TCTA

MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

CONTRACT № TCTA 07-041

CONSULTING SERVICES FOR MCWAP

PHASE 2: GEOTECHNICAL INVESTIGATIONS
STAGE 4: Steenbokpan - Matimba

VOLUME 1: GEOTECHNICAL DATA REPORT

July 2012

MOKOLO CROCODILE CONSULTANTS

Report No: 2A-R-111E-55 (Rev A)

MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

CONTRACT № TCTA 07-041

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Title: **Phase 2: Geotechnical Investigations**
Stage 4: Steenbokpan - Matimba
Volume 1: Geotechnical Data Report

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MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

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PHASE 2: GEOTECHNICAL INVESTIGATIONS STAGE 4: Steenbokpan - Matimba

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MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

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PHASE 2: GEOTECHNICAL INVESTIGATIONS STAGE 4: Steenbokpan - Matimba

VOLUME 1: GEOTECHNICAL DATA REPORT

EXECUTIVE SUMMARY

1 INTRODUCTION

Mokolo Crocodile Consultants (MCC) has been appointed by the Trans-Caledon Tunnel Authority (TCTA), the implementing agency, to undertake the detailed design of the Mokoloand Crocodile Water Augmentation Project (MCWAP).

The MCWAP is implemented using a phased approach. Phase 2 has, for practical reasons, been split into 4 stages. This Report deals with Phase 2: Stage 4 of the Project, extending from the Steenbokpan in the west to Matimba in the east, a distance of approximately 37.9 km. Similar and separate reports have been compiled and generated for the other 3 stages.

In partial fulfilment of Sub-Task 1.1.1E – Field Investigation Report of Appendix A of the Scope of Services for the MCWAP, further geotechnical investigations were undertaken. Following an evaluation of available geotechnical information obtained from feasibility stage investigations, this task comprised the planning and execution of geotechnical field investigations. The feasibility investigation work comprised test pitting on a nominal spacing of 200 m along the centreline. However, access was not possible to the whole centreline. In addition, the route in the vicinity of the new Medupi Power Station has since been realigned to follow the deviated road D1675 (to the north of the power station).

Report “Phase 2 Stage 4: Geotechnical Investigations” comprises three volumes, of which this is Volume 1:

- Volume 1: Geotechnical Data Report (**This Volume**);
- Volume 2: Annexures supporting Volume 1; and
- Volume 3: Geotechnical Interpretive Report.

This Volume contains the narrative, factual data, whilst Volume 2 contains the Annexures supporting the Report. Volume 3 interprets the data contained in Volumes 1 and 2 and should be read in conjunction with them.

2 BACKGROUND

The Department of Water Affairs (DWA) commissioned the Mokolo and CrocodileRiver (West) Water Augmentation Project (MCWAP) Feasibility Study to analyse the options for transferring water from the Mokolo Dam and Crocodile River (West). In April 2008 the Technical Module of this study was awarded to Africon (now incorporated in Aurecon) in association with Kwezi V3, VelaVKE and specialists. The focus of the Technical Module was to investigate the feasibility of options to:

- Augment the supply to the Lephalale area from Mokolo Dam to supply the growing water requirement for the interim period until a transfer pipeline from the Crocodile River (West) can be implemented (Phase 1); and
- Transfer water from the Crocodile River (West) to the Lephalale area (Phase 2).

The Technical Module had been programmed to be executed at a Pre-feasibility level of investigation to identify different options and recommend the preferred schemes. This was followed by a feasibility level investigation of the preferred water schemes. Recommendations on the preferred options for Phase 1 and Phase 2 were presented to DWA during October 2008 and draft reports were submitted during December 2008. The Feasibility Stage of the project commenced in January 2009 and considered numerous water requirement scenarios, project phasing and optimisation of pipeline routes. The study team submitted draft Feasibility Reports during October 2009 to the MCWAP Main Report in November 2009.

As part of the Tender Design stage for Phase 1, detailed geotechnical investigations have been performed for Phase 2 Stage 4 of the MCWAP. Components investigated include the pipeline route and borrow pits and foundations for structures at road, rail and conveyor crossings.

The Chainage reference system used increases from west to east (Steenbokpan to Medupi). The test pits were not numbered in any specific sequence.

The diameter of the pipeline has not yet been established. Interpretations given in the report assume a diameter of 2000 mm and will have to be amended once the actual pipe diameter is known.

3 PIPELINE ROUTE INVESTIGATIONS

During the Feasibility Stage of the project, investigations were carried out and entailed test pitting at nominal 200 m centres (400 m where only limited access was permitted) with laboratory testing and identification of potential borrow sources. The work was carried out by the soils testing laboratory, Civilab, under competitive tender. The relevant information from this investigation has been extracted from the Civilab report and is incorporated into this report.

The pipeline route investigation comprised test pitting at a nominal spacing of 200 m (using a TLB[2]) along the centreline of the pipeline route. The pits were dug to a depth of 4 m (or to refusal of the TLB) and were profiled in accordance with standard procedures and profiles of each test pit have been compiled. The soils encountered were sampled and tested to assess their suitability for use as bedding and selected backfill to the pipe. Laboratory tests (Indicator, compactability

[2]Minimum characteristics: Backhoe depth not less than 4 m; gross power not less than 70 kW; and bucket breakout force not less than 60 kN.

tests, etc.) were carried out on representative samples. Occasional pH, conductivity tests and chemical (SRB) tests were carried out on different soil types in order to assess the aggressiveness of the soils towards the steel pipeline.

Geotechnical tests (triaxial, shearbox, Constrained Soil Modulus (M_s) and Hydrostatic Compression) were carried out in order to quantify the characteristics of the soils when used as bedding or selected backfill to the pipeline.

The topsoil and subsoil (at borrow pit sites and along the centreline) were tested to establish their fertility and to provide baseline data when rehabilitating borrow pits and over the backfilled pipeline.

Dynamic penetrometer tests (DPLs, commonly incorrectly referred to as DCPs) were conducted in and adjacent to selected test pits in order to provide a quantitative assessment of the consistency of the soils encountered. These soundings were reduced to equivalent Standard Penetration Tests (SPT) N-values (blows per 300 mm penetrated) and are presented graphically (as SPT N-values versus depth) on the soil profiles.

Access was not permitted onto the farms Minnaarspan 322LQ and Loopleegte 302LQ and no additional test pitting (other than those dug during the Feasibility Study, at a spacing of 400 m) was possible, nor was it possible to prospect for a borrow pit in this area.

4 BORROW PITS

Eight borrow pits were located, providing suitable bedding and selected backfill material, generally at an economic spacing for haulage purposes during construction. The results of the borrow pit investigation are presented in Annexure B, and include locality plans, test pit profiles and results of laboratory testing. The main characteristics are summarised hereunder in Table 5.

Table 5: Borrow pit summary

BP no.	Location (WGS84 Lo27)		Chainage (m)	Offset to pipeline (m)	Est. volume bedding & soft backfill (m^3)	CF (range)
	Y	X				
15	-028 890	2 622 230	1,100	50 L	≈100,000	0.34 – 0.39
46	-034 374	2 620 484	6,800	100 L	≈90,000	0.24 – 0.38
59	-041 444	2 624 690	14,800	100 L	≈100,000	0.30 – 0.33
13	-047 261	2 623 428	20,000	1,500 R	≈80 000	0.33 – 0.43
14	-050 677	2 623 165	25,300	500 R	>100,000	0.28 – 0.44
12	-055 295	2 623 914	30,500	1,800 R	>100,000	0.30 – 0.41
51	-057 365	2 621 430	32,500	100 L	≈90,000	0.38 – 0.48
11#	-061 459	2,623 604	36,200	2100 R	≈45,000	0.25 – 0.48

# Common borrow pit with Phase 1
CF = Compactability Factor
L = Left/North of pipeline
R= Right/South of pipeline

In addition to these sources of natural materials, coarse ash from Matimba Power Station has been sampled and tested for use as granular bedding/backfill. It has proven to have acceptable physical characteristics for this use. Further testing is necessary to establish whether it may pollute groundwater.

5 SITE SPECIFIC INVESTIGATIONS

Core drilling was carried out at three sites where the pipeline crosses infrastructure (ash conveyor, road crossing and rail bridge). Two boreholes were drilled at each position and borehole logs and core photographs appear in the Annexures.

6 FINDINGS

Karoo sediments (sandstone, mudrocks, coal) are present to the north of the east-west trending Eenzaamheid Fault. The Karoo sediments are downthrown into contact with older Waterberg sandstone, which are present along the southern side of the fault. Extensive deposits of Quaternary sand are present, blanketing the underlying geology, particularly in the west. Calcrete and ferricrete frequently occur at the base of the sand.

