TRANSNET FREIGHT RAIL
WATERBERG STAGE 4

LEPHALALE YARD

Geotechnical Investigation Report

Prepared	J Viljoen	Project number	3424302
Reviewed	H Denysschen	File number	W(F)317/8/319/33
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GEOTECHNICAL INVESTIGATION AT LEPHALALE YARD

CONTENTS

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1. INTRODUCTION AND SCOPE OF WORK

The Waterberg complex is a strategic growth node for various activities within the mining and industrial sectors. Adequate rail infrastructure capacity is deemed critical to unlock the potential of this economic hub. The Waterberg region represents an in-situ coal resource in excess of 76 billion tons, and is expected to experience significant growth in coal and mineral production over the next 20 years. The purpose of rail expansion from Waterberg is to provide infrastructure along the coal railway line to increase the coal hauling capacity. In recent years there have been numerous requests from industry for an assessment and subsequent supply of long term rail network capacity from the Waterberg area to Richards Bay and Maputo, for export, and to various inland destinations, for the domestic market.

The Waterberg rail infrastructure upgrade is to meet the increased coal tonnage demand. The work to achieve this objective is planned to be carried out in stages over a number of years. Transnet Group Capital (TGC), is providing professional engineering services for the doubling of the existing Transnet Freight Rail's railway line with the Geotechnical Office of TGC executing the geotechnical investigation.

Transnet Group Capital (TGC), PD&E (Geotechnical) was approached by TGC Project Management in Johannesburg to conduct a geotechnical investigation for additional tracks at various distances from the existing track between kilometres 96.00 and 101.00 as well as for various facilities. The scope for this geotechnical work required for the FEL3 study, can be described as follows:

- Determine the nature, distribution and relevant applicable engineering properties of the near surface soil strata along the proposed new alignment of the loop
- Evaluate the near surface soil conditions in order to be able to classify the soils and provide recommendations for the railway formation layerworks. The formation layerworks are to meet the requirements of the Specification for Railway

Earthworks S410, (Grabe and Maree, March 2006) for a 20t axle loading line in a moderate climate

- Evaluate the near surface soil conditions in order to provide recommendations for founding of various culverts
- Submit a geotechnical interpretative report containing all the relevant information.

Layout and long section drawings no. 3424302-4-1A6-N-LA-0002, sheets 01 to 10, rev 1 by DJ prepared and issued by TGC Perway Office has subsequently been used during the fieldwork phase and to present the geotechnical information completed. The site drawing is included in Appendix A of this report.

This report covers the nature and findings of the geotechnical investigation that was carried out and presents the results and findings of the fieldwork and laboratory testing, the evaluation of the results and recommendations for railway formation layerworks, maintenance roads and structures.

2. SITE LOCATION, DESCRPITION AND PROPOSED DEVELOPMENT

The site is located approximately 30 km west of the town of Lephalale (Ellisras) at starting point (23°46’51.35” S, 27°25’52.19” E) and end point (23°44’53.14” S, 27°28’24.859” E) on the single railway line between Thabazimbi to Lephalale.

In general, topographically the Lephalale site is generally flat and slightly undulating with the highest points on the eastern and western perimeters, sloping gently towards the center in the direction of a major culvert at chainage Km 99+200. The existing formation level along the existing railway line’s alignment over this new length is located on fills (embankments of up to approximately ± 4.0m in height) with sections at grade and cuts (maximum depth in the order of ± 10.0m).

Game farms border the site on either side while the typical vegetation consists mostly of sparse grasses, shrubs and typical bushveld trees. Hard rock sandstone boulders outcrop at surface and in existing cuttings along the railway line, while no bedrock was observed.

Existing services encountered on site include the non-electrified railway line, along with a gravel service road located on the southern side and level crossings (at chainage Km 100+560) and several culverts.

The development of the site will comprise of a yard with several railway lines proposed and entail the following:

Southern section consisting of:

- A bypass line
- Decanting arrival/departure lines (2 No.)
- Departure line.

Northern section consisting of:

- An arrival line (denoted arrival line 1)
- Run around line
- Spare lines (3 No.).

The abovementioned sections are referenced to the existing main line or referenced as Arrival line 2 on the layout drawings.

In addition to the yard, several facilities are also proposed and comprise of single storey buildings, a rail over road bridge and fuel storage tanks.

The structures will be at the following chainages:

- Provisioning facility on main line between Km 97+800 and Km 97+900
- Provisioning facility on main line between Km 99+120 and Km 99+220
- Admin/Operations building and staff amenities adjacent to main line between chainages Km 99+240 and Km 99+340
- Infra office and amenities adjacent to the bypass line at chainages Km 3+140 and Km 3+180
- Rail over road bridge on bypass line at chainage Km 3+480
- Fuel Storage tanks between bypass line and main line at chainage Km 98+500.

At the time of the geotechnical investigation, no evidence of water ponding or seepage was observed during the investigation along the railway line.

A schematic layout of the proposed developments is given in Appendix A and photographs of the site at the time of the fieldwork are presented in Appendix E.

3. NATURE OF THE INVESTIGATION

The geotechnical investigation made use of both field and laboratory testing methods in order to determine the nature and distribution of the soil/rock strata underlying the site. The investigation was a phased approach comprising of **Phase 1** (or *Southern section*), **Phase 2** (or *Northern section*) and **Phase 3** for the proposed structures.

3.1 Fieldwork

The fieldwork was carried out during June to August 2017 and several test pits (± 93 No.) were set out, as per the layout/section drawings provided TGC Perway Office, along the various alignment routes of the proposed railway lines and proposed structure locations. Almost all the test pits were excavated by means of a tractor-mounted loader backhoe (TLB) model CAT 428E, with the exception of in isolated sections were hand excavated pits were required due to restricted access of the TLB machine. All test pits were profiled in-situ immediately after excavation and the soil profiles were recorded in detail using the recognised standard method for soil profiling given in the Revised Guide to Soil Profiling for Civil Engineering Purposes in Southern Africa. The parameters that were recorded are moisture content, colour, consistency, soil structure, soil type and origin. Representative disturbed samples were also recovered for laboratory testing purposes during this test pitting phase.

One metre long hand-held Dynamic Cone Penetrometer (DCP) tests were done next to each test pit from the existing ground surface level. The tests were performed to determine the in-situ strength of the near surface soils and were done to either refusal or a maximum depth of 1.0m. The advance of the cone for every 5 blows of the falling weight was recorded.

Thirty two (32 No.) rotary cored boreholes were formed at proposed cutting sections to be widened and major structures in order to determine the nature and relevant engineering properties of the soil/rock strata below the depth limit of the test pits.
Eighteen (18 No.) boreholes were drilled vertically while the remaining fourteen (14 No.) were drilled at an inclination of 60°. The holes were advanced using standard wash boring techniques with standard penetration tests (SPT's) at 1.5m intervals in the vertical boreholes up to where refusal occurred in the Residual Sandstone and/or Sandstone boulders/bedrock. Core samples from the underlying Sandstone bedrock were recovered using rotary core drilling.

Standard Penetration Tests (SPT samples) and core extracted from the rotary core drilling were profiled/logged in accordance with standard method of soil profiling and core logging procedures used for civil engineering purposes in South Africa.

The detailed test pits and borehole drilling logs with attributes, levels, reduced levels and co-ordinates as well as the DCP test results and graphs are presented in Appendix B and C respectively.

Laboratory Testing

Selected soil samples from the test pits were submitted for laboratory testing purposes. The following engineering tests were carried out:

Particle size grading analysis, including hydrometer analysis

- Atterberg Limits
- Moisture content and density (Modified AASHTO effort) relationship
- California Bearing Ratio (CBR)
- Natural moisture content
- Unconfined Compressive Tests (UCS) on rock samples.

Copies of the laboratory test results are presented in Appendix D. Where applicable, the laboratory test results are summarized in tables and included in the relevant sections of the report.

