Report to ARCUS GIBB on a Preliminary Geotechnical Comparison of Supplementary Alternative Routes for the Proposed 132 kV Westgate-Tarlton-Kromdraai TPL and Substations for EIA and Scoping Purposes

Reference : 07-776/2

Date : 22 September 2008

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1. INTRODUCTION AND SCOPE OF REPORT

At the request of Kasantha Moodley of ARCUS GIBB, Moore Spence Jones (Pty) Ltd (MSJ) were requested to provide a preliminary geotechnical comparison of supplementary corridors in addition to the original six separate alternative routes for the proposed 132 kV transmission powerline connecting Westgate, Tarlton and Kromdraai in Gauteng Province, for EIA and scoping purposes. A new substation has been proposed at the afore-mentioned Kromdraai site and has also required investigation in terms of geotechnical conditions and constraints at a preliminary level. MSJ provided a cost estimate for the work in a fax dated 14 May 2007 and referenced 07-776.01 and were appointed in a sub-consultant's contract dated 26 November 2007.

The purpose of this preliminary geotechnical assessment is to provide the following information:

- The general engineering and geological suitability along each of the proposed alternative corridors in the study area, with an indication of the preferred alternative from a geotechnical point of view.
- Recommendations on the design and construction of founding pylon structures for the 132 kV line.
- General groundwater issues with details on erosion, groundwater conditions and subsurface drainage caused by possible alterations in the hydraulics of the area.
- Other issues include the possible need for blasting and,
- Mitigation measures that should be put in place, including comments on access roads for maintenance of the line.
- A general comment and comparison of the proposed alternative substation sites.

The investigation was intended to be restricted to a desk study of available geological, geotechnical and hydrogeological information and subsequent analysis. As such, the results are intended to be relative and not absolute. However, a walk-over reconnaissance field visit to confirm findings was considered necessary and was completed.

Environmental and social issues that may affect the route determination were not considered as part of this report and analysis.

The proposed location of the development is between Westgate and Kromdraai via Tarlton on the West Rand.

2. INFORMATION SUPPLIED AND VARIOUS INVESTIGATIONS

The original site layout showing the six combined alternative routes was supplied by ARCUS GIBB at an approximate scale of 1:130 000 and a further site plan at a scale of 1:50 000 showing the additional supplementary corridors. This plan also showed the surrounding urban infrastructure, farm boundaries and nature reserves. The base maps also showed topographic information.

The project area has been divided into two areas, namely Westgate to Tarlton and Tarlton to Kromdraai. Five alternative corridors have been delineated in the former sub-area and three alternative corridors in the latter.

The published geological map covering the area (2626 West Rand, 1986) was consulted at a scale of 1:250 000. These studies were supplemented by The Geology of South Africa (CGS, 2006) and also by specific mining plans from Harmony Gold Mining.

Extensive use has been made of the Engineering Geology of Southern Africa, Vol 4 (Brink, 1985), which concentrates on the engineering properties of the Post-Gondwana Deposits.

The relevant regional hydrogeological maps covering the area were also utilised (DWAF and the WRC) and the Revised Sediment Yield Map of SA (WRC, 1992).

3. SITE DESCRIPTION

The site is located between Westgate and Kromdraai in the West Rand, Gauteng Province and generally follows existing powerline routes, roads and farm boundaries. The proposed power line routes comprise a variation of alternative corridors that intersect at Tarlton in the centre of the study area. Each alternative ranges in length from 14.25 to 19.3 km from Westgate to Tarlton and between 7.4 and 11.0 km in the Tarlton to Kromdraai section (see Figures).

The ground slope is gentle (< 5°) over the majority of the site from a low of 1450 masl in the north to a maximum of 1720 masl in the south to steep in isolated areas. The northern portion is heavily influenced by a number of significant catchment areas that drain into the Rietspruit. The strength of the underground aquifers is due to the dolomite bedrock that underlies most of the site and exemplified by the ubiquitous farm name Sterkfontein.

The proposed substation sites are located at Tarlton and Kromdraai.

The majority of the site is open veld and farmland, but significant mining concerns (notably gold and to a lesser extent brick-making clay) are located mainly in the southern portion of the area. The most significant and active mine occurs in the southern portion (originally Randfontein Estate Gold Mine, now Mogale Gold). Harmony Gold Mining Company Ltd has expressed concern regarding shallow (outcrop) undermining and the existence of soil pipes in the area.

