Millsite TSF Reclamation Project

Groundwater Assessment Report

Project Number:

SIB4276

Prepared for:

Sibanye Stillwater Limited

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DIGBY WELLS ENVIRONMENTAL

EXECUTIVE SUMMARY

Sibanye Gold Limited (SGL) is planning to reclaim the Millsite Tailings Storage Facility (TSF), process it through the Cooke plant and then deposit the resultant tailings in one or more of the surface pits which they are currently using to deposit reclaimed Dump 20 tailings.

This study examines the potential impact on the groundwater environment as a result of the Millsite TSF reclamation and deposition of the reprocessed tailings into the pits.

The following are the main conclusions made based on the groundwater study:

- Groundwater occurrences in the study area are predominantly restricted to the following aquifers.
  - Weathered rock aquifer in the Witwatersrand, Ventersdorp and Transvaal Formations;
  - Fractured rock aquifer in the Witwatersrand, Ventersdorp and Transvaal Formations;
  - Dolomitic and Karst Aquifers; and
  - Mine void aquifer.
- The groundwater elevation in the top weathered and dolomitic aquifers that are not connected with the mine void mimics the topography. Although the gradient is generally flatter in the dolomitic aquifer, the flow direction follows the topography and is towards the local streams. Monitoring data shows that that the groundwater level divide is similar to the surface watershed areas.
  - The natural groundwater flow direction in the A21D quaternary catchment (where Millsite TSF, Millsite Pit and Tweelopiespruit are located) is generally from south to north, while in the C23D catchment (where the rest of the pits are located) is generally from north to south.
  - The hydraulic head and groundwater flow direction in the mine void is controlled by the decant elevation, abstraction that is taking place at 8 Shaft, pit deposition positions, geological structures and mine interconnectivity. The natural decant rate is approximately 27 ML/d. Plans were presented to lower the water level in the mine void to below an environmental critical level (ECL), to minimise impact on surface and groundwater resources. The pumping to achieve this was proposed from a low-lying shaft (8 Shaft). Pumping to achieve this objective commenced in April 2012, but to date the water level has not been dropped substantially but has been kept a few metres below the decant point.
  - Although the pumping of 8 Shaft at the appropriate abstraction rate can avoid decanting, the lowering of the hydraulic head can affect the regional water level which could result in drying of springs and streams.

  - The Porges, SRK and Battery Pits are in the C23D catchment while the decant point and 8 Shaft are in the A21D catchment. However, the flow from the pits is towards the 8 Shaft against the topographic gradient. This is due to the lowering of the hydraulic head at the shaft together with the Witpoortjie Fault south of the pits which is predominantly a flow barrier.
- The water quality in majority of the monitoring points is either in the good or acceptable category. The main concern is the quality of the mine void and water at 17 Winze, 18 Winze, Borehole PH6 (located close to the Millsite Pit) and SRK Pit 2 where it is currently above the 150 mS/m Water Use License (WUL) limit.
  - The 17 and 18 Winzes pose a risk as they are upgradient of Tweelopiespruit East and their topography is around the decant elevation. It should, however, be noted that the water quality from both winzes have been improving since monitoring data is available in late 2009. The EC was approximately 500 mS/m in 2009 and has gradually decreased to its current value of approximately 325 mS/m.
  - The poor water quality of the winzes cannot be associated with the deposition of the reclaimed Dump 20 into the pits. The water quality was already unacceptable before the reclamation started and the trend has shown an improvement in the water quality in recent years.
  - The pH of the 17 and 18 winze water was approximately 5 until February 2013. Thereafter it steadily increased to the current pH of 6.45. Both winzes are within the WUL limit and the trend is that the pH will keep on increasing. The increase in pH is suspected to be a result of the discharge of the reclaimed Dump 20 tailings which has a pH of between 10 and 11. This is one of the positive impacts associated with the discharging of alkaline tailings into the pits, as this would mean that dissolved metals will precipitate.
- The geochemical results of the Millsite TSF have been compared to previous work conducted on Dump 20 to evaluate if the Millsite tailings is more of an environmental concern than Dump 20. The result shows that the two tailings have similar acid generation potential. The metals expected to leach under neutral or acidic conditions are also generally similar.
- The Millsite tailings was leached using the mine void water to determine the leachate characteristics. The mine water is already contaminated to a large extent and the addition of the tailings material does not dramatically change this level of contamination.
- The historical TSFs in the region (including Millsite TSF complex) are not lined and seepage is expected to drain into the underlying groundwater system, including the sensitive dolomitic aquifer. If the TSF is reclaimed, the recharge occurring through the TSF will be illuminated and ingress to the groundwater (including current decant volume) would have decreased, and it is likely that the dolomitic water pumped from the underground chambers would be of better quality than currently

    - Further to this, infiltration from the Millsite TSF will be reduced if the tailings is removed from surface, and the contaminant loads will be less from a pollution perspective. At present, the presence of the TSF and the continued dewatering activities in the compartment will encourage continued infiltration of seepage to the deeper aquifer units, the consequent deterioration of water quality, increased decant rates and increased volumes of water to be pumped from the underground chambers.
    - The long-term impact as a result of the reclamation operations at the TSF is therefore anticipated to be positive since the TSF, which is a source of contamination, will be removed and deposited below water level. In the short-term, however, the hydraulic reclamation could result in increased seepage through the TSF. The exposure of the tailings to oxygen and water can result in Acid Mine Drainage (AMD) formation.
- During the operational phase, water will be added to the pits with the tailings slurry. This will result in an increase in the pits and mine void water levels. As the pits are filled with tailings slurry, water level in the pits will be higher than the surrounding groundwater level. This is however expected to only be in the short-term since SGL will be pumping at a 1:1 ratio to the amount of slurry deposited. The pumping will take place from 8 Shaft with the intent of maintaining the groundwater level and the abstracted water will be used for the reclamation of the Millsite TSF complex. Excess water will be discharged to the environment after being treated with lime and air.
    - Without backfilling, the open pits are a constant source of water ingress into the Western Basin mine void as rainwater falls into the pits and enters into the mine voids. Filling the pits with tailings would therefore reduce the groundwater recharge thereby reducing decant volumes and subsequent water treatment costs.
    - The reprocessed tailings is treated with lime in the metallurgical plant and is generally deposited at high pH values (around 10 – 11). This is expected to have a positive impact in the groundwater quality as the pH of the mine void will increase and precipitate the dissolved metals.
    - Although the pumping of 8 Shaft at the appropriate abstraction rate can avoid decanting, the lowering of the hydraulic head can affect the regional water level which could result in drying of springs and streams.

There are a few municipal waste water treatment plants and mines operating in West Rand. The closure and rehabilitation of the Millsite TSF and surrounding pits by SGL will definitely have a positive impact on the surface and groundwater environment. However, a rehabilitation strategy that encompasses the nearby mines and municipal treatment activities is required for a lasting improvement within the regional footprint.

The following management plans are recommended to minimise impacts on the groundwater during the TSF reclamation and pit deposition:

- During the establishment phase, restrict areas that must be cleared of vegetation for construction activities to those of absolute necessity;
- Avoid constructing below the water table as far as possible;
- Minimise ponding of water within the reclamation area to avoid AMD seepage during the operational phase;
- Ensuring that the deposited tailings is alkaline;
- Ensuring that the cyanide is destroyed before deposited;
- Abstract a volume of water from 8 Shaft (which is connected with the pits) equal to the water being deposited into the pits to ensure that the water level or decant rate does not increase from what it would have been prior to the in pit deposition;
- The abstracted water can be used for the reclamation of the tailings or other ore treatment; and
- The water levels measured directly from the pits should be made available as this would help to assess their hydraulic connectivity. The water levels at 8 Shaft, 17 Winze and 18 Winze should also be made available;
- Rehabilitate the pits by properly shaping and capping with a soil/weathered material layer that will prevent ponding and minimise infiltration of rain water.

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LIST OF ABBREVIATION

Abbreviation	Stands for
ABA	Acid-base accounting
AMD	Acid mine drainage
amsl	Above mean sea level
AP	Acid potential
BPS	Booster pump station
ECL	Environmental critical level
EIA	Environmental impact assessment
EMP	Environmental management plan
DWA	Department of water affairs
DWS	Department of water and Sanitation
LCT	Leachable concentration threshold
MAE	Mean annual evaporation

Abbreviation	Stands for
MAP	Mean annual precipitation
NEM:WA	National environmental management: waste act
NGA	National groundwater archive
NNP	Net neutralisation potential
NP	Neutralisation potential
NPR	Neutralisation potential ratio
SGL	Sibanye Gold Limited
SPLP	Synthetic precipitation leaching procedure
TCT	Total concentration threshold
TSF	Tailings storage facility
WMA	Water management area
WUL	Water use license
XRD	X-ray diffraction

1 Introduction

Sibanye Gold Limited (SGL) commissioned Digby Wells Environmental (Digby Wells) to conduct an Environmental Impact Assessment (EIA) and to provide an Environmental Management Plan (EMP) for the proposed reclamation and deposition of the Millsite tailings complex, in the West Rand District, Gauteng Province.

This groundwater and geochemical assessment is a specialist study forming part of the EIA/EMP and also in support of the Water Use Licence (WUL) application.

1.1 Project Description

SGL has existing operations consisting of underground shafts (Cooke 1, 2 and 3) as well as surface reclamation activities for removing residual gold from historic sand and slime tailings, namely Dump 20 and Lindum Dump. The gold ore mined from underground workings is currently processed at the Harmony Doornkop Gold Plant while the surface sources are currently being hydraulically reclaimed and are reprocessed at the Cooke Gold Plant. SGL intends to further extend the life span of its Rand Uranium Cooke operation surface activities through the reclamation of the Millsite Tailings Storage Facility (TSF) Complex which is located adjacent to its current Dump 20 operation as shown in Figure 1-1 and Figure 1-2.

The Dump 20 project entails the mechanical reclamation of sand which is transported by train to the Cooke Plant as well as the hydraulic reclamation of the Dump 20 slimes residue and hydraulic transportation of the mixture from the existing Dump 20 booster station to the existing Cooke Plant for gold recovery, via a dedicated pipeline. The resultant residue tailings are disposed of into several open pits, namely the Millsite, Battery 1 & 2, Porges, SRK 2 & 3 and Training open pits (hereafter the pits). The position of the pits is shown in Figure 1-2. The pits formed part of the historical Lindum Reefs Operations which were previously dormant and required rehabilitation.

The focus of this document is on the inclusion of the Millsite TSF into the existing Cooke Operations and the specific activities to be undertaken. The hydraulic reclamation activity to be followed is identical to the current approved activities for Dump 20 and Lindum. An existing Booster Pump Station (BPS) is currently in place at Dump 20 which will remain and be utilised for the reclamation of the Millsite TSF and pumping it to the Cooke plant. A fine screen will be put in place at the toe of the Millsite TSF from where the slurry material will enter a sump. A drain pipe will be put in place from the sump to a vibrating screen prior to entering a tank from where it will be pumped in a slurry pipeline that will convey the tailings to the BPS at Dump 20. This slurry pipeline will be a 450 mm diameter pipeline with a 6 mm rubber lining.

The residue is to be deposited into the open pits at the rate of 400 000 tons/month. Cyanide destruction will take place in the Cooke Plant before the residue is deposited.

1.2 Project Motivation

Past mining and ore processing methods have produced vast volumes of tailings or residues, resulting in many mine tailings facilities scattered around residential areas and cities such as Randfontein. These historical tailings facilities still contain gold, uranium and other valuable metals which possibly may be economically recoverable. Recent technological advances make it possible for more gold, uranium and sulphur to be recovered from these old tailings facilities. SGL has successfully undertaken reclamation activities of the Dump 20 and numerous other sand dumps and tailings facilities. Similarly, the reclamation of the Millsite TSF complex will result in the recovery of remaining gold material as well as remove the 107 million tonnes of material from the Randfontein landscape.

The resultant residue tailings from the Cooke Plant is disposed of into one or more of the open pits. Filling the pits with tailings would reduce the groundwater recharge thereby reducing decant and subsequent water treatment costs. The filling of the pits is also a good closure alternative for an area which would otherwise represent a hazard. The initial intent was rotational filling of the pits to allow the pits to be filled in a manner which guarantees geotechnical stability of the tailings by allowing the tailings some time to settle and consolidate after filling. Some tailings has been deposited into each of the pits, however, the majority of the tailings material is being placed in Porges Pit as this pit has yet to seal and it is taking a lot more tailings than originally thought would be required for sealing it. The Millsite TSF complex will thus provide additional material to fill and seal the open pits.

Samples have been taken from the Millsite dumps and analysed to make sure that there is no changed impact on water quality from the material currently being deposited into the various pits. The result of the geochemical analysis is provided in Section 3.6 below. The Millsite TSF complex has similar geochemical characteristics to the material currently being deposited into it.

1.3 Site Location

The Rand Uranium Cooke Operations lie approximately 30 km south-west of Johannesburg city centre, 8 km south-west of Krugersdorp and approximately 20 km north of Westonaria. The operation area is shown in Figure 1-1 for the regional setting and Figure 1-2 for the site specific setting.

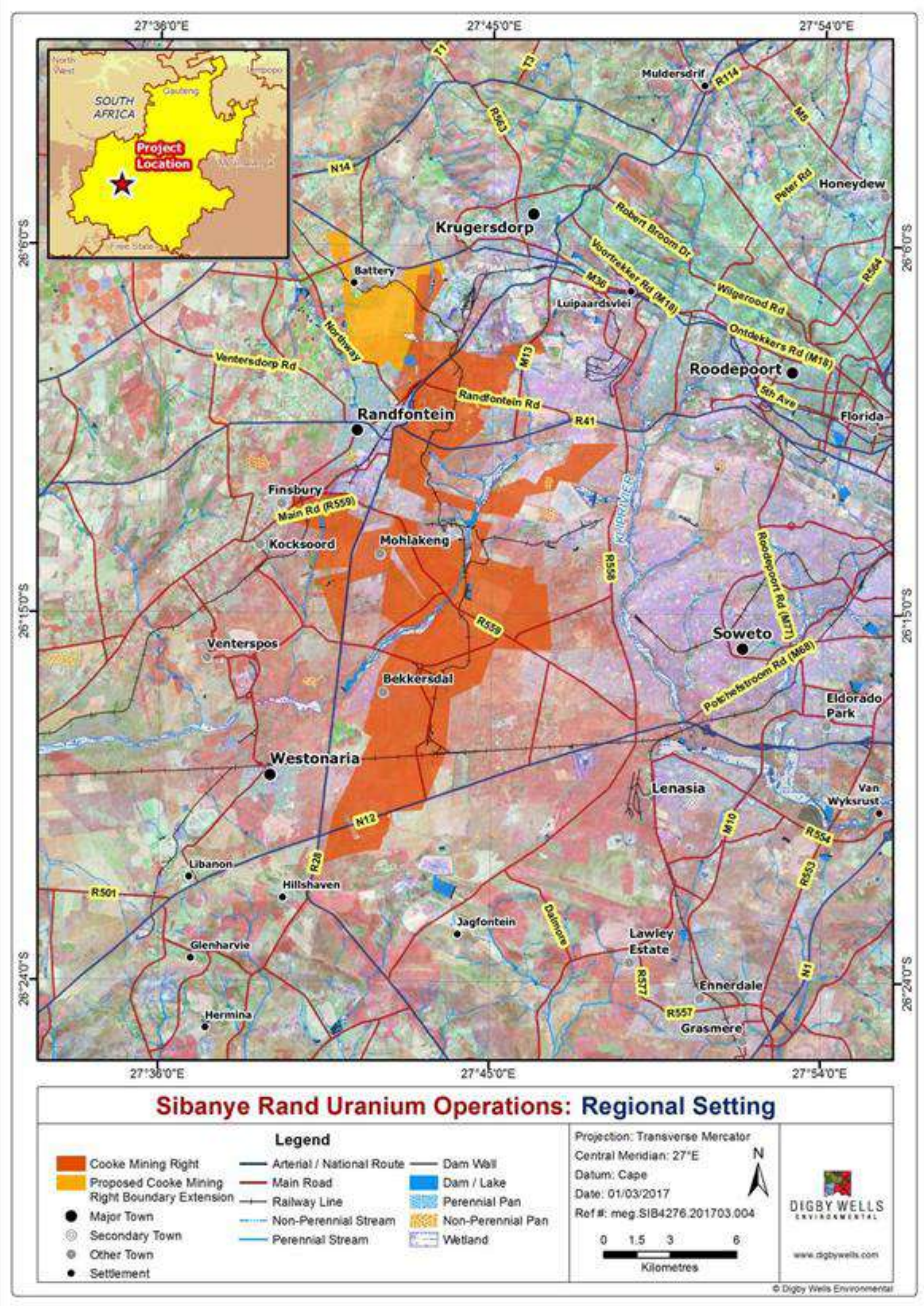

Figure 1-1: Regional Setting

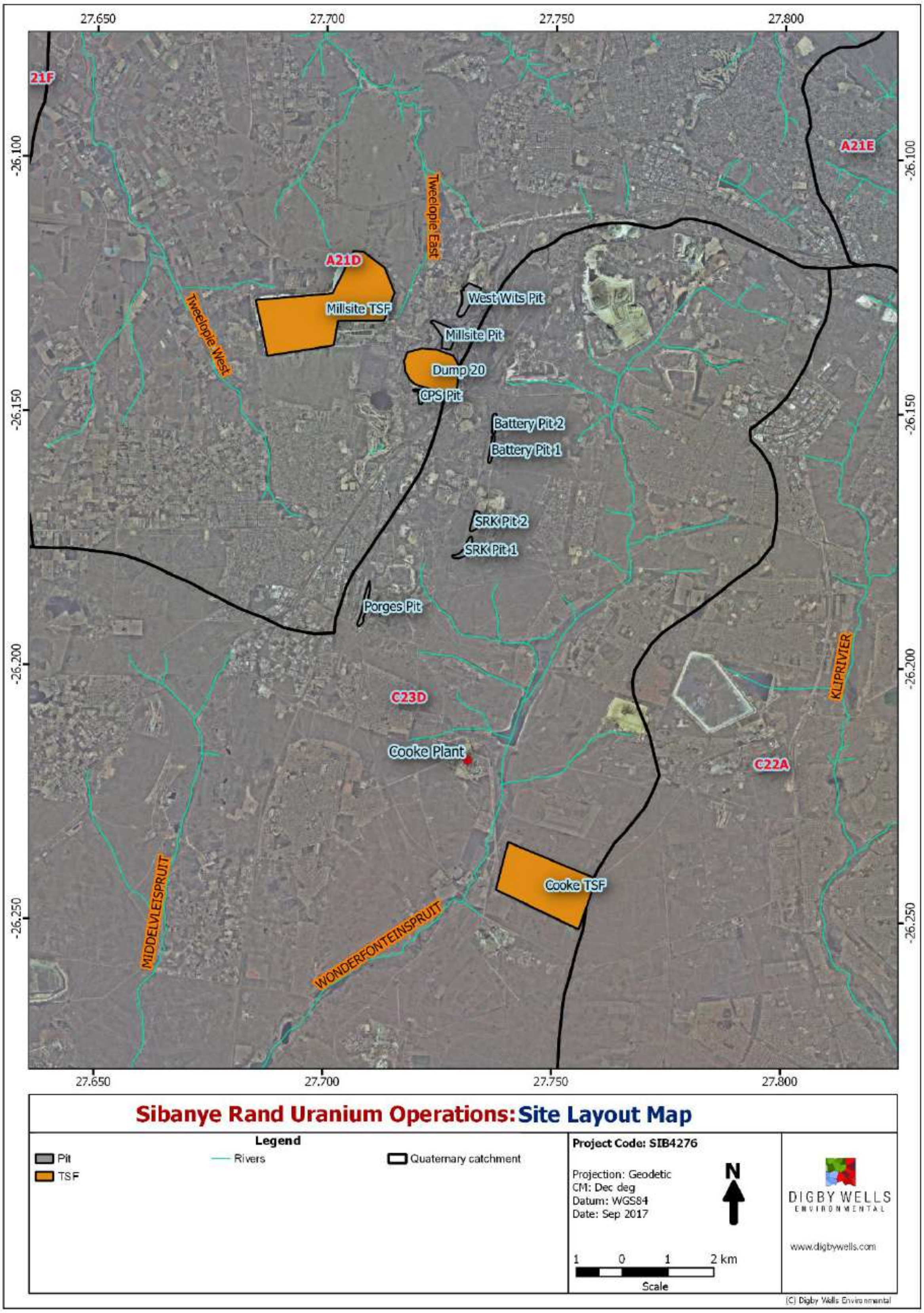

Figure 1-2: Site layout map

1.4 Topography and Drainage

The study area falls into two quaternary catchments. Millsite Complex is located in the A21D quaternary catchments of the Limpopo water management area (WMA), while Cooke Plant is located within C23E catchment of the Vaal WMA. The hydrological setting of the study area is shown in Figure 1-2.

The topography of the area is generally rolling to gently sloping with relatively flat stretches in some places. Elevation in topography varies between approximately 1,600 m above mean sea level (amsl) near the Cooke TSF and 1,730 m amsl in Randfontein at the golf course.

The A21D catchment is drained by two tributaries situated east and west (Tweelopiespruit) of the Millsite TSF and flows in a northerly direction to form the Rietspruit, which eventually joins the Crocodile River that drains into the Hartbeespoort dam. The eastern tributary also flows through the Krugersdorp Game Reserve.

The Millsite TSF and Millsite Pit fall in the A21D catchment.

The C23D catchment is drained by the Wonderfonteinspruit which flows in a south westerly direction; south of where the pit deposition will take place. The open pits relevant to this study that fall in the C23D catchment are the Battery Pits, SRK Pits and Porges Pit (Figure 1-2). The Wonderfonteinspruit is a tributary of the Mooi River, which flows into the Vaal River.

1.5 Climate

The study area is situated along the south-western perimeter of the Gauteng province, on the interior elevated plateau of South Africa, known as the “Highveld”. The area is known for its cold, dry frosty winter and moderate summer temperatures (Digby Wells, 2012).

Summer rainfall predominates with associated thunderstorms and occasional hail. The Mean Annual Precipitation (MAP) is approximately 664 mm (for C23D) and 713 mm (for A21D). The Mean Annual Evaporation (MAE) for the C23D and A21D quaternary catchment is between 1,600 and 1,700 mm.

