TCTA

MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

CONTRACT NO TCTA 07-041

CONSULTING SERVICES FOR MCWAP

PHASE 2: GEOTECHNICAL INVESTIGATIONS
STAGE 2: Vlieëpoort Weir – Transnet Rail Line (Tarantaalpan)

VOLUME 1: GEOTECHNICAL DATA REPORT

July 2012

MOKOLO CROCODILE CONSULTANTS

Report No: 2A-R-111E-53 (Rev A)

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Volume 1: Geotechnical Data Report

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PHASE 2: GEOTECHNICAL INVESTIGATIONS

STAGE 2: Vlieëpoort Weir – Transnet Rail Line (Tarantaalpan)

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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 Mokolo 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 2 of the Project, extending from Vlieëpoort Weir on the Crocodile (West) River in the south to the point where the pipeline joins the Thabazimbi – Lephalale railway line, approximately 42 km. Similar and separate reports have been 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 Phase 2, further geotechnical investigations were undertaken. This task comprised the planning and execution of geotechnical field investigations following evaluation of available geotechnical information obtained from feasibility stage investigations. This earlier work comprised a few (at 5km spacing) test pits along the centreline.

Report “Phase 2 Stage 2: 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 Report, whilst Volume 2 contains the Annexures supporting this Report. Volume 3 interprets the data contained in Volumes 1 and 2 and should be read in conjunction with it.

2 BACKGROUND

The Department of Water Affairs commissioned the Mokolo 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 Parsons), VelaVKE (now incorporated in SMEC) 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 in 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 2 of the MCWAP. Components investigated include the pipeline route, Vlieëpoort Weir, Abstraction Works (low and high lift pumps), Break Pressure Reservoir, road and river crossings, borrow pits and dolomitic stability investigations.

It must be noted that the chainage system used over this Stage is not continuous and is made up of the following Sub-sections:

- Chainage 0 to 5,364 m (Weir to Balancing Reservoir) (km 0 – 5.4);
- Chainage 0 to 28,900 m (Balancing Weir to Break Pressure Reservoir) (km 5.4 – 34.3); and
- Chainage 0 to 7,700 m (Break Pressure reservoir to Transnet Rail Line on farm Tarantaalpan) (southern end of Stage 1) (km 34.3 – 42.0).

The total length is 42.0 km. In order to make distance references more easily understood, continuous km distances (Weir to Transnet rail line) are also given, when this facilitates an appreciation of the spacing of elements.

The diameter of the pipeline has not yet been established. Interpretations given in the report assume a diameter of 2,000 mm and will have to be amended once the actual pipe diameter is known.

3 PIPELINE ROUTE INVESTIGATIONS

The pipeline route investigation comprised test pitting (using a TLB[2]) along the centreline of the pipeline route at a nominal spacing of 200 m. 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 tests, etc.) were carried out on representative samples. Occasional pH, conductivity and chemical (SRB) tests were carried out on different soil types in order to assess the aggressiveness of the soils towards the proposed steel pipeline.

Geotechnical tests (Triaxial, Shearbox and Constrained Soil Modulus (M_s)) 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 over the backfilled pipeline and at borrow pits.

Dynamic penetrometer tests (DPLs, commonly 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.

4 BORROW PITS

Four borrow pits were located, providing suitable bedding and selected backfill material. The targeted economic spacing of 5 km for borrow pits for haulage purposes during construction has not been achieved. Three of the four borrow pits identified have yielded material of marginal quality and are suitable only for selected fill blanket.

No suitable granular material could be located at the southern end of the route and a sandbank within the Crocodile River and just downstream of the weir was investigated in an attempt to provide material in this area. A limited volume (8,000 m^3) of good quality sand is present here (BP SS1). Environmental approval to work this source may be problematic.

Over much of the route, no access was permitted by landowners to prospect for borrow sources. Of the three other borrow sources investigated, one was unsuitable (BP35) while the other two (BP25 and BP30) yielded material suitable only for selected fill blanket.

[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.

The spacing between the various sources is variable:

- approximately 15 km between BPSS1 (located at Vlieëpoort Weir) and BP25 (km 14.9);
- approximately 16 km between BP25 and BP30 (km 30.9). Permission to prospect for borrow material was not forthcoming in this area; and
- approximately 12 km exists between BP30 (km 30.9) and the end of the stage. This is exacerbated by the fact that the nearest borrow source on Stage 1 (BP33) is a further 10 km north of the start of Stage 1.

Further investigation is necessary to resolve these shortcomings.

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 28: Borrow pit summary

5 BOREHOLES DRILLED

Rotary core boreholes were drilled where the pipeline crosses surfaced roads, at reservoir sites, at the proposed low and high lift pump stations and at the Vlieëpoort Weir on the Crocodile River. Percussion boreholes were drilled at the Weir in order to obtain representative samples and confirm bedrock profiles and at portions of the pipeline suspected of beingunderlain by dolomite. Geophysical surveys were carried out at the positions of the Vlieëpoort Weir/Abstraction Works and reservoir sites, as well as along sections of the pipeline route suspected of being underlain by dolomite.

6 GENERAL GEOLOGY

The geology of the pipeline route commences in the south on Pretoria Group strata (dolomite, chert, shale, quartzite and andesite), passes onto Ventersdorp Supergroup strata (lava, quartzite, conglomerate), then onto Basement Granite (1G). The route then swings north-eastwards and passes back onto Pretoria Group strata before crossing onto the Lebowa Granite Suite (3G1), which has been intruded by diabase (probably in the form of sills), with patches of Waterberg sandstone. Deposits of Quaternary sand occur to the north and west of Thabazimbi, blanketing the older rocks.

The investigation was carried out during February and July - August 2010. No seepage was encountered in any test pits, even though some were dug in the vicinity of the Crocodile River.

In addition to the granular 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 where the latter may be damaged during hauling operations.

Table 28: Potential borrow sources

BP no.	Location (WGS84 Lo27)		Est. volume material (m^3)	CF# (range)	Offset to pipeline (m)	Reference		Suitability@
	Y	X				Chainage	km	
SS1	-31 956	2 725 427	8,000	0.20/0.30	120 L+	0 (W/B)	0	1
25	-27 740	2 713 313	>250,000	0.36/0.48	50 L	9,500 (B/BP)	14.9	2
30	-34 122	2 706 490	>150,000	0.30/0.42	60 R	20,800(B/BP)	30.6	2
35	-38 204	2 703 766	65,000	0.32/0.40	80 R	25,200(B/BP)	36.2	3

L = Left of pipeline R= Right of pipeline
+ = On West/left bank of Crocodile River
# = Compactability Factor
(W/B) = Weir to Balancing Reservoir sub-section
(B/BP) = Balancing to Break Pressure Reservoirs sub-section
@ 1 = For all 2 = Selected fill blanket only...3 = Unsuitable

7 ROAD CROSSINGS AND OTHER STRUCTURES

Detailed Tender Design investigations of the Vlieëpoort Weir and abstraction works, which incorporates the low and high lift pump stations and Balancing Dam site, commenced with geophysical surveys. These comprised gravimetric and resistivity surveys, with the aim of identifying any linear features which might be present, as well as defining variations in bedrock elevation. Such anomalies were then targeted for follow-up exploratory drilling. Drilling included rotary core boreholes, as well as Symmetrix percussion boreholes. A Radon emanation survey was carried out in order to select optimal positions for siting further boreholes for subsequent groundwater monitoring. Limited laboratory testing, comprising foundation indicator testing, was carried out in order to characterise the geotechnical parameters of the materials.

The pipeline route between Vlieëpoort Weir and the Balancing Dam, traverses dolomitic rocks between about Ch 1,200 and 3,500 on Sub-section 1 (km 0.3 – 3.5) and a dolomite stability investigation was conducted by means of a gravity survey and follow-up exploratory drilling. A total of five percussion boreholes, numbered PBHP01 to PBHP05, were drilled at positions where gravity anomalies were recognised.

Geotechnical investigations for the Balancing Reservoir on farm Mooivallei 342KQ Ptn 1 Rem and Ptn 2 comprised geophysical surveys, followed by exploratory drilling (a total of eleven rotary core boreholes), and excavation of test pits (a total of sixteen test pits). Representative samples were submitted for laboratory testing, which comprised grading analyses and Atterberg Limits and compaction characteristics (Mods and CBRs).

The pipeline leading from the Balancing Reservoir, on the farm Moooivallei 342 KQ Rem Ptn1, crosses the D1649 (Dwaalboom) road at approximate Ch 1,800 m on Sub-section 2 (km 7.4). Two boreholes (BH43 and BH44) were drilled at the position of this road crossing.

At the site of the Break Pressure Reservoir two boreholes (BH45 and BH46) were initially drilled adjacent to the boundary fence. Four rotary core boreholes, numbered BH68 to BH71, were subsequently drilled on the selected footprint, after geophysical surveys were conducted. In addition, a total of nine test pits, numbered LB1 to LB9, were excavated at the site. Representative samples were submitted for laboratory testing.

At about Ch 0.100 m on Sub-section 2 (km 34.4), on the farms Zondagskuil 130 KQ and Diepkuil 135 KQ, the pipeline crosses the R510 road. Two boreholes, numbered BH47 and BH48, were drilled on the respective road shoulders to investigate the geological profile.

Investigations of the pipeline between Ch 0 and 2,300 m on Sub-section 3 (km 34.3 to 36.6) to the north of the Break Pressure Reservoir and suspected of traversing dolomitic strata, comprised a single-traverse gravity survey, followed by drilling of two percussion boreholes (PBHP06 and PBHP07) at positions where gravity anomalies were identified.

At the Vlieëpoort Weir and Low-Lift Pump Station the gravity and resistivity surveys revealed the presence of possible fault zones, as suggested by gravity and resistivity “lows”, and also showed some correlation between decreases in gravity and low-resistivity zones. These were considered possibly to reflect the effects of weathering via fault- and fracture zones. Extrapolation between the anomalies of the respective geophysical traverses indicated several possible alignments of these geological features, which were subsequently targeted for drilling. Boreholes revealed the site to be characterised by a substantial thickness of alluvial material, overlying bedrock comprising banded ironstone formation (BIF). The alluvium thickness generally varies between 20 and 30 m, but is shallower towards the respective flanks where alluvium thicknesses between 11 and 13 m were recorded. A maximum thickness of 39,5 m of alluvial material was recorded. The alluvium profile is variable, both laterally and vertically, and comprises horizons of fine material (clay or silt, or blends thereof), or sand horizons, with silt or clay or fine gravel fractions, or horizons of coarse material which comprise gravels or cobbles in a silty clay matrix. The BIF bedrock is intersected at depths which vary between 13 and 39,5 m. In certain boreholes two bedrock horizons are recognised, comprising an upper horizon of highly to completely weathered, medium hard or hard to soft rock BIF, and a lower horizon of comprising highly to moderately weathered, very hard rock BIF.

On the pipeline route between Vlieëpoort Weir and the Balancing Reservoir, between Ch 1,200 and 3,500 m on Sub-section 1, borehole PBHP01, drilled on aprominent gravity “low” revealed the colluvial overburden to be in excess of 40 m deep and bedrock was not intersected. The other four boreholes intersected dolomite bedrock at depths between 13 and 25 m, overlain by colluvium and dolomite residuum.

The published geological map indicates that the Balancing Reservoir is underlain by rocks of the Ventersdorp Supergroup, comprising mostly lavas. A general feature of the results of the resistivity surveys was the sub-horizontal resistivity layering, indicative of the weathering. A further feature of the resistivity profiles is the occurrence of dislocations or “steps” in the values, which are taken to indicate possible fault or fracture zones. Boreholes reveal the entire site to be covered by an horizon of fine-grained colluvial soils (hillwash / topsoil), comprising sandy clay or silty sand, varying between 0,35 and 2,2 m thick. In places a colluvial horizon is recognised which comprises angular to sub-rounded gravels and cobbles in a silty sand or fine gravel matrix. The underlying horizon of gravels and cobbles, with thickness between 1 m and more than 9,2 m, is recognised across the site. The base of this horizon was not always intersected.

Bedrock, which generally comprises agglomerate, but is sporadically identified as lava, was generally intersected at depths varying between 1,4 and 6,2 m although a number of boreholes failed to intersected the rockhead. Laboratory testing confirms the colluvial sands to comprise predominantly sand, although the clay and silt content is also significant. These upper colluvial materials could exhibit a low or medium potential expansiveness. Underlying horizons which comprise sand and gravel exhibit a low potential expansiveness.

At the crossing of Road D1649 (Thabazimbi – Dwaalboom) at approximate Ch 1,800 m on Sub-section 2, the two boreholes revealed a geological profile comprising upper horizons of transported sand and gravel which overlie hard rock, cemented talus. The thickness of the transported soil varies between 2,85 and 3,0 m, with hard rock, but highly variable, talus below these depths.

At the Break Pressure Reservoir on farm Leeuwbosch 129KQ the resistivity surveys revealed a horizontal structure, comprising a conductor overlying resistive basement. Abrupt changes in resistivity may indicate faults and fracture zones or lateral changes in rock type. The rotary core boreholes essentially confirm the sedimentary sequence of sandstones and shales / siltstones. One borehole intersected intrusive diabase, while another did not intersect bedrock and is presumably located in a shear zone. The test pits and laboratory testing indicate the fine-grained topsoil horizon (thickness 0,1 to 1,0 m) to possess a medium potential expansiveness according to van der Merwe (1964).

At the R510 road crossing at Ch 0.100 m on Sub-section 3, on farms Zondagskuil 130 KQ and Diepkuil 135 KQ, boreholes BH47 and BH48 revealed a rockhead at depths between 2,0 and 2,55 m. An upper horizon of silty to clayey sand covers the site, with variable amounts of fine gravels. Bedrock comprises alternating horizons of sandstone and shale or siltstone.

The gravity survey of the pipeline between Ch0 to 2,300 m, on Sub-section 3 to the north of the Break Pressure Reservoir, indicated a prominent gravity “high” and a prominent gravity “low”. Neither of the boreholes drilled at these respective anomalies intersected dolomite. The profile comprises a thin cover (1 to 2 m thick) of transported soils, comprising sandy clay or gravels with clayey sand, underlain by a weathered horizon comprising clayey, silty sand or clayey sand. Gravels may be present. Bedrock was intersected at 5 and 13 m respectively and comprises weathered diabase or granite.

Commercial sources of rock and sand are located far south and east of Thabazimbi and consideration should be given to utilising either low-grade waste ore or waste (overburden) rock from Thabazimbi Iron Ore Mine.

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 not bound into Volume 2, not interpreted in Volume 3 and are stored electronically in the Project Files.

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

MOKOLO AND CROCODILE WATER AUGMENTATION PROJECT

CONTRACT NO TCTA 07-041

PHASE 2: GEOTECHNICAL INVESTIGATIONS

STAGE 2: Vlieëpoort Weir – Transnet Rail Line (Tarantaalpan)

VOLUME 1: GEOTECHNICAL DATA REPORT

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GLOSSARY

ARC	Agricultural Research Council of South Africa
BH	Borehole
BIF	Banded Ironstone Formation
BP	Borrow pit
CBR	California Bearing Ratio
Ch	Chainage (m)
DCP	Dynamic Cone Penetrometer
DPL	Dynamic Probe – Light
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
ENE	East-north-east
GPS	Global Positioning System
MCC	Mokolo Crocodile Consultants
MDD	Maximum dry density
omc	Optimum moisture content
PI	Plasticity Index
PPI	Probable Performance Index
Ptn	Portion

MCWAP	Mokolo Crocodile Water Augmentation Project
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 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 Phase 2, further geotechnical investigations were undertaken. This task comprised the planning and execution of further geotechnical field investigations which were identified following the evaluation of existing available geotechnical information obtained from Feasibility Stage investigations. The earlier work comprised preliminary investigations of the sub-surface materials along the pipeline route and at the Balancing Reservoir and Weir sites.

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, the corrosion 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: Vlieëpoort Weir to Transnet Rail Line (on farm 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 2 of the Project. Separate but similar reports have been compiled for each of the other 3 Stages making up Phase 2. The location of the different Stages is shown on Figure 1: Phase 2 Locality Map (Drawing no. 2A-G3-020).

The diameter of the pipeline has not yet been established. Interpretations given in the report assumes a diameter of 2,000 mm and will have to be amended once the actual pipe diameter is known.

1.1 Background

1.1.1 Feasibility Investigations

The Department of Water Affairs (DWA) commissioned the Mokolo 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 Parsons), *Vela*VKE 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).

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 Feasibility investigations, geotechnical investigations were performed for Phase 2 Stage 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 5 km. 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 logs of each test pit were compiled. The soils encountered were sampled and tested to provide a preliminary assessment of their suitability for use as bedding and selected backfill to the pipe. Only Indicator tests were carried out on representative samples.

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.

No geotechnical testing was carried out. The fieldwork and laboratory testing was carried out under competitive tender by the soils testing laboratory, Civilab.

b) Potential Borrow Pits

No borrow pit investigations were carried out.

[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

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.

1.1.2 Current Investigations

Following selection of the final alignment, a detailed geotechnical investigation was carried out to characterise the material conditions along the pipeline, to define borrow sources along the route and at various specific sites where foundation/sub-surface information was required. The investigation comprised the following aspects:

a) Excavation of test pits along the pipeline at nominal 200 m centres;

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 at least 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) Geophysical surveys at the site of the Vlieëpoort Weir (and Low-Lift Pump Station), Balancing Dam (and High-Llift Pump Station), as well as along the pipeline route where it was suspected of traversing dolomite;

f) Rotary core drilling at the crossings of the R510 and D1649 surfaced roads, the site of the Vlieëpoort Weir, the Balancing Reservoir and Break Pressure Reservoir, in order to provide foundation and subsurface data at these positions;

g) A Radon emanation survey was conducted at the Vlieëpoort Weir site in order to identify the position of a fault traversing the river and therefore optimise the location of monitoring boreholes; and

h) Percussion drilling at the Vlieëpoort Weir site, as well as along two sections of pipeline where it was suspected of traversing dolomitic ground. Where representative samples were required (at the weir site), Symmetrix drilling was employed, with measurement of drilling parameters using the Jean Lutz system. Elsewhere conventional, reverse circulation percussion drilling was carried out. Monitoring boreholes were also drilled in the vicinity of the weir using percussion drilling.

The fieldwork and laboratory testing was carried out by Geostrada, under competitive tender. Rotary core and percussion drilling was carried out by Geomech Africa, also under competitive tender. The geophysical surveys were conducted by Engineering and Exploration Geophysical Services (EEGS), under competitive tender. The Radon survey was conducted by Dr M Levin of Aurecon, appointed by Geomech Africa.

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 for Phase 1 along the pipeline route from the Vlieëpoort Weir to the point at which it joins Transnet's Thabazimbi – Lephalale railway line (on farm Tarantaalpan), approximately 42.0 km.

A Locality Map for Phase 2 is included as Figure 1 (Drawing 2A-G3-024). It must be noted that the Chainage system used over this Stage is not continuous and is made up of sub-sections. For ease of reference, and to illustrate spacings between elements, positions of features are given both as the chainage value on each of the sub-sections making up the Stage and also as a kilometre distance from the weir. The latter facilitates an appreciation of the spacing/distance between elements.

The sub-sections making up the Stage, and the chainages and kilometre distances relating to each are given in Table 1 below.

Table 1: Schedule of Chainages and km Distances

Sub-section	Sub-section	Chainage (m)	km
Weir – Balancing Reservoir	1	0 – 5,400	0 – 5.4
Balancing Res. – Break Pressure Reservoir	2	0 – 28,900	5.4 – 34.3
Break Pressure Reservoir – Transnet Rail Line (Tarantaalpan)	3	0 – 7,700	34.3 – 42.0

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:

- Researching documented geology on published geological maps and previous reports;
- Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study: Technical Module: Supporting Report No. 8b: Detail Geotechnical Investigations: Phase 2; and
- Airphotos specifically flown for the project.

