Beeshoek Iron Ore Mine: Deep Dolomite Study

Report Prepared for

Assmang Beeshoek Iron Ore Mine

ASSMANG IRON ORE BEESHOEK MINE

Report Number 550354

Report Prepared by

srk consulting

May 2020

Beeshoek Iron Ore Mine: Deep Dolomite Study

Assmang Beeshoek Iron Ore Mine

Beeshoek Iron Ore Mine (Pty) Limited
Private Bag X03
Northlands 2116
South Africa

SRK Consulting (South Africa) (Pty) Ltd
265 Oxford Rd
Illovo 2196
Johannesburg
South Africa

e-mail: johannesburg@srk.co.za
website: www.srk.co.za

Tel: +27 (0) 11 441 1111
Fax: +27 (0) 11 880 8086

SRK Project Number 550354

May 2020

Compiled by:

John Stiff
Principal Engineering Geologist

Email: jstiff@srk.co.za

Authors:

John Stiff

Peer Reviewed by:

Dr Graham Howell
Corporate Consultant

Table of Contents

Disclaimer ... iii
1 Introduction and Terms of Reference ... 1
2 Scope of Work ... 1
3 Site Location and Description ... 1
4 Regional Geology ... 2
5 Geohydrology ... 2
6 Discussion of site inspection ... 3
7 Surface Deformation Monitoring ... 3
8 Dolomite Stability Discussion ... 4
9 Dolomite Stability Evaluation ... 5
9.1 Dolomite impact on pits ... 5
9.2 Dolomite impact on infrastructure ... 5
10 Conclusions and Recommendations ... 5
11 References ... 6

Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Beeshoek Iron Ore Mine (Pty) Limited (Beeshoek). The opinions in this Report are provided in response to a specific request from Beeshoek to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

1 Introduction and Terms of Reference

Beeshoek Mine appointed SRK Consulting (SRK) to carry out a deep dolomite study of their mine property as part of a water user license application lodged with the Kimberley Office of the Department of Water and Sanitation (DWS). Ms Marke Burger, Senior General Manager of Beeshoek Iron Ore Mine appointed John Stiff of SRK Consulting to carry out the study as contained the SRK proposal dated 07 June 2019 and reference 550354.

The Ghaap Plateau dolomite formations occur at depth and into the northeast of the Beeshoek Mine property where it outcrops in the Maremane Anticline. The dolomite formation in general, and the Ghaap dolomites in this case in particular, are a primary aquifer and an important groundwater reserve especially in the arid western regions of South Africa where the mine is located. The effects of groundwater abstraction on the stability of karst terrane (or dolomite land as described in SANS1936) is well documented. SANS 1936 provides standards for development on dolomite ground where dolomite formations occur within 100 m of surface. In these instances, a dolomite stability assessment is required to be conducted to assess the probability of dolomite hazards affecting surface infrastructure and causing risk to the public, personnel or property of affected parties.

It is understood that the request from Beeshooek Iron Ore Mine, as directed by the DWS, is made in light of these requirements. The deep dolomite study provides a broad overview of the dolomite occurrence and conditions across the site with a view to identifying whether further interventions and study are necessary.

2 Scope of Work

The study involved a desk study of available information, a site visit to inspect relevant aspects and features related to the study and a report detailing the findings thereof and recommendations and suggestions that may be required in mitigation of the identified risks.

The scope of work entailed the following aspects:

- Review available published geotechnical and geohydrological information contained in published maps, reports or papers relating to the dolomite formations of this region.
- Review of Assmang/Beeshoek documentation relating to geotechnical and geohydrological information relating to the site.
- Study available borehole logs.
- Review karst related instability incidents, if such have occurred.
- Evaluate waterborne services, water retaining structures and stormwater management of the site in light of the potential risks imposed on the dolomite formations and the potential for triggering instability.
- Assess the potential hazards and associated risks that the dolomite formations will pose, if any.
- Supplement the review being carried out by Dr Graham Howell of SRK in respect of issues that may have been identified and could have an impact on the dolomite related stability of tailings delivery and deposition.

3 Site Location and Description

The Beeshoek Mine is located approximately 10km from the town of Postmasburg in the Northern Cape. The iron ore mine was established in 1964. Assmang commissioned a new opencast mine, Beeshoek South, in 1999. The combined resources of Beeshoek North and South are currently exploited in five opencast pits with supporting infrastructure. The mine is currently expanding its East Pit and is also mining the Village Pit, which will significantly expand the life of mine (LOM) of the operation.

