Report on the aquatic assessment for the proposed alluvial diamond mining operations on a portion of states land including a portion of the Vaal River near the town of Delportshoop, Northern Cape Province.

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Executive Summary

This report is based on the results of the aquatic sampling survey conducted during December 2018 on the selected sites on states land on Farm 352 and a portion of the Vaal River.

The primary objectives of this project are as follows:

- Determine the biotic integrity (in terms of macro-invertebrates and fish) of the Vaal River in the vicinity of the proposed new diamond mining activity.

The aquatic ecosystem within the surrounding area of the proposed new diamond mining activity was assessed as being **largely modified (D)** after the current assessment. The majority of impacts on this system were associated with current and abandoned upstream mining activities, agriculture and instream habitat changes. These modifications in turn influenced the macro-invertebrate and fish community structures. The water quality results indicated that the water quality was overall good indicating no *in situ* parameters exceeding the limits. The main sources for the absence of the expected fish species and macro-invertebrates at the sites were from the accumulative effects of upstream mining and agricultural activities, impoundments and general anthropogenic activities.

As the study area does not fall within a Freshwater Ecological Protected Area (FEPA) it is not governed by its stringent management guidelines. However, normal guidelines should still be adhered to regarding any planned development as well as future management of the river. The impacts of the proposed new diamond mining activities in the system were found to be potential loss of aquatic habitat and increased turbidity and siltation in the river. The impacts will influence the water quality and also the biotic integrity of the system and mitigation measures need to be implemented to limit any adverse effects.

The following recommendations are made, based on the survey:

- Implementation of a suitable management action plan during the operation of the proposed diamond mine, based on analysis of bi-annual water quality and biological monitoring data collected at sites upstream and downstream of all activities;

- Prevention of exotic vegetation encroachment;

- Prevent further siltation within the river segment as well as downstream of activities;

- Unnecessary destruction of marginal and instream habitat should always be avoided during operations.

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List of Acronyms

ASPT	Average Score Per Taxon
BDI	Biological Diatom Index
DO	Dissolved Oxygen
DWA	Department of Water Affairs (previously known as DWAF)
DWS	Department of Water and Sanitation
EC	Ecological Category
EIA	Environmental Impact Assessment
FEPA	Freshwater Ecological Protected Area
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
GSM	Stones, Gravel, Mud
IHI	Index of Habitat Integrity
IH	Instream habitat
IHAS	Index Habitat Integrity Instream Habitat
LC	Least Concern
m.a.s.l	Meters above sea level
MAP	The mean annual precipitation
MIRAI	Macroinvertebrate Response Assessment Index
PES	Present Ecological State
%PTV	Percentage Pollution Tolerant Valves
RH	Riparian Habitat
RHI	River Health Index
RHP	River Health Programme
SPI	Specific Pollution sensitivity Index
SASS5	South African Scoring System, version 5
ToR	Terms of Reference
TWQR	Target Water Quality Range
WMAs	Water Management Areas
WQ	Water Quality

1. Introduction

Water is one of the most precious natural resources on earth and is utilised extensively for various applications. Rivers create a wide range of benefits to humankind including fisheries, wildlife, and agriculture, urban, industrial and social development close to water sources. The unfortunate effect of these anthropogenic activities is the degradation of the integrity of river systems around the world, due to mismanagement. Management strategies of water resources should be built upon the knowledge and expertise of various disciplines, with the biologist playing an important and sometimes the leading role.

Alluvial diamond mining activities in the Vaal and Orange Rivers have been conducted presently and historically for many years. It plays an important role in the economy of South Africa however, many of these activities have been found to be detrimental for the aquatic biota within these rivers.

Biological communities reflect overall ecological integrity by integrating different stressors over time and thus providing a broad measure of their aggregate impact. The monitoring of biological communities therefore provides a reliable ecological measure of fluctuating environmental conditions. The sampling protocols applied in this project should give a good reflection of the human impacts on the system under investigation. The habitat condition and availability, aquatic macro invertebrates and fish were investigated to determine the present ecological status (PES) of a portion of states land on Farm 352 and a portion of the Vaal River and the potential impact of the proposed new alluvial diamond mining activities on the ecological integrity of the receiving system in its vicinity.

2. Terms of Reference

The Terms of Reference (ToR) for the study were as follows:

- Monitor the present and future impacts of the construction and operations of the new proposed diamond mining project on the aquatic ecosystem.
- Monitoring the PES in terms of water, habitat, macro-invertebrate and fish integrity at sampling points identified during the survey.
- The sampling points were selected to be representative of the area on the Vaal River.
- The present study serves to report on the survey regime of the aquatic integrity (results from the 30-31 December 2018 sampling).

3. Project Team

This aquatic ecological assessment was conducted and managed by DPR- Ecologist and Environmental Services. The details of the Aquatic project team are included in
Table 3.1.

Table 3.1 Project team with associated areas of specialisation

Specialist	Area of Specialisation	Qualification
J. Potgieter	Aquatic Ecology	M.Sc. Aquatic Health DWA Accredited – SASS Macro-invertebrate monitoring Pr.Sci.Nat
A. Strydom	Aquatic Ecology	DWA Accredited – SASS Macro-invertebrate monitoring

4. Limitations

Unfortunately, some limitations were encountered even though all attempts were made to take samples under optimal conditions. The limitations to this study included:

4.1. Factors influencing sampling

- The techniques used for assessing habitat integrity were subjective.
- Electro-narcosis was the only technique used for sampling fish, and therefore certain habitats such as deep waters could not be properly sampled.

4.2. Factors influencing interpretation

The possible impacts on the river system from the proposed activities could be identified, but not fully quantified. This was due to the presence of other influencing activities in this area, namely livestock grazing and crop planting and existing weirs and upstream mining activities.

5. Study Site Description

A brief description of the location and biophysical characteristics of the study area that is relevant to the current study is included below.

5.1. Location

The study site is situated approximately 22 km North-west of Barkly West within the North-eastern region of the Northern Cape Province, on states land, Farm 352 and a portion of the Vaal River (Figure 6.1-1).

5.2. Climate

The proposed new diamond mine site falls within the Southern Kalahari region, which is typically characterised by warm wet summers and cold dry winters. The mean annual maximum and minimum temperatures ranges between 36°C and 19°C, respectively for the catchment. Maximum summer temperatures occur in January and minimum winter temperatures are experienced in July. Rainfall is unreliable and irregular, falling primarily during short-duration, high-intensity thunderstorms during the summer months (November to April). The mean annual rainfall decreases from the north (250mm) to the south (223mm) with very low humidity and high evaporation (DWA, 2004).

5.3. Topography

The Southern Kalahari can be described as a landscape with plains with low to moderate relief as well as hills with low to moderate relief. Vegetation of this region predominantly consists of Kalahari bushveld types. The study area lies within an elevation between 1000 m and 1010 m above sea level (m.a.s.l) in the Lower Vaal. The water from the Lower Vaal Water Management Area (WMA 10) flows into the Lower Orange Water Management Areas (WMAs) before reaching the Atlantic Ocean near the town of Alexander Bay in the western corner of the country (DWA, 2004).

5.4. Geology and Soils

The geology of the area consists mainly of sand, sandstone, tillite, quartzite, schist and biotite granites. Regarding the soils, the area is predominated by loam-sand, sand-loam, sand-clay-loam and sand-clay soils types (DWA, 2004).

5.5. Hydrology

The study area falls within the level 1 Ecoregion 29 and the level 2 Ecoregion 29.02, according to the South African River Health Programme (RHP) and Kleynhans *et al*. (2005). The aquatic monitoring sites investigated are located within quaternary catchment C91E (Figure 5.5-3), which forms part of the Lower Vaal River Catchment in the Northern Cape. The sampling sites in this study are on the Vaal River downstream of the town of Barkly West and upstream from Delportshoop. The surrounding area consists predominately of commercial farming, including livestock, game and agriculture. Figure below illustrates the Southern Kalahari Ecoregion (pink).

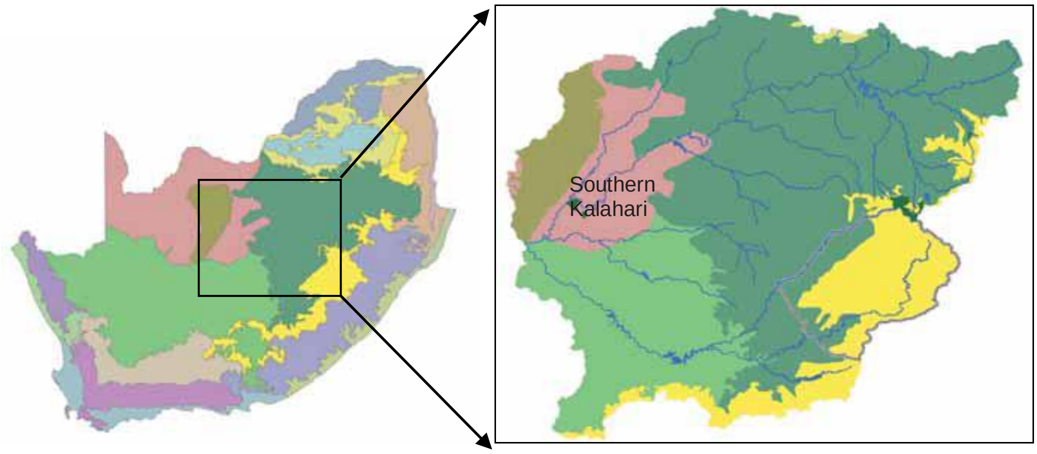

Figure 5.5-1. Illustrating the Southern Kalahari Ecoregion (RHP, 2003).

The flow gauging weir station, C9H026, is located just downstream of the study site. Due to missing monthly records for the flow at this weir the data prior to 2001 could not be used for flow analysis. Below in Figure 5.5-2 average monthly flow data for the period January 2018 to September 2018 are shown for the Delportshoop weir (DWS, 2019).