4. SITE GEOLOGY

4.1 Regional Geology

The general area is underlain by sedimentary rocks of the Waterberg Group comprising of sandstone and conglomerates. The various rock types are generally covered by a wide range of materials such as residual soils, and/or pedogenic soils overlain by transported soils and occasional fill. The layer thicknesses are highly variable.

4.2 Subsoil/rock Conditions

For ease of reference, the general occurrences of the various soil/rock horisons encountered on site have been summarised in the tables below. Depths are measured from existing ground level at the time of the fieldwork.

The remarks column provides a description of the existing earthworks and/or structures relative to natural ground level. (Information relevant to the bypass line is given in *Italics*).

Table 4.2.1: Summary of shallow subsoil/rock conditions encountered during test pitting phase – *Phase 1*

Test Pit No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)			Remarks
		Topsoil/ Fill	Transported (Alluvium)	Reworked/ Residual Sandstone	
TP.LL1	*Km 0+000*	*0.20*	*0.80*	*3.00 (FD)*	*Bank ± 1.8m*
TP.LL2	*Km 0+200*	*0.20*	*1.00*	*3.00 (FD)*	*Bank ± 1.9m*
TP.LL3	*Km 0+400*	*0.20*	*0.50*	*0.90+(R)*	*Bank ± 1.6m*
TP.LL4	*Km 0+600*	*0.20*	-	*0.50+(SR)*	*Bank ± 0.7m*
TP.LL5	*Km 0+800*	*0.20*	*0.40*	*0.90+(SR)*	*Level*
TP.LL6	*Km 1+000*	*0.20*	-	*0.60+(SR)*	*Level*
TP.LL7	*Km 1+200*	*0.17*	-	*0.50+(SR)*	*Cutting ± 1.0m*

Test Pit No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)			Remarks
		Topsoil/ Fill	Transported (Alluvium)	Reworked/ Residual Sandstone	
TP.LL8	*Km 1+400*	*0.15*	*0.65*	*3.00* *(FD)*	*Cutting ± 2.0m*
TP.LL9	*Km 1+600*	*0.30*	-	*0.85+(SR)*	*Cutting ± 3.0m*
TP.LL10	*Km 1+800*	*0.25*	*1.10*	*1.50+(SR)*	*NGL*
TP.LL11	*Km 2+000*	*0.20*	-	*2.35+(SR)*	*NGL*
TP.LL12	*Km 2+200*	*0.20*	-	*1.40+(SR)*	*NGL*
TP.LL13	*Km 2+400*	*0.20*	-	*1.40+(SR)*	*NGL*
TP.LL14	*Km 2+600*	*0.20*	-	*1.10+(SR)*	*NGL*
TP.LL15	*Km 2+800*	*0.20*	-	*0.70+(SR)*	*NGL*
TP.LL16	*Km 3+000*	*0.15*	*0.40*	*0.78+(SR)*	*NGL*
TP.LL17	*Km 3+200*	*0.10*	*0.34*	*0.50+(SR)*	*NGL*
TP.LL18	*Km 3+400*	*0.10*	*0.50*	*0.80+(SR)*	*NGL*
TP.LL19	*Km 3+480*	*0.10*	*0.70*	*0.84+(SR)*	*Underpass*
TP.LL20	*Km 3+600*	*0.10*	*0.30*	*1.30+(SR)*	*NGL*
TP.LL21	*Km 3+800*	*0.05*	*0.40*	*0.75+(SR)*	*NGL*
TP.LL22	*Km 4+000*	*0.20*	*0.60*	*2.50+(R)*	*NGL*
TP.LL23	*Km 4+200*	*0.20*	*0.65*	*1.90+(SR)*	*NGL*
TP.LL24	*Km 4+400*	*0.20*	*0.35*	*1.30+(SR)*	*Level*
TP.LL25	*Km 4+560*	*0.35*	-	*0.70+(SR)*	*Culvert*
TP.LL26	*Km 4+600*	*0.10*	-	*0.60+(SR)*	*Bank ± 0.5m*
TP.LL27	*Km 4+760*	*0.15*	-	*0.85+(SR)*	*New Pipe Culvert*
TP.LL28	*Km 4+800*	*0.15*	*0.42*	*3.00* *(FD)*	*Bank ± 0.4m*
TP.LL29	*Km 5+000*	*0.10*	*0.90*	*2.48+(R)*	*Level*
TP.LL30	*Km 5+200*	*0.10*	-	*0.60+(R)*	*Bank ± 1.6m*
TP.LL31	*Km 5+400*	*0.10*	*0.35*	*1.57+(SR)*	*Cutting ± 1.6m*

Test Pit No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)			Remarks
		Topsoil/ Fill	Transported (Alluvium)	Reworked/ Residual Sandstone	
TP.LL32	*Km 5+600*	*0.50*	-	*2.70+(SR)*	*Level*
TP.LL33	*Km 5+800*	*0.10*	*0.50*	*0.70+(SR)*	*Bank ± 1.6m*
TP.LL34	*Km 6+000*	*0.40*	-	*0.70+(SR)*	*Bank ± 1.8m*
TP.LL35	Km 97+000	0.10	0.40	3.00 (FD)	NGL
TP.LL36	Km 97+200	0.16	-	1.50+(FD)	Cutting ± 1.6m
TP.LL37	Km 97+400	0.15	-	1.25+(SR)	Cutting ± 1.8m
TP.LL38	Km 97+600	0.30	0.50	3.00 (FD)	Cutting ± 3.0m
TP.LL39	Km 97+800	0.15	0.50	3.00 (FD)	NGL
TP.LL40	Km 98+000	0.15	0.50	3.00 (FD)	NGL
TP.LL41	Km 98+200	0.20	0.65	2.30+(SR)	NGL
TP.LL42	Km 98+400	0.20	0.50	1.50+(SR)	NGL
TP.LL43	Km 98+600	0.20	0.40	2.00+(R)	NGL
TP.LL44	Km 98+800	0.30	0.80	1.40+(R)	NGL
TP.LL45	Km 99+000	0.30	0.45	1.80+(SR)	NGL
TP.LL46	Km 99+200	0.60	0.90	1.80+(SR)	Bank ± 2.0m
TP.LL47	Km 97+600	0.60	-	0.95+(R)	Cutting ± 1.90m
TP.LL48	Km 97+800	0.50	-	0.70+(R)	Cutting ± 2.10m
TP.LL49	Km 98+000	0.45	-	0.65+(R)	Cutting ± 2.00m
TP.LL50	Km 98+200	0.50	-	1.40+(SR)	Cutting ± 1.20m
TP.LL51	Km 98+400	0.40	-	1.30+(SR)	Cutting ± 0.40m
TP.LL52	Km 98+600	0.30	1.00	3.00 (FD)	Level
TP.LL53	Km 98+800	0.20	0.90	1.80+(R)	Bank ± 2.0m
TP.LL54	K 98+850	0.80	1.30	3.00 (FD)	Bank ± 1.8m New Culvert
TP.LL55	Km 99+000	0.50	1.30	2.80+(SR)	Bank ± 1.8m

Test Pit No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)			Remarks
		Topsoil/ Fill	Transported (Alluvium)	Reworked/ Residual Sandstone	
TP.LL56	Km 99+220	0.25	0.80	2.20+(SR)	Bank ± 2.8m Existing Culvert
TP.LL57	Km 99+400	0.65	1.10	2.00+(SR)	Bank ± 2.3m
TP.LL58	Km 99+600	0.60	0.85	3.00 (FD)	Bank ± 1.9m
TP.LL59	Km 99+800	0.15	0.45	2.50+(SR)	Bank ± 0.5m
TP.LL60	Km 100+000	0.60	1.50	2.90+(SR)	Cutting ± 1.6m
TP.LL61	Km 100+200	0.30	-	1.10+(SR)	Cutting ± 1.7m
TP.LL62	Km 100+400	0.30	0.70	1.40+(SR)	Level
TP.LL63	Km 100+640	0.30	0.85	2.40+(SR)	Bank ± 0.5m

Table 4.2.2: Summary of shallow subsoil/rock conditions encountered during test pitting phase – *Phase 2*