3.2 Published Information

Available geological information, including the published 1:250 000 scale geological maps (Council for Geoscience). The relevant sheets are:

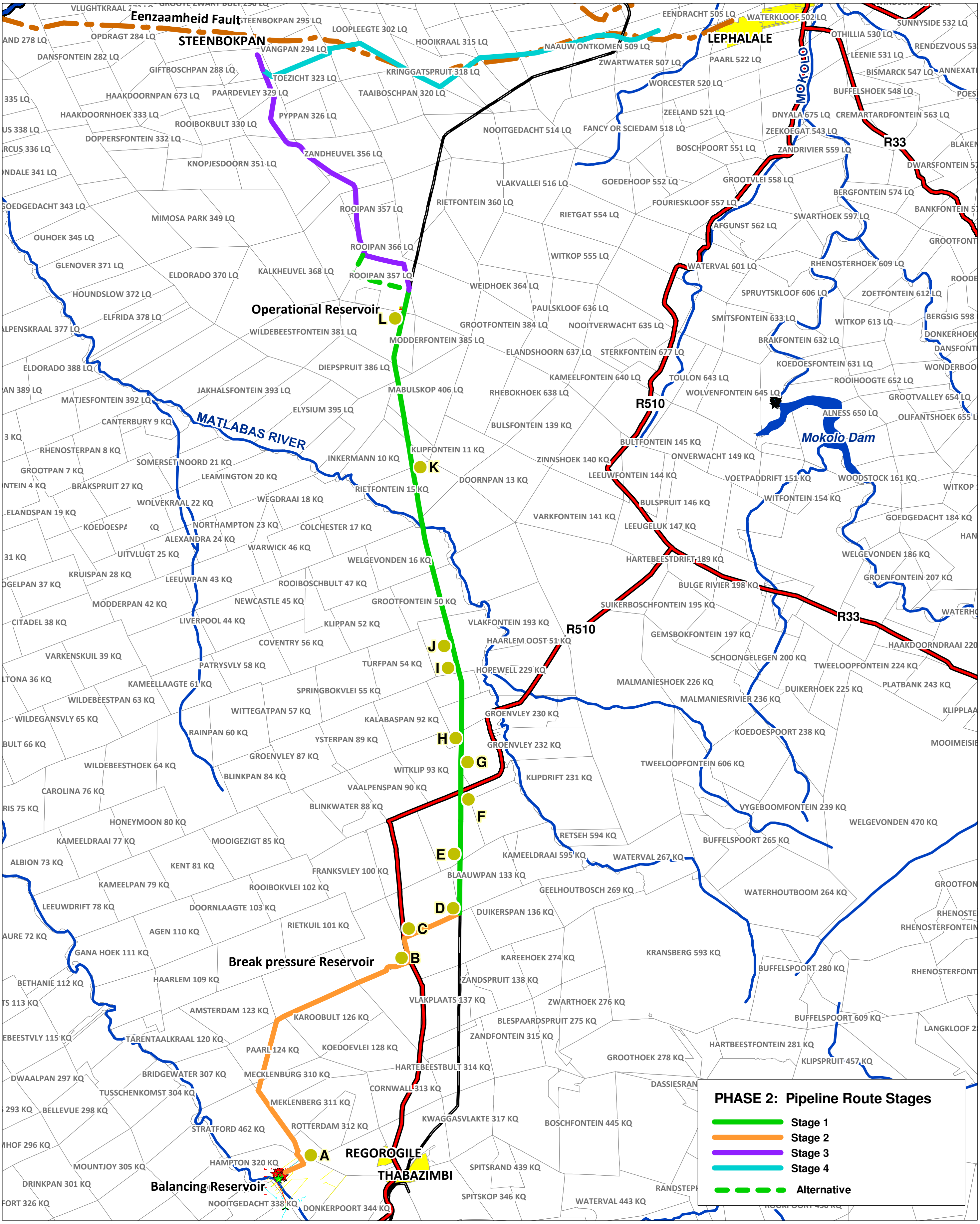
- Sheet 2326 Ellisras; and
- Sheet 2426 Thabazimbi.

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 5 km. 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 1" Report number P RSA A000/00/8409

In addition, a study was carried out of alternative routes in the vicinity of Thabazimbi. Test pits were excavated at a nominal spacing of 600 m and potential borrow sources were located. The findings were submitted to TCTA in a report entitled "Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP): Feasibility Report: Phase 2A Regorogile Route Alternative (Report no. 2A-R-VO01-12-1)".

Relevant data from these earlier reports has been extracted and is incorporated into this Report.



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Legend

Spoil Sites	Rivers
Main Roads	Farm Boundaries
Railway Line	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

Drawing Number: 2A-G3-024

Rev: FIG 1

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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 conducted is presented below. These comprised the following:

- Assessment of climate and weathering;
- Desk study of available information;
- Field verification of the geology;
- Geophysical surveys;
- Radon emanation survey;
- Rotary core drilling;
- Percussion drilling;
- Measurement of water levels in the these boreholes;
- Test pitting along the pipeline;
- Test pitting in potential borrow pits;
- Test pitting at the sites of the Balancing and Break Pressure Reservoirs;
- Dynamic Penetrometer Light (DPL) tests (often 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.

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, as well as published orthophotos (Chief Directorate: Surveys and Mapping) and images from Google Earth. Interpretation of stereographic airphotos was also carried out to yield detailed geological and structural information.

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

4.3 Field Verification of the Geology

During the field investigations a visual inspection of rock outcrops was carried out and areas of outcrop were marked up on aerial photographs in order to confirm the geology of the site. In addition, data from boreholes drilled on site has been used to further define the position of geological contacts.

The co-ordinates of test pits excavated along the pipeline were recorded using a hand-held GPS instrument. Coordinates comply with the WGS84 coordinate system, utilising the Hartebeeshoek94 Datum (South African Grid, Lo 27). Boreholes drilled at road crossings, the Abstraction Weir and at the Balancing Dam and Break Pressure Dam sites were set out using a hand-held GPS, but were accurately surveyed after completion.

4.4 Geophysical Surveys (see Annexure C3)

Geophysical surveys were conducted at the Vlieëpoort Weir site, two alternative Balancing Dam sites and the Break Pressure Reservoir in order to identify any prominent linear features (such as faults) which might represent potential weakness zones and to map changes in bedrock depth. In addition, gravity surveys were carried out along sections of the pipeline where the route was underlain by dolomitic rocks; in order to facilitate evaluation of the dolomite risk.

Geophysical techniques employed at the Vlieëpoort Weir site included gravity and resistivity surveys. Geophysical surveys at the Balancing Dam sites included a magnetic survey in addition to the gravity and resistivity surveys.

Geophysical surveys were also initially conducted at the proposed alternative site for the Balancing Dam. When it became apparent that this site, unlike the favoured site, was underlain by dolomitic rocks the decision was taken not to continue with further investigations at the alternative site. For this reason there will be no discussion of investigation results from the alternative Balancing Dam site.

4.5 Radon Survey (see Annexure C3.2)

A Radon emanation survey was conducted at the Vlieëpoort Weir site in order to identify the position of a presumed fault, as suggested by initial exploratory drilling. This knowledge enabled groundwater monitoring boreholes to be optimally located relative to this fault. The findings of the Radon survey are bound into Annexure C3.2.

4.6 Rotary Core Drilling (see Annexure C1)

Rotary core boreholes were drilled at the Vlieëpoort Weir site, the Balancing Dam site and at the Break Pressure Reservoir site and R510 and D1649 road crossings. This drilling was carried out to provide information regarding the in-situ conditions at these positions.

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 C1.1. Photographs of the core boxes are included in Annexure C1.2.

Borehole location and details are listed below in Table 2.

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 many instances the presence of gravels within the soil horizons, prevented reliable testing and resulted in "refusal" of the sampling spoon, possibly prematurely. SPT results are found in Annexure C1.3.1.

Water pressure (Lugeon) testing was carried out in the rotary core boreholes drilled at the Vlieëpoort Weir site only, but the tests were predominantly unsuccessful due to the inability of the packer in achieving a seal. Tests were conducted in accordance with the methodology described by Houlsby (1976) and appear in Annexure C1.3.2.

Table 2: Summary of rotary core borehole details

BH no.	Coordinates (WGS84, Lo27)		BH collar elev. (masl)	BH depth (m)	Remarks
	Y	X +(2 700 000)			
Vlieëpoort Weir					
VBH1	-031 909.10	25 592.05	901.70	18.50	
VBH2	-031 912.15	25 545.13	902.16	31.75	
VBH3	-031 989.59	25 568.85	901.80	47.80	
VBH5	-032 041.54	25 481.49	901.13	44.21	Angled borehole
VBH6	-032 065.11	25 509.26	900.78	31.32	
VBH7	-032 091.42	25 515.61	900.71	21.93	
VBH8	-032091.48	25 461.52	902.82	34.69	
VBH9A	-032 036.78	25 438.14	900.31	16.75	
VBH15	-032 097.47	25 501.52	900.87		High lift pump station BH cancelled, layout changed
BH27	-031 911.98	25 573.19	902.39	36.00	
BH28	-031 954.32	25 563.20	901.20	40.00	
BH29	-031 968.28	25 516.62	900.20	40.18	
BH30	-032 007.66	25 528.88	897.77	43.20	
BH31	-032 029.69	25 464.41	901.37	40.00	
BH32	-032 080.10	25 493.42	900.91	26.90	BH redrilled due to failure of core barrel
BH33	-032 019.06	25 556.95	898.42	48.57	Angled borehole
BH34	-032 077.13	25 520.26	901.04	32.50	
BH35	-032 026.78	25 411.05	900.86	20.06	
BH36	-032 074.00	25 463.21	900.77	32.71	
Road D1649 crossing (Mooivalei 342 KQ Rem. Ptn 1)					
BH43	-031 836.17	20 186.40	957.22	10.40	
BH44	-031 859.06	20 175.20	957.93	10.82	
Balancing Reservoir					
BH37	-030 418.32	20 752.23	941.73	10.00	
BH38	-030 097.09	20 909.70	937.34	10.00	

BH no.	Coordinates (WGS84, Lo27)		BH collar elev. (masl)	BH depth (m)	Remarks
	Y	X +(2 700 000)			
BH39	-030 631.56	21 128.01	944.96	10.08	
BH40	-030 020.92	21 362.86	912.19	9.31	
BH41	-030 834.78	21 472.23	926.68	70.71	
BH42	-030 493.28	21 263.27	920.11	9.27	
BH61	-030 255.71	21 520.11	937.03	9.36	
BH62	-030 151.19	20 959.44	937.11	10.07	
BH63	-030 028.73	21 017.68	935.34	10.00	
BH64	-030 630.93	21 506.94	945.17	12.00	
BH65	-030 546.26	21 533.02	943.90	12.54	
Break Pressure Reservoir (Leeuwbosch 129KQ)					
BH45	-041 081.29	02 110.67	1096.33	9.43	
BH46	-041 001.89	02 514.62	1098.50	10.03	
BH68	-041 191.22	02 506.12	1119.44	10.50	
BH69	-041 028.74	02 585.24	1117.74	10.50	
BH70	-041 102.51	02 765.33	1120.63	12.00	
BH71	-041 265.68	02 685.74	1121.58	10.50	
R510 road crossing (Zondagskuil 130KQ Rem / Diepkuil 135KQ)					
BH47	-041 227.45	02 414.19	1100.48	10.64	
BH48	-041 257.30	02 399.66	1100.37	10.37	

Where:

Boreholes VBH1 – VBH15 were rotary core boreholes drilled at Vlieëpoort Weir site during Feasibility Stage investigations.

Boreholes BH27 – BH36 were rotary core boreholes drilled at Vlieëpoort Weir site during Tender Design Stage investigations.

4.7 Rotary Percussion Boreholes (Annexure C2)

Rotary percussion boreholes were drilled at the Vlieëpoort Weir site, as well as at several locations along the pipeline route. The results of this drilling are listed in Annexure C2.

Boreholes numbered PBH1 to PBH6 were drilled at the Abstraction Weir site using Symmetrix equipment, with Jean Lutz monitoring, in order to obtain representative, uncontaminated samples of the alluvial profile and permit accurate characterisation of the materials.

A total of eight percussion boreholes, numbered MBH1 to MBH8, were drilled by conventional means, and equipped to function as monitoring boreholes. A further seven boreholes, numbered PBHP1 to PBHP7, were drilled along the pipeline route where the route was assumed to be underlain by dolomitic rocks and the gravity survey indicated the presence of gravity "lows".

Borehole chips were logged by an engineering geologist in accordance with accepted South African practice (SANS 633: 2009 DRAFT). Borehole logs were prepared using DotPlot® software and are included in Annexure C2.1.

The location and details of all percussion boreholes are listed below in Table 3.

Table 3: Summary of rotary percussion borehole details

Borehole No	Coordinates (WGS84, Lo27)		BH collar elevation (masl)	BH depth (m)	Remarks
	Y	X			
Vlieëpoort Weir					
PBH1	-31 898.74	2 725 583.60	901.73	27	
PBH2	-31 928.30	2 725 553.66	901.17	33	
PBH3	-31 956.50	2 725 522.10	900.97	35	
PBH4	-31 990.80	2 725 521.87	898.90	33	
PBH5	-32 053.68	2 725 493.80	900.97	24	
PBH6	-32 097.49	2 725 501.51	900.89	21	
MBH1	-31 846.434	2 725 535.85	902.14	22	
MBH2	-31 908.603	2 725 611.07	902.27	21	
MBH3	-32 070.610	2 725 458.78	901.04	24	
MBH4	-31 985.049	2 725 345.93	900.832	24	
MBH5	-31 502.969	2 725 072.35	900.771	36	
MBH6	-31 670.212	2 725 016.84	903.261	21	
MBH7	-32 179.366	2 726 187.32	902.565	39	
MBH8	-32 301.416	2 726 166.24	904.434	27	
Pipeline					
PBHP1	-30 651.33	2 722 534.18	929.63	40	
PBHP2	-31 069.71	2 723 183.34	927.32	30	
PBHP3	-31 523.04	2 723 702.89	927.73	30	
PBHP4	-31 684.93	2 724 321.20	934.04	30	
PBHP5	-31 828.74	2 724 820.48	927.50	32	
PBHP6	-40 859.93	2 701 333.72	1 102.92	18	
PBHP7	-40 667.33	2 700 559.88	1 095.10	30	

Where;

Boreholes PBH1 – PBH6 were percussion Symmetrix boreholes,

Boreholes MBH1 – MBH8 were percussion boreholes drilled for monitoring purposes, and

Boreholes PBHP1 – PBHP7 were percussion boreholes drilled to investigate gravity “lows” along the pipeline route.

4.8 Centreline Test Pitting (see Annexure A)

Test pits were dug along the pipeline route in order to assess the depths and quality of the in-situ material. The test pits were dug using a New Holland B90B 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 TLB are given below.

Table 4: Characteristics of TLB

Specification	New Holland B90B
Overall power (kW)	72
Maximum Torque (Nm/rpm)	400/1400
Bucket width (mm)	610
Maximum reach (mm)	4270

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 the conditions at each test pit is given in Annexure A1. The profiles encountered were logged by a geospecialist and samples were taken of representative horizons. Test pit profiles are included in Annexure A2. Test pits are numbered with the pipe section (as used during the Feasibility Stage) as a prefix. 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, 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 seepage was encountered in any of the test pits.

At the time of profiling in the field, 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 and 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.

4.9 Borrow Sources (see Annexures B and D)

Sources of material suitable for use as bedding or selected 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 2,000 mm pipe diameter 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. The estimated requirement of 100,000 m^3/5 km ignores the possibility that suitable bedding and backfill material may be available 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.

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

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

Table 5: Suitability of granular backfill material

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 borrow pit investigation are given in Annexure B and maps of the sources in Annexure D.

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

4.10 Laboratory Testing

Laboratory testing was carried out in order to quantify the characteristics of the materials encountered along the pipeline route, including the materials at the Abstraction Weir site and at the Balancing Dam and the Break Pressure Reservoir sites.

All laboratory testing was carried out by SANAS-accredited testing laboratories (Geostrada, ARC and Waterlab). The standard test methods employed are shown on the test results. The following tests were carried out:

- Road Indicator (sieve grading and Atterberg Limit determinations);
- Foundation Indicator (as above but with hydrometer gradings to quantify the silt and clay fractions);
- Compactability;
- pH and conductivity;
- CBR tests on potential gravel sources;
- SRB potential (carried out by Waterlab);
- Shear box;
- Triaxial ;
- M_s (Constrained Soil Modulus) ;
- Hydrostatic Compression; and
- Soil fertility tests (carried out by ARC).

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

- Annexure A – Centreline Data;
- Annexure B – Borrow Pit Data; and
- Annexure C – Site Specific Investigations.

4.11 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 at borrow pits. The samples were approximately 2 kg, and 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 results appear in Annexure A3.4 (for the centreline) and B2.4 (for borrow pits).

4.12 Corrosivity

The data relating to the soil analysed along the pipeline route, in accordance with the requirements of DIN 50 929-3 are detailed in Annexure A3.3 for the centreline and B2.3 for borrow pits. A neutral pH was obtained (average value 7.54).

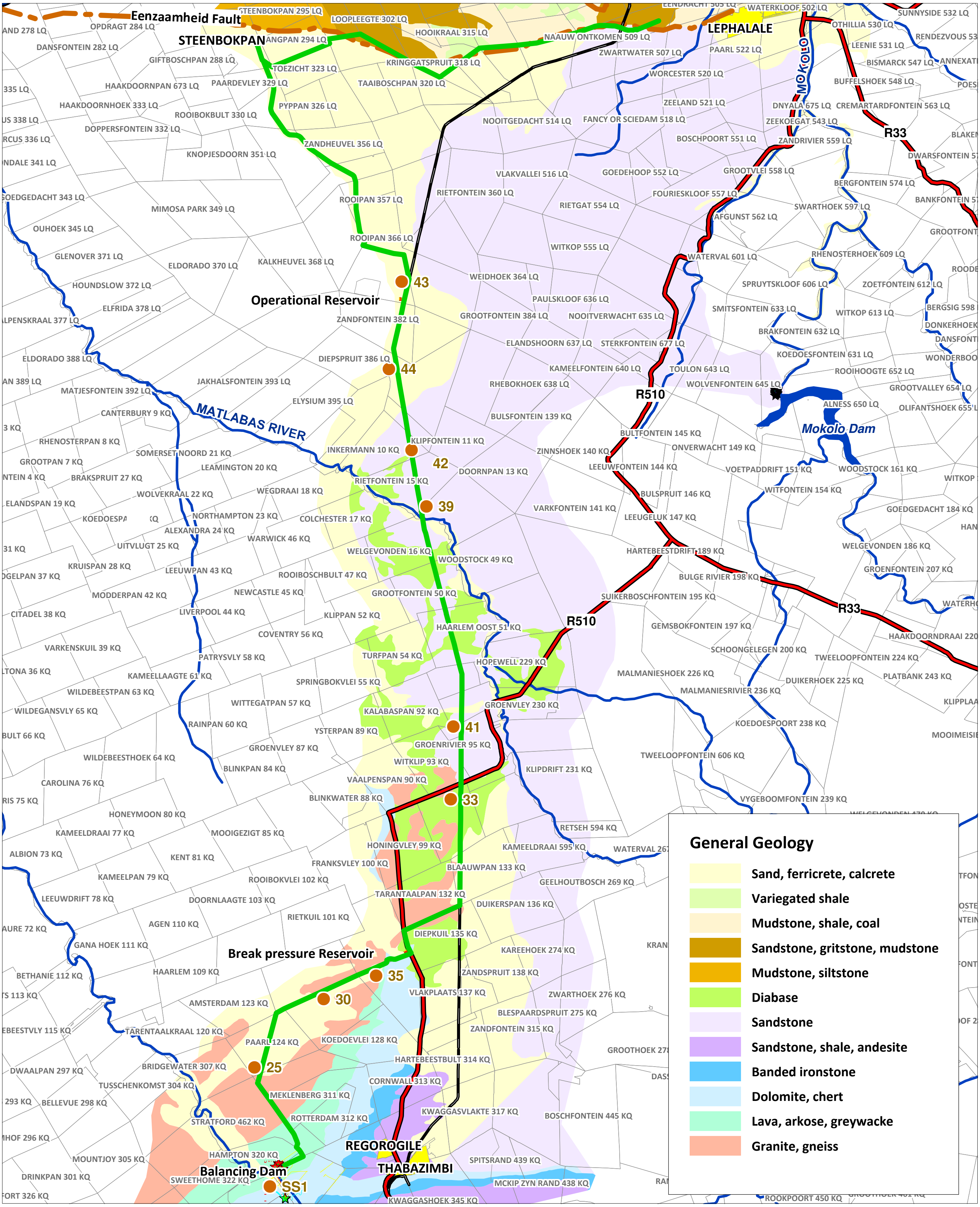
5 GENERAL GEOLOGICAL SETTING

5.1 Regional Geology

In the south the site is underlain by strata of the Transvaal and Ventersdorp Supergroups, which dip south-eastwards at 20 to 30˚. These are overlain in the north by the Waterberg Group, where Lebowa Suite (3G1) granite also occurs. In the west granite and gneiss of the Basement Complex is present. Diabase, generally in the form of dykes, has intruded the Pretoria and Ventersdorp strata, while it occurs as sills in the Waterberg Group and Lebowa Suite.

The units present range from as old as 3035 to 2777 Ma (Archaean Granite) to 2000 to 1700 Ma for the Waterberg sandstones. In the north and west the geology is blanketed by Quaternary Age sands which are younger than 1.8 million years.

The regional geology is shown on Figure 2: Regional Geology (Drawing Number 2A-G3-021).



A new word for water

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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

Drawing Number: 2A-G3-021

Rev: FIG 2

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5.2 Structural Geology

The Pretoria and Ventersdorp strata dip south-eastwards off the Basement Complex granites at between 20 and 30 ˚. 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. Numerous faults are recognised in the Transvaal and Ventersdorp strata.

The Transvaal strata are intensely faulted in the vicinity of Thabazimbi, giving them a T-shaped outcrop, with one leg trending east-west and the other north-southwards.

5.3 Economic Geology

Important iron ore deposits, comprising banded ironstones, are present in the lower parts of the Penge Formation, which is the uppermost Formation of the Chuniespoort Group of the Transvaal Supergroup. The pipeline does not cross the Penge Formation, though the Vlieëpoort Weir is located on it.