The investigation was carried out after the rainy season. Despite this, no groundwater was encountered in any of the test pits dug on the site.

In addition to the bedding material from the borrow pits, gravel (present below the sand) was identified and sampled for use in gravelling haul roads and regravelling of existing roads that may be damaged during hauling operations.

The nearest known commercial sources of crushed stone and crusher dust and concrete/building sand are located in the vicinity of Lephalale, about 10 km east of Matimba. These sources have been discussed in detail in the Stage 1 report on this project and are not repeated here.

Very soft rock sandstone was encountered at all the structures intersected by the pipeline at depths varying between 1.7 and 8 m, with harder rock present at between 5 and 8 m.

This Report outlines and summarises the results and findings of the geotechnical investigations.

At time of writing, not all laboratory test results have necessarily been supplied by the testing laboratory and the following cut-off dates apply:

- Received by 30 July 2011: bound into Annexures (Volume 2) and have been interpreted in Volume 3; and
- Received after 1 August 2011: are neither bound into Volume 2, nor interpreted in Volume 3 and are only stored in electronic format in the Project Files.

On the first page to each Annexure in Volume 2 a summary is included detailing any outstanding test results.

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VOLUME 1: GEOTECHNICAL DATA REPORT

GLOSSARY

ARC	Agricultural Research Council of South Africa
BH	Borehole
BP	Borrow pit
CBR	California Bearing Ratio
DCP	Dynamic Cone Penetrometer
DPL	Dynamic Probe – Light
DWA	Department of Water Affairs
MCC	Mokolo Crocodile Consultants
MCWAP	Mokolo and Crocodile Water Augmentation Project
PI	Plasticity Index
Ptn	Portion
SANAS	South African National Accreditation System
SPT	Standard Penetration Test
SRB	Sulphate Reducing Bacteria
TCTA	Trans-Caledon Tunnel Authority
TLB	Tractor-loader-backhoe
WGS84	World Geodetic System (dated 1984)

1 INTRODUCTION

Mokolo Crocodile Consultants (MCC) has been appointed by the Trans-Caledon Tunnel Authority (TCTA), the implementing agency, to undertake the detailed design of the Mokolo and Crocodile Water Augmentation Project (MCWAP).

The MCWAP is implemented using a phased approach. In partial fulfilment of Sub-Task 1.1.1E – Field Investigation Report of Appendix A of the Scope of Services for the MCWAP, further geotechnical investigations were undertaken. Following an evaluation of existing available geotechnical information obtained from Feasibility Stage investigations, this task comprised the planning and execution of further geotechnical field investigations which had been identified as being necessary. The earlier work comprised investigations of the sub-surface materials along the pipeline route.

The results of the geotechnical investigations conducted during the Feasibility Stage, and forming part of Sub-Task 1.1.1E, are presented and interpreted by MCC as baseline information on the engineering properties and the agricultural properties during the design, tender and construction stages.

For practical purposes Phase 2 is reported on in 4 separate Stages as follows:

- Stage 1: Tarantaalpan to Operational Reservoir (along Transnet rail line) (55.5 km);
- Stage 2: Crocodile River to Transnet Rail Line (Tarantaalpan) (42.0 km);
- Stage 3: Operational Reservoir to Steenbokpan (approximately 27.8 km); and
- Stage 4: Steenbokpan to Matimba (approximately 37.9 km).

This Report deals only with Phase 2 Stage 4 of the Project. Similar reports have been compiled for the other three Stages making up Phase 2. The location of the different Stages is shown on the Locality Plan (Figure 1).

The Chainage reference system used increases from west to east (Steenbokpan to Matimba). The test pits were not numbered in any specific sequence.

At time of writing, not all laboratory test results have necessarily been supplied by the testing laboratory and the following cut-off dates apply:

- Received by 30 July 2011: bound into Annexures (Volume 2) and have been interpreted in Volume 3; and
- Received after 1 August 2011: are neither bound into Volume 2, nor interpreted in Volume 3 and are only stored in electronic format in the Project Files.

On the first page to each Annexure in Volume 2 a summary is included detailing any outstanding test results.

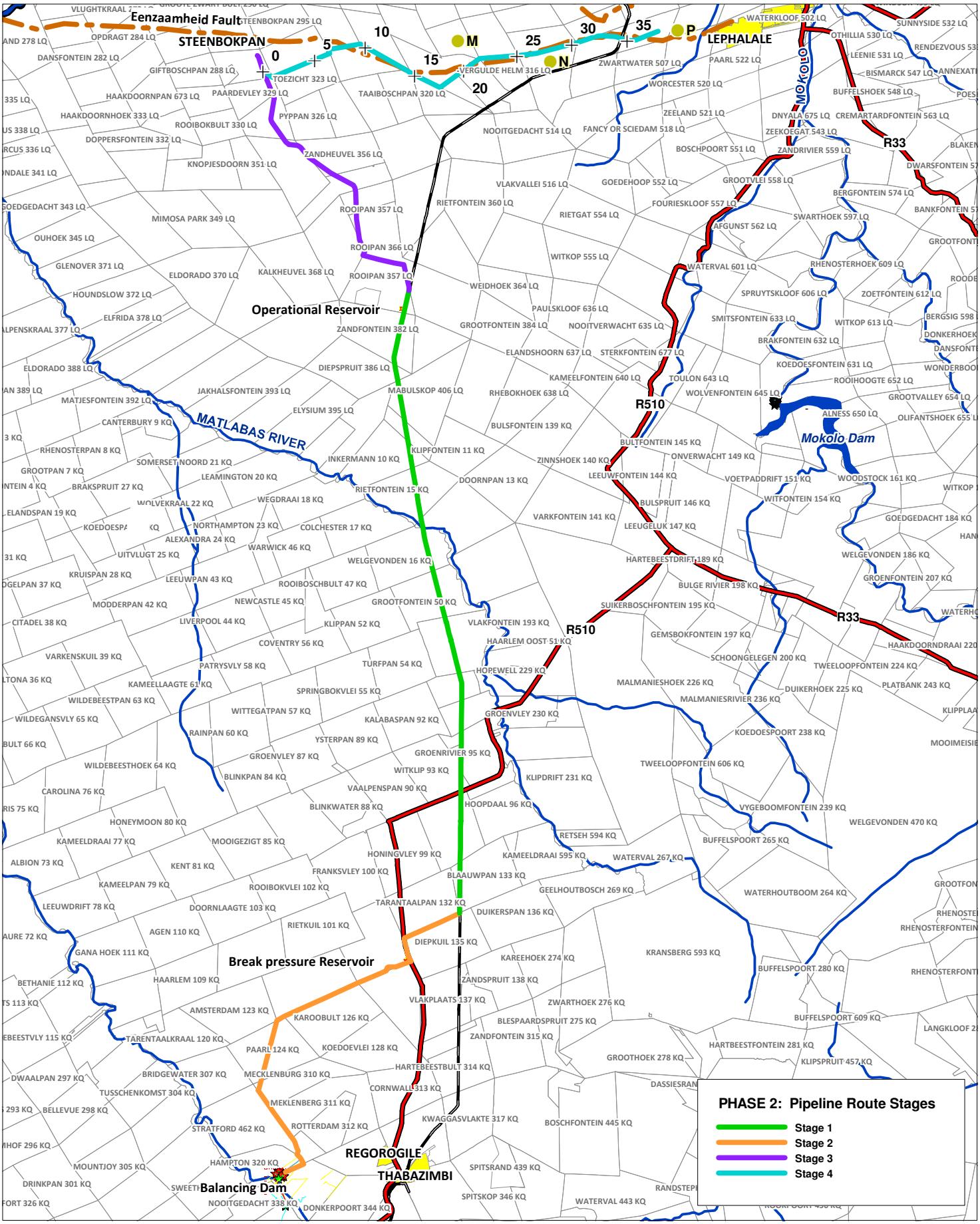
1.1 Background

1.1.1 Feasibility Investigations

The Department of Water Affairs (DWA) commissioned the Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study to analyse the options for transferring water from the Mokolo Dam and Crocodile River (West). In April 2008 the

Technical Module of this study was awarded to Africon (now incorporated in Aurecon) in association with Kwezi V3 (now incorporated in Worley Parson), VelaVKE and specialists. The focus of the Technical Module was to investigate the feasibility of options to:

- Augment the supply to the Lephalale area from Mokolo Dam to supply the growing water requirement for the interim period until a transfer pipeline from the Crocodile River (West) could be implemented (Phase 1); and
- Transfer water from the Crocodile River (West) to the Lephalale area (Phase 2).



