REPORT

Khumani Mine

Numerical Groundwater Flow and Contaminant Transport Model

Submitted to:

Assmang Khumani Mine

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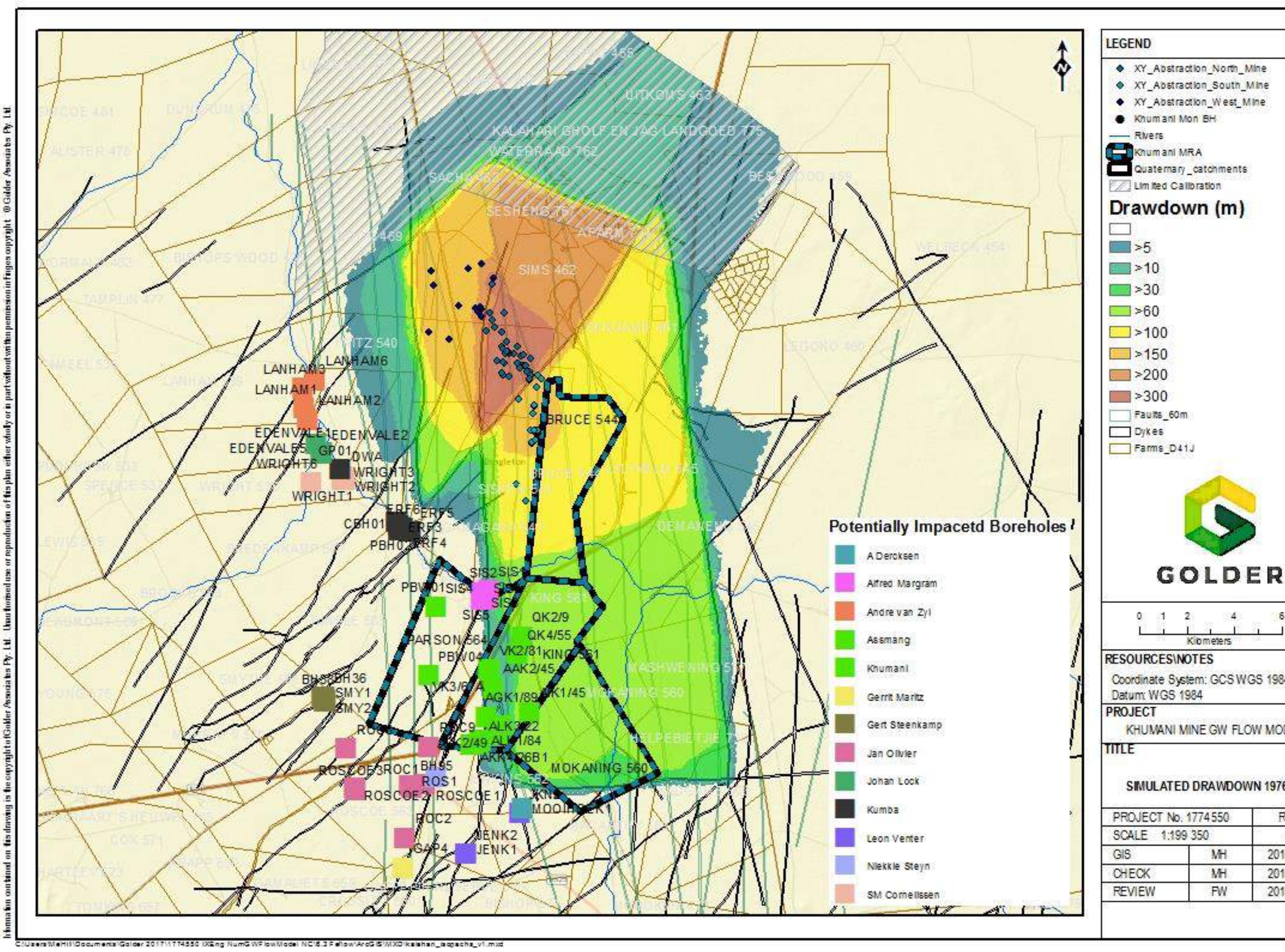
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APPENDICES

1.0 INTRODUCTION

Golder Associates Africa (Pty) Ltd (Golder) was appointed to update the existing numerical groundwater flow model for the Khumani Mine Site. The purpose of the update is to;

- Develop a numerical model which can aid in predicting the impacts of the Mine Residue Deposits on the receptors in vicinity of the mine, and to
- Quantify potential inflows to the open pit and characterise the potential extent and impact of mine dewatering on the aquifers.

2.0 PROJECT BACKGROUND

In 2017 Golder completed the groundwater augmentation study for Khumani mine. Khumani Mine is presently reliant on the Sedibeng pipeline for water supply purposes. However, it has been found that in the period October through to January of each year the mine has experienced diminished supply from the Sedibeng system. In order to meet the Mines water supply requirements, four boreholes were drilled for augmentation purposes. It was proposed that these boreholes are pumped at a cumulative rate of 44 l/s over the demand period (October – January) thus equating to an annualised abstraction of 456 192 m^3/a.

The highly pervious aquifers in the area are associated with the dolomitic formations which form the core of the Maremane anticline. The dolomites of this formations are intruded by dolerite dykes which have largely compartmentalised these aquifers (Meyer, 2009). The Khumani Iron Ore Mine (KIOM) and Sishen Iron Ore Mine (SIOM) are both housed within a single compartment.

Dewatering of the Sishen Open Pit initiated in 1976. Over the past 42 years, groundwater abstraction has ranged between 300 -500 l/s. Due to the presence of the dolerite/diabase dykes dewatering effects associated with the long terms abstraction are largely limited to the KIOM and SIOM compartment and drawdown within the compartment is extensive. Water levels measured in the Augmentation boreholes drilled in 2016, are up to 120 mbgl.

The modelling undertaken as part of the augmentation study has been expanded upon in this study to incorporate the evaluation of the open pit mines and mine related infrastructure. Key additional data considered in this model;

- Updated receptor information based on the 2017 hydrocensus
- Updated water Level data
- Updated water quality data
- Updated structural information
- Updated rainfall data
- Updated Sishen abstraction data
- Updated mine plan information

The most recent data and main data trends are outlined in ensuing sections. This information is used to inform the conceptual model and update the numerical groundwater flow model.

3.0 CONCEPTUAL HYDROGEOLOGICAL MODEL

The conceptual hydrogeological model which forms the basis of the numerical model is described below and is based largely on the following reports;

- Golder (2017) Augmentation of Water Resource for Assmang's Khumani Mine, Report No. 1529364
- Meyer (2009) Development of A conceptual Hydrogeological Model, an evaluation of the effect of dewatering and the design of the monitoring protocol, Sishen Iron Ore Mine, Report No. 009/09
- GPT (2010) Evaluation of the hydrogeological data at Khumani mine and the development of a groundwater management plan, Report no.: Kum-09-403
- Golder (2008) Sishen Mine Dewatering Boundary Study, Phase IV – Report on E and NE Areas
- Golder (2005) Sishen Mine Groundwater Investigation Programme Zones 3 & 4 Final Report, Report No.: 5157/6887/5/G

3.1 Catchment, topography and drainage

The Khumani and Sishen Mine occurs within the quaternary catchment D41J. Proximal to the mines, small hills are predominant on a north-south strike. The hills are reflective of the Maremane Anticline which trends north south. The study area is situated between two, north-south running mountain ranges, the Kuruman Hills forming the eastern boundary of the area and the Koranna Berg Mountains, forming the western boundary of the study area. These mountain ranges are in the order of 525m higher than the central parts of the quaternary catchment.

The surface elevation across the quaternary catchment drops by 300m from the southern surface water divide to the northern which spans a distance of 56 km and equates to gradient change of 0.5%.

The west and north-westerly flowing Go-Magara River and its tributaries drain the Kuruman Hill's in the south eastern portion of quaternary catchment D41J. The Olifantsloop drains the Korana Berg in the west of quaternary catchment D41J and joins the Gamagara River approximately 7 km west of Sishen North Pit.

The non-perennial Gamagara River has a recorded flow history since 1896 with 24 flow events recorded. Interestingly, 16 of these events were recorded since 1974 (period during and after the high rainfall events of 1974-1976). Ten of these floods reached Deben (Dibeng) and three (1955, 1974 and 1988) reached the Kuruman River confluence.

3.2 Regional & structural geology

The 1:250 000 geological maps sheets prepared by the Council for Geoscience (CGS), investigations undertaken by Wits University and the geological logs provided by Khumani mine form the basis for understanding of the geology of the area. Fries, 2009 (referenced in Meyer 2009) undertook detailed investigations of the characteristics and positions of dykes and fault zones within quaternary catchment D41J (Figure 1).

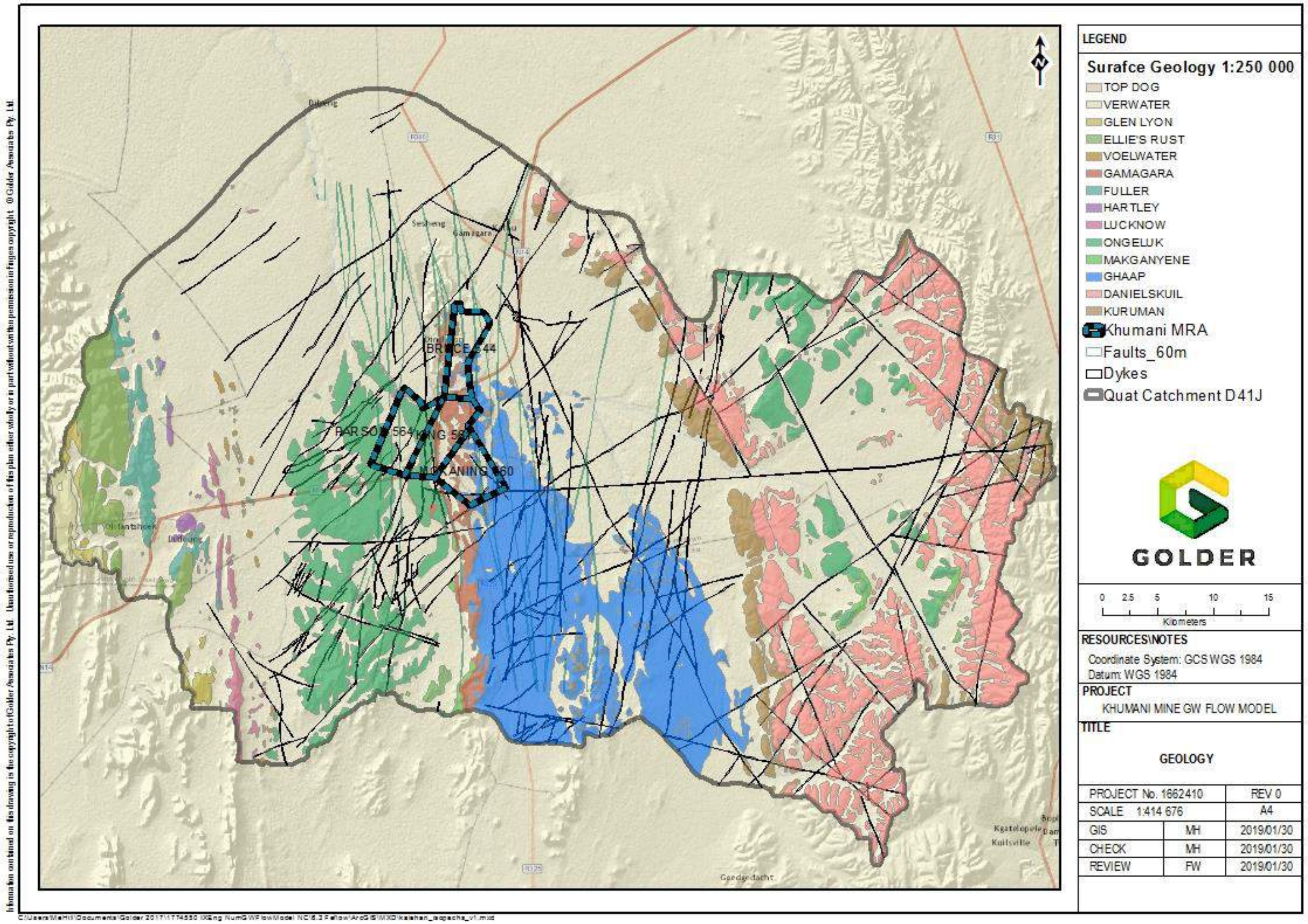


Figure 1: Geology Map (1:250 000 CGS Map Sheets)

A map based on the surface geology mapped by the CGS is illustrated in Figure 1. The central part of the study area consists of the Campbellrand Subgroup (Ghaap Group) and represents the Maremane Anticline (Dome). East of the dome is the Asbestos hills Subgroup (Kuruman Iron-Formation) in the form of large, easterly arching syncline, the Dimoten Syncline. The Ongeluk Formation (andesitic lavas) represents the cover rocks in the syncline, deposited on an unconformity. The western boundary of the Ghaap Group lies on a regional thrust fault system overlain by quartzite and shales of the Mapedi and Gamagara Formations.

The regional geology of the study area comprises of sedimentary and extrusive rocks of three Supergroup sequences, spanning a significant geological time span (between 2680 and 358 Ma) and is illustrated in Table 1. These sequences are partially covered by Tertiary-Quaternary sediments of the Kalahari Group and windblown sands of the Gordonia Formation.

The rock formations of the pre-Karoo Group are located close to the western margin of the Kaapvaal Craton. This margin has been subjected to intensive, structural deformation due to tectonism ~2400 – 1700 Ma (i.e. the Kheis Orogeny: folding, thrusting and faulting).

A thick succession of dolomites, Campbell Rand Subgroup, represents the central part of the Maremane anticline and consists of alternating layers of oolitic and stromatolitic dolomite with thin interbedded layers of shale and quartzite (Golder, 2014). This succession is believed to be several thousand meters thick, based on the stratigraphic core borehole drilled by the CGS just north of Sishen during the 1990’s. During the Kheis Orogeny, the basal units of the dolomite were exposed to palaeo-erosion and subsequent karstification of the dolomites. This process has played a major role in the enrichment (i.e. leaching of silica from the overlying BIF) of hematite and subsequently forming the vast amounts of iron ore occurrences in the study area.

The Asbestos Hills Subgroup lies conformably on the Campbellrand Subgroup and consists of typical banded ironstones of various thicknesses. The “blinkklip breccia”, a basal layer of banded iron stone, lies on the Campbell Rand Formation in the Maremane Anticline (see Table 1) and serves as a marker in the regional geological sequences in the area.

Table 1: Stratigraphic Sequence (Taken from Golder, 2017)

Sequence	Supergroup	Group/ Subgroup/ *Formation*	Lithology	Comments
(5)		Kalahari	Sand Calcrete/Clay Boulder Beds	*D41J: Moderate aquifer & local flow path.*
(4)	Karoo	Dwyka	Shale Diamictite	D41J: Karoo paleo-channel fill;
(2)	Olifantshoek	*Mapedi/Gamagara*	Quartzite/Shale Lava Shale Quartzite/Flagstone Shale Quartzite Shale Conglomerate	Represents western boundary formations of study area; Tectonism – regional, but low metamorphism.
(3)-(2)	Diabase			Intrusive, localised occurrence.

Sequence	Supergroup	<u>Group</u>/ Subgroup/ *Formation*	Lithology	Comments
(3)	Transvaal	Postmasburg: *Ongeluk* *Makganyene*	Andesitic lava ♣Diamictite	Western and Eastern flanks of the Maremane Dome (Anticline). ♣Localised occurrences
		Thrust Fault Zone		Originated from the west during regional tectonism (2400 Ma-2700Ma)
(1)	Transvaal	**<u>Ghaap:</u>** Asbestos Hills	Banded iron formation (BIF)	Western and Eastern flanks of the Maremane Anticline Large exposures on Dimoten Syncline in the east; and Forms the eastern high lands area and subsequent boundary of the study area.
		Chert Breccia		Localised, mainly in Maremane Dome (Anticline).
		<u>Ghaap:</u> Campbellrand	Dolomite (DLMT)	Large exposures in the centre of the Maremane Anticline Extremely thick succession (~3000m just north of Sishen – CGS Exploration bh.)
	Unconformities in geological profile (GCS, 2011 and Da Silva, 2011).			

The Postmasburg Group (Makganyane diamictite formation and the overlying Ongeluk lava formation) in the western part of the Maremane Dome, unconformable overlies the Ghaap Group (i.e. Campbellrand and Asbestos Hills Formations) and underlies the Gamagara Formation (Olifantshoek Group) with an unconformity–representing a local thrust fault package from the west which sits between the Asbestos hills Subgroup (lower) and the Makganyene diamictite and Ongeluk lava. The regional extent of this feature is not known; although it has been mapped in the Sishen and Beeshoek areas.

The Ongeluk Formation (andesite lava) forms the upper part of the Transvaal Supergroup and overlies the Makganyene Group. Andesitic lava belonging to this formation crops out in the Dimoten Syncline and southeast of the Maremane Anticline and disappears under the Kalahari sand cover further north.

The Gamagara Formation was deposited on the Maremane Anticline; this contact zone represents an unconformity overlying the dolomite and banded iron formations of the underlying formations.

Tertiary - Quaternary Deposits

The bedrock geology in the study area is partially concealed by sediments of the Kalahari Group. In the eastern parts of the study area the cover becomes thin and patchy and large areas of bedrock are exposed.

The Kalahari Group consists primarily of calcrete, gravel and clay beds. It is subdivided into five formations, i.e. Wessels Gravel Formation, overlain by the Budin Clay Formation and the Eden Sandstone Formation, followed by the Mokalanen Limestone Formation (mainly calcrete) with the Gordonia aeolian Sand Formation at the top.

Kalahari Group sediments with roughly a NE to SW strike direction varies in thickness from a few millimeters to over a hundred meters and covers the northern middle part of the study area. The thickness of the Kalahari sediments was controlled by the glacial erosional valleys developed in the underlying bedrock.

Intrusive Structures

The study area is relatively deformed and intense fracturing has occurred in the hard rock units. This fracturing is associated with the development of faults and in many cases dyke intrusions. Intrusive dolerite/diabase dykes are a common feature in the study area but seldom outcrops. Dolerite dykes are typically observed as major linear structures and intersect the geological formations perpendicular. These dykes are subjective to both positive and negative weathering, depending on the specific hydrological environment and their geochemical characteristics.

Chemical weathering is responsible for the deposition of secondary calcite on top of the dykes, with the intensive materializing of clayey decomposed dolerite at depth. These dykes naturally appear as ridges with depressions formed by the solution of the country rocks within the contact zone alongside the dykes. Most of

the surface water drainage channels are restricted to these features. These dolerite dykes with low permeability compartmentalize the dolomite aquifer.

3.3 Hydrogeology

Groundwater resources occur throughout the D41J catchment, but aquifer characteristics are highly variable due to the nature of the various rock formations and topographical effects. Intergranular (Kalahari Sediments), weathered and fractured BIF as well as karst dolomite bedrock aquifers are present in the different geological formations.

Previous authors (Meyer, 2009, Golder, 2014 and Ages 2012) have identified six hydrogeological zones of significance to the understanding of the groundwater situation proximal to the mines. These units are described as follows;

Zone 1: Kalahari sediments – The Kalahari sediments, in places, give rise to a primary porosity, unconfined aquifer. Where significant gravels are deposited and form the base of the succession, high yielding boreholes in the order of 5 l/s are encountered. The Kalahari aquifer are separated from the deep aquifer system, in some cases, by the deposition of clays and diamictite. However, in areas where deposition of diamictite and clay was not prevalent, the Kalahari sediment aquifer is in connection with deeper fractured aquifer.

Zone 2: Alluvial and sedimentary sand and clay lens deposits along the Gamagara River. The alluvial sediments have served as an important local aquifer for water users situated along the Gamagara River.

Zone 3: Deep hard rock formations such as the Andesitic Lava and Dwyka Diamictite are poor aquifers and are classed as aquitards. These units play an important role in controlling groundwater flow. As described above, the diamictite units result in limited connection between an upper aquifer and the deeper fractured aquifer in the northern portions of catchment.

While the lava, which is present west of the Khumani and Sishen mines, has limited flow potential where solid and non-fractured.

Zone 4: Weathered and highly fractured hard rock formations such as the banded iron formations (BIF), chert breccia and the Karstic dolomite formations are highly permeable aquifers. While the hydraulic conductivity of these units is variable, transmissivities exceeding 1000 m^2/d have been obtained.

The fractured BIF strata of the Asbestos hill formation which flanks the eastern extent of the catchment are regarded as a major recharge zone to the remainder of the catchment.

Zone 5: Intrusive dolerite or diabase dykes of both a north-south and east-west strike cross cut the compartment. The dykes have been found to be of low permeability and compartmentalize the dolomitic aquifers in the central portion of the domain.

Zone 6: Major Fault zones. The north-south trending fault zones throughout the catchment acts as a preferential flow paths for groundwater flow and interlinks the dolomite aquifer which is compartmentalized by dolerite/diabase dykes

3.3.1 Hydraulic conductivity

Aquifer parameters derived in previous studies and utilised in the numerical model presented by van Tonder (1993) are described in Table 2. While the presented values correspond with Sishen mine, the similarity in geology at Khumani Mine allows for estimated parameters at Sishen to be relevant to the Khumani area.

Table 2: Aquifer parameters obtained from previous investigations

Aquifer Reference	Transmissivity (m2/d)	Storativity (%)	Author & Date
Ghaap Plateau Dolomite			Smit, Water Balance,1970
Sishen Mine		1.1 – 1.4	Dziembowski – 1978
Sishen Mine		1.07	Gilding – 1979
Sishen Mine	100 – 3000	1.0	Lynch – 1982
Sishen Mine	350 – 614	0.39 – 0.73 0.6	Van Tonder, Dynamic Flow – 1993 Van Tonder, Equal Volume Method

Golder (2008, 2011 and 2016) undertook 31 aquifer tests (pump out and recovery) in boreholes proximal to the Sishen and Khumani mine areas. Seven additional tests were undertaken by SRK and GPT. The major lithology intersected in each of the tested boreholes was identified and is used to evaluate the variations in transmissivity based on lithology (Figure 2).

- Lava. Five boreholes intersected the Ongeluk Lava which outcrop west of the Khumani mine. Transmissivity values range between 1.4 and 168 m^2/d. The maximum transmissivity value corresponds with a borehole known to intersect a major fracture. The estimated hydraulic conductivity for the lava units are estimated to be in the order of 0.02 m/d – 0.09 m/d.

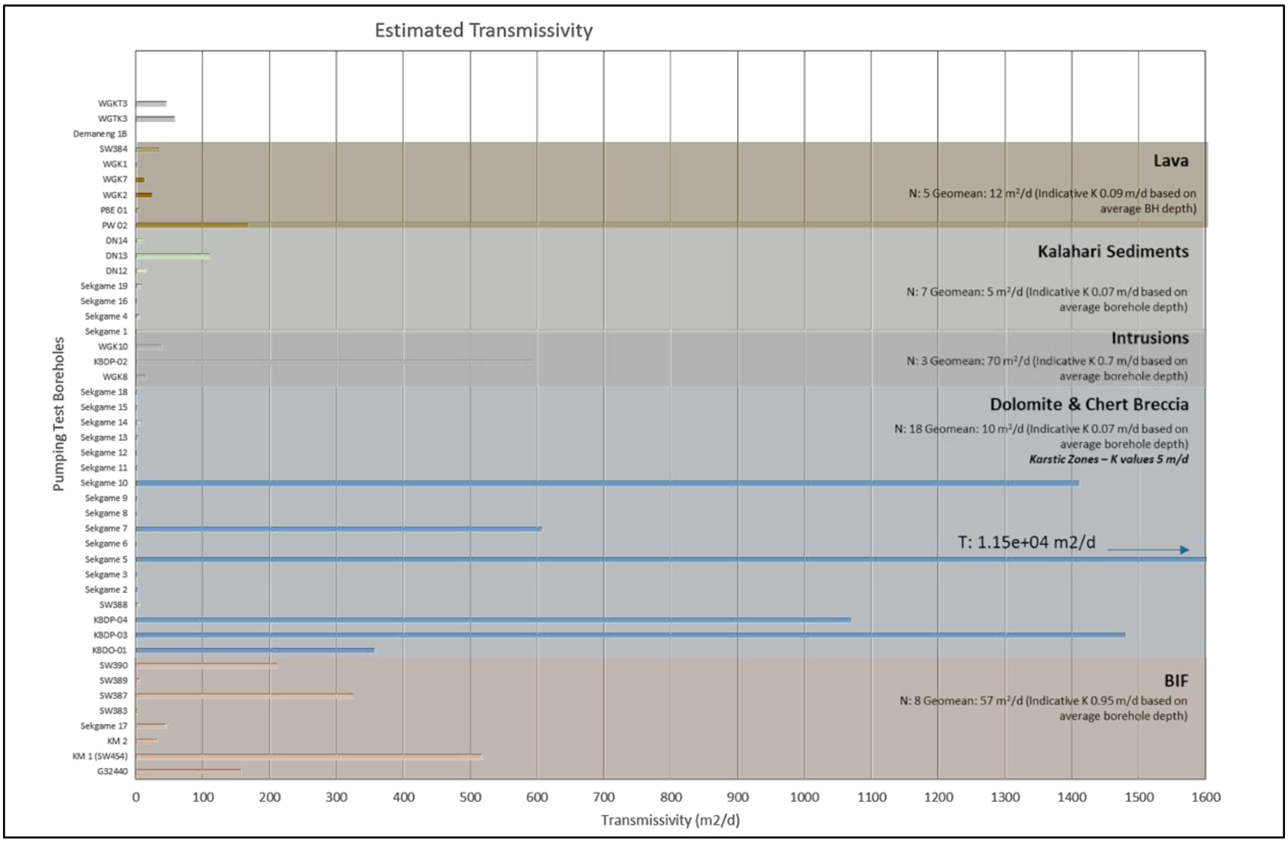


Figure 2: Estimated Aquifer Properties

- Dolomites. The boreholes drilled east of the mines intersecting the dolomites are typically of low transmissivity (less than 2 m^2/d). However within the mine area a high transmissivity zone within the dolomites is evident based on testing conducted, in these zones transmissivity values exceed 500 m^2/d and hydraulic conductivity exceeds 1 m/d. The area is folded and faulted and consequently it is assumed that the vertical hydraulic conductivity is equal in amplitude the estimated horizontal hydraulic conductivity.
- The Kalahari sediments have variable transmissivity values ranging between 0.1 and 111 m^2/d. It is estimated that a representative hydraulic conductivity value is in the order of 0.07 m/d. Due to the clay horizons present within the sediments the vertical hydraulic conductivity is assumed to be an order of magnitude smaller than the horizontal estimates.
- The boreholes intersecting the banded iron formation strata, typically have moderate to high transmissivity values and the estimated representative hydraulic conductivity is in the order of 0.95 m/d.

3.3.2 Storativity

Previous investigations yielded storage values ranging between 1.4-0.7%. The dolomite and BIF formations were assumed to be in the order of 0.6%.

3.3.3 Sources and sinks

The sources and sinks refer to the contribution of groundwater to the aquifers within the groundwater catchment considered and the sinks refer to the outflows from the aquifers. The primary source of groundwater is via vertical recharge associated with rainfall. While, the major sinks within the catchment include the contribution of baseflow to the Gamagara river system and abstraction for water supply and mine dewatering proximal to Sishen Mine.

3.3.3.1 Rainfall and recharge

Rainfall Data

Rainfall data at Sishen Mine has been collected from the 1960's and was used as the basis for recharge estimations in the present study. The mean annual precipitation is in the order of 380 mm/a. Rainfall occurs in the summer months of the year (October through to April), greater than 50% of annual rainfall occurs between January and March. Significant rainfall events occurred in 1974, 1988 (268 mm fell in February alone), 1991 and more recently during 2011 and 2014.

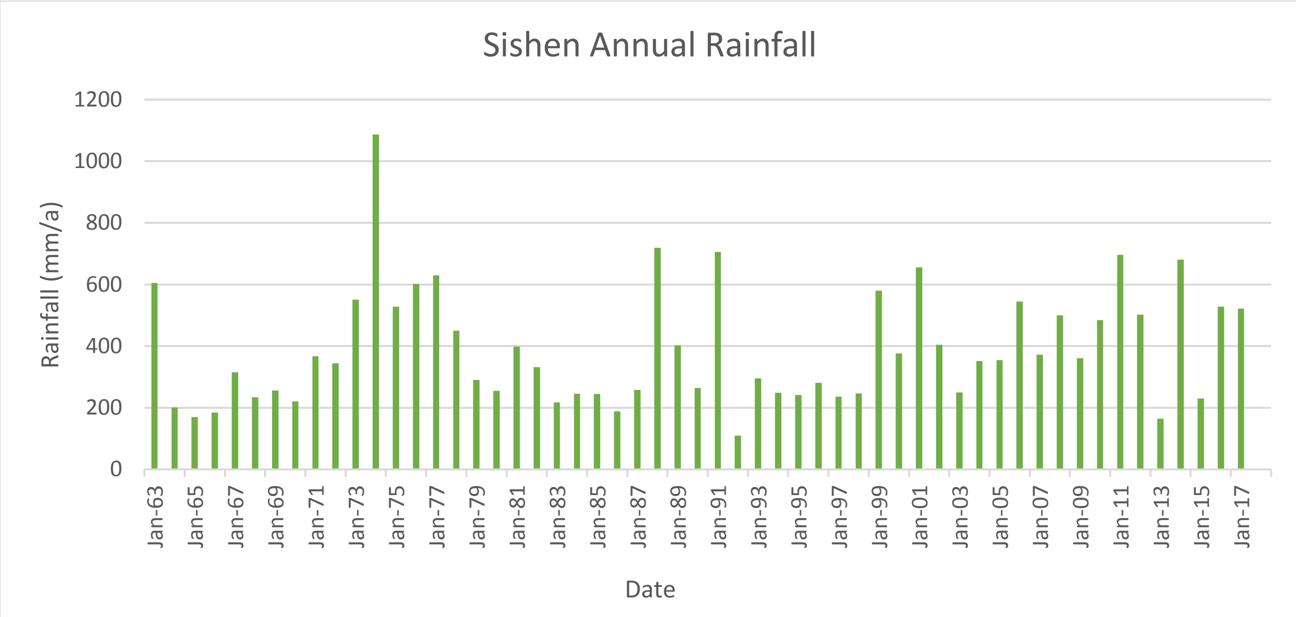


Figure 3: Sishen South Rainfall Station – Annual Rainfall Data

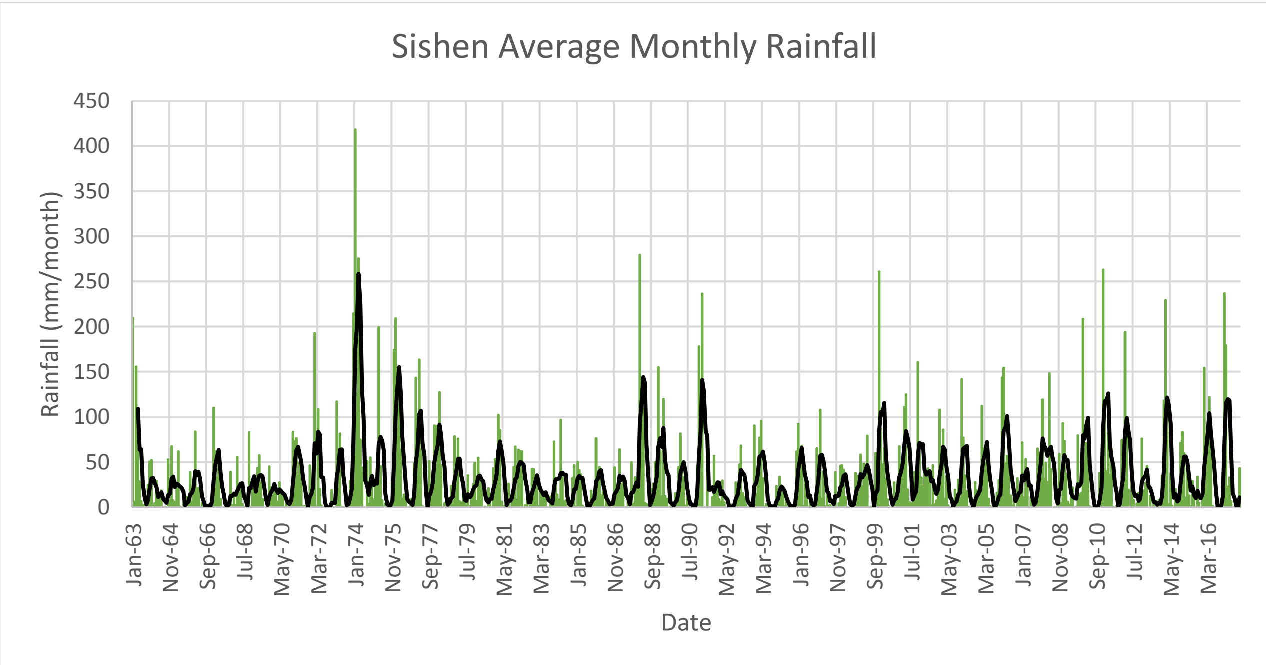


Figure 4: Sishen South Station – Monthly Rainfall Data

In addition to significant seasonal variations, quaternary catchment D41J, experiences significantly variable rainfall in the lowland areas (proximal to the mines) (360 -380 mm/a) compared with the highlands (Kuruman Hills and Koranna Berg) (480 mm/a).

Recharge Estimates

Utilising mean annual precipitation and groundwater chloride concentrations, recharge estimates were made at sub-groundwater management unit scale. The eastern groundwater units comprising the Kuruman hills displayed estimated recharge values in the order of 30 -45 mm/a. The Koranaberg hills and the catchment areas east of the mines were estimated to have recharge in the order of 22 mm/a. In the lowland areas (proximal to the mines) recharge was estimated to be 1 mm/a owing to the presence of the Kalahari sediments.

When considering recharge in a numerical model, it is necessary to evaluate not only a mean or median expected recharge value but also to assess the transient estimated recharge through time. In this way the mechanism of recharge to the aquifer can be better understood and answering questions such as;

- Does recharge infiltrate the aquifer in a linear manner or exponentially?
- Are increasing/or decreasing trends in water levels attributed to sinks such as pumping or is it a reflection in rainfall variations (floods/droughts),
- What storativity is required to account for the amplitude in water levels within the aquifer?

Through trial and error, it was found that the fluctuations in water levels were adequately obtained by considering a linear recharge trend derived from the cumulative rainfall departure. Where monthly rainfall exceeds the average long-term trend and a positive Cumulative Rainfall Departure prevails, water levels are expected to increase. The following key trends were identified;

- Water levels are expected to decrease over time as a consequence of negative cumulative recharge to the system from 1982 to 1988.
- High rainfall in 1988 caused an increasing trend until 1992 before a decreasing trend was again observed until 2000.
- Between 2000 to present a gradual increasing trend is observed.

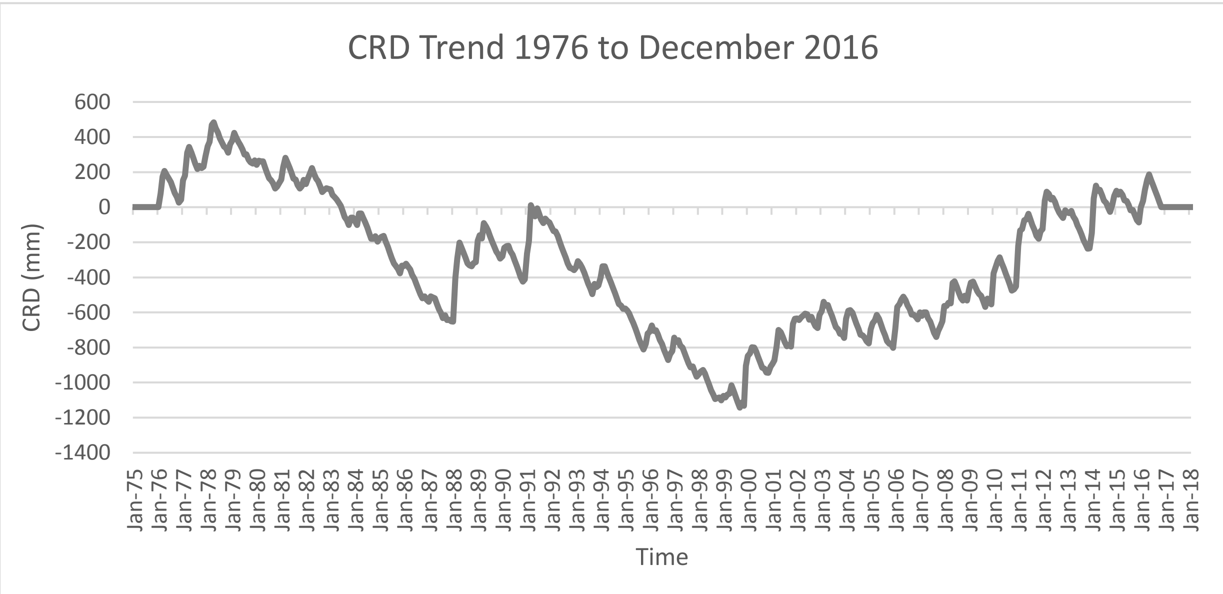


Figure 5: Cumulative Rainfall Departure based on Sishen recharge (1976 – 2016)

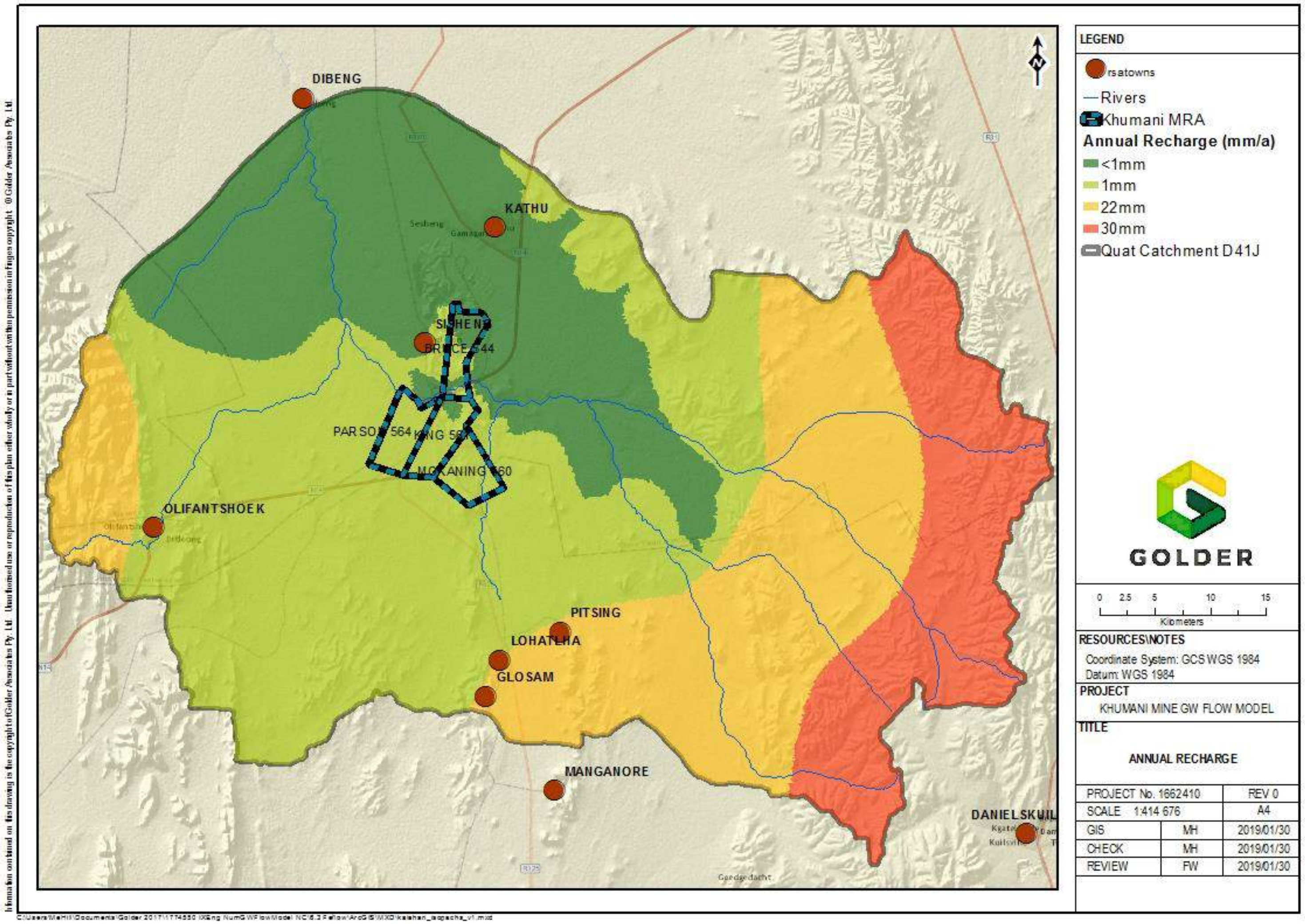


Figure 6: Recharge distribution Quaternary Catchment D41J

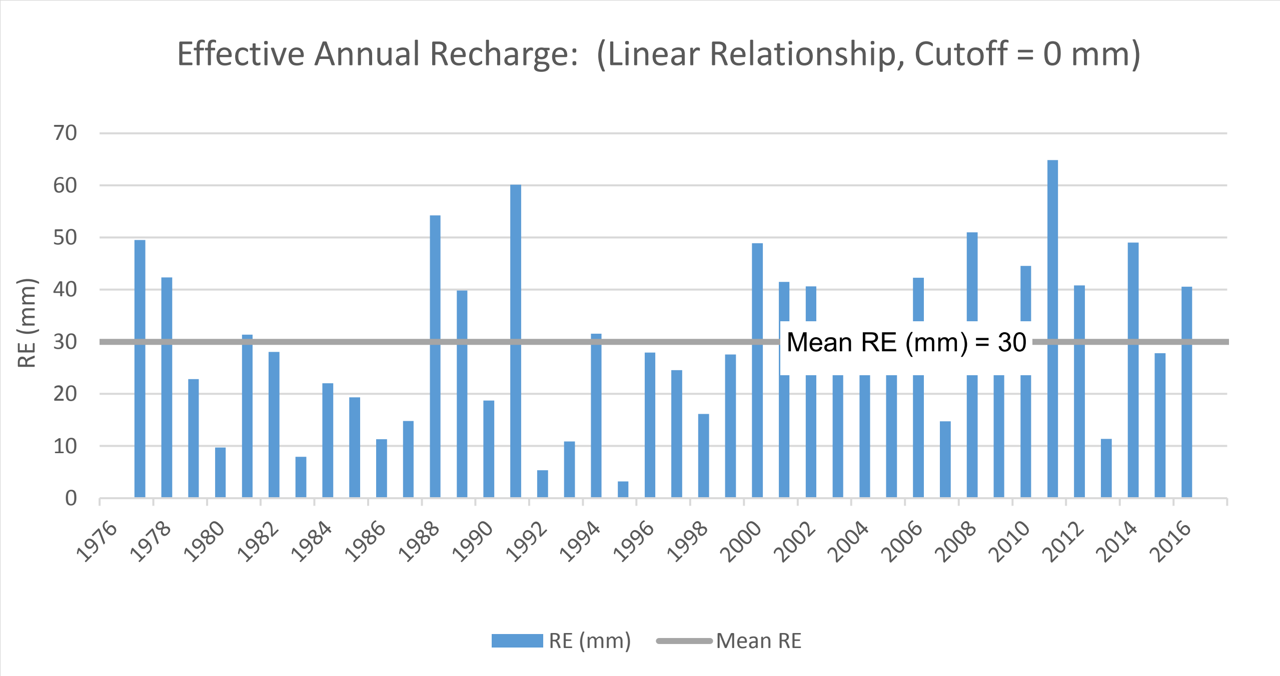


Figure 7: Effective annual recharge obtained from CRD analyses (average recharge: 30 mm/a)

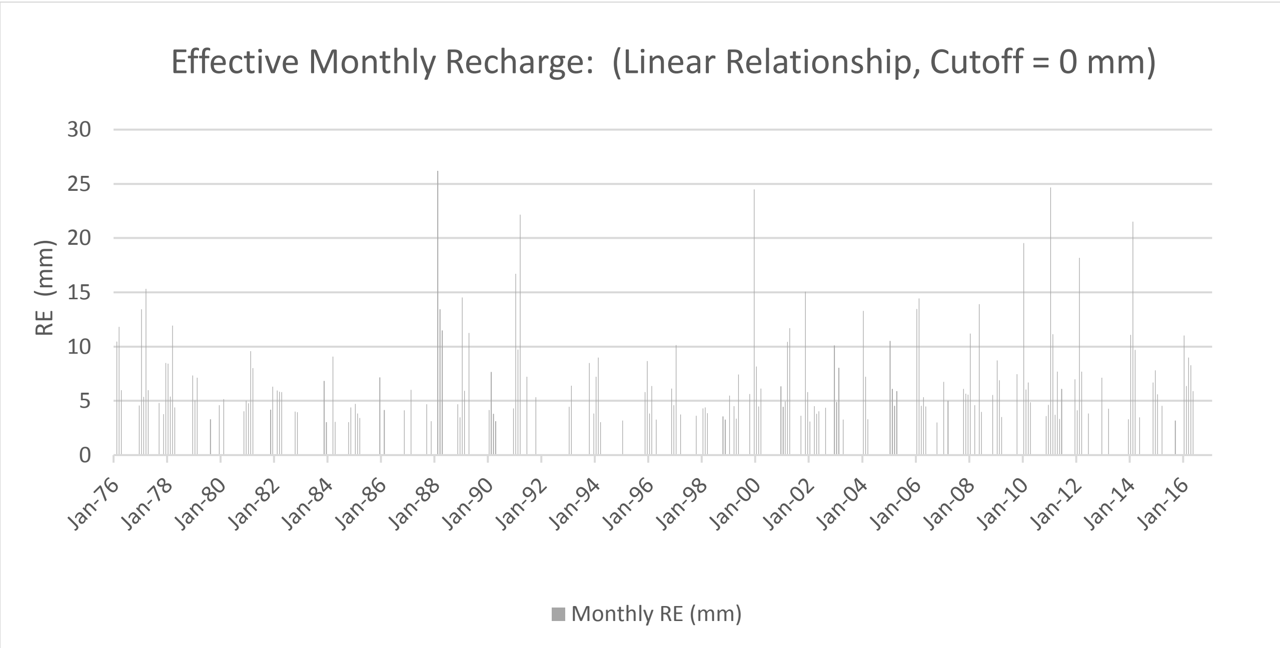


Figure 8: Effective monthly recharge obtained based on the CRD analyses (average recharge 30 mm/a)

3.3.3.2 Groundwater abstraction and mine dewatering

Abstraction for mine dewatering purposes was initiated in the 1970's due to the permissible ramp-up in production at Sishen mine following the completion of the rail network. The average pumping rate between 1976 and December 2016 is approximately 400 l/s. Abstraction has not gradually increased over time, rather the dewatering requirement has remained within the same magnitude over the past 40 years, with the exception of the period between 2000 - 2004 where abstraction rates were reduced to below 315 l/s. Due to the presence of the dolerite/diabase dykes which caused compartmentalised dewatering. The average rates of the North, South and West mines (compartmentalised by structures) are outlined below;

South Mine

- Abstraction from the South Mine area is on average 207 l/s. Hence approximately 50% of Sishen's total abstraction has historically been associated with South Mine, proximal to the Khumani area.
- The high pumping rates of South Mine is attributed to interflow between compartments along the Sekgame dyke due to the thick succession of Kalahari sediments overlying the structure.

North Mine

- Abstraction from the North Mine area is on average 121 l/s over the past 40 year abstraction period.

West Mine & additional abstraction

- Abstraction from the West Mine area is on average 22 l/s
- Water supply boreholes north of the mine (Golf Course and Kathu supply) accounts for approximately 50 l/s.

The dewatering rate over time proximal to the three mining areas are outlined in Figure 9.

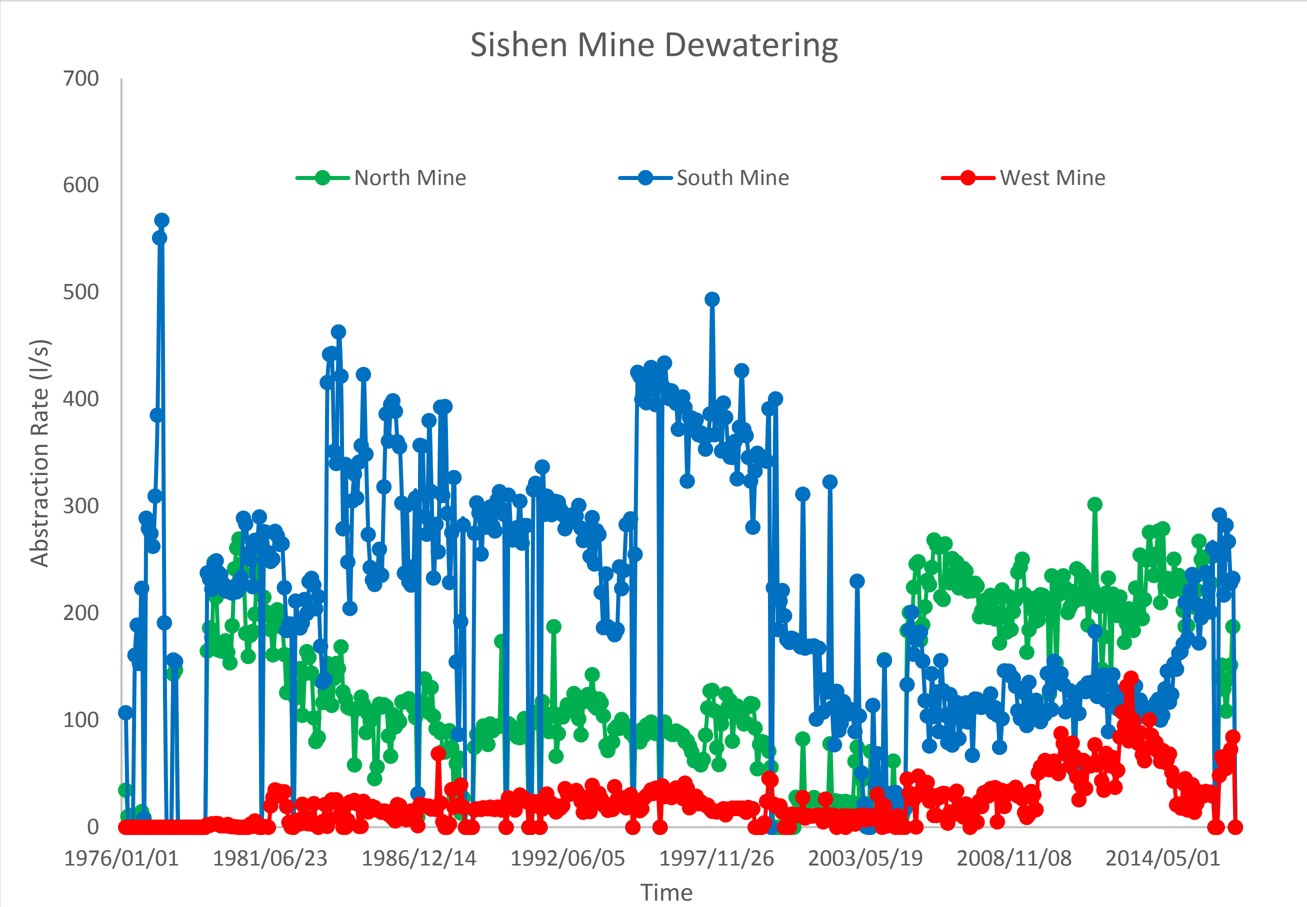


Figure 9: SIOM Dewatering

Khumani Abstraction

Presently Khumani mine does not intersect the water table at its various operations and as such does not require any dewatering. In addition, to date, all water supplied to the mine is via the Sedibeng network and hence groundwater has not to date been relied upon.

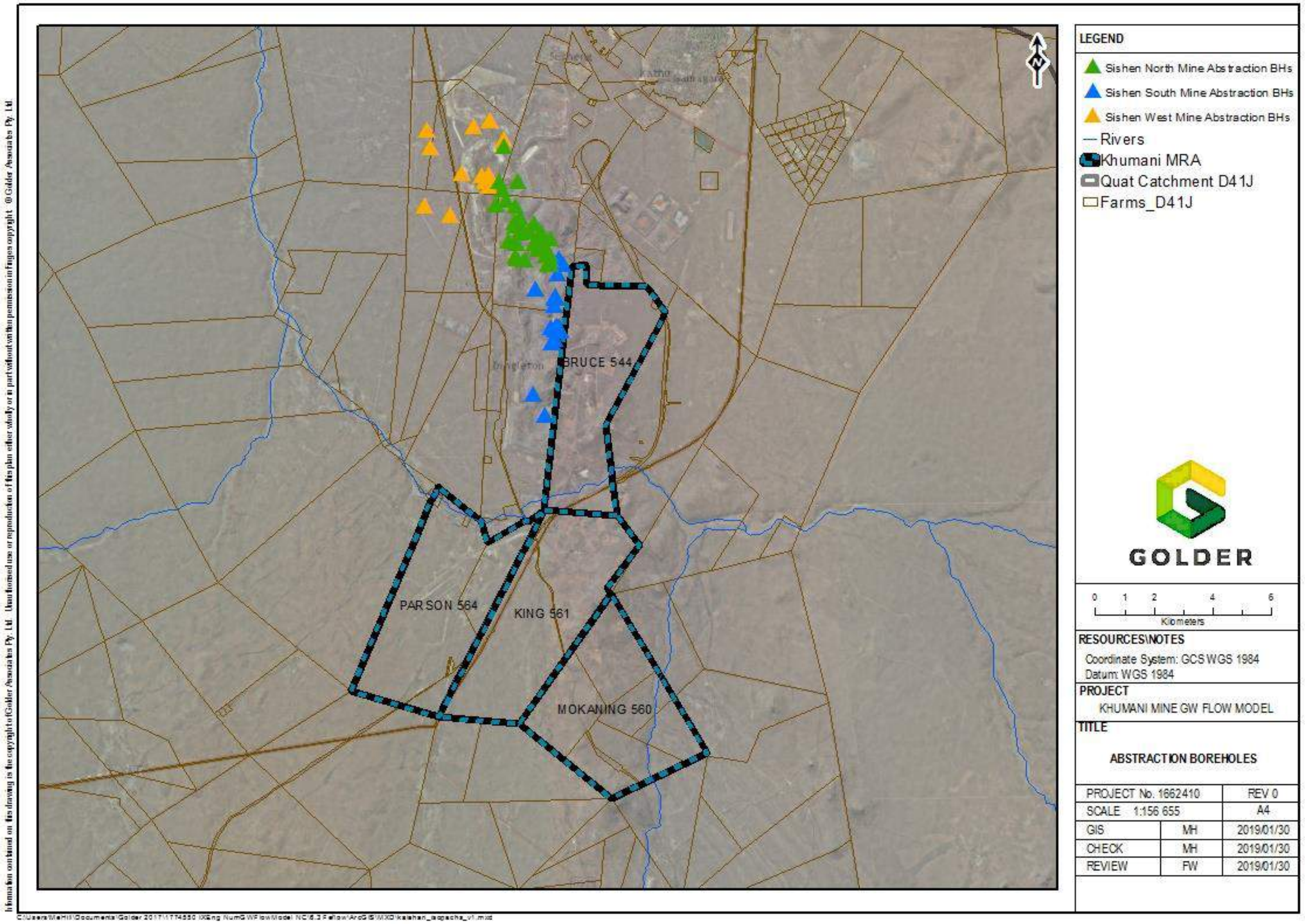


Figure 10: Mine Dewatering and Water Supply Boreholes proximal to SIOM & KIOM Mine

3.3.4 Groundwater flow directions and water levels

Understanding the extent of dewatering in the SIOM and KIOM compartment has been an on-going point of investigation since the early 2000's. Golder initiated this work in 2003 and undertook several phases to understand the control of the dykes and the extent of dewatering.

