AN AQUATIC STATUS ASSESSMENT OF THE WATERCOURSES ASSOCIATED WITH THE PROPOSED SYFERFONTEIN UNDERGROUND MINING OPERATION

SASOL MINING (PTY) LTD

NOVEMBER 2013

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Report Title:	**An aquatic status assessment of watercourses associated with the proposed Syferfontein underground mining operation**
Project Number:	**SAS1744**

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EXECUTIVE SUMMARY

INTRODUCTION

Sasol Mining (Pty) Ltd intends to extend their mining operations into the Block 4 reserves area. Mining is proposed to take place underground, with no surface infrastructure. Included in this assessment are the planned expansion areas to the north and south of the site. This study consists of an aquatic status assessment of the local watercourses which are therefore proposed to be undermined by the project. This study aimed to determine the health of the local watercourses and then to identify any potential impacts to the watercourses as a result of the project. In light of identified potential impacts, mitigation measures have been provided to preferably avoid any impacts.

METHODOLOGY

Methodologies formulated by the River Health Programme of South Africa were implemented for the study. The individual biophysical attributes of the watercourses were assessed at selected sampling sites, these findings were then compared to the reference conditions in order to determine the status of these systems. The selected drivers and biological responses include:

The abiotic driver assessment:

- *In situ* water quality; and
- Habitat features.

The biotic response indicator assessment:

- Invertebrate community structures; and
- Fish community structures.

Two surveys were completed for this study, one during the low flow period and the other during the high flow period.

FINDINGS

The findings of the study can be summarised as follows:

- The water quality associated with the proposed project can be seen to be in a fair state, with the exception of the levels of dissolved oxygen and conductivity at SYF2, which gave rise to concern.
- The quality of instream habitat ranged from “Poor” to “Adequate”. The river systems associated with the project had high sediment loads with a distinct lack of the “stones-in-current” habitat. The sites selected in the lower reaches of the river systems can be described as having riffle-run and pool physical habitat characteristics.

- Results of the invertebrate assessment indicated signs of eutrophication coupled by low habitat availability at selected sites. Additionally, invertebrate community structures at selected sites are also indicative of modified water quality.
- The macroinvertebrate assemblage is in a moderately modified state for the local systems. This is as a result of poor habitat availability, compounded by potentially poor water quality.
- The fish assemblage associated with the project area can be considered to be moderately modified. The reason for the moderately modified state of the fish community is due to the absence of selected fish species when compared to reference conditions, this is compounded by the addition of an alien invasive species namely Cyprinus carpio.
- The final ecological status for the project area was determined to be moderately modified.

IMPACT ASSESSMENT

The environmental impact assessment was only conducted for the Block 4 study area, whereas no impact assessment was completed for the proposed expansion areas. The focus for the impact assessment is the proposed underground mining of watercourses associated with Block 4. No surface infrastructure is planned for the project.

- **No Go Option:** The dominant land uses associated with the Block 4 study area are agricultural practices, notably crops and livestock farming. The local watercourses were determined to be in a moderately modified state. The current land uses have impacted on the state of these systems. The construction of impoundments (dams) has also contributed to the modification of these systems, resulting in changes to flow regimes and erosion of the channels. No mitigation measures have been provided for the identified impacts.
- **Underground mining:** Bord and pillar methods may result in unplanned surface collapses, changing the topographical features of the catchment permanently, resulting in changes to hydrological regime of the respective systems. Subsidence can also cause ground and surface water contamination due to acidification and salinisation of nearby aquifers.

RECOMMENDATIONS

The following recommendations have been provided in light of the planned underground mining operation.

- Commission a geotechnical investigation for the Block 4 study area in order to quantify this risk of subsidence should the area be mined; and
- Should the risk of subsidence occurring be high, it is recommended that no mining of the resource take place within a 100m buffer of the respective watercourses.

CONCLUSION

The integrity (health) of the local watercourses was determined to be moderately modified, largely as a result of the local agricultural activities, notably crop and livestock farming. According to this study, the prescribed attainable ecological management class for catchment is currently being attained.

The primary risk identified for the proposed underground mining of the watercourses is subsidence. It has been recommended that should the risk of subsidence be negligible, then mining of the watercourses may be permitted, however, should the risk of subsidence be determined to be high, the undermining of the watercourses should be avoided and a100m buffer zone allocated.

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1 INTRODUCTION

An increase in anthropogenic activities in river catchments places pressure upon local aquatic ecology (Van Vuren *et al*., 1994). Activities such as mining have the potential to disrupt and modify associated aquatic conditions (Van Vuren *et al*., 1994). Alterations caused through anthropogenic activities in the habitat and physico-chemical constituents of aquatic ecosystems have shown to alter the ecology of freshwater systems. Freshwater biota has shown to react according to particular stressors in the environment and therefore can serve as effective indicators of environmental and water quality alterations in environments affected through anthropogenic actions (Zhou *et al*., 2008). Due to the importance and use of aquatic biota as indicators of integrity it is important to monitor aquatic conditions of potential ecological degradation (Dickens and Graham, 2002).

Underground mining, particularly in Mpumalanga due to bord and pillar methods, has frequently resulted in unplanned surface collapse (Ochieng *et al.* 2010). This collapse has been the cause of ground and surface water contamination due to acidification and salinisation of nearby aquifers. Blodget and Kuipers (2002) elaborates that subsidence can cause fissures or pits which may result in loss of large volumes of ground or surface water if connected to the stream network. Although mining is an inevitable consequence of the compounding demand for fossil fuels, these requirements can be met by planning mining in such a way that sensitive areas are avoided.

In order to achieve the effective management of South African freshwater resources, the assessment of aquatic ecosystems needs to be completed. Through these assessments the levels of pollutants and the effects of anthropogenic activities can be determined.

2 TERMS OF REFERENCE

Digby Wells Environmental (Digby Wells) has been commissioned by Sasol Mining (Pty) Ltd to conduct an aquatic status assessment of the local watercourses associated with the proposed Syferfontein underground mining operation. The study area which was assessed consists of two project areas, these include:

1. Block 4: This area is proposed to be mined by underground methods and will be the focus for the impact assessment. Expansion areas associated with Block 4 will be incorporated into the Block 4 baseline description and impact assessment; and
2. Boundary Expansions: The expansion areas to the north of Block 4 will only have the baseline conditions described. This area is not yet proposed to be mined and as a result, no impact assessment is included.

This study supports the following regulations and regulatory procedures:

- Section 19 of the National Water Act (Act 36, 1998);
- Section 21 (c), (g) and (i) of the National Water Act (Act 36 of 1998);
- Section 21 of the Environment Conservation Act, 1989;

- Section 24 of the Constitution – Environment (Act 108 of 1996), and
- Section 5 of the National Environmental Management Act (Act 108 of 1998).