Legend

- Spoil Sites
- km
- Main Roads
- Railway Line
- Rivers
- Farm Boundaries
- Towns

Scale: 1:440,000

5 0 5 10
Kilometers

N

Project: Mokolo and Crocodile (West) Water Augmentation Project

Drawing Title: Phase 2 Locality Plan (Stage 4)

Drawing Number: 2A-G3-028

Rev: FIG 1

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The Technical Module had been programmed to be executed at a Pre-Feasibility level of investigation to identify different options and recommend the preferred schemes. This was followed by a Feasibility level investigation of the preferred water schemes. Recommendations on the preferred options for Phase 1 and Phase 2 were presented to DWA during October 2008 and draft and final reports were submitted during December 2008. The Feasibility Stage of the project commenced in January 2009 and considered numerous water requirement scenarios, project phasing and optimisation of pipeline routes. The study team submitted draft Feasibility Reports during October 2009 to the MCWAP Main Report in November 2009.

As part of the Feasibility investigations, geotechnical investigations were performed for Phase 2 of the MCWAP. These included the following:

a) Pipeline Route Investigations

The pipeline route investigation carried out during the Feasibility Stage comprised test pitting (using a TLB[3]) along the centreline of the pipeline route at a nominal spacing of 200 m. Access was permitted for a limited period only to the farms Minnaarspan 322KQ and Loopleegte 302KQ. In order to complete the work within the limited time allowed, the spacing between test pits was increased to 400 m. In addition, the route investigated passed south of Medupi Power Station, following the existing Lephalale to Steenbokpan road. The pits were dug to a depth of 4 m (or to refusal of the TLB), were profiled in accordance with standard procedures and logs of each test pit compiled. The soils encountered were visually evaluated to provide a preliminary assessment of their suitability for use as bedding and selected backfill to the pipe. Preliminary identification (maximum 6 test pits) of potential borrow sources was carried out and limited laboratory testing was carried out.

Dynamic penetrometer tests (DPLs, commonly referred to as DCPs) were conducted adjacent to and in selected test pits in order to provide a quantitative assessment of the consistency of the soils encountered. These soundings were reduced to equivalent Standard Penetration Tests (SPT) N-values (blows per 300 mm penetrated) and are presented graphically (as SPT N-values versus depth) on the soil profiles.

Applicable data from these investigations has been extracted from the reports on this work and is integrated into the current report.

The fieldwork was carried out under competitive tender by the soils testing laboratory, Civilab.

[3] Minimum characteristics: Backhoe depth not less than 4 m; gross power not less than 70 kW; and bucket breakout force not less than 60 kN.

b) Potential Borrow Pits

Five potential borrow pits were identified. No prospecting for borrow sources was permitted on Minaarspan 322LQ and Loopleegte 302LQ. Due to hunting activities, no prospecting was initially allowed on Kringgatspruit 318LQ. This resulted in an extensive gap of approximately 19 km between BP13 and BP15.

c) Feasibility Study Report

Supporting Report 8b – Detailed Geotechnical Investigations (Report Number P RSA A000/00/8409) prepared by the lead Consultant, Africon, in association with other consultants, covers the results obtained from these investigations undertaken during Feasibility Stage.

Applicable data from this investigation has been extracted from the above report and is integrated into the current report.

1.1.2 Current Investigations

Following selection of the final alignment, a detailed geotechnical investigation was carried out to address the shortcomings in the above report. The investigation aimed to characterise the material conditions along the pipeline and to define borrow sources along the route. The investigation comprised the following aspects:

a) Excavation of test pits at nominal 200 m centres along those sections of the pipeline that had not been covered during the Feasibility Study investigations;
b) The proving of sources of borrow material for bedding and backfill material at a nominal spacing of 5 km. Test pits were dug at a nominal spacing of 30 m to prove a nominal 100,000 m^3 of suitable material at each borrow site;
c) Laboratory testing (Indicators, pH, conductivity, compactibility, triaxial, shearbox, Constrained Soil Modulus, Hydrostatic Compression) was carried out to characterise the materials encountered;
d) Additionally, SRB and Fertility tests were carried out to define the corrosion potential of the soils encountered and to provide baseline data for rehabilitation along the pipeline and at borrow pits;
e) Core drilling was carried out at three sites along the route where this crosses infrastructure; and
f) A desk-top seismic hazard assessment.

The fieldwork and laboratory testing was carried out by Geostrada, under competitive tender.

2 SCOPE OF REPORT

2.1 Scope of Geotechnical Investigations

This Report covers and summarises the results of the detailed geotechnical investigations conducted during the Tender Design Stage along the pipeline route from Steenbokpan to Matimba, a distance of approximately 37,9 km. Over much of this length, the pipeline is next to the D1675 road, except in the west where it deviates from the road alignment to sub-parallel it about 2 km south of the road. This is to avoid sterilising any coal deposits in this area.

3 AVAILABLE GEOTECHNICAL INFORMATION

3.1 Desk Study

The investigations commenced with a desk study of available information; the findings of which are summarised hereunder:

- Feasibility Report as detailed in 1.1.1 (c) above; and
- Researching documented geology on published geological maps.

3.2 Published Information

Available geological information including the published 1:250 000 scale geological map (Council for Geoscience). The relevant sheet is:

- Sheet 2326 Ellisras.

3.3 Feasibility Study Investigations

During the Feasibility Study for the MCWAP, test pitting was carried out along the centreline of the pipeline route, at a nominal spacing of 200 m. Test pits were profiled and laboratory testing carried out. The investigation was reported to the (then) Department of Water Affairs and Forestry as the report “Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study: Technical Module: Supporting Report No. 8b: Detail Geotechnical Investigations: Phase 2”.

The data from the earlier report has been extracted and is incorporated into this Report.

4 INVESTIGATION METHODOLOGY

This section describes the investigation methodology followed during the Tender Design investigations.

4.1 Outline

A broad outline of the geotechnical investigations comprised the following:

- Assessment of climate and weathering;
- Desk study of available information;
- Field verification of the geology;

- Rotary core drilling at road, rail and conveyor crossings;
- Test pitting along the pipeline;
- Test pitting in potential borrow pits;
- Dynamic Penetrometer Light (DPL) tests (commonly referred to as DCP tests);
- Laboratory testing of material samples taken in the field; and
- Desk-top seismic hazard assessment.

As the pipeline diameter had not been fixed at the time of the investigations, these were based on an assumed diameter of 2,000 mm and a trench depth of 4,000 mm.

4.2 Desk Study

Available geological and geotechnical data was assessed in order to obtain background information relating to the expected geotechnical conditions on the site. On a broad level, the published geological maps (Council for Geoscience) were studied and images from Google Earth®

The available sources of information are listed in Section 3.2 above.

4.3 Field Verification of the Geology

During the field investigations the geology of the site was confirmed by occasional test pits that encountered bedrock.

The co-ordinates of test pits excavated along the pipeline were recorded using a hand-held GPS instrument. Boreholes drilled at structures were accurately surveyed after completion. Coordinates comply with the WGS84 coordinate system, utilising the Hartbeeshoek94 Datum (South African Grid, Lo 27.

4.4 Centreline Test Pitting (see Annexures A, B, C and D)

Test pits were dug along the pipeline route in order to assess the thicknesses and quality of the in-situ material. The test pits were dug using a New Holland B90B and a Hidromek 102B tractor-loader-backhoe (TLB). Excavation with a TLB gives a direct assessment of the excavatability of the materials present and allows their inspection in an undisturbed state.

The characteristics of the TLBs are given below:

Table 1: Characteristics of TLBs

Specification	New Holland B90B	Hidromek 102B
Overall power (kW)	72	75
Max. Torque (Nm/rpm)	400/1400	415/1350
Bucket width (mm)	610	600
Maximum reach (mm)	4270	4400

Holes were generally dug to refusal of the TLB, or to a maximum depth of 4 m (based on an assumed 2,000 mm diameter pipeline). A summary of all the test pits dug is given in Annexure A.

The profiles encountered were logged by a geospecialist and samples were taken of representative horizons. Test pit profiles appear in Annexure B. Profiles were logged in accordance with Brink and Bruin, 2002.

After logging and sampling the holes were immediately backfilled using the TLB. Where the nature of the in-situ materials permitted it, DPL tests were carried out in order to obtain a quantitative assessment of the consistency of the soils encountered. The DPL soundings were reduced to equivalent SPT N-values (blows per 300 mm penetrated) and presented graphically as N-value versus depth on the test pit profiles.

No groundwater was encountered in any of the test pits dug on the site.

