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

Aquatic Biodiversity Assessment Report

Project Number:

SAS5184

Prepared for:

Sasol Mining (Pty) Ltd

June 2018

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

Name	**Responsibility**	**Signature**	**Date**
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Russell Tate	Report Compiler	[signature]	February 2014
Andrew Husted	Internal Review	[signature]	February 2014
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DECLARATION OF THE SPECIALIST

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

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I, Byron Bester, 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 Aquatic Biodiversity 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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Experience (Years):	7 years
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EXECUTIVE SUMMARY

This study was commissioned by Sasol Mining (Pty) Ltd to assess the ecological state of the lotic aquatic ecosystems associated with the Sigma Colliery project area. The project is located in the Sasolburg area, Free State Province, and entails backfilling of old underground mine voids with ash. This report provides a summary of the findings originating from sampling along the reaches of the Rietspruit, Leeuspruit and Vaal Barrage during both the low-flow and high-flow surveys conducted in October 2013 and in January 2014, respectively.

Based on the results of the *in situ* water quality analysis and previous reports, the water quality varies from good, in the Vaal Barrage, to poor in the Rietspruit and Leeuspruit systems. The associated aquatic macroinvertebrate communities were composed of predominantly pollution tolerant species that are adapted to low flow conditions. The results of the South African Scoring System (Version 5, SASS5) and Macroinvertebrate Response Assessment Index (MIRAI) indicate that conditions are seriously modified (Ecological Category E), which have been attributed to altered water quality, as well as inherent lack of suitable habitat. Results of the fish community assessment showed that the community structure was in a poor condition due to impacted water quality (Leeuspruit) and water quantity (Rietspruit). Sensitive species which were expected to be present within the study area were not captured during the assessment indicating modified conditions.

The final EcoStatus for the assessed sites in the Leeuspruit received a rating of Class D/E, which indicates that conditions are largely/seriously modified. This was attributed to impacts on habitat as a result of fine particulate matter/material observed upstream and downstream of Site SAS5, which was most likely a result of ash backfilling project that occurred between 2009 and 2012. However, water quality is also a major negative influence on the overall EcoStatus of the Leeuspruit.

The impacts of the “no-go option” (existing impacts) were considered to be major due to the current presence of water and habitat quality impacts, as well as possible subsidence. The proposed project’s impacts were assessed to be high before mitigation and medium-low after mitigation. The potential for contamination is a concern as coal ash has been found to severely alter aquatic conditions. It should be noted that cumulative impacts on the aquatic systems will only occur if there is spillage, in which case the impact will be high. However, based on the IGS report, proposed Sigma backfilling methodology (2013), decant will not occur. Recommendations include the establishment of monitoring points on the Vaal Barrage at the confluences for both affected river courses (i.e. Rietspruit and Leeuspruit) as well as within the affected river courses themselves.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1 Introduction

Aquatic ecosystems of South Africa have come under pressure from anthropogenic activities (Wepener *et al*., 2005), including industrial activities, which have the potential to degrade the ecosystems associated with them (Van Vuren *et al*., 1994). The degradation of an aquatic ecosystem may be in the form of habitat destruction, water quality modification or water quantity modification resulting in a loss of species richness as well as overall biomass (Wepener *et al*., 2005). As a result of the potential for industrial activities to alter natural aquatic systems, the requirement for monitoring and the establishment of baseline conditions has arisen (Wepener *et al*., 2005).

The Vaal Barrage, forming the northern boundary of the Sigma project area, is described as South Africa's most important river system, supporting the Johannesburg metropolitan area and supplying water to over 12 million consumers in Gauteng and surrounding areas (Ashton *et al*., 2001). The Vaal River is 1,120 km in length and of significant importance is the Vaal River's Yellowfish species (*Labeobarbus aeneus* and *Labeobarbus kimberleyensis*). These species are considered important due to their role in subsistence fishing communities, sport fishing and as an indicator species in the management of aquatic ecosystems (O'Brien and De Villiers, 2011).

This study will focus on establishing the current conditions (status), including spatial and temporal (annual) trends, using desktop data as well as data accumulated through previous surveys. The data will allow for the determination of the effects that the surrounding land users may be having on the receiving aquatic ecosystems associated with the study area. This report will also address the possible impacts and risks associated with the ash backfilling project and will make subsequent recommendations.

2 Terms of Reference

Digby Wells Environmental (hereafter Digby Wells) was commissioned by Sasol Mining (Pty) Ltd to assess the ecological state of the lotic aquatic ecosystems associated with the Sigma project area. The project is located in the Sasolburg area, Free State Province, and entails backfilling of old underground mine voids with ash.

An ecological state assessment was completed in October 2013 on reaches of the Rietspruit, Leeuspruit and Vaal Barrage. The aim of this assessment was to determine the current ecological state (or health) of the aquatic ecosystems and report on any spatial patterns within them.

An impact assessment of the proposed ash backfilling project will also be completed.

3 Aims and Objectives

The systems which may be negatively impacted on by the current project are the Leeuspruit and Rietspruit systems, while the Vaal Barrage was identified as a secondary endpoint for potential negative impacts. Therefore, the aim of the assessment is to confirm the current ecological status of the associated Leeuspruit and Rietspruit systems. In addition, potential impacts are identified in order to propose a means of avoiding or mitigating them. The aims of this study will be met through the following objectives:

- Describe the condition of the aquatic habitat, including the *in situ* water quality states and biotope availability;
- Characterise the current ecological state of the aquatic ecosystem by making use of selected response indices, which address macroinvertebrate and ichthyofauna population attributes;
- Make recommendations on the management and conservation of the systems in order to increase the ecological integrity of potentially impacted aquatic ecosystems and to conserve the ecological integrity of healthy ecosystems;
- Make recommendations on a medium-term monitoring programme that should be implemented; and
- Recommend mitigation actions which may aid in the protection of local aquatic ecosystems.

4 Assumptions and Limitations

The following assumptions were made at the time of writing:

- The foundation of this study was based upon data collected at the time of the 2013/14 aquatic biomonitoring cycle and as such, it is assumed that the present ecological state defined at the time of the writing, as well as the subsequent findings of the authors, were still valid at the time of the most recent update and internal review (i.e. June 2018).

The following limitations were expressed at the time of writing:

- The application of the selected assessment indices should be interpreted with caution within the associated wetland-dominated watercourses, as each of the selected indices were primarily designed for application within typical riverine systems with a moderate hydrology and diverse habitat availability.

- The extent of the amendment included within the most recent update (i.e. June 2018) is limited by the on-site observations and conclusions made by the authors at the time of the surveys and as a result, any further changes would need to be supported by desktop-studies and/or founded upon more recent on-site observations.

5 Details of the Specialist

This Specialist Report has been compiled by the following specialists (CVs of the Project Team are available upon request):

Table 5-1: Details of the Specialist(s) who prepared this Report

Responsibility	**Report Compiler**
Full Name of Specialist	Brett Reimers
Highest Qualification	MSc Applied Marine Science (UCT)
Years of experience in specialist field	1 (at the time of writing)
Responsibility	**Report Compiler**
Full Name of Specialist	Russell Tate
Highest Qualification	MSc Aquatic Health (UJ)
Years of experience in specialist field	3 (at the time of writing)
Responsibility	**Technical Review**
Full Name of Specialist	Andrew Husted
Highest Qualification	MSc Aquatic Health (UJ)
Years of experience in specialist field	7 (at the time of writing)
Registration(s):	South African Council for Natural Scientific Professionals: *Professional Natural Scientist* (Reg. No. 400213/11)
Responsibility	**Update and Internal Review**
Full Name of Specialist	Byron Bester
Highest Qualification	MSc Aquatic Health (UJ)
Years of experience in specialist field	7 (at the time of update)
Registration(s):	South African Council for Natural Scientific Professionals: *Professional Natural Scientist* (Reg. No. 400662/15)

6 Study Area

The aquatic ecosystems associated with the study area are situated within close proximity of the town Sasolburg and located within quaternary catchment C22K of the Vaal Water management Area (WMA). Within the current project area the affected river courses are the Rietspruit (non-perennial) and Leeuspruit (perennial) which subsequently flow into the Vaal Barrage.

The project area contains large scale industrial and urban activities such as coal and sand mining, mineral processing, as well as other ancillary activities. Development along the Vaal Barrage itself has modified the aquatic conditions, as well as available habitat with a large amount of riparian vegetation replaced by alien vegetation.