The groundwater piezometric surface is illustrated in Figure 11 and conceptually represents the elevation of the historic and 2014 groundwater table in metres above mean sea level (mamsl) in the D41J QC. The demarcated GMU's of the study area are shown as well. The piezometric surface contours are shown in 10 m intervals

The piezometric map displays the following aspects of the water table elevation in the study area:

- Based on the colour coding used to display the surface, a gradual decline occurs from the eastern highlands (i.e. the Kuruman Hills) towards the west which indicates this area as the main recharge area in the study area.
- The piezometric surface decreases form ~1 500 mamsl in the Kuruman Hills towards the northwest (Dibeng) and southwest (Matsap) with elevations at ~1 000 mamsl.
- The magnitude of boundary effects cause by the dolerite dykes systems and subsequently forming individual dolomite compartments in the study area were used to delineate groundwater management units in the study area.
- The piezometric surface in the SIOM and KIOM areas is impacted by high groundwater abstractions in the D41J-G6 GMU.

The water level drawdown distributions and the interpreted impact area is indicated in Figure 12. Based on the comparisons in hydraulic head between the 2014 water level data and the Smit (1972) piezometric data, it is inferred that the Sishen mine impact area expands toward the Gamagara River. Hence, compared with the cone delineated by Meyer (2009) there is inferred additional drawdown to the west. The extent of drawdown in the north, south and east is comparable to that interpreted by Meyer (2009).

3.3.4.1 Groundwater levels proximal to Khumani Mine

Borehole water level monitoring data at Khumani Mine has been undertaken on a monthly basis from 2008 to present. Some boreholes have been mined out, blocked or destroyed as the mine has expanded over time. Additional boreholes have also been added to the network in recent years. Approximately 25 boreholes comprise the monitoring network at present. The monitoring boreholes and the maximum water level recorded at each hole are indicated in Figure 14.

The following subsection outlines the major trends observed at the monitoring boreholes. This information has been used to inform the conceptual hydrogeological understanding in the KIOM area. The trends of the monitoring boreholes are described in the preceding section.

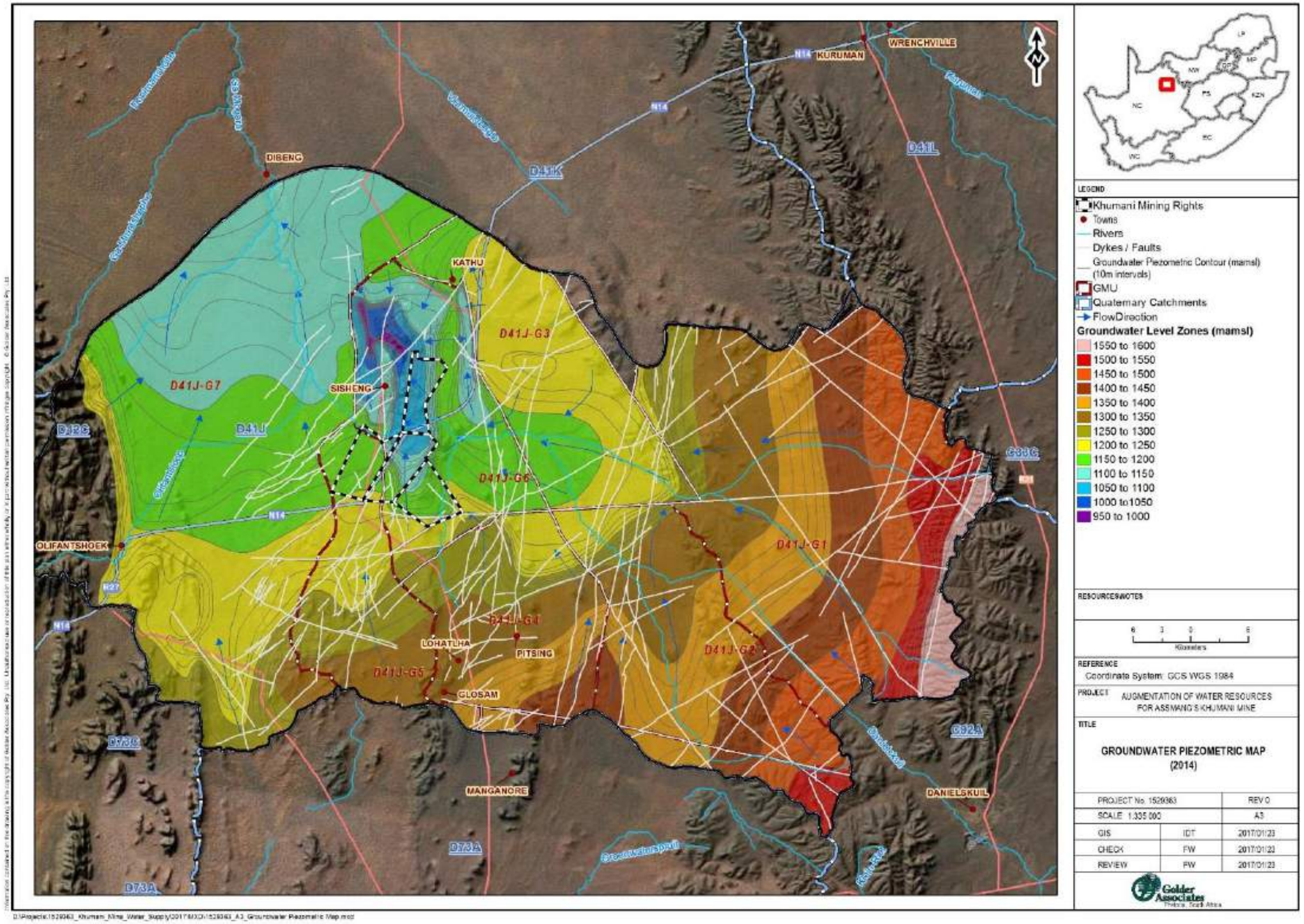


Figure 11: Groundwater piezometric surface – circa 2014

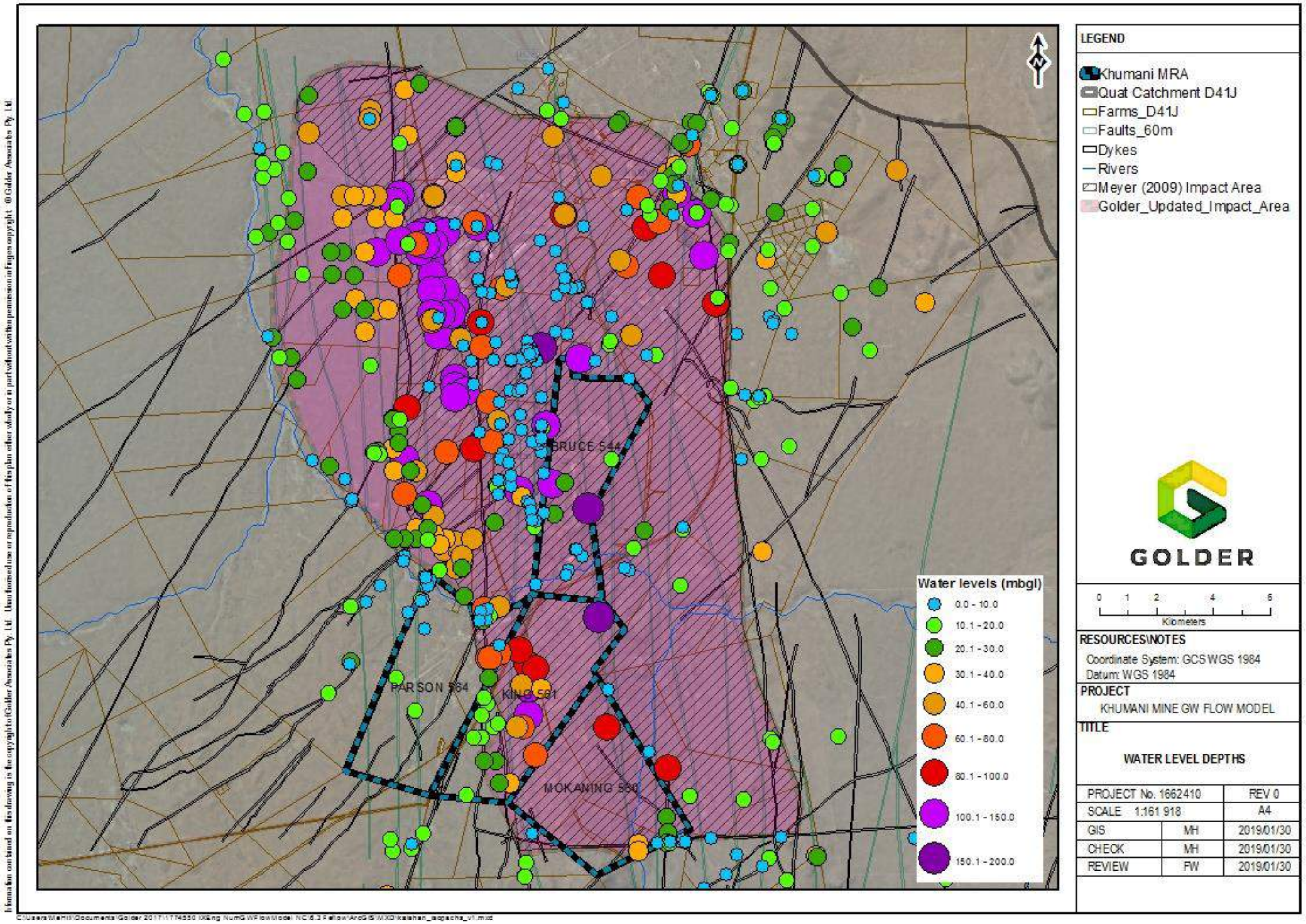


Figure 12: Water level (mbgl) distribution

Parsons Monitoring Boreholes & Boreholes beyond the mining area

Khumani Mine monitored two boreholes on the farm Parson. These boreholes are located on the western side of the dolerite dyke which has been previously identified to act as a boundary to the SIOM groundwater compartment. Water levels at PBW1 and PBW4 have been monitored on a monthly basis from 2010 to present. The recent water levels in these boreholes are approximately 7.5 and 12.6 mbgl respectively.

The water levels in these boreholes are shown to fluctuate with seasonal recharge events and have, in particular, shown a substantial water level rise following high rainfall and associated recharge in December 2016/January 2017. The most recent water levels at these boreholes are shallower than those measured in 2010 (Figure 13).

It is inferred, from the trends observed at this borehole, that drawdown from SIOM groundwater abstraction is not significantly impacting on the water levels west of the dyke. The trendlines for both PBW1 and PBW4 are flat i.e. over the monitoring period there has not been a significant rise or fall in water levels.

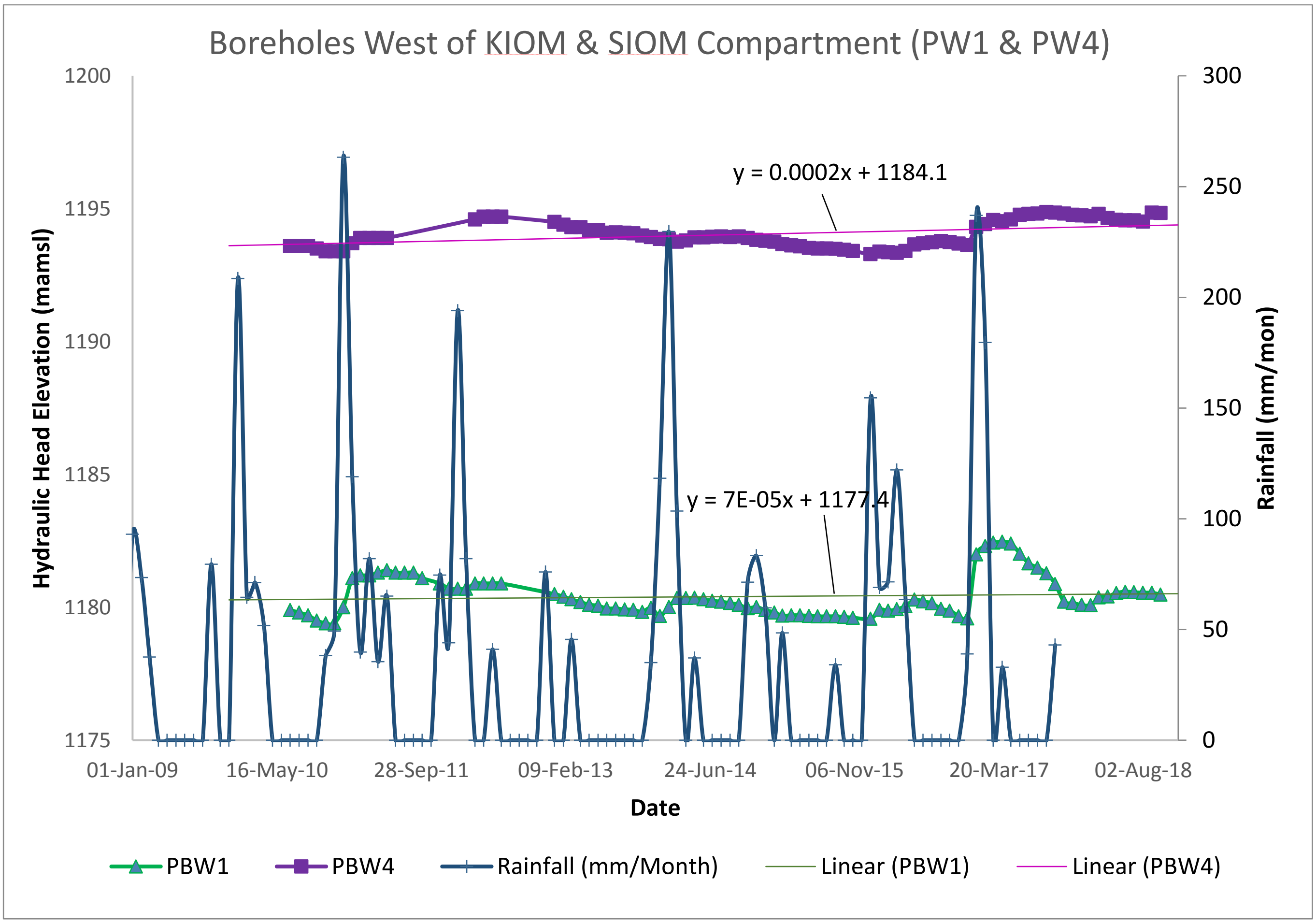


Figure 13: Parsons Boreholes – Water Level Trends

In addition to the Parsons boreholes, additional monitoring boreholes are monitored west and south west of the mine these include DE 08 on the farm dingle, BH8 on the farm Smythe, SW753 on the farm Bredenkamp and three boreholes (Roscoe 1 -3) on the farm Roscoe.

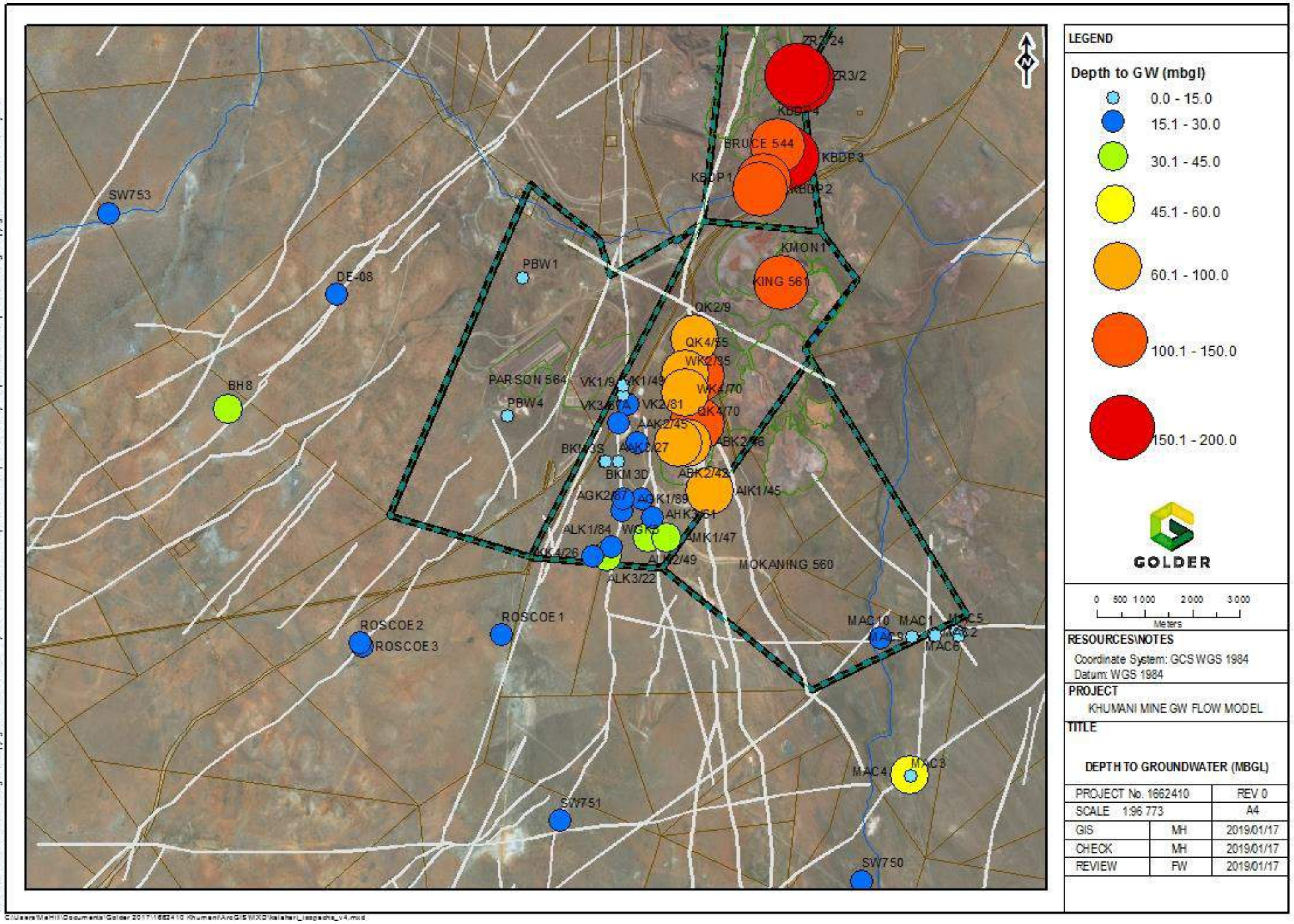


Figure 14: Khumani Mine Monitoring Boreholes – Maximum monitored depth to groundwater

DE 08 was affected by local groundwater pumping between 2015 and 2017 and has subsequently recovered to the water levels prior to pumping i.e. 2012 -2015 water level. The abstraction resulted in a 32 m drop in water level at this borehole. The most recent water level is higher than the water level at the start of monitoring in 2012 (Figure 15).

BH 8 on the farm Smythe is located along the same structure targeted by DE 08. Based on available data the water level has continued to decrease gradually despite the recharge events which positively influence the other monitoring boreholes. This decrease is attributed to local abstraction for supply on the farm. It is not thought to be related the mine dewatering as this borehole is located beyond DE 08 which showed no effect related to mine dewatering (Figure 15).

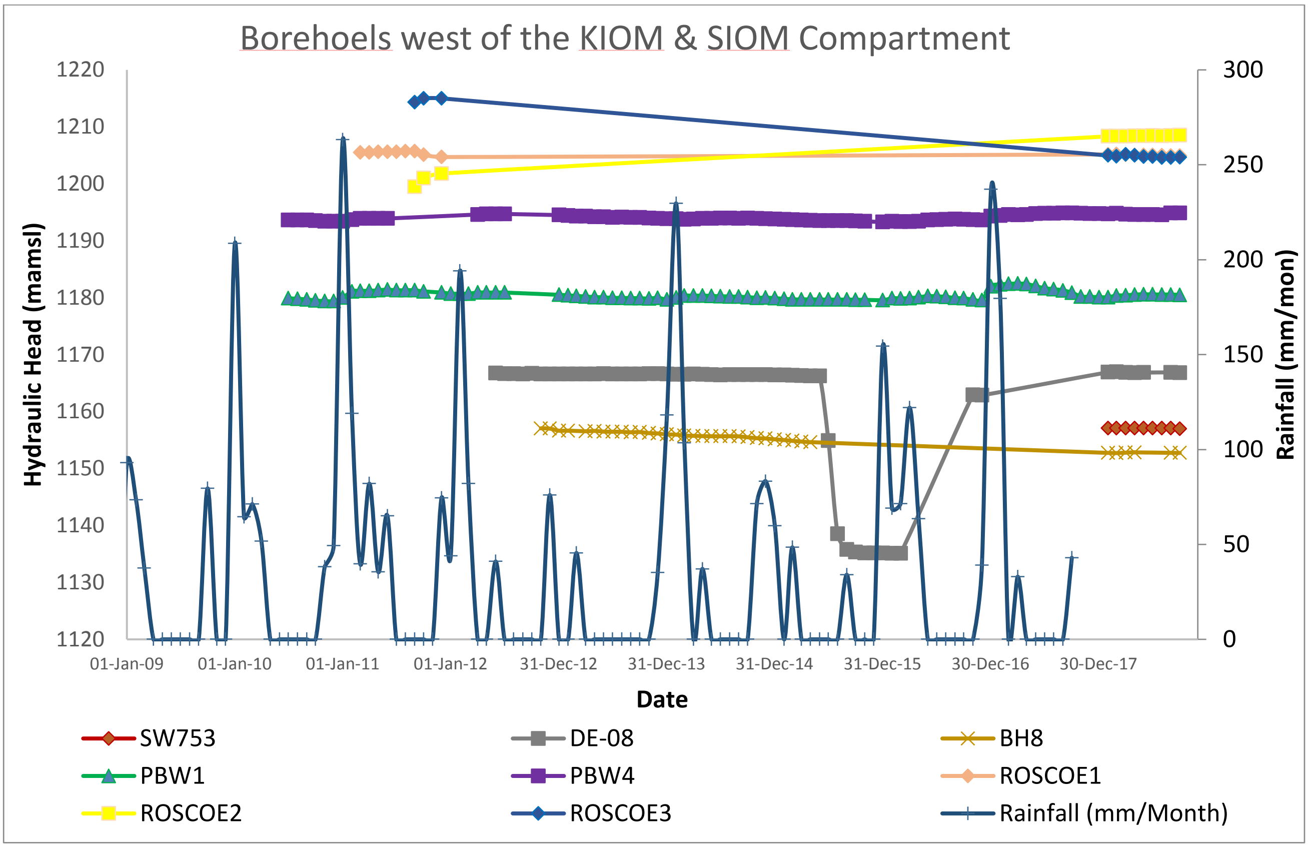


Figure 15: Boreholes West of the KIOM & SIOM Compartment

The Roscoe boreholes have been influenced by local abstraction, the water level at Roscoe 3 has dropped while at Roscoe 2 a rise in water level was observed.

There is no evident long term decreasing trend in these monitoring boreholes which could be attributed to SIOM pumping.

Kind Monitoring Boreholes

VK1/49, VK1/9, VK2/81, VK3/67A, and AAK2/45 are located on the lava and are proximal to the dyke which is inferred to behave as compartment boundary limiting drawdown in water levels beyond the dyke. The water level trends in all boreholes show significant seasonal fluctuation in response to recharge (Figure 16).

The amplitude in water level changes is most significant in VK3/67A which showed a 10 m water level rise following the rainfall events in December 2016 and January 2017. The trendlines for these boreholes shows a declining trend which is inferred to indicate the effects of SIOM dewatering. However, the effects of SIOM abstraction at these boreholes is not yet greater than the effects of recharge and consequently seasonal fluctuation is apparent.

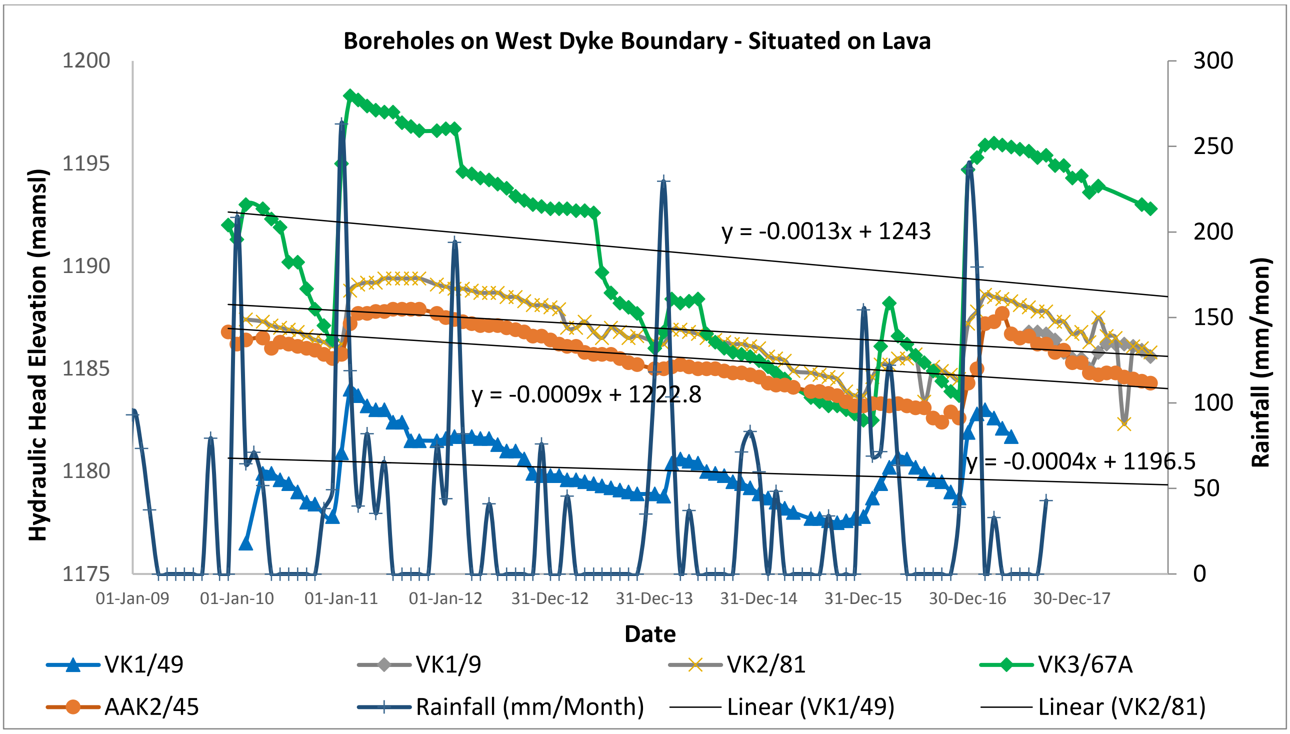


Figure 16: Boreholes on the West Dyke Compartment Boundary-13 Km South Sishen North Mine Area

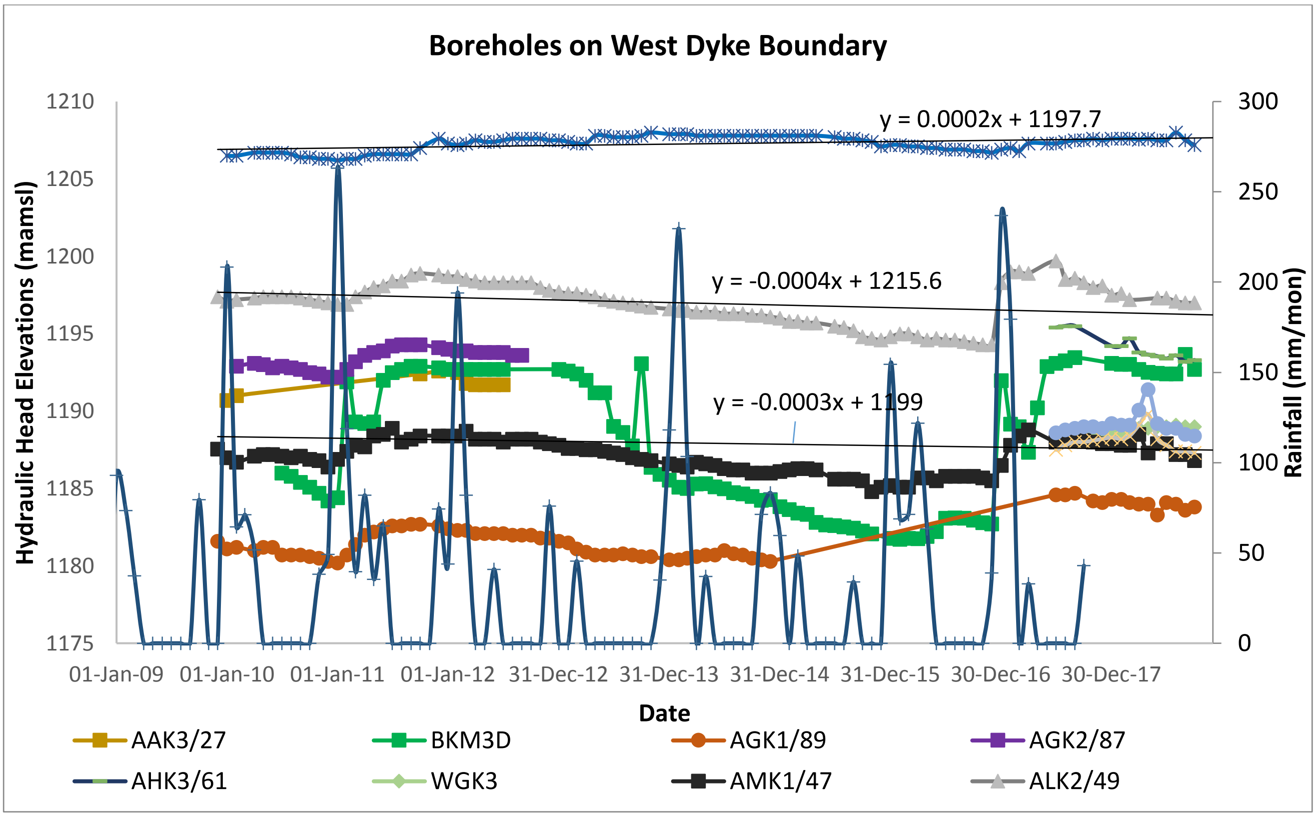


Figure 17: Boreholes on the West Dyke Compartment Boundary-16 km South Sishen North Mine Area (limited Influence of SIOM abstraction)

The boreholes depicted in Figure 17 are also situated along the compartment boundary dyke. Compared with boreholes near VK3/67A, the water levels in these boreholes show very little effect of SIOM dewatering. Several of these boreholes have water levels in 2018 which are higher than those measured in 2010 as a consequence of recent recharge events. The water levels at these boreholes are typically 15 -30 mbgl.

Boreholes east of the compartment dyke – Near King Pits

Boreholes east of the dyke and situated on the Farm King 561 are underlain by shales. The water levels in these boreholes typically range between 60 -100 mbgl. The deep water levels are indicative of dewatering associated SIOM dewatering (Figure 18). These boreholes are located near a recently identified north-south striking dyke. Based on available water levels, it is interpreted that water levels closer to the dyke (QK2/9,WK4/70,QK4/70) and QK4/70) are considerably deeper (Approximately 100 mbgl) than those boreholes further away from the dyke (QK4/55,WK2/35 and ABK2/45) which are typically 40 -60 mbgl.

- QK2/9 has a water level approximately 92 mbgl. The trend over the monitoring period has gradually increased over the monitoring period. This trend is in contrast with QK4/55 which has shown a decreasing trend between 2010 and 2017.
- The similarity in water level depth despite increasing distance from the SIOM well fields indicates that the structure along which QK2/9, WK4/70 and QK4/70 is highly conductive.

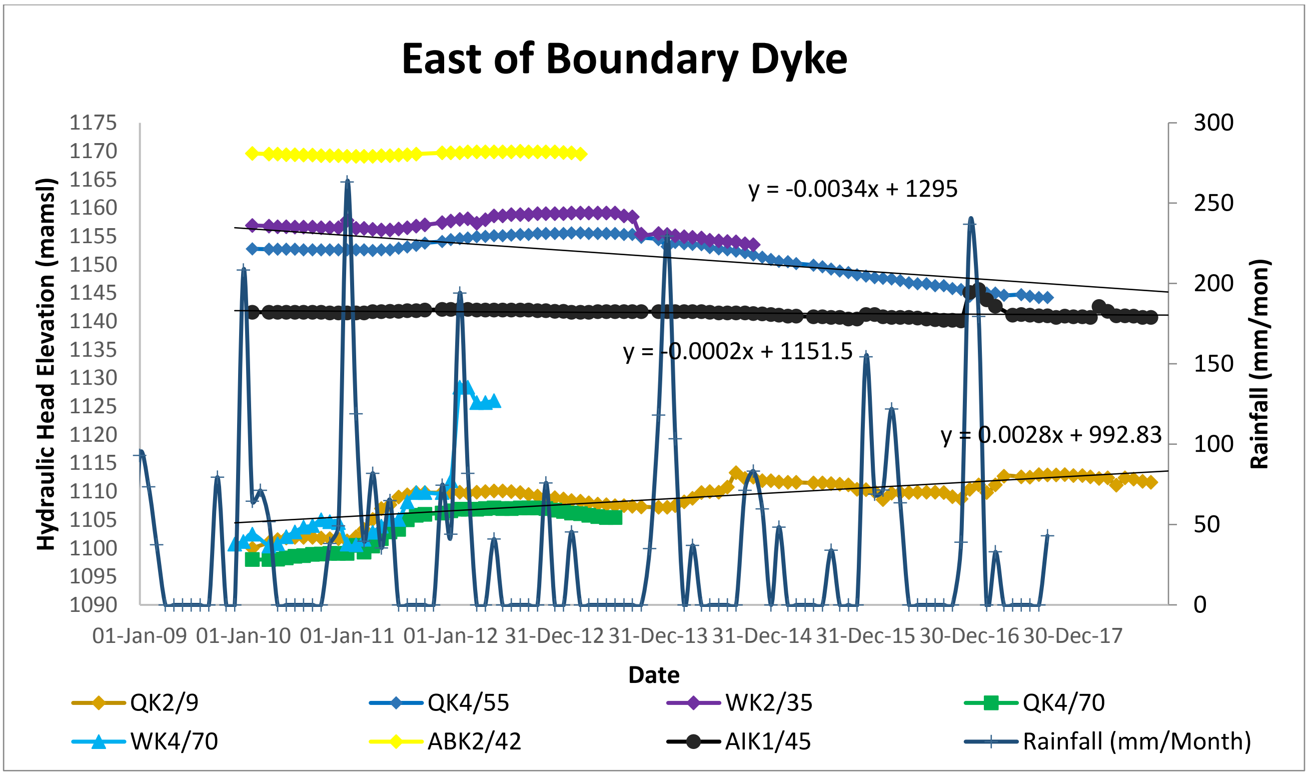


Figure 18: East of the Boundary Dyke - Water Level Trends

The KMON1 and KMON2 boreholes are located on the Northern part of the King Farm King in close proximity to the Paste Dam and the KMO2 pit respectively. Both boreholes show a decreasing trend throughout the monitoring period as a consequence of dewatering from SIOM (Figure 19). The influence of recharge events is not as significant as the trends observed at boreholes along the compartment boundary and beyond the compartment area.

- KMON 1 and KMON 2 is decreasing at rate of approximately 1.1 - 0.9 m per year

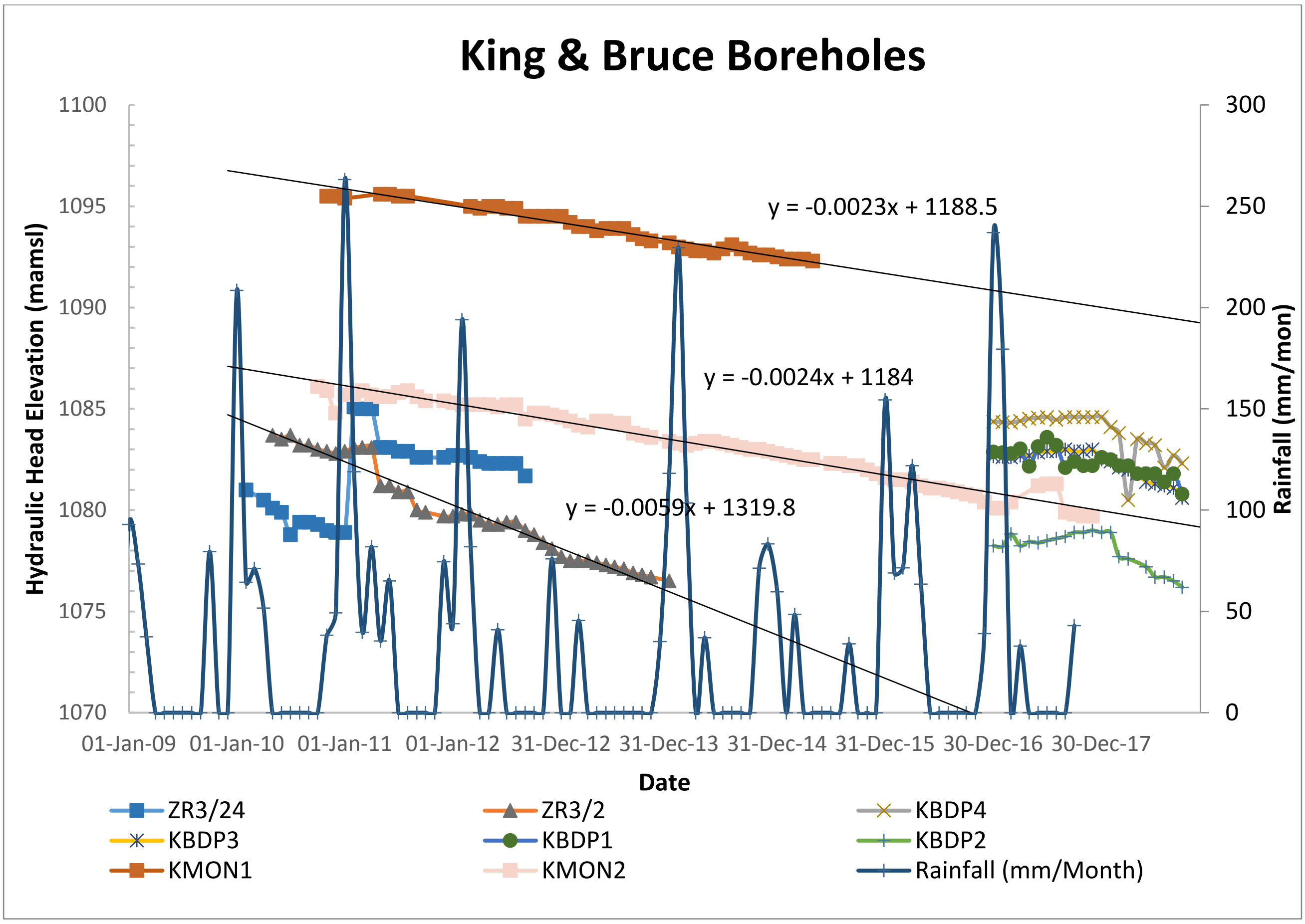


Figure 19: King & Bruce Boreholes

ZR3/24 & ZR 3/2

ZR3/24 and ZR 3/2 are the northern most Khumani monitoring boreholes and thus are located closest to the active SIOM dewatering boreholes. Hence it is expected that the boreholes have the deepest water levels. Monitoring at ZR 3/24 ceased in 2012 and ZR 3/24 stopped in 2014 (Figure 19).

- ZR3/24 from 2011 had a declining head in the order of 0.6 m/year. The last measured water level in 2012 was 184.3 mbgl.
- ZR3/2 had a declining water level rate in the order of 1.75 m/year. The last measured water level was 189.5 mbgl (2014). The borehole is located on a north-south fault zone and thus it may be that the greater rate of drawdown observed at this borehole compared to ZR3/24 could be attributed to the more conductive zone linked to the SIOM dewatering area.

KBDP 1, 2, 3, & 4

The newly drilled augmentation boreholes have been added to the Khumani monitoring network. Since January 2017, water levels in KBDP 1, 3 and 4 displayed a a gradual increasing trend following the high rainfall event in December 2016 and January 2017. Between 2018 to present a decreasing trend has been observed and water levels have dropped by approximately 2 m over this period.

3.3.5 Groundwater quality characteristics

Groundwater quality monitoring is undertaken at boreholes; PBW 01, PBW04, BKM3D, PBE01 and Markram typically on a bi-monthly basis and hence the program is focused primarily on the farms Parsons and King.

- PBW04 is located up gradient of the stockpile on Parsons 564 and occurs within the approved footprint for the stockpile. It therefore has limited longevity as a monitoring point and will be required to be replaced.
- PBW01 is located 200m west of the explosives storage area.
- PBE01 is located on the farm boundaries of parson and King, North east of the Parsons loading area.
- Markram borehole is located 3 Km North North East of the Loading Area and adjacent to the Gamagara river.
- BKM3D is located 2 km south east of the existing parson stockpile and is located up gradient of Parsons infrastructure. It is therefore expected to reflect background conditions.

Parsons farm is not dewatered due to the a regionally extensive dyke which traverses King. Consequently, potential contamination of the shallow aquifer is required to be monitored. East of the Dyke on King and Bruce, the shallow aquifers are dewatered and monitoring of the upper aquifer is irrelevant.

The baseline was established at PBE01, BKM3D, PBW01 and PBW04 in 2007.With exception of PBE01, It is evident from the baseline that water quality at the sampling points typically has a low salt load and is representative of unimpacted groundwater. The salt loads and the macro chemistry of the PBE01 varies from the other sites monitored. While all other boreholes represent the Ongeluk lava, PBE-01 is drilled into outcropping diamictite of the Makganyene formation which may explain the markedly different macro chemistry at this site.

Table 3: Groundwater quality baseline collected in 2007

Baseline Water Qualities as per the Groundwater Results dated April 2007:								
Analyte:	Unit:	Preliminary water quality Reserve Requirement:	Class I	Class II	PBE01	BKM3D	PBW01	PBW04
pH		8.3	9.5	10	8.2	7.6	7.7	7.7
Electrical Conductivity	mS/m	115.6	150	370	110	77	98	75
Total Dissolved Solids @ 180°C	mg/l	827	1000	2400	720	360	620	400
Calcium as Ca	mg/l	93.8	150	300	85	48	76	53
Magnesium as Mg	mg/l	70.4	70	100	44	51	52	38
Sodium as Na	mg/l	60	200	400	77	28	47	44
Potassium as K	mg/l	4.9	50	100	5.1	3.7	2	1.8
Chloride as Cl	mg/l	140.5	200	600	42	47	54	45
Total Alkalinity as CaCO3	mg/l	364.8			190	350	370	310

Baseline Water Qualities as per the Groundwater Results dated April 2007:								
Sulphate as SO4	mg/l	80.6	400	600	340	6.8	22	9
Nitrate as NO3 (presented as N on table 5)	mg/l	14.8	10	20	1.4	0.48	12	4.9
Fluoride as F	mg/l	0.5	1	1.5	0.65	0.14	0.33	0.23
Manganese as Mn	mg/l		0.1	1	0.005	0.02	0.005	0.06
Iron as Fe	mg/l		0.2	2	0.01	0.01	0.02	0.06
Total Hardness as CaCO3	mg/l				390	330	400	290
Suspended Solids	mg/l				18	120	60	66

The piper diagram below indicates the characteristics of the sampled borehole in 2007 (Baseline sampling) and in 2017. With the exception of all PBE-01, all samples plot as a Ca-Mg-HCO_3 type water which is indicative of unimpacted groundwater. It is inferred from the piper diagram that there have been no significant changes to the characteristics of groundwater chemistry in proximity of the monitoring boreholes during the operational phase.

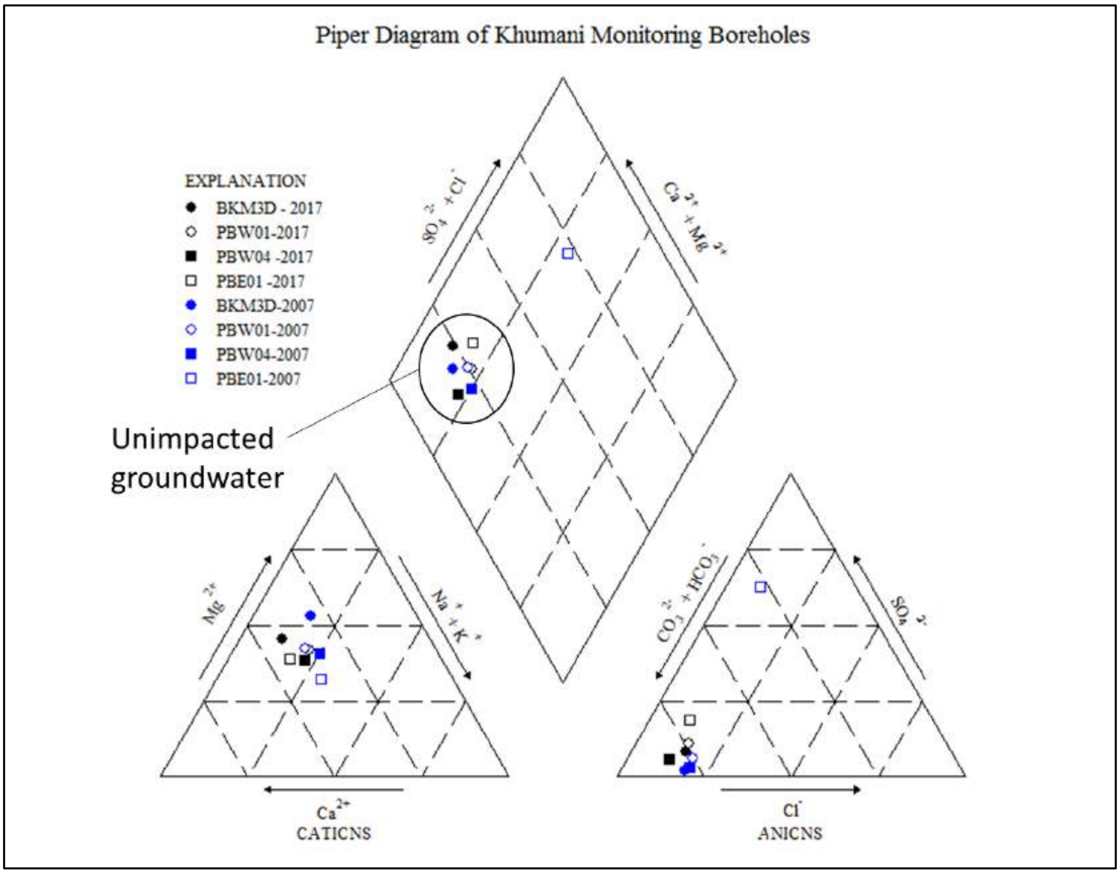


Figure 20: Khumani Mine - Piper Diagram 2007 versus 2017

The macro chemistry trends of the monitored boreholes are depicted in Figure 23 -Figure 27. The following observations are drawn from the trends presented;

- Following the high rainfall event in December 2016/January 2017 the sulphate, alkalinity, chloride, calcium and magnesium all increased in BKM3D. Sodium decreased significantly following the rainfall event.
- A similar trend was observed in chloride concentrations in all boreholes excepting the Markram Borehole following the rainfall even in 2016/2017.
- PBW01 has displayed comparatively high nitrate concentrations since the initiation of monitoring. An increasing nitrate concentration was observed between 2014 and August 2016. Thereafter a steeply decreasing trend has been apparent.

There concentrations of macro constituents and the trends observed are not indicative of contamination associated with the mining activities. The fluctuations are rather a reflection of recharge processes.

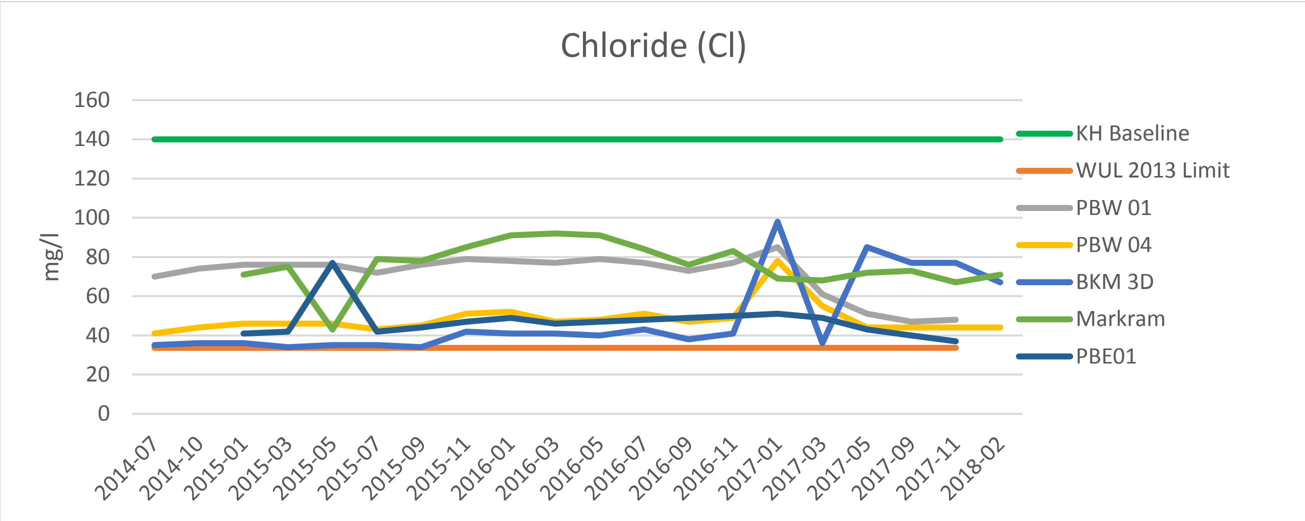


Figure 21: Chloride Trends

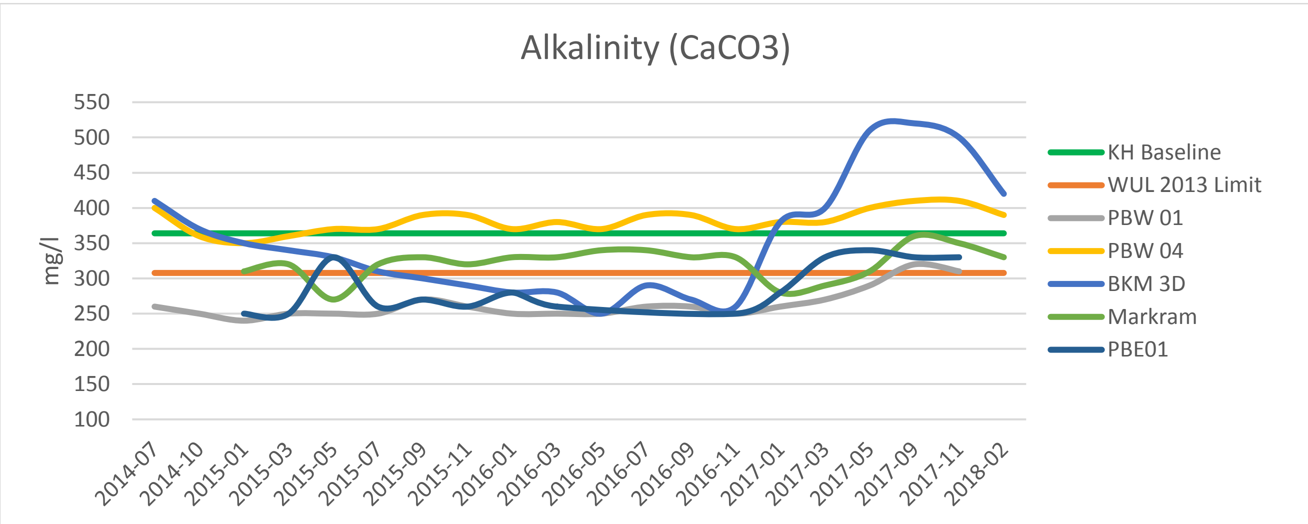


Figure 22: Alkalinity Trends

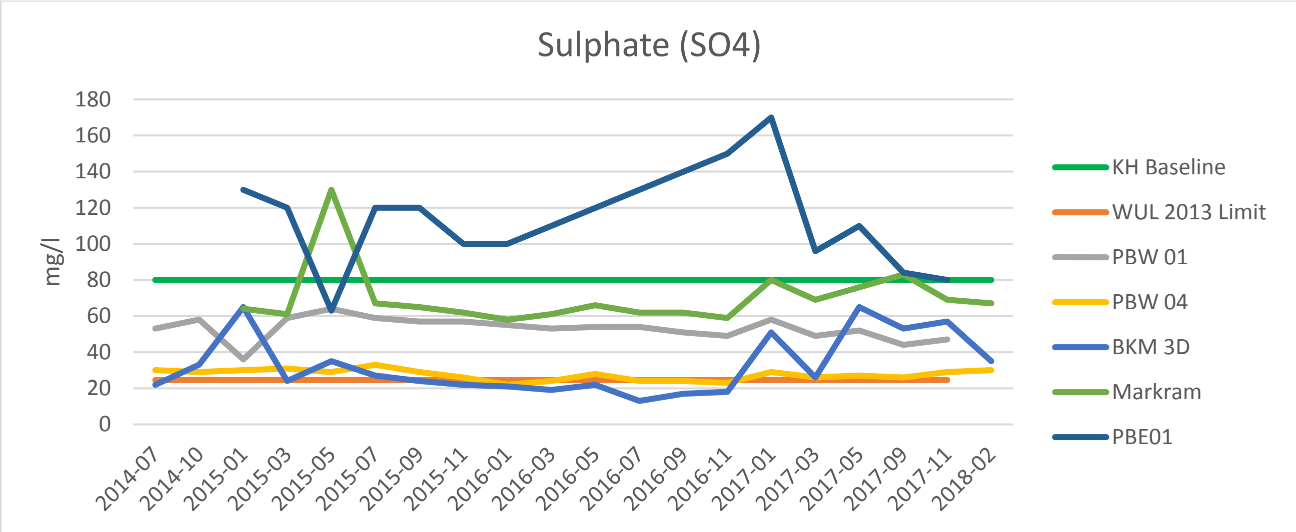


Figure 23: Sulphate Trends

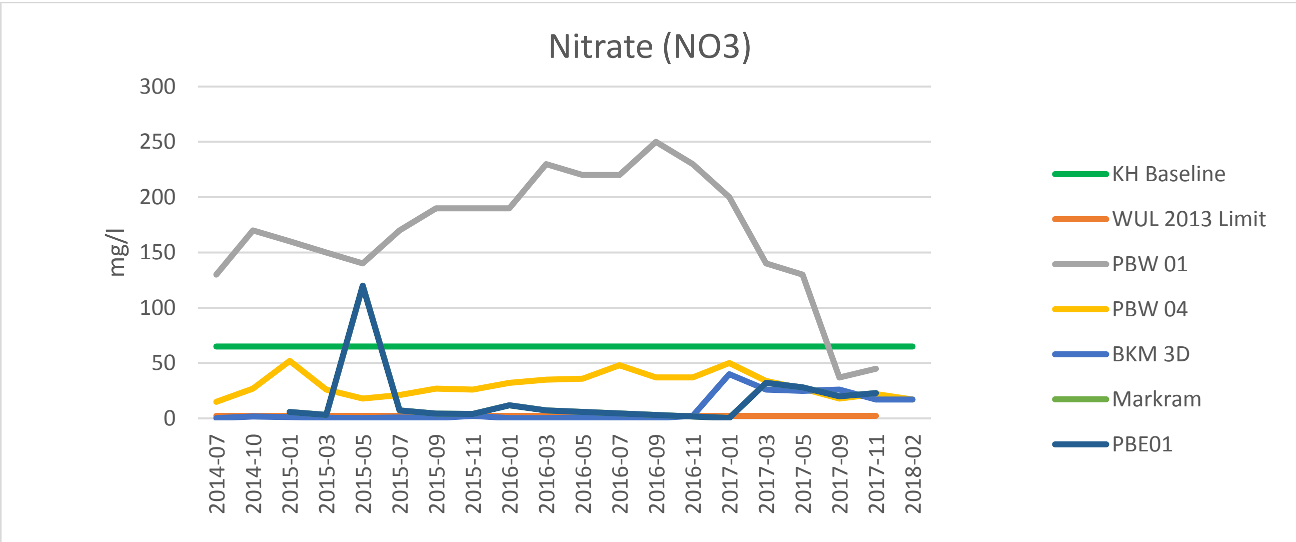


Figure 24: Nitrate Trends

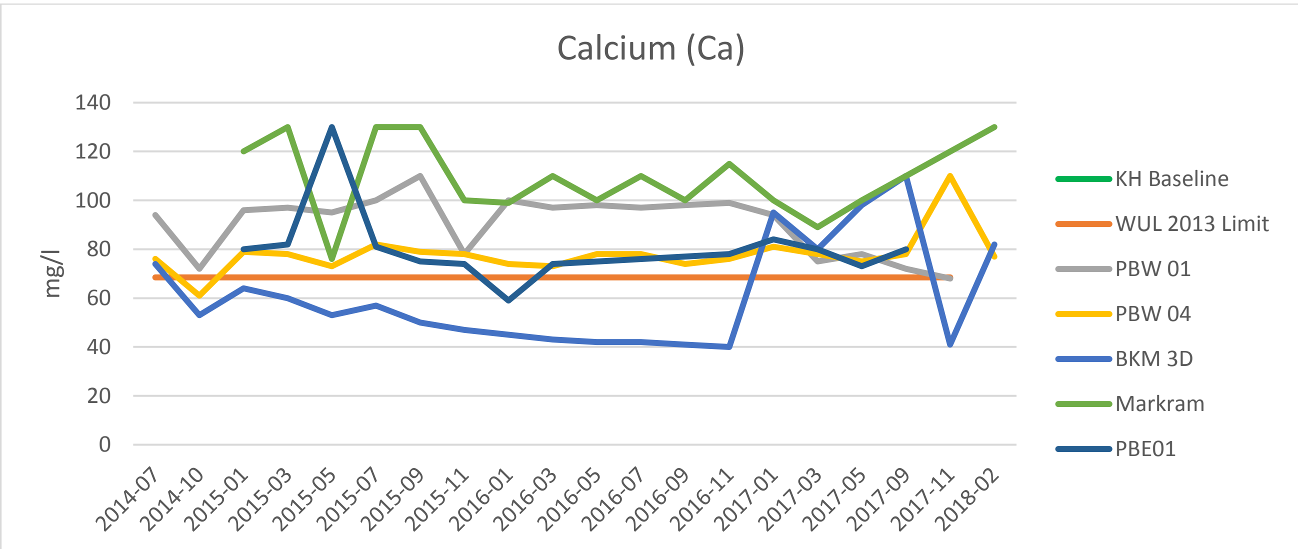


Figure 25: Calcium Trends

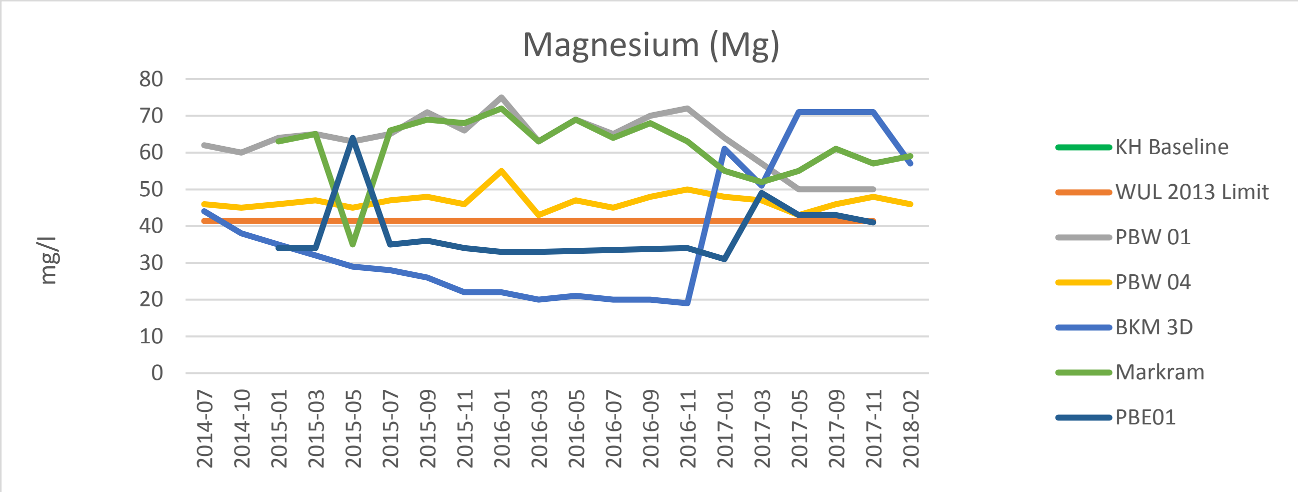


Figure 26: Magnesium Trends

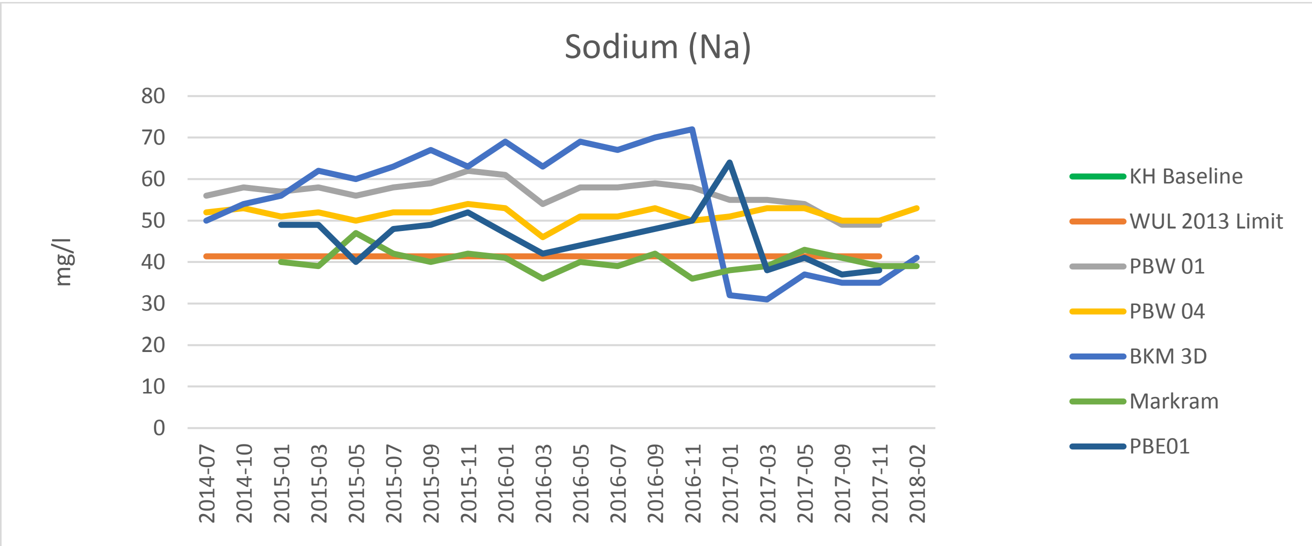


Figure 27: Sodium trends

3.3.6 Receptors

As outlined in the preceding section, the KIOM and SIOM compartment has been significantly affected by mine dewatering over the past 42 years, resulting in significant drawdown in water levels within the central portion of the compartment.