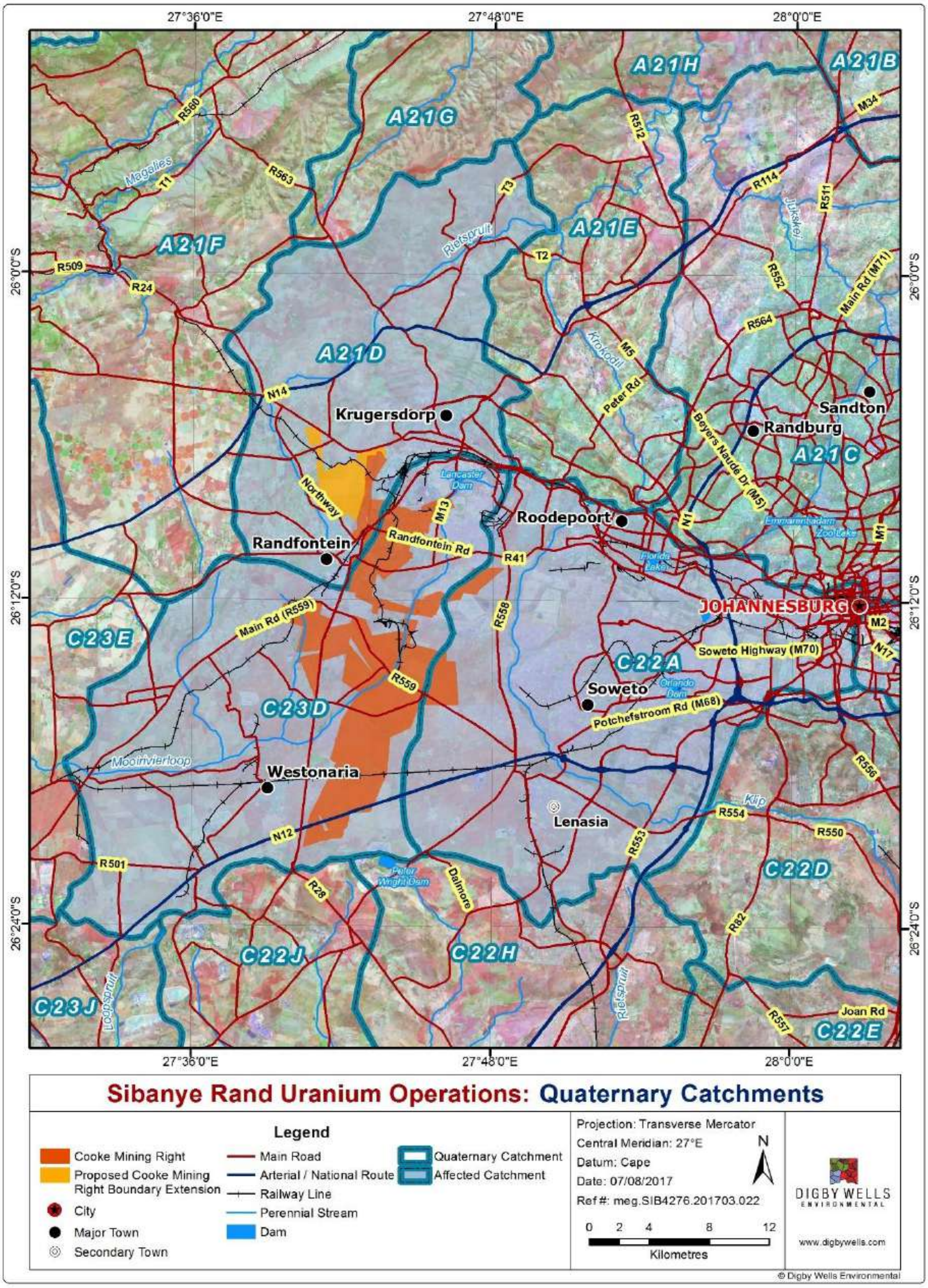

Figure 1-3: Site hydrological setting

2 Terms of Reference

2.1 Study Objectives

This study has looked into potential impacts (negative or positive) on the groundwater environment as a result of the proposed reclamation and deposition into the pits, specifically with regard to:

- Seepage into groundwater from the Millsite TSF and pits;
- Changes in groundwater levels and decant rates due to the proposed operations; and
- Changes in surface and groundwater quality due to the proposed operations.

2.2 Methodology

The project consisted a site visit, desktop study and reporting.

2.2.1 Site Visit

The site visit was conducted to familiarise with the hydrological and hydrogeological settings. Client meetings were also held for data collection and to acquaint with the ongoing surface and groundwater monitoring programmes. Samples from the Millsite TSF were collected for geochemical assessment.

2.2.2 Data Review

The data acquisition and desktop review of the following information (Table 2-1) were completed.

Table 2-1: Information sources

Information source	Data/Information obtained	Received from
Rand Uranium monitoring data up until May 2017	Surface and groundwater monitoring data	SGL
Groundwater Report for Gold One Cooke Optimisation Project, 2012, Digby Wells Environmental	Dump 20 reclamation impact assessment	Digby Wells
Harmony Gold Limited – Randfontein Operations Groundwater Monitoring – August 2008, Rison	Regional geological and hydrogeological setting	SGL

A Hydrogeological Assessment of Acid Mine Drainage Impacts in The West Rand Basin, Gauteng Province, 2017, CSIR	Local geological and hydrogeological setting	Public domain
Pits Groundwater Impact Assessment, January 2010, Report nr. 12121-9427-13, Golder	Groundwater baseline information	Gold One
Millsite Pit: Opinion on properties of WAD and likelihood of mobilization, March 2012, The Geotechnical HUB	Geochemistry	Gold One
Hydrogeology of the Millsite and Porges Pits, August 2010, Report nr. 12121-9915-19, Golder	Borehole and aquifer information	Golder
Cooke Uranium Project – interim disposal option, Baseline groundwater investigation of the opencast pits, August 2009, Report nr.12121-9178-10, Golder	Borehole and aquifer information	Golder
The National Groundwater Archive (NGA), May 2012, Department of Water Affairs (DWA)	Borehole, aquifer and hydrochemistry	DWA
2626 West Rand 1:250 000 Geological map, 1986, Geological Survey of South Africa.	Geology	CGS – vector data for project area
Johannesburg 2526 1:500 000 hydrogeological map, 2000, Department of Water Affairs and Forestry.	Aquifer information	Digby Wells

2.2.3 Geochemical Assessment

A geochemical assessment was undertaken of the Dump 20 tailings in 2012 to assess the composition of the material to be disposed of into the open pits. Similarly, a geochemical assessment has now been undertaken for the Millsite TSF complex to evaluate the characteristics of the Millsite TSF tailings comprising of acid-base accounting and leachate tests.

AMD and metal leaching are widespread phenomenon affecting the quality of water at many South African mines. To operate a mine in an informed, environmentally responsible manner, the metal leaching and AMD potential of all the materials excavated, exposed or otherwise disturbed must be understood and managed to prevent metal leaching and AMD through prediction and design, avoiding long-term mitigation and risk wherever possible. Sulphide minerals are the primary sources of acidity and dissolution of metals from mine wastes, and their measurement is a critical requirement in drainage chemistry prediction. This assessment focused on the multi-element composition, mineralogical composition, Acid Base Accounting (ABA) and leachate tests to evaluate the AMD generation and metal leachate concentrations of the reprocessed tailings materials.

Eight samples of approximately 2.5 kg of the tailings were collected for acid-base accounting (ABA) and leachate tests under static conditions. The locations of the sampling points are illustrated in Figure 2-1.

Samples 1 and 2 were collected from the top 0.5 m of the TSF to represent the oxidised (weathered) part. The remaining 6 samples (Samples 3 to 8) were collected from the fresh and saturated sections at a depth of approximately 1 m from surface.

The collected samples were sent to M&L Laboratory in Johannesburg for analysis of the following parameters:

- **Mineralogical examination** – X-ray diffraction (XRD) was utilised to identify the major and minor minerals in the tailings. XRD allows for the measurement of the crystal structures to identify the mineralogical composition to determine whether any reactive elements will lead to environmental risks through the study of the various minerals;
- **Acid-base accounting (ABA) and Sulphur Speciation** – these were conducted by evaluating the acid generation and acid neutralisation potential of the samples. The amount of the various sulphur species in the tailings was also analysed to determine their oxidation states since mine acid is primarily generated from sulphide sulphur;
- **Net Acid Generating (NAG) testing** – this was conducted to provide an indication of the behaviour of the samples under oxidising conditions (reaction with hydrogen peroxide), using a standard NAG test method; and
- **Static leach testing** – would provide an indication of the readily leachable components present in a samples by exposing the samples to a leachate extraction. Three tests were conducted in this study:
  - As specified in the NEM:WA Regulations (2013), a reagent (distilled) water was used to leach the samples at a 1:20 solid to water ratio (i.e. 5% reagent water extraction) was prepared and analysed by the laboratory. This analysis will be used to characterise the mobile metals that could be released from the tailings if a neutral pH conditions prevails;
  - The samples were also exposed to the Synthetic Precipitation Leaching Procedure (SPLP). The test was conducted under acidic environment of pH 4.2. The pH of the mine void is generally acidic but is expected to be neutral in the vicinity of the pits were the reclaimed tailings (which is high in pH of around 10-11) is being deposited. The leaching of the samples under neutral and acidic solution was conducted with the intention of reflecting the mine void water under a range of pH conditions;

  - The samples were also leached using water collected from 8 Shaft to simulate the actual mine void groundwater condition. The shaft is used to supply water for the hydraulic reclamation of Dump 20 and will also be used for the Millsite TSF reclamation; and
  - A waste classification as per the National Environmental Management Waste Act (NEMWA) was conducted as requested by SGL. Although the tailings will be deposited in the pits, a waste classification would be conducted to find out what the potential environmental impacts would have been and what type of liner would have been required had the tailings been deposited on surface.
- **Total Concentration Analysis -** Total concentration values were determined by *aqua regia* digestion as stipulated in the NEM: WA Regulations (2013). The objective of the total concentration analysis was to provide a measure of the solid-phase levels of various mineral-forming elements that may be of environmental concern. Combined with the metal leachate test, these levels allow the calculation of metal depletion times and can be used as a screening tool to detect constituents which occur in anomalously high concentrations and may, under unfavourable geochemical conditions, be of concern as a constituent in AMD.

As indicated above, the proposed hydraulic reclamation activity of the Millsite TSF complex to be followed is identical to the current approved activities for Dump 20 and Lindum. This includes that the residue is to be deposited into the open pit voids at the rate of 400 000 tons/month.

The geochemical results of the Millsite TSF have been compared to previous work conducted on Dump 20 to evaluate if the Millsite is more of an environmental concern than Dump 20. In 2012 three samples were analysed from Dump 20 for ABA and leachate assessments. The samples were collected from the sand residue, slime residue and composite sample (sand residue mixed with underground tonnage). In the discussions to follow, these samples are labelled as Dump 20 Sand, Dump 20 Slime and Dump 20 Composite; and have been compared with the Millsite TSF geochemistry.

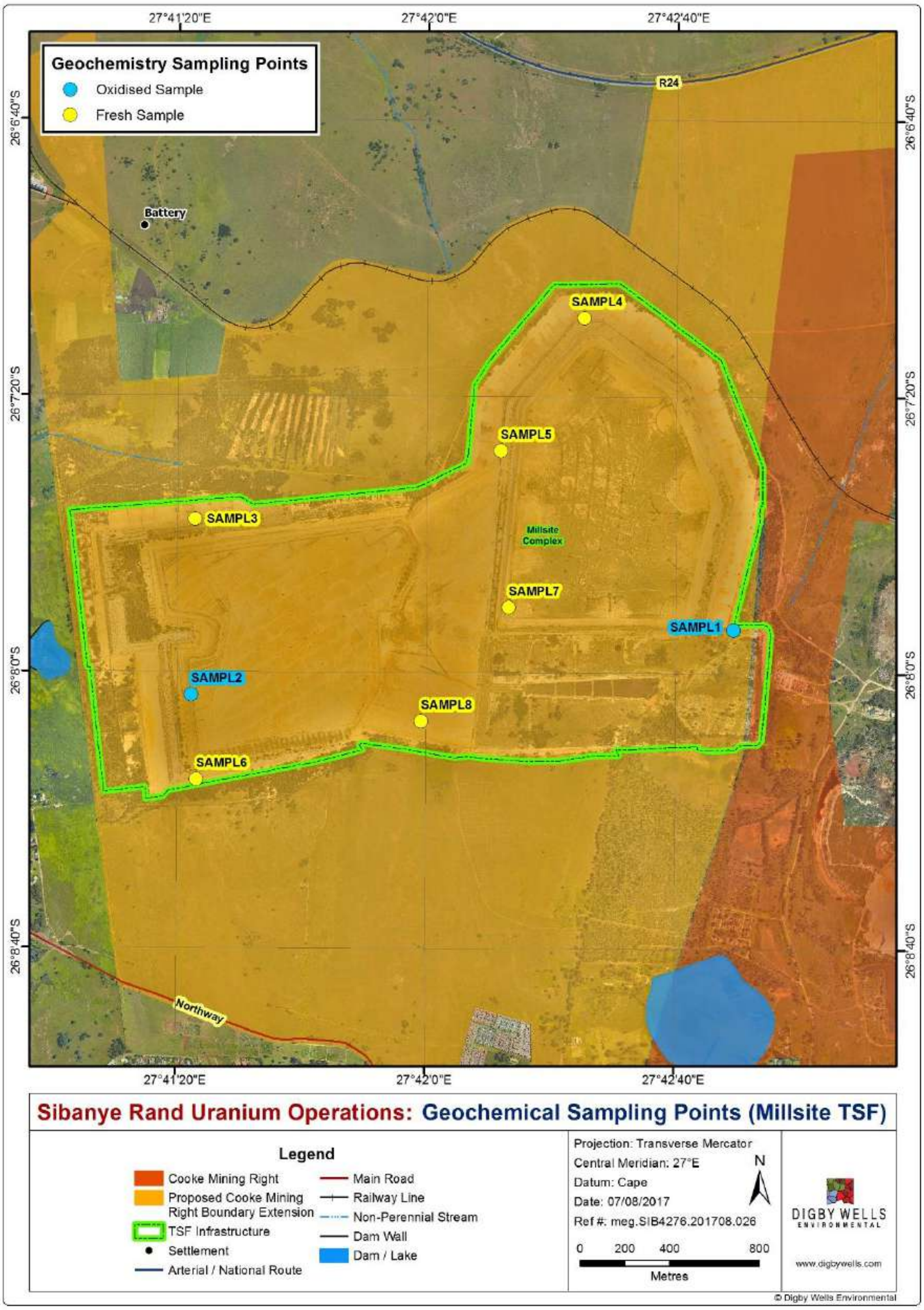

Figure 2-1: Location of the tailings sampling points

2.2.4 Impact Assessment

Impact identification was performed by using an Input-Output model which serves to guide Digby Wells in assessing all the potential instances of ecological and socio-economic change, pollution and resource consumption that may be associated with the mining operations.

Outputs may generally be described as any changes to the biophysical and socio-economic environments, both positive and negative in nature, and also included the product and anticipated waste produced by the proposed mining activities. Negative impacts could include, dust, noise, vibration, water pollution, safety issues and changes to the bio-physical environment such as destruction of habitats. Positive impacts may include skills transfer or benefits to the socio-economic environment. During the determination of outputs, the effect of outputs on the various components of the environment (e.g. soils and water quality) is considered.

During consultation with stakeholders, perceived impacts will also be identified. These perceived impacts will be included in the impact assessment and significance rating to differentiate between probable impacts and perceived impacts.

The methodology utilised to assess the significance of potential environmental and social impacts is discussed in detail below. The significance rating formula is as follows:

Significance = Consequence x Probability

Where

Consequence = Type of Impact x (Intensity + Spatial Scale + Duration)

And

Probability = Likelihood of an Impact Occurring

In addition, the formula for calculating consequence:

Type of Impact = ***+1*** *(Positive Impact) or* ***-1*** *(Negative Impact)*

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 2-2. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in this WULA/IWWMP. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 2-3, which is extracted from Table 2-2. The description of the significance ratings is discussed in Table 2-4.

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, i.e. there may already be certain types of mitigation measures included in the design (for example due to legal requirements). If the potential impact is still considered too high, additional mitigation measures are proposed.

Table 2-2: Impact Assessment Parameter Ratings

Rating	Severity		Spatial scale	Duration	Probability
	Environmental	Social, cultural and heritage			
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or eco system. Persistent severe damage. The positive impact will result in a significant improvement to the initial/post disturbance environmental status and will benefit ecological and natural resources.	Irreparable damage to highly valued items of great cultural significance or complete breakdown of social order. The positive impact will be of high significance which will result the improvement of the socio-economic status of a greater area beyond the boundary of the directly affected of the community and/or promote archaeological and heritage awareness and contribute towards research and documentation of sites and artefacts through phase two assessments.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Significant impact on highly valued species, habitat or ecosystem. The positive impact is of high significance which will result in a vast improvement to the environment such as ecological diversification and/or rehabilitation of endangered species.	Irreparable damage to highly valued items of cultural significance or breakdown of social order. The positive impact will be of high significance and will result in the upliftment of the surrounding community and/or contribute towards research and documentation of sites and artefacts through phase two assessments.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain/Highly probable: It is most likely that the impact will occur. <80% probability.

Rating	Severity		Spatial scale	Duration	Probability
	Environmental	Social, cultural and heritage			
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate. The positive impact will be moderately high and will have a long term beneficial effect on the natural environment.	Very serious widespread social impacts. Irreparable damage to highly valued items. The positive impact will be moderately high and will result in visible improvements on the socio-economic environment of the local and regional community, and/or promote archaeological and heritage awareness through mitigation.	Circle/Region Will affect the entire Circle or Region	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year The positive impact on the environment will be moderate with visible improvement to the natural resources and regional biodiversity.	On-going serious social issues. Significant damage to structures/items of cultural significance The positive impact on the socio-economic environment will be of a moderate extent and benefits should be experience across the local extent and/or potential benefits for archaeological and heritage conservation.	Commune Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Severity		Spatial scale	Duration	Probability
	Environmental	Social, cultural and heritage			
3	Moderate, short-term effects but not affecting ecosystem functions. Rehabilitation requires intervention of external specialists and can be done in less than a month. The positive impact will be moderately beneficial to the natural environment, but will be short lived.	Ongoing social issues. Damage to items of cultural significance. The positive impact will be moderately beneficial for some community members and/or employees, but will be short lived and/or there will be a moderate possibility for archaeological and heritage conservation	Local. Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/without help of external consultants. The positive impacts will be minor and slight environmental improvement will be visible.	Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected. Minor positive impacts on the social/cultural and/or economic environment.	Limited Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare/improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.
1	Limited damage to minimal area of low significance, (e.g. ad hoc spills within plant area). Will have no impact on the environment. The positive impact on the environment will be insignificant and will not result in visible improvements	Low-level repairable damage to commonplace structures. The positive impact on social and cultural aspects will be insignificant.	Very limited Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely/None: Expected never to happen. <1% probability.

Table 2-3: Probability / Consequence Matrix

Significance

Probability	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

Consequence

Table 2-4: Significance Ratings

Score	Description	Rating
109 to 147	A very beneficial impact which may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change.	Major (positive)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and/or social) environment.	Moderate (positive)
36 to 72	An important positive impact. The impact is insufficient by itself to justify the implementation of the project. These impacts will usually result in positive medium to long-term effect on the social and/or natural environment.	Minor (positive)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the social and/or natural environment.	Negligible (positive)
-3 to -35	An acceptable negative impact for which mitigation is desirable but not essential. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the social and/or natural environment.	Negligible (negative)
-36 to -72	An important negative impact which requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the social and/or natural environment.	Minor (negative)
-73 to -108	A serious negative impact which may prevent the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term change to the (natural and/or social) environment and result in severe effects.	Moderate (negative)
-109 to -147	A very serious negative impact which may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects.	Major (negative)

3 Baseline Hydrogeological Condition

3.1 Geology

The geological information presented below is summarised from Truswell (1977), Digby Wells (2012), and Rison (2008) and Hobbs et al. (2007).

A regional geological map of the project site is given in Figure 3-1 and the stratigraphic sequence is listed in Table 3-1. In chronological order (oldest first) the site geology is composed of:

- Witwatersrand Supergroup;
- Ventersdorp Supergroup;
- Transvaal Supergroup; and
- Karoo Supergroup.

Table 3-1: Simplified lithological sequence in the study area

Lithology	Lithostratigraphic Unit			Approximate age
Alluvium	Quaternary sediments			Late Cenozoic (<10 000 yrs)
Dolerite	post-Karoo dyke / sill intrusive structures			Early Mesozoic (150 - 190 Ma)
Tillite	Dwyka Formation		Karoo Supergroup	345 Ma
Ferruginous shale & quartzite, hornfels	Timeball Hill Formation	Pretoria Group	Transvaal Supergroup	2 225 Ma to 2 430 Ma
Quartzite, shale, chert, breccia	Rooihoogte Formation			
Dolomite	Malmani Formation	Chuniespoort Group		
Quartzite, shale	Black reef formation			2 650 Ma
Andesitic lava, pyroclastics	Westonaria formation	Klipriversberg Group	Ventersdorp Supergroup	2 700 Ma
Quartzite, conglomerate, shale	Turfontein subgroup	Central Rand Group	Witwatersrand Supergroup	2 750 Ma
Quartzite, conglomerate	Johannesburg subgroup			
Share, quartzite	Jeppestown subgroup	West Rand Group		
Quartzite, greywacke	Government subgroup			
Ferruginous shale, quartzite	Hospital Hill subgroup			3 000 Ma

3.1.1 Witwatersrand Supergroup

The Witwatersrand Basin is a thick sequence of shale, quartzite and conglomerate. The average dip of the strata varies between 10º and 30° south, although localised dips of up to 80° have been encountered in mine workings closer to the reef outcrop. There are two main divisions, a lower predominantly argillaceous unit, known as the West Rand Group and an upper unit, composed almost entirely of quartzite and conglomerates, known as the Central Rand Group. The West Rand Group is divided into three subgroups namely the Hospital Hill, Government Reef and Jeppestown. These rocks comprise mainly shale, but quartzite, banded ironstones, tillite and intercalated lava flows are also present. The rocks were subjected to low - grade metamorphism causing the shale to become more indurated and slaty. The original sandstone was recrystallised to quartzite.

3.1.2 Ventersdorp Supergroup

The younger Ventersdorp Supergroup overlies the Witwatersrand rocks. Although acid lavas and sedimentary intercalations occur, the Ventersdorp is composed largely of andesitic lavas and related pyroclastics. The Ventersdorp Supergroup consists of the Platberg Group and the Klipriviersberg Group.

The Alberton Formation is composed of green – grey amygdaloidal andesitic lavas, agglomerates and tuffs. The thickness amounts to 1 500 m. The lack of sediments in this sequence indicates a rapid succession of lava flows, which probably came from fissure eruptions. Material of similar composition forms the oldest dykes that have intruded the Witwatersrand rocks. The abundant agglomerates provide indications of periodic explosive activity. The removal of huge volumes of volcanic material from an underlying magma chamber gave rise to tensional conditions and as a result a number of faulted structures, horst and grabens, were formed.

3.1.3 Transvaal Supergroup

Overlying the Ventersdorp Lavas are the Black Reef Quartzite and dolomites of the Transvaal Supergroup. The Black Reef quartzite comprises coarse to gritty quartzite with occasional economically exploitable conglomerates (reefs). The entire area was peneplained in post-Ventersdorp time and it was on this surface that the Transvaal Supergroup was deposited, some 2 400 million years ago. The deposition commenced with the Kromdraai Member with the Black Reef at its base. The Black Reef is formed from material that has been eroded from the Witwatersrand outcrop areas. As a result the Black Reef contains zones (reefs) in which gold is present. The occurrence of the gold is not as widespread as in the Witwatersrand and is mainly restricted to north-south trending channels. The Black Reef is overlain by a dark, siliceous quartzite with occasional grits or small pebble bands. The quartzite grades into black carbonaceous shale. The shale then grades into the overlying dolomite through a transition zone approximately 10 m thick.

Overlying the Kromdraai Member is the dolomite of the Malmani Subgroup of the Chuniespoort Group. The dolomites that are 1 500 m thick are known for their huge water storage potential.

The dolomite also contains lenses and layers of chert. The dense, hard and fine-grained chert tends to stand out in relief. Chert (silica) replaces carbonate material.

The dolomites are overlain in the south by the Pretoria Group rocks. The Rooihoogte Formation forms the basal member of the Pretoria Group, consisting predominantly of shale and quartzite.

3.1.4 Karoo Supergroup

The Karoo Supergroup was deposited approximately 345 million years ago. It commenced with glacial period during which most of South Africa was covered by a thick sheet of ice. This ice cap slowly moved towards the south, causing extensive erosion of the underlying rocks. The erosion debris was eventually deposited as the Dwyka tillite. The latter is only partially preserved in the study area, as are the younger sedimentary deposits of the Karoo Supergroup comprising mudstone, shale and sandstone.

3.1.5 Structural Geology

The development and preservation of the Witwatersrand Basin is structurally controlled. The main structures detected in the project site are illustrated in Figure 3-2.