Table 6-1: The Ecological and Management Categories for the Quaternary Catchment C22k

Category	Description	State
EISC	Ecological importance and sensitivity category	Moderate
DEMC	Default ecological management class	Moderately sensitive systems
PESC	Present ecological state category	Class C (moderately modified)
AEMC	Attainable ecological management class	Class C (moderately modified)

(Source: Kleynhans, 2000)

Based on the ecological and management categories for the quaternary catchment (Kleynhans, 2000), the ecological importance and sensitivity category of the affected quaternary catchment is considered to be moderate indicating that there are some ecologically important species present within the quaternary catchment. The default ecological management class shows the presence of moderately sensitive species, meaning any development or modification in the catchment should be monitored carefully as sensitive organisms are potentially present. The Present Ecological State category of the affected catchment is Class C indicating the presence of a moderately modified ecosystem. The attainable ecological management class is Class C, meaning that management actions should aim to achieve this class. According to Kleynhans (2000) the current system is achieving the attainable management class and therefore development should strive to maintain this.

6.1 Sampling Sites

In order to establish the ecological integrity of the associated aquatic ecosystems several sites were selected on the associated tributaries as well as on the Vaal Barrage. A total of eleven sampling points were selected for the study. The GPS co-ordinates for each of the sampling sites are given in Table 6-2.

An illustration of the locations of the sampling sites in relation to the mine area is presented in Figure 6-1, while the photographs recorded for each sampling site for the current survey are presented in Appendix A.

Table 6-2: GPS Co-Ordinates and Short Descriptions of the various Study Sites

Site name	Coordinates	Description
The Vaal Barrage		
SAS1	26°45'02.66"S 27°47'24.50"E	This site is located in the main stem of the Vaal Barrage. The site comprises of sandy substrate with some *Phragmites* sp. as dominant marginal vegetation.
The Leeuspruit		
SAS2	26°50'18.55"S 27°48'43.43"E	This site is located in the upper reaches of the Leeuspruit below the fine/coarse ash dump facility and adjacent tar pits. The site was completely dry during the low flow survey
SAS3	26°48'07.12"S 27°47'56.43"E	This site is located above the R59 bridge crossing. The site is located adjacent an urban area and had *Salix babylonica* and grass as the predominant riparian vegetation.
SAS4	26°47'47.78"S 27°47'32.35"E	This site is located at the crossing point of a conveyor system. The site was located adjacent a sand mining operation.
SAS5	26°47'35.04"S 27°47'12.52"E	This site was located just upstream of the Vaal-Leeuspruit confluence adjacent to a scrap yard. A fine particulate matter was found at the site along with a large degree of sedimentation.
SAS10	26°48'37.04"S 27°48'03.28"E	This is believed to be the site where an ash spill entered the Leeuspruit. Evidence of ash mixed with sediment was found at this location
SAS11	26°47'32.11"S 27°47'02.46"E	Confluence of the Leeuspruit and the Vaal River. Lots of riparian vegetation. Only accessible by boat. Water level artificially elevated due to presence of the barrage.
The Rietspruit		
SAS6	26°50'15.13"S 27°45'18.65"E	This site is located within the upper reaches of the Rietspruit adjacent a cattle farm. The site was completely dry during the low flow survey.
SAS7	26°49'42.36"S 27°45'11.39"E	This site is situated at the R59 bridge crossing and was completely dry during the current low flow survey.
SAS8	26°48'59.46"S 27°44'45.46"E	This site is located within a game farm area. The site was completely dry during the low flow survey.
SAS9	26°48'02.75"S 27°44'35.52"E	This site is located within a game farm area. The site was completely dry during the low flow survey.
SAS12	26°46'41.00"S 27°44'28.34"E	Confluence of the Rietspruit and the Vaal River. Lots of riparian vegetation (*Phragmites australis*). Only accessible by boat. Water level artificially elevated due to presence of the barrage.

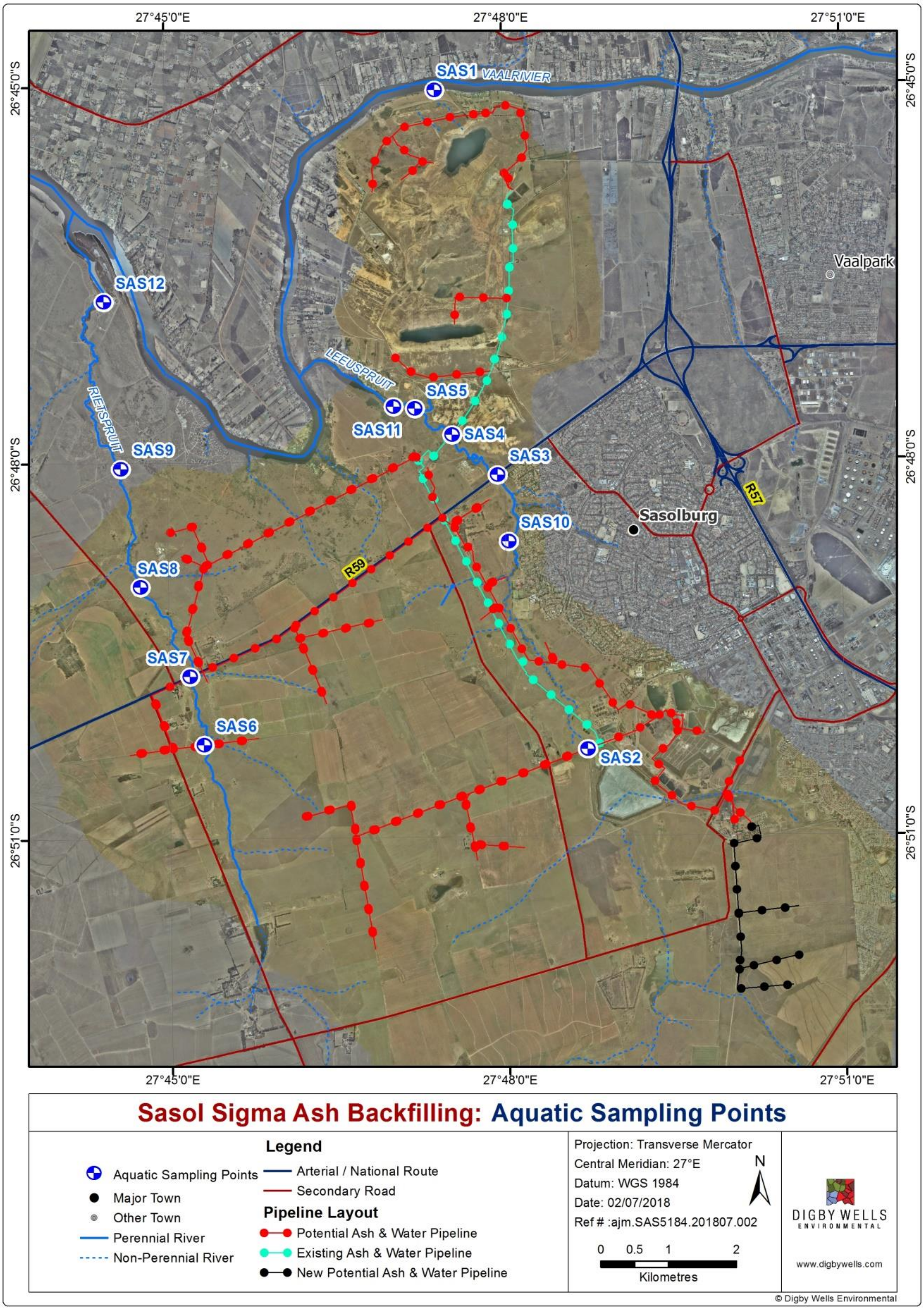

Figure 6-1: Location of Sampling Sites in relation to the Proposed Pipelines

7 Methodology

7.1 Phase 1: Desktop Study

A desktop study on the ecological state of the Vaal Barrage, as well as the Leeuspruit and Rietspruit was undertaken through the use of a literature review.

7.2 Phase 2: Ecological Integrity

In order to determine the ecological integrity of the aquatic environment, individual biophysical components of the streams in the study area were assessed. These biophysical attributes are assessed by implementing selected tools or indices that refer to selected drivers and biological responses of an aquatic ecosystem. Methodologies formulated by the RHP (RHP, 2001) were implemented and include:

- The abiotic driver assessment:
  - *In situ* water quality (DWAF, 1996);
  - The Index of Habitat Integrity (IHI) (Kleynhans et al, 2008); and
  - The Invertebrate Habitat Assessment System (IHAS) (McMillan, 1999).
- The biotic response indicator assessment:
  - South African Scoring System, Version 5 (SASS 5);
  - Macroinvertebrate Assessment Index (MIRAI); and
  - The Fish Response Assessment Index (FRAI).

