DIGBY WELLS ENVIRONMENTAL

Sasol Mining Sigma Colliery Ash Backfilling Project, Sasolburg, Free State Province

Surface Water Assessment Report

Project Number:

SAS5184

Prepared for:

Sasol Mining (Pty) Ltd

July 2018

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Report Type:	**Surface Water Assessment Report**
Project Name:	**Sasol Mining Sigma Colliery Ash Backfilling Project, Sasolburg, Free State Province**
Project Code:	**SAS5184**

Name	Responsibility	Signature	Date
Chenai Madamombe	Specialist Assessment		October 2013
Gary Morgan	1st Review		October 2013
Marcelle Radyn	2st Review		October 2013
Mashudu Rafundisani	Baseline Update		July 2018

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DECLARATION OF THE SPECIALIST

Digby Wells and Associates (South Africa) (Pty) Ltd

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I, Mashudu Rafundisani, as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Sasol Mining (Pty) Ltd, other than fair remuneration for work performed, specifically in connection with the update of the original Surface Water Assessment Process for the Basic Assessment process for the proposed Ash Backfilling Project within the Sasol Sigma Colliery. I am fully aware of and meet all the requirements for specialist assessment, and that failure to comply may result in disqualification of this assessment. I have disclosed to the applicant all material information that has or may have the potential to influence the decision of the Department or the objectivity of this report as part of the application.

In signing this declaration, I am aware that a false declaration is an offence in terms of Regulation 48 of the National Environmental Management Act (NEMA) Environmental Impact Assessment (EIA) Regulations, as amended.

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EXECUTIVE SUMMARY

Digby Wells Environmental (Digby Wells) was appointed as the independent environmental consultant by Sigma Colliery and subsidiary of Sasol Mining (Pty) Ltd to undertake an Environmental Impact Assessment (EIA)/ Environmental Management Plan (EMP). The information will be in support of an application to obtain authorisation for the proposed ash backfilling project of old underground mine voids at Sigma Colliery's defunct area, located in the Free State Province.

The Sasol Sigma project proposes to backfill old mine voids with ash in order to stabilise old underground mine workings and reduce the risk of subsidence. Sasol will use pipelines to transport the ash slurry and the water pumped from the voids.

The proposed project area is located within the Water Management Area (WMA) 08 in the Upper Vaal River system in quaternary catchment C22K.There are two tributaries (Leeuspruit and Rietspruit) to the Vaal which pass through the Sigma Colliery project site, with several proposed pipelines crossing these tributaries. The Leeuspruit drains the upper sections of the project site while the Rietspruit is draining the lower project area into the Vaal Barrage.

Rainfall is recorded at the Sasol Infrachem rainfall station and this indicates that higher rainfall occurs in summer months (October to March). Since backfilling will be carried out all year round, precaution will be taken in the rainy season as any spillages could be washed downstream before any mitigation can be implemented.

Activities currently taking place in the vicinity of Sigma include sand mining, agriculture (livestock and crop farming), housing developments and industry. These activities are contributing to the impacted surface water environment around the project area. Also, some of the area has had hydrology alterations as the catchment characteristics and surface topography is already impacted by subsidence, historical strip mining and sand mining developments.

The water quality results of the Leeuspruit and Rietspruit indicated water with a sodium-bicarbonate character with a sulphate enrichment downstream, whereas, the tributary flowing into Leeuspruit indicates water that changes from a calcium-bicarbonate character to a sodium-bicarbonate character enriched with sulphate. The parameters that are at unacceptable concentrations are chloride, phosphate and the suspended solids. Phosphate and suspended solids are elevated in the Leeuspruit and its tributary, exceeding the prescribe WQG;

The activities related to the project have the potential to impact on the surface water resources. The ash slurry or water pumped from the old underground mine voids could contaminate the surface water resources resulting in elevated levels of metals, salts and pH, if proper mitigation is not implemented.

Some of the findings of the surface water impact assessment include:

- The proposed project's impacts have been assessed to be of medium high to medium low before mitigation and minor to low significance post mitigation;
- The potential for contamination is a concern as coal ash could severely alter water quality conditions. Therefore, a high risk is associated with the current project if no mitigation is implemented;
- The cumulative impacts of the proposed project are high if contamination occurs and low if contamination does not occur;
- Mitigation is required to contain and prevent spillages of either ash slurry and mine water from dewatering; and
- Based on the IGS report, proposed Sigma backfilling methodology, 2013 decant will not occur.

Several recommendations are made in this study with regards to follow on work or important points to be managed during the life of the project:

- The methodology for ash backfilling should follow the methodology outlined by the IGS report (Lukas et al. 2013) in order to minimise or avoid impacts;
- The recommended impact mitigation measures should be implemented to ensure that the identified impacts can be reduced or eliminated to safeguard the water quality and quantity; and
- Water treatment technologies should be considered to treat water from the old mine voids during dewatering process.

Positive cumulative impacts could be anticipated if the current potential subsidence is counteracted by backfilling of voids. The impacts on the catchment morphology currently preventing runoff water from reporting into the streams and rivers by collecting in artificial pans and surface depressions will be minimised or restored.

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1 Introduction

Digby Wells Environmental (Digby Wells) was appointed as the independent environmental consultant by Sigma Colliery a subsidiary of Sasol Mining (Pty) Ltd to update the Environmental Impact Assessment (EIA)/ Environmental Management Plan (EMP) in support of an application to obtain authorisation for the proposed ash backfilling project of old underground mine voids at Sigma Colliery, located in the Free State Province (Figure 1-1). The Sigma Colliery project area is located near Sasolburg (Figure 1-2), at the southern side of the Vaal Barrage which is an area already impacted on by mining. The project will comprise linear surface infrastructure that will traverse several properties (Figure 1-3).

This report is an update of the Surface Water Assessment study which was undertaken in undertaken during 2013/2014 as part of the initial Environmental Authorisation (EA) application process.

1.1 Background

Sasol's Sigma Colliery commenced operations in 1952 and holds mineral rights to coal deposits in the Sasolburg district. Underground mining was the primary method of extracting these reserves including board-and-pillar, rib pillar, long wall and high extraction methods. Access to the underground operations was via several shafts, and then conveyed to a 'dry' coal handling plant at 3 Shaft where the coal was screened and fed to silos. In 1992, the Wonderwater and Mohlolo strip mines were developed to extract coal from the north-eastern side of the reserves and the underground mining was scaled down and ceased by 1999.

As a result of the underground mining activity, subsidence of the surface was identified as a major risk. An Assessment Report on Surface Areas of Old Sigma Workings (Potential Failure Report) was compiled in 2012 and analysed the probability of incidents occurring on the properties overlaying the defunct Sigma Colliery workings, their current mitigation measures, the proposed next steps and immediate actions required. This Report informed that some properties / areas, such as the Parys road (R59), are rated as having a very high risk potential. Sigma Colliery backfilled mine workings located beneath the Sasolburg-Parys Road, the Sewage Works and certain privately owned farms to minimise the safety risk in the area.

The risk potential that exists as a result of the voids is due to the fact that mining took place over three time periods. The first period was prior to the implementation of safety factors in underground coal mining. During this period the pillars that were left behind were not adequately sized to support the mines roof, resulting in eventual collapse and subsidence of the surface (with reference to the Coalbrook disaster). During the second phase of mining, safety factors were applied, however, they were based on research done in the Witbank coalfield (Salomon and Munro). The safety factors applied with this methodology resulted in pillars that were still inadequately sized. Although they provided an increase in safety, they would still collapse eventually. The safety factors were then amended and the calculation based on data from the Sasolburg coalfields, which resulted in more accurate factors of safety, which are still being used today

This report will detail the surface water findings relevant to the Ash backfilling project and anticipated impacts and mitigation recommendations.

1.2 Legal Framework

This specialist surface water assessment was compiled in support of the EIA/ EMP to be utilised in environmental authorisations legislated under the;

- The Constitution Act (Act 108 of 1996) , Section 24 on environmental rights;
- National Environmental Management Act (Act 107 of 1998), (NEMA) as amended;
- Environmental Impact Assessment Regulations of 2010;
- National Environmental Management Waste Act (Act 59 of 2008), (NEMWA); and
- National Water Act (Act 36 of 1998) (NWA);
- NWA amendment as per Regulation 704 (GN R 704, (1999)) on use of water for mining and related activities aimed at the protection of water resources and
- Government Notice 718 of 2009, for identified listed activities relevant to the backfilling project and the construction and operation of the required infrastructure.

In compilation of the surface water specialist report the following water related legislation and guidelines are also applied DWA Best Practice Guidelines (BPGs) series (2008).

1.3 Project Description

The proposed project is aimed at backfilling additional high risk mine voids with ash from Infrachem. The ash backfilling process will use several pipelines located above-ground to transport the ash slurry (comprising 20% fine ash and 80% water) from the Sasol Ash pump station at Infrachem, to the mined out voids. Return water pipelines (the main one already in place) will be used to dewater the voids before backfilling starts to prevent decant as a result of hydrostatic pressure. The water that will be pumped out will be sent for treatment at a planned Sasol Group water treatment plant (authorisation for this plant is not part of this project). Infrachem have approximately 10 million cubic meters (Mm^3) of ash to use for backfilling and stabilising the surface.

The pipelines transporting slurry will run aboveground on Sasol owned property and within existing servitudes where possible. Where this is not possible, existing culverts and crossings will be used; alternatively new agreements will be entered into with land owners. The pipeline route will be specifically selected to ensure that the pipes run along existing servitudes, linear infrastructure and disturbed areas to minimise the impact on the receiving environment.

1.4 Infrastructure

Sasol aims to utilise the flowing surface infrastructure:

- A number of constructed pipelines from the ash pump station to the various voids (for the transportation of ash slurry);
- A booster pump station at the existing constructed station site; and
- Existing as well as constructed return water pipes.