5.4 Seismic Hazard

According to Kijko, *et. al.* 2003, the area investigated has a low to moderate seismic hazard. Peak ground accelerations of up to 0.1 g have a 10% probability of being exceeded within a 50 year period.

5.5 Climate and Weathering

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.

The area lies in the summer rainfall area. Thabazimbi receives an average of 530 mm of rain a year, virtually all of which falls between October and March. Average midday temperatures are 31 (January) and 21 (June) with average night time temperatures of 19 (January) and 0 (June).

6 INVESTIGATION FINDINGS

6.1 Local Geology

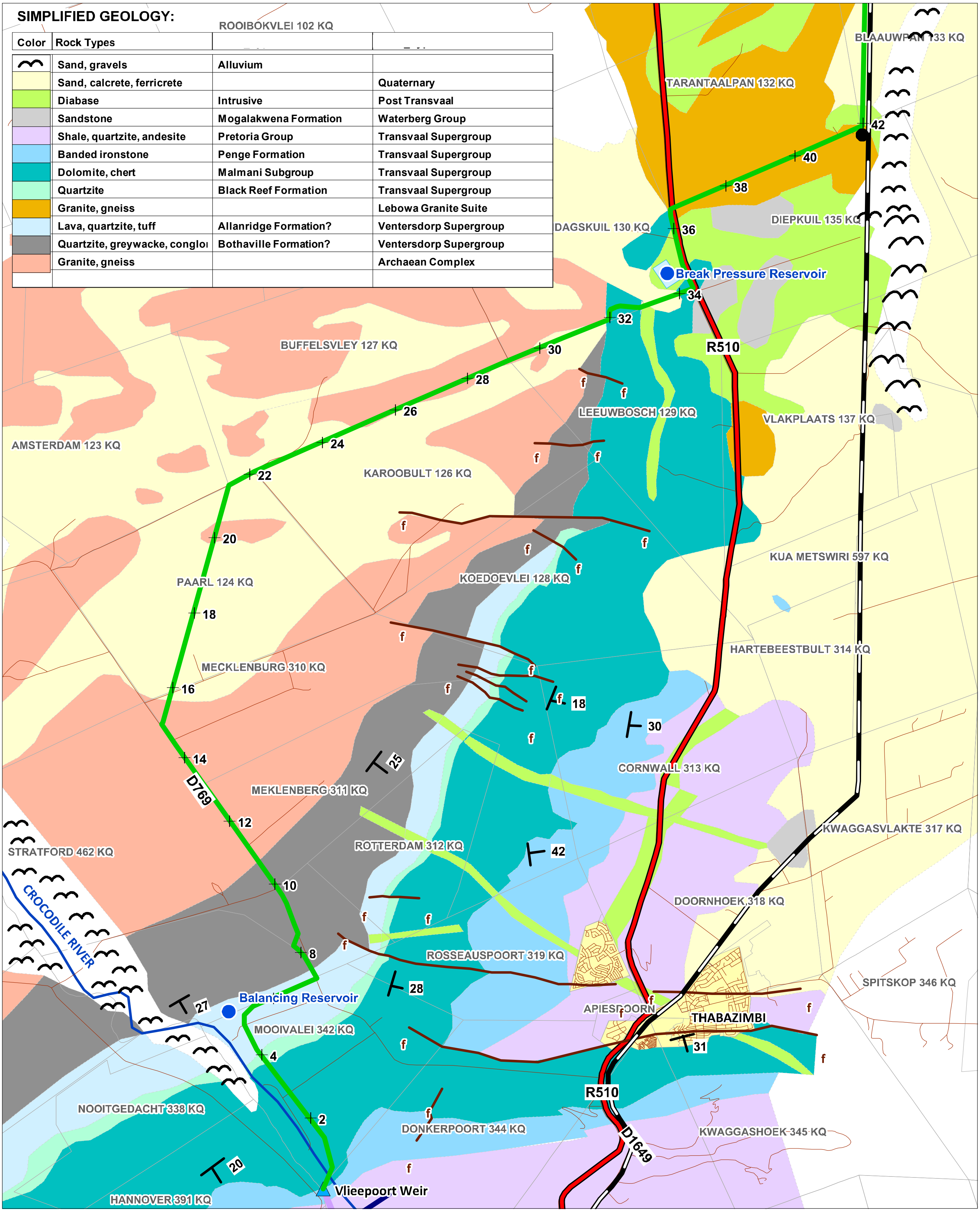
The pipeline route commences on strata of the Transvaal Supergroup, with the Vlieëpoort Weir located on the Banded Ironstone Formation (BIF) of the Penge Formation and the pipeline leading from the weir traversing dolomitic rocks of the Malmani Subgroup. These horizons dip south-eastwards at about 20 to 30 . The pipeline route initially runs north-westwards, crossing onto progressively older strata. This initially comprises the Black Reef Quartzite Formation, which is the basal member of the Transvaal strata, before passing onto Ventersdorp Supergroup strata (lava, quartzite, conglomerate) and then onto Basement Granite (1G).

The route swings north-eastwards and continues on granite before it passes back over Transvaal strata before crossing onto the Lebowa Granite Suite (3G1) and patches of Waterberg sandstone. Both these latter units have been intruded by diabase (probably in the form of sills), while the Pretoria and Ventersdorp have been similarly intruded, but mostly in the form of dykes. Deposits of Quaternary sand (usually with ferricrete and calcrete at the base) occur to the north and west of Thabazimbi, blanketing the older rocks. The geology along the route, as extracted from the published 1:250,000 geological map, is shown in Figure 3: Local Geology (Drawing no. 2A-G3-023).

The geology of the area may be summarised as shown on Table 6 below.

Table 6: Geology

<table>
<tr><th>Rock Types</th><th>Formation</th><th>Group</th><th>Remarks</th></tr>
<tr><td>Sand, ferricrete, calcrete</td><td></td><td></td><td>Quaternary</td></tr>
<tr><td>Diabase</td><td></td><td></td><td>Post-Waterberg intrusive</td></tr>
<tr><td>Sandstone, conglomerate.</td><td>Mogalakwena</td><td>Waterberg</td><td></td></tr>
<tr><td>Shale, quartzite, andesite</td><td></td><td rowspan="3">Pretoria</td><td rowspan="3">Transvaal Supergroup</td></tr>
<tr><td>Dolomite, chert</td><td>Malmani Subgroup</td></tr>
<tr><td>Quartzite, conglomerate</td><td>Black Reef</td></tr>
<tr><td>Granite, gneiss</td><td></td><td></td><td>Lebowa Granite Suite (3G1)</td></tr>
<tr><td>Lava, quartzite, tuff</td><td>Allanridge?</td><td></td><td rowspan="2">Ventersdorp Supergroup</td></tr>
<tr><td>Quartzite, greywacke, conglomerate</td><td>Bothaville?</td><td></td></tr>
<tr><td>Granite, gneiss</td><td></td><td></td><td>Basement Granite (1G)</td></tr>
</table>



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Legend

- Pipeline Route
- 30 Strike and Dip
- f—f Fault
- Main Roads
- Railway Line
- Streets
- Rivers
- Farm Boundaries
- Towns
- km

Scale: 1:125,000

2 0 2 4
Kilometers

N

Project: Mokolo and Crocodile (West) Water Augmentation Project

Drawing Title: Local Geology

Drawing Number: 2A-G3-023

Rev: FIG 3

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6.2 Vlieëpoort Weir Site

6.2.1 Investigations

Limited exploratory drilling was conducted during previous Feasibility Stage investigations. The information from this drilling was assessed and utilised when planning the current, detailed Tender Design investigations. These commenced with geophysical surveys, which comprised gravimetric and resistivity surveys, with the aim of identifying any linear features which might be present, as well as defining variations in bedrock elevation. Such anomalies were then targeted for follow-up exploratory drilling.

The findings of the geophysical surveys are presented in Annexure C3. Drilling was subsequently conducted, which included rotary core boreholes (Table 2), as well as Symmetrix percussion boreholes (Table 3). After the drilling, a Radon emanation survey was carried out in order to select optimal positions for siting further boreholes for groundwater monitoring (Table 3).

The findings of the Radon survey are presented in Annexure C3.2. Rotary core and percussion borehole logs are presented in Annexures C1 and C2 respectively. Limited laboratory testing, comprising foundation indicator testing, was carried out in order to characterise the geotechnical parameters of the materials. Laboratory test data is presented in Annexure C4.

Borehole positions and positions of geophysical and radon traverses are indicated on Figure 4: Vlieëpoort Weir and Low-Lift Pump Station. Site Investigation Layout (Drawing no. 2B-G3-023) and Figure 5: Vlieëpoort Weir and Low-Lift Pump Station. Borehole Layout (Drawing no. 2B-G3-021).

6.2.2 Geological Features

The gravity and resistivity surveys revealed the presence of possible fault zones, as suggested by gravity and resistivity “lows”, and also showed some correlation between decreases in gravity and low-resistivity zones which were considered possibly to reflect the effects of weathering via fault- and fracture zones. Extrapolation between the anomalies of the respective geophysical traverses indicates possible alignments of these geological features, which were subsequently targeted for drilling.

The findings of the Radon Survey were used to define the position of a presumed fault which is orientated approximately ENE across the valley, located between 30 and 100 m downstream of the Weir centreline (Figure 5: Drawing no. 2B-G3-021). The results of the Radon survey are bound into Annexure C3.2.

The possible occurrence of other, similar, features can however not be excluded.

CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	X CO-ORDINATE	Y CO-ORDINATE
MBH1	+ 2725535.855	– 31846.434
MBH2	+ 2725611.074	– 31908.603
MBH3	+ 2725458.780	– 32070.610
MBH4	+ 2725332.114	– 31983.312
MBH5	+ 2725063.457	– 31502.864
MBH6	+ 2725014.765	– 31676.439
MBH7	+ 2726163.173	– 32177.426
MBH8	+ 2726166.652	– 32298.936

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 C.
4. ONLY MONITORING BOREHOLES ARE SHOWN, FOR OTHER BOREHOLES AT VLIEEPOORT SEE DRG. 2B–G3–021.

LEGEND:

BH20 BOREHOLE POSITION

GEOPHYSICAL TRAVERSE

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	05/05/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:1000

SCALE 1 : 5000 — 0 25 50 100 150 200 250

MOKOLO CROCODILE Consultants

TCTA A new word for water

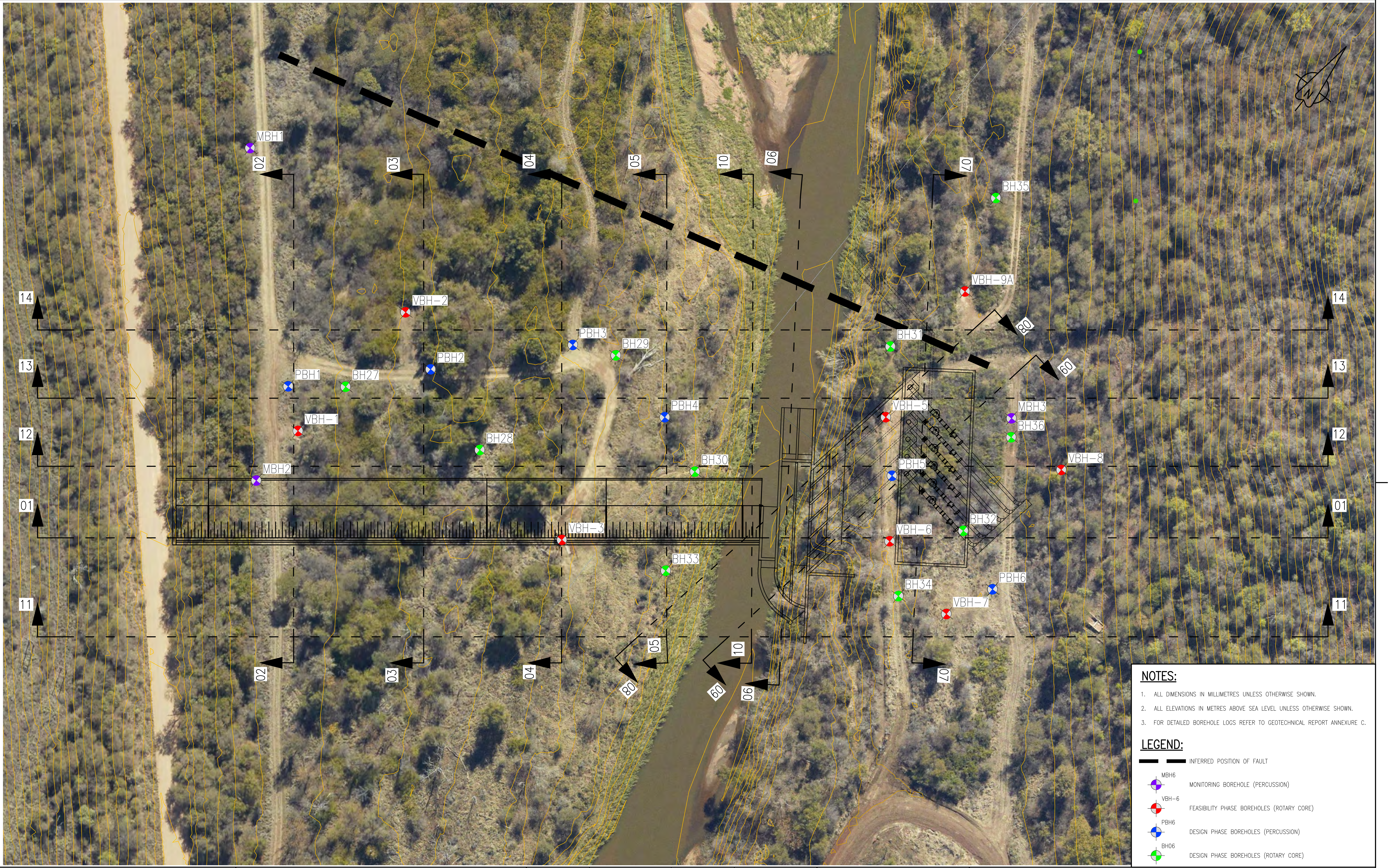
MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

VLIEëPOORT WEIR AND LOW–LIFT PUMP STATION

SITE INVESTIGATION LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2B – G3 – 023	REV No. A



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 C.

LEGEND:

INFERRED POSITION OF FAULT

MBH6 — MONITORING BOREHOLE (PERCUSSION)

VBH−6 — FEASIBILITY PHASE BOREHOLES (ROTARY CORE)

PBH6 — DESIGN PHASE BOREHOLES (PERCUSSION)

BH06 — DESIGN PHASE BOREHOLES (ROTARY CORE)

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	04/05/11	FOR INFORMATION	PLR
B	06/06/11	FAULT LINE ADDED	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:1000

SCALE 1 : 1000 0 5 10 15 20 25 50

MOKOLO CROCODILE Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

VLIEëPOORT WEIR AND LOW-LIFT PUMP STATION

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2B − G3 − 021	REV No. B

6.2.3 Geological Profile

The geological profile, as derived from the various boreholes, is summarised below in Table 7.

The site is characterised by a substantial thickness of alluvial material, overlying bedrock comprising Banded Ironstone Formation (BIF). The alluvium thickness generally varies between 20 and 30 m, but is shallower towards the flanks where alluvium thicknesses between 11 and 13 m were recorded. A maximum thickness of 39,5 m of alluvial material was recorded in borehole VBH3.

Table 7: Summarised geological profile, Vlieëpoort Weir (depths in metres)

BH no	Alluvium, possibly colluvium in places	Bedrock: upper horizon comprising highly to completely weathered, medium hard or hard to soft rock banded ironstone	Bedrock, comprising highly to moderately weathered, very hard rock banded ironstone
VBH 1	0 – 13,10		13,10 – 18,50+
VBH 2	0 – 27,00		27,00 – 31,75+
VBH 3	0 - 39,50		39,50 - 47,8+
VBH 5*	0 – 32,50	32,50 – 39,60	39,60 – 44,21+
VBH 6	0 – 27,30		27,30 - 31,32+
VBH 7	0 - 18,50		18,50 - 21,93+
VBH 8	0 - 29,35	29,35 - 30,35	30,35 - 34,69+
VBH9A	0 – 11,36	11,36 – 14,00	14,00 – 16,75+
BH27	0 – 19,10	19,10 – 23,25	23,25 – 36,00+
BH28	0 – 31,20		31,20 – 40,00+
BH29	0 – 32,42	32,42 – 34,46	34,46 – 40,18+
BH30	0 – 30,45	30,45 – 43,20+	
BH31	0 – 19,67	19,67 – 40,00+	
BH32	0 – 21,20	21,20 – 26,90+	
BH33*	0 – 42,00	42,00 – 48,57+	
BH34	0 – 20,60	20,60 – 32,50+	
BH35	0 – 12,47	12,47 – 20,06+	
BH36	0 – 27,10	27,10 – 32,71+	
PBH1	0 – 22		22 – 27+
PBH2	0 – 27	27– 30	30 – 33+
PBH3	0 - 33		33 – 35+
PBH4	0 - 30	30 – 33+	
PBH5	0 - 21	21 – 24+	
PBH6	0 - 13	13 - 15	15 -21+

**denotes angled borehole; reflected depths are as measured along borehole axis*

a) Alluvium

Alluvium thicknesses vary between 13 and 39,5 m. The alluvium profile is however variable, both laterally and vertically, and comprises horizons of fine material (clay or silt, or blends thereof), or sand horizons, with silt or clay or fine gravel fractions, or horizons of coarse material which comprise gravels or cobbles in a silty clay matrix.

Laboratory testing of the representative samples from the full vertical profile recovered from selected Symmetrix boreholes enabled detailed characterisation of the alluvial horizons, as listed below in Table 8. The following must however be borne in mind:

- Although the gravel fraction is recorded, it must be noted that the percussion drilling process would break the original gravels, cobbles and boulders. The grading of the gravel fraction is therefore not to be considered a true reflection of the actual particle diameter.
- Although borehole samples were recovered and bagged for each linear metre drilled, the geological horizons are unlikely to correspond exactly to the same sampling interval.
- The vertical (and lateral) material variability is expected to be gradational.

Limited sampling of the near-surface alluvium reveals that the material varies between clayey or slightly clayey sand and clayey, sandy silt. In this instance the samples were collected after a period of sustained high flows, when subsiding water levels enabled access, and is therefore likely to be representative of materials deposited after a period of peak flow, rather than during normal flow conditions.

Table 8: Vlieëpoort Weir: Grading characterisation of alluvial horizons

<table>
<tr><th>Depths (m)</th><th>PBH04
(mid-left bank)</th><th>PBH05
(right bank)</th><th>PBH02
(extreme right bank)</th></tr>
<tr><td>0-1</td><td>Clayey sand</td><td>Sandy, silty clay</td><td rowspan="3">Clayey sand</td></tr>
<tr><td>1-2</td><td>Slightly clayey sand with gravel</td><td rowspan="2">Slightly silty clay</td></tr>
<tr><td>2-3</td><td>Clayey sand</td></tr>
<tr><td>3-4</td><td rowspan="5">Sand with gravel</td><td>Slightly sandy and silty clay</td><td>Clayey, sandy silt</td></tr>
<tr><td>4-5</td><td>Sandy, silty clay</td><td rowspan="2">Clayey sand</td></tr>
<tr><td>5-6</td><td>Clayey sand</td></tr>
<tr><td>6-7</td><td rowspan="2">Sandy, silty clay</td><td>Slightly sandy and silty clay</td></tr>
<tr><td>7-8</td><td rowspan="2">Sandy, silty clay</td></tr>
<tr><td>8-9</td><td>Sand and gravel</td><td>Clayey sand</td></tr>
<tr><td>9-10</td><td>Sandy clay</td><td>Sand</td><td>Slightly sandy and silty clay</td></tr>
</table>

<table>
<tr><th>Depths (m)</th><th>PBH04
(mid-left bank)</th><th>PBH05
(right bank)</th><th>PBH02
(extreme right bank)</th></tr>
<tr><td>10-11</td><td>Sandy, silty clay</td><td></td><td rowspan="5">Sandy, silty clay</td></tr>
<tr><td>11-12</td><td>Clayey sand</td><td rowspan="2">Slightly clayey sand</td></tr>
<tr><td>12-13</td><td rowspan="3">Slightly clayey sand</td></tr>
<tr><td>13-14</td><td>Clayey sand</td></tr>
<tr><td>14-15</td><td>Clayey sand with gravel</td></tr>
<tr><td>15-16</td><td>Silty sand with gravel</td><td rowspan="2">Slightly clayey sand with gravel</td><td>Gravel with silty sand</td></tr>
<tr><td>16-17</td><td>Sand with gravel</td><td>Sand and gravel</td></tr>
<tr><td>17-18</td><td>Sand and gravel</td><td>Clayey sand with gravel</td><td>Gravel with sand</td></tr>
<tr><td>18-19</td><td rowspan="5">Silty sand with gravel</td><td rowspan="3">Sand and gravel</td><td>Clayey sand with gravel</td></tr>
<tr><td>19-20</td><td>Clayey, sandy silt with gravel</td></tr>
<tr><td>20-21</td><td rowspan="2">Clayey sand with gravel</td></tr>
<tr><td>21-22</td><td rowspan="10">Bedrock</td></tr>
<tr><td>22-23</td><td>Gravel with sand</td></tr>
<tr><td>23-24</td><td>Silty sand</td><td>Clayey, sandy silt with gravel</td></tr>
<tr><td>24-25</td><td>Sand</td><td rowspan="3">Sand</td></tr>
<tr><td>25-26</td><td>Silty sand</td></tr>
<tr><td>26-27</td><td rowspan="2">Sand</td></tr>
<tr><td>27-28</td><td rowspan="4">Bedrock</td></tr>
<tr><td>28-29</td><td>Silty sand with gravel</td></tr>
<tr><td>29-30</td><td></td></tr>
<tr><td>30-31</td><td>Bedrock</td></tr>
</table>

The colour shading indicates the summarised profile as follows;

Predominantly clay
Predominantly silt
Predominantly sand
Gravel fraction present
Bedrock

b) Bedrock

Bedrock comprises BIF and is intersected at depths which vary between 13 and 39,5 m, as indicated above in Table 7. No other lithologies were intersected in the boreholes.