According to Kleynhans and Louw (2007) the directional change in the attributes of the drivers and biota is referred to as a trend. Generally, an assessment may be approached from a driver perspective (Kleynhans & Louw, 2007). The driver components will be considered in order to determine the degree of contribution towards the current state of the biological communities.

7.2.1 Water Quality

The quality of water refers to the physical, chemical, biological and aesthetic properties determine its fitness for a variety of uses and for the protection of the health and integrity of aquatic ecosystems (DWAF, 1996). The various water quality parameters were all taken *in situ*. These parameters include pH, temperature (°C), conductivity (µS/cm), oxygen content (mg/l) and oxygen saturation (DO %) using calibrated water quality meters.

The South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996) was applied as the primary source of reference. The South African Water Quality Guidelines are similar to that of international literature; however, the information provided is specifically formulated for Southern African aquatic ecosystems and water users (DWAF, 1996).

7.2.2 Habitat Quality

The assessment of the composition of the surrounding physical habitat, which influences the quality of the water resource and the condition of the resident aquatic community, is referred to as a habitat assessment (Barbour *et al*., 1996). An important factor which determines the survival of a species in an ecosystem is the state of the available habitat. As a result of habitat loss, alteration and degradation of habitat the number of species present will decline (Karr, 1981). According to Karr (1981) the diversity of biota dependent on the habitat will decrease if the habitat integrity decreases.

The physical habitat of an aquatic ecosystem is a large component which affects the ecological integrity of an aquatic ecosystem and as a result, an assessment should be included in all bioassessments to assist in interpreting the results (Uys *et al*., 1996; McMillan, 1999; Dickens and Graham, 2002).

7.2.2.1 Index of Habitat Integrity (IHI)

The quality and diversity of the available habitat was assessed by means of the IHI (Kleynhans *et* al., 2008). The IHI was applied on a systems basis. The IHI integrity classes and a description of each class are presented in Table 7-1. This index assesses the number and severity of anthropogenic perturbations and the damage they potentially inflict on the habitat integrity.

Table 7-1: The IHI Integrity Classes and Short Descriptions of each Class

Integrity Class	Description	IHI Score (%)
A	Natural	>90
B	Largely Natural	80 – 90
C	Moderately Modified	60 – 79
D	Largely Modified	40 – 59
E	Seriously Modified	20 – 39
F	Critically Modified	0 - 19

(Source: Kleynhans *et al*., 2008)

7.2.3 Aquatic Invertebrate Assessment

Macroinvertebrate assemblages are good indicators of localised conditions because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life. They are particularly well-suited for assessing site-specific impacts (upstream and downstream studies) (USEPA, 2006). Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing comprehensive information for interpreting cumulative effects (USEPA, 2006).

7.2.3.1 Invertebrate Habitat Assessment System (IHAS)

The IHAS was specifically designed to be used in conjunction with the SASS 5, benthic macroinvertebrate assessments. The IHAS assesses the availability of the biotopes at each site and expresses the availability and suitability of habitat for macroinvertebrates, this is determined as a percentage, where 100% represents "ideal" habitat availability. A description based on the IHAS percentage scores is presented in Table 7-2.

Table 7-2: Description of IHAS Scores with the respective Percentage Category

IHAS Score (%)	Description
>75	Very Good
65 – 74	Good
55 – 64	Fair/Adequate
< 55	Poor

(Source: McMillan, 2002)

7.2.3.2 South African Scoring System (SASS)

The SASS 5 is the current index being used to assess the status of riverine macroinvertebrates in South Africa. According to Dickens and Graham (2002), the index is based on the presence of aquatic invertebrate families and the perceived sensitivity to water quality changes of these families. Different families exhibit different sensitivities to pollution, these sensitivities range from highly tolerant families (e.g. Muscidae and Psychodidae) to highly sensitive families (e.g. Oligoneuridae). SASS results are expressed both as an index score (SASS score) and the Average Score Per recorded Taxon (ASPT value).

Sampled aquatic macroinvertebrates were then identified using the Aquatic Invertebrates of South African Rivers Illustrations book, by Gerber and Gabriel (2002). Identification of organisms was made to family level (Thirion *et al*., 1995; Dickens & Graham, 2002; Gerber & Gabriel, 2002).

All SASS 5 and ASPT scores are compared with the SASS 5 Data Interpretation Guidelines (Dallas, 2007) for the relevant ecoregion (Table 7-3). This method seeks to develop biological bands depicting the various ecological states and is derived from data contained within the Rivers Database (www.riv.co.za) and supplemented with other data not yet in the database. Furthermore, the results are also compared to the SASS 5 and ASPT interpretation guidelines described by Chutter (1998) (Table 7-4).

Table 7-3: Highveld Lower Biological Banding

Class	SASS 5 Score	ASPT	Condition
A	>123	>5.6	Natural/unmodified
B	83 - 122	5.5 – 5.8	Minimally modified
C	64 – 82	5.1 – 5.5	Moderately modified
D	51– 63	4.6 – 5.1	Largely modified
E	<50	<4.6	Seriously modified

(Source: Dallas, 2007)

Table 7-4: The suggested SASS 5 and ASPT Interpretations

SASS 5	ASPT	Suggested interpretation
>100	>6	Water quality natural, habitat diversity high
<100	>6	Water Quality natural, habitat diversity reduced
>100	<6	Borderline case between water quality natural and some deterioration in water quality
50 - 100	<6	Some deterioration in water quality
<50	Variable	Major deterioration in water quality

(Source: Chutter, 1998)

Based on the interpretation guidelines the SASS 5 results at all sites indicate that there is major deterioration in water quality. This has been confirmed in the absence of fish species with sensitive tolerance ranges. Water quality results from chemical and *in situ* analysis correlate with the macro-invertebrate composition. The low SASS 5 and ASPT score is a result of limited habitat availability at all the sampling sites with compounding effects of poor water quality conditions.

7.2.3.3 Macroinvertebrate Response Assessment Index (MIRAI)

The aim of the MIRAI is to provide a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic invertebrate community from the reference condition. This does not preclude the calculation of SASS scores if required (Thirion, 2007). The four major components of a stream system that determine productivity for aquatic organisms are as follows:

- Flow regime;
- Physical habitat structure;
- Water quality; and
- Energy inputs from the watershed Riparian vegetation assessment.

7.2.4 Ichthyofauna

Fish were sampled by means of electro-narcosis or any other method deemed sufficient. An assessment of the ecological conditions (Ecological Category) in terms of the inhabiting fish assemblage was conducted by means of the Fish Response Assessment Index (FRAI). The purpose of the FRAI is to provide a habitat-based cause-and-effect underpinning to interpret the deviation of the fish assemblage from the identified reference conditions.

7.2.5 Ecological Description (or EcoStatus)

Ecological classification refers to the determination and categorisation of the integrity of the various selected biophysical attributes of ecosystems compared to the natural or close to natural reference conditions (Kleynhans and Louw, 2007). According to Iversen *et al*. (2000) EcoStatus may be defined as the totality of the features and characteristics of the system that bear upon its ability to support an appropriate natural flora and fauna. For the purpose of this study ecological classifications have been determined for biophysical attributes for the three associated water-courses.

8 Results and Discussions

8.1 Water Quality

Organisms which are present within freshwater ecosystems are directly affected by water quality. It is therefore essential to collate the water quality data in order to understand the responses of biota within the freshwater systems. The assessment of water quality of local river systems is based on selected *in situ* variables.

8.1.1 Vaal Barrage

Sites on the Vaal (or close to the confluence) are selected to serve as monitoring points to gauge if water quality issues in the tributaries are affecting water quality in the Vaal River.

Based on the results below (Table 8-1) the conditions at the SAS1 site would not negatively affect local aquatic biota. The *in situ* water quality is deemed to be in a good state.

Table 8-1: *In situ* Water Quality for the Vaal Barrage during the Low Flow Survey 2013

Constituent	Range	SAS1
pH	6.5 – 9	6.6
Temperature (°C)	5 – 30	18.1
Conductivity (µS/cm)	< 700	682
DO (mg/l)	> 5	6.7
DO (% saturation)	80 - 120	83

Temporal data of the conductivity of the Vaal Barrage above the Leeuspruit confluence is presented in Figure 8-1. The pH levels in the Vaal Barrage at the Leeuspruit confluence are presented in Figure 8-2.