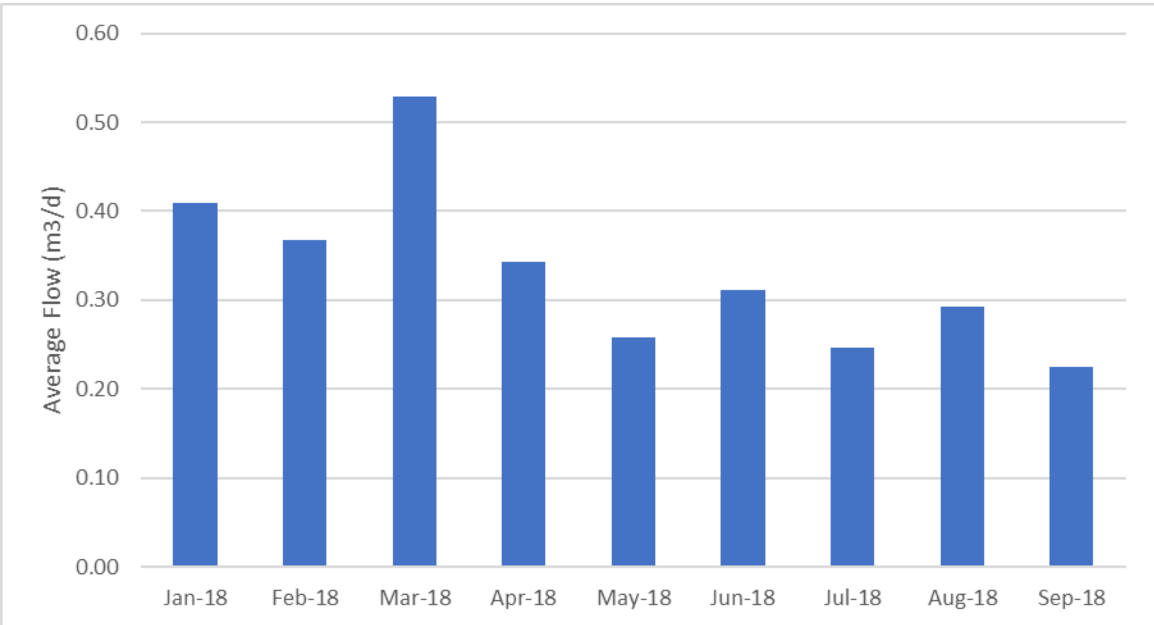

Figure 5.5-2. Illustrating the flow data for Delportshoop weir C9H026 (DWS, 2019).

The flow pattern at the weir follows a normal trend in connection with annual rainfall patterns of the areas and the low flow mainly due to the current dry conditions in catchment area.

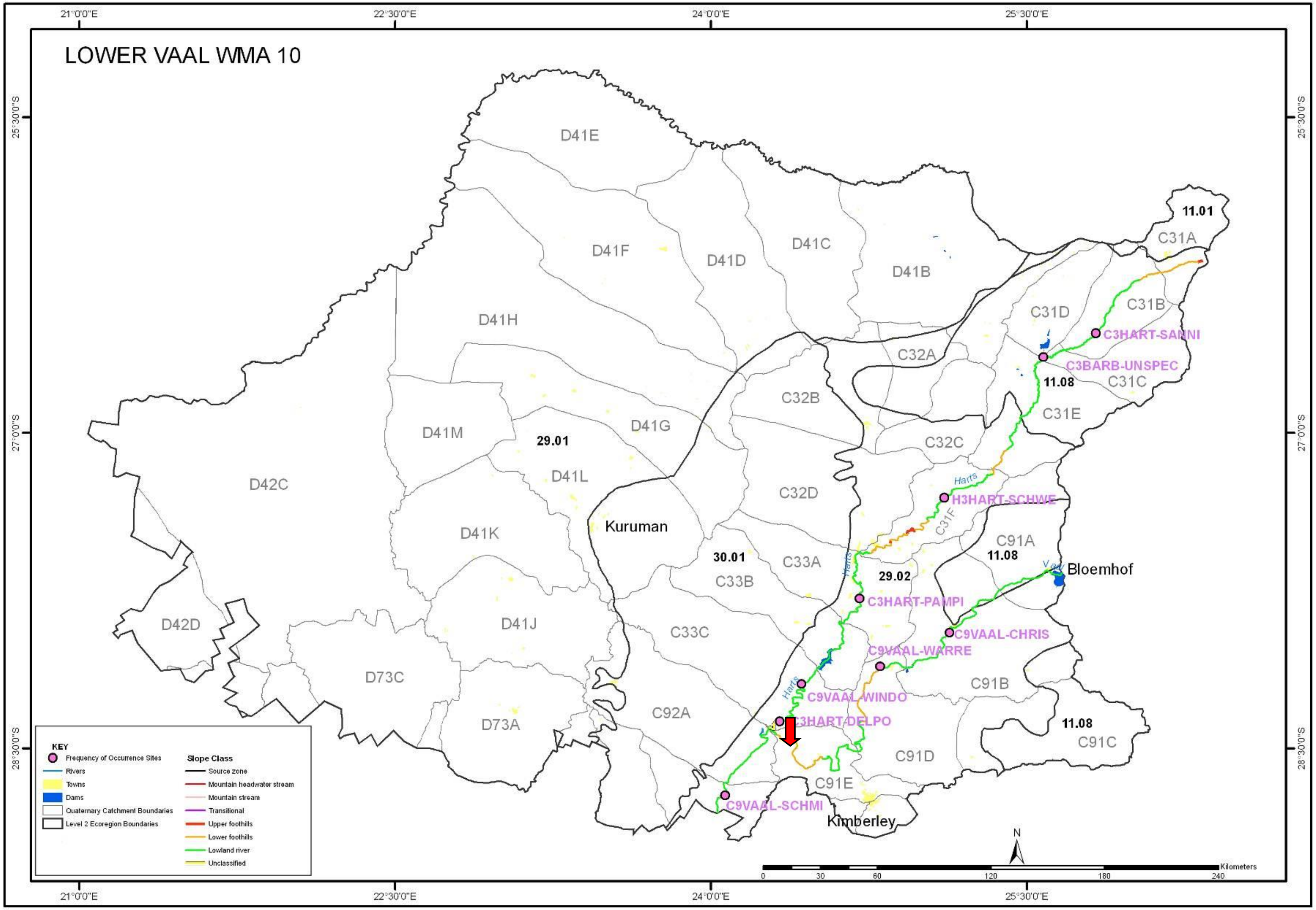

Figure 5.5-3. Quaternary Catchment

6. Methodology

The River Health Programme (RHP), a national biomonitoring programme for South African rivers, was implemented to monitor and thus improve and conserve the health of South African freshwater ecosystems (Todd and Roux, 2000). The RHP specifies that a sampling site must be representative of a river reach, have habitats amendable for sampling and suitable for biomonitoring of the different RHP indices i.e. SASS5, MIRAI and FRAI (DWA, 2008). These indices have been specifically designed for the flowing rivers of South Africa.

6.1. Sampling Site

The primary objective of this study was to establish the present ecological state of the river and impacts of the proposed new diamond mine on the aquatic ecosystems. The survey was undertaken in December 2018. The sites were chosen based on the position of the proposed mining activities and to be representing of the available habitats. The survey sites are summarised in Table 6.1.1. The sampling sites are illustrated in Figure 6.1-1 and their positions in the quaternary catchment in Figure 5.5-3.

Table 6.1.1 Selected survey site.

RIVER	SITE NAME	CO-ORDINATES		SAMPLING
Vaal	BW01	-28.456922° S	24.336013° E	31/12/2018
Vaal	BW02	-28.455814° S	24.328029° E	31/12/2018
Vaal	BW03	-28.450786° S	24.326954° E	31/12/2018