In certain boreholes two bedrock horizons are recognized, comprising an upper horizon of highly to completely weathered, medium hard or hard to soft rock BIF, and a lower horizon comprising highly to moderately weathered, very hard rock BIF. Both horizons were, however, not intersected in all boreholes.

6.2.4 Water Levels and Lugeon Test Data

Water levels were recorded in the majority of the boreholes drilled at the Vlieëpoort Weir site, including the water rest levels recorded for the previous Feasibility Stage investigation. These results are summarised below in Table 9.

In addition, packer or Lugeon tests were attempted within the bedrock in the rotary core boreholes. However, as a rule, the desired pressures could not be attained and the tests were not successful. The packer test results are summarised below in Table 9.

Table 9: Vlieëpoort Weir: Summarised water table measurements and Lugeon values

BH no.	Lugeon values (depths of testing in brackets)	Depth of water table (m)	Remarks
VBH 1		7,33	Total water loss at 13,25 m
VBH 2	? (28,75 – 31,75)	7,10	Unable to attain desired pressure. Total water loss at 27,15 m and 30,50 m
VBH 3	-	7,19	No packer test (packer sticking at 19,0 m)
VBH 4			
VBH 5	8 (35,7 – 38,3 m)	5,96	Loss of drilling water at 5,96 m. Decreasing Lugeon values indicate void filling. Test unable to attain higher pressures.
VBH 6	? (28,2 – 31,32 m)	8,05	Loss of drilling water recorded at 8,05 m. Lugeon test unable to reach desired pressure.
VBH 7			Drilling water loss of 30%, becoming 70% from depth of 18,40 m
VBH 8	? (31,5 – 34,69 m)	18,05	Unable to reach desired pressure. Increasing Lugeon values possibly indicates wash-out (or dilation)
VBH 9A		5,80	Water losses approximately 20%
BH27	? (32 – 34 m)	6,10	Water bypassing packer; test unsuccessful
BH28	? (34 – 37 m) ? (37 – 40 m)	5,46	Two Lugeon tests attempted but both unsuccessful; water bypassing packer (unable to seal) / unable to achieve desired pressure
BH29	? (34 – 37 m) ? (37 – 40 m)	4,60	Two Lugeon tests attempted but both unsuccessful; water bypassing packer / unable to achieve desired pressure
BH30			
BH31	? (32,0 – 36,27 m) 0 (35,5 – 40,00 m)	9.00	Upper test unable to achieve desired pressure due to “broken formation” Lower test indicates impermeable or “tight” founding conditions.
BH32			
BH33		6.00	

BH no.	Lugeon values (depths of testing in brackets)	Depth of water table (m)	Remarks
BH34			
BH35	0 (16 – 20 m)	9.00	One successful test indicates 0 Lugeon – but with negligible wash-out
BH36			
PBH1	-	14.00	Percussion borehole – no Lugeon test
PBH2	-	9.00	Percussion borehole – no Lugeon test
PBH3	-	8.00	Percussion borehole – no Lugeon test
PBH4	-	8.00	Percussion borehole – no Lugeon test
PBH5	-	0.00	Percussion borehole – no Lugeon test
PBH6	-	8 and 14	Percussion borehole – no Lugeon test

Notes: Measurements shown for VBH 5 (angled borehole) refer to vertical depths

Water levels for Feasibility boreholes were measured in 2009, Tender Design boreholes measured 2010.

Water table indicated for percussion boreholes represent depths of water strikes.

6.2.5 Standard Penetration Test (SPT) data

Where possible, Standard Penetration Tests (SPT) were conducted at 1,5 m intervals. Because of the lateral and vertical variability in the alluvial deposits, it is unrealistic to ascribe a SPT N-value to a specific horizon. Rather, the results from the various boreholes have been grouped on the basis of the dominant horizons, and the summarised results reflect the range of data. These are shown on the borehole logs and summarised values are presented in Table 10.

Table 10: Vlieëpoort Weir: Summarised SPT data, grouped on basis of predominant material type

Geological horizon	Clay / silty clay. Possible sand horizons	Sand	Clay / silt / sand with traces or abundant gravels	Gravels in matrix of sandy clay
Minimum N-value	5	3	19	12
Maximum N-value	62	56	52	55
Mean N-value	23	18	31	38
No. of tests	79	22	11	5
No. of instances of REFUSAL (not included in above analysis)	none	1	1	6

Elevated SPT values are evident in the horizon containing traces or abundant gravels, as well as in the horizons of gravels in a sandy clay matrix. These values must, however, be treated with caution due to the effect of the gravels. While the test results would appear to reflect the consistency of the matrix material (ignoring the values where refusal was recorded), even such values could be affected by the presence of gravels and would therefore be questionable.

6.2.6 Laboratory Test Data

Representative samples from selected Symmetrix percussion boreholes were submitted for determination of the Foundation Indicators (i.e. both sieve and hydrometer grading analyses as well as determination of Atterberg Limits). These properties were determined for the full alluvium profile in each of the selected boreholes (PBH02, PBH04 and PBH05). In addition, a limited number of alluvium samples were collected from the river bank prior to drilling in order to characterise the alluvial deposits at surface, to aid the modelling of the weir and pump station (sample numbers 1852 to 1854).

Detailed laboratory test data is presented in Annexure C4 with full grading analyses, as well as the full-profile variation in Atterberg Limits, and are summarised below in Table 11 and shown graphically in Figures 6 to 13 for Boreholes PBH02 and PBH04.

Table 11: Summarised grading and Atterberg Limit data, surface samples

Sample no.	Depth (m)	Material type	Soil composition				GM	Atterberg Limits			Activity
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)		LL (%)	WPI (%)	LS (%)	
1852	0	Slightly clayey sand	7	13	80	0	0.76	0	NP	0	0.0
1853	0	Clayey sand	11	22	67	0	0.48	25	7	3.0	0.6
1854	0	Clayey, sandy silt	11	36	53	0	0.45	26	8	3.0	0.7

PERCUSSION BOREHOLES CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
PBH P1	– 30652.417	+ 2722546.189
PBH P2	– 31066.292	+ 2723179.449
PBH P3	– 31514.185	+ 2723694.826
PBH P4	– 31687.067	+ 2724324.692
PBH P5	– 31827.260	+ 2724815.309

NOTES:

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

LEGEND:

PBH01 BOREHOLE POSITION

REFERENCE DRAWINGS

DRG. No.	TITLE

REVISIONS

REV No.	DATE	DESCRIPTION	APPR.
A	14/09/10	FOR INFORMATION	
B	26/10/10	ADDED CADASTRAL INFO, CHANGED BOREHOLE NUMBERS	
C	27/05/11	ROTATE DISPLAY	

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	P ENGELBRECHT		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:10000

SCALE 1 : 10000 — 0 50 100 150 200 250 500

MOKOLO CROCODILE Consultants

TCTA A new word for water

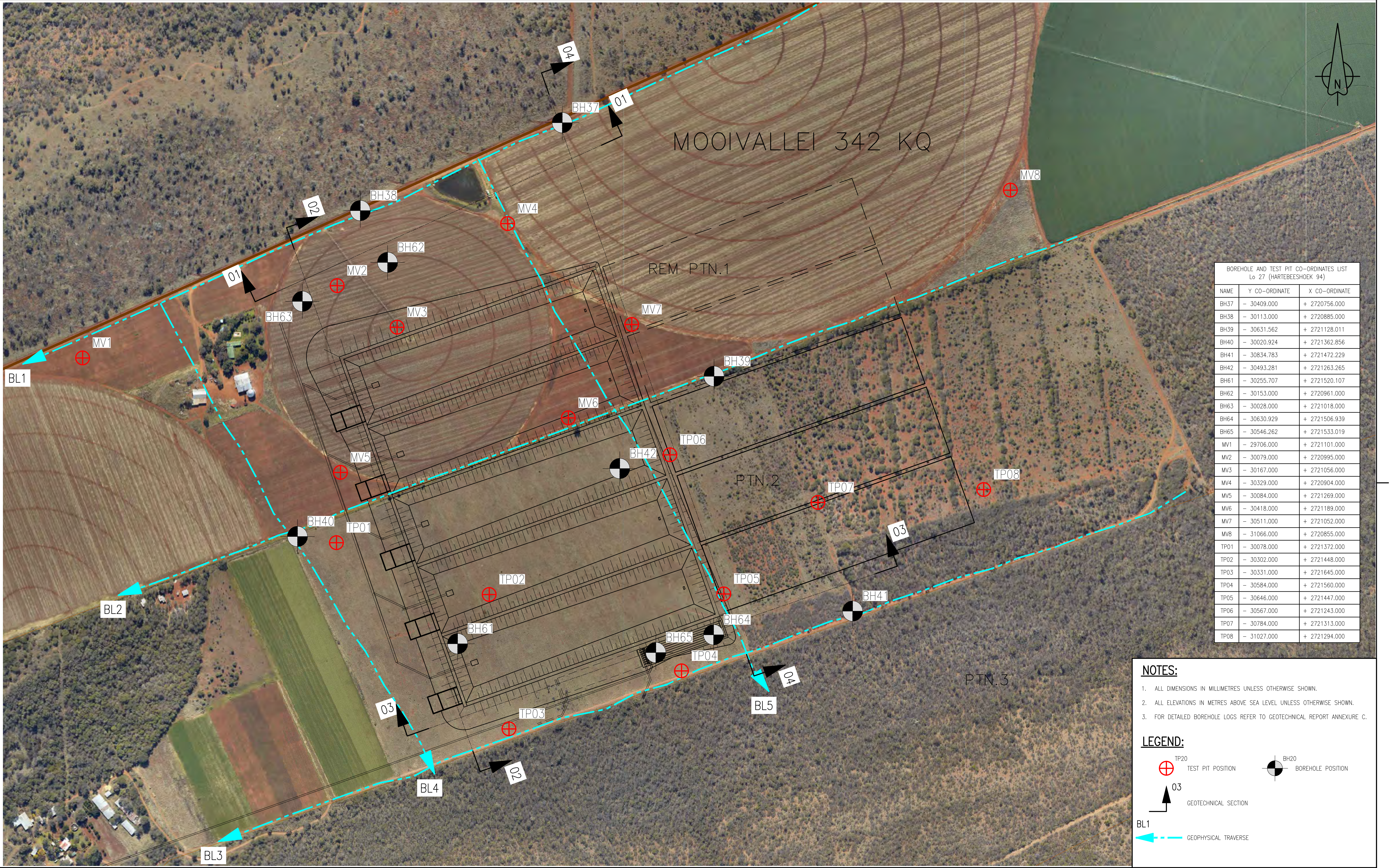
MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

PIPELINE BETWEEN VLIEEPOORT WEIR AND BALANCING RESERVOIR

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2A – G3 – 016	REV No. C



BOREHOLE AND TEST PIT CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH37	– 30409.000	+ 2720756.000
BH38	– 30113.000	+ 2720885.000
BH39	– 30631.562	+ 2721128.011
BH40	– 30020.924	+ 2721362.856
BH41	– 30834.783	+ 2721472.229
BH42	– 30493.281	+ 2721263.265
BH61	– 30255.707	+ 2721520.107
BH62	– 30153.000	+ 2720961.000
BH63	– 30028.000	+ 2721018.000
BH64	– 30630.929	+ 2721506.939
BH65	– 30546.262	+ 2721533.019
MV1	– 29706.000	+ 2721101.000
MV2	– 30079.000	+ 2720995.000
MV3	– 30167.000	+ 2721056.000
MV4	– 30329.000	+ 2720904.000
MV5	– 30084.000	+ 2721269.000
MV6	– 30418.000	+ 2721189.000
MV7	– 30511.000	+ 2721052.000
MV8	– 31066.000	+ 2720855.000
TP01	– 30078.000	+ 2721372.000
TP02	– 30302.000	+ 2721448.000
TP03	– 30331.000	+ 2721645.000
TP04	– 30584.000	+ 2721560.000
TP05	– 30646.000	+ 2721447.000
TP06	– 30567.000	+ 2721243.000
TP07	– 30784.000	+ 2721313.000
TP08	– 31027.000	+ 2721294.000

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 C.

LEGEND:

TP20 TEST PIT POSITION

BH20 BOREHOLE POSITION

03 GEOTECHNICAL SECTION

BL1 GEOPHYSICAL TRAVERSE

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	04/05/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:5000

SCALE 1 : 5000 0 25 50 100 150 200 250

MOKOLO CROCODILE Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

BALANCING RESERVOIR – FARM MOOIVALLEI 342KQ

SITE INVESTIGATION LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2B – G3 – 022	REV No. A

BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH43	– 31836.168	+ 2720186.396
BH44	– 31859.062	+ 2720175.202

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 C.

LEGEND:

600 REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 BOREHOLE POSITION

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	20/04/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:250

SCALE: 1:250 0 2,5 5 7,5 10 12,5

MOKOLO CROCODILE Consultants

TCTA A new word for water

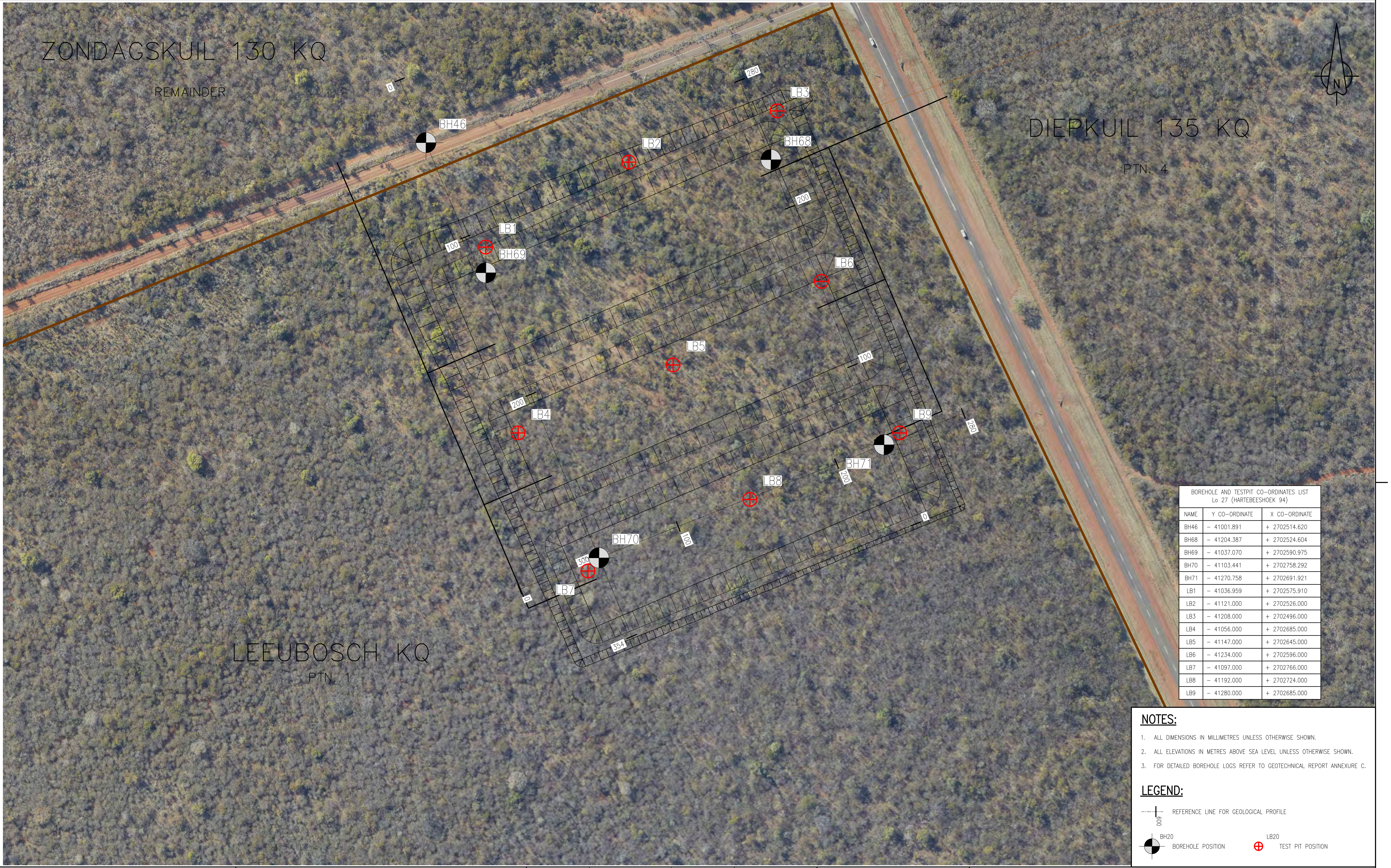
MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

D 1649/DWAALBOOM ROAD CROSSING – FARM MOOIVALLEI 342KQ REM PTN1 (BH43 TO BH44)

BOREHOLE LAYOUT

A3 | DWAF DRG. No. | DRAWING NUMBER 2C – G3 – 201 | REV No. A



BOREHOLE AND TESTPIT CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH46	– 41001.891	+ 2702514.620
BH68	– 41204.387	+ 2702524.604
BH69	– 41037.070	+ 2702590.975
BH70	– 41103.441	+ 2702758.292
BH71	– 41270.758	+ 2702691.921
LB1	– 41036.959	+ 2702575.910
LB2	– 41121.000	+ 2702526.000
LB3	– 41208.000	+ 2702496.000
LB4	– 41056.000	+ 2702685.000
LB5	– 41147.000	+ 2702645.000
LB6	– 41234.000	+ 2702596.000
LB7	– 41097.000	+ 2702766.000
LB8	– 41192.000	+ 2702724.000
LB9	– 41280.000	+ 2702685.000

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 C.

LEGEND:

600 REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 BOREHOLE POSITION

LB20 TEST PIT POSITION

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	21/04/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:2000

SCALE 1 : 2000   0 25 50 75 100

MOKOLO CROCODILE Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

BREAK PRESSURE RESERVOIR – FARM LEEUBOSCH KQ

SITE INVESTIGATION LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2D – G3 – 002	REV No. A

NOTE: FINAL CROSSING POINT APPROXIMATELY 100m SOUTH

BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH47	− 41227.453	+ 2702414.188
BH48	− 41257.303	+ 2702399.661

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 C.

LEGEND:

600 REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 BOREHOLE POSITION

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	20/04/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:250

SCALE: 1:250 0 2,5 5 7,5 10 12,5

MOKOLO CROCODILE Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

R510 ROAD CROSSING – FARM DIEPKUIL 135KQ (BH47 TO BH48)

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2E – G3 – 201	REV No. B

BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
PBH P6	– 40860.628	+ 2701338.997
PBH P7	– 40668.141	+ 2700560.210

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 C.