The topography is characterised by a broad flat plain and the mine is located at the southern end of a range of low hills known as the Klipfontein Hills.

The Kumba owned Kolomela Iron Ore Mine is located 2km to the SSE of Beeshoek Mine property.

4 Regional Geology

According to the 1:250 000 scale geological map series 2822 Postmasburg, the area is underlain by Manganore Iron Formation within palaeokarst features within dolomite, dolomitic limestone and chert of the Ghaap Plateau dolomite formations of the Campbell Rand Group. The regional geology of the site is complex and comprises of banded ironstone with amphibolite and crocidolite of the Asbesheuwels Ironstone Formation of the Ghaap Group.

The Beeshoek iron ore deposit is situated on the southern extent of the Maremane dome defined by carbonate rocks of the Campbell Rand Subgroup and iron-formations of the Asbesheuwels Subgroup of the Transvaal Supergroup dipping gently at less than 10' in an arc to the north, east, and south

A number of iron ore mines are located in the area with the Beeshoek mine producing 3.6 million tons per annum of iron ore The iron ore deposits are described as being contained within a sequence of early Proterozoic sediments of the Transvaal Supergroup deposited 2200-2500 million years ago (SRK, 2014). Two ore types are present within the sequence, namely conglomeratic iron ore (of the Doornfontein Conglomerate Member at the base of the Gamagara Formation) and laminated hematite (which forms part of the Manganore Iron Formation) (Johnson, et al., 2006).

The Manganore Iron Formation is a correlative of the Asbesheuwels iron formation succession of the Transvaal Supergroup and slumped into palaeo-sinkhole structures in the underlying Campbell Rand carbonate formations during the period of erosion that preceded the deposition of the Gamagara Formation. The Makganyene diamictite and Ongeluk lava of the Transvaal Supergroup are thrust over the Gamagara Formation to the west of the mine.

The Manganore Formation in expressed in a range of isolated hills (referred to as Klipfontein Hills) which are thought to represent the infill of former karst sinkholes, now exposed by preferential weathering of the dolostone host rocks. The Beeshoek iron ore deposits constitute large clusters of such former karst sinkholes developed at the southern and northern intersection points of the Klipfontein Hills with the N-S-striking Gamagara Ridge (Schalkwyk, 2005).

The peneplain areas are characterised by a cover of Kalahari Formation Tertiary soil, sand, rubble and calcrete. Detrital ore of recent origin can be found between dolomite pinnacles and as localised slope scree and alluvial outwash.

5 Geohydrology

The regional water level varies between surface level and 200 m below surface. The groundwater is drained from the catchment area by several flowing springs or eyes. The vast karst (underground catchment area) groundwater compartment is divided into 50 compartments by the numerous dolerite dykes which occur in the area (Smith, 1978).

There are number of monitoring boreholes around the mine of which the groundwater levels are measured on a monthly basis. The average shallowest groundwater level was 5 m bgl as measured at the DOOR10 monitoring borehole. The average deepest groundwater level was 182 m bgl as measured WH19 and WH20 monitoring boreholes. These measurements were taken from January 2019 to April 2020.

A dataset of water level readings recorded by the Mine from June 2012 to April 2019 are presented in Figure 5.1. It can be seen from these levels that there is probable compartmentalisation of the groundwater evidenced in the differing levels. It is also apparent that there is a steady lowering of the levels in each of the boreholes over the period due to both dewatering and groundwater use.

A hydrocensus is periodically carried out by consultants GPT, the latest of which is presented in a draft report titled “Hydrocensus Study for Assmang Iron Ore Beeshoek Mine - GPT Reference Number: AsBEE-17-2387 (2017). This document reports a similar steady lowering of the water table in the mining concession area encompassing the central region of their study area which includes the mine property and concludes ”A large north-south striking area is being dewatered by mining activities. This area of dewatering is possibly bounded by geological structures in the form of dykes and/or thrust faults to the west and east of Beeshoek mine as well as a structure immediately north of BN Pit.” A lowering water table has potential impacts on dolomite stability in the longer term.

6 Discussion of site inspection

A reconnaissance site visit was made on the 18 July 2019 to inspect a number of features and gained a broad appreciation of the geological and geomorphological setting, operations and relevant characteristics of the mine property. During the visit, the following locations were inspected.