Test Pit No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)			Remarks
		Topsoil/ Fill	Transported (Alluvium)	Reworked/ Residual Sandstone	
TP.LL1	Km 97+200	0.30	0.70	3.00 (FD)	Cutting ± 3.0m
TP.LL2	Km 97+300 - Set	0.15	0.70	1.90+(SR)	Cutting ± 1.8m
TP.LL3	Km 97+300 - Set	0.15	0.50	1.90+(SR)	Cutting ± 1.8m
TP.LL4	Km 97+340 - Set	0.30	0.40	2.50+(SR)	Cutting ± 1.8m
TP.LL5	Km 97+400 - Set	0.30	0.50	3.00 (FD)	Cutting ± 3.0m
TP.LL6	Km 97+600	0.25	0.70	2.46+(SR)	Cutting ± 5.0m
TP.LL7	Km 97+800	0.25	0.75	2.20+(SR)	Cutting ± 6.0m
TP.LL8	Km 98+000	0.20	0.40	2.50+(SR)	Cutting ± 3.0m
TP.LL9	Km 98+200	0.35	0.80	3.00 (FD)	Cutting ± 1.8m
TP.LL10	Km 98+400	0.20	0.40	1.90+(SR)	Cutting ± 1.0m

Test Pit No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)			Remarks
		Topsoil/ Fill	Transported (Alluvium)	Reworked/ Residual Sandstone	
TP.LL11	Km 98+600	0.10	0.30	0.60+(SR)	Level
TP.LL12	Km 98+800	0.30	0.70	1.50+(SR)	Bank ± 0.6m
TP.LL13	Km 98+850	0.20	0.60	1.50+(SR)	Bank ± 1.6m New Culvert
TP.LL14	Km 99+000	0.25	0.80	1.60+(SR)	Bank ± 1.7m
TP.LL15	Km 99+200	0.40	1.10	1.90+(SR)	Bank ± 1.8m
TP.LL16	Km 99+220	0.10	0.60	1.40+(SR)	Existing Culvert

(FD) – Final Depth (Bottom of test pit, not to refusal)

(SR/R) – Semi Refusal/Refusal of TLB-machine on very dense Residual Sandstone

Table 4.2.3: Summary of deeper subsoil/rock conditions encountered during rotary core drilling phase – *Phase 1*

Borehole No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)				*Remarks (Proposed development)*
		Topsoil/ Transported (Alluvium)	Reworked/ Residual Sandstone	Gravel/Boulder Sandstone	Sandstone Bedrock	
BH.01	*Km 1+200*	*0.50*	*6.0 (FD)*			*Cutting ± 5.0m*
BH.02	*Km 1+400*	*0.60*	*7.5 (FD)*			*Cutting ± 6.0m*
BH.03	*Km 1+600*	*0.50*	*4.72*	*8.50 (FD)*		*Cutting ± 7.5m*
BH.04	*Km 1+800*	*0.65*	*9.50 (FD)*			*Cutting± 8.5m*
BH.05	*Km 2+000*	*0.20*	*3.15*	-	*10.0 (FD)*	*Cutting ± 9.0m*
BH.06	*Km 2+200*	*0.20*	*2.88*	-	*10.00 (FD)*	*Cutting ± 9.0m*
BH.07	*Km 2+400*	*0.50*	*4.67*	*7.50 (FD)*		*Cutting ± 6.5m*

Borehole No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)				*Remarks (Proposed development)*
		Topsoil/ Transported (Alluvium)	Reworked/ Residual Sandstone	Gravel/Boulder Sandstone	Sandstone Bedrock	
BH.08	*Km 2+600*	*0.55*	*5.50 (FD)*			*Cutting ± 4.5m*
BH.09	*Km 1+100*	*0.60*	*5.00 (FD)*			*Cutting ± 4.0m*
BH.10	*Km 1+300*	*1.0*	*6.00 (FD)*			*Cutting ± 5.0m*
BH.11	*Km 1+500*	*0.70*	*3.50*	*7.50 (FD)*		*Cutting ± 6.5m*
BH.12	*Km 1+700*	*0.60*	*4.5*	*9.00 (FD)*		*Cutting ± 8.0m*
BH.13	*Km 1+900*	*0.4*	*9.0 (FD)*			*Cutting ± 8.0m*
BH.14	*Km 2+100*	*0.35*	*7.50*	*9.50 (FD)*		*Cutting ± 8.5m*
BH.15	*Km 2+300*	*0.20*	*7.50*	*8.50 (FD)*		*Cutting ± 7.5m*
BH.16	*Km 2+500*	*0.50*	*6.50 (FD)*			*Cutting ± 5.5m*
BH.17	Km 98+850	0.65	4.50 (FD)			Culvert

Table 4.2.4: Summary of deeper subsoil/rock conditions encountered during rotary core drilling phase – *Phase 2*

Borehole No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)				Remarks (Proposed development)
		Topsoil/Fill/ Transported (Alluvium)	Reworked/ Residual Sandstone	Gravel/Boulder Sandstone	Sandstone Bedrock	
BH.01	Km 96+600	1.00	2.63	-	5.50 (FD)	Cutting ± 4.5m
BH.02	Km 96+800	1.00	2.67	-	6.50 (FD)	Cutting ± 5.5m
BH.03	Km 97+000	0.40	3.00	-	7.50 (FD)	Cutting ± 6.5m
BH.04	Km 97+200	0.78	7.50 (FD)			Cutting± 6.5m
BH.05	Km 97+400	0.50	6.50 (FD)	-		Cutting ± 5.5m

Borehole No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)				Remarks (Proposed development)
		Topsoil/Fill/ Transported (Alluvium)	Reworked/ Residual Sandstone	Gravel/Boulder Sandstone	Sandstone Bedrock	
BH.06	Km 97+600	0.45	4.38	6.00 (FD)		Cutting ± 5.0m
BH.07	Km 97+750	0.75	4.95 (FD)			Cutting ± 4.0m
BH.08	Km 97+750	0.72	8.85 (FD)			Cutting ± 4.0m
BH.09	Km 97+700	1.00	6.00 (FD)			Cutting ± 4.5m
BH.10	Km 97+500	0.45	6.50 (FD)			Cutting ± 5.5m
BH.11	Km 97+300	1.00	7.00 (FD)			Cutting ± 6.0m
BH.12	Km 97+100	1.30	7.50 (FD)			Cutting ± 6.5m
BH.13	Km 96+900	1.25	4.20	7.00 (FD)		Cutting ± 6.0m
BH.14	Km 96+700	0.35	4.50	6.00 (FD)		Cutting ± 5.0m
BH.15	Km 96+500	0.30	5.50 (FD)			Cutting ± 4.0m
BH.16	Km 98+400	4.0	6.00 (FD)			Embankment

Table 4.2.5: Summary of general geotechnical conditions along the proposed alignment, combining the test pit and borehole information

Chainage (km)	Cut/Fill (approximate range in m)	Relevant Test Pits and Boreholes	General Soil/Rock Profile and Depth Range Below Existing Ground Surface (m)	General
0+000 to 0+450	Bank (0.0 to ± 2.00)	Phase 1 *TP.LL1 to TP.LL3*	*Generalised test pit profile* 0.20 – 1.00 Loose through to dense, Sand (occasionally Silty) and Sandy Gravels – Topsoil/Fill/Transported (Alluvium) * 0.90+ (S/R,R) – 3.00 + (FD) Medium dense through to very dense (occasionally loose), Sand (sporadically Silty/Ferruginised and/or Nodules) and Sandy Gravels, Residual Sandstone * + (S/R,R) - Semi refusal and/or refusal on dense to very dense Residual Sandstone	No ground water/seepage recorded