The central portion of the site (although situated further to the east and not affecting the initial proposed alignments) is dominated by the Krugersdorp Game Reserve. One of the supplementary alignments (corridor 7) is aligned along the western perimeter of this reserve.

Just outside the northern portion of the site is located the highly sensitive Sterkfontein Caves and the associated heritage site of Maropeng (Cradle of Humankind).

The layout of the site and proposed candidate powerline corridors is shown in Figure 1.

4. METHOD OF INVESTIGATION AND ANALYSIS

The geology was superimposed onto the distribution routes, together with the variation in topographic slope using the categories of gentle (<2°), moderate (2° to 12°) and steep (>12°). Each of the alternative routes was then divided into sections of similar constraints such as geology, soil cover, foundation conditions, groundwater and excavatability. Access to the various routes has been ignored.

A number of relevant geotechnical parameters or constraints were selected from an established set of criteria (Partridge, Brink and Wood, 1993) and assigned an importance rating according to the development of the proposed distribution line. The chosen geotechnical constraints were:

- Groundwater
- Foundation condition and dolomite stability
- Excavatability

Shallow undermining is also a distinct geotechnical constraint but affects all the initial alternative corridors in the southern portion (Westgate to Tarlton Section) of the site equally and does not affect the northern section (Tarlton to Kromdraai). This constraint has therefore been pre-empted but should not preclude detailed site investigations and stability analyses at detailed design and construction stages.

A rating system of 1 (good), 2 (moderate or fair) and 3 (poor) was assigned to each parametric constraint for each route length of similar constraints.

The ratings of each of the sections of a particular route was then sub-totalled and then adjusted for the proportional length of the section compared to the total length of the particular route. The final rating for a particular route was then determined as the sum of these adjusted ratings. **The most preferred route is that with the lowest adjusted rating total.**

Environmental and social issues were not considered during this analysis.

5. GEOLOGICAL AND GEOTECHNICAL CONSTRAINTS

5.1 General Geology of the Area

The majority of the project area is underlain by sedimentary rocks of Randian and Vaalian age and belonging to the Karoo, Transvaal and Witwatersrand Supergroups. A number of diabase dykes occur mostly in the northern portion and are post-Transvaal in age but pre-Karoo. Most of the more significant drainage paths have deposited recent alluvium (see Figure 1).

It is expected that the weathered rocks described above will be overlain in part by a mantle of discontinuous sandy soils of mixed origin (Brink, 1985) and significant residual products above the dolomite.

5.2 Geotechnical Constraints Attributable to Bedrock Geology

5.2.1 Transvaal Supergroup Sediments and Igneous Rocks

The fine-grained dolomite and Black Reef Quartzite sediments underlie the majority of the project area and those above the dolomite normally weather to deep, highly erodible and compressible residual soils (see Figure 1). However, inspection during the brief reconnaissance site visit showed significant rock outcrop of dolomite, chert and quartzite.

Of specific interest is the occurrence of dolomite or soluble carbonate rocks at the base of the Transvaal Supergroup sediments. **The determination of the stability of the dolomite rock is beyond the scope of this investigation and the geotechnical affects have therefore been restricted to an estimation of founding conditions based on the depth of weathering.**

Hard excavation or even blasting may be required to achieve foundation and a key-in depth of 2m or more in the northern portion (shallow and outcropping dolomite bedrock) and towards the south on the Black Reef Quartzite. Groundwater is expected to be shallow to deep and the ground slopes gentle and thus access will not be a constraint.

This geology will affect all the alternative routes and also both proposed substation sites.

5.2.2 Karoo Supergroup Sediments

The fine-grained sediments underlie the majority of the project area to the north in shallow depressions on the dolomite areas and normally weather to deep, expansive residual soils (see Figure 1).

Soft excavation is expected to achieve foundation and a key-in depth of 2m or more. Groundwater is expected to be shallow to deep and the ground slopes gentle and thus access will not be a constraint.

5.2.3 Witwatersrand Supergroup

The southern extremity of the site is underlain by gold-bearing quartzite and shale of the Witwatersrand Supergroup (see Figure 1).