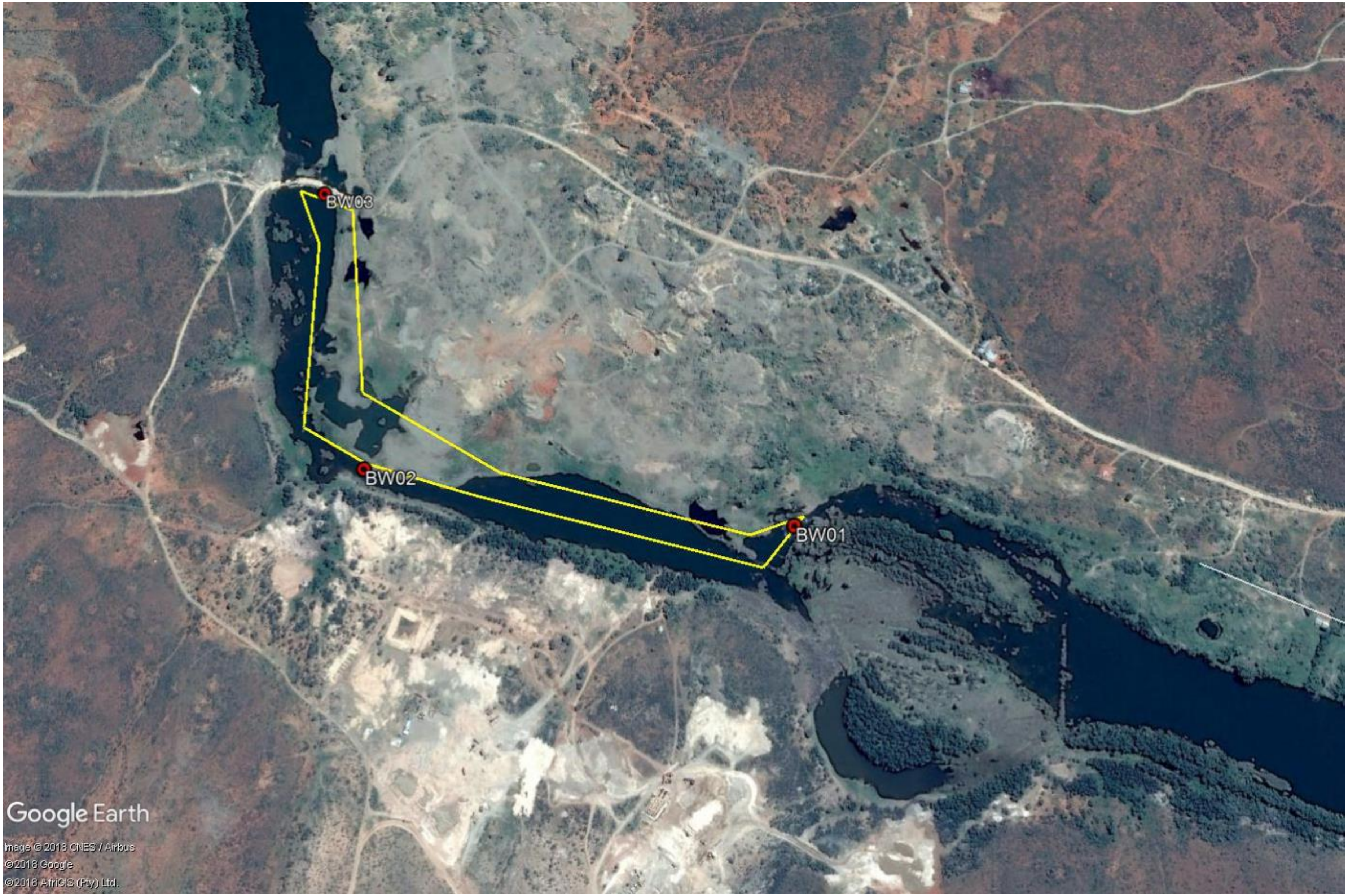

Figure 6.1-1 Aquatic sampling sites.

6.2. Present Ecological State

The Present Ecological Status (PES) of the Vaal River was determined by assessing the water quality, instream and riparian habitat, macro-invertebrates and fish community integrity. The ecological categories (EC) were used to assist in defining the current ecological condition of a river in terms of the deviation of biophysical components from the natural reference condition (Kleynhans and Louw, 2008). These categories range over a continuum of impacts, from natural (Category A) to critically modified (Category F) and are represented by characteristic colours defined by Kleynhans and Louw (2008) in Table 6.2.1**.** In some cases, there is an uncertainty as to which category a particular entity belongs. This situation falls within the concept of a "fuzzy" boundary, where a particular entity may potentially have membership of both classes. For practical purposes these situations are referred to as boundary categories and are denoted as for example B/C as depicted in Figure 6.2-1. In the current study, the ECs were assigned to the results obtained from the index scores of the IHI measuring habitat and FRAI scores measuring fish integrity. The SASS and ASPT scores were assigned ECs based on the Highveld - lower zone defined by Dallas (2007) and further discussed in Section 6.4.

Table 6.2.1 Present Ecological State codes and descriptions with standardised colour coding (adapted from Kleynhans and Louw, 2008)

CATEGORY	MIRAI, FRAI and IHI (%)	SASS5	ASPT	SHORT DESCRIPTION	LONG DESCRIPTION
A	90 – 100	>/=123	>/=5.6	**Natural**	**Natural** – Unmodified state with no impacts, conditions natural
B	80 – 89	>/=82<123	>/=4.8<5.6	**Largely natural**	**Largely natural** with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged
C	60 – 79	>/=64<82	>/=4.6<4.8	**Moderately modified**	**Moderately modified** – loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged
D	40 – 59	>/=51<64	>=4.2<4.6	**Largely modified**	**Largely modified** – a large loss of natural habitat, biota and basic ecosystem functions has occurred
E	20 – 39	<51	<4.2	**Seriously modified**	**Seriously modified** – the loss of natural habitat, biota and basic ecosystem functions are extensive
F	< 20	<51	<4.2	**Critically modified**	**Critically/Extremely modified** – modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible

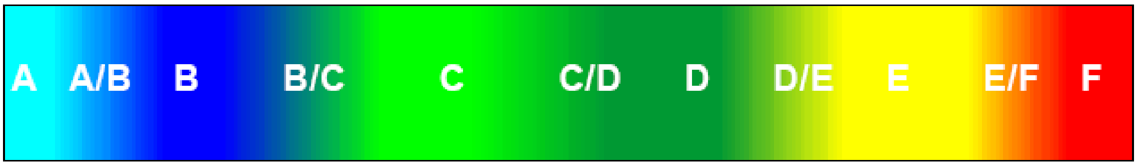

Figure 6.2-1 Illustration of the distribution of categories on a continuum as shown in Kleynhans and Louw (2008)

6.3. Water Quality

Water quality is used to describe the aesthetic, biological, chemical and physical properties of water that determine its condition for a variety of uses and for the protection of the health and integrity of aquatic ecosystems. Constituents in the water, dissolved or suspended, could influence the water quality. In some cases, anthropogenic activities can cause the physico-chemical constituents that occur naturally in the water to become toxic under certain conditions (DWA, 1996).

Determining the effects of changes in water quality on aquatic ecosystems is considered complex. Aquatic ecosystems often appear to have certain thresholds, beyond which it is difficult to recover or regain their functional capacity without mitigation. Each aquatic ecosystem possesses natural limits or thresholds to the extent and frequency of change it can tolerate without being irreversibly altered (DWA, 1996).

6.3.1. Physical water quality parameters

Five physical water quality parameters were measured *in situ* water quality including temperature, pH, dissolved oxygen (DO), percentage oxygen and electrical conductivity (EC). The variables were measured in the field by using a HI 9146 Dissolved Oxygen and Temperature Meter and a HI 98129 pH/EC/TDS/Temperature multi-sensor probe (Hanna Instruments). Field measurements were compared against the Target Water Quality Range (TWQR), which is a management objective developed by DWA (1996) for aquatic ecosystems and used to specify the desired or ideal concentration range and/or water quality requirements for a particular constituent.

6.3.2. Diatoms

Diatoms were collected from all aquatic sampling sites and analysed by Kundai Science Laboratory, according to the procedures described by Taylor *et al.* (2005) and Fore and Grafe (2002).

The specific water quality tolerances of diatoms have been resolved into different diatom-based water quality indices, used around the world. Most indices are based on a weighted average equation (Zelinka and Marvan, 1961). In general, each diatom species used in the calculation of the index is assigned two values; the first value (s value) reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value (v value) indicates how strong (or weak) the relationship is (Taylor, 2004). These values are then weighted by the abundance of the particular diatom species in the sample (Lavoie *et al*., 2006; Taylor, 2004; Besse, 2007). The main difference between indices is in the indicator sets (number of indicators and list of taxa) used in calculations (Eloranta and Soininen, 2002).

These indices form the foundation for developing computer software to estimate biological water quality. OMNIDIA (Lecointe *et al*., 1993) is one such software package; it has been approved by the European Union and is used with increasing frequency in Europe and has been used for this study. The program is a taxonomic and ecological database of 7500 diatom species, and it contains indicator values and degrees of sensitivity for given species. It permits the user to perform rapid calculations of indices of general pollution, saprobity and trophic state, indices of species diversity, as well as of ecological systems (Szczepocka, 2007).

Data was interpreted in terms of species present, abundances, number of species with deformed valves and characterised into 3 different indices calculated using OMNIDIA ver. 5.3 (Table 6.3.2.1) (Lecointe *et al*., 1993; database updated March 2009) and each was classified into a class ranging from deteriorated to high quality as defined by Eloranta and Soininen (2002)(Table 6.3.2.2).

Table 6.3.2.1 Diatom Indices Implemented in this assessment

Index	Index Abbreviation	Reference
Specific Pollution sensitivity Index	SPI	CEMAGREF (1982)
Biological Diatom Index	BDI	Lenoir & Coste (1996)
Percentage Pollution Tolerant Valves	%PTV	Kelly & Whitton (1995)

Table 6.3.2.2 Diatom categorised into various classes as Index score and class (Taylor, 2005)

Interpretation of index scores		
Ecological Category (EC)	**Class**	**Index Score (SPI Score)**
A	High quality	18 - 20
A/B		17 - 18
B	Good quality	15 - 17
B/C		14 - 15
C	Moderate quality	12 - 14
C/D		10 - 12
D	Poor quality	8 - 10
D/E		6 - 8
E	Bad quality	5 - 6
E/F		4 - 5
F		<4

6.4. Habitat Integrity (IHI)

The Index of Habitat Integrity (IHI) assessment protocol, described by Kleynhans (1996), was used to assess the impacts on the aquatic and surrounding habitats of all the sites sampled. Respectively the instream (IH) and riparian (RH) habitats are analysed based on a set of 12 weighted disturbances in the index. These disturbances represent some of the important and easily quantifiable anthropogenically induced impacts, including bank erosion, bed-, channel- and flow modification; exotic aquatic fauna, -macrophytes and -vegetation encroachment; indigenous vegetation removal; inundation; solid waste disposal and water abstraction. The respective impacts for the IH and RH habitats were calculated. Each disturbance was assigned an impact rating (

Table 6.4.1) and a confidence score. These values were used to calculate an impact score using the formula: (impact rating/25) x (the weight of that impact defined in

Table 6.4.2). The estimated impacts of all criteria were summed, expressed as a percentage and subtracted from 100, respectively. The habitat integrity value for the instream and riparian components were then obtained. The final IHI was calculated and characterized into one of the six categories defined by Kleynhans and Louw (2008) and indicated in Table 6.2.1.

