Aquatic Health Assessment of the Upper Olifants River Catchment, Mpumalanga Province, South Africa.

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ABBREVIATIONS

ASPT	Average Score per Taxon
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CSIR	Council of Scientific and Industrial Research
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
FRAI	Fish Response Assessment Index
GI	Geomorphological Index
GSM	Gravel, Sand and Mud
HI	Hydrological Index
IBI	Index of Biotic Integrity
IHI	Index of Habitat Integrity
IUCMA	Inkomati-Usuthu Catchment Management Area
MAR	Mean Annual Rainfall
MIRAI	Macroinvertebrate Response Assessment Index
MTPA	Mpumalanga Tourism and Parks Agency
NWA	National Water Act
DO	Dissolved Oxygen
PES	Present Ecological Status
PGM	Platinum Group Metal
RC	Reference Condition
RDM	Resource Directed Measures
REMP	River Eco-status Monitoring Programme
RHP	River Health Programme
RQOs	Resource Quality Objectives

SASS	South African Scoring System
SDC	Source Directed Controls
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TWQG	Target Water Quality Guidelines
TWQR	Target Water Quality Ranges
UNDESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
VEGRAI	Vegetation Response Assessment Index
WCWDM	Water Conservation and Water Demand Management Strategy
WDCS	Waste Discharge Charge System
WHO	World Health Organization
WMA	Water Management Area
WQI	Water Quality Index
WWF	World Wildlife Fund
WWTW	Waste Water Treatment Works
WUA	Water User Associations

SUMMARY

Water quality deterioration in South Africa is a common problem. The Olifants Water Management Area (WMA) covers about 54 570 km^2 and has three distinct zones, which are the upper Olifants, middle Olifants and lower Olifants. The total mean annual runoff in the Olifants WMA is approximately 2400 million cubic meters per year. Land use activities within the upper Olifants River catchment include coal mining, agriculture, wastewater treatment works, power generation, chemical manufacture and metal smelters. Crop irrigation and intensive livestock farming (piggeries and cattle feedlots) also take place in various parts of the catchment. The aim of this study was to conduct an aquatic assessment using biological indictors and water quality parameters and determine the anthropogenic impacts within the vicinity of the study sites in the upper Olifants River catchment. The objectives were to 1) determine the Present Ecological State (PES) of the upper Olifants River catchment, 2) identify possible sources of pollution and 3) assess the impacts of human activities on *in-situ* water quality.

Biomonitoring was conducted at selected sampling locations in the Bronkhorstspruit and Elands rivers, which are tributaries of the upper Olifants River main stem. The methods that were used for the study included the South African Scoring System (SASS5) for macroinvertebrates, sampling *in-situ* water quality parameters and data analysis using Eco-Status Models. Results indicate changes in the drivers of the aquatic system (i.e. water quality and flow), with resultant negative responses of sensitive biota. Changes in macroinvertebrate community composition from sensitive to tolerant taxa indicate impaired conditions. Flow modification and water quality pollution were considered the main sources of impairment during field sampling. Monitoring site B3ELAND-DETWE recorded the highest number of taxa, with 26 taxa recorded during the dry season. The lowest number of taxa was recorded at monitoring site B2BRON-MOOIF, with 7 taxa recorded during the dry season. The SASS5 scores ranged from 22 at monitoring site B2BRON-MOOIF during the August 2019 survey period to 180 at B3ELAND-DETWE during the June 2019 survey.

According to the Macroinvertebrate Response Assessment Index (MIRAI), the overall PES of the Elands River falls under ecological class C/D. The overall PES of the Bronkhorstspruit River falls under ecological class D. Monitoring site B2BRON-MOOIF recorded Low unacceptable levels of dissolved oxygen (DO) throughout the sampling period. Electrical conductivity (EC) was above the recommended Target Water Quality Range (TWQR) limit at all the monitored water quality sites throughout the sampling period. Water quality problems are mainly attributed to mining and irrigation effluent entering the rivers through stormwater runoff. It is recommended that strict compliance monitoring and enforcement is implemented

on water users within the catchment. This will help to prevent point source pollution and non-point source pollution contributing to the degradation of water quality in the upper Olifants River catchment.

CHAPTER 1: INTRODUCTION

Water covers about 71% of the Earth's surface, mostly being in oceans and other large waterbodies. Approximately 1.6% of water is stored underground in aquifers and 0.001% is stored as vapour, clouds and precipitation in the atmosphere (U.S. Geological Survey, 2000). The Southern African subcontinent is fundamentally a semi-arid region. According to (DWA, 2009), the mean annual rainfall is 450mm (which is below the 860mm world average), with 21% of the land receiving less than 200mm of rain per year. Furthermore, runoff and rainfall are highly unpredictable on numerous spatial and temporal scales (DWA, 2009).The average annual rainfall exceeds evaporation only in a few remote areas of the country (Schlacher and Wooldridge, 1996).The result of high evaporation losses is that the percentage of rainfall that becomes river flow quickly declines in areas of low rainfall (Schlacher and Wooldridge, 1996).

According to Clarke (1991), for about 18 years, South Africa has been occasionally imperilled by intense and lengthy droughts that are often ended by heavy flooding. Therefore, even though the climate is generally categorized as semi-arid, the frequent occurrence of droughts together with high evaporation losses compels extremely large water storage schemes to tide the country over during severe dry spells (Schlacher and Wooldridge, 1996).

As water demand increases in consistence with human population pressure and economic development activities, deterioration of river ecosystems will continue unless they are managed sustainably. The rapid growth in world population, the mounting complexity of the basic needs for the maintenance of modern day life style and the industrialization process have not only resulted in immensely increased pressure and water resources depletion, but have also resulted in enormous quantities of waste to be generated (Fuggle and Rabie, 1992). Water resource deterioration is mainly the result of increased pollution, which is caused by anthropogenic activities such as afforestation, urbanization, industry, agriculture, power generation, mining and unintended water pollution incidents (Ashton et al., 2008).

According to May et al. (2006), Surface water quality of aquatic ecosystems in catchments may decrease significantly as a result of anthropogenic activities. Water resources in a given catchment play a significant role in integrating or transporting municipal waste water, industrial waste water and run off from agricultural fields. River inflows may also contribute to key pollutants in water resources within a catchment, which in turn induce severe ecological and sanitary problems (Kunwaret al., 2005). Environmental pollution complications began in the first half of the 19th century in South Africa, together with township developments and industrial development as well as related accretion of wastes in built-up areas (DWAF, 1998a). The pollution of rivers as a result of anthropogenic activities has steadily become a threat to water resources and their biodiversity.

Pollution is defined as “*the direct or indirect alteration of the physical, chemical or biological properties of a water resource so as to make it less fit for the intended use*” (National Water Act, Act 36 of 1998). According to Weale (1992), water is regarded as polluted when it has been impaired by pollutants and in turn does not support human uses, such as drinking water and other domestic purposes or undergoes changes in its ability to sustain its fundamental biotic communities such as macroinvertebrates and fish. The National Water Act, Act 36 of 1998 also states that water use activities that may contaminate or pollute water resources must be authorized by the Department of Water and Sanitation (DWS), in order to ensure suitable and accurate management practices on our water resources by implementing guidelines such as stormwater management plans, watercourse rehabilitation plans, wetland offset guidelines and water quality management guidelines. Even though water quality monitoring forms part of the water use license conditions issued by DWS, most rivers such as the Olifants River continue to deteriorate. These water use activities mostly pollute the rivers through effluent discharge and seepage.

River ecosystems include the full diversity of streams and rivers as well as the riparian areas and groundwater systems connected to them (Yu et al., 2019). They also provide important ecological services, have significant scientific value, and support a variety of animal and plant life. Similarly, river ecosystems support a range of human uses such as recreation and fisheries. River health assessment has become a crucial part of ecosystem health research, and the strains on the function and structure of ecosystems from anthropogenic activities have since been recognized around the world (Yu et al., 2019).

The degradation of aquatic ecosystems such as rivers, lakes and wetlands is common and consequently, there has been a decline of approximately 81% in freshwater species diversity since the 1970’s (WWF, 2016). The preservation and maintenance of healthy rivers has become a crucial objective of river management (Karr, 1991) and it has also been included as a target in Sustainable Development Goal six (6), which aim to ensure or guarantee availability, equal access and sustainable management of water as well as sanitation for all (UN DESA, 2018). Studies on river health have been continuing for a number of years, and various publications focus on components of river health such as definitions, indicators, monitoring and assessment as well as management (Yu et al., 2019).

Integrated ecological health assessment has been identified as one of the key solutions for efficient river management and is regularly used as a tool for identifying major factors in impaired ecosystems. Degradation of river ecosystem health is mainly associated with chemical pollution and physical habitat modification due to rapid industrialization and urbanization (Lee and An, 2010). River ecosystems are quickly disturbed by heavy sources of pollution such as municipal wastewater discharges, industrial effluents and intense agricultural activities (Yeom et al., 2007). These sources of pollution canals modify longitudinal patterns of nutrients (nitrogen and phosphorus) and physical habitat from headwaters to downstream near estuaries. These pollution sources may directly or indirectly influence ecological functions of trophic compositions and species tolerance in aquatic biota. Hence, indicator analyses of components in river ecosystems are necessary for assessing and diagnosing the river health.

The Index of Biotic Integrity (IBI) is a term that was first developed by (Karr, 1991). The IBI is also known as "biological monitoring". As defined by Plafkin et al (1989), biological monitoring *"is the use of biological indicators to assess changes in the environment, commonly resulting from anthropogenic sources*". Karr (1991) developed this term in order to assist water resource managers to assess and describe water conditions, thereby providing water resource managers with a technique of evaluating biological or biotic condition of water resources. Therefore, *"Biotic integrity is based on the premise that the status of living systems provides the most direct and effective measure of the integrity of water"* (Karr, 1997).

For decades anthropogenic influences or impacts on stream systems have been managed by restricting amounts of chemicals that enter them. Government institutes developed "water quality standards" to make sure that the chemical concentrations in rivers do not surpass the set limits (Karr and Chu, 1997). This has been successful in limiting chemical pollution sources, but the impacts that land alteration as well as non-point pollution have on water quality were not recognized (Karr and Chu, 1997).

Karr and Dudley (1981) highlighted that when aquatic ecosystems are disturbed by anthropogenic or human induced pollution, erosion and drought, organisms cannot adapt to the changed environment and as a result they migrate or die. Only those which are tolerant adapt to the disturbed conditions. After such disturbance, there are changes in species composition, numbers and diversity which leads in most of cases to changes in the ecosystem structure and ecosystem functions (Karr and Dudley, 1981). Biomonitoring programs are able to measure the biological integrity of those disturbed aquatic ecosystems and relate their conditions to the degree of human disturbance and watershed characteristics by using biological indicators (Karr and Dudley, 1981).

A river ecosystem's instream biological condition is determined by a number of factors, for example, hydrological and hydraulic regimes, geomorphological characteristics, chemical and physical water quality as well as the nature of the riparian vegetation (Roux, 1999). Aquatic communities assimilate and replicate the impacts of all these factors and other chemical and physical effects occurring over prolonged periods of time. Therefore, these communities are regarded as good indicators of the overall ecological integrity. According to Roux (1999), aquatic biomonitoring refers to gathering of information on these biological indicators for the purpose of making a particular type of environmental assessment.

According to Hohls (1996), there are certain advantages and disadvantages associated with biomonitoring.

Advantages:

- It is a standardised method used to compare water quality of different resources;
- Identify changes in water flow;
- Detects changes in water quality;
- It is inexpensive and quick;
- Biomonitoring is a practical means of assessing water resources; and
- Detects water quality changes that may possibly be missed by chemical sampling.

Disadvantages:

- Biomonitoring requires more training;
- It is usually open to subjective interpretation;
- Has no legal standing;
- Biomonitoring makes no provision of accurate figures of water quality; and
- Reflects change but cannot point out the cause.

Aquatic community components that are representative of the larger ecosystem and are practical to measure should be given attention when designing a biomonitoring programme (Roux, 1999). Depending on the type of aquatic ecosystem being assessed, the taxonomic groups may vary. For example, benthic macroinvertebrates and fish are often the taxonomic groups used when assessing flowing waters, algae and zooplankton are used in lakes and estuaries, while plants are used in wetlands (Roux, 1999). A Biomonitoring programme design should be customized for the particular type of water bodies assessed (e.g. lake, wetland, river, stream, or estuary) (Phillips and Rainbow, 1993).

Generally biomonitoring entails the use of indicators, for example macroinvertebrates, fish, diatoms and algae. Some plants which are found in water are also good indicators for pollutants e.g. nutrient enrichment (Phillips and Rainbow, 1993). A biomonitoring program can be quantitative, qualitative or semi-quantitative and it is also a respected evaluation instrument that is receiving augmented use in various water quality monitoring programs (Phillips and Rainbow, 1993).

The Department of Water and Sanitation has put measures in place in order to protect water resources and sustainable use (DWA, 2011a). These include Source Directed Controls (SDC), Resource Directed Measures (RDM), and River Health Programmes. The South African Scoring System (SASS) was developed by Chutter (1998). This system is currently in version 5 (SASS5) (Dickens and Graham, 2002) and it has become the standard accepted method for rapid evaluation of water quality using macroinvertebrates in South Africa.

In this method, aquatic macroinvertebrate taxa are assigned a score between 1 (tolerant) and 15 (sensitive), informed by their known sensitivities to water quality or other drivers. SASS has proven to be a practical and efficient way of evaluating water quality deterioration and general river health (Chutter, 1998). In order to conduct a complete assessment of the aquatic ecosystem, it is important to investigate and evaluate water quality, aquatic biota, particulate matter and the physical characteristics of the water body (UNEP-WHO, 1996).

Macroinvertebrates are bottom dwelling organisms which are large enough to see with the naked eye. Diverse types of macroinvertebrates are able to endure different stream conditions and pollution levels, and this makes them perfect indicator species (O'Keeffe and Dickens, 2000). Different macroinvertebrates found in a stream are able to make predictions regarding water quality. Various types of aquatic macroinvertebrates include Heptageniidaesp (mayflies), Hydropsychesp (caddisflies), Coleoptera (beetles), Hemiptera (bugs), Perlodidaesp (stoneflies) and Mollusca (snails).

According to O'Keeffe and Dickens (2000), these assemblages and communities mirror the overall stream condition as they assimilate various ecological preferences such as water quality, flow and habitat. Consequently, the responding community provides a snapshot of the presence of contaminants or pollution in a river system, the extent of the exposure to pollution, which in turn provide an indication of the health and integrity of the river system. Therefore, this means that aquatic macroinvertebrates are important in assessing river ecosystems because they are able to show a thorough ecological condition of a river (O'Keeffe and Dickens, 2000).

According to Plafkin et al. (1989), there are proven advantages and disadvantages of using macroinvertebrates. Macroinvertebrates are abundant and can be found in most aquatic habitats. They consist of a large number of species, and different strains produce different macroinvertebrate communities. Macroinvertebrates communities can also be found in small order streams which does not support fish communities. Macroinvertebrates have constrained mobility and are therefore ideal indicators of local environmental conditions. According to Barbour et al. (1999), macroinvertebrates accumulate toxic substances (bioaccumulate), therefore, chemical analysis permits detection in them where levels are untraceable in the water resource.

According to Barbour et al. (1999), "*aquatic macro-invertebrate assemblages are made up of a broad range of species from different trophic levels and tolerances, thus providing information for interpreting cumulative effects, furthermore, as there are a large number of species, different stresses produce different macro-invertebrate communities*". Using a rapid assessment protocol in the sampling of aquatic macroinvertebrates is comparatively easy and only needs a few people and minimal equipment (Barbour et al., 1999). Sampling has limited detrimental effects on the local biota or habitat. The identification process to family level is easy and many "intolerant" taxa can easily be identified to lower taxonomic levels (Plafkin et al., 1989).

Kleynhans and Louw (2007), described Ecological Classification as the determination and categorization of the Present Ecological State (PES), health or integrity of different biophysical characteristics of rivers relative to the undisturbed natural or slightly natural reference condition. Furthermore, the core function of the Eco-Classification process is to develop an understanding of the causes and sources of the variation of the PES of biophysical characteristics from the reference condition. Therefore, Eco-Classification provides the information that is required to develop the necessary future ecological objectives of a river.

The Ecological Classification process is also an important element of the Ecological Reserve determination method and of every Environmental Flow Requirement method (Kleynhans and Louw, 2007). In order to recommended flows and water quality conditions, information on the predicted resulting state, which is the Ecological Category must be available. The River Eco-status Monitoring Programme (REMP), through biological monitoring, also uses the Eco-Classification process to assess biological data responses in relation to the severity of biophysical changes.

However, REMP main focus is biological responses as indicators of ecosystem health, without a broad assessment of the cause and effect relationship amongst the drivers and the biological responses. In essence the Eco-status symbolizes an ecologically integrated state, which demonstrate the drivers (geomorphology, hydrology, physico-chemical) and responses (aquatic invertebrates, fish and riparian vegetation) (Kleynhans and Louw, 2007).

1.1 BACKROUND OF THE STUDY

The Olifants River is regarded as one of the major river systems in South Africa. It is also a highly utilised and regulated catchment. The Olifants River originates from its source on the Highveld region and flows into Mozambique, where it joins the Limpopo River before discharging into the Indian Ocean. The Olifants River flows through three distinct regions. The upper Olifants River includes the headwaters and main stem, Bronkhorstspruit, Elands, Wilge, Moses and Kliene Olifants rivers. The middle Olifants River includes the Steelpoort River. The lower Olifants River occurs right after the river passes through the Drakensberg Escarpment and it includes the Blyde River (DWA, 2011b).

The Olifants River is recognized as one of the hardest working rivers in the country (van Vuuren, 2009). Water demand for mining, industry, power generation, domestic use and agriculture within the Olifants River Catchment have gradually increased beyond the rate of population growth over the years and have been accompanied by equally significant increases in the quantity of effluents discharged into the river system and its tributaries (Ashton, 2007).

The water resources within the Olifants River system are critically stressed in respect of both water quantity and quality (DWS, 2018). This is due to an accelerated rate of development and the scarcity of water resources. Uneven rainfall patterns lead to periodic droughts that are often followed by unexpected floods, while the eastern portion of the Olifants River catchment in Mozambique frequently experiences effects of tropical cyclones (Christie and Hanlon, 2001).