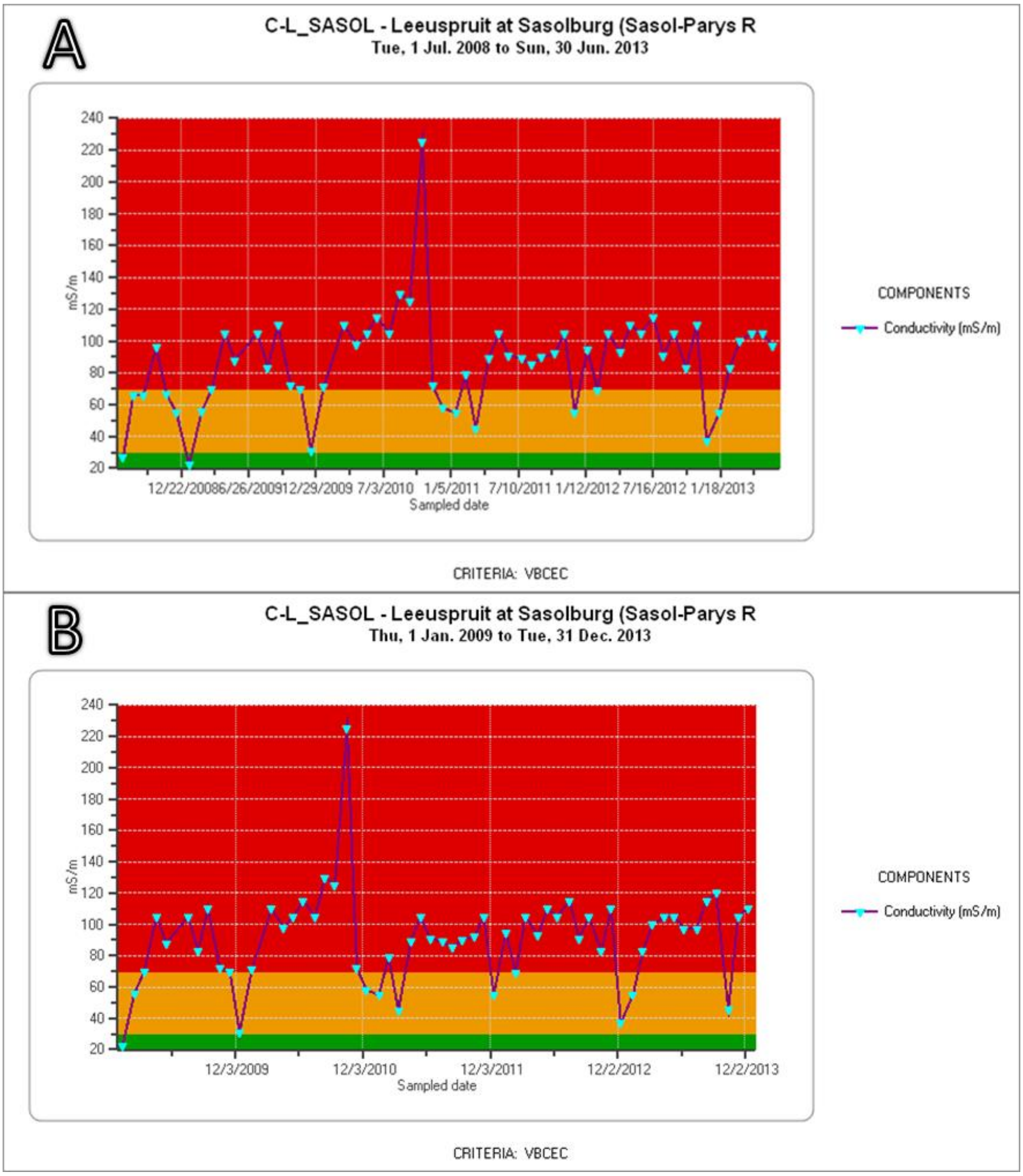

Figure 8-1: Conductivity (mS/m) changes from (A) 1 July 2008 to 30 June 2013 and (B) 1 January 2009 to 31 December 2013

Note: 1 µS/cm = 0.1mS/m

(Source: http://www.reservoir.co.za/timeseries_barrage.htm, accessed 10/10/2013 and 06/02/2014)

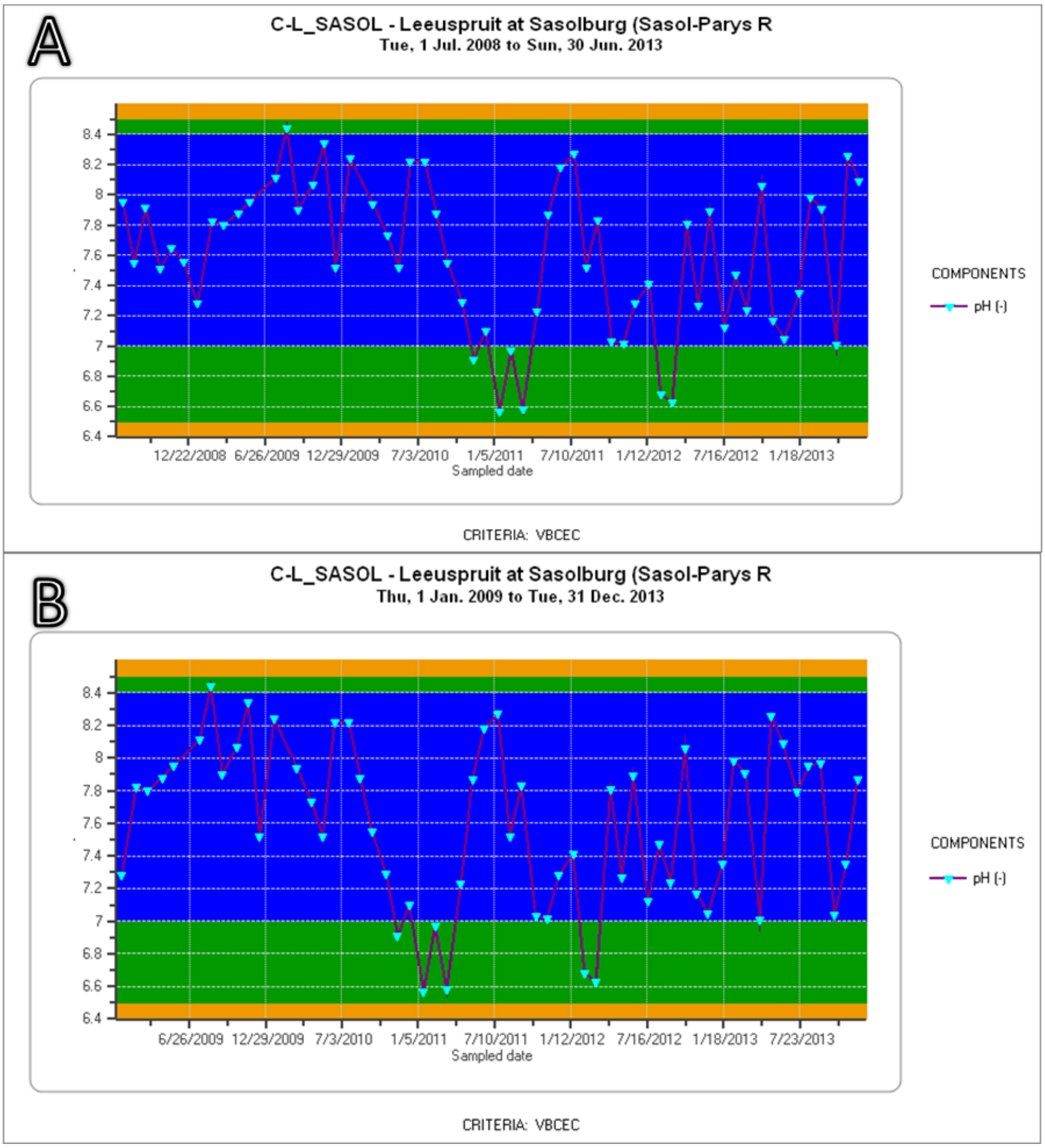

Figure 8-2: pH fluctuations from (A) 1 July 2008 to 30 June 2013 and (B) 1 January 2009 to 31 December 2013

(Source: http://www.reservoir.co.za/timeseries_barrage.htm, accessed 10/10/2013 and 06/02/2013 respectively)

The conductivity of the Vaal Barrage above the Leeuspruit confluence has fluctuated between 30 ms/m and 90 ms/m in the past year. The pH levels fluctuate between pH 7 and pH 8.5. Based on these results the water quality of the Vaal Barrage is stable with a relatively low fluctuation. Fluctuations in these water quality parameters are likely as a result of water releases from the Vaal Dam.