A 2017 survey was undertaken to identify potential receptors beyond the KIOM and SIOM compartment which may become impacted as a consequence of mining associated dewatering in the future. However, as discussed in the preceding section, there is currently no evidence to suggest that significant dewatering occurs beyond the western compartment dyke and hence there is no evidence to suggest dewatering of the Lava aquifers as a consequence of mine dewatering. The borehole positions surveyed, and the farm owners are indicated in figure.

42 boreholes were located south and south west of Khumani mine. The water levels in these boreholes ranged between 12 and 28 mbgl and on average the water level was in the order of 20 mbgl.

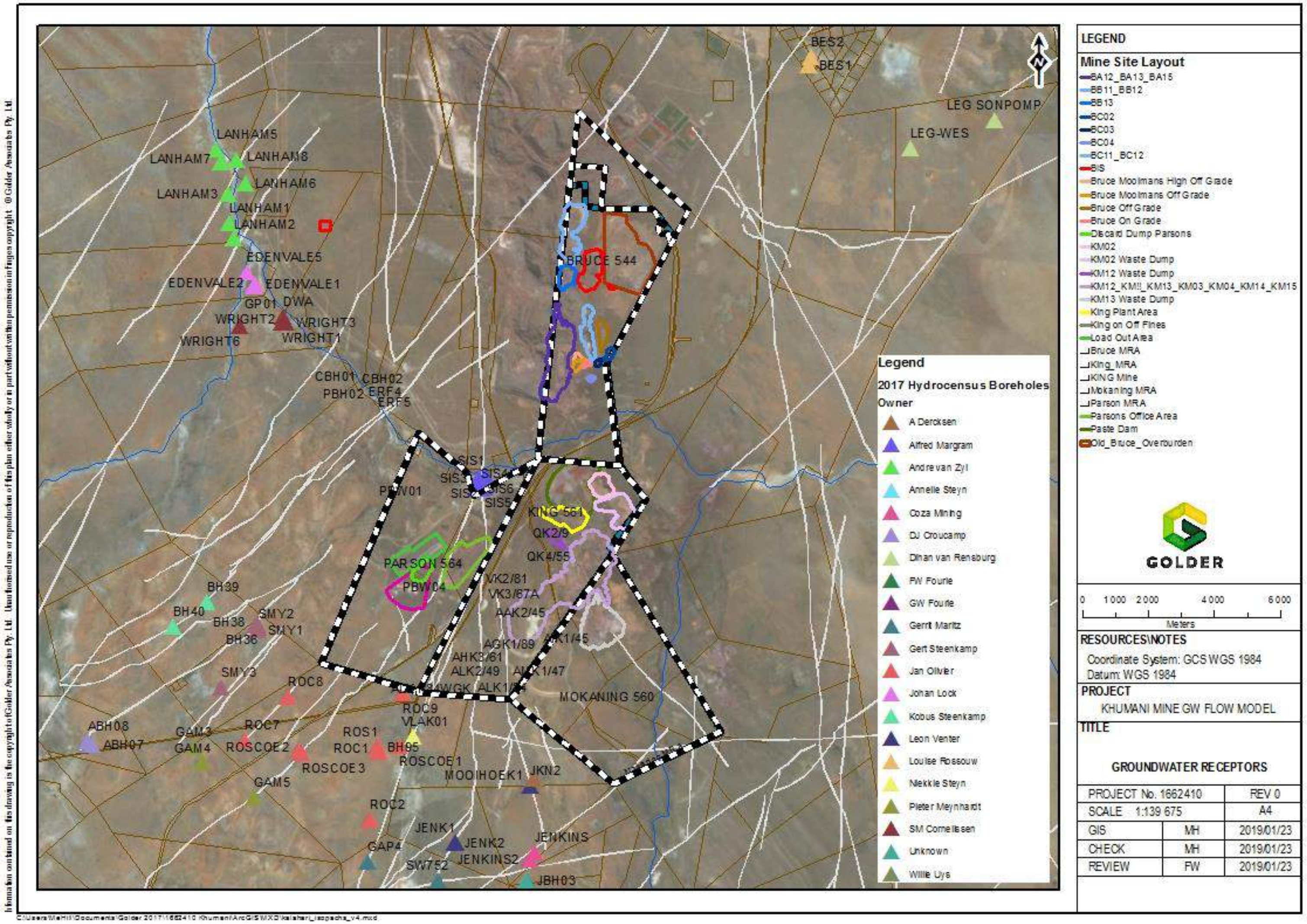


Figure 28: Hydrocensus Boreholes

3.4 Infrastructure and open pits

The Khumani mining right application area (MRA) comprises four farms, namely: Bruce 544, King 561, Parsons 564 and Mokaning 560.

On the farm Bruce, in addition to the mining pits, there are various stockpiles and a large overburden dump. The Paste Dam is located on the northern portion of the property King along with the King Plant and Waste rock dumps, KM02 and KM12. Waste Rock dump, KM13 is located adjacent to the King Pits on the farm Mokaning 560. The Parsons Offices, Load out area, Discard dump and Stockpile are located on the farm Parsons 564 (Figure 30).

The current impact assessment underway includes the expansion and development of the following facilities (Figure 31);

- Expansion of Bruce Low Grade ROM SP
- Expansion of Mokaning Low Grade ROM SP
- Expansion of Discard Dump (labelled A)
- New MRD (J) at King
- New MRD (H) at King

Mining at Khumani occurs on the farms Bruce and King via a series of open pits. The life of mine is projected currently to 2039.The deepest Bruce Pit, BA12, is planned to attain a maximum pit elevation of 930 mamsl which equates to a pit depth relative to the pre-mining surface of 270 m. The King Pits are similarly projected to be mined up until 2039 and KM15, the deepest of the King pits, is projected to reach a maximum mining elevation of 930 mamsl or approximately 280 m below the pre-mining surface (Table 4, Table 5 and Figure 29.)

Table 4: Bruce Pit Depths and backfill schedule (Pit Bottom elevation in mamsl)

Bruce	BA15	BA13	BA14	BA12	BC12	BC11	BB13	BB12	BB11
2017	1160	1160	1200	1200	1160	1180	1200	1190	1160
2018	1150	1160	1190	1200	1120	1180	1190	1180	1160
2019	1130	1160	1180	1200		1180	1190	1170	1160
2020		1160	1170	1200		1180	1190	1160	1160
2021		1150	1160	1190		1180	1190	1150	1160
2022		1140	1140	1180		1170	1190	1130	1160
2023		1130	1120	1170		1160	1190	1110	1160
2024		1120	1100	1160		1150	1190	1090	1160
2025		1110	1080	1150		1140	1190	1070	1150
2026			1060	1140		1130	1180	1050	1140
2027			1040	1130		1120	1170		1130

Bruce	BA15	BA13	BA14	BA12	BC12	BC11	BB13	BB12	BB11
2028			1010	1120		1110	1160		1120
2029				1110		1100	1150		1110
2030				1100		1080	1140		1100
2031				1090			1120		1090
2032				1080			1100		1070
2033				1060			1080		1050
2034				1040			1050		1030
2035				1020			1020		
2036				1000					
2037				980					
2038				960					
2039				930					
	Backfill					Mined Out			

Table 5: King Pit Depths and backfill schedule

King	KM02	KM11	KM12	KM13	KM14	KM15
2017	1160	1240	1230	1220	1220	1210
2018	1140	1240	1230	1210	1220	1210
2019	1110	1240	1230	1210	1220	1210
2020		1240	1230	1200	1220	1210
2021		1230	1220	1200	1220	1210
2022		1220	1210	1190	1220	1210
2023		1210	1200	1180	1210	1210
2024		1200	1190	1170	1200	1210
2025		1190	1180	1160	1190	1210
2026		1180	1170	1150	1180	1210
2027			1150	1140	1170	1200
2028			1130	1130	1160	1190

King	KM02	KM11	KM12	KM13	KM14	KM15
2029			1100	1120	1150	1180
2030			1070		1130	1160
2031					1110	1140
2032					1090	1120
2033					1080	1100
2034					1070	1080
2035					1060	1060
2036						1040
2037						1010
2038						980
2039						940
	Backfill		Mined Out			

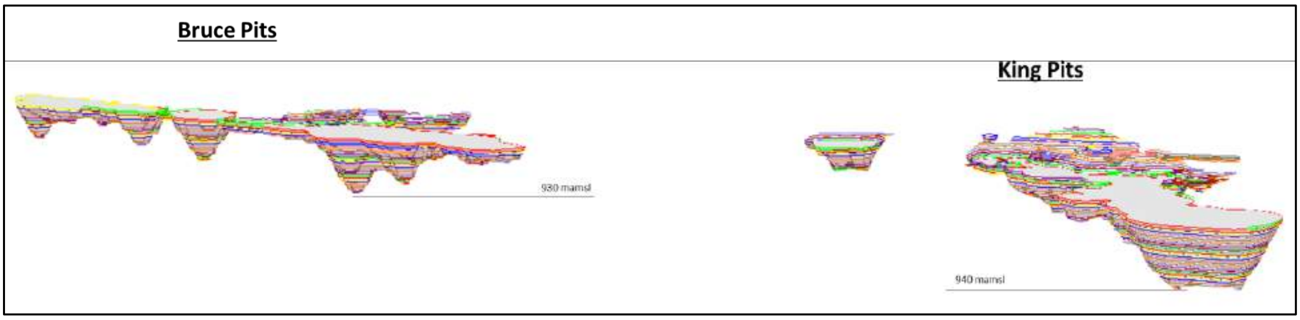


Figure 29: Three dimensional schematic of the Bruce & King Pits

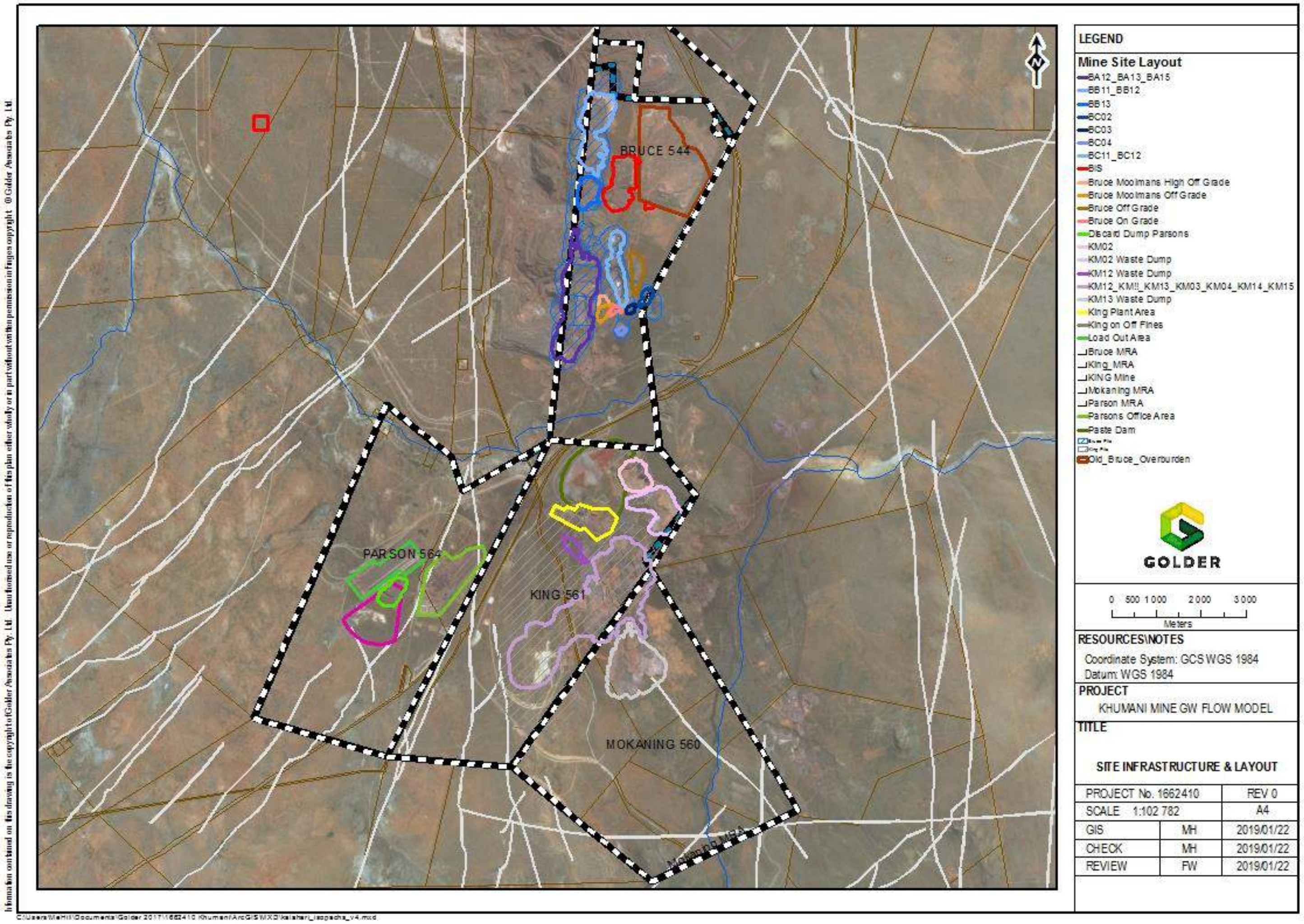


Figure 30: Site Layout and Infrastructure

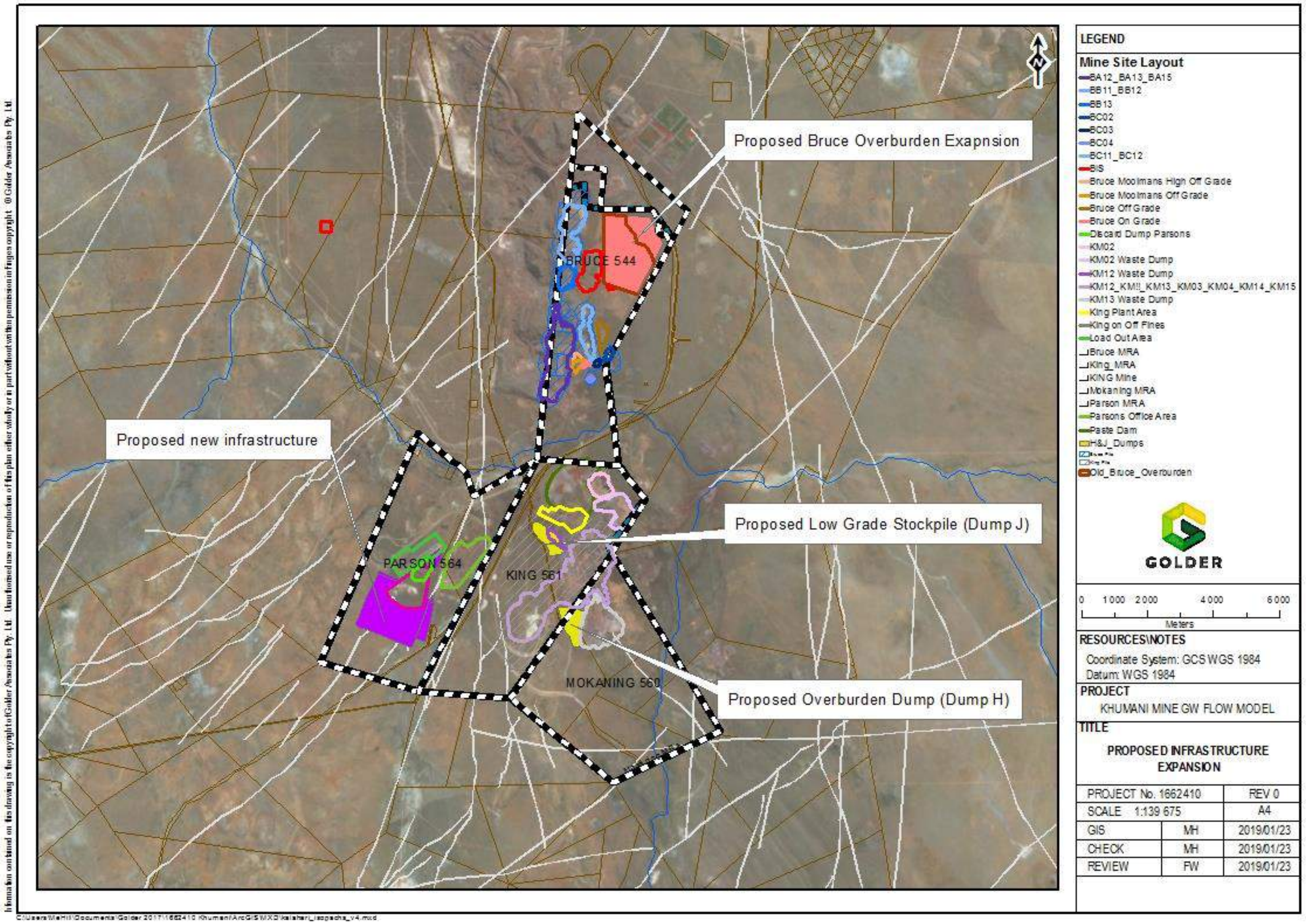


Figure 31: Proposed Infrastructure expansion

4.0 NUMERICAL GROUNDWATER FLOW MODEL

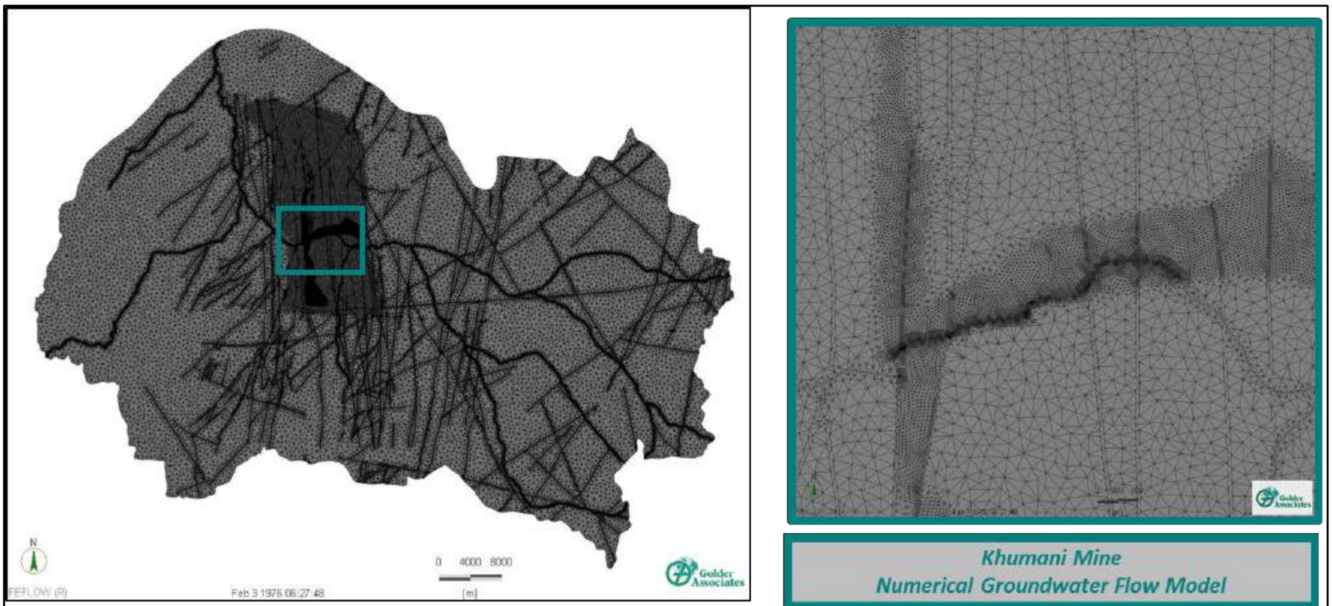
The catchment wide numerical groundwater flow model developed by Golder in 2017, which was developed to encompass the KIOM and SIOM, was used as the basis for impact prediction in this study. While the objectives have shifted, the robust catchment model has been refined in some areas to allow for the simulations of pit development and solute mass transport simulation associated with the proposed infrastructure.

The key objectives of the modelling are outlined below;

- Estimate the groundwater inflows expected to the Khumani Mine Pits over the remaining life of mine.
- Evaluate the incremental impact receptors as a consequence of pit dewatering.
- Evaluate the impacts on receptors considering the expansion and development of the proposed infrastructure at Khumani Mine;
  - The expansion of the Bruce overburden dump
  - The development of the overburden dump (Dump H) on King 561 and Mokaning 560.
  - The development of low grade stockpile (Dump J) on King 561.
  - Expansion of the stockpile and associated infrastructure on the Parsons 546.

4.1 Numerical Model Setup

The groundwater flow and contaminant transport software package Feflow® (Finite-element simulation system for subsurface flow and transport processes) developed by DHI-WASY GmbH was selected for development



Numerical Mesh Setup & Quality			
Slices	10	Interior Holes	0
Layers	9	Obtuse Angles	2.3% > 120⁰,32.6% > 90⁰
Nodes per slice	61 597	Meshing Method	Triangle
Elements per slice	122 046	Numerical Solver	SAMG

of the groundwater flow model to represent the catchment containing the Khumani Iron Ore Mine.

Figure 32: Khumani Mine - Numerical Groundwater Flow Model - Mesh Setup

4.1.1 Mesh development

Feflow ©, unlike many other modelling packages, takes a conceptual model approach to mesh development. In this way, the mesh is developed to explicitly include structures such as fault zones, dykes drainage lines, site layout, geological contacts and boreholes. The finite element mesh allows for variable size elements and thus for refinement around points of interest such as abstraction boreholes. The mesh design and quality is summarised in Figure 32.

4.1.2 Mesh Layering

From the conceptual understanding it understood that the deposition of the Kalahari sediments and hence the vertical depth to dyke and fault zones are important for groundwater flow (i.e. Compartmentation and leakage between compartments). In order to adequately express the Kalahari sediments and underlying fractured rock, the model has been vertically discretised in to 9 Layers. The three dimensional model is presented in Figure 33.

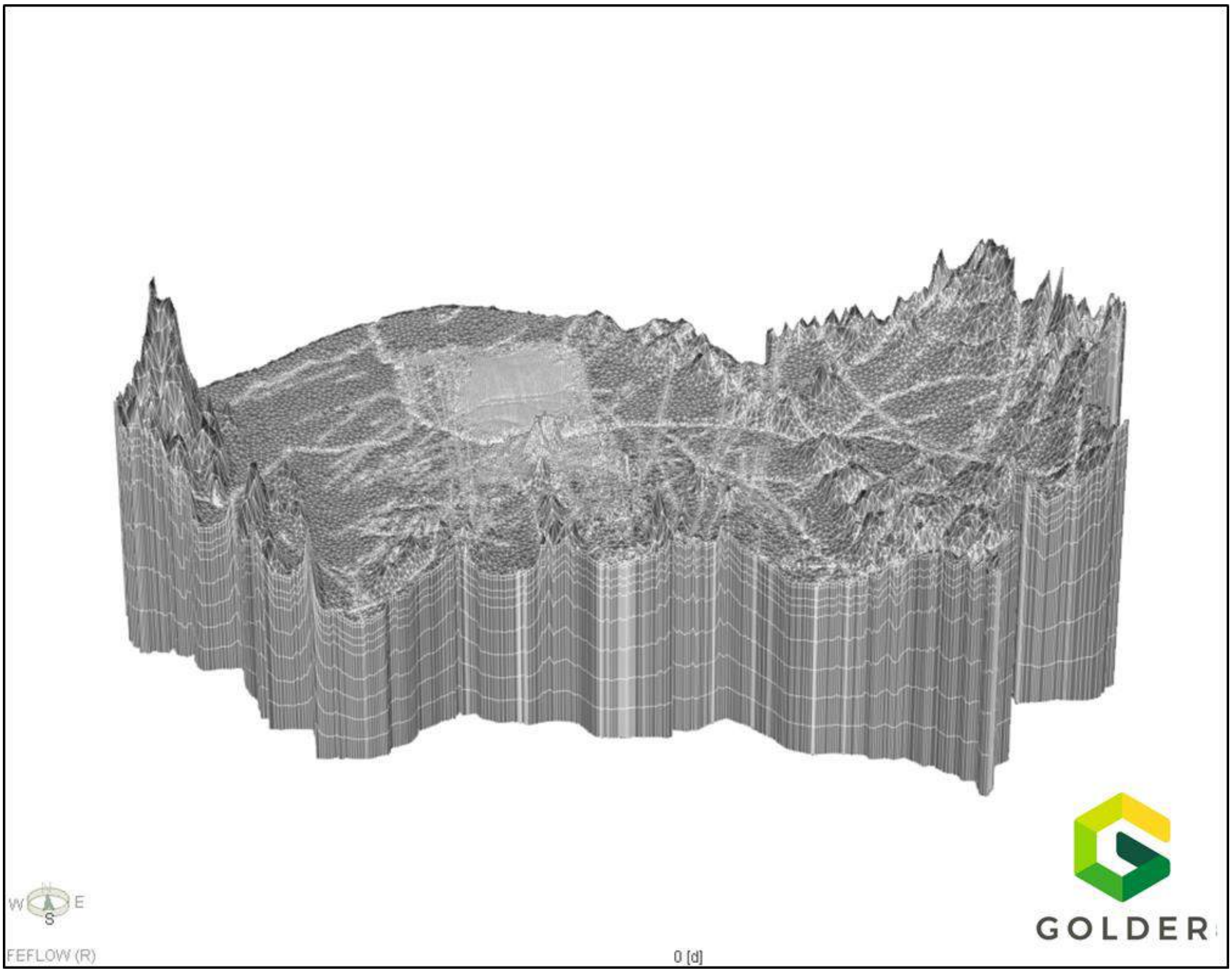


Figure 33: Three-dimensional numerical model - Khumani Mine

The model has a variable thickness due to the topographical highs in the west and east of the domain. The layer thicknesses are outlined below (Table 6);

Table 6: Model Layers

Slice	Thickness	Geology
1	15	Kalahari Sands/Bedrock
2	45	Kalahari Clay/Bedrock
3	30	Kalahari Gravel/Bedrock
4	100	Dwyka/Bedrock
5	157	Bedrock
6	157	Bedrock
7	157	Bedrock
8	157	Bedrock
9	157	Bedrock
10	157	Base of Model

The western limb of the Maremane anticline, is documents to dip at 16^0 to 20^0 and has been presented as such in the model. The eastern Limb of the anticline has a dip of approximately 5^0. The dip of the strata is indicated below (Figure 34).

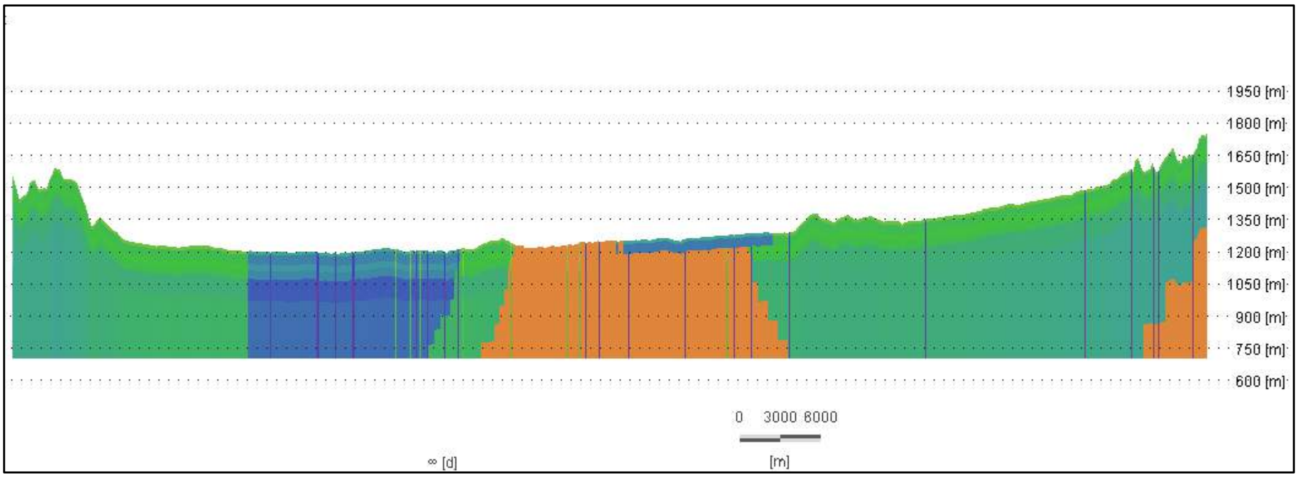


Figure 34: West - East Cross Section depicting Hydrogeological zones built into the model.

The geological layering was evaluated by considering the Khumani Geological data base and the sections developed by Meyer (2009). While a perfect fit is not numerically achievable for the geological model due to the scale of the model good agreement was found between the conceptualised geological understanding and the developed model. Note the sections presented are vertically exaggerated. The Meyer (2009) sections extent to 900 mamsl, while the model sections extend to 720 mamsl. It is important to note that the faults and dykes are built into the model to terminate at the base of the Dwyka formation where present, alternatively the Kalahari sediments (Figure 35 - Figure 43).

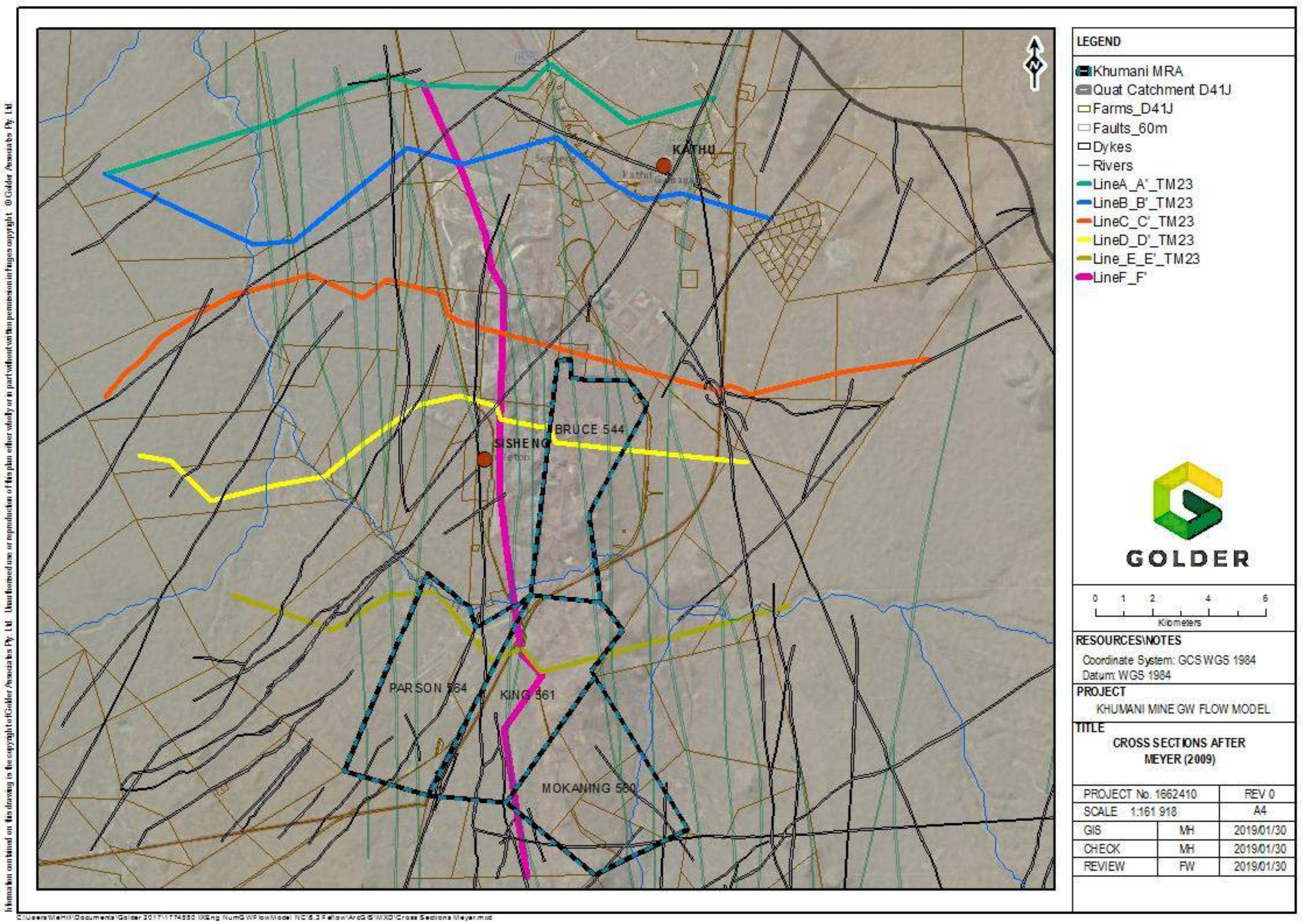


Figure 35: Cross section locations after Meyer (2009)

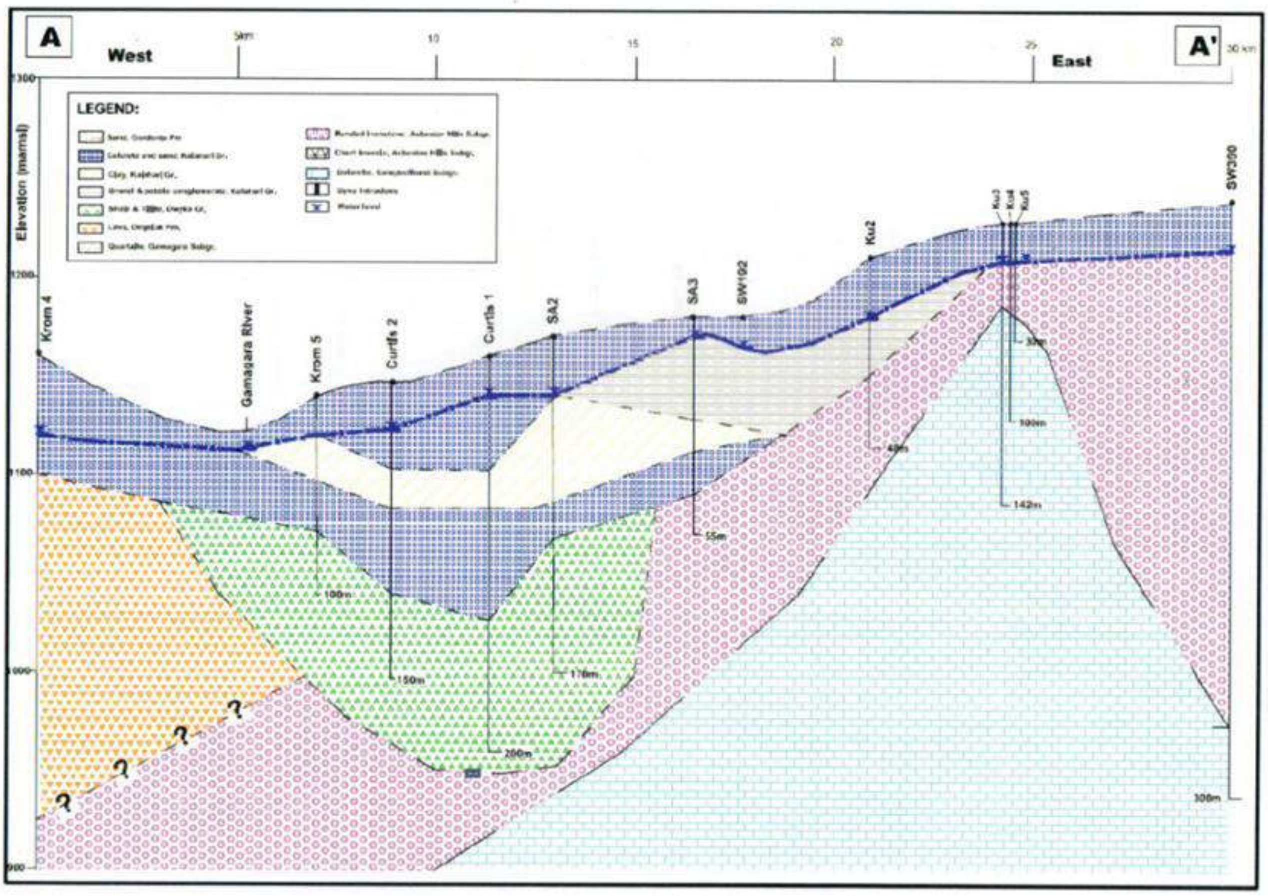


Figure 36: Section A-A' (after Meyer, 2009)

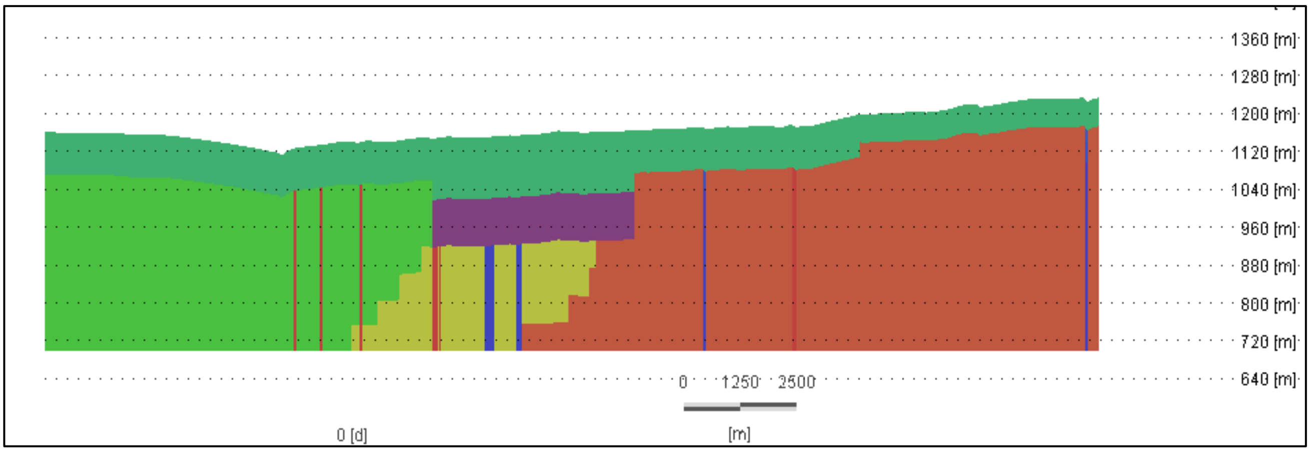


Figure 37: Section A-A' (Dark green = Kalahari Sediments, Purple = Dwyka, Light green = lava, Red = dolomite, yellow = BIF & Quartzite), Blue= Dykes & Bright red = faults)

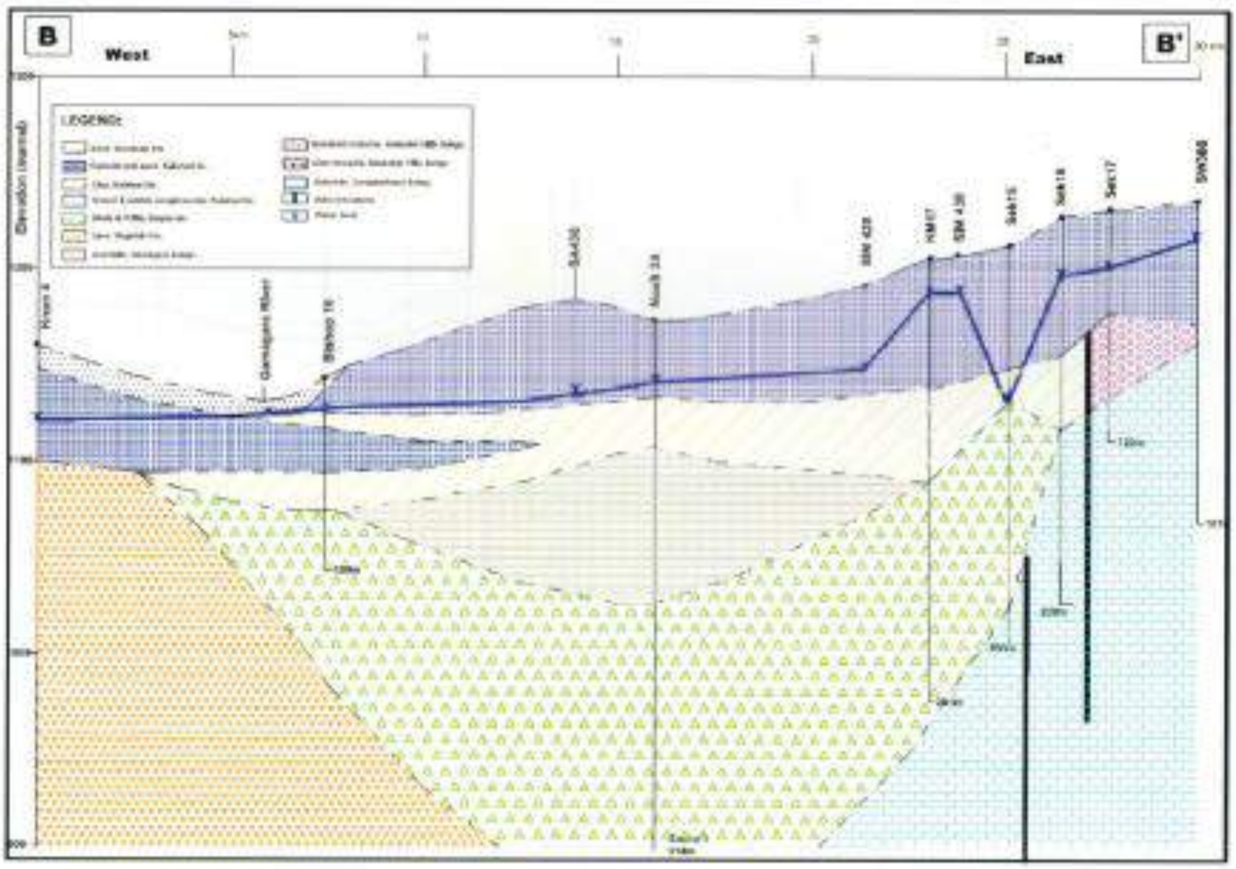


Figure 38: Section B-B' (after Meyer, 2009)

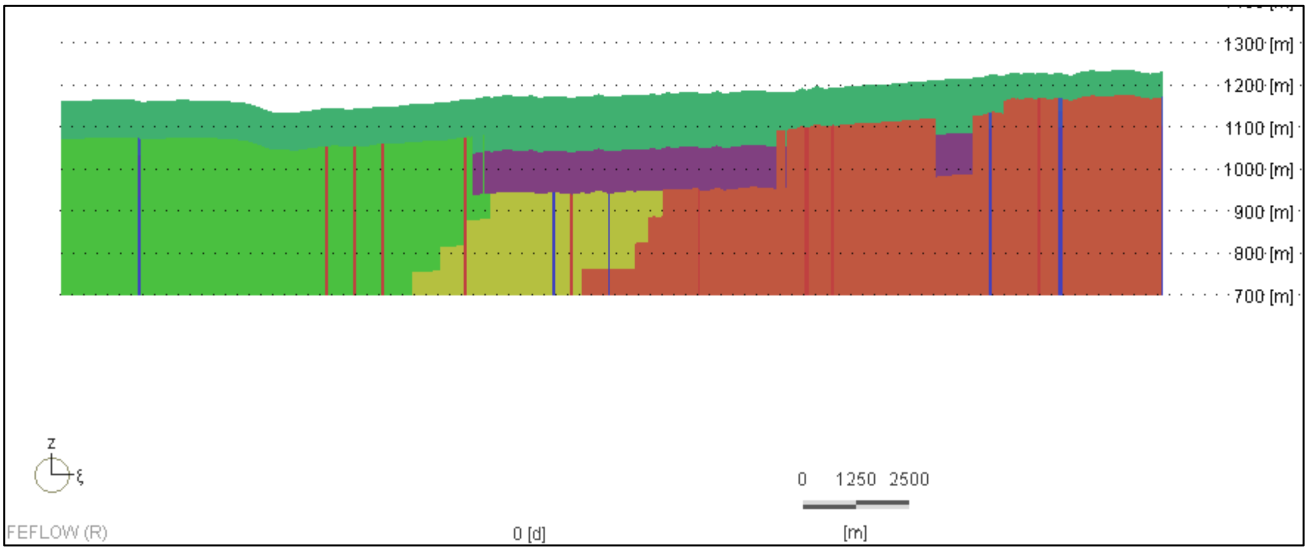


Figure 39: Section B-B' (Dark green = Kalahari Sediments, Purple = Dwyka, Light green = lava, Red = dolomite, yellow = BIF & Quartzite), Blue= Dykes & Bright red = faults)

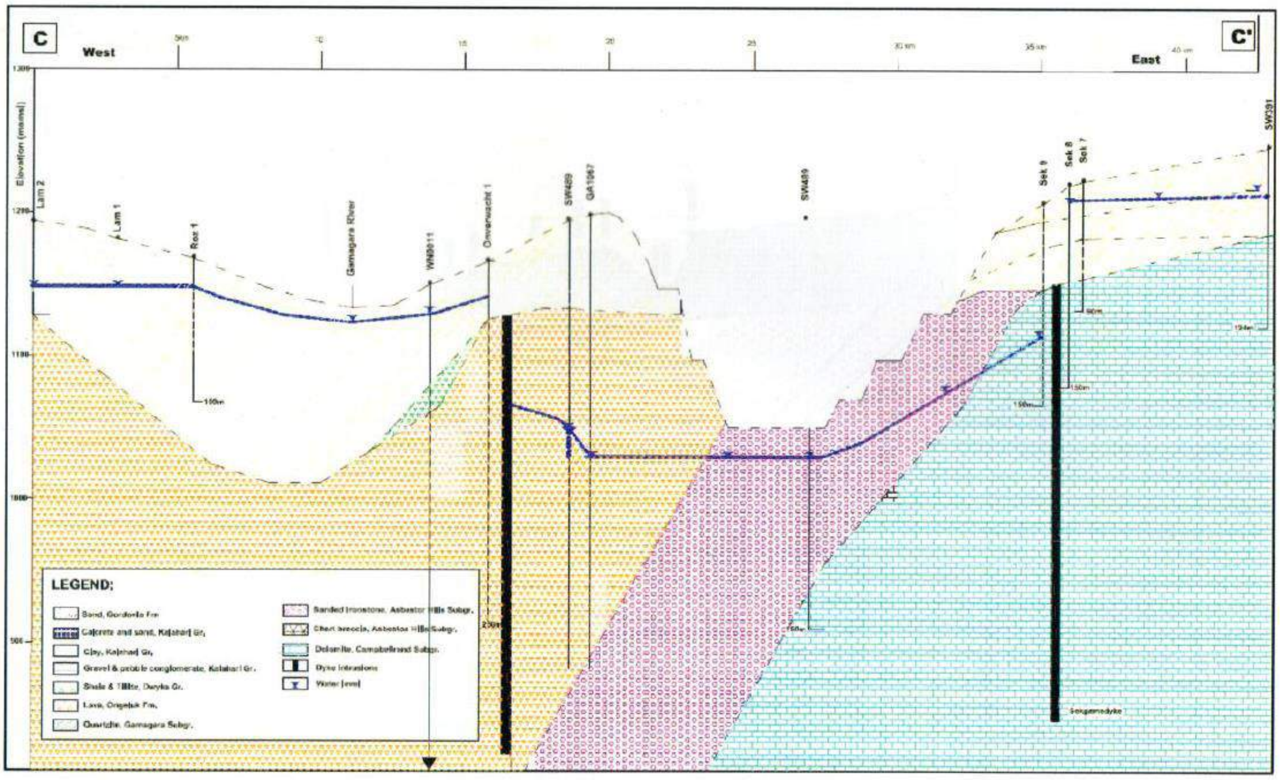


Figure 40: Section C-C' (after Meyer, 2009)

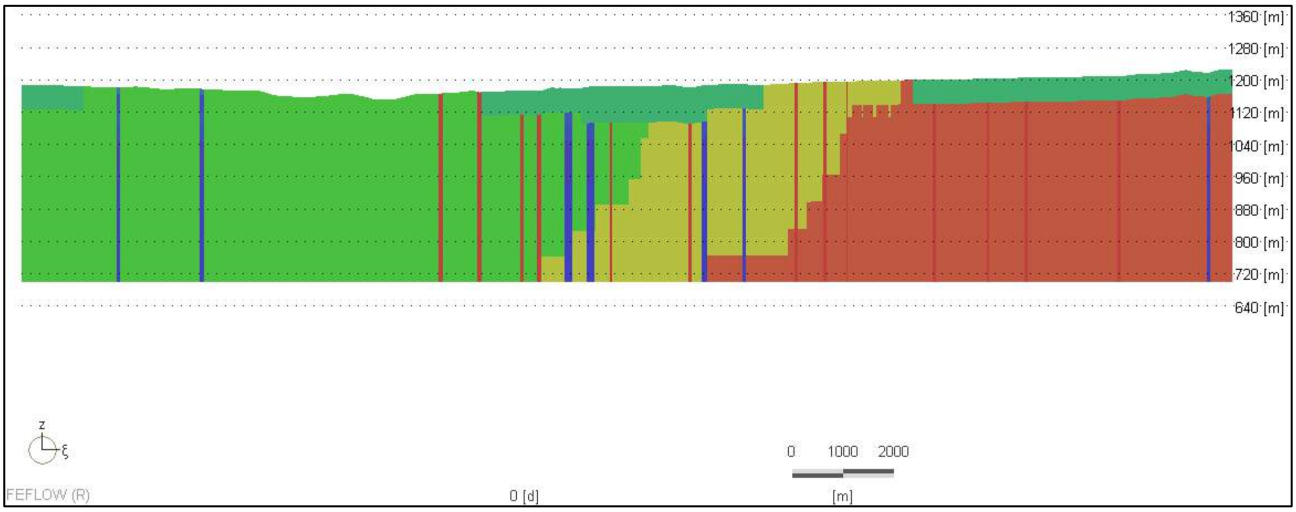


Figure 41: Section C-C' (Dark green = Kalahari Sediments, Purple = Dwyka, Light green = lava, Red = dolomite, yellow = BIF & Quartzite), Blue= Dykes & Bright red = faults)

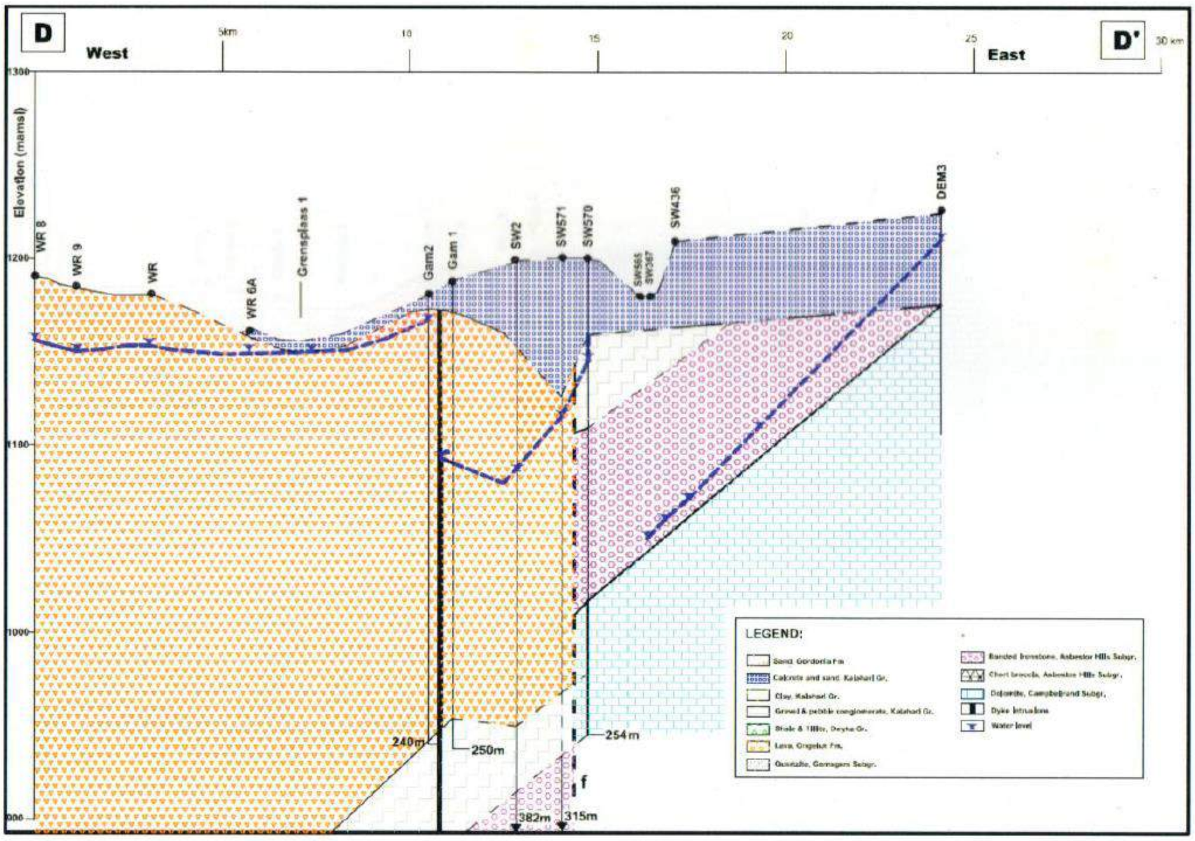


Figure 42: Section D-D' (After Meyer, 2009)

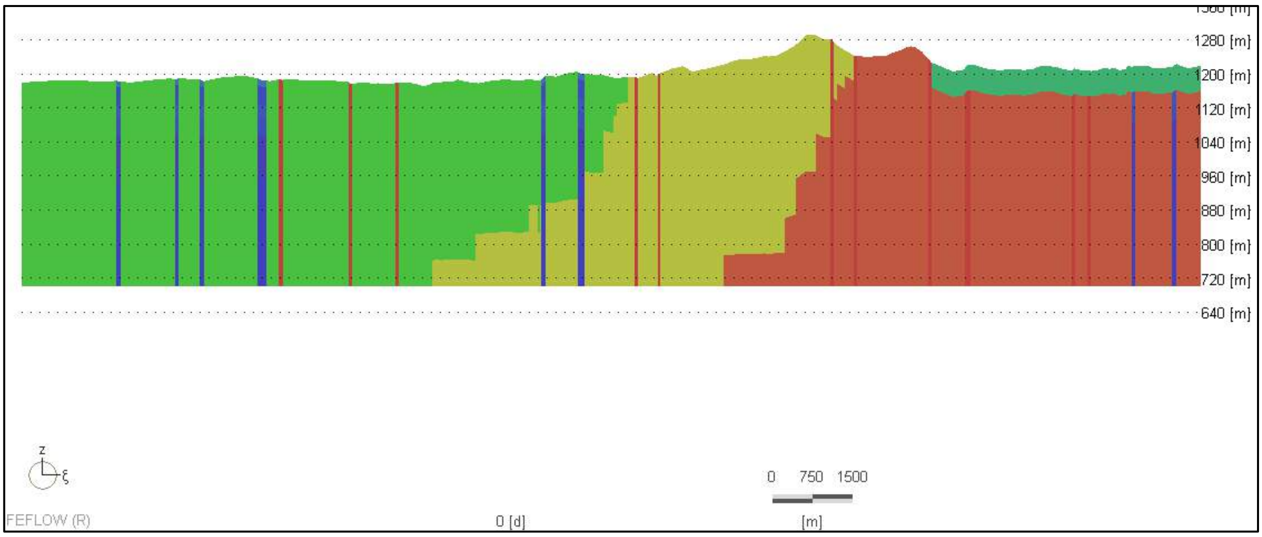


Figure 43: Section D-D' (Dark green = Kalahari Sediments, Purple = Dwyka, Light green = lava, Red = dolomite, yellow = BIF & Quartzite), Blue= Dykes & Bright red = faults)

4.2 Model Boundaries

As described in preceding sections, the model catchment was delineated to coincide with the surface water catchment D41J. The boundaries of the quaternary catchment are reflective of surface water divides and it is assumed that these divides similarly act as groundwater divides. As such for the purpose of the numerical model these boundaries are considered a special type of Neumann boundary; "no flow boundary".

