water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Report Number: P WMA 04/B50/00/8310/7

DEVELOPMENT OF A RECONCILIATION STRATEGY FOR THE OLIFANTS RIVER WATER SUPPLY SYSTEM

WP10197

Water Quality Report

Original

FINAL REPORT

December 2011

DEVELOPMENT OF A RECONCILIATION STRATEGY FOR THE OLIFANTS RIVER WATER SUPPLY SYSTEM

WP10197

Water Quality Report

Report no.: P WMA 04/B50/00/8310/7

Prepared by:

aurecon

Contact person:
WP Comrie
Aurecon Centre,
Lynnwood Bridge Office Park,
4 Daventry Street, Lynnwood Manor, 0081, South Africa

T: +27 12 427 3108
F: +27 86 764 3649
M: +27 82 808 0435
E: Werner.Comrie@aurecongroup.com

In association with

ILISO Consulting (Pty) Ltd

MBB Consulting Services (Nelspruit) (Pty) Ltd

WFA Aquatic Ecology (Pty) Ltd

Chuma Development Consultants CC

WFA Water Resources (Pty) Ltd

Submitted
December 2011

PROJECT NAME	**:**	**DEVELOPMENT OF A RECONCILIATION STRATEGY FOR THE OLIFANTS RIVER WATER SUPPLY SYSTEM (WP 10197)**
REPORT TITLE	**:**	WATER QUALITY REPORT
AUTHORS	**:**	M Van Veelen and Ndomupei Dhemba
REPORT STATUS	**:**	Final Report
REPORT NO.	**:**	P WMA 04/B50/00/8310/7
DATE	**:**	December 2011

Submitted by:

2011.12.09

M VAN VEELEN
ILISO CONSULTING
(Date)

12-12-2011

J BEUMER
Study Leader - AURECON
(Date)

12-12-2011

W.P. COMRIE
Water Unit Manager - AURECON
(Date)

Approved for the Department of Water Affairs:

03-02-2012

T NDITWANI
Chief Water Resource Planner : NWRP (North)
(Date)

23/2/2012

J.A. VAN ROOYEN
Director NWRP
(Date)

LIST OF REPORTS

Title	Report Number
Inception Report	P WMA 04/B50/00/8310/1
Summary Report	P WMA 04/B50/00/8310/2
Extent of Invasive Alien Plants and Removal Options	P WMA 04/B50/00/8310/3
Future Water Reuse Possibilities	P WMA 04/B50/00/8310/4
Possible Water Conservation and Demand Management Measures	P WMA 04/B50/00/8310/5
Water Requirements and Water Resources	P WMA 04/B50/00/8310/6
Water Quality	**P WMA 04/B50/00/8310/7**
Preliminary Screening and Schemes to be investigated	P WMA 04/B50/00/8310/8
Management and Development Options and Cost Alternatives	P WMA 04/B50/00/8310/9
Groundwater Options	P WMA 04/B50/00/8310/10
Evaluation of Ecological Consequences of Various Scenarios	P WMA 04/B50/00/8310/11
Environmental Screening Report	P WMA 04/B50/00/8310/12
Preliminary Reconciliation Strategy	P WMA 04/B50/00/8310/13
Final Reconciliation Strategy	P WMA 04/B50/00/8310/14
Main Report with Executive Summaries of Reconciliation Strategies	P WMA 04/B50/00/8310/15
Yield Assessment of De Hoop and Flag Boshielo Dam	P WMA 04/B50/00/8310/16
Liability of the Responsible Authority for Changes in Yield Assessment	P WMA 04/B50/00/8310/17
EcoClassification of the 1999 Assessment at EWR Sites in the Olifants River (WMA4)	P WMA 04/B50/00/8310/18

Glossary of Terms

Allocatable Water
Water which is available to allocate for consumptive use.

Database
Accessible and internally consistent sets of data, either electronic or hard copy with spatial attributes wherever possible.

Environmental Water Requirement
The quantity, quality and seasonal patterns of water needed to maintain aquatic ecosystems within a particular ecological condition (management category), excluding operational and management considerations.

IWRM Objectives
The objectives and priorities for water resource management, for a given time frame, which have been agreed by the parties as those which will best support the agreed socio economic development plans for the basin.

IWRM Plans
A set of agreed activities with expected outcomes, time frames, responsibilities and resource requirements that underpin the objectives of IWRM.

Management Information System
Systems such as GIS which provide a user friendly interface between databases and information users.

Resource Classification
A process of determining the management class of resources by achieving a balance between the Reserve needs and the beneficial use of the resources.

Acid Mine Drainage
Decanting water from defunct mines which have become polluted and acidic and that reach the resource.

Level of Assurance
The probability that water will be supplied without any curtailments. The opposite of Level of Assurance is the risk of failure.

Internal Strategic Perspective
A DWA status quo report of the catchment outlining the current situation and how the catchment will be managed in the interim until a Catchment Management Strategy of a CMA is established.

List of Abbreviations & Acronyms

DEAT	Former Department of Environmental Affairs and Tourism (Rep. of South Africa)
DWA	Department of Water Affairs, Republic of South Africa
DWAF	Former Department of Water Affairs and Forestry, now the Department of Water Affairs, Republic of South Africa
EC	Electrical Conductivity
EMF	Environmental Management Framework
EMP	Environmental Management Plan
LBPTC	Limpopo Basin Permanent Technical Committee
ILISO	ILISO Consulting (Pty) Ltd
NEMP	National Eutrophication Monitoring Programme
NWRP	Department of Water Affairs and Forestry: Directorate of National Water Resource Planning
OLEMF	Olifants and Letaba Rivers Catchment Areas
ORF	Olifants River Forum
PCB	Poly Chlorinated Biphenyls
PCDD	Poly Chlorinated Dibenzo-p-Dioxins
PCDF	Poly Chlorinated Dibenzo Furans
POP	Persistent Organic Pollutants
RHP	River Health Programme
RSA	Republic of South Africa
RWQOs	Resource Water Quality Objectives
TDS	Total Dissolved Substances
WC	Water Conservation
WDM	Water Demand Management
WHO	World Health Organisation
WMA	Water Management Area
WRM	Water Resources Management
WWTW	Wastewater Treatment Works

EXECUTIVE SUMMARY

The purpose of this report is to document the outcomes of the Water Quality Assessment Task, Review of Water Quality of Surface Water Resources for the Development of a Reconciliation Strategy for the Olifants River System. This report is an assessment of the water quality situation in the Olifants River System in relationship to the land uses, activities, population, natural features, institutional arrangements, water quantity of the catchment and any other negative or positive impacts that will influence the water quality status.

The report focuses on the current water quality, but uses historical data to highlight "stresses" on the current water quality which illustrates whether there is deterioration or improvement of the water quality of the surface water in the Olifants River System

The upper part of the Olifants River catchment forms part of the Highveld and is composed of undulating plains and pans, and a large open flat area, referred to as the Springbok Flats. These areas are divided from the Lowveld by the escarpment, which consists of various hills and mountain terrain. The Lowveld consists mainly of plains and undulating plains. The catchment contains three basic rock types which are sedimentary, igneous and metamorphic. The most important economic potential lies in the mining of granite and gneiss for use as polished stone and the occurrence of gold, platinum and other minerals in the greenstone lavas.