The Vaal Barrage is important to the study as a reference site for monitoring potential water quality impacts occurring from the Leeuspruit and Rietspruit systems. There is a steady regular supply of water quality data available from monitoring site controlled by the Department of Water Affairs (now referred to as the Department of Water and Sanitation).

8.1.2 Leeuspruit

The results of the low flow and high flow surveys for the Leeuspruit are presented in Table 8-2. It should be noted that the conductivity is elevated above the guideline levels (DWAF, 1996). Since conductivity is a measure of the concentrations of dissolved ions in the water column (Oche, 2007), this is an indication of a potential pollution occurrence within the sites associated with the Leeuspruit.

Table 8-2: *In situ* Water Quality Results for the Leeuspruit River System

Constituent	Range	SAS2	SAS3	SAS4	SAS5	SAS10	SAS11
Low flow							
pH	6.5 – 9	DRY	7.42	7.22	7.60	-	-
Temperature (°C)	5 – 30	DRY	13.5	14.6	17.2	-	-
Conductivity (µS/cm)	< 700	DRY	1128	1062	1471	-	-
DO (mg/l)	> 5	DRY	9.20	11.21	6.97	-	-
DO (% saturation)	80 - 120	DRY	111	123	89	-	-
High flow							
pH	6.5 – 9	7.70	-	7.51	-	7.34	7.75
Temperature (°C)	5 – 30	21.3	-	27.3	-	21.7	25.0
Conductivity (µS/cm)	< 700	559	-	724	-	1835	874
DO (mg/l)	> 5	6.4	-	1.43	-	3.81	Not measured
DO (% saturation)	80 - 120	83	-	21.1	-	47	Not measured

A previous study of the Leeuspruit (Mafanya, 2013) indicates that water quality is negatively influenced by anthropogenic activity and is “possibly related to surface runoff from nearby mining activities and stockpiles”. The recent Mafanya (2013) study shows that magnesium, nitrate, iron, fluoride, manganese, ammonium and phosphate levels are elevated.

8.1.3 Rietspruit

The results of the high flow survey for the Rietspruit are presented in the below Table 8-3. The sites associated with the Rietspruit were dry during the low flow assessment. The dry occurrence of these sites during the dry season emphasises the importance of the wet season sampling when assessing non perennial rivers. Previous studies have shown that when flowing, the water quality is similar to the Leeuspruit with the exception of conductivity levels and manganese concentrations (being higher in the Leeuspruit) (Mafanya, 2013).

From the collected data, it is apparent that water quality in the Rietspruit is in a better condition than the Leeuspruit. This is demonstrated by the fact that the conductivity values recorded fall within acceptable levels throughout all points sampled, which was identified as a variable of potential concern within the afore-described Leeuspruit.

It should also be noted that wet seasonal flow helps in diluting the salts that accumulate in pools when flow is restricted.

Table 8-3: Rietspruit High Flow *in situ* Water Quality

Constituent	Range	SAS6	SAS8	SAS9	SAS12
High flow					
pH	6.5 – 9	7.30	7.60	7.51	7.11
Temperature (°C)	5 – 30	27.3	27	29	26
Conductivity (µS/cm)	< 700	226.7	151	157	273.2
DO (mg/l)	> 5	2.3	5.6	1.7	5.12
DO (% saturation)	80 - 120	32.8	92	24.6	91

8.1.4 Water Quality Concluding Remarks

The results of the *in situ* water quality analysis show that conditions vary from a good state in the Vaal Barrage to poor in the Leeuspruit and moderate in the Rietspruit (during high flows). Previous studies confirm the findings of the current survey. Chemical analysis done in previous studies revealed high concentrations of nutrients (phosphates, nitrates and ammonium), metals (iron, magnesium and manganese) and non-metals (fluoride), thus corroborating the current results of the low flow assessment. This shows that poor water quality from the Vaal Rivers tributaries have the ability to negatively affect the water quality of the Vaal itself.

8.2 Habitat

The IHI assesses the number and severity of anthropogenic impacts and the damage they potentially inflict on the habitat integrity of aquatic ecosystems.

Only a single low flow survey was completed and therefore the results of the IHI should be interpreted with caution. Additionally the representative sites on the Rietspruit were dry during the low flow survey and only the high flow survey was used to calculate the IHI.

Some of the factors considered for the IHI and the project area are given in the below figures (Figure 8-3, Figure 8-4, Figure 8-5).

Figure 8-3: Eutrophication

Figure 8-4: The presence of Impoundments such as Weirs and Road Crossings

Figure 8-5: Habitat Modification (Siltation)

The results of the IHI for the Leeuspruit River and Rietspruit River are presented in Table 8-4.

Table 8-4: IHI Results for the Leeuspruit and Rietspruit Systems

Component	Score	Description
Leeuspruit		
Instream IHI %	54.7	Largely modified
Instream Category	D	
Riparian IHI %	56.4	Largely modified
Riparian Category	D	
Rietspruit		
Instream IHI %	55.8	Largely Modified
Instream Category	D	
Riparian IHI %	63.6	Moderately Modifier
Riparian Category	C	

8.2.1 Leeuspruit

From the IHI for the reach of the Leeuspruit assessed it can be noted that the instream habitat is in a largely modified condition. The modified instream habitat is a result of habitat modification with most sites assessed affected by eutrophication and severe sedimentation. At Site SAS5, the instream habitat was completely modified through sedimentation of ash and/or sand from the local sand mining operation and industrial activities within the catchment area. The siltation is partially linked to the ash spill that occurred in the area during the 2009-2012 ash backfilling project (Figure 8-6).

Figure 8-6: Photograph depicting the Nature of Siltation at Site SAS5

8.2.2 Rietspruit

The results of the Rietspruit indicate a less impacted river system when compared to the Leeuspruit. Riparian vegetation is only moderately modified. The largest concern is the hydrology section, which reflects the issues relating to flow and impoundments. However this metric should be used cautiously as it is only based on the high flow assessment.

8.2.3 IHI Conclusion

The findings at this site illustrate the potential negative impacts of the proposed project on the local aquatic ecosystems if a spill should occur. The riparian habitat was found to be in a largely modified condition at the sites visited (all sites) for the project. The predominant impacts associated with this were urban encroachment and river crossings.

8.3 Macroinvertebrate Assessment

As a result of aquatic macroinvertebrates integrating the effects of physical and chemical changes in the aquatic ecosystems, they are good, short-term indicators of ecological integrity. Integration of biological indicators (like aquatic invertebrates) with chemical and physical indicators will ultimately provide information on the ecological status of the river (RHP, 2001).

8.3.1 Habitat for Aquatic Macroinvertebrates (IHAS)

The dominant feature of the invertebrate habitat is the marginal vegetation and sandy substrate which dominates the sites. Limited stones in or out of current biotopes were found at any of the sites. During the survey aquatic and marginal vegetation was abundant. Flow velocities during the surveys were also found to be low/not discernible during the low flow with flows increasing slightly in the wet season. The results of the IHAS assessment are presented in Table 8-5.

Table 8-5: IHAS Results for the Leeuspruit System

Low Flow				
IHAS Component	**SAS2**	**SAS3**	**SAS4**	**SAS5**
Flow speed (m/s)	DRY	0.3	0.1	0.1
Total score (%)	DRY	57	48	21
Suitability	DRY	Fair	Poor	Poor
High Flow				
IHAS Component	**SAS2**	**SAS4**	**SAS5**	**SAS10**
Flow speed (m/s)	0.1	0.4	-	0.2
Total score (%)	52	48	57	64
Suitability	Poor	Poor	Fair	Fair

8.3.1 Leeuspruit

8.3.1.1 Low flow

The habitat at site SAS3 is considered to be fair and will support some species diversity. Site SAS4 was assessed to have poor invertebrate habitat which consisted predominantly of aquatic and marginal vegetation. Site SAS5 was considered to be poor due to the presence of fine particulate sediment covering the substrate throughout the site. As a result of the above results, the macroinvertebrate diversity at the sites can be expected to be low.

8.3.1.2 High Flow

Habitat at SAS2 and SAS4 was considered to be poor, while habitat at SAS5 and SAS10 was seen to be fair. Again fine particulate matter was present particularly at site SAS10 and

SAS5. Signs of sewage were detected at SAS4, these included eutrophication, odour and the discolouration of the water.