0+450 *to* *2+600* and 96+550 to 98+560	Cut (0.0 to ± 10.0)	<u>Phase 1</u> *TP.LL4* *to* *TP.LL14*, TP.LL35 to TP.LL42 and BH.01 to BH.16 <u>Phase 2</u> TP.LL1 to TP.LL10 and BH.01 to BH.15	<u>*Generalised test pit profile*</u> 0.10 – 1.10 * As per above 0.50$^{+ (S/R,R)}$ – 3.00$^{+ (FD)}$ * As per above $^{+ (S/R,R)}$ - Semi refusal and/or refusal on dense to very dense Residual Sandstone <u>*Generalised borehole profile*</u> 0.20 – 1.00 Loose through to dense, Sand (occasionally Silty/Gravels) – Topsoil/Transported (Alluvium) 2.60 – 9.00 Medium dense through to very dense (occasionally loose), Sand (sporadically Silty/Ferruginised and/or Nodules) and Sandy Gravels, Residual Sandstone 5.50 – 10.0+ Soft through to hard rock Sandstone Boulders and Bedrock encountered in isolated localities (as per the attached tables 4.2.3 and 4.2.5)	No ground water/seepage recorded
2+600 *to* *3+910* and 98+560 to 99+870	Bank (0.0 to ± 4.00)	<u>Phase 1</u> *TP.LL15* *to* *TP.LL21*, TP.LL43 to TP.LL59 <u>Phase 2</u> TP.LL11 to TP.LL13	<u>*Generalised test pit profile*</u> 0.05 – 1.30 * As per above 0.50$^{+ (S/R,R)}$ – 3.00$^{+ (FD)}$ * As per above $^{+ (S/R,R)}$ - Semi refusal and/or refusal on dense to very dense Residual Sandstone	No ground water/seepage recorded
3+910 *to* *4+440* and 99+870 to 100+420	Cut (to ± 1.40)	<u>Phase 1</u> *TP.LL22* *to* *TP.LL24*, TP.LL60 to TP.LL62	<u>*Generalised test pit profile*</u> 0.20 – 1.50 * As per above 1.10 – 2.90$^{+ (S/R,R)}$ * As per above $^{+ (S/R,R)}$ - Semi refusal and/or refusal on dense to very dense Residual Sandstone	No ground water/seepage recorded
4+440 *to* *4+440*	Bank (to ± 1.80)	<u>Phase 1</u> *TP.LL25*	<u>*Generalised test pit profile*</u> 0.10 – 1.10 * As per above	No ground water/seepage recorded

		to *TP.LL34*, and <u>Phase 2</u> TP.LL14 to TP.LL16	0.60+ (S/R,R) – 3.00 + (FD) * As per above + (S/R,R) - Semi refusal and/or refusal on dense to very dense Residual Sandstone	

Table 4.2.6: Summary of shallow subsoil/rock conditions encountered during test pitting phase for the proposed structures – *Phase 3*

Test Pit No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)			Remarks
		Topsoil/ Fill	Transported (Alluvium)	Reworked/ Residual Sandstone	
TP.LL1	Km 97+810	0.20	0.60	3.00 (FD)	*Provisioning facility* to be founded in <u>Cut</u>
TP.LL2	Km 97+905	0.30	1.10	3.20 (FD)	
TP.LL3	Km 99+125	0.80	1.00	1.80 +(SR)	*Provisioning facility* to be placed on <u>Embankment</u>
TP.LL4	Km 99+188	0.70	1.00	1.90 +(SR)	
TP.LL5	Km 99+152	0.30	0.80	3.00 (FD)	
TP.LL6	Km 99+207	0.25	0.80	3.10 (FD)	
TP.LL7	Km 99+287	0.20	0.80	3.00 (FD)	*Admin/Operations building and staff amenities* to be placed on <u>Embankment</u>
TP.LL8	Km 99+230	0.20	0.55	3.00 (FD)	
TP.LL9	Km 99+330	0.20	0.40	2.20 +(SR)	
TP.LL10	Km 99+285	0.20	0.60	2.70 +(SR)	
TP.LL11	Km 3+147	0.20	0.60	2.20 +(SR)	*Infra Office and Amenities* to be placed on <u>Embankment</u>
TP.LL12	Km3+179	0.20	0.50	2.10 +(SR)	

Test Pit No.	Position (chainage)	Depth encountered/bottom of layer (m below NGL)			Remarks
		Topsoil/ Fill	Transported (Alluvium)	Reworked/ Residual Sandstone	
TP.LL13	Km 98+477	0.25	0.65	2.20 +(SR)	*Fuel Storage Tanks* to be founded in Cut/Level
TP.LL14	Km 98+513	0.20	0.40	2.10 +(SR)	
TP.LL15	Km 99+220	0.30	0.80	2.00 (FD)	Bottom of Embankment

(FD) – Final Depth (Bottom of test pit, not to refusal)

(SR/R) – Semi Refusal/Refusal of TLB-machine on very dense Residual Sandstone

4.3 Ground and Surface Water Conditions

No groundwater seepage or surface water was encountered at the time of the investigation but it should be noted that the investigation was done during the dry season. In addition, the soil profile in some test pits contains pedogenic material (ferruginised nodules) which generally develops when a fluctuating shallow perched water table is present. The occurrence of a shallow perched water table can be expected especially during and/or after periods of heavy and/or continuous rainfall.

5. GEOTECHNICAL EVALUATION

5.1 Excavation Classification

Excavation procedures likely to be encountered on the site have been evaluated in terms of the SANS 1200D - Earthworks classification system. In terms of this classification system, *soft excavation* conditions are expected in the Topsoil/Fill/Transported and Reworked/Residual Sandstone within a variable depth range of 0.50m and beyond 3.20m below NGL. Below these depths, *intermediate and/or hard (sporadically boulder)* rock excavation in terms of the abovementioned standard occurs on the Sandstone boulders and/or bedrock with typical Unconfined Compressive Strength (UCS) values in the range of 32 MPa to 127 MPa.

Excavation on site could be hampered by the presence of shallow/standing water particularly at culverts and should be taken into account, while overbreak of excavation sides may occur (due to the loose consistency of some soils). In addition, care must be taken so that the integrity of the adjacent railway line is not compromised at any stage during the excavation and construction in close proximity. Safe passage of trains should be guaranteed at all times during the construction period.

5.2. In situ Strength of Subsoils

The results of the DCP field tests have been used to evaluate the in-situ strength or CBR values of the near surface subsoils for ***Phase 1 and 2***. Cognisance of the moisture content and potentially gravelly nature of the subsoils in the soil profile should be taken into account when using these DCP-derived CBR values. The results of the DCP tests are given in Appendix C and should be referred to for specific details.

The tables below summarise all the DCP test results in terms of the average in-situ CBR values with depth for tests conducted from surface. The tables present the average CBR obtained from the in-situ DCP test values at specific depth intervals with different colours denoting the different layers as specified in the Railway Specifications for Earthworks S410. The summarised tables do not include the laboratory results, which mean it does not take certain parameters such as the plasticity index into account. Below the tables, a legend specifying the various colours according to the obtained CBR values is presented.

Table 5.2.1: Summary of average in-situ CBR Value (%) from surface – *Phase 1*

Depth (mm)	DCP 1	DCP 2	DCP 3	DCP 4	DCP 5	DCP 6	DCP 7	DCP 8	DCP 9	DCP 10
100	11	50	0	81	84	56	100	84	93	27
200	81	73	11	100	97	100	Ref	77	95	38
300	100	58	28	Ref	100	Ref		62	100	33
400	Ref	59	73		Ref			54	100	26
500		88	93					55	96	25
600		91	100					56	82	39
700		91	100					51	100	49
800		71	Ref					51	100	45
900		67						49	92	63
1000		59						56	92	86

Depth (mm)	DCP 11	DCP 12	DCP 13	DCP 14	DCP 15	DCP 16	DCP 17	DCP 18	DCP 19	DCP 20
100	0	21	25	21	23	36	48	21	29	21
200	0	25	23	21	24	39	38	9	32	19
300	0	15	13	48	43	33	42	9	27	Ref
400	4	14	35	60	53	71	Ref	13	55	
500	8	7	59	69	58	92		Ref	59	
600	17	7	73	43	63	95			92	
700	14	33	80	95	91	100			98	
800	15	18	95	100	97	100			Ref	
900	19	41	97	100	91	64				
1000	25	41	100	88	82	100				