There is significant mining, predominantly for coal, and other industrial activities around the Wilge, Bronkhorstspruit, Klein Olifants and Olifants Rivers, which are the main contributors to poor in-stream and riparian habitat conditions where acid leachate from mines is a primary contributor to poor water quality and instream conditions. Other water uses include domestic, livestock watering and, power generation.

Water quality is determined by the activities on the catchment, the land use and the geology. Water quality guidelines published by the Department as well as the water quality reserve were used to develop combined guidelines for the study area based on Domestic, Agriculture and Aquatic Ecosystem water guidelines.

The water quality in the study area is generally presents no problem with respect to irrigation urban use and industrial use, although there are some exceptions. The Middelburg Dam (station B1H004) is under pressure as reflected by the pH, levels of ammonia as well as nitrite/nitrate levels. The low pH levels may be due to acid rain as a result of mining activities in the study area. The high levels of ammonia and nitrate/nitrite levels may be due to use of fertilisers and is an important indicator of faecal pollution as a result of poor sewage treatment (WHO, 1996). The phosphates are slightly high throughout the study area, but within the acceptable range. This may be due to improper use of fertilisers as well as discharge of sewage into water sources. Although the hlorides are generally within the ideal range, trend analyses show that they are on an upward trend. This may be due to the various mining activities in the area.

The sulphate levels range between ideal and unacceptable with some of stations showing sulphate levels within unacceptable ranges (stations B1H020, B1H019, B1H005 in the Witbank Dam Catchment, stations B1H012 in the Wilge River and Loskop Dam Catchment and station B3H002 in the Middle Olifants Catchment). The results also show an upward trend in sulphates for most stations except stations B1H019, BH017, BH021, BH002 and

BH012. The high levels of sulphates may be due to use of ammonium sulphate fertilisers as well as mining activities in the area.

The EC values are also slightly high, but within acceptable and tolerable ranges. The trends analysis also shows EC as being in an upward trend for most of the stations. During the late 1990s there was a sudden increase in the electrical conductivity of the water in the Loskop Dam. This was maintained until 2005/2006, after which there has been a gradual reduction in electrical conductivity. This can possibly be related to the neutralisation of acid mine drainage water in the catchment, which was discontinued around 2005

Most of the dams in the Olifants River System are in a low trophic state, except for the Bronkohorstspruit Dam which is in a hypertrophic state. However, the Olifants River and the Loskop Dam are fast approaching eutrophic state. This may be due to the substantial sewage treatment plant return flow volumes in the Klipspruit, Witbank Dam and Witbank and Middelburg Dam to Loskop Dam catchments. The return flows contribute to the base flow into Loskop Dam and have been cited as a cause of eutrophication in the upper reaches of the Loskop Dam and the Klein Olifants River (DWA, 2004).

Table of Contents

List of Tables

List 0f Figures

Appendices

1. INTRODUCTION

The Olifants River is one of the main river systems in South Africa, and has been described as one of the most polluted rivers in Southern Africa, with the Loskop Dam acting as a repository for pollutants from the upper catchment of the Olifants River system (Grobler et al., 1994). Although previous and current studies have shown that the Olifants is indeed a polluted river, none of these studies have been used to look into the fitness for use of the surface water of the Olifants River System. Therefore the main objective of this study is to ascertain whether these water quality problems have any effect on the availability of acceptable quality of water for all users in the catchment, by making use of the water quality guidelines as developed by the DWA, South Africa (DWAF, 1996 - South African Water Quality Guidelines Volumes 1 to 7 (second edition)) as the main set of criterion for the evaluation process.

1.1 BACKGROUND TO THE RECONCILIATION STRATEGY STUDY

Water resource reconciliation studies involve an assessment of the availability, use, and future demands for water and how these can be ‘reconciled’ through various strategies. The Reconciliation Strategy Studies have the following objectives:

- Develop future water requirement scenarios for the Olifants River System;
- Investigate all possible water resources and interventions, which can be implemented to provide additional water;
- Investigate all possible methods for reconciling the requirements for water with the available resources;
- Provide recommendations for development and implementation of interventions and actions required; and
- Offer a system for continuous updating into the future.

1.2 PURPOSE OF THE STUDY

The objective of this study is to develop a strategy that will set out a course of action to ensure adequate and sustainable reconciliation of future water requirements in the Olifants River System for at least 25 years. This study will:

- Investigate future water requirements scenarios for the Olifants River System;
- Identify and address serious water quality problems;
- Investigate possible water resource development options;
- Identify and investigate possible water resource management interventions; and
- Provide recommendations for reconciling water availability and water requirements through reconciliation interventions which can be management or administrative/regulatory interventions or structural interventions.

1.3 PURPOSE OF THIS REPORT

The purpose of this report is to document the outcomes of the water quality Assessment Task for the Development of a Reconciliation Strategy for the Olifants River System. This report is an assessment of the water quality situation in the Olifants

River System in relation to the land uses, activities, population, natural features, institutional arrangements, water quality of the area and any other negative or positive impacts that will influence the water quality status.

The intention of this report is not to provide a detailed analysis of the water quality problems, potential problems and their causes, but rather to provide an overview of the fitness for use of the surface water of the Olifants River System.

1.4 STRUCTURE OF THE REPORT

This report begins with a summary of previous water quality studies in the study area, followed by a description of the study area and the existing water uses. This theme is continued with a discussion of the sources of potential pollution or contamination and the negative impacts this could have on the water quality.

The availability and collection of data and the process of the analysis of the data are then discussed as a prelude to the presentation of the results of the water quality assessment.

A presentation of the trophic and the ecological state follows with a view to understand the findings of other studies and put these into context with the water quality assessment.

The report ends with a final discussion, recommendations and conclusion of the water quality assessment. Although this report is a sub-study every effort has been made to structure this report as a “stand-alone” document.

2. PREVIOUS AND CURRENT WATER QUALITY STUDIES

A number of water quality studies have been conducted in the Olifants River catchment. A summary of recent and current water related studies in the Olifants catchment is provided in the Summary Report (Report No. P WMA 04/B50/00/8310/2 of this study).

2.1 REPORT TITLE: THE DEMISE OF THE NILE CROCODILE (*CROCODYLUS NILOTICUS*) AS A KEYSTONE SPECIES FOR AQUATIC ECOSYSTEM CONSERVATION IN SOUTH AFRICA: THE CASE OF THE OLIFANTS RIVER.

In 2009, CSIR conducted a study into the deaths of large numbers of the Nile crocodiles (*Crododylus niloticus*) at several points along the Olifants River. The Nile crocodile is considered a keystone species for the Olifants River (Joubert, 2007), making the crocodile deaths a major cause for concern.

In recent years the crocodile populations in several South African rivers and lakes have undergone severe setbacks (Branch, 1998) with particularly dramatic declines recorded for different sections of the Olifants River (Jacobsen, 1984; Swanepoel, 1999, 2001; Botha, 2006; Van Vuuren, 2009; Botha, 2010a, b). Recent surveys have shown that Nile crocodile populations have reached alarmingly low levels in the Loskop Dam and Flag Boshielo Dam and the lower reaches of the Olifants River, with far fewer large individuals of reproductive age recorded (Botha, 2006, 2010a, b). The available evidence suggests that habitat alteration and adverse water quality are responsible for these changes (Botha, 2010a, b).