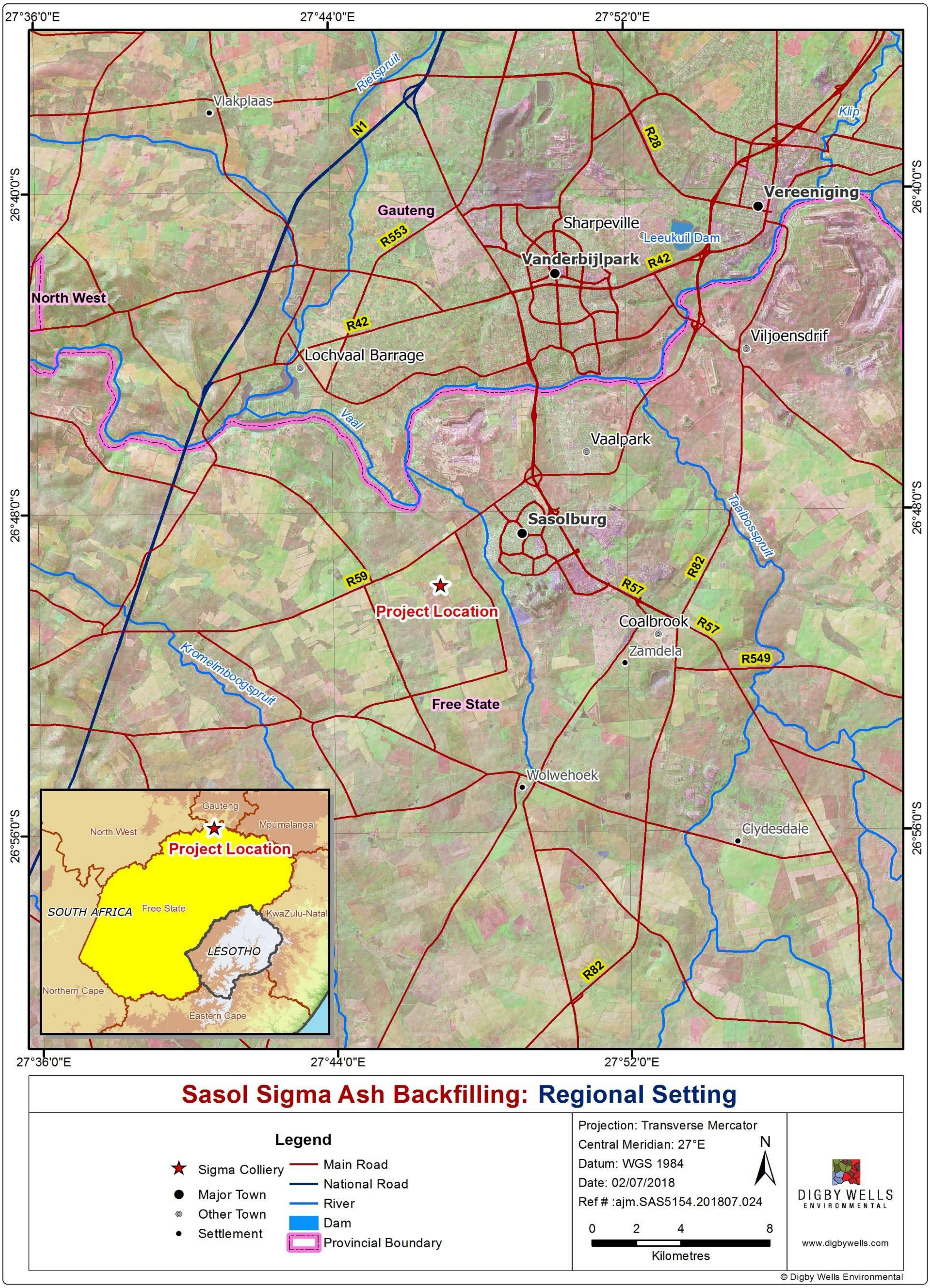

Figure 1-1: Project Regional Setting

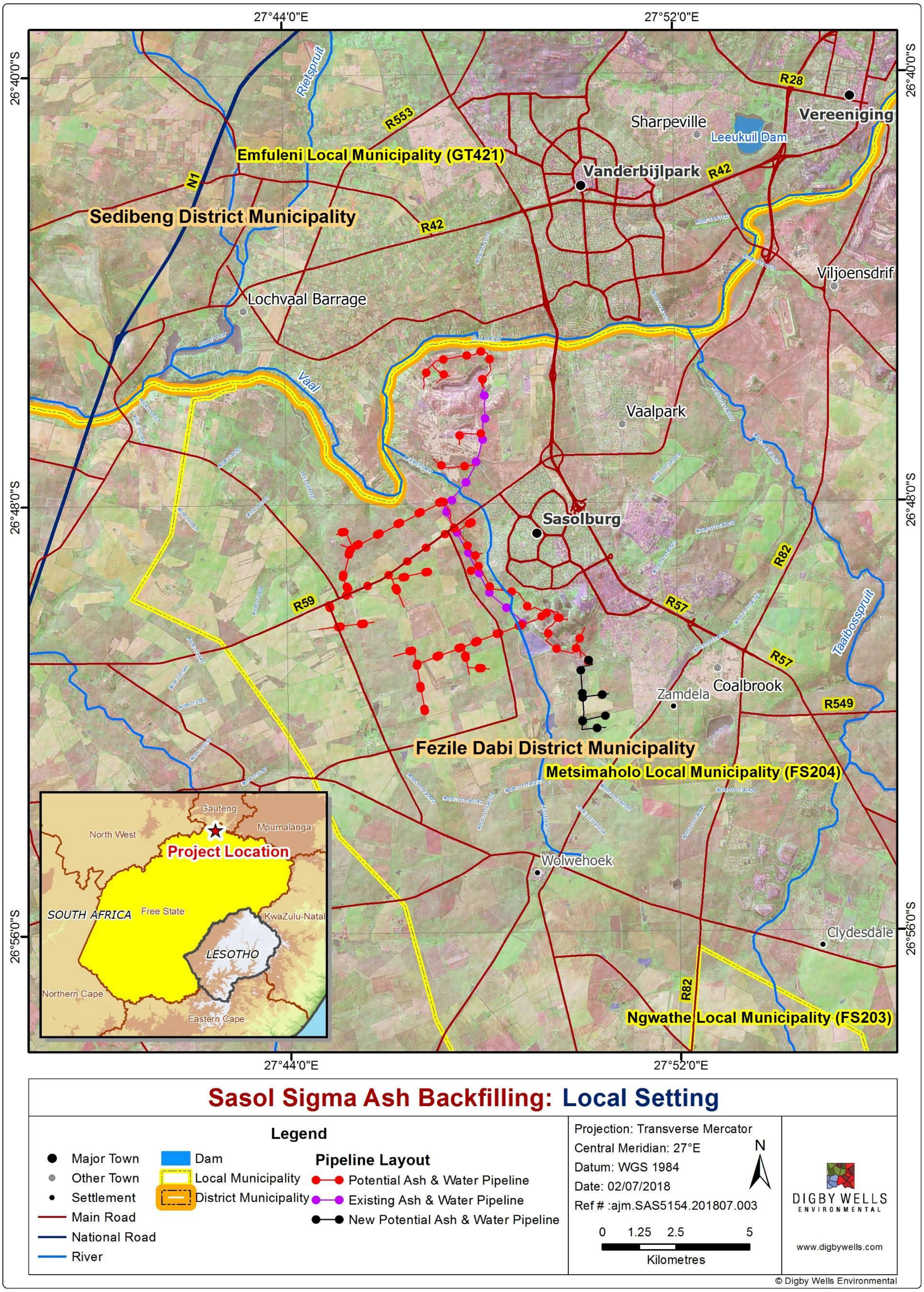

Figure 1-2: Project Local Setting

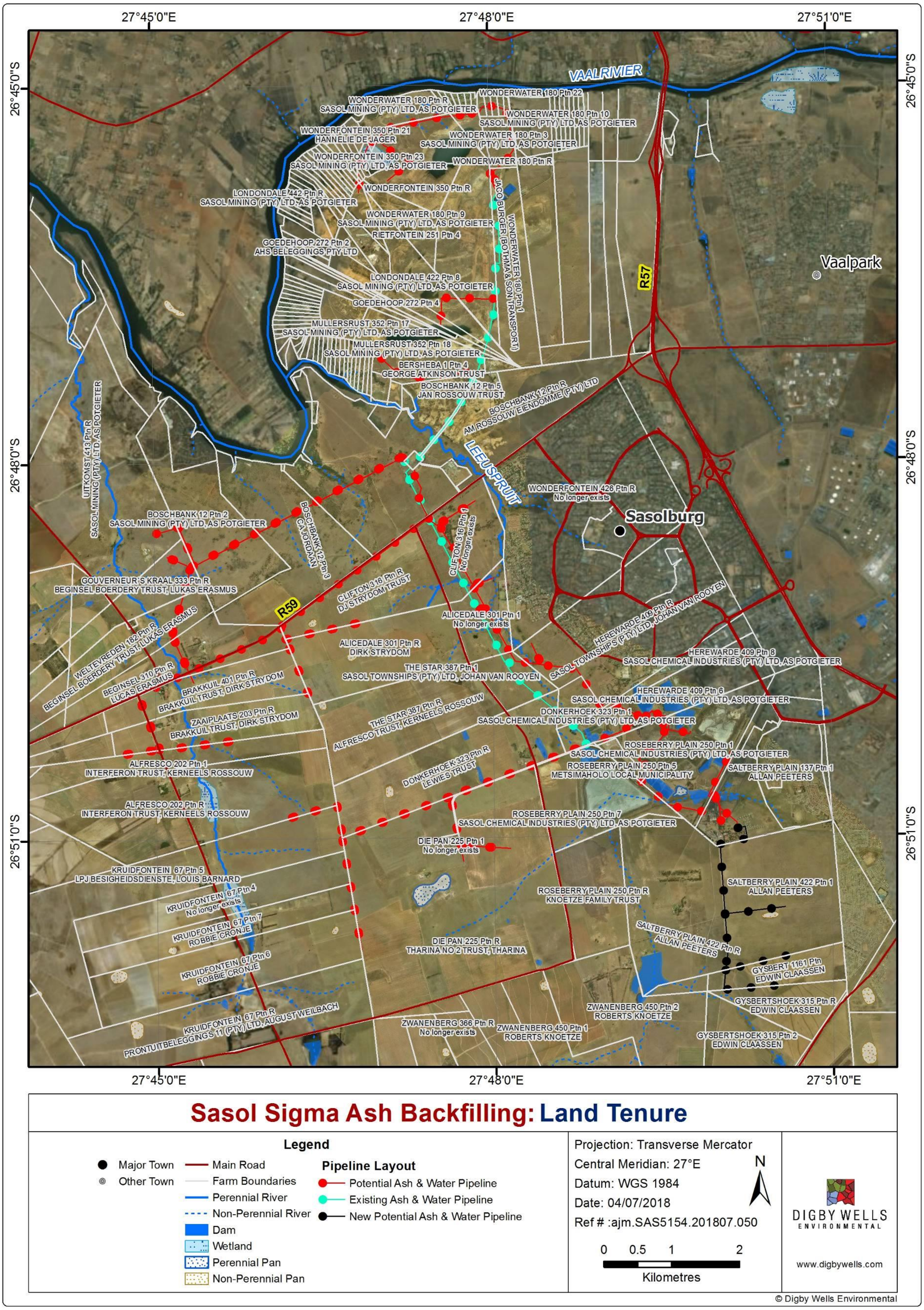

Figure 1-3: Land Tenure

2 Terms of Reference

Surface water assessment is undertaken within the proposed scope of work as outlined in the gap analysis in the recommended work to compile a stand-alone specialist surface water report that can support the EIA/ EMP authorisation is as follows:

- Update of the climate and catchment characteristic information in line with the WRC (2012) report;
- To update description of the hydrology and where there are stream crossings by the infrastructure, the flood peaks should be recalculated for these areas;
- To review and update the monitoring sites to cover up- and downstream locations and to sample new/ identified monitoring sites;
- Use database to determine deviations of current water quality status from baseline using the Leeuspruit/ Taaiboschspruit Water Quality Objectives (WQO) as benchmarks;
- Update surface water user survey;
- Undertake impact assessment for both water quality and quantity for the specific ash backfilling activities using the updated Digby Wells methodology;
- Update the surface water management plan to be specific for mitigation of updated impacts and to ensure that it covers pipeline and backfilling specifically; and
- Write up a storm water management plan (SWMP) within the DWA BPG guidelines.

3 Expertise of the Specialist

Digby Wells is an independent Environmental Consulting firm with a team of in-house specialists providing services to the mining and resources industry. CVs of the hydrology specialists who undertook various aspects of this study are attached (Appendix A).

4 Study Area

4.1 Land Tenure

The Sigma ash backfilling project falls under the jurisdiction of the Metsimaholo Local Municipality (MLM) situated in the Fezile Dabi District Municipality (FDDM) close to the town of Sasolburg (Figure 1-2). The Sigma project traverses several farms as depicted in (Figure 1-3).

4.2 Climate

The area has a temperate climate characterised by warm summers and cold winters. Average annual rainfall is 658 mm and occurs mainly during summer months. Average daily temperatures vary between 8.9°C in June to 21.7°C in January. The climate is typically a cool temperate Highveld climate characterised by a cool to warm summers and cold winters.

Table 4-1 present the average monthly rainfall for the quaternary catchments C22K and rainfall zone C2C. This is based on the averages of monthly rainfall data from a period of 1920 to 2009. The summary climatic data (Rainfall and Evaporation) for C22K quaternary catchment is also presented in Figure 4-1.

Table 4-1: Summary of Rainfall Data extracted from the WR2012

Months	MAP (mm)
January	112.4
February	83.3
March	77.7
April	44.6
May	18.7
June	7.3
July	6.0
August	8.0
September	21.4
October	66.6
November	94.5
December	103.3
MAP	**644**

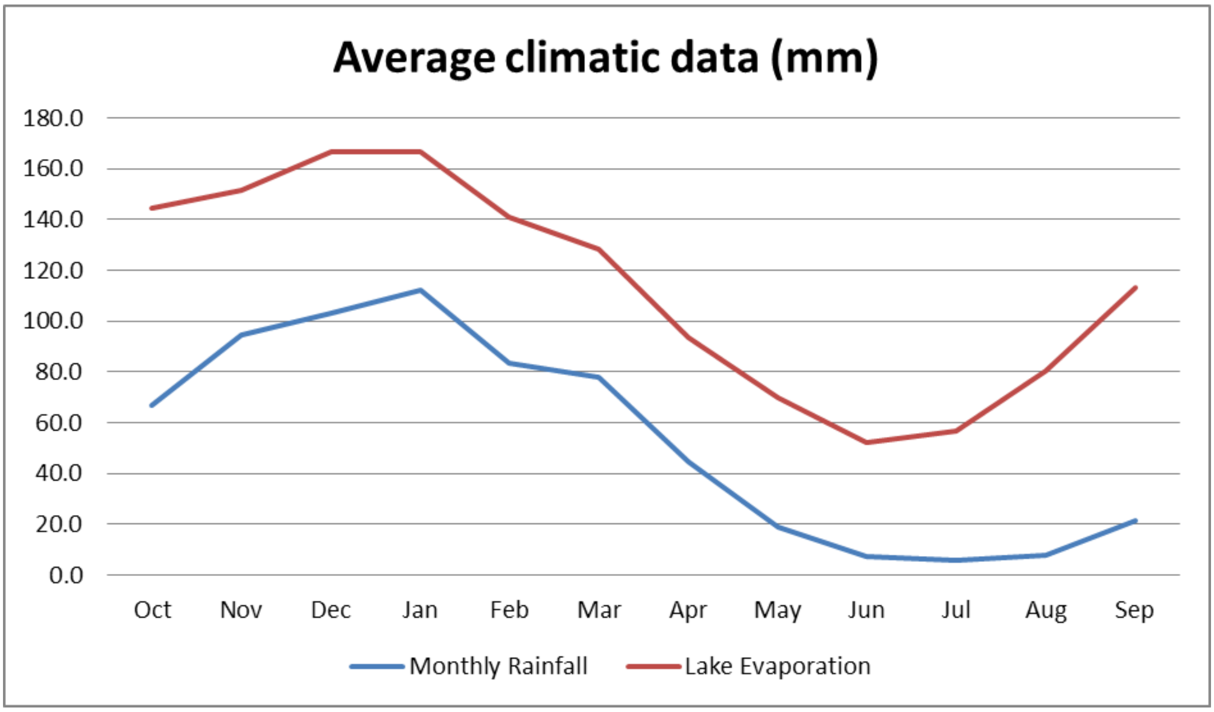

Figure 4-1: Summary of the Average Monthly Climatic Data for C22K Quaternary Catchment

Rainfall is recorded at the Sasol Infrachem rainfall station, from the rainfall recorded at Sasol Infrachem, the years 2006, 2008, 2009, 2010, 2011, 2013, and 2016 exceed the MAP (highlighted in yellow) determined for the catchment from the WRC 2012 of 644 mm. The rainfall records clearly show that Sasol Sigma experienced a drier precipitation cycle for the period 2002 to 2005 and wetter cycle in the later years, when compared to the estimated MAP. The Table 4-2 summarises the annual precipitation for a 16 year period. In wetter months care should be taken as in the event of spillages, the impacts on water quality are quickly transported downstream from increased streamflow.

Table 4-2: Summary of the Annual Precipitation from 2002-2017

Years	Total Annual Rainfall
2002	551
2003	423
2004	601
2005	582
2006	979
2007	555
2008	810
2009	1043

Years	Total Annual Rainfall
2010	941
2011	846
2012	691
2013	687
2014	643
2015	581
2016	909
2017	617

Source: Sasol (Rainfall-Sasol 1-2008-2017 – to mine) Excel File

5 Methodology

The methodology used to meet the set objectives entailed a 3 phase approach of desktop, site assessment and reporting.

- The desktop assessment entailed study area description from several literature of existing studies, a baseline hydrology (catchment delineation and flood peak flow analysis) and characterise the surface water quality and carry out an EIA;
- The site visit on the 19 September 2013 constituted carrying out site inspection to familiarise with the proposed project site especially the Leeuspruit and stream crossings;
- The Rietspruit site visit was integrated with other Wetland and Aquatics specialist studies; and
- Report Compilation of the findings.

5.1 Hydrology

5.1.1 Catchment Description

WRC 2012 report was utilised for the catchment description complemented by GIS data and the results of field analysis and several existing reports (WRC, 2012)

5.1.2 Design Rainfall Storm Depth

The 24 hour design rainfall depth model was run on a Design Rainfall Estimation (DRE) in South Africa (2003) to determine the 1: 5 up to 1: 200 year return periods utilising identified rainfall station data captured. The DRE accesses information from rainfall stations through its interphase and uses the algorithms specified by Smithers and Schulze (2003).

5.1.3 Flood Peak Flows

The peak flood flows were calculated for the 1: 50 and 1: 100 return year periods taking into account the parameters determined from the delineated sub-catchments above (SANRAL, 2007) using rainfall runoff models in the Utilities Programmes for Drainage (UPD).

The peak flows are determined and will be utilized in the design of engineering infrastructure for establishing the mitigation measures. Therefore, the infrastructure must be capable of accommodating the flows and storage volume emanating from the peak rainfall into the respective design.

The Rational Method, Alternative Rational Method (ARM), the standard design flow and the empirical method were selected to determine the peak flow estimates based on the catchment size.

The slope characteristics of the catchments classified according to the Drainage Manual (SANRAL, 2007) inputs for the UPD represent the following

- 0 - 3% as vleis and pans;
- 3 -10% as flat;
- 10 - 30% as the hilly slopes; and
- >30% as the steep slopes.

Most of the slopes in the catchment areas are within the in 0-3%and 3-10% slope class which is relatively flat slope. Few of the slopes had some characteristic of hilly slopes within the catchments.

5.2 Water Quality

The Institute for Groundwater Studies at the University of the Free State was appointed by Sasol Mining (PTY) LTD to conduct the water monitoring of the Sigma Colliery, this report will provide a summary of the water quality descriptions based on the latest water quality report by IGS which outlines the results of the on-going bi-annual monitoring programme conducted for Old Sigma Colliery. The monitoring programme focuses on an integrated approach where all water resources are holistically monitored for potential impacts of mining.

The existing water quality data, which has been verified by IGS, obtained from analysis carried out at an independent South African National Accreditation Systems (SANAS) accredited laboratory were analysed. For the variables analysed in the laboratory are listed in Table 5-1.

Table 5-1: Summary of the Parameters/Variables Analysed

pH	EC	TDS	Ca	Mg	Na	K
P-Alk	M-Alk	Cl	SO4	NO2/NO3 as N		Cd
Al	Fe	Mn	NH4/NH3	as	N	B
Cr	Co	Cu	Pb	PO4	COD	DOC
phenols	TOC	Turbidity	Suspended Solids	Faecal Coliform	Si	F

The units are mg/l except pH and EC measured in pH units and mS/m respectively.

5.2.1 Data Quality Control

Once the water quality data was received from the laboratory, error checking was done, comparing the new set of data with historic records. An ion balance error of ± 5% was used as an acceptable range. The data was then stored in the Sigma Colliery WISH database.

5.2.2 Reporting

Data will be reported in the form of figures, trend or time series graphs, and hydrochemical diagrams, i.e. Piper, Stiff and Expanded Durov diagrams. The results reported cover for the period December 2016 to May 2017 and these will be compared against historic database for ease of continuity, with courtesy of WISH software. Data will be discussed according to the identified hydrogeological zones existing in Sigma Colliery Mining Rights Area (SCMRA). Data will further be compared against:

- Surface water quality guidelines of the Leeu/Taaibosch Spruit (LTF) Catchment.

The existing monitoring programme and data was based on the expired DWS License, However, this monitoring programme is deemed to be sufficient to comply with the newly authorised Water Use Licence (2017-10-11).

6 Results and Discussion

6.1 Surface Water Hydrology

6.1.1 Catchment Description

The proposed project area is located within the Water Management Area (WMA) 05 in the Vaal River system. The proposed area is located within the secondary drainage C2 (Vaal River Catchment) in quaternary catchment C22K (Figure 6-2). The catchment characteristics for the C22K are presented in Table 6-1 are summarised from Water Research Commission

(WRC), 2012. The resultant MAR after evaporation and recharge is 3%. Where Mean Annual Precipitation is MAP, Mean Annual Evaporation is MAE and Mean Annual Runoff is MAR.