Depth (mm)	DCP 21	DCP 22	DCP 23	DCP 24	DCP 25	DCP 26	DCP 27	DCP 28	DCP 29	DCP 30
100	7	5	31	62	84	38	33	19	48	91
200	47	10	27	80	Ref	Ref	62	26	92	Ref
300	96	10	21	69			69	25	100	
400	95	11	29	70			78	38	Ref	
500	Ref	11	51	100			69	54		
600		15	58	100			60	75		
700		17	73	95			66	73		
800		17	73	86			60	60		
900		13	68	97			43	39		
1000		18	77	Ref			35	50		

Depth (mm)	DCP 31	DCP 32	DCP 33	DCP 34	DCP 35	DCP 36	DCP 37	DCP 38	DCP 39	DCP 40
100	86	56	75	58	39	96	41	4	67	15
200	Ref	60	80	64	75	69	88	17	82	25
300		64	100	100	Ref	37	100	84	73	23
400		94	100	100		20	100	96	89	25
500		100	100	100		16	100	91	80	29
600		Ref	97	77		31	Ref	100	86	29
700			100	89		39		91	93	29
800			95	Ref		60		80	100	27
900			81			59		75	100	25
1000			73			100		86	100	33

Depth (mm)	DCP 41	DCP 42	DCP 43	DCP 44	DCP 45	DCP 46	DCP 47	DCP 48	DCP 49	DCP 50
100	21	6	15	5	7	75	15	64	42	75
200	25	16	41	9	26	100	77	100	29	68
300	42	24	54	36	46	100	100	100	53	92
400	55	27	66	48	75	91	Ref	Ref	46	100
500	48	36	96	56	96	Ref			49	95
600	55	49	100	75	96				Ref	95
700	58	77	100	84	100					Ref
800	68	80	100	96	100					
900	84	63	100	96	100					
1000	96	75	97	100	100					

Depth (mm)	DCP 51	DCP 52	DCP 53	DCP 54	DCP 55	DCP 56	DCP 57	DCP 58	DCP 59	DCP 60
100	68	13	21	42	0	55	32	9	5	73
200	95	58	24	68	9	Ref	39	31	53	97
300	Ref	75	41	86	81		79	86	100	100
400		86	25	79	Ref		97	92	100	100
500		97	25	Ref			Ref	91	100	Ref
600		Ref	46					100	96	
700			67					Ref	71	
800			82						52	
900			Ref						43	
1000									56	

Depth (mm)	DCP 61	DCP 62	DCP 63
100	9	51	100
200	28	97	100
300	37	Ref	100
400	82		94
500	Ref		73
600			55
700			66
800			73
900			92
1000			73

Table 5.2.2: Summary of average in-situ CBR Value (%) from surface – *Phase 2*

Depth (mm)	DCP 1	DCP 2	DCP 3	DCP 4	DCP 5	DCP 6	DCP 7	DCP 8	DCP 9	DCP 10
100	5	13	4	10	9	7	0	0	5	5
200	10	42	9	75	41	20	0	5	19	10
300	28	62	37	82	27	27	9	48	94	23
400	34	39	97	78	38	25	28	97	95	26
500	66	41	Ref	80	77	27	36	100	86	27
600	82	45		82	68	Ref	38	100	96	25
700	95	29		73	64		39	95	100	17
800	100	33		73	53		35	Ref	86	19
900	84	43		66	48		29		84	23
1000	80	41		65	9		23		79	44

Depth (mm)	DCP 11	DCP 12	DCP 13	DCP 14	DCP 15	DCP 16
100	65	9	11	Ref	Ref	Ref
200	Ref	57	93			
300		86	100			
400		100	100			
500		92	100			
600		100	100			
700		96	100			
800		100	100			
900		100	100			
1000		96	100			

Legend

Legend	CBR % Value	S410 Classification
(blue)	60+	SSB
(dark green)	60	SB
(light green)	30	A
(yellow)	20	B
(orange)	10	Bulk Earthworks
(red)	5	Sub - Bulk Earthworks

5.3 Formation Layerworks Materials

The laboratory tests results have been used to evaluate and classify the near surface in-situ soils for their suitability for re-use in the formation layerworks and should be referred to for specific details, as contained in Appendix D. A summary of the classification of the soils encountered at each test pit for possible re-use in the construction of the formation layers and optimum/natural moisture content is given below.

The main criteria for the classification were based on the CBR compacted strength of the various soil horisons. In general, certain materials do not fully meet the specifications with respect of its grading modulus and grading envelopes and plasticity index (PI)>

Table 5.3: Summary of Results of Particle Size Distribution Analysis and Atterberg Limit Determinations, Compaction, CBR

Test Pit No.	Depth (m)	Description	Particle Size (%)				Atterberg Limits (%)			GM	OMC (%)	MDD (kg/m3	SAR Index	% Swell	CBR (%) at Minimum Compaction of Mod AASHTO Density					S410 Specification	TRH14 Classification
			Clay	Silt	Sand	Gravel	LL	PI	LS						90	93	95	98	100		
Phase 1																					
LL 1 [B]	1.5-3.0	Pale orange brown sand-residual sandstone	9	19.1	36.9	35	34	16	7	1.7	14.6	1931	45.3	0.00	6	8	10	13	16	Bulk earthworks	G10
LL 3 [B]	0.5-0.9	Pale orange brown sand-residual sandstone	10	13.0	42	35	CBD	NP	0	1.7	7.1	2092	45.2	0.00	10	14	23	30	36	Layer A	G8
LL 5 [C]	0.4-0.9	Pale orange brown sand-residual sandstone	11	19.3	67.7	2	CBD	NP	1	1.1	7.4	2104	45.3	0.00	12	15	16	20	22	Layer A	G7
LL 8 [C]	0.15- 0.65	Pale orange brown sand-Transported	18	25.8	49.2	7	27	10	7	0.95	12.9	1916	45.4	0.00	3	5	8	13	19	Spoil	G10
LL 8 [C]	0.65-1.75	Orange brown sand-residual sandstone	30	25.8	42.2	2	27	9	7	0.71	12.2	1928	45.6	0.00	6	8	9	13	15	Bulk earthworks	G10
LL 9 [C]	0.3-0.85	Pale orange brown sand-residual sandstone	20	16.4	61.6	2	17	6	3	1.03	8.9	2095	45.4	0.00	3	3	4	6	8	Spoil	G10
LL10 [C]	1.1-1.5	Orange brown sand-Residual Sandstone	NR	NR	NR	NR	NR	NR	NR	NR	7.1	2138	NR	0.00	3	8	9	11	15	Spoil	G10

LL11 [C]	2.1 - 2.35	Orange Brown Sand- Residual Sandstone	17	13.9	68.1	1	CBD	NP	0	1.2	7.2	2130	45.3	0.00	3	5	6	10	14	Layer B	G10
LL14 [C]	0.2-0.7	Orange Brown Sand- Residual Sandstone	14	19.2	65.8	1	15	6	3	1.1	7.1	2178	45.3	0.00	8	10	12	16	20	Layer B	G9
LL17 [B]	0.34-0.50	Orange Brown Sand- Residual Sandstone	18	18.2	36.8	27	32	13	6	1.1	10.0	2020	45.4	0.00	2	3	3	4	5	Spoil	G10
LL19 [B]	0.70-0.84	Orange Brown Sand- Residual Sandstone	16	19.7	48.3	16	19	6	2.5	1.0	7.8	2143	45.4	0.00	1	2	3	8	14	Spoil	G10
LL20 [B]	0.80-1.30	Orange Brown Sand- Residual Sandstone	26	18.3	33.7	22	35	12	6	0.9	14.5	1896	45.4	0.00	1	2	3	4	4	Spoil	G10
LL22 [C]	0.6-2.3	Orange Brown Sand- Residual Sandstone	12	12.8	73.2	2	CBD	NP	0	1.2	5.9	2032	45.2	0.00	4	10	16	20	24	Layer A	G10
LL24 [C]	0.35-1.1	Pale Orange Brown Sand- Residual Sandstone	19	35.7	40.3	5	29	12	5	0.7	14.9	1867	45.5	0.00	2	4	6	11	16	Spoil	<G10
LL28 [B]	0.95-2.7	Orange Brown Sand- Residual Sandstone	13	14.2	71.8	1	CBD	NP	0	1.2	7.7	2149	45.3	0.00	8	10	12	14	17	Layer B	G9
LL29 [B]	0.9-1.7	Orange Brown Sand- Residual Sandstone	11	8.4	79.6	1	CBD	NP	0	1.3	5.9	2023	45.2	0.00	4	7	11	16	22	Layer A	G10
LL29 [B]	1.7-2.32	Orange Brown Sand- Residual Sandstone	6	11.4	57.6	25	CBD	NP	0	1.8	6.4	2204	45.2	0.00	20	29	36	50	63	Layer A	G7