Table 6.4.1 The IHI scoring of each criterion to describe the extent of each impact (from Kleynhans, 1996)

IMPACT CLASS	DESCRIPTION	SCORE
None	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability is limited.	1-5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are fairly limited.	6-10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not affected	11-15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16-20

IMPACT CLASS	DESCRIPTION	SCORE
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21-25

Table 6.4.2 Criteria and weightings used for the assessment of Instream and Riparian Habitat Integrity (Kleynhans, 1996)

INSTREAM CRITERIA	WEIGHT		RIPARIAN CRITERIA	WEIGHT
Water abstraction	14		Vegetation removal	13
Water quality	13		Exotic vegetation	12
Flow modification	13		Bank erosion	14
Bed modification	13		Channel modification	12
Channel modification	14		Water abstraction	13
Inundation	10		Inundation	11
Exotic macrophytes	9		Flow modification	12
Exotic fauna	8		Water quality	13
Rubbish dumping	6			

6.5. Habitat Availability

6.5.1. Habitat Availability for macro-invertebrates

Most aquatic fauna are largely influenced by the habitat diversity within an aquatic ecosystem. As such different biotope diversities for macro-invertebrates were evaluated i.e. stones in current (bedrock, cascade, chute, boulder rapid, riffle and run), stones out of current (bedrock, backwater, slack-water and pool), instream vegetation, marginal vegetation and GSM (gravel, sand and mud). Each of these biotopes were scored, rated on a scale from 0 to 5 according to presence of biotopes, namely absent (0), rare (1), sparse (2), common (3), abundant (4) or entire (5) (Dallas, 2005). The invertebrate habitat assessment system (IHAS) index was not incorporated into the present study. However, some of the categories from the IHAS were identified, including algal presence, biotopes and dominant vegetation types.

6.5.2. Fish Habitat Availability

A fish habitat assessment was done to provide a measure of the fish refuge potential associated with each of the sampling sites. This assessment characterises the fish habitats into four velocity-depth classes (including slow-deep, slow-shallow, fast-deep and fast-shallow habitat class, where fast is greater than 0.3 m/s, slow is less than 0.3 m/s, deep is greater than 0.3m and shallow is less than 0.3 m) and associated cover present at each of the habitats

(Dallas, 2005). All of these were quantified on a scale from 0 to 5, being absent (0), rare (1), sparse (2), common (3), abundant (4) or entire (5) (Dallas 2005). Measuring these various habitat types are an essential component in the interpretation of the fish integrity because it can influence (by creating or restricting) the fish populations and communities present within each sampling site.

6.6. Macro-invertebrates

Macro-invertebrate communities were sampled using the SASS5 (South African Scoring System, version 5) method described by Dickens & Graham (2002). Macro-invertebrates were collected using a standard SASS net in stones, vegetation and gravel, sand and mud (GSM) within specified time frames. Fifteen minutes were taken to identify the presence and approximate abundances of macro-invertebrate families in each of the habitat. SASS5 and MIRAI scores could be calculated to determine the current ecological status of the macro-invertebrates.

6.6.1. SASS5 index

The assessment of macro-invertebrate communities in a river system is a recognised means of determining river "health" (Dickens and Graham, 2002). Macro-invertebrates are good indicators because they are visible, easy to identify and have rapid life cycles. Macro-invertebrate communities were assessed using the SASS5 method described by Dickens & Graham (2002). SASS5 is a rapid assessment index of the macro-invertebrate status of a flowing instream system. As such could not be calculated for non-flowing streams. In the flowing systems, the SASS5 score was calculated by the sum of the sensitivity scores of the present families. The average score per taxon (ASPT) was calculated by dividing the total SASS score by the total number of taxon. The results were interpreted based on the SASS5 interpretation guidelines by Dallas (2007), using the ecological categories derived for the Southern Kalahari Ecoregion (Figure 6.6.1-1) and defined in Table 6.2.1.

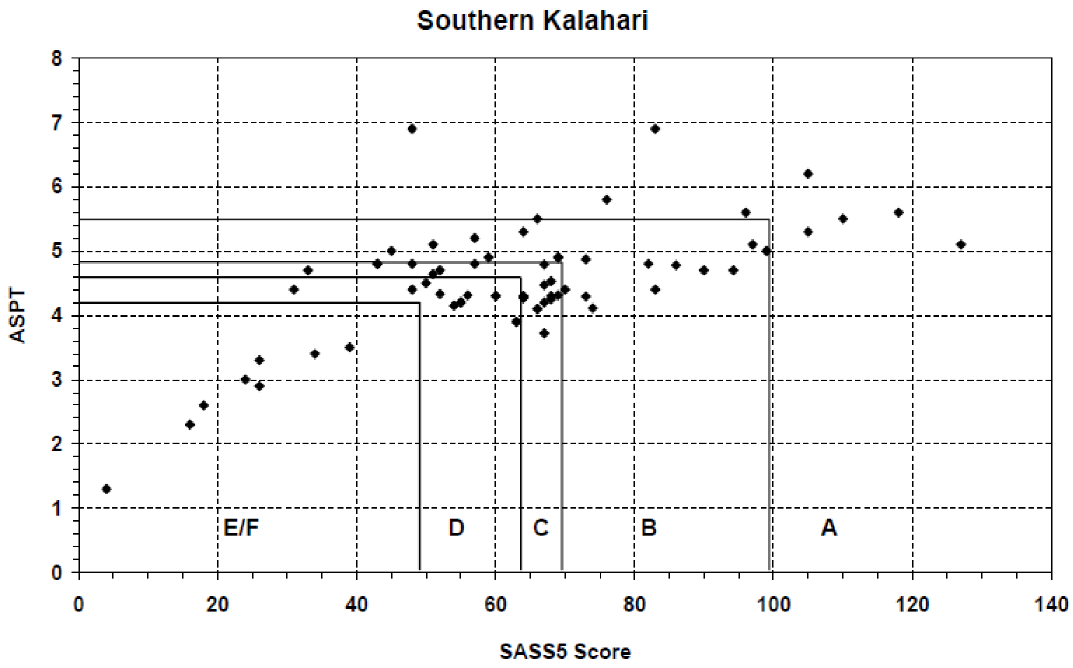

Figure 6.6.1-1 Ecological categories for the Southern Kalahari, calculated using percentiles (Dallas, 2007)

6.6.2. MIRAI

The MIRAI was incorporated in this study, as an alternative to the SASS5, to determine the PES of the macro-invertebrate community assemblage. The index integrates the ecological requirements of the invertebrate taxa in a community or assemblage and their response to modified habitat conditions, whilst comparing the present assemblage with a reference list (Thirion, 2007). The reference list for this study was derived by using numerous literature sources including historical data from the Rivers Database (2007) and past experience within this quaternary catchment and results obtained from the previous studies in the area. In addition, the functional feeding groups and river continuum were considered.

The MIRAI model makes a comparison between the expected macro-invertebrate families with the present assemblages obtained using SASS5 sampling protocol (Thirion, 2007). The habitat preferences for each of the macro-invertebrates were incorporated in terms of flow, habitat and water quality. Each component was rated within a metric in terms of how much the macro-invertebrate presence and abundances changed from reference and were done for each of the metrics. After all the metrics were scored, the model generated a MIRAI score for each site and was characterised into an EC as defined in Table 6.2.1.

6.7. Ichthyofauna

6.7.1. Fish Integrity

The fish community integrity was assessed using the Fish Response Assessment Index (FRAI) developed by Kleynhans (2008). At each site, the fish were sampled according to the methodologies recommended for FRAI. This included sampling fish by means of electro-narcosis in three different river segments (where possible), for approximately 20 minutes in each segment. The sampled fish were identified to species level using Skelton (2001) and safely returned to the aquatic system before they were documented into the separate segments and habitat types. The FRAI model makes a comparison between the expected fish species list obtained from the FROC report by Kleynhans *et al.* (2007) and the FROC of sampled fish species. It incorporates the habitat preferences in terms of velocity-depth, substrate, water quality, alteration in physical-chemical composition of the water, as well as migration requirements of each fish species. The intolerances and preferences are divided into metric groups that relate to the requirements and preferences of individual species. This allows for the understanding of cause-effect relationships between drivers and responses of the fish assemblage to these drivers of change. Having compared the expected list to the actual sampled list, the model generates a FRAI score for each site, which can be characterised into an EC as defined in Table 6.2.1.

7. Results and Discussion

7.1. Sampling site description

The results for the current field sampling (30-31 December 2018) are summarised in the tables below, along with the general information for the sites, which are presented in Table 7.1.1**,** Table 7.1.2, Table 7.1.3. The tables are then followed by the water quality, diatom, habitat, macro-invertebrate and fish integrity results and discussions.