Table 6-1: Summary of the Surface Water Attributes for the Two Affected Quaternary Catchments

Quaternary Catchment	Area (km2)	Rainfall Zone	MAP (mm)	MAR (mm)	MAR m^3* 10^6	Evaporation Zone	MAE (mm)	% MAP/ MAR
C22K	434	C2C	644	20.9	9.11	11A	1625	3

(Source: WRC, 2012)

There are two tributaries to the Vaal which pass through the Sigma Colliery project site, with about 17 pipeline crossing locations (Figure 6-4) identified. The two main tributaries are the Leeuspruit which drains the upper sections of the project site and the Rietspruit draining the lower project boundary into the Vaal Barrage. The Leeuspruit and Rietspruit rivers flow parallel to each other towards Vaal Barrage.

The Taaibos Spruit drains the area to the east of Sasolburg and is not influenced by the Colliery. At the time of the site visit the Rietspruit was dry whilst the Leeuspruit was flowing. Photos presented in Figure 6-1 below show some sections of the Rietspruit and Leeuspruit during site visit. The Rietspruit presented well-defined dry river channels whilst the Leeuspruit was slow flowing with varying channel shapes. The Kromelmboogspruit flows outside of the project boundary to the west.

Figure 6-1: Photographs of the Leeuspruit (Left) and the Rietspruit (Right) River Channels

The Sasol Sigma project is managed at one of the few Catchment Management Agencies (CMAs) in the Upper Vaal. The Sigma project is situated within the Vaal Barrage Catchment management forums, the Leeu/Taaibos Spruit forum.

The catchment under the Leeu/Taaibos Spruit forum includes the Kromelmboogspruit as the western boundary, the meander in the Vaal River to the east, cutting off just before the Vaal Dam. The Vaal River (including the Vaal Barrage) forms the northern boundary as depicted in Figure 6-3.

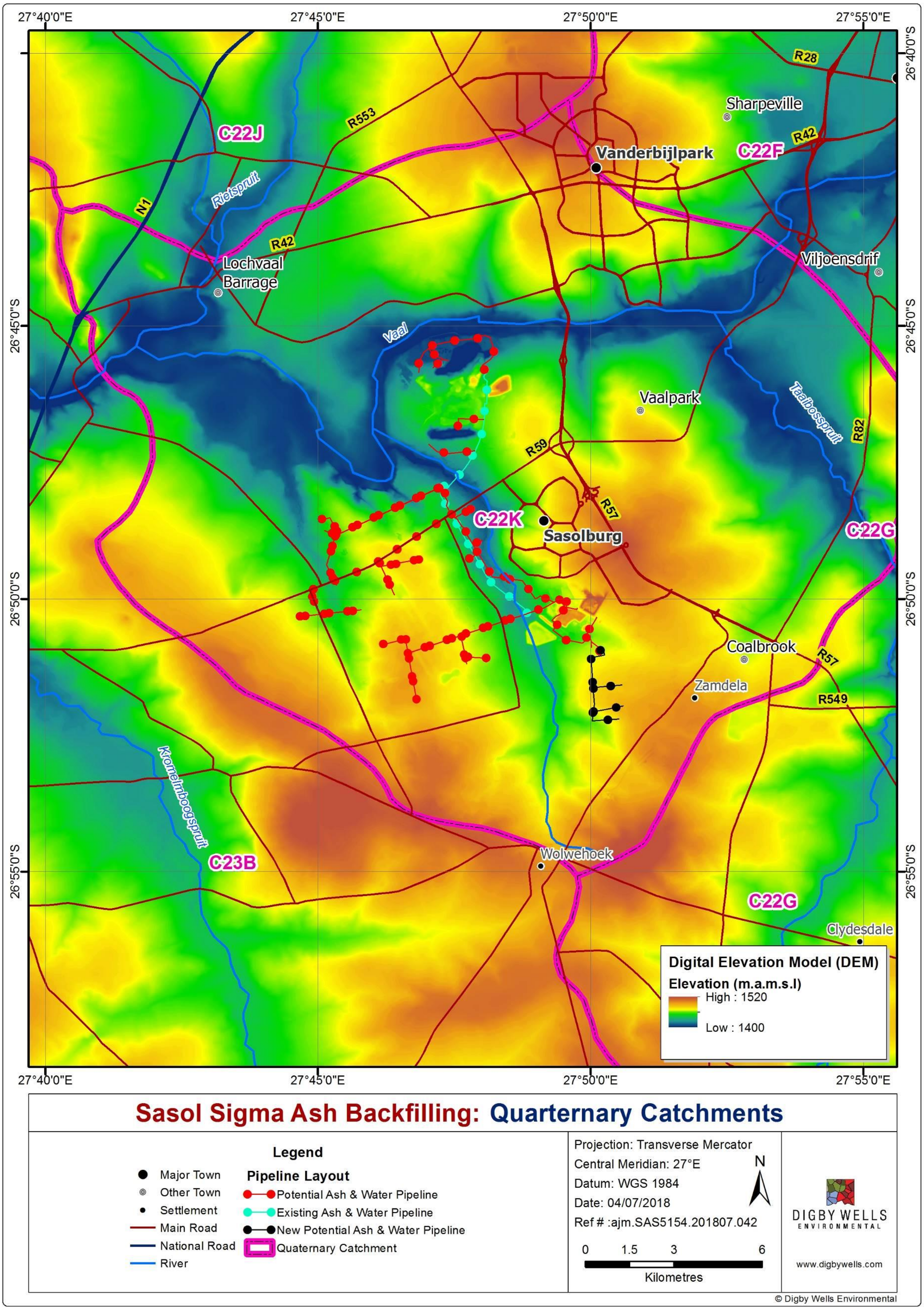

Figure 6-2: Affected and Surrounding Quaternary Catchments

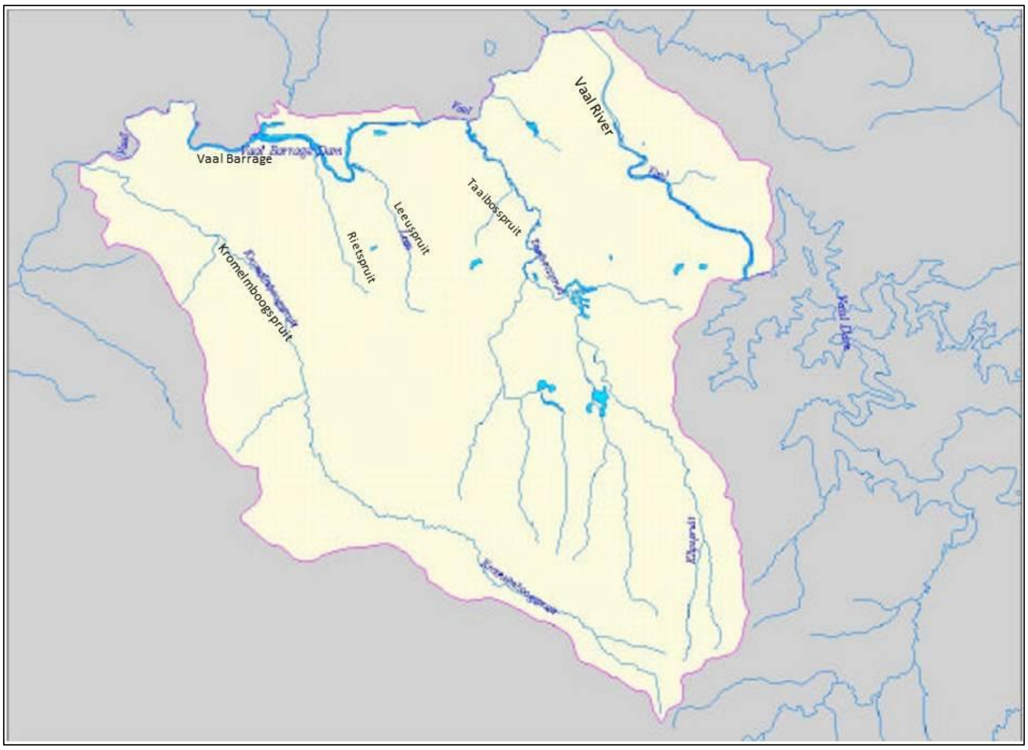

Figure 6-3: Image depicting the location of the Leeu-Taibos Spruit

Source: www.reservoir.co.za - leeutaai_terms of rerefence_jan2003.pdf

The Sigma project site surface topography of the landscape is undulating and sloping towards the Vaal River (Figure 6-5). Most of the surface is predominantly characterised by slopes in the classes 0 to 3% and lesser extent by slopes of class 3 to10%. However, the historic mining activities have significantly altered the topography and surface water flow in the north east. Elevation within these river valleys varies from around 1430 m at the valley bottoms to 1490 m at the valley tops. Slopes are predominantly flat across the landscape except for isolated pockets of steeper slopes along the banks of the Vaal Barrage and where mining activities have taken place.

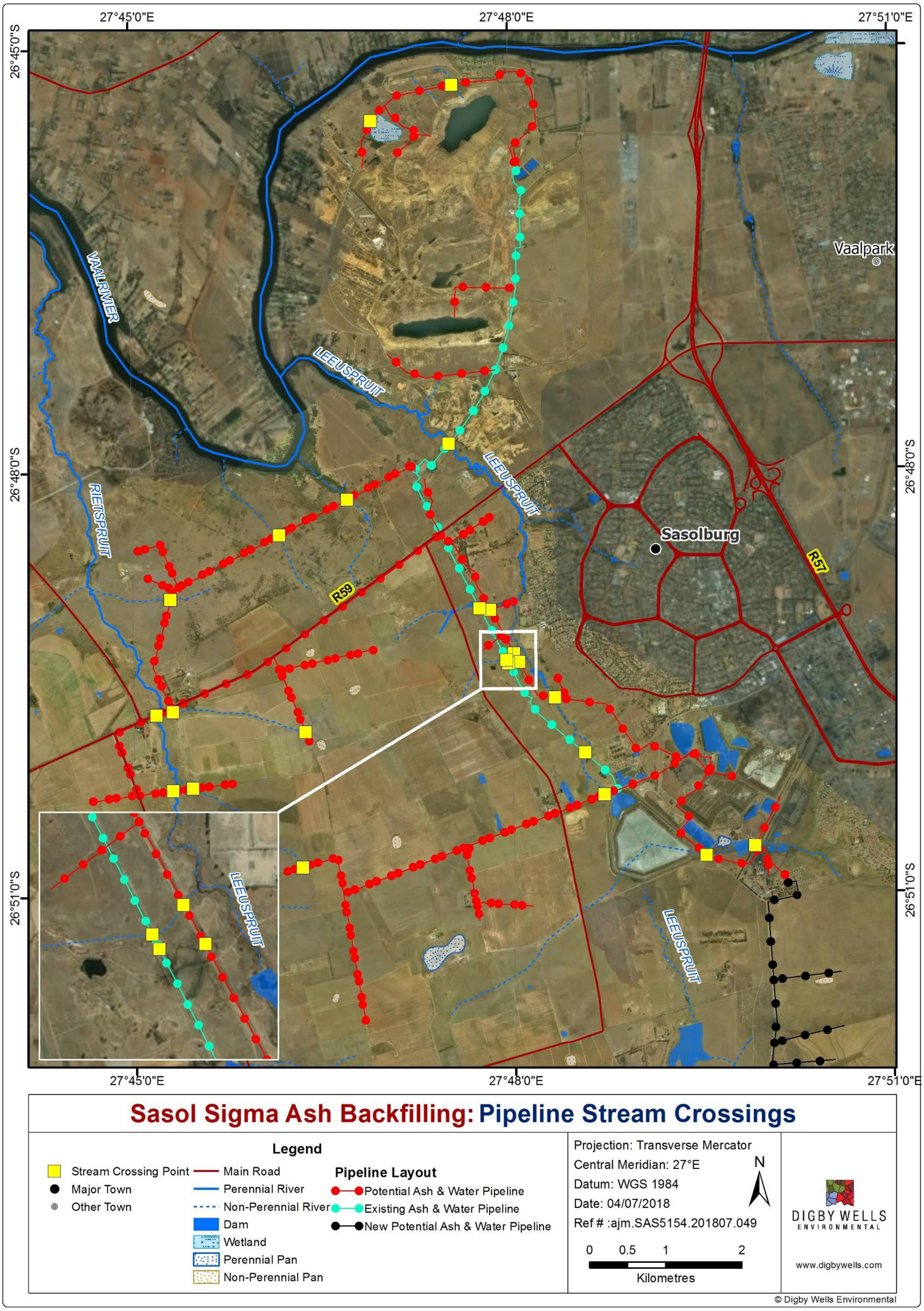

Figure 6-4: Summary of Stream Crossings from the Proposed Sigma Ash Backfilling Pipeline

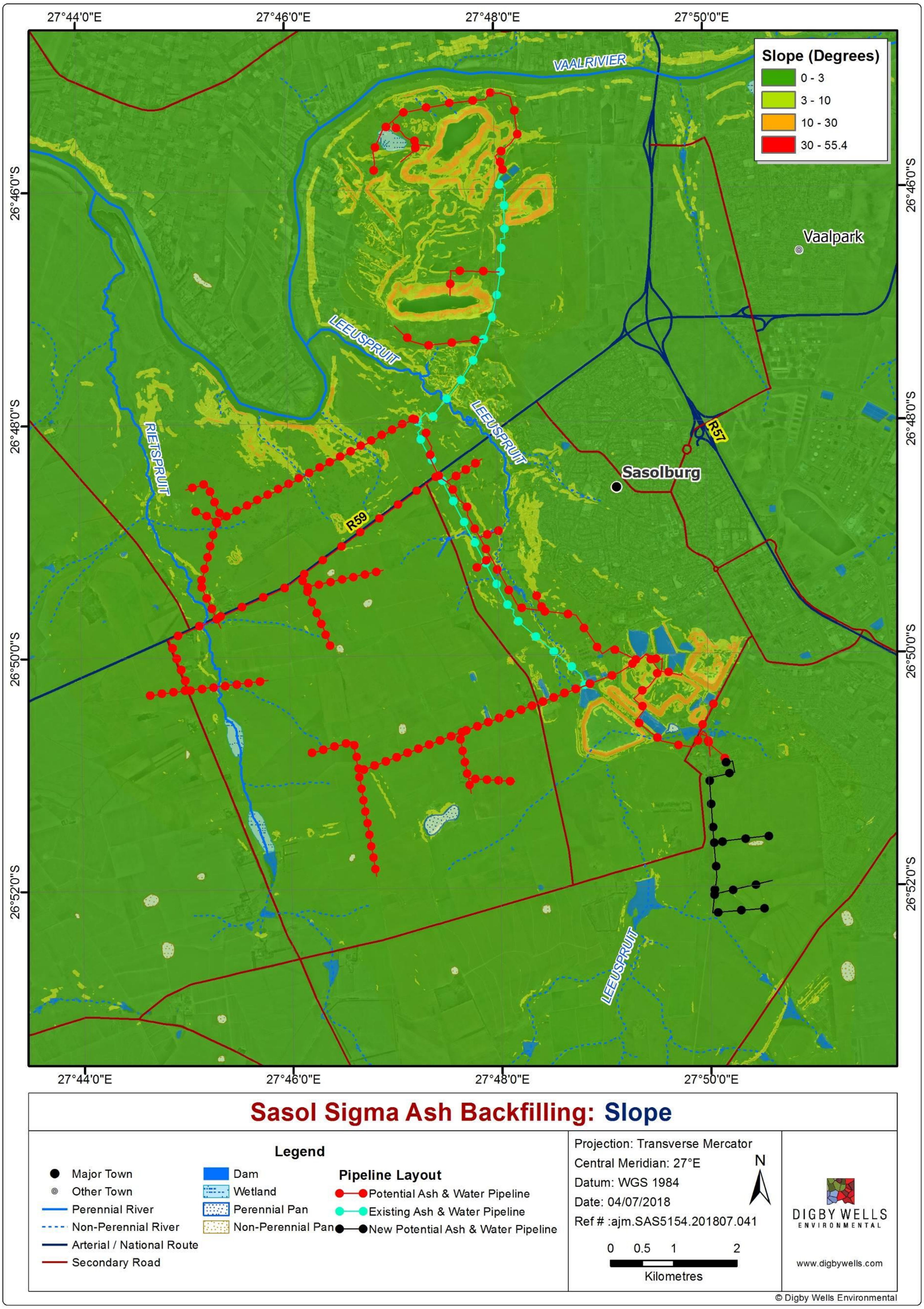

Figure 6-5: Topographical or Slope of the Project area and Surrounding

6.1.2 Catchment Delineation

Two major catchments areas delineated in the EMPR for Sigma (1997) and these are the Leeuspruit and the Rietspruit catchments, which will be traversed by the pipelines for the ash backfilling project.

