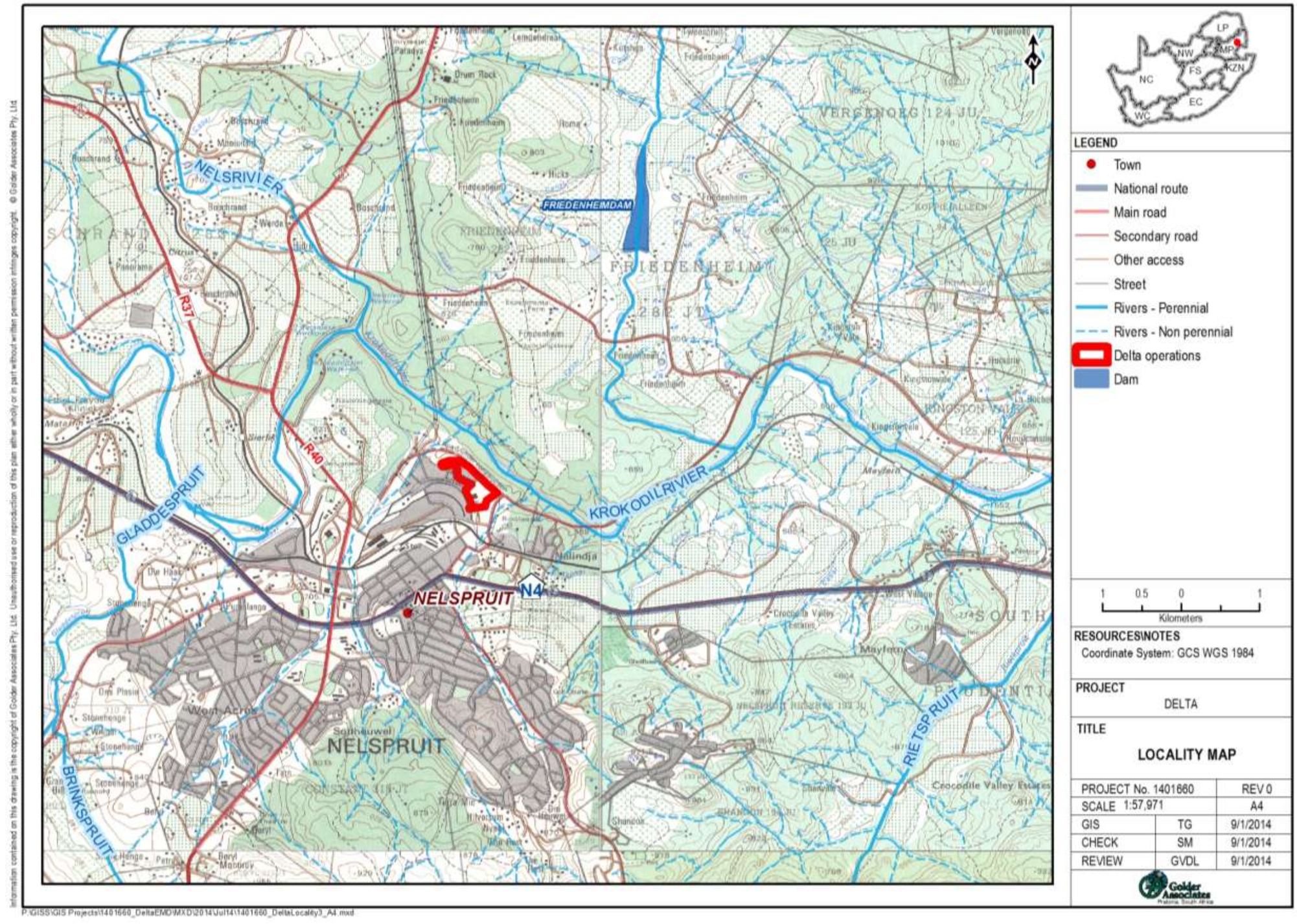

Figure 1: Site Location

5.3 Location of the Geophysical Survey Lines

The geophysical traverse lines to be utilised for the geotechnical assessment (Line DE01 and Line DE03) were undertaken in combination with other geophysical traverse lines (Line DE02, Line DE04, Line DE05) being undertaken as part of a groundwater investigation to assess the possible extent of contamination present on the site.

For completeness the geographical coordinates of the start and end of all five traverse lines are included in Table 1 with their spatial distribution shown in Figure 2. As Lines DE01 and DE03 were undertaken primarily for the purpose of a geotechnical assessment of the underlying strata only they will be considered further in this report. However, details relating to the assessment of the other three geophysical traverses can be found in Groundwater Report (Report 1401660-13021-3).