The Gamagara River was assumed to behave as a gaining type river and thus was assigned dirichlet boundaries equal in elevation to the surface topography and with a constraint to allow only gaining type conditions where applicable. Hence where hydraulic head elevations permit, groundwater exits the model domain via the river systems. However where the hydraulic head is below the river system no water is lost from the model via the river system and similarly no water is added to the model via the river boundary conditions.

4.3 Model Calibration

A three dimensional steady state groundwater flow model representing the study area was constructed to represent pre-mining groundwater flow conditions. These conditions serve as the initial conditions for the transient simulations of groundwater flow and mass transport associated with mine development.

The three dimensional groundwater flow equation on which Feflow modelling is based is expressed below;

$$\frac{\partial}{\partial x}\left(Kx\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Ky\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(Kz\frac{\partial h}{\partial z}\right)\pm W=S\frac{\partial h}{\partial t}$$

Where;

h: Hydraulic Head [L]

Kx, Ky, Kz = Hydraulic conductivity [L/T]

S = storage coefficient

T = Time [T[

W = Source and sinks [L/T]

The numerical groundwater flow model was calibrated iteratively in steady state and under transient conditions. A piezometric head distribution representative of hydraulic heads in 1972 was used to guide the steady state calibration i.e. the state prior to any significant stresses within the catchment. Thereafter the steady state heads were used as the initial conditions for the transient simulations which evaluate time varying rainfall and abstraction from Sishen mine and surrounds.

The transient simulations were run for a period of 41 years i.e. initiating at the start of pumping in February 1976 and proceeding to December 2017. The hydraulic head drawdown data generated from these simulations was evaluated against the Khumani monitoring data and selected Sishen monitoring points. The Khumani data spans a period of six years (December 2009 to present). Based on goodness of fit between the simulated versus observed data the steady state model was re-adjusted in terms of hydraulic conductivities and then again transiently simulated until suitable agreement was observed between the transient drawdown and the time-varying observation data.

4.3.1 Steady state calibration (1972 water level contours) (Scenario1)

Calibration is the process of identifying a suitable set of hydraulic parameters, boundary conditions and stresses that best describe the observed hydraulic heads or fluxes within a defined catchment (Anderson and Woesner,1992).

Under steady state conditions the groundwater flow equation is reduced to exclude storativity and only transmissivity (or hydraulic conductivity) and recharge are considered in the calibration process.

The suitability of the calibrations was evaluated on five criteria;

- Residual error (m): < 10% of the model thickness

- Absolute residual (m): <10% of the model thickness
- Root mean square error (m): <10% of the model thickness
- Normalized root mean square error (m): <10%
- Correlation: >0.95

In order to assess the goodness of fit between the simulated pre-mining conditions and real conditions, fictitious hydraulic head data was abstracted from the 1972 piezometric surface (Smit, 1972). Relatively good agreement was observed between the observed versus the simulated as depicted in Figure 45 and Table 7.

Table 7: Calibration Criteria

Parameter	Value
Error	-3.0
Absolute Error	5.2
RMSE	6.8
NRMSE	7.2%

The simulated piezometric surface representative of 1972 conditions is depicted in Figure 44, below. As conceptualised, groundwater flow occurs from the Kuruman hills and Koranna Berg in the east and west toward the Gamagara and its tributaries. Alike to field observations, the simulated heads are shown to be controlled by the North-South and East-West dykes structures which traverse the catchment

The steady state water balance is depicted in Table 8. Steady state recharge to the system was assumed to be 1.04E+05 m^3/d across the catchment spanning a total area of 3906 km^2, thus equating to an average recharge of 9.75 mm/a, or approximately 3% of MAP. Recharge to the system under steady state conditions exits the system via groundwater contribution to baseflow of the Gamagara River and its tributaries, spring outflow along low permeability dyke margins and domestic water supply.

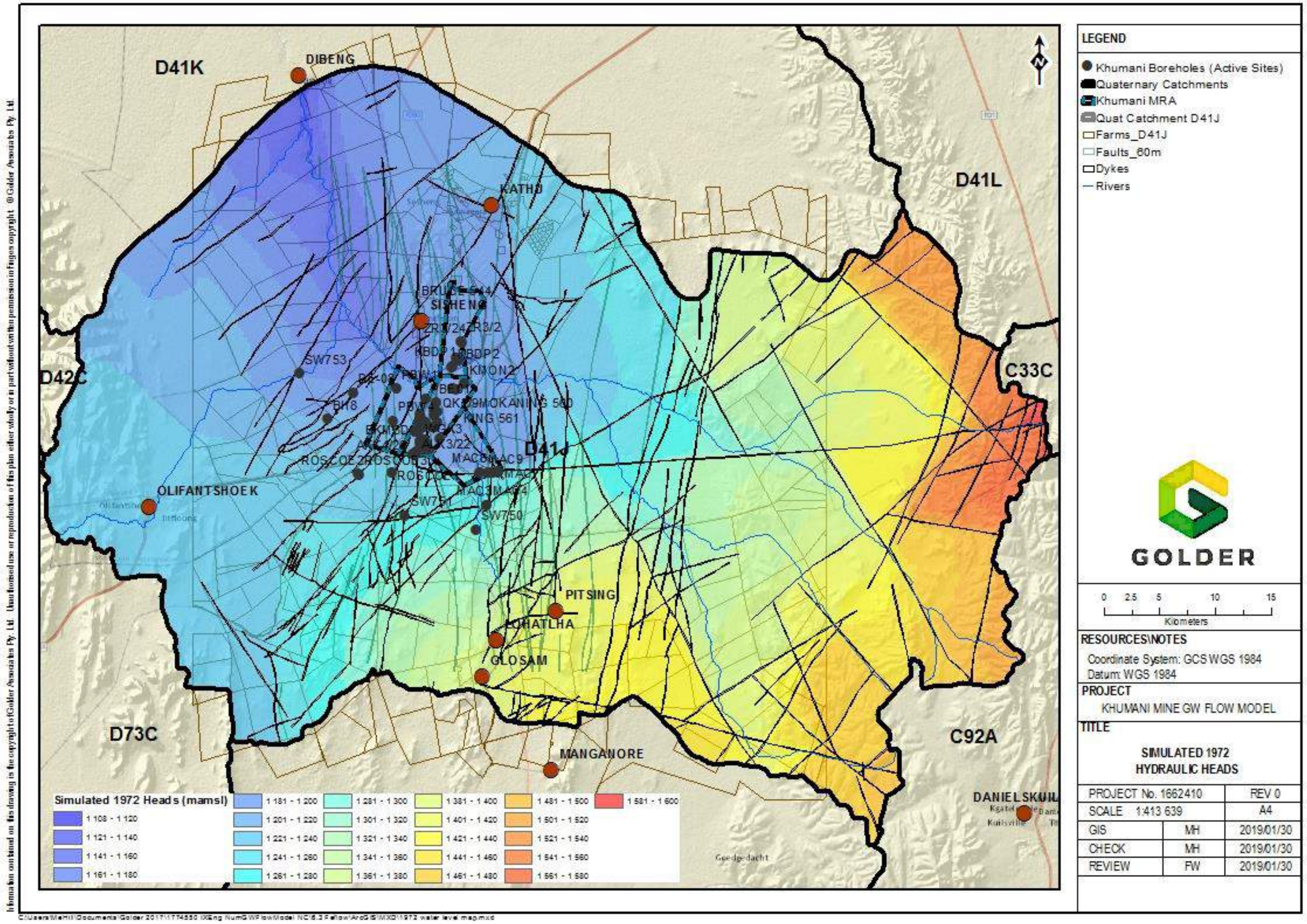


Figure 44: Simulated Hydraulic Heads Representative of 1972 conditions

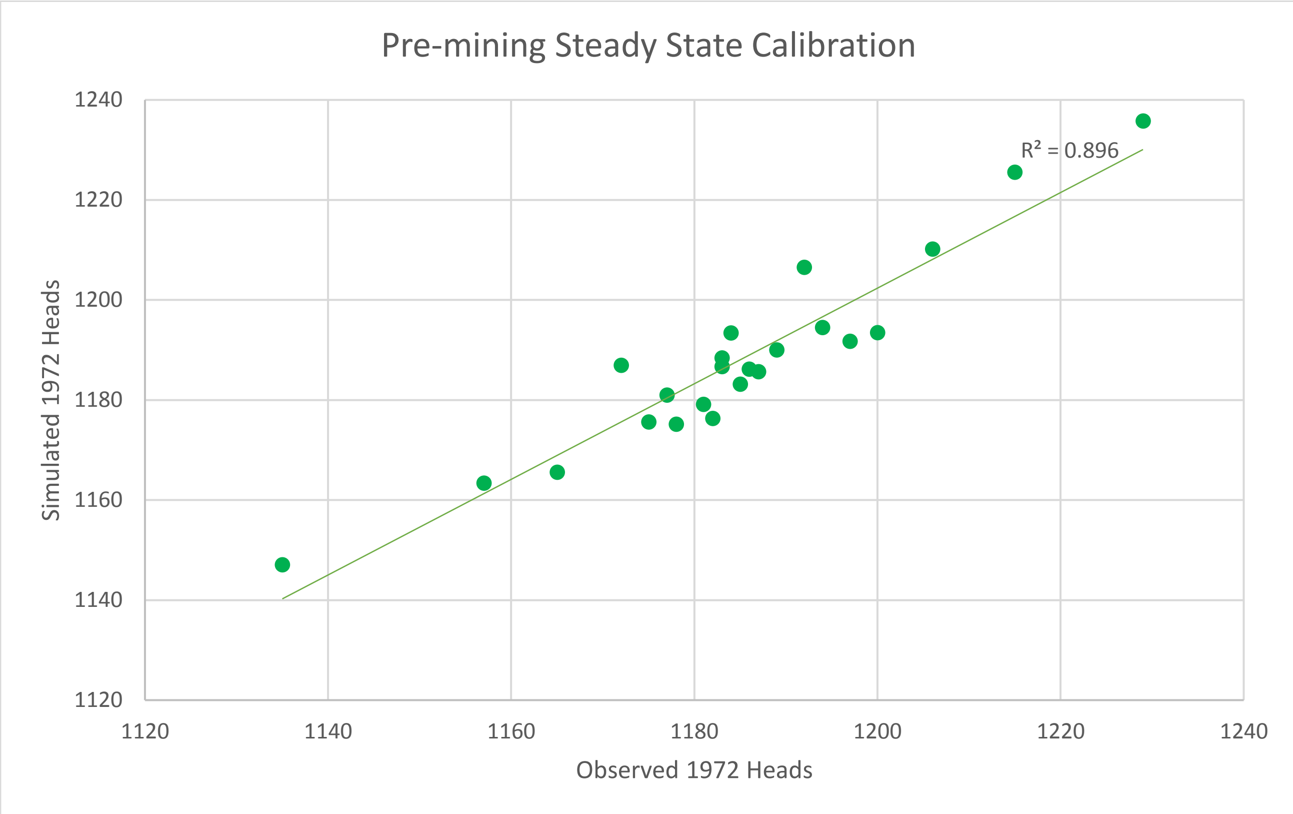


Figure 45: Pre-mining Steady State Calibration - Representative of 1972 hydraulic heads

Table 8: Steady State Water Balance

Scenario 1: Steady State Water Balance			
Parameter	**Inflow**	**Outflow**	**Balance**
Sources (Recharge) (m^3/d)	104 000	0	104 000
Sinks (Abstraction, base flow, springs)(m^3/d)	0	-104 000	-104 000
Khumani Abstraction	0	0	0
Sinks (Mine Dewatering) (m^3/d)	0	0	0
Storage (m^3/d)	0	0	0
Balance(m^3/d)	104 000	-104 000	0

The flow across the Sekgame Dyke into the Khumani and Sishen mine groundwater compartment from the catchment area originating in Kuruman hills is in the order of 2000 m^3/d or approximately 0.73 Mm^3/a.

The calibrated hydraulic parameters used to describe the hydrogeological model are outlined in Table 9.

Table 9: Model parameters

		Kalahari Sediments	Dwyka	Dolomite	BIF & Quartzite	High Conductivity Zones Associated with Karst	Lava	Dykes
Layer 1	Re (m/d)	Variable recharge (Refer to Section						
	Kx (m/d)	3.00E-02		0.2	0.2	1.00E+00	2.00E-02	5.00E-04
	Kx:Ky:Kz	Kx=Ky=10Kz		Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz
	Ss (1/m)	2.00E-05		2.00E-05	2.00E-05	1.00E-05	1.00E-06	1.00E-05
Layer 2	Kx (m/d)	5.00E-03		0.2	0.2	1.00E+00	2.00E-02	5.00E-04
	Kx:Ky:Kz	Kx=Ky=10Kz		Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz
	Ss (1/m)	2.00E-05		0.00002	0.00002	1.00E-05	1.00E-06	1.00E-05
Layer 3	Kx (m/d)	5.00E-03		0.2	0.2	1.00E+00	2.00E-02	5.00E-04
	Kx:Ky:Kz	Kx=Ky=10Kz		Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz
	Ss (1/m)	2.00E-05		0.00002	0.00002	1.00E-05	1.00E-06	1.00E-05
Layer 4	Kx (m/d)		5.00E-04	0.2	0.2	1.00E+00	2.00E-02	5.00E-04
	Kx:Ky:Kz		Kx=Ky=10Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz
	Ss (1/m)		2.00E-05	0.00002	0.00002	1.00E-05	1.00E-06	1.00E-05
Layer 5-9	Kx (m/d)			0.2	0.2	1.00E+00	2.00E-02	5.00E-04
	Kx:Ky:Kz			Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz	Kx=Ky=Kz
	Ss (1/m)			2.00E-05	2.00E-05	1.00E-05	1.00E-06	1.00E-05

4.3.2 Transient calibration – water level data records & 2017 piezometric surface

As described above, the steady state heads reflecting pre-mining conditions were used as the initial hydraulic head distribution for the transient simulations. The Khumani monitoring borehole database was used to aid the calibration process. The simulated water level trends versus the observed data are depicted in Figure 46 – Figure 59. The location of the Khumani monitoring wells are depicted in Figure 48.

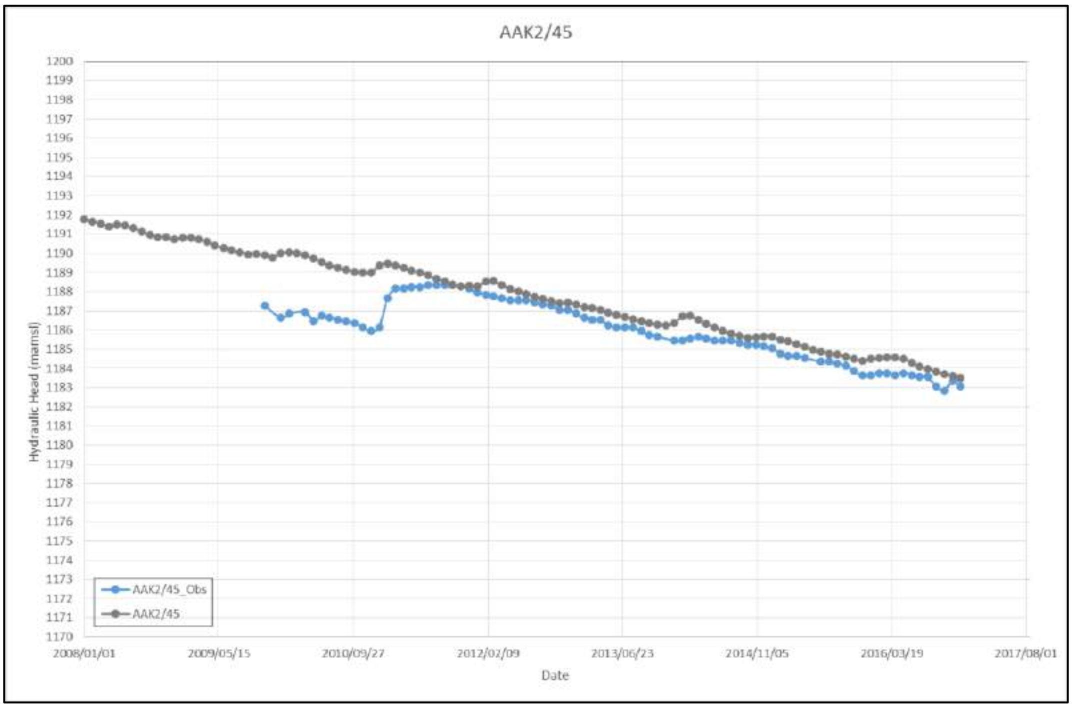


Figure 46: Simulated and Observed Heads - Borehole AAK2/45

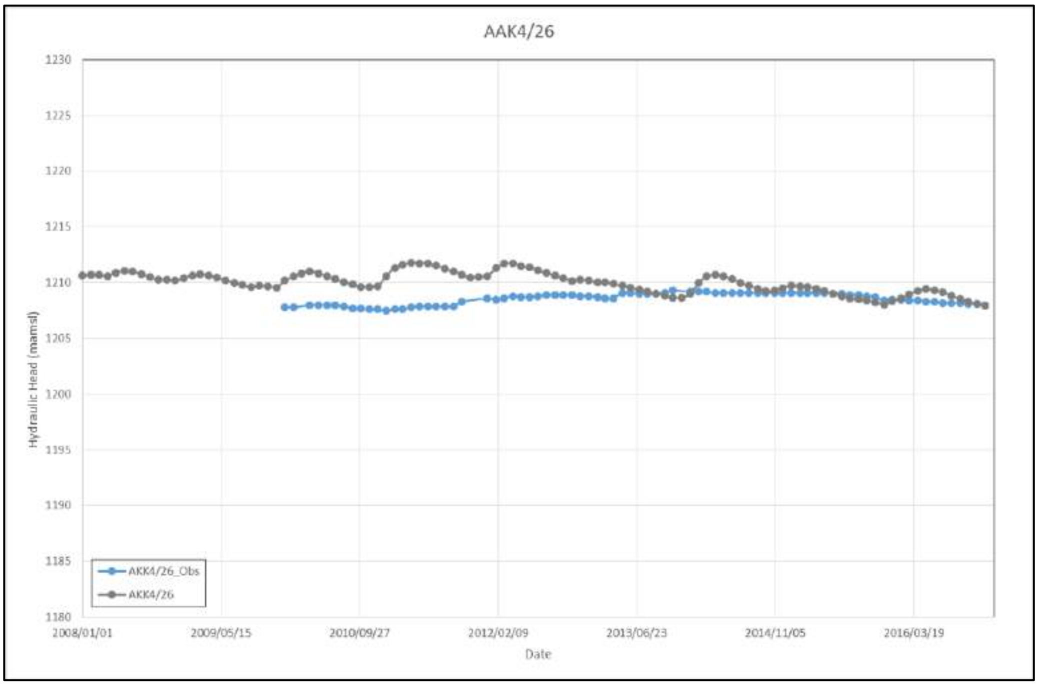


Figure 47: Simulated and Observed Heads - Borehole AAK4/26

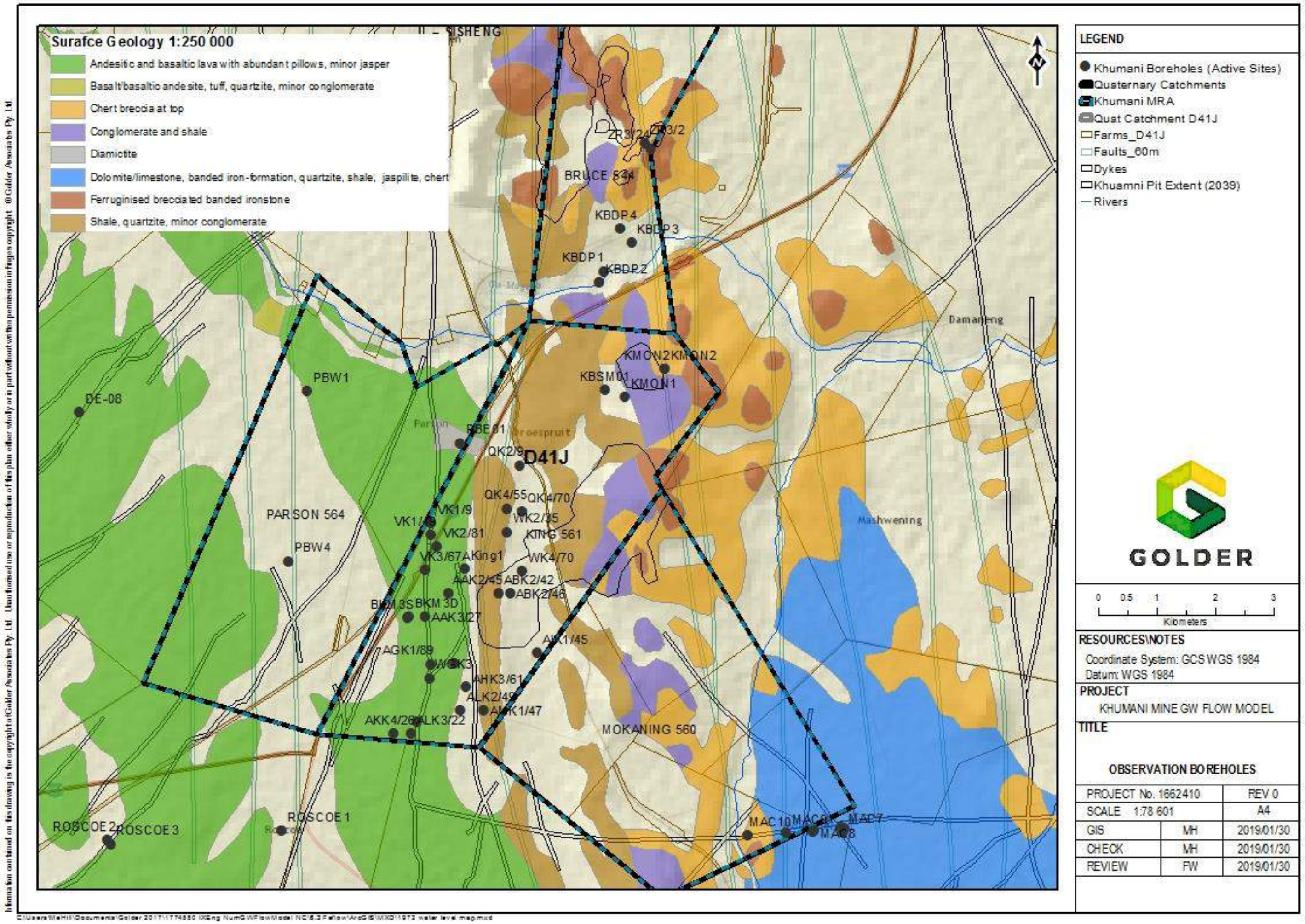


Figure 48: Khumani monitoring Boreholes

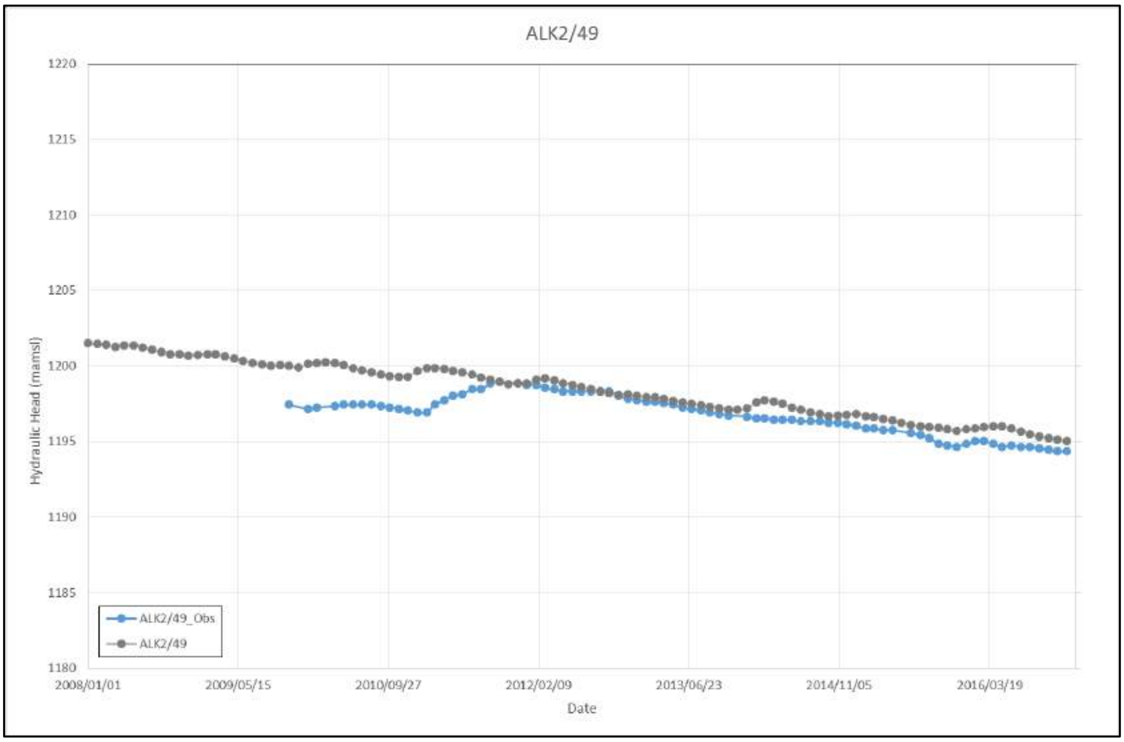


Figure 49: Simulated and Observed Heads - Borehole ALK2/49

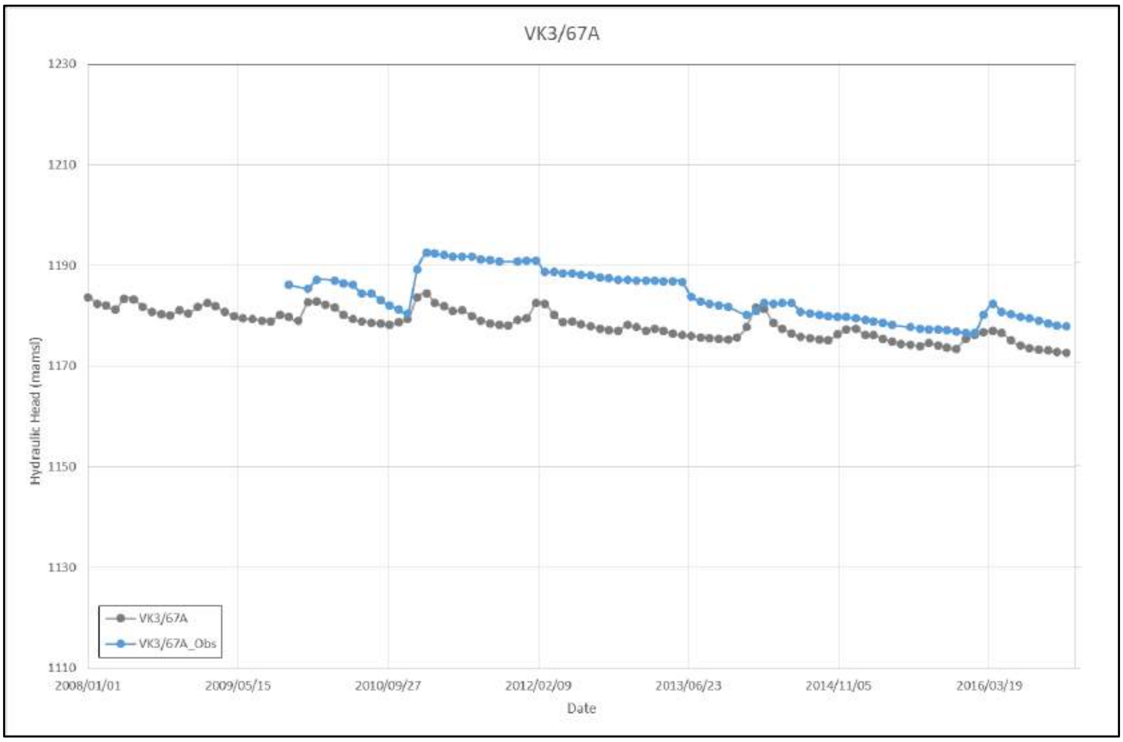


Figure 50: Simulated and Observed Heads - Borehole VK3/67A

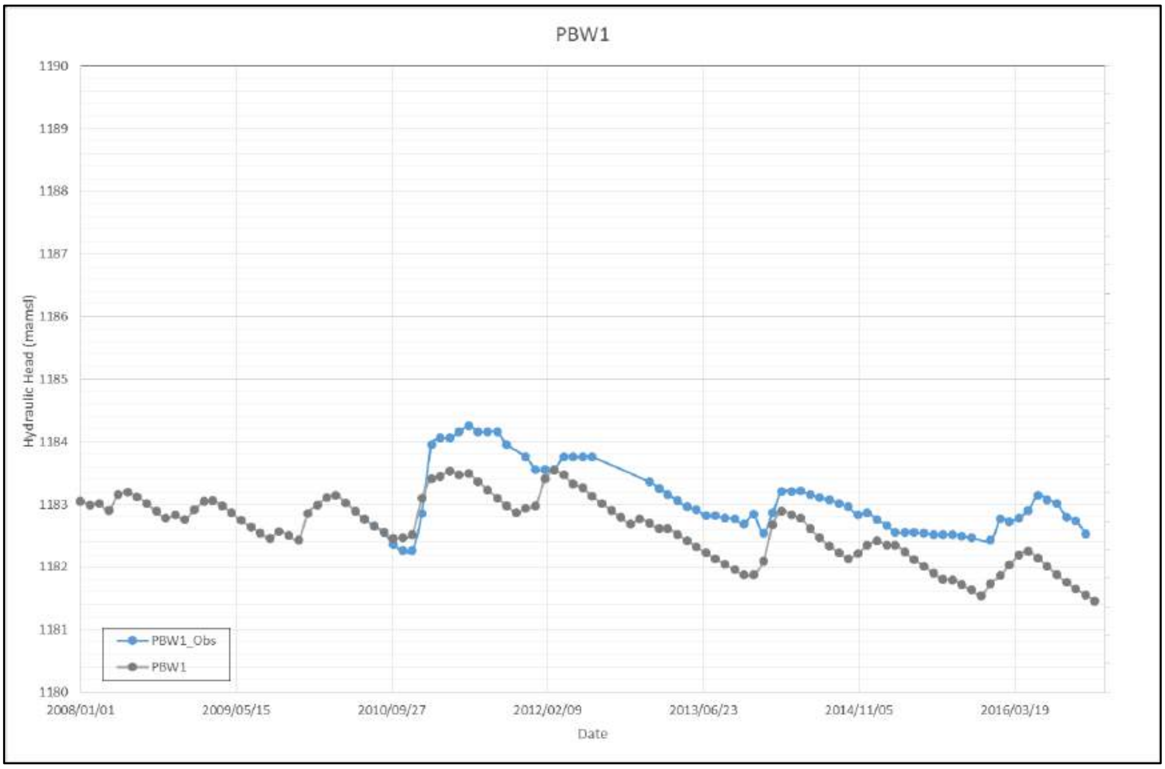


Figure 51: Simulated and Observed Heads - Borehole PBW1

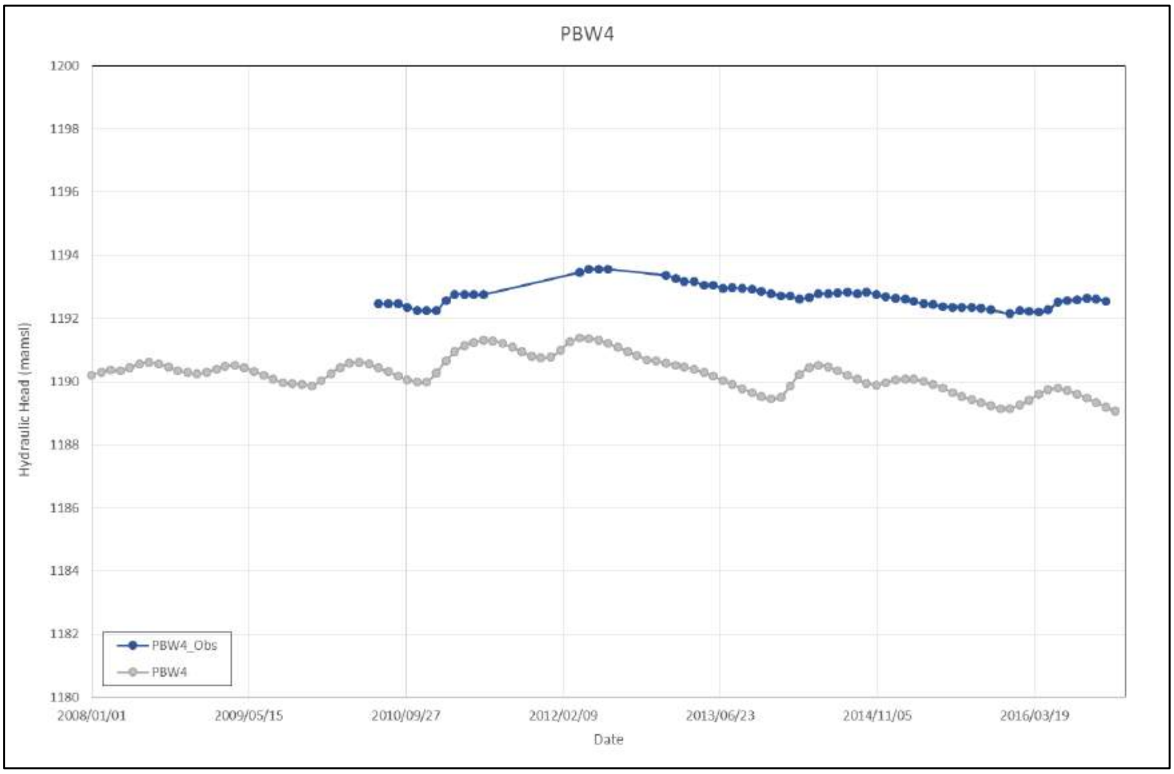


Figure 52: Simulated and Observed Heads - Borehole PBW4

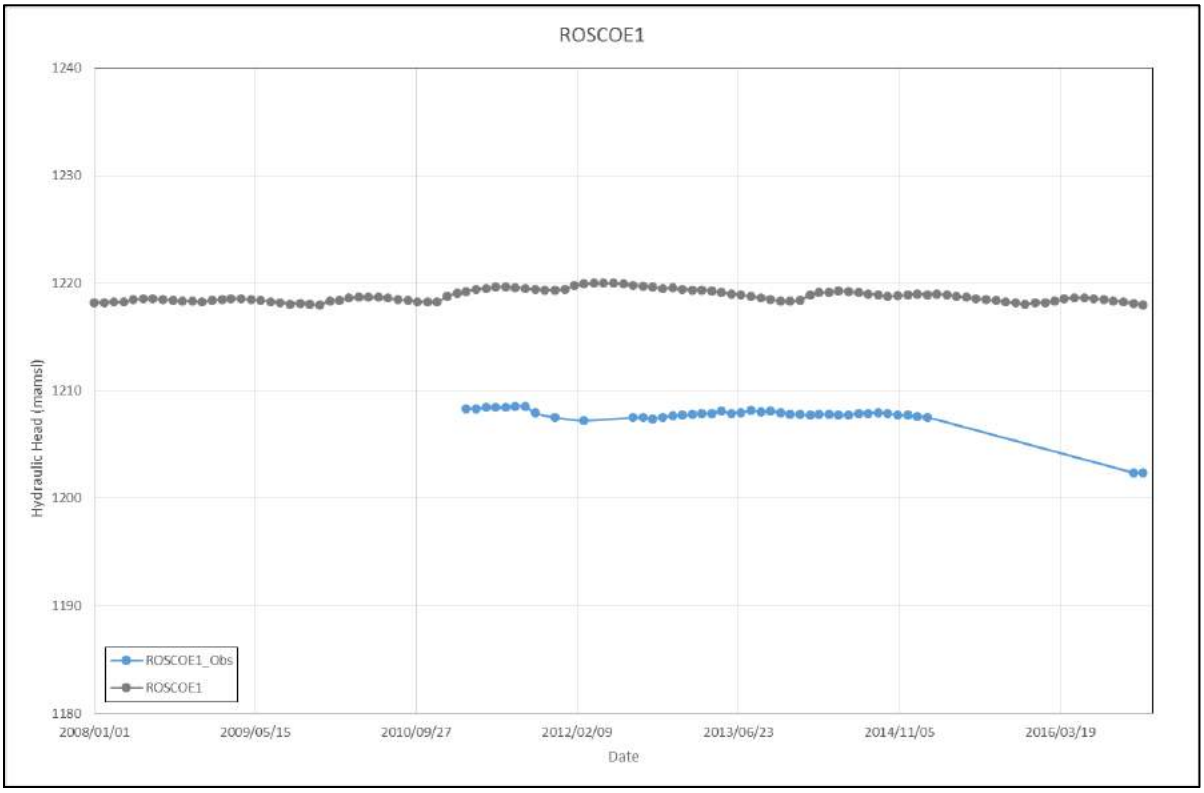


Figure 53: Simulated and Observed Heads - Borehole ROSCOE 1

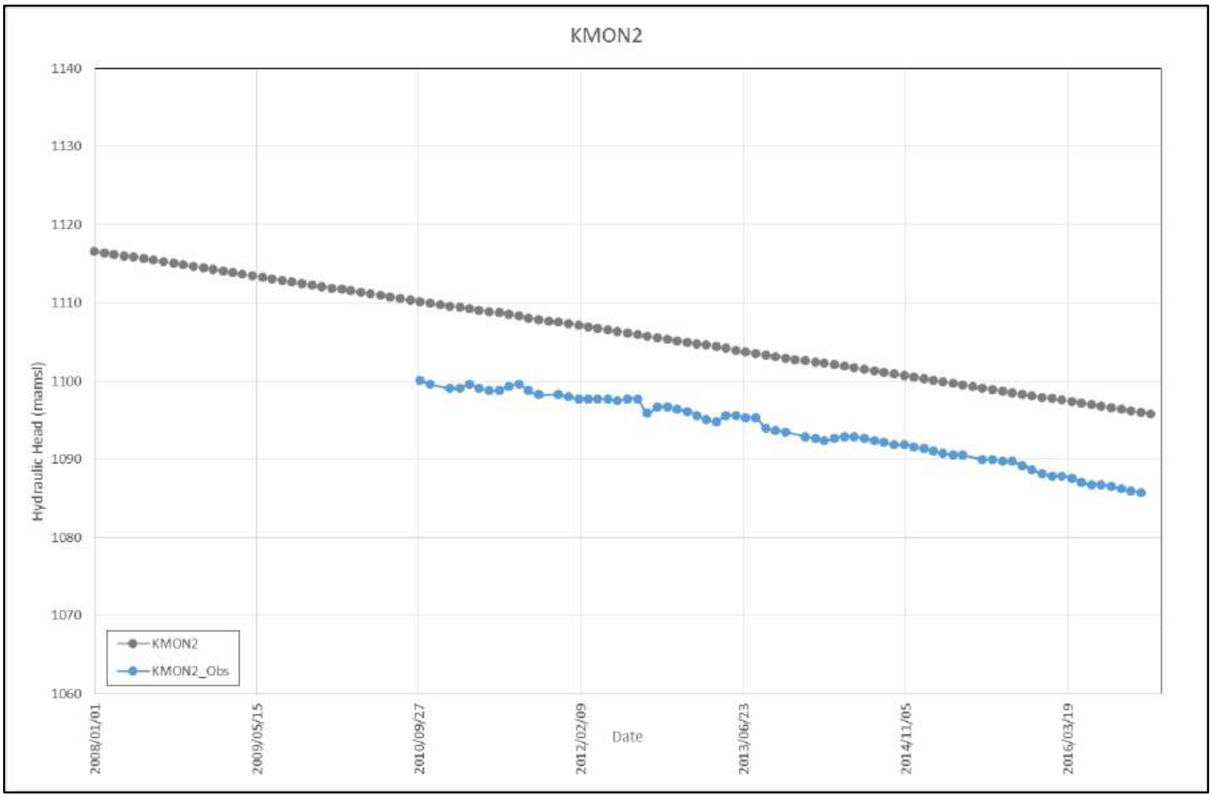


Figure 54: Simulated and Observed Heads - Borehole KMON2

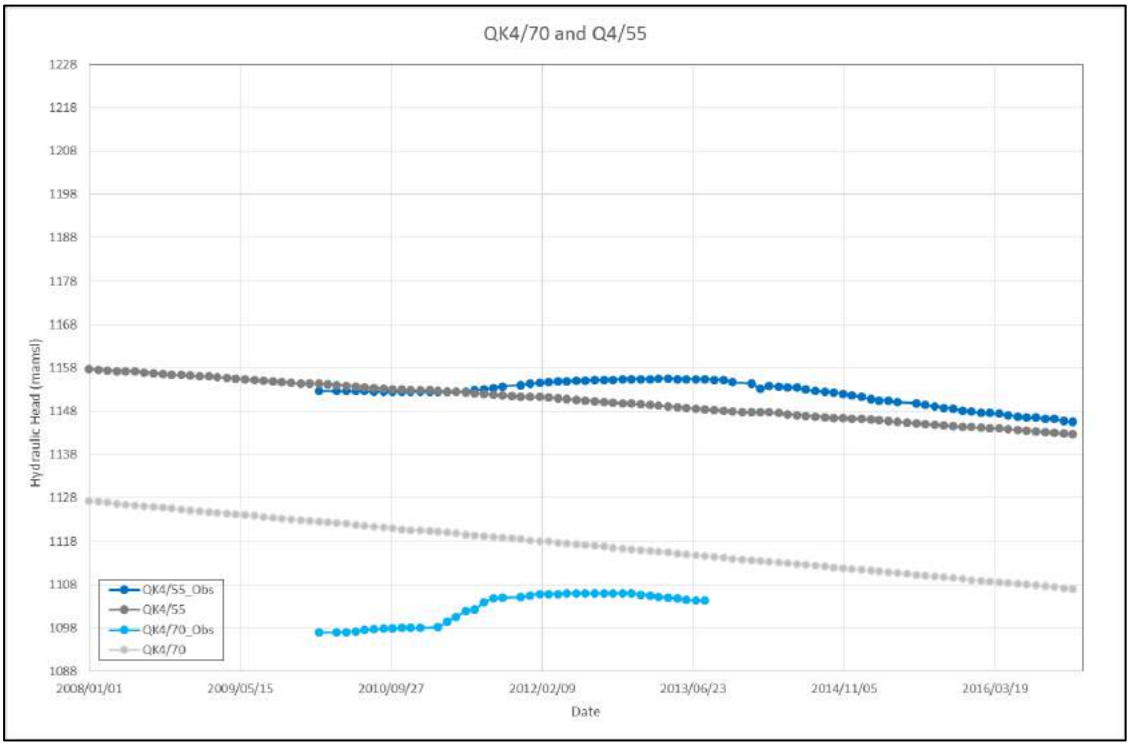


Figure 55: Simulated and Observed Heads – Boreholes QK4/70 and Q4/55

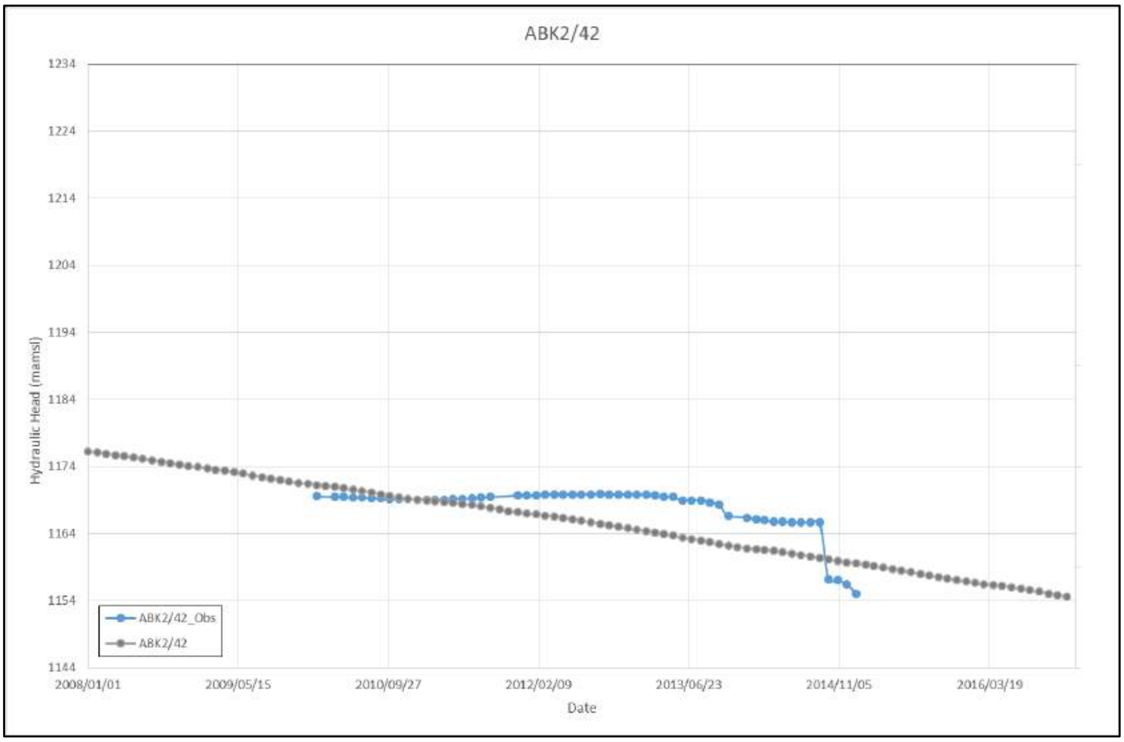


Figure 56: Simulated and Observed Heads - Borehole ABK2/42

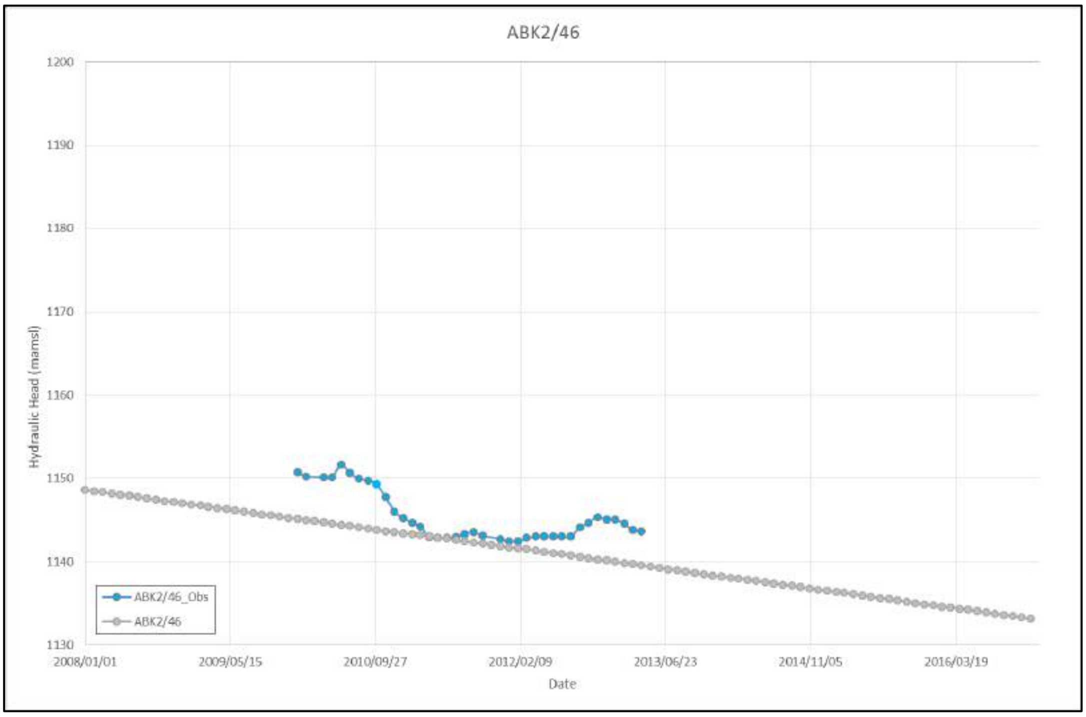


Figure 57: Simulated and Observed Heads - Borehole ABK2/46

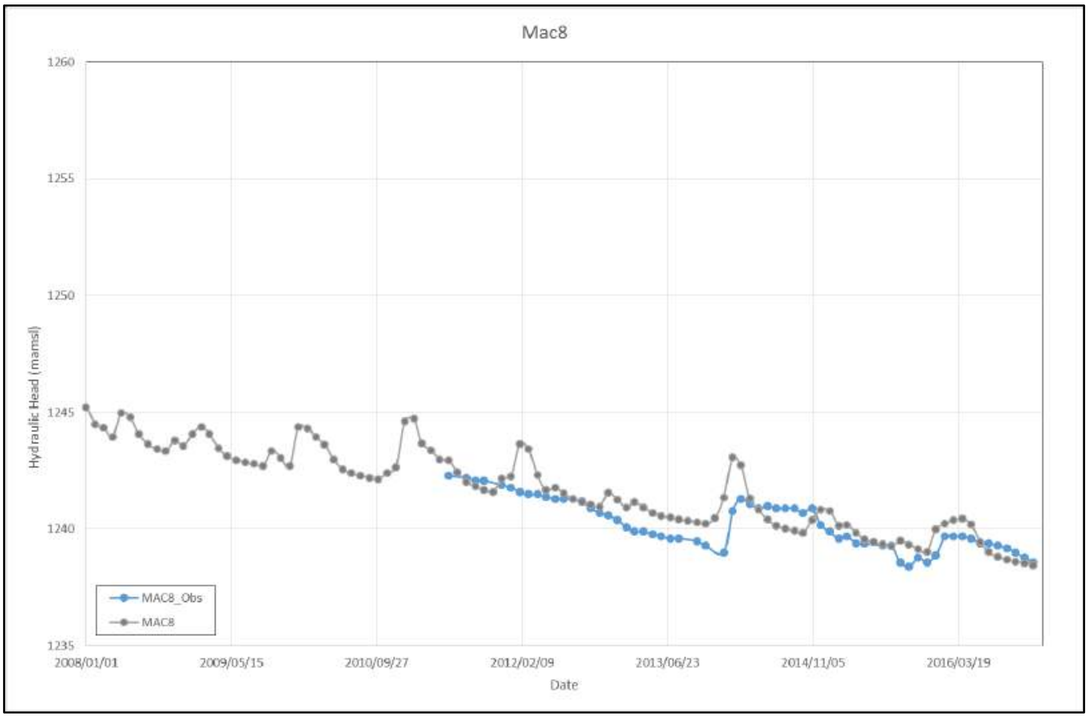


Figure 58: Simulated and Observed Heads - Borehole Mac8

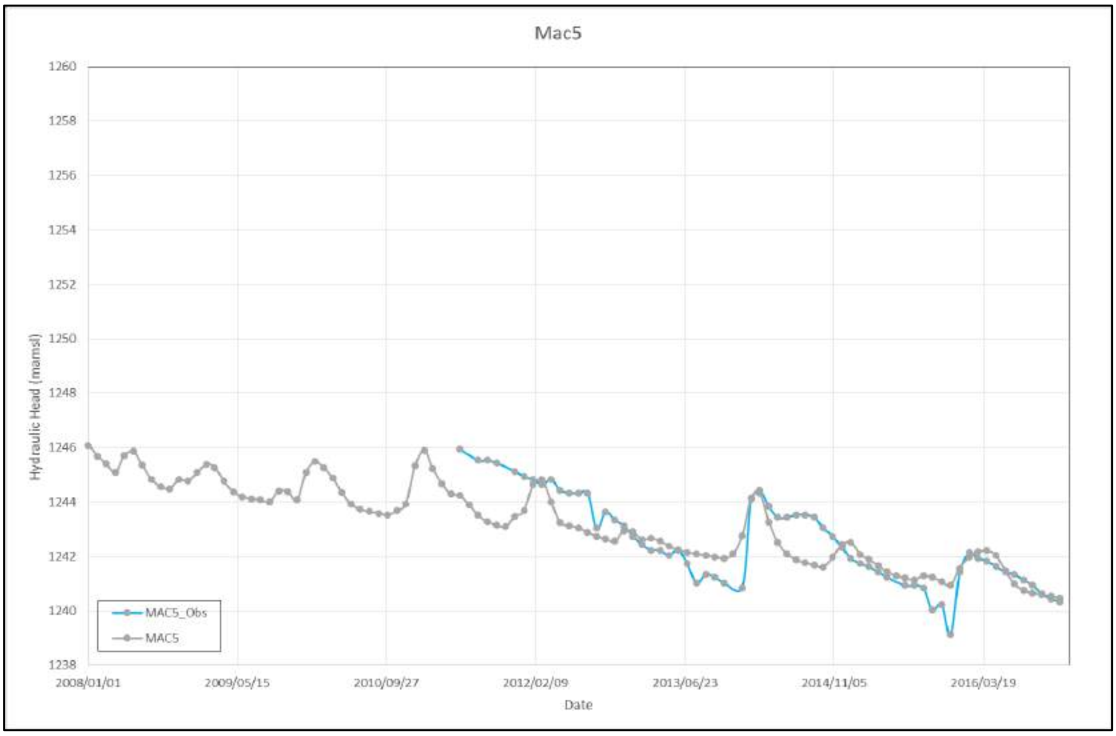


Figure 59: Simulated and Observed Heads - Borehole Mac 5

The model was found to suitably mimic hydraulic head distribution for boreholes outside the SIOM and KIOM groundwater compartment as well as those boreholes located within the major impact area. The final head distribution is reflective of December 2017 and is thus comparable to the 2017 piezometric surface. Alike to the steady state calibration suitable agreement was found between the simulated heads and observed heads depicted in the 2017 piezometric map (Figure 60 and Table 10).