3 AIMS AND OBJECTIVES

The aim of the assessment is to determine the current ecological integrity of the aquatic ecosystems associated with the proposed mining operation. The aim of this project will be met through the following objectives.

- Characterise the current ecological state of the aquatic ecosystems by making use of selected driver indices which address *in situ* water quality states and habitat;
- Characterise the current ecological state of the aquatic ecosystem by making use of selected responder indices which address macroinvertebrate and ichthyofauna population attributes;
- Conduct an ecological impact assessment of the construction and operation phases of the proposed underground mining operation;
- Provision of management and a mitigation measures for the identified impacts to the local watercourses; and
- Make recommendations on the management and conservation of the systems in order to maintain or increase the ecological integrity of potentially impacted aquatic ecosystems.

4 LIMITATIONS

No limitations are anticipated for this project.

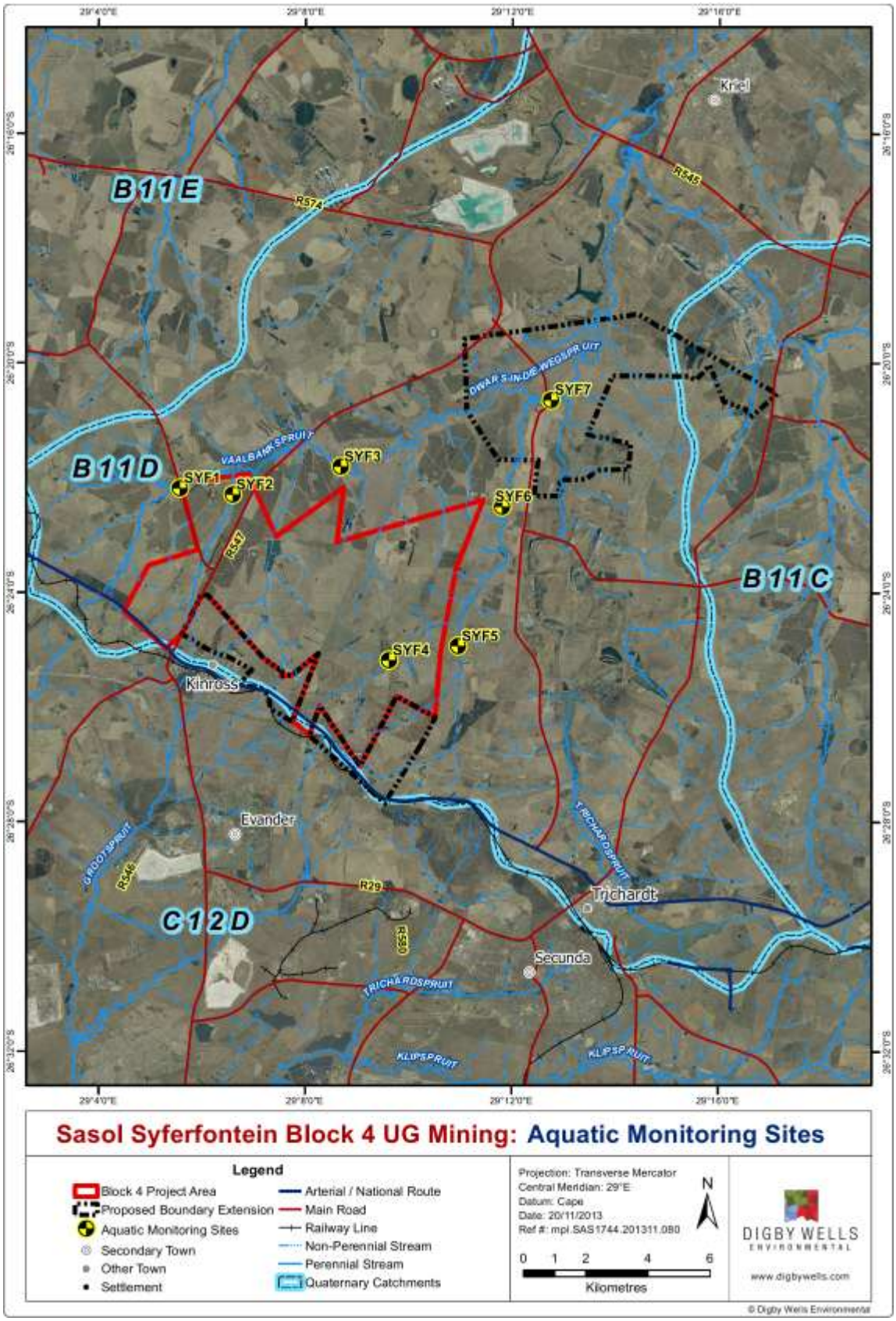
5 STUDY AREA

5.1 Catchments & watercourses

The aquatic ecosystems associated with the Syferfontein project area north of the towns of Kinross and Trichardt, and south of Kriel. The study area is situated within the Olifants Water Management Area (WMA4). The watercourses associated with Block 4 are situated in the upper reaches of the B11D quaternary catchment. The expansion area north of Block 4 is situated within the middle reaches of B11D as well as encroached into the B11C quaternary catchment.

The local primary watercourses which are associated with the Block 4 and greater expansion areas are the Vaalbankspruit and Trichardspruit with the respective confluence of these two systems in the northern expansion areas. The Rietspruit which is a tributary of the Vaalbankspruit and which flows through Block 4 was also assessed. The Dwars-in-die-wegspruit stems from this confluence, with the Dwars-in-die-wegspruit being a tributary of the Steenkoolspruit which then flows into the Olifants River. The locations of the Block 4 and greater expansion areas in relation to the local watercourses is presented in Figure 5-1.A

total of seven survey sites were selected for this project, the locations of these sites in relation to the two respective study areas are presented in Figure 5-1.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26°20'0"S
26°24'0"S
26°28'0"S
26°32'0"S
Kriel
B11E
R574
R545
DWARS-IN-DIE-WEGSPR UIT
SYF7
VAALBANK-SPRUIT
B11D
SYF1
SYF2
SYF3
SYF6
R547
B11C
SYF4
SYF5
Kinross
Evander
GROOTSPRUIT
R546
R29
C12D
R550
TRICHARDSPRUIT
Trichardt
Secunda
KLIPSPRUIT
Sasol Syferfontein Block 4 UG Mining: Aquatic Monitoring Sites
Legend
Block 4 Project Area
Proposed Boundary Extension
Aquatic Monitoring Sites
Secondary Town
Other Town
Settlement
Arterial / National Route
Main Road
Railway Line
Non-Perennial Stream
Perennial Stream
Quaternary Catchments
Projection: Transverse Mercator
Central Meridian: 29°E
Datum: Cape
Date: 20/11/2013
Ref #: mpl.SAS1744.201311.080
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Figure 5-1: The location of Block 4 and the expansion areas in relation to local watercourses and the associated quaternary catchment

5.2 Survey sites

In order to establish the ecological integrity of the associated aquatic ecosystems several sites were selected on the river systems associated with the project. A total of seven sampling points were selected for the study on the associated river systems. Sampling sites where selected upstream (where possible) of the project area in order to provide a reference description for the project. Additional sites were selected within and downstream of the study areas in order to monitor the status of these system to discuss the trends of these watercourses should the proposed mining operation be authorised.