The geophysical traverse lines (Line DE01 and Line DE03) were undertaken along an open roadway across the northern boundary of the site and along a section of the road to the north of the facility. The extent to which each of the two lines could be extended was limited by:

- **On site** – the availability of sufficient lengths of accessible roadway on site and presence of underground services and access; and
- **Off-site** – safety limitations along the road to the north by which the final section was limited to that section which allowed sufficient observation viewpoints and distance between the geophysical team and passing vehicles.

Descriptions of the position of the survey lines that were undertaken for geotechnical purposes are provided below:

- Line DE01: traversed from SE - NW along the boundary fence within the site, to the northeast of the plant; and
- Line DE03: traversed from SE – NW situated outside to the north east of the plant, along the main road to Kanyamazane.

Table 1: Geographical attributes of the Geophysical Traverses

Traverse	Starting Latitude (Decimal degrees)	Starting Longitude (Decimal degrees)	Finishing Latitude (Decimal degrees)	Finishing Longitude (Decimal degrees)
Line 1 - DE01	-25.4587	30.98722	-25.4575	30.98598
Line 2 - DE02	-25.4561	30.98244	-25.4596	30.98784
Line 3 - DE03	-25.4606	30.98529	-25.4588	30.98514
Line 4 - DE04	-25.4602	30.98690	-25.4578	30.98413
Line 5 - DE05	-25.4599	30.98746	-25.4580	30.98528