The area is expected to be underlain by hard shallow bedrock, outcropping ridges and a deep water table and gentle slopes. Access will not be a constraint but foundations will require blasting to achieve required key-in depth.

Outcrop mining and shallow under-mining exists within the project area and could affect all the corridors in this part of the site. The following recommendations have been proposed:

1. Abandoned shallow stopes up to 2 m wide may create sudden and differential settlements of this order at ground level and relocation of the pylon positions to solid ground would be the preferred option. The most suitable area would be to the west of the shallow stoping.
2. Existing pylons located on areas of shallow stoping should not be burdened with any additional new power lines.
3. Plans for all corridors in close proximity to existing slimes dams should be discussed with the mining company concerned since sufficient space for maintenance, expansion and re-processing will be required.

5.2.4 Diabase Dykes

The combination of the softer sediments and intrusions of diabase has generally contributed to the formation of impermeable subterranean groundwater barriers in the northern portion of the site. Alternative route to the north (Tarlton to Kromdraai) will be affected by this lithology, together with the proposed substation site at Tarlton.

The diabase dykes are, however, expected to be deeply weathered to medium expansive clay but the lateral width of less than 50 m can be avoided by adjusting the pylon placements.

5.3 Geotechnical Constraints Attributable to Soil Cover

5.3.1 Transported Aeolian Sand

This soil type is expected throughout the site, except in areas of shallow or outcropping bedrock, especially to the extreme north and south of the site.

The soil fabric is expected to be potentially collapsible and subject to creep movements. The topography is gentle and the groundwater deep. Slope stability should not be a problem as foundation excavation into the bedrock will not be excessive.

Foundations can be placed through the aeolian cover onto the underlying bedrock.

These soils have a very low cation exchange capacity and very low pH values, possibly due to intense leaching. Due to the frequent existence of aluminium toxicity, plant growth is inhibited and these soils are susceptible to erosion. However, the revised sediment yield map of SA (WRC, 1992) shows that only the northern portion will be affected by soils with a moderate erodibility index of between 9 and 15, whilst the remainder reflect a low erodibility index of 16 to 20.

These soils are neither expansive nor dispersive.

5.3.2 Alluvium

Thin to moderately thick alluvial soils should be expected in the river and stream sections and most significantly in the Rietspruit in the northern portion of the project area. Moderately expansive conditions producing significant ground heaves and compressible soils are expected with perched water tables and occasional flooding of the area.

Foundation for the pylons in these areas will require over-excavation to the residual soils or bedrock, temporary shoring of the side-walls and possible de-watering and flood protection of the excavations. Mass concrete bases will be required to resist any lateral erosion forces and scour due to stream flow.

Access and maintenance roads will require subgrade treatment (addition of dumprock), road-bed elevation and possibly culvert protection.

A more practical solution would be to plan the pylon locations to span these areas where possible.

5.3.3 Pedogenic Duricrusts

If these secondary deposits occur they will consist of possibly nodular to hardpan ferricrete. The foundation conditions will vary from good to excellent, depending on the degree of cementation but the main constrain may be the hard excavation (possibly even pneumatic assistance or localised blasting) required to achieve the minimum foundation depth to satisfy key-in depth and prevent overturning and wind forces.

This soil type may only affect the central and northern portions of the site.

5.3.4 Residual Soils

The majority of the routes and both substation sites will be affected by this soil type, but the thickness of this soil layer is not thought to be significant.

Residual soils above the dolomite are expected to be highly variable from non-existent (outcrop and sub-outcrop) to deeply weathered chert and wad conducive to sinkhole and doline development. Groundwater is expected to be deep and the ground slope gentle. Access and maintenance roads should not encounter any problems.

Foundation design for the pylons and substations will be dependent on the inherent risk of the underlying dolomite and residuum and in the worst case will probably entail either soil mattresses and RC rafts or piling to dolomite bedrock.

6. GROUNDWATER AND SEEPAGE

Groundwater is expected to be generally deep (>15m), except in the low-lying areas occupied by drainage paths. A number of isolated marshy areas were identified within both sections.