Table 10: Calibration Criteria

Parameter	Value
Error	-1.02
Absolute Error	11.5
RMSE	14.3
NRMSE	10.0%

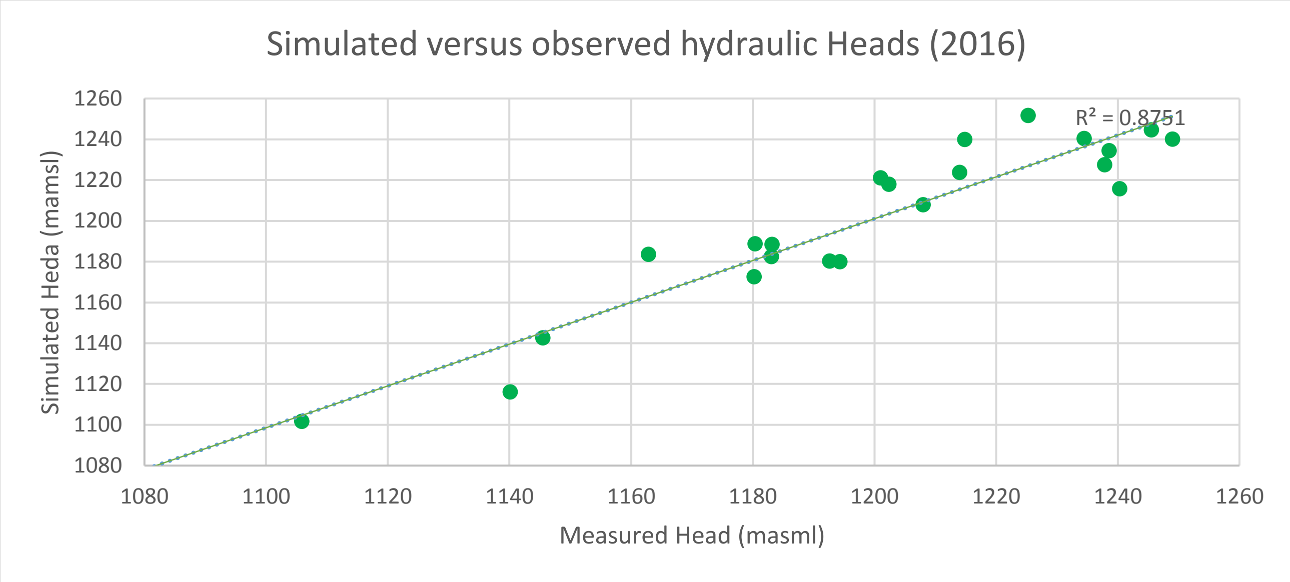


Figure 60: Simulated versus observed hydraulic heads (2016)

The simulated versus observed hydraulic heads are depicted in Figure 60 and the spatial distribution is depicted in Figure 61. The extensive dewatering at Sishen mine over the past forty years coupled with the low permeability dykes which sub-compartmentalise the catchment and low natural recharge, has resulted in significant dewatering of the SIOM/KIOM compartment and consequently has resulted in steep hydraulic gradients along the dyke margins. Due to the compartmentalisation limited drawdown is experienced east and west of the dykes compared to that seen within the compartment. This aligns with the conceptual understanding provided by Meyer (2009).

The complete water balance (presented in Million cubic meters) spanning the period February 1976 to December 2016 and the annualised water balanced presented in Mm3/a is outlined in Table 11.

Table 11: Water Balance 1976 -2016

Scenario 1: Total Water Balance (Mm3) 1976 -2016 & Annualized Balance Mm^3/a			
Parameter	**Inflow**	**Outflow**	**Balance**
Sources (Recharge) (Mm^3) ***(Mm3/a)***	1 557 ***(38.11)***	0	1557 ***(38.11)***
Sinks (Local water supply, base flow, springs) (Mm^3)	0	-1520 ***(-37.20)***	-1520 ***(-37.20)***
Khumani Abstraction (Mm3)	0		0
Sinks (Mine Dewatering) (Mm^3)	0	-414 ***(-10.12)***	-414 ***(-10.12)***
Storage (Mm^3)	376 ***(9.22)***	0	376 ***(9.22)***
Balance(Mm^3)	1 933 ***(47.31)***	-1 934 ***(-47.32)***	-0

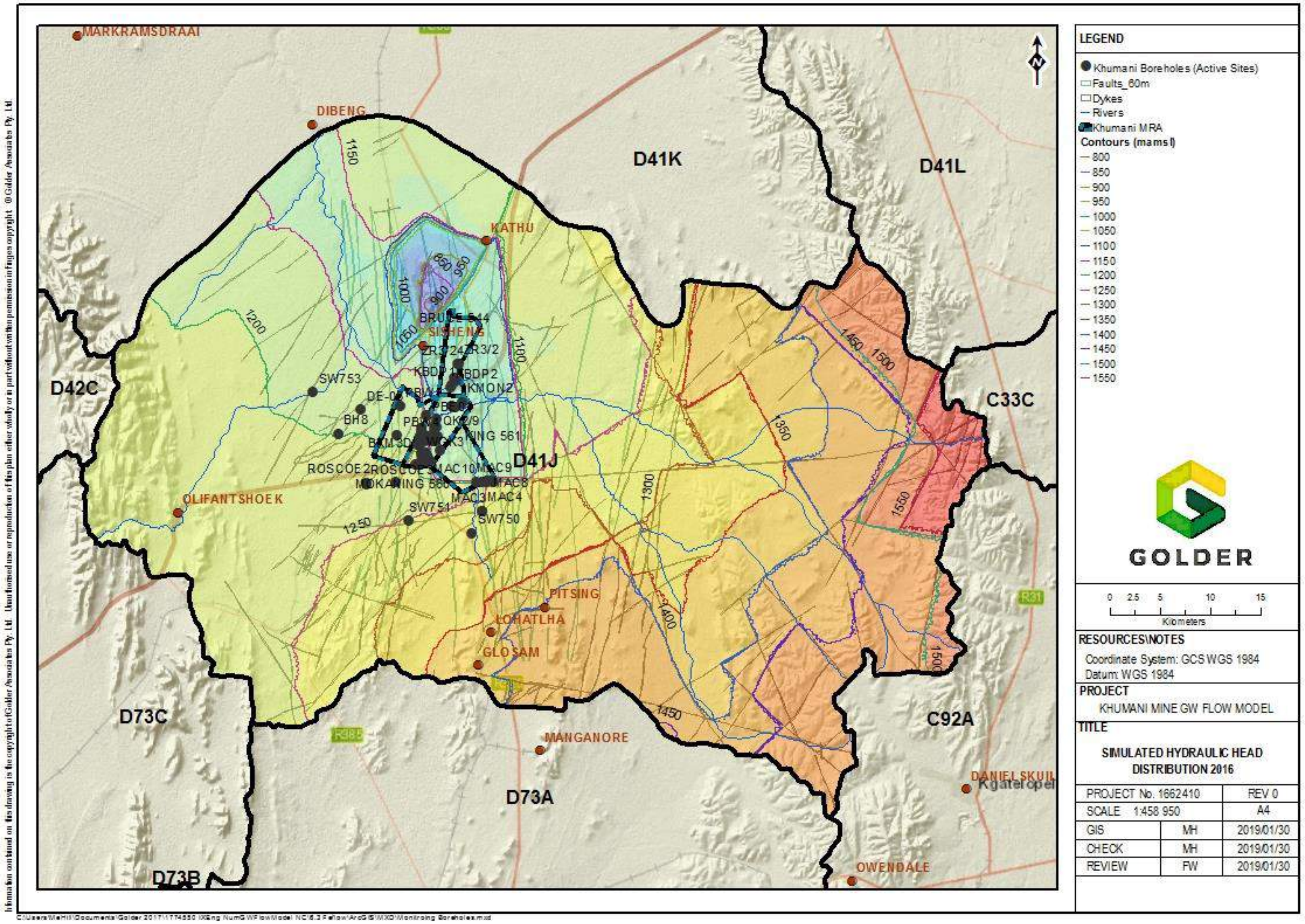


Figure 61: Simulated Hydraulic Head distribution - 2016

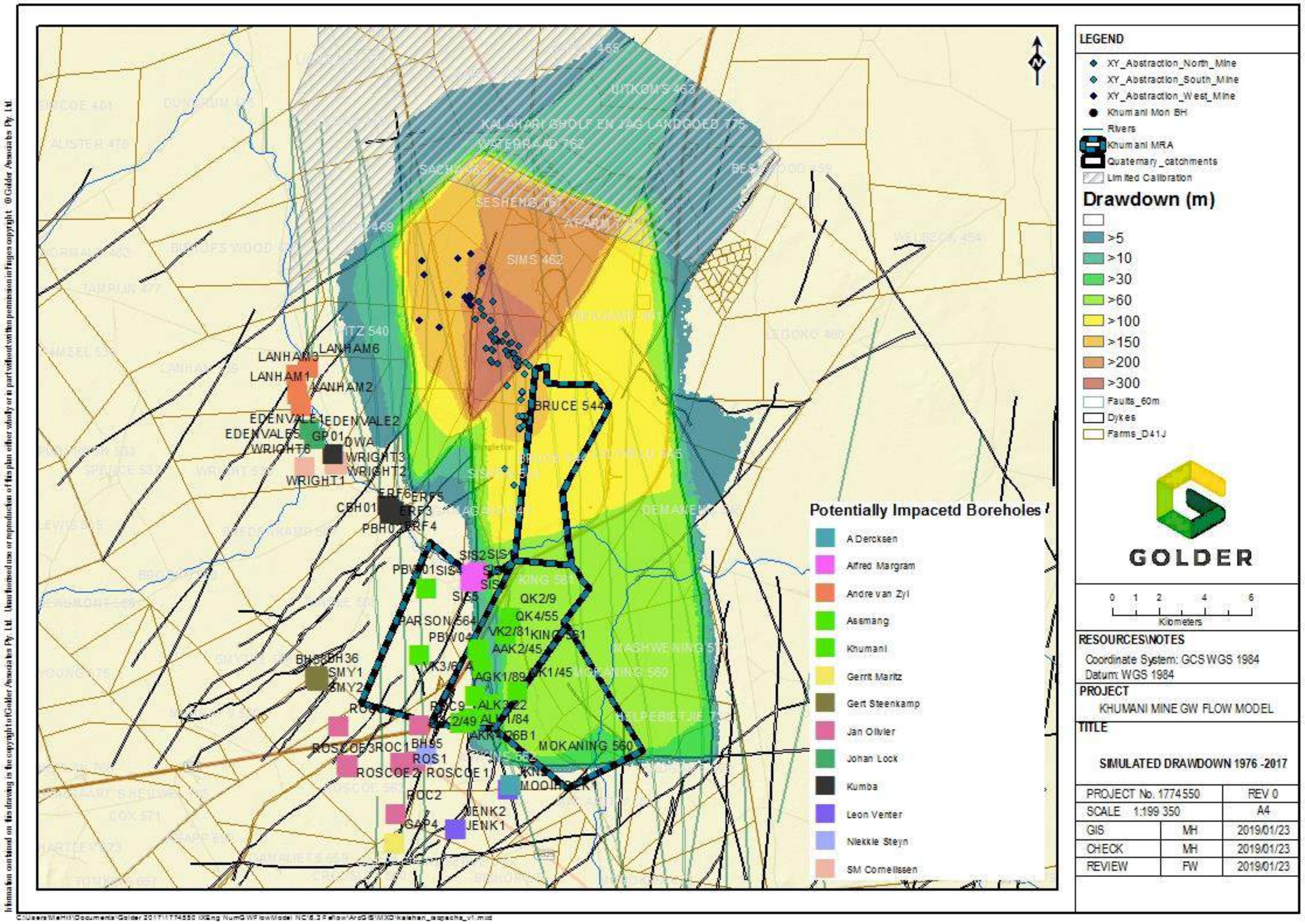


Figure 62: Simulated Drawdown in water levels between 1976 and 2017

4.4 Predictive scenarios

As described above the purpose of the current impact prediction model is to evaluate the expected inflows to the open pits and evaluate the potential impacts of the additional proposed infrastructure on receptors in vicinity of Khumani Mine.

4.4.1 Groundwater Inflows to King and Bruce Pits

The calibrated model was utilised to predict inflows into the open pits, the assumptions and limitations are outlined below;

- As described in preceding sections, the boreholes utilised for dewatering of the Sishen pits have cumulatively abstracted approximately 320 l/s. The Sishen abstraction has a major control on the groundwater levels within the KIOM & SIOM compartment. It is assumed that the current abstraction rate at SIOM will continue throughout the operational period of KIOM i.e. up to 2039.

  Should abstraction at SIOM vary significantly from the applied average, the model prediction would be required to be re-evaluated.

- Hydraulic head distribution is based on calibration against the available water level data. Observation boreholes are concentrated west of the King Pit Area. While no transient water level data is available east of the pits. It is assumed that the hydraulic head distribution, inferred from available boreholes, is representative of the system.
- With Exception of the testing undertaken on the augmentation boreholes, no aquifer parameters are derived within the Khumani Pit areas. An inference of conductivity was made based on testing in the wider catchment area and on calibration of water level data.

Inflows to the Bruce Pit Area is projected to begin in 2034. Based on the calibrated aquifer parameters, the inflows are expected to gradually increase to approximately 74 l/s (6400 m^3/d) by 2039 (Figure 63).

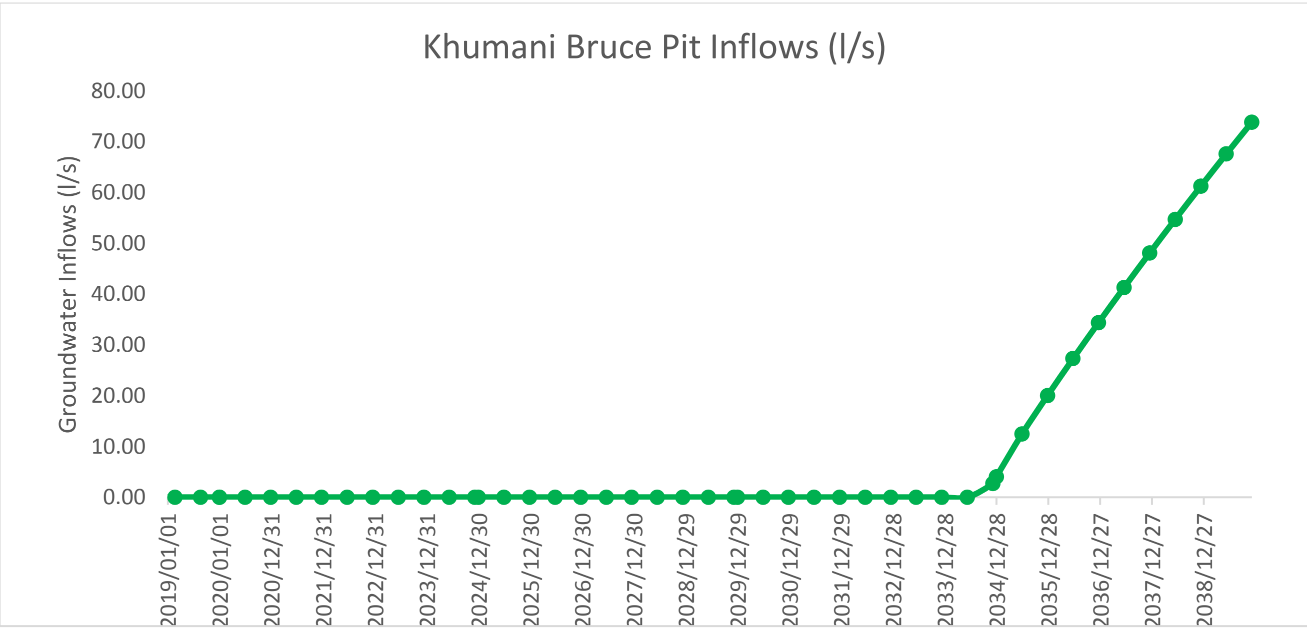


Figure 63: Projected groundwater inflows to the Bruce Pit

Inflows into the King Pits are expected to begin in 2024. The pit cross cuts a north south structure which appears to create a step in water levels in the pit area. East of the dyke, the piezometric heads are considerably lower than those to the west. Consequently, inflows are expected to initiate in the western pit area. The inflows to King Pit are expected to gradually increase and are to peak at approximately 114 l/s (Figure 64).

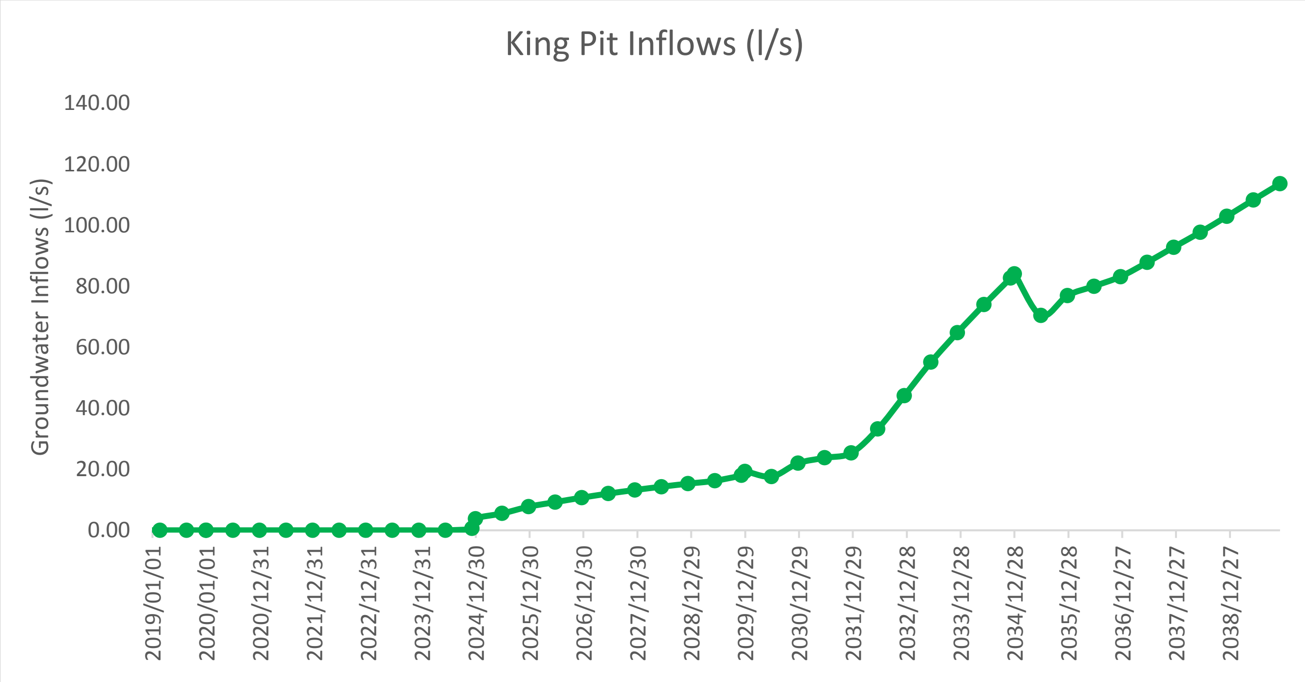


Figure 64: Projected groundwater inflows to the King Pit

The cumulative inflows to the pits at life of mine are expected to be in the order of 190 l/s (16 400 m3/d). The groundwater balance for catchment D41J in 2039 (i.e.at completion of mining at KIOM) is outlined below. As indicated in Table 12, on a quaternary catchment scale the projected abstraction of groundwater from KIOM and SIOM is approximately 40% of total catchment recharge. However, due to the limitation of groundwater flow as a consequence of regionally extensive dykes, abstraction from the KIOM/SIOM compartment for mine dewatering draws primarily from groundwater storage and consequently significant declines in water level are observed within the compartment.

Table 12: Groundwater Balance Quaternary Catchment D41J

Groundwater Water Balance – December 2039 (Khumani Mine life of Mine)			
Parameter	**Inflow**	**Outflow**	**Balance**
Sources (Recharge) (m3/d)	1.04E+05	0.00E+00	1.04E+05
Sinks (Local water supply, base flow, springs) (m3/d)	0.00E+00	-1.01E+05	-1.01E+05
Khumani Abstraction (m3/d)	0.00E+00	-1.63E+04	-1.63E+04
Sishen Abstraction (m3/d)	6.98E-01	-2.77E+04	-2.77E+04
Storage (m3/d)	4.03E+04	0.00E+00	4.03E+04
Balance(m3/d)	1.45E+05	-1.45E+05	-1.30E+00

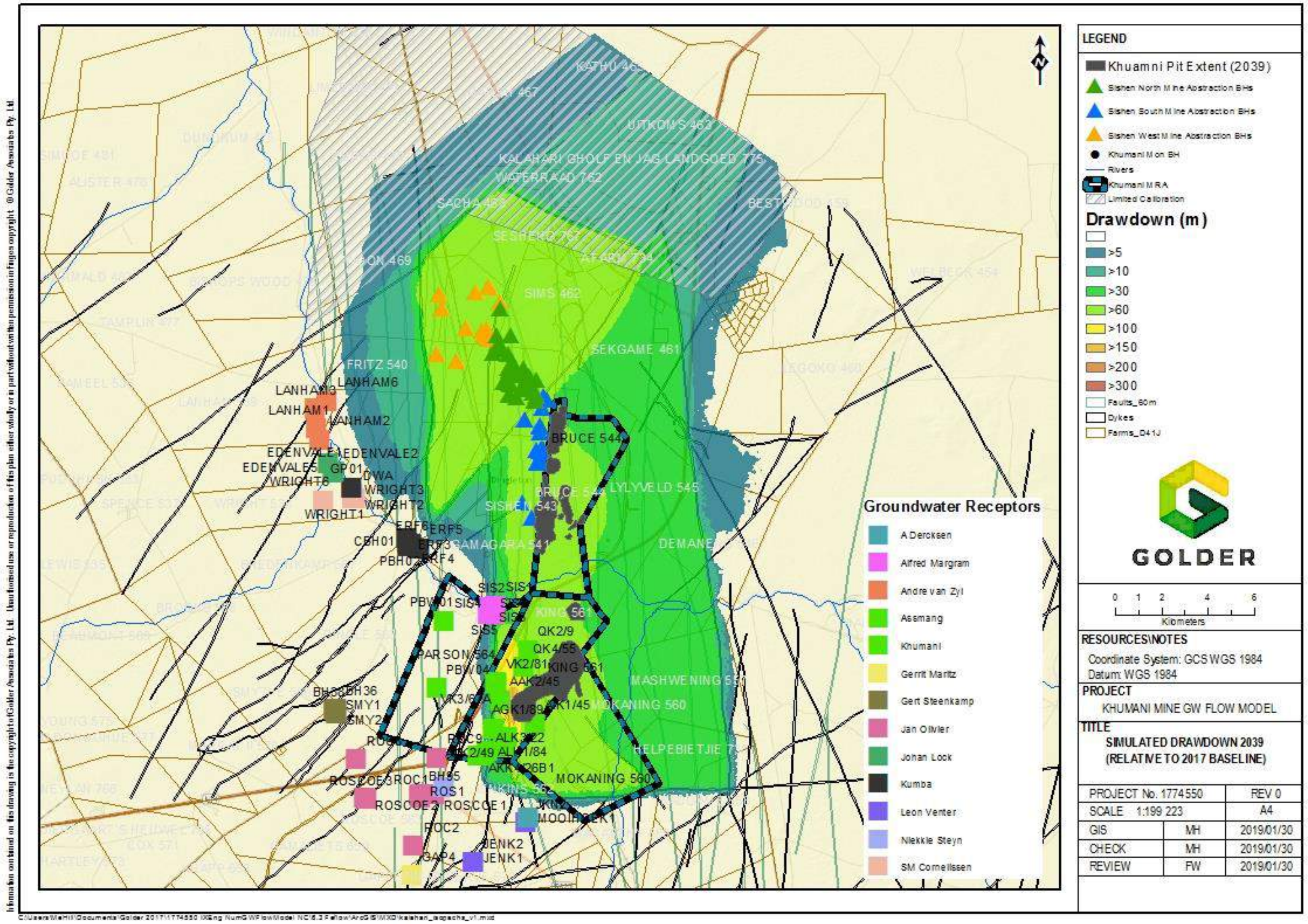


Figure 65: Predicted Drawdown 2039 (Khumani Groundwater abstraction & Sishen abstraction) (Relative to the 2017 baseline)

Limited drawdown is expected beyond the compartment boundaries delineated by dykes. No water users beyond the catchment area are expected to become impacted during the operational period as a consequence of mine dewatering.

4.4.2 Impact associated with infrastructure expansion and development

As described above, it is proposed to undertake the following infrastructure expansion at Khumani mine;

- The expansion of the Bruce overburden dump
- The development of the overburden dump (Dump H) on King 561 and Mokaning 560.
- The development of low grade stockpile (Dump J) on King 561.
- Expansion of the stockpile and associated infrastructure on the Parsons 546.

As part of a 2014 study undertaken by Geo Pollution Technologies (GPT REF: KHU-12-319), the onsite waste was characterised, and the contamination potential was assessed. As part of this investigation a leach test was undertaken on a paste sample and water associated with the Paste facility was sampled and assessed. It was found that material is considered unlikely to generate contamination under the natural geochemical conditions in the paste facility. The sampled paste water does not indicate any contamination potential in terms of the constituents analysed. The source terms associated with the stockpiles and waste rock dumps are not characterised but are assumed to have similar characteristics to that of the paste facility.

Sample Nr.	Paste	Class 0 (ideal)	Class I (acceptable)	Class II (maximum)
Ca	36.00	< 80	80 - 150	150 - 300
Mg	34.00	< 30	30 - 70	70 - 100
Na	60.00	< 100	100 - 200	200 - 400
K	19.60	< 25	25 - 50	50 - 100
Mn	0.08	< 0.1	0.1 - 1.0	1.0 - 2.0
Fe	0.18	< 0.1	0.1 - 0.2	0.2 - 2
F	1.30	< 1.0	1.0 - 1.5	1.5 - 3.5
NO_3	25.00	< 25	25 - 44	44 - 88
Al	0.19	< 0.15	0.15 - 0.5	-
Zn	0.00	< 3	3.0 - 5.0	5.0 - 10.0
HCO_3	223.62	-	-	-
Cl	90.00	< 100	100 - 200	200 - 600
SO_4	114.00	< 200	200 - 400	400 - 600
TDS by sum	620.75	< 450	450 - 1000	1000 - 2400
M-Alk($CaCO_3$)	184.00	-	-	-
pH	7.60	6.0 - 9.0	5.0 - 9.5	4.0 - 10.0
EC	95.50	70	70 - 150	150 - 370

Notes:
Class 0: Ideal quality
Class I: Target quality
Class II: Moderate effects
Exceeding maximum allowable concentration - adverse effects
na- not analysed
All concentrations are presented in mg/l, EC is presented in mS/m
0 = below detection limit of analytical technique

Figure 66: ICP Scan of Khumani Paste Water Sample (After GPT,2014)

Sample Nr.	Paste	Limit
As	0.01	5.8
Cd	0.00	7.5
Cr(III)	0.00	46000
Cr(VI)	0.00	6.5
Co	0.00	300
Cu	0.00	16
Pb	0.00	20
Mn	0.14	740
Ni	0.00	91
V	0.00	150
Zn	0.12	240
Cl	7.00	12000
F	1.20	30
NO3+NO2	0.70	120
SO4	25.00	4000

Notes:
Exceeding maximum allowable standard for domestic use
na- not analysed
All concentrations are presented in mg/l, EC is presented in mS/m
0 = below detection limit of analytical technique

Figure 67: Chemical Results of Distilled Water Leach Test for the Khumani Paste Facility Material Sample (after GPT, 2014)

For the purpose of evaluating the potential impact that the expansion of the proposed facilities may have on the receiving environment and in particular groundwater users proximal to the mine, a mass transport model was setup. Seepage was simulated using sulphate as a tracer. The source concentrations correlate with the sulphate concentrations obtained from the paste water sample collected, discussed above.

The water levels beneath the various waste facilities are summarised below;

- **Overburden dump:** Water levels beneath the overburden are approximately 150 mbgl and expected to increase to xxx mbgl by LoM.
- **Paste Facility & Waste Rock Dump KM02:** Water levels in vicinity of the past facility are currently over 120 mbgl.
- **Dump H& J and waste rock dump KM12:** Water levels on the farm king below these facilities exceeds 120 m.
- **Stockpile on Parsons:** the depth to groundwater beneath the existing stockpile on Parsons is in the order of 4 -6 mbgl.

It is evident from the summary above, the seepage from the facilities on the farms Bruce and King would need to travel over a 100 m through the unsaturated zone before entering the groundwater system. It is probable that significant sorption of solutes will occur. Never the less, to adopt the most conservative approach, it has been assumed that the sulphate concentration will instantaneously reach the saturated zone. The input parameters used for model setup are summarised in Table 12

Table 13: Mass transport simulations – model setup parameters

Parameter	Value
Porosity	3%
Longitudinal Dispersivity (m)	5
Transverse dispersivity (m)	0.5
Sources – Sulphate (mg/l)	115
Background	15

Two simulations were undertaken to demonstrate the plume migration associated with Khumani mine infrastructure:

- **Scenario A** depicts the sulphate plume at LoM from the existing infrastructure which has been licenced as part of the existing water use licence, Figure 68.
- **Scenario B** depicts the sulphate plumes at LoM associated with the existing and proposed infrastructure, Figure 69.

In both Scenario A and Scenario B it is shown that the mass transport plumes expected at completion of the Mine at Khumani are not expected to impact upon receptors proximal to the mine. The plume distribution maps indicate that the infrastructure expansions proposed as part of the current study are expected to result in negligible changes to the mass transport plumes associated with the site infrastructure.

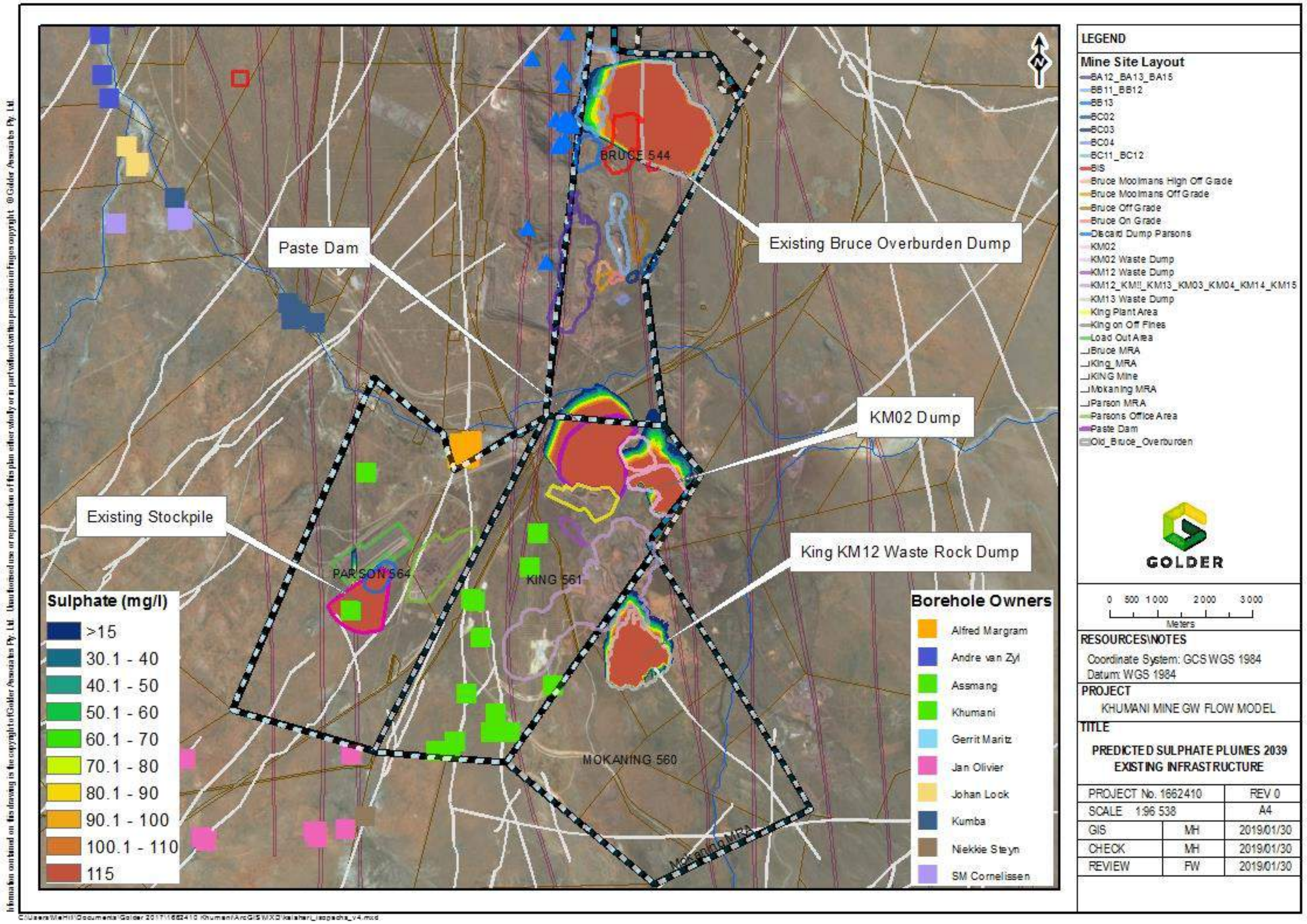


Figure 68: Scenario A: Sulphate plumes at LoM associated with Existing Infrastructure

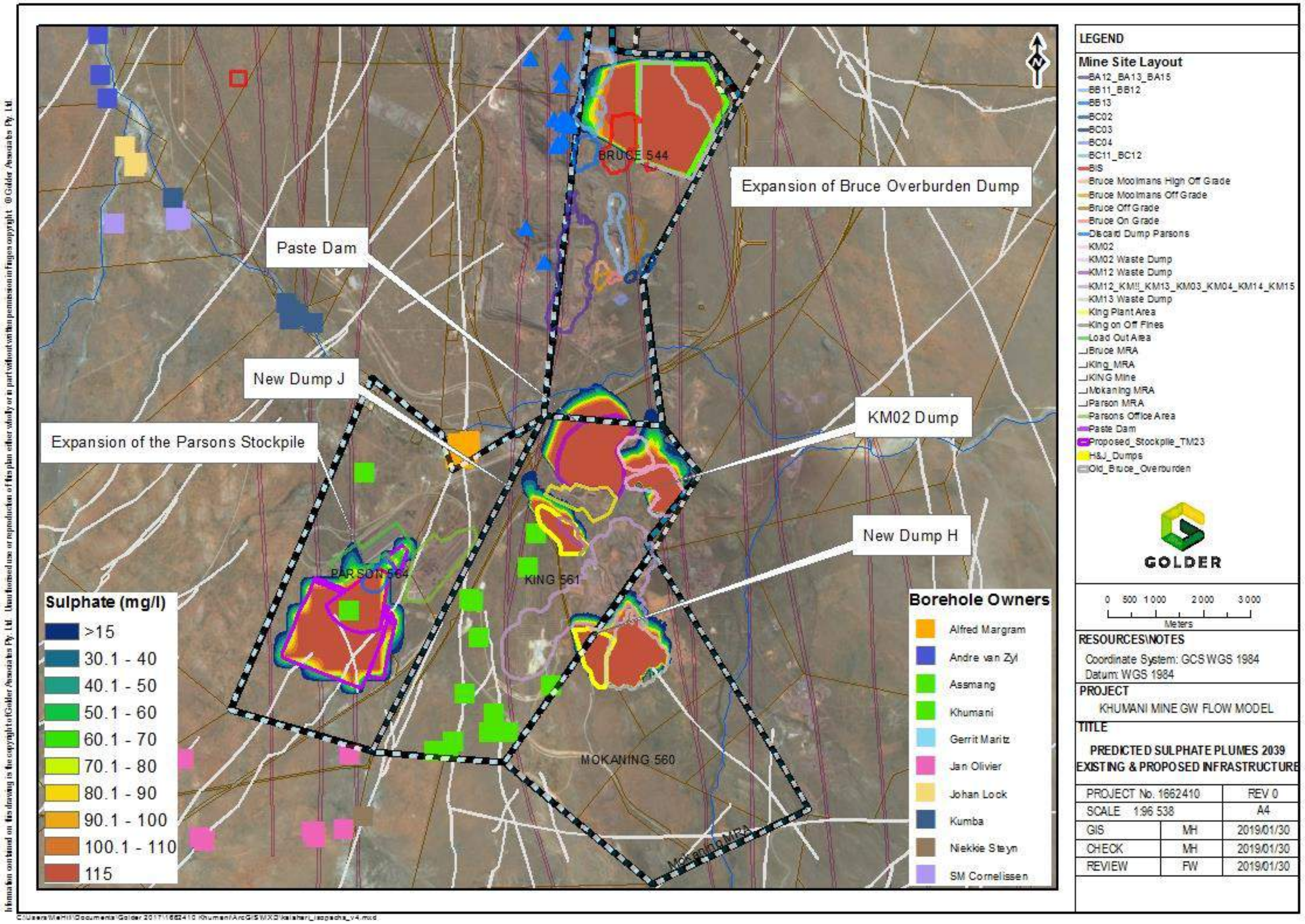


Figure 69: Scenario B: Sulphate plumes at LoM associated with Existing & Proposed Infrastructure

4.4.3 Post closure recovery and post closure seepage

For the purpose of the post closure evaluation it is assumed that all mining will cease in the groundwater compartment in 2039 and water levels will thereafter begin to rebound. As described elsewhere, abstraction from the KIOM/SIOM compartment has drawn largely on aquifer storage and has consequently resulted in the deep water levels observed in the compartment. Limited interflow occurs into the compartment from the adjacent catchment areas due to regionally extensive dykes and recharge is estimated to be very low (1 mm/a). As a consequence of the factors rebound in water levels within the compartment is expected to be slow. It was demonstrated through the numerical modelling undertaken that complete recovery in compartment water levels will take more than 200 years.

Post closure seepage from mining infrastructure will be contained within the compartment for up to 300 years as the water levels rebound. Only after rebound will seepage from Waste rock and the Paste facility migrate toward surface water receptors such as the Gamagara River. The seepage quality is not however expected to have any constituents of concern which exceed drinking water quality guidelines and consequently the post closure impact resulting from seepage are considered to be negligible.

5.0 IMPACT ASSESSMENT

The hydrogeological impact assessment was based on a numerical groundwater flow model developed for the groundwater catchment which encompasses the Khumani and Sishen mines. The groundwater flow model was developed and calibrated using data collected from both mines. This included water levels data, rainfall records, water quality data, and hydrogeological parameters obtained through aquifer testing and Sishen abstraction records.

The numerical flow model was used to simulate pit dewatering and mass transport during the operational phase and rebound and particle tracking in groundwater levels during the post operational phase. The simulation of mine dewatering and seepage from the mine related facilities was utilised to guide the impact assessment presented below.

As described elsewhere, the purpose of the study is to understand the impacts of the additional infrastructure proposed at Khumani Mine. The mine already has an existing water use licence which encompasses several facilities. The current conditions within the catchment serve as the baseline against which the infrastructure expansions are evaluated against.

For the purposes of this impact assessment, the project timeframe has been subdivided into two phases:

- Operational/Mining Phase; and
- Decommissioning and Closure Phase.

Each impact will be assessed according to Magnitude, Duration and Extent (Table 14).

The impact assessment methodology will employ subject matter specialist assessment, existing baseline condition reviews, and predictive modelling to inform assessment. It will be narrative and will combine the magnitude, duration and extent of the specific impact occurring at each of the relevant project phases.

Magnitude: is the degree of change in an attribute, a measurement or analysis endpoint; classified as negligible, low, moderate or high; and is based on a set of criteria pertinent to the discipline area.

- Negligible: An effect that is not measurable and not likely to be noticed by stakeholders;
- Low: An effect below levels expected to cause concern;
- Moderate: An effect that will be observed and may be of concern, therefore typically requiring mitigation;
- High: An effect above limits that requires mitigation

Duration refers to the length of time over which an impact may occur: short-term, medium term and long-term.

- Short-term is defined as less than the construction phase (less than 2 years)
- Medium-term as longer than short-term and up to the operational duration of the Project plus up to four years of active closure (2 to 15 years)
- Long-term is greater than medium term (greater than 15 years).

Extent or scale refers to the area that could be affected by the impact and is classified as local, regional and beyond regional and has been defined as follows:

- Local – effect restricted to the study area
- Regional – Effect extends beyond the study area
- Beyond regional – Effect extends more than 50 km from the Project

Table 2, below, presents the classifications used in the assessment. Table 3 shows how these factors are used to arrive at a level of significance of the effect.

Table 14: Factor of the Impact Assessment

Magnitude	Duration	Scale
Negligible	Short-term	Local
Low	Medium-term	Regional
Moderate	Long-term	Beyond regional
High		

Table 15: Environmental Impact Significance Determination

Magnitude	Extent	Duration	Impact Significance
Negligible	Local Regional Beyond regional	Short-term Medium-term Long-term	**Negligible**
Low	Local	Short-term	**Negligible**
Low	Local	Medium-term	**Low**
Low	Local	Long-term	**Low**
Low	Regional	Short-term	**Low**
Low	Regional	Medium-term	**Medium**
Low	Regional	Long-term	**Medium**
Low	Beyond regional	Short-term	**Low**

Magnitude	Extent	Duration	Impact Significance
Low	Beyond regional	Medium-term	**Medium**
Low	Beyond regional	Long-term	**Medium**
Moderate	Local	Short-term	**Low**
Moderate	Local	Medium-term	**Low**
Moderate	Local	Long-term	**Medium**
Moderate	Regional	Short-term	**Medium**
Moderate	Regional	Medium-term	**Medium**
Moderate	Regional	Long-term	**High**
Moderate	Beyond regional	Short-term	**Medium**
Moderate	Beyond regional	Medium-term	**High**
Moderate	Beyond regional	Long-term	**High**
High	Local	Short-term	**Medium**
High	Local	Medium-term	**High**
High	Local	Long-term	**High**
High	Regional	Short-term	**Medium**
High	Regional	Medium-term	**High**
High	Regional	Long-term	**High**
High	Beyond regional	Short-term	**High**
High	Beyond regional	Medium-term	**High**
High	Beyond regional	Long-term	**High**

The two main identifiers used to characterise impact on the groundwater system are groundwater levels and water quality. The magnitude of the potential impacts are rated based on these two factors; water quality and water level. Water quality is evaluated both in terms of the baseline and in terms of drinking water quality guidelines. Water level is evaluated on the level of drawdown.

The key impacts identified during the operational phase and post operation phase are outlined below;

Operational Phase

1) **Reduction in groundwater levels and water supply potential at receptor boreholes in proximity of Khumani Mine**

Currently Sishen abstraction is the only major dewatering activity occurring within the compartment as the Khumani pits are presently above the water table. The model indicates that dewatering will be required from the Khumani King Pits in 2024 and at the Bruce pits in 2034. The inflows are expected to gradually increase from 3 l/s in 2024 up to 190 l/s in 2039.

Monitoring to date has indicated that there has been limited water level drawdown on the lavas west of Khumani Mine. This is a consequence of the regionally extensive boundary dyke which separates the mine compartment from adjacent aquifers and consequently limits the impact area. The nearest receptors to Khumani Mine are farmers utilising boreholes drilled into the lava West and South of the KIOM/SIOM compartment area. The predictive modelling undertaken demonstrates that there will limited impact on groundwater users west and south of the compartment boundary through the remaining life of mine.

Magnitude: Magnitude of the impact arising from Khumani dewatering is regarded as negligible as surrounding water levels in receptors boreholes are not expected to be significantly drawn down as a consequence of Khumani dewatering.

Extent: The extent is limited to the SIOM/KIOM compartment and is therefore considered local.

Duration: As abstraction at Khumani Mine will continue for a period 15 year, the duration of the potential impact is regarded as medium term.

Due to the magnitude rating, this impact is regarded as negligible.

2) Impact on groundwater receptors as a consequence of seepage from the Khumani Mine infrastructure

A study undertaken by GPT in 2014 demonstrated that seepage from the Paste facility is unlikely to generate constituents of concern that exceed drinking water quality guidelines. It therefore follows that groundwater users would not be impacted by seepage from the Paste facility. It is inferred that the other infrastructure on site such as the waste rock dumps, overburden and stockpiles would have comparable seepage chemistry to the Paste facility.

In addition to the seepage quality results, a mass transport simulation was undertaken to demonstrate the pathway that seepage from Khumani mine infrastructure would migrate along in the saturated zone. The groundwater catchment is significantly dewatered and consequently the seepage would first require to migrate through >100 m of unsaturated zone. This would result in significant sorption and it is expected that very little mass will ultimately reach the saturated zone. Nevertheless the source terms derived for the paste facility were assumed to directly enter the saturated zone and hence the simulation represents a worst case.

The modelling shows that by life of mine the seepage from the mine infrastructure is not expected to impact upon any existing groundwater receptor boreholes in proximity of the mine and it is not expected that seepage will reach the Gamagara river.

Magnitude: The magnitude of the impact associated with seepage is therefore regarded as negligible.

Extent: The extent is limited to the SIOM/KIOM compartment and is therefore considered local.

Duration: Seepage will occur during the operational and beyond the operational phase, the duration of the potential impact is regarded as long term.

As a consequence of the magnitude the impact is regarded as negligible.

Post Operational Phase

3) **Contaminated seepage emanating from Khumani mine infrastructure and impacting upon groundwater receptors.**

As described elsewhere, the groundwater catchment has been extensively dewatered as consequence of abstraction within the catchment for over 40 years, the abstraction has pumped largely storage from the compartment. Very little cross compartment inflows occur due the extensive regional dykes which bound the compartment. Recharge is estimated to be 1 mm/a and consequently rebound within the compartment is expected to be slow. It was demonstrated through the model that it will take a minimum of xx years for water levels within the compartment to rebound to water levels similar to those observed in the 1970s.

Particle tracking was used to evaluate the migration pathway of potential seepage from the Khumani Mine infrastructure such as the waste rock dumps and Paste facility. It is shown in a 200-year period it is not anticipated that seepage from the Khumani Mine infrastructure will impact on existing borehole receptors in adjacent aquifers and it is unlikely that the Gamagara river system would become impacted over time.

Magnitude: The magnitude of the impact associated with seepage is therefore regarded as negligible.

Extent: The extent is limited to the SIOM/KIOM compartment and is therefore considered local.

Duration: If unrehabilitated seepage will occur for long term.

As the magnitude is negligible, the overall impact rating for post operational seepage from mine infrastructure is considered negligible.

6.0 SUMMARY AND CONCLUSIONS

A hydrogeological assessment was undertaken in order to identify and quantify the impacts associated with the proposed expansion of infrastructure at Khumani Iron Ore Mine.

Khumani Mine has a projected life of mine to 2039. Iron or is mined via a series of pits situated on the Farms Bruce 544 and King 561. Waste rock dumps and, offices and stockpiles are located on the Parsons 564 and Mokaning 560.

The proposed infrastructure expansions include the following activities;

- The expansion of the Bruce overburden dump
- The development of the overburden dump (Dump H) on King 561 and Mokaning 560.
- The development of low grade stockpile (Dump J) on King 561.
- Expansion of the stockpile and associated infrastructure on the Parsons 546.

The key findings of the study are outlined below;

Groundwater Inflows & drawdown impacts

- The Bruce Pits are expected to reach a maximum mining elevation of 940 mamsl (270 mbgl) at BA 12 in 2039. Groundwater inflows to these pits are expected to begin in 2034. Based on the calibrated aquifer parameters, the inflows are expected to gradually increase to approximately 74 l/s (6400 m^3/d) by 2039
- The King Pits are similarly projected to be mined up until 2039 and KM15, the deepest of the King pits, is projected to reach a maximum mining elevation of 930 mamsl or approximately 280 m below the pre-mining surface.
- Inflows at King are expected to begin in 2034 and gradually increase over time to a peak groundwater inflow rate in the order of 114 l/s.
- The maximum cumulative inflows to the pits are life of mine are expected to be in the order of 190 l/s. Which will be required to be abstracted from the open pits to ensure safe mining conditions.

These predictions are based on the calibrated numerical model developed for the evaluation of mine dewatering impacts on the catchment. The aquifer parameters (conductivity and storage) are based on calibration of the model against transient water levels collected at Khumani mine and aquifer parameters derived from testing in the broader catchment area. No aquifer tests have been conducted within the mining pits.

- Khumani Mine is located within a groundwater compartment which is bound by regionally extensive dolerite dykes. Water levels within the compartment are significantly impacted as a consequence of Sishen Iron ore mine dewatering which has been active within the compartment since 1976.
- Extensive investigations have found that there is limited drawdown in water levels beyond the dyke boundaries which are inferred to delineate the groundwater compartment. Based on the calibrated model developed for the catchment, it was demonstrated that the dewatering which will be required from the Khumani mine pits results in negligible addition impacts to receptors beyond the mine compartment.

Infrastructure expansion

- Mass transport simulations were run for in order to evaluate the existing impact associated with Khumani mine infrastructure and the additional impacts that could be expected with the expansion of the infrastructure on Bruce 544, King 561 and Parsons 564.
- Leach tests and water quality analysis associated with the Paste facility was undertaken in 2014 by GPT. The analyses demonstrated that the seepage from the Paste facility is not expected to adversely effect water quality in the underlying aquifers. Based on the constituents analysed, it is not expected that groundwater quality concentration beneath the Paste facility and other Khumani Mine infrastructure will not exceed Sans 241:2015 drinking water quality standards.
- A mass transport simulation was however undertaken in order to evaluate the pathway of seepage from existing a proposed infrastructure. It was demonstrated that the mass plumes associated with licenced infrastructure is not expected to impact receptors proximal to Khumani Mine during life of mine. Similarly, it was shown that the additional infrastructure will not result in impact on surrounding receptors during the operational phase.

Post closure impacts

- The water levels within the compartment containing the Khumani and Sishen Mines have been significantly impacted as a consequence of dewatering since 1976. Complete recover of water levels in the compartment will take over 300 years.
- Particle tracking associated with mine infrastructure was used to demonstrate the pathways and potential receptors that could potentially become impacted from seepage in the post operational phase. It was shown that after a 300 years of recovery no existing water users beyond the Khumani mine property are expected to be impacted by seepage from the Khumani mine infrastructure.

Signature Page

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APPENDIX A

Document Limitations

GOLDER

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Report on a Phase 1 Archaeological Assessment of proposed mining areas on the farms Bruce, King, Mokaning and Parson, between Postmasburg and Kathu, Northern Cape.

David Morris
Kimberley : February 2005

Introduction

The archaeology of the Northern Cape is rich and varied, covering long spans of human history. Concerning Stone Age sites here, C.G. Sampson has observed: "It is a great and spectacular history when compared to any other place in the world" (Sampson 1985). Some areas are richer than others, and not all sites are equally significant. Heritage impact assessments are a means to facilitate development while ensuring that what should be conserved is saved from destruction, or adequately mitigated and/or managed.

The present report concerns archaeological observations on proposed mining areas and associated infrastructure development on the properties Bruce, King, Mokaning and Parson.

This report also provides background information on the archaeology of the wider region against which field survey observations may be assessed.

Terms of reference

Terms of reference were to detail observations based on a field survey on the properties in question and to assess significance of impact should mining proceed. The report was to provide: Site description; Methodology; Impact assessment (including all linear infrastructure) for construction, operation and decommissioning phases; and Mitigation measures and recommendations.

Legislation

The National Heritage Resources Act (No 25 of 1999) (NHRA) provides protection for archaeological resources.

It is an offence to destroy, damage, excavate, alter, or remove from its original position, or collect, any archaeological material or object (defined in the Act), without a permit issued by the South African Heritage Resources Agency (SAHRA).

Section 35 of the Act protects all archaeological and palaeontological sites and requires that anyone wishing to disturb a site must have a permit from the relevant heritage resources authority. Section 36 protects human remains older than 60 years. In order for the authority to assess whether approval may be given for any form of disturbance, a specialist report is required. No mining, prospecting or development may take place without heritage assessment and approval.

The Provincial Heritage Resources Agency (PHRA) in the Northern Cape is renewing an agreement whereby SAHRA at national level is requested to act on an agency basis where archaeological sites are concerned. Permit applications should be made to the SAHRA office in Cape Town.

Methods and limitations

A background literature/museum database search provides indications of what might be expected in the region.

During the site investigation, areas of proposed mining and associated infrastructure construction were examined in some detail. In several instances there were extensive areas that were not considered to be of high potential. These were checked at various points, while features in the respective landscapes that were more likely to have been foci for past human activity were assessed more carefully.