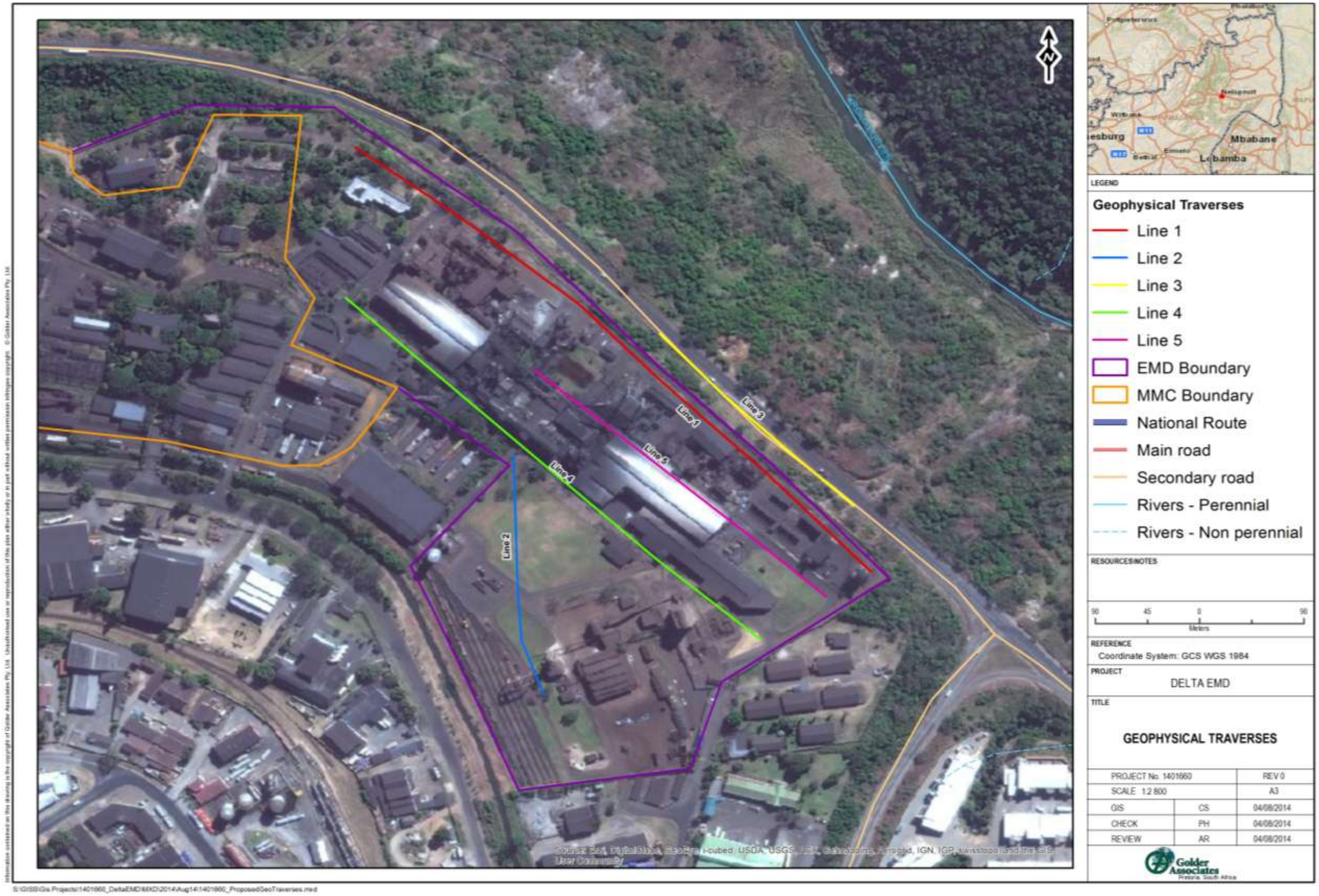

Figure 2: Geophysical Traverses

5.4 Geophysical Interpretation

The interpreted sections for Lines DE01 and DE03 are provided respectively as profiles in Figure 3 and Figure 4.The geophysical surveys and subsequent processing identified the changes in resistivity along the two traverses. Changes in resistivity are taken to indicate changes in the concentration of highly conductive material (e.g. water) and therefore such changes can be indicative of potential fracturing, depth of weathering, and the presence of geological structures in the solid strata.