Over the past 15 years isolated incidents of large-scale fish mortality have also been recorded at different times in the Loskop Dam, accompanied by occasional deaths of soft-shelled terrapins (*Pelusios sinuatus*). These incidents have become more frequent since 2003 and have coincided with Nile crocodile mortalities (Botha, 2006; Driescher, 2008). The most recent crocodile survey on the Loskop Dam suggests that the crocodile population has declined from approximately 30 animals in 1984 to a total of 8 in 2009, with no individuals of reproductive age present (Botha, 2010a). Histopathological examinations of Nile crocodile and terrapin carcasses from the Loskop Dam indicated that their deaths could be ascribed to pansteatitis, which is associated with the intake of rancid fish after a fish die-off (Ashton, 2010). In turn, the massive fish kills (each comprising several tonnes) in the Loskop Dam appear to have resulted from sporadic incidents of acid mine drainage flowing into the lake (Driescher, 2008; Oberholster et al., 2010).

The dam wall of the Flag Boshielo Dam, located downstream of the Loskop Dam, was raised by 5m in 2005. When the reservoir filled after heavy rains, rising water flooded extensive areas of marginal vegetation that had not been cleared from the dam basin during construction, eliminating most of the basking sites used by large crocodiles. In the absence of suitable shoreline sites, three large crocodiles attempted to bask on the crest of the dam’s main spillway and fell to their deaths (DWAF, 2006). Since the raising of the dam wall, Flag Boshielo’s Nile crocodile population has declined from approximately 135 individuals in 2005 to 98 in 2009, with many individuals retreating to refuges in tributary rivers (Botha, 2010a). Importantly, the numbers of large individuals of reproductive age were also greatly reduced. The largest recorded mortalities of Nile crocodiles along the lower reaches of the Olifants River and its gorge section inside the KNP, with 170 carcasses recorded in 2008 and a further 28 carcasses in 2009. Intensive studies of the water chemistry and sediment quality in areas where dead Nile crocodiles were found revealed elevated concentrations of aluminium and iron in the sediments, although no evidence was found for the presence of possible toxicants (Ashton, 2010).

While it may be relatively straightforward to identify a keystone species in a particular ecosystem, it is seldom as easy to identify the ecosystem functions of the species or the mechanisms by which it exerts influence on that ecosystem (Simberloff, 1998). An important issue is that when the population of a keystone species such as the Nile crocodile declines, it is seldom a simple matter to identify the precise cause. In the Olifants River, the available evidence suggests that there is a link between the already high and steadily increasing levels of water pollution and the sporadic fish kills that occur mainly during the winter months. In turn, the presence of pansteatitis in dead Nile crocodiles and terrapins suggests that this has been caused by the consumption of rancid fish (Oberholster et al., 2010). In combination, therefore, the evidence implicates sources of water pollution (excessively high concentrations of nutrients, organic compounds, metal ions and dissolved salts) as the most likely root cause for the Nile crocodile deaths.

According to Ashton, 2010, the Olifants River situation highlights the problem that arises when a single keystone species such as the Nile crocodile is used as the sole indicator of aquatic ecosystem health. Because of their stealthy nature and tendency to avoid interactions with humans, crocodiles are difficult to monitor accurately (Botha, 2010a). By the time that the death of one or more crocodiles indicates that an adverse effect has occurred, other harmful effects must have already happened at lower trophic levels, making it difficult to collect, disentangle and interpret the evidence to identify the original source of the problem.

2.2 REPORT TITLE: WATER RESOURCE PLANNING SYSTEM SERIES: WATER QUALITY PLANNING SUB SERIES NO. WQP 2.0 RESOURCE DIRECTED MANAGEMENT OF WATER QUALITY: PLANNING LEVEL REVIEW OF WATER QUALITY IN SOUTH AFRICA

2.2.1 Introduction

A number of water quality issues have been identified in previous studies conducted in the Olifants river catchment area. One of the studies was done by the Department of Water Affairs as part of the Water Resources Planning Systems Series. The study focused on the water quality status and trends in streams and rivers. The nineteen water management areas (WMAs), including the Olifants WMA, which form the major river basins of South Africa served as the basis for the water quality perspective assessment.

2.2.2 Purpose

The primary goals were to characterise the state of surface-water quality (river chemistry); determine temporal trends at those sites that have been consistently monitored for a decade (January 1999 to February 2008); and build an understanding of how natural features and human activities have affected the water quality of our water resources.

2.2.3 Approach

The methodology used involved comparing the in-stream water quality to a generic set of Resource Water Quality Objectives (RWQOs) for all users throughout all WMAs. Resource Water Quality Objectives (RWQOs) is a mechanism through which the balance between sustainable and optimal water use and protection of the water resource can be achieved. RWQOs are the water quality components of the Resource Quality Objectives (RQOs) which are defined by the National Water Act as “clear goals relating to the quality of the relevant water resources” (DWAF, 2006a).

Six parameters were selected to provide an indication of the fitness for use of water resources by the designated user groups. These include:

- **Electrical Conductivity (EC) (mS/m):** to provide an indication of salinisation of water resources (increase in salinisation of the country’s water resources);
- **Orthophosphate (PO_4-P) (mg/l)**: as an indicator of the nutrient levels in water resources (eutrophication is becoming a threat). Nitrate (NO_3+NO_2-N) (mg/l) was assessed but showed a 97% compliance to ideal RWQOs due to the fact that the upper limit is set at 6 mg/l based on the most sensitive user.
- **Sulphate (SO_4^{2-}) (mg/l)**: as an indicator of mining impacts. Sulphate is a major issue in many catchment areas;
- **Chloride (Cl-) (mg/l)**: as an indicator of agricultural impacts, sewage effluent discharges and industrial impacts;
- **Ammonia (NH_3-N) (mg/l)**: as an indicator of toxicity; and
- **pH (pH units)**: as an indicator for mining impacts as well as natural variability nationally.

In stream water quality of surface water resources was assessed using chemical monitoring data at a range of monitoring sites throughout the country (in each of the 19 WMAs) which was compared to a generic set of conservative level RWQOs to determine compliance for the selected water quality variables. The 95th percentile values were used to assess EC, sulphate, chloride, ammonia and pH compliance to the RWQOs, while the 50^{th} percentile values were used to assess phosphate compliance.

A generic set of RWQOs for the country’s surface water resources was used to assess compliance and determine current water quality status. While it is known that water resources vary considerably and different management RWQOs are in place in many catchment areas, it was necessary to provide a generic set of assessment RWQOs which would provide a consistent indication of fitness for use of water resources anywhere in the country. The RWQOs used for the compliance assessment were derived using the Resource Water Quality Objectives (RWQOs) Model (Version 4.0) (DWAF, 2006d) which uses as its basis the South African Water Quality Guidelines (DWAF, 1996), Quality of Domestic Water Supplies: Assessment Guide, Volume 1 (WRC, 1998) and Methods for determining the Water Quality Component of the Reserve (DWAF, 2008a) and are based on the strictest water user criteria and thus represent fairly conservative limits.