The Sigma topography is altered by the mining operations as a result of some subsidence as well as strip mining operation. The main project areas are the strip mining area as well as the underground mining area in the Rietspruit and the Leeuspruit catchments. In order to cater for the different topography and proposed stream crossings the area was further delineated into 11 sub-catchments. The delineated sub-catchments are depicted in Figure 6-6 and shown in Table 6-2.

Table 6-2: Summary of the Delineated Sub-Catchments

Sub-catchment	Description
SubA	Upstream on the Leeuspruit, upstream of the ash dumps up to stream crossing downstream of the ash dump. SIG/2 is located in this catchment
SubB	Catchments in which the Sasol Sigma ash dumps are located. This catchment has two stream crossings. SIG/6 and SIG/5 are located in this sub-catchment
SubC	Possible 4 stream crossings are located in these catchment with three toward its downstream and one at the boundary with SubA
SubD	Tributary to the Leeuspruit with no stream, crossings but affecting streamflow in Leeuspruit. There will be no backfilling pipe traversing this catchment
SubE	Further downstream catchment of the Leeuspruit towards its confluence with the Vaal Barrage. It includes all the clean catchment outside the rehabilitated N and S open pit. SIG/1 is located in this catchment
SubF	The open pit area catchment that is influenced by the rehabilitated strip mining areas. The water in this flows into the remaining voids and is also characterized by several artificial wetlands. Two possible stream, crossings were identified
SubG	A tributary to the Vaal with a possible stream, crossing
SubH	Possible seven stream crossings are located in this catchment. It is the catchment on the upstream of the Rietspruit. SIG/3 and SIG/4 are located in this catchment
SubI	Tributary to the Rietspruit with no present anticipated stream crossings
SubJ	Downstream on the Rietspruit with possible backfilling to take place in this catchment
SubK	Tributary to the Rietspruit with no present anticipated stream crossings

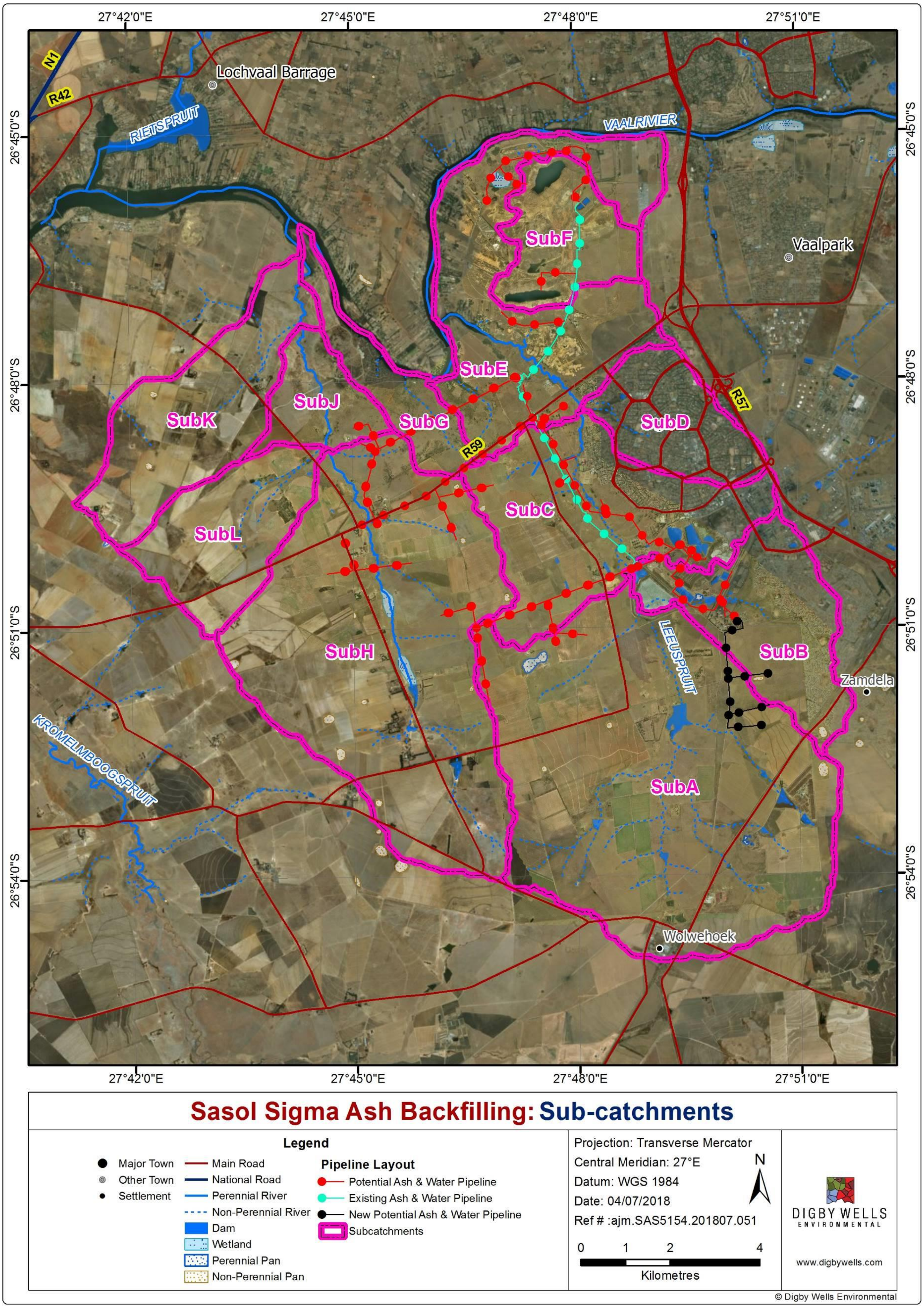

Figure 6-6: Delineated Sub-catchments for Sigma Project

6.1.3 Storm Rainfall Depths

Rainfall stations closest to the Sasol Sigma were identified in the DRE and are listed in Table 6-3.

Table 6-3: Summary of the Closest Rainfall Stations

Station Name	SAWS Number	Record (Years)	Latitude		Longitude		MAP (mm)	Altitude (mamsl)
			(°)	(')	(°)	(')		
Sasolburg (Mun)	0438588_W	46	26	48	27	48	639	1462
Saltberry Plain	0438597_W	35	26	50	27	50	643	1477
Pietershoogte	0438533_W	67	26	52	27	47	646	1482
Zandfontein	0438404_W	31	26	44	27	44	612	1418
Barrage (RWB)	0438315_W	82	26	45	27	41	657	1420
Klein-Leeuwkuil	0438703_W	47	26	43	27	54	628	1430

The design rainfall for the Sigma project site for a 24 hour storm is presented in Table 6-4. Based on the GNR 704, a 1:50 year 24 hour storm depth should be utilised in planning of water storages. In this case a depth of 104 mm should be considered for the designs.

Table 6-4: Summary of the 24 Hour Design Rainfall Depth (mm)

Duration	Return period rainfall (mm)					
	1:5	1: 10	1: 20	1: 50	1: 100	1: 200
24hr	58.5	78.1	91.1	104	121	133

6.1.4 Calculation of Flood Peak Flows

Average peak flows determined for the sub-catchments are highlighted in Table 6-5.

Table 6-5: Summary of Peak Flows Determined for the Sub-catchments of the Sigma Project in m^3/s

Sub-catchment	Area (km2)	1:2	1:5	1:10	1:20	1:50	1:100	1:200
SubA	47.6	39	72	103	140	195	247	318
SubB	12.0	23	38	54	72	95	121	165
SubC	18.8	27	42	59	79	95	122	151
SubD	7.5	20	32	46	61	83	106	138
SubE	13.5	19	28	40	52	59	76	87

Sub-catchment	Area (km2)	1:2	1:5	1:10	1:20	1:50	1:100	1:200
SubG	5.3	19	31	44	59	80	104	112
SubH	40.6	37	58	83	110	140	178	227
SubI	10.0	19	31	44	59	78	99	131
SubJ	4.8	11	16	23	31	38	49	56
SubK	15.4	33	53	76	102	141	179	234

6.1.5 The Normal Dry Weather Flow

6.1.5.1 Rietspruit

The Rietspruit has low flows of zero. It is non-perennial with stream flows during the wet season. It was dry during the fieldwork which was undertaken in the dry season.

6.1.5.2 Leeuspruit

The Leeuspruit is a perennial stream with flow in the dry season as was observed during the site visit, which was undertaken in the dry season.

6.2 Surface Water Quality

The on-going surface water monitoring is conducted at appropriate locations / stream crossings, on the Rietspruit, Leeuspruit and the Vaal River. The ash utilised for ash backfilling is likely to have certain specific contaminants, hence variables of concern or parameters that are analysed as part of water quality monitoring includes is based on the constituents of the ash.

6.2.1 Surface Water Quality Sampling

Six water quality monitoring location Sigma project are presented in Table 6-6 and the locations are illustrated in (Figure 6-7). Water quality sampling is also performed at two other sites located on the Vaal River upstream of the proposed Sigma project. The sampling sites capture impacts downstream and upstream of stream crossings sites of the proposed pipeline.

Table 6-6: Summary of Existing Sigma Surface Water Sampling Points Locations

Site ID	Farm Name	X - coord	Y-coord
SIG/1	LILIAN DALE	77815.00	-2964512.00
SIG/2	SALTBERRY	81819.00	-2972680.00
SIG/3	BEGINSEL	74889.17	-2968560.83
SIG/4	KRUIDFONTEIN	76724.00	-2973912.00
SIG/5	LEEUSPRUIT	83888.00	-2970662.00

Site ID	Farm Name	X - coord	Y-coord
SIG/6	LEEUSPRUIT	82500.00	-2970440.00
VAAL DOWNSTREAM	VAAL DOWNSTREAM	78057.00	-2960097.00
VAAL UPSTREAM	VAAL UPSTREAM	79920.00	-2960051.00
WW-DUIKER	WONDERWATER WEST DUMP RUNOFF	77681.00	-2961491.00
WW-KOLGANS	WONDERWATER	79843.00	-2961512.00
WW-HAMMERKOP	WONDERWATER	79775.05	-2961567.85
WW-NORTH REH DAM	WW-NORTH FINAL VOID DAM	78913.00	-2960802.00
WW-SOUTH REH DAM	WW-SOUTH FINAL VOID DAM	78383.00	-2963519.00
WW-BLESBOK	WONDERWATER EAST DUMP RUNOFF	80010.00	-2961637.00

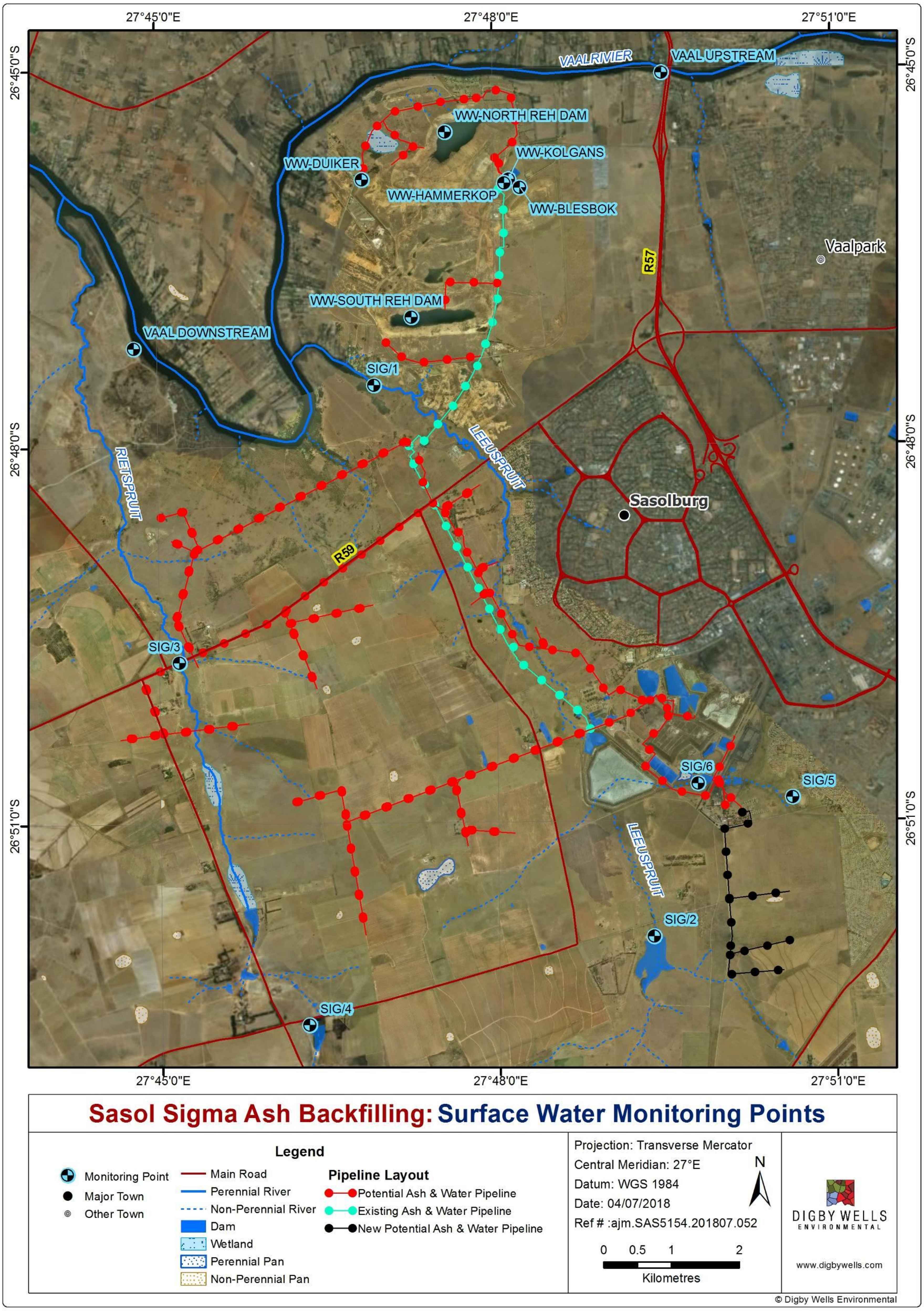

Figure 6-7: Water Quality Monitoring Locations

6.2.2 Water Quality Descriptions

The water quality report discussed all possible impacts of the surface water system by the Sigma Colliery. It also included the following, for all monitoring points.

- The hydro-chemical status of the water, with trends over time. These trends are classified as:
  - I. Improving water quality or
  - II. Deteriorating water quality
  - III. Sideways, if there is no clear indication of the water quality trend
- The impact of the water quality on the area.
- Determination of the long-term sufficiency of monitoring requirements.

6.2.2.1 Leeuspruit

Water quality results of the Leeuspruit indicated water with sodium-bicarbonate character; however, SIG/1 downstream is enriched with sulphate (Figure 6-8) with a concentration of 225 mg/l.

The tributary flowing into the Leeuspruit indicates water that changes from a calcium-bicarbonate character to a sodium-bicarbonate character enriched with sulphate (Figure 6-8). There is a definite improvement of water quality in the downstream direction of Leeuspruit and a deteriorating water quality in the downstream direction of the tributary.