Table 7.1.1 Survey results and associated information for BW01

<table>
<tr><th colspan="9">BW01</th></tr>
<tr><th colspan="4">UPSTREAM</th><th colspan="5">DOWNSTREAM</th></tr>
<tr><th colspan="9">2018</th></tr>
<tr><td colspan="4"></td><td colspan="5"></td></tr>
<tr><td colspan="2">River</td><td colspan="7">Vaal River</td></tr>
<tr><td colspan="2">Site Description</td><td colspan="7">Perennial river located on the farm 352</td></tr>
<tr><td colspan="2">GPS co-ordinates of sampling point</td><td colspan="7">-28.456922° S; 24.336013° E</td></tr>
<tr><td colspan="2">Altitude (m.a.s.l)</td><td colspan="7">1002 m</td></tr>
<tr><td colspan="2">Quaternary Catchment</td><td colspan="7">C91E</td></tr>
<tr><td colspan="2">WMA (Midgley et al. 1994)</td><td colspan="7">Lower Vaal Water Management Area 10</td></tr>
<tr><td colspan="2">Ecoregion</td><td colspan="7">29.02</td></tr>
<tr><td colspan="2">Ecoregion Name</td><td colspan="7">Southern Kalahari Basin</td></tr>
<tr><td colspan="2">Regional Vegetation Type</td><td colspan="7">Kalahari Bushveld Bioregion</td></tr>
<tr><td colspan="2">Riparian Vegetation Type</td><td colspan="7">Grasses and Sedges</td></tr>
<tr><td colspan="2">Geomorphological Zonation (Rowntree and Wadeson 2000)</td><td colspan="7">Lower Foothills</td></tr>
<tr><td colspan="2">Channel Type:</td><td colspan="7">Valley bottom with channel</td></tr>
<tr><td colspan="2">Water Surface Dimensions</td><td colspan="7">Width:5–15m; Depth: 0.5–1.5m</td></tr>
<tr><td colspan="2">Water Turbidity (Dallas 2005)</td><td colspan="7">Discoloured and silty</td></tr>
<tr><td colspan="2">Algal presence</td><td colspan="7">Moderate</td></tr>
<tr><td colspan="2">Dominant Velocity-depth Classes</td><td colspan="7">Slow shallow, Slow deep, Fast shallow</td></tr>
<tr><td colspan="2">Dominant Biotope Diversity</td><td colspan="7">Pools, run, ripples</td></tr>
<tr><td colspan="2">Water Quality Parameters</td><td colspan="7">T(°C) = 27; pH = 8.60; EC(mS/m) = 66.40; DO(mg/l) = 8.10; DO(%) = 97</td></tr>
<tr><td colspan="2">Other Biota</td><td colspan="7">Fish</td></tr>
<tr><td colspan="2">Highly Sensitive Taxa (Score 11-15)</td><td colspan="7">None</td></tr>
<tr><th>DATE</th><th>SAMPLER</th><th>SASS5</th><th>ASPT</th><th>No of Taxa</th><th>PER CLASS</th><th>IHI</th><th>MIRAI</th><th>FRAI</th></tr>
<tr><td>31/12/2018</td><td>A. Strydom</td><td>74</td><td>5.29</td><td>14</td><td>C</td><td>D</td><td>D</td><td>D</td></tr>
<tr><td colspan="2">EXISTING THREATS</td><td colspan="7">Algal growth
Sedimentation
Upstream mining</td></tr>
</table>

Table 7.1.2 Survey results and associated information for BW02

BW02	
UPSTREAM	***DOWNSTREAM***
2018	
	

River	Vaal River
Site Description	Perennial river located on the farm 352
GPS co-ordinates of sampling point	-28.455814° S; 24.328029° E
Altitude (m.a.s.l)	1002 m
Quaternary Catchment	C91E
WMA (Midgley *et al.* 1994)	Lower Vaal Water Management Area 10
Ecoregion	29.02
Ecoregion Name	Southern Kalahari Basin
Regional Vegetation Type	Kalahari Bushveld Bioregion
Riparian Vegetation Type	Grasses and Sedges
Geomorphological Zonation (Rowntree and Wadeson 2000)	Lower Foothills
Channel Type:	Valley bottom with channel
Water Surface Dimensions	Width: 5–15m; Depth: 0.5–1.5m
Water Turbidity (Dallas 2005)	Discoloured and silty
Algal presence	Extensive
Dominant Velocity-depth Classes	Slow shallow, Slow deep, Fast shallow
Dominant Biotope Diversity	Pools, run, ripples
Water Quality Parameters	T(°C) = 27; pH = 8.60; EC(mS/m) = 67.50; DO(mg/l) = 6.90; DO(%) = 99
Other Biota	Fish
Highly Sensitive Taxa (Score 11-15)	Heptageniidae

DATE	SAMPLER	SASS5	ASPT	No of Taxa	PER CLASS	IHI	MIRAI	FRAI
31/12/2018	A. Strydom	**72**	**13**	**13**	**C**	**D**	**D**	**D**

EXISTING THREATS	• Algal growth • Sedimentation • Livestock grazing

Table 7.1.3 Survey results and associated information for BW03

<table>
<tr><th colspan="9">BW03</th></tr>
<tr><th colspan="4">UPSTREAM</th><th colspan="5">DOWNSTREAM</th></tr>
<tr><th colspan="9">2018</th></tr>
<tr><td colspan="4"></td><td colspan="5"></td></tr>
<tr><td colspan="2">River</td><td colspan="7">Vaal River</td></tr>
<tr><td colspan="2">Site Description</td><td colspan="7">Perennial river located on the farm 352</td></tr>
<tr><td colspan="2">GPS co-ordinates of sampling point</td><td colspan="7">-28.457860° S; 24.3926954° E</td></tr>
<tr><td colspan="2">Altitude (m.a.s.l)</td><td colspan="7">1002 m</td></tr>
<tr><td colspan="2">Quaternary Catchment</td><td colspan="7">C91E</td></tr>
<tr><td colspan="2">WMA (Midgley et al. 1994)</td><td colspan="7">Lower Vaal Water Management Area 10</td></tr>
<tr><td colspan="2">Ecoregion</td><td colspan="7">29.02</td></tr>
<tr><td colspan="2">Ecoregion Name</td><td colspan="7">Southern Kalahari Basin</td></tr>
<tr><td colspan="2">Regional Vegetation Type</td><td colspan="7">Kalahari Bushveld Bioregion</td></tr>
<tr><td colspan="2">Riparian Vegetation Type</td><td colspan="7">Grasses and Sedges</td></tr>
<tr><td colspan="2">Geomorphological Zonation (Rowntree and Wadeson 2000)</td><td colspan="7">Lower Foothills</td></tr>
<tr><td colspan="2">Channel Type:</td><td colspan="7">Valley bottom with channel</td></tr>
<tr><td colspan="2">Water Surface Dimensions</td><td colspan="7">Width:5–15m; Depth: 0.5–1.5m</td></tr>
<tr><td colspan="2">Water Turbidity (Dallas 2005)</td><td colspan="7">Discoloured and silty</td></tr>
<tr><td colspan="2">Algal presence</td><td colspan="7">Extensive</td></tr>
<tr><td colspan="2">Dominant Velocity-depth Classes</td><td colspan="7">Slow shallow, Slow deep,</td></tr>
<tr><td colspan="2">Dominant Biotope Diversity</td><td colspan="7">Pools, run</td></tr>
<tr><td colspan="2">Water Quality Parameters</td><td colspan="7">T(°C) = 25; pH = 8.50; EC(mS/m) = 66.80; DO(mg/l) = 7.80; DO(%) = 104</td></tr>
<tr><td colspan="2">Other Biota</td><td colspan="7">Fish</td></tr>
<tr><td colspan="2">Highly Sensitive Taxa (Score 11-15)</td><td colspan="7">None</td></tr>
<tr><th>DATE</th><th>SAMPLER</th><th>SASS5</th><th>ASPT</th><th>No of Taxa</th><th>PER CLASS</th><th>IHI</th><th>MIRAI</th><th>FRAI</th></tr>
<tr><td>31/12/2018</td><td>A. Strydom</td><td>38</td><td>4.22</td><td>9</td><td>D</td><td>D</td><td>D</td><td>D</td></tr>
<tr><td colspan="2">EXISTING THREATS</td><td colspan="7">• Sedimentation
• Algae
• Inundation</td></tr>
</table>

7.2. Water Quality

It is important to assess WQ variables in order to determine the impacts within an ecosystem that may contribute toward changes within the biotic integrity.

Physical (in situ) water quality parameters

All the *in situ* physical variables were measured and the values along with their associated TWQRs, as defined by DWA (1996), are presented in Table 7.2.1. Each water quality parameter and the TWQR will be discussed in the section below.

In the study area, the physical water quality indicated overall good results. Comparing the results with the TWQR it is observed that the water quality at the site shows no deterioration from recommended guidelines and all of the values fell within the target WQ range (Table 7.2.1).

Table 7.2.1 The *in situ* constituents analysed at the site and Target Water Quality Range (TWQR)

	TWQR[a]	**BW01**	**BW02**	**BW03**
pH	6-9	8.60	8.60	8.50
DO (mg/ℓ)	>8	8.10	6.90	7.80
DO (%)	80-120	97	99	104
Temp. (°C)	5-30	27	26	25
EC (mS/m)	70	66.40	67.50	66.80
Figures in bold are characterised as high but not detrimental to the aquatic integrity				

7.3. Diatoms

A summary of the diatom results is provided in Table 7.3.1 and the presence of Pollution Tolerant Valves (PTVs) is also indicated in Table 7.3.1.

Table 7.3.1 Survey diatom results

Site	**No species**	**SPI score**	**Ecological Category**	**Class**	**PTV (%)**
BW01	23	12.1	**C**	Moderate quality	1.50%
BW02	24	13.2	**C**	Moderate quality	1.30%
BW03	37	12.3	**C**	Moderate quality	2.80%

At site BW01 the SPI score was 12.1 **(C)** and the biological water quality was **moderate.** Organic pollution levels were not problematic according to the TDI (Kelly and Whitton, 1995) Pollution Tolerant Valves (PTVs) made up 1.5 % of the total count (Table 7.3.1).

Most species sampled generally had an affinity for good to moderate water quality. The overall diatom community indicated that site BW01 was classified as moderately polluted with intermediate levels of nutrients, fresh brackish and continuous high oxygen rates. Dominant species included:

- *Staurosirella elliptica:* Found in clean waters with moderate to high electrolyte content (Taylor *et al*., 2007b).
- *Pseudostaurosira brevistriata:* Found in clean alkaline fresh waters ranging from oligotrophic to eutrophic (Taylor *et al*., 2007b).
- *Achnanthidium minutissima:* Found in well oxygenated, fresh waters.
- *Staurosirella pinnata:* Found in clean waters with moderate to high electrolyte content (Taylor *et al*., 2007b

The composition of sub-dominant species *Mastogloia smithii*, *Encyonopsis microcephala* *Gyrosigma attenuatum* and *Nitzschia* species suggested that an influx of water with moderate to high electrolyte content and nutrients has entered into the Vaal River system. No valve deformities were noted, suggesting that metal toxicity were below detection limits.

The SPI score for site BW02 was 13.2 **(C)** and the biological water quality was **moderate**. Organic pollution levels were low according to the TDI (Kelly and Whitton, 1995) PTVs made up 1.3% of the total count (Table 7.3.1).