Extreme fluctuations in river flow, together with increasing water pollution have resulted in a dramatic decline in water quality in recent years, which has led to increased vulnerability of all the aquatic ecosystems in the catchment and also the vulnerability of the people from communities who rely on the water resources of this river system for their livelihoods (Dabrowski and de Klerk, 2013).

Formal economic activity in the Olifants River system is highly diverse and is characterised by commercial and subsistence agriculture (irrigated and rain fed), various mining activities, manufacturing, tourism and commerce (DWS, 2018). The ecological status of the Elands River is unacceptable, and this is mainly attributed to commercial agricultural activities. Consequently, because the area around the Elands River has been extensively developed by farmers, much of the river has an ill-defined channel with disconnected tributaries and often flows during, or after rainfall (De Villiers and Mkwelo, 2009).The Bronkhorstspruit River, upstream of the Premier Mine Dam is heavily infested with the invasive alien species water hyacinth (*Eichhornia crassipes*). It is also subjected to high inputs of partially treated sewage from nearby waste water treatment plants (De Villiers and Mkwelo, 2009).

Large amounts of coal deposits are found in the Middelburg areas and eMalahleni (upper Olifants) and the Steelpoort River catchment consist of large platinum group metal (PGM) deposits, while copper is found in the Phalaborwa area (DWS, 2018). Several large thermal power stations which are sources of energy for most parts of the country can also be found within the upper Olifants River catchment. The Loskop Dam area, the lower catchment near the confluence of the Blyde and Olifants rivers, the Steelpoort Valley and the upper Selati catchment as well as the upper catchments of the Groot Letaba River are all surrounded by extensive agricultural practices (DWS, 2018).

There is also a large informal economy that also exists in the middle Olifants, middle Letaba and Shingwedzi river catchments, with a large number of resource-deprived farmers dependent upon ecosystem services (DWS, 2018). The Olifants WMA has several essential tourist destinations, including the Kruger National Park and the Blyde River Canyon. Land use in the Olifants River system is diverse and consists of irrigated and dryland cultivation, improved and unimproved grazing, mining, industry, forestry and urban and rural settlements (DWS, 2018). All these human activities contribute to water quality deterioration within the Olifants River catchment.

Ecosystem health can be regarded as a value judgement of the overall condition of an ecosystem, based on the economic development, social well-being as well as the ecological integrity within that particular system (Roux, 1997). Management decisions depend on the availability of suitable and adequate data ecosystem components in order to find balance that will sustain ecosystem health. The data on ecological integrity is gathered by monitoring key ecological indicators. The ecological indicators can be divided into biological indicators (e.g. fish or macroinvertebrate community characteristics) as well as non-biological indicators (e.g. habitat). All these indicators can be utilized in measuring and calculating the ecological changes within an ecosystem (Roux et al., 1999).

Ecological Classification is valuable in determining and categorizing the PES of biophysical components of rivers when compared to the natural reference condition (RC). The main purpose of Eco-Classification is to gain understanding on the causes and origins of the deviation of the PES from the RC. This will provide reliable data needed to develop desired and attainable realistic future ecological objectives within the Olifants River catchment (Roux, 1999).

Eco-Classification is done through the River Health Programme (RHP), now known as the River Eco-status Monitoring Programme (REMP), which is a national South African monitoring initiative that was developed to serve as a source of information regarding the overall ecological status of river ecosystems (Roux, 1999).The RHP developed biomonitoring as an assessment tool in order to assess the ecological status of riverine ecosystems. Biomonitoring include biological assessment which interpret the biophysical components in terms of biological responses i.e. the use of bio-indicators (macroinvertebrates, fish, diatoms and algae) as indicators of overall ecological condition (Roux, 1999).

For the RHP (currently known as REMP), sampling of macroinvertebrates in rivers is conducted using the SASS 5 (Dickens and Graham, 2002). Biomonitoring indices employed in South Africa include the Riparian Vegetation Response Assessment Index (VEGRAI), Macroinvertebrates Response Assessment Index (MIRAI), and the Fish Response Assessment Index (FRAI) (Thirion, 2008). All these indices are combined to determine the overall Eco-status of a river system.

1.2 MOTIVATION OF STUDY

The current state of most South African water resources is dire and in order to gain a better understanding of the impacts on water resources it is necessary to conduct studies of this nature. This study focuses on the upper Olifants sub-catchment, which drains to the Mpumalanga and Gauteng Highveld and also connects to the Loskop Dam. The Bronkhorstspruit and Elands rivers were assessed. Both these rivers flow/drain into the Olifants River situated within the Olifants WMA. The Olifants WMA is about 54 570 km^2 and it covers the Gauteng, Limpopo and Mpumalanga (DWA, 2010). The Olifants WMA also includes eight District Municipalities and 25 Local Municipalities (DWA, 2010).

There are several water use and terrestrial activities of strategic importance to South Africa that are taking place within the upper Olifants River system, i.e. agriculture, power generation and mining (Dabrowski and de Klerk, 2013). These activities severely depend on a range of goods and services that they gain from the aquatic ecosystems in the area (Dabrowski and de Klerk, 2013). However, the Olifants River has been labelled as one of the most polluted rivers in Southern Africa. This is mainly because of the number of human induced stressors that exist within the catchment (Grobler et al., 1994).

These stressors include coal-fired power generation (Dabrowski et al., 2008), industrial activities (e.g., chemical manufacturers, steel and chrome smelters), intensive coal mining activities (Hobbs et al., 2008) as well as agriculture, together with an overall deterioration in the operation and management of wastewater treatment infrastructures, specifically sewage treatment (DWA, 2011c). According to Hobbs et al. (2008), the contaminants or pollutants generated by these activities include general acidification of the system, a range of potential pollutants contained in industrial effluent; excessive inputs of nutrients such as phosphorus and nitrogen from sewage effluent and agricultural effluent (Oberholster et al., 2009).

The presence of pollutants generated by the above mentioned activities leads to an increase in concentrations of most key water quality parameters, which may result in detrimental impacts on human health and aquatic ecosystems. Other investigations and field evaluations also reveal that these threshold concentrations are gradually becoming under threat (Dabrowski and de Klerk, 2013). The presence of pollutants has recently been observed in a number of critical ecological and human health concerns further downstream of the upper Olifants catchment, more particularly in Loskop Dam (Dabrowski and de Klerk, 2013). Therefore, there is an urgency to make sure that the water resources within the upper Olifants River system are able to retain their level of uses and also be maintained at their preferred or desired state.

This study therefore provide useful ecological information that can assist in the management of our water resources. The reason for using biological monitoring is that the integrity of biota residing in river ecosystems provides a comprehensive, precise and integrated measure of the health or integrity of the river, with a concept of remediation and imminent or future catchment management. It is also crucial to link particular water quality impacts to land use activities that are occurring within the upper Olifants River catchment and to highlight water quality impacts and linked sources at a catchment level (Dabrowski and de Klerk, 2013).

1.3 HYPOTHESIS, AIM AND OBJECTIVES

1.3.1 HYPOTHESIS

There has been an outpouring of water quality problems in South Africa recently. These problems can be ascribed to anthropogenic activities such as mining, industrial, agricultural and urban activities (Dabrowski and de Klerk, 2013). There is a need to better understand the risk various pollution sources have on water resources. It is therefore of the utmost importance to gather as much data and information on these impacts in order to better understand the nature of the impacts on the water resources. Managing water pollution is very complex because water pollution is often the result of surrounding anthropogenic activities (Dabrowski and de Klerk, 2013). Irrigation of a diversity of crops takes place in various parts of the upper Olifants River catchment. Intensive farming in the form of piggeries and cattle feedlots is also scattered throughout the catchment (Dabrowski and de Klerk, 2013).

The hypothesis of this study is therefore that: Anthropogenic activities in the Bronkhorstspruit and Elands rivers, the main tributaries of the upper Olifants River catchment, are resulting in the deterioration of water quality, altering the ecological integrity of the Olifants River catchment.

1.3.2 AIM

The aim of this study is to provide useful ecological information through an aquatic assessment and to determine the impacts of human activities within the vicinity of the study site by assessing the current state of the upper Olifants River catchment using biological indictors and water quality parameters.

1.3.3 OBJECTIVES

The aims of this study will be met by meeting the following objectives:

- Determine the Present PES of the upper Olifants River catchment by monitoring the diversity and abundance of macroinvertebrates using the SASS5 and the MIRAI methodology.
- Identify possible sources of pollution using the Index of Habitat Integrity (IHI)
- To assess the impacts of human activities on the *in situ* water quality parameters of the upper Olifants River catchment by monitoring *in-situ* water quality parameters using portable water quality meters.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Rivers have for some time been misused for the discarding of waste. Environmental pollution challenges begun in the first half of the 19th century in South Africa (Oberholster and Ashton, 2008). River pollution by anthropogenic activities has now become a major threat to our water resources and their biodiversity. Water quality deterioration can badly affect human health and also have dire economic consequences for various sectors such as industrial sectors and agricultural sectors (Oberholster and Ashton, 2008). Polluted or contaminated water is known to contain bacteria and viruses, intestinal parasites, as well as other harmful microorganisms, which are known to induce waterborne diseases such as typhoid, dysentery and diarrhoea. Although streams and rivers have the ability to self-purify, the capability is modified as a result of anthropogenic activities within the river catchment, and eventually leading to the devastation of this vital ecosystem. Surface water is more prone to pollution exposure since they are easily accessed for the disposal of wastewaters (Samarghandi et al., 2007).

The introduction of industries, afforestation, urbanization, agriculture, mining and power generation has been shown in various studies to cause variations or changes in water resources. The shift in water quality caused by waste disposal, effluent discharge and seepage from these anthropogenic activities changes the ecological procedures that naturally purify the water naturally (Fuggle and Rabie, 1992). It is also a good indicator of the socio-economic situation and environmental perception as well as the attitude or mindset of its users. All activities that take place within the catchment area are reflected in the quality of the water that flows through that particular catchment, mainly because the results of human induced activities eventually end up in rivers, through runoff and effluent discharge (Fuggle and Rabie, 1992).

When human population pressure and economic development activities increases the demand of water also increase. Consequently, river ecosystems start to deteriorate unless they are managed in a sustainable manner. The rapid increase in world population, the mounting complexity of needs and activities to maintain everyday lifestyle as well as the industrialization process resulted in the deterioration of vital natural resources. (Fuggle and Rabie, 1992). According to Parsons and Jolly (1994), unwanted production of human activities by-products or waste is inevitable in modern society. As the level of civilization become more advanced, more wastes (both in liquid and solid form) are produced. (Fuggle and Rabie, 1992). Therefore, the use and safeguarding of water resources in a sustainable manner is necessary for the future generation of South Africa. Safeguarding environmental needs requires instruments or tools that can be used to assess environmental conditions and setting ecological goals and objectives, in order to ensure suitable and sustainable management of all water resources (Roux et al., 1999).

2.2. River Health Programme (RHP)/ River Ecostatus Monitoring Program (REMP)

The RHP, which is now known as the REMP, is a South African national monitoring programme that focuses on assessing and determining the ecological state of river ecosystems. The program was designed and initially implemented in the Mpumalanga Province, specifically in the Elands River in 1996 and also in early 1997 (Roux et al., 1999).

RHP was formed with the overall goal of increasing the ecological data information on aquatic resources, in order to cater for the support and provision of the rational management of these systems (Roux, 1997). The official design was introduced in 1994 by the DWS, then known as the DWAF. The programme's main purpose was to serve as a source of information regarding the overall status of river ecosystems throughout South Africa.

The REMP utilize instream biological response monitoring to characterize the response of the aquatic environment to various modifications and disturbances. The FRAI and the MIRAI are the indices that were developed for instream assessment (Karr and Chu, 1997). Monitoring as used in REMP apply Eco-Classification procedures to assess the degree of transformation from a reference condition or perceived natural state. The advancement of an Eco-Classification procedure which uses all the indices has aided South Africa to determine the present ecological state of most of the rivers throughout the country, including the Olifants River and all its sub-catchments.

According to Karr (1991), there has been development and an increase in the use of biological indices with the intent of conveying and interpreting exactly how similar groups or assemblages at sites are in relation to its undisturbed state over the previous decades. These indices are usually cumulative i.e., the sum of several computed variables identified as metrics, which are obtained from sampling the assemblage. In this context, a metric is defined as an ecological characteristic of the assemblage approximate from a collection of organisms and their associated responsive action or disturbances (Barbour et al., 1995).

2.3. Biomonitoring

Rivers monitoring programmes have for some time been established for physical and chemical attributes of water and were done regularly throughout South Africa. The use of biological monitoring has over the years developed to be a point of focus for governments and organizations that are interested in the determination of biological characteristics and current status of rivers in South Africa (Roux, 1994). In Mpumalanga Province, the Olifants River main stem and most of its tributaries undergoes quarterly monitoring undertaken by the DWS whereas the Mpumalanga Tourism and Parks Agency (MTPA) monitor the river twice per year, using both macroinvertebrates and fish as their biological indicators (Roux et al., 1999).

2.3.1. Macroinvertebrates

Aquatic macroinvertebrates are more commonly used compared to any other biological assemblage to evaluate the biological integrity of riverine ecosystems with a rather reasonably good success all over the world (O'Keeffe and Dickens, 2000). Macroinvertebrates have been extensively used in lotic rivers to evaluate water quality and complement physico-chemical surveys mainly because they show a wide variation of response to pollutants (Shutes, 1985). Macroinvertebrates are also large enough to be seen with the naked eye (Plafkin et al., 1989). They dwell in all forms of running waters, from slow moving muddy rivers to fast flowing mountainous streams. Types of macroinvertebrates may include insects in their nymph or larval form, clams, crayfish, worms, and snails. Most of them live partial or majority of their life cycle affixed to submerged logs, rocks, and vegetation or in the sediments (Plafkin et al., 1989).

Indices that are based on macroinvertebrate assemblages have been proven to be valuable measures of river health and are broadly applied today in South Africa (Chutter, 1998). The South African Scoring System developed by Chutter (1998), is the most common index of biotic integrity presently used. The SASS index is centered on the presence of families of aquatic macroinvertebrates and their sensitivity to water quality changes. The SASS index is presently in its fifth version of development i.e. SASS5. The computed results are expressed quantitatively as total score (SASS5 score) and an average score per taxa (ASPT value). The ASPT provide an indication of the average sensitivity of the taxa found within the system (Dickens and Graham, 2002).

2.3.2. Water Quality

Water quality problems are usually identified or recognized through sampling and analysis of parameters such as total dissolved solids (TDS), biochemical oxygen demand (BOD), dissolved oxygen (DO), nitrate, pesticides, heavy metals, pH, phosphorus, total suspended solids (TSS) and turbidity. Kleynhans and Hill (1999) determined that urbanization, industrialization, and agricultural practices have immediate or direct impacts on the deterioration of water quality. According to (DWA, 1986), physico-chemical monitoring was previously the main focus of water quality monitoring in South Africa. The control and management of surface water quality was regulated through the control of effluent discharges into water resources. Traditional physico-chemical monitoring has been inadequate as it did not take into consideration other structural impacts that may have led to loss of habitat area, flow alterations, obstructions to passage through riparian zones and stream degradation (Harris, 1995). The use of other indicators is widely accepted, and complementary to the physico-chemical water quality monitoring, can be beneficial in the assessment and management of aquatic ecosystems (Salanki et al., 2003). According to (UNEP, 2016), water quality monitoring enables the assessment of the long term changes of waterbodies, thereby providing a snapshot of the current water quality status, while the use of bioindicators provides a time integrated approach to aquatic ecosystem monitoring (Gerhardt, 2001). As a result, biomonitoring has become a principal tool in analysing the state of aquatic ecosystems.

2.4. Study Area

2.4.1 Description of the Study Area

The Olifants WMA is about 54 570 km^2 and drains Gauteng, Limpopo and Mpumalanga provinces (DWA, 2010). The WMA also includes eight district municipalities and 25 local municipalities. The Olifants River catchment includes the Steenkoolspruit, the Klein Olifants River, the Wilge River, the Moses River, the Elands River, the Steelpoort River, the Blyde River, the Ga-Selati River, the Klaserie River and the Great Letaba River (DWA, 2011d).The upper Olifants catchment covers an area of 11 461 km^2 falling, mainly within the Gauteng and Mpumalanga Provinces (Figure 1). The area includes the towns of Bronkhorstspruit, Delmas, Douglas, Kriel, Kinross, Ogies, Evander, Secunda, Bethal, eMalahleni and Steve Tshwete. The upper Olifants catchment is the most urbanised of the four sub-catchments, with the majority of the urban population located in eMalahleni and Steve Tshwete local municipalities. The upper Olifants River drains the Mpumalanga and Gauteng Highveld and connects to the Loskop Dam (DWA, 2011d).