The Global Positioning System (GPS) co-ordinates and a photograph for each of the sampled sites as well as the respective watercourse are given in Table 5-1.

Table 5-1: GPS co-ordinates and short descriptions of the survey sites

Site name	Coordinates	Watercourse	Photographs
SYF1	26° 22' 15.5"S 29° 05' 32.9"E	Vaalbankspruit	
SYF2	26° 22' 19.6"S 29° 06' 34.2"E	Vaalbankspruit	
SYF3	26° 21' 50.5"S 29° 08' 39.5"E	Vaalbankspruit	
SYF4	26° 25' 12.4"S 29° 09' 35.9"E	Rietfontein	

Site name	Coordinates	Watercourse	Photographs
SYF5	26° 24' 57.8"S 29° 10' 55.6"E	Rietfontein	
SYF6	26° 22' 32.1"S 29° 11' 47.3"E	Rietfontein	
SYF7	26° 20' 40.2"S 29° 12' 43.9"E	Dwars-in-die-wegspruit	

5.3 Desktop findings

5.3.1 Ecological management classifications

In spite of the fact that the Block 4 and greater project expansion areas are associated with two quaternary catchments, namely B11C and B11D, the systems which we assessed for the project are situated within the quaternary catchment B11D. As a result of this, the desktop assessment primarily focussed on the quaternary catchment B11D.

A summary of the ecological integrity (health) and management categories for the affected river systems within the quaternary catchment B11D is presented in Table 5-2.

Table 5-2: The ecological and management categories for the quaternary catchment B20E (Kleynhans, 2000)

Category	Description	State
EISC	Ecological importance and sensitivity category	Low / Marginal
DEMC	Default ecological management class	Class D: Resilient systems
PESC	Present ecological status category	Class D: Largely Modified
AEMC	Attainable ecological management class	Class C: Moderately modified

The ecological importance and sensitivity of the affected quaternary catchment is low/marginal in the quaternary catchment B11D (Kleynhans, 2000). The default ecological

management class of the quaternary is Class D, suggesting that the local watercourses are resilient systems. The present ecological status category for the affected catchment is Class D (Largely Modified) and according to Kleynhans (2000), the attainable ecological management class is Class C (Moderately modified).

5.3.2 National Freshwater Ecological Priority Area programme

Based on the National Freshwater Ecological Priority Areas (NFEPA) programme for Mpumalanga Aquatic Biodiversity sub-catchments (Driver *et al.*, 2011), the aquatic biodiversity of the quaternary catchment B11D is not associated with any areas which have been classified as priority areas. The project area is on a catchment divide and is adjacent to the quaternary catchment C12D which has catchment areas classified by the NFEPA programme as river FEPAs and Upstream Management Areas. The location of the larger project area in relation to the NFEPA programme is presented in Figure 5-3. These Upstream Management Areas were identified in moderately modified rivers (Class C), only in cases where it was not possible to meet biodiversity targets for river ecosystems in rivers that were still in good condition (Class A or B). The river condition of these areas should not be degraded further, as they may in future be considered for rehabilitation once FEPAs in good condition are considered fully rehabilitated and well managed.