The dominant diatoms comprised of species with an affinity for moderate water quality and moderate electrolyte content. Dominant species included:

- *Staurosirella elliptica:* Found in clean waters with moderate to high electrolyte content (Taylor *et al*., 2007b).
- *Pseudostaurosira brevistriata:* Found in clean alkaline fresh waters ranging from oligotrophic to eutrophic (Taylor *et al*., 2007b).
- *Achnanthidium minutissima:* Found in well oxygenated, fresh waters.
- *Staurosirella pinnata:* Found in clean waters with moderate to high electrolyte content (Taylor *et al*., 2007b)
- *Synedra tenera*: A cosmopolitan species found in mesotrophic to eutrophic waters.

The composition of sub-dominant species *Synedra ulna*, *Synedra nana* and *Fragilaria capucina* suggested that elevated flows occurred at this site, as these species usually indicate fresh inundation and improved oxygenation levels (Taylor *et al*., 2007b).

The diatom results for BW03 indicated a SPI score of 12.3 (**C**) and the biological water quality was **moderate**. Organic pollution levels were low and PTVs made up 2.8% of the total count (Table 7.3.1).

The dominant diatoms comprised of species with an affinity for moderate water quality and moderate electrolyte content. Dominant species included:

- *Staurosirella elliptica:* Found in clean waters with moderate to high electrolyte content (Taylor *et al.*, 2007b).
- *Pseudostaurosira brevistriata:* Found in clean alkaline fresh waters ranging from oligotrophic to eutrophic (Taylor *et al.*, 2007b).
- *Achnanthidium minutissima:* Found in well oxygenated, fresh waters.
- *Staurosirella pinnata:* Found in clean waters with moderate to high electrolyte content (Taylor *et al.*, 2007b)
- *Encyonopsis microcephala*: A cosmopolitan species found in calcareous waters with moderate electrolyte content (Taylor *et al.*, 2007b).
- *Fragilaria capucina:* Found in circum-neutral, oligo- to mesotrophic waters with moderate electrolyte content (Taylor *et al.*, 2007b).

Organic pollution levels were not problematic at the time of sampling and the majority of species present had an affinity for brackish conditions. No valve deformities were noted, suggesting that metal toxicity was below detection limit.

7.4. Habitat Integrity

The habitat integrities of the sites were assessed and presented in Figure 7.4-1. The riparian and instream habitats were classified as being **moderately modified (D)** for all the sites sampled. Instream habitats for sites BW01 and BW02 were found to be higher than at BW03. The reduced instream habitat at BW03 was mainly due to the presence of the weir downstream of the site resulting in low flow and no shallow fast moving habitats. The poor condition of the non-marginal zone has also influenced the instream integrity, with the main impacts being substrate exposure due to clearing and possible remediation of past mining activities (BW01 & BW02).

In general, the deterioration of the sites was largely due to bed modifications from algae, sedimentation, channel- and flow modifications observed at all sites, caused by agriculture, weirs and mining activities. These habitat modifications indirectly changed the biotope availability, velocity-depth flow structures, which influenced the biotic component of the ecosystem at the sites.

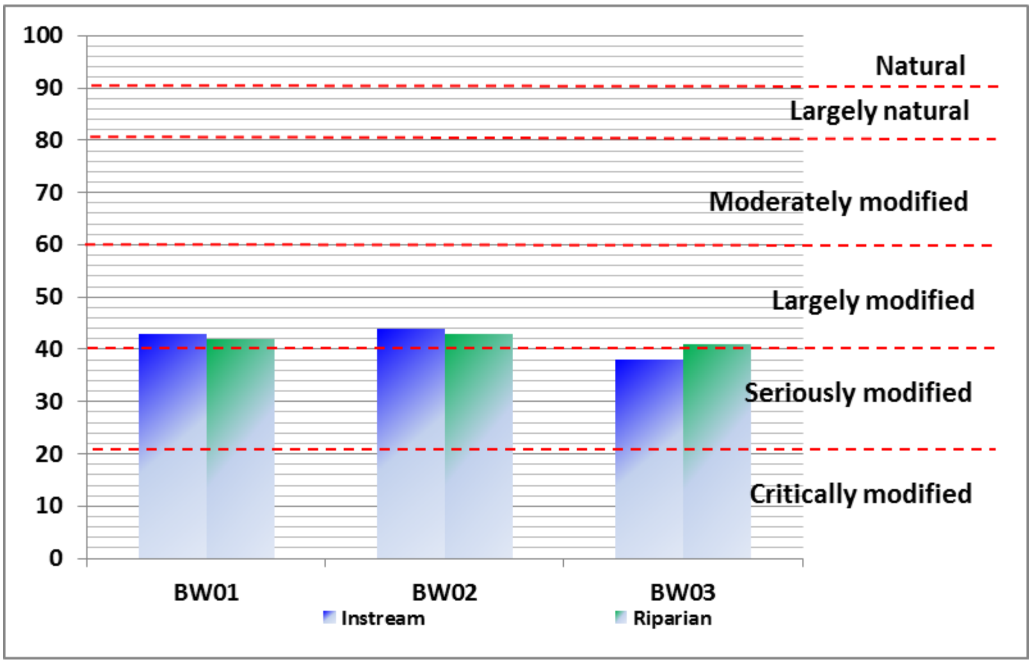

Figure 7.4-1. Impacts associated with the decrease in habitat integrity of the instream and riparian zone at the sampling site during the survey (as determined using HI of Kleynhans (1996)).

7.5. Macro Invertebrates

7.5.1. SASS5

The PES and impacts on the macro-invertebrate communities were assessed using SASS5 and ASPT scores according to the interpretation guidelines by Dallas (2007) and presented in Table 7.5.1.1. The family assemblage of this baseline assessment is represented in Appendix A. The macro-invertebrate integrity was calculated to be **moderately modified (C)** for sites BW01 and BW02 and **largely modified (D)** for site BW03.

Table 7.5.1.1 The SASS5 result from the aquatic sampling site during the survey.

		Biomonitoring		
	Ref[a]	**BW01**	**BW02**	**BW03**
SASS Score	200	74	72	38
ASPT	6.5	5.29	5.54	4.22
PES		**C**	**C**	**D**
No. of families	49	14	13	9
No. of airbreathers		3	2	5
% airbreathers		21	15	55
MIRAI Score	-	51	52	43
MIRAI EC	-	**D**	**D**	**D**

- Not available
a-Reference obtained from historical data, functional feeding groups and Ecoregion

The SASS5 and ASPT scores were used to interpret the impacts on the community assemblage during this survey. All the sampled sites had low SASS5 scores, BW1A (74), BW2A (72) and BW3A (38), in relation to the reference score (200). From the results site BW3A (38) had the lowest SASS5 score. Sites BW01 and BW02 were classified as

moderately modified (C) and site BW03 was **largely modified (D)** and these changes were mostly due to a reduction in family diversity due to the absence of good habitat.

Site BW01 (74) had the highest score and more families (14) were present than at the other 2 sites sampled. There was also a low percentage of airbreathers in the macro-invertebrate integrity of sites BW01 (21%) and BW02 (15%), with site BW03 having a high percentage of 55%. A reduction in family diversity combined with a low number of sensitive families was found at the sites. In addition, the habitats were influenced by the presence of algae and silt which reduced habitat availability at the sites. The two sites, BW01 and BW02 were the only sites having "stones in-current" habitat hence, the reason these sites indicated higher scores. Although less airbreather families were sampled at sites BW01 and BW02 the overall family assemblage consisted of high number of tolerant families. These sites were also impacted by algae and sedimentation on the rocks. This can be mainly due to the reduced flow caused by the mining activities and other anthropogenic activities and had a large influence on the MIRAI score at all three of these sites.

It must also be noted that the reference list of the macro-invertebrates consisted out of 49 families. From the reference list it can be indicated that the sites are impacted on because much less species (9 - 14) were sampled at the sites compared to reference conditions. This result suggests that the macro-invertebrate communities were impacted due to possible deteriorated water quality and habitat, as discussed above.

7.5.2. MIRAI

The MIRAI score and EC of the current study are summarised in Table 7.5.1.1. The reference list derived for the MIRAI index had a maximum SASS5 and ASPT score of 200 and 6.5 respectively. Therefore, the site was calculated to being **largely modified (D)** compared to reference conditions. These modifications were due to three main causes, namely:

- A much lower number of families in comparison with the reference assemblages.
- Reduction in the number of sensitive taxa, namely Leptophlebiidae, Tricorythidae and more than two species of Baetidae.
- Abundance of tolerant families.

A further indication that these macro-invertebrate community structures were impacted on, was through the assessment of the abundances of present families. Tolerant families, such as Chironomidae and Corbiculidae were observed in abundance at the sites. These families are algae scrapers, shredders and gatherers and were most likely present as a result of the excessive algae content and sedimentation in the Vaal River caused by the upstream mining activities, organic enrichment from agriculture and cattle farming as well as flow modifications by weirs and river crossings.

MIRAI measures the response of the macro-invertebrates to certain drivers, namely flow, habitat and water quality. The decrease in flow (caused by abstraction and impoundments) and increase of algae and sedimentation on the stones biotopes caused the absence of various families that prefer these habitats (

Table **7.5.2.1**).

It should be noted that even though the SASS5 results showed higher scores in the current report, the MIRAI indicates that these increases were as a result of the stones biotope as well as an increase in algae and aquatic plants (BW01 & BW02) and as a result of this the macro-invertebrates that preferred this habitat had increased. None of these macro-invertebrates were considered as being sensitive. Therefore, MIRAI is a better indication of the macro-invertebrate community structure because it compares the reference conditions with the current conditions of these rivers. This in turn indicated that they are severely impacted on by flow and WQ drivers.