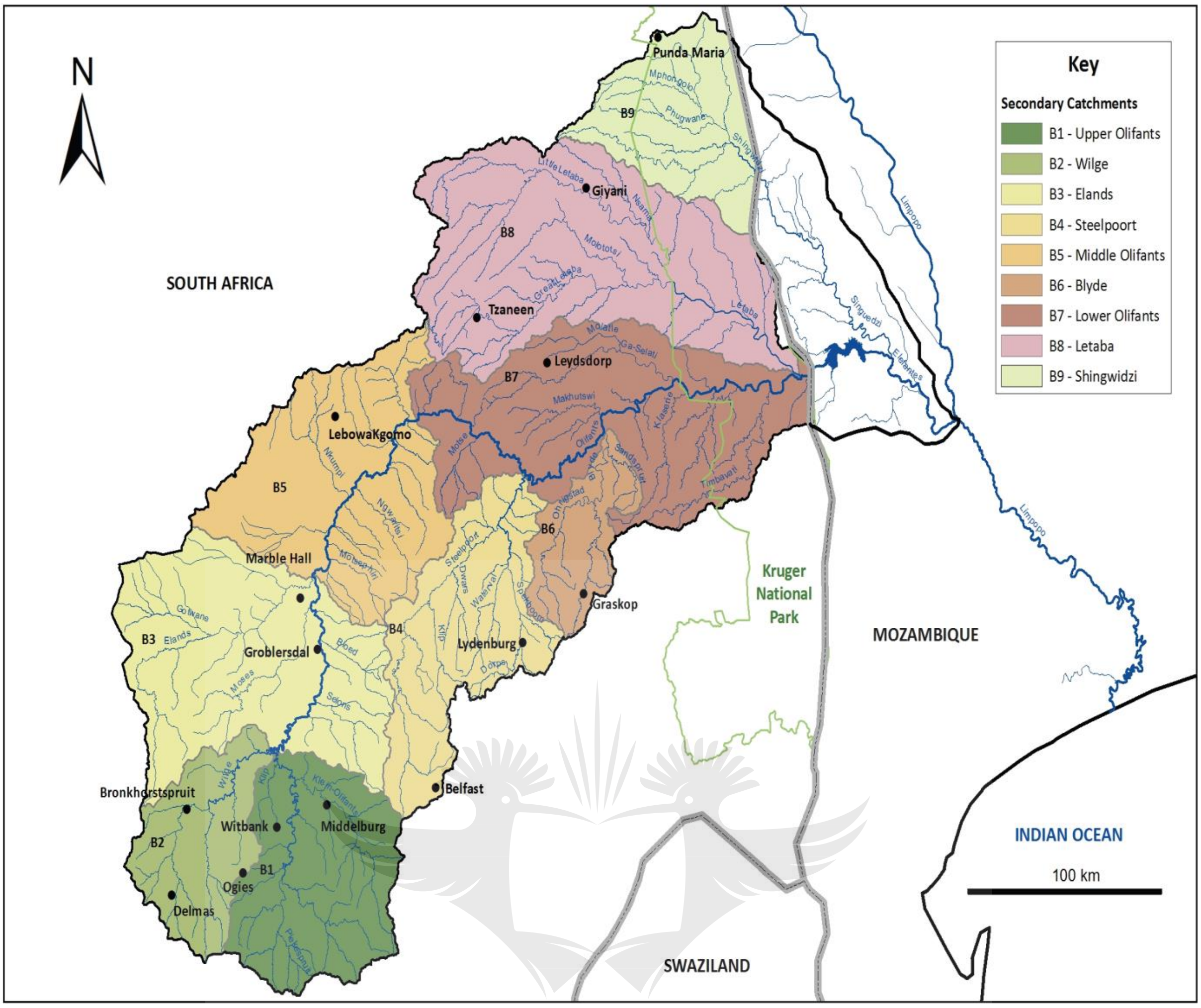

Figure 1: The Olifants Water Management Area (DWA, 2011d)

The Upper Olifants catchment comprises three sub-catchments (Table 1) and includes the upper Olifants River, Klein Olifants River and Wilge River, as well as smaller tributaries such as the Bronkhorstspruit. Dams in the catchment include Witbank Dam, Bronkhorstspruit Dam, Middelburg Dam and Trichardsfontein Dam, as well as smaller town dams such as Premier Mine Dam in Bronkhorstspruit (DWS, 2018). River flow in the area is highly seasonal and depends mostly on groundwater base flows, especially during the drier, winter months of the year (DWS, 2018).The mean annual rainfall (MAR) of the catchment is 318.2 Mm^3/year and 174.84 Mm3/year for the B11 + B12 and B20 quaternary catchments respectively. Relatively large volumes of water (approximately 172 Mm^3/year) are transferred into the upper Olifants River catchment from the Komati, Vaal and Usutu catchments to the south and east as part of the transfer scheme (DWS, 2018). Most of this water is used consumptively as cooling water in the coal-fired power plants that are situated in the catchment (DWS, 2018).

Table 1: The Upper Olifants sub-catchment areas (DWS, 2018)

Sub-Catchment	Sub-catchment area with main river	Quaternary catchments	Gross area (km^2)
Upper Olifants	Olifants River	B11A - L;	4 714 km^2
	Klein Olifants	B12 A – E;	2 391 km^2
	Wilge/ Bronkhorstspruit River	B20 A - J	4 356 km^2

2.4.2 Climate

The climate is very cool in the southern Highveld region of the WMA and sub-tropical in the east parts of the escarpment, with temperature reaching the minimum of 1˚C during winter.The catchment is located in the Highveld region, with moderate maximum temperatures and cold winter nights, with severe frost occurring regularly (Ashton and Dabrowski, 2011). The peak rainfall months are January and February and rainfall occurs generally as thunderstorms. Average annual rainfall varies between 550 mm - 750 mm/a, with evaporation well in excess of the rainfall (DWS, 2018). The rivers always impact the dam levels under normal rainfall season because of the inflow into the dams. Climate change has been acknowledged as an important concern in the basin, with the potential to impact both floods and droughts (DWS, 2017a).

2.4.3 Topography

The topography of the upper Olifants River catchment varies from approximately 2300m above mean sea level in the Drakensberg, to less than 300m above sea level in the Lowveld of the Kruger National Park (Ashton and Dabrowski, 2011).The Olifants River and its major tributaries have incised deep gorges through the hills and mountain ranges which form spectacular landscape units. The Olifants River catchment consist of five ecoregions namely: Great Escarp Mountains, Highveld, Central Highlands, Bushveld Basin, and the Lowveld. Most of the catchment consists of relatively undulating terrain separated by ranges of steep-sided hills and mountains (Ashton and Dabrowski, 2011).

2.4.4 Vegetation

The Elands River has invasive alien riparian vegetation which includes Eucalypts (*Eucalyptus sp*) and also Sesbania (*Sesbania punicea*) and Seringa (*Media azedarach*). The Bronkhorstspruit and Wilge River has vegetation which includes amongst others alien species called wattles (*Acacia elata*) that are found in the riparian zone (River Health

Programme, 2006). These alien species compete with indigenous vegetation for water which reduces the availability of water for the indigenous plant species.

2.4.5 Geology

The Olifants River catchment is situated over the eastern portion of the Kalahari Craton and forms the largest and one of the most economically important sub-basins of the Limpopo basin. The Archaean cratonic rocks consist mostly of crystalline granitic and gneissic rocks, which are intruded by a variety of greenstone belts, dolerite dykes and sills as well as silicified sedimentary formations (Ashton and Dabrowski, 2011).

Karoo System rocks extend beyond large areas of the south western (upper) portion of the catchment. These are also associated with younger sedimentary rocks and crystalline rocks which consist mainly of carbon-rich mudstones, sandstones, shales and conglomerates. Recent sedimentary deposits line part of the river valleys and provide essential farming areas (Johnson et al., 2006). A simplified geological map of the western portion of the catchment illustrates the major lithological units that are present in the catchment (Figure 2).

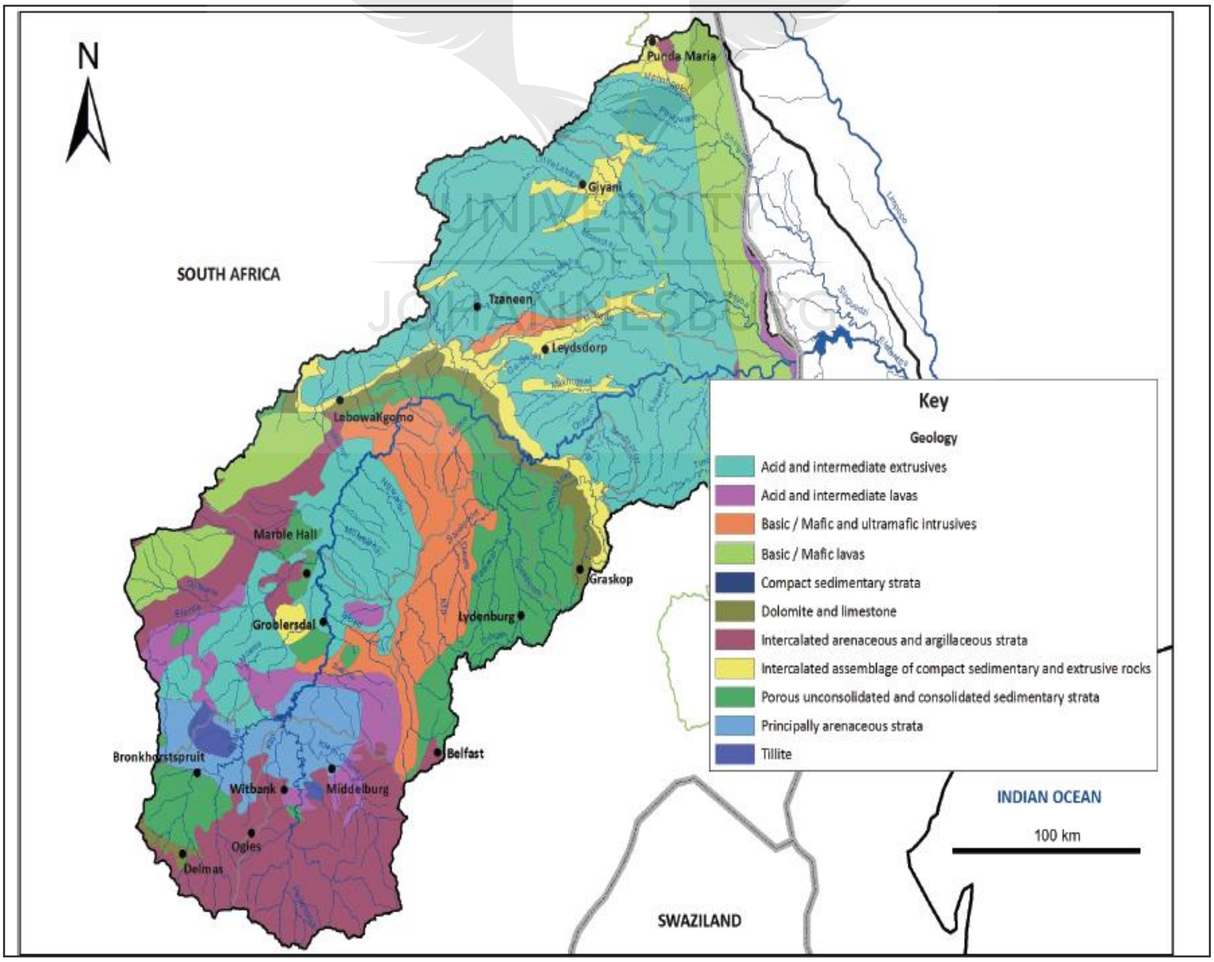

Figure 2: Geological map with major lithological units (Ashton and Dabrowski, 2011)

2.4.6 Land use activities

As mentioned in chapter 1, the upper Olifants River is highly developed for a number of land use sectors which include coal mining, agriculture, waste water treatment works, coal-fired power generation and the industry which includes chemical manufacturers, chrome and steel smelters. Irrigation of diverse crops takes place in various parts of the catchments (Dabrowski and de Klerk, 2013). Intensive farming in the form of piggeries and cattle feedlots is also scattered throughout the catchments (Dabrowski and de Klerk, 2013).

The anthropogenic stressors have resulted in Olifants River catchment having poor water quality. Mining activities has resulted in the presence of pollutants such as heavy metal ions, sulphates in the river catchment (Dabrowski and de Klerk, 2013). The Industrial effluent has resulted in a variety of potential pollutants contaminating the river catchment. Excessive nutrient pollutants and microbiological pollution found in the Olifants catchment is from agriculture and sewage works (Dabrowski and de Klerk, 2013).

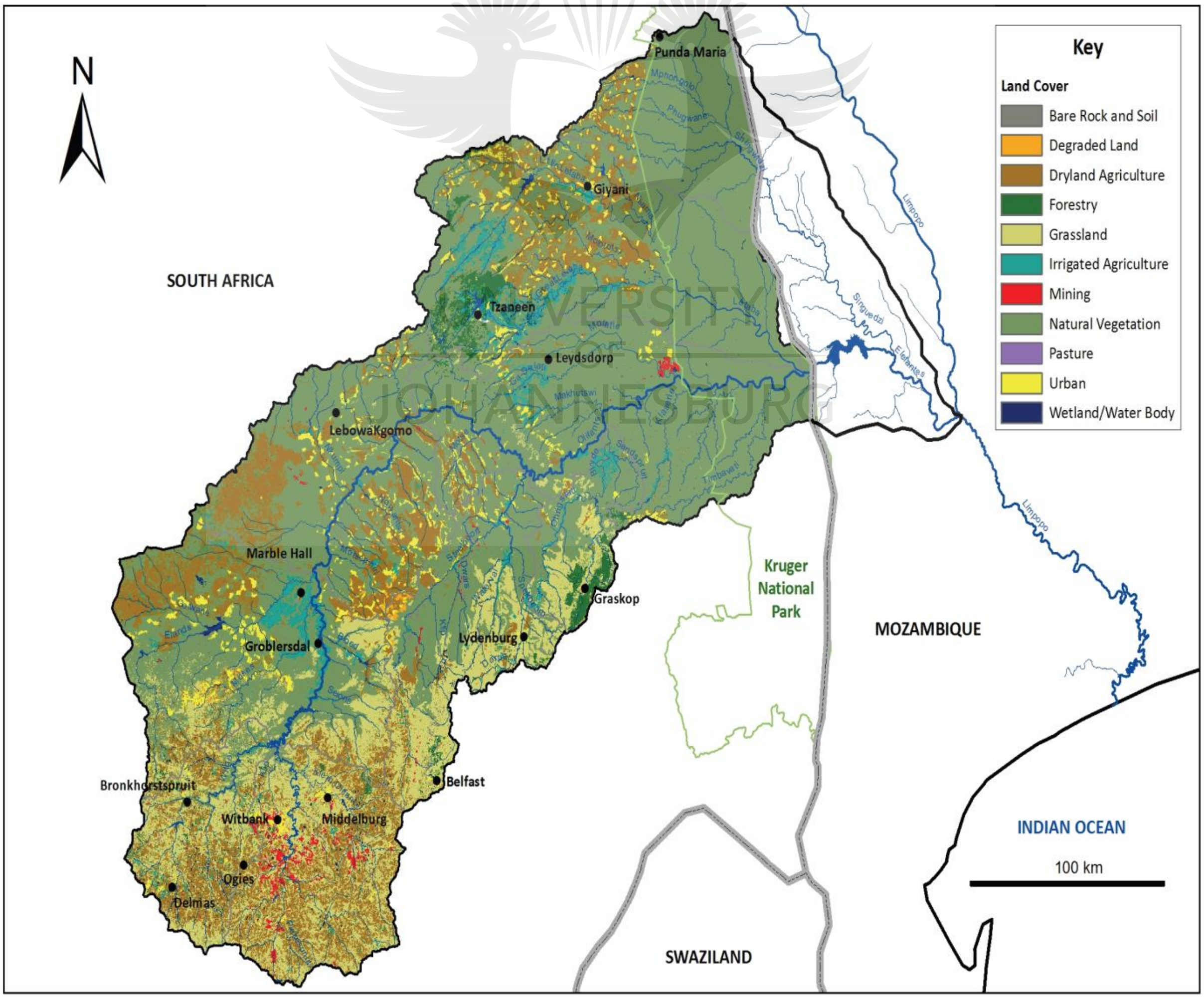

Figure 3: Land uses within the Olifants River catchment (Ashton and Dabrowski, 2011)

2.4.7 Ecological Classification

The ecological condition of the Olifants, Steenkoolspruit and upper Klein Olifants rivers are degraded and mostly in an E category due to the coal mining activities, large dams and urbanisation (DWA, 2013). Their ecological importance is low except around the Witbank Dam area. This area still has some local, undeveloped areas. A number of wetlands are present in the upper reaches of the catchment. One Ecological Water Requirement (EWR) site is present on the Olifants River below Witbank Dam (DWA, 2013).

The Bronkhorstspruit, Saalboomspruit and upper Wilge rivers are in a moderately modified state (category C) with less developed areas in the catchment. Impacts from agriculture, dams and some mining, as well as untreated sewage from poorly managed WWTW in the Delmas and Bronkhorstspruit areas. The importance of these water resources is moderate, especially in terms of good water quality (DWA, 2013).

The ecological state of lower Klein Olifants and Selons rivers, and the Loskop Dam water resources have been degraded (B to C category), mainly due to the upstream impacts from the Olifants and Klein Olifants rivers. However, the presence of unproclaimed wilderness areas and nature reserves provides habitats for the various biota in the system that gives it a high ecological importance (DWA, 2013).

2.5 Site Selection

According to the National Water Act, Act 36 of 1998, government is the custodian of all the water resources. Hence, the DWS is responsible for conducting the REMP in the upper Olifants WMA in order to ascertain the current Eco-status of the river system.

The Eco-status of the WMA is obtained through the use of instream and riparian biological information such as riparian vegetation and invertebrates which are indicators that are used to describe the response of the aquatic environment to disturbances (Kleynhans and Louw, 2007).The sites were selected based on the activities in the catchment as well as the main aim of the study. Currently there are six sites that are monitored. The sites were verified with the assistance of Gauteng Department of Agriculture and Rural Development (GDARD). The sampling points are within the Bronkhorstspruit and Elands rivers, which are tributaries of the upper Olifants River main stem. Moreover, accessibility and safety of the sites were taken into consideration.

Table 2: Biomonitoring sites selected in the upper Olifants catchment (DWS, 2017b)

	ELANDS RIVER				
	Reach	**Site name**	**River**	**Latitude**	**Longitude**
1	Located downstream of Rhenosterkop Dam	B3ELAND-SPRIN(R57)	ELANDS	25°24'28.80"S	28°34'8.40"E
2	Tweedespruit gravel road	B3ELAND-DETWE	ELANDS	25°33'3.60"S	28°34'4.80"E
3	Next to Cullinan township	B3ELAND-DOORN	ELANDS	25°34'30.00"S	28°34'37.20"E
	BRONKHORSPRUIT RIVER				
4	Within the farm	B2BRON-BRONK	BRONKHORSTSPRUIT RIVER	25°48'21.10"S	28°48'26.50"E
5	Below the bridge	B2BRON-KLIPE	BRONKHORSTSPRUIT RIVER	25°49'40.80"S	28°43'1.20"E
6	Farm horses drinking point	B2BRON-MOOIF	BRONKHORSTSPRUIT RIVER	25°51'50.40"S	28°42'28.80"E

Figure 4: Google Earth image of the sampling sites along the Elands River and the Bronkhorstspruit River (obtained from DWS REMP database, 2017b)

Figure 5: Sampling Point B3ELAND-SPRING (R57) next to Cullinan Township taken in February 2019

Figure 6: Sampling Point B2BRON-KLIPE below the bridge taken in June 2019

CHAPTER 3: METHODOLOGY

Biomonitoring was conducted in the upper Olifants River catchment in order to assess its aquatic health status. This was achieved through the use of in-stream biological information i.e. macroinvertebrates, which are indicators that are used to characterize the response of the aquatic environment to disturbances. The study was conducted as a field based quantitative research. A total of six sites that have been selected and verified with the assistance of the DWS and GDARD were monitored.