2.2.4 Findings

2.2.4.1 Olifants Water Quality Status

The water quality data covering the period 2006 to 2008 was analysed statistically and compared to Resource Water Quality Objectives (RWQOs) to determine the water quality variables of concern in the different parts of the catchment. Trends were also analysed for over the period 1999 to 2008. The analysis results highlight the following: -

- The salinity related impacts due to mining, power generation and industries in the upper areas of the WMA are highlighted with EC and sulphate concentrations at unacceptable levels.
- The unacceptable EC concentrations in the lower reaches of the Elands River are due to irrigation return flows and concentration due to evaporation of water from the low flows.
- The pH in places marginally exceeds the 8.4 upper limit. There are however localised acid conditions in sub-catchments associated with acid mine drainage. The acid mine drainage generally emanates from defunct coal mines.
- The trophic status in the dams is mesotrophic. However in the upper reaches of the Loskop Dam, eutrophic conditions have been observed. These have resulted in blooms of blue-green algae. The eutrophic conditions in the upper reaches of Loskop Dam are due to high nutrient inputs from the sewage works discharging below Witbank Dam.
- There are unacceptable phosphate concentrations in the Selati and in the lower Olifants below the Selati confluence. These are associated with sewage return flows and effluents from the mining and industrial activities around Phalaborwa.
- There is limited heavy metal concentration information in the catchment. The available data however shows unacceptably high levels in parts of the catchment. In fact high aluminium concentrations have been cited as a possible cause of the fish deaths in Loskop Dam.
- The intensive agricultural activities in the Elands and Moses River catchments could contribute pesticides and herbicides to the people downstream.

2.2.4.2 Water Quality Issues and Concerns in the Olifants Catchment

The following issues were identified during the study:

Water Quality Issues	Driver	Effect
Eutrophication	Waste water treatment works, intensive agriculture fertiliser use and dense urban sprawl un-serviced sewage	Algal growth, smell, toxic algae, water treatment extra costs, taste and odour, irrigation clogging, aesthetics, recreational water users
Microbial contamination	Waste water treatment works, informal dense settlements	Recreational users (human health), washing and bathing
Turbidity	Informal dense settlements urbanisation, mining, agriculture, point source discharge	Dam sedimentation, water treatment costs, irrigation clogging
Salinisation	Mines (operational and decommissioned), waste water treatment works, agricultural (intensive irrigation)	Increased water treatment costs, soil salinity, irrigation system clogging
Toxicants	Pesticides (subtropical fruits, nuts) industry	Fish kills, bio accumulation, KNP mammals
Altered flow regime	Dams and weirs	Turbidity (erosion), Algal growth, water temperature increase, dissolved oxygen changes, taste and odour changes, impact on recreational water users, Fish kills, changes in environmental flows
Acid mine drainage	Mines (operational and decommissioned), controlled releases	Mobilisation of metals, fish and crocodile kills, bio accumulation, KNP mammals
Metal contamination	Mines (operational and abandoned)	Mobilisation of metals, fish and crocodile kills, bio accumulation, KNP mammals

The findings of the abovementioned investigation are supported by the findings in the Olifants Water Management Area Internal Strategic Perspective, which states that the water quality problems in the Middle Olifants and Steelpoort sub-areas are salinity, eutrophication, toxicity and sediment. The salinity and eutrophication problems are due to the irrigation return flows, mining impacts and sewage treatment plant discharges. Pesticides and herbicides have been cited as the cause of the toxicity problems. The sediment is related to poor agricultural practice due to overgrazing in the rural areas. The production of sediment, particularly in the Middle Olifants sub-area causes operational problems at the downstream Phalaborwa Barrage. The release of water to maintain the base flow into the Kruger National Park (KNP) has led to fish kills due to the sediment laden waters.

In the Lower Olifants Sub-area, the water quality is influenced by the water quality of the return flows from the mining complex around Phalaborwa in the Ga-Selati River. This water quality is problematic and impacts on the Olifants River. The water emanating from the Blyde River is of ideal quality in terms of the identified uses, and together with the water from the Mohlapitse River that is of a comparable quality, maintains the water quality in the Olifants River in the KNP at an acceptable quality.

2.3 REPORT TITLE: OLIFANTS RIVER WATER RESOURCES DEVELOPMENT PROJECT: ENVIRONMENTAL IMPACT ASSESSMENT - WATER QUALITY ASSESSMENT. REPORT NO. P WMA 04/B50/00/3104. DEPARTMENT OF WATER AFFAIRS AND FORESTRY. PREPARED BY CSIR ENVIRONMENTEK. MARCH 2005.

2.3.1 Purpose

This specialist report deals with the anticipated water quality impacts of the De Hoop Dam and the evaluation of impacts related to the construction, maintenance and decommissioning of the dam, associated pipelines and realignment of a section of the R555 national road.

2.3.2 Major Findings

Water resources in the Olifants River are stressed, with water requirements for mining, agricultural and domestic supplies exceeding the current supply. Mean annual evaporation ranges from 1300 mm in the east (Lydenburg) to 1700 mm at the De Hoop Dam site in the west (Janse van Vuuren, et al., 2003). The ecological Reserve study indicates that the Steelpoort River is considered to be in a fair state for water quality. There are significant increases in total dissolved salts in the downstream areas of the river, which can be attributed to mining activities, irrigation and land use practices. There are concerns about heavy metal contamination from chromium and vanadium mining in the catchment. The existing mines use mainly Municipal and borehole water. Vast expansion of mining activity is expected in this area.

During low flow months, high TDS concentrations were recorded in the downstream end of the Steelpoort River. Nutrients were slightly elevated, probably as a result of treated domestic effluent from Burgersfort. Erosion and sedimentation have led to a reduction of available habitat, thereby reducing abundance, diversity and size class of fish. Turbidity and sedimentation also have affected invertebrates.

2.4 REPORT TITLE: ASSESSMENT OF WATER AVAILABILITY IN THE OLIFANTS WMA BY MEANS OF WATER RESOURCE RELATED MODELS: WATER QUALITY SITUATION ASSESSMENT ANALYSIS. REPORT NO. P WMA 04/B50/00/5607. DEPARTMENT OF WATER AFFAIRS AND FORESTRY. PREPARED BY SSI AND AFRICON (NOW ÁURECON) IN ASSOCIATION WITH KNIGHT PIESOLD, SIGODI MARAH MARTIN AND UMFULA WEMPILO. SEPTEMBER 2008.

2.4.1 Purpose

To provide general modelling and water resource evaluation services for allocable water quantification and to support integrated water resource planning for the Olifants Water Management Area (WMA). The report aims to characterise the water quality of the Lower Olifants WMA, by graphically representing key monitoring stations with their 50th percentile (P50) of certain problematic chemicals over space and over time.

2.4.2 Major Findings

Saline input: The water entering the main stem of the Olifants River via Flag Boshielo Dam is already salinised, with the exceedance of the Target Water Quality Range for TDS for more than 50% of the time.

Rooipoort Dam: The Total Water Quality Requirement for salinity is exceeded more than three-fold for 50% of the time at Zeekoegat, the site of the planned Rooipoort Dam, with even higher peak concentrations. This is a particular concern for the intended irrigation use.