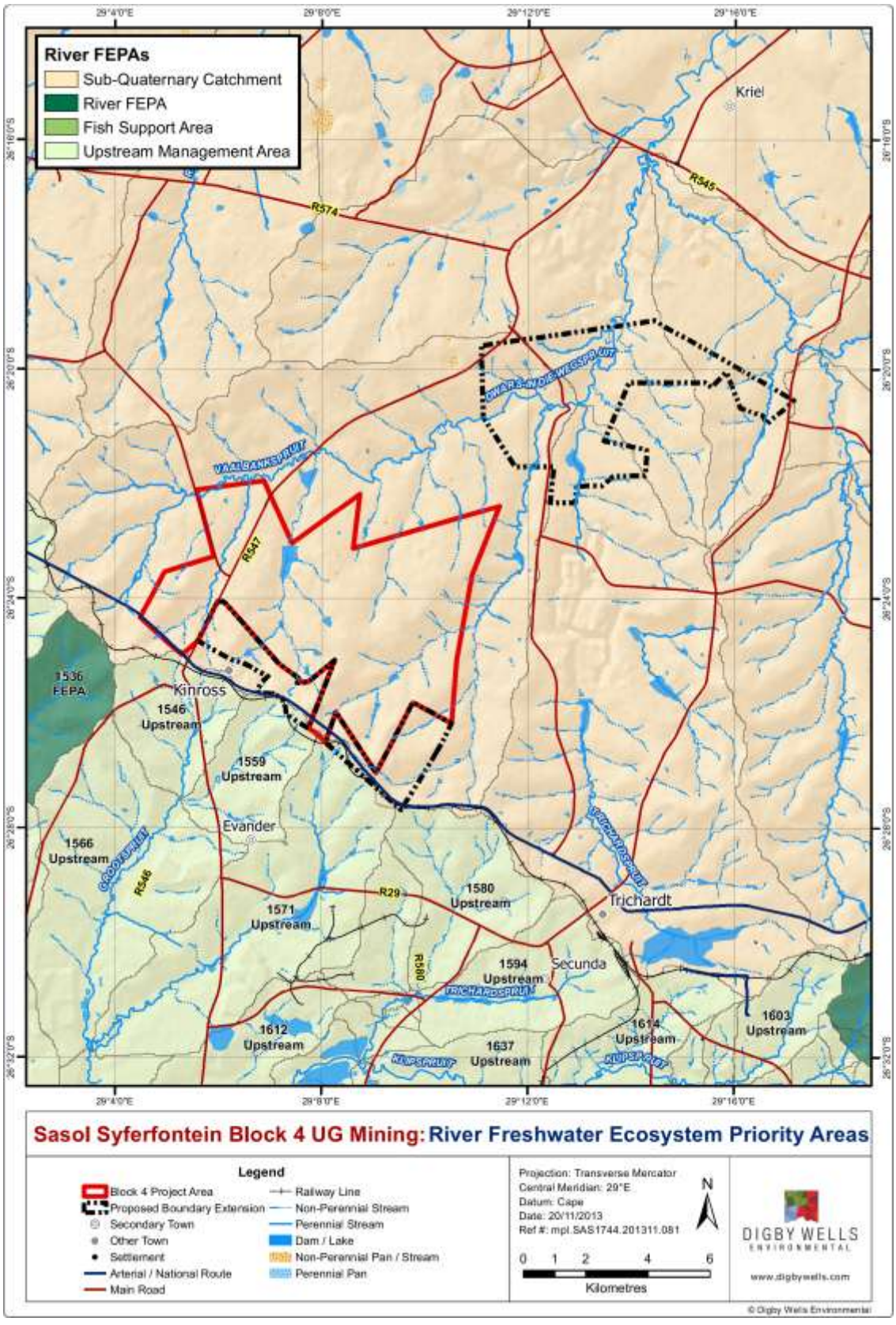
River FEPAs
Sub-Quaternary Catchment
River FEPA
Fish Support Area
Upstream Management Area
Kriel
Kinross
Evander
Trichardt
Secunda
R574
R545
R547
R546
R29
R580
1536 FEPA
1546 Upstream
1559 Upstream
1566 Upstream
1571 Upstream
1580 Upstream
1594 Upstream
1603 Upstream
1612 Upstream
1614 Upstream
1637 Upstream
Sasol Syferfontein Block 4 UG Mining: River Freshwater Ecosystem Priority Areas
Legend
Block 4 Project Area
Proposed Boundary Extension
Secondary Town
Other Town
Settlement
Arterial / National Route
Main Road
Railway Line
Non-Perennial Stream
Perennial Stream
Dam / Lake
Non-Perennial Pan / Stream
Perennial Pan
Projection: Transverse Mercator
Central Meridian: 29°E
Datum: Cape
Date: 20/11/2013
Ref #: mpl.SAS1744.201311.081
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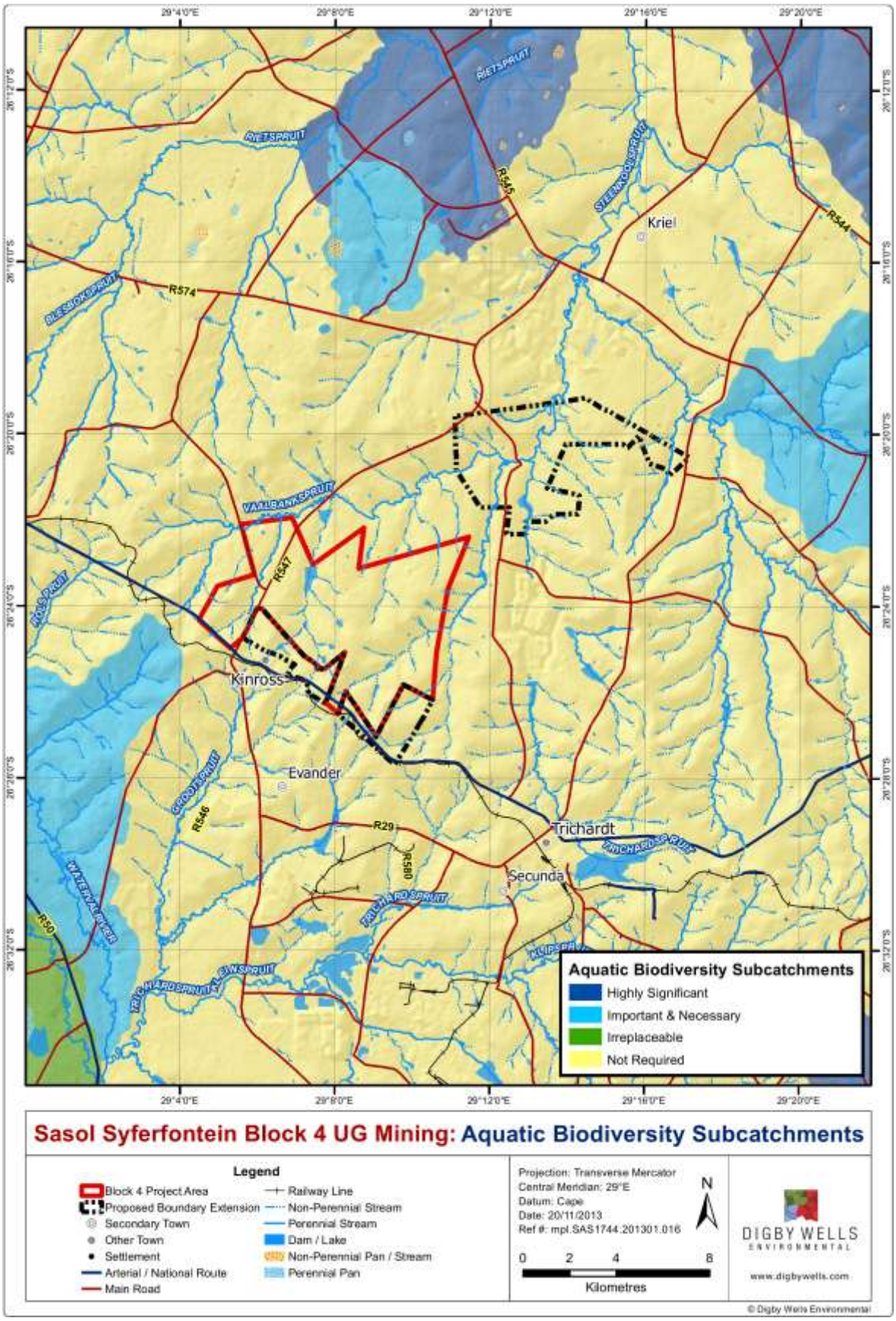
Figure 5-2: The location of Block 4 and the greater expansion area in relation to the NFEPA programme

5.3.3 The Mpumalanga Biodiversity Conservation Plan

The Mpumalanga Biodiversity Conservation Plan (MBCP) identifies healthy sub-catchments using a combination of PESC (Kleynhans,2000) and loss of natural habitat in each sub-catchment. The greater project area is classified as “Not Required” according to the MBCP.