The structural patterns control the regional flow of groundwater. It is important to understand which structural features act as conduits and which act as groundwater flow barriers. Dykes and sills of at least four different ages have intruded the Witwatersrand strata. The intrusion of the dykes has often taken place along fault planes. The oldest dykes are usually diabase, representing feeder dykes to the overlying Ventersdorp lavas. The second are intrusions of pyroxenite, gabbro and dolerite probably of Bushveld age. A third group belongs to the basic or alkaline dyke swarm related to the Pilansberg alkaline complex. Finally the youngest intrusions are of Karoo dolerite.

The following significant features are noteworthy:

- *The Witpoortjie Horst.* This feature is an uplifted block of ground (horst) where the younger and gold-bearing Central Rand strata has been eroded. What remained is an unmined block that effectively separates the West Rand Mining Basin (that includes the old Randfontein section) just north of the Cooke TSF as shown in Figure 3-2 from the more southerly and westerly workings. As shown in the figure, the horst is bounded by the Witpoortjie Fault in the north and Roodepoort Fault in the south.
- *The West Rand Fault.* The West Rand fault is a prominent north – south striking feature on which the Millsite TSF is resting. Previous investigations (Krantz, 1999) indicated that this fault is in a state of compression and can be regarded as a groundwater barrier.
- *The Rietfontein Fault.* This fault is an east-west trending fault located just to the north of the Millsite tailings dam. This fault is still active and is believed to be responsible for structural damage at the Percy Stewart water treatment facility that is located in Krugersdorp West (Rison, 2008). This fault is a potential water-bearing conduit.
- *Compartmentalisation of the Sterkfontein Dolomite.* A study undertaken by Bredenkamp et al. (1986) included geophysical investigations such as gravity, ground magnetic, electromagnetic and resistivity surveys. Based on these investigations the Sterkfontein Dolomites were divided into various groundwater compartments and sub-compartments (Figure 3-2).

- *Compartmentalisation of the Southern Dolomite.* Similar investigations to that mentioned above were undertaken by mining companies to delineate compartments within these dolomite formations. Several of the southern dolomitic compartments have been dewatered by mining, showing their hydrogeological independence. The various compartments in the southern dolomite are shown in (Figure 3-2).

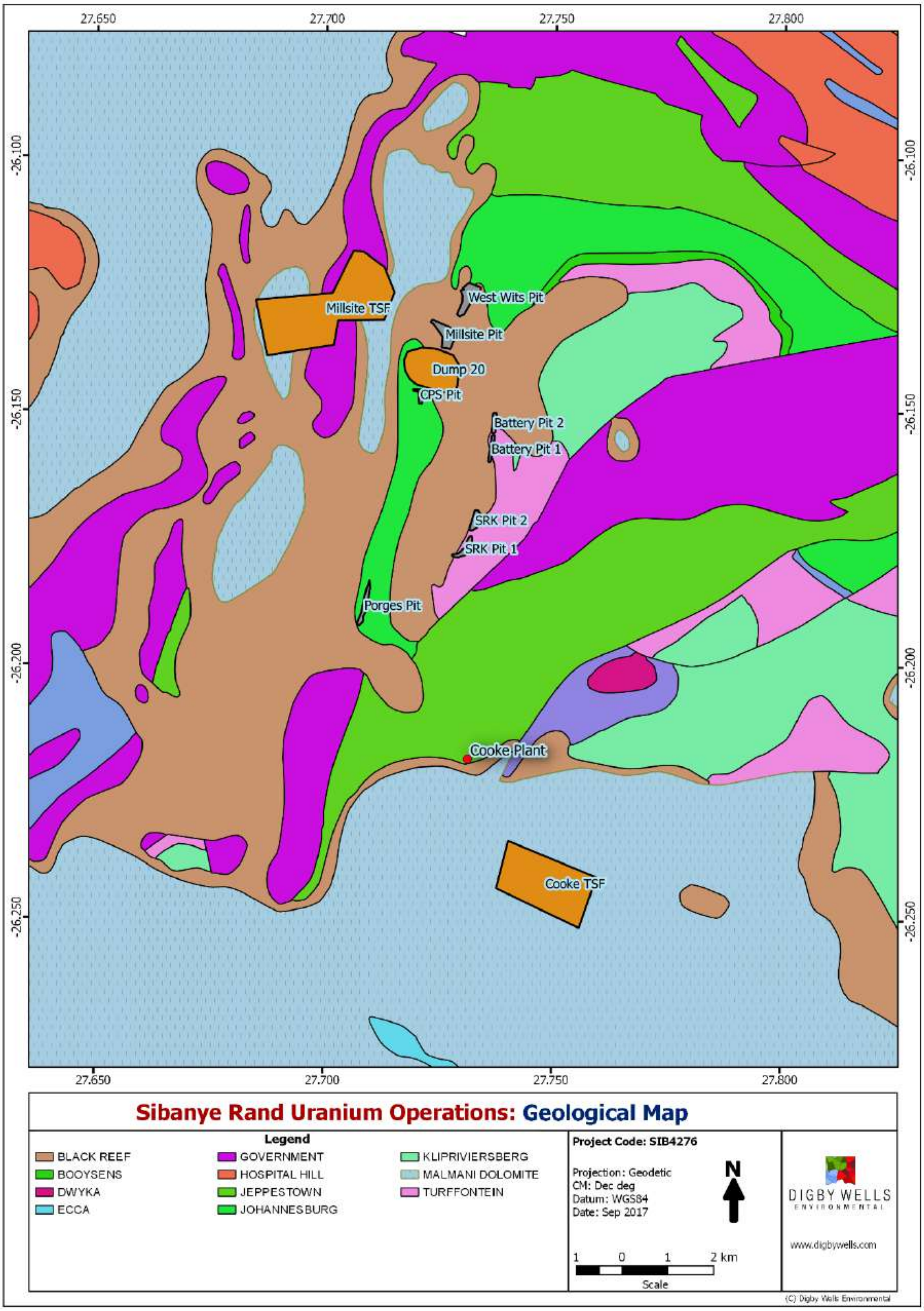

Figure 3-1: Geological Map

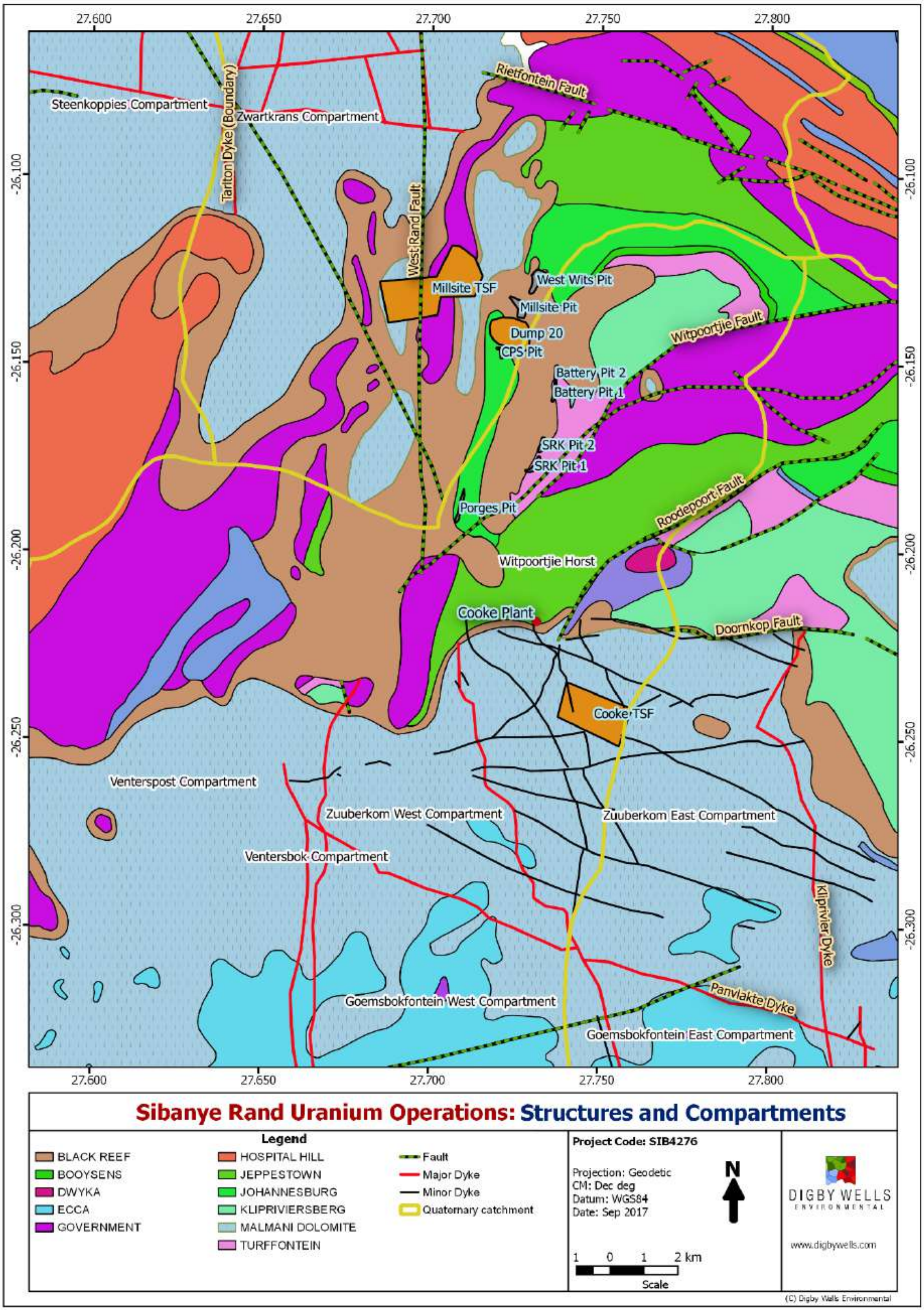

Figure 3-2: Structural Geology

3.2 Aquifer Characterisation

Groundwater occurrences in the study area are predominantly restricted to the following aquifers.

- Weathered rock aquifer in the Witwatersrand, Ventersdorp and Transvaal Formations;
- Fractured rock aquifer in the Witwatersrand, Ventersdorp and Transvaal Formations;
- Dolomitic and Karst Aquifers; and
- Mine void aquifer.

3.2.1 Weathered and Fractured Aquifers

Groundwater occurs in the weathered sedimentary deposits (quartzite and shale) of the Witwatersrand and Transvaal strata as well as in the lavas of the Ventersdorp Supergroup. Both rock types (sedimentary and igneous) have similar weathering characteristics and therefore aquifer characteristics. These formations are not considered to contain economic and sustainable aquifers, but localised high yielding boreholes may, however, exist where significant fractures are intersected. Groundwater occurrences are mainly restricted to the weathered formations, although fracturing in the underlying fresh bedrock may also contain water. Experience has shown that these open fractures seldom occur deeper than 60 m. The base of the aquifer is the impermeable quartzite, shale and lava formations, whereas the top of the aquifer would be the surface topography. The groundwater table is affected by seasonal and atmospheric variations and generally mimics the topography. These aquifers are classified as semi-confined. The two aquifers (weathered and fractured) are mostly hydraulically connected, but confining layers such as clay and shale often separates the two. In the latter instance the fractured aquifer is classified as confined. The aquifer parameters, which includes transmissivity and storativity is generally low and groundwater movement through this aquifer is therefore also slow.

3.2.2 Dolomite Aquifers

Dolomite aquifers are known to contain large quantities of groundwater and are commonly associated with sustainable groundwater abstraction. The Millsite TSF is located in close proximity to the Sterkfontein Dolomite Aquifer, which hosts the Cradle of Humankind World Heritage Site. The Cooke TSF is located on the Zuurbekom Dolomitic Groundwater Compartment, whereas a portion of the Millsite TSF (Sterkfontein Dolomite) straddles dolomitic outlier. The dolomite is not gold bearing and as such none of the pits is located within the dolomitic aquifers.

The Sterkfontein Dolomite and in particular the Zwartkrans groundwater compartment represents the most prominent aquifer in close proximity to the Millsite tailings facility. DWS (1986) described the formation of this aquifer in detail and a brief description is included below.

Carbonate rocks are practically impermeable and therefore devoid of any effective primary porosity. During its geological history, the dolomite strata have been subjected to at least four periods of karstification and erosion (tertiary to recent). The potential for large-scale groundwater exploitation depends solely on the extent to which the dolomite has been leached by percolating rainfall to and groundwater drainage and the degree to which it has been transformed into aquifers capable of yielding significant quantities of water and sustaining high abstraction capacities.

During dissolution processes, the carbonate is removed from the dolomite and residual products such as silica, iron and manganese oxides and hydroxides are left behind. The residual mass is of low density and high void volume. This residuum is called “wad”, which is a geological term meaning “weathered and altered dolomite”. Fissures and caves also develop.

There is almost certainly a lithostratigraphical control on the leaching of dolomite, and the subsequent development of high storage and permeable horizons. The aquifer therefore comprises of an extensive cover of residual solution debris and in places younger sediments. Then underlying this is karstified dolomite, which is irregular and inhomogenic, with hydraulic conditions varying from phreatic to confined. The karstified superficial zone of the strata acts as the main aquifer although fractures could extend to considerable depths.

The area south of the Doornkop fault is covered by the Malmani Dolomite, which is locally known as the Zuurbekom Dolomite Compartment. Although the pits are located within the C23D quaternary catchment where the Zuurbekom Compartment is found, the two are hydraulically disconnected due to the Witpoortjie Fault and Witpoortjie Horst (as shown in Figure 3-2).

The Kliprivier Dyke in the east, the Panvlakte Dyke in the south and the Magazine Dyke in the west mark the boundaries of the Zuurbekom – East Compartment. The northern boundary is marked by the sub-outcrop of the dolomite against the Doornkop fault. The Zuurbekom – East Groundwater Compartment, which underlie the Cooke TSF area, is a non-dewatered compartment, although significant abstraction has taken place via a Rand Water borehole. The latter is used to supplement the water supply to the greater Johannesburg.

Due to extensive erosion only the lowermost Oaktree Formation is present in the study area. This formation consists of chert-poor homogeneous dark-grey dolomite with interbedded carbonaceous shale. The dolomite has a gentle regional dip to the south and attains a total thickness of approximately 200 m (Parsons, 1990) in the study area. As a result of superficial deposits, the dolomites are not visible on surface.

About 1300 Ma ago the region was subjected to tension resulting in the formation of a number of large north to north-easterly striking faults. Many of the faults penetrated the full Transvaal sequence as well as the underlying Ventersdorp and Witwatersrand Supergroups. Some of the faults were filled by Pilanesberg age dykes, which subdivided the dolomite into the abovementioned watertight compartments. The Zuurbekom – East groundwater compartment is further divided into sub-compartments by a number of smaller dykes. The weathered dolomite, together with its dissolution products (wad) forms the main aquifer in the area.

3.2.3 Mine Void Aquifer

Over 100 years of gold mining in the Randfontein and Krugersdorp area created an underground mine void, referred to as the West Rand Basin Mine Void. Pumping as much as 40 Megalitres per day (Ml/d) during mining was reported to lower the water levels at Randfontein and West Rand Consolidated Mines.

Disposal of reclaimed tailings from Dump 20 has shown that the pits are interconnected with the underground mine voids at Porges. Although deposition has been on-going since 2014, the Porges pit is still not filled and is connected to the mine void.

3.3 Water Level and Flow Direction

3.3.1 Shallow Aquifer

The groundwater elevation in the top weathered and dolomitic aquifers that are not connected with the mine void mimics the topography. Although the gradient is generally flatter in the dolomitic aquifer, the flow direction follows the topography and is towards the local streams. Regional groundwater contours for the study area is shown in Figure 3-3, while the local hydraulic head in the vicinity of the Millsite TSF and pits is shown in Figure 3-4. It is evident that the groundwater level divide is similar to the surface watershed areas.

The natural groundwater flow direction in the A21D quaternary catchment (where Millsite TSF, Millsite Pit and Tweelopiespruit are located) is generally from south to north, while in the C23D catchment (where the rest of the pits are located) is generally from north to south.

3.3.2 Mine Void Aquifer

The hydraulic head and groundwater flow direction in the mine void is controlled by the decant, abstraction that is taking place at 8 Shaft, pit deposition, mine interconnectivity, and geological structures connecting the mine void with the shallow aquifer. A conceptual flow direction in the mine void (after Hobbs et al., 2007) is illustrated in Figure 3-5.

When mining was discontinued in the area, the defunct workings started to flood and, in September 2002, the mine water started to decant from a previously unknown Black Reef Shaft next to the Tweelopie East Stream. The decant point, referred to as the Black Reef Incline (BRI), is at an elevation of 1662.98 m amsl. The water level in the mine void continued to rise even after the decant level was reached. This indicated that the BRI is restricted and that the outflow at that point does not represent the inflow into the void.

The decant rate is approximately 27 ML/d (Turton, 2016). Plans were presented to lower the water level in the mine void to below an environmental critical level (ECL), to minimise impact on surface and groundwater. The discharge was proposed from a low-lying shaft (8 Shaft). Pumping to achieve this objective commenced in April 2012 (Borralho 2014).

The ECL is defined as the highest potentiometric head in the mine workings at which mine water will not daylight in the dolomite outlier. This elevation was initially set at 1 636 m amsl (JFA, 2006), which corresponds to that of the Hippo Dam in the Krugersdorp Game Reserve. It was then lowered to 1 530 mamsl (Hobbs et al. 2007) which corresponds to the elevation of the Aviary Spring downgradient of the Hippo Dam.

Although the pumping of 8 Shaft at the appropriate abstraction rate can avoid decanting, the lowering of the hydraulic head can affect the regional water level which could result in drying of springs and streams.

The Porges, SRK and Battery Pits are in the C23D catchment while the decant point and 8 Shaft are in the A21D. However, the flow from the pits is towards the 8 Shaft against the topographic gradient. This is due to the lowering of the hydraulic head at the shaft together with the Witpoortjie Fault south of the pits which is predominantly a flow barrier.