The project area traverses DWAF tertiary drainage regions C22 in the south to A21 in the north (DWAF, 1999), which marks the main Watershed/Continental Divide. The area to the north comprises the Limpopo-Indian Drainage Basin and to the south the Vaal-Orange-Atlantic Drainage Basin

Hydrogeologically the bedrock aquifers can be classed as intergranular and fractured and are classed as minor aquifers (DWAF & WRC, 1999), except for the dolomite occurrence confined mostly to the Tarlton-Kromdraai corridor, but also in the northern and central portions of the Westgate-Tarlton corridor. The dolomite is classed as a major and sensitive strategic resource aquifer. Better yields are usually found on the upper and lower contacts of the diabase dykes.

In terms of aquifer susceptibility, the area to the south and east of the dolomite occurrence is classed as *medium* (due to moderate vulnerability and minor aquifer classification). **The dolomite is classed as *highly susceptible*** and all aquifers to the west of the dolomite have a *low susceptibility* (DWAF & WRC, 1999).

The Tarlton-Kromdraai link is affected by dyke barrier intrusions which have compartmentalised the dolomite into the Steenkoppies Compartment to the west and the Zwartkrans Compartments to the east. A number of important springs also occur such as Maloneys Eye to the west and Kromdraai and Danielspruit Eye to the east.

The groundwater generally occurs at a depth of more than 15m below surface.

The groundwater quality is suitable for most uses as indicated by an EC value of 70 to 300 mS/m and TDS of < 300 mg/l. Underground precautionary measures for concrete or reinforcing are not envisaged due to groundwater but a low pH in the transported soils should be accounted for.

A perched groundwater should also be expected at the interface of the surficial soils and the underlying bedrock or hardpan ferricrete.

7. MINERAL RESOURCES AND UNDERMINING

From the available information studied during this preliminary survey (Randfontein Holding Map at 1:2 000 and Mine Void Map of Randfontein Estate GM Co (W) Ltd at 1:10 000, dated 1946), the proposed powerline corridor in the southern portion is undermined at shallow depth along the outcrop reef. These areas have been delineated on the geological and geotechnical maps (Figures 1 and 2) and occur at the following chainages along the initial corridor A-B:

Section 1: 1.8 km to 2.0 km
Section 2: 2.45 km to 2.65 km
Section 3: 4.1 km to 4.35 km

The stope and outcrop reef is oriented roughly north-south and commonly 200 m long where traversed by the proposed corridor. Section 3 can be resolved by re-alignment to the west onto the footwall of the stope. Section 2 can also be resolved by re-aligning the corridor so that it passes close to the Krugersdorp Highway (R28) since substantial pillars have been left to ensure the stability of the road in that area. There are linear portions of land to the south of Section 1 which have not been mined and the proposed re-alignment in this section should consider this area.

The mining took place over 50 years ago and the stope height is 1.5 m. No major subsidence causing significant tilting of the existing powerline pylons as been recorded.

Mineral resources (generally gold, silver and manganese) occur in the underlying quartzite within the West Rand North Gold Field and manganese deposits within the manganese field underlain by the dolomite.

The most significant mining concerns (notably gold and to a lesser extent brick-making clay) are located all over the area of concern. The most significant and active mine occurs in the southern portion (originally Randfontein Estate Gold Mine, now Mogale Gold) and potential power line corridors traverse the northern portion of Harmony's Lindum Mining Lease.

Shallow open-cast brick-making clay pits occur mostly within the Karoo deposits overlying the dolomite.

8. SEISMICITY

The majority of the Westgate-Tarlton-Kromdraai corridor is affected by a very likely probability for liquefaction with a peak horizontal acceleration of > 200 cm2/s (Welland, 2002) and is based on a seismic intensity of VI (Modified Mercalli Scale) with a 10% probability of being exceeded in 50 years (Fernandez & Guzman, 1979).

No known earth tremors have been recorded in the immediate vicinity.

9. SUMMARY OF SUBSTATION SITES

9.1 Westgate A

This substation site is underlain by quartzite and shale of the Black Reef Formation.

The regional preliminary shallow geotechnical assessment (see Figure 2) shows the area to be represented by possibly shallow quartzite bedrock with good founding conditions and the geotechnical constraints can be listed as follows:

Constraint	Most favourable	Intermediate	Least favourable
Erodibility		Intermediate	
Excavatability			Shallow bedrock-blasting
Steep slopes	Flat		
Slope stability	Negligible risk		
Shallow undermining	West of outcrop		Isolated areas
Flooding	No risk		

9.2 Tarlton E

The substation site at Tarlton is underlain by dolomite and possibly influenced by the presence of the Tarlton East Dyke.