8.3.2 Rietspruit

During the low flow survey the Rietspruit was dry. Upon returning during the high flow survey, enough water was present to support aquatic life. The results of the IHAS survey are reported in Table 8-6 below.

Table 8-6: IHAS Results for the Rietspruit High Flow Survey

High Flow			
IHAS Component	**SAS6**	**SAS8**	**SAS9**
Flow speed (m/s)	-	-	0.1
Total score (%)	44	43	59
Suitability	Poor	Poor	Fair

The river was dry during the low flow; in the high flow sampling pools had formed but were separated by large sections of dry river bed and impoundments. SAS6 and SAS8 both have poor habitat while SAS9 has fair habitat.

8.3.3 SASS version 5

The findings of the macroinvertebrate assessment for the system recorded taxa with sensitivity scores ranging from highly pollution tolerant to moderately pollution tolerant.

8.3.4 Leeuspruit

According to Kleynhans (2000) the Leeuspruit consists of aquatic biota that is moderately sensitive and of a moderate ecological importance. During the low and high flow surveys (2013/2014), no sensitive organisms were sampled. The absence of these sensitive taxa confirms the classification of Klenyhans (2000). The SASS 5 results for the two surveys of the Leeuspruit are given in Table 8-7.

Based on the biological banding (Highveld lower) set out below (Table 7-3), the sites were categorised as largely modified at site SAS3 to seriously modified at sites SAS4 and SAS5 in the low flow. Water quality is not seen to improve during the high flow at SAS4. The SASS 5 indicates that the water quality is seriously modified at all of the sites assessed during the high flow.

Table 8-7: SASS 5 Scores for the Leeuspruit System

Low Flow			
Site	**SAS3**	**SAS4**	**SAS5**
SASS Score	59	41	31
Taxa	14	10	8
ASPT	4.2	4.1	3.8
Category	D	E	E
High Flow			
Site	**SAS4**	**SAS10**	**SAS11**
SASS Score	35	37	13
Taxa	10	11	5
ASPT	3.5	3.36	2.6
Category	E	E	E

8.3.5 Rietspruit

During the low flow (2013) the Rietspruit was dry. However during the high flow sample, pools of water were located. These contained many aquatic invertebrates of which the results of the SASS 5 sampling are presented in Table 8-8.

Table 8-8: SASS 5 Scores for the Rietspruit System during High Flow Survey

High Flow				
Site	**SAS6**	**SAS8**	**SAS9**	**SAS12**
SASS Score	90	53	71	26
Taxa	18	13	17	8
ASPT	5	4.07	4.18	3.25
Category	D	E	E	E

Using the biological banding seen in Table 7-3 the sites are classified as largely modified (SAS6) to seriously modified (SAS8, SAS9 and at the confluence). As mentioned above habitat was seen to be poor to fair which would affect the species richness within this river.

8.3.6 MIRAI

The Leeuspruit system falls within the 11.03 Highveld ecoregion and therefore MIRAI reference data was available. The MIRAI results are given in Table 8-9.

Table 8-9: MIRAI Results for the 2013 Survey

Component	Leeuspruit
MIRAI (%)	39.57
EC: MIRAI	E
Category	Seriously modified
Component	**Rietspruit**
MIRAI (%)	50.82
EC: MIRAI	D
Category	Largely Modified

Based on the MIRAI, the macroinvertebrate communities associated with the study sites within the Leeuspruit are seriously modified. The modified state of the macroinvertebrate community is primarily due to the absence of expected species that are adapted to unmodified water quality and the stones in current habitat. Several species adapted to high flow velocities and flows between 0.1 m/s – 0.3 m/s were also absent from the current survey, however, flow was determined to be adequate and therefore the absence of these species suggests water quality modification.

Based on the results of the MIRAI it can be noted that the modified macroinvertebrate community is a reflection of poor water quality and habitat availability caused by siltation and eutrophication. The FRAI results confirm this along with the SASS 5 assessment (see below).

In contrast to the water quality issues faced by the Leeuspruit, the Rietspruit has comparatively good water quality and has been primarily impacted on by farming. The major issue is the Rietspruit is the damming and construction of impoundments, which poses a threat to migratory species and removes flow from the system. Pooling occurs and as was seen in the low flow months the riverbed dries up completely. The Rietspruit is seen to be largely modified in terms of MIRAI.

8.3.7 Macroinvertebrate Conclusion

The macroinvertebrate communities associated with the proposed project area are composed of predominantly pollution tolerant species that are adapted to low flow conditions. The results of the SASS 5 and MIRAI indicate that conditions are largely to seriously modified.

The modified conditions have been attributed to alteration of water quality in the Leeuspruit and lack of flow in the Rietspruit, resulting in limited macroinvertebrate habitat.

8.4 Fish Assessment

The use of fish as a means to determine ecological disturbance has many advantages (Zhou *et al*., 2008). Fish are long living, respond to environmental modification, continuously exposed to aquatic conditions, often migratory and fulfil higher niches in the aquatic food web. Therefore fish can effectively give an indication into the degree of modification of the aquatic environment. The RHP uses the FRAI which is based on the preferences of various fish species as well as the frequency of occurrence. A variety of techniques were applied to sample the available fish species within the project area. These sampling methods included cast nets and electroshocking. During the survey all sampling techniques were applied at all sites where possible and a variety of fish species were captured

8.4.1 Leeuspruit

The expected species of the C22K quaternary catchment is presented in Table 8-10. It should be noted that the expected species list contains several alien invasive species. Species which are present in the Vaal Barrage have also been considered as affected species but not included in the expected species list.

8.4.2 Rietspruit

The expected species list for the Rietspruit is the same as the Leeuspruit as it falls within the same catchment. The Rietspruit was only sampled in the wet season due to its dry state during the winter months. Fish were only found closer to the confluence where impoundments and the quantity of water were sufficient to support them.

Table 8-10: Expected Fish Species of the C22K Quaternary Catchment

Fish species	Common name	Captured	
		Low flow	High flow
Enteromius paludinosus	Straightfin Barb	Yes	No
Enteromius trimaculatus	Three spot Barb	No	No
Enteromius anoplus	Chubby head barb	Yes	No
Enteromius cf. neefi	Sidespot Barb	No	No
Clarias gariepinus	Sharptooth catfish	Yes	Yes
*Cyrpinus carpio**	Carp	Yes	Yes
*Gambusia affinis**	Mosquito fish	Yes	Yes
Labeo capensis	Mudfish	No	No
Labeo umbratus	Moggel	No	No
Pseudocrenilabrus philander	Southern mouth brooder	Yes	Yes
Tilapia sparrmanii	Banded Tilapia	Yes	No
* Alien species			

The FRAI assessment was adjusted to suit the site specific requirements with the frequencies of occurrence (FROC) of particular species adjusted from the expected species list (Kleynhans *et al*., 2007). The FRAI and FROC have been adjusted according to the following factors: sampling effort, habitat type, cover combination, stream lengths and altitude.

The results of the fish survey (FRAI) are presented below in Table 8-11.

Table 8-11: The combined FRAI Results for the 2013/2014 Aquatic Survey

Component	Results
FRAI (%)	43.4
EC: FRAI	D
Category	Largely modified

The FRAI results as indicated in the table above indicate that the fish community is in a largely modified state. A total of seven species were captured out of the expected eleven species. Species captured included two alien invasive species, the *Cyprinus carpio* as well as the *Gambusia affinis*. A dominant feature among the current fish assemblage is the tolerance to modified water quality. The species *Enteromius cf. neefi* has a moderate intolerance to modified water quality. The absence of this fish confirms the impacted state of the water quality associated with the Leeuspruit as habitat was available and sampled for this species. All species captured have a tolerance to modified water quality conditions and therefore were able to exist in the modified conditions.

It should be noted that conditions at site SAS5 were altered to such an extent that no fish were sampled from this site in the low flow. However, during the high flow assessment fish were observed in the stream channel. *Cyprinus carpio* and *Micropterus sp.* were observed. Available habitat was covered with fine particulate sediment which covered most available habitat and provided limited cover for aquatic organisms.

8.4.3 Additional Notes on Fish Study

Based on the results of the desktop fish study, red data species are present within the affected watercourses (Vaal Barrage) of the proposed project. The species which is protected is *Labeobarbus kimberleyensis* (Largemouth Yellowfish).