The time graphs for the electrical conductivity, pH, chloride and sulphate for Leeuspruit and its tributary are illustrated in Figure 6-9. Over the past two years, the overall water quality of Leeuspruit remained sideways. pH values exceeding eight have been recorded in the past at SIG/1 downstream. There are momentary peaks of sulphate concentrations over time (Figure 6-9 and Figure 6-10) which is possibly the result of surface water runoff from the nearby fine ash dams and coal stockpiles.

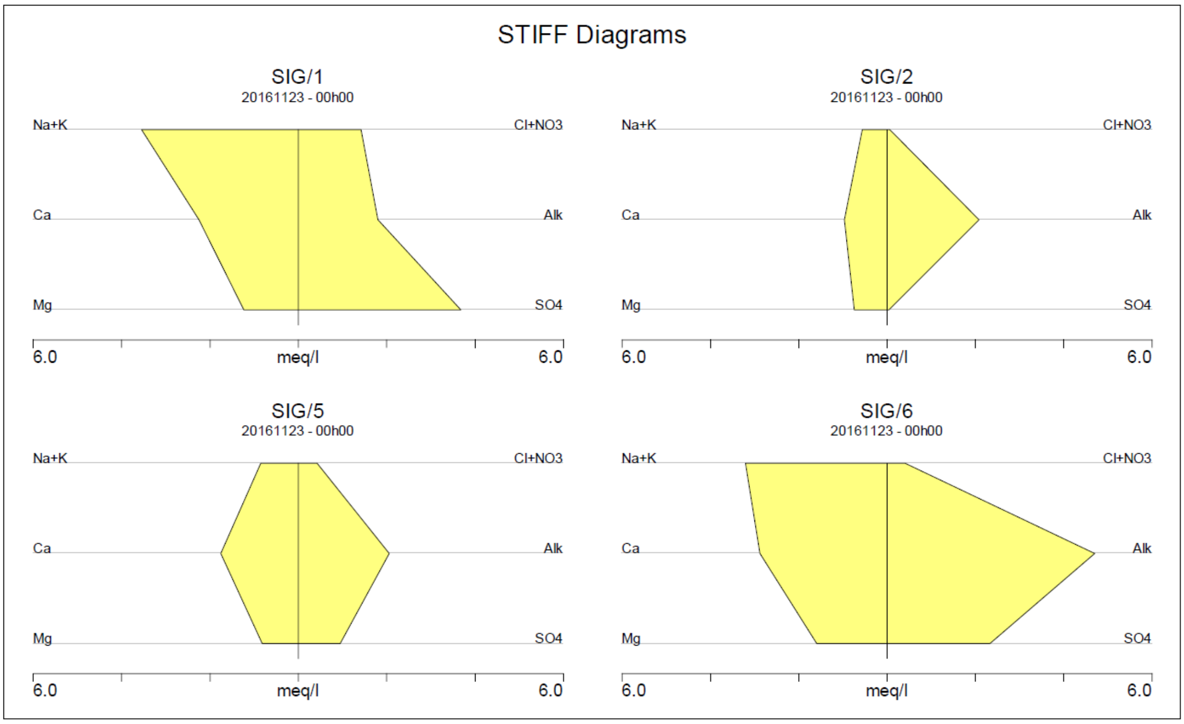

Figure 6-8: Stiff Diagrams Illustrating the Water Quality of Leeuspruit (SIG/1 & SIG/2) and its Tributary (SIG/5 & SIG/6) during November 2016

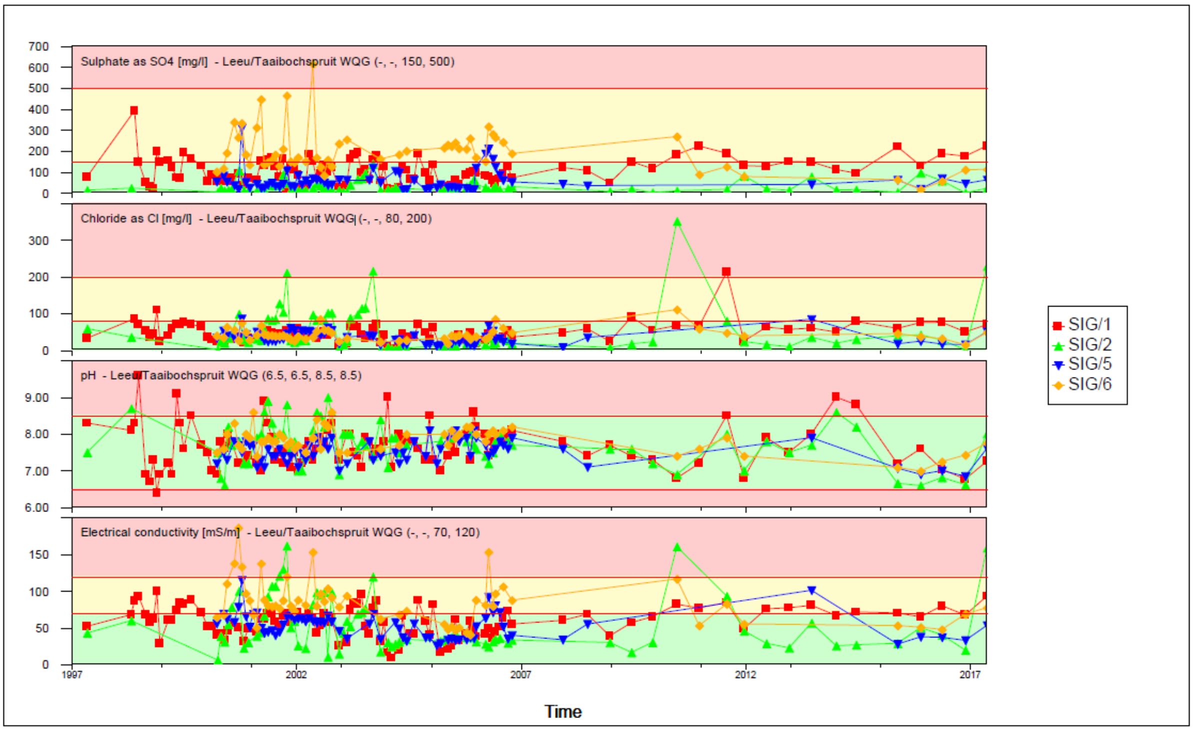

Figure 6-9: Electrical Conductivity, pH, Chloride and Sulphate Time Graphs for Leeuspruit (SIG/1 & SIG/2) and its tributary (SIG/5 & SIG/6)

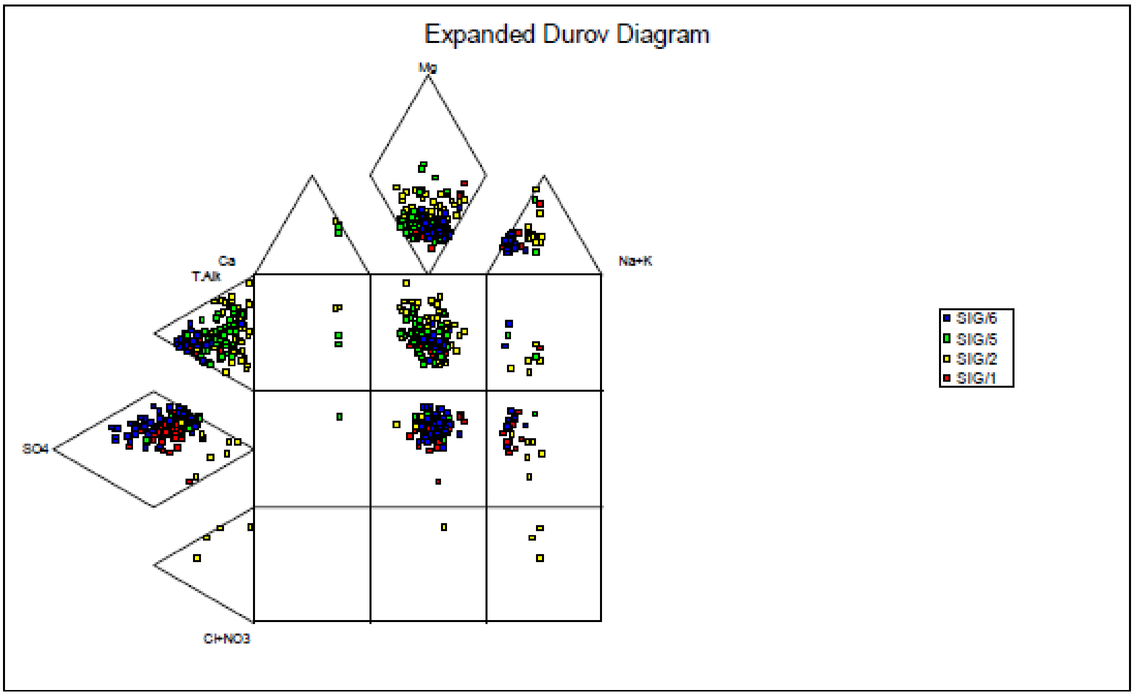

Figure 6-10: Expanded Durov Diagram of the Leeuspruit and its tributary Illustrating Historic Water Quality Trends

When the Leeuspruit is benchmarked with the prescribed Leeu/Taaiboschspruit Water Quality Guidelines (Table 6-7), the parameters that are at unacceptable concentrations are chloride, phosphate and the suspended solids. Phosphate and suspended solids are elevated in the Leeuspruit and its tributary, exceeding the prescribe WQG. Magnesium and sodium is also slightly elevated at the upstream sample (SIG/2) of the Leeuspruit but is still within the tolerable limit, whereas ammonium at the downstream sample is within the tolerable limit. The elevated constituents are probably animal related.

The faecal coliforms of the Leeuspruit and its tributary exceed the prescribed limit for the Leeu/Taaiboschspruit catchment WQG. E.Coli is also detected in the Leeuspruit and its tributary.

Table 6-7: Leeuspruit Water Quality vs. the Prescribed Leeu/Taaiboschspruit Catchment Water Quality Guidelines (May 2017)

SiteName	EC	pH	Ca	Mg	Na	K	PAlk	MAlk	F	Cl	NO2(N)
SWQG	mS/m		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Acceptable	<70	6.5-8.5	N/S	<30	<100	N/S	N/S	N/S	<0.7	<150	<3.0
Tolerable	70-120	N/S	N/S	30-70	100-150	N/S	N/S	N/S	0.7-1.0	150-200	3.0-6.0
Unacceptable	>120	<6.5; >8.5	N/S	>70	>150	N/S	N/S	N/S	>1.0	>200	>6.0
SIG1	93	7.3	69	23	99	16.1	0	167	0.21	70	<0.01
SIG2	159	8.0	107	68	116	87.9	0	510	<0.1	229	<0.1
SIG5	54	7.6	45	11	46	21.8	0	138	0.23	50	<0.01
SIG6	78	7.8	56	18	90	14.0	0	231	0.39	49	0.07
SiteName	**NO3(N)**	**PO4**	**SO4**	**Al**	**Fe**	**Mn**	**NH4(N)**	**TDS**	**B**	**Si**	**Cd**
SWQG	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Acceptable	<3.0	<0.4	<300	<0.3	<0.5	<0.5	<1.5	N/S	N/S	N/S	N/S
Tolerable	3.0-6.0	0.4-0.6	300-500	0.3-0.5	0.5-1.0	0.5-1.0	1.5-5.0	N/S	N/S	N/S	N/S
Unacceptable	>6.0	>0.6	>500	>0.5	>1.0	>1.0	>5.0	N/S	N/S	N/S	N/S
SIG1	<0.05	0.65	225	0.141	0.291	0.131	3.13	674	0.407	4.83	<0.003
SIG2	0.02	<1	23	0.071	0.075	0.465	0.32	1143	0.055	10.37	<0.003
SIG5	1.87	0.15	63	0.167	0.109	<0.020	0.08	385	0.075	5.27	<0.003
SIG6	2.26	1.45	114	0.058	0.040	0.034	0.29	585	0.153	5.20	<0.003
SiteName	**Co**	**Cr**	**Cu**	**Pb**	**Turb**	**COD**	**Susp. Solids**	**Phenol**	**DOC**	**TOC**	
SWQG	mg/L	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/IO2	mg/L	
Acceptable	N/S	N/S	N/S	N/S	N/S	N/S	<30	N/S	N/S	N/S	
Tolerable	N/S	N/S	N/S	N/S	N/S	N/S	30-55	N/S	N/S	N/S	
Unacceptable	N/S	N/S	N/S	N/S	N/S	N/S	>55	N/S	N/S	N/S	
SIG1	<0.020	<0.020	0.008	<0.015	48	137	67	<0.01	17	20	
SIG2	<0.020	<0.020	0.007	<0.015	12	100	16	<0.01	32	36	
SIG5	<0.020	<0.020	0.013	<0.015	3	32	5	<0.01	11	13	
SIG6	<0.020	<0.020	0.008	<0.015	176	266	360	<0.01	8	9	

SWQG - Leeu/Taaiboschspruit prescribed Surface Water Quality Guidelines

N/O – Not specified

6.2.2.2 Rietspruit

The water quality of the Rietspruit indicated water with a calcium/sodium-bicarbonate character. The time graphs for the electrical conductivity, pH, chloride and sulphate are illustrated in Figure 6-11. The overall water quality trend for SIG/3 downstream remained sideways over time, whereas the quality SIG/4 upstream behaves erratic over time. The historic trends for SIG/4 indicate periods of prominent chloride and sulphate rich waters (Figure 6-12). The higher concentrations of chloride and sulphate are probably the result of evaporation during the dry winter season when the salt concentration increases as the water from the stream evaporates.

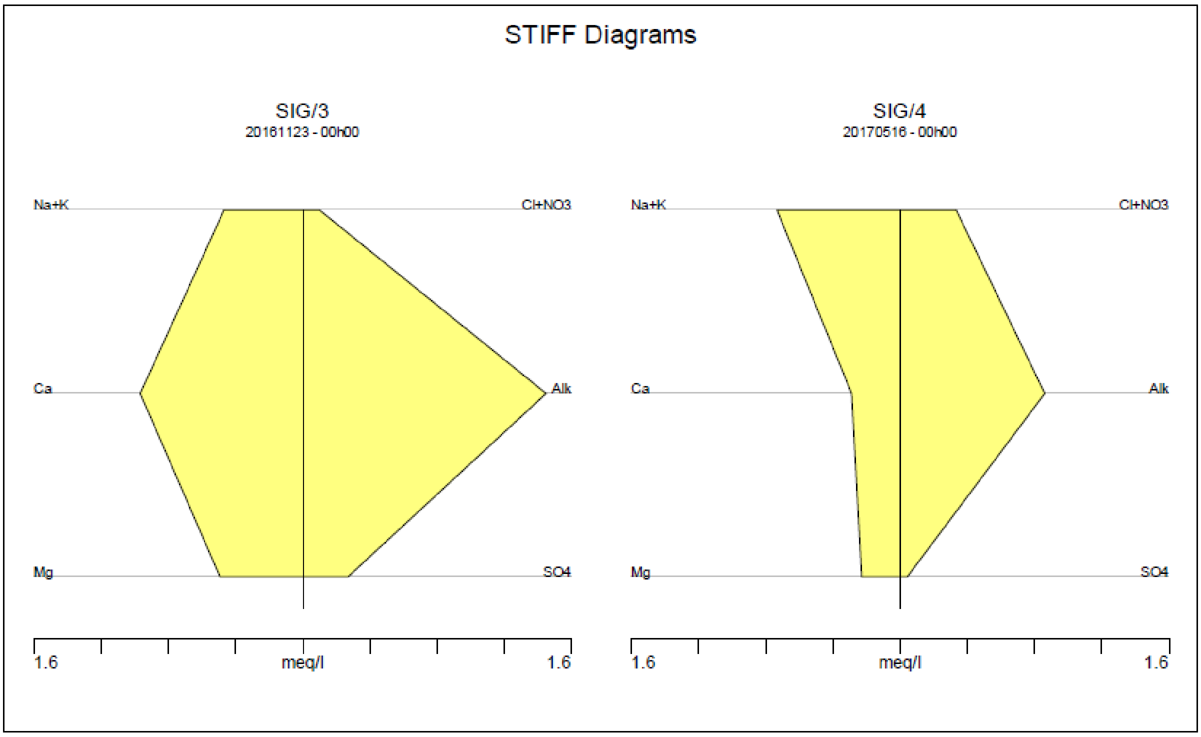

Figure 6-11: Stiff Diagrams of the Rietspruit Upstream (SIG/4) and Downstream (SIG/3) during May 2017