Ga-Selati River: Extremely high salinity in the lower Ga-Selati River renders the water unfit for domestic and irrigation use. This threatens the sensitive environment of the Kruger National Park and the associated tourism industry. Catchment development: Upstream and local mining, industrial, irrigation, urban and infrastructure development is expected to continue to degrade water quality of the lower Olifants River.

De Hoop Dam: is expected to have acceptable water quality. But it will reduce the diluting effect of runoff to the downstream Steelpoort and Olifants River system.

Transboundary flows: Development and water allocation in the Olifants catchment will affect the salinity of the runoff into Moçambique, especially at Massingir Dam.

Monitoring deficiencies: The cessation of critical water quality monitoring at Zeekoegat from 1989 has left a very serious gap in the data, given the high salinity at this point and the plans to build Rooipoort Dam.

2.5 REPORT TITLE: INTEGRATED WATER RESOURCE MANAGEMENT PLAN FOR THE UPPER AND MIDDLE OLIFANTS CATCHMENT. REPORT NO. P WMA 04/000/00/7007. DEPARTMENT OF WATER AFFAIRS IN ASSOCIATION WITH WATER RESOURCE PLANNING. PREPARED BY GOLDER ASSOCIATES. JULY 2009.

2.5.1 Purpose

To present the Integrated Water Resource Management Plan for the study area. The report is regarded as an interim report, until the model of the study area and the modelling of the Middle Olifants area is completed.

2.5.2 Major findings

The current water quality situation is that there are acid conditions in the Klipspruit and Kromdraaispruit catchments due to failed neutralisation plants. The sulphate concentrations exceed the Resource Water Quality Objectives (RWQOs) in a number of catchments. The TDS and sulphate concentrations in the Witbank, Middelburg and Loskop Dams have been increasing since 1970. Sulphate load will have to be removed from the system to arrest the increase. This will involve the management of the sources of pollution which include decants and seepages from defunct mines, seepages from waste facilities located next to streams and spills from polluted water management systems.

The sources are not only mines but also power stations and industries. The trophic status of the rivers and dams are mesotrophic. Four of the 5 major WWTPs discharge into streams which report directly into the upper end of the Loskop Dam. This has resulted in eutrophic conditions in the dam with periodic blue green algae blooms.

Many of the mines are filling with water and have reached a stage where they are generating excess water that needs to be managed. This excess mine water is in excess of the contribution that would be made naturally by the mined catchment area. Mine water treatment and reclamation is being pursued by a number of mines using desalination technologies to treat mine water to potable standards. The Emalahleni Mine Water Reclamation Plant (MWRP) is operational and the Optimum MWRP is under construction.

The reconciliation situation assessment showed that the water supply from Witbank and Middelburg Dams to Emalahleni and Steve Tshwete Local Municipalities (LMs) requires immediate augmentation. The water requirements of Steve Tshwete LM will exceed the 50 year yield of the Middelburg dam by 2012. In the case of Emalahleni LM, the current water requirements exceed the 50 year yield of Witbank Dam and the supply from the Emalahleni MWRP. The water reconciliation situation in the Western Highveld Region is in balance due to the supply from Rand Water. However to maintain the balance, the water supply infrastructure constraints and the reduction in water requirements through water conservation and demand management (WCDM) will have to be realised. The Loskop Dam is able to meet the requirements of the irrigators and the small towns at an adequate assurance of supply.

2.5.3 Water Quality Management Strategy

The key elements of the water quality management strategy are the setting of the RWQOs; source based salinity and nutrient management as well as bolstering of management resources and information systems. The RWQOs were determined based on the current set of RWQOs in the Witbank, Klipspruit and Middelburg Dam catchments modified to account for the available water quality component of the ecological Reserve. The current ecological Reserve for salinity water quality variables was developed using outdated methodology. Where RWQOs were not set, the South African Water Quality Guidelines together with the present water quality status were used to determine RWQOs.

The set of RWQOs determined in the study are interim RWQOs that will be reviewed in 5 years' time once the water quality component of the ecological Reserve has been updated. The management of salinity involves the reduction of loads into the system. The strategy has been divided into the management of the defunct and operational mines. The defunct mine strategy involves refurbishing the Brugspruit neutralisation plant and collection system which will address the acidity issue. A committee needs to be set up to develop a defunct mine strategy which prioritises and looks for synergies with operating mines to manage the decants.

The required reductions in load from the operational mines, power stations and industries will be achieved by source management through audits, Integrated Waste and Water Management Plans, Water Use Licensing, compliance monitoring and reporting. The waste discharge charge will also be implemented to ensure that the source reductions are achieved and that money is raised to fund an appropriate institutional structure to manage water quality. The nutrient management strategy involves the upgrading of the 5 major WWTPs and sanitation systems as well as revising the phosphate discharge standard to 1 mg/L for the major works. The smaller WWTP must be audited to ensure that the plant performance is aligned with the technology installed.

2.5.4 Reconciliation Strategy

The application of the yield model to investigate the further development of surface water resources showed that the construction of additional dams did not increase the yield of the system of dams in the study area. The yield was merely transferred from the downstream dams to the upstream dams. This highlights the need for the development of an integrated reconciliation strategy for the entire catchment. The immediate concerns are the augmentation of the water supply to Steve Tshwete and Emalahleni LM.

The use of excess mine water was investigated. The available volumes of mine water were determined over time and compared to the water requirement projections. The findings are that there is sufficient mine water available however the water will require treatment and the process of allocating the water will need management. The other actions that will be implemented to assist with reaching reconciliation are the elimination of the unlawful water use, on-going application of the catchment modelling systems, trading of water rights and the development of groundwater for supply to rural areas.

2.6 REPORT TITLE: SURVEY OF CERTAIN PERSISTENT ORGANIC POLLUTANTS IN MAJOR SOUTH AFRICAN WATERS, WRC REPORT NI. 1213/1/05. PREPARED BY THE WATER RESEARCH COMMISSION. JUBE 2005.

2.6.1 Purpose

A countrywide assessment of persistent organic pollutants (POPs) in a selection of major water bodies was conducted. One of the objectives was to indicate geographical areas (such as industrial and or residential) where more concerted action, management or research needs to be focussed.

POPs are considered organic compounds of natural or anthropogenic origin that resist photolytic, chemical and biological degradation, and also have toxic properties. They are compounds with low water solubility, readily soluble in lipid and can therefore accumulate in fatty tissue of biota. Because of the long persistence times and (low) volatility, they can be transported in the environment in low concentrations via water and air movements, as well as with migrating animals. This means that POPs can be transported to areas where they have never been used, and can therefore affect human and environmental health globally - consequently the need for international action on POPs.

The initial group of 12 POPs includes a number of pesticides - aldrin, dieldrin, DDT, endrin, heptachlor, chlordane, hexachlorobenzene, mirex and toxaphene. The other three chemicals are actually classes of compounds that include the PolyChlorinated Dibenzo-p-Dioxins (dioxins in short) (PCDD), PolyChlorinated DibenzoFurans (dibenzofurans in short) (PCDF) and polychlorinated biphenyls (PCB).