Table 7.5.2.1 The dominant biotope diversities observed for each site by means of Dallas (2005)

	BW01	BW02	BW03
Invertebrate habitat			
Stones in current (SIC)	3	3	0
Stones out of current (SOOC)	2	2	2
Bedrock	1	1	1
Aquatic Vegetation	1	1	0
Marg Veg in Current	1	1	0
Marg Veg out of Current	2	2	2
Gravel, sand and mud (GSM)	3	2	2
0=absent, 1=rare, 2=sparse, 3=moderate, 4=abundant and 5=very abundant			

7.6. Ichthyofauna

7.6.1. Fish habitat assessment

The location of the study area was within the Lower Vaal River catchment causing the stream to have a naturally low range of suitable habitats (

Table **7.6.1.1**). The sites on the Vaal River had a diverse number of habitats, although it did not have any fast-deep habitats. Therefore, the sampling at this site was undertaken in order to describe the fish diversity.

Table 7.6.1.1 The dominant velocity-depth classes observed for each site by means of Dallas (2005)

	BW01	BW02	BW03
Fish habitat			
Slow-deep	1	2	2
Fast-deep	0	0	0
Slow-shallow	4	3	3

Fast-shallow	0	3	0
0=absent, 1=rare, 2=sparse, 3=moderate, 4=abundant and 5=very abundant			

7.6.2. Presence of fish species

Reference list

The reference list used in current study was compiled by the most recent data provided by Kleynhans *et al*. (2007). The reference list consisted of 11 expected indigenous and two alien fish species and presented in Table 7.6.2.1. The fish species that should occur in quaternary catchment C91E included *Barbus anoplus*, *Enteromius paludinosus (Barbus paludinosus), Clarias gariepinus, Labeo capensis, Labeo umbratus, Labeobarbus aeneus, Austroglanis sclateri, Enteromius trimaculatus (Barbus trimaculatus), Pseudocrenilabrus philander, Labeobarbus kimberleyensis, Tilapia sparrmanii* and the exotic species *Cyprinus carpio* and *Gambusia affinis.*

Table 7.6.2.1 Expected and sampled fish species for the river system associated with the Lower Vaal River.

FAMILY	SPECIES	COMMON NAME	CONSERVATION STATUS	SAMPLED
CYPRINIDAE	*Barbus anoplus*	Chubbyhead barb	LC	**No**
CYPRINIDAE	*Enteromius paludinosus (Barbus paludinosus)*	Straightfin barb	LC	**No**
CLARIIDAE	*Clarias gariepinus*	Sharptooth catfish	LC	**Yes**
CLARIIDAE	*Austroglanis sclateri*	Rock catfish	LC	**No**
CYPRINIDAE	*Enteromius trimaculatus (Barbus trimaculatus)*	Three-spot barb	LC	**No**
CYPRINIDAE	*Labeo capensis*	Orange River mudfish	LC	**Yes**
CYPRINIDAE	*Pseudocrenilabrus philander*	Southern mouthbrooder	LC	**Yes**
CYPRINIDAE	*Labeo umbratus*	Moggel	Introduced locally	**No**
CYPRINIDAE	*Labeobarbus aeneus*	Vaal Orange Smallmouth yellowfish	LC	**Yes**
CYPRINIDAE	*Labeobarbus kimberleyensis*	Vaal Orange Largemouth yellowfish	NT	**No**
CYPRINIDAE	*Tilapia sparrmanii*	Banded Tilapia	LC	**Yes**
Alien and Invasive Fish Species				
CYPRINIDAE	*Cyprinus carpio*	Carp	Alien	**No**
POECILIIDAE	*Gambusia affinis*	Mosquito fish	Alien	**Yes**
LC = Least concern; NT = Near threatened				

Species sampled

Six (6) of the 13 expected fish species were sampled in the current study and presented in

Table 7.6.2.2. Pictures of the fish species sampled are included in Appendix B. This included the indigenous species namely *Lb. aeneus, L. capensis, P. philander, C. gariepinus* and *T. sparrmanii.* The alien species *G. affinis* was also sampled during this survey. None of these species were classified as red data species and were all generally tolerant.

The habitat preferences of *P. philander*, *T. sparrmanii,* are predominantly slow pools with aquatic and marginal vegetation (Kleynhans, 2008; Skelton, 2001), which was abundant at the sites (

Table **7.6.1.1**). These species prefer shallow sheltered waters and does not colonize the open water. This together with their lack of sensitivity to flow and water quality changes further indicates why they were present at the sites.

C. gariepinus is widely tolerant of many different habitats, even the upper reaches of estuaries, but is considered to be a freshwater species. It favours floodplains, slow flowing rivers, lakes and dams (Skelton 2001). It can tolerate waters high in turbidity and low in dissolved oxygen, and is often the last or only fish species found in remnant pools of drying rivers (Safriel & Bruton 1984, Van der Waal 1998).

L. capensis prefers running waters of large rivers but also survives well in large impoundments. They gather in shallow rocky rapids where they breed during the summer season. *Lb. aeneus* favours good habitats with fast flowing water and deep pools but, are also found in large dams. These species are moderately intolerant to no flow and their cover preference includes a very high water column (Kleynhans, 2008; Skelton, 2001; Scott *et al.* 2006).

The alien invasive species *G. affinis* were intentionally introduced in many areas with large mosquito populations to decrease the population of mosquitoes by eating the mosquito larvae (Skelton, 2001). They are found most abundantly in shallow water where they are protected from larger fish. This species can survive relatively inhospitable environments, and are resilient to low oxygen concentrations, high salt concentrations and also temperatures variations (Skelton, 2001). They have been known for their aggressive behaviour towards other fish species.

Table 7.6.2.2 Reference and current fish frequency of occurrence

	Reference FO	BW01	BW02	BW03
# of indigenous species	11	**4**	**5**	**2**
Total abundances	3	**37**	**41**	**44**
# of exotic species	2	**0**	**1**	**1**
FRAI score %	NA	**50**	**52**	**41**
FRAI EC	NA	**D**	**D**	**D**
Barbus anoplus	3	-	-	-
Enteromius paludinosus	3	-	-	-
Clarias gariepinus	3	1	-	-
Austroglanis sclateri	3	-	-	-
Enteromius trimaculatus	3	-	-	-
Labeo capensis	3	-	2	-
Pseudocrenilabrus philander	3	2	2	-
Labeo umbratus	3	-	-	-
Labeobarbus aeneus	3	1	4	-
Labeobarbus kimberleyensis	3	-	-	-
Cyprinus carpio	NA	-	-	-
Tilapia sparrmanii	3	33	22	22
Gambusia affinis	NA	-	11	20

- Not sampled
NA = Not available
FO-frequency of occurrence scoring according to Kleynhans *et al*. (2008)

Pseudocrenilabrus philander
Southern mouthbrooder

Gambusia affinis
Mosquito fish

Figure 7.6.2 Images of two of the fish species sampled.

Species not sampled

The expected indigenous species that were not sampled included *L. umbratus, Lb. kimberleyensis, B. anoplus* and *Austroglanis sclateri* (

Table 7.6.2.2). *Lb. kimberleyensis*, also the only species that has a conservation status according to the IUCN and is considered to be near threatened (NT), favours good habitats with fast flowing water and deep pools but, are also found in large dams. These species are moderately intolerant to no flow and their cover preference includes a very high water column (Kleynhans, 2008; Skelton, 2001; Scott *et al.* 2006). Based on this, these species were not sampled in the study area because of the lack of these habitats and flow conditions at the sampling sites.

L. umbratus prefers standing or slow flowing water and thrives in shallow impoundments and farm dams (Skelton 2001; Scott *et al.* 2006). They are tolerant to modified water quality conditions (Kleynhans 2008) and because they were locally introduced, it is possible that they might not occur in the area of sampling.

Enteromius paludinosus are hardy and prefers quiet, well-vegetated waters in lakes, swamps or marginal areas of larger rivers and slow flowing streams (Skelton, 2001). *E. trimaculatus* are mostly found in shallow water near river outlets or close to swampy areas. They are hardy species and commonly occur in a wide variety of habitats, especially where there is vegetation (Skelton, 2001).

B. anoplus prefers predominantly slow pools with aquatic and marginal vegetation (Kleynhans, 2008; Skelton, 2001). They are tolerant to modified water quality conditions (Kleynhans 2008) and it is possible that the presence of the alien species *G. affinis* at the sites might be a contributing factor of their absence during sampling.

Austroglanis sclateri prefers rocky habitat in mainstream areas of major rivers. It is omnivorous and feeds on invertebrates especially from rock surfaces with larger specimens also feeding on small fish (Skelton 2001).

7.6.3. FRAI

The FRAI score and EC are summarized in

Table 7.6.2.2. The score was calculated to be **largely modified (D)**. The baseline study indicates that there is deterioration in the fish community assemblages in the area compared to expected reference list. This was because only six (6) of the 13 expected species were sampled.

Although, only six of the reference list species were sampled of the possible 13 at the sites, all of the eleven indigenous species expected under reference conditions are still expected to be present under the present conditions at these sites and in the river. This was mainly as a result of reduced habitat availability caused by channel and bed modification, inundation and also the migration barriers formed by weirs and dams present upstream and downstream of the sites. It is expected that species which are moderately intolerant to no flow conditions (*Lb. kimberleyensis* and *A. sclateri*) will still be present as they will survive and be sustained in the current habitat for extended periods, but that their spawning success and recruitment will be reduced.

Due to flow modifications and reduced flows and floods there is a loss of FD and FS habitats as well as substrate as cover, due to siltation and algae, reducing the occurrence of *A. sclateri*, *L. umbratus* and *Lb. kimberleyensis*. Large pools are present as a result of inundation and channel modification, and all the species will be able to utilise the pools as cover and refugia.

The presence of the alien species *G. affinis* (mosquito fish) at all the sites may also have an impact on the occurrence of indigenous species as this species is known to impact other species in competition for suitable breeding habitat.