According to Ferrar & Lötter (2007), “Not Required” refers to areas with no natural habitat remaining, and as a result, these transformed areas that make no contribution to meeting targets. The MBCP classification of the local sub-catchments in relation to the project area is presented in Figure 5-4.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26°20'0"S
26°24'0"S
26°28'0"S
26°32'0"S
RIETSPRUIT
STEENKOOLSPRUIT
BLESBOKSPRUIT
VAALBANKSPRUIT
ROOIKOPSPRUIT
GROOTSPRUIT
WATERVALSPRUIT
RICHARDSPRUIT
KLIPSPRUIT
R544
R545
R547
R546
R574
R29
R580
R50
Kriel
Kinross
Evander
Trichardt
Secunda
Aquatic Biodiversity Subcatchments
Highly Significant
Important & Necessary
Irreplaceable
Not Required
Sasol Syferfontein Block 4 UG Mining: Aquatic Biodiversity Subcatchments
Legend
Block 4 Project Area
Proposed Boundary Extension
Secondary Town
Other Town
Settlement
Arterial / National Route
Main Road
Railway Line
Non-Perennial Stream
Perennial Stream
Dam / Lake
Non-Perennial Pan / Stream
Perennial Pan
Projection: Transverse Mercator
Central Meridian: 29°E
Datum: Cape
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Figure 5-3: The MBCP sub-catchment classification in relation to the project area

6 METHODOLOGY

Individual biophysical components of the river systems in the study area were assessed. These biophysical attributes were considered by implementing selected tools or indices that refer to selected drivers and biological responses of an aquatic ecosystem. Methodologies formulated by the River Health Programme (RHP) of South Africa (RHP, 2001) were implemented. The selected drivers and biological responses include:

The abiotic driver assessment:

- *In situ* water quality (DWAF, 1996); and
- The Invertebrate Habitat Assessment System (IHAS) (McMillan, 1999).

The biotic response indicator assessment:

- South African Scoring System 5 (SASS 5);
- Macroinvertebrate Assessment Index (MIRAI); and
- 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 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.

Two surveys were completed for this study, one during the low flow period (August 2013) and the other during the high flow period (November 2013).

6.1 Water quality

The physical, chemical, biological and aesthetic properties of water that determine its fitness for a variety of uses and for the protection of the health and integrity of aquatic ecosystems refers to the quality of water (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 to this study as the primary source of reference information. The South African Water Quality Guidelines contains information similar to that which is available in the international literature; however, the information provided is specifically formulated for Southern African aquatic ecosystems and water users (DWAF, 1996).

6.2 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 strong information for interpreting cumulative effects (USEPA, 2006). The assessment and monitoring of benthic macroinvertebrate communities forms an integral part of the monitoring of the health of an aquatic ecosystem.

6.2.1 Invertebrate Habitat Assessment System

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 6-1.

Table 6-1: Description of IHAS scores with the respective percentage category (McMillan, 2002)

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

6.2.2 South African Scoring System

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 invertebrates were 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 Highveld lower ecoregion. This method seeks to develop biological bands depicting the various ecological states and is derived from data contained within the Rivers Database and supplemented with other data not yet in the database. Table 6-2 illustrates the biological banding and classification for the study.

Table 6-2: 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

6.2.3 Macroinvertebrate Response Assessment Index

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; and
- Water quality.

6.3 Fish assessment

The information gained using FRAI gives an indication of the present ecological state of the river based on the fish assemblage structures observed. All fish were identified in the field and released at the point of capture. Fish species were identified using the guide Freshwater Fishes of Southern Africa (Skelton, 2001). The identified fish species were compared to those expected to be present for the B11G quaternary catchments. The expected fish species list was developed from a literature survey and included sources such as (Kleynhans *et al*., 2007) and Skelton (2001).

6.4 Ecological description

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.

6.5 Impact assessment

The impacts of the development and operation of the proposed pipeline and ash back-filling project on the receiving wetlands areas within the project area were assessed at different stages of the development of the mine according to the methodology indicated in Table 6-3.

A clearly defined rating scale is used to assess each impact in terms of severity, spatial extent and duration (which determines the consequence) and in terms of the frequency of the activity and the frequency of the related impact (which determines the likelihood of occurrence). The overall impact significance, is then determined via a significance rating matrix (Table 6-4) utilising the scores obtained for consequence and likelihood of occurrence, in order to assign a final impact rating.

Table 6-3: Impact Assessment methodology.

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.
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.

Rating	Severity	Spatial scale	Duration	Probability
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 functions. 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
1	Limited damage to minimal area of low significance, (e.g. 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.

Table 6-4 Significance categories

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

Significance		
High (Major)	108- 147	
Medium-High (Moderate)	73 - 107	
Medium-Low (Minor)	36 - 72	
Low (Negligible)	0 - 35	

7 RESULTS & DISCUSSION

7.1 Water quality

The results for the *in situ* analysis for the low and high flow periods are presented in Table 7-1. Based on the results of the *in situ* analysis the pH ranged from a low of 6.5 to a high of 8.3. The temperature recorded during the bi-annual surveys ranged from a low of 14°C to a high of 28°C. Levels of conductivity ranged from 302 µS/cm to 779 µS/cm. Dissolved oxygen concentrations fluctuated from a low of 4.48 mg/l to a high of 10 mg/l.

Table 7-1: *In situ* water quality results for the assessment

Site	**Flow**	**pH**	**Temperature (°C)**	**Conductivity (µS/cm)**	**DO (mg/l)**	**DO (% saturation)**
		6.5 – 9	5 – 30	< 700	> 5	80 - 120
SYF1	**Low**	7.6	16	367	12.4	143
	High	6.5	19	585	8.11	105

SYF2	**Low**	7.8	14	690	16.9	198
	High	7.4	24	779	4.48	64
SYF3	**Low**	7.8	14	411	8.82	93
	High	8.8	26	584	7.9	102
SYF4	**Low**	8	16	350	15.9	151
	High	8.2	28	354	9	120
SYF5	**Low**	7.5	15	525	12.1	131
	High	8.2	19	432	10	137
SYF6	**Low**	8.3	16	530	11.8	101
	High	7.9	21	302	8.42	114
SYF7	**Low**	7.5	17	580	13	161
	High	7.8	23	377	7.56	106

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 following results have been highlighted:

- Based on the findings of the *in situ* water quality analysis the pH at the sites was determined to be neutral and ranged from 6.5 to 8.3. When this is compared to the DWAF (1996) guidelines it is considered to be natural and therefore not negatively affecting aquatic biota;
- The water temperatures at the sites was also considered to be normal (DWAF, 1996) and was 14°C during winter and 28°C during the summer period;
- Conductivity is a measure of the concentrations of ions which are dissolved into the water column (DWAF, 1996). A high level of conductivity is indicative of water which has a high level of dissolved ions as a result of input from the surrounding local land use patterns as well as local geology. Conductivity in natural streams is usually low (<700 µS/cm) and does not have a large fluctuation between sampling surveys. During the current assessment conductivity was found to be exceeding the threshold 700 µS/cm guideline level at one site (Site SYF2) indicating potential environmental impacts during the high flow period; and
- The levels of dissolved oxygen in the associated all sites with the exception of SYF2 were found to be in an adequate concentration to support aquatic biota (DWAF, 1996). In addition to the concentrations of oxygen, the oxygen saturation levels were

considered to be adequate with the exception of site SYF2. The low levels of oxygen at this site is thought to be as a result of eutrophication which is occurring upstream of the site. A photograph of the eutrophication is given below in Figure 7-1.

Figure 7-1: A photograph of eutrophication recorded at SYF2

7.2 Aquatic invertebrate 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). Methods used by the RHP were utilised during the current high and low flow surveys the results are given under the various sub-headings below.