At the time of profiling, a visual assessment of the conditions encountered in the hole was made in order to allow interpolation of laboratory test results between the sites, and comments were recorded relating to:

- depth of refusal and nature of material on which refusal took place;
- stability of trench sides;
- likely longer term (safe) sideslopes during construction;
- the presence of groundwater/seepage, level of occurrence, initial inflow and rest level after 24 hours;
- the anticipated utilisation (as bedding or soft backfill) of the soils encountered; and
- any other observations relevant to construction of the pipeline.

It must be accepted that these comments were made without the benefit of laboratory test results or detailed analysis, are indicative only of the observations made on site. The comments must NOT be relied on, and do not form part of the interpretation of the data.

The laboratory test results are given in Annexure C (Feasibility Stage investigations by Civilab) and in Annexure D (Tender Design Stage investigations by Geostrada). Photographs of the test pits are given in Annexure C2 (for Civilab investigations) and Annexure D2 (for Geostrada investigations).

4.5 Borrow Sources (see Annexure E)

Sources of material suitable for use as bedding or soft backfill to the pipe were sought at a nominal spacing of 5 km along the pipeline and volumes were proven by digging test pits on a grid of 30 m. Assuming a pipe diameter of 2,000 mm and corresponding trench dimensions, the target volume of material was 100,000 m^3 per borrow pit, which approximates to 200% of the volume of material required as bedding/backfill for 5 km of pipeline. The estimated requirement of 100,000 m^3/5 km ignores the fact that suitable bedding and backfill material may be sourced from the pipe trench.

With reference to borrow sources of potential bedding and selected backfill material, the investigation was aimed at locating material with the following minimum quality characteristics:

a) Maximum particle size 19 mm;
b) Not more than 5% passing the 13.2 mm sieve;
c) Not more than 20% passing the 0.425 mm sieve; and
d) PI less than 12.

While these do not necessarily meet the specification for bedding and selected backfill, they were target values for identifying borrow sources.

The compactability requirements for the selected granular material are ideally as follows:

Table 2: Suitability of granular backfill material (3)

Compactability Factor[4]	Suitability
≤0.1	Material suitable
> 0.1 ≤0.4	Material suitable (except for flexible pipes that may be subject to waterlogged conditions) but require extra care in compaction
> 0.4	Material unsuitable

Where gravel is present below the bedding material, this was sampled and tested to define its use in gravelling haul and access roads.

The results of the laboratory testing are given in Annexures C and D and plans of individual borrow pits are given in Annexure G

4.6 Laboratory Testing (see Annexures A - E)

Laboratory testing was carried out in order to quantify the characteristics of the materials encountered along the pipeline route.

All laboratory testing was carried out by SANAS-accredited testing laboratories (Geostrada, Civilab, ARC, Waterlab) and the test methods are specified on the test results.

The following tests were carried out:

- Road Indicators (sieve grading and Atterberg Limit determinations);
- Foundation Indicators (as above but including hydrometer gradings);
- Compactability and moisture content;
- pH and conductivity;
- CBR tests on potential gravel sources;
- SRB potential;
- Shearbox;
- Triaxial;
- M_s (constrained soil modulus);
- Hydrostatic Compression;
- Fine and coarse aggregate for concrete (SABS 1083); and
- Soil fertility (carried out by ARC).

[4] *per SABS 1200 LB and SABS 0120: Part 3 LB*

The results of the laboratory testing are given in the Annexures as follows:

- Annexure A to D– Centreline Data; and
- Annexure E – Borrow Pit Data.

4.7 Soil Fertility Testing

Samples of fertile soil were taken from the topsoil (0 to 300 mm) and subsoil (300 to 600 mm) with a minimum of two soil test pits per property in order to establish baseline parameters of the agricultural properties of the fertile segment. Samples were also taken from borrow pits. The samples, of approximately 2 kg, were placed in clean plastic bags for laboratory testing.

The following soil analyses were determined on each fertile soil sample:

- Plant available nutrients – P, K, Mg, Ca;
- pH (TMH1 A20);
- %C;
- Soil particle size;
- %N;
- Cation Exchange Capacity (CEC); and
- Electric conductivity (TMH1 A21T).

Testing was carried out in accordance with the standards given in the Soil Science Society of SA handbook. The test results are given in Annexure D1.4 (for the centreline) and Annexure E2.4 (for borrow pits).

4.8 Rotary Core Drilling (Annexure F)

Rotary core boreholes were drilled at the crossing of Road D1675, at the crossing of the Matimba ash conveyor and at the crossing of the Thabazimbi – Grootegeluk coal mine rail line. This drilling was carried out to provide information regarding the in-situ conditions at these positions. As neither the pipe diameter nor the embedment depth was known at the time of investigation, all boreholes were drilled to a nominal depth of 10 m.

Borehole cores were logged by an engineering geologist in accordance with accepted South African practice (SANS 633: 2009 DRAFT) and the cores photographed. Borehole logs were prepared using DotPlot® software and are included in Annexure F. Photographs of the core boxes are included in Annexure F. Borehole location and details are listed below in Table 3 below.

The borehole cores are available for inspection at the Department of Water Affairs' premises in Brits.

Standard Penetration Testing (SPT) was conducted in the rotary core boreholes as a rule. In some instances the presence of gravels within the soil horizons, has rendered the SPT values unreliable. SPT values are reflected on the borehole logs.

Table 3: Summary of rotary core borehole details

Bh no.	Coordinates (WGS84, Lo27)		BH collar elev. (mamsl)	BH depth (m)
	Y	X		
D1675 / Conveyor Crossing				
BH23	-061 263.04	2 621 676.41	875.67	10.01
BH24	-061 170.49	2 621 717.10	876.24	10.01
Road D1675 Crossing				
BH25	-061 000.01	2 621 783.41	877.73	10.17
BH26	-060 911.41	2 621 762.08	877.73	10.20
Road D1675 / Rail Crossing				
BH66	-059 678.62	2 621 639.42	902.11	10.42
BH67	-059 656.18	2 621 630.69	901.45	10.46

5 GENERAL GEOLOGICAL SETTING

5.1 Regional Geology

Most of the site is underlain by sandstones of the Waterberg Group, which are considered to be between 1,700 and 2,000 million years in age (Johnson et. al., 2006). Diabase is known from elsewhere on the project to intrude the sandstones, but none was encountered in any of the test pits.

Limited occurrences of Karoo Supergroup sediments (sandstone, mudrocks, coal) are present along the pipeline where its alignment crosses onto the northern side of the Eenzaamheid Fault. These sediments range from 160 to 270 million years in age.

The sediments are largely covered by Quaternary Age sands, which are younger than 1.8 million years.

The regional geology is shown on Figure 2 (Drawing Number 2A-G3-026).

5.2 Structural Geology

The sandstones of the Waterberg Group are near-horizontally bedded with a very shallow dip towards the north. Prominent NE- and NW-striking lineaments are recognised elsewhere on the project where outcrops exist. Elsewhere on the project, diabase is intruded in irregular bodies (generally sills or inclined sheets) into the Waterberg.

The sedimentary strata of the Karoo Supergroup are essentially sub-horizontally bedded, but are extensively faulted. Some of these faults may be traced for significant distances. The east-west trending Eenzaamheid Fault has a downthrow on its northern side, juxtaposing the younger Karoo with the older Waterberg sediments.

5.3 Economic Geology

Extensive coal deposits are present in the Karoo Supergroup (Grootegeluk Formation). These form the Waterberg coalfield and are the impetus for the development in the region. The pipeline has been positioned to avoid the coal deposits.