The sampling points are within the Bronkhorstspruit and Elands rivers, which are tributaries of the upper Olifants River main stem. Samples were collected over three seasons (i.e. summer, winter and autumn), twice during the dry season and once during the wet season (Table 3) and compared with data obtained from the Department of Water and Sanitation REMP database. The methodology for data collection is as follows:

Table 3: Seasonal surveys conducted in the Bronkhorstspruit and Elands rivers

WET SEASON	DRY SEASON
February 2019	June 2019
	August 2019

3.1 Materials and Methods

3.1.1 Macroinvertebrates and SASS5

The SASS5 is a rapid biomonitoring index using macroinvertebrates as indicators (Dickens and Graham, 2002). SASS5 has been examined and it is commonly used in South Africa as an instrument or tool for assessing water quality and river health (Dallas, 2007). SASS5 uses aquatic macro invertebrates as indicator organisms to evaluate the impact of changes in water quality in the river system (Dickens and Graham, 2002).

3.1.2 Geomorphology and GI

Geomorphology is one of several important components used to assess the overall condition of a river. The geomorphological processes and flow determine the morphology of the channel, which in turn, provides the physical framework for the stream biota (Rowntree and Wadeson, 2000). Water and sediment therefore predominantly shape the river channel and also affect water quality with high sedimentation and silt loading contributing to water quality deterioration.

Structural changes in the river channels influence the form, diversity and distribution of available physical habitat. This affects the composition and diversity of in stream and riparian biological communities (Rowntree and Wadeson, 2000).Changes in stream biota in the absence of other disturbances can therefore be attributed to possible changes in channel morphology and channel condition whether this change is of natural or anthropogenic influence (Rowntree and Wadeson, 2000).

The geomorphological index (GI) is used in REMP implementation to assess the physical condition of river channels morphology. The development of this index is ongoing, and its accuracy, applicability and reliability are dependent upon availability of data from various river systems across the country (River Health Programme, 2006).

3.1.3 Flow and HI

Flow conditions and channel physical characteristics affect the distribution and abundance of the biota by creating dynamic habitat characterized by current speed, water depth and substratum characteristics. The collection of past and present flow data from gauging weirs is very important for tracing changes in flow that are likely to occur due to natural or anthropogenic impacts. Dams, inter-basin transfers, hydroelectric power generation and other anthropogenic impacts have altered most rivers flow regimes in South Africa.

Flow conditions are also altered by natural processes such as large floods (temporarily inundating most habitats and resulting in sparse diversity), and droughts that result in low flow (loss of habitats). Although the prototype of the Hydrological Index (HI) has been developed the index is currently not being used in REMP implementation. Flow data for interpretation of biological data and to trace temporal changes in river flow are obtained and analyzed from DWS gauging weirs (River Health Programme, 2006).

3.1.4 Water quality and WQI

Water quality assessment is important in the overall assessment of ecological status of aquatic ecosystems. The term water quality describes the physical, chemical, and aesthetic properties of water, which determines its fitness for the protection of health and integrity of aquatic ecosystems (DWAF, 1996). Aquatic organisms are therefore adapted to live within limited water quality ranges due to their evolutionary history.

Variations in water quality conditions can have harmful effects on aquatic biota and thereby affect their capability to provide natural cleansing activities in aquatic ecosystems which include breaking down of organic matter. The Water Quality Index (WQI) that has been developed is not frequently used in South Africa and is currently not used in REMP monitoring. For the REMP, water quality data is obtained from the DWAF gauging weirs. Physical water quality variables such as conductivity, temperature, dissolved oxygen and pH are measured on site at each sampling occasion.

3.2 Sampling

3.2.1 Macroinvertebrates

Macroinvertebrates Sampling

The minimum amount of equipment necessary is: a soft 1mm mesh net on a 30cm square frame on a stout handle, white or cream flat-bottomed trays, soft plastic wide mouth pipettes, timer, magnifying lens, pencil, rubber, Petri dish, waders, a pair of boots or appropriate foot protection, identification books and SASS5 scoring sheets. Samples were collected from three biotopes, stone biotope (in current, and out of current), vegetation and gravel-sand-mud biotope (Thirion et al., 1995).

- **Stones biotope:**

Portable stones, bedrock or any solid object in and out of current (where current is defined as adequate flow that prevent settling of fine silt) were sampled. Samples from both in and out of current were merged into a single sample.

Stones in current: The net was positioned close but downstream of the stones to be kicked, to allow the current to carry the dislodged biota into the net. The kicking of stones was done for two minutes. In the case where the stones were attached or difficult to move, especially bedrock, the sampling was done for up to five minutes maximum and this was noted (Dickens & Graham, 2002).

Stones out of current: Stones, bedrock or other solid objects were sampled for about one minute by dislodging the biota by kicking, scraping and turning them with feet and/or hands, whilst continuously sweeping the net through the disturbed area. Both the out of current and in current samples collected were combined into one Stones (S) biotope sample (Dickens & Graham, 2002).

- **Vegetation biotope:**

Marginal vegetation hovering or growing at the edge of the stream was sampled both in and out of current. The total length of distance that was sampled is 2m, preferably over more than one location and if present, on more than one vegetation type. Aquatic vegetation (usually submerged or floating vegetation) was also sampled and was merged with the marginal vegetation to provide a single vegetation biotope score.

- **Gravel, sand and mud biotope (GSM):**

The gravel, sand and mud biotopes were sampled separately, both in and out of current and merged to provide a single gravel, sand and mud biotope score. Gravel, sand and mud biotope is sampled for not more than 1 minute.

- **Hand Picking and Visual Observation**

Around one minute of hand-picking was taken into consideration during sampling. This is done to identify and record specimen that might have been missed during the sampling process. This also included visual observation of Gyrinidae, snails and pond skaters.

Once collection of the samples was completed, each aforementioned sample was washed down to the bottom of the net, and then carefully placed into the three separate trays by inverting the net. The net was flushed out with water to make sure that biota do not remain in it. Sufficient clean water was then added to the tray to immerse the sample. Before identification of organisms large obstructions were removed from the trays but were carefully shaken into the water and checked for clinging biota before being removed.

3.3 Analysis

The samples collected were placed in three different trays according to their groupings i.e. Stones, Vegetation and GSM. Identification was allowed for 15 minutes per tray. The abundance of identified families were scored 1 if only one (1) specimen was found, A if between 2-10 of specimens were found, B if between 10 and 100 Specimen were found, C if between 100 and 1000 specimens were found and D if more than 1000 specimen were found i.e. 1=1, A=2-10, B=10-100, C=100-1000, D=>1000 (Dickens & Graham, 2002).

The results were expressed as an index score (SASS score) and the Average Score per Taxon (ASPT). Each family taxon is allocated values between 1 and 15, which is based on its sensitivity to water quality change. Number of taxa and ASPT value (i.e., SASS5/number of taxa) were also obtained. ASTP was used to determine the river health class by using the following benchmark ranges: Natural -7, Good -6, Fair -5 and Poor < 5 (Dickens & Graham, 2002) (Table 4).

Table 4: Default benchmark river health class boundaries for SASS5 (Dickens and Graham, 2002)

CLASS BOUNDARY	RANGE OF ASPT SCORES	Ecological Perspective	Management Perspective
Natural	7	Little or no modification of in-stream and riparian habitats and biota.	Relatively untouched by humans; no discharges or impoundments allowed.
Good	6	Ecosystems essentially in good state; biodiversity largely intact.	Some human-related disturbance but mostly of low impact.
Fair	5	Sensitive species may be lost; lower abundances of biological populations are likely to occur, and/or higher abundances of tolerant or opportunistic species occur.	Disturbances associated with socio-economic development, such as: impoundment, habitat modification and water quality degradation.
Poor	<5	Habitat diversity and availability have declined; Mostly only tolerant species present; biota can no longer reproduce, and/or alien species have invaded the ecosystem.	High human densities or extensive resource exploitation. Management intervention is needed to improve river

3.3.1 Index of Habitat Integrity (IHI)

The Index of Habitat Integrity (IHI) was used to identify possible sources of pollution. The assessment of IHI measure or determine the degree of river modification from its natural state. The IHI incorporates a subjective numerical assessment of the amount and severity of anthropogenic disturbances within a river system and the damage they potentially impose upon the system. These disruptions or disturbances include abiotic and biotic factors, which are viewed as the main or primary cause of river degradation. The degree or intensity of each impact is ranked using the six-point scale, where 0 indicate (no impact), 1 to 5 (small impact), 6 to 10 (moderate impact), 11 to 15 (large impact), 16 to 20 (serious impact) and 21 to 25 (critical impact) (DWAF, 1999). The IHI assessment is based on the computation of the impacts of two components of the river, which are the instream habitat and the riparian habitat (Kemper, 1999). Evaluations are made separately for both components. However, data for the riparian habitat is interpreted mainly in terms of the potential impact on the instream component. The estimated impact of each criterion is calculated as follows:

Rating for the criterion/maximum value (25) x weight (percent)

The approximate impacts of all criteria calculated are summed, expressed as a percentage and subtracted from 100 to arrive at an assessment of habitat integrity for the riparian and instream components respectively (Kemper, 1999). Therefore, the total scores for the instream and riparian habitat components are then used to place the habitat integrity of both components in a specific habitat category (Table 5).

Table 5: Habitat Integrity categories (Based on Kemper, 1999)

Category	Description	Score (% of Total)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In worst instances, basic ecosystem functions have been destroyed and changes are irreversible.	0

3.3.2 *In-situ* Water quality Parameters

Water quality parameters that were measured on site include pH, temperature (T), dissolved oxygen (DO), electrical conductivity (EC) and total dissolved solids (TDS). A Hanna multi-parameter water quality meter (Figure 7) was used to measure all the above mentioned parameters.

Figure 7: Hanna multi-parameter water quality meter

3.3 Data Analysis

The Overall Eco-status was determined by using the MIRAI model (Thirion, 2008). The MIRAI is a rule-based model recently developed by the Department of Water and Sanitation (Thirion 2008). It integrates the ecological requirements of the invertebrate taxa in a community or assemblage to their response to modified habitat conditions. Metrics that form part of MIRAI are flow modification, water quality, habitat, connectivity and seasonality (Thirion, 2008).

Statistical analysis for correlating water quality and macroinvertebrates community assemblage was done using principle component analysis and Pearson's correlation coefficient using Canoco version 5.

Table 6: Generic ecological categories for Eco-Status (Kleynhans et al., 2006 & DWS, 2016)

CATEGORY	GENERIC DESCRIPTION OF ECOLOGICAL CONDITIONS	SCORE (% OF TOTAL)
A	Unmodified/natural, close to natural or close to predevelopment conditions within the natural variability of the system drivers: hydrology, physico-chemical and geomorphology. The habitat template and biological components can be considered close to natural or to pre-development conditions. The resilience of the system has not been compromised.	> 92-100
B	Largely natural with few modifications. A small change in the attributes of natural habitats and biota may have taken place in terms of frequencies of occurrence and abundance. Ecosystem functions and resilience are essentially unchanged.	>82 - <=88
C	Moderately modified. Loss and change of natural habitat and biota have occurred in terms of frequencies of occurrence and abundance. Basic ecosystem functions are still predominantly unchanged. The resilience of the system to recover from human impacts has not been lost and it is ability to recover to a moderately modified condition following disturbance has been maintained. >62 - <=78	>62 - <=78
D	Largely modified. A large change or loss of natural habitat, biota and basic ecosystem functions have occurred. The resilience of the system to sustain this category has not been compromised and the ability to deliver Ecosystem Services has been maintained.	>42 - <=58
E	Seriously modified. The change in the natural habitat template, biota and basic ecosystem functions are extensive. Only resilient biota may survive and it is highly likely that invasive and problem (pest) species may dominate. The resilience of the system is severely compromised as is the capacity to provide Ecosystem Services. However, geomorphological conditions are largely intact but extensive restoration may be required to improve the system's hydrology and physico-chemical conditions.	20 - <=38
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete change of the natural habitat template, biota and basic ecosystem functions. Ecosystem Services have largely been lost This is likely to include severe catchment changes as well as hydrological, physico-chemical and geomorphological changes. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. Restoration of the system to a synthetic but sustainable condition acceptable for human purposes and to limit downstream impacts is the only option.	<20

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Water Quality Results

Water quality is a term used to describe the physical, chemical, biological and aesthetic properties of water that define its appropriateness for a variety of uses and for the protection of health and integrity of aquatic ecosystems (DWAF, 1996). In aquatic ecosystems, system variables influence ecosystem processes such as spawning and may also alter ionic and osmotic balance of individual organisms (DWAF, 1996). Aquatic biota are often well adapted to a particular aquatic ecosystem and the natural changes in water quality during seasonal successions of that particular system. Changes in the frequency and duration of such seasonal succession and anthropogenic impacts on the system may disrupt the ecological and physiological functions of aquatic organisms and therefore the ecology of the entire system (Ramollo, 2008). Each aquatic ecosystem possesses a natural buffering capacity which allows it to compensate for changes in the environment such as leaching from the soil, anthropogenic inputs and natural floods (Chapman and Kimstach, 1996). Poor water quality occurs when external environmental conditions exceed the aquatic ecosystems capacity to compensate for the alterations (Chapman and Kimstach, 1996). This study assessed the various physico-chemical water quality parameters of the Elands and Bronkhorstspruit rivers in order to measure the impacts of human activities within the catchment. The water quality constituents were compared with the South African Target Water Quality Guidelines (TWQG) for aquatic ecosystems (Table 7). The water quality results are presented in (Table 8). These water quality results were also essential in helping with the interpretation of the macroinvertebrate results due to the direct influence that water quality has on aquatic macroinvertebrate communities.

Table 7: Target Water Quality Rage for in-situ water quality parameters for aquatic ecosystems

Parameters	TWQR (DWAF,1996)
Temperature (˚C)	5 - 30
pH	6.5 – 9.0
Dissolved Oxygen (DO) (mg/ℓ)	>5.0
Electrical Conductivity (EC) (µS/cm)	<300

Table 8: In-situ water quality parameters for the Bronkhorstspruit and Elands rivers

***In-situ* Water Quality Parameters: Dry Season**			**Temp °C**	**Conductivity µS/cm**	**pH**	**DO (mg/ℓ)**
REMP Site Code	**River**	**Date**				
B3ELAND-SPRIN (R57)	Elands	07/6/2019	10.6	668.1	7.9	9.4
B3ELAND-DETWE	Elands	07/6/2019	13.8	305.1	8.2	8.8
B3ELAND-DOORN	Elands	07/6/2019	14.8	657.4	7.9	10.7
B2BRON-KLIPE	Bronkhorstspruit	06/6/2019	12.3	316.0	7.9	8.5
B2BRON-MOOIF	Bronkhorstspruit	06/6/2019	9.5	604.5	7.7	4.4
B3ELAND-SPRIN (R57)	Elands	23/8/2019	13.6	323.6	8.4	8.8
B3ELAND-DETWE	Elands	23/8/2019	14.0	320.5	8.1	8.8
B3ELAND-DOORN	Elands	23/8/2019	16.7	304.4	8.2	8.8
B2BRON-KLIPE	Bronkhorstspruit	22/8/2019	13.9	336.9	8.1	7.9
B2BRON-MOOIF	Bronkhorstspruit	22/8/2019	13.6	665.0	7.97	4.04
B2BRON-BRONK	Bronkhorstspruit	06/6/2019 & 22/8/2019	No Sample	No Sample	No Sample	No Sample
***In-situ* Water Quality Parameters: Wet Season**			**Temp °C**	**Conductivity µS/cm**	**pH**	**DO (mg/ℓ)**
REMP Site Code	**River**	**Date**				
B3ELAND-SPRIN (R57)	Elands	27/2/2019	20.4	678.1	7.8	9.2
B3ELAND-DETWE	Elands	27/2/2019	20.0	648.2	8.0	8.6
B3ELAND-DOORN	Elands	27/2/2019	20.1	657.4	8.2	8.8
B2BRON-KLIPE	Bronkhorstspruit	26/2/2019	21.2	620.5	7.9	8.4
B2BRON-MOOIF	Bronkhorstspruit	26/2/2019	21.0	670.4	8.1	4.0
B2BRON-BRONK	Bronkhorstspruit	26/2/2019	No Sample	No Sample	No Sample	No Sample

Site B2BRON-BRONK was not sampled due to river covered by water hyacinth (*Eichhornia crassipes*)

Changes in these variables due to pollution, geomorphological or hydrological factors have detrimental and lethal effect on aquatic organisms. Tolerance levels of individual organisms, and the combination of variables acting, determine to what extent the fauna are affected by such changes (Uys et al., 1996).

4.1.1 Variables

Temperature

Temperature was monitored *in-situ* at the bio-monitoring sites during the three surveys that were undertaken. The Temperature of river systems depends on hydrological, climatological and structural features of the catchment (DWAF, 2005). High water temperatures result in a decline in oxygen solubility and promote highly toxic behaviour of some chemical variables, resulting in increased stress of biota (Wepener, 2016). A change in temperature may alter the biological composition of a system because temperature changes affect the periods of reproduction, developmental rate, and emergence time of aquatic organisms (DWAF, 2005). The maximum temperature of the water in the selected sites was 20.4 °C, which is well within the required limit for aquatic ecosystems. According DWAF (1996), in South Africa, the temperature of inland waters is generally in the range of 5-30 °C.