LEGEND:

600 REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 BOREHOLE POSITION

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	21/04/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:5000

SCALE 1 : 5000 — 0 25 50 100 150 200 250

MOKOLO CROCODILE Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

PIPELINE AT CH 1350 TO CH 2150 – FARM DIEPKUIL 135KQ

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2E – G3 – 206	REV No. A

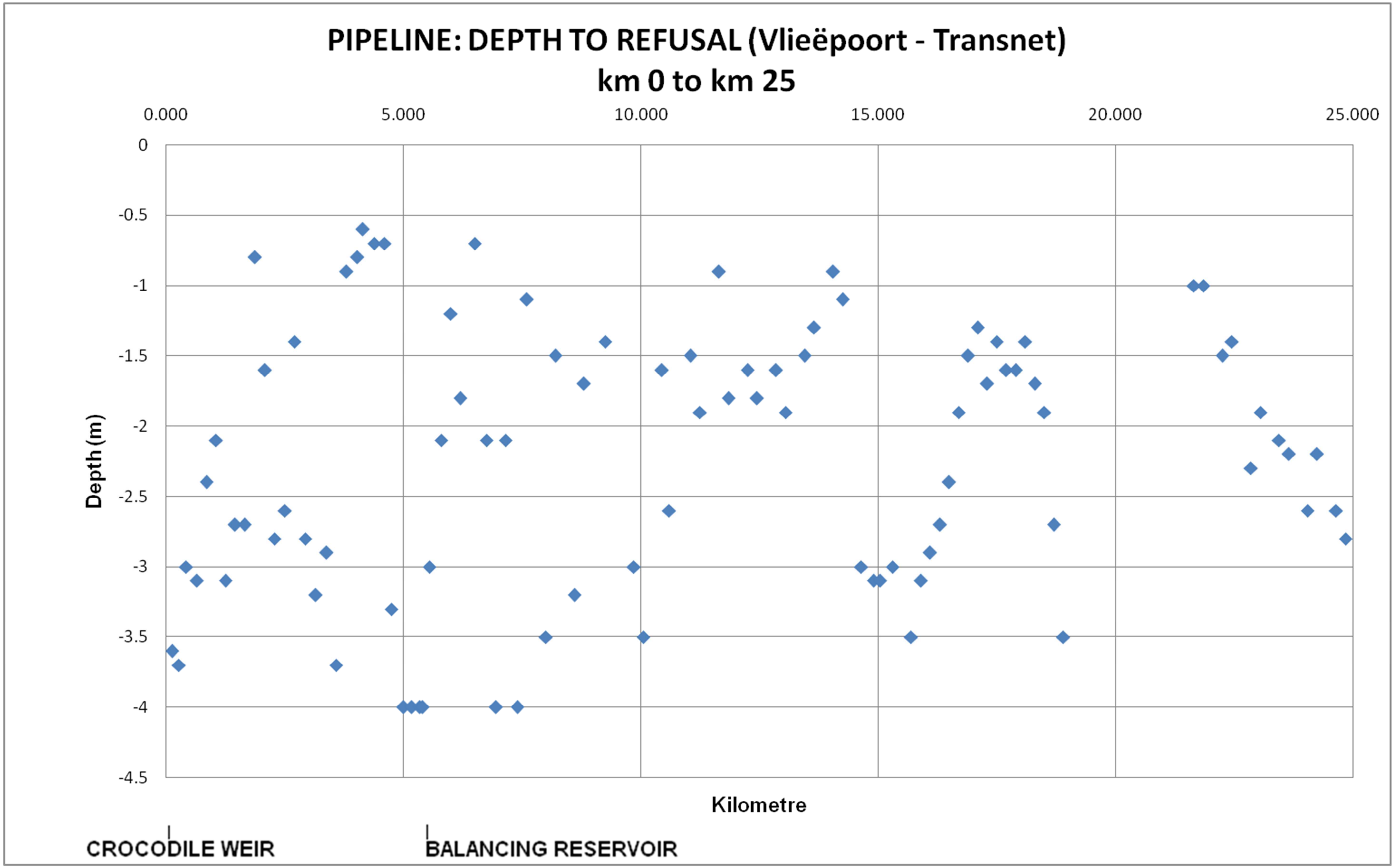


Figure 12: Vlieëpoort weir and Low–Lift Pump Station: Borehole PBH04: Graphical Grading Data (Bar data)

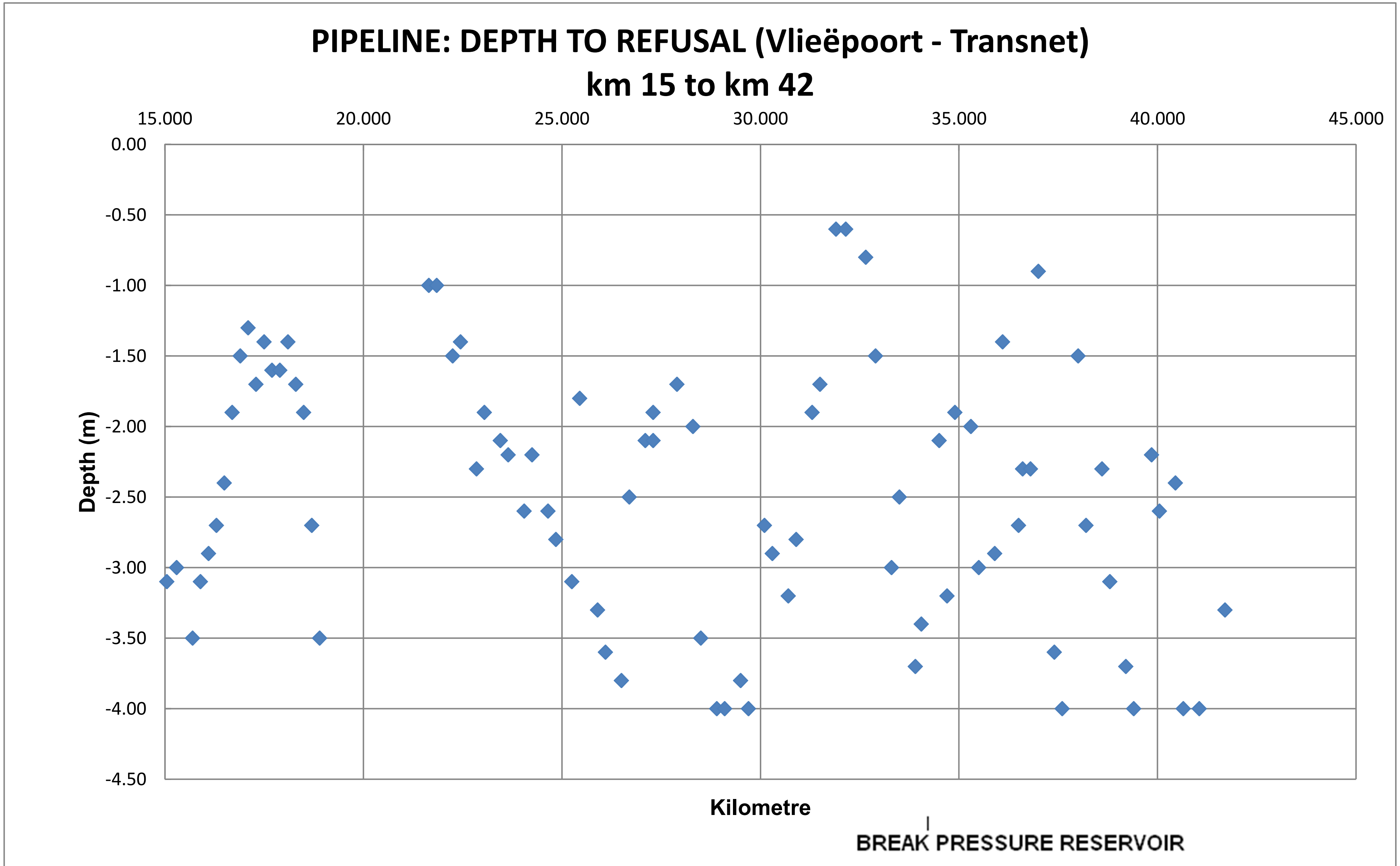


Figure 13: Vlieëpoort weir and Low–Lift Pump Station: Borehole PBH04: Graphical Grading Data (XY data)

6.3 Pipeline between Vlieëpoort Weir and the Balancing Dam (Ch 0,250 to 3,550 m (Sub-section 1)

6.3.1 Investigations

The pipeline route between Vlieëpoort Weir and the Balancing Dam traverses dolomitic rocks. In order to investigate the risks of subsidence associated with these dolomitic rocks, a dolomite stability investigation was conducted by means of a geophysical survey and follow-up exploratory drilling. The results of the geophysical surveys carried out along the pipeline appear in Annexure C3.4: Pipeline geophysics.

The geophysical investigation of the pipeline route between Chainages 0,250 to 3,550 m comprised a gravity survey utilising a single-line traverse with stations set approximately 10 m apart. The results of the gravity survey revealed a relatively uniform gravity profile – with the exception of a prominent gravity “low” and “high” anomalies, located near the northern and southern ends of the traverse line, respectively. Results of the geophysical surveys are bound into Annexure C3.4.

A total of five percussion boreholes, numbered PBHP01 to PBHP05, were subsequently drilled at positions along the pipeline route where anomalies were recognised within the gravity survey results. Figure 14: Pipeline between Vlieëpoort Weir and the Balancing Reservoir (Ch 0 to 5,400 m): Borehole Layout (Drawing no. 2A-G3-016) shows the positions of the boreholes along this portion of the pipeline route.

Borehole logs are presented in Annexure C2, while the results of the gravity survey are presented in Annexure C3. Summarised drilling results are presented below in Table 12.

PERCUSSION BOREHOLES CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
PBH P1	− 30652.417	+ 2722546.189
PBH P2	− 31066.292	+ 2723179.449
PBH P3	− 31514.185	+ 2723694.826
PBH P4	− 31687.067	+ 2724324.692
PBH P5	− 31827.260	+ 2724815.309

NOTES:

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

LEGEND:

PBH01 BOREHOLE POSITION

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	14/09/10	FOR INFORMATION	
B	26/10/10	ADDED CADASTRAL INFO, CHANGED BOREHOLE NUMBERS	
C	27/05/11	ROTATE DISPLAY	

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	P ENGELBRECHT		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:10000

SCALE 1 : 10000 0 50 100 150 200 250 500

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TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

PIPELINE BETWEEN VLIEEPOORT WEIR AND BALANCING RESERVOIR

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2A – G3 – 016	REV No. C

6.3.2 Drilling Results

Borehole PBHP01, drilled on the prominent gravity “low” revealed the colluvial overburden to be in excess of 40 m deep and bedrock was not intersected. Boreholes PBHP02 and PBHP03 revealed similar conditions; colluvial material extending to a depth between 6 and 8 m, underlain by dolomite residuum extending to a depth of 21 m and dolomite bedrock below 21 m. Borehole PBHP04, drilled on a slightly elevated gravity “high”, revealed a profile comprising colluvial materials overlying dolomite bedrock which was intersected at a depth of 13 m. Borehole PBHP05 is located in an area characterised by an irregular gravity profile and this is reflected in a geological profile which comprises transported colluvial gravels and sand extending to a depth of 15 m, underlain by dolomite residuum to a depth of 25 m, below which dolomite bedrock occurs.

Table 12: Pipeline route between Vlieëpoort Weir and the Balancing Reservoir (Ch 0,250 to 3,550 m): Summarised drilling results

BH no.	Transported soils (gravels and clayey sand), occasional clay	Dolomite residuum (fine material, including possible wad)	Dolomite residuum (coarse material)	Dolomite bedrock
PBHP01	0 – 40+	-	-	-
PBHP02	0 - 8	-	8 – 21	21 – 30+
PBHP03	0 - 6	-	6 – 21	21 – 30+
PBHP04	0 - 13	-	-	13 – 30+
PBHP05	0 - 15	15 - 19	19 – 25	25 – 32+

6.3.3 Groundwater Measurements

Water levels were recorded in these percussion boreholes and are summarised below in Table 13.

Table 13: Pipeline between Vlieëpoort Weir and the Balancing Reservoir (Ch 0,259 to 3,550 m): Water level measurements

BH no.	Water level measurements (metres from surface)
PBHP01	21.5
PBHP02	18.5
PBHP03	18.5
PBHP04	not recorded
PBHP05	20.5

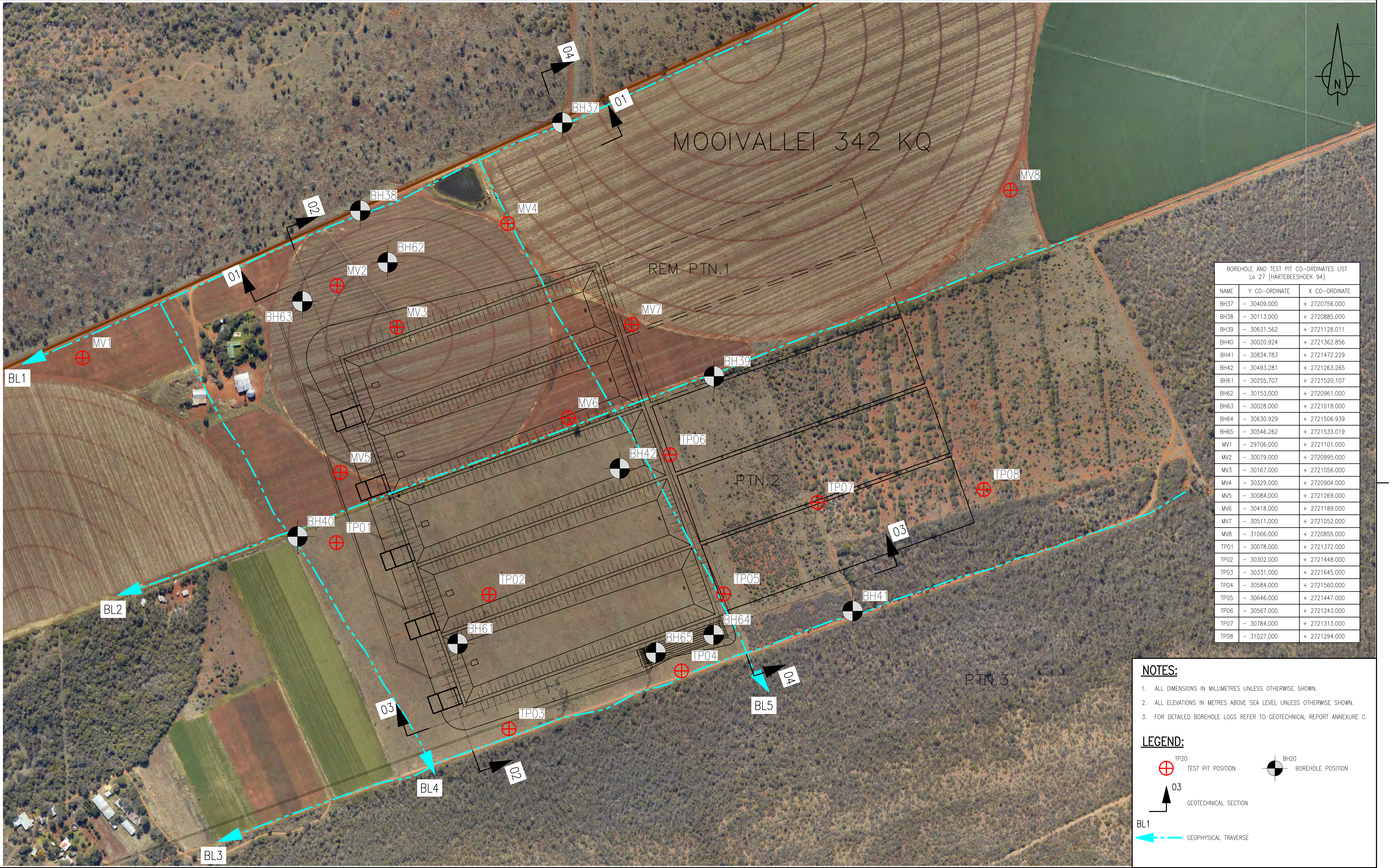
6.4 Balancing Dam (farm Mooivalei 342 KQ Ptn1 Rem and Ptn2)

6.4.1 Investigations

Geotechnical investigations for the Balancing Dam on farm Mooivalei 342KQ Ptn 1 Rem and Ptn 2 comprised geophysical surveys, followed by exploratory drilling and excavation of test pits. Representative samples were also submitted for laboratory testing. The positions of boreholes, test pits and geophysical traverses are shown on Figure 15.

A total of eleven (11) rotary core boreholes, numbered BH37 to BH42 and BH61 to BH65, were drilled. A total of sixteen (16) test pits were excavated. Test pits numbered TP1 to TP8 were excavated in Mooivallei Ptn 2 and test pits numbered MV1 to MV8 were excavated on Mooivallei Ptn 1 Rem. Laboratory testing included determination of Foundation Indicators and compaction characteristics, comprising Mods and CBRs.

Borehole logs are in Annexure C1, while results from the geophysical surveys and the laboratory test results are in Annexure C3 and Annexure C4, respectively. Test pit profiles are bound into Annexure C6.



BOREHOLE AND TEST PIT CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH37	− 30409.000	+ 2720756.000
BH38	− 30113.000	+ 2720885.000
BH39	− 30631.562	+ 2721128.011
BH40	− 30020.924	+ 2721362.856
BH41	− 30834.783	+ 2721472.229
BH42	− 30493.281	+ 2721263.265
BH61	− 30255.707	+ 2721520.107
BH62	− 30153.000	+ 2720961.000
BH63	− 30028.000	+ 2721018.000
BH64	− 30630.929	+ 2721506.939
BH65	− 30546.262	+ 2721533.019
MV1	− 29706.000	+ 2721101.000
MV2	− 30079.000	+ 2720995.000
MV3	− 30167.000	+ 2721056.000
MV4	− 30329.000	+ 2720904.000
MV5	− 30084.000	+ 2721269.000
MV6	− 30418.000	+ 2721189.000
MV7	− 30511.000	+ 2721052.000
MV8	− 31066.000	+ 2720855.000
TP01	− 30078.000	+ 2721372.000
TP02	− 30302.000	+ 2721448.000
TP03	− 30331.000	+ 2721645.000
TP04	− 30584.000	+ 2721560.000
TP05	− 30646.000	+ 2721447.000
TP06	− 30567.000	+ 2721243.000
TP07	− 30784.000	+ 2721313.000
TP08	− 31027.000	+ 2721294.000

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 C.

LEGEND:

TP20 TEST PIT POSITION
BH20 BOREHOLE POSITION
03 GEOTECHNICAL SECTION
BL1 GEOPHYSICAL TRAVERSE

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	04/05/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:5000

SCALE 1 : 5000 0 25 50 100 150 200 250

MOKOLO CROCODILE Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

BALANCING RESERVOIR – FARM MOOIVALLEI 342KQ

SITE INVESTIGATION LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2B – G3 – 022	REV No. A

6.4.2 Geological Map

The published geological map indicates that the site of the Balancing Reservoir is underlain by rocks of the Ventersdorp Supergroup, comprising lavas (possibly the Allanridge Formation).

A ridge parallel to the southern boundary of the site comprises Black Reef quartzites of the Transvaal Supergroup, while the ridge located beyond the northern site boundary comprises quartzites of the Ventersdorp Supergroup (possibly Bothaville Formation?).

6.4.3 Geophysical Surveys

Geophysical surveys conducted at the site of the Balancing Reservoir comprised gravity, conductivity and resistivity surveys, as well as a magnetic survey, and are bound into Annexure C3.

A general feature of the results of the resistivity surveys was the sub-horizontal layering, resulting from horizons of variable resistivity, where a surface resistor is recognised with a thickness in the order of 10 m, underlain by an horizon with a resistivity about one tenth of the surface bed (i.e. a “conductor”), underlain in turn by a basement resistor with a resistivity approximately ten times that of the surface bed. The overall horizontal nature of the resistivity layering is indicative of the weathering. A further feature of the resistivity profiles is the occurrence of dislocations or “steps” in the values, which are taken to indicate possible fault or fracture zones. A number of these anomalies were selected as drilling targets for rotary core drilling (Section 6.4.2 d).

The results from the residual gravity survey reflect a north-easterly trend of alternating gravity “low” and gravity “highs”, which is similar to the geological strike and may be a reflection of the varying properties of the different beds in the volcanic sequence.

6.4.4 Test Pitting (see Annexure C6)

A total of fifteen test pits were excavated on the greater site of the Balancing Reservoir using a light TLB. Test pit details are summarised below in Table 14, while borehole and test pit positions are shown in Figure 15.

Table 14: Balancing Reservoir, (farm Mooivalei 342 KQ Ptn1 Rem and Ptn2); Summarised test pit details

Test Pit no.	Coordinates (WGS84, Lo27)		Remarks
	Y	X (+2 700 000)	
TP01	-30 078	21 372	Refusal at 1,5 m on lava bedrock
TP02	-30 302	21 448	Near-refusal at 2,2 m on densely packed gravels
TP03	-30 331	21 645	Near-refusal at 2,1 m on densely packed gravels

Test Pit no.	Coordinates (WGS84, Lo27)		Remarks
	Y	X (+2 700 000)	
TP04	-30 584	21 560	Near-refusal at 2,4 m on densely packed gravels
TP05	-30 646	21 447	Near-refusal at 1,7 m on densely packed gravels
TP06	-30 567	21 243	Near-refusal at 2,2 m on densely packed gravels
TP07	-30 784	21 313	Near-refusal at 1,5 m on densely packed gravels
TP08	-31 027	21 294	Near-refusal at 1,7 m on densely packed gravels
MV1	-29 706	21 101	No refusal
MV2	-30 079	20 995	No refusal
MV3	-30 167	21 056	Refusal at 1,4 m on calcrete
MV4	-30 329	20 904	Refusal at 1,7 m on calcrete
MV5	-30 084	21 269	Refusal at 1,5 m on calcrete
MV6	-30 418	21 189	Refusal at 1,9 m on calcrete
MV7	-30 511	21 052	Refusal at 1,6 m on calcrete
MV8	-31 066	20 855	Refusal at 1,5 m on calcrete

The test pits reveal the following generalised soil profile (not all horizons are present in all parts of the site):

- A shallow cover of topsoil / hillwash, underlain by
- A horizon of transported sandy soil, on the northern portion of the site, extending towards the eastern portion;
- A pedogenic horizon; and
- A lower horizon of colluvial gravels and cobbles in a sandy matrix, representing talus material, particularly in the area of the southern site boundary.