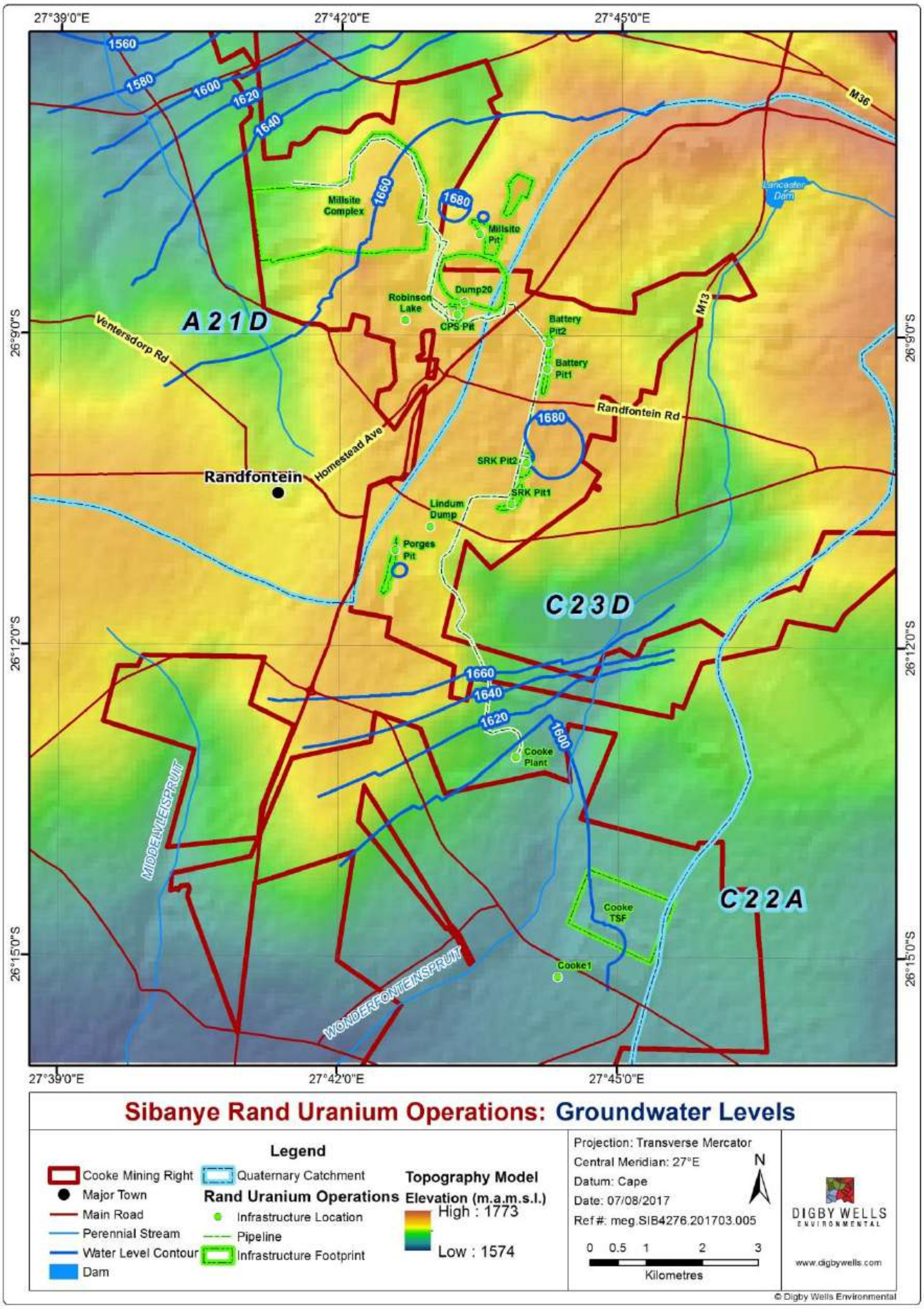

Figure 3-3: Regional Groundwater Elevation and Flow Direction

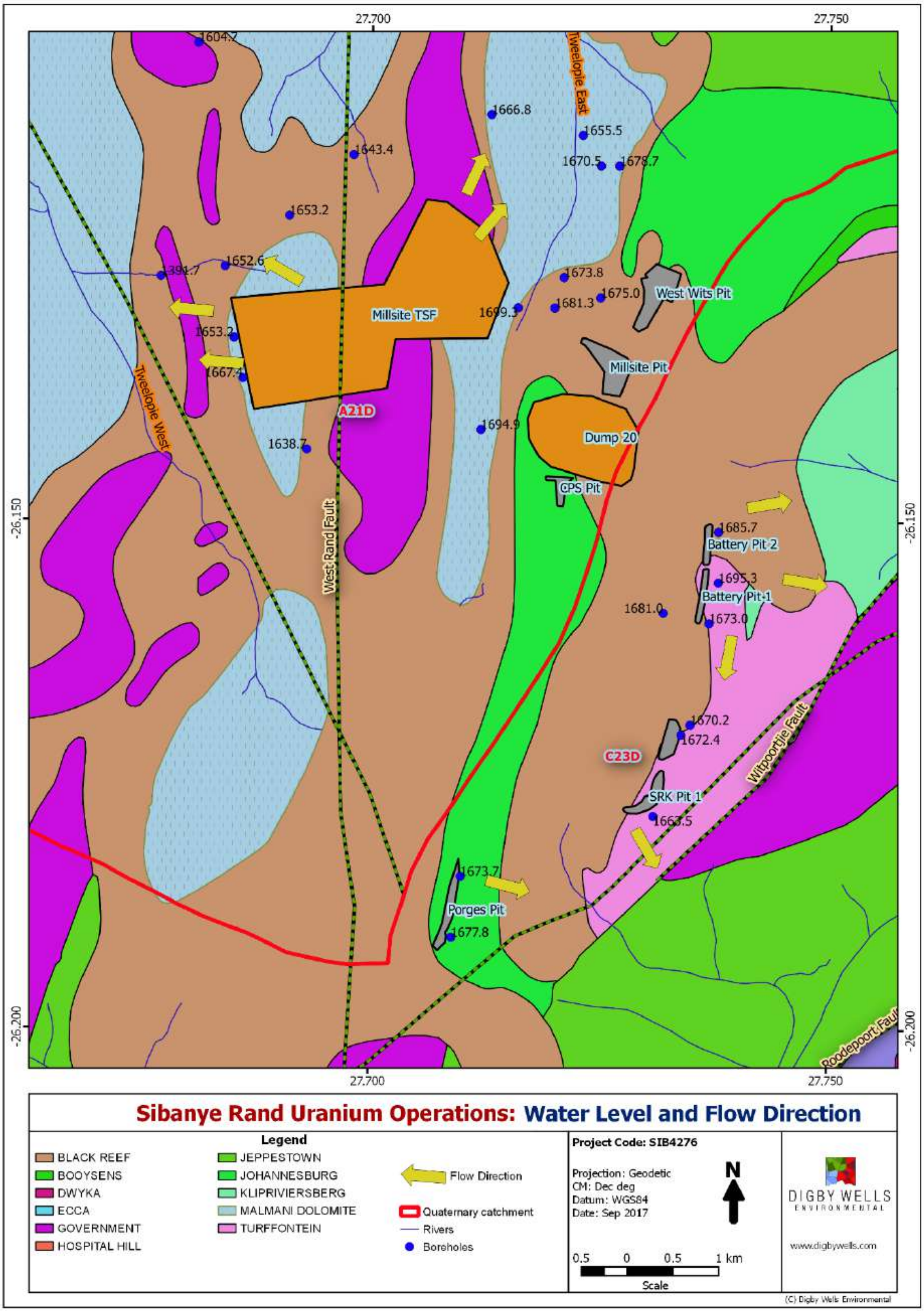

Figure 3-4: Water level and flow direction in the shallow weathered aquifer

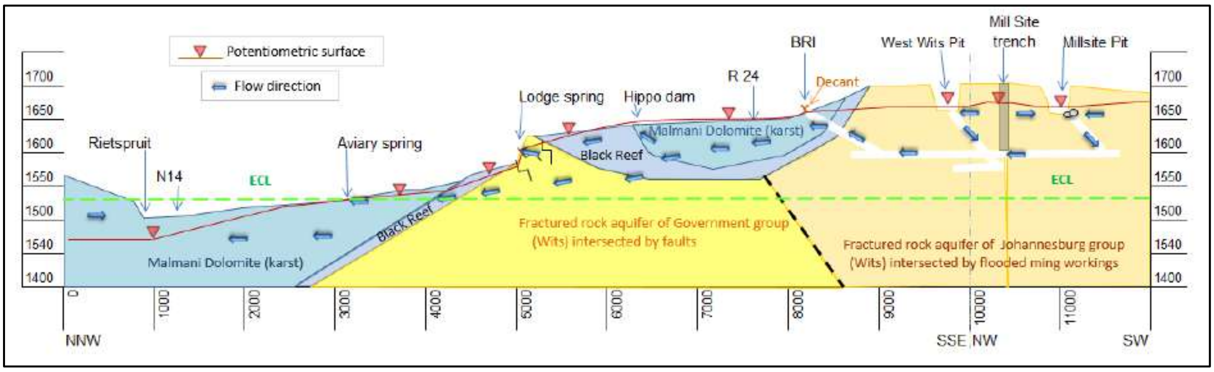

Figure 3-5: Groundwater flow direction and the concept of ECL

3.4 Groundwater Quality

SGL conducts groundwater monitoring in the area of the Millsite TSF, the pits, and Tweelopiespruit as shown in Figure 3-6. Water quality is compared with the existing WUL limits listed in Table 3-2.

Table 3-2: WUL for groundwater quality

Variables	Limit
pH	5-9.5
Electrical conductivity (mS/m)	70-150
Calcium (mg/L)	80-150
Chloride (mg/L)	100-200
Fluoride (mg/L)	0.7-1.0
Magnesium (mg/L)	70-100
Nitrate (mg/L)	6-10
Sodium (mg/L)	100-200
Sulphate (mg/L)	200-400

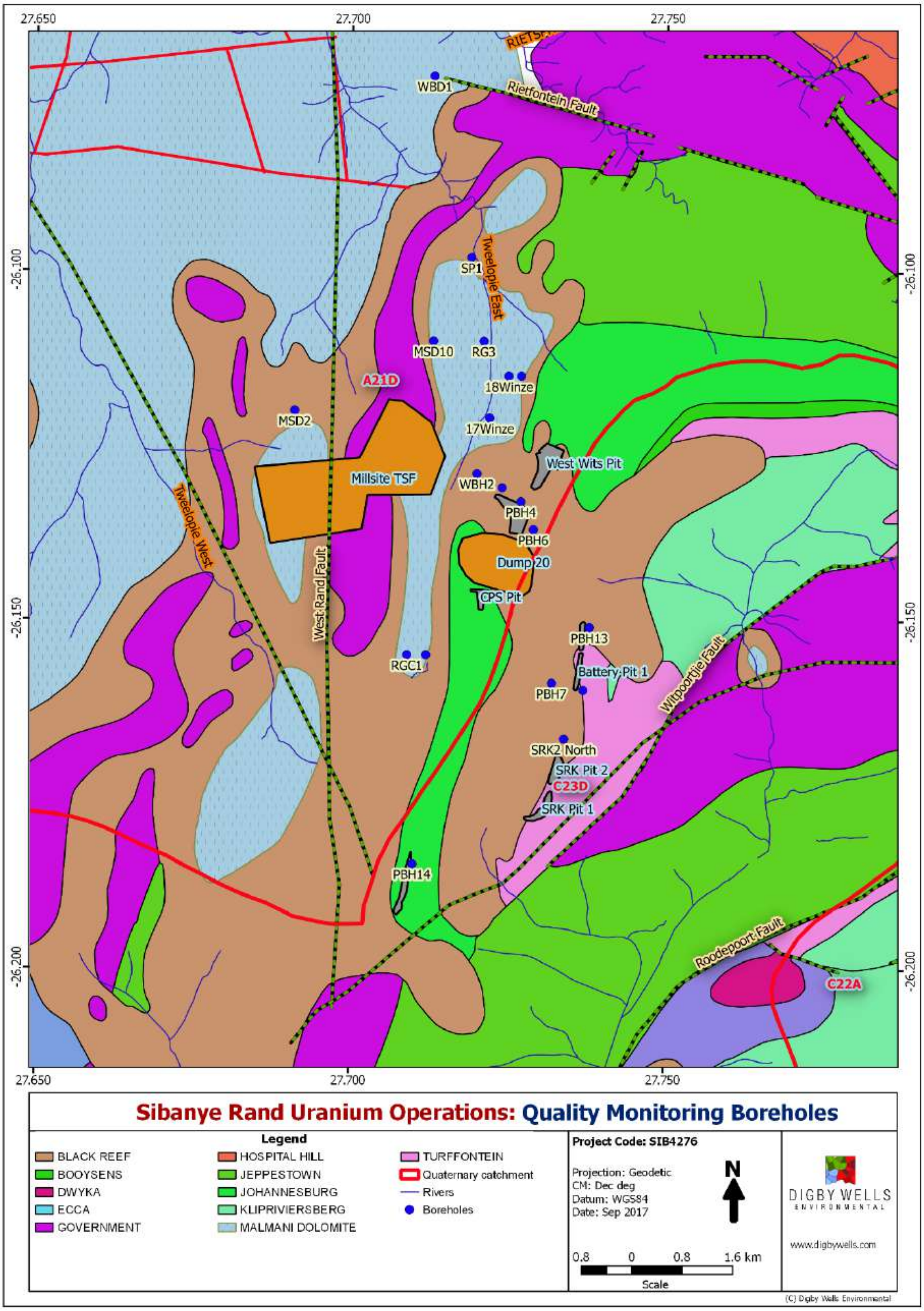

Figure 3-6: Groundwater monitoring boreholes

3.4.1 Electrical Conductivity

The electrical conductivity (EC) limit for the groundwater is set between 70 and 150 mS/m.

The time series data for the EC is presented in Figure 3-7 and indicates three groups: the first defined by an EC of below 70 mS/m and is good in quality. The second is between 70 and 150 mS/m and is acceptable quality. The third is in excess of 150 mS/m and is unacceptable quality.

The water quality in majority of the monitoring points is either in the good or acceptable category. The main concern is the quality of the 17 Winze, 18 Winze, Borehole PH6 (located close to the Millsite Pit) and SRK Pit 2 where it is currently above the 150 mS/m limit.

The 17 and 18 Winzes pose a risk as they are upgradient of Tweelopiespruit East and in the vicinity of the decant position. It should, however, be noted that the water quality from both winzes have been improving since monitoring data is available in late 2009. The EC was approximately 500 mS/m in 2009 and has gradually decreased to its current value of approximately 325 mS/m.

The poor water quality of the winzes cannot be associated with the deposition of the reclaimed Dump 20 into the pits. The water quality was already unacceptable before the reclamation started and the trend has improved over the past number of years.

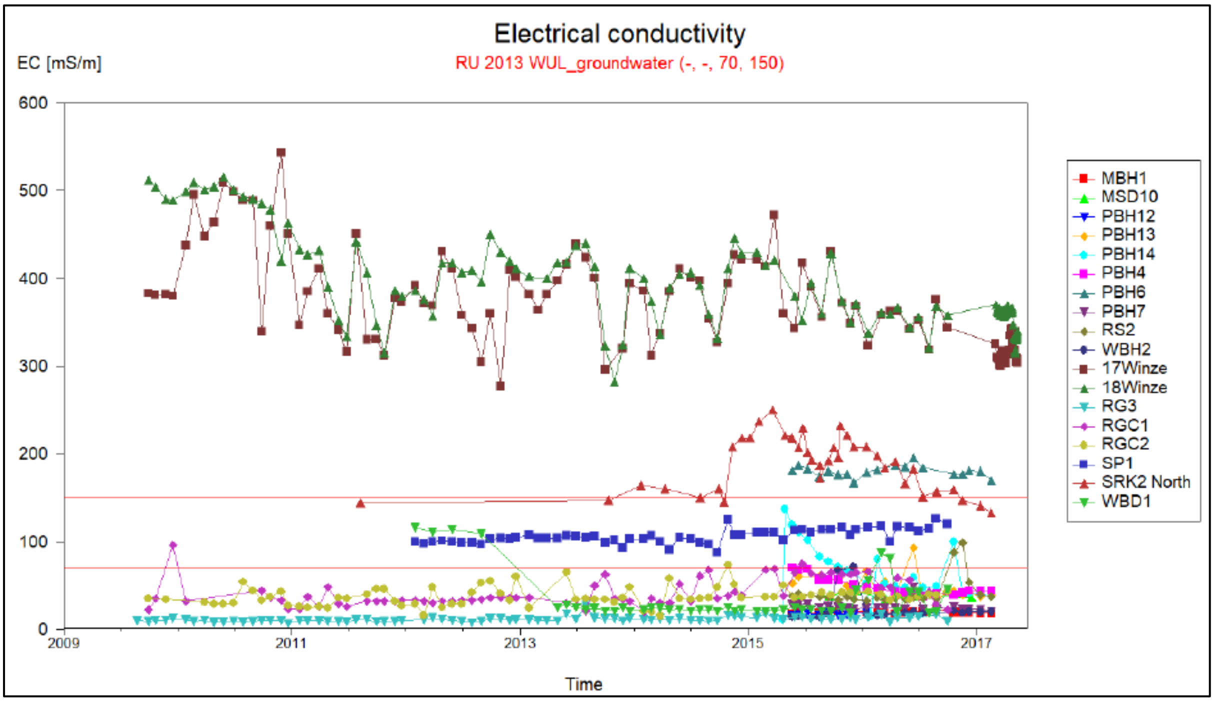

Figure 3-7: Electrical conductivity trend

3.4.2 pH

The pH trend (Figure 3-8) shows that the Battery Pit 2 (monitoring borehole PBH13) and SRK Pit 2 are consistently below the WUL limit of 5. The pH of Battery Pit 1 (monitoring PBH12) is also below this value but no monitoring data is available since January 2016.

The pH of the 17 and 18 Winzes was approximately 5 until February 2013. Thereafter it steadily increased to the current pH of 6.45. Both monitoring points are within the WUL limit and the trend is that the pH will keep on increasing. The increase in pH is suspected to be a result of the discharge of the reclaimed Dump 20 tailings which has a pH of between 10 and 11. This is one of the positive impacts associated with the discharging of alkaline tailings into the pits, as this would mean that dissolved metals will precipitate.

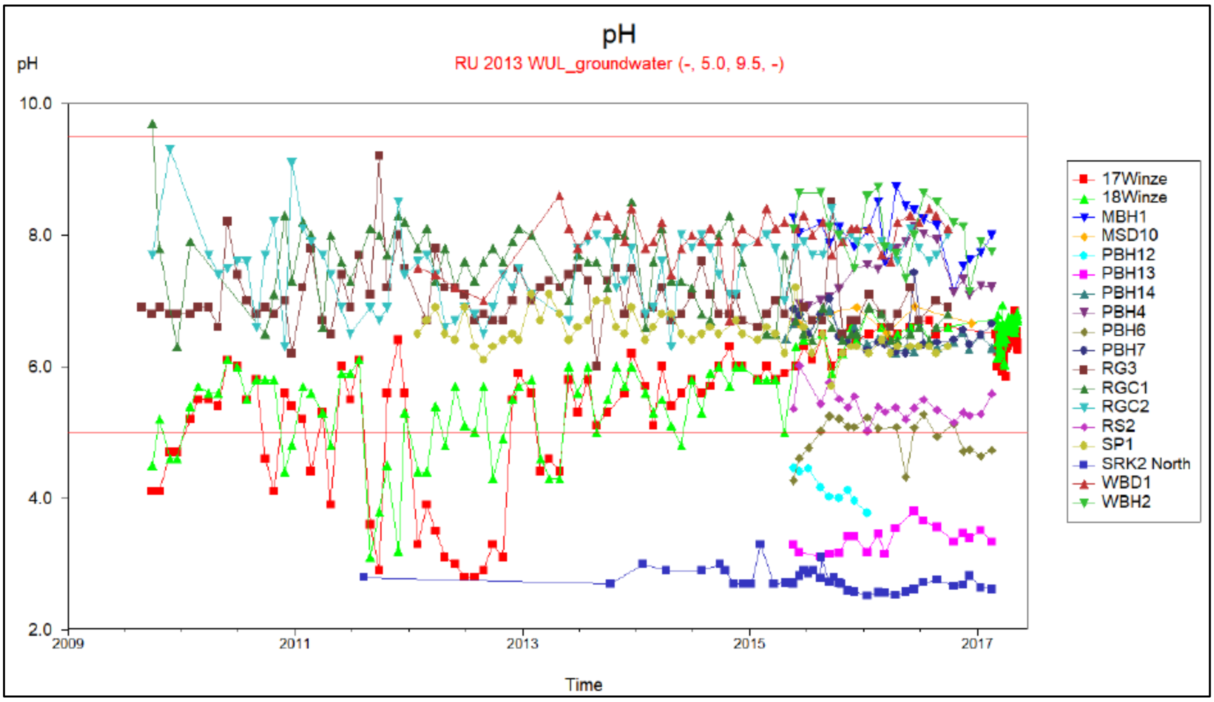

Figure 3-8: pH trend

3.4.3 Calcium

The WUL stipulates that Ca concentration to be between 80 and 150 mg/L. The trend (Figure 3-9) shows that the water from the 17 and 18 Winzes is poor in quality at a concentration of approximately 610 mg/L.

Both these winzes are upgradient of the Tweelopiespruit and is an environmental concern. At a concentration of 247 mg/L, the Millsite Pit water quality is also above the WUL limit.

The rest of the monitoring boreholes are within the WUL limit and are not at a risk of Ca contamination.

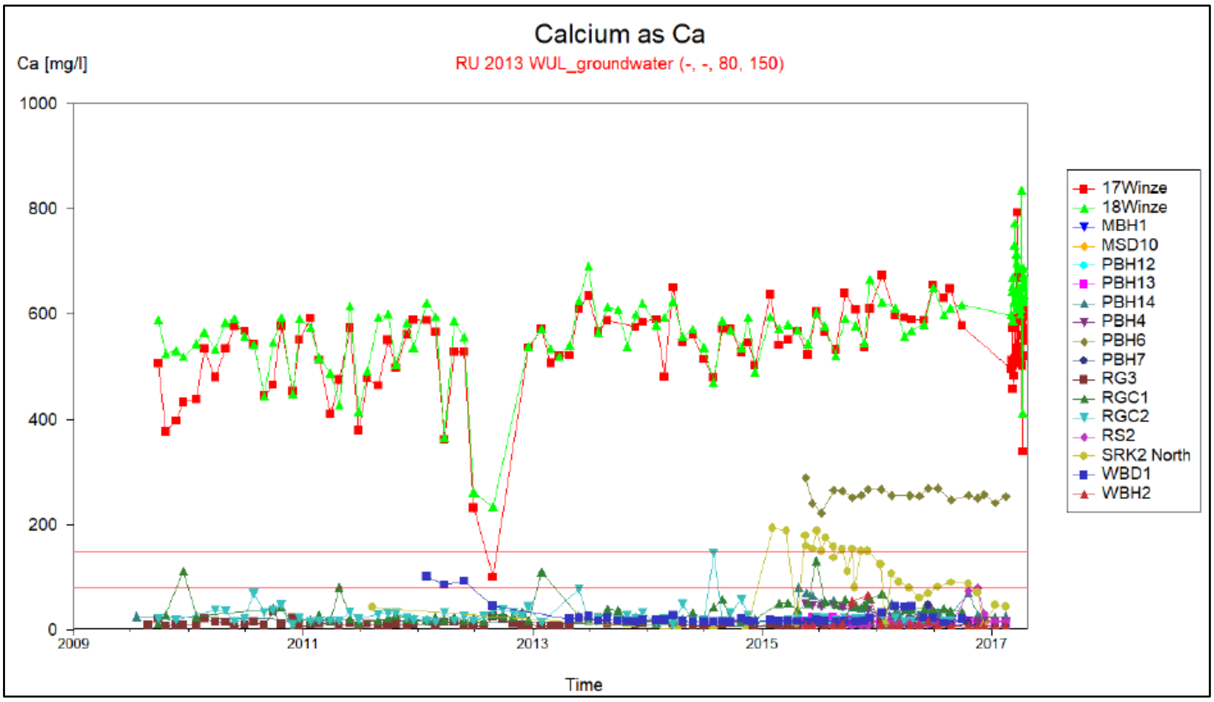

Figure 3-9: Ca trend

3.4.4 Magnesium

Magnesium concentration is illustrated in Figure 3-10 and shows that it is only 17 and 18 Winze's that are above the WUL limit. The rest of the monitoring points are not at a risk of Mg contamination.

The trend in the winzes has been decreasing continuously since June 2010; from 300 mg/L to the current value of 100 mg/L (which is the WUL upper limit). The trend is that Mg will not be a concern even in the winzes as it is likely to decrease below the WUL limit. The on-going decrease in Mg is not suspected to be associated with the Dump 20 deposition as it was already decreasing before 2012 and no change in trend has been recorded that could be linked with the deposition.

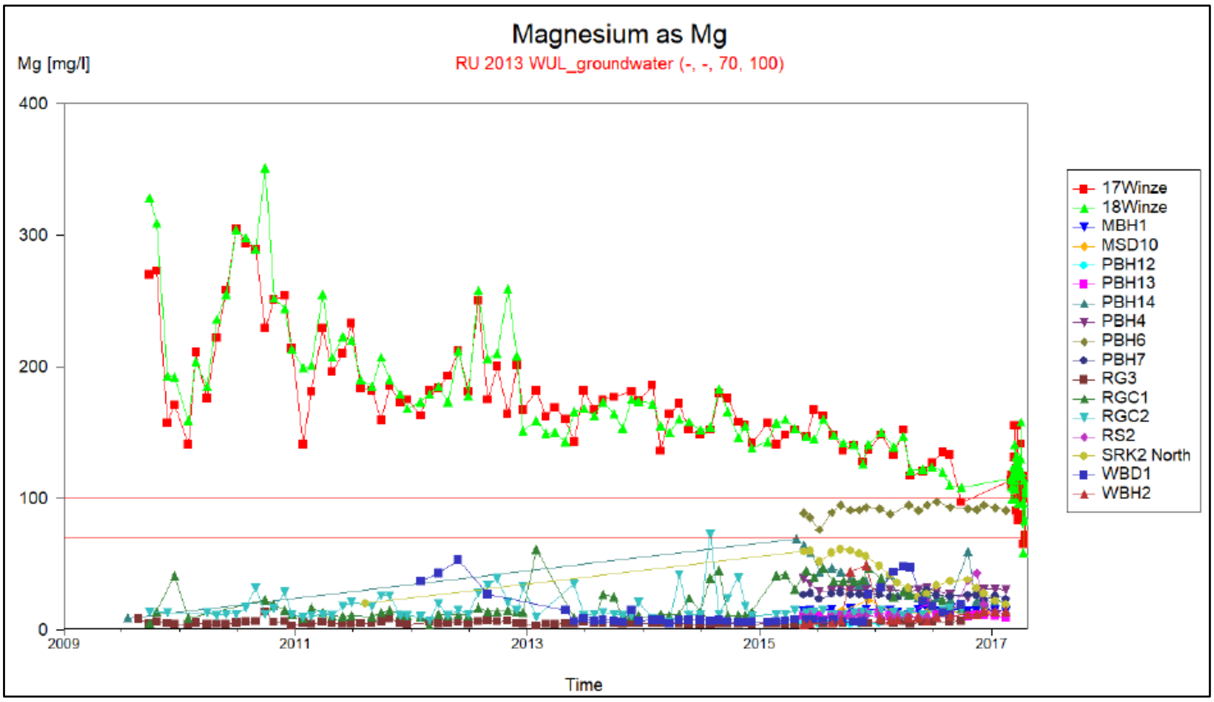

Figure 3-10: Mg trend

3.4.5 Sulphate

The sulphate trend (Figure 3-11) is similar to that of EC and Mg. Although the winzes water quality is above the WUL limit of 600 mg/L, it has been consistently decreasing since monitoring data is available in 2010. The trend has not changed and cannot be associated with the in-pit deposition of the reclaimed Dump 20. The quality of the Millsite Pit (borehole PBH6) and SRK Pit 2 is also above the WUL limit.

The rest of the monitoring boreholes are below 400 mg/L and are not at a risk of contamination.