8.4.4 Concluding Remarks on the Associated Fish Communities

Findings of the fish assessment indicate that the community structure of the fish population in the associated sites is in a poor condition due to impacted water quality. Sensitive species such as *Enteromius cf. neefi* which were expected to be present within the water course were not captured during the assessment indicating modified conditions. Additionally, habitat at site SAS5 and downstream from site SAS5 was covered in fine particulate matter.

9 Integrated Ecological State

9.1 Low Flow

Sites located within the Rietspruit were dry and therefore the ecostatus could not be determined. The final ecostatus for the associated sites in the Leeuspruit received a final ecostatus of Class D/E. This is an indication that conditions within the associated sites are largely/seriously modified (Table 9-1).

Table 9-1: The Ecological Classification of Study Components and the Resulting Ecostatus for the Low Flow 2013 Survey

River	Leeuspruit				Rietspruit
Component	SAS2	SAS3	SAS4	SAS5	
Water quality (*in situ*)	DRY	C	C	C	DRY
Habitat	DRY	D	E	E	DRY
Fish	DRY	D			DRY
Invertebrates	DRY	D	E	E	DRY
Ecostatus	DRY	D	E	E	DRY
Ecostatus (River reach)		D/E			DRY

9.2 High Flow

The high flow results for the ecological classification are presented below in Table 9-2.

The modified nature of the Leeuspruit is due to habitat impacts (sedimentation) and modified water quality. The modification of the Rietspruit is due to the creation of impoundments that has led to a loss of flow and the formation of isolated pools.

Table 9-2: The Ecological Classification of Study Components and the Resulting Ecostatus for the High Flow 2014 Survey

River	Leeuspruit			Rietspruit			
Component	SAS2	SAS4	SAS5	SAS6	SAS8	SAS9	SAS12
Water quality (*in situ*)	B/C	C	C	B	B	B	B
Habitat	C	E	E	D	D	D	D
Fish	D						
Invertebrates	E	E	E	D	E	E	E
Ecostatus	D	E	E	D	D	D	D
Ecostatus (River reach)	D/E			D			

When the current study is compared to the ecological and management categories for the quaternary catchments set out in Kleynhans (2000) it is noted that the PESC of the river reaches in this study are not moderately modified (Class C), but largely/seriously modified (Class D/E). The ecological importance and sensitivity as described in Kleynhans (2000) was moderate. This study sampled aquatic species which were tolerant to modification with some species of importance (*Labeobarbus kimberleyensis*) and therefore, the ecological importance is seen as high. The attainable ecological management class is Class C and management towards this class should continue.

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: The Impact Table for the Proposed Ash Backfilling Project

Rating	Severity	Spatial scale	Duration	Probability
7	Very significant impact on the environment. Irreparable damage to highly valued species, habitat or eco system. Persistent severe damage.	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.

Rating	Severity	Spatial scale	Duration	Probability
6	Significant impact on highly valued species, habitat or ecosystem.	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	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	Municipal Area Will affect the whole municipal area	Long term 6-15 years	Probable Has occurred here or elsewhere and could therefore occur.
3	Moderate, short-term effects but not affecting ecosystem function. Rehabilitation requires intervention of external specialists and can be done in less than a month.	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.	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

Rating	Severity	Spatial scale	Duration	Probability
1	Limited damage to minimal area of low significance, (eg ad hoc spills within plant area). Will have no impact on the environment.	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: The Significance Rating for each Potential Impact

		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

Table 10-3: A Description of the Significance Classes for each Impact

Significance		
High	108- 147	
Medium-High	73 - 107	
Medium-Low	36 - 72	
Low	0 - 35	

10.1 Issues and Impacts

10.1.1 Impacts and Issues of Current Land Use (The "No-Go" Option, without the Proposed Project Going Ahead)

The current impacts to the aquatic ecosystems located within the project are considered as the "no-go" option. The "no-go" option also takes into consideration the effects of subsidence caused by no backfilling of the voids and the subsequent possibility of subsidence occurring.

The current land use associated with the river course is urban and heavy industrial activities. Based on the current survey the aquatic conditions are seriously modified as a result of water quality modification.

Due to the presence of weirs and various land use patterns, sedimentation is occurring within the catchment area, the quality and availability of freshwater habitats are being negatively affected (Mantel et al., 2010). Additionally, the removal of water effects the volumes and flow velocities within the associated water courses, thereby affecting the available habitat structures as well as altering the flow-depth scenarios, affecting the biotic structures of the system. During the low flow assessment severe sedimentation was also found at site SAS5, impacting on natural aquatic habitat. If the proposed project does not go ahead the potential for subsidence exists which will result in the following:

- Modification of riparian zones via urban encroachment and industrial activities;
- Sedimentation from surrounding land use patterns; and
- Subsidence.

10.1.2 Impacts of the Proposed Ash Backfilling Project

10.1.2.1 Construction Phase

10.1.2.1.1 Issue 1: Effects of Altered Habitat and Impaired Water Quality

Site clearing and associated construction activities is likely to facilitate erosive potential of the adjacent soils within the study area and as such, increased sedimentation within the receiving watercourses is to be expected. In addition, the direct loss of vegetation and the replacement of a less permeable surface (e.g. compacted soils) is likely to result in an elevated surface runoff velocity from these areas into the surrounding watercourses, which further expected to amplify the erosive potential of the area.

Accidental spillage of hydro-carbon based fuels and associated habits from construction vehicles (e.g. oil leaks), materials (e.g. corrosive chemicals) and personnel (e.g. litter) are likely to contaminate the surface runoff and in turn the receiving watercourses. This will have a direct implication of the sensitive aquatic biota occurring within the study area.

- Impact 1: Sedimentation of the associated watercourses
- Impact 2: Water quality impairment

Construction activities and site clearing					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significance***
Impact 1	**Sedimentation**				
Pre- Mitigation	Serious (4)	Local (3)	Medium term (3)	Almost certain (6)	60 (Medium-Low)
Post-Mitigation	Serious (4)	Limited (2)	Medium term (3)	Unlikely (3)	27 (Low)
Impact 2	**Water quality impairment**				
Pre- Mitigation	Serious (4)	Local (3)	Medium term (3)	Certain (7)	60 (Medium-Low)
Post-Mitigation	Serious (4)	Limited (2)	Medium term (3)	Unlikely (3)	27 (Low)

10.1.2.1.2 Mitigation and Management

It is recommended that the following mitigation actions are planned for the proposed project:

- Develop soil management measures for the construction area/s that will prevent an increased runoff into the associated watercourse, such as the construction of trenches and/or the use of silt curtains;
- Erosion control structures and mechanisms, such as surface storm water drainage systems, should be implemented so as to reduce the potential occurrence of erosion and sedimentation within and adjacent to the associated watercourses;
- The disturbance of instream channels and riparian zones must be minimized, where possible;
- Construction vehicles and machinery repairs must only take place in a designated workshop area;
- Vehicles must be maintained according to their maintenance plans;
- Surface water draining off contaminated areas containing oil and petrol would need to be channelled towards a sump which will separate these chemicals and oils;
- Portable septic toilets are to be provided and maintained (including their removal without sewage spillage) for construction crews outside of the 1-100 year floodline; and
- Store all litter carefully so it cannot be washed or blown into any of the watercourses within the study area.

10.1.2.2 Operational Phase

10.1.2.2.1 Issue 1: Effects of Impaired Water Quality on Aquatic Biota

The water quality impact assessment is largely dependent on the results of the geochemical and groundwater studies.

Coal contains trace amounts of many toxic elements including arsenic, cadmium, chromium, mercury, lead, selenium and vanadium. During the combustion process carbon is removed and the abovementioned elements become concentrated in the coal ash (Jackson, 2011). Previous studies have revealed that leachable trace elements have the potential to elicit toxic physiological effects on exposed organisms and “cause the extirpation of entire aquatic populations” (Garett and Inman, 1984, Sorensen *et al*., 1984).

In addition to impacts of coal ash on the concentrations of metals and salts the proposed project has the potential to alter the pH of the streams. The ash water will have a high pH and the potential for alkaline mine drainage must be considered.

Although the abovementioned factors (pH, salts and metals) have not been determined for the ash that will be used in the proposed project, previous toxicity tests have been conducted (Mafanya, 2013). Based on those results the water is considered acutely toxic, meaning aquatic biota exposed to the water will be impacted upon (Mafanya, 2013).