7.2.1 Invertebrate Habitat Assessment System

The IHAS was applied at all sites and the results are given in Table 7-2 below.

Table 7-2: IHAS results for the assessment

IHAS Component	SYF1	SYF2	SYF3	SYF4	SYF5	SYF6	SYF7
Total score (%)	41	32	62	46	53	60	61
Suitability	Poor	Poor	Adequate	Poor	Poor	Adequate	Adequate
Flow (M/s)	0.6	No flow	0.3	0.2	0.1	1	1.1

Based on the IHAS results the invertebrate habitat ranges from “Adequate” to “Poor”. Flows during the high flow assessment ranged from 0.1 m/s to 1.1 m/s. The following results have been highlighted:

- The river systems associated with the project area namely the Vaalbankspruit, Dwars-in-die-wegspruit and associated tributaries had high sediment loads with a distinct lack of the “stones-in-current” habitat. This has resulted in many sites selected in the systems reflecting poor invertebrate habitat. The IHAS scores in the sites range from 32 – 61 indicating that invertebrate habitat is limited. Based on this result, low macroinvertebrate species diversity and subsequent SASS 5 scores can be anticipated due to lack of sufficient habitat; and
- The sites selected in the lower reaches of the river systems (SYF6 & SYF7) can be described as having riffle-run and pool physical habitat characteristics. The substrate at the site consisted of “stones-in-current”, bedrock with intermittent regions of Gravel, Sand and Mud (GSM) biotype. Marginal and instream vegetation at the site was limited due to erosion and livestock impacts, however, it is anticipated that during periods of greater flow volumes the marginal vegetation will become inundated and therefore available. At site SYF6 the dominant habitat feature was bedrock and pools as depicted in the below picture (Figure 7-2).

Figure 7-2: Bedrock pools at SYF6

7.2.2 South African Scoring System

Standard methods of the SASS 5 protocol were applied during the current invertebrate sampling. Results of the low and high flow results are given in Table 7-3.

Table 7-3: The scores for the SASS 5 assessment

Site	Flow	SASS Score	Taxa	ASPT	Category
SYF1	Low	114	21	5.4	B
	High	89	20	4.4	B
SYF2	Low	25	8	3.1	E
	High	11	4	2.7	E
SYF3	Low	73	16	4.5	C
	High	96	21	4.5	B
SYF4	Low	50	12	4.1	D
	High	42	12	3.5	E
SYF5	Low	92	19	4.8	B
	High	89	19	4.6	B
SYF6	Low	87	19	4.6	B
	High	83	18	4.6	B
SYF7	Low	109	21	5.1	B
	High	92	20	4.6	B

Based on the results of the SASS 5 assessment the, SASS 5 scores ranged from a low of 25 to a high of 114. The number of taxa at the sites ranged from 4 to 21 with the ASPT was found to range between 2.7 and 5.4. The following results have been highlighted:

- Based on the results of the SASS 5, the assessment of the sites associated with the Vaalbankspruit were shown to have variable SASS 5 scores ranging from 25 to 114. The low 25 score is thought to be a result of eutrophication coupled by low habitat availability at the site. The low SASS 5 score at site SYF3 is a result of low flow velocities at the site. Sites associated with the Dwars-in-die-wegspruit had higher SASS 5 scores as a result of higher flow velocities;
- Based on the ASPT results obtained from the sites in the Vaalbankspruit, the ASPT values ranged from 2.7 to 4.5. The low 2.7 was obtained from site SYF2 which also had a low SASS 5 score. The low ASPT values at this site are indicative of modified water quality. Sites located in the Dwars-in-die-wegspruit had higher ASPT values which ranged from 3.5 to 4.6. Although the ASPT values from the Dwars-in-die-wegspruit were higher, the ASPT values are still considered to be low. The low ASPT

value are a result of a dominance of pollution tolerant (low scoring) taxa which has resulted in a low ASPT. In addition to dominant pollution tolerant taxa the absence of sensitive species such as Heptageniidae has effectively lowered the ASPT at these sites.

The overall classification of the sites in the Dwars-in-die-wegspruit as category B (Largely natural) is based on the categories set out in Dallas, 2007. The current sites are not located near any SASS 5 reference sites and should therefore be considered in light of this. Based on the geomorphology of the sites it can be noted that some of the sites have transitional properties between the lower reaches and the upper reaches and therefore can be considered to be transitional (Gerber and Gabriel, 2002). This would result in the SASS 5 categorisation of sites in the Dwars-in-die-wegspruit as higher than what it should be. Based on the previous statement it can then be seen that the SASS 5 categorisation obtained in the current study may be lower than currently categorised. Therefore, sites should be viewed as moderately modified rather than largely natural.

7.2.3 Macroinvertebrate Response Assessment Index

In order to comprehensively understand the macroinvertebrate assemblage at the sites, the MIRAI was conducted. The MIRAI was conducted at sites as per a reach of the river system and therefore combined into a single score. The MIRAI was applied using results obtained in the SASS 5 survey and the results of the MIRAI are presented in Table 7-4.

Table 7-4: MIRAI results for the 2013 surveys

Component	Scores
MIRAI (%)	61.7
EC: MIRAI	C
Category	Moderately modified

As seen in the results of the MIRAI the sites received a categorisation of Class C meaning the macroinvertebrate assemblage is in a moderately modified state.

The moderately modified state of the invertebrate communities is a result of poor habitat availability , compounded by potentially poor water quality. This conclusion has been drawn by the distinct absence of pollution intolerant species such as Perlidae and Heptageniidae at sites with sufficient flow (>0.6m/s). The most sensitive species found during the assessment was Atyidae and Hydracarina and these were present at sites with appropriate habitat. Only few sites had adequate invertebrate habitat resulting in low Frequency of Occurrence (FROC) values of habitat sensitive species such as the family Heptageniidae.

Although flow and in situ water quality was determined to be adequate to sustain the sensitive species (mentioned above) the absence of these species indicates that conditions in the associated river courses are modified and thereby resulting in modified MIRAI scores.

As stated above, aquatic biota are continuously exposed to water conditions and therefore accurately depict environmental conditions. Based upon this it can be noted that although "snap-shot" analysis (*in situ* and *ex situ*) indicate ideal conditions, the biota still classifies the systems as modified due to the absence of sensitive species as a result of modified water quality.

Due to the lack of suitable invertebrate habitat as well as the absence of sensitive species at the most of the sites, the MIRAI results in a Class C categorisation.

7.3 Fish assessment

The expected fish species for the river systems survey during the 2013 period are given in the Table 7-5. It should be noted that no expected fish species list is available for quaternary catchment B11C, as a result of this, an expected fish list was derived from quaternary catchment B11G, which is further downstream on the Olifants River.