8. Current Impacts on Aquatic Ecosystems

The current aquatic impacts are summarised below:

- The aquatic habitats were impacted due to general catchment activities including upstream alluvial diamond mining, agricultural activities and weirs that induced modifications to flow regime, in-stream channel, and water quality.
- The aquatic biota was also modified from natural assemblages. The macro-invertebrate assemblages were largely modified due to alterations in the habitat, water quality and abundance of tolerant families. The fish assemblages were also impacted, with some the of expected fish species absent within this study due to modified habitat at the sites.

9. Possible impacts from new mining activities

The possible future impacts from the proposed new development on the freshwater biota are given below:

- Increased turbidity and siltation of the river and aquatic habitats.

- Potential loss of aquatic habitats.
- Deterioration of water quality.

10. Conclusion

The aquatic ecosystem within the surrounding area of the proposed new diamond mining activity was assessed as being **largely modified (D)** in relation to the habitat integrity and macro-invertebrate assessment. Although the SASS5 results showed higher scores in the current report, the MIRAI indicates that these increases were mainly as a result of the higher abundance of tolerant species and the presence of stones habitat. The PES for the fish assessment also showed a **largely modified (D)** ecological state after the current assessment. The majority of the impacts on this system were associated with upstream mining, agriculture and instream habitat changes. These modifications in turn influenced the macro-invertebrate and fish community structures. The physical water quality results indicated that the water quality were good at the site, with current impacts on water quality mainly attributed to upstream anthropogenic activities. The main sources for the absence of the expected fish species and macro-invertebrates at all the sites assessed, were from the absence of suitable habitat due to accumulative effects of impoundments, upstream mining and general anthropogenic activities.

As the study area does not fall within a Freshwater Ecological Protected Area (FEPA) it is not governed by its stringent management guidelines. However, normal guidelines should still be adhered to, regarding any planned development as well as future management of the river. The impacts of the proposed new diamond mining activities in the system were found to be potential loss of aquatic habitat and increased turbidity and siltation in the river. The impacts will influence the water quality and the biotic integrity of the system and mitigation measures need to be implemented to limit any adverse effects.

The diatom results for sites BW01, BW02 and BW03 indicated that all sites were classified as moderate quality. Dominant species generally stayed the same at all the sights and comprised of species with affinities for moderate and brackish waters.

No valve deformities were noted at any of the sites, suggesting that metal toxicity was below detection limit during the time of sampling. As Seen in Table 7.3.1 there was a slight increase in the biological water quality from site BW01 toward site BW02 and BW03, which can be because of elevated flow that occurred in between sites. Organic pollution was also low at all sites.

The diatom community indicated that nutrient and salinity levels were moderate at the time of sampling. No major impacts were detected but the overall diatom communities and the sub-dominant species indicated that the diatoms are shifting towards saline conditions as most of the species present at these sites has affinities for high electrolyte content conditions.

Although no follow up assessments are currently planned, it is highly recommended that a follow-up survey be planned to further assess the aquatic ecosystems. It is recommended that the recommendations and mitigation measures from this report are adhered to and be continuously monitored.

11. Recommendations

- Implementation of a suitable management action plan during the installation and operation of the proposed diamond mining activities, based on analysis of bi-annual water quality and biological monitoring data collected at sites upstream and downstream of all activities;

- Prevention of exotic vegetation encroachment;
- Prevent further siltation within the river segment as well as downstream of activities;
- Unnecessary destruction of marginal and instream habitat should always be avoided during operations.

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Appendix

Appendix A Biomonitoring Data for aquatic assessment December 2018

TAXON	REF	BW01	BW02	BW03
PORIFERA (Sponge)	A	-	-	-
COELENTERATA (Cnidaria)		-	-	-
TURBELLARIA (Flatworms)	A	-	-	-
ANNELIDA Oligochaeta (Earthworms)	A	A	A	A
Hirudinea (Leeches)		1	-	-
CRUSTACEA Amphipoda (Scuds)		-	-	-
Potamonautidae* (Crabs)	A	A	-	-
Atyidae (Freshwater Shrimps)	A	B	B	B
Palaemonidae (Freshwater Prawns)		-	-	-
HYDRACARINA (Mites)	A	-	-	-
PLECOPTERA (Stoneflies) Notonemouridae		-	-	-
Perlidae		-	-	-
EPHEMEROPTERA (Mayflies) Baetidae 1sp		A	A	-
Baetidae 2spp		-	-	-
Baetidae >2spp	A	-	-	-
Caenidae (Squaregills/Cainfles)	A	A	-	-
Ephemeridae		-	-	-
Heptageniidae (Flatheaded mayflies)	A	-	A	-
Leptophlebiidae (Prongills)	A	A	A	-
Oligoneuridae (Brushlegged mayflies)		-	-	-
Polymitarcyidae (Pale Burrowers)		-	-	-
Prosopistomatidae (Water specs)		-	-	-
Teloganodidae SWC (Spiny Crawlers)		-	-	-
Tricorythidae (Stout Crawlers)	A	-	-	-
ODONATA (Dragonflies & Damselflies) Calopterygidae ST,T (Demoiselles)		-	-	-
Chlorocyphidae (Jewels)	A	A	-	-
Synlestidae (Chlorolestidae)(Sylphs)	A	-	-	-
Coenagrionidae (Sprites and blues)	A	-	-	A
Lestidae (Emerald Damselflies/Spreadwings)	A	-	-	-
Platycnemidae (Stream Damselflies)		-	-	-
Protoneuridae (Threadwings)		-	-	-
Aeshnidae (Hawkers & Emperors)	A	-	-	-
Corduliidae (Cruisers)		-	-	-
Gomphidae (Clubtails)	A	-	-	1
Libellulidae (Darters/Skimmers)	A	-	1	-
LEPIDOPTERA (Aquatic Caterpillars/Moths) Crambidae (Pyralidae)		-	-	-
HEMIPTERA (Bugs) Belostomatidae* (Giant water bugs)	A	-	-	-
Corixidae* (Water boatmen)	A	-	-	-
Gerridae* (Pond skaters/Water striders)	A	-	-	-
Hydrometridae* (Water measurers)	A	-	-	-
Naucoridae* (Creeping water bugs)	A	1	A	A
Nepidae* (Water scorpions)	A	A	-	A
Notonectidae* (Backswimmers)	A	-	-	-
Pleidae* (Pygmy backswimmers)	A	-	-	A
Veliidae/M...veliidae* (Ripple bugs)	A	-	-	-
MEGALOPTERA (Fishflies, Dobsonflies and Alderflies) Corydalidae (Fishflies & Dobsonflies)		-	-	-
Sialidae (Alderflies)		-	-	-
TRICHOPTERA (Caddisflies) Dipseudopsidae		-	-	-
Ecnomidae		-		-
Hydropsychidae 1 sp		1	-	-

TAXON	REF	BW01	BW02	BW03
Hydropsychidae 2 sp		-	-	-
Hydropsychidae > 2 sp	A	-	-	-
Philopotamidae	A	-	-	-
Polycentropodidae		-	-	-
Psychomyiidae/Xiphocentronidae		-	-	-
Cased caddis: Barbarochthonidae SWC		-	-	-
Calamoceratidae ST		-	--	-
Glossosomatidae SWC		-	-	-
Hydroptilidae	A	-	-	-
Hydrosalpingidae SWC		-	-	-
Lepidostomatidae		-	-	-
Leptoceridae	A	-	-	-
Petrothrincidae SWC		-	-	-
Pisuliidae		-	-	-
Sericostomatidae SWC		-	-	-
COLEOPTERA (Beetles) Dytiscidae/Noteridae* (Diving beetles)	A	-	-	-
Elmidae/Dryopidae* (Riffle beetles)	A	-	-	-
Gyrinidae* (Whirligig beetles)	A	-	-	-
Haliplidae* (Crawling water beetles)		-	-	-
Helodidae (Marsh beetles)		-	-	-
Hydraenidae* (Minute moss beetles)		-	-	-
Hydrophilidae* (Water scavenger beetles)	A	-	-	-
Limnichidae (Marsh-Loving Beetles)		-	-	-
Psephenidae (Water Pennies)		-	-	-
DIPTERA (Flies) Athericidae (Snipe flies)		-	-	-
Blepharoceridae (Mountain midges)		-	-	-
Ceratopogonidae (Biting midges)	A	-	A	-
Chironomidae (Midges)	A	-	A	A
Culicidae* (Mosquitoes)	A	-	-	-
Dixidae* (Dixid midge)		-	-	-
Empididae (Dance flies)		-	-	-
Ephydridae (Shore flies)		-	-	-
Muscidae (House flies, Stable flies)	A	-	-	-
Psychodidae (Moth flies)		-	-	-
Simuliidae (Blackflies)	A	-	-	-
Syrphidae* (Rat tailed maggots)		-	-	-
Tabanidae (Horse flies)	A	1	1	-
Tipulidae (Crane flies)	A	-	-	-
GASTROPODA (Snails) Ancylidae (Limpets)	A	1	A	-
Bulininae*		-	-	-
Hydrobiidae*		-	-	-
Lymnaeidae* (Pond snails)	A	-	-	-
Physidae* (Pouch snails)	A	-	-	A
Planorbinae* (Orb snails)	A	-	A	-
Thiaridae* (=Melanidae)	A	-	-	-
Viviparidae* ST		-	-	-
PELECYPODA (Bivalves) Corbiculidae (Clams)	A	A	A	-
Sphaeriidae (Pill clams)	A	-	-	-
Unionidae (Perly mussels)		-	-	-
SASS Score	200	74	72	38
No. of Taxa	49	14	13	9
ASPT	6.5	5.29	5.54	4.22
EC		**C**	**C**	**D**

Appendix B Fish species sampled for the aquatic assessment December 2018


Barbus paludinosus


Labeo capensis


Pseudocrenilabrus philander


Tilapia sparrmanii


Clarias gariepinus