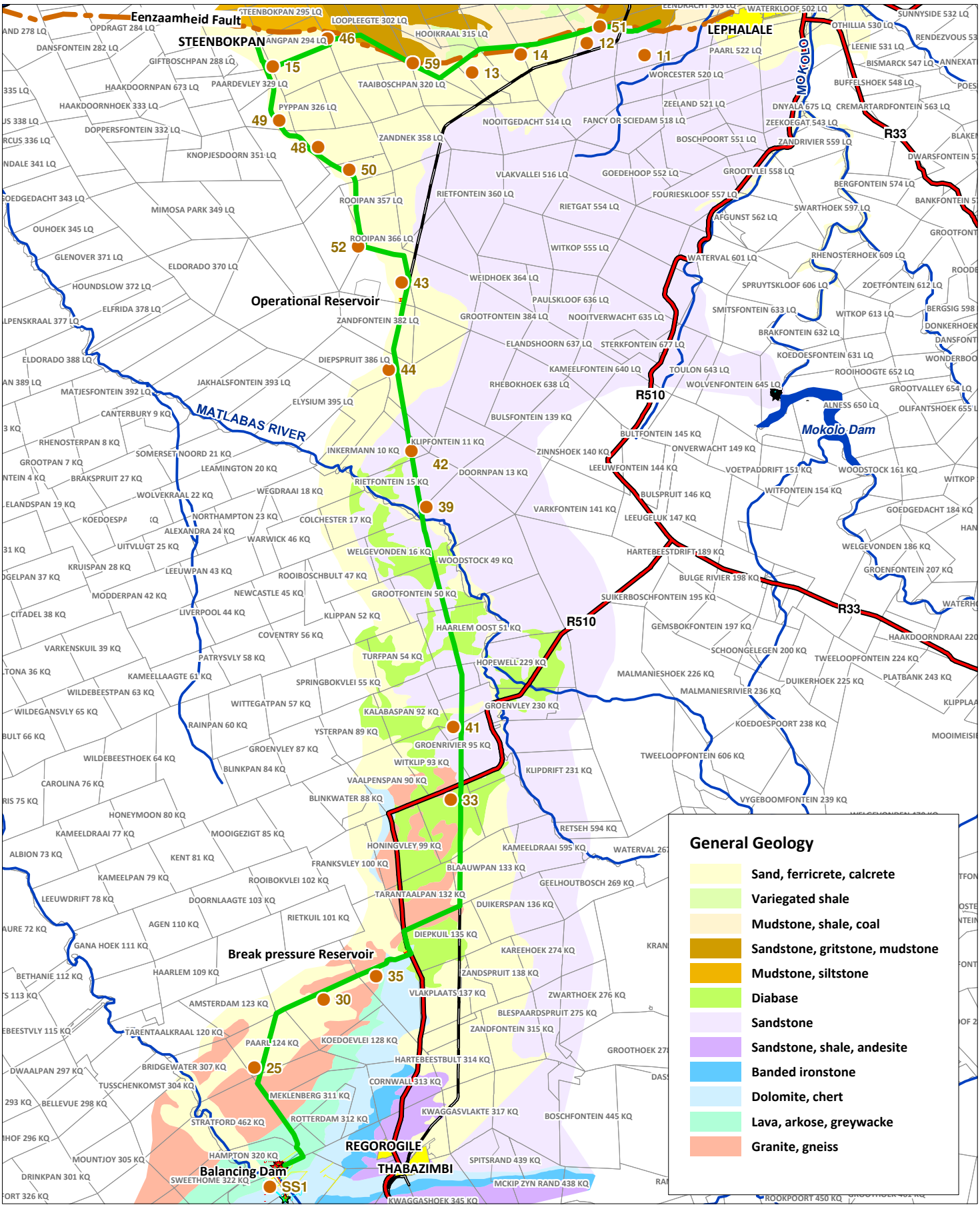
5.4 Climate and Weathering

Average annual rainfall for Steenbokpan is about 400 mm, most of which falls between November and March. Average midday temperatures range between a high of about 33 C in January to a low of about 15˚C in June.

The study area lies to the west of the climatic N = 5 line (Weinert, 1980), which indicates that mechanical disintegration is the dominant mode of weathering, but both chemical and mechanical modes of weathering are likely to have an influence.

5.5 Seismic Hazard

According to Kijko, et. al. 2003, the area of interest is associated with Peak Ground Acceleration values between 0,08 and 0,10 g, with a 10% probability of being exceeded in a 50 year period.



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Legend

PIPELINE ROUTES
- Phase 2
- Main Roads
- Borrow Pits

- Railway Line
- Rivers
- Farm Boundaries
- Towns

Scale: 1:440,000

5 0 5 10
Kilometers

N

Project: Mokolo and Crocodile (West) Water Augmentation Project

Drawing Title: Regional Geology (Stage 4)

Drawing Number: 2A-G3-026

Rev: FIG 2

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6 INVESTIGATION FINDINGS

6.1 Local Geology

The geology of the area may be summarised as shown on Table 4.

Table 4: Geology

Rock Type	Formation	Group	
Sand, ferricrete, calcrete			Quaternary
Variegated shale	Eendrachtpan		Karoo Supergroup
Mudstone, shale, coal	Grootegeluk	Ecca	
Sandstone, gritstone, mudstone	Swartrant		
Diabase			Post-Waterberg intrusive
Sandstone, conglomerate.	Mogalakwena	Waterberg	

The Local Geology is shown on Figure 3: (Drawing No. 2A-G3-027)

6.2 Centreline Investigation (see Annexure A)

Test pits were excavated at a nominal spacing of 200 m along the pipeline. Locations are shown on Drawings 2E-G7-064 to-089, included in Annexure H. The test pit profiles are given in Annexure B and photographs of the test pits in Annexure D5.

Test pits were dug to refusal or a maximum depth of 4m (this assumes a pipe diameter of 2,000 mm). Pits were excavated using a TLB (New Holland B90B or Hidromek 102B) and profiled by a geospecialist in accordance with the standards given in the Geoterminology Workshop 1990 (Brink and Bruin, 2002). Over much of the length of the pipeline, test pits were, for ease of access, dug within the D1675 road reserve. They may thus be up to about 20 m off the centreline. They are nevertheless considered to be representative of the conditions along the pipeline.

During the Feasibility Study, access was only permitted onto the farms Minnaarspan 322LQ and Loopleegte 3012LQ for a limited period of time. In order to complete test pitting in the available time, pits were dug at 400 m centres. It had been intended to fill in between these to achieve a spacing of 200 m. However, no access at all was permitted during the current investigations.

The terms used are on the profiles defined in Annexure E. Dynamic Penetrometer Light (DPL) soundings were undertaken adjacent to and within the test pits in order to provide a quantitative assessment of the consistency of the in-situ materials. These soundings are shown graphically as equivalent SPT N-values (blows per 300 mm penetrated) on the relevant soil profiles.

A summary of the ground conditions at each test pit position along the pipeline route is given on spreadsheets in Annexure A. A graphical representation of the excavation depth for each test pit is included as Figure 4.

Project: Mokolo and Crocodile (West) Water Augmentation Project

Drawing Title: Local Geology (Stage 4)

Drawing Number: 2A-G3-027

Rev: FIG 3

Legend

PIPELINE ROUTES

- Phase 2
- Main Roads
- Railway Line
- Rivers
- Farm Boundaries
- Towns
- f f Fault

Local Geology

Qs	Alluvium
Tre	Quaternary sand
Pgr	Eendrachtpan (variegated shale)
Ps	Grootegeluk (mudstone, shale, coal)
C-Pwe	Swartrant (sandstone, gritstone, shale)
Mm	Wellington (mudrock)
	Mokgalakwena (sandstone, conglomerate)