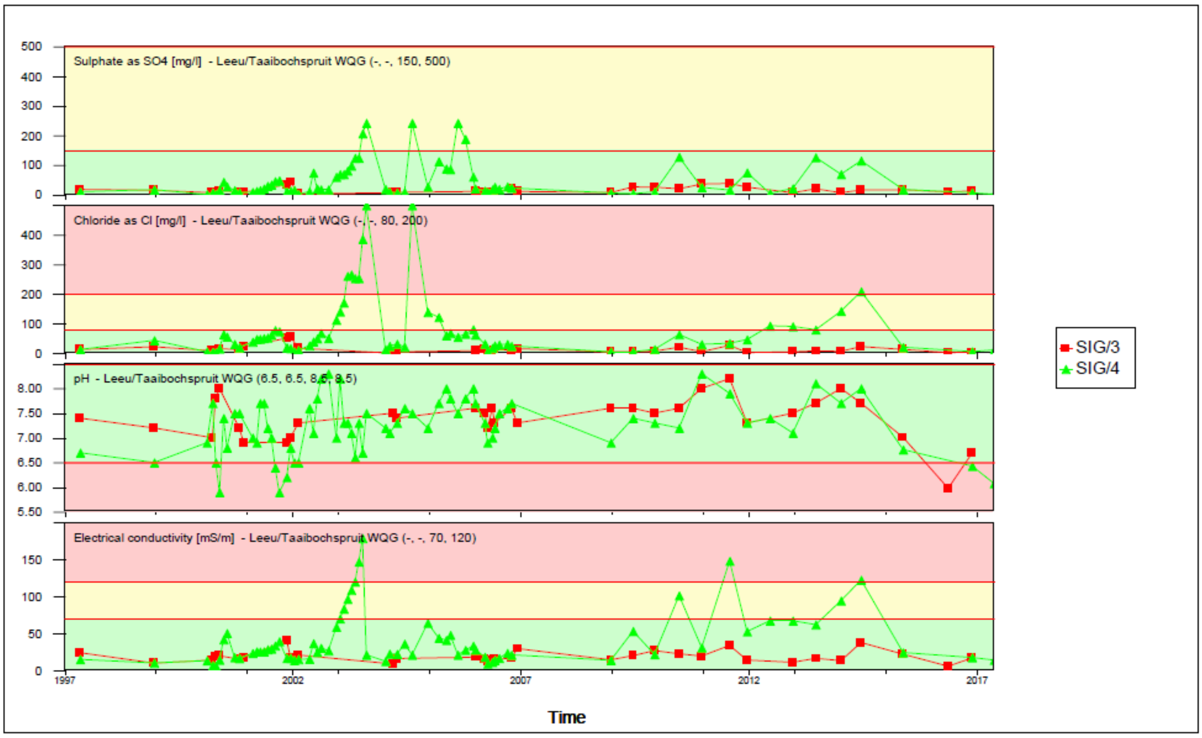

Figure 6-12: Electrical Conductivity, pH, Chloride and Sulphate Time Graphs for the Rietspruit

When the Rietspruit is benchmarked with the prescribed Leeu/Taaiboschspruit Water Quality Guidelines, for the Rietspruit upstream and downstream sampling points for May 2017, Aluminium, iron, pH and the suspended solids are the only constituents that exceed the prescribed Leeu/Taaiboschspruit WQG. All the other constituents are well within the prescribed acceptable limits. The faecal coliforms concentration in the Rietspruit exceeds the prescribed Leeu/Taaiboschspruit WQG but is still within the tolerable limit. E.Coli is also detected in Rietspruit.

6.2.2.3 Vaal River Barrage

The latest water quality for Vaal River represented by Vaal Upstream and Vaal downstream, revealed sodium sulphate signatures (Figure 6-13). The upstream sampling point's water quality is generally worse than the downstream sampling point. Thus, indicating that there are other sources influencing the quality of the Vaal River upstream from the Sigma operations.

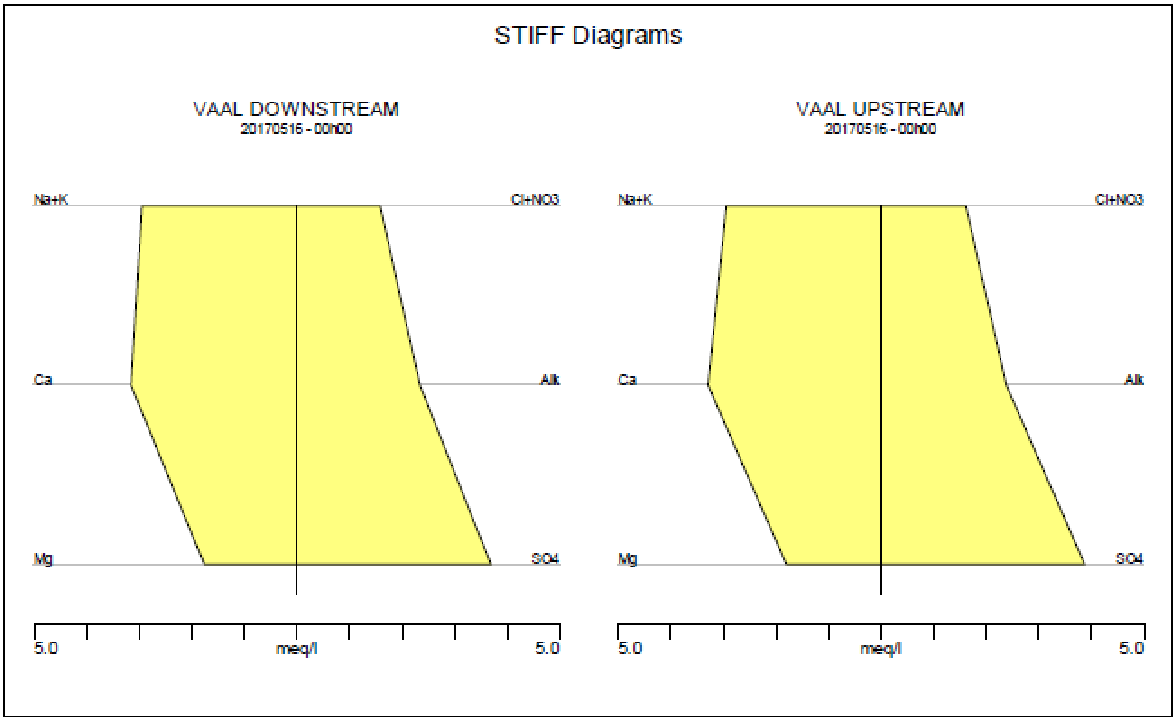

Figure 6-13: Stiff Diagrams of the Vaal River Upstream and Downstream

The historic water quality data as shown in Figure 6-14 reveals the current calcium sulphate signatures from the latest data. The time series Stiff diagrams (Figure 6-15) indicate that the water quality downstream varies between calcium sulphate and sodium bicarbonate water.

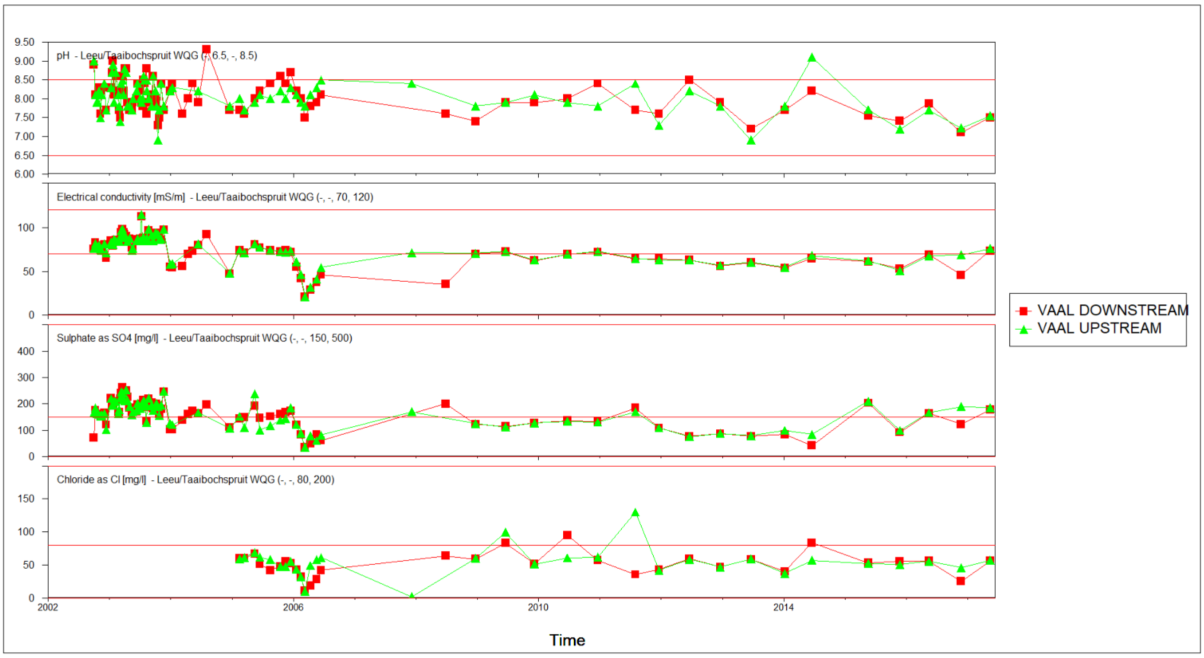

Figure 6-14: Major Cation, Anion and Electrical Conductivity Time Graphs of the Vaal River Upstream and Downstream

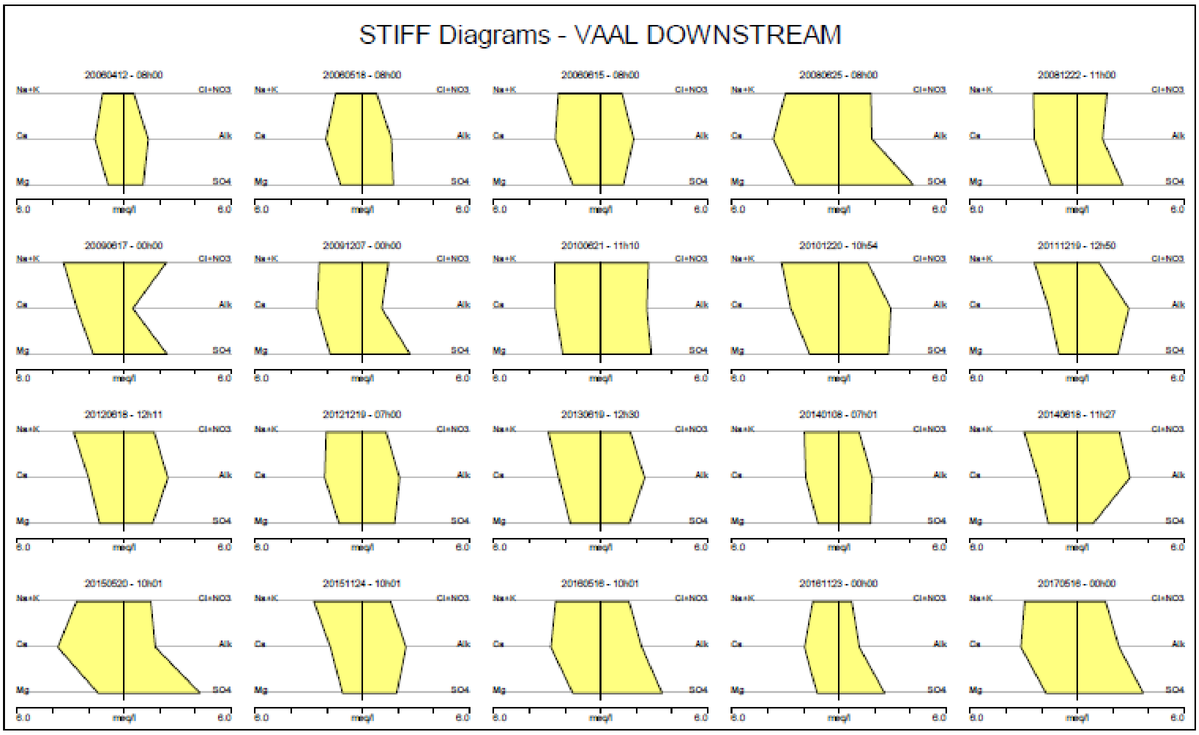

Figure 6-15: Stiff Diagrams of the Vaal River Upstream and Downstream

When the water quality for the Vaal River upstream and downstream sampling points for May 2017 is benchmarked with the prescribed Leeu/Taaiboschspruit Water Quality Guidelines, only phosphate and the suspended solids that exceeds the prescribed Leeuspruit/Taaiboschspruit WQG. Nitrate and ammonium is also elevated but within the tolerable prescribed limit. All the other constituents are well within the acceptable range.

Faecal coliforms are elevated but within the acceptable limit. E.coli is also detected in the Vaal River.

6.2.2.4 Wonderwater Surface Water Dams

It must be emphasized that the HAMMERKOP and KOLGANS Dams were used to store mine water when the mine was operational and now they only collect rain water/runoff. WW-BLESBOK and WW-DUIKER are only sampled if there is seepage visible from the old dumps.

The water quality of the Wonderwater surface water dams are all enriched with sulphate. REH-NORTH REH DAM (Lake Nussey) and REH SOUTH REH DAM (Chrissiesmeer) have a magnesium-sulphate character (water qualities are similar). When comparing this current water quality with the historic records, the high sulphate signatures correlates well with that of the past records (Figure 6-17). The high sulphate character (>1 000 mg/l) of the final voids is typical of waters associated with open cast coal mining activities.