LL31 [B]	0.85-1.57	Pale Orange Brown Sand- Residual Sandstone	5	10	32.0	53	29	5	5	2.1	9.2	2116	45.2	0.00	1	3	5	11	20	Spoil	<G10
LL32 [B]	1.0-1.8	Orange Brown Sand- Residual Sandstone	13	11.9	74.1	1	18	6	3	1.3	7.2	2145	45.2	0.00	17	26	34	51	67	Layer A	G7
LL35 [C]	0.4-2.8	Orange Brown Sand- Residual Sandstone	9	16	73.0	2	20	6	3	1.3	12.5	1946	45.3	0.00	0	1	2	5	12	Spoil	<G10
LL37 [C]	0.8-1.25	Orange Brown Sand- Residual Sandstone	8	10.2	27.8	54	0	0	1	2.1	13.5	1900	45.2	0.00	7	10	14	19	21	Layer A	G9
LL38 [C]	1.25-3.0	Orange Brown Sand- Residual Sandstone	9	27.1	54.9	9	CBD	NP	0	1.1	11.6	1969	45.4	0.00	4	6	8	11	14	Layer B	G10
LL41 [C]	0.65-1.15	Orange Brown Sand- Residual Sandstone	8	9	62	21	CBD	SP	1.5	1.3	NR	NR	45.2	NR	NR	NR	NR	NR	NR	NR	NR
LL41 [C]	1.15-2.30	Pale Orange Brown Sand- Residual Sandstone	5	10	49	36	CBD	SP	1.5	1.5	7.3	2174	45.2	0.00	8	14	20	36	54	Layer A	G9
LL43 [B]	0.40-1.30	Orange Brown Sand- Residual Sandstone	14	16.3	52.7	17.0	23	6	3.0	1.1	7.9	2069	45.3	0.00	1	1	3	11	29	Spoil	G10
LL45 [B]	0.45-1.40	Orange Brown Sand- Residual Sandstone	15	35.5	47.5	2	34	12	5	0.8	12.4	2003	45.5	0.7	0	1	1	3	5	Spoil	<G10
LL45 [B]	1.4-1.8	Orange Brown Sand- Residual Sandstone	12	29.9	46.1	12	33	14	6	1.1	14.3	1871	45.4	1.2	3	5	6	9	11	Spoil	G10

LL 47 [B]	0.6-0.95	Orange Brown Sand –Residual Sandstone	10	18.3	41.7	30	27	10	5	1.5	9.3	2067	45.3	0.0	1	1	1	1	1	Spoil	<G10
LL 50 [B]	0.5-1.0	Orange Brown Sand- Residual Sandstones	19	17.4	39.6	24	31	12	4	1.4	11	1951	45.4	0.2	2	2	3	3	4	Spoil	<G10
LL 51 [B]	0.4-1.3	Orange Brown Sand- Residual Sandstone	7	16.3	72.7	4	29	12	6	1.2	8.4	2088	45.2	0.00	2	2	3	3	4	Spoil	<G10
LL 52 [B]	0.3-1.0	Pale Orange Brown Sand - Transported	12	10.8	73.2	4	CBD	SP	1	1.2	8.1	2184	45.2	0.00	4	5	7	8	10	Bulk earthworks	<G10
LL 52 [B]	1.0-2.05	Orange Brown Sand – Residual Sandstone	21	18.7	59.3	1	23	10	4	1.0	9	2063	45.4	2.0	3	4	5	7	9	Spoil	<G10
LL 52 [B]	2.05-2.5	Pale Orange brown Sand – Residual Sandstone	12	34.7	50.3	3	32	13	6	0.9	12.5	1957	45.5	1.8	2	2	3	4	4	Spoil	<G10
LL 52 [B]	2.5-3.0	Pale Orange brown Sand – Residual Sandstone	20	18.7	52.3	9	33	14	5	1.1	13.3	1906	45.4	0.4	2	3	3	4	5	Spoil	<G10
LL 53 [B]	1.8-3.0	Orange Brown Sand –Residual Sandstone	16	17.6	41.4	25	26	7	6	1.4	11.9	1952	45.3	0.9	4	4	5	5	5	Spoil	G10
LL 54 [B]	1.3-3.0	Orange Brown Sand – Residual Sandstone	26	12.5	59.5	2	25	7	5	1.0	11.4	1964	45.4	0.7	1	2	2	4	6	Spoil	<G10
LL 55 [B]	0.5-1.3	Pale Orange Brown Sand- Transported	11	11	77	1	0.00	SP	1	1.2	7.6	2142	45.2	0.00	7	9	11	14	17	Layer B	G10
LL 56 [B]	0.25-0.8	Pale Orange Brown Sand – Transported	10	13.8	49.2	27	16	7	2	1.6	8.1	2116	45.2	0.00	4	7	9	11	13	Spoil	G10

LL 56 [B]	1.2-2.2	Orange brown Sand – Residual Sandstone	14	33.4	27.6	25	36	15	8	1.2	15.3	1814	45.5	0.00	3	3	3	3	3	Spoil	G10
LL 58 [B]	0.85-3.0	Orange Brown Sand – Residual Sandstone	17	34.2	41.8	7	29	9	7	0.9	12.5	1884	45.5	0.5	4	5	7	8	9	Spoil	G10
LL 59 [B]	0.45-0.95	Orange Brown Sand – Residual Sandstone	14	14.1	70.9	1	CBD	SP	1	1.0	7.8	2108	45.3	0.00	3	5	7	11	16	Spoil	G10
LL 59 [B]	0.95-2.5	Pale Orange Brown Sand – Residual Sandstones	22	22	49	7	22	7	3	1.0	9.3	2053	45.4	0.5	3	3	4	6	7	Spoil	G10
LL 60 [C]	0.6-1.5	Pale Orange Brown Sand - Transported	10	19.9	68.1	2	CBD	NP	0	1.0	6.8	2039	45.3	0.00	4	7	11	16	19	Layer B	G10
LL 60 [C]	2.1-2.9	Orange Brown Sand- residual Sandstone	9	11.4	28.6	51	27	6	5	2.0	8.7	2114	45.2	0.2	2	3	4	6	7	Spoil	<G10
LL 62 [C]	0.7-1.2	Orange Brown Sand – Residual Sandstone	17	19.4	61.6	2	18	7	3	1.0	7.8	2138	45.4	0.00	7	10	14	22	29	Layer B	G9
LL 62 [B]	1.2-1.4	Pale Orange Brown Sand – Residual Sandstone	19	9.5	59.5	12	19	8	3	1.3	11.1	2061	45.3	0.00	3	3	4	4	5	Spoil	G10
LL 63 [B]	0.3-0.85	Pale Orange brown Sand -Transported	14	11.5	73.5	1	CBD	SP	2	1.1	7.6	2120	45.3	0.00	5	7	10	15	20	Layer A	G10
LL 63 [B]	0.85-1.65	Orange Brown Sand- Residual Sandstone	24	21.4	50.6	4	25	10	6	0.9	11.5	1970	45.5	0.2	3	3	4	5	6	Spoil	G10
Phase 2																					