A new word for water

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N

2 0 2 4 6

Kilometers

Scale: 1:160,000

K:\Projects\Mokolo\WORKSPACES\April_11\MCWAP_Local Geology_Stage4_a4.WOR

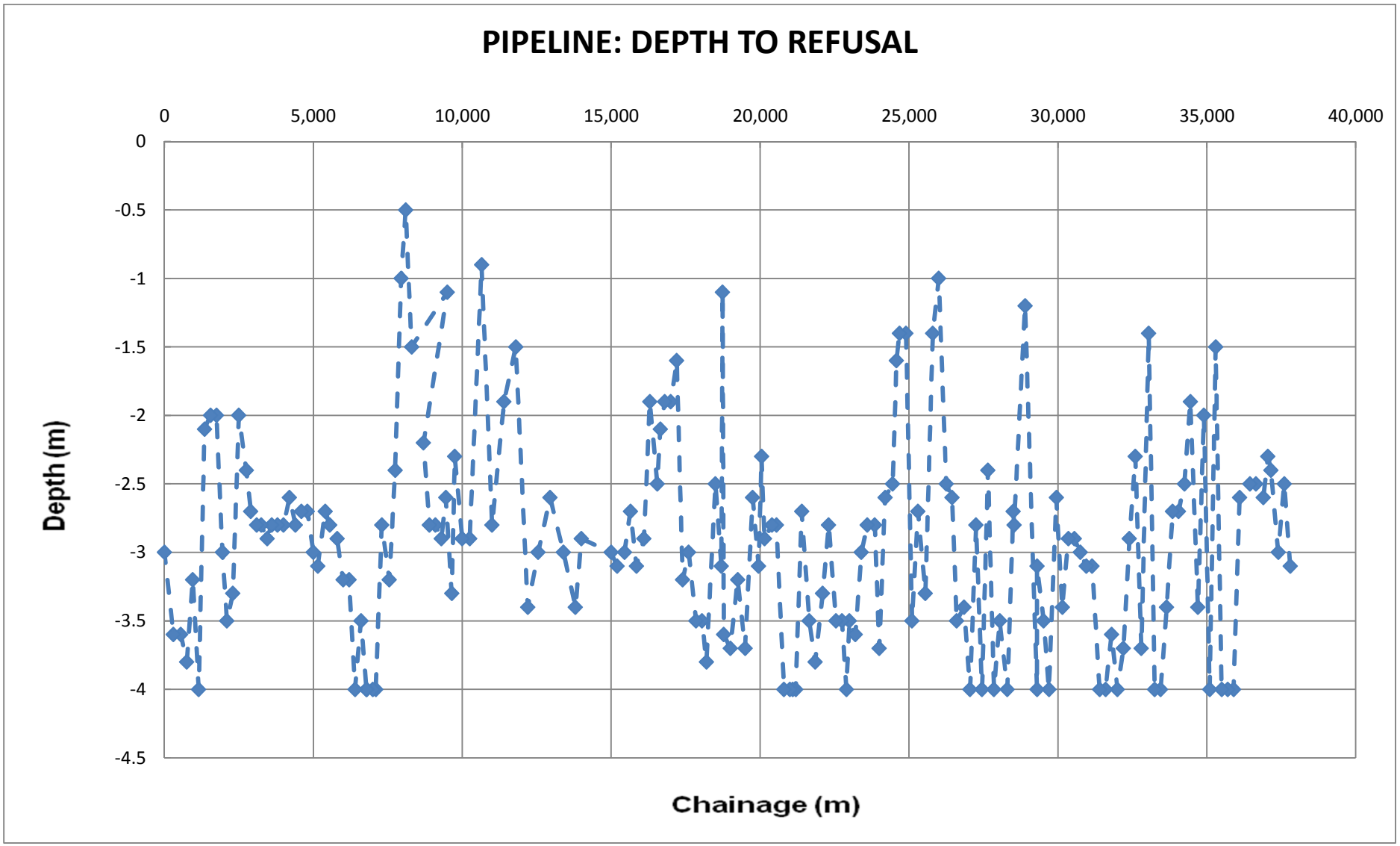

Figure 4: Summary of Refusal Depths – Steenbokpan to Matimba (Chainage 0 – 37,965 m)

None of the test pits excavated showed evidence of instability of the sides of the pit. This is based on an assessment of test pits of limited length and which stood open for about 20 minutes before being backfilled. Shearbox tests were conducted on the various soils encountered in order to provide a quantitative assessment of the stability of the test pit sides and allow prediction of their stand-up time. The results of these tests are given in Table 5.

Table 5: Summary of Shearbox test results

Test pit no.	Depth (m)	Angle of internal friction Ø (˚)#	Cohesion c (kPa)#	Classification (AASHTO/USC)
C14/05A	0.3 – 1.2	40	4	A2-4
C14/28A	0.2 – 2.0	32	10	A2-4
C14/45A	0.3 – 2.1	41	0	A2-4
C25A/15A	0.3 – 2.4	42	0	Not tested
C25C/17A	0.4 – 3.2	37	0	A3

= Cohesion at Mod AASHTO 90 % density

6.2.1 pH and Conductivity

The pH and conductivity of the soils present was measured in laboratory tests and these indicate that the pH ranges from 4.70 to 8.41, and the conductivity from 0.003 to 2.643 S/m. The results of laboratory tests are shown in Annexure D1.

6.2.2 Compactability

The compactability of the materials encountered, ranges from 0.30 to 0.60. The SABS criteria in this regard are given in Table 2.

6.3 Borrow Materials (see Annexure E)

6.3.1 Granular Backfill Material

In order to locate suitable bedding and soft backfill material, an investigation of potential borrow sources was undertaken. It was intended to locate borrow pits (BP) at a nominal spacing of 5 km, each capable of providing at least 100,000 m^3 of material. The results of this investigation are presented in Annexure E, and include test pit profiles and results of laboratory testing, and are summarised hereunder in Table 6 Borrow Pit Summary. Borrow pit plans are presented in Annexure C in Volume 2.1.

Table 6: Borrow pit summary

BP no.	Location (WGS84 Lo27)		Chainage (m)	Offset to pipeline (m)	Est. volume bedding & soft backfill (m^3)	CF (range)
	Y	X				
15	-028 890	2 622 230	2,500	50 L	≈100,000	0.34 – 0.39
46	-034 374	2 620 484	6,850	100 L	≈90,000	0.24 – 0.38
59	-041 444	2 624 690	14,800	50 L	>100,000	0.30 – 0.33
13	-047 261	2 623 428	20,600	1,000 R	≈80 000	0.33 – 0.40
14	-050 677	2 623 165	25,300	300 R	>100,000	0.28 – 0.44
12	-055 295	2 623 914	30,500	1,800 R	≈90,000	0.30 – 0.41
51	-057 365	2 621 430	32,600	100 L	≈90,000	0.38 – 0.48
11[#]	-061 459	2,623 604	36,100	2,100 R	≈45,000	0.20 – 0.46

L = Left/North of pipeline

R= Right/South of pipeline

[#] Common to Phase 1 and Stage 4.

In addition to oversize material that is present in some of the borrow materials; roots occur frequently, often for the full depth of the test pits. The roots are shown on the photographs bound into Annexure D5. It must be noted that the test pits were positioned to avoid large trees.

The results of the compactability tests undertaken on samples recovered at certain borrow pits are given in Annexure E2. The criteria used for this classification are given in Table 2: Suitability of granular backfill material. Of the samples analysed the compactability factor ranges from 0.20 to 0.44, with most being less than 0.40 (i.e. usable for bedding in terms of Table 2). A summary of the laboratory test results for each borrow pit is given in Annexure E2.

The characteristics of each borrow pit are discussed separately.

a) Borrow pit 15

This sand source is located on Portion 1 of Vangpan 294LQ and is immediately adjacent to and on the northern side of the pipeline. It was accessed from the north along an existing farm road from Road D1675.

The source has the following characteristics:

- Area: roughly 210 x 205 m;
- 1,700 to 4,100 mm thick;
- Classifies as an A2-4;
- Plasticity Index (PI) = NP;
- Grading Modulus (GM): 0.98 to 1.36;
- Maximum size: nil >9.5 mm;
- Vegetation: grass, old land;

- Estimated volume: >100,000 m^3; and
- Underlain by ferricrete gravel.

b) Borrow pit 46

This sand source is located on the farm Zandbult 300LQ and is adjacent to and on the northern side of the pipeline. It was accessed along an existing 3.5 km farm road from the surfaced D1675 road.

The source has the following characteristics:

- Area: roughly 240 x 100 m;
- 3,300 to 4,300 mm thick;
- Classifies as an A2-4;
- PI is NP;
- GM: 1.18 to 1.38;
- Maximum size: nil >9.5 mm;
- Vegetation: bush and grass;
- Estimated volume: ≈90,000 m^3; and
- Underlain very occasionally by ferricrete and weathered sandstone gravel.

c) Borrow pit 59

This sand source is located on Pontes Estates 699LQ (and is adjacent to and on the northern side of the pipeline). It is accessed along an existing farm road from the surfaced Road D1675, a distance of about 3,3 km.

The source has the following characteristics;

- Area: roughly 200 x 230 m;
- 2,400 to 3,400 mm thick;
- Classifies as an A2-4 or A3;
- PI + NP;
- GM: 1.19 to 1.36;
- Maximum size: single sample shows 1% >9.5 mm;
- Vegetation: sparse bush and grass;
- Estimated volume: > 100,000 m^3; and
- Underlain by ferricrete gravel.

d) Borrow pit 13

This sand source is located on the Remainder of farm Buffelsjagt 317LQ and is about 1,000m south of the pipeline. It is accessed along an existing farm road from the D1675 surfaced road.

The south-western portion of this source is too clayey (classifies as A6 material) and only the remainder is suitable. The remainder of the source has the following characteristics:

- Area: roughly 300 x 150 m;

- 1,500 to 2,700 mm thick;
- Classifies as an A2-4 / A2-6/A4;
- PI <14;
- GM: 0.84 to 1.20;
- Maximum size: nil >9.5 mm;
- Vegetation: grass (old land) and sparse bush;
- Estimated volume: ≈80,000 m^3; and
- Underlain by ferricrete gravel.

e) Borrow pit 14

This sand source is located on Portion 321 of farm Vergulde Helm 316LQ and is about 300m south of the pipeline and the surfaced D1675. It is accessed along an existing farm road from the D1675.