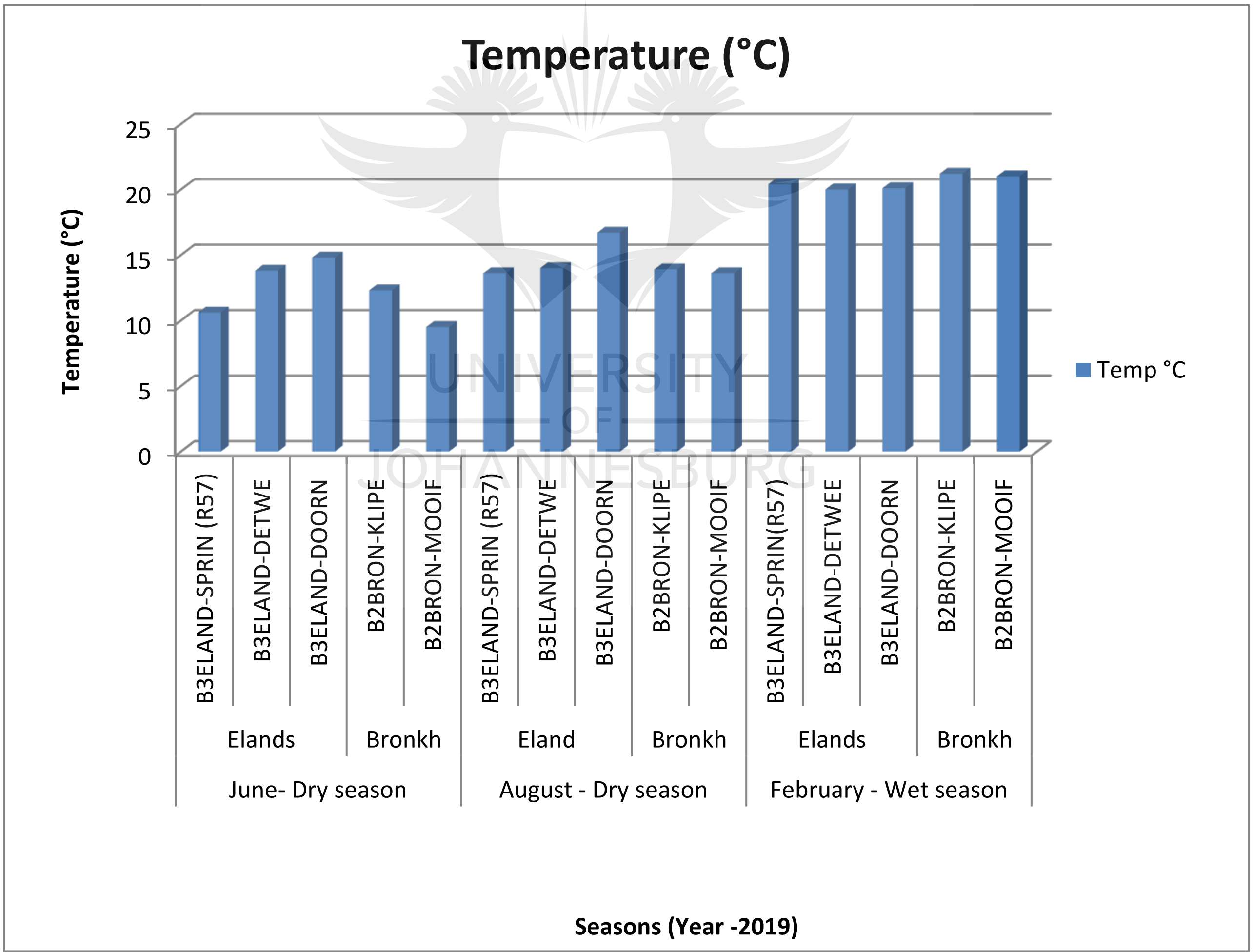

Figure 8: Temperature values recorded at the bio-monitoring monitoring sites during the three sampling periods in the Eland River and Bronkhorstspruit River

pH

pH is the measure of the amount of hydrogen ions in a solution. This affects the solubility of many substances and the activity of most biological systems (DWAF, 1996). The pH of natural waters is determined by geological aspects of the area and biotic activities. Values of pH recorded in both seasons were consistently alkaline at all sites (Figure 9). The highest pH value of 8.4 was recorded at site B3ELAND-SPRIN (R57) in august during dry season.

The lowest value of 7.7 was recorded at Site B2BRON-MOOIF. The results show that the pH was within the targeted water quality range of 6.0 -9.0 (Table 7) for aquatic ecosystems throughout the monitoring period at all the monitored water quality sites.

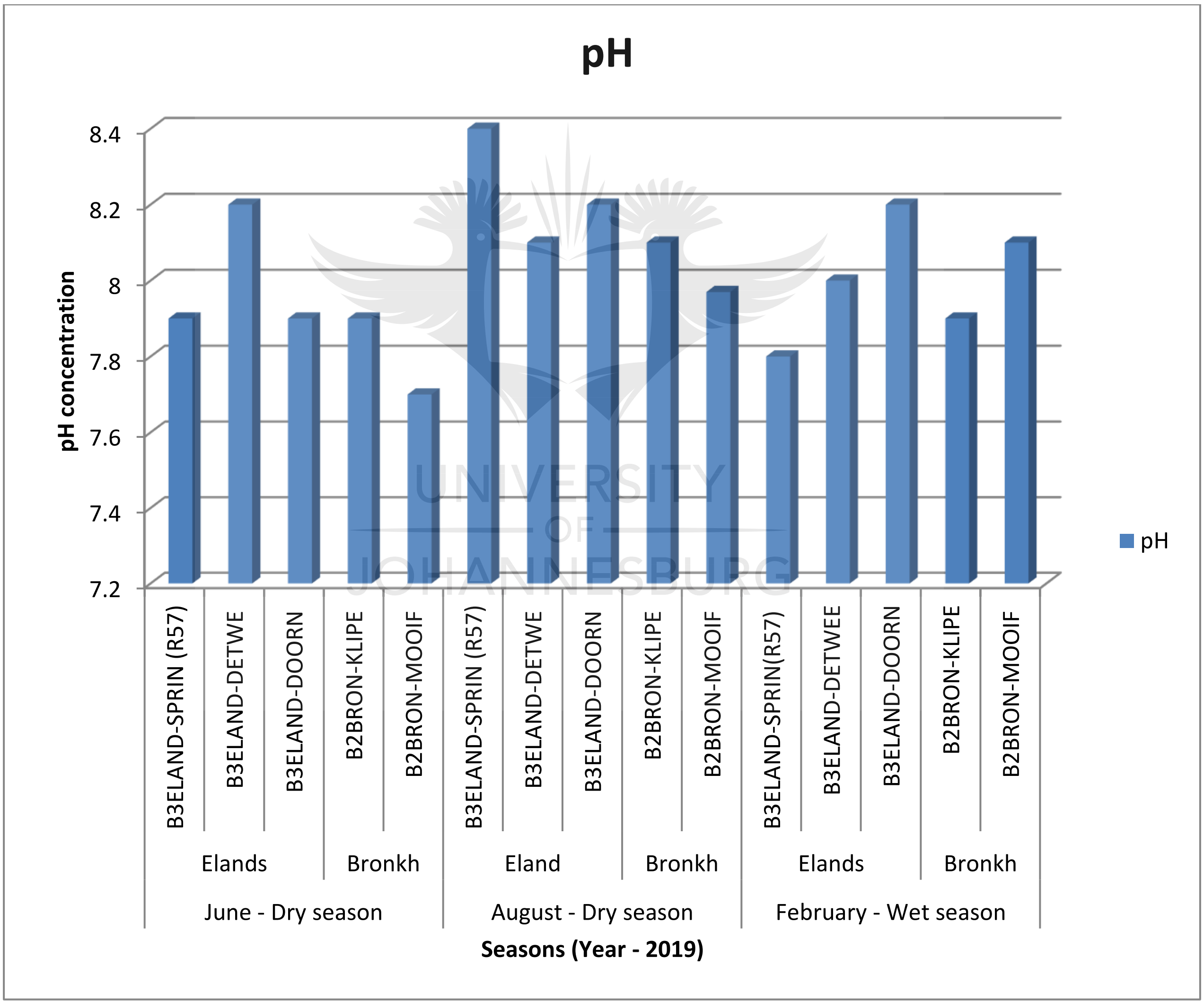

Figure 9: pH values recorded at the bio-monitoring monitoring sites during the three sampling periods in the Eland River and Bronkhorstspruit

Electrical Conductivity (EC)

Electrical conductivity (EC) is the measure of the ability of water to conduct an electrical current (DWAF, 1996). Electrical conductivity correlates with the amount of TDS in the system, which is the amount of inorganic salts dissolved in water and is also an acceptable indicator for water quality (DWAF, 1996). Ions such as carbonate, sodium, nitrate, magnesium and calcium are responsible for EC/TDS. Most of the macroinvertebrate taxa found within rivers are sensitive to salinity (Bailey and James, 2000).

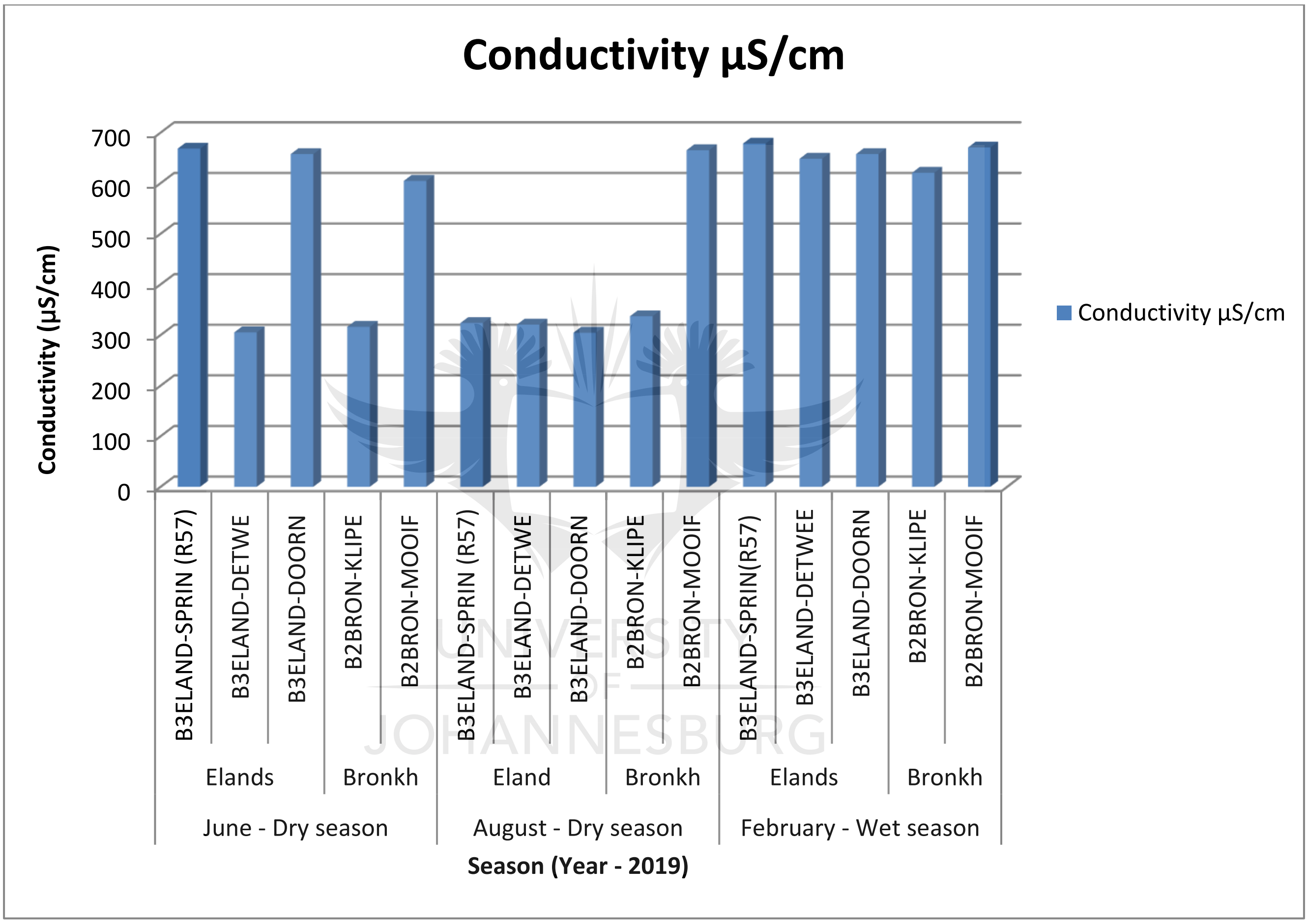

Figure 10: Electrical Conductivity (EC) recorded at the bio-monitoring monitoring sites during the three sampling periods in the Elands and Bronkhorstspruit River

Figure 10 shows that the EC was above the <3001µS/cm TWQR limit at all the monitored water quality sites throughout the sampling period. The highest value of 678.1µS/cm was recorded during the wet season at site B3ELAND-SPRIN (R57). These elevated levels may have a negative effect on local aquatic biota. The presence of salts in water is due to water moving from upstream areas to the downstream areas and is added through natural and anthropogenic activities within the study area.

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is critical for all aerobic aquatic biota, including fish, plants and microorganisms, as they depend on it for the respiration process, survival and functioning (DWAF, 1996). Healthy and biologically diverse aquatic ecosystems are dependent on concentrations of dissolved oxygen maintained at regularly high levels. According to DWAF (1996), various species of fish and invertebrates avoid anoxic or oxygen-depleted environments. The mean DO concentrations measured for most sites in this study were above the 5 mg/l, which is the acceptable TWQR limit (Table 7). However, unacceptable values which are below 5 mg/l were recorded at site B2BRON-MOOIF during both the dry season and the wet season.

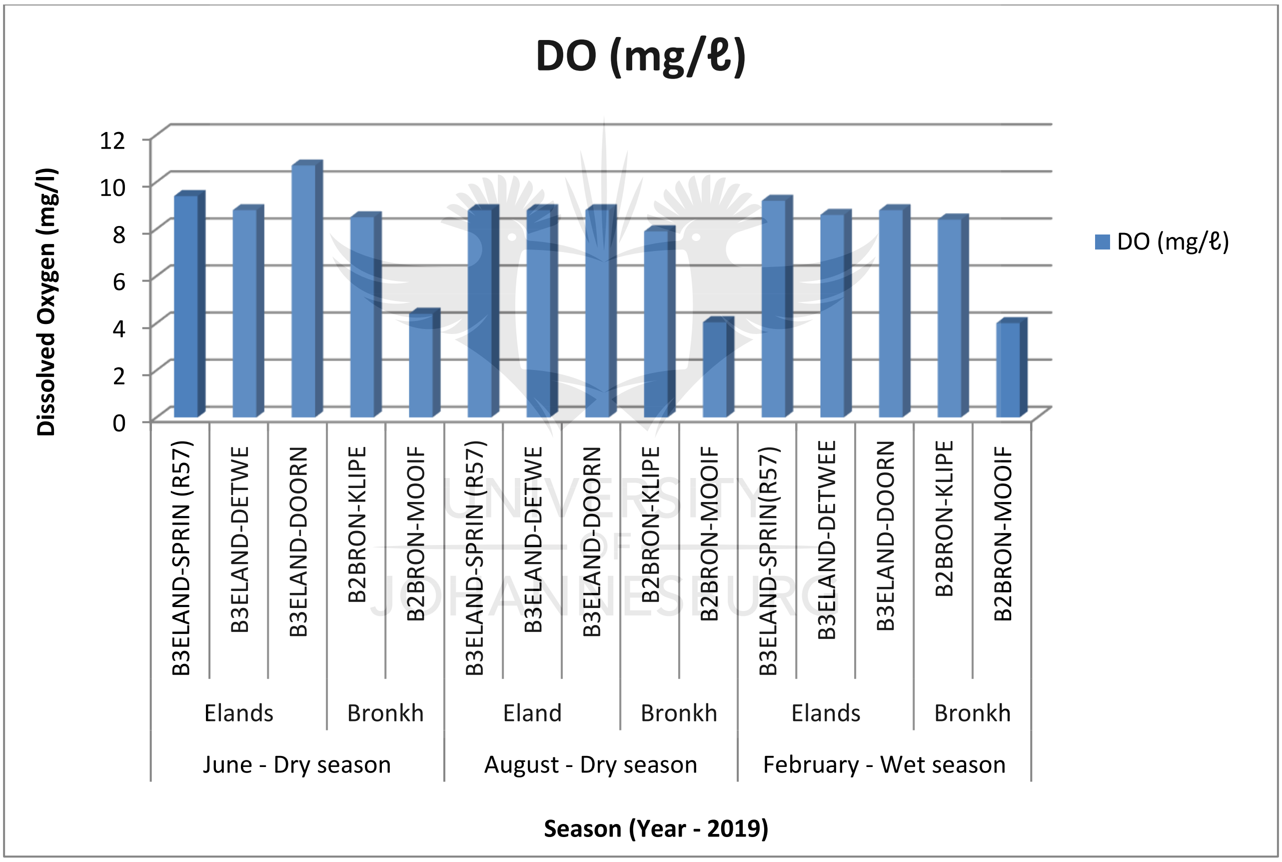

Figure 11: Dissolved Oxygen (DO) concentrations recorded at the bio-monitoring monitoring sites during the three sampling periods in the Eland River and Bronkhorstspruit River

According to Bartram and Ballance (1996), temperature, salinity and atmospheric pressure influence the amount of DO. Electrical conductivity is a general indicator of salts and their related impacts (e.g. mining and farming), therefore high EC recorded within site B2BRON-MOOIF may also be contributing to low dissolved oxygen levels.

4.2 Index of Habitat Integrity (IHI)

Table 9: Instream Habitat Integrity results

Weights	14	13	13	13	14	10	9	8	6		
SITE	**Water abstraction**	**Flow modification**	**Bed modification**	**Channel modification**	**Water quality**	**Inundation**	**Exotic macrophytes**	**Exotic fauna**	**Solid waste disposal**	**Total Score (%)**	**Classification**
B3ELAND-SPRIN (R57)	8	12	9	10	9	7	1	1	6	64	C Moderately modified
B3ELAND-DETWE	6	11	9	6	8	8	2	1	7	68	C Moderately modified
B3ELAND-DOORN	8	10	11	10	6	6	7	3	4	64	C Moderately modified
B2BRON-KLIPE	7	15	13	11	9	5	9	6	3	49	D Largely modified
B2BRON-MOOIF	10	15	15	11	10	8	0	6	11	53	D Largely modified

None (0)	**Small (1-5)**	**Moderate (6 – 10)**	**Large (11 – 15)**	**Serious (16 –20)**	**Critical (21 – 25)**

Table 10: Riparian Habitat Integrity results

Weights	13	12	14	12	13	11	12	13		
SITE	**Vegetation removal**	**Alien encroachment**	**Bank erosion**	**Water abstraction**	**Flow modification**	**Channel modification**	**Water quality**	**Inundation**	**Total Score (%)**	**Classification**
B3ELAND-SPRIN (R57)	9	8	15	7	11	12	9	6	48	D Largely modified
B3ELAND-DETWE	3	1	10	5	8	5	8	0	76	C Moderately modified
B3ELAND-DOORN	2	3	8	8	6	5	9	0	75	C Moderately modified
B2BRON-KLIPE	9	10	11	6	12	11	8	9	43	D Largely modified
B2BRON-MOOIF	15	11	12	13	8	6	12	6	28	E Seriously modified

None (0)	**Small (1-5)**	**Moderate (6 -10)**	**Large (11-15)**	**Serious (16-20)**	**Critical (21-25)**

Table 11: Combined Habitat Integrity (Kemper, 1999)

RIVER	INSTREAM HABITAT	RIPARIAN HABITAT	IHI SCORE	CLASS
Elands	65	66	65	C Moderately modified
Bronkhorstspruit	51	35	43	D Largely modified

From the results of the application of the IHI to the sites within Elands and Bronkhorstspruit rivers, it is evident that there are several limited, moderate and extensive impacts on the habitat of the aquatic systems at the sites that were evaluated.