Traverse DE01

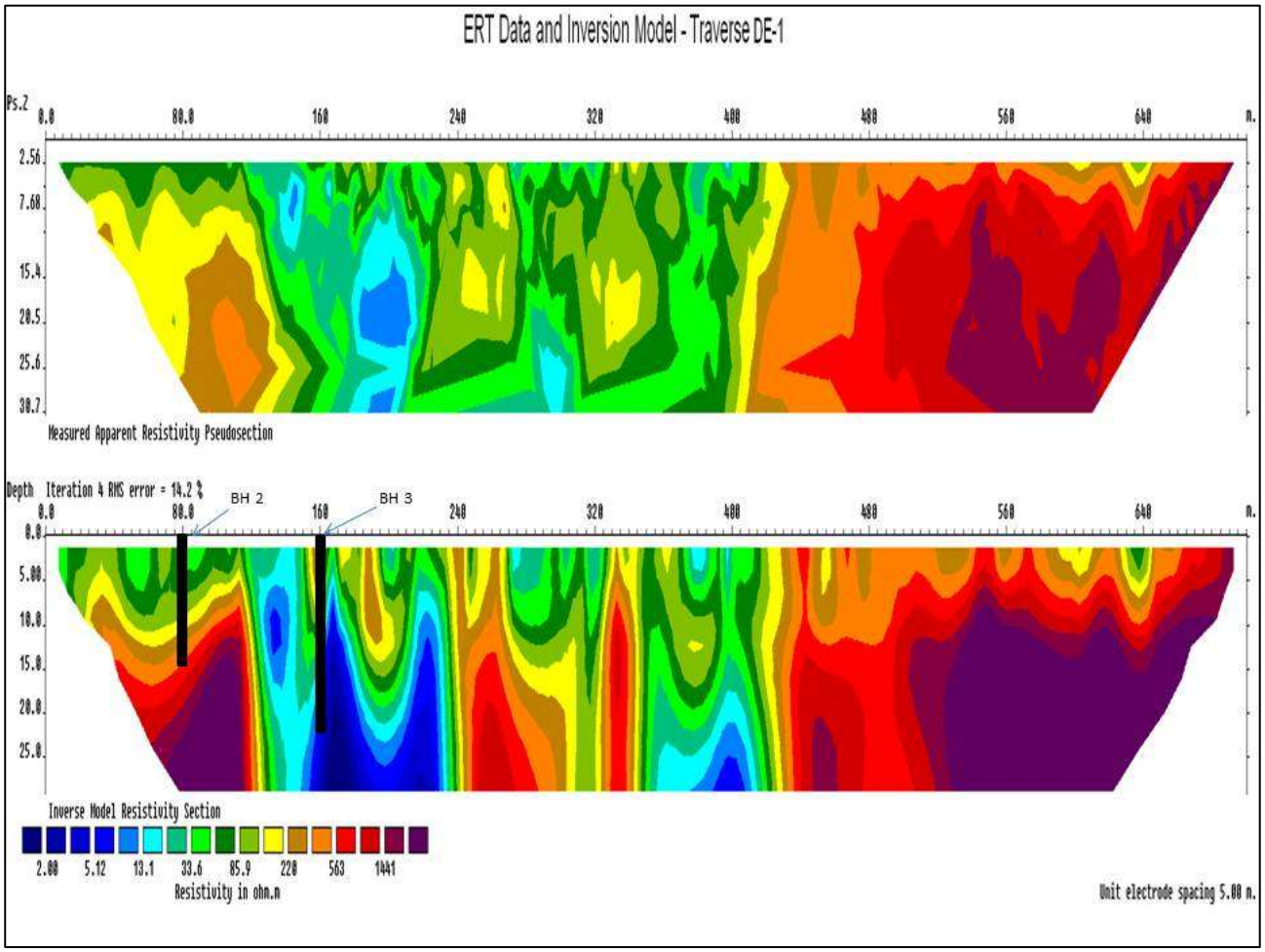

Figure 3: Line 1 - DE01

Traverse DE01 was 600m long and was undertaken in South-East to North-West direction, within the site, along the internal road forming the northern boundary of the site. Two sections of low resistivity were identified along the traverse (120m to 230m; 350m to 415m – *blue colour*) and separated by area of high resistivity (230m to 350m – *red/brown colour*). To the eastern end of the line (<120m) and western end of the line (>350m) area of high resistivity are also present; these areas of high resistivity correlate with site observations that indicate near proximity to an elevated rock level forming the south-eastern boundary of the site to the east and general rise in site topography to the west.

Areas of low resistivity (33.6 to 85.9 ohm.m – *green colour*) are taken to be indicative of highly weathered strata. Fresh rock with a reduced potential for fracturing is considered to be indicated by the 220 ohm.m boundary (*yellow/brown colour*). The areas of very low resistivity (<13.1 ohm.m – *blue colour*) are considered to be representative of areas of increased weathering and indicative of areas where near surface highly conductive contamination within a shallow weathered aquifer may be present on site; the presence of conductive material within the blue zone has the effect of masking the interpretation of the underlying strata such that the depth to which weathered rock extends appears deeper than may actually be the case. It is considered that the depth to fresh rock is greater in the blue areas however it is suggested that such may only be in the order of 1 or 2 metres. This has been confirmed by drilling on the eastern side of the site (see Section 6).