The respective horizons are described in more detail below.

i) Topsoil / hillwash

The upper topsoil horizon generally varies in thickness between 0,2 and 0,3 m, but occasionally attains a thickness up to 1,2 m. The horizon generally comprises slightly moist, brown to dark brown, loose to dense or medium dense, intact, sandy, clayey silt to silty sand. The horizon contains roots and is therefore organic-rich.

ii) Transported sandy soil

An underlying horizon of transported colluvial sandy soils is present across the site. The horizon thickness varies between 0,4 and 0,8 m, and occasionally as much as 1,7 m. The horizon comprises slightly moist to moist, reddish brown, loose to medium dense to dense, intact, silty sand, occasionally coarse sand or fine gravel. In places termite channels are present leading to a slightly pinholed structure.

iii) Pedogenic horizon

An horizon of ferricrete / manganocrete / calcrete development is recognised, primarily on the northern portion of the site. This horizon is variable; in places the horizon comprises slightly moist, reddish brown mottled black, densely packed manganocrete nodules in a matrix of silty sand, where the overall consistency of the horizon is medium dense, to weakly cemented to cemented calcrete or ferricrete. Where present above the refusal depth, this pedogenic horizon varies in thickness between 0,4 and 1,7 m.

On the northern portion of the site the majority of the test pits recorded refusal on cemented calcrete, at depths varying between 1,4 and 1,7 m.

iv) Transported gravel and cobble horizon

On the southern boundary of the site, effectively on the footslopes of the low ridge which comprises Black Reef quartzites, a lower horizon of colluvial material is present which comprises mixed gravels and cobbles in a silty sand matrix. This horizon is considered to represent colluvial talus material and can be comprehensively described as slightly moist, dark reddish brown, densely packed, angular to sub-rounded gravels and cobbles of mixed origin (quartzite, lava, shale) in a matrix of slightly pinholed, silty sand

The minimum thickness of this horizon varies between 0,5 and 1,9 m, becoming thinner in a northerly direction. In all instances where this material was intersected (test pits TP03 to TP8), the horizon was intersected at the base of the respective test pits, where conditions of near-refusal were recorded and the base of this horizon was not intersected.

6.4.5 Rotary core drilling

A total of eleven rotary core boreholes were drilled at the site of the Balancing Reservoir, with borehole positions indicated on Figure 15. Borehole logs are bound into Annexure C1.1.

Drilling results are summarised below in Table 15.

Table 15: Balancing Reservoir, (farm Mooivalei 342 KQ Ptn1 Rem and Ptn2): Summarised drilling results

Borehole no.	Transported (colluvial) soils (silty clay or sand)	Colluvial gravels / cobbles in sandy matrix	Highly and completely weathered agglomerate comprising sandy matrix and gravels / cobbles, *or* rarely very soft to medium hard rock	Moderately to highly weathered, medium hard or hard rock, occasionally soft rock agglomerate / lava
BH37	0 – 1.5	-	1.5 – 6.2	6.2 – 10.0+
BH38	0 – 1.6	-	1,6 – 10.0+	-
BH39	0 – 0.35	-	0.35 – 1.4	1.4 – 10.08+
BH40	0 – 1.5	-	1.5 – 9.31+	-
BH41		0 – 2.15	2.15 – 10.71+	-
BH42	0 – 0.7	0.7 – 2.0	2.0 – 6.05	6.05 – 9.27+
BH61	0 – 1.5	-	1.5 – 4.15	4.15 – 9.36+
BH62	0 – 0.8	0.8 – 4.7	4.7 – 10.07+	-
BH63	0 – 1.6	-	1.6 – 4.5	4.5 – 10.0+
BH64	0 – 2.2	-	2.2 – 12.0+	
BH65	0 – 0.8	0.8 – 3.35	3.35 – 12.54+	

The entire site is covered by an horizon of fine-grained colluvial soils (hillwash / topsoil), with a thickness varying between 0,35 and 2,2 m. This material generally comprises sandy clay or silty sand.

In places a colluvial horizon is recognised which comprises angular to sub-rounded gravels and cobbles, predominantly of hard rock quartzite, in a silty sand or fine gravel matrix. The colluvial origin of these gravels / cobbles is not readily distinguishable from the underlying completely weathered agglomerate which is commonly recovered as similar gravels and cobbles in a sandy clay matrix.

The horizon of angular to sub-rounded gravels and cobbles consisting of quartzite, chert and lava which is ascribed to completely weathered agglomerate, is recognized across the site. This horizon varies in thickness between 1 m and more than 9,2 m. The base of this horizon was not always intersected and the maximum thickness could therefore not be determined. The gravels and cobbles occur within a matrix of clayey, silty sand, although this matrix is generally not recovered in the drilling process.

Bedrock was generally intersected at depths varying between 1,4 and 6,2 m although a number of boreholes failed to intersect the rockhead before termination of the holes at 10 to 12,5 m. Boreholes where the rockhead was not intersected are located near the southern boundary of the site, with the single exception a borehole near the northern boundary.

The bedrock generally comprises agglomerate but is sporadically identified as lava (i.e. in boreholes BH62 and BH42). The bedrock may be described as moderately to highly weathered, very closely to closely to medium jointed, occasionally widely jointed, orange brown to light brown, medium hard to hard rock occasionally soft rock. In places the rock appears brecciated.

6.4.6 Water level measurements

No water rest levels were recorded in the exploratory boreholes drilled for the investigation of the Balancing Reservoir.

6.4.7 Standard Penetration Test (SPT) results

Standard Penetration Testing (SPT) was conducted in the majority of the boreholes, but as a rule, only a single test was possible due to the gravelly soils. A high percentage of the tests further recorded refusal within these gravel horizons, or within the medium hard rock agglomerate.

SPT results are bound into Annexure C1.3.1 and summarised below in Table16.

Table 16: Balancing Reservoir (farm Mooivalei 342 KQ Ptn1 Rem and Ptn2): Summarised SPT data

Depth of test (m)	BH37	BH38	BH39	BH42	BH61	BH62	BH63	BH64
1,5	N = 38 Sand and gravels	N = 56 Gravels in sand matrix	N = REF Medium hard rock agglomerate	N = 38 Sand and nodules / gravels	N = REF Gravels and cobbles	N = REF Sand / clay with gravels	N = 49 Gravels	N = 19 Silty sand with fine gravels
2,62						N = 50 Sand / clay with gravels		

6.4.8 Laboratory test results

The results of the laboratory tests are bound into Annexure C4 and summarised below. The grading analyses and Atterberg Limits appear in Table 17 and the compaction characteristics (Mods and CBRs) in Table 18.

Table 17: Balancing Reservoir: Summarised grading analyses and Atterberg Limits

Test pit	Depth (m)	Material type	Soil composition				GM	Atterberg Limits			Activity
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)		LL (%)	WPI (%)	LS (%)	
Colluvial sands											
TP1	0,35 – 1,1	Sandy clay	21	21	56	2	0.67	34	17	8.5	1.0

Test pit	Depth (m)	Material type	Soil composition				GM	Atterberg Limits			Activity
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)		LL (%)	WPI (%)	LS (%)	
TP2	0,3 – 1,0	Sandy clay	22	23	52	3	0.69	35	17	9.0	1.0
TP5	0 -0,5	Sandy clay	21	22	55	2	0.66	30	15	7.5	0.9
TP8	0,2 – 0,65	Clayey sand	19	21	55	5	0.8	34	16	8.5	1.1
MV1	0,2 – 2,0	Clayey sand	17	9	73	1	0.83	24	6	3.5	0.5
MV2	0,3 – 1,1	Sandy clay	23	21	53	3	0.68	33	14	7.5	0.8
MV4	0,3 – 1,0	Clayey sand	17	17	61	5	0.8	25	10	6.5	0.8
MV5	0,2 – 1,1	Slightly sandy clay with gravel	15	16	45	24	1.22	29	9	6.5	0.9
MV8	0,2 – 0,6	Sandy gravel	9	12	34	45	1.71	29	7	6.5	1.8
Transported gravel and cobble horizon											
TP2	1 – 1,75	Gravel and clayey sand	11	13	29	47	1.75	37	9	9.5	2.1
TP4	0,3 – 2,4	Gravels with silty sand	3	12	27	58	1.99	26	4	4.5	4.3
MV6	0,6 – 1,7	Sandy gravel	7	7	19	67	2.22	27	4	6.5	2.0
Pedogenic horizon											
TP6	0,7 – 2,0	Sand and gravel	10	11	35	44	1.75	30	7	7.5	1.6
MV1	2,0 – 3,7	Sandy gravel	5	9	34	52	1.96	31	6	6.5	3.2
MV2	1,1 – 1,3	Sandy gravel	11	12	28	49	1.8	43	10	10.5	2.2
MV4	1 – 1,7	Sandy gravel	7	8	23	62	2.1	28	5	6.5	2.1
MV8	0,6 – 1,0	Sandy gravel	8	11	23	58	1.97	30	6	7.0	2.0
Blended sample; colluvial sands and pedogenic horizon											
MV7	0,2 – 1,2	Sandy gravel	11	9	32	48	1.78	30	7	7.0	1.5

Legend
GM = Grading modulus
LL = Liquid Limit
WPI = Weighted Plasticity Index
LS = Linear Shrinkage
Activity = Activity of the soil according to Van der Merwe's method

The values presented in Table 17 may be summarised as follows:

The **colluvial sands** predominantly comprise sand (generally between 50 and 60%) although the clay and silt content is also significant (15 to 23%, and 9 to 23%, respectively). The gravel content is generally less than 5%. The grading modulus (GM) is generally moderate (0,67 to 0,83). Values of the Liquid Limit and the weighted Plasticity Index (WPI) are generally moderate, or moderate to low, respectively. This, together with the moderate clay content (approximately 20%) indicates these upper colluvial materials could exhibit a low or medium potential expansiveness, after van der Merwe (1964).

The **colluvial gravel and cobble horizon** predominantly comprises gravel and sand (47 to 67%, and 19 to 20%, respectively). Clay and silt fractions are relatively minor constituents (3 to 11%, and 7 to 13%, respectively). The GM values are correspondingly very high (1,75 to 2,22). The Liquid Limit (LL) values are moderate (26 to 37%) and the WPI values low to very low (4 to 9%). This, coupled with the low clay content, indicates this horizon of coarse-grained colluvial material has a low potential expansiveness.

The **pedogenic horizon** in the main comprises sandy gravel. The gravel content typically varies between 44 and 62%, while the sand content varies between 23 and 35%. Clay and silt fractions vary between 5 and 11%, and 8 and 12%, respectively. The values for the GM are correspondingly very high and vary between 1,75 and 2,10. The values of the LL are moderate (28 to 43%), while the values for the weighted WPI are low (5 to 10%). Together with the clay content values, these tests indicate this layer has a low potential expansiveness.

Table 18: Balancing Reservoir: Summarised compaction test data

Hole no.	Depth (m)	Material type	OMC (%)	MDD (kg/m^3)	Swell (%)	CBR at various densities (Mod AASHTO)			
						90%	93%	95%	97%
Colluvial sands									
TP1	0,35 – 1,1	Sandy clay	11.1	1983	0.1	15	18	20	22
MV1	0,2 – 2,0	Clayey sand	7.9	2052	0.0	8.2	12	16	22
MV2	0,3 – 1,1	Sandy clay	11.5	1940	0.1	11	18	26	35
MV4	0,3 – 1,0	Sandy clay	10.0	2050	0.1	9.4	13	15	18
MV5	0,2 – 1,1	Slightly sandy clay with gravel	10.6	2020	0.1	7.5	14	21	31
MV8	0,2 – 0,6	Sandy gravel	8.4	2100	0.0	10	16	20	32
Transported gravel and cobble horizon									
TP2	1 – 1,75	Gravel and clayey sand	9.7	2040	0.0	15	25	35	47
TP4	0,3 – 2,4	Gravel with silty sand	7.7	2111	0.0	23	42	62	82
Pedogenic horizon									
MV1	2.0 – 3,7	Sandy gravel	8.3	2096	0.0	11	18	25	35
MV4	1 – 1.7	Sandy gravel	5.3	2334	0.0	25	29	31	34
MV6	0,6 – 2.0	Sandy gravel	6.7	2180	0.0	14	26	39	54
MV8	0.6 - 1	Sandy gravel	9.7	2116	0.1	8.8	9.2	9.5	18

Legend
OMC = Optimum moisture content
MDD = Maximum dry density (Mod. AASHTO)
Swell = Soaked at 100% Mod.AASHTO compaction

The above results (Table 18) may be summarised as follows:

The **colluvial sands** have a high maximum dry density (MDD) and moderate optimum moisture content (omc). The CBR swell values are very low and yielded moderate CBR values at densities typically specified in the field (93 to 95 %). The material classifies as G7 or G8 material according to the TRH 14 guidelines.

The **transported gravel and cobble horizon** has a high MDD and low to moderate omc. The CBR swell values are very low (0%) and the CBR values at densities that are typically specified in the field (93 to 95 %), are high. The material is classified as a G6 or a G4.

The **pedogenic horizon** has a high to very high MDD and low to moderate omc. The CBR swell values are very low (0 to 0,1%). The CBR values at densities that are typically specified in the field (93 to 95 %) are moderate to high, although a single exception is recorded where the values are low. The material classifies as a G6.

6.5 D1649 Dwaalboom Road Crossing (farm Mooivalei 342 KQ Rem Ptn1)

6.5.1 Investigations

The pipeline leading from the Balancing Dam, on the farm Mooivalei 342 KQ Rem Ptn1, crosses the D1649 Road at approximate Ch. 1,800 m (Sub-section 2) (km 7.2).

Two boreholes (BH43 and BH44) have been drilled at the position of this road crossing. Borehole details are reflected earlier in Table 2. The borehole positions as indicated on Figure 8 were initially set out with the use of a handheld GPS but were subsequently accurately surveyed. Figure 16: Dwaalboom Road Crossing (farm Mooivalei 342 KQ Rem Ptn1): Borehole Layout (Drawing no. 2C-G3-201) indicates the borehole layout and also depicts the position of the cross section.

Borehole logs and borehole core photographs are in Annexure C1.

6.5.2 Drilling results

The geological profile comprises upper horizons of transported sand and gravel which overlie hard rock, cemented talus. The thickness of the transported soil varies between 2,85 and 3,0 m, with hard rock talus below these depths. The recemented talus material is variable, in places the material predominantly comprises fine-grained matrix with fine rock fragments and in other places the hard rock talus comprises medium-size, angular gravels of banded ironstone, dolomite and chert in a fine matrix. The geological profile, as intersected in the respective boreholes, is summarised below (Table 19).

Table 19: D1649 Road Crossing (farm Mooivalei 342 KQ Ptn1 Rem): Summarised geological profile (depths in metres)

BH no.	Transported material, comprising silty sand and fine- to medium gravels	Bedrock, generally comprising moderately weathered, hard rock talus
BH43	0 – 2,85	2.85 – 10.49+
BH44	0 – 3,0	3,0 – 10,82+

BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH43	− 31836.168	+ 2720186.396
BH44	− 31859.062	+ 2720175.202

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 C.

LEGEND:

600 REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 BOREHOLE POSITION

REFERENCE DRAWINGS		REVISIONS			
DRG. No.	TITLE	REV No.	DATE	DESCRIPTION	APPR.
		A	20/04/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:250

SCALE: 1:250 0 2,5 5 7,5 10 12,5

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GEOTECHNICAL

D 1649/DWAALBOOM ROAD CROSSING – FARM MOOIVALLEI 342KQ REM PTN1 (BH43 TO BH44)

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2C – G3 – 201	REV No. A

6.5.3 Water Level Measurements

No water rest levels measurements were recorded in the boreholes.

6.5.4 Standard Penetration Testing (SPT) data

Standard Penetration Tests (SPT) were only conducted in borehole BH44. Three tests were carried out, all of which yielded refusal – either on the gravels in a clayey, silty sand matrix or, unsurprisingly, within the horizon comprising moderately to slightly weathered, closely jointed, hard rock talus.

6.6 Break Pressure Reservoir (farm Leeuwbosch 129KQ Ptn1)

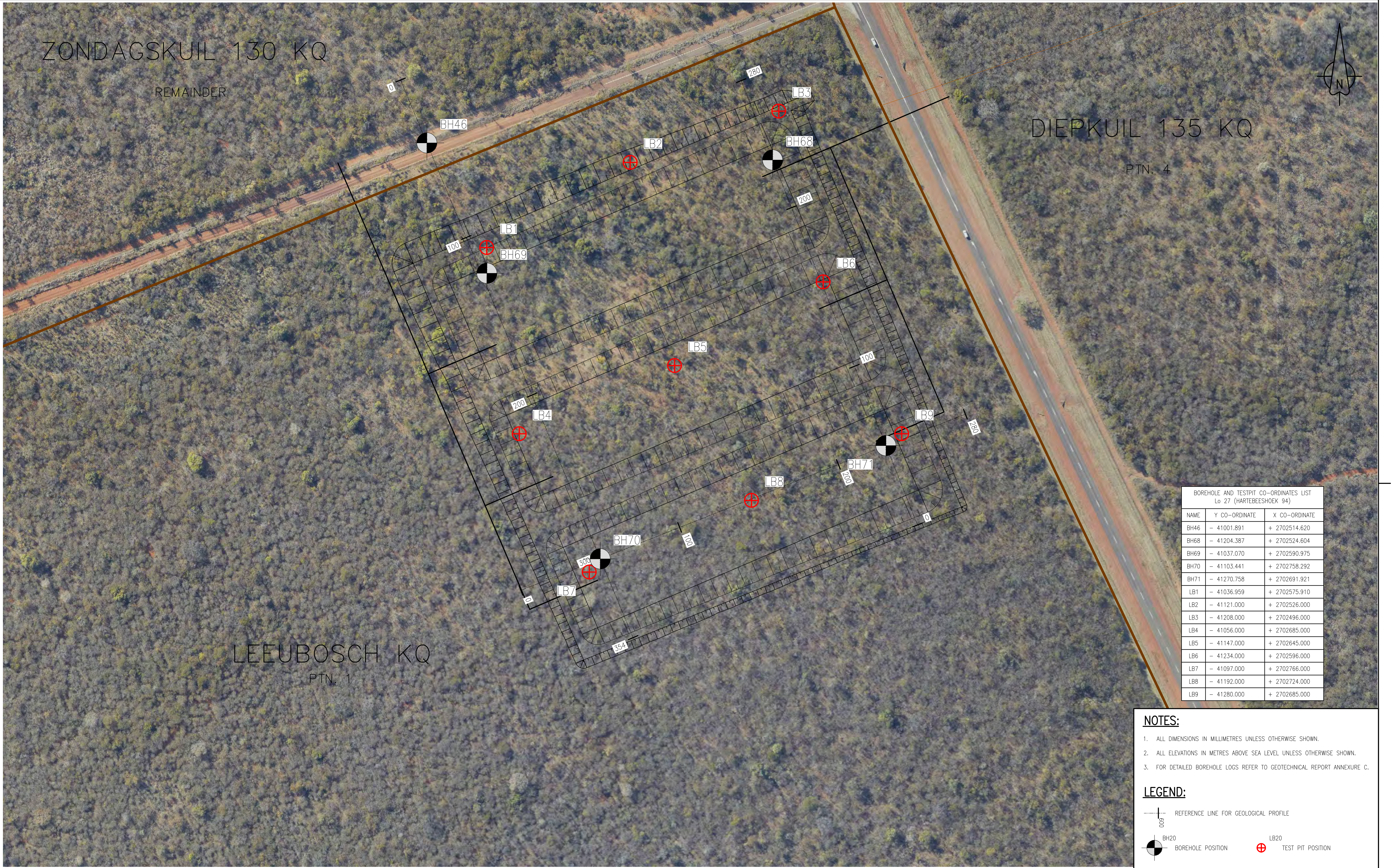
6.6.1 Investigations

An initial appraisal of the proposed site for the Break Pressure Reservoir on farm Zondagskuil 130KQ Rem suggested that the defined site might be underlain by dolomitic rocks. Because of the risks of dolomite-related subsidences, the initial focus of the geotechnical investigations was to confirm the underlying geology. A walk-over survey was conducted on the farm, where scattered outcrop of chert confirmed the likelihood of underlying dolomitic rocks. Initially access was denied for the drilling of boreholes on the farm Zondagskuil 130KQ Rem and, as a compromise, two boreholes (BH45 and BH46) were drilled in the road reserve of the farm access road, along the farm boundary. One of these boreholes indicated dolomite. The decision was subsequently taken to move the site of the Break Pressure Reservoir to the farm Leeuwbosch 129KQ Ptn1, south of the access road.

Four rotary core boreholes, numbered BH68 to BH71, were subsequently drilled at this site after considerable bush-clearing had been conducted. Limited SPTs were conducted in the boreholes. In addition, a total of nine test pits, numbered LB1 to LB9, were excavated at the site. Representative samples were submitted for laboratory testing (see Annexure C5).

The borehole and test pit positions are shown on Figure 17: Break Pressure Reservoir (farm Leeuwbosch KQ Ptn1): Site Investigation Layout (Drawing no. 2D-G3-002).