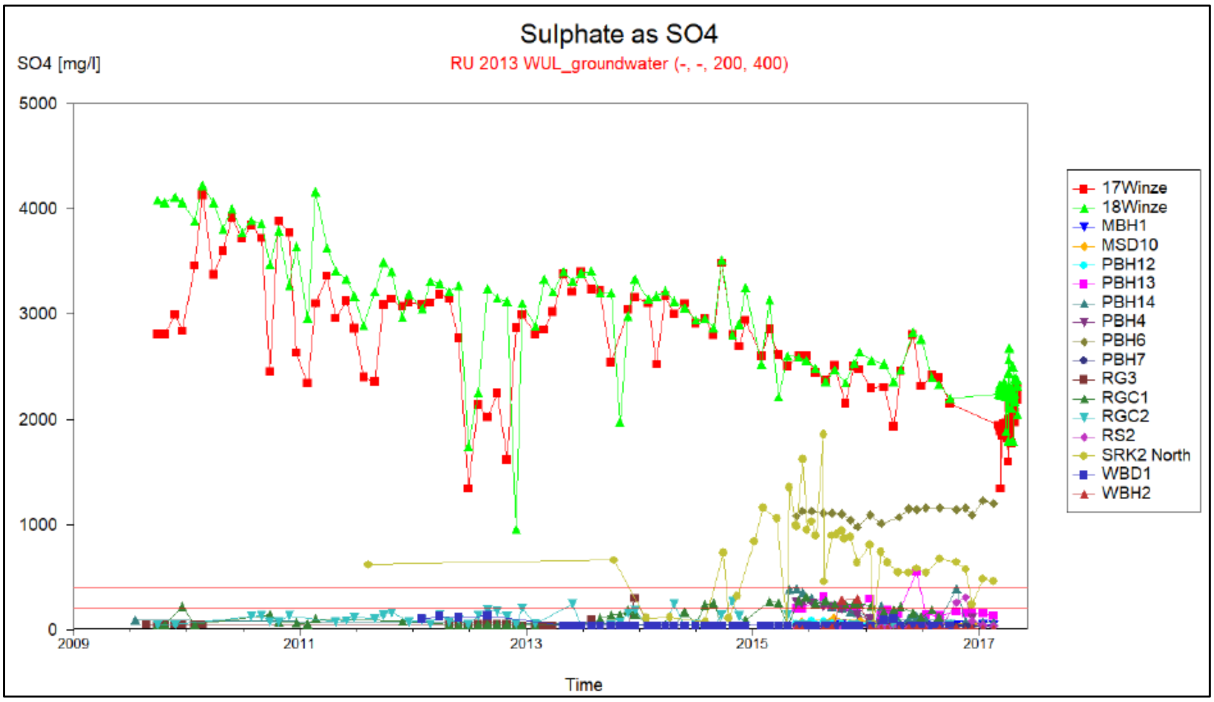

Figure 3-11: Sulphate trend

3.4.6 Metals

The concentration of Mn, Fe and Al is illustrated in Figure 3-12. The concentration of all these metals is above the WUL in the 17 and 18 Winzes.

Fe concentration has been decreasing consistently since 2013 and could be linked with the deposition of Dump 20. However, Mn has been decreasing since 2010 before the deposition started.

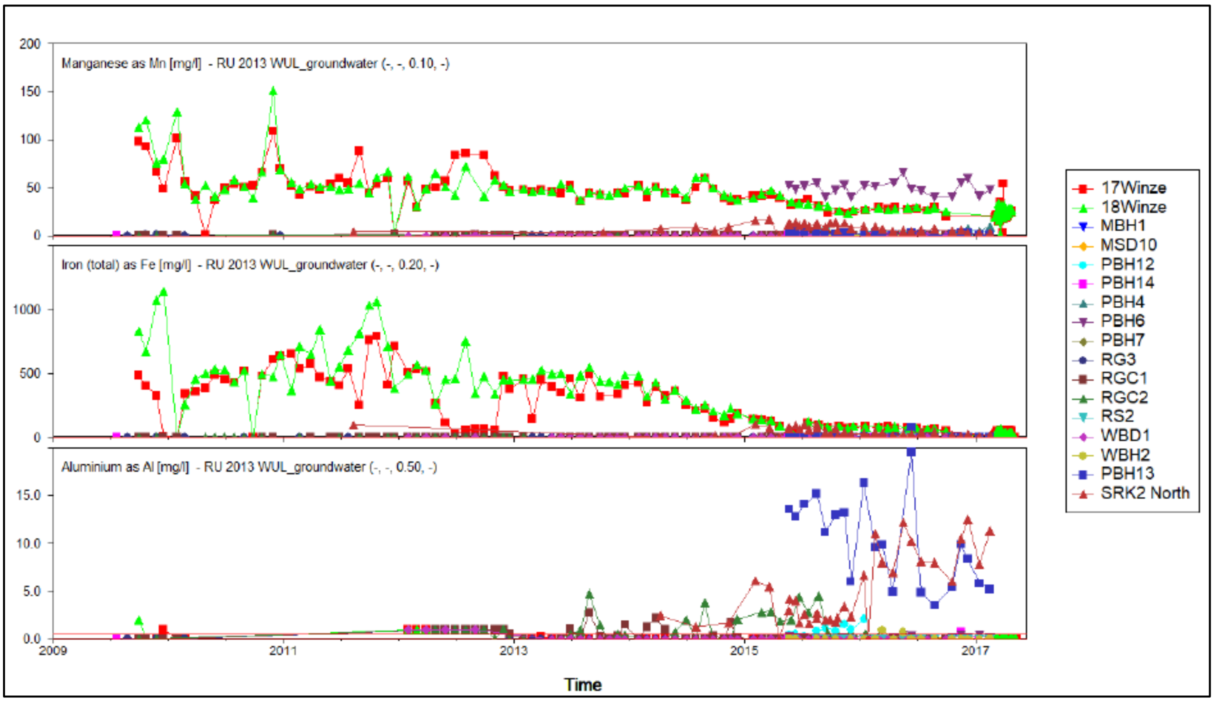

Figure 3-12: Metals (Al, Fe, Mn) trend

3.5 Groundwater Receptors

Groundwater usage in the area occurs on agricultural holdings some 2.5 km to the north of Millsite TSF and small farms immediately to the west of the tailings dam. Groundwater usage is primarily for domestic purposes although large scale irrigation takes place from the Sterkfontein dolomite. The tailings dam also has the potential to impact on the Tweelopie West and East streams that flow through the Krugersdorp Game Reserve and ultimately into the Cradle of Humankind World Heritage Site.

Groundwater usage in the area between the Millsite TSF and Cooke TSF is mainly on agricultural holdings. Several of the smallholdings are owned by SGL/Rand Uranium. Farming operations to the west of the Wonderfonteinspruit utilise groundwater for stock watering and domestic purposes.

Surface water and groundwater interactions occur when the water level elevations intersect the surface topography. Such interactions are often expressed as springs, wetlands and base flows. The groundwater contribution to base flow, in the Randfontein area, is estimated to be 25 mm per annum (Vegter, 1995). Significant streams that could be impacted if the groundwater quality deteriorates include the Wonderfonteinspruit, Tweelopiespruit and Mooirivierloop. These streams are particularly vulnerable to AMD seepage and salt loading as a result of tailings seepage in the shallow groundwater zone and decant of mine water through old shafts.

3.6 Geochemical Assessment

3.6.1 Mineralogy

Identification of the mineralogy of the tailings is necessary for determining the potentially leachable metals and the acid generating and neutralizing minerals, and is thus valuable information for site-specific predictions of drainage chemistry.

The mineralogical composition of the tailings samples is given in Table 3-3. The samples are dominated by silicate minerals, particularly quartz, pyrophyllite, muscovite and kaolinite. Quartz is the primary constituent ranging between 33.1 to 93.1% by weight. The difference in the samples mineralogy is suspected to be due to the tailings being sourced from different ores and have been deposited on the Millsite TSF over the years.

The non-silicate minerals are dominated by hematite and jarosite, which are oxidised Fe minerals. Pyrite was only detected in Sample 6, at a concentration of 0.6% by weight meaning that pyrite is not an issue in the tailings. Although no calcite minerals have been detected in any of the samples, pyrophyllite, muscovite, jarosite, and kaolinite are hydroxides and have the potential to buffer acidity.

Based on the mineralogy alone, the TSF is acid neutralising although pockets of potential acid generation (e.g. in the area where Sample 6 was collected) cannot be excluded. However, this needs to be supported by the ABA analysis that will be discussed in the subsequent sections.

The mineralogy of the Dump 20 is also in included in Table 3-3 for comparison purposes. At 1.4%, the pyrite content is higher than that of Millsite where the maximum recorded is 0.6%. At the same time, there are more silicate hydroxides (mainly Chloritoid and Chlorite) in Dump 20 which could assist in buffering any acid generation. More comparisons on the ABA and leachate quality between the two TSFs are discussed below.

Table 3-3: Weight % of the mineralogy of the Millsite TSF samples

Mineral	Approximate Formula	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Dump 20 composite
Quartz	SiO_2	83.24	93.09	82.94	77.47	33.14	81.71	70.81	84.99	90.59
Pyrophyllite	$Al(Si_2O_5)(OH)$	10.68	5.04	10.92	9.21	4.78	11.66	16.7	9.89	2.83
Hematite	Fe_2O_3				3.69	59.56				
Muscovite	$KAl_2((OH)_2AlSi_3O_{10})$	3.48	1.86	3.38	4.52	1.22	3.79	6.48	1.87	2.04
Jarosite	$KFe_3(SO_4)_2(OH)_6$	2.6		2.75	2.94	1.3	2.21	2.78	1.69	
Bassanite	$CaSO_4{\bullet}0.5H_2O$				2.18			1.57	1.57	
Kaolinite	$Al_4(OH)_8(Si_4O_{10})$							1.66		
Pyrite	FeS_2						0.63			1.41
Chloritoid	$(Fe,Mg,Mn)_2Al_4Si_2O_{10}(OH)_4$									2.42
Chlorite	$(Mg,Fe,A1)_6(Si,A1)_4O_{10}(OH)_8$									0.71

3.6.2 Acid-Base Accounting

ABA is the most widely used static test to predict acid-mine drainage potential. The ABA results are summarised in Table 3-4 below and laboratory certificates are available in Appendix A.

The test consisted of six measurements:

- The paste pH;
- The amount of acidity a sample is likely to produce (acid potential or AP);
- The inherent neutralization potential (NP) of the same sample;
- Sulphur speciation;
- The net neutralisation potential (NNP) which is NP-AP; and
- The neutralisation potential ration (NPR) which is NP/AP.

Table 3-4: Summary of the ABA results

Sample ID	paste pH	AP (kg/t)	NP	NNP	NPR	Total S%	Sulphate S %	Sulphide S%	NAG pH
Sample1	3.1	9.68	0.1	-9.68	0.01	0.31	0.1	0.21	4.7
Sample2	3.3	8.12	0.24	-8.12	0.030	0.26	0.21	0.05	4.9
Sample3	1.9	34.3	0.1	-34.3	0.003	1.1	0.82	0.28	2.6
Sample4	2.6	27.5	0.1	-27.5	0.004	0.88	0.84	0.04	4.6
Sample5	6.9	0.31	9.45	9.45	30.48	<0.01	<0.01	0.01	7.1
Sample6	1.7	22.8	0.1	-22.8	0.004	0.73	0.11	0.62	2.1
Sample7	2.1	21.8	0.1	-21.8	0.005	0.7	0.44	0.26	3.3
Sample8	2	18.7	0.1	-18.7	0.005	0.6	0.33	0.27	2.9
Dump 20 Composite	10.1	87.53	1.96	-85.57	0.02	2.8	0.01	2.78	2.2
Dump 20 Slime	8.4	22	9.4	-12.6	0.4	1	0.88	0.71	2.9
Dump 20 Sand	8.4	21	9.1	-11.9	0.4	0.91	0.71	0.67	2.8

3.6.3 Paste pH

The paste pH is a type of ABA used to provide a preliminary estimation on the acid generation potential of a rock sample. The sample is placed in a plastic beaker and 10 mL of distilled water (pH 5.33) is added to make a paste. The paste is stirred with a wooden spoon to wet the powder. This way, a quick measure of the relative acid-generating (pH<4) or acid-neutralizing (pH>7) potential of the waste material can be evaluated (Sobek et al. (1978)).

The paste pH of the samples was found to be acidic ranging between 1.7 and 3.3 (with the exception of Sample 5 at a pH of 6.9). Although this indicates the potential for the residue to generate acid, paste pH alone is not a conclusive methodology for ABA classification. The sulphide content, acid generating and acid neutralisation materials of the tailings need to quantified for a more comprehensive ABA evaluations.

The paste pH of Dump 20 was found to be alkaline with an average of 9.0; indicating that without oxidising the residue is leached in alkaline conditions.

3.6.4 Sulphur Speciation

The objective of sulphur analysis is to identify and measure the concentration of different sulphur species present in the sample. Sulphide minerals are the primary sources of acidity and leaching of trace metals, and their measurement is a critical requirement for acid drainage chemistry prediction.

A set of rules, which has been derived based on several of the factors calculated in ABA, was reported by Soregaroli and Lawrence (1998). It has been shown that for sustainable long-term acid generation, at least 0.3% Sulphide–S is needed. Values below this can yield acidity but this is likely to be only of short-term significance.

The sulphur species analysed for the tailings samples included total sulphur-S, sulphate-S and sulphide-S. The highest Sulphide-S was detected in Sample 6 at 0.62%. The rest of the samples have approximately 0.25% which is slightly less than the 0.3% benchmark required to generate acid sustainably. As discussed above, pyrite was only detected in Sample 6. The 0.25% sulphide-S should therefore be present in other Fe containing trace minerals that do not form part of the main minerals present in the tailings.

Sulphur species and mineralogical assessment were also conducted by Mintek (2013) on 8 different samples from the Millsite TSF. The sulphide-S and pyrite were found at higher concentrations than those conducted during this study. The sulphide concentration ranged between 0.3 and 0.7%, with the average being 0.6%. This is a clear indication that there is sufficient sulphide to generate acid. The pyrite content was also found to range between 0.7 and 1.7 and are likely to be the source of the sulphides. Although the depth of sampling is not available, the samples tested by Mintek are expected to have been collected from a greater depth where it is less oxidised and hence higher pyrite and sulphide content.

The sulphide content of the Dump 20 was on average 1.4% and is more than that of Millsite. It could generate acid more sustainably than Millsite if not buffered by the alkaline minerals present. This is also in line with the mineralogical content since more pyrite was detected in Dump 20.

3.6.5 Net Neutralisation Potential (NNP)

The difference between the neutralisation potential (NP) and the acid potential (AP) is defined as the net neutralization potential (NNP); i.e. NNP = NP-AP.

A positive NNP would indicate that there is more neutralising material than acid forming material in any given sample, i.e.:

- If NNP is less than 0 then the sample has the potential to generate acid;

- If NNP is more than 20 then the sample has the potential to neutralise acid; and
- If the NNP is between 0 and 20, the acid properties are not certain and further investigation would be needed to confirm the properties of the sample.

The NP, AP and NNP of the samples is given in Table 3-4 and shows that the samples are all acid neutralising. Although the neutralisation potential is variable for each sample, their overall acid generation potential is considerably less than the neutralisation potential.

The average NP is 1.3 $CaCO_3$/tonne, while the average AP is 17.9 $CaCO_3$/tonne. This means that the average NNP is -16.7 $CaCO_3$/tonne, indicating that the samples are potentially acid generating.

Sample 5 is unique whereby the NNP is 9.5 $CaCO_3$/tonne. This together with its relatively high paste pH (6.9) and low sulphide content (0.01%), the sample is different from the rest and not potentially acid-generating.

The average NNP of the Dump 20 was -36.7 $CaCO_3$/tonne and is slightly more acid generating than Millsite.

3.6.6 Neutralisation Potential Ratio

Similar to the NNP, the Neutralisation Potential Ratio (NPR) is used to identify and separate potentially acidic generating from not potentially acidic generating materials. The NPR is calculated by dividing the NP by the AP.

The potential for acid generation was evaluated by using the screening criterion set by Price (1997) as shown in Table 3-5. The NPR of the tailings samples (excluding Sample 5) was quantified between 0.0 and 0.03, the average being 0.01, which confirms that the TSF is likely to be acid generating (Figure 3-13). The geochemistry of Sample 5 is excluded from the rest of the samples as its NPR is 30.5 and falls in the non-acid generating category. This sample is an exception and overall Millsite TSF can be classified as potentially acid generating.

The NPR of Dump 20 is also included in Figure 3-13. The three samples from this TSF are marked with red and all fall on the potentially acid-generating zone and have similar geochemical ABA values to that of the Millsite TSF.

Table 3-5: Criteria for interpreting ABA results

Potential for ARD	Criterion	Comments
Likely	NPR<1	Potentially acid generating, unless sulphide minerals are non-reactive
Possible	1<NPR<2	Possibly acid generating if NP is insufficiently reactive or is depleted at a rate faster than sulphides

Potential for ARD	Criterion	Comments
Low	2<NPR<4	Not potentially acid generating unless significant preferential exposure of sulphide
None	NPR>4	Non-acid generating

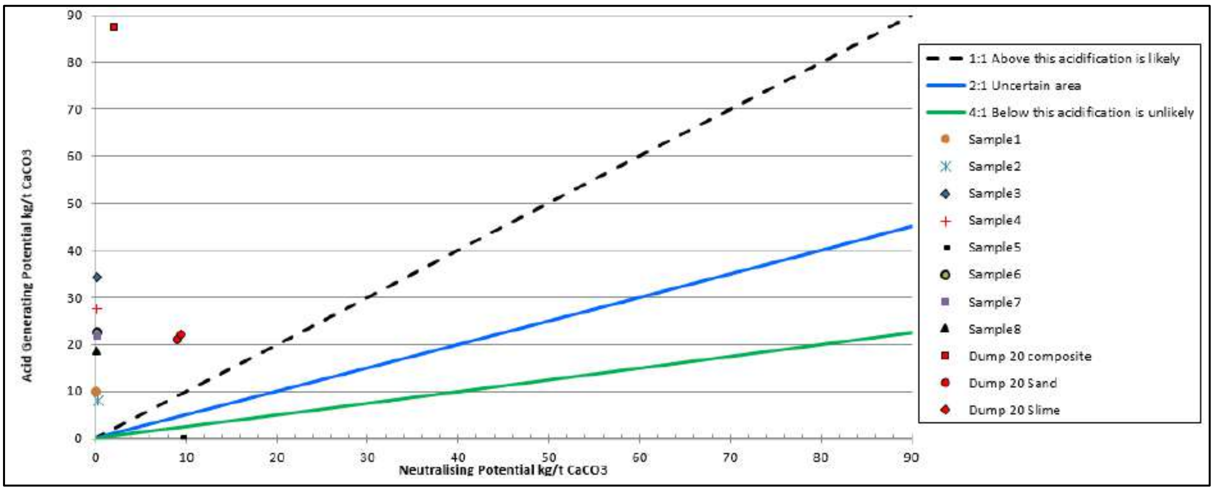

Figure 3-13: Comparison of the neutralisation potential and acid potential of the sample

Another method for classifying non-potentially acid-generating material from the potentially acid-generating materials is based on the ratio of neutralisation potential ratio (NPR) versus sulphide-sulphur (Soregaroli and Lawrence, 1998). Should the NPR be less than 1 and the sulphide-S content greater than 0.3%, the sample is considered to be potentially acid generating.

As can be seen in Figure 3-14, half of the samples (inducing Dump 20) are acid generating due to their sulphide content being more than 0.3% and NPR values being less than 1. The remaining half fall in the non-acid generating zone due to their sulphide content being less than 0.3%, although their NPR values are still less than 1.

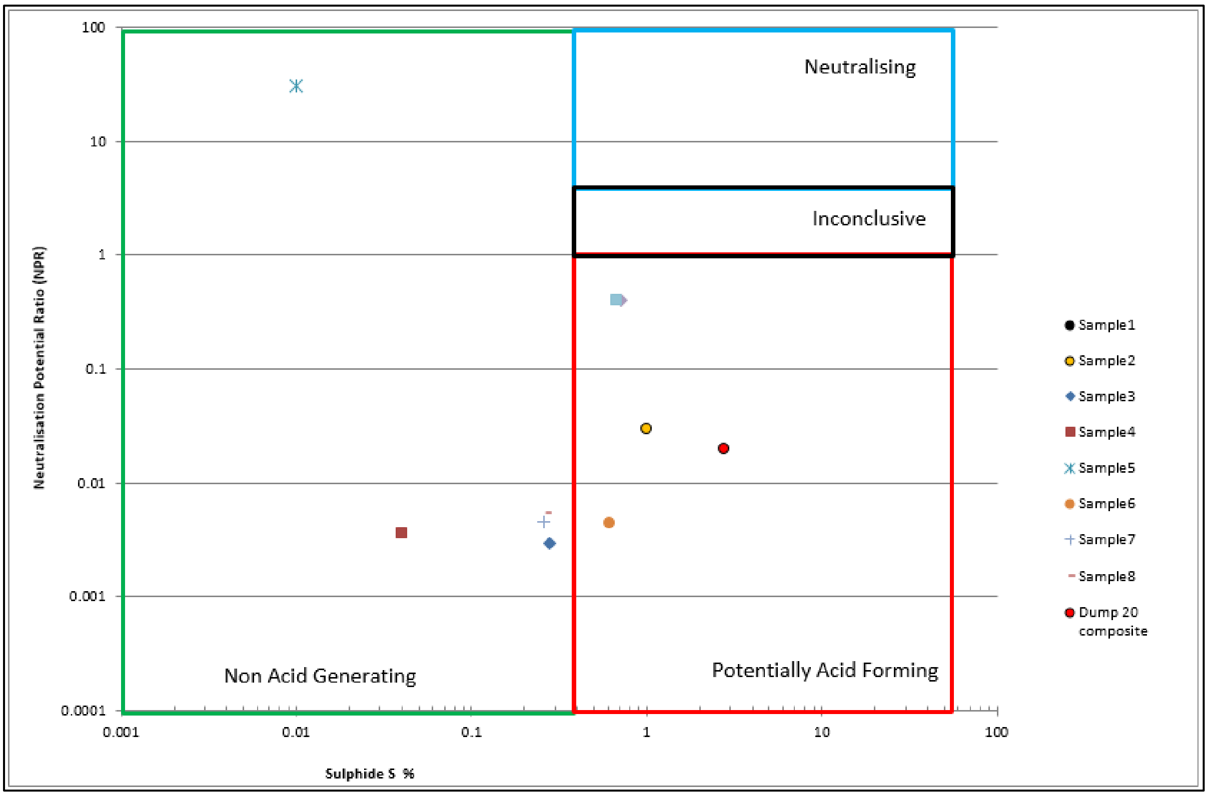

Figure 3-14: Sulphide-S vs NPR

3.6.7 Net Acid Generation (NAG)

The net acid generating (NAG) test is associated with ABA to classify the acid generating potential of a sample. It is conducted by reacting the sample with hydrogen peroxide to assess the components released by fast mineral dissolution and oxidation reactions, especially sulphide oxidation and carbonate dissolution. Both acid generation and acid neutralization reactions occur simultaneously and the net result represents a direct measure of the amount of acid generated. A pH after reaction (NAG pH) of less than 4.5 indicates that the sample is net acid generating. This subdivision is slightly arbitrary and can serve as a rough guideline but not as stand-alone criteria in categorising the sample.

Figure 3-15 is a plot of NPR and NAG pH and identifies four quadrants.

- Samples with NPR greater than 1 and NAG pH greater than 4.5 plot in the non-acid forming quadrant. Only Sample 5 falls in this zone;
- Samples with NPR less than 1 and NAG pH less than 4.5 plot in the potentially acid forming quadrant. Sample 5 falls in this quadrant;
- Samples with conflicting ABA and NAG results plot in the uncertain quadrants. In Figure 3-15, only Sample 2 plot in the uncertain quadrant and follow up testing can be targeted on this sample to confirm the classification; and

- The remaining 7 Millsite and 3 Dump 20 samples fall in the potentially acid forming category.