The aims of the project were:

- To establish the presence and levels of 7 PCDD. 10 PCDF and 12 PCBs in fish from major South African rivers and estuaries.
- To determine the possible implications and future obligations for South Africa, of the presence and levels of these POPs under the international, legally binding, Persistent Organic Pollutant Convention.
- To establish the basis for further investigations, if levels found are deemed of concern.
- To investigate alternative and cheaper means of analysis for PCDD/PCDF and PCBs in South Africa.
- Through an initial risk assessment, based on analytical data from this project, establish the risk associated with the levels found.

- To develop a short course on environmental sampling and Good Laboratory Practice.

2.6.2 Approach

A total of 22 sites were selected to represent primarily areas with potentially high POPs concentrations in South Africa. The Loskop Dam on the Olifants River and the Olifants River, just before it exits South Africa, were sampled. The Olifants River and the Buffalo River were sampled because both drain that part of the country known for its coal mining and coal combustion electricity plants.

The study did not aim to address the issue of the risks of PCDD/PCDF and PCB to humans or wildlife directly. Risk is a factor of both exposure and hazard (toxicity). An assessment of the risks posed by PCDD/PCDF and PCB would need to consider the bio-availability of each congener as well as other factors that would affect potential exposure (Hilscherova *et al*. 2003).

2.6.3 Findings

The results showed that dioxin-like substances are present in all 22 sites sampled. The Olifants River and the Loskop Dam showed very low Toxic Equivalency Factors (TEQ) (approximately 0.22 ng/kg). The study also showed that rivers that were selected to be sampled because of their association with coal mining and electricity producing areas, such as the Olifants River and the Loskop Dam had low PCB and PCDD/PCDF concentrations.

2.7 CONCLUSION

Most of the water quality problems in the Olifants River catchment area are pollution problems which have to be addressed at source, except for acid mine drainage which has to be addressed by intercepting and treating the water. If the water is not treated then the water will become unfit for use. In most cases if the water is fit for human consumption, then it is fit for industry, except for a few cases in which the water must be pre-treated.

3. OBJECTIVES OF THE WATER QUALITY ASSESSMENT

3.1 INTRODUCTION

Initially DWA put the emphasis of water resource management around ensuring that users have sufficient quantities of water. However, as more water gets used and re-used, and as the quantities of water are limited, it is the quality of the water that begins to take on a dominant concern in water supply management (DWAF, February 2004). Therefore, through the effective management of water quality by the responsible authorities in a catchment, more water can be made available in a more cost effective manner to the water users.

The first step in the process of managing water quality is to determine the status of the water quality, set criteria or objectives to which the water quality must be managed and put in place a monitoring or measuring mechanism to check on and review the water quality status.

3.2 OBJECTIVE OF THE WATER QUALITY ASSESSMENT (SURFACE WATER)

The water quality task has been based on the requirements, as outlined by the DWA, of a summary list of the water quality framework for water availability assessment studies.

The objectives of the study include assessing potential water quality problems, types of sources of water quality impairment including industrial, commercial, mining and agricultural activities, establishing a set of water quality criteria that take into consideration the water uses in the study area including international requirements and the Reserve, and compliance to these water quality criteria.

The study also focuses on some other related issues as it applies to water quality assessment. These include:

- **Eutrophication**
  Eutrophication is a problem in many dams in South Africa and therefore is a concern to the DWA. Eutrophication is the enrichment of a water body with mineral and organic nutrients (DWAF, 2003). The objective of this part of the report is to highlight the trophic status in the Olifants River System.

- **River Ecology**
  The ecological status of a river is its overall condition and includes the assessment of all of the features and characteristics of a river and its riparian areas. An ecological assessment determines a river's ability to support a natural array of species (DEAT, March 2005). The objective of this section of the report is to include existing available information in support of the water quality assessment's findings.

4. DESCRIPTION OF THE STUDY AREA

4.1 LOCALITY

The Olifants River System originates just within and east of the Gauteng Province and the main stem flows in a northerly direction (**Figure 4.1**). Beyond Flag Boshielo Dam it changes direction eastwards and after cutting through the Drakensberg Mountains, enters the Kruger National Park near Phalaborwa and flows further east to the Mozambican border. Just beyond this border is the Massingir Dam in Moçambique. Further downstream the Olifants River joins the Limpopo River. Before the Olifants River reaches the Moçambican border, the Letaba River joins with it. The size of the whole Olifants water management area (WMA) is 54 570 m^2, only representing the RSA portion of the Olifants River Catchment.

The Olifants WMA falls within three provinces, namely Gauteng, Mpumalanga and the Limpopo provinces. It has been sub-divided into four sub-areas, for the purposes of the Internal Strategic Perspective (ISP). The sub-areas are the Upper Olifants, Middle Olifants, Steelpoort and Lower Olifants Sub-areas.

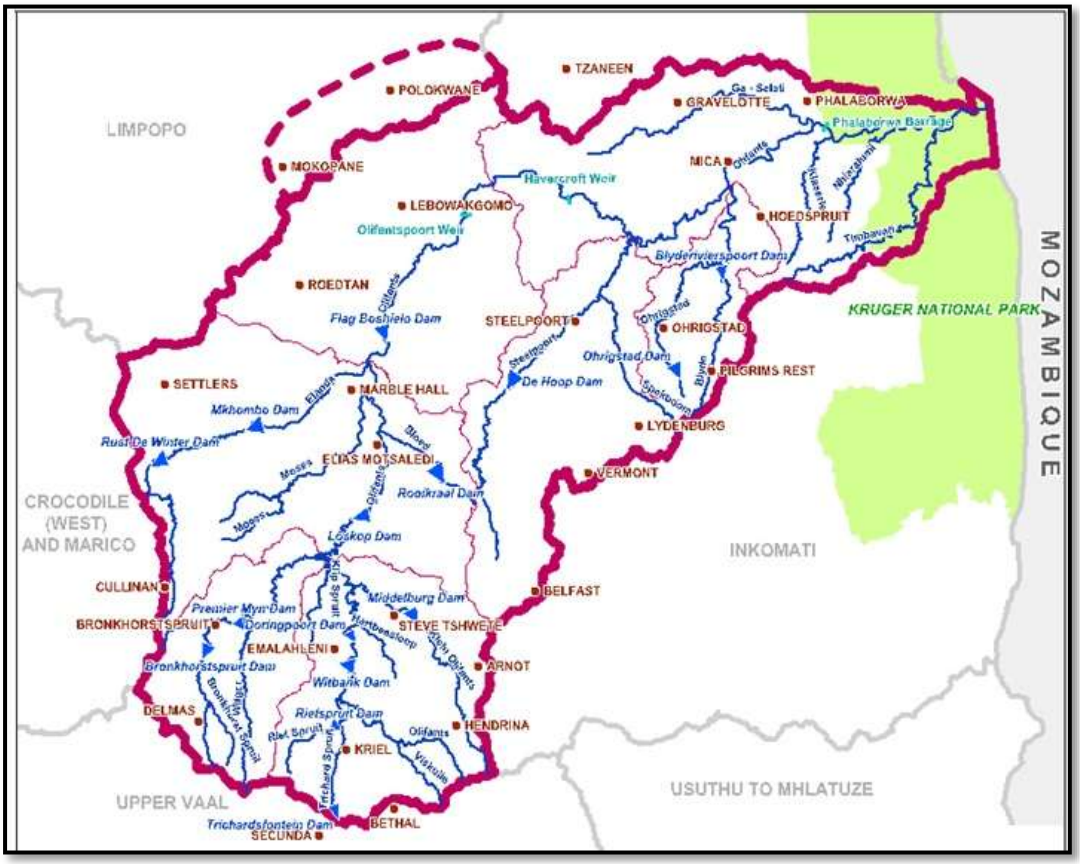


Figure 4.1: Study Area

The Olifants Letaba Environmental Management Framework (EMF) identifies several environmental management zones within the Olifants WMA (see **Figure 4.2**) and the strategic Environmental Management Plan (EMP) provides guidelines for each zone.