Borehole and test pit results are summarised below in Table 20 and Table 21, respectively, while detailed logs and core photographs are in Annexure C.



BOREHOLE AND TESTPIT CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
BH46	– 41001.891	+ 2702514.620
BH68	– 41204.387	+ 2702524.604
BH69	– 41037.070	+ 2702590.975
BH70	– 41103.441	+ 2702758.292
BH71	– 41270.758	+ 2702691.921
LB1	– 41036.959	+ 2702575.910
LB2	– 41121.000	+ 2702526.000
LB3	– 41208.000	+ 2702496.000
LB4	– 41056.000	+ 2702685.000
LB5	– 41147.000	+ 2702645.000
LB6	– 41234.000	+ 2702596.000
LB7	– 41097.000	+ 2702766.000
LB8	– 41192.000	+ 2702724.000
LB9	– 41280.000	+ 2702685.000

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 C.

LEGEND:

600 REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 BOREHOLE POSITION

LB20 TEST PIT POSITION

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	21/04/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:2000

SCALE 1 : 2000 0 25 50 75 100

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BREAK PRESSURE RESERVOIR – FARM LEEUBOSCH KQ

SITE INVESTIGATION LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2D – G3 – 002	REV No. A

6.6.2 Geological Map

The published geological map of the area (1:250 000, 2426 Thabazimbi Sheet – Council for Geoscience) indicates the bedrock geology in the area of the Break Pressure Reservoir comprises dolomitic rocks of the Transvaal Supergroup and sandstones of the Waterberg Group which have been intruded by younger diabase sills and dykes.

6.6.3 Geophysical Surveys

The geophysical surveys conducted in the vicinity of the Break Pressure Reservoir comprised a resistivity survey, in order to assist with defining the geological contacts and identify major structural features, and a gravity survey, primarily to identify gravity "lows" and "'highs" for dolomite stability purposes specifically for the pipeline (see Section 6.8).

The results of the resistivity surveys revealed a horizontal structure comprising a conductor overlying resistive basement. Abrupt changes in resistivity may indicate faults and fracture zones or lateral changes in rock type. Extrapolation of these possible geological contacts would appear to confirm the general trend of the contacts, namely in a rough ENE direction.

The results of the geophysical surveys are bound into Annexure C3.5.

6.6.4 Rotary Core Drilling

The boreholes drilled at the Break Pressure Reservoir essentially confirm the sedimentary sequence of sandstones and shales / siltstones (Waterberg Group). One borehole intersected intrusive diabase, while another did not intersect bedrock and is presumably located in a shear zone. Borehole logs appear in Annexure C1.

In addition to the four boreholes drilled on the site of the Break Pressure Reservoir, three boreholes drilled in close proximity to the site are also relevant, namely BH46 drilled in the road reserve and boreholes BH47 and BH48 drilled at the road crossing (Section 6.7).

Table 20: Break Pressure Reservoir (farm Leeuwbosch KQ Ptn1): Summarised drilling results – all depths in metres

BH no.	Transported materials	Residual soils	Bedrock
BH68	0 – 1,5 Clayey sand	1,5 – 3,0 Clayey coarse sand with gravels	3,0 – 10,5+ Interbedded shale and sandstone
BH69	0 – 3,0 Sands and gravels	3,1 – 3,9 Completely weathered horizon of sandy clay	3,9 – 10,5+ Shale to 7,5 m, underlain by diabase
BH70	0 – 7,9 Sandy clay to 1,9 m, then predominantly gravels	7,9 – 12,0+ Predominantly gravels (presumed shear zone)	-
BH71	0 – 1,25 Clayey, silty sand	1,25 – 2,4 Interbedded sandstone / shale (variable hardness)	2,4 – 10,5+ Interbedded shale / sandstone

The various horizons can be described in more detail as follows:

i) Transported soils

The upper horizon of transported soils generally varies in thickness between 1,25 and 3 m, with the exception of a thickness of 7,9 m revealed in borehole BH70. These transported materials vary in composition between clayey, silty sand or sandy clay with various proportions of gravel.

ii) Residual soils

Boreholes BH68 and BH71 drilled on the north-eastern portion of the site intersected an horizon of residual soils derived from the weathering of the underlying sandstone. The horizon comprises clayey, coarse sand with gravels or very soft rock shale. The horizon thickness varies between 0,9 and 1,5 m.

Borehole BH46 drilled in the road reserve on the north-western site boundary also intersected a horizon of residual sand with a thickness of approximately 2 m.

iii) Bedrock

Bedrock was intersected in three of the four boreholes drilled at the site of the Break Pressure Reservoir, at depths varying between 2,4 and 3,9 m. Borehole BH70 drilled in the southern corner of the site did not intersect bedrock within the full depth of the borehole (12 m).

Typically bedrock comprises variably weathered, alternating strata of hard or medium hard rock sandstone and very soft rock to medium hard rock shale. Borehole BH69 intersected very soft rock to soft rock diabase at a depth of 7,5 m beneath weathered shale.

Bedrock was not intersected in the southern portion of the site; the borehole intersected gravels or clayey gravel extending to a depth of 12,0 m, which are considered to represent a possible shear- or fault-zone. A lower sub-horizon is recognised where the gravels comprise predominantly dolomite and chert.

6.6.5 Test Pitting

A total of nine test pits were excavated on the footprint of the proposed Break Pressure Reservoir. The soil profiles are bound into Annexure C5.2 and summarised in Table 21.

Table 21: Break Pressure Reservoir (farm Leeuwbosch KQ Ptn1): Summarised test pit profiles; depths in metres

Test Pit No.	Transported material (fine)	Transported material (coarse)	Pedogenic material	Residual material	Weathered bedrock horizons	Remarks
LB1	0 – 0.2	-	-	-	0,2 – 0,5	Refusal at 0.5 m
LB2	0 – 0.2	-	0.2 – 1.2	-	1.2 – 2.3	Refusal at 2.3 m
LB3	0 – 0.3	0.3 – 0.8	-	-	0.8 – 1.4	Near-refusal at 1,4 m
LB4	0 – 0.2	-	0.2 – 0.9	-	-	Near-refusal at 0.9 m
LB5	0 – 0.2	0.2 – 0.9	0,9+	-	-	Refusal at 0.9 m
LB6	0 – 0.1	0.1 – 1.0	1.0 – 1.6	-	-	Near-refusal at 1.6 m
LB7	0 – 1.0	-	1,0 – 1,6	-	-	Near refusal at 1.6 m
LB8	0 – 0.1	0.1 – 0.5	-	-	0.5 – 0.9	Near-refusal at 0.9 m
LB9	0 – 0.2	0.2 – 1.2	-	-	1.2 – 1.9	Near-refusal at 1.9 m

The site is covered by a thin upper horizon of **topsoil** comprising loose, silty to gravelly sand. The horizon varies between 0,1 and 0,3 m thick.

On the eastern half of the site the topsoil layer is underlain by an horizon of **coarser-grained colluvium** comprising loose to medium dense, silty, sandy gravel. The horizon varies in thickness between 0,4 and 1,0 m. This horizon may be ferruginised in places.

An horizon of **pedogenic material, comprising ferricrete** is present over the greater portion of the reservoir site. The horizon is described as comprising cemented to strongly cemented ferricrete and refusal of the TLB occurred on it. Where present the horizon varies in thickness between 0,6 m and a minimum of 1,0 m.

Test pits excavated on the northern and southern areas of the site revealed a lower horizon of weathered**, very soft to soft rock sandstone bedrock**.

6.6.6 Laboratory Test Data

Selected soil samples from the test pits were submitted for laboratory testing. Test data is presented in Annexure C4 and summarised in Tables 22 and 23.

Table 22: Break Pressure Reservoir: (farm Leeuwbosch KQ Ptn1): Summarised grading analyses and Atterberg Limits

TP	Depth (m)	Material type	Soil composition				GM	Atterberg Limits			Activity
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)		LL (%)	WPI (%)	LS (%)	
Fine-grained colluvial material (topsoil)											
LB7	0.2 – 1.0	Clayey sand ("slightly clayey silty sand")	26	19	51	4	0.74	33	13	8.5	0.7
Coarse-grained colluvium											
LB5	0.2 – 0.9	Silty, sandy gravel	2	5	31	62	2.24	19	2	2..5	3.0
LB9	0.2 – 1.2	Sandy gravel	5	8	31	56	2.06	23	3	4..5	1.8
Pedogenic horizon											
LB2	0.2 – 1.2	Sandy gravel ("weakly cemented ferricrete")	4	6	31	59	2.18	20	2	4.0	2.3
LB4	02. – 0.9	Sandy gravel ("cemented to strongly cemented ferricrete")	5	5	27	63	2.22	30	3	6.0	2.6
Weathered bedrock horizon											
LB9	1.2 – 1.9	Sandy gravel	5	7	31	57	2.08	24	3	5.0	2.0
LB2	1.2 – 2.3	Sandy gravel	11	10	26	53	1.88	52	9	9.5	2.3

Legend
TP + Test pit
GM = Grading modulus
LL = Liquid Limit
WPI = Weighted Plasticity Index
LS = Linear Shrinkage
Activity = Activity of the soil according to Van der Merwe's method

The **fine-grained topsoil horizon** comprises clayey sand with 26% clay content and 51% sand fraction. The silt fraction comprises 19%, while the gravel fraction is a negligible 4%. The GM is a moderate 0,74. The WPI is a moderate 13% and together with the 26% clay fraction, indicates an horizon with a potential medium expansiveness according to Van der Merwe (1964).

The **coarser-grained colluvial horizon** predominantly comprises sandy gravel, with a gravel content between 56 and 62% and a sand content of 31%. The clay and silt fractions are minor constituents, varying between 2 and 5%, and 5 and 8%, respectively. The GM values are very high and vary between 2,06 and 2,24. The Whole PI values are very low at 2 to 3% and, considering the very low clay fraction, this indicates a very low potential expansiveness according to van der Merwe, 1964.

The material from the **ferricrete (pedogenic) horizon** is very similar to the overlying coarse-grained colluvial material. The horizon comprises sandy gravel, with a gravel content between 59 and 63% and a sand content between 27 and 31%. The clay and silt fractions are minor constituents, varying between 4 and 5%, and 5 and 6%, respectively. The GM values are very high and vary between 2,18 and 2,22. The WPI values are very low at 2 to 3% and, considering the very low clay fraction, this indicates a very low potential expansiveness according to van der Merwe, 1964.

The samples of **weathered sandstone bedrock** comprise clayey, sandy gravel. The gravel content varies between 53 and 57%, while the sand content varies between 26 and 31%. The clay content is 5 to 11%, while the silt content is 7 to 10%. The GM is very high (1,88 to 2,08). The WPI is very low to low (3 to 9%) and, together with the clay content of 5 to 11%, indicates a low potential expansiveness according to van der Merwe, 1964.

Table 23: Break Pressure Reservoir: Summarised compaction data

TP	Depth (m)	Material type	omc (%)	MODD (kg/m^3)	Swell (%)	CBR at various densities (Mod AASHTO)			
						90%	93%	95%	97%
Fine-grained colluvial material (topsoil)									
LB7	0.2 – 1.0	Sandy clay (“slightly clayey silty sand”)	12.4	1920	0.1	4.1	6.6	9.1	13
Coarse-grained colluvium									
LB5	0.2 – 0.9	Silty, sandy gravel	6.4	2271	0.0	28	50	72	109
LB9	0.2 – 1.2	Sandy gravel	6.9	2250	0.0	8.7	17	27	42
Pedogenic horizon									
LB2	0.2 – 1.2	Sandy gravel (“weakly cemented ferricrete”)	6.4	2286	0.0	9.0	19	30	46
LB4	02. – 0.9	Sandy gravel (“cemented to strongly cemented ferricrete”)	7.5	2160	0.0	10	20	32	51
Weathered bedrock horizon									
LB9	1.2 – 1.9	Sandy gravel	7.7	2220	0.0	7.0	15	25	41
LB2	1.2 – 2.3	Sandy gravel	9.7	2104	0.1	6.6	8.2	9.5	12

Legend
omc = Optimum moisture content
MDD = Maximum dry density (Mod.AASHTO)
Swell = Soaked at 100% Mod AASHTO compaction

The **fine-grained colluvial material (topsoil)** has a moderate maximum dry density (MDD) and high optimum moisture (omc) content. The CBR swell values are very low and the material yielded low CBR values at densities typically specified in the field (93 to 95%). The material classifies as a G10 material according to the TRH 14 guidelines.

The **coarse-grained colluvial material** has a very high MDD and low omc. The CBR swell values are very low and the sandy gravel yielded moderate to very high CBR values at densities typically specified in the field (93 to 95%). The variable material classifies as a G7 or G4.

The **pedogenic horizon** has a very high MDD and low omc. The CBR swell values are very low and the sandy gravel yielded moderate to high CBR values at densities typically specified in the field (93 to 95%). The material classifies as a G6.

The samples of **weathered rock material,** recovered as sandy gravel**,** have a high or very high MDD and low to moderate omc. The CBR swell values are very low and the sandy gravel yielded low to moderate CBR values at densities typically specified in the field (93 to 95%). The material classifies as a G6 or G9.

6.6.7 Water Level Measurements

No water levels were measured in the boreholes drilled on the footprint of the reservoir. However, levels were recorded nearby in the two boreholes drilled at the site of the R510 road crossing (boreholes BH47 and BH48), at respective depths of 2,4 and 2,7 m. Further north a water rest level was recorded in borehole BH45 at a depth of 7,75 m, i.e. 6,65 m beneath dolomite bedrock rockhead.

It must be noted that water is used during the drilling process and although time is allowed after drilling for the water table to stabilise before measurement, it is possible that the time is insufficient and that measured water rest levels are not a true reflection of the water table.

No seepage was noted in any of the test pits, dug to a maximum depth of 1.9 m.

6.6.8 Standard Penetration Test (SPT) results

Limited SPT testing was carried out in the four boreholes drilled on the reservoir footprint, but it must be noted that all horizons tested comprised gravels to varying degrees and the results are therefore questionable. Results are bound into Annexure C1.3.1 and summarised below in Table 24.

Table 24: Break Pressure Reservoir (farms Zondagskuil 130KQ Rem and Leeuwbosch 129KQ Ptn1), Summarised SPT N-values

Depth (m)	BH68	BH69	BH70	BH71
1,5	N = REF (clayey, coarse sand with abundant gravels)	N = 25 (clayey, sandy gravel)	N = REF (sandy clay with abundant gravels)	N = 47 (very soft rock shale)
3,0			N = 25 (gravels in matrix of sand)	

6.7 R510 Road Crossing at Ch 0,100 m (farm Diepkuil 135KQ)

6.7.1 Investigations

On farm Diepkuil 135 KQ, the pipeline crosses the R510 road. Two core boreholes, numbered BH47 and BH48, were drilled on the respective road shoulders to investigate the geological profile. Detailed borehole logs are included in Annexure C1, and the results are summarised below (Table 25).

It must be noted that, subsequent to drilling of the boreholes on the farms Zondagskuil 130KQ and Diepkuil 135KQ, the position of the Break Pressure Reservoir was changed. The final crossing position is thus approximately 100 m south of the original position where the boreholes were drilled.

The borehole positions are shown in Figure 18, which shows the testing positions for the Break Pressure Reservoir.

BOREHOLE CO-ORDINATES LIST
Lo 27 (HARTEBEESHOEK 94)

NAME	Y CO-ORDINATE	X CO-ORDINATE
BH47	− 41227.453	+ 2702414.188
BH48	− 41257.303	+ 2702399.661

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 C.

LEGEND:

600 REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 BOREHOLE POSITION

REFERENCE DRAWINGS	
DRG. No.	TITLE

REVISIONS			
REV No.	DATE	DESCRIPTION	APPR.
A	20/04/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:250

SCALE: 1:250 0 2,5 5 7,5 10 12,5

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GEOTECHNICAL

R510 ROAD CRORSSING – FARM DIEPKUIL 135KQ (BH47 TO BH48)

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2E – G3 – 201	REV No. B

Table 25: R510 Road Crossing at Ch 0,100 m (farm Diepkuil 135 KQ): summarised drilling results (depths in metres)

BH no.	Transported sands with gravels	Residual sands with gravels	Bedrock
BH47	0 – 0.6	0.6 – 2.0	2.0 – 10.64+ Alternating sandstone and shale; very soft rock to medium hard rock
BH48	0 – 2.55	-	2.55 – 10.37+ Alternating sandstone and shale; soft rock to medium hard rock

6.7.2 Drilling Results

An upper horizon of silty to clayey sand covers the site, with variable amounts of fine gravels. The horizon thickness varies between 2 and 2,55 m.

The rockhead is intersected at depths between 2,0 and 2,55 m in the boreholes.

Bedrock comprises alternating horizons of sandstone and shale or siltstone. For the most part the sandstone is highly to moderately weathered and comprises soft to medium hard rock. An upper bedrock horizon is recognised in borehole BH47 which is described as highly to completely weathered sandstone and comprises very soft rock sandstone. Localised zones (thickness 150 mm) of hard rock sandstone also occur within the succession. The interbedded shale or siltstone horizons typically comprise soft rock. These shale horizons are of variable thickness; either narrow bands 100 to 300 mm in thickness or horizons between 850 and 2300 mm.

6.7.3 Water Level Measurements

Water levels were measured in both boreholes after completion. These water rest levels are summarised below in Table 26.

It must be noted that water is used during the drilling process and, although time is allowed after drilling for the water table to stabilise before measurement, it is possible that the time is insufficient and that measured water rest levels are not a true reflection of the water table.

Table 26: R510 Road Crossing Ch 0,100 m (farm Diepkuil 135 KQ): Water level measurements

Borehole number	Water rest level (June 2010); depths in metres below surface
BH47	2,4
BH48	2,7

No seepage was encountered in any of the test pits dug (to a maximum of 1.9 m) at the adjacent Break Pressure Reservoir site.

6.7.4 SPT Results

Only a single SPT was conducted. The test was conducted in borehole BH48 within the upper horizon of colluvial hillwash, comprising clayey sand with abundant fine gravels, and yielded an SPT N-value of 26.

6.8 Pipeline at Ch 0,100 to 2,300 m (farms Diepkuil 135 KQ and Tarentaalpan 132 KQ)

The published geological maps indicate that the pipeline traverses dolomitic rocks of the Malmani Subgroup to the north and west of the Break Pressure Reservoir. In view of the potential risks associated with dolomite-related subsidences, additional dolomite-stability investigations were conducted in this area with the aim of understanding the ground conditions to be traversed.

Investigation of the pipeline alignment to the north of the Break Pressure Reservoir comprised a single-traverse gravity survey followed by drilling of two (2 no.) percussion boreholes, numbered PBHP06 and PBHP07, at positions where gravity anomalies were identified.

The gravity survey results and the drilling results are included in Annexure C3.4, while the summarised drilling results are presented below in Table 27. Borehole positions are shown in Figure 19: Pipeline at Ch. 1,350 to 2,150 m (farms Diepkuil 135 KQ and Tarentaalpan 132 KQ): dolomite stability investigation layout (Drawing no. 2E-G3-206).

N

BOREHOLE CO-ORDINATES LIST Lo 27 (HARTEBEESHOEK 94)		
NAME	Y CO-ORDINATE	X CO-ORDINATE
PBH P6	– 40860.628	+ 2701338.997
PBH P7	– 40668.141	+ 2700560.210

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 C.

LEGEND:

600 REFERENCE LINE FOR GEOLOGICAL PROFILE

BH20 BOREHOLE POSITION

REFERENCE DRAWINGS

DRG. No.	TITLE

REVISIONS

REV No.	DATE	DESCRIPTION	APPR.
A	21/04/11	FOR INFORMATION	PLR

DESIGNED:	G DAVIS	PROJECT ENGINEER:	P LE ROUX
DRAWN:	D VAN COLLER	TCTA:	
CHECKED:	G DAVIS		
CHIEF DESIGNER:	G DAVIS	SCALE:	1:5000

SCALE 1 : 5000

0 25 50 100 150 200 250

MOKOLO CROCODILE Consultants

TCTA A new word for water

MOKOLO CROCODILE WATER AUGMENTATION PROJECT (MCWAP)

GEOTECHNICAL

PIPELINE AT CH 1350 TO CH 2150 – FARM DIEPKUIL 135KQ

BOREHOLE LAYOUT

A3	DWAF DRG. No.	DRAWING NUMBER	2E – G3 – 206	REV No. A

Table 27: Pipeline at Ch. 0,100 to 2,300 m (farms Diepkuil 135 KQ and Tarentaalpan 132 KQ): Summarised drilling results; depths in metres

BH no.	Transported material	Residual soils	Bedrock
PBHP06	0 – 2.0 Gravels with clayey sand	2.0 – 5.0 Dolerite gravels with clayey sand	5.0 – 18+ Weathered dolerite/diabase
PBHP07	0 – 1.0 Sandy clay	1.0 – 13.0 Clayey silty sand	13 – 30+ Weathered dolerite/diabase (13 – 20 m); weathered granite from 20 m

The gravity survey indicate a prominent gravity “high” between approximate Ch. 1,200 and 1,700 m and a prominent gravity “low” between Ch. 0,200 and 0,900 m. Boreholes PBHP06 and PBHP07 were drilled at positions corresponding to these respective “high” and “low” anomalies.