The southern portion of this source is too clayey (classifies as A6/A4 material) and only the remainder is suitable. The remainder of the source has the following characteristics:

- Area: roughly 360 x 220 m;
- 1,000 to 3,600 mm thick;
- Classifies as an A2-4/A2-6/A4;
- PI <13;
- GM: 0.95 to 1.23;
- Maximum size: nil >9.5 mm;
- Vegetation: sparse bush and grass;
- Estimated volume: > 100,000 $m^{3;}$ and
- Underlain by ferricrete (and weathered sandstone in places).

Borrow pit 12

This sand source is located on the farm Eenzaamheid 512LQ and is about 2 km south of the pipeline. It was accessed along a partly gravel and partly surfaced road paralleling the western boundary of the Medupi construction site.

The sand has the following characteristics:

- Area: roughly 300 x 180 m;
- 1,100 to 2,100 mm thick;
- Classifies as an A2-4/ A2-6/ A4/ A6;
- PI <13;
- GM: 0.99 – 1.90;
- Maximum size: a single sample shows1% >9.5 mm;
- Vegetation: bush and grass;
- Estimated volume: > 90,000 m^3; and
- Underlain by ferricrete gravel.

Borrow pit 51

This sand source is located on the farm Naauw Ontkomen 509LQ and is immediately north of the realigned, surfaced D1675 (bypass to the north of Medupi) about 100m north of the pipeline. It was accessed from the west along a gravel road sub-paralleling the pipeline on the northern side of the D1675.

The source has the following characteristics:

- Area: roughly 470 x 100 m;
- 1,600 to 2,500 mm thick;
- Classifies as an A2-4PI <12;
- GM: 0.87 to 1.29;
- Maximum size: nil >9.5 mm;
- Vegetation: ush and grass;
- Estimated volume: ≈ 90,000 m^3; and
- Underlain by ferricrete and calcrete gravel.

f) Borrow pit 11

This sand source is located on the farm Zwartwater 507LQ and on the western side of the Matimba ash dump and was accessed by way of the gravelled access road to the dump. It is about 2,100m south of the pipeline.

The source is intended for use both on Stage 4 and on Phase 1. The area defined for use on this Stage is west of the Phase 1 source. A large portion of this site is unsuitable with high plasticity and classifies as an A6.

The remaining extent of the source has the following characteristics:

- Area: roughly 180 x 150 m;
- 900 to 3,400 mm thick;
- Classifies as an A2-4/A2-6;
- PI <13;
- GM: 1.12 to 1.44;
- Maximum size: 2 samples show between 1 and 20% >9.5 mm;
- Vegetation: sparse bush and grass;
- Estimated volume: ≈45,000 m^3; and
- Underlain by quartz gravel.

6.3.2 Chemical Analyses

The chemical analyses show that the pH of the soils tested from borrow pits ranges from 3.95 to 9.65, and the conductivity from 0.001 to 0.380 S/m. The results are given in Annexure E2.

6.3.3 Gravel for Haul and Access Roads

No specific sources of gravel for use on haul and access roads have been identified. In all the borrow pits discussed above (except BP46) gravel occurs below the bedding sand. The gravel comprises ferricrete, calcrete and weathered sandstone. The results of the testing on these are given in Annexure E. The sources identified are summarised in Table 7, together with an estimate of the volume of gravel available.

Table 7: Gravel borrow sources

BP no.	Location (WGS84 Lo27)		Ch. (m)	Offset to pipeline (m)	Estimated volume (m^3)	Comments
	Y	X				
15	-028 890	2 622 230	2,500	50 L	4,000	Ferricrete
46	-034 374	2 620 484	6,850	100 L	0	No gravel
59	-041 444	2 624 690	14,800	50 L	15,000	Ferricrete
13	-047 261	2 623 428	20,600	1000 R	50,000	Ferricrete
14	-050 677	2 623 165	25,300	300R	50,000	Ferricrete
12	-055 295	2 623 914	30,500	1800 R	20,000	Ferricrete & sandstone
51	-057 365	2 621 430	32,600	100 L	20,000	Ferricrete, calcrete
11#	-061 459	2 623 604	36,100	2100R	15,000	Quartz gravel

6.3.4 Commercial Sources of Construction Materials

The nearest known commercial sources of stone and sand aggregate for concrete are in the vicinity of Lephalale. These have been discussed in detail in the Stage 2 geotechnical report. The haul distance from Lephalale to Matimba is approximately 10 km.

6.4 Site Specific Investigations

6.4.1 Ash Conveyor Crossing (farm Hanglip 508LQ Rem)

The pipeline crosses the ash conveyor at approximate Ch.36,270 m .

Two boreholes (BH23 and BH24) have been drilled at the position of this 80 m wide reserve to the ash conveyor leading from Matimba Power Station to the its ash dump. Road D1675 crosses over the conveyor, which has a gravel service road on its eastern side within the 80 m reserve. Borehole details are reflected above in Table 3. The borehole positions as indicated on Figure 5 were initially set out with the use of a handheld GPS but were subsequently accurately surveyed. Figure 5: Conveyor Crossing (farm Hanglip 508LQ): Borehole Layout (Drawing no. 2E-G3-207) indicates the borehole layout and also depicts the position of the cross section.

Borehole logs and borehole core photographs are in Annexure F.

a) Drilling results

The geological profile comprises upper horizons of clayey, silty sand with ferricrete and calcrete nodules which overlie very soft and soft rock sandstone. The thickness of the soil varies between 1.70 and 3.20 m, with very soft to soft rock, highly weathered sandstone below these depths. The geological profile, as intersected in the respective boreholes, is summarised below (Table 8).

Table 8: Conveyor Crossing (farm Hangklip 508LQ): (Drawing no. 2E-G3-207): Summarised geological profile (depths in metres)

BH no.	Transported material: clayey, silty sand with calcrete or ferricrete nodules	Residual sandstone: silty sand with ferricrete nodules	Bedrock: very soft and soft rock sandstone
BH23	0 – 0.50		0.50 – 10.01+
BH24	0 – 2.15	2.15 – 3.20	3.20 – 10.01+

BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH23	– 61263.044	+ 2621676.405
BH24	– 61170.494	+ 2621717.098

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE SHOWN.
2. ALL ELEVATIONS IN METRES ABOVE SEA LEVEL UNLESS OTHERWISE SHOWN.
3. FOR DETAILED BOREHOLE LOGS REFER TO GEOTECHNICAL REPORT ANNEXURE F.

LEGEND:

600 — REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 — BOREHOLE POSITION

REFERENCE DRAWINGS		REVISIONS			
DRG. No.	TITLE	REV No.	DATE	DESCRIPTION	APPR.
		A	17/08/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:500

SCALE 1 : 500 — 0 2.5 5 10 15 20 25

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TCTA — A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

CONVEYOR CROSSING – FARM HANGKLIP 508 LQ (BH23 & BH24)

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2E – G3 – 207	REV No. A

b) Water Level Measurements

Water rest levels were measured at 5.50 m in BH23 and at 3.69 m in BH24. It must be accepted that water is used during drilling and levels measured may reflect this water.

c) Standard Penetration Testing (SPT) data

SPTs were conducted in the soils above the rockhead and yielded a value of N = 13 in BH24 at a depth of 1.5 m (in clayey, silty sand), while refusal was recorded in BH23 at this depth. This latter value is considered unreliable due to the presence of gravel in the profile.

6.4.2 D1675 Road Crossing (farm Hanglip 508LQ Rem)

The pipeline crosses the surfaced D1675 (Lephalale – Steenbokpan road) at approximate Ch.35,920 m .

Two boreholes (BH25 and BH26) have been drilled at the position of this oblique crossing. The boreholes were positioned outside the road reserve, about 110 m apart. At this point, a gravel access track is present along the southern road reserve and BH 25 was drilled beyond this. Borehole details are reflected above in Table 3. The borehole positions as indicated on Figure 6 were initially set out with the use of a handheld GPS but were subsequently accurately surveyed. Figure 6: Road Crossing (farm Hanglip 508LQ): Borehole Layout (Drawing no. 2E-G3-208) indicates the borehole layout and also depicts the position of the cross section.

Borehole logs and borehole core photographs are in Annexure F.

a) Drilling Results

The geological profile comprises upper horizons of transported, clayey to silty sand with ferricrete and calcrete nodules which overlie very soft and soft rock sandstone, becoming harder with depth. The thickness of the soil varies between 1.90 and 3.15 m, with very soft to soft rock, highly to completely weathered sandstone below these depths. The geological profile, as intersected in the respective boreholes, is summarised below (Table 9).