When assessing archaeological resources, surface indications may be regarded as providing a fair estimate of the nature and range of material present in this environment, where soils are generally shallow. However, some tracts are mantled with Kalahari sands (see remarks below under "General description of the terrain and remarks on archaeological visibility"). Hence, subsurface traces and features may occur. In the event that any major feature is encountered, for example a burial or a cache of ostrich eggshell flasks, then work should be halted and a professional archaeologist consulted. It was not considered necessary in this environment to sink test trenches to assess potential subsurface occurrences since archaeological visibility (density of resources) was expected to be low.

Basic documentation of cemeteries has been included in this report, but heritage features such as old farming and mining infrastructure have not been detailed. No such features or buildings that were considered to be of special note from a heritage perspective were observed.

Appendix 1 indicates criteria used here in archaeological significance assessment.

Background: archaeological resources in the region

While much of the surrounding region has yet to be examined from an archaeological viewpoint, certain areas have been investigated in great detail, particularly in the last quarter century. This is especially true of the Kathu area (Beaumont & Morris 1990; Beaumont 2004; Morris & Beaumont 2004), to the north of Bruce, where renewed research by an international team in partnership with the McGregor Museum was commenced in August 2004. This existing work suggests that sites of great significance may yet be brought to light in the region. Broadly speaking, the archaeological record of this region reflects the long span of human history from Earlier Stone Age times (more than one and a half million to about 270 000 years ago), through the

Middle Stone Age (about 270 000 – 40 000 years ago), to the Later Stone Age (up to the protocolonial era). The last 2000 years was a period of increasing social complexity with the appearance of farming (herding and agriculture) alongside foraging, and of ceramic and metallurgical (Iron Age) technologies alongside an older trajectory of stone tool making. Of interest in this area is evidence of early mining of specularite, a sparkling mineral that was used in cosmetic and ritual contexts in from early times (Beaumont 1973). Rock art is known in the form of rock engravings.

In the area within and immediately to the north of the BKMP farms, the Earlier Stone Age is represented by 11 known sites (including one on the farm Bruce, as well as Kathu, Uitkoms, Sishen, Demaneng, Lylyveld and Mashwening); the Middle Stone Age by 5 sites (all in the vicinity of Kathu); various phases of the post-12 000 year old Later Stone Age by 10 sites (including one on King, one at Mashwening and eight at Kathu); the Iron Age by 3 sites (Demaneng, Lylyveld and Kathu); while rock engravings are (or have been) known from Sishen and Bruce (the latter site was salvaged and recorded by Fock & Fock 1984), as well as Beeshoek, to the south (Fock & Fock 1984; Morris 1992; Beaumont 1998). Specularite sources are known on Demaneng and Lylyveld, and were mined in Stone Age times at a site on Doornfontein to the south (Beaumont 1973; Beaumont & Boshier 1974) and at Tsantsabane on the eastern side of Postmasburg (Beaumont 1973; Thackeray *et al*. 1983): numerous other specularite workings are on record (Beaumont 1973).

Information on these sites is on hand at the McGregor Museum in Kimberley (Beaumont 1973; Beaumont & Morris 1990; Beaumont 2004; Morris & Beaumont 2004; Fock & Fock 1984).

At a regional level the sites of Wonderwerk Cave (east side of the Kuruman Hills) and the Kathu complex of sites provide important sequences against which to assess the age and significance of finds made during the present survey.

Observations

General description of the terrain and remarks on archaeological visibility.

The terrain comprises, broadly, three kinds of topographical elements: undulating plains; hills with occasional prominent rocky outcrops; and non-perennial water courses, the principal one being the valley of the Gamogara River. Each of these has represented different opportunities in terms of human settlement and activity in the past, and cultural/heritage residues are not likely to be evenly distributed across them. It was expected that areas of higher sensitivity would include the margins of water courses, and sheltered locales such as in the vicinity of rocky outcrops. The plains are mantled with aeolian sand with thornveld and *Tarchonanthus* vegetation, while the hills comprise mostly scree with combinations of *Tarchonanthus* and *Acacia mellifera* vegetation.

All these zones were examined. Observations indicated that archaeological visibility is generally lower on the plains and higher along the river banks and on hills, especially in the vicinity of prominent outcrops. It is possible that on the plains in particular archaeological material would occur mainly below the surface, and hence eroded and disturbed areas were examined especially to assess how much material might be expected to be sub-surface. The impression of lower visibility on the plains was sustained. However, the possibility of sub-surface features in those areas constitutes one of the limitations of this report and is a reason for monitoring to take place during the construction phase.

<u>Archaeological and heritage observations</u>

Observations made on the properties in question are tabulated below and their significance ranked relative to Tables of Significance (See Appendix 1). Table 1 significance data provide an *estimate of site potential*, where Type 3 sites tend to be those with higher archaeological potential (there are notable exceptions, such as the renowned rock art site Driekopseiland, near Kimberley, which is on landform L1 Type 1. Generally, moreover, the older a site, the poorer the preservation. Estimation of potential, in the light of such variables, thus requires specialist interpretation). Table 2 significance data are a measure for assessing *site value by attribute*, where the relative strengths of a range of attributes are ranked (aspects of this matrix remain qualitative, but attribute assessment is a good indicator of the general archaeological significance of a site, with Type 3 attributes being those of highest significance).

<u>Cemeteries/graves</u>

Four cemeteries, previously identified, were inspected and briefly characterised. Only the last of these appears to be threatened by the proposed mining and associated infrastructure.

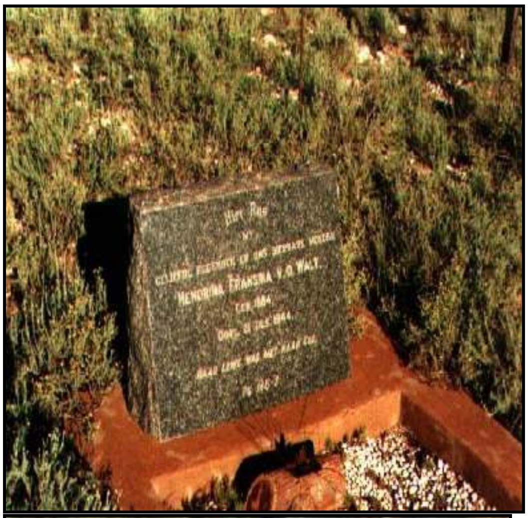
1. On the property Parson, at 27°52.926' S 22°58.345' E, a small farm cemetery, with four graves, each with a headstone inscribed as follows:

"In tere herinnering aan PIETER WILLEM VD WALT Geb 13 Julie 1940 Ov 9 Maart 1941. Rus in Vrede"

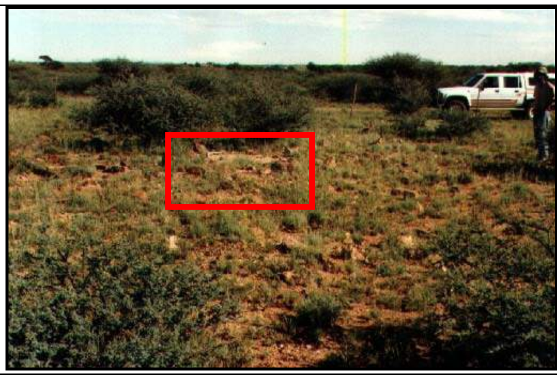
"Hier rus my geliefde eggenoot en ons dierbare moeder HENDRINA FRANSINA VD WALT. Geb 1884, Oorl 21 Des 1944. Haar lewe was met haar God. Ps 146:3"

"In liefdevolle herinnering aan ons dierbare eggenoot en vader NICOLAAS VD WALT. Geb 18 Feb 1908 Oorl 30 Jan 1946. Tot weersiens liefling. Ps 116:15. Veilig in Jesus arme."

"In tere herinnering aan my eggenoot en ons vader PIETER WILLEM VAN EEDEN. Geb 3 Des 1868 Oorl 13 Julie 1943. Ps 116:vi".

2. Also on the property Parson, on a hill south of and overlooking the GaMogara valley at 27°50.478’ S 22°58.270’ E, a small farm cemetery probably used by farm workers. There are at least 10 graves, none of which has any inscribed headstone. The present generation of farm-workers do not know who is buried here. The style of burial is similar to that observed in other mainly rural farm-worker or related graves, having an oval shape in plan, with upright stones at the head and foot ends.

3. Again, on the property Parson, on the north bank of the GaMogara, at

27°50.097’ S 22°58.368’ E, a small farm cemetery with four graves, only two of which have inscriptions:

“In memory 1955C P L E. PRICE 5th SAMR [South African Mounted Rifles] 14-2-16. Erected by his comrades.”

“HENRY MARKRAM Gebore 6 April 1940 Oorlede 27 Junie 2003. Ps 23. Die swerwer het tot rus gekom”.

4. On the property King A large rectangular cemetery with north east and south west corners at GPS positions: 27°50.005’ S; 22°53.125’ E and 27°50.121’ S; 22°53.098’ E respectively. This cemetery with several tens of graves dates from about the late 1960s to within the last few years. It has an interesting lych gate with half “ossewa” wheel design element. Burials are markedly segregated along apartheid lines.

This cemetery had been in the course of a proposed linear development, namely the servitude of proposed 32 kV powerline; but since the powerline will now be rerouted to following the conveyor servitude, there will be no impact on the cemetery.

Plains

A very sparse scatter of Stone Age artefacts, principally on jaspilite, was observed at several points inspected on the flat and gently undulating plains on the four properties. No major sites could be distinguished and it was determined that on the whole this topographic feature has generally low archaeological visibility.

River courses

The lower banks of the GaMogara bore traces of Stone Age sites, over generally low density. However, an area with much higher density was noted at 27°50.344’ S 22°58.394’ E on the south bank of the GaMogara on the property Parson.

Artefacts on jaspilite included flakes with prepared platforms, ascribable to the Middle Stone Age or Fauresmith.

(Photo: Artefacts).

Hills

As on the plains, a low density of artefacts was found on some parts of hills, for example in the vicinity of 27°50.576’ S 23°01.854’ near the eastern boundary of King. It was possible that prominent rocky outcrops could have been locales offering shelter or a range of resources making them more attractive for dwelling or other activities in the past, and hence sites of greater archaeological visibility. Amongst the outcrops in the vicinity of the above GPS position it appeared possible that cavities amongst the rocks had been formed by artificial extraction possibly of specularite, a substance used for cosmetic and ritual purposes.

The prominent outcrop of rocks, one of the landmarks of the area, some hundreds of metres to the north of there, in the vicinity of 27°49.989’ S 23°01.421’ E clearly had been a focus of human activity in the past. Pot fragments reflecting Tswana settlement in the region were found, in addition to rich surface spreads of Middle Stone Age or Fauresmith stone artefacts.

(Photos: Shelter and Outcrop)

<u>Other observations</u>

None of the rock outcrops examined appeared to be of a nature suitable for rock engravings and no rock art was found (at Beeshoek, Gamagara shale was favoured – no outcrops of this rock were encountered in the course of the survey).

No indubitable specularite workings with associated artefacts were found, although, as noted above, there were places where cavities may have been hollowed out artificially and were possibly sources for pigment in the past.

The very scattered low visibility dispersal of artefacts observed over much of the terrain examined is consistent with a scenario of sporadic discard over perhaps millennia by hunter-gatherers away from their home-base, while the more concentrated spreads at places along the GaMogara and near prominent rocky outcrops on hills probably represent places where people were living or focusing more concerted activities.

It is possible that sub-surface features of an archaeological nature (ostrich eggshell cache, high density artefact horizons, burials) *may* be found during mining. In the event of these being found, an archaeologist should be contacted immediately to assess significance and recommend mitigation measures.

Assessment of impacts during construction, operational and decommissioning phases of mining.

The greatest impact on archaeological resources is likely to be during the construction and operational phases of the proposed mining, with negative impacts (where they are likely to occur) being non-reversable (archaeological resources are non-renewable and therefore rehabilitation is not a concept that can be applied). Mitigation is recommended (see below) in a few instances.

Longer-term management of heritage resources will need to be applied mainly in relation to the cemeteries.

Recommendations

The proposed mining is not expected to have a significant negative impact on the archaeological resources of the region.

It is suggested that the following mitigation measures be implemented, together with monitoring during construction/operation phases.

Graves

It does not appear that any of the graves/cemeteries will be directly impacted by the proposed mining. The recommendation is that these should be adequately fenced and protected.

There may be a desire by family members to be able to gain access to the graves, most probably in the case of the large cemetery on King. Provision would need to be made for this.

Stone Age sites

Since Stone Age material scattered over the entire area will be impacted, it is recommended that Phase 2 surface collections be made at two localities (see below) in order to characterise the material observed in higher density occurrences and to salvage a representative sample of these as part of the South African National Estate.

It is recommended that a Pleistocene age Stone Age site on the south bank of the GaMogara at 27°50.344' S 22°58.394' E (Parson Site 1) should be sampled systematically, as well as a shelter and a talus slope on the east side of King at 27°49.989' S 23°01.421' E (King Site 1) where Iron Age pottery and Pleistocene age material was found, and 27°49.932' S 23°01.463' E (King Site 2) where there is ample Pleistocene age material.

In each case it is felt that collection of a representative sample is called for and will provide some insight into the nature of material sparsely scattered over adjacent areas that will be mined. It is not felt that the sites warrant fencing off.

Appendix 1 significance criteria for these three sites (see Appendix 1 for explanation of criteria):

Site: **Parson 1**					
Table 1		*Table 2*			
Landscape L 1/3	Archaeological Traces Class A3	Class 1	Class 2	Class 3	Classes 4-7
Type 2	Type 1	Type 1	Potentially Type 2	Type 1	Low

Site: **King 1**					
Table 1		*Table 2*			
Landscape L 8	Archaeological Traces Class A3	Class 1	Class 2	Class 3	Classes 4-7
Type 2	Type 2	Type 1	Potentially Type 2	Type 1	Low

Site: **King 2**					
Table 1		*Table 2*			
Landscape L 1/3	Archaeological Traces Class A3	Class 1	Class 2	Class 3	Classes 4-7
Type 2	Type 1	Type 1	Potentially Type 2	Type 1	Low

Relatively poorer preservation of older archaeological traces, e.g. of Pleistocene age (where absence of organic material is essentially the norm in this landscape) is to be expected, so that seemingly low significance scores in some classes can be misleading. This is the case in some of the sites in question.

A permit would be required from SAHRA to undertake this work. (All sites are protected by law: a permit would also be required if any site is to be destroyed during mining).

A funding schedule for this and for monitoring is provided separately.

Procedure in the event of sites being found during construction or mining

In the event that sites or features are found during construction or mining, an archaeologist should be alerted immediately in order to assess the find and make recommendations for mitigation, if necessary. All archaeological traces are protected by legislation (see section headed “Legislation”, above). The McGregor Museum would normally be in a position to send an archaeologist at short notice, or to recommend an accredited archaeologist for such work.

Acknowledgements

I thank Mr Vincent Dinku who assisted in the field, and Ivuzi Water, Environmental and Earth Science Consultants, particularly Ms Tanja Thorius.

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Appendix 1

Criteria to be used for archaeological significance assessment

In addition to guidelines provided by the Act, archaeological criteria for use in assessing relative significance of archaeological resources have been developed and found to be suitable in Northern Cape settings (Morris 2000).

Estimating site potential

Table 1 is a classification of landforms and visible archaeological traces for estimating the potential for archaeological sites (after J. Deacon nd, National Monuments Council). Type 3 sites tend to be those with higher archaeological potential. There are notable exceptions, such as the renowned rock art site Driekopseiland, near Kimberley, which is on landform L1 Type 1. Generally, moreover, the older a site the poorer the preservation. Estimation of potential, in the light of such variables, thus requires some interpretation.

Assessing site value by attribute

The second matrix (Table 2) is adapted from Whitelaw (1997), who developed an approach for selecting sites meriting heritage recognition status in KwaZulu-Natal. It is a means of judging a site's archaeological value by ranking the relative strengths of a range of attributes. While aspects of this matrix remain qualitative, attribute assessment is a good indicator of the general archaeological significance of a site, with Type 3 attributes being those of highest significance.

Table 1. Classification of landforms and visible archaeological traces for estimating the potential for archaeological sites (after J. Deacon, National Monuments Council).

Class	Landform	Type 1	Type 2	Type 3
L1	Rocky surface	Bedrock exposed	Some soil patches	Sandy/grassy patches
L2	Ploughed land	Far from water	In floodplain	On old river terrace
L3	Sandy ground, inland	Far from water	In floodplain or near feature such as hill	On old river terrace
L4	Sandy ground, coastal	>1 km from sea	Inland of dune cordon	Near rocky shore
L5	Water-logged deposit	Heavily vegetated	Running water	Sedimentary basin
L6	Developed urban	Heavily built-up with no known record of early settlement	Known early settlement, but buildings have basements	Buildings without extensive basements over known historical sites
L7	Lime/dolomite	>5 myrs	<5000 yrs	Between 5000 yrs and 5 myrs
L8	Rock shelter	Rocky floor	Sloping floor or small area	Flat floor, high ceiling
Class	**Archaeo-logical traces**	**Type 1**	**Type 2**	**Type 3**
A1	Area	Little deposit	More than half	High profile site

	previously excavated	remaining	deposit remaining	
A2	Shell or bones visible	Dispersed scatter	Deposit <0.5 m thick	Deposit >0.5 m thick; shell and bone dense
A3	Stone artefacts or stone walling or other feature visible	Dispersed scatter	Deposit <0.5 m thick	Deposit >0.5 m thick

Table 2. Site attributes and value assessment (adapted from Whitelaw 1997)

Class	Attribute	Type 1	Type 2	Type 3
1	Length of sequence/context	No sequence Poor context Dispersed distribution	Limited sequence	Long sequence Favourable context High density of arte/ecofacts
2	Presence of exceptional items (incl regional rarity)	Absent	Present	Major element
3	Organic preservation	Absent	Present	Major element
4	Potential for future archaeological investigation	Low	Medium	High
5	Potential for public display	Low	Medium	High
6	Aesthetic appeal	Low	Medium	High
7	Potential for implementation of a long-term management plan	Low	Medium	High

HERITAGE IMPACT ASSESSMENT

(REQUIRED UNDER SECTION 38(8) OF THE NHRA (No. 25 OF 1999)

FOR THE PROPOSED KHUMANI IRON ORE MINE PROJECT, SISHEN, NORTHERN CAPE

Type of development:

Mine infrastructure development

Client:

Envirogistics

Client info:

Tanja Bekker

E – mail: tanja@envirogistics.co.za

Developer: DRA Khumani

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Report Author:

Mr. J. van der Walt

Project Reference:

HCAC Project number 2170511

Report date:

May 2017

APPROVAL PAGE

Project Name	**Khumani Mine**
Report Title	Heritage Impact Assessment Khumani Mine
Authority Reference Number	TBC
Report Status	Final Report
Applicant Name	DRA Khumani

	Name	Signature	Qualifications and Certifications	Date
Document Compilation	Jaco van der Walt		MA Archaeology ASAPA #159	May 2017

DOCUMENT PROGRESS

Distribution List

Date	Report Reference Number	Document Distribution	Number of Copies
31 May 2017	2170511	Envirogistics	Electronic Copy

Amendments on Document

Date	Report Reference Number	Description of Amendment

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REPORT OUTLINE

Appendix 6 of the GNR 326 EIA Regulations published on 7 April 2017 provides the requirements for specialist reports undertaken as part of the environmental authorisation process. In line with this, Table 1 provides an overview of Appendix 6 together with information on how these requirements have been met.

Table 1. Specialist Report Requirements.

Requirement from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(a) Details of - (i) the specialist who prepared the report; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Section a Section 12
(b) Declaration that the specialist is independent in a form as may be specified by the competent authority	*Declaration of Independence*
(c) Indication of the scope of, and the purpose for which, the report was prepared	Section 1
(cA)an indication of the quality and age of base data used for the specialist report	Section 3.4 and 7.1.
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	9
(d) Duration, Date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 3.4
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Section 3
(f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Section 8 and 9
(g) Identification of any areas to be avoided, including buffers	Section 9
(h) Map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers	Section 8
(I) Description of any assumptions made and any uncertainties or gaps in knowledge	Section 3.7
(j) a description of the findings and potential implications of such findings on the impact of the proposed activity **including identified alternatives on the environment** or activities;	Section 9
(k) Mitigation measures for inclusion in the EMPr	Section 9 and 10
(l) Conditions for inclusion in the environmental authorisation	Section 9 and 10
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 9 and 10
(n) Reasoned opinion - (i) as to whether the proposed activity, activities or portions thereof should be authorised; (iA) regarding the acceptability of the proposed activity or activities; and (ii) if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Section 10.2
(o) Description of any consultation process that was undertaken during the course of preparing the specialist report	Section 6
(p) A summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	Refer to BA report
(q) Any other information requested by the competent authority	Section 10

Executive Summary

DRA Khumani appointed Envirogistics to conduct a Basic Assessment for a new Sorter Plant and the establishment of two new Silos/Magazines (King and Bruce Silos) at Khumani Mine, in the Northern Cape. HCAC was appointed to conduct a Heritage Impact Assessment of these three project components to determine the presence of cultural heritage sites and the impact of the proposed development on these non-renewable resources. The study areas were assessed both on desktop level and by a field survey. The field survey was conducted as a non-intrusive pedestrian survey to cover the extent of the development footprint.

No archaeological sites or material of significance was recorded during the survey and an independent paleontological study has been commissioned. No further mitigation prior to construction is recommended in terms of the archaeological component of Section 35 for the proposed development to proceed. In terms of the built environment of the area (Section 34), no standing structures older than 60 years occur within the study areas. In terms of Section 36 of the Act no burial sites were recorded. If any graves are located in future they should ideally be preserved *in-situ* or alternatively relocated according to existing legislation. No public monuments are located within or close to the study area. The study area is surrounded by existing mining developments and infrastructure and the proposed development will not impact negatively on significant cultural landscapes or viewscapes. During the public participation process conducted for the project no heritage concerns was raised.

Due to the lack of significant heritage resources in the study area the impact of the proposed project on heritage resources is considered low and it is recommended that the proposed project can commence on the condition that the following recommendations are implemented as part of the EMPr and based on approval from SAHRA:

- Implementation of a chance find procedure.

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Declaration of Independence

Specialist Name	Jaco van der Walt
Declaration of Independence	I declare, as a specialist appointed in terms of the National Environmental Management Act (Act No 108 of 1998) and the associated 2014 Environmental Impact Assessment (EIA) Regulations, that I: • I act as the independent specialist in this application; • I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant; • I declare that there are no circumstances that may compromise my objectivity in performing such work; • I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity; • I will comply with the Act, Regulations and all other applicable legislation; • I have no, and will not engage in, conflicting interests in the undertaking of the activity; • I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority; • All the particulars furnished by me in this form are true and correct; and • I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.
Signature	
Date	25/05/2017

a) Expertise of the specialist

Jaco van der Walt has been practising as a CRM archaeologist for 15 years. He obtained an MA degree in Archaeology from the University of the Witwatersrand focussing on the Iron Age in 2012 and is a PhD candidate at the University of Johannesburg focussing on Stone Age Archaeology with specific interest in the Middle Stone Age (MSA) and Later Stone Age (LSA). Jaco is an accredited member of ASAPA (#159) and have conducted more than 500 impact assessments in Limpopo, Mpumalanga, North West, Free State, Gauteng, KZN as well as he Northern and Eastern Cape Provinces in South Africa.

Jaco has worked on various international projects in Zimbabwe, Botswana, Mozambique, Lesotho, DRC Zambia and Tanzania. Through this he has a sound understanding of the IFC Performance Standard requirements, with specific reference to Performance Standard 8 – Cultural Heritage.

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ABBREVIATIONS

AIA: Archaeological Impact Assessment
ASAPA: Association of South African Professional Archaeologists
BGG Burial Ground and Graves
BIA: Basic Impact Assessment
CFPs: Chance Find Procedures
CMP: Conservation Management Plan
CRR: Comments and Response Report
CRM: Cultural Resource Management
DEA: Department of Environmental Affairs
EA: Environmental Authorisation
EAP: Environmental Assessment Practitioner
ECO: Environmental Control Officer
EIA: Environmental Impact Assessment*
EIA: Early Iron Age*
EIA Practitioner: Environmental Impact Assessment Practitioner
EMP: Environmental Management Programme
ESA: Early Stone Age
ESIA: Environmental and Social Impact Assessment
GIS Geographical Information System
GPS: Global Positioning System
GRP Grave Relocation Plan
HIA: Heritage Impact Assessment
LIA: Late Iron Age
LSA: Late Stone Age
MEC: Member of the Executive Council
MIA: Middle Iron Age
MPRDA: Mineral and Petroleum Resources Development Act
MSA: Middle Stone Age
NEMA National Environmental Management Act, 1998 (Act No. 107 of 1998)
NHRA National Heritage Resources Act, 1999 (Act No. 25 of 1999)
NID Notification of Intent to Develop
NoK Next-of-Kin
PRHA: Provincial Heritage Resource Agency
SADC: Southern African Development Community
SAHRA: South African Heritage Resources Agency

**Although EIA refers to both Environmental Impact Assessment and the Early Iron Age both are internationally accepted abbreviations and must be read and interpreted in the context it is used.*

GLOSSARY

Archaeological site (remains of human activity over 100 years old)
Early Stone Age (~ 2.6 million to 250 000 years ago)
Middle Stone Age (~ 250 000 to 40-25 000 years ago)
Later Stone Age (~ 40-25 000, to recently, 100 years ago)
The Iron Age (~ AD 400 to 1840)
Historic (~ AD 1840 to 1950)
Historic building (over 60 years old)

1 Introduction and Terms of Reference:

Heritage Contracts and Archaeological Consulting CC (**HCAC)** has been contracted by Envirogistics to conduct a heritage impact assessment of the proposed infrastructure (plant and two silos) at the exisitng Khumani Mine. The report forms part of the Basic Assessment Report (BAR) and Environmental Management Programme Report (EMPR) for these additional activities at the existing Khumani Mine.

The aim of the study is to survey the proposed development footprint to identify cultural heritage sites, document, and assess their importance within local, provincial and national context. It serves to assess the impact of the proposed project on non-renewable heritage resources, and to submit appropriate recommendations with regard to the responsible cultural resources management measures that might be required to assist the developer in managing the discovered heritage resources in a responsible manner. It is also conducted to protect, preserve, and develop such resources within the framework provided by the National Heritage Resources Act of 1999 (Act No 25 of 1999). The report outlines the approach and methodology utilized before and during the survey, which includes: Phase 1, review of relevant literature; Phase 2, the physical surveying of the area on foot and by vehicle; Phase 3, reporting the outcome of the study.

During the survey, no heritage sites were identified. General site conditions and features on sites were recorded by means of photographs, GPS locations, and site descriptions. Possible impacts were identified and mitigation measures are proposed in the following report. SAHRA as a commenting authority under section 38(8) of the National Heritage Resources Act, 1999 (Act No. 25 of 1999) require all environmental documents, complied in support of an Environmental Authorisation application as defined by NEMA EIA Regs section 40 (1) and (2), to be submitted to SAHRA. As such the Basic Assessment report and its appendices must be submitted to the case as well as the EMPr, once it’s completed by the Environmental Assessment Practitioner (EAP).

1.1 Terms of Reference

Field study

Conduct a field study to: (a) locate, identify, record, photograph and describe sites of archaeological, historical or cultural interest; b) record GPS points of sites/areas identified as significant areas; c) determine the levels of significance of the various types of heritage resources affected by the proposed development.

Reporting

Report on the identification of anticipated and cumulative impacts the operational units of the proposed project activity may have on the identified heritage resources for all 3 phases of the project; i.e., construction, operation and decommissioning phases. Consider alternatives, should any significant sites be impacted adversely by the proposed project. Ensure that all studies and results comply with the relevant legislation, SAHRA minimum standards and the code of ethics and guidelines of ASAPA.

To assist the developer in managing the discovered heritage resources in a responsible manner, and to protect, preserve, and develop them within the framework provided by the National Heritage Resources Act of 1999 (Act No 25 of 1999).

Table 2: Project Description

Size of farm and portions	The additional activities will be situated on the RE Portion of the Farm King 561, Portion 1 of the Farm Mokaning 260, RE Portion of the Farm Parson 564 and the RE of the Portion of the Farm Bruce 544 (Figure 1 and 2)..
Magisterial District	Gamagara Local Municipality which forms part of the John Taolo Gaetsewe Districts Municipality
1: 50 000 map sheet number	2722DD
Central co-ordinate of the development	Plant 27° 50' 56.9845" S, 23° 00' 10.0585" E Bruce Silo 27° 48' 40.1111" S, 23° 01' 10.5022" E King Silo 27° 53' 12.2659" S, 23° 00' 17.2975" E

Table 3: Infrastructure and project activities

Type of development	Mining infrastructure developments
Project size	Less than 5 hectares
Project Components	It is the intention of the mine to initiate certain additional activities on site. These will include the establishment of a Low Grade ROM (Run of Mine) Sorter Plant south west of the existing King Plant, the decommissioning of the existing Magazines and Silos on site, and the establishment of two new Silos/Magazines areas on site. The first project: The mine intends to establish a new Low Grade ROM Sorter Plant to beneficiate the low grade ROM from the Khumani Opencast Pit operations at the King Mine. The project will be developed in a phased approach. Phase 1 will involve the processing of 700tph ROM through a sorter plant. Phase 2 will be the doubling-up of Phase 1, with the addition of another 700tph ROM along with a second sorter plant. During Phase 3, the -32mm size fraction will be processed. The intention is to beneficiate a product which is currently not being processed by the current plant at Khumani Iron Ore The second project: The mine will decommission the existing silos at King and Parson Mines. The purpose of the decommissioning is: At King Mine, the Silos will be moved away from the mining infrastructure and encroaching mining activities. The new silos will be established on the Mokaning farm, which forms part of the King Mining area. This area will comprise of an Emulsion Silo [capacity of approximately 67 cubic meters (89 tons)] and a second Silo, which will house ammonium nitrate [approximately 65 cubic meters (52 tons)]. Two magazines will also be established at this area with 200 cases at each magazine.

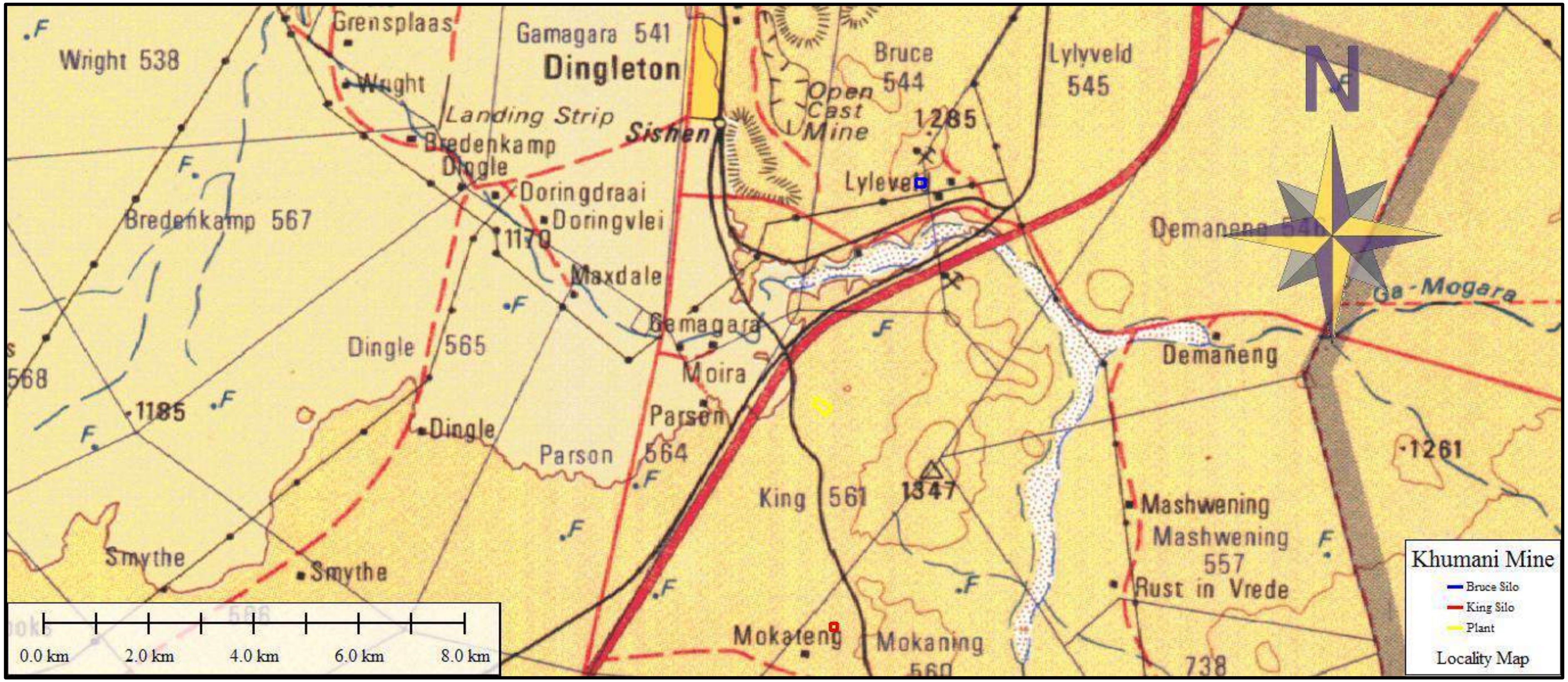

Figure 1. Provincial locality map (1: 250 000 topographical map)

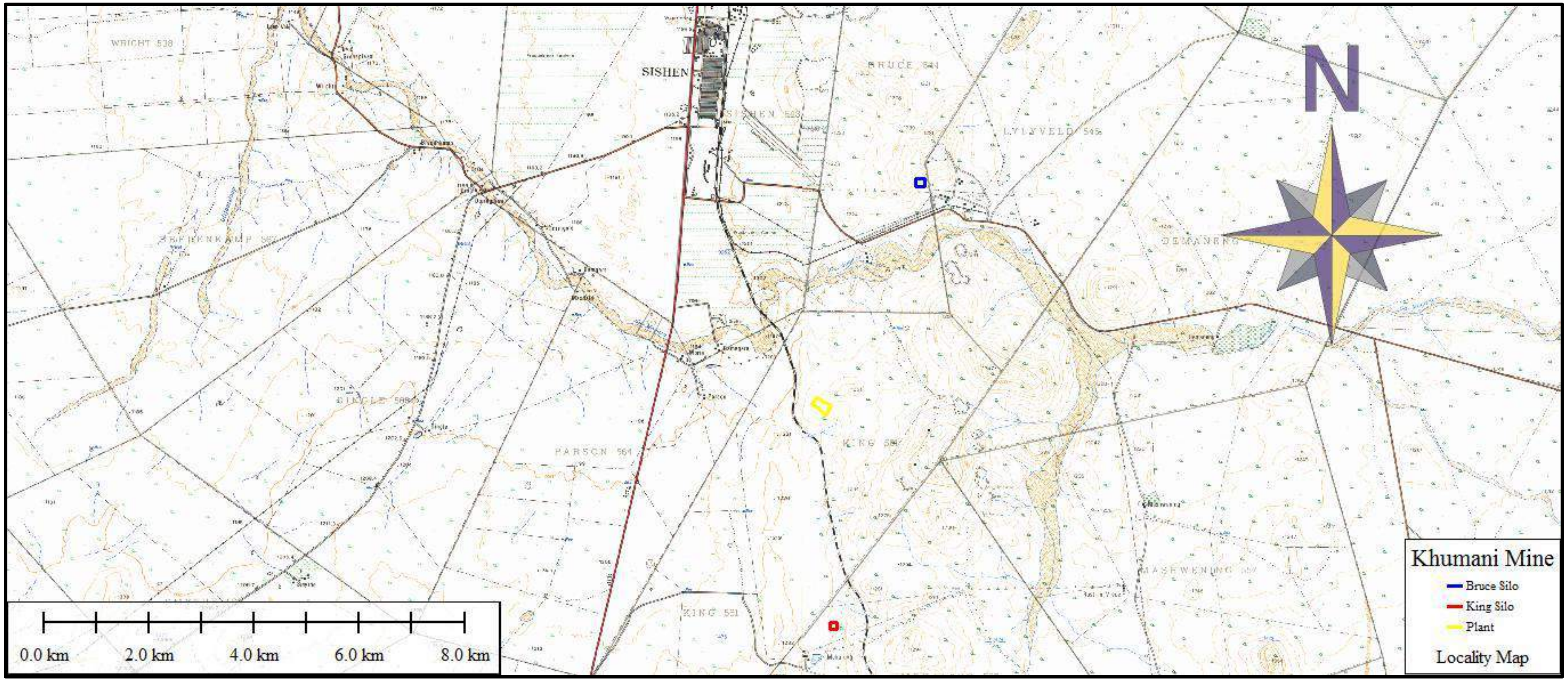

Figure 2: Regional locality map (1:50 000 topographical map).

Figure 3. Satellite image indicating Bruce Silo (Google Earth 2016).

Figure 4. Satellite image of the King Silo study area.

Figure 5. Satellite image indicating the plant area

2 Legislative Requirements

The HIA, as a specialist sub-section of the EIA, is required under the following legislation:

- National Heritage Resources Act (NHRA), Act No. 25 of 1999)
- National Environmental Management Act (NEMA), Act No. 107 of 1998 - Section 23(2)(b)
- Mineral and Petroleum Resources Development Act (MPRDA), Act No. 28 of 2002 - Section 39(3)(b)(iii)

A Phase 1 HIA is a pre-requisite for development in South Africa as prescribed by SAHRA and stipulated by legislation. The overall purpose of heritage specialist input is to:

- Identify any heritage resources, which may be affected;
- Assess the nature and degree of significance of such resources;
- Establish heritage informants/constraints to guide the development process through establishing thresholds of impact significance;
- Assess the negative and positive impact of the development on these resources; and
- Make recommendations for the appropriate heritage management of these impacts.

The HIA should be submitted, as part of the impact assessment report or EMPr, to the PHRA if established in the province or to SAHRA. SAHRA will ultimately be responsible for the professional evaluation of Phase 1 AIA reports upon which review comments will be issued. 'Best practice' requires Phase 1 AIA reports and additional development information, as per the impact assessment report and/or EMPr, to be submitted in duplicate to SAHRA after completion of the study. SAHRA accepts Phase 1 AIA reports authored by professional archaeologists, accredited with ASAPA or with a proven ability to do archaeological work.

Minimum accreditation requirements include an Honours degree in archaeology or related discipline and 3 years post-university CRM experience (field supervisor level). Minimum standards for reports, site documentation and descriptions are set by ASAPA in collaboration with SAHRA. ASAPA is based in South Africa, representing professional archaeology in the SADC region. ASAPA is primarily involved in the overseeing of ethical practice and standards regarding the archaeological profession. Membership is based on proposal and secondment by other professional members.

Phase 1 AIA's are primarily concerned with the location and identification of heritage sites situated within a proposed development area. Identified sites should be assessed according to their significance. Relevant conservation or Phase 2 mitigation recommendations should be made. Recommendations are subject to evaluation by SAHRA.

Conservation or Phase 2 mitigation recommendations, as approved by SAHRA, are to be used as guidelines in the developer's decision making process.

Phase 2 archaeological projects are primarily based on salvage/mitigation excavations preceding development destruction or impact on a site. Phase 2 excavations can only be conducted with a permit, issued by SAHRA to the appointed archaeologist. Permit conditions are prescribed by SAHRA and includes (as minimum requirements) reporting back strategies to SAHRA and deposition of excavated material at an accredited repository.

In the event of a site conservation option being preferred by the developer, a site management plan, prepared by a professional archaeologist and approved by SAHRA, will suffice as minimum requirement.

After mitigation of a site, a destruction permit must be applied for with SAHRA by the applicant before development may proceed.

Human remains older than 60 years are protected by the National Heritage Resources Act, with reference to Section 36. Graves older than 60 years, but younger than 100 years fall under Section 36 of Act 25 of 1999 (National Heritage Resources Act), as well as the Human Tissues Act (Act 65 of 1983), and are the jurisdiction of SAHRA. The procedure for Consultation Regarding Burial Grounds and Graves (Section 36[5]) of Act 25 of 1999) is applicable to graves older than 60 years that are situated outside a formal cemetery administrated by a local authority. Graves in this age category, located inside a formal cemetery administrated by a local authority, require the same authorisation as set out for graves younger than 60 years, in addition to SAHRA authorisation. If the grave is not situated inside a formal cemetery, but is to be relocated to one, permission from the local authority is required and all regulations, laws and by-laws, set by the cemetery authority, must be adhered to.

Human remains that are less than 60 years old are protected under Section 2(1) of the Removal of Graves and Dead Bodies Ordinance (Ordinance No. 7 of 1925), as well as the Human Tissues Act (Act 65 of 1983), and are the jurisdiction of the National Department of Health and the relevant Provincial Department of Health and must be submitted for final approval to the office of the relevant Provincial Premier. This function is usually delegated to the Provincial MEC for Local Government and Planning; or in some cases, the MEC for Housing and Welfare. Authorisation for exhumation and reinternment must also be obtained from the relevant local or regional council where the grave is situated, as well as the relevant local or regional council to where the grave is being relocated. All local and regional provisions, laws and by-laws must also be adhered to. To handle and transport human remains, the institution conducting the relocation should be authorised under Section 24 of Act 65 of 1983 (Human Tissues Act).

3 METHODOLOGY

3.1 Literature Review

A brief survey of available literature was conducted to extract data and information on the area in question to provide general heritage context into which the development would be set. This literature search included published material, unpublished commercial reports and online material, including reports sourced from the South African Heritage Resources Information System (SAHRIS).

3.2 Genealogical Society and Google Earth Monuments

Google Earth and 1:50 000 maps of the area were utilised to identify possible places where sites of heritage significance might be located; these locations were marked and visited during the field work phase. The database of the Genealogical Society was consulted to collect data on any known graves in the area.

3.3 Public Consultation and Stakeholder Engagement:

Stakeholder engagement is a key component of any BAR process, it involves stakeholders interested in, or affected by the proposed development. Stakeholders are provided with an opportunity to raise issues of concern (for the purposes of this report only heritage related issues will be included). The aim of the public consultation process was to capture and address any issues raised by community members and other stakeholders during key stakeholder and public meetings. The process involved:

- Placement of advertisements and site notices
- Stakeholder notification (through the dissemination of information and meeting invitations);
- Stakeholder meetings undertaken with I&APs;
- Authority Consultation
- The compilation of a Basic Assessment Report (BAR).

Please refer to section 6 for more detail.

3.4 Site Investigation

Conduct a field study to: a) systematically survey the proposed project area to locate, identify, record, photograph and describe sites of archaeological, historical or cultural interest; b) record GPS points of sites/areas identified as significant areas; c) determine the levels of significance of the various types of heritage resources recorded in the project area.

Table 4: Site Investigation Details

	Site Investigation
Date	23 May 2017
Season	Early winter –vegetation in the study area is low with good archaeological visibility. The impact area was sufficiently covered (Figure 6 - 8) to adequately record the presence of heritage resources.

Figure 6: Track logs of the survey in black (Bruce Silo area)

Figure 7. Track logs of the survey in the King Silo area.

Figure 8. Track logs of the survey in the plant area

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3.5 Site Significance and Field Rating

Section 3 of the NHRA distinguishes nine criteria for places and objects to qualify as 'part of the national estate' if they have cultural significance or other special value. These criteria are:

- Its importance in/to the community, or pattern of South Africa's history;
- Its possession of uncommon, rare or endangered aspects of South Africa's natural or cultural heritage;
- Its potential to yield information that will contribute to an understanding of South Africa's natural or cultural heritage;
- Its importance in demonstrating the principal characteristics of a particular class of South Africa's natural or cultural places or objects;
- Its importance in exhibiting particular aesthetic characteristics valued by a community or cultural group;
- Its importance in demonstrating a high degree of creative or technical achievement at a particular period;
- Its strong or special association with a particular community or cultural group for social, cultural or spiritual reasons;
- Its strong or special association with the life or work of a person, group or organisation of importance in the history of South Africa;
- Sites of significance relating to the history of slavery in South Africa.

The presence and distribution of heritage resources define a 'heritage landscape'. In this landscape, every site is relevant. In addition, because heritage resources are non-renewable, heritage surveys need to investigate an entire project area, or a representative sample, depending on the nature of the project. In the case of the proposed project the local extent of its impact necessitates a representative sample and only the footprint of the areas demarcated for development were surveyed. In all initial investigations, however, the specialists are responsible only for the identification of resources visible on the surface. This section describes the evaluation criteria used for determining the significance of archaeological and heritage sites. The following criteria were used to establish site significance with cognisance of Section 3 of the NHRA:

- The unique nature of a site;
- The integrity of the archaeological/cultural heritage deposits;
- The wider historic, archaeological and geographic context of the site;
- The location of the site in relation to other similar sites or features;
- The depth of the archaeological deposit (when it can be determined/is known);
- The preservation condition of the sites; and
- Potential to answer present research questions.

In addition to this criteria field ratings prescribed by SAHRA (2006), and acknowledged by ASAPA for the SADC region, were used for the purpose of this report. The recommendations for each site should be read in conjunction with section 10 of this report.

FIELD RATING	*GRADE*	*SIGNIFICANCE*	*RECOMMENDED MITIGATION*
National Significance (NS)	Grade 1	-	Conservation; national site nomination
Provincial Significance (PS)	Grade 2	-	Conservation; provincial site nomination
Local Significance (LS)	Grade 3A	High significance	Conservation; mitigation not advised
Local Significance (LS)	Grade 3B	High significance	Mitigation (part of site should be retained)
Generally Protected A (GP.A)	-	High/medium significance	Mitigation before destruction
Generally Protected B (GP.B)	-	Medium significance	Recording before destruction
Generally Protected C (GP.C)	-	Low significance	Destruction

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3.6 Impact Assessment Methodology

The criteria below are used to establish the impact rating on sites:

- The **nature**, which shall include a description of what causes the effect, what will be affected and how it will be affected.
- The **extent**, wherein it will be indicated whether the impact will be local (limited to the immediate area or site of development) or regional, and a value between 1 and 5 will be assigned as appropriate (with 1 being low and 5 being high):
- The **duration**, wherein it will be indicated whether:
  - ∗ the lifetime of the impact will be of a very short duration (0-1 years), assigned a score of 1;
  - ∗ the lifetime of the impact will be of a short duration (2-5 years), assigned a score of 2;
  - ∗ medium-term (5-15 years), assigned a score of 3;
  - ∗ long term (> 15 years), assigned a score of 4; or
  - ∗ permanent, assigned a score of 5;
  - The **magnitude**, quantified on a scale from 0-10 where; 0 is small and will have no effect on the environment, 2 is minor and will not result in an impact on processes, 4 is low and will cause a slight impact on processes, 6 is moderate and will result in processes continuing but in a modified way, 8 is high (processes are altered to the extent that they temporarily cease), and 10 is very high and results in complete destruction of patterns and permanent cessation of processes.
  - The **probability of occurrence**, which shall describe the likelihood of the impact actually occurring. Probability will be estimated on a scale of 1-5 where; 1 is very improbable (probably will not happen), 2 is improbable (some possibility, but low likelihood), 3 is probable (distinct possibility), 4 is highly probable (most likely) and 5 is definite (impact will occur regardless of any prevention measures).
  - The **significance**, which shall be determined through a synthesis of the characteristics described above and can be assessed as low, medium or high; and
  - the **status**, which will be described as either positive, negative or neutral.
  - the degree to which the impact can be reversed.
  - the degree to which the impact may cause irreplaceable loss of resources.
  - the *degree* to which the impact can be mitigated.

The **significance** is calculated by combining the criteria in the following formula:

S=(E+D+M)P

S = Significance weighting

E = Extent

D = Duration

M = Magnitude

P = Probability

The **significance weightings** for each potential impact are as follows:

- < 30 points: Low (i.e., where this impact would not have a direct influence on the decision to develop in the area),
- 30-60 points: Medium (i.e., where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- 60 points: High (i.e., where the impact must have an influence on the decision process to develop in the area).

3.7 Limitations and Constraints of the study

The authors acknowledge that the brief literature review is not exhaustive on the literature of the area. Due to the subsurface nature of archaeological artefacts, the possibility exists that some features or artefacts may not have been discovered/recorded during the survey and the possible occurrence of unmarked graves and other cultural material cannot be excluded. Similarly, the depth of the deposit of heritage sites cannot be accurately determined due its subsurface nature. This report only deals with the footprint area of the proposed development and consisted of non-intrusive surface surveys. This study did not assess the impact on medicinal plants and intangible heritage as it is assumed that these components would have been highlighted through the public consultation process if relevant. It is possible that new information could come to light in future, which might change the results of this Impact Assessment.

4 Description of Socio Economic Environmental

The following information was obtained from an EIA conducted in 2015 by GCS:

"Population and Household
The population size (persons) for the Gamagara District Municipality increased by 25.47% over the 1995 to 2011 time period, whereas the John Taolo Gaetsewe District Municipality only grew by 12.49% over the same period. Households have also grown over the 1995 to 2011 time period, with the Gamagara Local Municipality showing a 30.36% increase and the John Taolo Gaetsewe District Municipality by 27.23%.

Age
It is important to assess the age distribution of persons in order to determine both the current and future needs of an area. Age is an important indicator as it relates to education, skills and dependency. A young population may require an improved educational system, whereas an older society may need an accented focus on healthcare. The largest percentage of people in the Gamagara Local Municipality, 71.9% fall within the working age category (16-64 years of age). 25.5% of the population are between the age of 0 and 14. And the elderly population forms 2.5% of the municipality's population. (Statistics South Africa, census 2011) Persons younger than 15 years of age do not form part of the Economically Active Population (EAP) of the area.

Education
The largest percentage (89,5%) of the Gamagara Local Municipality population has obtained some form of primary schooling. 24.9% of the population has attained matric and a further 3.6% with higher education.

Employment and Labour
The largest sector of employment in the Local Municipality is the mining sector, supplying just over a third of the jobs in the area. Followed by wholesale and retail trade jobs, which make up around 12% of the total employment. The main reason for this distribution are mines, like Sishen and Khumani in the area that are the largest employers in the municipality. The main average income of households in the Gamagara Local Municipality is between R9,601 and R307,600 as derived from the census 2011 data. It should however be noted that around 10% of the population in the municipality do not earn an income."

5 Description of the Physical Environment:

The plant area measures approximately 5 ha in size and is situated to the south of the existing King Mine operations. The site is relatively flat and covered with grass and bushes. The site is disturbed by mining related activities and the establishment of infrastructure like sewer pipes, roads and power lines (Figure 9 & 10).

Bruce Silo measures less than 1 hectare in size and is situated to the east of the existing Bruce Mine operations. The proposed site is relatively flat and located at the foot of a low ridge. The site is partially impacted on by what could have been exploration roads. The site is highly overgrown with *Senegalia erubescens* (Figure 11 & 12).

King Silo measures less than 1 hectare in size and is situated well to the south of the existing King Mine operations. The proposed site is relatively flat and located to the west of a low ridge. The site is characterised by Aeolian sand with sparse grass cover and a few low bushes (Figure 13 & 14).

The vegetation and landscape is described by Mucina and Rutherford (*The Vegetation of South Africa, Lesotho and Swaziland*, South African National Biodiversity Institute, Kirstenbosch, August 2006) as Kuruman Mountain Bushveld. The geological forms in the study area is described as Transvaal,Rooiberg and Griqualand-West

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Figure 9. General Site conditions in the plant area.

Figure 10. General site conditions in the plant area.

Figure 11. General site conditions – Bruce Silo

Figure 12. General site conditions – Bruce silo

Figure 13. General site conditions – King silo

Figure 14. General site conditions – King silo.

6 Results of Public Consultation and Stakeholder Engagement:

6.1.1 Stakeholder Identification

The current Stakeholder Database on the mine was utilised as a basis for the development of the consultation register for this project. In addition, relevant government departments, municipalities and affected ward councillors were contacted to inform them of the proposed project and to obtain their issues and comments in this regard. The following stakeholders were consulted as part of the project:

- DWS;
- DMR;
- NCDENC;
- Local Municipality;
- Districts Municipality;
- Ward Councillor;
- Surrounding Landowners; and
- Other Identified Stakeholders.

6.1.2 Notification

Stakeholders were notified by means of the following systems:

- Notices;
- Background Information Documents (BIDs); and
- Advertisements.

Proof of email submissions can be requested from the EAP.

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6.1.3 Site Notices

In order to inform surrounding communities and adjacent landowners of the proposed project, five (5) site notices were erected on site (on 8 May 2017) and at visible locations close to the site.

Site Notices were place at the following locations:

- King Mine Entrance;
- Bruce Mine Entrance;
- Parson Silo Entrance;
- Kathu Municipality; and
- Olifantshoek Municipality.

6.1.4 Background Information Documents

Background Information Documents were distributed via email to all parties on the database on 12 May 2017.

6.1.5 Advertisements

The formal announcement of the proposed project was undertaken by placing an advertisement in the Kathu Gazette on 13 May 2017 to invite all Interested and Affected (I&APs) to register. The advertisements were published in both Afrikaans and English.

The objective of this newspaper advertisement was to:

Inform I&APs of the proposed project;

Inform I&APs of the Environmental Impact Assessment procedure and the way in which I&APs could lodge any objections to the proposed development and provide comments; and

Invite I&APs to become involved in the proposed project by registering as I&APs.

6.1.6 Document Review

All registered stakeholders were informed of the availability of the draft BAR for the opportunity to review this document. No comments outside of those presented in the draft reports were received.

7 Literature / Background Study:

7.1 Literature Review

The following reports were conducted in the immediate vicinity of the study area and were consulted for this report:

Author	Year	Project	Findings
Kruger, N.	2015	Sishen Iron Ore Company (SIOC): Proposed Lyleveld North Waste Rock Dump Expansion and Lyleveld South Haul Road Extension Project, Sishen Mine, Northern Cape Province	2 Stone Age occurrences and 1 site attributed to mechanical weathering.
Morris, D.	2005	Archaeological Impact assessment of mining areas on the farms Bruce, King, Mokaning and Parson between Postmasburg and Kathu in the Northern Cape.	4 Cemeteries and Stone Age artefacts were identified.
Beaumont, P.	2005	Heritage Assessment for an EMPR amendment relating to a proposed crusher at Sishen Iron Ore Mine near Kathu in the Northern Cape province.	No sites were identified.

7.1.1 Genealogical Society and Google Earth Monuments

No known grave sites are indicated in the study area.

7.2 General History of the area

7.2.1 Archaeology of the area

The archaeological record for the greater study area consists of the Stone Age and Iron Age.

7.3. Stone Age

South Africa has a long and complex Stone Age sequence of more than 2 million years. The broad sequence includes the Later Stone Age, the Middle Stone Age and the Earlier Stone Age. Each of these phases contains sub-phases or industrial complexes, and within these we can expect regional variation regarding characteristics and time ranges. For Cultural Resources Management (CRM) purposes it is often only expected/ possible to identify the presence of the three main phases. Yet sometimes the recognition of cultural groups, affinities or trends in technology and/or subsistence practices, as represented by the sub-phases or industrial complexes, is achievable (Lombard 2011). The three main phases can be divided as follows;

- Later Stone Age; associated with Khoi and San societies and their immediate predecessors. Recently to ~30 thousand years ago.
- Middle Stone Age; associated with Homo sapiens and archaic modern humans. 30-300 thousand years ago.
- Earlier Stone Age; associated with early Homo groups such as Homo habilis and Homo erectus. 400 000-> 2 million years ago.

The larger study area has a wealth of pre-colonial archaeological sites (Morris & Beaumont 2004). Famous sites in the region include the world renowned Wonderwerk Cave to the north of the study area. Closer to Kuruman two shelters on the northern and southern faces of GaMohaan (in the Kuruman Hills north west of the town) contain Later Stone Age remains and rock paintings. Rock art is known to occur at Danielskuil to the north east and on Carter Block (Morris 2008). Middle Stone Age material is on record around the study area.

Archaeological surveys have shown rocky outcrops and hills, drainage lines, riverbanks and confluences to be prime localities for archaeological finds and specifically Stone Age sites, as these areas where utilized for settlement of base camps close to water and hunting ranges.

7.4. Iron Age

Iron Age expansion southwards past Kuruman into the Ghaap plato and towards Postmasburg dates to the 1600's (Humphreys, 1976 and Thackeray, 1983). Definite dates for Tswana presence in the Postmasburg area are around 1805 when Lichtenstein visited the area and noted the mining activities of the Tswana (probably the Thlaping) tribes in the area. The Thlaro and Thlaping settled the area from Campbell in the east to Postmasburg and towards the Langeberg close to Olifantshoek in the north west before 1770 (Snyman, 1988). The Korana expansion after 1770 started to drive the Thlaro and Thlaping further north towards Kuruman (Shillington, 1985).