LL 1 [C]	0.7-2.3	Orange brown Sand- Residual Sandstone	14	30.3	50.7	5	28	11	6	1.0	11.5	2004	45.4	0.00	1	1	2	3	4	Spoil	<G10
LL1 [C]	2.3-3.0	Pale Orange brown Sand- Residual Sandstone	9	17	59	15	27	12	6	1.5	14.5	1885	45.3	1.5	2	3	4	6	8	Spoil	<G10
LL 2 [C]	0.7-1.9	Orange Brown Sand – Residual Sandstone	14	29	44	13	30	14	7	1.1	12	1828	45.4	0.00	1	1	1	1	2	Spoil	<G10
LL 4 [C]	0.4-1.6	Pale Orange brown Sand- Residual Sandstone	19	30	49.7	1	20	6	3	0.8	13.3	1837	45.5	0.0	1	1	1	2	3	Spoil	<G10
LL 4 [C]	1.6-2.3	Orange brown Sand – Residual Sandstone	10	28.6	48.4	13	24	8	5	1.1	14.5	1838	45.4	0.00	5	6	7	9	10	Bulk earthworks	G10
LL 6 [C]	0.7-1.5	Pale Orange Brown Sand – Residual Sandstone	11	14.1	71.9	3	0	0	1	1.3	8.7	2020	45.3	0.4	2	2	2	2	3	Spoil	<G10
LL 6 [C]	1.5-2.4	Orange brown Sand – Residual Sandstone	18	18.7	58.3	5	0	0	2	1.1	12.3	1999	45.4	0.00	3	4	5	5	6	Bulk earthworks	G10
LL 8 [C]	0.4-1.2	Pale Orange Brown Sand – Residual Sandstone	10	9.2	79.8	1	0	0	1	1.3	7.9	2107	45.2	2.1	3	3	4	5	7	Spoil	G10
LL 8 [C]	1.2-2.2	Orange Brown Sand- Residual Sandstone	14	6.8	75.2	4	0	0	1	1.3	7.1	2156	45.2	0.0	8	12	17	21	27	Layer B	G10
LL 10 [C]	0.4-1.6	Orange brown Sand- Residual Sandstone	16	12.7	70.3	1	25	12	6	1.2	8.7	2138	45.3	0.6	3	4	7	9	11	Spoil	G10

LL 13 [C]	0.6-1.0	Orange Brown Sand – Residual Sandstone	26	24.1	48.9	1	25	9	5	0.8	12.6	2007	45.5	0.0	3	4	5	8	10	Spoil	G10
LL 13 [C]	1.0-1.5	Orange brown Sand – Residual Sandstone	12	31.8	54.2	2	29	10	7	0.9	13.6	1877	45.4	0.0	2	3	4	5	7	Spoil	<G10
LL 15 [B]	0.4-1.1	Pale Orange Brown Sand - Transported	10	16.4	72.6	1	CBD	SP	1	1.2	6.1	2176	45.3	0.0	8	12	18	26	34	Layer A	G9
LL 15 [B]	1.1-1.9	Orange Brown Sand – Residual Sandstone	14	27.2	47.8	11	34	15	7	1.1	14.7	1845	45.4	0.0	7	8	10	12	14	Bulk earthworks	G9
Structures																					
LL 1 (ST)	0.2-0.6	Pale Orange Brown Sand - Transported	16	10.2	72.8	1	CBD	SP	1	1.1	7.2	2141	45.3	0.00	10	15	18	26	33	Layer A	G7
LL 1 (ST)	0.6-2.0	Orange Brown Sand – Residual Sandstone	20	9.5	68.5	2	24	13	4	1.1	9.6	2086	45.3	0.5	3	4	5	7	8	Spoil	G10
LL 1 (ST)	2.0-3.0	Orange Brown Sand –Residual Sandstone	14	30	50	6	22	9	5	0.9	10	1997	45.4	0.2	4	4	5	5	6	Spoil	G10
LL2 (ST)	1.1-2.2	Orange brown Sand- Residual Sandstone	9	12.1	67.9	11	CBD	NP	0	1.3	6.1	1972	45.2	0.0	4	8	12	18	22	Layer A	G10
LL2 (ST)	2.2-3.2	Orange brown Sand- Residual Sandstone	5	22.9	69.1	3	CBD	NP	0	1.3	6.2	1931	45.3	0.0	3	6	10	20	32	Layer A	G10
LL3 (ST)	0.8-1.1	Pale Orange brown Sand-Transported	8	16.9	73.1	2	CBD	NP	0	1.2	6.7	2143	45.2	0.0	9	13	18	30	42	Layer A	G9

LL3 (ST)	1.1-1.8	Orange brown Sand- Residual Sandstone	16	28.3	46.7	9	22	7	4	1.0	13.5	1923	45.4	0.0	4	5	6	8	10	Spoil	G10
LL5 (ST)	0.8-1.8	Orange brown Sand- Residual Sandstone	12	25.1	54.9	8	21	6	4	1.1	12.1	1864	45.4	0.4	3	4	5	7	8	Spoil	G10
LL5 (ST)	1.8-3.0	Pale Orange brown Sand- Residual Sandstone	21	24.9	50.1	4	33	17	6	0.9	14	1904	45.5	0.8	3	4	4	5	5	Spoil	G10
LL6 (ST)	0.5-0.8	Pale Orange brown Sand-Transported	8	10.4	74.6	1	CBD	SP	1	1.2	6.8	2178	45.2	0.0	10	15	21	30	38	Layer A	G7
LL6 (ST)	0.8-3.0	Orange brown Sand	13	26.8	51.2	9	32	15	5	1.1	12.1	1932	45.4	0.0	4	6	8	10	12	Spoil	G10
LL7 (ST)	0.2-0.8	Pale orange brown Sand-Transported	26	29.6	42.4	2	25	11	4	0.8	11.7	1914	45.6	1.2	3	5	5	6	7	Spoil	G10
LL7 (ST)	0.8-3.0	Orange brown Sand- Residual Sandstone	13	26.6	56.4	4	32	11	6	1.0	14.1	1863	45.4	0.0	1	1	2	3	4	Spoil	<G10
LL8 (ST)	0.2-0.55	Pale orange brown Sand-Transported	17	16.2	64.8	2	CBD	SP	2	1.1	7.1	2148	45.3	0.2	7	9	12	18	25	Layer A	G9
LL8 (ST)	0.55-1.5	Orange brown Sand- Residual Sandstone	15	27.4	49.6	8	31	12	7	1.0	12.9	1899	45.4	1.0	4	5	5	6	6	Spoil	G10
LL9 (ST)	0.4-2.2	Orange brown Sand – Residual Sandstone	16	31.1	47.9	5	28	12	4	0.9	11	2015	45.5	1.0	2	2	3	3	4	Spoil	<G10
LL10 (ST)	0.6-1.4	Orange brown Sand-Transported	19	17.8	59.2	4	32	15	7	1.0	14.6	1831	45.4	0.4	3	4	5	6	8	Spoil	G10

LL11 (ST)	0.2-0.6	Pale Orange brown Sand- Transported	25	7.8	65.2	2	22	6	3	1.0	10.5	1995	45.3	0.1	3	3	4	4	5	Spoil	G10
LL11 (ST)	0.6-1.4	Orange brown Sand- Residual Sandstone	14	22.2	53.8	10	32	12	6	1.1	14.4	1842	45.4	0.6	3	4	5	6	7	Spoil	G10
LL12 (ST)	0.5-2.1	Orange brown Sand- Residual Sandstone	20	16	59.1	4	36	16	7	1.0	14.9	1821	45.4	1.4	1	2	2	4	5	Spoil	<G10
LL1 (FT)	0.65-1.10	Pale Brown Sand- Residual Sandstone	17	12.9	69.1	1	23	10	4	1.1	9.5	2005	45.3	0.0	3	4	5	6	7	Spoil	G10
LL1 (FT)	1.1-2.2	Pale Orange Brown Sand- Residual Sandstone	22	8.4	66.6	3	24	11	3	1.1	8.6	2020	45.3	0.1	3	5	7	9	12	Spoil	G10
LL2 (FT)	0.4-1.3	Orange Brown Sand- Residual Sandstone	18	5.9	75.1	1	21	5	3	1.2	7.9	2145	45.2	0.2	3	5	6	9	12	Spoil	G10
LL1 (EMB)	0-0.3	Light Red Sand- Fill	6	6.1	41.9	46	CBD	SP	1	2.1	6.4	2265	45.1	0.0	7	9	11	15	18	Layer B	G9
LL1 (EMB)	0.8-2.0	Orange brown Sand- Transported	23	13.8	58.2	5	32	12	5	1.0	13.5	1945	44.4	0.1	3	4	6	7	9	Spoil	G10