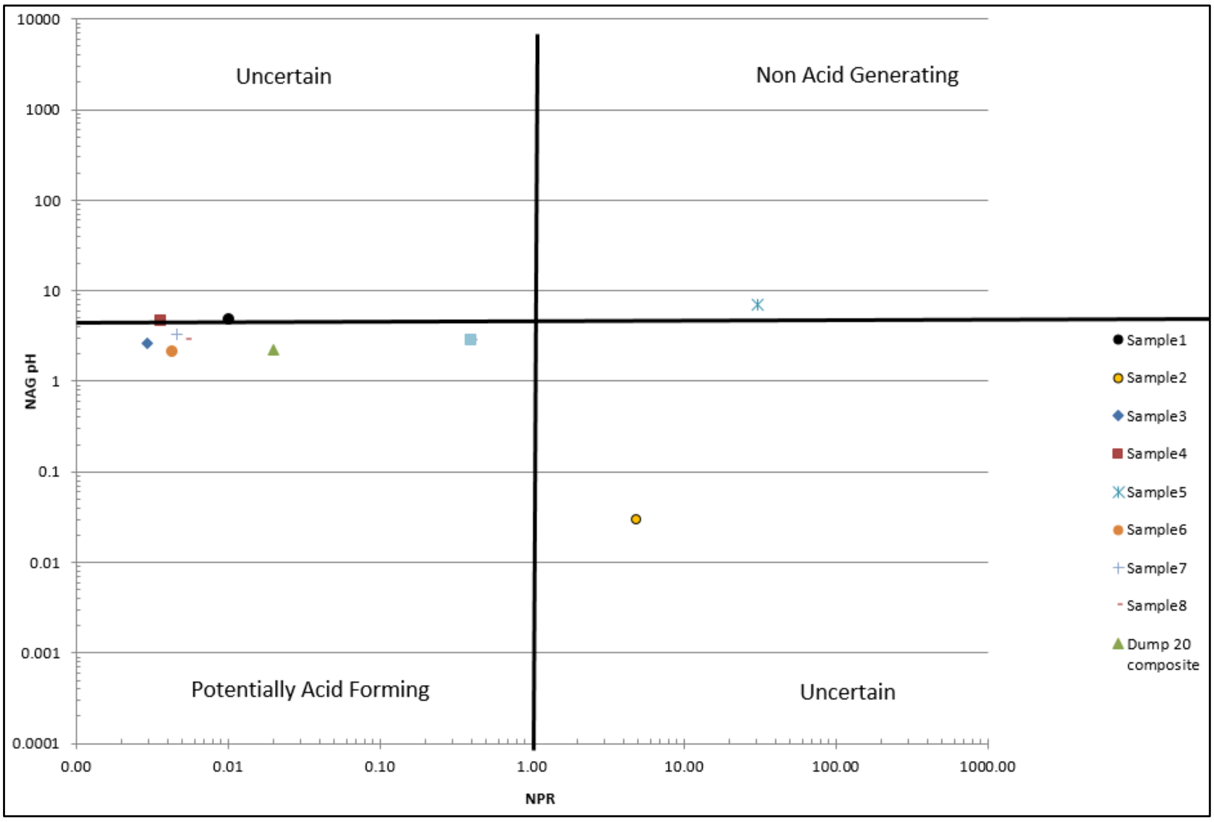

Figure 3-15: NNP vs NAG pH

3.6.8 Total Concentration

The objective of the total concentration analysis is to provide a measure of the solid-phase levels of various mineral-forming cations that may be of environmental concern. Combined with the metal leachate test, these levels allow the calculation of metal depletion times and can be used as a screening tool to detect constituents which occur in anomalously high concentrations and may, under unfavourable geochemical conditions, be of concern as a constituent in AMD.

In this study, determination of which elements occur in high concentrations is made by comparing the multi-element analytical results with the average range of concentrations of these elements in the continental crust as shown in Table 3-6. The average range of metal concentrations in the crust is obtained from Price (1997).

A number of elements (the most being in Sample 5) are found at higher concentrations in the samples than they are usually encountered in the crustal rocks (highlighted in orange in Table 3-6), out of which arsenic can be considered as the main elements that should be looked at from an environmental perspective. This is to be expected from a mineralised and enriched sample.

Noteworthy is the scarcity of uranium in the tailings. This is because uranium had been previously extracted and its concentration in the tailings is below the detection limit.

The Dump 20 samples were not exposed to aqua regia digestion in 2012 and their multi element analysis is not included in Table 3-6.

Table 3-6: Result of the multi-element composition analysis

Element (mg/Kg)	Average value in continental crust (ppm)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Si	281,500	<0.400	<0.400	<0.400	<0.400	<0.400	<0.400	<0.400	<0.400
Ti	5,650	227	199	193	200	210	199	184	147
Al	82,300	28,815	17,500	31,310	24,110	16,870	50,095	48,030	13,290
Fe	56,300	20,515	18,370	23,930	39,310	430,800	16,965	12,110	11,270
Mn	950	193	183	187	185	454	136	70	177
Mg	23,300	1,251	1,399	1,104	971	1,767	1,135	698	551
Ca	41,500	1,427	2,760	1,102	7,254	6,993	1,711	4,649	3,623
Na	23,550	712	306	586	599	318	628	1,215	241
K	20,850	2,431	951	2,363	4,573	1,306	2,808	3,531	1,280
As	1.8	269	51	45	350	1,363	62	98	56
Co	25	5	3	41	37	703	11	12	26
Cr	102	188	130	186	138	140	156	179	97
Cu	60	37	14	67	36	773	12	51	28
Ni	84	26	20	122	72	928	22	38	65
Sb	0.2	<1.000	<1.000	<1.000	<1.000	<1.000	<1.000	<1.000	<1.000
Be	2.8	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200
Bi	0.0085	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500
Cd	0.15	2	1	1	3	10	1	1	1
Pb		43	27	42	273	275	38	41	48

Element (mg/Kg)	Average value in continental crust (ppm)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
	14								
Mo	1.2	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Se	0.05	16	10	12	32	363	<3.000	<3.000	<3.000
Sr	370	32	16	25	33	9	28	44	22
Tl	0.85	<0.900	<0.900	<0.900	<0.900	<0.900	<0.900	<0.900	<0.900
Th	9.6	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200
Sn	2.3	<2.000	<2.000	13	<2.000	11	<2.000	<2.000	<2.000
U	2.7	<0.400	<0.400	<0.400	<0.400	<0.400	<0.400	<0.400	<0.400
V	120	38	27	33	24	44	31	28	17
Zn	70	51	77	110	138	515	32	67	73
Zr	165	95	78	90	88	44	82	81	64
Ba	425	55	28	52	130	31	56	62	30

3.6.9 Leachate Test

Three types of leachate tests were conducted to assist in characterising the mobile elements that could be released from the tailings under various pH conditions. The tests are compised of leaching with distilled water under, Synthetic Precipitation Leaching Procedure (SPLP) and mine void water collected from 8 Shaft.

The distilled water leachate results are given in Table 3-7, the SPLP are given in Table 3-8 and the mine water leachate results are given in Table 3-9. All results have been compared with the mine's WUL for groundwater quality.

3.6.9.1 Distilled Water Leachate

The pH of the leachate is acidic and is below the WUL limit of 6.0, with the exception of Sample 5 where it is 8.2. This is in line with the paste pH results whereby all samples were acidic (except for Sample 5).

The metals that exceed the WUL include:

- Ca in all samples, except in Sample 3;
- EC in samples 3, 5, and 8;
- Fe in samples 3, 4, 6, 7 and 8;
- Mn in samples 1, 3, 4, 7 and 8;
- Although As is found at higher concentrations in the solid phase (as observed using the multi-element analysis), it is inert in neutral solvent and its solubility is below the detection limit of 0.02 mg/L; and
- The concentration of U is below the detection limit of 0.004, which is way below the WUL limit of 0.07 mg/L.

3.6.9.2 SPLP Leachate

The pH of the SPLP leachate is similar to that of the distilled water. All of the samples leached at a pH that is below the WUL limit, except for Sample 5 where it is 7.3. This is a further confirmation that Sample 5 has more neutralisation potential that was also confirmed using the ABA analysis and can buffer acid generated at least in the short-term. The rest of the samples are likely to generate acid with no or limited buffering capacity.

More metals leached under acidic condition (SPLP) than when the solution is neutral (reagent water). The metals that exceed the WUL include:

- Ca and Fe in all samples;
- Mn in all but Samples 2, 5 and 6;
- There is no arsenic limit provided in the WUL. However, it is expected to leach to some extend if an acidic environment prevails. This is particularly true for Sample 5 where the As concentration is 2.6 mg/L; and

- As was the case with the distilled water leach result, the concentration of U is below the detection limit of 0.004.

3.6.9.3 Mine Void Water Leachate

Before leaching the tailings, the mine void water quality was analysed as shown in Table 3-9. The mine water is already contaminated to a large extent and the addition of the tailings material does not dramatically change this level of contamination.

There is not too much difference between leaching in distilled and SPLP water. Although there is increased Na concentration, there are no heavy metals coming out of solution when leached with the mine void water.

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Table 3-7: Distilled water leachate results

Variables	WUL limits	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8	Dump 20 composite	Dump 20 Slime	Dump 20 Sands
pH	6.0 - 8.5	4.1	4.9	2.7	3.9	8.2	3	3.2	3	10	9.1	9
EC (mS/m)	150	38.2	58.6	174	113	148.4	71.9	88	153.5		20	33
Ca (mg/L)	32.01	48	138	25	307	386	44	133	223	195	30	52
Mg (mg/L)	21.73	6.5	0.7	48	1.7	22	1.1	3.7	25	0.315	2.9	4.2
Na (mg/L)	12.21	3	2.8	2.7	2.9	4.9	3	3	3.2	21	1.6	1.4
Alkalinity (CaCO3 mg/L)	100	-	4	-	-	30	-	-	-		20	15
Cl (mg/L)	10.23	0.8	0.7	1.4	0.8	1.5	0.7	0.7	1.6	101	1.1	0.46
SO4 (mg/L)	600	156	225	726	525	713	161	276	621	360	70	139
Nitrate (mg/L)	0.74	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1
F (mg/L)	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	<0.2	0.21	0.25
Al (mg/l)	NA	6.3	0.1	83	1.6	0.07	1.7	7.7	14.6	3.3	0.42	0.5
As (mg/l)	NA	<0.020	<0.020	<0.020	<0.020	2.9	<0.020	<0.020	<0.020	<0.01	0.01	<0.01
Cr (mg/l)	NA	<0.003	<0.003	0.61	0.003	<0.003	0.008	0.04	0.16	0.11	0.008	0.004
Cu (mg/l)	NA	0.21	0.01	2	0.05	0.008	0.05	0.2	0.35	<0.01	<0.02	<0.02
Fe (mg/L)	0.2	0.04	0.04	28	0.25	0.11	6.7	0.83	1.3	0.047	<0.05	<0.05
Hg (mg/L)	NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.0001	<0.0001
Mn (mg/L)	0.1	0.31	0.03	2.4	1.5	0.002	0.04	0.46	13.1	<0.01	<0.01	<0.01
Ni (mg/l)	NA	0.14	0.01	4.6	0.12	<0.003	0.08	0.5	5	<0.01	<0.005	<0.005
Pb (mg/l)	NA	<0.01	<0.	<0.	<0.01	<0.	<0.	<0.01	<0.	<0.01	<0.01	<0.01

Variables	WUL limits	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8	Dump 20 composite	Dump 20 Slime	Dump 20 Sands
		0	010	010	0	010	010	0	010			
U (mg/L)	0.07	<0.00 4	<0. 004	<0. 004	<0.00 4	<0. 004	<0. 004	<0.00 4	<0. 004	<0.01	0.02	0.02
Zn (mg/l)	NA	0.12	0.05	3.7	0.31	0.005	0.21	0.69	4. 8	<0.01	0.03	<0.01

Table 3-8: SPLP leachate results

Variables	WUL limits	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8	Dump 20 composite	Dump 20 Slime	Dump 20 Sands
pH	6.0 - 8.5	4.1	4.7	2.7	3.8	7.3	2.7	3.1	3.2	6.7	5.7	5.8
EC (mS/m)	150.0	45.3	64.8	194	132.0	49.3	125.0	115.0	128.0		89.0	85.0
Ca (mg/L)	32.0	53	142	51	346	92	80	190	210	278	210	160
Mg (mg/L)	21.7	10.6	0.8	70	2.1	10.6	2.5	5.4	16.6	27	18	16
Na (mg/L)	12.2	3.0	3.6	3.1	3.1	4.0	3.2	3.1	3.2	21	6.5	9.9
Alkalinity (CaCO3 mg/L)	100.0	-	1.0	-	-	22.0	-	-	-		400	450
Cl (mg/L)	10.2	0.5	0.2	0.9	0.3	1.3	0.4	0.2	0.6	86	<0.05	0.6
SO4 (mg/L)	600.0	180.0	240.0	814	622	163.0	273.0	475.0	567.0	330.0	164.0	73.0
Nitrate (mg/L)	0.7	0.1	<0.1	<0.1	0.2	0.4	0.2	0.1	<0.1	0.2	<0.1	<0.1
F (mg/L)	0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.2	0.1	0.1
Al (mg/l)	NA	10.8	0.5	118.0	2.2	0.1	4.6	12.0	16.8	0.1	0.2	0.0
As (mg/l)	NA	0.1	0.1	<0.02	0.1	2.6	0.0	0.1	0.1	0.0	0.0	0.0
Cr (mg/l)	NA	<0.003	<0.003	0.8	<0.003	<0.003	<0.003	<0.003	<0.003	0.1	0.0	<0.002

Variables	WUL limits	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	SAMPLE 7	SAMPLE 8	Dump 20 composite	Dump 20 Slime	Dump 20 Sands
Cu (mg/l)	NA	0.2	<0.002	2.3	0.0	<0.002	0.1	1.4	0.6	<0.01	1.9	0.1
Fe (mg/L)	0.2	0.58	0.32	44	0.95	1.4	37	1.4	1.1	0.2	1.3	<0.05
Hg (mg/L)	NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.0001	<0.0001
Mn (mg/L)	0.1	0.45	<0.001	3	1.6	<0.001	0.0	0.54	10.4	1.57	1.3	2.1
Ni (mg/l)	NA	0.2	0.0	5.5	0.2	0.0	0.3	0.6	4.2	0.7	0.4	0.4
Pb (mg/l)	NA	<0.010	0.0	0.0	0.0	0.0	<0.010	<0.010	0.0	<0.01	0.0	<0.01
U (mg/L)	0.1	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.194	0.1	0.1
Zn (mg/l)	NA	0.2	0.1	4.6	0.4	0.0	0.7	1.0	4.0	0.2	3.3	0.2

Table 3-9: Mine water leachate results

Variables	WUL limits	SAMPL E 1	SAMPL E 2	SAMPL E 3	SAMPL E 4	SAMPL E 5	SAMPL E6	SAMPL E 7	SAMPL E 8	Mine water
pH	6.0 - 8.5	4.5	5.8	2.7	4.0	7.7	5.1	3.4	2.9	6.8
EC (mS/m)	150.0	319.0	309.0	418.0	309.0	318.0	307.0	322.0	369.0	361.0
Ca (mg/L)	32.0	668.0	652.0	700.0	625.0	679.0	606.0	663.0	622.0	669.0
Mg (mg/L)	21.7	122.0	118.0	177.0	133.0	131.0	120.0	121.0	174.0	122.0
Na (mg/L)	12.2	186.0	187.0	190.0	196.0	188.0	191.0	187.0	186.0	122.0
Alkalinity (CaCO3 mg/L)	100.0	19.0	24.0	0.0	0.0	55.0	27.0	0.0	0.0	28.0
Cl (mg/L)	10.2	63.0	63.0	65.0	66.0	64.0	62.0	65.0	65.0	62.0

Variables	WUL limits	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE6	SAMPLE 7	SAMPLE 8	Mine water
SO4 (mg/L)	600.0	2529.0	2492.0	3528.0	2342.0	2409.0	2405.0	2617.0	2850.0	2172.0
Nitrate (mg/L)	0.7	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
F (mg/L)	0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	0.1
Al (mg/l)	NA	5.4	0.2	141.0	3.4	0.1	0.3	8.6	35.0	0.1
As (mg/l)	NA	0.0	<0.001	0.0	0.0	0.3	<0.001	0.0	0.0	<0.001
Cr (mg/l)	NA	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.2	0.0
Cu (mg/l)	NA	0.2	0.0	2.2	0.1	0.0	0.0	0.2	0.9	0.0
Fe (mg/L)	0.2	0.1	0.1	13.7	0.2	0.4	16.6	0.2	1.3	1.3
Hg (mg/L)	NA	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn (mg/L)	0.1	20.0	19.5	23.0	24.0	12.5	21.0	21.0	45.0	19.1
Ni (mg/l)	NA	0.2	0.0	4.4	0.3	0.0	0.1	0.5	9.4	0.0
Pb (mg/l)	NA	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
U (mg/L)	0.1	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Zn (mg/l)	NA	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0	<0.005	<0.005

3.7 Waste Classification

Although the reclaimed tailings will be deposited into the pits, a waste classification was conducted to evaluate what type of waste the Millsite TSF is and what liner class would be required had the tailings been deposited on surface.

The waste classification is conducted in accordance with the National Environmental Management: Waste Act (NEM:WA) Regulations (2013). The assessment was undertaken by comparing the tailings' leachate concentration (LC) to the leachable concentration threshold (LCT), and the tailings' total concentration (TC) to the total concentration thresholds (TCT). The total concentration values were determined by *aqua regia* digestion while the leachable concentrations were prepared by a leachate of 1:20 solids per reagent water as per the NEM:WA guideline.

3.7.1 Introduction

TCT is measured in mg/Kg and is subdivided into three categories as follows:

- TCT0 limits based on screening values for the protection of water resources, as contained in the Framework for the Management of Contaminated Land (DEA, March 2010);
- TCT1 limits derived from land remediation values for commercial/industrial land (DEA, March 2010); and
- TCT2 limits derived by multiplying the TCT1 values by a factor of 4, as used by the Environmental Protection Agency, Australian State of Victoria.

LCT is measured in mg/L and is subdivided into four categories as follows:

- LCT0 limits derived from human health effect values for drinking water, as published by the Department of Water and Sanitation (DWS), South African National Standards (SANS), World Health Organization (WHO) or the United States Environmental Protection Agency (USEPA);
- LCT1 limits derived by multiplying LCT0 values by a Dilution Attenuation Factor (DAF) of 50, as proposed by the Australian State of Victoria;
- LCT2 limits derived by multiplying LCT1 values by a factor of 2; and
- LCT3 limits derived by multiplying the LCT2 values by a factor of 4.

A waste is classified from high risk (Waste Type 0) to low risk (Waste Type 4) based on comparison of the TC and LC of individual constituents in the waste against the TCT and LCT limits as per Table 3-10 and Table 3-11.

Table 3-10: Waste classification criteria

Waste Type	Element or chemical substance concentration	Disposal
0	LC > LCT3 **OR** TC > TCT2	Not allowed
1	LCT2 < LC ≤ LCT3 **OR** TCT1 < TC ≤ TCT2	Class A or Hh:HH landfill
2	LCT1 < LC ≤ LCT2 **AND** TC ≤ TCT1	Class B or GLB+ landfill
3	LCT0 < LC ≤ LCT1 **AND** TC ≤ TCT1	Class C or GLB- landfill
4	LC ≤ LCT0 **AND** TC ≤ TCT0 for metal ions and inorganic anions **AND** all chemical substances are below the total concentration limits provided for organics and pesticides listed	Class D or GLB- landfill

Table 3-11: Total and leachable concentration threshold limits

Parameter	Unit	TCT0	TCT1	TCT2	Unit	LCT0	LCT1	LCT2	LCT3
As, Arsenic	mg/kg	5.8	500	2000	mg/L	0.01	0.5	1	4
B, Boron	mg/kg	150	15000	60000	mg/L	0.5	25	50	200
Ba, Barium	mg/kg	62.5	6250	25000	mg/L	0.7	35	70	280
Cd, Cadmium	mg/kg	7.5	260	1040	mg/L	0.003	0.15	0.3	1.2
Co, Cobalt	mg/kg	50	5000	20000	mg/L	0.5	25	50	200
Cr total	mg/kg	46000	800000	N/A	mg/L	0.1	5	10	40
Cr (IV), Chromium (IV)	mg/kg	6.5	500	2000	mg/L	0.05	2.5	5	20
Cu, Copper	mg/kg	16	19500	78000	mg/L	2	100	200	800
Hg, Mercury	mg/kg	0.93	160	640	mg/L	0.006	0.3	0.6	2.4
Mn, Manganese	mg/kg	1000	25000	100000	mg/L	0.5	25	50	200
Mo, Molybdenum	mg/kg	40	1000	4000	mg/L	0.07	3.5	7	28
Ni, Nickel	mg/kg	91	10600	42400	mg/L	0.07	3.5	7	28
Pb, Lead	mg/kg	20	1900	7600	mg/L	0.01	0.5	1	4
Sb, Antimony	mg/kg	10	75	300	mg/L	0.02	1	2	8
Se, Selenium	mg/kg	10	50	200	mg/L	0.01	0.5	1	4
V, Vanadium	mg/kg	150	2680	10720	mg/L	0.2	10	20	80
Zn, Zinc	mg/kg	240	160000	640000	mg/L	5	250	500	2000

Parameter	Unit	TCT0	TCT1	TCT2	Unit	LCT0	LCT1	LCT2	LCT3
Chloride as Cl	mg/kg	n/a	n/a	n/a	mg/L	300	15000	30000	120000
Sulphate as SO_4	mg/kg	n/a	n/a	n/a	mg/L	250	12500	25000	100000
Nitrate as N	mg/kg	n/a	n/a	n/a	mg/L	11	550	1100	4400
F, Fluoride	mg/kg	100	10000	40000	mg/L	1.5	75	150	600
CN total, Cyanide total	mg/kg	14	10500	42000	mg/L	0.07	3.5	7	28

3.7.2 Total Concentration Results

The TC and LC results as compared to the TCT and LTC values are shown in Table 3-12 and Table 3-13 respectively.

Based on the total concentration results:

- All the samples are above the TCT0 by at least one parameter;
- Arsenic concentration is above the TCT1 in Sample 5 and above TCT0 in all samples;
- Antimony concentration is above TCT0 in all samples; and
- Selenium concentration is above TCT2 in Sample 5.

3.7.3 Leachable Concentration Results

Based on the leachable results:

- All samples (except for Sample 2) are above LTC0 by at least one parameter;
- Sample 5 falls above the LCT2 due to arsenic; and
- Samples 3 and 8 fall above the LTC1 due to nickel.

3.7.4 Classification

Statistically the Millsite TSF is a Type 3 waste as the TC of all of the samples is above the TCT0 threshold by at least one parameter, and the LC of all of the samples (expect for Sample 2) is above the LCTO threshold.

Type 3 waste can be disposed at a Class C landfill site as illustrated conceptually in Figure 3-16 and would require a 1.5 mm thick HDPE liner followed by a 300 mm thick clay liner. This would mean that if the reclaimed tailings was to be deposited on surface, a liner of a considerable cost would have been required due to the waste type and potential environmental impact.