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. It should be noted that similar species were sampled at the respective sites for each survey. The results of the FRAI assessment for the 2013 period are given in the Table 7-6. It should be noted that the FRAI assessment is based on the river reaches assessed.

Table 7-5: Expected species in the B20E quaternary catchment for the 2013 period

Fish species	Common name	Captured
Barbus anoplus	Chubbyhead Barb	Yes
Barbus neefi	Spotted Barb	No
Barbus paludinosus	Straightfin Barb	Yes
Barbus trimaculatus	Threespot Barb	No
Clarias gariepinus	Straightfin Barb	Yes
Cyprinus carpio*	Carp	Yes
Gambusia affinis	Mosquito Fish	Yes
Labeobarbus polylepis	Small-scale Yellowfish	Yes
Micropterus salmoides*	Largemouth Bass	No

Fish species	Common name	Captured
Pseudocrenilabrus philander	Southern Mouthbrooder	Yes
Tilapia sparrmanii	Banded Tilapia	Yes

Note: (*) denotes exotic fish species

Table 7-6: Results of the FRAI assessment for the 2013 period

Component	Results
FRAI (%)	60.7
EC: FRAI	C/D
Category	Moderately modified

Based on the results of the FRAI assessment the fish assemblage associated with the Syferfontein project area can be considered to be moderately modified. The reason for the moderately modified state of the fish community is due to the absence of selected fish species when compared to reference conditions, this is compounded by the addition of an alien invasive species namely *Cyprinus carpio*. The following results have been highlighted:

- The absence of species which are sensitive to water quality modification, most notably *Barbus neefi*, as well as considering the presence of habitat suitable for these species, indicates that water quality modification may be the reason the absence of these species; and
- If the FRAI scores are taken into consideration with the MIRAI scores, a similarity can be seen as both are categorised as moderately modified. The reason for the lowered MIRAI score was due to the absence of species intolerant to water quality modification. The modified FRAI score can be seen to be as a result of similar conditions with the compounding effect of the alien invasive species such as *Gambusia affinis, Cyprinus carpio* and *Micropterus salmoides*.

8 STUDY SUMMARY

The ecological class of the study components are presented in **Error! Reference source not found.**. The overall ecological classification is done according to the overall scores of biotic indices. The ecological class of the study components are presented in **Error! Reference source not found.**. The overall ecological classification is done according to the overall scores of biotic indices.

Table 8-1: The ecological classification of study components and the resulting Ecostatus for respective sites

River	Vaalbankspruit				Dwars-in-die-wegspruit		
Component/Site	**SYF1**	**SYF2**	**SYF3**	**SYF7**	**SYF4**	**SYF5**	**SYF6**
Water quality (in situ)	B	C	B	B	B	B	B
Habitat	D	E	D	C	D	D	C
Invertebrates	B	E	B	C	E	C	C
Fish	C						
Ecostatus	C	E	C	C	C	C	C
Ecostatus: River reach	C				C		

The final Ecostatus for the Vaalbankspruit was determined to be Class C (moderately modified). This moderately modified status is a result of modified invertebrate assemblages as a result of poor habitat availability. Some sites located within the Dwars-in-die-wegspruit are considered to be classified as a Class B (Largely natural), this is as a result of high SASS scores and invertebrate habitat availability.

When the current study is compared to the ecological and management categories for the quaternary catchments set out in Kleynhans (2000) the following findings can be observed. Based on the biota found at the site the ecological importance and sensitivity can be considered resilient as predominant pollution tolerant species were found to be present at the located in the Dwars-in-die-wegspruit. The PES according to Kleynhans (2000) for the quaternary catchment B11D was Class D (largely modified), this study found the Ecostatus had improved to a Class C (moderately modified). The attainable ecological management class for the quaternary catchment is Class C (moderately modified) and this class is currently being attained.

However, it should be noted that these classifications are based on two surveys using rapid assessment techniques and therefore should be considered with caution.

9 IMPACT ASSESSMENT

The environmental impact assessment was only conducted for the Block 4 study area, whereas no impact assessment was completed for the proposed expansion areas. The focus for the impact assessment is the proposed underground mining of watercourses associated with Block 4. No surface infrastructure is planned for the project.

9.1 Assessment of the current impacts (No Go Option)

The dominant land uses associated with the Block 4 study area are agricultural practices, notably crops and livestock farming.

9.1.1 Issue 1: Degradation of integrity for watercourses

The local watercourses were determined to be in a moderately modified state. The current land uses have impacted on the state of these systems. The construction of impoundments (dams) has also contributed to the modification of these systems, resulting in changes to flow regimes and erosion of the channels. No mitigation measures have been provided for the identified impacts.

- Impact 1: Changes to flow regimes;
- Impact 2: Deterioration of water quality; and
- Impact 3: Loss of habitat features and quality

<table>
<tr><th colspan="5">IMPACT DESCRIPTION: Changes to flow regimes</th></tr>
<tr><td>Predicted for project phase:</td><td>Pre-construction</td><td>Construction</td><td>Operation</td><td>Decommissioning</td></tr>
<tr><th>Dimension</th><th>Rating</th><th colspan="3">Motivation</th></tr>
<tr><td colspan="5">PRE-MITIGATION</td></tr>
<tr><td>Duration</td><td>Permanent (7)</td><td>These are established land uses</td><td rowspan="4">Consequence: Highly detrimental (-14)</td><td rowspan="4">Significance: Moderate - negative (-98)</td></tr>
<tr><td>Extent</td><td>River reach (3)</td><td>Reaches are inundated, but these do recover further downstream</td></tr>
<tr><td>Intensity x type of impact</td><td>Moderately high - negative (-4)</td><td>This impact will most likely intensify over time, resulting in further changes to the flows</td></tr>
<tr><td>Probability</td><td>Certain (7)</td><td colspan="2">These land uses are currently being conducted</td></tr>
<tr><td colspan="5">MITIGATION:
Not applicable</td></tr>
<tr><td colspan="5">POST-MITIGATION</td></tr>
<tr><td>Duration</td><td>N/A</td><td>As for pre-mitigation</td><td rowspan="3">Consequence: Negligible (0)</td><td rowspan="4">Significance: 0 (0)</td></tr>
<tr><td>Extent</td><td>N/A</td><td>As for pre-mitigation</td></tr>
<tr><td>Intensity x type of impact</td><td>N/A</td><td>Mitigation will maximise local job creation</td></tr>
<tr><td>Probability</td><td>N/A</td><td colspan="2">Mitigation will maximise probability that local recruitment targets are achieved and local benefits optimised</td></tr>
</table>