LL – Liquid Limit
OMC – Optimum Moisture Content

PI – Plasticity Index
MDD – Maximum Dry Density

LS – Linear Shrinkage
CBD – Cannot Be Determined

NP/SP – Non/Slightly Plastic
CBR – California Bearing Ratio

NR – No Result
[C] / [B] – Denotes sample tested at proposed Cut/Bank

5.4 Foundation Conditions at Structures

The alignment for this proposed new loop is such that several pipe/box culverts exist along the proposed development. Based on the results of the fieldwork, it is apparent that all the subsoils encountered at these locations influence the founding conditions. The test pits dug at these culverts reveal variable and generally loose to medium dense *Topsoil, Fill and Transported* horisons and are considered unsuitable founding horisons. Ideally foundations should be placed at an average depth of 0.85m on more competent subsoil horisons of dense to very dense *Residual Sandstone*.

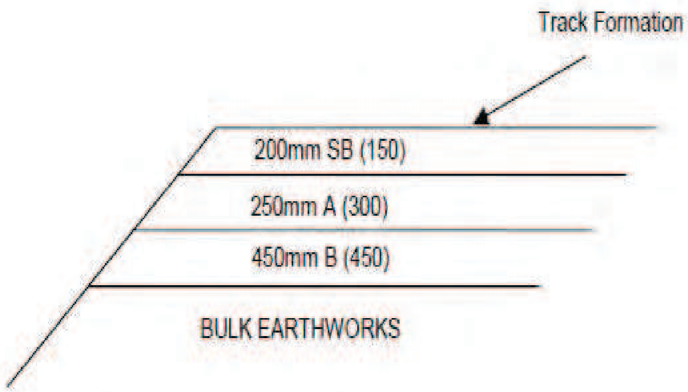
It is generally understood that in general cut to fill and/or fill procedures will be carried out for the founding of the proposed structures and these are likely to impact on the anticipated founding depths. Actual founding depths will depend on the final cut and/or embankment levels. Using the information summarised in table 4.2.6, the proposed structures to be founded in Cut should be placed on the competent dense to very dense *Residual Sandstone*. For the proposed structures to be placed on Embankment materials due diligence will need to be given, specifically to the design of embankments in order to avoid excessive founding depths and potential settlements.

The exact loads for the proposed structures were unknown at the time of writing this report. The above should only be used for conceptual design and must be revised when the actual foundation configuration and loads are known. As part of the design of the foundations, calculations for bearing capacity failure must also be conducted.

The settlement of a foundation is almost always the governing criteria and it is therefore proposed that the bearing capacity evaluation be conducted for the actual foundation configurations loads.

5. RECOMMENDATIONS AND CONCLUSIONS

The proposed development of Lephalale Yard and the recommendations given below need to be implemented in terms of the S410 Specification for Railway Earthworks. The specified layerworks for unstabilised layers for 20 ton axle loading conditions will apply:



In accordance with the abovementioned criteria, the following ***general earthworks considerations*** are recommended for the proposed yard:

- **Embankment sections** (up to ± 4.0m high) the following are recommended:

- Remove (to stockpile for re-use) any topsoil/fill with grass and roots
- Compact in-situ soil to achieve a minimum CBR of 5%
- Import and construct appropriate layerworks including Bulk Earthworks B, A and SB (sub-ballast) formation layers according to the Specification for Railway Earthworks S410 (Grabe & Maree, 2006). For example, in application this will require the imported SB (sub-ballast) material to have a PI of between 3 and 10, a minimum grading modulus of 1,8 and a CBR of not less than 45%, compacted to a minimum of 95% Mod AASHTO density.

- **Cutting sections** of up to 10.m deep:

- Remove (to stockpile for re-use) any topsoil with grass and roots
- Excavate (for a 4m wide strip at 2.6m from the centerline of the existing track) to a level equivalent to 0.9m below final formation level. When encountered, large sandstone boulders and/or bedrock to be excavated to the required depth. Blasting may be required. If due to blasting the cutting is over excavated, the A layer must be provided and placed before construction of the SB layer commence. The depth of the cut will vary along the doubling according to the variation in ground level relative to the top of rail level
- Where possible (based on the geotechnical investigation this in-situ material is expected to comprise of dense to very dense silty sand/sand (occasionally gravels) and/or soft to hard rock sandstone boulders/rock), compact in-situ material to a minimum 90% Mod AASHTO density, if complying to the requirements for Bulk Earthworks layer
- Import and construct appropriate including B, A and SB (sub-ballast) formation layer according to the S410 Specification for Railway Earthworks (March 2006). The imported SB (sub-ballast) material shall have a PI of between 3 and 10, a minimum grading modulus of 1,8 and a CBR of not less than 45%, compacted to a minimum of 95% Mod AASHTO density.

- **Level/Cut sections** (< 1.0m deep)

- Remove (to stockpile for re-use) any topsoil with grass and roots.
- Excavate to a level equivalent to 0,90m below final formation level and stockpile material for re-use in isolated sections where needed. The depth will be different depending on the ground level and the required height of the rail.
- Compact in-situ material to a minimum of 90% Mod AASHTO to achieve a minimum strength CBR of 5%, if complying with the requirements for Bulk Earthworks layer.
- Import and construct appropriate layerworks including B, A and SB (sub-ballast) formation layers according to the S410 Specification for Railway Earthworks (Grabe & Maree, 2006).

In general permanent cut and fill slopes are not to be steeper than 1 : 2 and are to include benching where appropriate.

The **service road** is to be constructed in accordance with the specifications given in the S410 specification. The minimum layers required are the 300mm thick B-Layer (compacted to a minimum of 93% Mod AASHTO density) and the 150mm thick wearing course (compacted to a minimum of 95% Mod AASHTO density) in accordance with the S410 material specification. The full thickness of the wearing course is to extend above the existing ground level. The foundation beneath the B-layer is to be a 150mm deep in-situ rip (only in non-cohesive soils) and re-compacted to a minimum of 90% Mod AASHTO density.

The results of this investigation of the in-situ geotechnical conditions along the alignment for the proposed loop are presented and evaluated in this report. While particular sections are faced with geotechnical conditions that are not conducive to the specific application in the natural condition, these problem areas can be overcome with the use of good engineering design principles and construction methods. These have been presented and discussed in the report and include removal of substandard material and/or thick cohesive horisons (if encountered) in isolated sections and replacement with appropriate quality soil (formation layerworks), provision of water control measures, safe slope angles for excavated cutting slopes and newly constructed embankment slopes, in-situ preparation methods for general earthworks and foundation types for structures.

It should be noted that the information presented in this report and summarised in the tables has been taken from the geotechnical fieldwork and results of the laboratory tests. A certain amount of interpretation was necessary in the generalisation of the results during the evaluation. During construction, site conditions should be constantly monitored to ensure that the actual conditions are not at variance with the generalisations made in this report. Should variations be found, these areas would be treated on an ad hoc basis at the time. The contents of this report are an interpretation of the findings and are therefore not a design report. Consequently, design of the various components of the project such as railway line formation (preparation and layerworks), embankments, cuttings, foundations, 20 ton axle load sections, new turnouts and crossovers should still be carried out.

J. VILJOEN
Senior Engineering Geologist