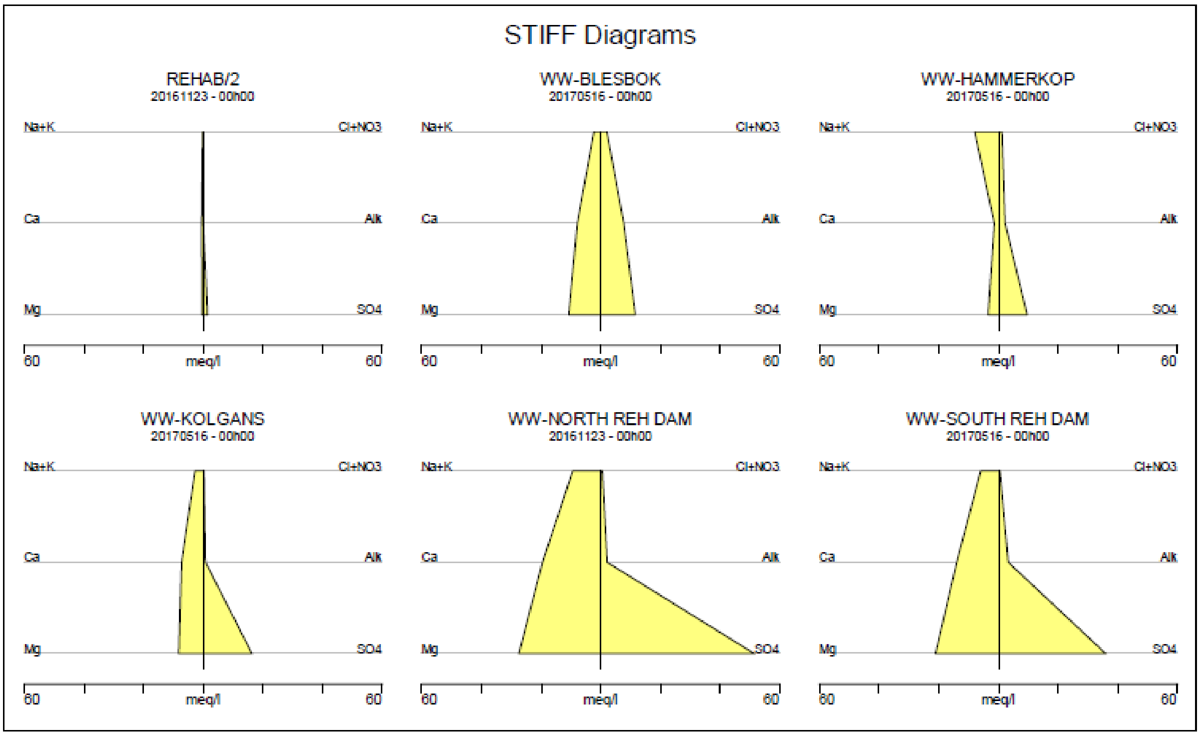

Figure 6-16: Stiff Diagrams of the Wonderwater Surface Water Dams

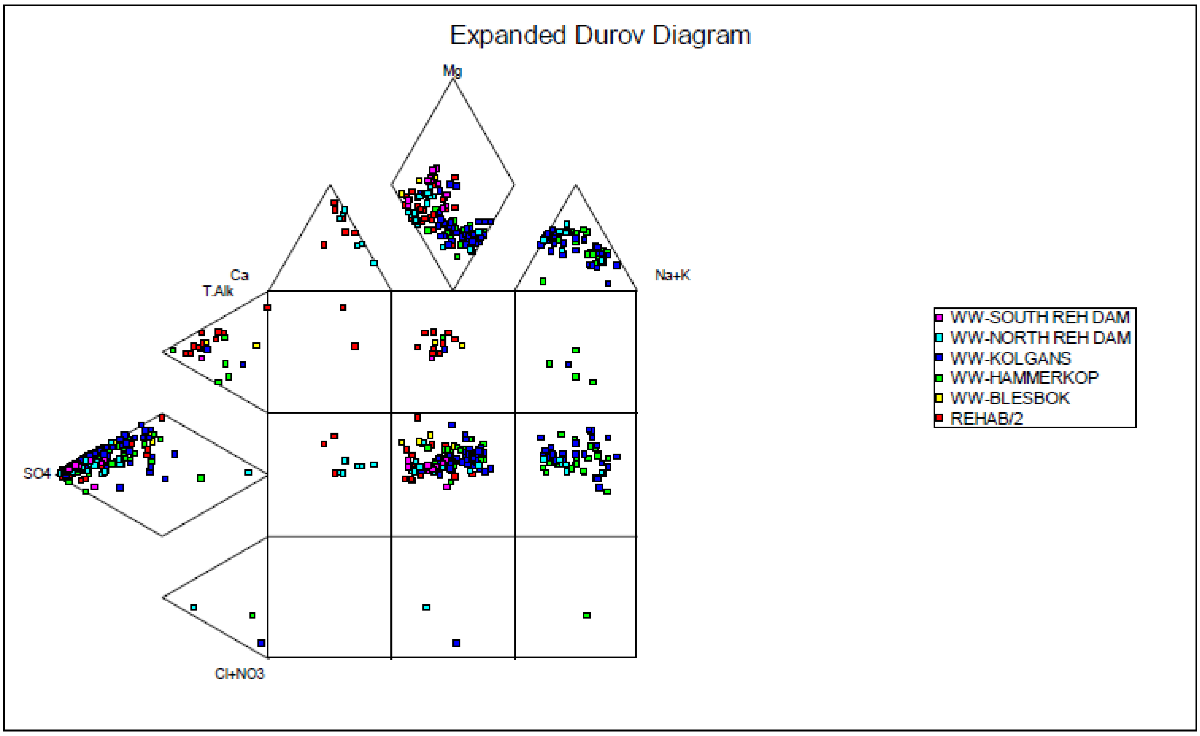

Figure 6-17: Stiff Diagrams of the Wonderwater Surface Water Dams

The time graphs for the electrical conductivity, chloride and sulphate are illustrated in Figure 6-18. The water quality for REHAB/2 remained sideways overtime, whereas there is a deterioration trend observed for all the other surface water dams since 2009. The chloride concentration of WW-NORTH REH DAM, WW-HAMMERKOP and WW-KOLGANS was exceptionally high in June 2014 but has improved to previous values. This may be the result of evaporation, increasing the salt concentration; this is especially the case for WW-HAMMERKOP and WW-KOLGANS. WW-BLESBOK deteriorated over the last six months, indicating that the quality of the runoff water from the Wonderwater East Dump might be affected by the dump to some degree.

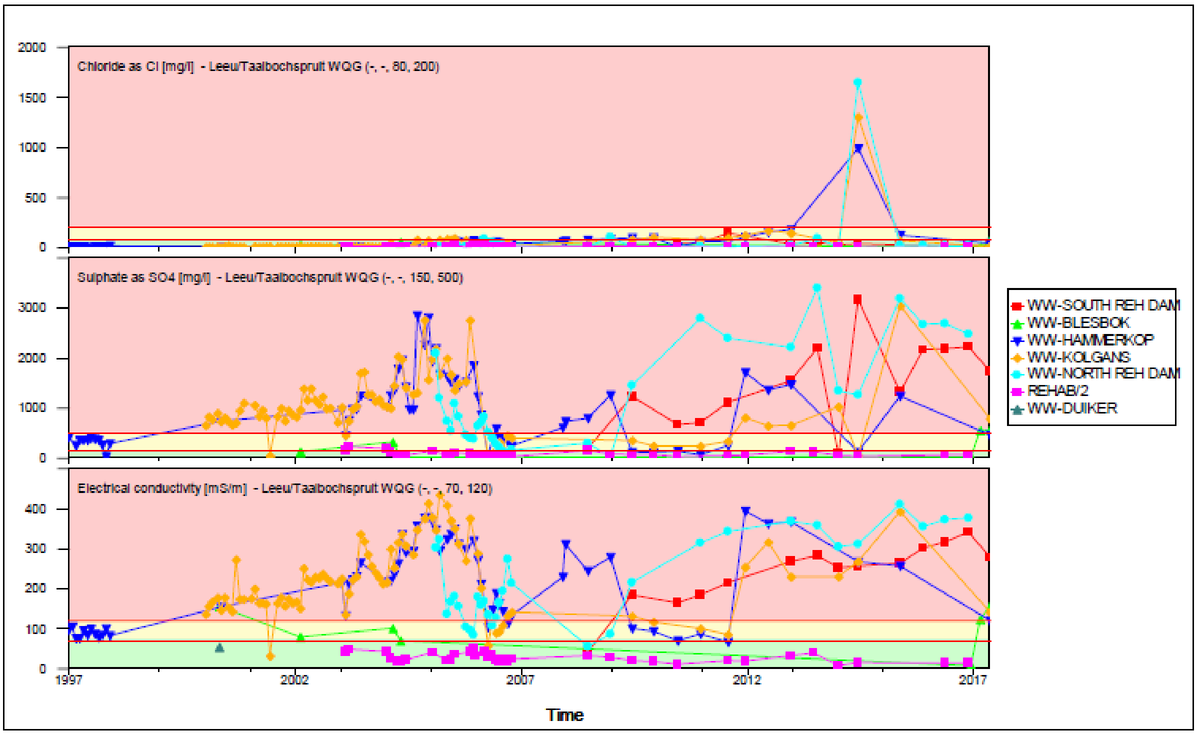

Figure 6-18: Electrical Conductivity, Chloride and Sulphate Time Graphs of the Wonderwater Surface Water Dams

When the water quality for the Wonderwater surface water dams for May 2017 is benchmarked with the prescribed Leeu/Taaiboschspruit Water Quality Guidelines, the quality of the final voids (WW-NORTH & WW-SOUTH REH DAM), WW-BLESBOK and WW-KOLGANS exceeds the prescribed Leeu/Taaiboschspruit WQG. Magnesium and sulphate are the constituents exceeding the prescribed limits. The suspended solids concentration in WW-BLESBOK and WW-HAMMERKOP also exceed the prescribed WQG. All the other constituents are well within the prescribed acceptable range.

Faecal coliform exceeds the prescribed WQG in WW-BLESBOK. E.coli is also detected in all the Wonderwater surface dams that are being monitored.

7 Water Uses

The current water uses are linked to land uses. Identified activities during the fieldwork were;

- Agricultural use for livestock;
- Wildlife;
- Industry;
- Domestic water use at settlements; and
- Sand mining activities in the Leeuspruit catchment.

Downstream impacts of the sand mining are already evident as indicated in Figure 7-1, shown by the murky water with evidence of algal growth. The algal growth can be attributed to the impacts form agricultural activities and sewage bursts in the vicinity and upstream.

The landscape is dominated by maize, wheat and livestock farming in the central, western and southern areas; urban built-up areas to the east and sand mining activities to the north and east.

Figure 7-1: Location on Leeuspruit Downstream of the Sand Mining and Agricultural Activities at the Pipeline Stream Crossing

8 Water Authority

The area falls within the DWA Gauteng Region.

9 Baseline Conclusions and Recommendations

9.1 Baseline Conclusions

The following conclusions are drawn from the baseline data:

- The major surface water resources draining the project area are the Leeuspruit and the Rietspruit, which flow into the Vaal Barrage;
- The project area falls within two quaternary catchments C22K. The catchment was delineated into eleven sub-catchments for hydrological assessments;
- The project area hydrology is altered with catchment characteristics and surface topography already impacted by subsidence, historical strip mining and sand mining developments;
- Surface water quality is not pristine as several anthropogenic impacts have deteriorated the rivers over the years, these include, sand mining, farming, previous coal mining (in the event of decant), ash backfilling spill years back, informal settlements, urban development as well as burst sewer pipes;
- The water quality results of the Leeuspruit indicates water with a sodium-bicarbonate character with a sulphate enrichment downstream, whereas, the tributary flowing into Leeuspruit indicates water with a that changes from a calcium-bicarbonate character to a sodium-bicarbonate character enriched with sulphate. The parameters that are at unacceptable concentrations are chloride, phosphate and the suspended solids. Phosphate and suspended solids are elevated in the Leeuspruit and its tributary, exceeding the prescribe WQG;
- The water quality of the Rietspruit indicates water with a calcium/sodium-bicarbonate character. Aluminium, iron, pH and the suspended solids are the only constituents that exceed the prescribed Leeu/Taaiboschspruit WQG. The faecal coliforms concentration in the Rietspruit exceeds the prescribed Leeu/Taaiboschspruit WQG but is still within the tolerable limit. E.Coli is also detected in Rietspruit;
- The latest water quality for Vaal River represented by Vaal Upstream and Vaal downstream, revealed sodium sulphate signatures. The upstream sampling point's water quality is generally worse than the downstream sampling point. Thus, indicating that there are other sources influencing the quality of the Vaal River upstream from the Sigma operations;

The predominant water uses are agriculture (farming and livestock). The runoff water from these activities flows into the Vaal Barrage from the Rietspruit and the Leeuspruit.

10 Impact Assessment

The impact assessment methodology for the proposed Sigma ash backfilling project will consist of two phases, namely:

- Impact identification; and
- Impact significance rating.

In brief, impacts and risks are identified based on a description of the existing and proposed future activities to be undertaken as part of the propose project. The impact assessment and significance ratings are determined for these proposed activities.

The mitigation measures for all impacts and risks will be incorporated into an EMP.

The significance rating process for impacts follows the established impact/risk assessment formula where:

- Significance = Consequence x Probability;
- Consequence = Severity + Spatial Scale + Duration; and
- Probability = Likelihood of an impact occurring.

The weight assigned to the various parameters for positive and negative impacts in the formula is presented in Table 10-1.

Table 10-1: Impact Assessment Parameter Rating out of 7

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.	Irreparable damage to highly valued items of great cultural significance or complete breakdown of social order.	International The effect will occur across international borders.	Permanent: No Mitigation No mitigation measures of natural process will reduce the impact after implementation.	Certain/ Definite. The impact will occur regardless of the implementation of any preventative or corrective actions.
6	Significant impact on highly valued species, habitat or ecosystem.	Irreparable damage to highly valued items of cultural significance or breakdown of social order.	National Will affect the entire country.	Permanent: Mitigation Mitigation measures of natural process will reduce the impact.	Almost certain/Highly probable It is most likely that the impact will occur.
5	Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate.	Very serious widespread social impacts. Irreparable damage to highly valued items.	Province/ Region Will affect the entire province or region.	Project Life The impact will cease after the operational life span of the Project.	Likely The impact may occur.
4	Serious medium term environmental effects. Environmental damage can be reversed in less than a year.	On-going serious social issues. Significant damage to structures / items of cultural significance.	Municipal Area Will affect the whole municipal area.	Long term 6-15 years.	Probable Has occurred here or elsewhere and could therefore occur.

Rating	Severity		Spatial scale	Duration	Probability
	Environmental	Social, cultural and heritage			
3	Moderate, short-term effects but not affecting ecosystem functioning. Rehabilitation requires intervention of external specialists and can be done in less than a month.	On-going social issues. Damage to items of cultural significance.	Local Local extending only as far as the development site area.	Medium term 1-5 years.	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.
2	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/ without help of external consultants.	Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Limited Limited to the site and its immediate surroundings.	Short term Less than 1 year.	Rare/ improbable Conceivable, but only in extreme circumstances and/ or has not happened during lifetime of the Project but has happened elsewhere. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures.
1	Limited damage to minimal area of low significance (e.g. ad hoc spills within plant area). Will have no impact on the environment.	Low-level repairable damage to commonplace structures.	Very limited Limited to specific isolated parts of the site.	Immediate Less than 1 month.	Highly unlikely/None Expected never to happen.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in the EMP. The significance of an impact is then determined (Table 10-2) and categorised into one of four categories, as indicated in Table 10-3.

Table 10-2: Significance Threshold Limits

Category	Description	Colour
High	108- 147	
Medium-High	73 - 107	
Medium-Low	36 - 72	
Low	0 - 35	

Table 10-3: Probability Matrix

Significance										
		Consequence (severity + scale + duration)								
		1	3	5	7	9	11	15	18	21
Probability / Likelihood	1	1	3	5	7	9	11	15	18	21
	2	2	6	10	14	18	22	30	36	42
	3	3	9	15	21	27	33	45	54	63
	4	4	12	20	28	36	44	60	72	84
	5	5	15	25	35	45	55	75	90	105
	6	6	18	30	42	54	66	90	108	126
	7	7	21	35	49	63	77	105	126	147

10.1 Impact Assessment

Eighteen pipeline stream crossings were identified, with major crossing on the Leeuspruit at an existing conveyor crossing point. These stream crossing points are indicated on Figure 6-4. The water quality is already impacted, with some parameters exceeding the Leeuspruit / Taaibos Spruit WQG. It is not anticipated that the proposed activities related to the pipeline will create new impacts, but if the project is mismanaged further impact negatively on the water quality.

10.1.1 Impact of the Pipeline Construction and Operation

During the construction phase, pipelines will be constructed above ground to fill the old underground mining voids. In the operation phase ash slurry will be pumped through the pipelines to the underground voids from Sasol Infrachem ash pump station. The potential impacts related to surface water are both positive and negative, with the positive impacts outweighing the negative, provided mitigation is implemented successfully.

10.1.1.1 Issue 1: Surface Water Quality Deterioration

During the construction phase surface water quality impacts are not anticipated. However during the operation phase the possibility of pipe bursts or leaks do exist.

Ash typically contains trace amounts of many toxic elements including arsenic, cadmium, chromium, mercury, lead, selenium and vanadium. Coal ash could also contain metals and salts. However this depends on the type of coal and the coal processing methods utilised in the processes at Sasol Infrachem. In the event of pipe bursts or leaks over stream crossings ash will be deposited directly in the streams resulting in contamination of the surface water. Given the stream crossings identified, the impact on the surface water will be at the farm dams and the tributaries of the Vaal Barrage.

- Impact 1: Introduction of pollutants in the form of dissolved metals, suspended solids/ particulate matter and salts from ash slurry;
- Impact 2: Changes in the natural pH to alkaline resulting in mobilisation of certain elements.
- Impact 3: Water contamination from the mine water pumped out, in the case of a burst pipe.