The regional preliminary shallow geotechnical assessment (see Figure 2) shows the area to be represented by potentially poor founding conditions. Depending on the proximity of the site to nearby pinnacled dolomite outcrops, the following preliminary geotechnical constraints can be listed:

Constraint	Most favourable	Intermediate	Least favourable
Foundation			Medium to high risk of sinkholes
Collapsible soil	Depth < 750mm	Depth > 750mm	
Erodibility		Intermediate	
Excavatability	Scattered boulders and dolomite pinnacles		
Steep slopes	No risk		
Slope stability	Low risk		
Flooding		Possible	

9.3 Kromdraai J

The proposed new substation site at Kromdraai is underlain by dolomite and possibly Karoo mudrock.

The regional preliminary shallow geotechnical assessment (see Figure 2) shows the area to be represented by potentially poor founding conditions. Depending on the proximity of the site to a nearby drainage path (Rietspruit), the following preliminary geotechnical constraints can be listed:

Constraint	Most favourable	Intermediate	Least favourable
Foundation			Medium to high risk of sinkholes
Collapsible soil	Depth < 750mm	Depth > 750mm	
Erodibility		Intermediate	
Excavatability	Scattered boulders		
Steep slopes		Between 6 and 12º	
Slope stability	Low risk		
Flooding		Adjacent to known drainage path.	

A detailed foundation investigation would be required to determine the most suitable site in terms of geotechnical conditions and should involve a dolomite stability investigation and determination of the thickness of Karoo cover.

10. RANKING ANALYSIS OF THE ROUTES

The tables in the Appendix show the results of the analysis of each corridor or combinations of corridors. The tables in the following subsections below show the summary of the ranking of each corridor and the final ranking order.

10.1 Westgate-Tarlton Corridor

Table 1: Ranking Analysis Summary of the Westgate-Tarlton Routes

Corridor	Distance (km)	Adjusted Rating	Ranking
8a	14.25	5.30	1
7	16.9	5.31	2
2	17.3	5.34	3
3 & 8b	19.3 & 15.0	5.47	=4
1	19.3	5.48	6

10.2 Tarlton-Kromdraai Corridor

Table 2: Ranking Analysis Summary of the Tarlton-Kromdraai Routes

Corridor	Distance (km)	Adjusted Rating	Ranking
4 & 7b	10.5	4.93	=1
6	8.6	5.03	3
8a	7.4	5.16	4
5	11.0	5.36	5

11. CONCLUSIONS

This report contains the results of a relative preliminary geotechnical analysis of three alternative routes and further supplementary routes between the proposed substations at Westgate and Tarlton and three between the afore-mentioned Tarlton substation and the proposed substation at Kromdraai for the proposed 132 kV transmission power line for ARCUS GIBB and Eskom. The analysis was limited to a desk study of available information and a limited walk-over reconnaissance survey.

Based on a rating system of geotechnical constraints, the preferred route in the Westgate-Tarlton section is Corridor 8a, due mainly to the avoidance of a significant portion of dolomite. In the Tarlton-Kromdraai section the preferred alternative is either Corridor 4 or 7b.

The effect of the potential instability within the extensive dolomite section (potential sinkhole and doline formation) cannot be assessed at this preliminary level and has been excluded from the investigation. The potential problems and constraints generally affect all alternative routes in the Tarlton-Kromdraai section, but also the central and northern sections of the Westgate-Tarlton corridor. It is, however, essential that a dolomite stability investigation be completed for the final chosen route, so that appropriate foundation and water precautionary measures can be recommended.

Isolated sections of shallow undermining have been identified as a potential geotechnical constraint affecting the main corridor from A to B in the southern portion of the Westgate-Tarlton Section. Various re-alignment possibilities have been discussed in the report.

At this preliminary level, no definitive comment can be made on each of the substations at Tarlton or Kromdraai. Further more detailed foundations investigations at each site would have to be completed.

Finally, the ground conditions described in this report refer specifically to those determined from a desk study of available information (supplemented by a limited walk-over reconnaissance survey) and should not replace a comprehensive site investigation. It is therefore quite possible that conditions at variance with those discussed above can be encountered elsewhere.

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APPENDIX A
TABLES OF COMPARISONS

FIGURES