Traverse DE03

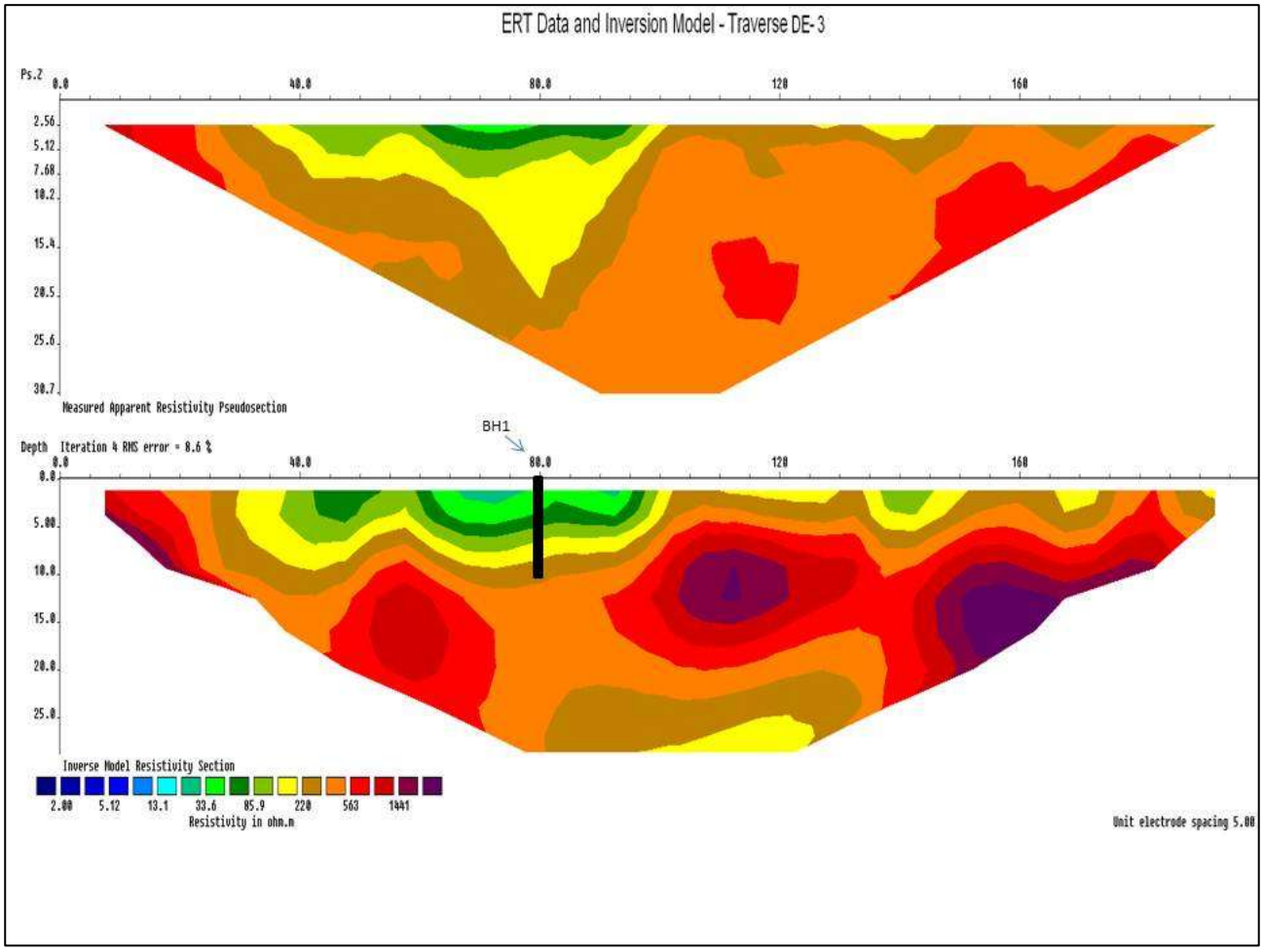

Figure 4: Line 3 - DE03

Traverse DE03 was 200m long and was undertaken in a South-East to North-West direction outside of the site along the edge of the hard-shoulder of the road located along the northern boundary of the site. The start point of DE03 was offset (due to site access restraints) from the relative starting position of Line DE01 by a distance of approximately 40m. The survey identified relatively low to moderate resistivity readings in section of the survey extending from approximately 35m to 100m. This section is considered to represent a zone of increased weathering with top of fresh rock taken to be between 6m and 9m below ground level (approximate resistivity reading of 220 ohm.m – *yellow/brown colour*); it is also considered to be a section where near surface seepage of waters and possible contaminant migration may have occurred. Outside of this section high resistivity strata has been identified and this is considered to be representative of fresh unweathered strata in the near surface.

6.0 BOREHOLE DRILLING

6.1 Borehole Drilling

Three geotechnical investigation cored boreholes were drilled at NWD4 size during the investigation. The first borehole was located off-site within the layby adjacent to the road to the north of the site. The other two boreholes were located on-site along the northern boundary road in front of the Eastern Plant. Following review of the geophysical survey results the two on-site boreholes were positioned to target the high resistivity zone to the east of the site and the very low resistivity zone also located to the east of the site. All boreholes were installed with 50mm diameter piezometers taken to the base of the borehole, backfilled with fine quartz sand and finished with a bentonite seal and a flush borehole cover.

Borehole co-ordinates for the three geotechnical boreholes are provided in Table 2. A borehole location drawing is provided as Figure 5. Borehole BH1 was drilled approximately 80m, along Geophysical Traverse Line 3 - DE03. Borehole BH2 and BH3 were drilled approximately 80m and 160m respectively along Geophysical Traverse Line 1 - DE01. Indicative borehole locations along the geophysical sections are shown on Figure 3 and Figure 4.

Table 2: Coordinates of the newly installed boreholes

BH ID	Latitude (Decimal degrees)	Longitude (Decimal degrees)	Elevation (mamsl)	Drilled Depth (mbgl)	Plain PVC Casing (50 mm)		Slotted PVC (50mm)	
					From (m)	To (m)	From (m)	To (m)
BH1	-25.45836	30.98669	617	9.41	0	1	1	9.41
BH2	-25.45914	30.98729	622	14.90	0	1	1	14.90
BH3	-25.45854	30.98668	624	22.15	0	1	1	22.15

6.2 Borehole Logging

Borehole logs for the three geotechnical boreholes are provided in Table 3, Table 4 and Table 5

TCR = Total Core Recovery; SCR = Solid Core Recovery; RQD = Rock Quality Designation; IF = Fracture Spacing

Table 3: BH1 Log

From (mbgl)	To (mbgl)	Description	TCR	SCR	RQD	IF(mm)
0	0.9	Very soft red-brown becoming yellow very gravelly sandy clay. MADE GROUND.	-	-	-	-
0.9	2.13	Weak completely weathered grey granite recovered as gravel. [RESIDUAL GRANITE].	28	0	0	-
2.13	3.63	Weak to strong moderately weathered grey to pink highly fractured coarse grained GRANITE. Highly fractured with fracture spacing at 60mm; brown staining along discontinuity surfaces.	80	41	23	60
3.63	5.93	Moderately strong to very strong moderately weathered pink to grey highly fractured GRANITE. Highly fractured with fracture spacing at 80 to 100mm. Fractures orientated at 45 degrees. *Note. The base of this section is considered to be the base of the weathered aquifer.*	85	85	70	100
5.93	9.41	Fresh very string to extremely strong pale grey to pink coarse grained GRANITE. Fracture spacing at 400 to 700mm.	100	100	100	700