Issue 1	**Water quality deterioration from spillages and leakages**					
	Parameter	**Scale**	**Duration**	**Severity**	**Probability**	**Significance**
Impact1	**Pre-Mitigation**	National	Medium term	Significant	Likely	**Medium High**
		6	3	6	5	**75**
	Post-Mitigation	Local	Short term	Significant	Rare / Improbable	**Low**
		3	2	6	2	**22**
Impact 2	**Pre-Mitigation**	Province/ Region	Long term	Very serious	Unlikely / Low probability	**Medium Low**
		5	4	5	3	**42**
	Post-Mitigation	Local	Short term	Moderate	Rare / Improbable	**Low**

Issue 1	Water quality deterioration from spillages and leakages					
	Parameter	**Scale**	**Duration**	**Severity**	**Probability**	**Significance**
		3	2	3	2	**16**
Impact 3	**Pre-Mitigation**	National	Long term	Significant	Likely	**Medium High**
		6	4	6	5	**80**
	Post-Mitigation	Local	Medium term	Serious	Rare / Improbable	**Low**
		3	3	4	2	**20**

10.1.1.2 Issue 2: Catchment Hydrology / Surface Water Quantity Modification

The pipeline could impede flows in the catchments where they traverse streams and drainage lines however this impact could be very small. However, greater impacts could arise if accidental pipe bursts of slurry occur in large amounts on or close to stream crossings as these could result in particulate matter sedimentation in river channels which could alter the hydrology.

Given the impacts of subsidence on hydrology, backfilling is likely to result in a reduction of hydrology modification. However this will only be applicable on areas to be backfilled and have not already subsided.

- Impact 4: Stream channel modification from potential ash slurry spillages;
- Impact 5: A positive impacts where the landscape can be maintained further reducing natural landscape modifications;

Issue 2	Changes in the catchment hydrology					
	Parameter	**Scale**	**Duration**	**Severity**	**Probability**	**Significance**
Impact 4	**Pre-Mitigation**	Municipal area	Long term	Very serious	Likely	**Medium Low**
		4	4	5	5	**65**
	Post-Mitigation	Local	Short term	Minor	Rare / Improbable	**Low**
		3	2	2	2	**14**
Impact 5	**Pre-Mitigation**	National	Project life	Serious	Certain/Definite	**Medium High (positive)**
		6	5	4	7	**105**

10.1.1.3 Mitigation Description

Based on the identified impacts, the following mitigation actions are planned for the proposed project:

- Surface pipelines should be inspected for leaks on regular basis (weekly);
- Ensure that the pipes at stream crossings are mounted on stilts with concrete structures or other material to make sleeves which can contain material from spillages and allow the pipeline to cross at an elevation above the natural water level;
- Prioritize backfill at the potential subsidence areas to reduce or minimize the potential hydrological modifications
- Cut off valves should be installed on the pipeline with pressure sensors, which stop the flow in the event of a spill;
- Monitoring of potential surface water contamination is vital. Local river systems as well as boreholes should be monitored on a regular basis (as prescribed in monitoring programme);
- If ash spills/leakage occurs the following mitigation is recommended:
  - Contain the ash as much as possible using berms and cut off trenches;
  - Ash which is present within the river reaches should be removed by mechanical means;
  - Accidental spillages or leaks or pipe bursts should be reported and downstream users cautioned until any potential impacts are remediated.
- Although the IGS report for backfilling methodology (Lukas *et al.* 2013) indicates that the risk of decant is minimal when using the proposed methodology. However if any emerging decant points are observed during operation, monitoring should be implemented weekly with mitigation until impacts subside. Backfilling should be carried out under the guidelines of all specialist report compiled for this project.

10.1.2 Impacts of Construction of Pump Booster Station

10.1.2.1 Issue 1: Water Quality Deterioration

The booster pump station will entail the use of hydrocarbon lubricants for the machine moving parts, which, if not well maintained, could be a source of hydrocarbon contamination. Accidental spillage of hydrocarbon containing materials such as oils or lubricants may occur.

- Impact 6: Surface water contamination from hydrocarbon containing material

10.1.2.1.1 Mitigation Description

As the booster pump station is already existent with bunding and hard park areas, clean-up kits for accidental spillage must be available on-site to prevent the spread of accidental spillages and associated impacts. The mine personnel must be trained for clean-up of and report hydrocarbon containing material spillages.

Issue 3:	**Hydrocarbon contamination of surface water**					
	Parameter	**Scale**	**Duration**	**Severity**	**Probability**	**Significance**
Impact 6	**Pre-Mitigation**	Local	Project life	Very serious	Unlikely / Low probability	**Medium Low**
		3	5	5	3	**39**
	Post-Mitigation	Local	Project life	Minor	Highly Unlikely /None	**Low**
		3	5	2	1	**10**

10.1.3 Impacts from the Backfilled Underground Voids

IGS report of 2013 (Lukas *et al.* 2013) indicates that it is not anticipated that decant that will occur. The details on the specific underground impacts and plume modelling are outlined in the Geo-hydrological assessment report.

In the event that decant occurs, it could be collected to prevent it from flowing into the natural rivers. Decant water should be collected and treated before discharge.

11 Impact Assessment Statement

The current project has a high risk potential on the surface water system if mitigation is not implemented. This could occur if ash-water or mine water spills/ decants and would cause contamination of surface water resources. This would result in elevated levels of metals, salts and pH levels as well as alteration of stream hydrology regimes. Based on the proposed backfilling methodology the ash backfilling project should prevent further subsidence and should not decant into the surrounding water resources (IGS, Proposed backfilling methodology 2013). If no decant or leakages occur and subsidence is prevented the proposed project will have a beneficial impact on the catchment hydrology.

12 Cumulative Impacts

The area supplied by the Vaal River System stretches far beyond the catchment boundaries of the Vaal River and includes most of Gauteng. It also supports other socio economic activities namely Eskom power stations and Sasol's petro-chemical plants on the Mpumalanga Highveld, the North-West and Free State goldfields, Kimberley, several small towns along the main course of the river, as well as irrigation all along the main stem of the river and the large Vaalharts Irrigation Scheme.(JJ Van Wyk, et al, 2010)

However several of these existing activities have been key contributors to pollution including salinization of the integrated Vaal River System from sewage return-flows, AMD and diffuse pollution. The issues important in the Vaal are:

- Salinity – building up of salts – direct impact on quality;
- Nutrients – P and N creating eutrophication problems; and
- Microbiological – health issues from untreated sewage effluent.

The Vaal is already experiencing deterioration in water quality. Mitigations measures must ensure potential impacts to the already impacted catchment is minimised or prevented. Ash quality and leachates geochemistry should be fully considered even before the backfilling occurs. The cumulative deterioration of water quality in the quaternary catchment will have compounding impacts and water quality may be felt at a regional scale.

Positive cumulative impacts could be anticipated if the current potential subsidence is counteracted by backfilling of voids. The impacts on the catchment morphology currently preventing runoff water from reporting into the streams and rivers by collecting in artificial pans and surface depressions will be minimised or restored.

13 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.

A monitoring program is used as an early detection tool for surface water quality and is used to determine when mitigation must be implemented. Monitoring should be implemented throughout the project. The impacts on water quality will be determined by benchmarking the monitoring data against the Leeuspruit/ Taaibosspruit WQG.

The existing surface water monitoring programme (as provided in IGS report, 2017) is deemed sufficient for Sigma Colliery and this report recommends a continuation of the that monitoring programme to ensure compliance with the newly (2017) authorised Water Use Licence.

Table 13-1: Monitoring Programme

Location	Monitoring objectives	Frequency of monitoring	Parameters to be monitored
At all surface water monitoring sites in Table 6-6	-To monitor impacts on water quality in the stream -To detect any spillages and -To confirm that no decant is taking place into the surface water	- Monthly when backfilling is being undertaken at points upstream and downstream of the backfilled area - Reduce to quarterly on backfilled areas; - This can further be reduced to biannually (wet and dry season) when no impacts are detected for a period of Three years after the project has ceased as is standard practice.	- All parameters as indicated in Table 5-1

14 Impact Assessment Conclusion

The conclusions of the study are:

- The impacts of the “no-go option”/ present state were considered to be on water quality and on both the Rietspruit and the Leeuspruit. These impacts on water quality will be of similar significance if impacts occur from the backfilling process. In terms of the catchment morphology ash backfilling will result in improvement hence less impacts on water quantity;
- The proposed project’s impacts have been assessed to be of medium high to medium low before mitigation and minor to low significance post mitigation;
- The potential for contamination is a concern as coal ash could severely alter water quality conditions. Therefore, a large risk is associated with the current project if no mitigation is implemented;
- The negative cumulative impacts of the proposed project were seen to be high if contamination occurs and low if contamination does not occur;
- The positive cumulative impacts are anticipated to restore catchment runoff patterns in that further increase ponded water in subsidence zones is prevented by backfilling;
- Mitigation measures should be put in place in order to contain and prevent spillages of either ash slurry during backfilling or mine water during dewatering; and
- Based on the IGS report, proposed Sigma backfilling methodology, 2013 decant will not occur if the proposed methodology is followed.

15 Recommendations and Knowledge Gaps

The following recommendations were made after completion of the specialist study, and can be implemented as follow on work or important points to manage during the project life:

- The ash backfilling methodology should follow that by the IGS report (Lukas et al. 2013;
- The recommended impact mitigation measures should be implemented to ensure that the identified impacts on water quality and quantity can be reduced or prevented; and
- Water treatment technologies should be considered for treating water from the old mine voids during dewatering process which will be implemented with the ash backfilling.

Appendix A: Specialist CVs

Mr Mashudu Rafundisani

Hydrologist

Manager: Surface Water

Digby Wells Environmental

1 Education

1.1 Formal

Qualification: BSc Honours Degree in Environmental Management

Institution: University of Venda, Limpopo

Date Completed: 2012

1.2 Short Courses and Certificates

- Free Surface Water Flow Modelling (New HEC-RAS version 5.0) - University of Pretoria, 2015
- Project Management: Primeserv Corporate Training – 2016
- Flood Hydrology and Urban Runoff Modelling [PCSWMM] (University of Pretoria, March 2018)

2 Language Skills

- Tshivenda: Excellent
- English: Excellent
- Zulu: Fair
- Tsonga: Fair

3 Employment

- October 2013 - Present: Surface Water Consultant (Hydrologist) at Digby Wells Environmental.
- January 2012 – 2013 - Technical Research Assistant (University of Venda)

4 Software Experience

- ArcGIS
- ArcHydro

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*Non-Executive

- Utilities Programme for Drainage (UPD)
- Visual SCS-SA
- HEC-RAS 1D and 2D
- HEC-GeoRAS
- WRSM2000
- PCSWMM

5 General Experience

- Proposal writing.
- Baseline hydrological studies by reviewing literature and analyzing data such as rainfall, temperature, humidity, wind speed, Stream flows, soils, etc. of a study area to obtain the existing hydrological conditions. This includes report writing and summarizing the above data into graphs, tables and figures.
- Conducting hydrological studies into the impacts that developments (mostly mining) may have on the surface water environment. This includes using an adopted impact assessment methodology to determine the significance of the impacts. Reports include the description of the methods used and the results obtained as well as to provide mitigation measures for identified impacts.
- Water quality sampling and the interpretation of water quality results by summarizing results into tables, graphs and figures. This includes the generation of a report describing the sampling methods used and results obtained, and identification of possible sources of pollution, as well as suggesting mitigation measures to reduce the pollution.
- Setup of water quality monitoring networks.
- Streamflow monitoring and the interpretation of flow monitoring measurements.
- Floodline modelling using HEC-RAS software to determine flood water elevations. This includes delineating catchments using GIS software, determining the flood peaks for the delineated catchments by analyzing rainfall, land use, slope, soils, etc., and using an appropriate method to determine the flood peaks.
- Development of storm water management plans according to GN704 to separate clean and dirty water at development sites.
- Development of water and salt balances in order to manage mine water.

6 Project Experience (Selected)

- *Randgold Resources Limited, Luolo Gold Mine in Mali*, Water Treatment Options Using a Constructed Wetland. The study involved the design and operational needs to treat contaminated mine water to acceptable discharge levels, this research based work required the understanding of the right combination of vegetation, saturation of porous media (i.e. the macrophyte zone that could enable the treatment of the contaminated discharge water by removing Sulphates, Nitrates, Arsenic and Cyanide.

- *HCI Coal*: Setting-up of a water quality monitoring network and programme, Monthly water sampling from their mine sites and surrounding rivers over a 2 year period to determine whether the mine operations are impacting on the natural water quality. Monthly monitoring reports describing the water quality for the month and identifying possible sources of pollution as well as providing mitigation measures.
- *Elandsfontein Colliery*: Development of the mine wide storm water management plan to ensure separation of clean and dirty water within the mine in accordance with the Best Practice Guideline G1: Storm Water Management issued by Department of Water and Sanitation in 2006, the developed or recommended storm water management infrastructures also ensures minimisation of dirty areas/catchments and maximisation of clean areas to try and conserve as much clean water as possible within and around the Elandsfontein Mine.
- *Sibanye Gold (Pty) Limited*, The project was known as the West Rand Tailings Retreatment Project (WRTRP) which is located in the Gauteng province approximately 60 km south east of Johannesburg, where they envisage reclamation of the various mine Tailings Storage Facilities (TSFs) for gold and uranium production. My role was to undertake surface water assessment study, the study included the following: catchment description, climate analysis (rainfall & evaporation), flood peaks determination, water quality analysis of the streams surrounding the area, flood lines determination and the impact assessment on the quantity and quality of water.
- *Sasol Mining (Pty) Ltd, Sigma Mooikraal Colliery and other several Mines*: Mine water salt balance, i have compiled the water balance model that can be utilized to investigate and establish current and forecasted long term impacts, solutions and associated costs for mining operations with regards to their water requirements. This study also forecasted the water quality impact on the surrounding stream by calculating the forecasted concentrations of the stream when mine water is discharged. This enabled the mine to take pre-cautionary measures on the quality of their waste water to prevent the associated surface water impacts.
- *Exarro:* Environmental and Social Impact Assessment for a proposed coal mine in Hendrina, Mpumalanga Province. Undertaking the project from application forms, scoping and EIA report, compiling the specialist reports and public participation outcomes to a final submission of the ESIA report for environmental authorisation;
- *Building Energy S.A:* Surface Water Assessment study as part of the Basic Assessment Report for a proposed construction of Solar PV facility on a farm in the

Northern Cape Province. This included an application for IWULA General Authorisation for Section C & I water use in accordance with the in terms of section 39 of the National Water Act, 1998 (act no. 36 of 1998), Notice 509 promulgated in August 2016;

- *Glencore Operations South Africa (Pty) Ltd*: Water Balance Models-. Construction of Excel based water and salt balances based for the operational mine activities. Develop a reporting tool of quarterly water uses at the Mines. Construction water balance based on monthly time step water for proposed mining activities.
- *Ergo Mining (Pty) Ltd*: Storm Water Management Plan, South Africa. Assessment of the existing mine water management infrastructure, draft a report and compile a current water balance model for the mine, reporting of conclusions, whilst providing the necessary recommendations.
- *Eskom Holdings; Transmission Lines*; Flood lines determination 1:100 and 1:50 year floods - Assessments included hydrology modelling, model preparation in ArcGIS software HecGeoRas, hydraulic structures surveys on site, setting up 10 HecRAs Models, flood lines determination reporting of conclusions, whilst providing the necessary recommendations.
- *Randgold Resources Limited* - Integrated Mine Water Management Plan and Water Balance Model, Mali. Undertaking and assessment of the existing mine water management infrastructure, draft a report and compile a current water balance model for the mine, reporting of conclusions, whilst providing the necessary recommendations in line with the Mali Water Resources Commission permit requirements.

7 Professional Registration

- 2017: Registered as a Certified Natural Scientist with The South African Council for Natural Scientific Professions. Registration number: 115066

8 Professional affiliations

- Water Institute of Southern Africa, WISA (No. 25305)