- Exposed karst cave in the vicinity to the BN pit – in 2016 a large cavity manifested in a pit adjacent to the BN pit in the mining area north of the property. The cavity measures 170 m by 95 m by 46 m deep to the water table and was exposed when the rock arch of the cavity roof collapsed after a period of inactivity. Figure 6.1 shows the surface expression of the opening. The Wolhaarkop Formation brecciated chert can be seen in the cavity walls. It is suspected that the cavity extends to a significant depth below the water table as an attempt to plumb the depth was not successful.
- Current operational and disused pits – the variable depth to bedrock is evidenced in Figure 6-2 where pinnacles of dolomite as exposed in the pit face showing recent (Quaternary) infill between successive pinnacles.
- Detrital mining area – in the lower lying areas detrital iron ore deposits are blanketed under an horizon of windblown Kalahari sand as illustrated in Figure 6.3.
- Subsidence in the southeastern area of the mine property: A doline was inspected which has occurred in the south-eastern area of the site. The Kolomela Mine alerted the Beeshoek Mine of a potential surface deformation in this area. The feature shows roughly circular depression with a radius of 90 – 100 m that has subsided by approximately 1.0 m in the centre of the depression. That area has been fenced off to make it safe and prevent unauthorised entry. Figure 6-4 shows a section of the circular crack and gives an indication of the magnitude of the opening thereof. It is probable that this incident is related to ground water lowering from dewatering.
- Current Tailing Storage Facility in the north of the mine site – the TSF was inspected at the embankment wall against which the supernatant water has ponded on the northern side of the facility. Figure 6-5 shows the supernatant pond and barge from where the return water is pumped.

7 Surface Deformation Monitoring

Surface deformations, both naturally occurring and induced by mining activities, pose as a risk to assets, health and the environment in a karst environment. The Mine is underlain by dolomite both near surface and at depth. The buried karst terrane is notorious for the development of subsidences and sinkholes. InSAR remote sensing is a useful tool to monitor surface deformations and these radar interferometry techniques can measure centimetre to sometimes millimetre scale deformation on the earth surface.

The Satellite Application Centre of the CSIR has monitored the Beeshoek mining licence area and has provided surface deformation reports for the licence areas of interest on a 12 and 24 day intervals from August 2017 to June 2019. The reports show the occurrence of the following surface deformation observations as follows:

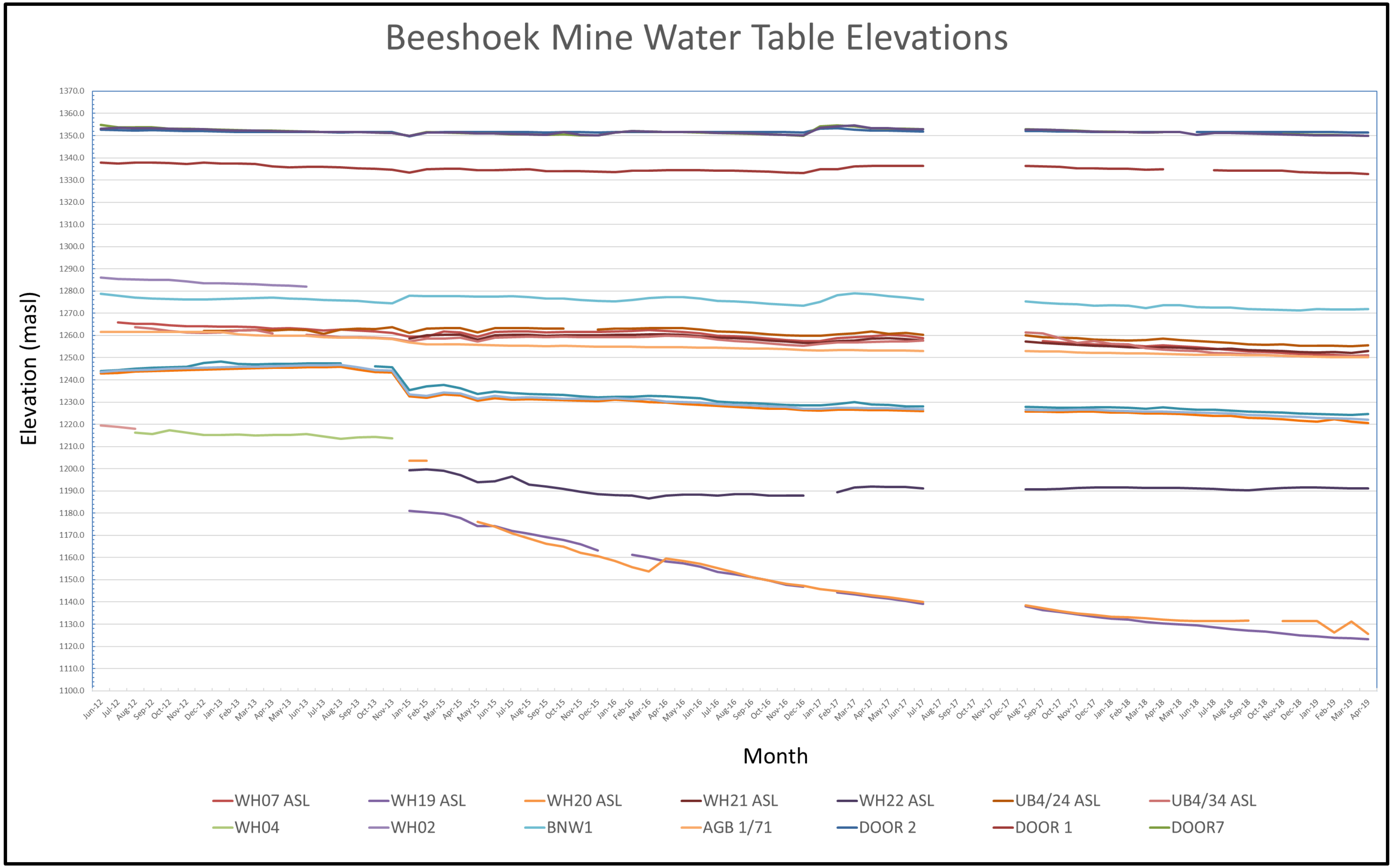
- 20 August 2017 – southwestern side of the railway line immediately north of the railway bridge – 21 mm subsidence

- 18 December 2017 – village pit rock dump – 8 mm subsidence
- 30 December 2017 – village pit rock dump – further 130 mm subsidence
- 11 January 2018 – village pit rock dump – further 42 mm subsidence
- 12 March 2018 – northern main rock dump – 55 mm subsidence. 16 June 2018 – two zones at crest of eastern pit wall of the BF pit - 22 mm and 29 mm subsidence respectively
- 28 June 2018 – northeastern crest of eastern pit - 33 mm subsidence
- 19 November 2018 – further deformation at the southwestern side of the railway line immediately north of the railway bridge – 18 mm subsidence
- 6 May 2019 –three zones in eastern pit rock dump - 10 mm subsidence
- 6 May 2019 – village pit rock dump – further 140 mm subsidence
- 18 May 2019 – 5 zones on the eastern pit and rock dump – max. 22 mm subsidence
- 18 May 2019 – 2 zones in village pit rock dump – further 136 mm subsidence
- 30 May 2019 – northern basin of the TSF – 110 mm subsidence
- 30 May 2019 – village pit rock dump – further <10 mm subsidence
- 11 June 2019 – two zones in the central and southern basin of the TSF – 28 mm subsidence

A number of the deformation records relate to the rock dumps and these are unlikely to be dolomite related, but rather consolidation settlement of loosely packed spoil. Deformation associated with pit slope crests are also more likely to be response to stress relief on pit walls.

The subsidence in the vicinity of the railway line, where subsidence was noted on the 20 August 2017 and 19th November 2018 and 21 mm and 18 mm of subsidence recorded respectively, is possibly also attributable to karst terrane dewatering consequences.