Neither of the two boreholes intersected dolomite.

The two boreholes reveal a thin cover (1 to 2 m thick) of transported soils comprising sandy clay or gravels with clayey sand. This is underlain by a weathered horizon comprising clayey, silty sand or clayey sand. Gravels may be present. This last-mentioned horizon either represents residual dolerite (with / without corestones) or possibly an extension of the upper colluvial layer.

Bedrock was intersected at 5 and 13 m respectively. Bedrock in borehole OBH06 comprises weathered dolerite. Borehole PBHP07 intersects weathered granite at a depth of 20 m.

6.9 Centreline Investigation (see Annexure A)

6.9.1 Test Pitting

Test pits were excavated at a nominal spacing of 200 m along the pipeline. Locations where excavation was not possible, due to rock outcrop or inaccessible areas, were recorded and are shown on Drawings 2C-G6-001 to 024 and 2E-G7-001 to 006 included in Annexure E in Volume 2.4. The test pit profiles are given in Annexure A2 together with photographs of the test pits.

Pits were excavated using a TLB (New Holland B90B) and profiled by a geospecialist in accordance with the standards given in the Geoterminology Workshop 1990 (Brink and Bruin, 2002). The terms used are defined in Annexure A6. Dynamic Penetrometer Light (DPL or DCP) 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 A1. Graphical representations of the excavation depth for each test pit are included as Figures 20 and 21. No test pitting has been carried out on the approximately 2 km section of centreline (about km 19 to km 21) where this crosses the Remainder of Paarl 124KQ as access was not permitted to this property.

6.9.2 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 4). The depth to refusal for each test pit is summarised in Annexure A1 and is shown on the profiles bound into Annexure A2. In certain areas where extensive outcrop occurs, no test pits were dug. The extent of such areas is shown on Drawings 2E-G7-001 to 004 and 1D-G7-001 to 026 included in Annexure E in Volume 2.4.
Access was denied to parts of the farm Paarl 124KQ (approximately km 18.6 to 21) and thus no test pits could be dug here.

6.9.3 Observed Groundwater Levels

No groundwater seepage was encountered in any of the test pits. Areas where hydrophilic vegetation was observed are shown in Drawings 2C-G7-001 to 024 and 2E-G7-001 to 006, included in Annexure E.

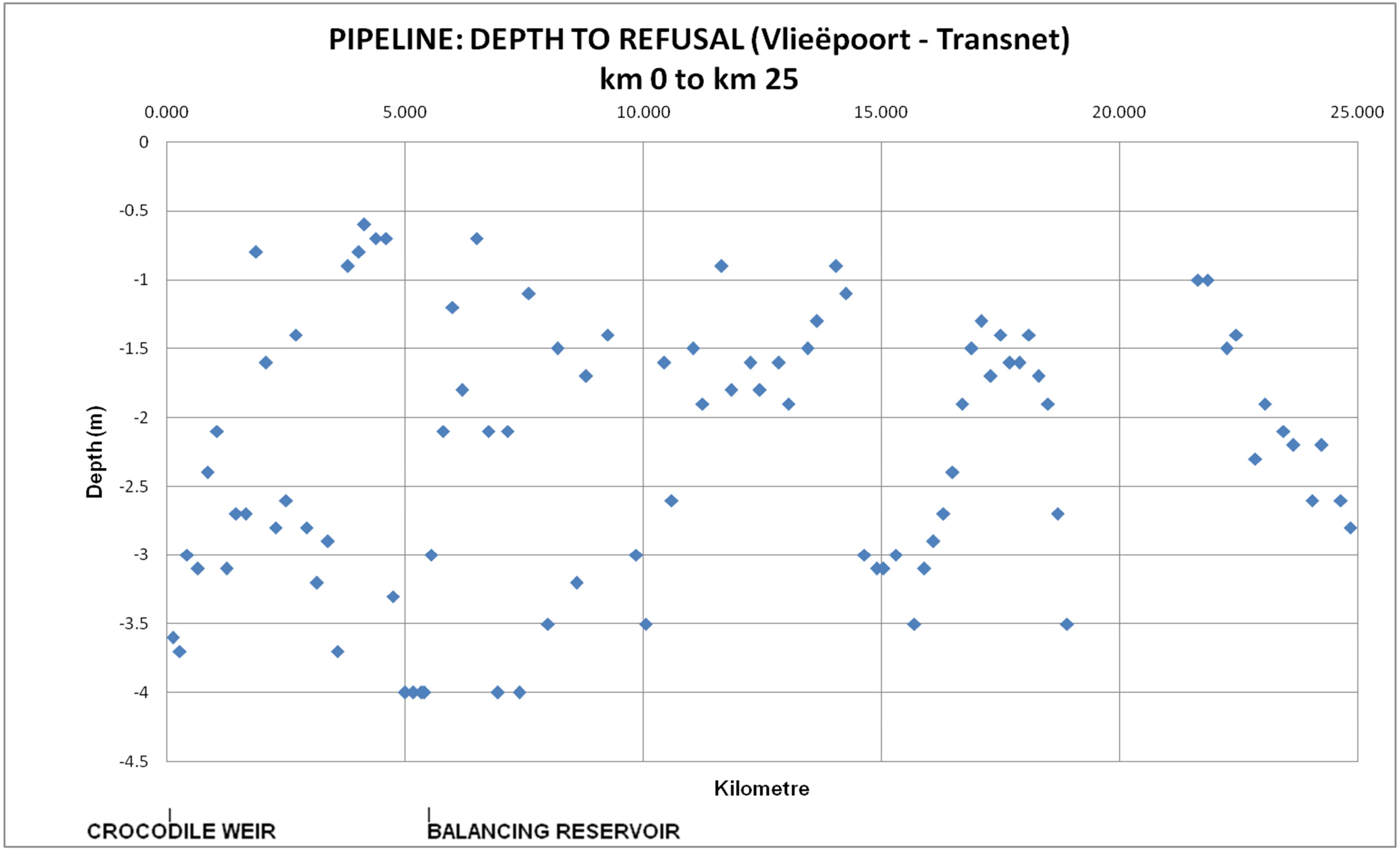

Figure 20: Summary of refusal depths – Vlieëpoort weir to Tarantaalpan (km 0 to km 25)

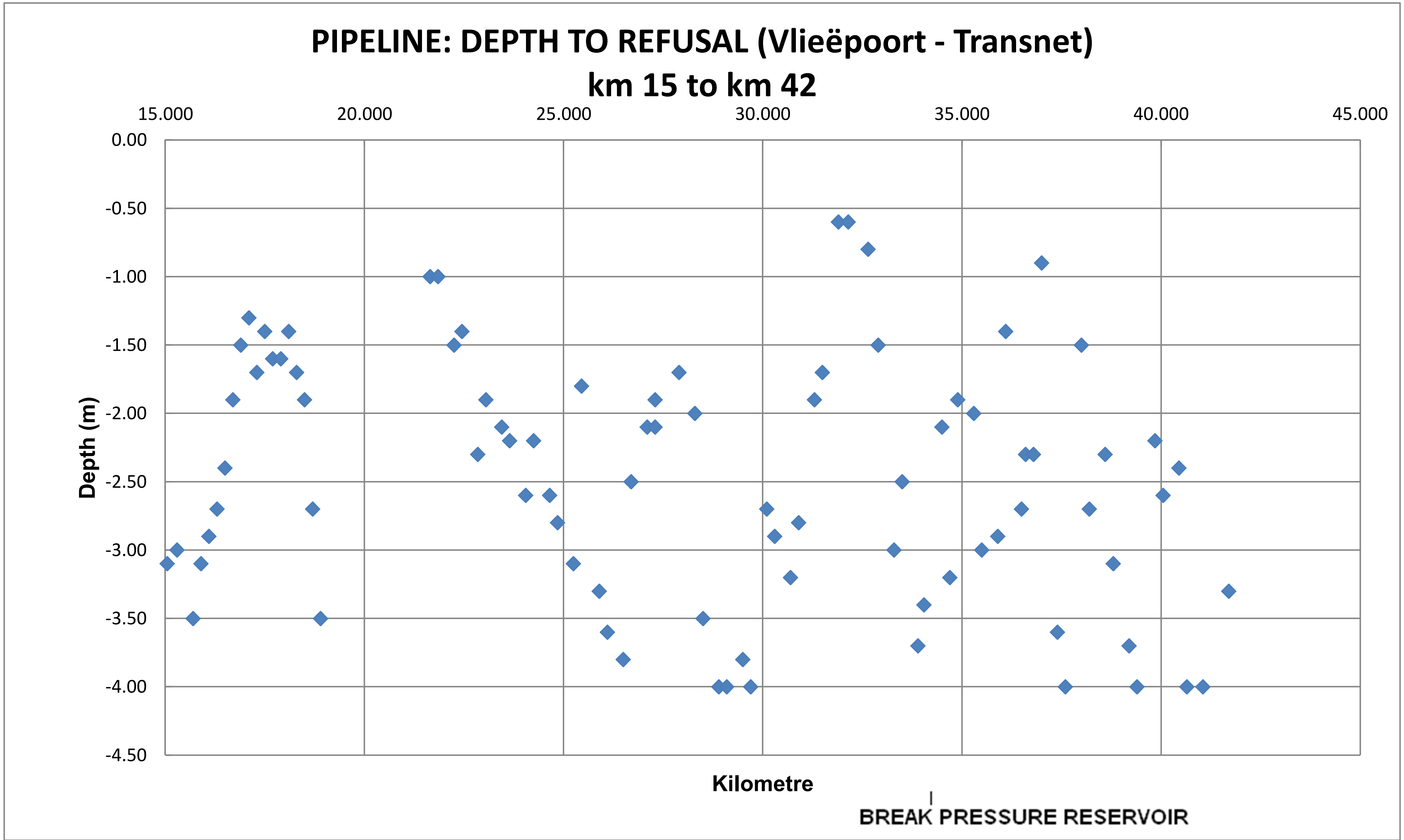

Figure 21: Summary of refusal depths – Vlieëpoort weir to Tarantaalpan (km 15 to km 42)

The sides of the majority of pits were stable with vertical sides. This is based on an assessment of test pits of limited length and which stood open for about 20 minutes.

The DCP soundings are shown as equivalent SPT N-values (blows per 300 mm) and are shown graphically as N-value versus depth on the soil profiles. The pits terminated on a variety of materials (ferricrete, talus, sandstone, granite). The TLB used was able to excavate into weathered and less cemented pedogenics, but refused on unweathered rock or cemented pedogenic material, where encountered.

6.9.4 pH and Conductivity

The pH and conductivity of the soils present was measured in laboratory tests and these indicate that the pH ranges from 4.36 to 8.00 and the conductivity from 0,006 to 0.111 S/cm. The results of laboratory tests are shown in Annexure A3.

6.10 Borrow Materials (see Annexure B): Bedding and granular material

6.10.1 Borrow Sources

In order to provide suitable bedding and selected backfill material, an investigation of potential borrow sources was undertaken. It was intended to locate borrow pits 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 B, and include locality plans, test pit profiles and results of laboratory testing, and are summarised hereunder in Table 28: Potential borrow sources and borrow pit plans are presented in Annexure D in Volume 2.4.

Table 28: Potential borrow sources

BP no.	Location (WGS84 Lo27)		Est. volume material (m^3)	CF# (range)	Offset to pipeline (m)	Reference		Suitability@
	Y	X				Chainage	km	
SS1	-31 956	2 725 427	8,000	0.20/0.30	120 L+	0 (sub-section 1)	0	1
25	-27 740	2 713 313	>250,000	0.36/0.48	50 L	9,500 (sub-section 2)	14.9	2
30	-34 122	2 706 490	>150,000	0.30/0.42	60 R	20,800(Sub-section 2)	30.6	2
35	-38 204	2 703 766	65,000	0.32/0.40	80 R	25,200(sub-section 2)	36.2	3

L = Left of pipeline R= Right of pipeline

+ = On West/left bank of Crocodile River # = Compactability Factor

(Sub section 1) = Weir to Balancing Reservoir

(Sub-section 2) = Balancing to Break Pressure Reservoirs

@Suitability" 1 = For all applications 2 = Selected fill blanket only 3 = Unsuitable

Borrow pit plans are presented in Annexure D in Volume 2.3.

Test pits were dug at a nominal 30 m spacing at the borrow pits in order to prove volume.

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 B3. It must be noted that the test pits were generally positioned to avoid large trees.

The results of the compactability tests undertaken on samples recovered from certain borrow pits are given in Annexure B2.1. The criteria used for this classification are given in Table 5: Suitability of granular backfill material. Of the samples analysed the compactability factor ranges from 0.20 to 0.48, with most being in excess of 0.4 (i.e. usable for bedding in terms of Table 5).

The borrow pits are commented on individually as follows.

a) BP SS1. This source in located on the western side of the channel of the Crocodile River, just downstream of the Vlieëpoort Weir site (on the farm Hannover 341KQ). It was accessed from a gate on the gravel D676 road (which parallels the river on its western side), via a 1000 m long track used to access the weir site. At the time of sampling, the top of the sandbank was about 500 mm above river level, making estimation of the volume of material present difficult. DCP probes appear to confirm that the sand is at least 1.5 m thick and that more than 8,000 m^3 of material is present. The material is an alluvial, fine gravel/sand classifying generally as an A1-b/A2-4, but with some A3 (fine sand/silt) present. The GM of the material varies between 1.3 and 2.0 and its Compactability Factor (CF) ranges from 0.20 to 0.30. In terms of Bedding Material Type (BMT) it falls into the SC2 class.
b) BP 25. This triangular-shaped source is located between an Eskom powerline and the southern and western boundaries of the farm Mecklenburg 310KQ. The gravel D769 (Rooibokkraal) road follows the south-western boundary of the source. The site is covered by trees and grass and it is estimated that there is in excess of 250,000 m^3 of material present and is up to 3,500 mm thick. Ferricrete and calcrete gravel occurs beneath the sand. The material is a clayey sand, generally classifying as an A2-6 or A6, with PI between 7 and 14, but averaging about 10. The GM is generally about 1.1 and CF varies from 0.36 to 0.48, but averaging in excess of 0.4. In terms of BMT it falls, on average, into the SC3 class.
c) BP 30. This source is located on the southern side of the private gravel road leading from the R510 (Thabazimbi – Lephalale) on the farm Karoobult 126KQ. It is located immediately south of a landing strip which parallels the access road and farm boundary between Karoobult to the south and Buffelsvley to the north. The site is covered by fairly sparse bush and grass. The material is a clayey sand, generally classifying as an A2-6 or A6, but with A2-4 and A1-b material present. Plasticity ranges from non-plastic (NP) to 14. The GM ranges from 1 to 1.5 and the CF varies from 0.30 to 0.42. In terms of BMT it classifies as an SC2 to SC3/4. The volume of material present is estimated at 150,000 m^3. Calcrete gravel occurs below the sand.
d) BP 35. This source is also located on the southern side of the private gravel road as BP30, but is only about 3.5 km from the R510 (Thabazimbi – Lephalale) T-junction, on Portion 1 of the farm Leeuwbosch 129KQ. The site is covered by fairly

thick bush and grass. The material is a fine, clayey sand, generally classifying as an A6, with PI generally of the order of 11 or more. The GM ranges from 0.8 to 1.3 and the CF varies from 0.32 to 0.40. In terms of BMT it classifies as an SC3/4. There is an estimated 65,000 m^3 of material present. Ferricrete gravel occurs below the sand.

6.10.2 Gravel for Haul and Access Roads

No specific sources of gravel for use on haul and access roads have been identified. In most cases gravel occurs below the bedding sand and it is assumed that these gravels will be utilised once the sand has been extracted. The results of the testing on these gravels are given in Annexure B. The sources identified are summarised in Table 29.

Table 29: Gravel borrow sources

BP no.	Location (WGS84 Lo27)		Gravel (m^3)	Offset to pipeline (m)	km	Comments
	Y	X				
SS1	-31 956	2 725 427	0	120 L^+	0	In river bed
25	-27 740	2 713 313	>30,000	50 L	14.9	Ferricrete, calcrete
30	-34 122	2 706 490	>20,000	60 R	30.6	Calcrete
35	-38 204	2 703 766	>20,000	80 R	36.2	Ferricrete

6.10.3 Commercial Sources of Construction Materials

The nearest known commercial sources of stone and sand aggregate for concrete are in the vicinity of Lephalale and Thabazimbi.

These are discussed separately:

- Thabazimbi area

  Stone is crushed commercially to produce crushed stone and crusher sand at mines south and east of Thabazimbi. It is reported that “calcite” and “hornfels quartzite” is crushed at Swartklip and Leeupoort respectively. Details of the suppliers and results of laboratory testing of the material are included in Annexure B2.6. Haul distance from to Thabazimbi, are about 82 km from Swartklip and about 65 km from Leeupoort.

- Lephalale area

  The stone aggregate comprises two distinct materials; well-rounded alluvial gravels and crushed sandstone. Sand is dredged from nearby river courses, and is usually suitable for use as bedding and soft backfill material. Details of the suppliers and results of laboratory testing of the material have been provided in the Stage 1 report and are not repeated. Haul distance from Lephalale to Thabazimbi is approximately 120 km.

6.10.4 Chemical Analyses

The chemical analyses show that the pH of the soils tested from borrow pits ranges from 5.10 to 8.75 and the conductivity from 0.004 to 0.033 S/m. The results are given in Annexure B2.1.

6.11 Spoil Sites

In addition to the potential borrow sources discussed in Section 6.6.1, potential spoil sites (old borrow sites (BP) from construction of the railway line and roads) were identified. These are listed in Table 30. Their positions are shown in Figure 1.

Table 30: Potential Spoil Sites

Site no.	Co-ordinates (WGS84, Lo27)		Approx. km distance	Estimated volume (m^3)	Comments
	Y	X			
A	-031 600	2 719 400	8	30,000	Old BP
B	-041 150	2 702 400	34.3	20,000	Old BP
C	-040 650	2 699 850	36.6	30,000	Old BP (1km north along R510)
D	-045 491	2 698 008	19,8	40,000	Old BP

It must be noted that negotiations regarding their use as spoil sites have not yet been initiated with the owners of these sites. An EIA process must also be undertaken to define the rehabilitation measures to be followed.

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 routes, and at a nominal spacing of 30 m at borrow pit locations.

Borrow pits were targeted at an economic spacing of 5 km and 100,000 m^3 per source, assuming a 2,000 mm pipe diameter and corresponding trench dimensions to provide granular material for bedding and backfill to the pipeline. In the vicinity of the Weir and Balancing Reservoir soils are clayey and no borrow sources could be located here. In an effort to source suitable material, a sandbank in the Crocodile River just downstream of the Weir was sampled. This has yielded approximately 8,000 m^3.

In many areas, no access to prospect for borrow materials was permitted by landowners. This limited the areas where suitable material could be sought. BPs 25, 30 and 35 have all yielded material of marginal quality. The four sources sampled have resulted in the following spacing between borrow pits: Weir (BPSS1) to BP25 is 14.9 km, BP25 to BP30 is 15.7 km, BP30 to BP35 is 5.6 km, BP35 to BP33 (southernmost BP on Stage 1) is 23.7 km.

Rotary core and percussion drilling was carried out at various sites to investigate specific foundation conditions. Geophysical surveys (magnetic, resistivity and gravimetric) were performed at certain of these sites to assist in positioning boreholes and to locate geological features (faults, contacts, bedrock depths, etc).

Vlieëpoort Weir is underlain by banded ironstone formation with thick alluvium (11 to 13 m on average, but as thick as 39.5 m in the centre of the floodplain).

At the pipeline crossing of Road D1649 (Thabazimbi - Dwaalboom), sand and gravel about 3 m thick overlies cemented talus.

At the pipeline crossing of Road R510 (Thabazimbi – Lephalale road), sand and gravel is present to about 2.5 m depth, overlying sandstone and shale.

At the Balancing Reservoir, the typical profile is 0 to 2 m soils (silty clay, clay) classifying as G7/G8, overlying very soft to hard rock sandstone and shale; 2 - 3 m gravels and cobbles classifying as G4/G6; 3 – 9 m weathered agglomerate (lava) classifying as G6, overlying soft to hard rock agglomerate lava.

At the Break Pressure Reservoir the typical profile is 0 to 2 m soils (sand, gravel and clay) classifying as G10, overlying very soft to hard rock sandstone and shale and diabase. One borehole encountered gravel to its full depth of 12 m.

In places the pipeline route is underlain by dolomitic rocks of the Malmani Subgroup. In these areas, a gravimetric survey was carried out to provide a profile of the bedrock topography and was followed by percussion drilling at identified gravity “highs” and “lows”.

On the section of pipeline between the Weir and the Balancing Reservoir the colluvium was found to be more than 40 m thick, with dolomite bedrock being found elsewhere at between 13 and 25 m depth. In the vicinity of the Break Pressure Reservoir, the route was also thought to be underlain by dolomite. Drilling however encountered only diabase and granite.

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

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