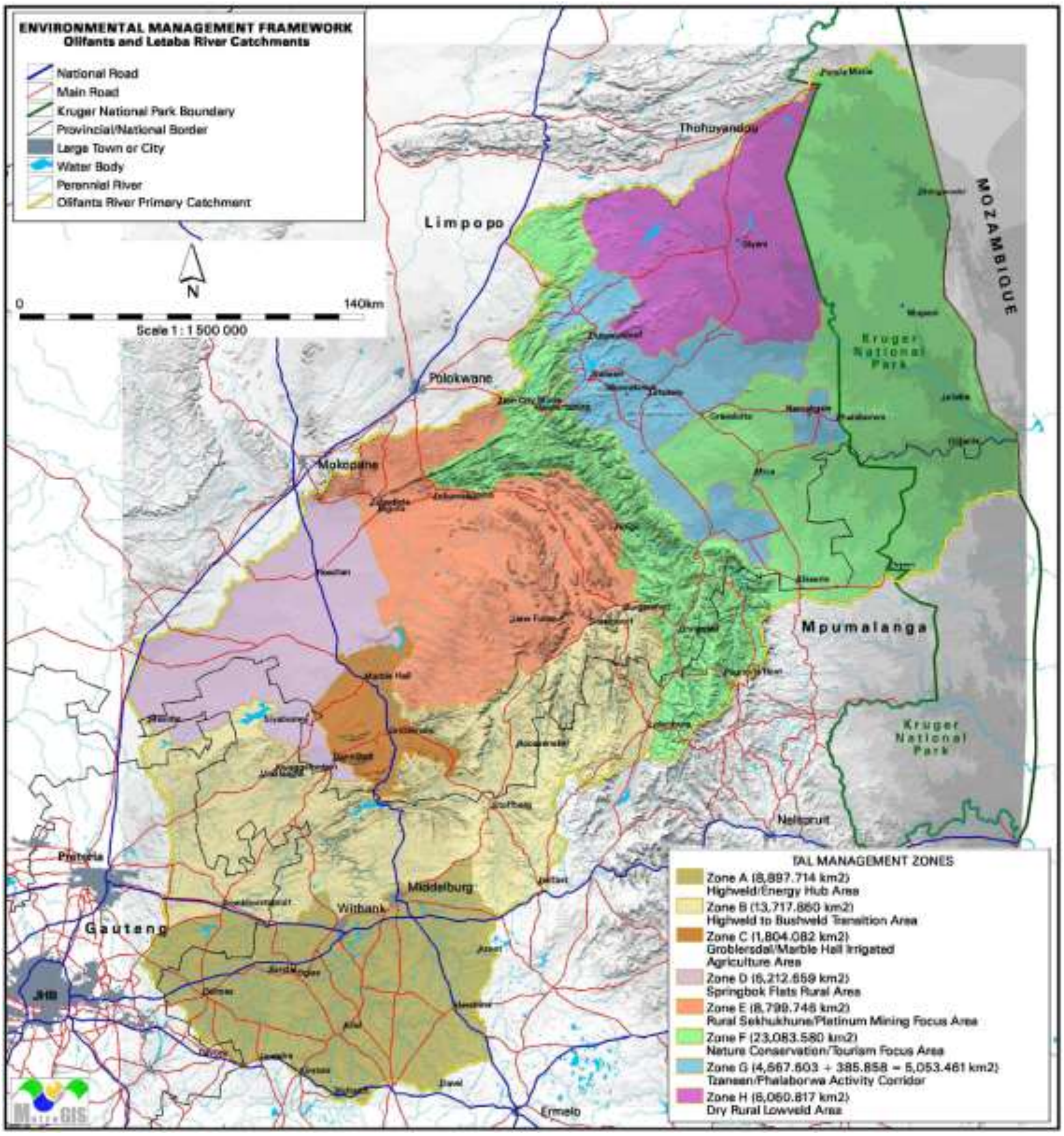


Figure 4.2: Environmental Management Zones in the Olifants Letaba Catchments (Source: DEA, 2009)

4.2 GEOLOGY

According to the EMF for the Olifants and Letaba Rivers Catchment Management Areas, the geology of the study area is widely varied. The area contains exposed rocks from the early Precambrian Era that contains three of the basic rock types, namely sedimentary, igneous and metamorphic.

Archaean Granite and Gneiss Basement Complex is the oldest exposed rock formations in the area and forms the basement rock complex for other rock systems. It occurs in the extreme east Lowveld part of the study area and consist mainly of Granite and Gneis formations and primitive groups of schistose rocks. The most important economic potential lies in the mining of granite and gneiss for use as polished stone and the occurrence of gold and other minerals in the greenstone lavas.

The Transvaal Supergroup in the study area consists of sedimentary rock laid down in a basin. It consists of the so-called Pretoria Group (after its typical form in the Pretoria area) composed of three quartzite formations (Timeball Hill, Daspoort and Magalies) with intervening shales and lavas. It forms the mountains of Sekhukuneland (eastern Bankenveld) at the edge of the Bushveld Basin as well as the bold escarpment of the Transvaal Drakensberg consisting of Black Reef Quartzite overlain by the Malmani Dolomite of the Chuniespoort Group, where the dramatic change in topography gives rise to dramatic scenic views and vistas. The Malmani Dolomite is also present in the Delmas and Marble Hall areas.

The Bushveld Igneous Complex was formed in a series of magma and is spread over the central part of the Transvaal basin. The area contains Nebo Granites in the central parts, as well as Gabbro and Norite in the east. The Bushveld Igneous Complex contains important minerals such as large quantities of platinum, small quantities of gold and silver and a variety of base metals.

The rocks of the Soutpansberg Group and Waterberg Basin are composed mostly of sedimentary rocks but may have intrusive volcanic rocks in places.

The Karoo Supergroup consists mainly of sedimentary and basalt rocks deposited horizontally in a vast basin, with a few satellite basins to the north. It is a relatively young plateau system that is in the slow process of being removed by erosion from the sub-Karoo surface. The Ecca Group of the Karoo Supergroup contains bands of coal within the sedimentary layers. Alluvial Deposits in the area consist of sand created by the weathering of older rocks. The composition of these small loose grains varies depending on the source of rock.

4.3 LANDSCAPE, CLIMATE AND RAINFALL

The WMA is large and the topography across the area is very varied. The topographical information correlates closely with the geological information. The area contains Highveld, which is composed of undulating plains and pans, and a large open flat area, referred to as the Springbok Flats. These areas are divided from the Lowveld by the escarpment, which consists of various hills and mountain terrain. The Lowveld consists mainly of plains and undulating plains. **Figure 4.3** shows the physical geography/terrain morphological description of the study area.