The settlements noted in the basin of the TSF on the 30 May 2019 and the 11th June 2019 where 110 mm and 28 mm of subsidence were recorded is significant and may indicate localised subsidence in the TSF basin response to water ingress.



srk consulting

BEESHOEK DEEP DOLOMITE STUDY
Beeshoek Mine Water Table Elevations

Project No.
550354

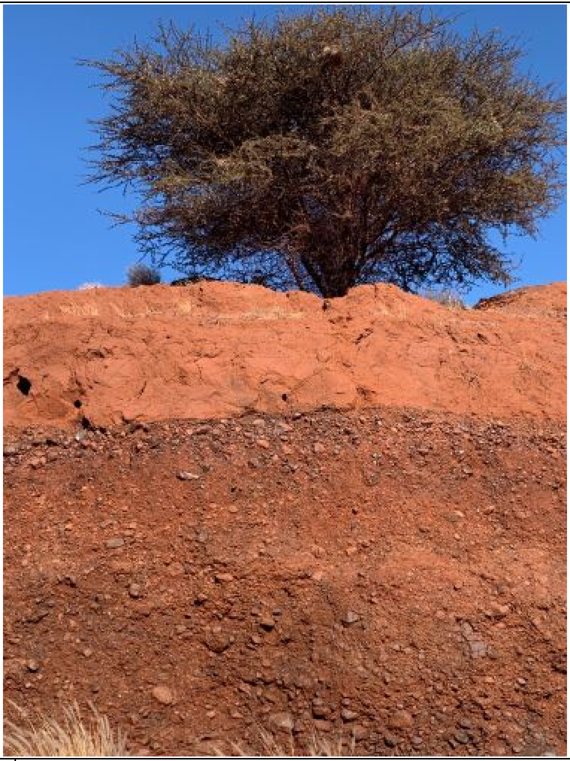
Figure 5-1 Water table monitoring records from June 2012 to April 2019 at Beeshoek Mine

srk consulting	BEESHOEK DEEP DOLOMITE STUDY	Project No. 550354

Figure 6-1 Large cavern in BN pit annex.

srk consulting	BEESHOEK DEEP DOLOMITE STUDY	Project No. 550354

Figure 6-2 Pinnacles of dolomite exposed in excavation face



srk consulting	**BEESHOEK DEEP DOLOMITE STUDY**	Project No. 550354

Figure 6-3 Aeolian Kalahari sand overlying detrital ore

srk consulting	**BEESHOEK DEEP DOLOMITE STUDY**	Project No. 550354

Figure 6-4 Wide cracks in the ground denoting a doline subsidence to the left of picture

srk consulting	BEESHOEK DEEP DOLOMITE STUDY	Project No. 550354

Figure 6-5 Supernatent pond adjacent to TSF embankment

8 Dolomite Stability Discussion

The occurrence of dolomite related instability is influenced by a number of factors and the degree of risk is determined by the nature of the blanketing horizon and its mobilisation potential, the size of the potential development space, the availability of a receptacle space within the bedrock, presence of mobilisation agencies and the groundwater levels from time to time.

Karst cave systems exist within the Campbell Rand Formation and are well documented and the mechanism by which these cavities cause surface instability are governed by the following factors:

- Nature of blanketing layer and mobilization – the southern lower lying areas of the mine site are more characterised by blanketing layers of windblown sand and detrital ore horizons of slope scree and alluvium. These horizons allow arching over subsurface cavities and with time break through to surface in the form of sinkholes and dolines under the right conditions such as the doline event in the eastern portion of the site.
- Potential development space – the development space of these features is influenced by the nature and thickness of the blanketing layers and this will determine the size of the feature that breaks through to surface.
- Receptacle space – the receiving space is located within the bedrock and sometimes within cavities in the blanketing horizons. The size interconnecting nature of the cavities determines the volume of eroded material that can be received and whether the full sinkhole/cavity can be developed. The size of these receiving cavities can be quite significant as is seen in the cavern exposed in the north of the site.
- Mobilisation agencies – the presence of mobilising agencies which are primarily concentrated water from leaking water bearing services, retarded stormwater and unlined water impoundments are the primary causes of land development induced dolomite instability and account for 98% of events.
- Groundwater level – groundwater level is an important factor in the ability of instability features to develop. The level of the water table in relation to the caverns and voids in the bedrock and

blanketing horizons governs whether mobilisation is possible as water-filled voids block these receiving zones in the substrate. The decreasing level in the groundwater from dewatering and periods of drought or over-abstraction ‘activates’ these receiving zones and invariably initiates incidences of subsidence or sinkhole formation with time.

9 Dolomite Stability Evaluation

9.1 Dolomite impact on pits

The presence of cavities below the base of Wolhaarkop Formation breccia has been shown to occur on the site. One such large cavern is present as exposed in the BN Pit annex. While this may be a once off occurrence, this cannot be assumed to be the case with any certainty. The occurrence of these is difficult to predict as they occur within the bedrock at the base of the Wolhaarkop chert breccia where solution cavities may be present. Although they are likely to be rare occurrences, they do pose a significant risk to mining activities.