7.4.1. Anglo-Boer War

There are no battlefields or concentration camp sites close to the study area.

7.4.2. Cultural Landscape

The Khumani mine was constructed from October 2006 (http://www.assmang.co.za/content.asp?pg=7), prior to this the area was undeveloped and characterised by sparse vegetation. The surrounding area have been characterised by intensive mining activities.

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8. Findings of the Survey

It is important to note that only the development footprint of each project was surveyed. The study area was surveyed over a period of 1 day in the company of mine officials. The proposed plant area is situated to the south and adjacent to the existing King Mine operations. The site is relatively flat and covered with grass and bushes. The site is disturbed by mining related activities and the establishment of infrastructure like sewer pipes, roads and power lines that would have impacted on any surface indications of heritage sites.

Bruce Silo is situated to the east of the existing Bruce Mine operations. The proposed site is relatively flat and located at the foot of a low ridge. The site is partially impacted on by what could have been exploration roads and is highly overgrown with *Senegalia erubescens*. King Silo is situated well to the south of the existing King Mine operations in a green field's area. The proposed site is relatively flat and located to the west of a low ridge. The site is characterised by Aeolian sand with sparse grass cover and a few low bushes with no raw material suitable for knapping.

In terms of the national estate as defined by the NHRA no sites of significance were found during the survey as described below.

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8.3. Built Environment (Section 34 of the NHRA)

No standing structures older than 60 years occur in the study area.

8.4. Archaeological and palaeontological resources (Section 35 of the NHRA)

No archaeological sites or material was recorded during the survey. Therefore, no further mitigation prior to construction is recommended in terms of the archaeological component of Section 35 of the NHRA for the proposed development to proceed. According to the SAHRIS palaeontological sensitivity map the study area is of palaeontological sensitivity and a Paleontological study was commissioned for the study area.

8.5. Burial Grounds and Graves (Section 36 of the NHRA)

In terms of Section 36 of the Act no burial sites were recorded.

8.6. Cultural Landscapes, Intangible and Living Heritage.

Long term impact on the cultural landscape is considered to be negligible as the surrounding area consists of an area that has been subjected to extensive mining activities from 2006 onwards. Visual impacts to scenic routes and sense of place are also considered to be low due to the extensive developments in the area.

8.7. Battlefields and Concentration Camps

There are no battlefields or concentration camp sites close to the study area.

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8.8. Potential Impact

The chances of impacting unknown archaeological sites in the study area is considered to be negligible. Any direct impacts that did occur would be during the construction phase only and would be of very low significance. Cumulative impacts occur from the combination of effects of various impacts on heritage resources. The importance of identifying and assessing cumulative impacts is that the whole is greater than the sum of its parts. In the case of the development, it will, with the recommended mitigation measures and management actions, not impact any heritage resources directly. However, this and other projects in the area could have an indirect impact on the larger heritage landscape. The lack of any heritage resources in the immediate area and the extensive existing mining activities minimises additional impact on the landscape.

8.8.1. Pre-Construction phase:

It is assumed that the pre-construction phase involves the removal of topsoil and vegetation as well as the establishment of infrastructure needed for the construction phase. These activities can have a negative and irreversible impact on heritage sites. Impacts include destruction or partial destruction of non-renewable heritage resources.

8.8.2. Construction Phase

During this phase, the impacts and effects are similar in nature but more extensive than the pre-construction phase. These activities can have a negative and irreversible impact on heritage sites. Impacts include destruction or partial destruction of non-renewable heritage resources.

8.8.3. Operation Phase:

No impact is envisaged for the recorded heritage resources during this phase.

Table 5. Impact Assessment table.

Nature: During the construction phase activities resulting in disturbance of surfaces and/or sub-surfaces may destroy, damage, alter, or remove from its original position archaeological material or objects.		
	Without mitigation	**With mitigation (Preservation/ excavation of site)**
Extent	Local (1)	Local (1)
Duration	Permanent (5)	Permanent (5)
Magnitude	Low (2)	Low (2)
Probability	Not probable (2)	Not probable (2)
Significance	**16 (Low)**	**16 (Low)**
Status (positive or negative)	Negative	Negative
Reversibility	Not reversible	Not reversible
Irreplaceable loss of resources?	No resources were recorded	No resources were recorded.
Can impacts be mitigated?	Yes, a chance find procedure should be implemented.	Yes
Mitigation: Due to the lack of apparent significant archaeological resources no further mitigation is required prior to construction.		
Cumulative impacts: A Chance Find Procedure should be implemented for the project should any sites be identified during the construction process.		

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Residual Impacts:
If sites are destroyed this results in the depletion of archaeological record of the area. However, if sites are recorded and preserved or mitigated this adds to the record of the area.

9. Conclusion and recommendations

HCAC was appointed to conduct a Heritage Impact Assessment for a new Sorter Plant and the establishment of two new Silos/Magazines (King and Bruce Silos) at Khumani Mine, close to Sishen in the Northern Cape. The proposed plant area is situated to the south and adjacent to the existing King Mine operations. The site is relatively flat and covered with grass and bushes. The site is disturbed by mining related activities and the establishment of infrastructure like sewer pipes, roads and power lines that would have impacted on any surface indications of heritage sites. Bruce Silo is situated to the east of the existing Bruce Mine operations. The proposed site is relatively flat and located at the foot of a low ridge. The site is partially impacted on by what could have been exploration roads and is highly overgrown. King Silo is situated well to the south of the existing King Mine operations in a green field's area. The proposed site is relatively flat and located to the west of a low ridge. The site is characterised by Aeolian sand with sparse grass cover and a few low bushes with no raw material suitable for knapping.

During the survey, no archaeological sites or material was recorded. Therefore, no further mitigation prior to construction is recommended in terms of the archaeological component of Section 35 for the proposed development to proceed. According to the SAHRIS palaeontological sensitivity map the study area is of palaeontological sensitivity and a Paleontological study was commissioned for the study area.

In terms of the built environment of the area (Section 34), no standing structures older than 60 years occur within the study area. In terms of Section 36 of the Act no burial sites were recorded. If any graves are located in future they should ideally be preserved *in-situ* or alternatively relocated according to existing legislation. No public monuments are located within or close to the study area. The study area is surrounded by mining developments and infrastructure and the proposed development will not impact negatively on significant cultural landscapes or viewscapes. During the public participation process conducted for the project no heritage concerns was raised.

Due to the lack of significant heritage resources in the study area the impact of the proposed project on heritage resources is considered low and it is recommended that the proposed project can commence on the condition that the following chance find procedure are implemented as part of the EMPr and based on approval from SAHRA

9.1. Chance Find Procedures

The possibility of the occurrence of subsurface finds cannot be excluded. Therefore, if during construction any possible finds such as stone tool scatters, artefacts or bone and fossil remains are made, the operations must be stopped and a qualified archaeologist must be contacted for an assessment of the find and therefor chance find procedures should be put in place as part of the EMP. A short summary of chance find procedures is discussed below.

This procedure applies to the developer's permanent employees, its subsidiaries, contractors and subcontractors, and service providers. The aim of this procedure is to establish monitoring and reporting procedures to ensure compliance with this policy and its associated procedures. Construction crews must be properly inducted to ensure they are fully aware of the procedures regarding chance finds as discussed below.

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- If during the pre-construction phase, construction, operations or closure phases of this project, any person employed by the developer, one of its subsidiaries, contractors and subcontractors, or service provider, finds any artefact of cultural significance or heritage site, this person must cease work at the site of the find and report this find to their immediate supervisor, and through their supervisor to the senior on-site manager.
- It is the responsibility of the senior on-site Manager to make an initial assessment of the extent of the find, and confirm the extent of the work stoppage in that area.
- The senior on-site Manager will inform the ECO of the chance find and its immediate impact on operations. The ECO will then contact a professional archaeologist for an assessment of the finds who will notify the SAHRA.

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10. References

Beaumont, P. 2005. Heritage Assessment for an EMPR amendment relating to a proposed crusher at Sishen Iron Ore Mine near Kathu in the Northern Cape province.

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Mucina, L. & Rutherford,M.C. 2006. The vegetation map of South Africa, Lesotho and Swaziland. SANBI, Pretoria.

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Shillington, K. 1985. The Colonisation of the Southern Tswana, 1870-1900. Braamfontein: Ravan Press.

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South African Heritage Information System 2015

http://www.assmang.co.za/content.asp?pg=7

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11. Appendices:

Curriculum Vitae of Specialist

Jaco van der Walt
Archaeologist

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Education:

Particulars of degrees/diplomas and/or other qualifications:

Name of University or Institution:		University of Pretoria
Degree obtained	:	BA Heritage Tourism & Archaeology
Year of graduation	:	2001
Name of University or Institution:		University of the Witwatersrand
Degree obtained	:	BA Hons Archaeology
Year of graduation	:	2002
Name of University or Institution	:	University of the Witwatersrand
Degree Obtained	:	MA (Archaeology)
Year of Graduation	:	2012
Name of University or Institution	:	University of Johannesburg
Degree	:	PhD
Year	:	Currently Enrolled

EMPLOYMENT HISTORY:

2011 – Present:	**Owner – HCAC (Heritage Contracts and Archaeological Consulting CC)**.
2007 – 2010 :	**CRM Archaeologist,** Managed the Heritage Contracts Unit at the University of the Witwatersrand.
2005 - 2007:	**CRM Archaeologist**, Director of Matakoma Heritage Consultants
2004:	**Technical Assistant**, Department of Anatomy University of Pretoria
2003:	**Archaeologist**, Mapungubwe World Heritage Site
2001 - 2002:	**CRM Archaeologists,** For R & R Cultural Resource Consultants, Polokwane
2000:	**Museum Assistant**, Fort Klapperkop.

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Countries of work experience include:
Republic of South Africa, Botswana, Zimbabwe, Mozambique, Tanzania, The Democratic Republic of the Congo, Lesotho and Zambia.

SELECTED PROJECTS INCLUDE:

Archaeological Impact Assessments (Phase 1)

Heritage Impact Assessment Proposed Discharge Of Treated Mine Water Via The Wonderfontein Spruit Receiving Water Body Specialist as part of team conducting an Archaeological Assessment for the Mmamabula mining project and power supply, Botswana
Archaeological Impact Assessment Mmamethlake Landfill
Archaeological Impact Assessment Libangeni Landfill

Linear Developments

Archaeological Impact Assessment Link Northern Waterline Project At The Suikerbosrand Nature Reserve
Archaeological Impact Assessment Medupi – Spitskop Power Line,
Archaeological Impact Assessment Nelspruit Road Development

Renewable Energy developments

Archaeological Impact Assessment Karoshoek Solar Project

Grave Relocation Projects

Relocation of graves and site monitoring at Chloorkop as well as permit application and liaison with local authorities and social processes with local stakeholders, Gauteng Province.
Relocation of the grave of Rifle Man Maritz as well as permit application and liaison with local authorities and social processes with local stakeholders, Ndumo, Kwa Zulu Natal.
Relocation of the Magolwane graves for the office of the premier, Kwa Zulu Natal
Relocation of the OSuthu Royal Graves office of the premier, Kwa Zulu Natal

Phase 2 Mitigation Projects

Field Director for the Archaeological Mitigation For Booysendal Platinum Mine, Steelpoort, Limpopo Province. Principle investigator Prof. T. Huffman
Monitoring of heritage sites affected by the ARUP Transnet Multipurpose Pipeline under directorship of Gavin Anderson.
Field Director for the Phase 2 mapping of a late Iron Age site located on the farm Kameelbult, Zeerust, North West Province. Under directorship of Prof T. Huffman.
Field Director for the Phase 2 surface sampling of Stone Age sites effected by the Medupi – Spitskop Power Line, Limpopo Province

Heritage management projects

Platreef Mitigation project – mitigation of heritage sites and compilation of conservation management plan.

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MEMBERSHIP OF PROFESSIONAL ASSOCIATIONS:

- Association of Southern African Professional Archaeologists. Member number 159

  Accreditation:
  - Field Director Iron Age Archaeology
  - Field Supervisor Colonial Period Archaeology, Stone Age Archaeology and Grave Relocation
- Accredited CRM Archaeologist with SAHRA
- Accredited CRM Archaeologist with AMAFA
- Co-opted council member for the CRM Section of the Association of Southern African Association Professional Archaeologists (2011 – 2012)

PUBLICATIONS AND PRESENTATIONS

- A Culture Historical Interpretation, Aimed at Site Visitors, of the Exposed Eastern Profile of K8 on the Southern terrace at Mapungubwe.
  - J van der Walt, A Meyer, WC Nienaber
  - Poster presented at Faculty day, Faculty of Medicine University of Pretoria 2003
- 'n Reddingsondersoek na Anglo-Boereoorlog-ammunisie, gevind by Ifafi, Noordwes-Provinsie. South-African Journal for Cultural History 16(1) June 2002, with A. van Vollenhoven as co-writer.
- Fieldwork Report: Mapungubwe Stabilization Project.
  - WC Nienaber, M Hutten, S Gaigher, J van der Walt
  - Paper read at the Southern African Association of Archaeologists Biennial Conference 2004
- A War Uncovered: Human Remains from Thabantšho Hill (South Africa), 10 May 1864.
  - M. Steyn, WS Boshoff, WC Nienaber, J van der Walt
  - Paper read at the 12th Congress of the Pan-African Archaeological Association for Prehistory and Related Studies 2005
- Field Report on the mitigation measures conducted on the farm Bokfontein, Brits, North West Province .
  - J van der Walt, P Birkholtz, W. Fourie
  - Paper read at the Southern African Association of Archaeologists Biennial Conference 2007
- Field report on the mitigation measures employed at Early Farmer sites threatened by development in the Greater Sekhukhune area, Limpopo Province. J van der Walt
  - Paper read at the Southern African Association of Archaeologists Biennial Conference 2008
- Ceramic analysis of an Early Iron Age Site with vitrified dung, Limpopo Province South Africa.
  - J van der Walt. Poster presented at SAFA, Frankfurt Germany 2008

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- Bantu Speaker Rock Engravings in the Schoemanskloof Valley, Lydenburg District, Mpumalanga (*In Prep)*
    - J van der Walt and J.P Celliers
- Sterkspruit: Micro-layout of late Iron Age stone walling, Lydenburg, Mpumalanga. W. Fourie and J van der Walt. A Poster presented at the Southern African Association of Archaeologists Biennial Conference 2011
- Detailed mapping of LIA stone-walled settlements' in Lydenburg, Mpumalanga. J van der Walt and J.P Celliers
    - Paper read at the Southern African Association of Archaeologists Biennial Conference 2011
- Bantu-Speaker Rock engravings in the Schoemanskloof Valley, Lydenburg District, Mpumalanga. J.P Celliers and J van der Walt
    - Paper read at the Southern African Association of Archaeologists Biennial Conference 2011
- Pleistocene hominin land use on the western trans-Vaal Highveld ecoregion, South Africa, Jaco van der Walt.
    - J van der Walt. Poster presented at SAFA, Toulouse, France. Biennial Conference 2016

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KHUMANI IRON ORE MINE

MINE WIDE WATER STUDY

Report prepared for

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No appendices.

REVISION TRACKING

Rev 0: Original document

Disclaimer

The opinions expressed in this report have been based on the information supplied to Geo Tail SA (Pty) Ltd by the Client. The opinions in this report are provided in response to a specific request from the Client to do so. Geo Tail SA has exercised all due care in reviewing the supplied information. Whilst Geo Tail SA 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. Geo Tail SA 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 Geo Tail'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 Geo Tail SA had no prior knowledge nor had the opportunity to evaluate.

1. INTRODUCTION

Geo Tail SA (Pty) Ltd (Geo Tail) was appointed by Khumani Iron Ore Mine to provide a mine-wide assessment of the mine's water management. Water management was assessed against:

- Operational/behavioural suitability and areas where improvements can be made
- Infrastructure deficiencies

In addition to this, a high-level GN 704 audit was conducted and some areas of GN 704 non-compliance were identified.

The outcomes of the study are to provide recommendations for infrastructure and operational improvements.

The effect of the King paste disposal facility Compartment 3B commissioning was also looked at, and recommendations were made to mitigate the effect of anticipated limited return from the compartment in the early stages of its commissioning.

2. STUDY AREAS

The study included the following areas:

- Parsons plant
  - Plant and loadout area
  - Process, domestic and storm water circuits
- King plant
  - Paste plant, paste disposal facility (PDF), and Mining
  - Process, domestic and storm water circuits
  - Waste rock dumps whose storm water is collected in the King storm water dams
- Bruce operations
  - Mining, process, domestic water
  - Storm water circuits

2.1 Facilities Referred to in this Report

Some dams, plants and other infrastructure appear to have non-standard names and are referred to by many names. The figures below show the locations and names of infrastructure referred to in this report. Various stakeholders may know this infrastructure by different names, but these figures can be referred to when reading this document.

FIGURE 1: PARSONS INFRASTRUCTURE

FIGURE 2: KING INFRASTRUCTURE

3. GN 704 COMPLIANCE AND STORM WATER MANAGEMENT FINDINGS

3.1 Legislation and Guidelines

3.1.1 Applicable Legislation

Government Notice 704 of the South African National Water Act (GN 704), Act 36 of 1998 restricts the mixing of clean and dirty water to a frequency of once in fifty years on average. Section 6b and 6d state the following:

6 Every person in control of a mine or activity must-

(b) design, construct, maintain and operate any ***clean water system*** *at the mine or activity so that it is* ***not likely to spill into any dirty water system more than once in 50 years****;*

(d) design, construct, maintain and operate any ***dirty water system*** *at the mine or activity so that it is* ***not likely to spill into any clean water system more than once in 50 years****; and*

This legislation is used to guide the GN 704 compliance.

3.1.2 Applicable Guidelines

The South African Best Practice Guideline BPG-G1 Storm Water Management was also used to guide storm water management auditing and recommendations.

3.1.3 Clean and Dirty Water Definition

Process waters on the mine generally have relatively low dissolved solids concentrations but high sediment loads. Clean and dirty water identification is thus relatively easy in most cases, based on a visual inspection.

As a rule of thumb, clean water can be consumed without resulting in medical complications or having poor taste characteristics. Clean water is always clear and will not harm indigenous wildlife. The South African Water Quality Guidelines stipulate acceptable levels of dissolved solids for water to considered as clean.

Dirty water on Khumani Mine will generally contain high sediment loads and may also have elevated dissolved solids concentrations. This water will have a poor taste and may even result in medical complications if consumed, and may harm indigenous wildlife.

3.2 Parsons Storm Water Management and GN 704 Compliance Findings

The Parsons storm water management and GN 704 compliance is summarised in the figure below. A more detailed assessment is provided in Sections 3.2.1 to 3.2.3.

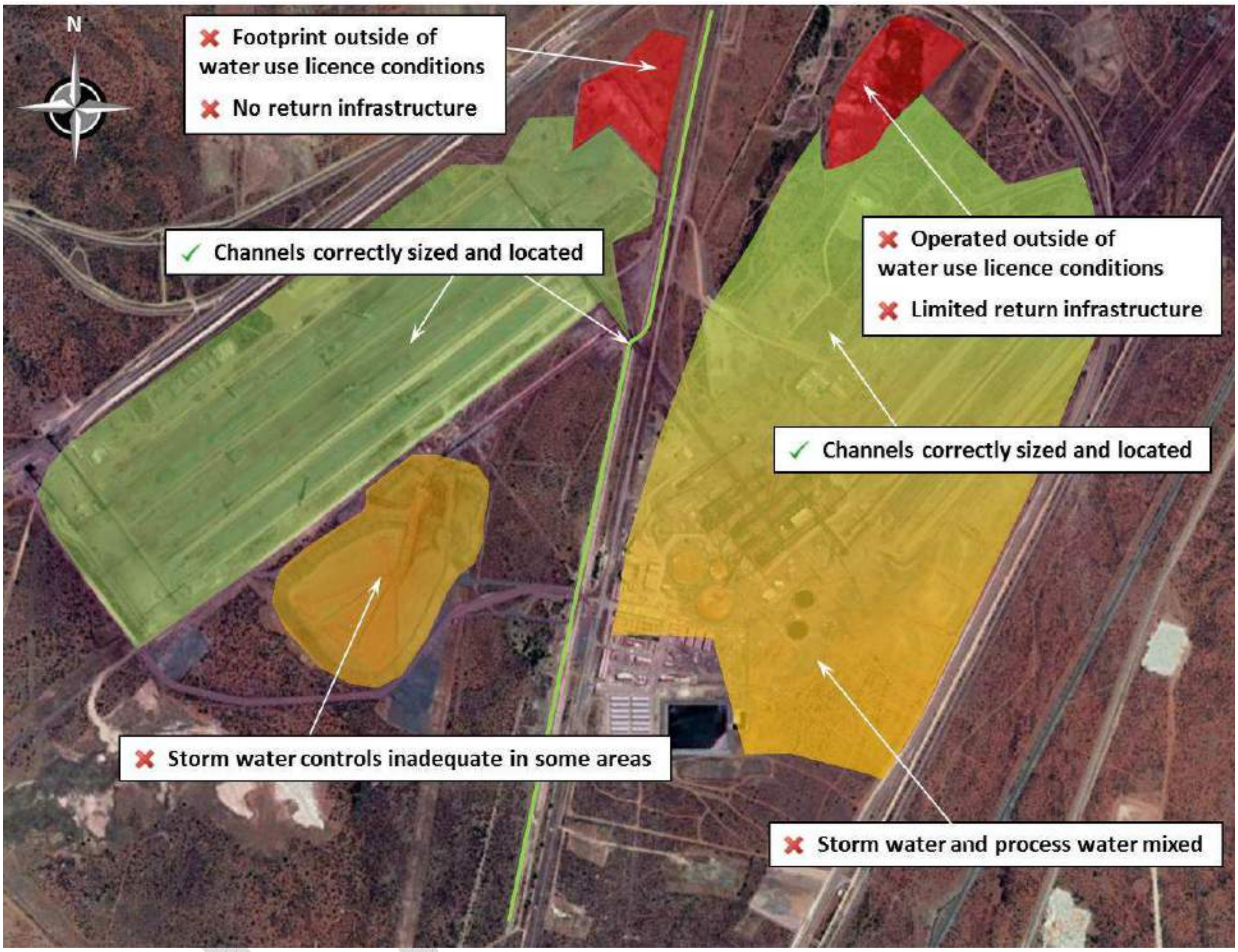

FIGURE 3: SUMMARY OF THE PARSONS STORM WATER MANAGEMENT AND GN 704 COMPLIANCE FINDINGS

The following as a list of findings from the high-level audit conducted:

3.2.1 Loadout Storm Water Dam

- All channels that route water to the Loadout Storm Water Dam are adequately sized and located.
- Loadout Storm Water Dam eastern wall has been breached. This allows an old excavation adjacent to the dam's eastern wall to be used as additional storage capacity. This additional storage capacity ensures that the Loadout Storm Water Dam has sufficient storage capacity. The breaching of the eastern wall appears to be in response to the loss of some

of the dam's original capacity, due to the loadout area encroaching on the Loadout Storm Water Dam footprint. However, the new footprint is outside of water use licence conditions.

- Return pumping infrastructure is non-functional at the Loadout Storm Water Dam, and as a result, it cannot comply with GN 704. The Loadout Storm Water Dam has overflowed recently.

3.2.2 Parsons Storm Water Dam

- The Parsons Storm Water Dam capacity is approximately equal to the 50-yr design storm volume. This means that the Parsons Storm Water Dam must be operated empty at all times. However the Parsons Storm Water Dam is used as a process recovery dam, so return abilities need to be very good. The return pumping infrastructure is poor at the Parsons Storm Water Dam, so process recovery is poor and the Parsons Storm Water Dam therefore cannot comply with GN 704.
- By using the Parsons Storm Water Dam as a process recovery dam, it is being operated outside of its water use licence conditions.
- In addition to this, storm water and process water are mixed which is not in keeping with best practice storm water management.

3.2.3 Discard dump

- Discard dump storm water controls are non-existent in some areas around its perimeter.

FIGURE 4: WATER REGULARLY FLOWS DOWN THE TRENCHES TOWARDS THE PARSONS STORM WATER DAM

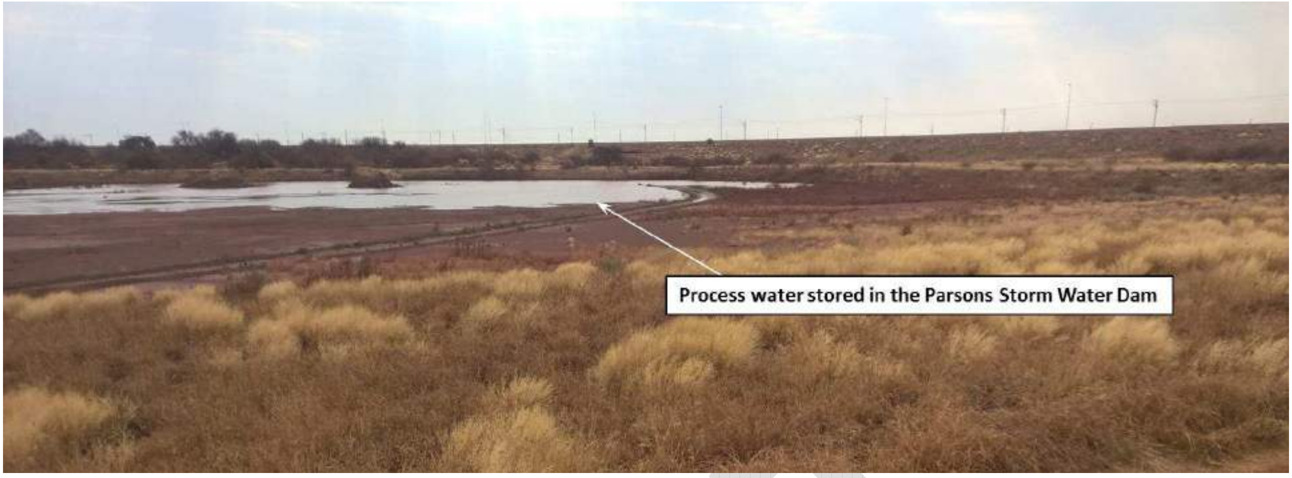

FIGURE 5: WATER CONTAINED IN THE PARSONS STORM WATER DAM

3.3 King Storm Water Management and GN 704 Compliance Findings

The King storm water management and GN 704 compliance is summarised in the figure below. A more detailed assessment is provided in Sections 3.2.1 to 3.2.3.

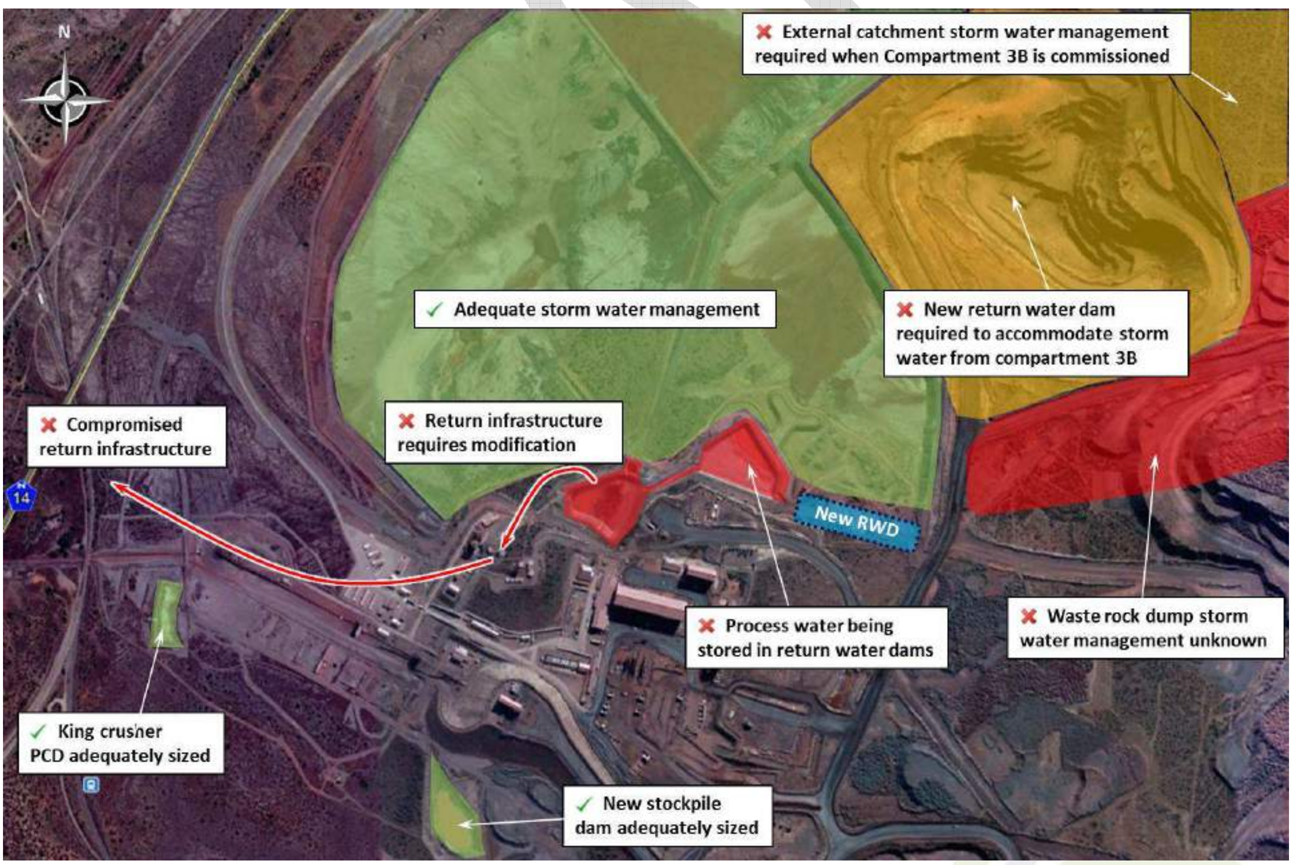

FIGURE 6: SUMMARY OF THE KING STORM WATER MANAGEMENT AND GN 704 COMPLIANCE FINDINGS

The following as a list of findings from the high-level audit conducted:

- The current storm water infrastructure for the PDF is adequate, but not utilised correctly.
  - Process water is being stored in the King return water dams to supply King mining and crushing. This uses up capacity that is supposed to be reserved for storm water management (and GN 704 compliance) and therefore the system as a whole can only comply with GN 704 by transferring the risk onto the PDF – by storing water on the PDF that should be stored in the return water dams.
- Once Compartment 3B is operational, GN 704 cannot be achieved without significant risk to the King PDF. Storm water will need to be stored on the PDF due to insufficient RWD capacity. A new return water dam has already been adequately sized and designed.
- Once Compartment 3B is operational, clean storm water must be diverted away from the compartment.
- Waste rock dump storm water management around Compartment 3B is unknown and poses a significant risk to the PDF.
- The return infrastructure between the King plant and the Parsons plant is limited. One of the pipelines is leaking. This effects both storm water management and process water management. A project is currently underway to repair a pipeline between the King and Parsons plants.
- The King crusher PCD and New Stockpile Dam are adequately sized.
- No storm water controls exist for all King waste rock dumps.

3.4 Bruce Storm Water Management and GN 704 Compliance Findings

The following as a list of findings from the high-level audit conducted:

- Storm water channels that route water to the pollution control dam are brick lined. The mine's water use licence specifies concrete lined channels.
- Storm water dam and operations are adequate.
- No storm water controls exist for all Bruce waste rock dumps.

4. DOMESTIC AND PROCESS WATER MANAGEMENT FINDINGS

The mine's water circuits and water balance are well documented and understood by multiple employees on the mine. The water balance understanding spans across multiple employee levels and spans multiple departments. The mine is served with an excellent array of flow meters and the data is very well managed. The level of understanding and analysis of the data is high, and the mine even employs a full-time staff member to analyse data. All data collection and management is proactive and well supported. There are therefore no negative findings against the water balance and data management systems on the mine. In fact, these should be commended.

4.1 Parsons Plant

The following as a list of findings from the investigations conducted:

- The process water system functions well under normal operating conditions.
- The process water system has insufficient storage capacity to accommodate upset conditions or fluctuations in Gamagara water supply.
- An analysis of lost production attributed to insufficient process water showed that 740 hours of production was lost between July 2017 and May 2018. This equates to approximately 10% of available operating hours.
  - It must be noted that this lost production currently has no impact on production targets. The production targets appear to be downstream constrained by rail limitations.
  - Further to this, the plant is able to make up these production losses using various production levers including (but not limited to) compressing maintenance periods, not utilising additional maintenance periods that are available in the original planning, and overtime shifts.
  - The periods of high production place stress on the King PDF.
  - If the rail bottle neck is lifted, the annual production targets can be lifted and these production losses may become relevant.
  - The reduction in plant downtime will allow for more maintenance time and a more efficient plant operation.
- The lost production caused by insufficient process water is often attributed to a lack of Gamagara water. This is not always the case, but when it is, it highlights the lack of storage capacity in the Gamagara water supply system to accommodate upset conditions. A detailed analysis of the Gamagara water supply is provided in Section 6.4 on page 13.
- The primary thickeners are no longer being dumped to the King PDF. The primary thickeners are now dumped to the Process Water Recovery Dam via a dewatering system (refer to Figure 7). This represents a significant improvement in process water management.
- The return capacity from the Parsons Storm Water Dam is inadequate.
  - Process water recovery after shutdowns and upset conditions is therefore poor. Process water that discharges or overflows from the plant water systems are routed

under gravity to the Parsons Storm Water Dam. The capacity to recover this water is limited so the make-up demand is transferred to the Gamagara system, placing additional burdens on this system.

- Observations during multiple site visits indicate that process water appears to continuously flow down to the Parsons Storm Water Dam. This contravenes the water use licence conditions of the Parsons Storm Water Dam (also discussed in Section 3.2.2, on page 5). It also points to an area where process water management can be improved. This also results in the mixing of process water and storm water which is contrary to best practice storm water management (also discussed in Section 3.2.2, on page 5).

FIGURE 7: DEWATERING CYCLONES AND SILT TRAP AT THE PROCESS RECOVERY DAM

4.2 King Plant

The following as a list of findings from the investigations conducted:

- The King Braithwaite tank is leaking at an estimated 150 m^3/day. This is approximately 6% of Gamagara water pumped to King. This water flows into the King PDF Compartment 1 via the gland service collection system. The tanks have been leaking since 2008, but a project to replace the tank is underway. At the time of the site visits, limited progress was evident, but anecdotal evidence suggests that project delays have been rectified.
- The King PDF return water dams are being used to store water for mining (crushers and dust suppression). While this has a positive effect on King process water management, it adds risk to the King PDF or GN 704 non-compliance (also discussed in Section 3.3, on page 6).

- The pumping system to return water to Parsons/provide mining is a manual system and this is not managed effectively. The infrastructure is shared with the mining supply system which reduces the effectiveness of returning water to the Parsons plant.
- The return infrastructure between the King plant and the Parsons plant is limited. One of the pipelines is leaking. A project is currently underway to repair a pipeline between the King and Parsons plants. This effects both storm water management and process water management (also discussed in Section 3.3, on page 6).

FIGURE 8: KING BRAITHWITE TANK LEAKING

4.3 Bruce Plant

There were no negative findings.

5. MINE WIDE WATER SYSTEM SUMMARY

The mine wide water balance was modelled using a GoldSim daily time step model. The mine's water systems are not static and experience significant variations in flow, slurry densities, operating conditions and upset conditions. These variations are built into the GoldSim water balance model to allow the dynamics of the mine's water balance to be accounted for as realistically as possible. The model makes extensive use of probabilistic inputs and operational variations such as upset conditions. Regular activities such as shutdowns and slurry distribution network flushing are also accounted for. Climate data inputs use a long term daily rainfall record (over 86 years of good quality daily rainfall) and monthly average evaporation data published in the WR2005 water Research Commission study.

The GoldSim water balance model was calibrated on recorded data and good calibration results were obtained. The confidence level in the GoldSim water balance model is high. The model was used to for all scenario analysis and to guide all recommendations.

The mine's water balance is very large and complex. However, for the purposes of this report, a simplified water balance schematic is presented in Figure 9.

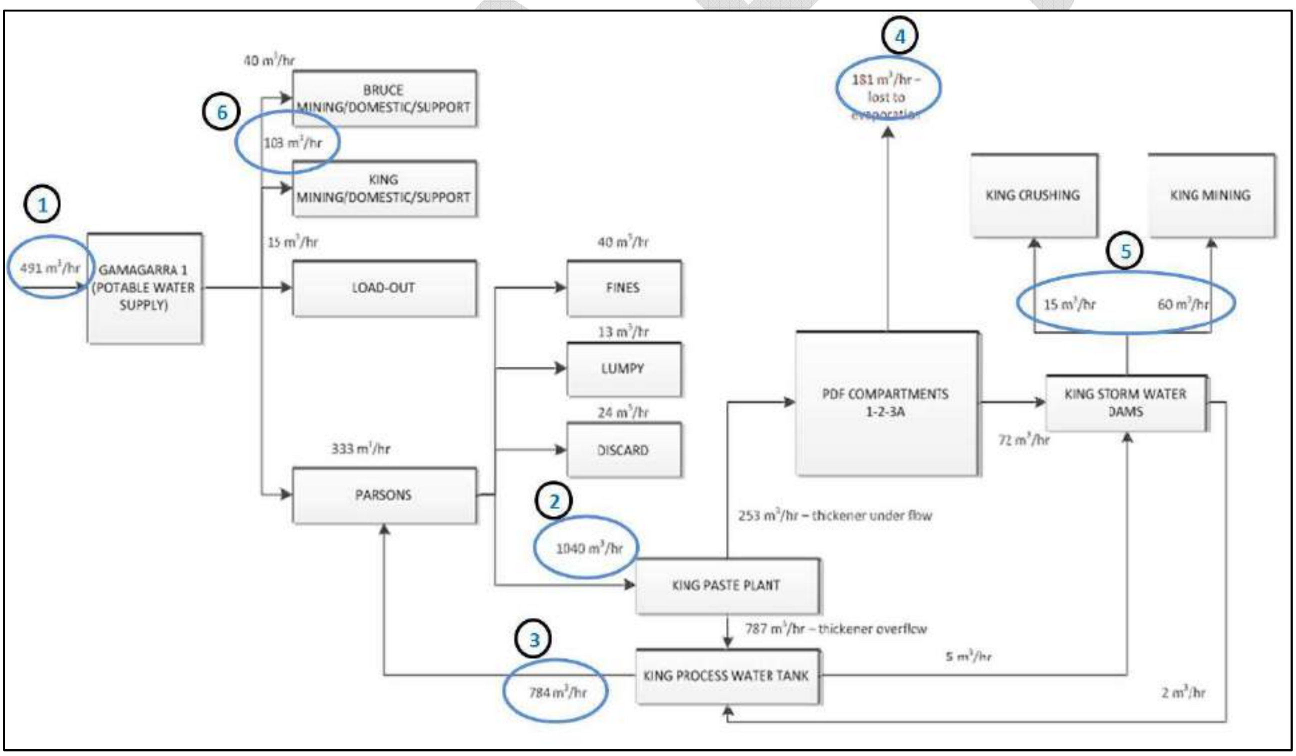

FIGURE 9: HIGH LEVEL WATER BALANCE SCEMATIC PROVIDED BY THE MINE

The most important flows are highlighted and discussed below:

TABLE 1: KEY FLOWS IN THE KHUMANI WATER BALANCE

Item	Description	Flow - m^3/day (m^3/hr)	Comments
1	Gamagara potable water supply	11 780 (491)	This is the lifeline of the mine and provides all make-up
2	Tailings (slurry water)	25 000 (1 040)	This is the largest movement of water on the mine and is the bulk of the water leaving the Parsons plant
3	King secondary paste thickener overflow	18 860 (784)	This is the largest inflow into the Parsons plant making up ±70% of water inflows
4	Losses on the King PDF	4 350 (181)	This is the largest consumer of water on the mine. Most of this water is lost to interstitial lockup and evaporation
5	King mining and crushing dust suppression	1 800 (75)	Much of this water is used for thickener reagents. Some of this water is used for King mining dust suppression and ancilliary services such as crushing. A portion of this water is also used for flushing.
6	Additional water pumped to King for mining and other uses	2470 (103)	

The actual values above change slightly as further analysis and investigations continue, but they provide an excellent overview of the main drivers of the mine's water balance.

The king return flow is the most crucial inflow into the Parsons plant and makes up approximately 70% of all inflows. When this flow is compromised, the Parsons plant has to draw additional water from the Gamagara water storage system. This system is described in more detail in the following section.

6. ANALYSIS OF GAMAGARA WATER SUPPLY

6.1 Raw Water Cost

Khumani mine currently pays approximately R 13/m^3 for raw water supplied by Sedibeng Water. This raw water is referred to on the mine as both Sedibeng water and Gamagara water. This report refers to Gamagara water as the raw water and Sedibeng Water as the raw water supplier.

It is likely that the raw water cost will increase in the near future. Values of between R 20/m^3 and R 50/m^3 have been proposed. The general consensus on the mine is that the future costs will likely be at the higher end of this spectrum.

6.2 Raw Water Wastage

There are no blatant instances of large-scale Gamagara water wastage. However, there are many small areas where Gamagara water management can be improved. This can translate into annual direct water cost savings and reduced production losses. These are discussed throughout this report.

6.3 Raw Water Storage

The mine stores Gamagara water in three reservoirs – Gamagara 1, 2 and 3. Gamagara 1 has a reported capacity of 10 000 m^3. Gamagara 2 and 3 have a reported capacity of 20 000 m^3 each. The combined Gamagara water storage is therefore 50 000 m^3. The system is not run at 100% capacity as this would result in frequent spillages as some surge capacity is required in a dynamic system such as this one. The system is generally run between 80% and 90% which is considered appropriate. This provides 42 500 m^3 of storage (85%). This is considered inadequate as it provides just over 2 days' supply if the King return is interrupted (occurs frequently) and under 4 days' supply if the Gamagara supply is fully interrupted (occurs rarely). Partial Gamagara water interruptions occur frequently.

6.4 Raw Water Supply

Because of this relatively small buffer storage, the mine operates a run-of-river type extraction from the Sedibeng Water system. This means that the mine has little insulation against short term variations in Gamagara water supply.

A narrative exists (Narrative 1) where there is limited Gamagara water supply between November and January due to shortages in the larger Sedibeng Water supply system. The data does show increased volatility in supply during these periods with some reduction in flow. However, when viewed at a monthly level the impact is relatively small, implying short term flow reductions cannot be accommodated by the mine's process water systems. This is discussed in the preceding section. A larger water storage system is required to provide more insulation against short term fluctuations in the Gamagara supply, especially when combined with upset conditions in the plant. The poor return capacity at Parsons Storm Water Dam exacerbates the problem as water that flows to the Parsons Storm Water Dam under upset conditions needs to be recovered from the Gamagara system while the water in the Parsons Storm Water Dam is slowly bled back into the system.

A second narrative exists (Narrative 2) where the mine is unable to extract additional water from the Sedibeng Water supply system to fill any additional buffer storage. The mine's allocation significantly exceeds its current Gamagara water demand, so legally the mine is entitled to significantly more Gamagara water than what it currently utilises. It is true that during certain periods of the year, Sedibeng Water limits Gamaraga water, but the data suggests that there is potential for additional water abstraction potential. The caveat is that these periods are not necessarily aligned with periods of higher Gamagara demand so this potential cannot be exploited through a run-of-river type extraction. Long-term storage is therefore required to benefit from this potential.

The mine's flow meter data (gauge 603 Gamagara Tank Supply) was statistically analysed to show trends and statistics. Data between May 2014 and July 2018 was analysed.

Note that all analysis was done on daily flow data and all hourly data presented assumes a 24-hr flow day. The analysis of the 2017 calendar year data is also done where appropriate. 2017 was selected for three reasons:

- Many anecdotal accounts of Gamagara water shortages in late 2017 are prevalent on the mine
- It's a closer approximation of the current operating conditions, compared to say 2014.
- It is fairly recent and more fresh in the memory of this report's audience.

It must be noted that this data represents the lesser of demand and supply limitations – a demand and supply limited data set. If additional Gamagara water is available, but the mine cannot accept available water in addition to its demand, then only its demand will be drawn from the Gamagara water supply. The data therefore does not necessarily show the actual volume of water that would be available for the mine's consumption. There is a very high likelihood that there are days where supply exceeds demand. There is no data to determine this though, but various Khumani staff members have confirmed that there are days when supply exceeds demand and this additional supply cannot be utilised. This is a lost opportunity for water assurance of supply.

This data will therefore provide a minimum availability and it can be assumed that there will be periods where additional Gamagara water is available.

6.4.1 Long term time series

The time series of the data is presented in Figure 10. The figure shows the following:

- There is a growth of over 3 000 m^3/day (125 m^3/hr) in the average demand from May 2014 to July 2018 (shown by the red linear trend line).

- The maximum recorded abstraction is approximately 30 000 m^3/day (1 250 m^3/hr). There are three other instances of recorded flows over 24 000 m^3/day (1 000 m^3/hr) which reduces the possibility that these peak flows are data errors.
- There are limited seasonal characteristics to the flow data (shown by the black 30-day moving average line). This is further corroborated in the Section 6.4.3).
- The current average demand is approximately 510 m^3/hr. This correlates well with the value of 491 m^3/hr that is generally accepted on the mine. The long-term average of the full data set is 453 m^3/hr. The average for 2017 was 484 m^3/hr. This is in line with an increasing demand trend.
- The 30-day moving average also shows that there are extended periods where Gamagara water demand exceeds the average demand, as well as the converse. Since this is a demand and supply limited data set, it is likely that additional water is available during these periods of higher than average demand.

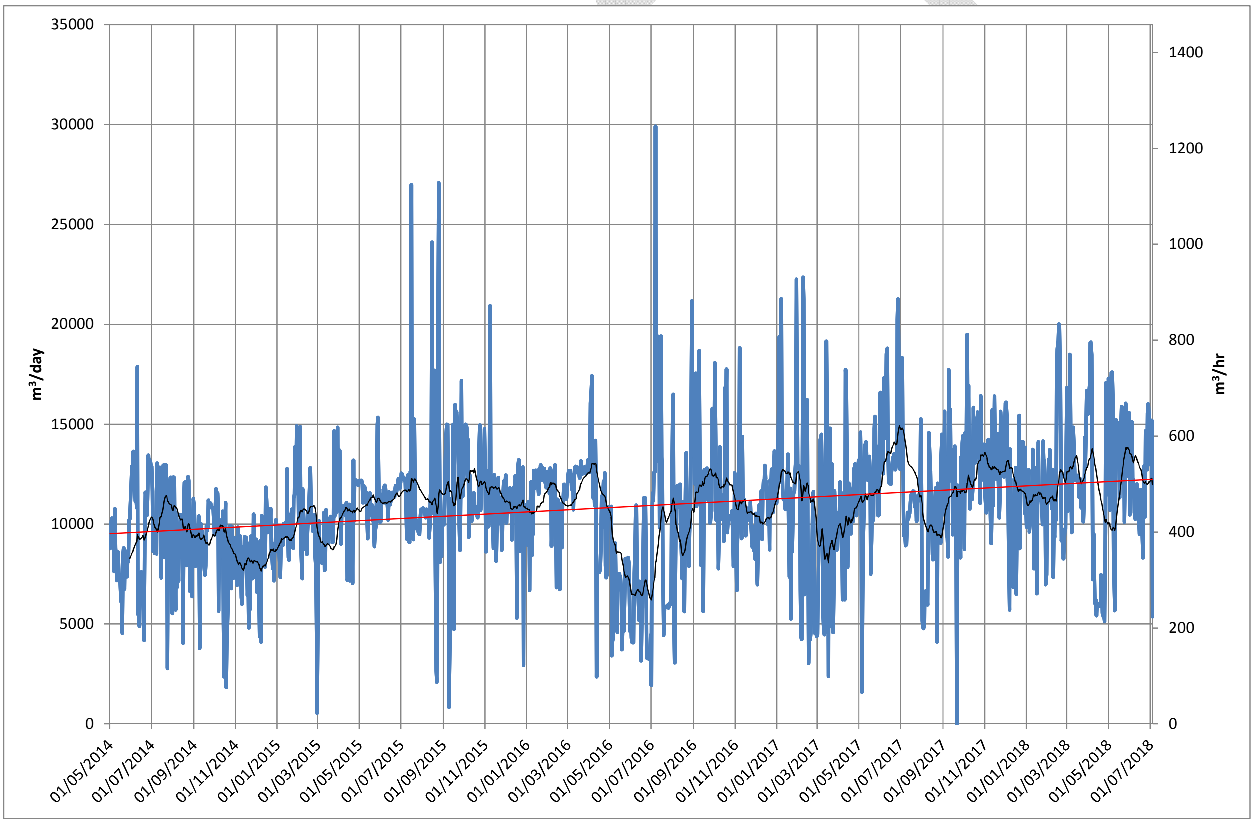

FIGURE 10: TIME SERIES OF 603 GAMAGARA TANK SUPPLY

6.4.2 Probability of flow

A histogram of probability of certain flow ranges is presented in Figure 11.

The figure shows that most of the flow is concentrated in the 400 – 500 m^3/hr and the 500 – 600 m^3/hr ranges. The 2017 data shows a bias towards higher pumping, compared to the full record (maroon bars mostly higher than blue bars for the high flow ranges and the converse for the low flow ranges). This implies a higher demand as well as a higher availability of water during the 2017 calendar year. However this analysis does not show the monthly distribution of the flows.

This analysis partly speaks to the second narrative and shows that for 47 days of 2017, between 600 and 700 m^3/hr was abstracted. In fact, in 2017, 14 400 m^3/day (600 m^3/hr) was exceeded 66 days of 2017 (18%) and 16 800 m^3/day (700 m^3/hr) was exceeded 19 days of 2017 (5%).

This analysis effectively concludes that there are periods where water availability significantly exceeds the average demand.

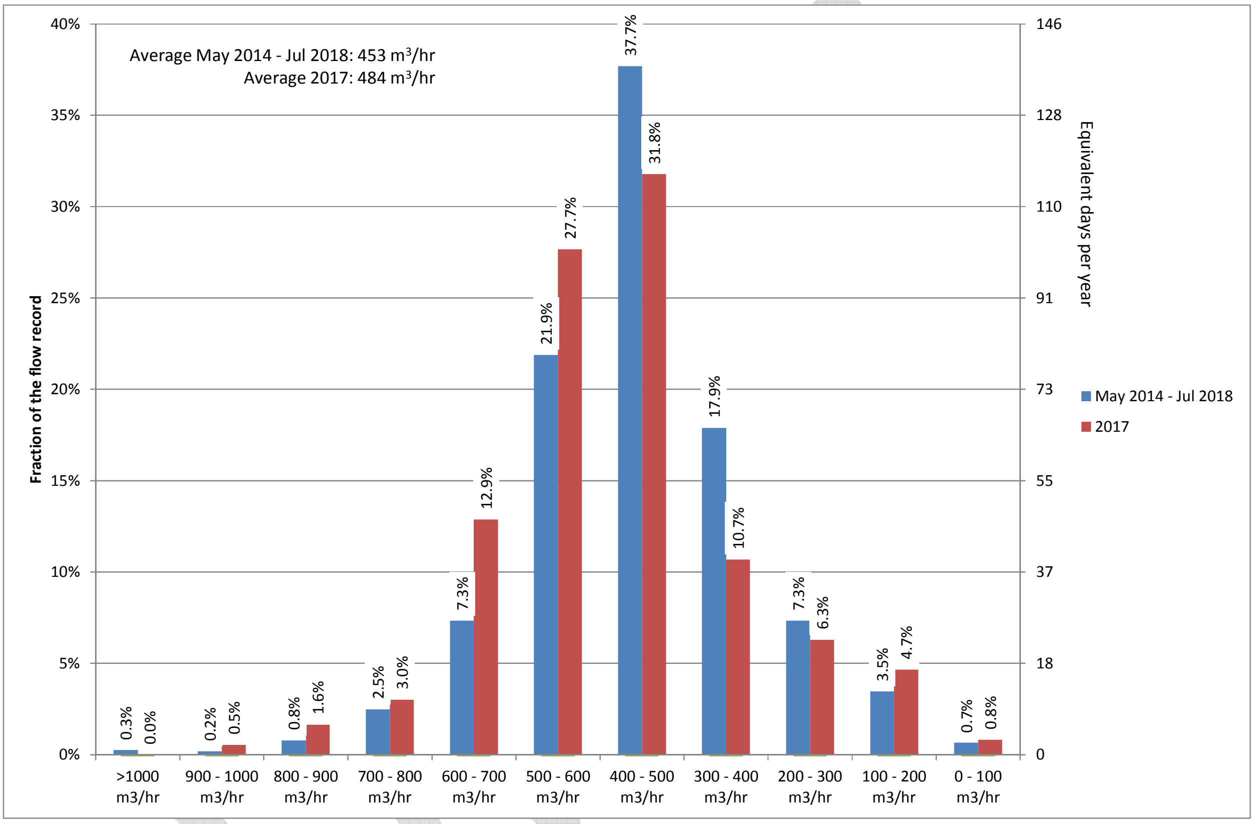

FIGURE 11: PROBABILITY OF FLOW

6.4.3 Average monthly flow

The temporal analysis is shown in a series of graphs below.

The data presented in Figure 12 shows average monthly Gamagara intake for both the full record period (May 2014 to July 2018) as well as the 2017 calendar year.

Figure 12 shows that between May 2014 and July 2018 there is a reduction in inflow during November and December, but there is a significant recovery in January. However, the reduction, when viewed at a monthly scale is small (±13 m^3/hr). The shortfall in May and August is higher and the April shortfall is slightly less. The August shortfall is attributed to annual shutdown. The 2017 data also shows a reduction in Gamagara water intake from October through to February.

However, the December 2017 period was approximately the average intake. Narrative 1 (discussed in Section 6.4) suggests that shutdowns occur in November and December due to Gamagara water supply shortfalls. While Narrative 1 can't be dismissed, it clearly indicates that relatively small shortfalls on a monthly scale (compared to average demand) in Gamagara water supply result in plant shutdowns.

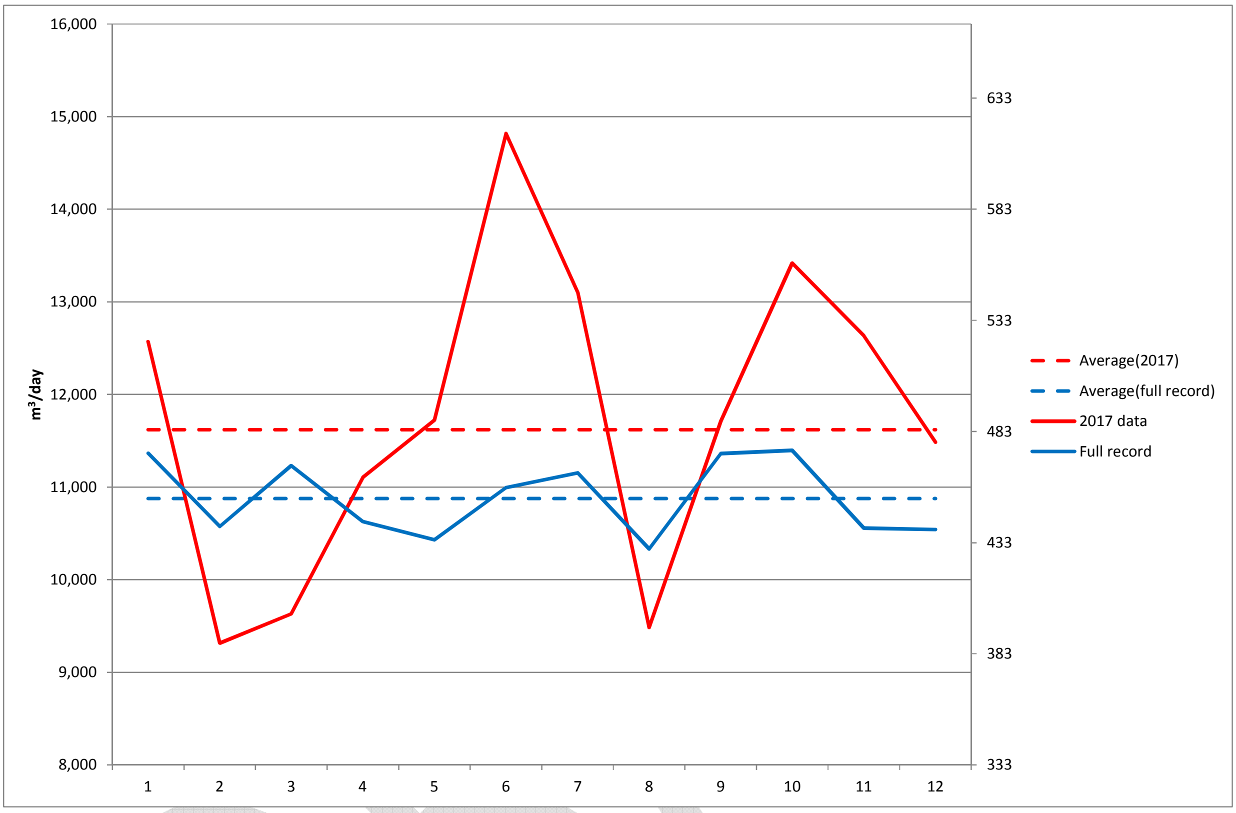

FIGURE 12: AVERAGE MONTHLY GAMAGARA WATER INTAKE

An additional point to note is that Khumani mine makes its annual production target, despite plant shutdowns due to water supply problems. This is achieved by increasing production when required. December is historically the month with the highest production – probably in an effort to meet or exceed the annual target. This is shown in Figure 13. This practice exacerbates the Gamagara water supply problem, as the months with the most erratic supply are the months where the volume of water required is the highest.