4.2.1 Instream zone impacts

Small to large instream impacts comprise of activities such as water abstraction, exotic fauna, exotic macrophytes, channel and bed modification, solid waste disposal, inundation, channel and water quality modifications. Large impacts of flow modification were observed along all the sites assessed. Overall, the Elands River achieved 65% score for instream integrity and the Bronkhorstspruit River achieved 51% score for instream integrity (Table 9).

4.2.2 Riparian zone impacts

Riparian zone impacts ranged from small to large in nature. Small impacts within the riparian zone comprise of water abstraction, flow, channel and bed modification along with water quality, inundation and exotic vegetation encroachment impacts. Large impacts were observed in the form of bank erosion and Vegetation removal specifically in site B2BRON-MOOIF. Overall, the Elands River achieved 66% score for riparian integrity and the Bronkhorstspruit River achieved 35% score for riparian integrity (Table 10).

Elands River achieved a combined overall IHI rating of 65%, which according to Kemper (1999) indicate that it is moderately modified (class C). This means that a loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged. Bronkhorstspruit River achieved a combined overall IHI rating of 43%, which according to Kemper (1999) indicate that it is largely modified (class D). This means that a large loss of natural habitat, biota and basic ecosystem functions has occurred (Table 11).

4.2.3 Sources of Pollution

The greatest impacts observed on the upper Olifants River catchment are from mines, agriculture, urbanization and municipal wastewater treatment works which impacts considerably on downstream users.

As observed on site, there is a large amount of coal mining and other industrial activities around the Bronkhorstspruit and Elands rivers, which are the primary contributors to poor instream and riparian habitat conditions. Acid leachate from the surrounding mines may also be slightly contributing to poor water quality and poor instream conditions. Irrigation return flows are also causing a rise in salinity levels downstream of irrigated areas. In some areas around the Bronkhorstspruit and Elands rivers, access roads that were constructed for surrounding mines and industries have resulted in severe disruptions of riparian habitats, and increased erosion on land and river beds.

The riparian vegetation surrounding the Bronkhorstspruit River is under pressure from overgrazing, specifically at the sampled sites as observed in the Riparian Habitat Integrity results, and also from alien vegetation such as wattles that occur within the riparian zone, which compete with indigenous vegetation and reduce available water. The primary impact in the Elands River is ecologically insensitive releases of water from the Rhenosterkop Dam. For example, no flow on a particular day followed by flooding on the next day. These artificial flow regimes change the river bed, thereby causing erosion and resulting in undesirable habitat conditions for instream biological communities.

4.3 Macroinvertebrates Assessment

4.3.1 The South African Scoring System Version 5 (SASS5)

Aquatic macroinvertebrates were used to assess the biological integrity of the Olifants River ecosystem. This is because aquatic macroinvertebrates are sedentary, which allow the detection of local disturbances. Other various factors such as habitat quality and quantity were considered when interpreting SASS5 results (Dickens and Graham, 2002)

A total of 43 aquatic invertebrate taxa were recorded in the Bronkhorstspruit and Elands rivers, which are tributaries of the upper Olifants River main stem during the three sampling periods (Appendix A). The highest number of taxa was recorded at biomonitoring site B3ELAND-DETWE, with 26 taxa recorded during the June 2019 and August 2019 survey (dry season). The site is surrounded by wetlands. The stream consists of stones and abundant riparian vegetation. ASPT values recorded at this site ranged from 6.0 to 6.9, which according to Dickens and Graham (2002) means there is some human related disturbance, but mostly of low impact. The ecosystem is essentially in a good state and biodiversity is largely intact. This is evident by the presence of multiple Baetidae species and Heptageniidae.

Site B3ELAND-SPRIN (R57) recorded 17 taxa during the wet season. Fifteen taxa were recorded in June and 10 taxa recorded in August (dry season). The site is located next to a farm and downstream of the Rhenosterkop Dam. There are a few residential properties along the river banks. The flow was low and water clear throughout the sampling period. The bedrock is widespread within the stream. The ASPT values recorded at this site ranged from moderate low score of 4.8 to 5.1 which according to Dickens and Graham (2002) means that sensitive species were lost and there is higher abundance of tolerant (e.g. Oligochaeta, Chironomidae) or opportunistic species (e.g. Gomphidae, Baetidae) occurring.

Site B3ELAND-DOORN recorded 20 taxa during the wet season. Seventeen taxa were recorded in June (dry season) and 20 taxa recorded in August (dry season), indicating a moderate diversity of invertebrates. The ASPT values recorded at this site ranged from 5.2 to 6.1. The site is located downstream of a wastewater treatment works and is highly dominant with boulders. The poor water quality is likely a product of low flow conditions, combined with high inputs of polluted waters from upstream communities.

At B2BRON-KLIPE 17 taxa were recorded during the wet season. Eighteen taxa were recorded in June (dry season) and 16 taxa recorded in August (dry season). A lower diversity of sensitive taxa was recorded. The site is located below a low lying bridge of a gravel road within a small holding farming area and is also downstream of the Bronkhorstspruit Dam. The flow was medium and the water was clear. Algae were covering the biotopes. This may be attributed to run off from agricultural fields, where chemical fertilizers have been applied.

The lowest number of taxa was recorded at Bio-monitoring site B2BRON-MOOIF, with 7 taxa collected during the August 2019 survey (Table 11). According to Dickens and Graham (2002), this means that habitat diversity and availability have declined, tolerant species are mostly only present; biota can no longer reproduce, and/or alien species have invaded the ecosystem. The site has a bridge of a gravel road and is within a farming area. Few Eucalyptus tresses were spotted along the river banks. The site is also upstream of the Bronkhorstspruit Dam. The poor water quality is mainly attributed to high runoff entering from agricultural fields. The riparian vegetation is overgrazed and over utilized. As a result, river banks are collapsing due to erosion and sedimentation occurs in the riverbed.

Table 12: SASS5 score, number of taxa and ASPT for all three surveys in the Elands River and Bronkhorstspruit River

BIO-MONITORING SITE	SASS SCORE	NUMBER OF TAXA	ASPT	SASS SCORE	NUMBER OF TAXA	ASPT	SASS SCORE	NUMBER OF TAXA	ASPT
	Feb 2019			**June 2019**			**August 2019**		
B3ELAND-SPRIN (R57)	83	17	4.8	74	15	4.9	51	10	5.1
B3ELAND-DETWE	144	22	6.5	180	26	6.9	174	26	6.7
B3ELAND-DOORN	105	20	5.3	103	17	6.1	105	20	5.2
B2BRON-KLIPE	86	17	5.1	91	18	5.1	79	15	5.2
B2BRON-MOOIF	52	13	4.0	58	14	4.2	22	7	3.1

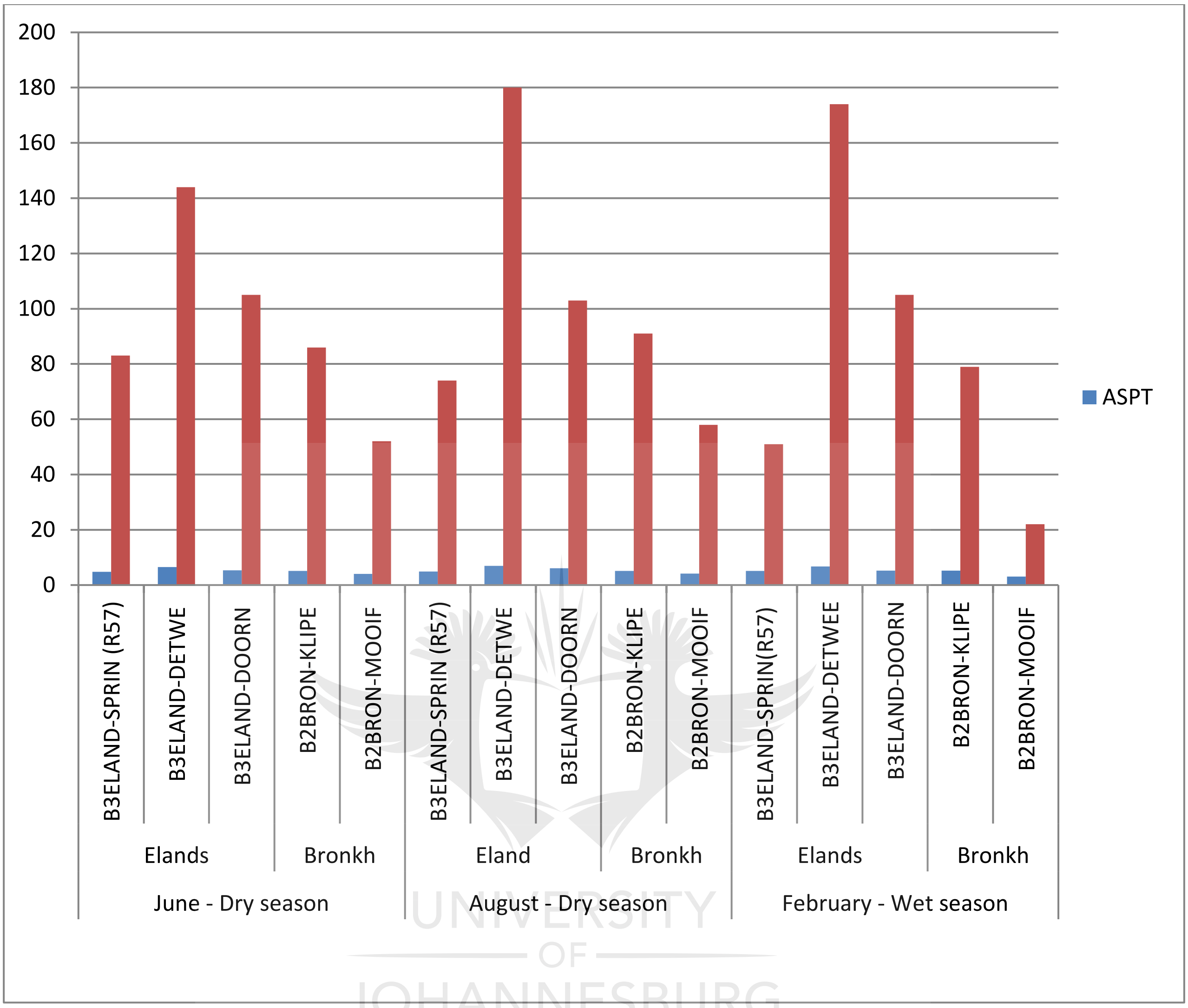

Figure 12: Graphical representation of SASS5 scores and ASPT

4.3.2 The Macroinvertebrates Response Assessment Index (MIRAI)

According to Roux (1999), flow regime, water quality, physical habitat structure, and energy inputs are the four major components of a river system that control productivity, with specific reference to aquatic organisms. An interaction amongst these factors (mainly habitat and food sources availability) causes the discontinuous, patchy distribution pattern of aquatic macroinvertebrates (Roux, 1999).

In order to relate environmental drivers to such changes in habitat and aquatic invertebrate conditions, there are two key elements that are required. Initially, habitat preferences and requirements for each taxa present must be obtained. Subsequently, reference conditions can be established against which any response to the drivers can be measured. Habitat features must then be evaluated in terms of suitability and the aforementioned requirements. Therefore, the expected and actual patterns are assessed in order to achieve the Ecological Category rating. The overall Present Ecological State (PES) is obtained by determining the mean of all sites (Thirion, 2008).

Based on the aforementioned key requirements, the MIRAI provides a method of deriving and interpreting aquatic invertebrate response to driver changes. The index was applied to the aquatic sites following methodology described by Thirion (2008).

Table 13: Macroinvertebrate Response Assessment Index (MIRAI) scores for the different biomonitoring sites in the Elands and Bronkhorstspruit Rivers

Site code	River	Ecological Category Percentage	Ecological Category
B3ELAND-SPRIN (R57)	Elands	49.8	D
B3ELAND-DETWE	Elands	69.8	C
B3ELAND-DOORN	Elands	57.4	D
B2BRON-KLIPE	Bronkhorstspruit	55.3	D
B2BRON-MOOIF	Bronkhorstspruit	36.7	E

It is evident that the MIRAI results (Table 13) confirmed the results that were obtained using the SASS5 method. The Present Ecological State obtained from the application of MIRAI (Thirion, 2008) was as follows; Site B3ELAND-SPRIN (R57) was determined to fall under category D

(49.8%). Site B3ELAND-DETWE was determined to fall under category C (69.8%). Site B3ELAND-DOORN was determined to fall under category D (57.4%). Site B2BRON-KLIPE was determined to fall under category D (55.3%). Site B2BRON-MOOIF was determined to fall under category E (36.7%). Therefore, the overall Present Ecological State (PES) of the Elands River falls under ecological class C/D and the overall PES of the Bronkhorstspruit River falls under ecological class D.

When compared with previous results that were obtained from the DWS REMP database (Table 14), it is clearly evident that there is an overall general deterioration in terms of macroinvertebrate community integrity throughout the sites along the Bronkhorstspruit River and Elands River. The previous and current results show that all biomonitoring sites along the Bronkhorstspruit River and Elands River have degraded to a lower ecological class.

Table 14: ASPT score and MIRAI results (obtained from DWS REMP data base, 2017b)

SASS sites	SQ Reach	ASPT (Average)	MIRAI
B3ELAND-SPRIN (R57)	Elands	5.0	C/D
B3ELAND-DETWE	Elands	6.9	B/C
B3ELAND-DOORN	Elands	6	C
B2BRON-KLIPE	Bronkhorstspruit	5.5	C
B2BRON-MOOIF	Bronkhorstspruit	4.8	D

CHAPTER 5: CONCLUTION AND RECOMMENDATIONS

Society has long focused on the management of water quantity, maintaining dam volumes, stream flow and water supply, whereas water quality is given less focus, specifically in terms of policy instruments to allow and encourage authorities to protect and manage this vital aspect of freshwater (Hattingh and Claassen, 2008).

Mining and industries within the upper Olifants River catchment have significant impacts on water quality, especially when effluent release and water use are not properly managed (DEAT, 2009). Agricultural activities also constitute a large portion of land use in the upper Olifants River catchment and they result in a number of point and non-point sources of water pollution (Ashton et al., 2001). These sources include effluent discharges from livestock feedlots, pollution originating from agricultural return flows and sediments caused by erosion of cultivated land. Loss or a decrease of aquatic biodiversity and sensitive taxa is largely driven by impacts such as instream flow modification, altered water quality and habitat loss. Human health and welfare, industrial development and the ecosystem on which they depend are all at risk, unless the resources are managed more effectively than they have been in the past (Ashton et al., 2001).

The aim of this study was to provide useful ecological information through an aquatic assessment and to determine the impacts of human activities within the vicinity of the study site by assessing the current state of the upper Olifants River catchment using biological indictors and water quality parameters.

The first objective was to determine the PES of the upper Olifants River catchment by monitoring the diversity and abundance of macroinvertebrates. The results show that the overall PES of the Elands River falls under ecological class C/D. The overall PES of the Bronkhorstspruit River falls under ecological class D. This confirms that the system is largely modified and a large change or loss of natural habitat, biota and basic ecosystem functions have occurred.

The second objective was to identify possible sources of pollution using the IHI. The results show that a large loss of natural habitat, biota and basic ecosystem functions has occurred. Pressures from low water crossings, erosion and sedimentation, alien vegetation, inundation, farming, small farm dams, vegetation removal, irrigation, runoff/effluent from irrigation and mining, grazing and trampling by livestock and large amounts of water abstraction observed within the sites have resulted in poor instream and riparian habitat conditions within the Bronkhorstspruit River and Elands River.

The third objective was to assess the impacts of human activities on the *in-situ* water quality parameters of the upper Olifants River catchment. The results show that EC was above the recommended TWQR limit at all the monitored water quality sites. High salinity mine water discharges and irrigation return flows are causing a rise in salinity levels within the upper Olifants River catchment. Values of pH recorded at all sites were consistently alkaline throughout the sampling period. This may be due to artificial liming. Unacceptable levels of dissolved oxygen (DO) were recorded at monitoring site B2BRON-MOOIF throughout the sampling period. Site B2BRON-MOOIF is situated directly inside a farm, therefore low levels of DO are mainly caused by excess nitrogen and phosphorus from extensive agricultural activities.

The hypothesis that anthropogenic activities in the Bronkhorstspruit and Elands rivers are resulting in the deterioration of water quality, altering the ecological integrity of the upper Olifants River catchment is therefore accepted. The results indicate changes in the drivers of the aquatic system (i.e. water quality and flow), with resultant negative responses of sensitive biota. Changes in the stream community from sensitive to tolerant taxa indicate impaired conditions.

RECCOMENDATIONS

The management of mining activities in the upper Olifants sub-catchment is crucial to the management of water quality both in the short term to alleviate the salt loads being released to the Witbank, Middleburg and Loskop Dams (Ashton and Dabrowski, 2011), and long term to manage the impacts of mine closure and mine decants. A major intervention in terms of current mining development practices is required if the situation in the upper Olifants sub-catchment is to be alleviated.

A strategy to optimise water use and reduce the impact of irrigation return flows need to be developed in collaboration with the relevant Water User Associations (WUA) and National and Provincial Departments. The intervention strategy will require water quantity, Water Conservation and Water Demand Management Strategy (WCWDM) and water quality approaches. By improving water quality, the water may be made available to other users within the WMA.