Table 4: BH2 Log

From (mbgl)	To (mbgl)	Description	TCR	SCR	RQD	IF(mm)
0	0.30	Loose very wet dark brown very gravelly clayey sand. MADE GROUND.	-	-	-	-
0.30	1.88	Soft dark grey gravelly very clayey/very sandy clay. MADE GROUND.	-	-	-	-
1.88	5.15	Very weak/weak highly weathered/completely weathered pale grey coarse grained GRANITE.	33	17	13	-
5.15	6.32	Very weak completely weathered pale beige coarse grained granite. Recovered as gravel [RESIDUAL GRANITE].	31	7	0	-
6.32	7.12	Very weak highly weathered pale brown GRANITE. Fractures approximately horizontal, spaced at 90mm and stained brown.	100	5	66	90
7.12	8.62	Strong to very strong slightly weathered pale grey coarse grained GRANITE. Sub-vertical fractures with much red-brown staining. Near horizontal fractures at 180mm spacing. *Note: vertical fractures predominate.*	84	15	15	180
8.62	9.80	Strong to very strong moderately weathered pale cream coarse grained GRANITE with occasional coarse phenocrysts of quartz. Highly weathered along fractures displaying surface pitting. Fracture spacing 130 to 200mm. Fractures orientated at 60 degrees to the horizontal. Significant fracture zone at 8.74 to 8.94m	100	67	67	200
9.80	11.40	Strong to very strong dark grey moderately weathered highly fractured fine grained DOLERITE. Much brown and red staining along fractures. Fractures predominantly vertical but where not then 60 degrees. Significant fracture zones: 9.80 to 10.00; 10.22 to 10.50; 10.90 to 11.50 (vertical). *Note. Possible dolerite intrusion along fracture zone/fault?*	73	27	20	-
11.40	14.90	Very strong fresh coarse grained pink and grey GRANITE. Weathered fractures closely spaced to 11.90m then spaced at 330mm. Note drilling induced fractures fresh and horizontal at 400mm spacing. *Note. This represents a transition zone between the weathered aquifer and underlying fresh granite. Majority of groundwater flow in this zone considered to be above 12.60m.*	100	87	85	330

Table 5: BH3 Log

From (mbgl)	To (mbgl)	Description	TCR	SCR	RQD	IF (mm)
0	2.70	Loose dark brown gravelly very clayey sand with occasional cobbles of coarse grained granite. MADE GROUND.	-	-	-	-
2.70	5.10	Very weak completely weathered red-brown coarse-grained granite. Recovered as highly fractured core, sand and gravel. [RESIDUAL GRANITE].	29	0.18	0	-
5.10	7.00	Very weak highly weathered pale brown GRANITE. Fracture spacing typically 90mm; fracture condition rough.	100	16	16	90
7.00	8.18	Very strong fresh pink coarse grained GRANITE. Fracture spacing typically 300mm. Fractures typically along coarse grained sections within core.	100	100	100	300
8.18	12.75	Very strong to extremely strong pale grey GRANITE. Fractures orientated at 15 to 20 degrees to the horizontal Fractures widely spaced. Fractured zones: 8.38m to 8.43m; 11.74m to 11.84m; 12.20 to 12.49m.	100	100	76	700
12.75	17.12	Extremely strong fresh grey GRANITE. Weathered along fractures with brown staining. Fractures orientated at 15 to 20 degrees to the horizontal. Fractures widely spaced. Fracture Zones: 13.60 to 13.90; 15.50 to 15.62; 15.76 to 15.96. *Note. Major water bearing zone extending to 15.62m bgl.*	100	100	82	700
17.12	22.15	Extremely strong pink and grey coarse-grained GRANITE. *Note. 20.45m to 20.65m mica rich band.*	100	100	98	700

Figure 5: Borehole Location Drawing

7.0 POINT LOAD TESTING

Point load testing was undertaken on selected sections of core. Results of the point load testing are provided in Table 6.