The end of year production push will unlikely change, regardless of whether a stable water supply system is in place or not. This reinforces the need for greater resilience to Gamagara supply fluctuations during November and December.

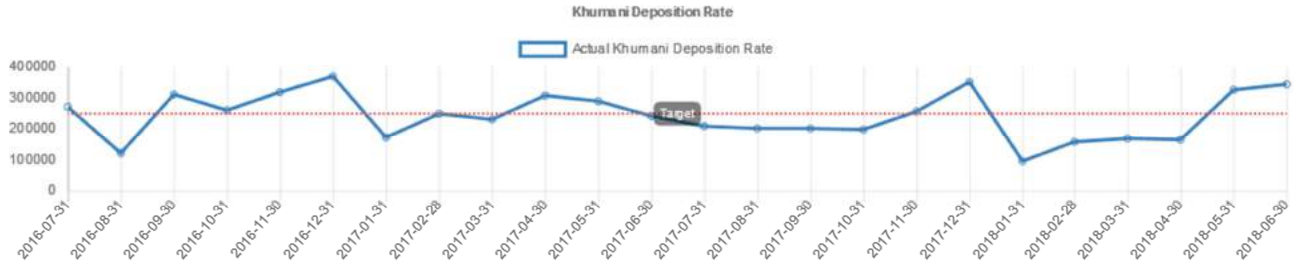

FIGURE 13: DEPOSITION RATE TO THE KING PDF

6.4.4 Monthly flow

A monthly time series analysis is shown in Figure 14. The graph is busy, but shows the following:

- Two critical seasonal periods are shown:
  - Brown shaded areas representing the dry Nov – January period
  - Blue shaded areas representing the wet mid-May to mid-August period
- There is a clear pattern of lower flows during the dry period. This supports Narrative 1 (discussed in Section 6.4).
- These shortfalls vary in intensity between 10% and 20% of the assumed demand. The assumed demand is extrapolated from preceding and following months.
- However, the biggest shortfalls occur outside of the dry period. Many of the bigger shortfalls occur in the wet period. These are shown in Figure 14 by the  symbols.
- These shortfalls do not correspond to the scheduled August maintenance period.

The fact that bigger shortfalls occur outside of the dry period points to the fact that the monthly flow data is driven by both demand and supply limitations. All apparent shortfalls could be limited by low demand, low supply, or both. The shortfalls during the dry periods could therefore also be caused by low demand. January 2018 is a good example of this (refer to Figure 13 for the deposition rate to the King PDF – a good indicator of production and therefore demand).

An analysis of tonnes processed does not reveal with certainty whether these are supply or demand limitations, as processed tonnes is directly coupled with water supply/demand. December production is usually high and January production is generally low so this understanding can be read into the data. The higher demand and lower assurance of supply in November and December reinforces the anecdotal accounts of dry period water shortfalls.

However, the shortfalls during the dry periods are not catastrophic in conventional water supply terms. The fact that they cause shutdowns clearly demonstrates that the Khumani water system cannot accommodate relatively small fluctuations in supply, especially in high demand periods. The mine's water supply system has not been brought in line with current production cycles.

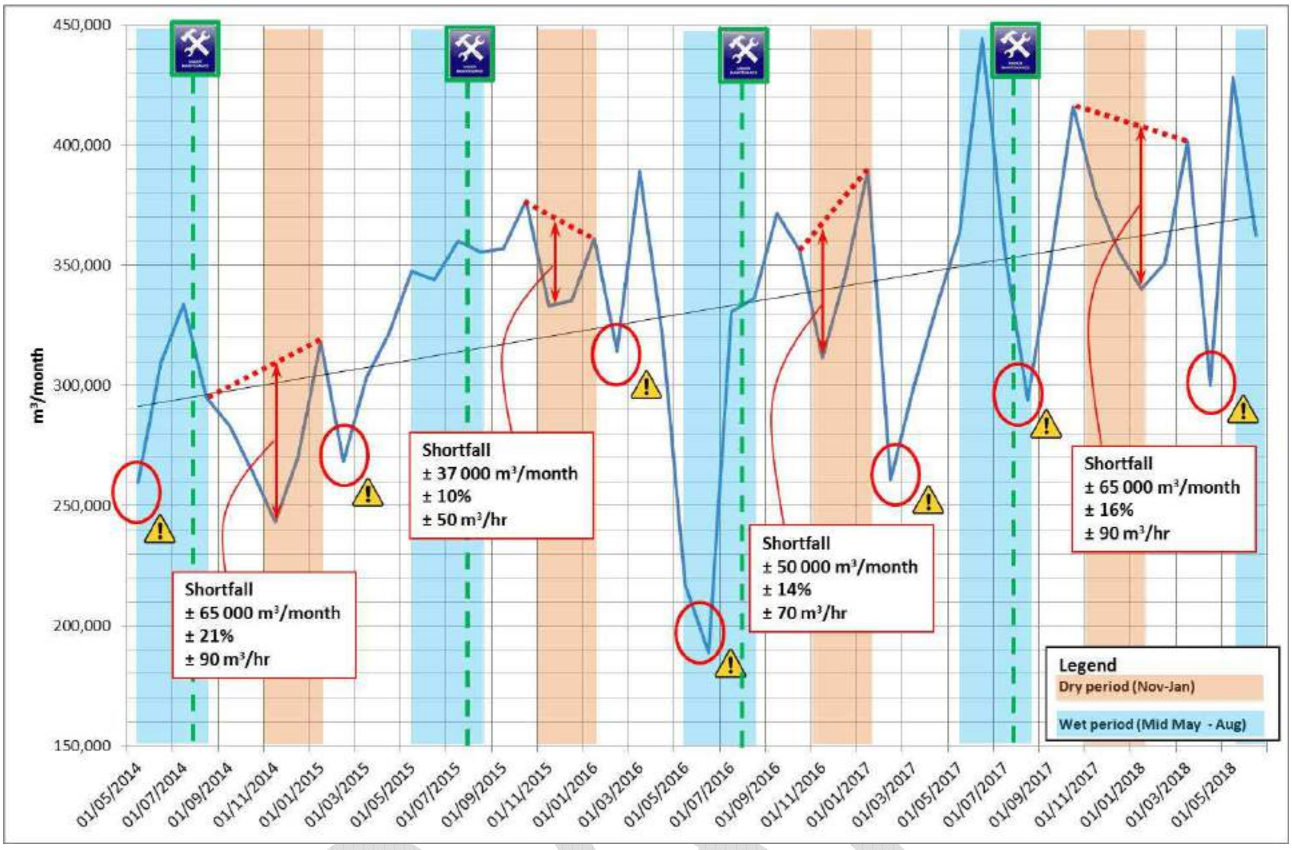

FIGURE 14: MONTHLY TIMESTEP ANALYSIS OF GAMAGARA INFLOW

6.4.5 Consolidation and interpretation of the above analysis

Narrative 1 (discussed in Section 6.4) is valid but is far more complex than a simple Gamagara water shortage problem. Narrative 2 (also discussed in Section 6.4) appears not to be true and is more a factor of lack of somewhere to put water when it is available. The following are the key findings of the analysis done:

- Significant short term fluctuations do exit in the Gamagara supply.
- When viewed at a broader level, these fluctuations smooth out.
- Production cycles are at odds with periods of reliable and less reliable Gamagara water supply. The mine's water supply system is not suitable for this production cycle (high production late in the year).
- Khumani mine has approximately 2 days' water supply storage to buffer against no return from the King plant.
- Khumani mine has less than 4 days' water supply storage to buffer against no flow from Gamagara.
- The inconsistent returns from the King plant cannot be absorbed by the mine's water supply infrastructure.
- The low return capacity at the Parsons Storm Water Dam exacerbates this problem of low buffer storage capacity because any water that flows to the Parsons Storm Water Dam

must be replaced with Gamagara water in the short term. For continuous flows, this is less critical but becomes critical when large amounts of process water flow to the Parsons Storm Water Dam.

These findings are confirmed in the following case studies.

6.4.6 Case study 1 (1 November 2017 to 28 November 2017)

The Parsons plant was shut down on the 27th of November 2017 due to water shortages. Figure 15 shows five process water reservoir levels (Gamagara 1, 2 and 3, Dirty Water Dam and the Process Water Dam), the Gamagara inflows and King returns leading up to this period. Pertinent areas are highlighted in red ovals, numbered and discussed below.

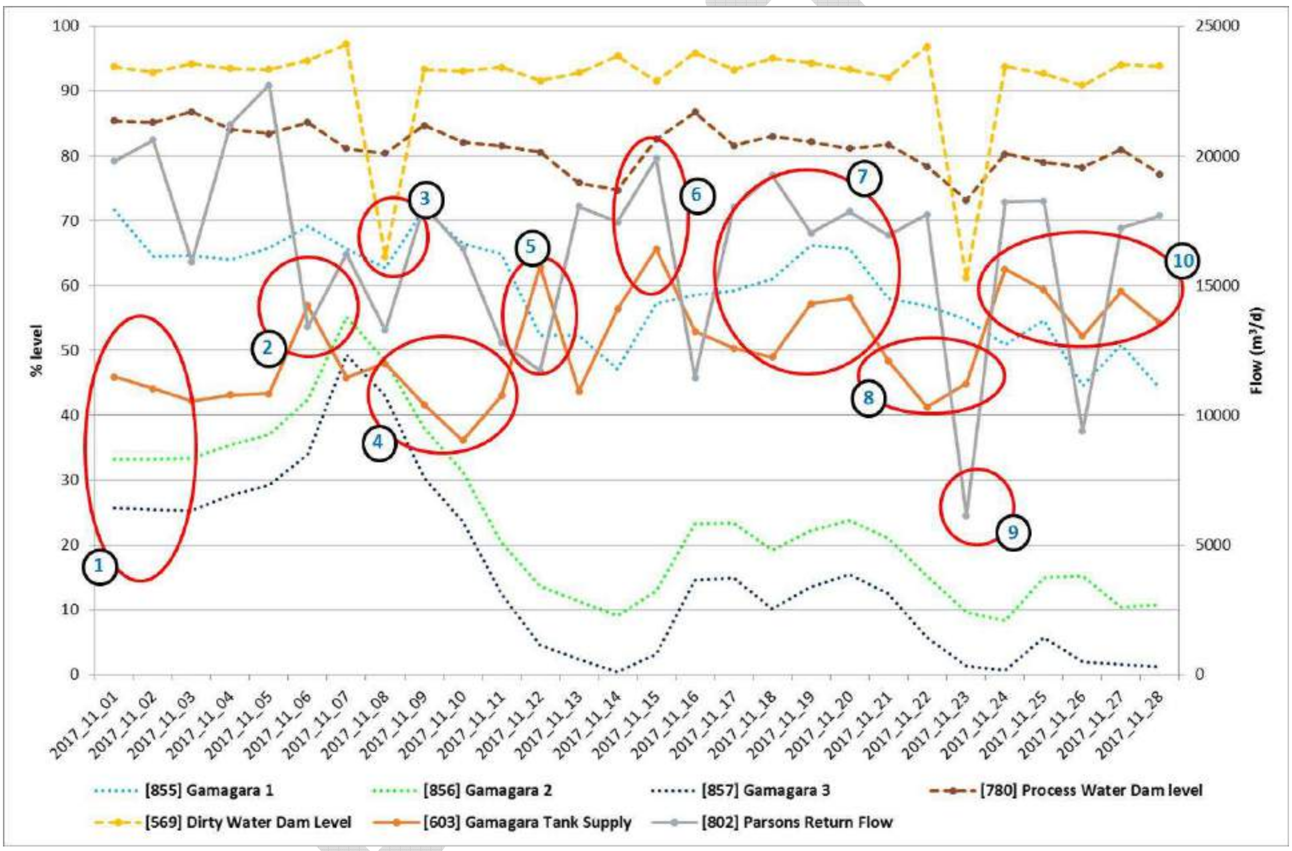

FIGURE 15: CASE STUDY 1

1. The period starts with Gamagara 2 and 3 levels being low – around 30%. Gamagara inflows are normal.
2. Gamagara water inflows increase to above average and the levels in Gamagara 2 and 3 increase to around 50%. King return starts becoming unstable.
3. The dirty water dam levels drop significantly, probably as a result of poor King returns.
4. Gamagara flows drop slightly below average, but Gamagara 2 and 3 water is used to refill the Dirty Water Dam. The levels in Gamagara 2 and 3 begin to drop sharply and are below 40%.

5. Gamagara flow increases sharply but is balance by poor King return flows. The levels in all three Gamagara dams continue to drop. Gamagara 2 and 3 are now below 20% and dropping.
6. Both Gamagara inflows and King return flows increase, resulting in a recovery of all three Gamagara Dams – 1(10%), 2 (20%) and 3 (58%).
7. Gamagara inflows are now consistently higher than average and King returns stabilise after a brief dip. Gamagara 2 and 3 levels stabilise ate 25% and 15% respectively.
8. Gamagara inflows reduce slightly but average at about 480 m^3/hr for three days. All three Gamagara reservoirs continue to decline.
9. King return drops off, causing a reduction in the Dirty Water Dam and Process Water Dam levels.
10. Gamagara inflows increase substantially, but Poor King return on 26 November precipitate a reduction in Gamagara 1 and 3 levels. The plant is shut down due to lack of water the next day.

During this case study, the Gamagara inflows average 11 300 m^3/day (470 m^3/day). This is not significantly below the 2017 average flow (484 m^3/hr) and above the long term average. Inconsistent returns from the King plant could not be absorbed by the water supply system.

6.4.7 Case study 2 (24 August 2018 to 9 October 2018)

The Parsons plant was shut down in early October due to water shortages. Figure 16 shows five process water reservoir levels (Gamagara 1, 2 and 3, Dirty Water Dam and the Process Water Dam), the Gamagara inflows and King returns leading up to this period. Pertinent areas are highlighted in red ovals, numbered and discussed below.

1. The plant is running normally, with Gamagara 1, 2, and 3 running between 70 and 80% full. Gamagara inflows are below average, resulting in a gradual lowering of Gamagara 1, 2 and 3.
2. Gamagara 1, 2 and 3 are filled to close to 80% by drawing in more Gamagara water.
3. King return drops off significantly and causes small reductions in all five reservoirs. However the reservoir levels recover in the following days and Gamagara 1, 2 and 3 levels are generally above 80%.
4. Four consecutive days of low Gamagara water intake result in a significant reduction the levels of Gamagara 1, 2 and 3 reservoirs. Gamagara 2 and 3 are below 50%.
5. Gamagara inflows return to normal. Gamagara 1 levels increase to 80%. Gamagara 2 and 3 levels increase slightly but are still under 50%.
6. Gamagara 2 and 3 levels drop significantly to 36% and 28% respectively. This is possibly as a result of reduced King return or some other factor not included in the data presented.
7. King return is very high on the 12th of September. This results in Gamagara 2 and 3 recovering to above 40% and the Process Water Dam being almost full.
8. However, a period of low Gamagara intake and low King return cause a reduction in Gamagara 2 and 3 levels to below 40% and 30% respectively.

9. A second period of low Gamagara intake and low King return precipitate a catastrophic collapse of Gamagara 1 and 3 levels.
10. It is presumed that Gamagara 2 levels follow the same trend, but data is not available. Gamagara 2 appears to be kept fuller that Gamagara 3 throughout the data period so it is likely that this trend continues.
11. Gamagara inflows recover to significantly above normal, but only Gamagara 1 levels increase. The extra Gamagara water could have been stored in Gamagara 2. Later in the data set, Gamagara 2 levels are significantly higher than Gamagara 3.
12. Further instability in Gamagara inflows and King returns follow this, Gamagara 1 levels reduce to below 30% and the plant is forced to shut down.

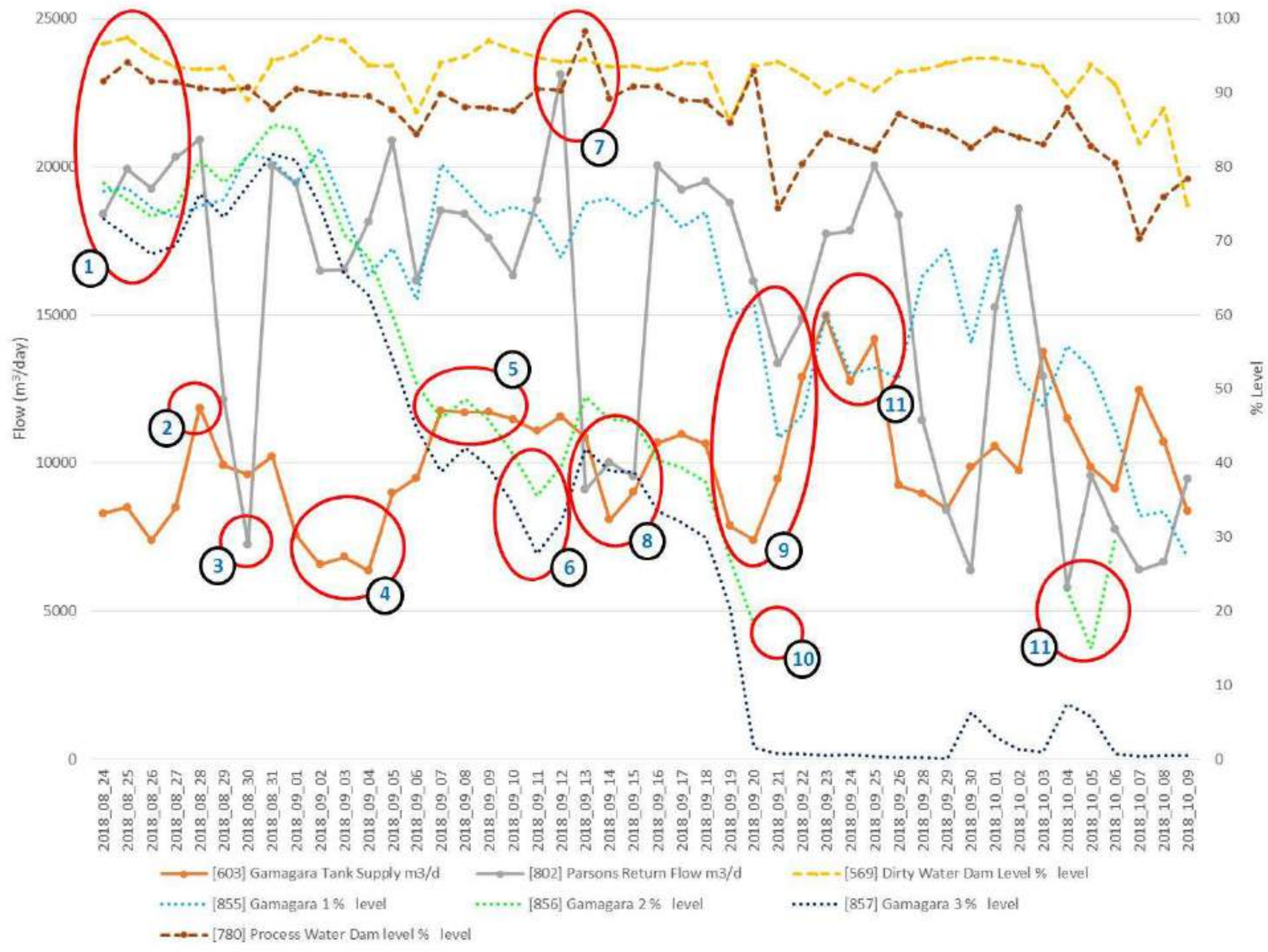

FIGURE 16: CASE STUDY 2

This case study demonstrates the validity of Narrative 1, but the situation is exacerbated by inconsistent returns from the King plant.

7. RECOMMENDATIONS

7.1 Storm water management

It never rains at Khumani…until it rains. There is never storm water at Khumani…until there is storm water. One gets the impression that storm water is viewed as an upset condition. This is understandable as it is not a regular occurrence. However, storm water needs to viewed as a resource, valued at R13/m^3 (minus pumping and infrastructure costs). This value could increase threefold in the near term if Sedibeng Water increases their prices as expected.

The mine should place an emphasis on returning storm water back into the process as soon as possible. This will result in improved GN 704 compliance and reduced risk at King PDF.

7.2 Infrastructure Requirements

7.2.1 Parsons

The following recommendations should be implemented:

- The return capacity from the Parsons Storm Water Dam should be increased to at least 100 m^3/hr.
- The return capacity from the Loadout Storm Water Dam should be increased to at least 65 m^3/hr.
- Storm water controls must be put in place around the discard dump at the loadout area. These can be earth walled paddocks as per the original design intent.
- The Loadout Storm Water Dam and Parsons Storm Water Dams need to be licenced correctly so that their use is in line with the mine's water use licence.

This is illustrated in Figure 17.

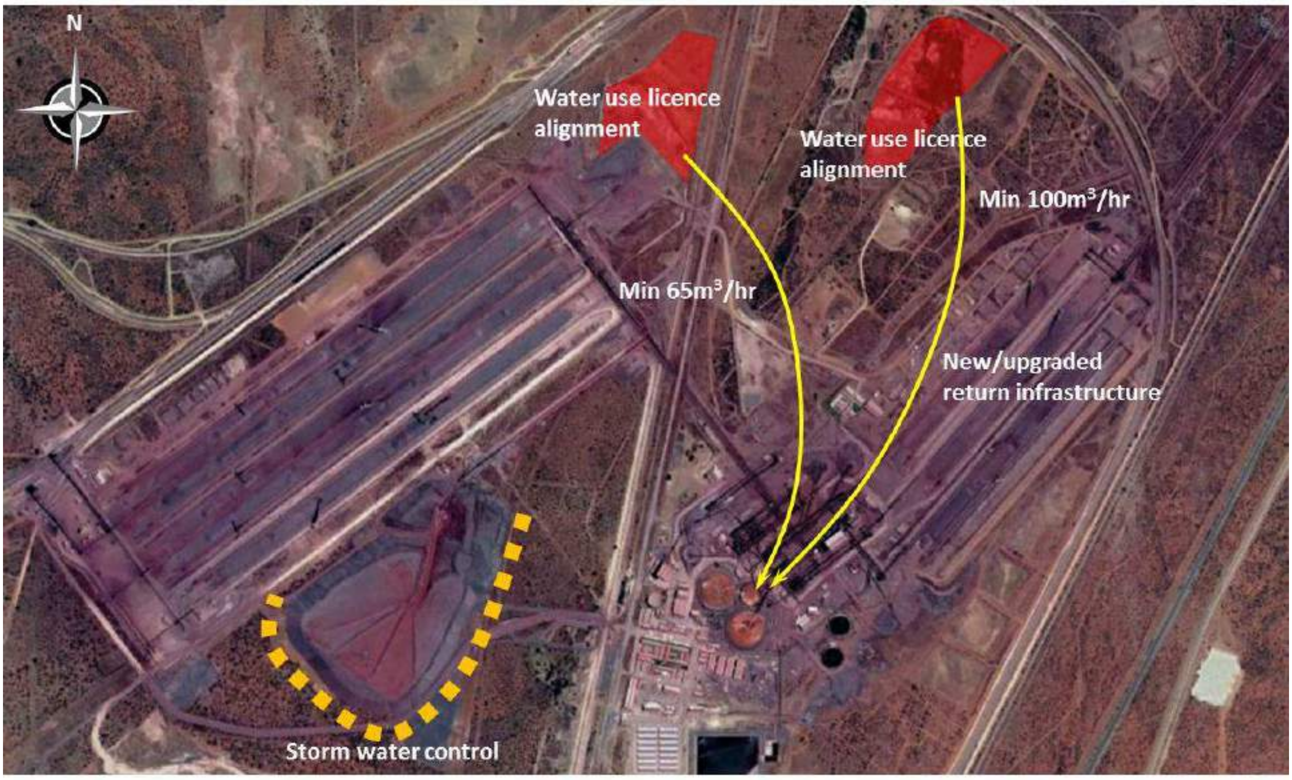

FIGURE 17: PARSONS INFRASTRUCTURE REQUIREMENTS

7.2.2 King

The following recommendations should be implemented:

- Once Compartment 3B is operational (refer to Figure 18):
  - a third return water dam will be required. Geo Tail has sized and designed this dam.
  - a clean storm water diversion will be required.
- All waste rock dumps must be designed to comply with the mine's water use licence and GN 704. This will required new designs for many, if not all of Khumani's waste rock dumps.
- Process water may not be stored in the King PDF return water dams. A separate water storage facility must be constructed to serve this purpose. Water balance modelling shows that a dam with a capacity of more than 30 000 m^3 will not be adequately utilised. It is therefore recommended that this dam have a capacity of between 25 000 m^3 and 30 000 m^3. This facility can be a dam or a tank. A tank has water use licencing benefits and evaporation losses from it can be more easily controlled.
  - It must be noted that this reservoir will add no additional assurance of water supply benefit than what is currently experienced. The purpose of this reservoir is to de-risk the King PDF and provide GN 704 compliance.
- The King PDF return water system should be split into two dedicated systems as shown in Figure 19:

  - o System 1 allows water to be pumped from the King return water dams to mining and the crusher tanks. The existing capacity is deemed adequate.
  - o System 2 allows up 300 m^3/hr to be pumped from the King return water dams to the concrete dam.
- The pipeline that returns water to the Parsons plant must have a capacity of 1 200 m^3/hr, although 1 500 m^3/hr is ideal. This capacity is made up as follows:
  - o Up to 800 m^3/hr nominal pumping capacity
  - o Up to 1 100 m^3/hr for normal operations plus storm pumping capacity
  - o Up to 1 200 m^3/hr for upset conditions when the plant is in feed forward
  - o Up to 1 500 m^3/hr for upset conditions plus storm pumping capacity
- Barge pumping infrastructure at the King PDF must have the capacities shown in Figure 19.

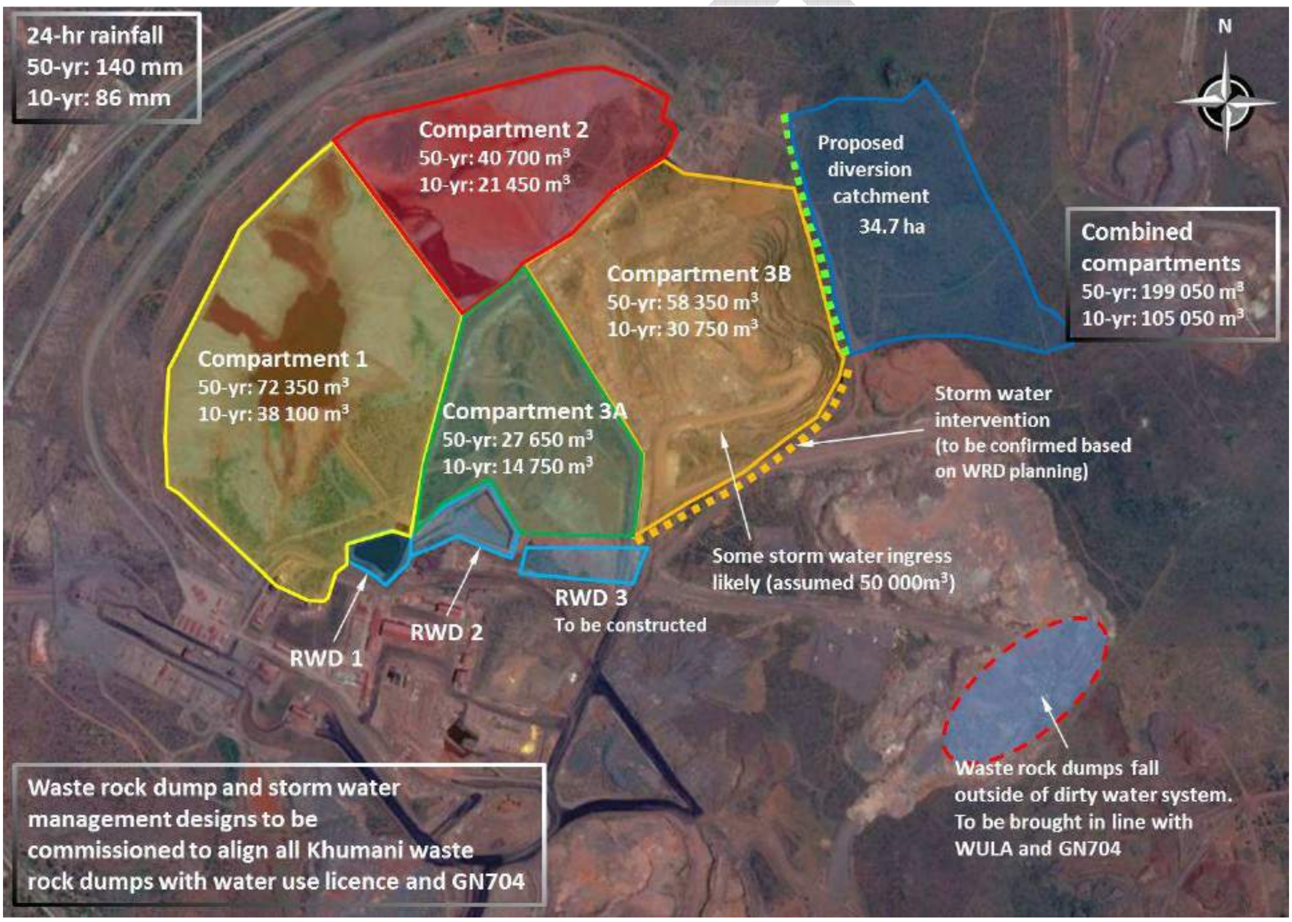

FIGURE 18: KING STORM WATER MANAGEMENT REQUIREMENTS

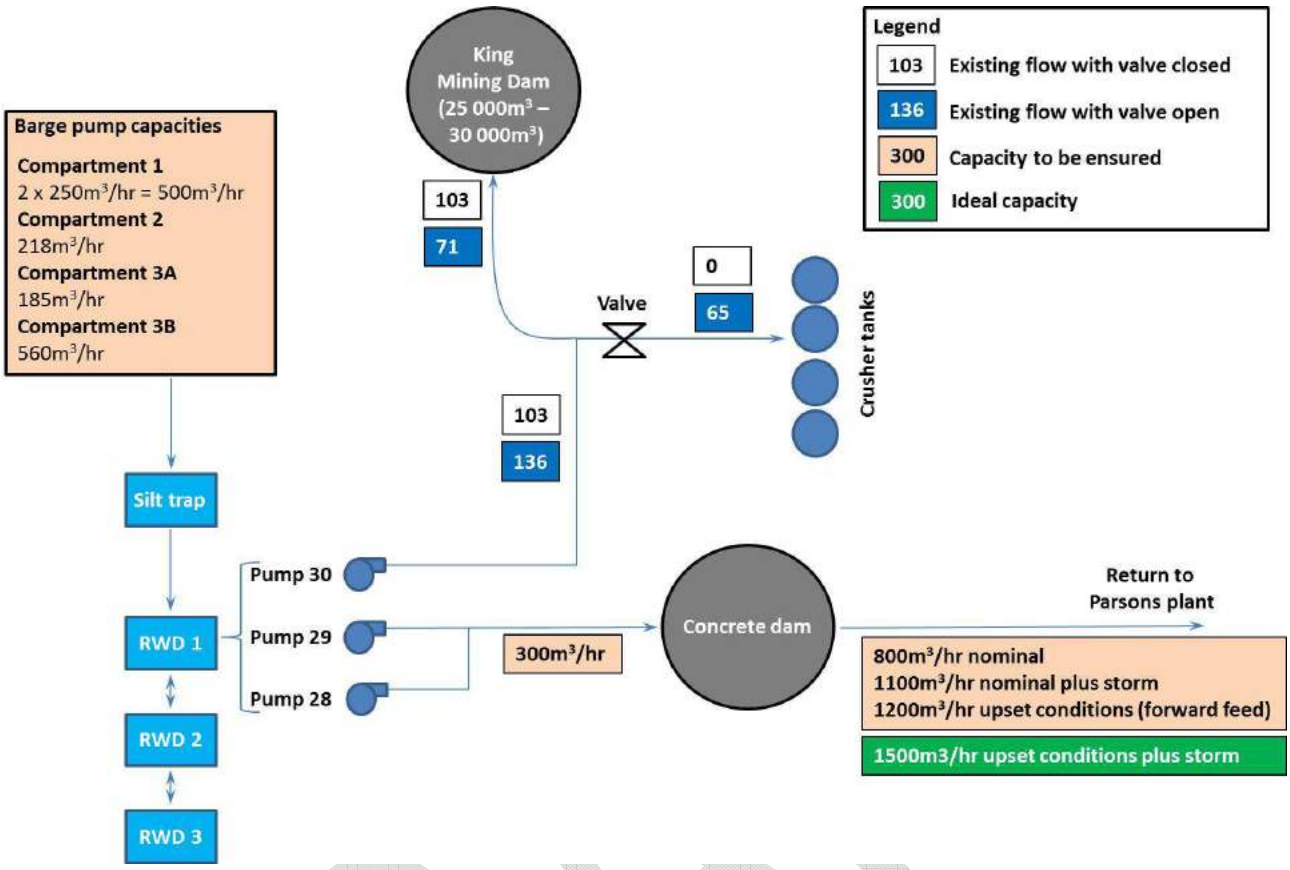

FIGURE 19: REQUIRED PUMPING INFRASTRUCTURE AT KING

7.2.3 Bruce

The following recommendations should be implemented:

- All waste rock dumps must be designed to comply with the mine's water use licence and GN 704. This will required new designs for many, if not all of Khumani's waste rock dumps.
- The storm water channels that route storm water to the pollution control dam should be concrete-lined to comply with the mine's water use licence. Alternatively, the licence conditions should be changed to allow for the current lining to remain in place. If the water quality parameter of concern is suspended solids, then a brick-lined channel will not result in ground water pollution.

7.3 Additional Water Storage

The proposed solution to reduce plant stoppages due to water shortages involves increasing the capacity of Gamagara or process water stored on the mine. Extra storage on the mine will insulate the Parsons plant from unstable Gamagara water supply and King returns. The current storage volumes have been shown to be inadequate and result in approximately 10% lost production hours.

At current production targets, this loss can be made up by various methods and production targets are still met. However, this comes at a cost of reduced maintenance time, the King PDF is placed under stress, and a plant that is pushed too hard in some employees opinion. Should the rail bottleneck be lifted and production targets increased, the mine may not be able to increase production too much beyond current production rates due to water supply constraints.

The water balance described in Section 5 on page 11 was used to determine the effect of increasing storage of process/Gamagara water on Parsons plant downtime due to water shortages. The results of the simulations are summarised in Figure 20.

It is assumed that additional water can be abstracted from the Sedibeng water supply system during most months of the year, as shown in Figure 21. Two sets of abstractions were analysed – a high abstraction peaking at 480 m^3/day (20 m^3/hr) during the typical high flow months, and a low abstraction peaking at 360 m^3/day (15 m^3/hr) during the typical high flow months.

In addition to the two abstraction scenarios, the effect of evaporation reduction on the additional water storage reservoir was analysed. It is assumed that no evaporation protection is added to other water reservoirs on the mine. The effect of a 70% evaporation reduction and no evaporation reduction was analysed. Evaporation reduction methods are described in Section 8.

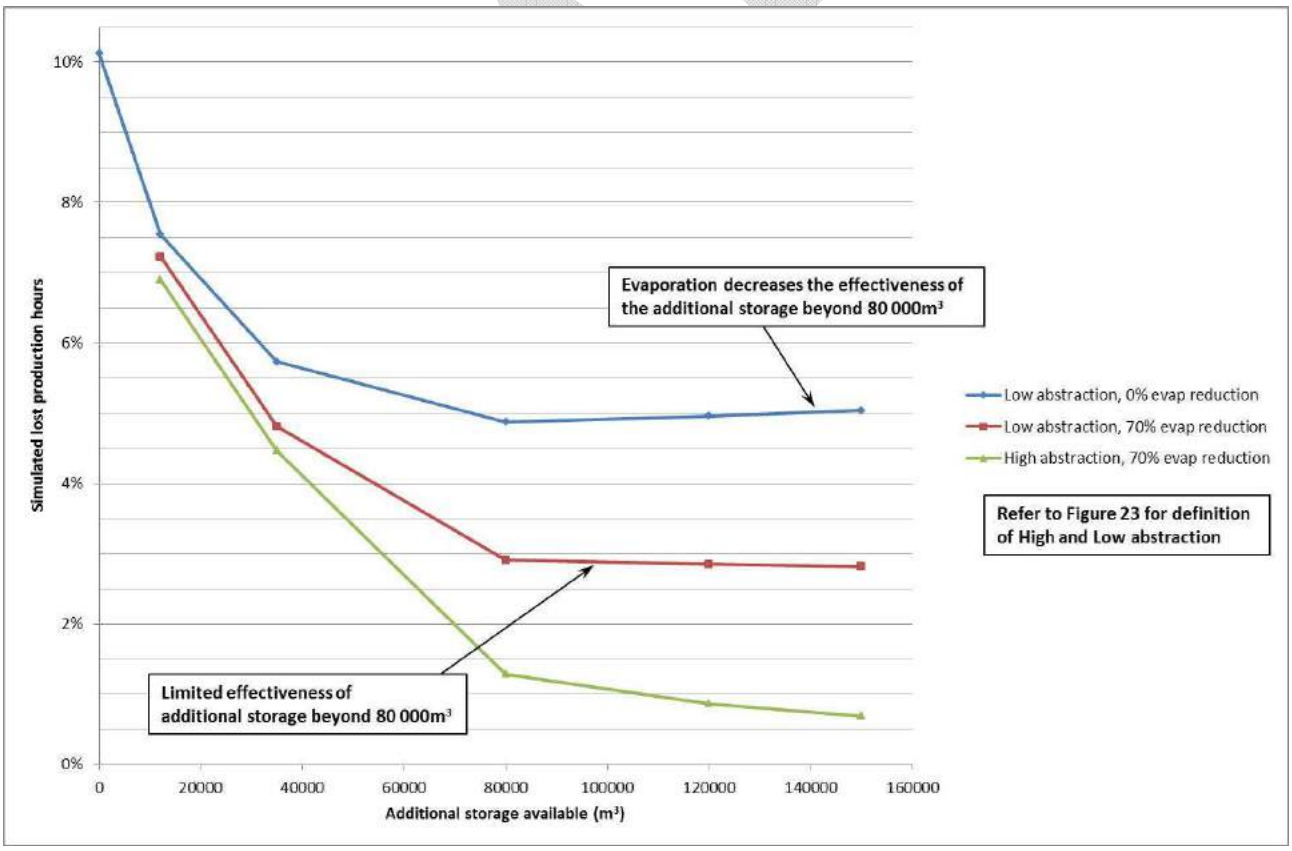

FIGURE 20: SUMMARY OF RESULTS OF EFFECTIVENESS OF INCREASED STORAGE

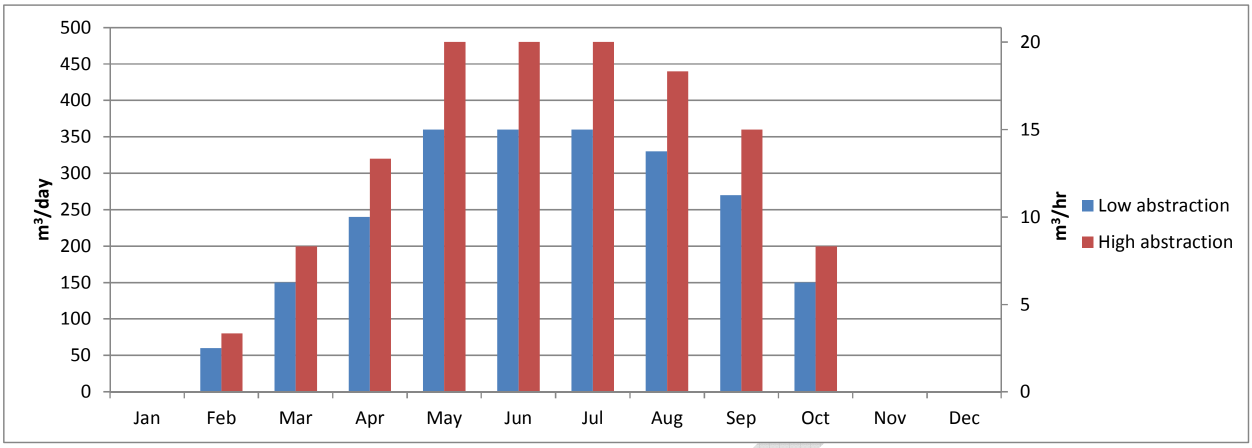

FIGURE 21: ASSUMED AVAILABILITY OF ADDITIONAL GAMAGARA WATER

7.3.1 Interpretation of results

The results of the above analysis show that increased additional storage of process/Gamagara water on the mine insulates the mine from shortfalls or instability in Gamagara water supply, as well as from instability in the King returns.

For the combination of low abstraction and no evaporation reduction, storage beyond 80 000 m^3 provides decreasing benefits as evaporation losses associated with a larger reservoir negate the additional incoming water. The base scenario (as is currently the case), yields approximately 10% loss of production hours. The combination of low abstraction and no evaporation reduction halves this loss of production hours.

For the combination of low abstraction and 70% evaporation reduction, storage beyond 80 000 m^3 provides limited benefit as there in insufficient additional Gamagara water being added to the system to take advantage of higher storage volumes. Simulated loss of production hours is reduced to from 10% to 3% with a storage of 80 000 m^3 and 70% evaporation protection on the additional water storage reservoir.

The combination of high abstraction and 70% evaporation reduction yields less than 1% simulated lost production hours with 150 000 m^3 additional water storage. The benefit reduces beyond 80 000 m^3 of additional storage, but the benefits are still significant beyond 80 000 m^3 of additional storage.

Note that under no instance does the mine ever approach their abstraction allowance from Sedibeng Water. The modelling also assumes that all the recommendations in Section 7.1 and 7.2 are implemented.

7.3.2 Locations for additional water storage

The process recovery dam is currently used when one or both of the primary thickeners needs to be dumped. It is unlikely that both thickeners will require complete emptying at the same time, so there is some capacity in the process recovery dam that can be utilised for additional water storage. This will come at no capital cost, but will come with a small risk in event that both primary thickeners need to be fully emptied at the same time.

The process recovery dam appears to have a capacity of 90 000 m^3. Each thickener has a 45 000 m^3 capacity. Based on discussions with many staff, no more than 30 000 m^3 capacity will generally be required for thickener dumping. Up to 60 000 m^3 of storage can therefore be utilised for additional water storage. It is recommended that evaporation reduction infrastructure be employed on the Process Recovery Dam if it is to be used for long term water storage.

Four excavations near the existing Gamagara 2 and 3 reservoirs can also provide suitable locations for additional water storage reservoirs. The excavations have already been made and limited earthworks would be required to utilise them as water storage facilities. They would require HDPE lining to prevent seepage losses and the use of evaporation protection is strongly recommended. The locations of these excavations, along with their current capacities is shown in Figure 22.

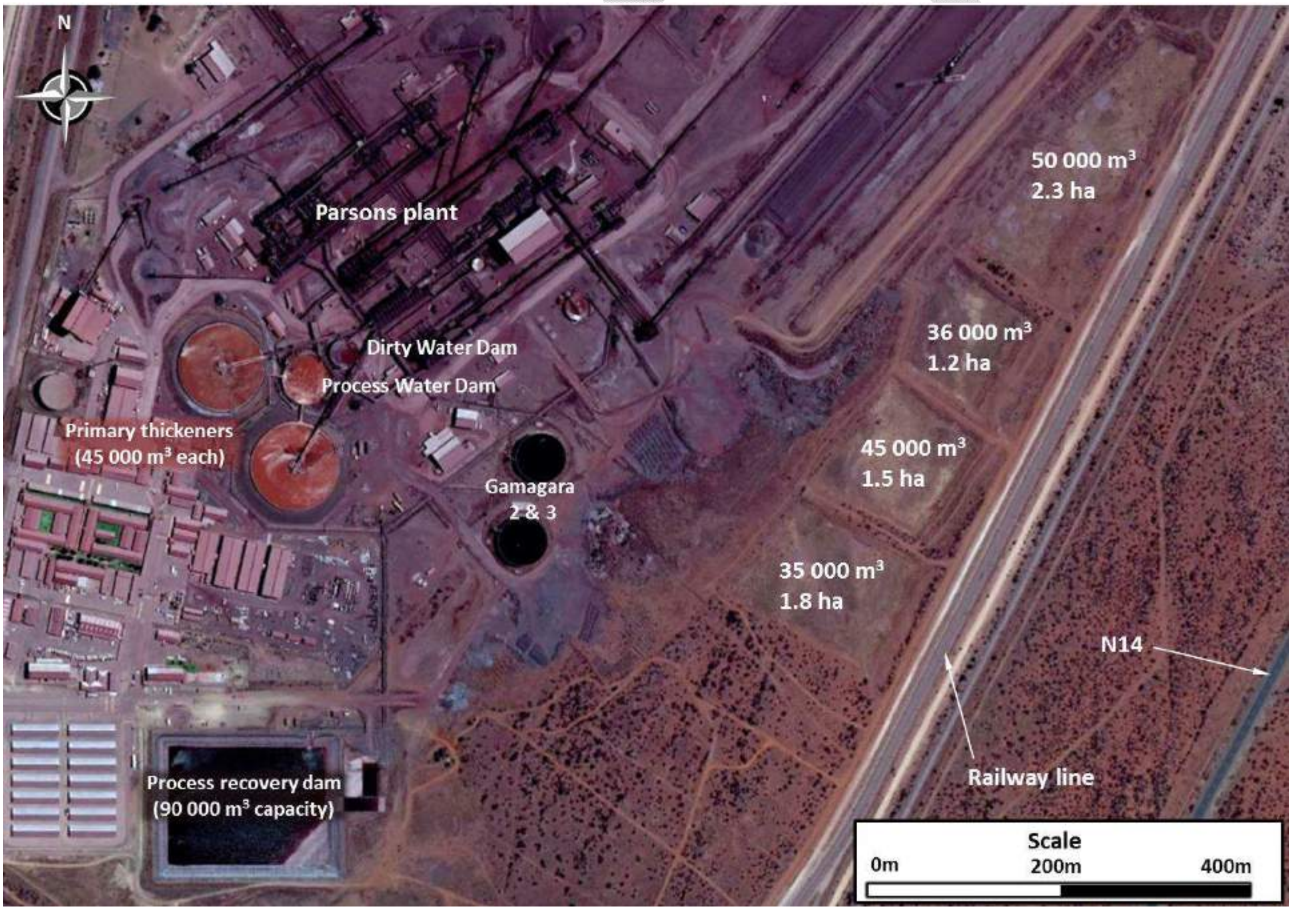

FIGURE 22: POTENTIAL SITES FOR ADDITIONAL WATER STORAGE

It is likely that water use licence amendments and other environmental authorisations may be required to use any of these facilities for long term water storage.

8. EVAPORATION REDUCTION

Various evaporation reduction technologies are available. Some of them are shown in Figure 23. Floating balls are the most common and provide evaporation reduction of between 70% and 90%. It is important to use balls that are weighted to prevent them from being lifted off the dam by strong winds.

Full covers are the most effective but are prohibitively expensive.

Aqua Armour™ provide hexagonal modules that automatically fit together and can provide up to 90% evaporation reduction.

The cost of using evaporation reduction technology can be offset by Gamagara water cost savings. Average simulated evaporation losses were used to calculate indicative costs of water that is lost to evaporation. These are listed below and assume a Gamagara water cost of R13/m^3:

- Total Parsons ≈ R750 000 pa
  - Process Recovery Dam ≈ R31 000 pa, assuming not used for Gamagara water storage
  - Parsons Storm Water Dam ≈ R660 000 pa
  - Loadout Storm Water Dam ≈ R61 000 pa
- Total King ≈ R175 000 pa
  - King RWD 1 ≈ R155 000 pa
  - King RWD 2 ≈ R20 000 pa

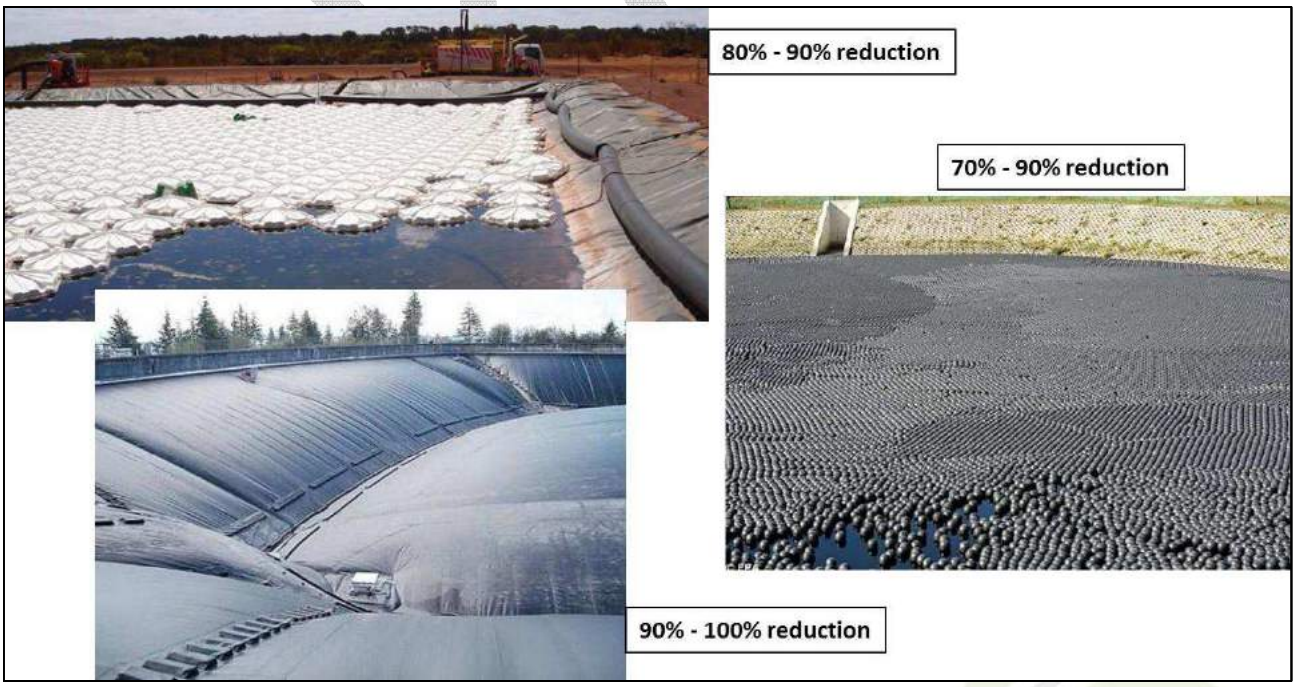

FIGURE 23: EVAPORATION REDUCTION TECHNOLOGY

9. COMPARTMENT 3B COMISSIONING

When Compartment 3B is commissioned, it is likely that no or limited water recovery will be possible for an estimated period of a 1 to 3 months. The timeframe is impossible to predict so these timeframes are rough estimates. The loss to the mine's water balance could be approximately 1 700 m^3/day (70 m^3/hr).

Additional water will need to be pumped into the mine's water balance. The additional make-up can either come from:

- Additional Gamagara water (uncertain)
- Water stored in buffer

There is no buffer storage available on the mine, except in the Process Recovery Dam. However, the process recovery dam is needed to empty the primary thickeners into it. Possible solutions include:

- Partially utilise the process recovery dam
- Dump thickeners to the King PDF Compartment 1 via the King secondary thickeners and recover the water and fully utilise the Process Recovery Dam
- Consider evaporation reduction measures in the Process Recovery Dam
- Stronger emphasis on Parsons Storm Water Dam recovery to create additional Gamagara water
- Attempt to recover Compartment 3B water as soon as possible by utilising mobile pumping equipment.

The time taken to deplete the Process Recovery Dam from various starting levels is shown below for reference:

- 90 000 m3 = 52 days
- 75 000 m3 = 44 days
- 60 000 m3 = 35 days

10. CONCLUSIONS

Water management on Khumani Mine is generally good but some areas require additional infrastructure to bring the mine's water management in line with their water use licence and GN 704.

Fluctuations in Gamagara water availability and King return result in plant shutdowns. The lost time is able to be made up through increased shifts and other production enhancement levers, and annual production targets are being met. However these periods of high production put pressure on the King PDF and other infrastructure.

Additional process/Gamagara storage, coupled with more water drawn from Sedibeng Water can reduce the frequency of lost production due to water shortages.

11. ACTION LIST SUMMARY

The following is a summary of the actions required as highlighted in this report:

11.1 Parsons (refer to Figure 17 on page 24)

- The return capacity from the Parsons Storm Water Dam should be increased to at least 100 m^3/hr.
- The return capacity from the Loadout Storm Water Dam should be increased to at least 65 m^3/hr.
- Storm water controls must be put in place around the discard dump at the loadout area. These can be earth walled paddocks as per the original design intent.
- The Loadout Storm Water Dam and Parsons Storm Water Dams need to be licenced correctly so that their use is in line with the mine's water use licence.

11.2 King (refer to Figure 18 and Figure 19 on page 25)

- Once Compartment 3B is operational:
  - a third return water dam will be required. Geo Tail has sized and designed this dam.
  - a clean storm water diversion will be required.
- All waste rock dumps must be designed to comply with the mine's water use licence and GN 704.
- A separate water storage facility must be constructed to store water for King mining and crushing.
- The King PDF return water system should be split into two dedicated systems:
  - System 1 allows water to be pumped (probably via pump 30) from the King return water dams to mining and the crusher tanks. The existing capacity is deemed adequate.
  - System 2 must allow up 300 m^3/hr to be pumped (probably via pump 28 and 29) from the King return water dams to the concrete dam.
- The pipeline that returns water to the Parsons plant must have a capacity of 1 200 m^3/hr, although 1 500 m^3/hr is ideal.
- Barge pumping infrastructure at the King PDF must have the following capacities:
  - Compartment 1: 500m^3/hr
  - Compartment 2: 218 m^3/hr
  - Compartment 3A: 185 m^3/hr
  - Compartment 3B: 560 m^3/hr.

11.3 Bruce

- All waste rock dumps must be designed to comply with the mine's water use licence and GN 704.
- The storm water channels that route storm water to the pollution control dam should be concrete-lined to comply with the mine's water use licence. Alternatively, the licence conditions should be changed to allow for the current lining to remain in place. If the water quality parameter of concern is suspended solids, then a brick-lined channel will not result in ground water pollution.

11.4 Additional Process/ Gamagara Water Storage

The results of water balance modelling show that increased additional storage of process/Gamagara water on the mine insulates the mine from shortfalls or instability in Gamagara water supply, as well as from instability in the King returns.

Up to 150 000 m^3 should be installed to reduce water shortage related downtimes from 10% to less than 1%. Evaporation reduction technologies must be employed on all long-term water storage dams. It is not necessary to install this technology on the mines tanks.

This capacity can be incorporated in the existing Process Recovery Dam and/or new dams.