Waste Discharge Charge System (WDCS), which is a system used to promote waste reduction and water conservation needs to be introduced as soon as possible. Loads need to be determined for catchments where pollution is severe and allocated to the relevant impactors. Load reduction requirements need to be determined so that the impactors are made aware of how much load they will need to reduce by and can budget for specific interventions.

Water quality monitoring must be consistently carried out at all monitoring points according to the agreed upon monitoring programme to enable all strategic points to build up reliable data sets in the Olifants River Catchment. The water quality monitoring variables currently analysed are largely concentrated on chemical constituents. The monitoring system therefore needs to be extended to include biological and microbiological parameters, as well as metals and other emerging contaminants, such as targeted pesticides in areas where these are used. Other indices such as fish and diatoms should also be incorporated in biomonitoring.

Strict compliance monitoring and enforcement must be implemented on water users within the catchment. Compliance monitoring and the capturing of compliance data should be revitalised, in order to determine the true extent of the impacts on the water resources of the upper Olifants River catchment. This would include monitoring of the point source discharges from mines, industries, wastewater treatment works and irrigation canals that discharge into the Olifants River or its major tributaries. Such monitoring will enable better management of point source pollution and non-point source pollution contributing to the degradation of water quality in the upper Olifants River catchment.

Environmental and conservation issues must be placed within the context of social and economic uses of the river by the community and therefore requires the perception of local residents, landowners, the water industry and other stakeholders to be taken into account. Integrated management is accomplished through solutions and activities at the community level together with political and managerial support. Awareness creation, education and training at all levels of government and community play an important role. Public participation and awareness, skills development and institutional capacity are essential components of integrated water resource management and must be implemented.

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APPENDICES

APPENDIX A: SASS VERSION 5 SCORE SHEETS

APPENDIX B: MIRAI

APPENDIX A: SASS VERSION 5 SCORE SHEETS

Date (dd:mm:yr):	27-Feb-19	Grid reference (dd mm ss.s) Lat:	S		25.408d
Site Code:	B3ELAN-SPRIN	Long:	E	28°34'8.40"E	28.569d
Collector/Sampler:	ASHLA, BISMARK & MATIMBA	Datum (WG S84/Cape):			
River:	Elands	Altitude (m):			
Level 1 Ecoregion:		Zonation:			
Quaternary Catchment:	Upper Olifants				

(dd.ddddd)

Temp (°C):	20.1	Routine or Project? (circle one)	
pH:	7.8	Project Name:	
DO (mg/L):	9.4		
Cond (mS/m):	678.1		
Flow:	Medium		
Clarity (cm):			
Turbidity:			
Colour:	Clear		

Site Description:
The site is used a drinking spot by livestock. As a result different livestock pathways have been created.

Riparian Disturbance: Disturbed by livestock grazing
Instream Disturbance: Livestock have created a path way to cross the stream

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	2	FALSE
Stones Out Of Current (SOOC)	2	FALSE
Bedrock	3	FALSE
Aquatic Veg	3	FALSE
MargVeg In Current	3	FALSE
MargVeg Out Of Current	4	FALSE
Gravel	1	FALSE
Sand	3	FALSE
Mud	4	FALSE
Hand picking/Visual observation	YES	
OVERALL BIOTOPE SUITABILITY	64%	Category B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3		A		A
ANNELIDA					
Oligochaeta (Earthworms)	1	A			A
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3	1			1
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6	B	B	B	B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6	A	1	A	B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9	A			A
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8	A	1		A
Coenagrionidae (Sprites and blues)	4		A	1	A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6	B		B	B
Libellulidae (Darters/Skimmers)	4			A	A
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7	A			A
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishfies & Dobsonfies)	8				
Sialidae (Alderfies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5	A			A
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	B	A	B	B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10	1			1

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	A	1	B	B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House fies, Stable fies)	1	1			1
Psychodidae (Moth flies)	1		1		1
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse fies)	5				
Tipulidae (Crane fies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeridae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					83
No. of Taxa					17
ASPT					4.8
Other biota:					

Comments/Observations:
Tedpole and fish were also caught.

Date (dd:mm:yr):	07-Jun-19				(dd.ddddd)
Site Code:	B3ELAN-SPRIN	Grid reference (dd mm ss.s) Lat:	S		25.408d
Collector/Sampler:	ARINAO, BISMARK & MATIMBA	Long:	E	28°34'8.40"E	28.569d
River:	Elands	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:			

Temp (°C):	10.6	**Routine or Project? (circle one)**	Flow:	Low
pH:	7.9	Project Name:	Clarity (cm):	
DO (mg/L):	9.4		Turbidity:	
Cond (mS/m):	668.1		Colour:	Clear

Site Description:
The site is used a drinking spot by livestock. As a result different livestock pathways have been created.

Riparian Disturbance: Disturbed by livestock grazing
Instream Disturbance: Livestock have created a path way to cross the stream

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	2	FALSE
Stones Out Of Current (SOOC)	2	FALSE
Bedrock	3	FALSE
Aquatic Veg	3	FALSE
MargVeg In Current	3	FALSE
MargVeg Out Of Current	4	FALSE
Gravel	1	FALSE
Sand	3	FALSE
Mud	4	FALSE
Hand picking/Visual observation	YES	
OVERALL BIOTOPE SUITABILITY	64%	Category: B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1		1	1	1
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6	B	B	B	B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6	A			A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4	A	B	A	A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10		1		1
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	A		B	B
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3	A	A		A
Corixidae* (Water boatmen)	3	A		1	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		A		A
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4			A	A
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5	1			1
Elmidae/Dryopidae* (Riffle beetles)	8	A	1	A	A
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		A		A
Chironomidae (Midges)	2				
Culicidae* (Mosquitoes)	1	A	A	A	A
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		A	A	A
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					74
No. of Taxa			10	9	15
ASPT			-		4.9
Other biota:					

Comments/Observations:
Tedpole and fish were also caught

Date (dd:mm:yr):	23-Aug-19			(dd.ddddd)	Biotopes Sampled (tick & rate)	Rating	Weight
Site Code:	B3ELAN-SPRIN	Grid reference (dd mm ss.s) Lat:	S	25.408d	Stones In Current (SIC)	2	FALSE
Collector/Sampler:	ASHLA, BISMARK & MATIMBA	Long:	E 28°34'8.40"E	28.569d	Stones Out Of Current (SOOC)	2	FALSE
River:	Elands	Datum (WGS84/Cape):			Bedrock	2	FALSE
Level 1 Ecoregion:		Altitude (m):			Aquatic Veg	2	FALSE
Quaternary Catchment:	Upper Olifants	Zonation:	Lowland River		MargVeg In Current	4	FALSE
	Temp (°C): 13.6	Routine or Project? (circle one)	Flow:	Trickle	MargVeg Out Of Current	4	FALSE
Site Description:	pH: 8.4	Project Name:	Clarity (cm):	no equipment to measur	Gravel	3	FALSE
The site is used a drinking spot by livestock. As a result different livestock pathways have been created.	DO (mg/L): 8.8	REMP GAUTENG Province	Turbidity:	Medium	Sand	3	FALSE
	Cond (mS/m): 323.6		Colour:	Light Browm	Mud	3	FALSE
	Riparian Disturbance:	Livestock have created a path way to cross the stream			Hand picking/Visual observation	Yes	Category
	Instream Disturbance:	Livestock have created a path way to cross the stream			OVERALL BIOTOPE SUITABILITY	64%	B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3	1		1	A
ANNELIDA					
Oligochaeta (Earthworms)	1				
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8		1		1
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6		B	B	B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6	A			A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4	A	B	1	B
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6	B	A		B
Libellulidae (Darters/Skimmers)	4	B	1		B
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7		B		B
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5		A		A
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	B		A	B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					51
No. of Taxa					10
ASPT					5.1

Other biota:

P.Philander C Fish

Tadpole

Comments/Observations:

ORP 40.0

Date (dd:mm:yr):	27-Feb-19				(dd.ddddd)
Site Code:	B3ELAN-DETWE	Grid reference (dd mm ss.s) Lat:	S		25.551d
Collector/Sampler:	MBALI & ANDISWA	Long:	E	28°34'4.80"E	28.568d
River:	Elands	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:			

Site Description:	Temp (°C):	20.0	Routine or Project? (circle one)	Flow:	Low
	pH:	8.0	Project Name:	Clarity (cm):	
	DO (mg/L):	8.6		Turbidity:	
	Cond (mS/m):	648.2		Colour:	Clear
	Riparian Disturbance:				
	Instream Disturbance:				

Biotopes Sampled (tick & rate)	Rating	Weight		
Stones In Current (SIC)	3	FALSE		
Stones Out Of Current (SOOC)	3	FALSE		
Bedrock	1	FALSE		
Aquatic Veg	3	FALSE		
MargVeg In Current	3	FALSE		
MargVeg Out Of Current	3	FALSE		
Gravel	3	FALSE		
Sand	3	FALSE		
Mud	2	FALSE		
Hand picking/Visual observation	Yes			Category
OVERALL BIOTOPE SUITABILITY			64%	B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	1	1	A	A
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3	A	1		A
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12	A			A
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12	B	A	A	B
Caenidae (Squaregills/Cainfles)	6	B	A	A	B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13	A	A	B	B
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	1			1
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10	A	A		A
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4	1	B		1
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8	1	1		A
Gomphidae (Clubtails)	6	A	A	A	B
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3		A	A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12	A		A	B
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6	A			A
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	1	1	A	A
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10	A			A

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5	1	1		A
Chironomidae (Midges)	2	B	B	B	B
Culicidae* (Mosquitoes)	1	1	A		A
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	B	B	A	B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6			A	A
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5		1	1	A
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					144
No. of Taxa					22
ASPT					6.5
Other biota:					

Comments/Observations:

Date (dd:mm:yr):	07-Jun-19				(dd.ddddd)
Site Code:	B3ELAN-DETWE	Grid reference (dd mm ss.s) Lat:	S		25.551d
Collector/Sampler:	MBALI & ANDISWA	Long:	E	28°34'4.80"E	28.568d
River:	Elands	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:			

Temp (°C):	14.0	**Routine or Project? (circle one)**	Flow:	Low
pH:	8.1	Project Name:	Clarity (cm):	
DO (mg/L):	8.8		Turbidity:	
Cond (mS/m):	320.5		Colour:	Clear
Riparian Disturbance:				
Instream Disturbance:				

Site Description:

Biotopes Sampled (tick & rate)	Rating	Weight		Category
Stones In Current (SIC)		FALSE		
Stones Out Of Current (SOOC)		FALSE		
Bedrock		FALSE		
Aquatic Veg		FALSE		
MargVeg In Current		FALSE		
MargVeg Out Of Current		FALSE		
Gravel		FALSE		
Sand		FALSE		
Mud		FALSE		
Hand picking/Visual observation				
OVERALL BIOTOPE SUITABILITY			64%	B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1			A	A
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3	1			1
Atyidae (Freshwater Shrimps)	8	A	1	1	A
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8	A			A
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12	B	A	B	B
Caenidae (Squaregills/Cainfles)	6	B	1	A	B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13	A	1	A	B
Leptophlebiidae (Prongills)	9	B	A	A	B
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	A		1	A
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10		1		1
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A	1	A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	A			A
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6	A	1	A	A
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3		A		A
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7		1	1	A
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		A	1	A
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6		A	A	
Hydropsychidae > 2 sp	12	A			B
Philopotamidae	10	A		1	A
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6	1	A		A
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8	1		1	A
Gyrinidae* (Whirligig beetles)	5		A	A	B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10	1		1	A

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	A		A	A
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	A	A	A	B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5	1			1
Tipulidae (Crane flies)	5	1		1	A
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					180
No. of Taxa					26
ASPT					6.9

Other biota:

Comments/Observations:

Date (dd:mm:yr):	23-Aug-19				(dd.ddddd)
Site Code:	B3ELAN-DETWE	Grid reference (dd mm ss.s) Lat:	S		25.551d
Collector/Sampler:	MBALI & ANDISWA	Long:	E	28°34'4.80"E	28.568d
River:	Elands	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:			

Site Description:	Temp (°C):	13.8	Routine or Project? (circle one)	Flow:	Low
	pH:	8.2	Project Name:	Clarity (cm):	
	DO (mg/L):	8.8		Turbidity:	Very low
	Cond (mS/m):	305.1		Colour:	Clear
	Riparian Disturbance:				
	Instream Disturbance:				

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	3	FALSE
Stones Out Of Current (SOOC)	3	FALSE
Bedrock	1	FALSE
Aquatic Veg	1	FALSE
MargVeg In Current	2	FALSE
MargVeg Out Of Current	2	FALSE
Gravel	3	FALSE
Sand	3	FALSE
Mud	2	FALSE
Hand picking/Visual observation	Yes	
OVERALL BIOTOPE SUITABILITY	64%	Category: B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3	A			A
ANNELIDA					
Oligochaeta (Earthworms)	1	A	A	B	B
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3	A	1		A
Atyidae (Freshwater Shrimps)	8		A		A
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12	A			A
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12	B	B	B	B
Caenidae (Squaregills/Cainfles)	6	B	A	A	B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13	A	1		A
Leptophlebiidae (Prongills)	9	A	1	A	B
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	A			A
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10	A	A		A
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4	1	B		B
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8	1	1		A
Gomphidae (Clubtails)	6	A	A	A	B
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3			A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6			1	
Hydropsychidae > 2 sp	12	B			B
Philopotamidae	10	A			A
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6	A			A
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		1		1
Chironomidae (Midges)	2	A	B	B	B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	B	A	A	B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6		A	A	A
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5	1		A	A
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					174
No. of Taxa					26
ASPT					6.7
Other biota:					

Comments/Observations:

Fish sampled; Flows very low; no solid waste disposal

Date (dd:mm:yr):	27-Feb-19					(dd.ddddd)
Site Code:	B3ELAN-DOORN	Grid reference (dd mm ss.s)	Lat:	S		25.575d
Collector/Sampler:	ARINAO & BISMARK		Long:	E	28°34'37.20"E	28.577d
River:	Elands		Datum (WGS84/Cape):			
Level 1 Ecoregion:			Altitude (m):			
Quaternary Catchment:	Upper Olifants		Zonation:		Lowland river	

Site Description:
the site is found with small livestock farming area. The area is less developed with sparsely farm houses.

Temp (°C):	16.7	Flow:	Low
pH:	8.2	Clarity (cm):	no eqiupment to measur
DO (mg/L):	8.8	Turbidity:	Medium
Cond (mS/m):	304.4	Colour:	Normal Transparent
Riparian Disturbance:	None		
Instream Disturbance:	None		

Routine or Project? (circle one)
Project Name: REMP GAUTENG PROVINCE

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	4	FALSE
Stones Out Of Current (SOOC)	4	FALSE
Bedrock	0	FALSE
Aquatic Veg	2	FALSE
MargVeg In Current	3	FALSE
MargVeg Out Of Current	3	FALSE
Gravel	3	FALSE
Sand	3	FALSE
Mud	3	FALSE
Hand picking/Visual observation	YES	
OVERALL BIOTOPE SUITABILITY	64%	Category B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	1			1
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3	1			1
Atyidae (Freshwater Shrimps)	8		A		A
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4		1		1
Baetidae 2 sp	6				
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6	A			A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13	A		A	B
Leptophlebiidae (Prongills)	9	A		1	A
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	A	1	1	B
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6		A	A	B
Libellulidae (Darters/Skimmers)	4	1			1
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3		A		A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3		1		1
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	A	1	A	B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10	1			1

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5	1	1	1	A
Chironomidae (Midges)	2	A	A	A	B
Culicidae* (Mosquitoes)	1			1	1
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		A	A	A
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5	A			A
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5		1		1
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					105
No. of Taxa		13	6	9	20
ASPT			-		5.3

Other biota:
Fish (T.Spar and mosquito fish)

Comments/Observations:
TDS 198.25, ORP 192.1

Date (dd:mm:yr):	07-Jun-19				(dd.ddddd)
Site Code:	B3ELAN-DOORN	Grid reference (dd mm ss.s) Lat:	S		25.575d
Collector/Sampler:	ARINAO & BISMARK	Long:	E	28°34'37.20"E	28.577d
River:	Elands	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:			

Temp (°C):	14.8	**Routine or Project? (circle one)**	Flow:	Low
pH:	7.9	Project Name:	Clarity (cm):	
DO (mg/L):	10.7		Turbidity:	
Cond (mS/m):	657.4		Colour:	Clear
Riparian Disturbance:	None			
Instream Disturbance:	None			

Site Description:

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	4	FALSE
Stones Out Of Current (SOOC)	3	FALSE
Bedrock	2	FALSE
Aquatic Veg	3	FALSE
MargVeg In Current	1	FALSE
MargVeg Out Of Current	3	FALSE
Gravel	3	FALSE
Sand	3	FALSE
Mud	2	FALSE
Hand picking/Visual observation	YES	
OVERALL BIOTOPE SUITABILITY	64%	Category: B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	A		A	A
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3			1	1
Atyidae (Freshwater Shrimps)	8	1		1	1
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12	A	A		A
Caenidae (Squaregills/Cainfles)	6	A	1	A	A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13	A		A	A
Leptophlebiidae (Prongills)	9			A	A
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	A			A
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8			1	1
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4	1			1
Veliidae/M...veliidae* (Ripple bugs)	5		A	A	A
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4			A	A
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	A	A	A	A
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2				
Culicidae* (Mosquitoes)	1	1			1
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		B		A
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5			1	1
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5			1	1
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					103
No. of Taxa			5	12	17
ASPT			-		6.1

Other biota:

Comments/Observations:

Date (dd:mm:yr):	23-Aug-19				(dd.ddddd)
Site Code:	B3ELAN-DOORN	Grid reference (dd mm ss.s) Lat:	S		25.575d
Collector/Sampler:	ASHLA, BISMARK & MATIMBA	Long:	E	28°34'37.20"E	28.577d
River:	Elands	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:		Lowland river	

Temp (°C):	16.7	**Routine or Project? (circle one)**	Flow:	Low
pH:	8.2	Project Name:	Clarity (cm):	no eqiupment to measur
DO (mg/L):	8.8	REMP GAUTENG PROVINCE	Turbidity:	Medium
Cond (mS/m):	304.4		Colour:	Normal Transparent
Riparian Disturbance:		None		
Instream Disturbance:		None		

Site Description:
the site is found with small livestock farming area. The area is less developed with sparsely farm houses.