Table 9: Road Crossing (farm Hanglip 508LQ): (Drawing no. 2E-G3-208): Summarised geological profile (depths in metres)

BH no.	Transported material: clayey, silty sand with calcrete or ferricrete nodules	Bedrock: very soft and soft rock sandstone	Soft rock sandstone with hardpan calcrete (hard rock)
BH25	0 – 2.90	2.90 – 7.85	7.85 – 10.17+
BH26	0 – 3.15	3.15 – 8.30	8.30 – 10.20+

BOREHOLE CO-ORDINATES LIST
Lo 27 (HARTEBEESHOEK 94)

NAME	Y CO-ORDINATE	X CO-ORDINATE
BH23	– 61263.044	+ 2621676.405
BH24	– 61170.494	+ 2621717.098

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE SHOWN.
2. ALL ELEVATIONS IN METRES ABOVE SEA LEVEL UNLESS OTHERWISE SHOWN.
3. FOR DETAILED BOREHOLE LOGS REFER TO GEOTECHNICAL REPORT ANNEXURE F.

LEGEND:

- 000 — REFERENCE LINE FOR GEOLOGICAL PROFILE
- BH20 — BOREHOLE POSITION

REFERENCE DRAWINGS

DRG. No.	TITLE

REVISIONS

REV No.	DATE	DESCRIPTION	APPR.
A	17/08/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:500

SCALE 1 : 500 0 2.5 5 10 15 20 25

Mokolo Crocodile Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

ROAD CROSSING – FARM HANGKLIP 508 LQ (BH25 & BH26)
BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2E – G3 – 208	REV No. A

b) Water Level Measurements

Water rest levels were measured at 4.00 m in BH25 and at 7.10 m in BH26. It must be accepted that water is used during drilling and levels measured may reflect this water.

c) Standard Penetration Testing (SPT) data

SPTs were conducted only in the soils above the rockhead and yielded similar results at 1.5 m depth (N = 28 in BH25 and N = 31 in BH26).

6.4.3 Railway Crossing (farm Naauw Ontkomen 509LQ

The pipeline crosses the Thabazimbi – Lephalale railway line on the realigned part of D1675 (north of Medupi Power Station) at about Ch.35,550 m.

Two boreholes (BH66 and BH67) have been drilled at the position of this crossing. The boreholes were positioned outside the rail reserve, about 25 m apart. The borehole positions as indicated on Figure 7 were initially set out with the use of a handheld GPS but were subsequently accurately surveyed. Figure 7: Railway Crossing (farm Naauw Ontkomen 509LQ): Borehole Layout (Drawing no. 2E-G3-209) indicates the borehole layout and also depicts the position of the cross section.

Borehole logs and borehole core photographs are in Annexure F.

a) Drilling Results

The geological profile consists of upper horizons of fill, comprising silty and clayey sand with sandstone and quartz gravel. The fill overlies a transported, clayey gravel and cobbles of sub-rounded quartz. Bedrock occurs below the gravel layer and comprises soft to hard rock. The fill varies between 1.95 and 3.80 m, and the gravel layer 4.30 and 7.93 m depths, with soft to hard rock, highly to slightly weathered sandstone below these depths. The geological profile, as intersected in the respective boreholes, is summarised below (Table 10).

Table 10: Railway Crossing (farm Naauw Ontkomen 509LQ): (Drawing no. 2E-G3-209): Summarised geological profile (depths in metres)

BH no.	Fill. Silty and clayey sand	Fill. Quartz gravel with silty sand matrix	Transported gravel of quartz with sandstone cobbles in clayey silty sand matrix	Soft rock sandstone, highly weathered	Medium hard to hard rock sandstone, highly to slightly weathered
BH66	0 – 0.79	0.79 – 1.95	1.95 – 4.30		4.30 – 10.42
BH67	0–1.50 2.76 –3.80	1.50- 2.76	3.80 – 7.93	7.93 – 8.08	8.08 – 10.46

BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH66	– 59678.624	+ 2621639.417
BH67	– 59656.184	+ 2621630.686

NOTES:

1. ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE SHOWN.
2. ALL ELEVATIONS IN METRES ABOVE SEA LEVEL UNLESS OTHERWISE SHOWN.
3. FOR DETAILED BOREHOLE LOGS REFER TO GEOTECHNICAL REPORT ANNEXURE F.

LEGEND:

600 — REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 — BOREHOLE POSITION

REFERENCE DRAWINGS		REVISIONS			
DRG. No.	TITLE	REV No.	DATE	DESCRIPTION	APPR.
		A	17/08/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:500

SCALE 1 : 500 0 2.5 5 10 15 20 25

Mokolo Crocodile Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

RAILWAY CROSSING – NAAUW ONTKOMEN 509 LQ (BH66 & BH67)

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2E – G3 – 209	REV No. A

b) Water Level Measurements

Water rest levels were measured at 4.30m and at 7.93 m (i.e. at rockhead level) in BH66 and in BH67 respectively. It must be accepted that water is used during drilling and levels measured may reflect this water.

c) Standard Penetration Testing (SPT) data

SPTs were conducted only in the soils above the rockhead. Values of between N = 27 and 58 were recorded in the gravelly soils, while refusal was recorded at the rockhead in BH66. The values recorded in the soils must be considered unreliable due to the presence of gravel in the profile.

6.5 Spoil Sites

Three existing borrow pits which may be usable as spoil sites were observed along the route. These are shown on Figure 2 and their estimated capacities are given in Table 11.

Table 11: Potential spoil sites

Site	Co-ordinates		Estimated capacity (m^3)
	Y	X	
M	-045 673	2 622 769	10,000
N	-055 323	2 623 304	30,000
P	-056 903	2 624 194	40,000

No negotiations have been initiated with the landowners, nor have any environmental studies been undertaken on these sites.

In addition to these sites, depending on when construction takes place, the site from which sandstone aggregate is currently quarried for Medupi, may be available as a spoil site. The quarry is located just south of the Medupi site and the volume available should be large.

6.6 Excavatability Basis

The excavatability of the materials encountered in the centreline test pits is based on the performance of the TLB used to excavate them (see Table 2). The depth to refusal for each test pit is summarised in Annexure B, is shown on the profiles bound into Annexures C and D and presented graphically on Figure 4. In most instances refusal occurred on ferricrete or calcrete.

6.7 Observed Groundwater Levels

A total of 196 test pits were dug along the pipeline route. Seepage was encountered in 5 test pits, all north of the Medupi construction site. No occurrence of hydrophilic vegetation, which might be indicative of shallow groundwater conditions, was observed along the route.

7 SUMMARY AND CONCLUSIONS

The investigation for the pipeline and borrow pits was undertaken by means of test pitting, with a TLB. The pits were excavated at nominal 200 m spacing along the pipeline route, and at a nominal spacing of 30 m at borrow pit locations.

The geology of the area comprises virtually solely Waterberg sandstone, with limited occurrences of Karoo Supergroup sediments where the pipeline crosses to the northern side of the Eenzaamheid Fault. Quaternary sand blankets the underlying geology, particularly in the west near Steenbokpan.

8 INTERPRETATION

An interpretation of the findings of the geotechnical investigations has been carried out in order to assist in the design process and to aid Tenderers in their pricing of the project. The interpretation is given in Volume 3 of this Report.

9 REFERENCES

Brink, ABA and Bruin, RMH (Eds). 2002. “Guidelines for soil and rock logging in South Africa”. Proceedings of the Geoterminology Workshop 1990. Produced by SAIEG, SAICE Geotechnical Division and AEG. Second Impression, 2002.

Johnson, MR, Anhaeusser, CR and Thomas, RJ (Eds.). 2006. “The Geology of South Africa”. Geological Society of South Africa, Johannesburg / Council for Geoscience, Pretoria.

Weinert, HH 1980. “The Natural Road Construction Materials of South Africa", H & R Academia Publications, Pretoria (1980)

Council for Geoscience, Pretoria

“1:250,000 Geological Map: Sheet 2326 Ellisras”

Kijko, A, Graham, G, Bejaichund, M,Roblin, DL and Brandt, MBC 2003. Probabilistic Seismic Hazard Maps for Southern Africa.Council for Geoscience.

“Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study: Technical Module: Supporting Report No. 8a: Detail Geotechnical Investigations: Phase 1”.

South African Bureau of Standards.

- 2006. Specification: Aggregates from natural sources – Aggregates for concrete. SABS 1083: 2006.

- 2009. Draft SA Standard: Profiling, and percussion and core borehole logging in Southern Africa for engineering purposes. SANS 633: 2009 (Draft).
- 1983. Standardised specification for civil engineering construction Section LB: Bedding (pipes). SANS 1200LB
- 1986 Code of practice for use with standardised specifications for civil engineering construction and contract documents Part 3: Guidance for design.

ANNEXURE A

DIN 50929-3 SOIL AGGRESSIVENESS (NO RESULTS)

ANNEXURE B:

LAND CAPABILITY RATING