Table 6: Point Load Testing Record

Borehole	From (m)	To (m)	A/D	Height (mm)	Width (mm)	Load at Failure (kN)	Notes	Estimated UCS* (kN)	Rock Strength Assessment
BH1	2.42	2.55	D		50	4.07		98	High
	2.42	2.55	A	48		3.70		89	High
	2.80	2.90	D		50	21.60		>250	Extremely High
	2.80	2.90	A	70		>16.50	Incorrect Failure	n/a!	n/a
	2.96	3.04	D		50	5.60		134	Very High
	3.76	3.88	D		50	13.03	Failure along joint @ 60	>250	Extremely High
	3.88	4.23	D		50	14.60		>250	Extremely High
	3.88	4.23	A	66		5.76		138	Very High
	3.88	4.23	D		50	13.23		>250	Extremely High
	3.88	4.23	D		50	17.01		>250	Extremely High
	3.88	4.23	D		50	16.55		>250	Extremely High
	3.88	4.23	A	58		17.26		>250	Extremely High
	6.00	6.23	D		50	25.63		>250	Extremely High
	6.00	6.23	D		50	26.13		>250	Extremely High
	6.00	6.23	D	52		23.38		>250	Extremely High
	6.00	6.23	A		50	17.75		>250	Extremely High
BH2	5.03	5.15	D		50	6.00		144	Very High
	5.03	5.15	D		50	6.76		162	Very High
	5.03	5.15	A	54		5.83		140	Very High
	6.95	7.12	D		50	2.24		54	High
	6.95	7.12	D		50	1.98		48	Medium High
	8.12	8.32	D		50	0.50	Failure along vertical	12	Weak
	8.12	8.32	D		50	4.76		114	Very High
	8.92	9.22	D		50	5.58		134	Very High
	8.92	9.22	D		50	2.65	Failure along vertical	64	High
	8.92	9.22	D		50	4.90		118	Very High
	10.00	10.26	D		50	4.18		100	Very High
	8.92	9.22	D		50	5.58		134	Very High

Borehole	From (m)	To (m)	A/D	Height (mm)	Width (mm)	Load at Failure (kN)	Notes	Estimated UCS* (kN)	Rock Strength Assessment
	10.00	10.26	A	51		1.55	Failure along fracture	37	Medium High
	11.20	12.00	D		50	14.66		>250	Extremely High
	11.20	12.00	A	60		>10.00	Incorrect Failure	n/a	n/a
	12.00	12.38	D		50	14.22		>250	Extremely High
	12.00	12.38	A	67		18.70		>250	Extremely High
BH3	5.50	5.60	D		50	2		42	Medium High
	5.50	5.60	A	60		1.76		40	Medium High
	5.60	5.70	D		50	1.66		34	Medium High
	6.80	6.95	D		50	1.39		36	Medium High
	6.80	6.95	A	58		1.52		36	Medium High
	7.00	7.24	D			13.46		>250	Extremely High
	7.00	7.24	D			14.00		>250	Extremely High
	7.00	7.24	D			10.00		240	Very High
	7.00	7.24	D			8.46	Failure along a joint @ 60	203	Very High
	7.00	7.24	A	65		16.45		>250	Extremely High
	7.00	7.24	A	75		22.29		>250	Extremely High
	7.24	7.32	A	66		>15.18	Incorrect Failure	#n/a	n/a
	7.24	7.32	D		50	14.72		>250	Extremely High
	7.32	7.40	D		50	12.16		>250	Extremely High
	7.32	7.40	A	65		16.45		>250	Extremely High
	8.00	8.18	D		50	18.15		>250	Extremely High
	8.00	8.18	D		50	12.02		>250	Extremely High
	8.00	8.18	A	63		17.18		>250	Extremely High
	8.70	8.80	D		50	13.46		>250	Extremely High
	8.70	8.80	A	55		7.18	Failure along a joint @ 60	172	Very High
	9.58	9.68	D		50	27.38		>250	Extremely High
	13.90	14.05	D		50	16.55		>250	Extremely High

*UCS=24*Is(50)

8.0 CONCLUSIONS

The following sections provide conclusions with regards to ground conditions identified at the site and techniques for excavation that could potentially be employed if constructing trenches along the northern boundary of the site or along the road to the north of the site.

8.1 Summary

The site is underlain by made ground, weathered granite and fresh granite. The made ground is a clayey and sandy fill which extends to approximately 1m to 3m below ground level on site and 1m bgl off-site. The weathered granite varies in weathering grade between completely weathered (near the surface) and slightly weathered (closer to the fresh rock) and extends to between 12m and 15m bgl on site and an estimated 1m to 6m bgl off-site. The weathered rock is highly fractured and displays evidence of staining associated with water flow through the fractures. The weathered rock on site to a depth of 11.40m is weak to extremely strong and has a Rock Quality Designation (RQD) that varies between very poor and fair. Below this depth the RQD is good to excellent. The weathered rock off-site is weak to strong and similarly has a RQD that varies between very poor and fair; the fresh rock has an excellent RQD and an extremely strong rock strength assessment.

Two weathered and fractured “zones” providing preferential pathways for groundwater (and potentially contaminant) migration are considered to be present on site and can be identified at 120m to 230m and 350m to 415m along Line DE01.