Table 3-12: TCT Classification

Parameter	Unit	TCT0	TCT1	TCT2	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
As, Arsenic	mg/kg	6	500	2,000	269	51	45	350	1,363	62	98	56
Ba, Barium	mg/kg	63	6,250	25,000	55	28	52	130	31	56	62	30
Cd, Cadmium	mg/kg	8	260	1,040	2	1	1	3	10	1	1	1
Co, Cobalt	mg/kg	50	5,000	20,000	5	3	41	37	703	11	12	26
Cr total	mg/kg	46,000	800,000	N/A	188	130	186	138	140	156	179	97
Cu, Copper	mg/kg	16	19,500	78,000	37	14	67	36	773	12	51	28
Mn, Manganese	mg/kg	1,000	25,000	100,000	193	183	187	185	454	136	70	177
Mo, Molybdenum	mg/kg	40	1,000	4,000	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Ni, Nickel	mg/kg	91	10,600	42,400	26	20	122	72	928	22	38	65
Pb, Lead	mg/kg	20	1,900	7,600	43	27	42	273	275	38	41	48
Sb, Antimony	mg/kg	10	75	300	<1.000	<1.000	<1.000	<1.000	<1.000	<1.000	<1.000	<1.000
Se, Selenium	mg/kg	10	50	200	16	10	12	32	363	<3.000	<3.000	<3.000
V, Vanadium	mg/kg	150	2,680	10,720	38	27	33	24	44	31	28	17
Zn, Zinc	mg/kg	240	160,000	640,000	51	77	110	138	515	32	67	73

Table 3-13: LCT Classification

Parameter	Unit	LCT0	LCT1	LCT2	LCT3	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
As, Arsenic	mg/L	0.01	0.5	1.0	4.0	<0.020	<0.020	<0.020	<0.020	2.9	<0.020	<0.020	<0.020
B, Boron	mg/L	0.5	25	50	200	0.09	0.06	0.21	0.08	0.05	0.11	0.08	0.08
Cd, Cadmium	mg/L	0.003	0.15	0.30	1.20	<0.001	<0.001	0.01	<0.001	0.01	<0.001	0.001	0.01
Co, Cobalt	mg/L	0.5	25	50	200	0.05	0.005	1.6	0.06	0.02	0.07	0.2	2.1
Cr total	mg/L	0.1	5	10	40.0	<0.003	<0.003	0.61	0.003	<0.003	0.008	0.04	0.16
Cu, Copper	mg/L	2	100	200	800	0.21	0.01	2	0.05	0.008	0.05	0.2	0.35
Mn, Manganese	mg/L	0.5	25	50	200	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mo, Molybdenum	mg/L	0.07	3.5	7.0	28.0	0.003	0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001
Ni, Nickel	mg/L	0.07	3.5	7.0	28.0	0.14	0.01	4.6	0.12	<0.003	0.08	0.5	5
Pb, Lead	mg/L	0.01	0.50	1.0	4.0	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sb, Antimony	mg/L	0.02	1.0	2.0	8.0	0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Se, Selenium	mg/L	0.01	0.50	1.0	4.0	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
V, Vanadium	mg/L	0.20	10.0	20	80	<0.002	0.003	0.02	0.005	0.01	0.004	0.006	0.01
Zn, Zinc	mg/L	5	250	500	2,000	0.12	0.05	3.7	0.31	0.005	0.21	0.69	4.8

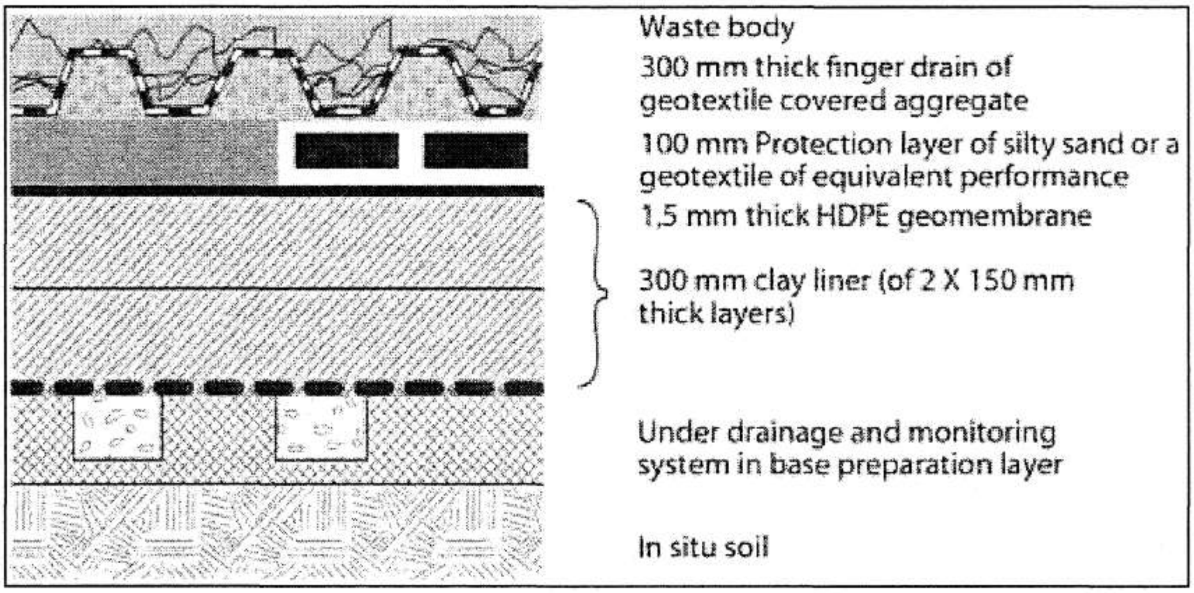

Figure 3-16: Class C liner requirements

4 Analytical Modelling

In 2012 during the assessment of the Dump 20 reclamation, the pits were assumed to be disconnected from the underground voids either due to the sealing of the foundation or the pit depth being shallow and not reaching the underground voids. As observed in the last four years of deposition in the Porges Pit from Dump 20, however, the pit is connected. The deposited tailings has seeped into the voids, with the exception of small heap that has started to accumulate on a portion of the Porges Pit.

The tailings in the Millsite TSF is estimated to be 107 million tonnes (Digby Wells, 2017). Considering a dry density of 2.5 t/m^3, the tailings has a volume of 42.8 million m^3. The volume could increase when water is retained in the wet slurry.

As shown in Table 4-1, the total capacity of the pits is 13.9 million m^3 (Ezendalo, 2009). If the slurry is deposited without disappearing to the underground mining voids, there is sufficient material to completely fill and rehabilitate the pits. The impact assessment in this study has been conducted with the assumption that the pits will be filled completely. Some slurry will enter the underground voids but it is not unreasonable to assume that with the already deposited Dump 20, the Millsite TSF (and possible other TSFs in the area that might be reclaimed in the future) is sufficient to completely backfill the pits and the mining voids.

SGL intends to deposit the residue at the rate of 400 000 tons/month into the pits. As per the WUL, at least 1 m^3 of water will be pumped out from the standing water of the pits or from 8

Shaft for each m^3 of tailings deposited into the pit. This will be conducted to ensure that the water table in the vicinity of the deposition pits does not rise and does not impact the groundwater flow direction. The decant will also not increase as a result of pit deposition.

As long as this pumping philosophy is not breached, the deposition into the pits is not expected to alter the groundwater flow direction or the decant rate. Any mounding of water level in the deposition area is expected to be temporary as the flow velocity through the mine void connecting the pits and 8 Shaft is significant.

The pumping of 8 Shaft is expected to create a cone of depression and the flow direction in the mine void is towards the shaft. The abstracted water will partly be used for the reclamation of the Millsite TSF and will partly be treated with lime before it is discharged downstream to compensate the groundwater baseflow feeding the Tweelopiespruit.

Table 4-1: Pit volumes (m^3)

Pit complex	Name	Pit Volume
Battery	North	312,530
	South	196,290
Porges	Porges Main	2,031,351
	Stubbs	
	RTR South	
	RTR North	363,041
SRK	SRK 2B	2,087,699
	SRK 3	951,582
Training Centre		189,471
Millsite		7,745,067
Total		**13,877,031**

5 Impact Assessment

The proposed reclamation of Millsite TSF and deposition of reprocessed tailings into the pits could have both positive and negative impacts on the groundwater environment. Potential impacts are assessed in the subsequent subsections considering the establishment, operational and closure phases.

5.1 Establishment Phase

The project activities, interactions and potential impacts during the establishment phase are listed in Table 5-1.

Table 5-1: Interactions and impacts during the establishment phase

Interaction	Impact
Construction of the surface infrastructure (installation of pipelines, access roads, site clearing and storm water trenches)	Groundwater contamination

No impact on the groundwater is expected as long as these activities are taking place above the water table which ranges between 3.5 and 11.1 m in the vicinity of the Millsite TSF. Diesel or other organic fluids and inorganic solvents might be spilled on the ground surface, or leak from storage tanks during the construction. Considering the depth of the water level, however, they are expected to volatilise and unlikely to reach the groundwater.

Establishment will also be conducted in a relatively short period compared to the operational and post-closure phases. Impacts on the groundwater environment are therefore rated as Negligible as provided in Table 5-2 below.

Table 5-2: Potential impact on groundwater quality during the establishment phase

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater quality deterioration			
Prior to mitigation/ management			
Duration	Short term (2)	The construction activities are expected to take place over less than 1 year.	Negligible (negative) – 8
Extent	Very limited (1)	Impact will be limited to specific isolated parts of the site	
Intensity	Minimal (1)	Considering the depth of the water table and the current groundwater quality, the impact intensity (if any) is expected to be minimal.	
Probability	Rare (2)	It is unlikely for any seepage during the	

Dimension	Rating	Motivation	Significance
		construction activity to seep and contaminate the groundwater, considering the water depth, construction duration and construction activities	
Nature	Negative		
Mitigation/ Management actions			
▪ Restrict areas that must be cleared of vegetation for construction activities to those of absolute necessity; ▪ Avoid constructing below the water table as far as possible; and ▪ Continue the existing monitoring programme.			
Post- mitigation			
Duration	Short term (1)	Any impact on the groundwater is expected to recover after the construction phase is completed	Negligible (negative) – 6
Extent	Limited (1)	Only isolated areas where there will be spillages or site cleaning below the water table (if any) will be affected	
Intensity	Minimal natural impact (1)	Considering the duration of the construction period and water table depth, the intensity will be minimal	
Probability	Improbable (2)	It is unlikely for groundwater impact to occur during the construction phase, especially with the implementation of the above proposed management plan	
Nature	Negative		

5.2 Operational Phase

The activities during the operational phase that are relevant to the groundwater environment are the hydraulic reclamation of the Millsite TSF complex and the discharge of the reprocessed tailings into the open pits.

5.2.1 Tailings Reclamation

The historical TSFs in the region (including Millsite TSF complex) are not lined and seepage is expected to drain into the underlying groundwater system, including the sensitive dolomitic aquifer. The current hypothesis is that if there were no TSFs located directly over the dolomites, the current decant volume would have decreased, and it is likely that the dolomitic water pumped from the underground chambers would be of better quality than the current status. In addition, the pumping and treatment cost would be substantially less if the TSFs seepage portion could be eliminated.

Further to this, infiltration from the Millsite TSF will be reduced if the tailings is removed from surface, the contaminant loads will be less from a pollution perspective. At present, the presence of the TSF and the continued dewatering activities in the compartment will encourage continued infiltration of seepage to the deeper aquifer units, the consequent deterioration of water quality, increased decant rates and increased volumes of water to be pumped from the underground chambers.

The long-term impact as a result of the reclamation operations at the TSF is therefore anticipated to be positive since the TSF, which is a source of contamination, will be removed. In the short-term, however, the hydraulic reclamation could result in the partial seepage through the TSF (Table 5-4). The exposure of the tailings to oxygen and water can result in AMD.

Table 5-3: Interactions and impacts during the TSF reclamation

Interaction	Impact
Hydraulic reclamation	Seepage through the TSF of the water to be used for hydraulic reclamation inside the foot print
Tailings exposure to oxygen and water	Acid mine drainage
Pump station or pipelines	Slime or process spillage from pump station or pipeline

The potential impacts associated with the reclamation of the TSF are provided in Table 5-4.

Table 5-4: Potential impact during the operation phase of the re-mining of the TSF

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater contamination due to seepage during hydraulic re-mining			
Prior to mitigation/ management			
Duration	Project Life (5)	Seepage of contaminated water could occur during the operation phase	Minor (negative) – 44

Dimension	Rating	Motivation	Significance
Extent	Local (3)	The impact is expected to be local	
Intensity	Moderate (3)	The contamination will be moderate as it will be local and an area that is already contaminated	
Probability	Probable (4)	Seepage due to the water used during hydraulic re-mining is probable	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels; and ▪ Minimise ponding of water within the reclamation area.			
Post- mitigation			
Duration	Project Life (5)	Contamination due to the hydraulic reclamation will persist during the life of mine	Negligible (negative) – 24
Extent	Limited (2)	The seepage is expected to be limited to the TSF footprint area	
Intensity	Minimal (1)	Impact will be underneath the TSF only due to the dolomitic nature and vertical hydraulic gradient	
Probability	Unlikely (3)	Impact to the groundwater outside the TSF areas is unlikely	
Nature	Negative		
Impact Description: Acid mine drainage due to the TSF disturbance and exposure to oxygen and moisture			
Prior to mitigation/ management			
Duration	Project Life (5)	Acid mine drainage can be generated and heavy metals can be mobilised. This is likely to persist throughout the life of operation	Minor (negative) – 54
Extent	Local (3)	The pollution plume is expected to be local laterally, but with a potential of migrating vertically to the underground	

Dimension	Rating	Motivation	Significance
		mines	
Intensity	Minor (2)	The area is already contaminated. The existence of dolomite is also beneficial to buffer the acid generated. The centre of the tailings dam is probably alkaline and will not become acidic if it is removed quickly.	
Probability	Almost certain (6)	AMD generation is during the reclamation process and tailings disturbance is almost certain	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality; and ▪ Minimise area of disturbance to avoid AMD at multiple places.			
Post management			
Duration	Long-term (4)	AMD generation will stop once the TSFs have been reclaimed	Negligible (negative) – 21
Extent	Limited (2)	With the reclamation from one end of the TSF, instead of multiple areas is likely to render AMD generation at controlled sites only	
Intensity	Minimal (1)	Once the AMD generation is controlled, the environmental impact in the area that is already contaminated is expected to be minimal	
Probability	Unlikely (3)	AMD is unlikely to occur if the above recommended procedures are implemented	
Nature	Negative		

5.2.2 Pit Deposition

Backfilling of the open pits with the reprocessed tailings is likely to result in the increase of the groundwater level, increase of decant rate and potentially impact on the groundwater quality. The impact rating for all the pits is expected to be similar, although the water level recovery will be quicker in the smaller pits such as the Battery Pits than the larger Porges and Millsite Pits.

The water in the underground mine void is affected by AMD and is already of poor quality with pH of approximately 3. Without backfilling, the open pits are a constant source of water ingress into the Western Basin mine void as rainwater falls into the pits and enters into the mine voids. This rainwater then comes into contact with pyrite on the exposed pit walls and assumes the characteristics of acid mine drainage, similar to that of the underlying mine void. Filling the pits with tailings would therefore reduce the groundwater recharge thereby reducing decant and subsequent water treatment costs.

The reprocessed tailings is treated with lime in the metallurgical plant and is generally deposited at high pH values (around 10 – 11). This is expected to have a positive impact in the groundwater quality as the pH of the mine void will increase and precipitate the dissolved metals. As described in the water quality section above; 17 and 18 Winzes represented poor water quality of pH less than 5 up until 2012. This has been improving since then to its current value of 6.5. This is likely to be due to the alkaline slurry deposited from Dump 20 and is one of the positive impacts associated with the discharging of alkaline tailings into the pits, as this would mean that dissolved metals will precipitate.

The deposition of the slurry is, however, expect to increase the salt load which overall has a negative impact.

During the operational phase, water will be added to the pits in the tailings slurry. This will result in an increase in the pits and mine void water levels. As the pits are filled with tailings slurry, water levels in the pits will be higher than the surrounding groundwater level. This is however expected to only be in the short-term since SGL will be pumping at a 1:1 ratio to the amount of slurry deposited. The pumping will take place from 8 Shaft with the intent of maintaining the groundwater level and the abstracted water will be used for the reclamation of the Millsite TSF complex. Excess water will be discharged to the environment after being treated with lime.

Although the pumping of 8 Shaft at the appropriate abstraction rate can avoid decanting, the lowering of the hydraulic head can affect the regional water level which could result in drying of springs and streams. If no abstraction from 8 Shaft is to take place to balance the deposition, however, there is a possibility of an increase in discharge from the decant point due to the displacement of water in the pits by the newly deposited tailings.

The project activities, interactions and potential impacts during the pit deposition are listed in Table 5-5.

Table 5-5: Interactions and impacts during pit deposition

Interaction	Impact

Interaction	Impact
Pit deposition	Rising of water level in the vicinity of the pits
	Increase of decant rates
	Deterioration of groundwater quality

The potential impacts associated with the TSF reclamation and pit deposition are given in Table 5-6.

Table 5-6: Potential impact during the operation phase due to pit deposition

Dimension	Rating	Motivation	Significance
Impact Description: Groundwater contamination due to pit deposition			
Prior to mitigation/ management			
Duration	Project Life (5)	Contaminants will be added as part of the slurry throughout the life of mine	Minor (negative) – 45
Extent	Local (3)	The impact is expected to be local	
Intensity	Minimal (1)	The intensity is rated as minimal since the area is already contaminated. In fact the reprocessed tailings is has alkaline pH and is expected to have a positive impact as it will neutralise the acidic mine water but the salt load is expected to increase.	
Probability	Likely (5)	The salt load of the mine void water is likely to increase	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels; ▪ Ensuring that the deposited tailings is alkaline; and ▪ Ensuring that the cyanide is destroyed before deposited.			
Post- mitigation			
Duration	Project Life (5)	Contamination due to the hydraulic reclamation will persist during the life of mine	Negligible (negative) – 32
Extent	Limited (2)	The impact is expected to be local	
Intensity	Minimal (1)	Impact will be underneath the TSF only	

Dimension	Rating	Motivation	Significance
		due to the dolomitic nature and vertical hydraulic gradient	
Probability	Probable (4)	The impact is likely to occur even with the above proposed mitigation measures	
Nature	Negative		
Impact Description: impact on the groundwater level			
Prior to mitigation/ management			
Duration	Project Life (5)	The water level is expected to increase due to the pit deposition throughout the life of mine	Minor (negative) – 36
Extent	Local (3)	The radius of influence is expected to be local as it will be maintained by the decant point and hydrostatic pressure	
Intensity	Minor (2)	The rise in water level is not expected to be minor as the slurry will settle in the mine void	
Probability	Probable (4)	The rise in water level is likely to occur as the slurry is discharged into the pits	
Nature	Negative		
Mitigation/ Management actions			
▪ Monitoring of groundwater level; ▪ Abstract equal volume of water from 8 Shaft (which is connected with the pits) to ensure that the water level or decant rate does not increase; and ▪ The abstracted water can be used for the reclamation of the tailings or discharged to the environment after treatment.			
Post management			
Duration	Short-term (2)	With the abstraction of equal volume of water from 8 Shaft, the rise in water level is expected to be temporary	Negligible (negative) – 10
Extent	Limited (2)	The rise in water level is expected to only be in the immediate vicinity of the pits	

Dimension	Rating	Motivation	Significance
Intensity	Minimal (1)	No impact on the water level or decant rate is expected with the abstraction of equal volume of water	
Probability	Rare (2)	AMD is unlikely to occur if the above recommended procedures are implemented	
Nature	Negative		

5.3 Decommissioning and post closure

5.3.1 Tailings Reclamation

The impact as a result of the reclamation is anticipated to be positive after closure. This is due to the removal of the TSF, which is a source of contamination.

As discussed above, the Millsite TSF complex is not lined and seepage is expected to drain into the underlying groundwater system. Seepage from the TSF, which is partly over dolomite, would impact the water quality negatively. This implies that if infiltration of tailings seepage can be reduced, the contaminant loads will be less from a pollution perspective and decant rates will be less.

The interactions and potential impacts after the TSF reclamation is listed in Table 3-6 above.

Table 5-7: Interactions and impacts after the TSF reclamation

Interaction	Impact
TSF removal	No seepage and AMD drainage

The potential impacts associated with the reclamation of the TSF are provided in Table 5-8.

Table 5-8: Potential impacts after closure due to the TSF reclamation

Dimension	Rating	Motivation	Significance
Impact Description: Impact on groundwater contamination due to re-mining of the Millsite TSF			
Prior to mitigation/ management			
Duration	Permanent (7)	Seepage of contaminated water will permanently be removed	Moderate (positive) – 105
Extent	Local (3)	The impact is expected to be local as the site is already contaminated	

Dimension	Rating	Motivation	Significance
Intensity	Serious (5)	There will be significant environmental advantages when the unlined TSF is removed	
Probability	Definite (7)	There are sound scientific reasons to expect that the positive impact will definitely occur	
Nature	Positive		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels; and ▪ Rehabilitation of old TSF footprints.			
Post- mitigation			
Duration	Permanent (7)	The source of the contamination plume will be permanently removed	Moderate (positive) – 105
Extent	Local (3)	The impact is expected to be local as the area is already contaminated	
Intensity	Serious (5)	There is positive environmental advantages once the unlined TSF is removed	
Probability	Definite (7)	There are sound scientific reasons to expect that the positive impact will definitely occur	
Nature	Positive		

5.3.2 Pit Deposition

After the pits have been backfilled, the tailings will be left to dewater and consolidate. The tailings backfill should be domed, shaped, profiled and capped with a soil/weathered material layer that will prevent ponding and minimise infiltration of rain water. The recharge from the pits to the underground mine void will be significantly less than the recharge prior to backfilling. During this period sulphide oxidation and AMD formation is expected to be limited significantly as a result of the soil cap that excludes exposure of the deposited tailings to atmospheric oxygen.

The filling of the underground mine void will also minimise the volume available for decant, meaning that the decant rate will be minimised

The interactions and potential impacts after the deposition in the pits is given in Table 5-6 above.

Table 5-9: Interactions and impacts of pit deposition after the closure phase

Interaction	Impact
Pit rehabilitation	No seepage from the pits Decrease of decant rate

The potential impacts associated with the closure of the pits are given in Table 5-10.

Table 5-10: Potential impacts after closure due to pit rehabilitation

Dimension	Rating	Motivation	Significance
Impact Description: Impact on groundwater contamination			
Prior to mitigation/ management			
Duration	Permanent (7)	When the pits are completely filled, there will be no source of AMD ingress into the underground	Moderate (positive) – 78
Extent	Local (3)	The impact is expected to be local as the site is already contaminated and improvement in the pit recharge quality will only have a local extent	
Intensity	Moderate (3)	The backfilling of the pits will reduce recharge of poor quality and will have positive environmental significance	
Probability	Highly probable (6)	The closure of the pits will definitely have a positive impact	
Nature	Positive		
Mitigation/ Management actions			
▪ Monitoring of groundwater quality and water levels; and ▪ Rehabilitation of the pits by properly shaping and capping with a soil/weathered material layer that will prevent ponding and minimise infiltration of rain water.			
Post- mitigation			
Duration	Permanent (7)	The source of the contamination plume and groundwater ingress will be permanently removed	Moderate (positive) – 98
Extent	Local (3)	The impact is expected to be local as the sites are already contaminated	
Intensity	Moderate (4)	The rehabilitation and vegetating of the pits will have a positive impact of moderate intensity	
Probability	Definite (7)	The closure and rehabilitation of the pits will definitely have a positive impact	
Nature	Positive		

6 Unplanned Events and Low Risks

The unplanned event that may happen at the project site and the proposed mitigation plan are listed in Table 6-1.

Table 6-1: Unplanned events, low risks and their management measures

Unplanned event	Potential impact	Mitigation/ Management/ Monitoring
Hydrocarbon spillage and spillages from pipelines, and pump station	Deterioration of groundwater quality	■ It is recommended that diesel or other chemicals be used without spillage, and machinery should be properly maintained. ■ Fuel and oil reservoirs must be in a bunded area. ■ If a considerable amount of fluid is accidentally spilled, the contaminated soil should be scraped off and disposed of at an acceptable dumping facility. The excavation should be backfilled with soil of good quality. ■ Monitoring of pipelines for seepage should be conducted. Seeping pipeline should be sealed. ■ Monitoring boreholes, particularly those located within the environs of the Millsite and pits have to be monitored for both water level and quality.

7 Cumulative Impacts

There are a few municipal sewage waste water treatment plants and mines operating in West Rand. Sources of future surface and groundwater impacts in the affected catchments will therefore not be from the Millsite TSF reclamation only.

The current water qualities of the Tweelopiespruit and the Wonderfonteinspruit are poor when benchmarked with WUL limits. This is mainly due to decant from the old mine workings and also discharge of partially treated mine water. There is also a Waste Water Treatment Plant that discharges into the catchments and this could possibly have contributed onto the existing water quality status.