- Impact 1: Introduction of pollutants in the form of dissolved metals and salts, as well as alteration of pH levels

Effects on water quality					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significance***
Impact 1	**Introduction of pollutants**				
Pre- Mitigation	Very Significant (7)	Municipal (4)	Long term (5)	Certain (7)	112 (High)
Post-Mitigation	Serious (5)	Municipal (4)	Project life(4)	Unlikely (3)	39 (Medium-Low)

10.1.2.2.2 Issue 2: Effects on Aquatic Habitat

The proposed project has the potential to alter aquatic habitat through the influx of fine particulate matter in the form of ash. Ash, if present near to the river systems, will settle in local river systems and cover available habitat thus reducing diversity and restricting the presence of habitat sensitive species.

- Impact 1: Reduced habitat availability in the local river systems.

Issue 2	**Effects on aquatic habitat**				
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significance***
Impact 1	**Reduced habitat availability**				
Pre- Mitigation	Very serious (5)	Local (3)	Project life (5)	Probable (4)	52 (Medium-Low)
Post-Mitigation	Very serious (5)	Local (3)	Project life (5)	Unlikely (3)	39 (Medium-Low)

10.1.2.2.3 Mitigation and Management

The current mitigation and management is based on the above impact assessments for water and aquatic habitat, based on the impact and aquatic assessments as well as the presence of red data species it is recommended that the following mitigation actions are planned for the proposed project:

- Strictly adhering to the engineering and geotechnical procedure for the pumping of the ash slurry;
- Surface pipelines should be inspected for leaks on a weekly basis ;
- Cut off valves should be installed on the pipeline to be operated in the event of a spillage;
- All identified spill points in the vicinity of the ash filling area should be monitored on a weekly basis during the ash filling process ;
- All boreholes and potential decant points should be identified and secured before the ash backfilling occurs;
- Monitoring of potential surface water contamination is vital. Local river systems as well as boreholes should be monitored on a regular basis (weekly);
- Surface water and aquatic bi-annual biomonitoring should be conducted for the duration of the project as well as after the project is completed;
- If ash spills occur the following mitigation is recommended:
  - Contain the ash using berms and cut off trenches and create emergency shutoff points that should be activated;
  - Ash within the river reaches should be removed by mechanical means; and
  - Investigate potential emergency temporary storage areas should the ash need to be redirected.

10.1.2.3 Decommissioning, Closure and Post-Closure Phase

10.1.2.3.1 Issue 1: Effects of Impaired Water Quality

Removal of the pipeline infrastructure is intended to restore the baseline conditions to some extent (e.g. original topography, restored catchment yield, re-establish connectivity between fragmented watercourses). However, the increased movement of heavy machinery and vehicle during the particular phase is expected to increase the risk of potential water quality impairment (i.e. hydrocarbon leaks) and/or loss riparian habitat through increased operational footprint.

- Impact 1: Impaired water quality within the associated watercourses

Decommissioning and rehabilitation activities					
Parameters	***Severity***	***Spatial scale***	***Duration***	***Probability***	***Significance***
Impact 1	**Water quality impairment**				
Pre- Mitigation	Moderate (3)	Limited (2)	Medium term (3)	Almost certain (6)	48 (Medium-Low)
Post-Mitigation	Moderate (3)	Limited (2)	Medium term (3)	Unlikely (3)	24 (Low)

10.1.2.3.2 Mitigation and Management

It is recommended that the following mitigation actions are planned for the proposed project:

- Care should be taken not to impact areas that have remained un-affected throughout the life of the mine.
- On-going rehabilitation should be conducted throughout the decommissioning and closure phase. Only the removal of remaining infrastructure and re-shaping the final topography should occur during the closure phase.
- Continuous post-closure monitoring is required so that drastic deterioration in surface and groundwater quality is detected as soon as it occurs, allowing for mitigation measures to implemented early. Monitoring is recommended to be conducted until satisfactory groundwater quality is reached and thereafter signed off by the relevant authorities. Should an impact be detected through monitoring, affected receptors should be compensated and monitoring programme should be adapted to assess potential changes within the study area.
- As an additional consideration, it is recommended that geotechnical surveys are undertaken on a regular basis (Every two years) to ensure the stability of the potential subsidence areas following the ash-backfilling project.

10.1.3 Impact Conclusion

The proposed project poses a high potential risk to the local aquatic ecosystems. However, this risk is based on the fact that only if ash or ash-water contamination occurs, aquatic conditions will be negatively affected through changes in water chemistry as well as aquatic habitat. Based on reports on the proposed backfilling methodology the ash backfilling project is likely to prevent further subsidence and should not decant (IGS, Proposed backfilling methodology 2013). If no ash spills or leakages occur and subsidence is minimised the proposed project will have a beneficial effect (due to stabilization of conditions) on local aquatic ecosystems.

11 Cumulative Impacts

The watercourses associated with the current project were determined to be in a Class D/E ecostatus. Current conditions in the local aquatic systems are modified with predominantly pollution tolerant species present. Therefore, the proposed project will not further degrade the current aquatic conditions as conditions are at current seriously modified. However, the attainable management class for the C22K catchment is Class C and therefore the associated river courses should be managed in a way in which the Class C can be attained. However, if surface water contamination occurs it could result in the attainable class being lowered. This will have a high cumulative impact in the catchment. However, if the contamination of the river courses is avoided through careful mitigation and remediation the proposed project will have no impact on the aquatic ecology. Based on the IGS, Proposed backfilling methodology 2013 report, decant into surface water is unlikely and therefore the cumulative impact of the proposed project is low.

12 Monitoring Programme

12.1 Location

The monitoring programme should include sites/locations where biological monitoring has occurred previously. The sites included in this study will be sufficient for future monitoring in the high flow season.

12.2 Parameters

The following parameters should be monitored by qualified specialists:

- *In situ* and *ex situ* water quality constituents;
- Sediment metal analysis;
- Habitat integrity;
- Aquatic macroinvertebrates;
- Fish assemblages; and
- Riparian vegetation.

12.3 Objectives

The objectives of the programme would be to monitor the state of the aquatic ecosystem through the measurement of physical and biological properties. As of this study the baseline data is established and can be used to compare with in future studies as a means to determine if ecological degradation has occurred.

12.4 Key Performance Indicators

Key performance indicators would include the improvement of fish communities associated with the project area.

It is recommended that Atyidae (shrimp) population is to be monitored for changes in water quality and habitat sensitivity as they are relatively sensitive taxa and are still present in deeper regions that are less suited to SASS 5. A decline in their population may be an indication of increased pollution and/or habitat modification.

12.5 Responsibility

Rehabilitation manager

12.6 Frequency

Biomonitoring activities should occur bi-annually with the high flow assessment should be conducted in middle to late February with the low flow assessment in May, during the ash backfilling project.

12.7 Resources

Aquatic specialist/Geo-hydrologist.

12.8 Reporting Structure

A biomonitoring report should be provided annually on completion of the two surveys.

12.9 Threshold or Limits

If modifications to the system occur, a reduced biological diversity will be observed. Proliferation of pollution tolerant species may also be an indication of a deterioration of ecological integrity. If there is further reduction in species diversity further studies should be undertaken which should include water quality analysis as well as the accumulation of pollutants in the sediments.

13 Conclusion

Sites located within the Rietspruit were dry and therefore the ecostatus could not be determined during the low flow survey. The final ecostatus for the associated sites in the Leeuspruit is Class D/E. This is an indication that conditions are largely/seriously modified within the associated sites. During the High flow the final ecostatus of the Rietspruit was found to be Class D or largely modified.

The modified nature of the conditions in the Leeuspruit is due to habitat impacts due to input of fine particulate material covering habitat upstream and downstream site SAS5 compounded by modified water quality throughout the Leeuspruit.

The impacts of the “no-go option” (current conditions) were considered to be major due to modified water quality and habitat in the Leeuspruit and the subsidence currently occurring in the area. Aquatic biota in the Rietspruit are already impacted by the systems low flows due to impoundments and conditions would deteriorate for them if an ash spill were to occur and result in the deterioration of water quality.

The proposed projects impacts were assessed to be major before mitigation and low after mitigation. The potential for contamination is a concern as coal ash has been found to severely alter aquatic conditions. The cumulative impacts of the proposed project are high if contamination occurs and low if contamination does not occur. Based on the IGS report, proposed Sigma backfilling methodology, 2013 decant will not occur.

Recommendations include the establishment of monitoring points on the Vaal Barrage at the confluences for both affected river courses (Rietspruit and Leeuspruit) as well as within the potentially affected water courses.

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Appendix A: Photographs of Sampling Sites

SAS1

SAS2

SAS3

SAS4

SAS5

SAS6

SAS7

SAS8

SAS9

SAS10

SAS11

SAS12