9.2 Dolomite impact on infrastructure

The impact of dolomite related instability on infrastructure is likely to be the highest risk where dolomite bedrock is shallow or underlies a blanketing layer or layers of unconsolidated soils and deposits. This is particularly relevant where water-bearing services are involved and the risk of leakage is always possible. Concentrations of surface water such as from stormwater or from unlined impoundments such as tailings storage facilities that are unlined pose a risk.

Infrastructure such as roads bridges and pipelines will be at risk due to the presence of a blanketing layer of recent soils which overlie buried karst ground at depth. Leaking services and other concentration of water in the vicinity of infrastructure such as stormwater ponding result in water ingress into the ground causing subsurface erosion into receiving cavities in the dolomite bedrock.

A geotechnical investigation of the Beeshoek TSF embankment wall in a report titled “Beeshoek Iron Ore Mine Tailings Storage Facility - Geotechnical Investigation – SRK Report no. 547755” shows seepage to be occurring through the wall of the embankment. The CSIR InSAR deformation reports show two instances of subsidences within the basin of the TSF, which is underlain by dolomite at a shallow depth. The relationship between these observations and the risk to stability of the basin and embankments must be established by further investigation.

10 Conclusions and Recommendations

There is evidence that dewatering has had some effect on surface instability on the property. It is recommended that a study be conducted to explore techniques that will aid the identification of potential problems area. Such techniques include inter alia geophysical methods such as a gravity survey to identify low gravity anomalies that will aid identifying voids in bedrock. There is a suggestion from a dewatering borehole near the western pit that a similar cavity may exist at depth in this area too. Investigation of known or suspected features will give a good opportunity to test if such geophysical methods will indicate cavernous conditions and can be used in future to identify these ground conditions in advance so they can be mitigated. The eastern doline can be investigated in a similar fashion to confirm ground conditions that lead to these surface deformation events.

In mining of the Manganore Formation, the presence of cavities at the base of the Wolhaarkop Formation can be identified by targeted gravity surveys in future operational areas and drilling in advance of mining operations. Risks associated with the TSF from seepage trough embankments and seepage through the basin need to be better understood. Investigation by gravity surveying and targeted drilling need to be explored to understand and quantify the risks. Wet services, such as water supply and slurry pipelines delivering waste to the TSF and stormwater accumulation and ponding, should be monitored especially where they traverse ground where dolomite bedrock dolomite outcrops or occurs beneath a blanketing horizon of recent soils or deposits. Small scale surface mapping of which areas of the mine site are underlain or have inferred underlying dolomite will be necessary, if these are not already available, to characterise risk.

The development of a Dolomite Risk Management Plan (DRMP) is recommended to mitigate the risks posed by dolomite related instability and involves devising an appropriate monitoring programme and reaction plan to incidents to mitigate against the risks.

Specific recommendations are:

- Surface mapping of outcrops and ancilliary (potential) geological aspects (surface risk mapping)
- Remote sensing/gravity surveys for near-surface and deep risk issues

11 References

Brink, A.B.A. *Engineering Geology of Southern Africa. Volume 1*. Building Publications (1979).

Eriksson, P.G. *The Transvaal Supergroup and its Precursors*. The Geology of South Africa. The Geological Society of South Africa (2006).

Draft report *Hydrocensus Study for Assmang Iron Ore Beeshoek Mine* – Geopollution Technologies. Reference Number: AsBEE-17-2387 (2017).

Schalkwyk, G.A.C. *Genesis and Characterisation of the Wolhaarkop Breccia and Associated Manganore Iron Formation*. M.Sc. Dissertation. University of Pretoria (2005).

Prepared by

SRK Consulting - Certified Electronic Signature
550354/43981/Report
7327-116-3262-STIJ-01/06/2020
This signature has been printed digitally. The Author has given permission for its use for this document. The details are stored in the SRK Signature Database

John Stiff

Principal Engineering Geologist/Partner

Reviewed by

SRK Consulting - Certified Electronic Signature
550354/43981/Report
8674-5245-9108-HOWG-01/06/2020
This signature has been printed digitally. The Author has given permission for its use for this document. The details are stored in the SRK Signature Database

Dr Graham Howell

Corporate Consultant/Principal Engineer