The closure and rehabilitation of the Millsite TSF and surrounding pits by SGL will definitely have a positive impact on the surface and groundwater environment. However, a rehabilitation strategy that encompasses the nearby mines and municipal treatment activities is required for a lasting improvement with a regional footprint.

8 Monitoring Programme

A monitoring programme is essential as a management tool to detect negative impacts as they arise and to ensure that the necessary mitigation measures are implemented. It also ensures that storm water management structures are in working order. The on-going monitoring should be maintained throughout the project life.

Water monitoring and analysis are conducted by an external contractor at Rand Uranium Cooke operations and in accordance to the license requirements. This section provides the details of the existing monitoring programme that will continue to be carried out at the Rand Uranium Cooke operations. The monitoring programme covers all watercourses that interact and are affected by the operation.

8.1 Groundwater Monitoring

The groundwater monitoring programme comprises the monitoring of boreholes at the open pits, Cooke groundwater and the Millsite groundwater. Water samples are collected on a monthly basis in the open pits for full chemical analysis while the Cooke and Millsite groundwater are sampled and analysed quarterly. The groundwater sampling points are provided in Table 8-1 below as well as shown in Figure 8-1 below.

Table 8-1: Groundwater Sampling Locations

Sample ID	Sample Description	Coordinates	Coordinates
Open Pits			
PBH1	North of Millsite North Pit	26° 7'53.57"S	27°43'30.15"E
PBH4	East of Millsite Pit	26° 7'58.56"S	27°43'37.82"E
PBH6	Southeast of Millsite Pit	26° 8'11.86"S	27°43'43.49"E
PBH7	East of deep pit	26° 9'33.04"S	27°43'54.16"E
PBH8	East of SRK2 North Pit	26°10'16.1"S	27°44'3.4"E
PBH9	Northeast of SRK2 North Pit	26°10'10.3"S	27°44'7.01"E
PBH10	Southeast of SRK3 Pit	26°10'42.99"S	27°43'53.10"E

PBH11	-	26° 9'20.48"S	27°44'16.39"E
PBH12	-	26° 9'34.81"S	27°44'12.77"E
PBH13	-	26° 9'3.37"S	27°44'15.05"E
PBH14	East of Porges Pit	26°11'6.54"S	27°42'36.54"E
PBH15	South of Porges Pit	26°11'28.28"S	27°42'33.74"E
Cooke Ground Water			
ZZM6	West Rand AH - ZB compartment	26°18'35.20"S	27°47'28.90"E
Z-ZM36	West Rand AH - ZB compartment	26°18'22.50"S	27°46'31.00"E
ZZM43	West Rand AH - ZB compartment	26°17'27.87"S	27°44'37.08"E
L5	Lindum reef borehole adjacent to Lindum north TSF	26°10'51.60"S	27°43'11.35"E
CSD3	Northeast of Cooke TSF	26°14'25.50"S	27°45'25.40"E
CSD7	Northwest of Cooke TSF	26°14'16.60"S	27°44'59.50"E
CHostel1	Cooke 1 hostel groundwater	26°15'15.18"S	27°44'26.94"E
CPlotX	Chicken farmer groundwater	26°14'30.97"S	27°44'8.04"E
CPlotX	Chicken farmer groundwater	26°14'28.58"S	27°44'6.60"E
CSRK8	Southwest of Cooke TSF	26°14'39.10"S	27°44'16.90"E
CSRK5D	Southeast of Cooke TSF	26°14'54.12"S	27°44'52.62"E
CSRK12	North of Cooke TSF RWD	26°14'16.27"S	27°44'21.23"E
GABH4	Lower west of plant	26°13'7.10"S	27°43'33.70"E
GABH5	Middle west of plant	26°13'1.90"S	27°43'38.30"E
GABH6	Upper west of plant	26°12'55.30"S	27°43'34.10"E
GABH7	Northwest of plant	26°12'57.60"S	27°43'27.90"E

Millsite Groundwater			
Millsite North	Millsite North Pit	26° 8'2.31"S	27°43'32.39"E
SRK2 North Pit	SRK2 North Pit	26°10'14.18"S	27°43'58.98"E
SRK2 South Pit	SRK2 South Pit	26°10'19.46"S	27°43'58.44"E
SRK3 Pit	SRK3 Pit	26°10'37.33"S	27°43'50.97"E
Main Porges Pit	Main Porges Pit	26°11'8.20"S	27°42'33.69"E
FTN1	Fountain NW of decant shaft	26° 6'40.10"S	27°43'21.30"E
Decant	Decant from closed shaft	26° 6'54.91"S	27°43'29.63"E
RS2	East of decant shaft	26° 6'55.35"S	27°43'35.70"E
WBH2	Behind Millsite rock dump	26° 7'46.03"S	27°43'12.33"E
MBH1	Millsite borehole at corner	26° 7'51.02"S	27°43'26.39"E
Fountain A	Fountain west of Millsite TSF	26° 7'34.58"S	27°40'36.01"E
Fountain B	Fountain west of Millsite TSF	26° 7'36.00"S	27°40'37.40"E
Farmers Dam	Farmer dam Northeast of Millsite TSF	26° 7'3.50"S	27°43'24.30"E
Plot43	Groundwater north of Millsite TSF	26° 6'21.80"S	27°41'53.50"E
Plot45	Groundwater north of Millsite TSF	26° 6'18.40"S	27°41'48.20"E
Plot47	Groundwater north of Millsite TSF	26° 6'11.70"S	27°41'42.00"E
Plot63	Groundwater Northeast of Millsite TSF	26° 6'51.30"S	27°40'41.50"E
Plot69	Groundwater Northeast of Millsite TSF	26° 6'37.90"S	27°40'29.50"E

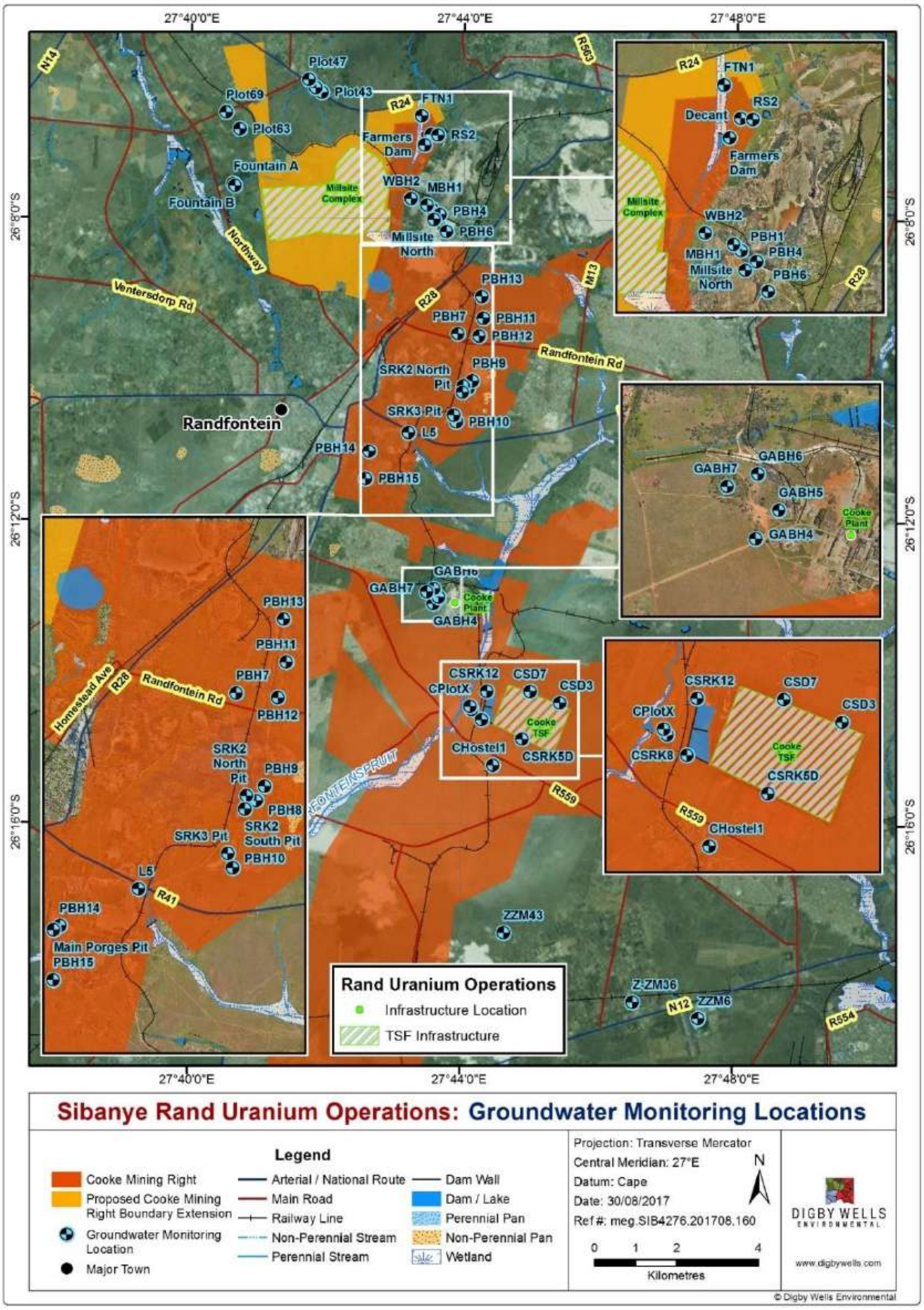

Figure 8-1: Groundwater Monitoring Points

8.2 Surface Water Monitoring

The surface water monitoring programme consists of monitoring points within the Tweelopiespruit West and East as well as the Wonderfonteinspruit. Water samples are collected on a monthly basis for a full chemical analysis while the water discharged into Cooke Shaft 1 and Cooke Shaft 2 into the Wonderfonteinspruit is sampled and analysed on a weekly basis.

The surface water sampling points are provided in Table 8-2 below as well as shown in Figure 8-2.

Table 8-2: Surface Water Sampling Locations

Sample ID	Sample Description	Coordinates	Coordinates
POINT2	Tweelopies West Point 2 overflow near Greenhills Avenue	26° 9'56.30"S	27°41'16.20"E
POINT3	Tweelopies West Point 3 Elandsvlei dam overflow	26° 8'44.80"S	27°40'47.78"E
POINT4	Tweelopies West Point 4 bridge on dirt road below slimes dam 41	26° 8'29.68"S	27°40'32.06"E
POINT5	Tweelopies West Point 5 Spring entering Elandsvlei	26° 7'33.82"S	27°40'19.54"E
POINT6	Tweelopies West Point 6 bridge Krugersdorp/ Venterdorp road	26° 6'54.93"S	27°39'41.41"E
POINT7	Tweelopies WEST Point 7 Dirk Mellet Plot 129	26° 7'45.51"S	27°40'36.23"E
POINT8	Tweelopies WEST Point 8 (Plot 132)	26° 7'36.45"S	27°40'30.84"E
W4	West Rand Cons slimes effluent	26° 8'29.14"S	2 7°45'53.06"E
W5	Wonderfonteinspruit at Kagiso low bridge	26° 9'21.75"S	27°45'52.15"E
W6	Wonderfonteinspruit at Randfontein/Roodepoort bridge no. 450	26° 9'52.60"S	27°46'0.88"E
W7	Wonderfonteinspruit at Kagiso bridge	26°10'22.25"S	27°46'40.09"E
W8	Wonderfonteinspruit upstream of Flip Human	26°10'39.30"S	27°45'58.65"E

	STP		
W9	Flip human STP effluent discharge	26°10'55.58"S	27°46'12.97"E
W10	Attenuation dam outlet	26°12'58.89"S	27°44'29.33"E
W11	Cooke Plant effluent		
W12	Wonderfonteinspruit before Cooke TSF	26°13'58.70"S	27°44'12.75"E
W13	Wonderfonteinspruit after Cooke TSF	26°14'43.77"S	27°43'51.21"E
Cooke1	Cooke1# discharge to the Wonderfonteinspruit	26°14'57.18"S	27°44'5.26"E
W15	Wonderfonteinspruit at bridge before Cooke 2#	26°15'57.27"S	27°41'56.74"E
Cooke2	Cooke2# discharge to Magazine pan	26°16'47.64"S	27°43'32.46"E
W17	Donaldson dam inflow	26°16'16.72"S	27°41'35.74"E
W18	Donaldson dam outflow	26°16'55.48"S	27°41'1.11"E
TCTA (V2)	BRI Dam mixture to HDS Plant	26° 6 55.67S	27° 43 22.31E
TCTA V1.A	Uncontrolled Overflow into collection pond (trench)	26° 6 27.50S	27° 43 20.54E
TCTA V1.B	RU Treated water before game reserve - collection pond (trench)	26° 7 15.61S	27° 43 11.73E
8 Shaft	Water pumped from western basin void (Shaft)	26° 08 07.42S	27° 43 10.15E
TCTA V1.C	Uncontrolled and Treated water combined into game reserve (mixing sump)	26° 6 24.96S	27° 43 20.16E

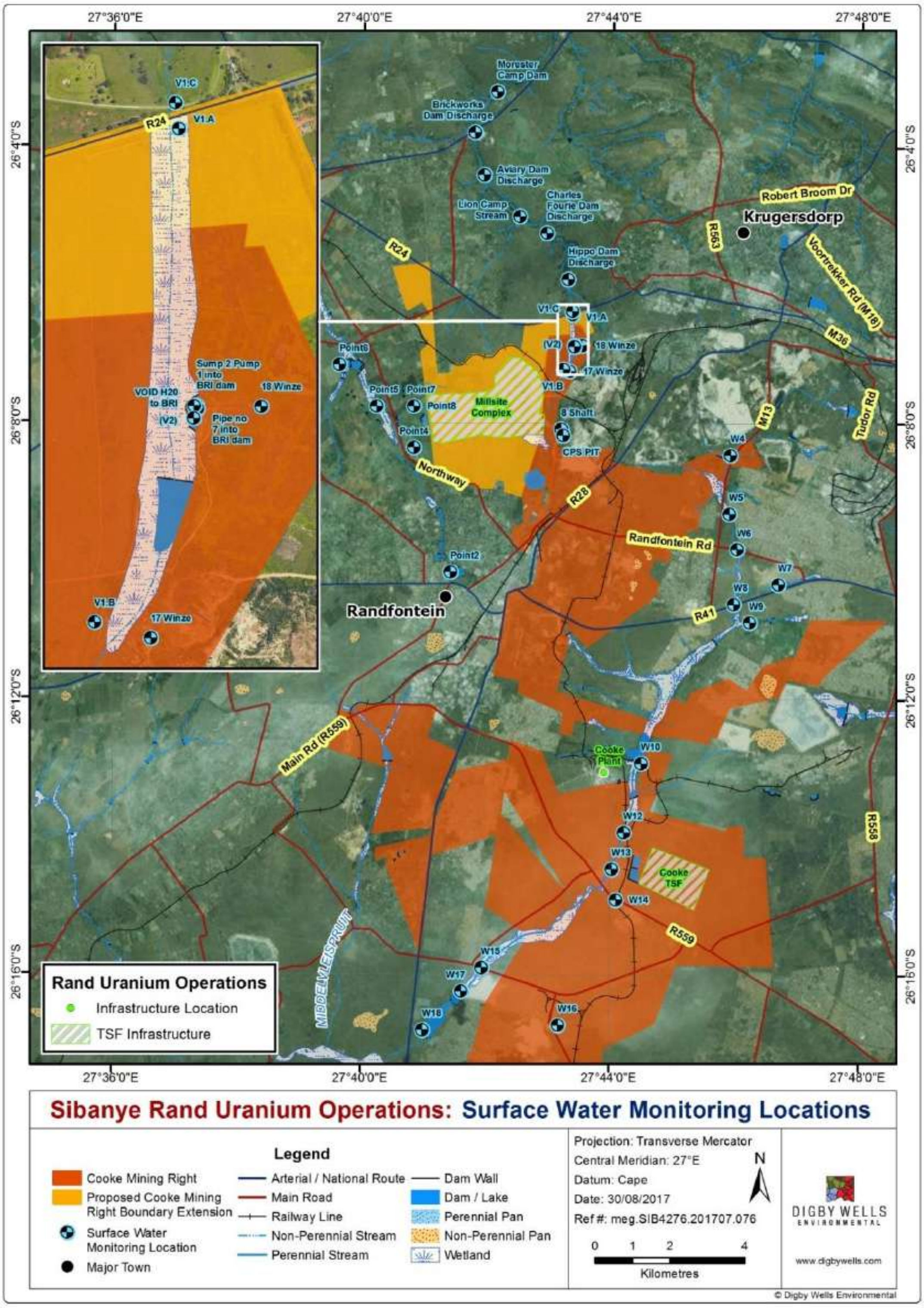

Figure 8-2: Surface Water Monitoring Points

9 Conclusion and Recommendation

9.1 Conclusion

The following conclusions are made based on the groundwater study:

- Groundwater occurrences in the study area are predominantly restricted to the following types of aquifers:
  - Weathered rock aquifer in the Witwatersrand, Ventersdorp and Transvaal Formations;
  - Fractured rock aquifer in the Witwatersrand, Ventersdorp and Transvaal Formations;
  - Dolomitic and Karst Aquifers; and
  - Mine void aquifer.
- The groundwater elevation in the top weathered and dolomitic aquifers that are not connected with the mine void mimics the topography. Although the gradient is generally flatter in the dolomitic aquifer, the flow direction follows the topography and is towards the local streams. Monitoring data shows that that the groundwater level divide is similar to the surface watershed areas.
  - The natural groundwater flow direction in the A21D quaternary catchment (where Millsite TSF, Millsite Pit and Tweelopie Stream are located) is generally from south to north, while in the C23D catchment (where the rest of the pits are located) is generally from north to south.
  - The hydraulic head and groundwater flow direction in the mine void is controlled by the decant, abstraction that is taking place at 8 Shaft, pit deposition, geological structures and mine interconnectivity. Plans were presented to lower the water level in the mine void to below an environmental critical level (ECL), to minimise impact on surface and groundwater. The discharge was proposed from a low-lying shaft (8 Shaft). Pumping to achieve this objective commenced in April 2012.
  - Although the pumping of 8 Shaft at the appropriate abstraction rate can avoid decanting, the lowering of the hydraulic head can affect the regional water level which could result in drying of springs and streams.
  - The Porges, SRK and Battery Pits are in the C23D catchment while the decant point and 8 Shaft are in the A21D. However, the flow from the pits is towards the 8 Shaft against the topographic gradient. This is due to the lowering of the hydraulic head at the shaft together with the Witpoortjie Fault south of the pits which is predominantly a flow barrier.

- The water quality in majority of the monitoring points is either in the good or acceptable category. The main concern is the quality of the 17 Winze, 18 Winze, Borehole PH6 (located close to the Millsite Pit) and SRK Pit 2 where it is currently above the 150 mS/m WUL limit.
  - The 17 and 18 Winzes pose a special concern as they are upgradient of the Tweelopiespruit East and in the area of the decanting elevation. It should, however, be noted that the quality from both winzes have been improving since monitoring data is available in late 2009. The EC was approximately 500 mS/m in 2009 and has gradually decreased to its current value of approximately 325 mS/m.
  - The poor water quality of the winzes cannot be associated with the deposition of the reclaimed Dump 20 into the pits. The water quality was already unacceptable before the reclamation started and the trend has not changed as a result of the input deposition.
  - The pH of the 17 and 18 winzes was approximately 5 until February 2013. Thereafter it steadily increased to the current pH of 6.45. Both winzes are within the WUL limit and the trend is that the pH will keep on increasing. The increase in pH is suspected to be a result of the discharge of the reclaimed Dump 20 tailings which has a pH of between 10 and 11. This is one of the positive impacts associated with the discharging of alkaline tailings into the pits, as this would mean that dissolved metals will precipitate.
- The geochemical results of the Millsite TSF have been compared to previous work conducted on Dump 20 to evaluate if the Millsite is more of an environmental concern than Dump 20. The result shows that the two tailings have similar acid generation potential. The metals expected to leach under neutral or acidic conditions are also generally similar.
- The Millsite tailings was leached using the mine void water to determine the leachate characteristics. The mine water is already contaminated to a large extent and the addition of the tailings material does not dramatically change this level of contamination.
- The historical TSFs in the region (including Millsite TSF complex) are not lined and seepage is expected to drain into the underlying groundwater system, including the sensitive dolomitic aquifer. If the TSF is reclaimed, the current decant volume would have decreased, and it is likely that the dolomitic water pumped from the underground chambers would be of better quality than the current status. In addition, the pumping cost would be substantially less if the TSFs seepage portion could be eliminated.

- Further to this, infiltration from the Millsite TSF will be reduced if the tailings is removed from surface, the contaminant loads will be less from a pollution perspective. At present, the presence of the TSF and the continued dewatering activities in the compartment will encourage continued infiltration of seepage to the deeper aquifer units, the consequent deterioration of water quality, increased decant rates and increased volumes of water to be pumped from the underground chambers.
- The long-term impact as a result of the reclamation operations at the TSF is therefore anticipated to be positive since the TSF, which is a source of contamination, will be removed. In the short-term, however, the hydraulic reclamation could result in the partial seepage through the TSF. The exposure of the tailings to oxygen and water can result in AMD.

- During the operational phase, water will be added to the pits in the tailings slurry. This will result in an increase in the pits and mine void water levels. As the pits are filled with tailings slurry, water level in the pits will be higher than the surrounding groundwater level. This is however expected to only be in the short-term since SGL will be pumping at a 1:1 ratio to the amount of slurry deposited. The pumping will take place from 8 Shaft with the intent of maintaining the groundwater level and the abstracted water will be used for the reclamation of the Millsite TSF complex. Excess water will be discharged to the environment after being treated with lime.
  - Without backfilling, the open pits are a constant source of water ingress into the Western Basin mine void as rainwater falls into the pits and enters into the mine voids. Filling the pits with tailings would therefore reduce the groundwater recharge thereby reducing decant and subsequent water treatment costs.
  - The reprocessed tailings is treated with lime in the metallurgical plant and is generally deposited at high pH values (around 10 – 11). This is expected to have a positive impact in the groundwater quality as the pH of the mine void will increase and precipitate the dissolved metals.
  - Although the pumping of 8 Shaft at the appropriate abstraction rate can avoid decanting, the lowering of the hydraulic head can affect the regional water level which could result in drying of springs and streams.

9.2 Recommendation

There are a couple of municipal sewage waste water treatment plants and mines operating in West Rand. The closure and rehabilitation of the Millsite TSF and surrounding pits by SGL will definitely have a positive impact on the surface and groundwater environment. However, a rehabilitation strategy that encompasses the nearby mines and municipal treatment activities is required for a lasting improvement with a regional footprint.

The following management plans are recommended to minimise impacts on the groundwater during the TSF reclamation and pit deposition:

- During the establishment phase, restrict areas that must be cleared of vegetation for construction activities to those of absolute necessity;
- Avoid constructing below the water table as far as possible;
- Minimise ponding of water within the reclamation area to avoid AMD seepage during the operation phase;
- Ensuring that the deposited tailings is alkaline;
- Ensuring that the cyanide is destroyed before deposited;
- Abstract equal volume of water from 8 Shaft (which is connected with the pits) to ensure that the water level or decant rate does not increase;
- The abstracted water can be used for the reclamation of the tailings or discharged to the environment after treatment;
- The water levels measured directly from the pits should be made available as this would help to assess their hydraulic connectivity. The water levels at 8 Shaft, 17 Winze and 18 Winze should also be made available;
- Rehabilitate the pits by properly shaping and capping with a soil/weathered material layer that will prevent ponding and minimise infiltration of rain water.

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