8.2 Depth of base of Weathered Aquifer

Based upon review of the fractures and condition of weathering the probable depth of the weathered/fractured aquifer at the drilling locations is provided in Table 7.

Table 7: Base of Weathered/Fractured Aquifer

Borehole ID	Surface Elevation mamsl	Depth to base of Weathered/Fractured Aquifer mbgl	Base Elevation mamsl
BH1	617	5.93	611.07
BH2	622	12.60	609.40
BH3	624	15.62	608.38

8.3 Excavatability Assessment at Borehole Locations

In accordance with Pettifer and Fookes (1994) and based upon review of the condition of the drilling core, including rock strength and fracture spacing, the following estimates with regards to depths of excavation and potential excavation techniques that could be utilised are provided in Table 8, Table 9, and Table 10 for each of the three borehole locations respectively.

Table 8: BH1 – Excavatability Assessment

Borehole ID	From (mbgl)	To (mbgl)	Excavatability Assessment
BH1	0	0.9	Easy Digging to Hard Digging (TLB)
	0.9	3.63	Easy Ripping (D6,D7) to Hard Ripping (D8)
	3.63	5.93	Hard Ripping (D8)
	5.93	9.41	Blasting Required

Table 9: BH2 – Excavatability Assessment

Borehole ID	From (mbgl)	To (mbgl)	Excavatability Assessment
BH2	0	1.88	Easy Digging (TLB)
	1.88	5.15	Easy Ripping (D6,D7)
	5.15	7.12	Easy Ripping (D6,D7) to Hard Ripping (D8)
	7.12	9.80	Hard Ripping (D8)
	9.80	14.90	Blasting Required

Table 10: BH3 – Excavatability Assessment

Borehole ID	From (mbgl	To (mbgl)	Excavatability Assessment
BH3	0	2.70	Easy Digging (TLB)
	2.70	7.00	Easy Ripping (D6,D7)
	7.00	8.18	Extremely Hard Ripping (D11 or Hydraulic breaker +D9)
	8.18	12.75	Extremely Hard Ripping (D11 or Hydraulic breaker +D9) to Blasting
	12.75	22.05	Blasting Required

8.4 Excavatability Assessment for the Site

In accordance with Pettifer and Fookes (1994) and based upon review of the fracture spacing, degree of weathering, rock strength and resistivity the depth of excavation and potential methods for excavation that could be utilised are provided for the internal northern boundary road and public road to the north of the site (as per Geophysical Traverses Line DE01 and Line DE03).

Table 11: Site Excavatability Assessment

Area	Section Length		Depth (m bgl)	Thickness (m)	Excavatability Assessment
	From (mbgl)	To (mbgl)			
0 to 600m Internal Road Northern Boundary **(Line – DE01)**	0	240	0 to 2	2	Easy Digging (TLB)
			2 to 7	5	Easy Ripping (D6,D7)
	240	270	0 to 2	2	Extremely Hard Ripping (D11 or Hydraulic breaker +D9)
			2 to 4	5	Blasting
	270	325	0 to 2	2	Easy Digging (TLB)
			2 to 7	5	Easy Ripping (D6,D7)
	325	345	0 to 2	2	Extremely Hard Ripping (D11 or Hydraulic breaker +D9)
			2 to 7	5	Blasting
	345	400	0 to 2	2	Easy Digging (TLB)
			2 to 7	5	Easy Ripping (D6,D7)
	400	600	0 to 7	7	Blasting
0 to 200m External Road	0	35	0 to 4	4	Blasting

Area	Section Length		Depth (m bgl)	Thickness (m)	Excavatability Assessment
	From (mbgl)	To (mbgl)			
North of Site **(Line – DE03)**	35	100	0 to 1	1	Easy Digging to Hard Digging
			1 to 4	3	Easy Ripping (D6, D7) to Hard Ripping (D8)
	100	150	0 to 1	1	Extremely Hard Ripping (D11 or Hydraulic Breaker + D9)
			1 to 4	3	Blasting
	150	200	0 to 4	4	Blasting

The possible methods of excavation involve digging with an excavator (with or without a hydraulic breaker) or blasting. It is considered that due to the proximity of site infrastructure blasting is unlikely to be undertaken. Therefore, the depth of potential excavation that will most probably be achievable will be limited to that possible using an excavator i.e. typically up to 2m bgl but locally up to 7m bgl in highly weathered and fractured zones.

9.0 REFERENCES

Pettifer GS, Fookes PG (1994) A revision of the graphical method for assessing the excavatability of rock. Q J Eng Geol 27:145-164.

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APPENDIX A

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GOLDER ASSOCIATES AFRICA (PTY) LTD

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