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	4	FALSE
Stones Out Of Current (SOOC)	4	FALSE
Bedrock	0	FALSE
Aquatic Veg	2	FALSE
MargVeg In Current	3	FALSE
MargVeg Out Of Current	3	FALSE
Gravel	3	FALSE
Sand	3	FALSE
Mud	3	FALSE
Hand picking/Visual observation	YES	
OVERALL BIOTOPE SUITABILITY		64%

Category: B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	A			A
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3	1			1
Atyidae (Freshwater Shrimps)	8		A		A
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4		A		A
Baetidae 2 sp	6				
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6	A			A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13	A		A	B
Leptophlebiidae (Prongills)	9	A		A	B
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	A		A	B
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6	A		A	B
Libellulidae (Darters/Skimmers)	4	1			1
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3		A		A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3		1		1
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	A	1	A	B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10	1			1

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		1	1	A
Chironomidae (Midges)	2	A	A	A	B
Culicidae* (Mosquitoes)	1			1	1
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	A			A
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5	A			A
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5			1	1
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					105
No. of Taxa		13	6	9	20
ASPT			-		5.2

Other biota:
Fish (T.Spar and mosquito fish)

Comments/Observations:
TDS 198.25, ORP 192.1

Date (dd:mm:yr):	26-Feb-19				(dd.ddddd)
Site Code:	B2BRON-KLIPE	Grid reference (dd mm ss.s) Lat:	S	25°49'40.80"	25.828d
Collector/Sampler:	Mbali & Andiswa	Long:	E	28°43'1.20"	28.717d
River:	Bronkhorstspriut	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:			

Temp (°C):	21.2	Routine or Project? (circle one)	Flow:	Medium
pH:	7.9	Project Name:	Clarity (cm):	
DO (mg/L):	8.4	GAUTENG REMP	Turbidity:	Low
Cond (mS/m):	620.5		Colour:	Clear

Site Description: the site has a low lying bridge of a gravel road and is within a small holding farming area.

Riparian Disturbance: NONE

Instream Disturbance: The instream flow has been affected by water hycenth water hyacinth (*Eichhornia crassipes*)

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	4	FALSE
Stones Out Of Current (SOOC)	4	FALSE
Bedrock	0	FALSE
Aquatic Veg	3	FALSE
MargVeg In Current	3	FALSE
MargVeg Out Of Current	3	FALSE
Gravel	2	FALSE
Sand	3	FALSE
Mud	1	FALSE
Hand picking/Visual observation	Yes	

		Category
OVERALL BIOTOPE SUITABILITY	64%	B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3	A	A		A
ANNELIDA					
Oligochaeta (Earthworms)	1	A	A	A	B
Hirudinea (Leeches)	3	A		A	A
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8	A			A
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12	A	A	A	B
Caenidae (Squaregills/Cainfles)	6	B	B	A	B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A		A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	A			A
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6	A		A	A
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3		A	A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		A	A	A
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4	A		A	B
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	A	B		B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	A		A	B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	A	A	A	B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6	A	A	A	B
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3	A		A	B
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					86
No. of Taxa		14			17
ASPT					5.1

Other biota:

Comments/Observations: Algae covering biotopes

Date (dd:mm:yr):	06-Jun-19			(dd.ddddd)	**Biotopes Sampled (tick & rate)**	Rating	Weight
Site Code:	B2BRON-KLIPE	Grid reference (dd mm ss.s) Lat:	S	25°49'40.80"	25.828d	Stones In Current (SIC)	4	FALSE
Collector/Sampler:	Arinao & Bismark	Long:	E	28°43'1.20"	28.717d	Stones Out Of Current (SOOC)	4	FALSE
River:	Bronkhorstspriut	Datum (WGS84/Cape):				Bedrock	0	FALSE
Level 1 Ecoregion:		Altitude (m):				Aquatic Veg	3	FALSE
Quaternary Catchment:	Upper Olifants	Zonation:				MargVeg In Current	3	FALSE

Temp (°C):	12.3	**Routine or Project? (circle one)**	Flow:	Medium	MargVeg Out Of Current	3	FALSE
pH:	7.9	Project Name:	Clarity (cm):		Gravel	2	FALSE
DO (mg/L):	8.5	GAUTENG REMP	Turbidity:	Low	Sand	3	FALSE
Cond (mS/m):	316.0		Colour:	Normal Transparent	Mud	1	FALSE

Site Description:
the site has a low lying bridge of a gravel road and is within a small holding farming area.

Riparian Disturbance: NONE

Instream Disturbance: The instream flow has been affected by water hycenth water hyacinth (*Eichhornia crassipes*)

Hand picking/Visual observation: YES

OVERALL BIOTOPE SUITABILITY: 64% — Category: B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	A		A	A
Hirudinea (Leeches)	3	A	A	A	A
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8		A		A
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6	B	B	B	B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6	A	A	1	A
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13	A			A
Leptophlebiidae (Prongills)	9	A	A	1	A
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	B			B
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		B		B
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4	A			A
Veliidae/M...veliidae* (Ripple bugs)	5		1		1
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4	A		A	A
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5	A	B		A
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5			1	1
Chironomidae (Midges)	2	A	A	A	A
Culicidae* (Mosquitoes)	1	A			A
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	A	A		A
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6	A			A
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					91
No. of Taxa					18
ASPT					5.1

Other biota:

Comments/Observations:

Date (dd:mm:yr):	22-Aug-19						(dd.ddddd)
Site Code:	B2BRON-KLIPE		Grid reference (dd mm ss.s)	Lat:	S	25°49'40.80"	25.828d
Collector/Sampler:	Arinao & Bismark			Long:	E	28°43'1.20"	28.717d
River:	Bronkhorstspriut			Datum (WGS84/Cape):			
Level 1 Ecoregion:				Altitude (m):			
Quaternary Catchment:	Upper Olifants			Zonation:			
	Temp (°C):	13.9	Routine or Project? (circle one)	Flow:		Medium	
Site Description:	pH:	8.1	Project Name:	Clarity (cm):			
the site has a low lying bridge of a gravel road and is within a small holding farming area. It is downstream of the Bronkhorstspriut Dam	DO (mg/L):	7.9	REMP Gauteng Province	Turbidity:		Medium	
	Cond (mS/m):	336.9		Colour:		Normal Transparent	
	Riparian Disturbance:		NONE				
	Instream Disturbance:		Bridge of a Gravel road crossing the stream with two culverts function properly				

Biotopes Sampled (tick & rate)	Rating	Weight		
Stones In Current (SIC)	4	FALSE		
Stones Out Of Current (SOOC)	4	FALSE		
Bedrock	0	FALSE		
Aquatic Veg	3	FALSE		
MargVeg In Current	1	FALSE		
MargVeg Out Of Current	3	FALSE		
Gravel	2	FALSE		
Sand	3	FALSE		
Mud	1	FALSE		
Hand picking/Visual observation	YES			Category
OVERALL BIOTOPE SUITABILITY			64%	B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	A		A	B
Hirudinea (Leeches)	3	B			B
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8			1	1
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6	A	B	A	B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6	A	A		B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	A	1	A	B
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A		A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5				
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6	A			A
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8		1		1
Gyrinidae* (Whirligig beetles)	5		A	A	B
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	A	A		B
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5		B		B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5	1			1
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6	A			A
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5	B			B
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					79
No. of Taxa			8	5	15
ASPT					5.2

Other biota:

Tadpole

Comments/Observations:

Date (dd:mm:yr):	26-Feb-19				(dd.ddddd)
Site Code:	B2BRON-MOOIF	Grid reference (dd mm ss.s) Lat:	S	28°42'28.80"	28.708d
Collector/Sampler:	ASHLA & BISMARK	Long:	E	28°42'28.80"	28.708d
River:	Bronkhorstspriut	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:			
	Temp (°C): 4.4	**Routine or Project? (circle one)**	Flow:	medium	
Site Description:	pH: 8.1	Project Name:	Clarity (cm):		
	DO (mg/L): 4.0		Turbidity:		
	Cond (mS/m): 670.4		Colour:	clear	
	Riparian Disturbance:	NONE			
	Instream Disturbance:	NONE			

Biotopes Sampled (tick & rate)	Rating	Weight		
Stones In Current (SIC)	4	FALSE		
Stones Out Of Current (SOOC)	4	FALSE		
Bedrock	0	FALSE		
Aquatic Veg	3	FALSE		
MargVeg In Current	1	FALSE		
MargVeg Out Of Current	3	FALSE		
Gravel	3	FALSE		
Sand	3	FALSE		
Mud	3	FALSE		
Hand picking/Visual observation	YES			Category
OVERALL BIOTOPE SUITABILITY			64%	B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	B	B	B	B
Hirudinea (Leeches)	3		B	A	B
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3		A	1	A
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6	A	A	B	B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	1		1	1
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		1		1
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3	1	A	A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		A		A
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5		A		A
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		A	A	A
Chironomidae (Midges)	2	A	A	B	B
Culicidae* (Mosquitoes)	1		1	A	A
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	B	C	B	B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					52
No. of Taxa			12	10	13
ASPT			-		4.0
Other biota:					

Comments/Observations:

Date (dd:mm:yr):	06-Jun-19				(dd.ddddd)
Site Code:	B2BRON-MOOIF	Grid reference (dd mm ss.s) Lat:	S	28°42'28.80"	28.708d
Collector/Sampler:	ASHLA & BISMARK	Long:	E	28°42'28.80"	28.708d
River:	Bronkhorstspriut	Datum (WGS84/Cape):			
Level 1 Ecoregion:		Altitude (m):			
Quaternary Catchment:	Upper Olifants	Zonation:			

Temp (°C):	9.5	**Routine or Project? (circle one)**	Flow: medium
pH:	7.7	Project Name:	Clarity (cm):
DO (mg/L):	4.4		Turbidity:
Cond (mS/m):	604.5		Colour: clear
Riparian Disturbance:	NONE		
Instream Disturbance:	NONE		

Site Description:

Biotopes Sampled (tick & rate)	Rating	Weight
Stones In Current (SIC)	4	FALSE
Stones Out Of Current (SOOC)	4	FALSE
Bedrock	0	FALSE
Aquatic Veg	3	FALSE
MargVeg In Current	1	FALSE
MargVeg Out Of Current	3	FALSE
Gravel	3	FALSE
Sand	3	FALSE
Mud	3	FALSE
Hand picking/Visual observation	YES	
OVERALL BIOTOPE SUITABILITY	64%	Category: B

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	B	A	B	B
Hirudinea (Leeches)	3			A	A
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3		A		A
Atyidae (Freshwater Shrimps)	8				
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA (Mites)	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6	B	A	B	B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	1			1
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		1		1
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3		A	A	A
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7				
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		1		1
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5		1		1
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5		A	A	A
Chironomidae (Midges)	2	A	A	B	B
Culicidae* (Mosquitoes)	1		1	A	A
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	B	C	B	B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5				
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6	1	A		A
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3				
Viviparidae* ST	5				
PELECYPODA (Bivalves)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score					58
No. of Taxa					14
ASPT					4.2
Other biota:					

Comments/Observations:

Date (dd:mm:yr):	22-Aug-19					(dd.ddddd)	
Site Code:	B2BRON-MOOIF	Grid reference (dd mm ss.s) Lat:	S	28°42'28.80"	28.708d		
Collector/Sampler:	ASHLA & MATIMBA	Long:	E	28°42'28.80"	28.708d		
River:	Bronkhorstspriut	Datum (WGS84/Cape):					
Level 1 Ecoregion:		Altitude (m):					
Quaternary Catchment:	Upper Olifants	Zonation:		Lowland River			
	Temp (°C): 13.6	**Routine or Project? (circle one)**		Flow:	Medium		
Site Description:	pH: 8.0	Project Name:		Clarity (cm):			
The site has a bridge of a gravel road and is within a farming area. It is upstream of the Bronkhorstspriut Dam	DO (mg/L): 4.0	REMP Gauteng Province		Turbidity:	Medium		
	Cond (mS/m): 665.0			Colour:	Light Green		
	Riparian Disturbance:	NONE					
	Instream Disturbance:	NONE					

Biotopes Sampled (tick & rate)	Rating	Weight		
Stones In Current (SIC)	4	FALSE		
Stones Out Of Current (SOOC)	4	FALSE		
Bedrock	0	FALSE		
Aquatic Veg	3	FALSE		
MargVeg In Current	1	FALSE		
MargVeg Out Of Current	3	FALSE		
Gravel	3	FALSE		
Sand	3	FALSE		
Mud	3	FALSE		
Hand picking/Visual observation	YES			Category
OVERALL BIOTOPE SUITABILITY			64%	B

Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5					**HEMIPTERA (Bugs)**						**DIPTERA (Flies)**					
COELENTERATA (Cnidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3					Corixidae* (Water boatmen)	3					Blepharoceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5				
Oligochaeta (Earthworms)	1		B	B	B	Hydrometridae* (Water measurers)	6					Chironomidae (Midges)		B	B	A	B
Hirudinea (Leeches)	3	B	B		B	Naucoridae* (Creeping water bugs)	7					Culicidae* (Mosquitoes)	1		A	A	B
CRUSTACEA						Nepidae* (Water scorpions)	3					Dixidae* (Dixid midge)	10				
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3					Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3		1		1	Pleidae* (Pygmy backswimmers)	4					Ephydridae (Shore flies)	3				
Atyidae (Freshwater Shrimps)	8					Veliidae/M...veliidae* (Ripple bugs)	5					Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10					**MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)**						Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8					Corydalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5				
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1				
Notonemouridae	14					**TRICHOPTERA (Caddisflies)**						Tabanidae (Horse flies)	5				
Perlidae	12					Dipseudopsidae	10					Tipulidae (Crane flies)	5				
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					**GASTROPODA (Snails)**					
Baetidae 1sp	4					Hydropsychidae 1 sp	4					Ancylidae (Limpets)	6	A	A	A	B
Baetidae 2 sp	6					Hydropsychidae 2 sp	6					Bulininae*	3				
Baetidae > 2 sp	12					Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Cainfles)	6					Philopotamidae	10					Lymnaeidae* (Pond snails)	3				
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flatheaded mayflies)	13					Psychomyiidae/Xiphocentronidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9					**Cased caddis:**						Thiaridae* (=Melanidae)	3				
Oligoneuridae (Brushlegged mayflies)	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					**PELECYPODA (Bivalvles)**					
Prosopistomatidae (Water specs)	15					Glossosomatidae SWC	11					Corbiculidae (Clams)	5				
Teloganodidae SWC (Spiny Crawlers)	12					Hydroptilidae	6					Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9					Hydrosalpingidae SWC	15					Unionidae (Perly mussels)	6				
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					**SASS Score**					22
Calopterygidae ST,T (Demoiselles)	10					Leptoceridae	6	A			A	**No. of Taxa**			6	4	7
Chlorocyphidae (Jewels)	10					Petrothrincidae SWC	11					**ASPT**					3.1
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					**Other biota:**					
Coenagrionidae (Sprites and blues)	4					Sericostomatidae SWC	13					NONE					
Lestidae (Emerald Damselflies/Spreadwings)	8					**COLEOPTERA (Beetles)**											
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5										
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8										
Aeshnidae (Hawkers & Emperors)	8					Gyrinidae* (Whirligig beetles)	5					**Comments/Observations:**					
Corduliidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5					TDS 429 & DO 37.8%.					
Gomphidae (Clubtails)	6					Helodidae (Marsh beetles)	12										
Libellulidae (Darters/Skimmers)	4					Hydraenidae* (Minute moss beetles)	8										
LEPIDOPTERA (Aquatic Caterpillars/Moths)						Hydrophilidae* (Water scavenger beetles)	5										
Crambidae (Pyralidae)	12					Limnichidae (Marsh-Loving Beetles)	10										
						Psephenidae (Water Pennies)	10										

APPENDIX B: MIRAI SUMMARY

Summary of the MIRAI model for bio-monitoring Site B3ELAND-SPRIN (R57)

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	54.4	*0.310*	16.8687	2	90
HABITAT	H	61.8	*0.345*	21.3014	1	100
WATER QUALITY	WQ	33.8	*0.345*	11.6484	1	100
CONNECTIVITY & SEASONALITY	CS	100.0	*0.000*	0	3	0
						290
INVERTEBRATE EC				49.8186		
INVERTEBRATE EC CATEGORY				D		
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						

Summary of the MIRAI model for bio-monitoring Site B3ELAND-DETWE

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	FM	70.9	*0.333*	23.6364	1	100
HABITAT	H	69.4	*0.333*	23.1183	1	100
WATER QUALITY	WQ	69.3	*0.333*	23.1061	1	100
CONNECTIVITY & SEASONALITY	CS	80.0	*0.000*	0	0	0
						300
INVERTEBRATE EC				69.8607		
INVERTEBRATE EC CATEGORY				C		
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						

Summary of the MIRAI model for bio-monitoring Site B3ELAND-DOORN

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	**FM**	59.4	*0.345*	20.4672	1	100
HABITAT	**H**	60.2	*0.310*	18.6692	2	90
WATER QUALITY	**WQ**	53.1	*0.345*	18.3142	1	100
CONNECTIVITY & SEASONALITY	**CS**	80.0	*0.000*	0	0	0
						290
INVERTEBRATE EC				57.4505		
INVERTEBRATE EC CATEGORY				D		
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						

Summary of the MIRAI model for bio-monitoring Site B2BRON-KLIPE

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	**FM**	56.8	*0.339*	19.2455	1	100
HABITAT	**H**	67.6	*0.305*	20.6178	2	90
WATER QUALITY	**WQ**	41.7	*0.339*	14.1243	1	100
CONNECTIVITY & SEASONALITY	**CS**	80.0	*0.017*	1.35593	3	5
						295
INVERTEBRATE EC				55.3435		
INVERTEBRATE EC CATEGORY				D		
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						

Summary of the MIRAI model for bio-monitoring Site B2BRON-MOOIF

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	**FM**	39.8	*0.339*	13.5046	1	100
HABITAT	**H**	46.9	*0.305*	14.3193	2	90
WATER QUALITY	**WQ**	22.3	*0.339*	7.54641	1	100
CONNECTIVITY & SEASONALITY	**CS**	80.0	*0.017*	1.35593	3	5
						295
INVERTEBRATE EC				36.7263		
INVERTEBRATE EC CATEGORY				E		
>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F						