IMPACT DESCRIPTION: Deterioration of water quality				
Predicted for project phase:	Pre-construction	Construction	Operation	Decommissioning
Dimension	**Rating**	**Motivation**		
PRE-MITIGATION				
Duration	Permanent (7)	These are established land uses	Consequence: Highly detrimental (-14)	Significance: Moderate - negative (-98)
Extent	Catchment area (4)	Impaired water quality will impact on downstream users, also considering cumulative impacts		
Intensity x type of impact	Moderate - negative (-3)	The cumulative impact is somewhat reduced due to the site being in the upper catchment. Additionally, some dilution is provided		
Probability	Certain (7)	These land uses are currently being conducted		
MITIGATION:				
Not applicable				
POST-MITIGATION				
Duration	N/A	As for pre-mitigation	Consequence: Negligible (0)	Significance: 0 (0)
Extent	N/A	As for pre-mitigation		
Intensity x type of impact	N/A	Mitigation will maximise local job creation		
Probability	N/A	Mitigation will maximise probability that local recruitment targets are achieved and local benefits optimised		

IMPACT DESCRIPTION: Loss of habitat features and quality				
Predicted for project phase:	Pre-construction	Construction	Operation	Decommissioning
Dimension	**Rating**	**Motivation**		
PRE-MITIGATION				
Duration	Permanent (7)	These are established land uses	Consequence: Highly detrimental (-14)	Significance: Moderate - negative (-98)
Extent	River reach (3)	Reaches are inundated, but these do recover further downstream		
Intensity x type of impact	Moderately high - negative (-4)	Dams have resulted in direct loss of habitat, and erosion of systems as a result of dams results in sedimentation		
Probability	Certain (7)	These land uses are currently being conducted		
MITIGATION:				
Not applicable				
POST-MITIGATION				
Duration	N/A	As for pre-mitigation	Consequence: ()	Significance: ()
Extent	N/A	As for pre-mitigation		
Intensity x type of impact	N/A	Mitigation will maximise local job creation		
Probability	N/A	Mitigation will maximise probability that local recruitment targets are achieved and local benefits optimised		

9.2 Impact of the proposed underground mining activity

The Block 4 study area is proposed to be mined by underground methods, no supporting infrastructure will accompany the operation. The focus for the assessment will therefore be on the potential impacts associated with undermining the watercourses.

9.2.1 Issue 1: Degradation of integrity for watercourses

Underground mining, particularly bord and pillar methods may result in unplanned surface collapses, changing the topographical features of the catchment permanently. Changes to the topography will result in changes to geomorphology of the catchment which will further result in changes to hydrological regime of the respective systems. Subsidence can also as a result, cause ground and surface water contamination due to acidification and salinisation of nearby aquifers. Additionally, subsidence may also result in a loss of water quality for the catchment due to fissures or pits which may result

- Impact 1: Changes to flow regimes; and
- Impact 2: Deterioration of water quality.

Management and mitigation measures

A geotechnical investigation should be conducted in order to quantify this risk of subsidence occurring. Should the risk of subsidence occurring be high, it is recommended that no mining of the resource take place within a 100m buffer of the respective watercourses.

IMPACT DESCRIPTION: Changes to flow regimes				
Predicted for project phase:	Pre-construction	Construction	Operation	Decommissioning
Dimension	**Rating**	**Motivation**		
PRE-MITIGATION				
Duration	Permanent (7)	This will be a permanent feature, post decommissioning	Consequence: Highly detrimental (-15)	Significance: Minor - negative (-60)
Extent	Catchment area (4)	The larger catchment area will be impacted on by the topographical changes		
Intensity x type of impact	Moderately high - negative (-4)	This impact will most likely intensify over time, resulting in further changes to the flows		
Probability	Probable (4)	It is probable, unplanned collapses are recorded in the Mpumalanga coal field		
MITIGATION: - Conduct a geotechnical investigation to quantify the risk of subsidence, as well as determine the likeliness of subsidence - Should subsidence be identified as a high risk, allocate a 100m buffer to all watercourses and avoid mining these area				
POST-MITIGATION				

Duration	Permanent (7)	As for pre-mitigation	Consequence: Highly detrimental (-14)	Significance: Negligible - negative (-14)
Extent	Catchment area (4)	As for pre-mitigation		
Intensity x type of impact	Moderate - negative (-3)	The extent of subsidence may be reduced, but impacts are still associated		
Probability	Highly unlikely (1)	Mitigation will prevent the likeliness of subsidence occurring		

IMPACT DESCRIPTION: Deterioration of water quality				
Predicted for project phase:	Pre-construction	Construction	Operation	Decommissioning
Dimension	**Rating**	**Motivation**		
PRE-MITIGATION				
Duration	Permanent (7)	This will be a permanent feature, post decommissioning	Consequence: Highly detrimental (-16)	Significance: Minor - negative (-64)
Extent	Catchment area (4)	The larger catchment area will be impacted on by the topographical changes		
Intensity x type of impact	High - negative (-5)	May result in contamination due to acidification and salinisation of nearby aquifers, impacting on downstream users		
Probability	Probable (4)	It is probable, unplanned collapses are recorded in the Mpumalanga coal field		
MITIGATION: - Conduct a geotechnical investigation to quantify the risk of subsidence, as well as determine the likeliness of subsidence - Should subsidence be identified as a high risk, allocate a 100m buffer to all watercourses and avoid mining these area				
POST-MITIGATION				
Duration	Permanent (7)	As for pre-mitigation	Consequence: Highly detrimental (-15)	Significance: Negligible - negative (-15)
Extent	Catchment area (4)	As for pre-mitigation		

Intensity x type of impact	Moderately high - negative (-4)	The extent of subsidence may be reduced, but impacts to water quality will affect downstream users		
Probability	Highly unlikely (1)	Mitigation will prevent the likeliness of subsidence occurring		

10 RECOMMENDATIONS

The following recommendations have been provided in light of the planned underground mining operation. These recommendations reiterate the provided mitigation measures to preferably avoid impacts to the local watercourses. The recommendations include:

- Commission a geotechnical investigation for the Block 4 study area in order to quantify this risk of subsidence should the area be mined; and
- Should the risk of subsidence occurring be high, it is recommended that no mining of the resource take place within a 100m buffer of the respective watercourses.

11 CONCLUSION

The integrity (health) of the local watercourses was determined to be moderately modified. Modifications to the watercourses are a result of the local agricultural activities, notably crop and livestock farming. These activities have impacted on the water and habitat quality associated with the systems. The current state of the watercourses differed from the study desktop findings, which described the catchment area as largely modified. According to this study, the prescribed attainable ecological management class for catchment is currently being attained.

The primary risk identified for the proposed underground mining of the watercourses is subsidence. It has been recommended that should the risk of subsidence be negligible, then mining of the watercourses may be permitted, however, should the risk of subsidence be determined to be high, the undermining of the watercourses should be avoided and a100m buffer zone allocated.

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