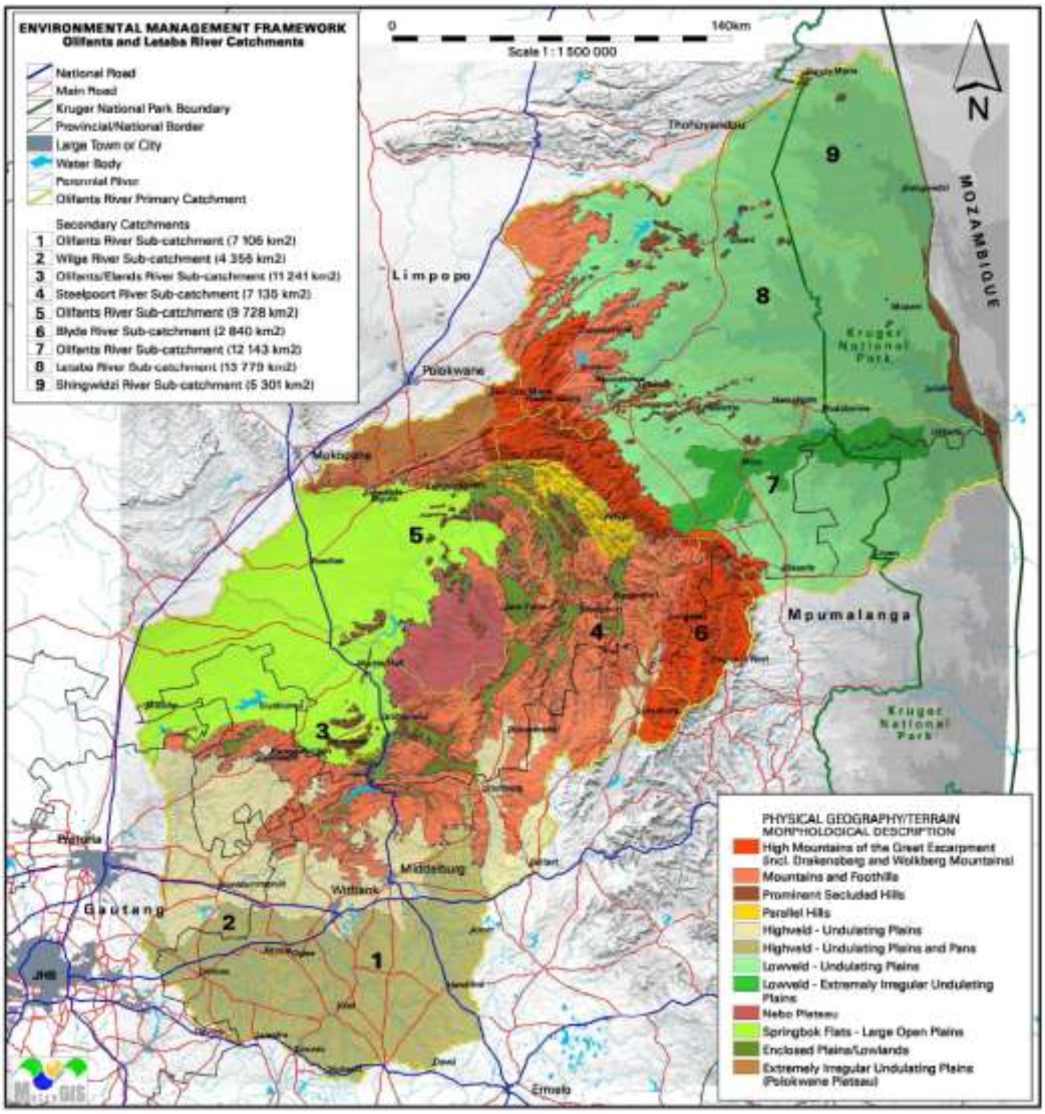


Figure 4.3: Physical Geography / Terrain Morphological Description (Source: DWA, 2009)

The study area falls across four climatic regions, which include:

- The Highveld, with moderate maximum temperatures and cold winter nights, with severe frost occurring regularly;
- The Bushveld, with high maximum temperatures and cool winter nights without severe frost occurring;
- the escarpment, which partly lies in the mist belt, with moderate maximum temperatures and cool winter nights; and
- The eastern Lowveld with a hot sub-tropical climate.

The whole study area falls within the summer rainfall region. The mean annual precipitation within the study area varies greatly:

- Dry areas with 325 mm/annum to 550 mm/annum occur in parts of Sekhukhune and the northern parts of the eastern Lowveld;
- In the Highveld region and the southern part of the eastern Lowveld the rainfall varies between 550 mm/annum to 750 mm/annum;

- The escarpment receives a higher rainfall of between 750 mm/annum to 1000 mm/annum; and
- The Wolkberg area receives an annual rainfall exceeding 1000mm.

4.4 CONSERVATION AREAS

There are a number of ecologically important areas within the Olifants WMA and various conservation areas have been proclaimed in the WMA (DWAF, 2004a):

- Blyde River Canyon Reserve
- Klaserie Game Reserve
- Thorny Bush Game Reserve
- Umbabat Nature Reserve
- Timbavati Nature Reserve
- Wolkberg Wilderness Area
- The Dawns Nature Reserve
- Selati Game Reserve
- Mount Sheba Game Reserve
- Sterkspruit Nature Reserve
- Lydenburg Nature Reserve
- Gustav Klingbiel Nature Reserve
- Ohrigstad Dam Nature Reserve
- Loskop Dam Nature Reserve

The most well-known conservation area is the Kruger National Park (KNP) located in the Lower Olifants sub-area of the Olifants WMA. There are other ecologically important areas in the WMA, which have not been proclaimed as conservancy areas. These include the Mohlapitse River, which was identified during the ecological Reserve determination study as an ecologically important area due to the numerous cool mountain streams that join the Olifants River. The mix of hot and cold waters provides habitat with a high diversity and numerous red data and endemic fish species and frogs occur in these environments. The Mohlapitse River also has several wetlands. It is important to maintain the status quo as far as flow and water quality regimes are concerned in this area of the WMA.

There are also numerous pans and wetlands located in the Upper Olifants Sub-area. Many of these pans and wetlands are under threat by mining. This is due to undermining, mining through or the use of the pans for the storage and evaporation of saline mine water.

There are also numerous gorges. The more important gorges are located upstream of the Moçambique border in the Kruger National Park; in the transition from the Highveld to the Lowveld; and upstream of the Loskop Dam.

There are two centres of endemism within the Olifants WMA: namely the Sekhukhuneland, and Wolkberg Centres of Endemism. The Sekhukhuneland Centre of Endemism is entirely within the catchment while approximately half of the Wolkberg Centre of Endemism is within the catchment. These Centres of Endemism contain high levels of diversity with many species restricted entirely to these areas. As such they are of high priority in terms of conservation. The high biodiversity and the many unique plant species restricted to these areas means that they are particularly vulnerable. **Figure 4.4** shows areas with the threatened ecosystems in the study area.

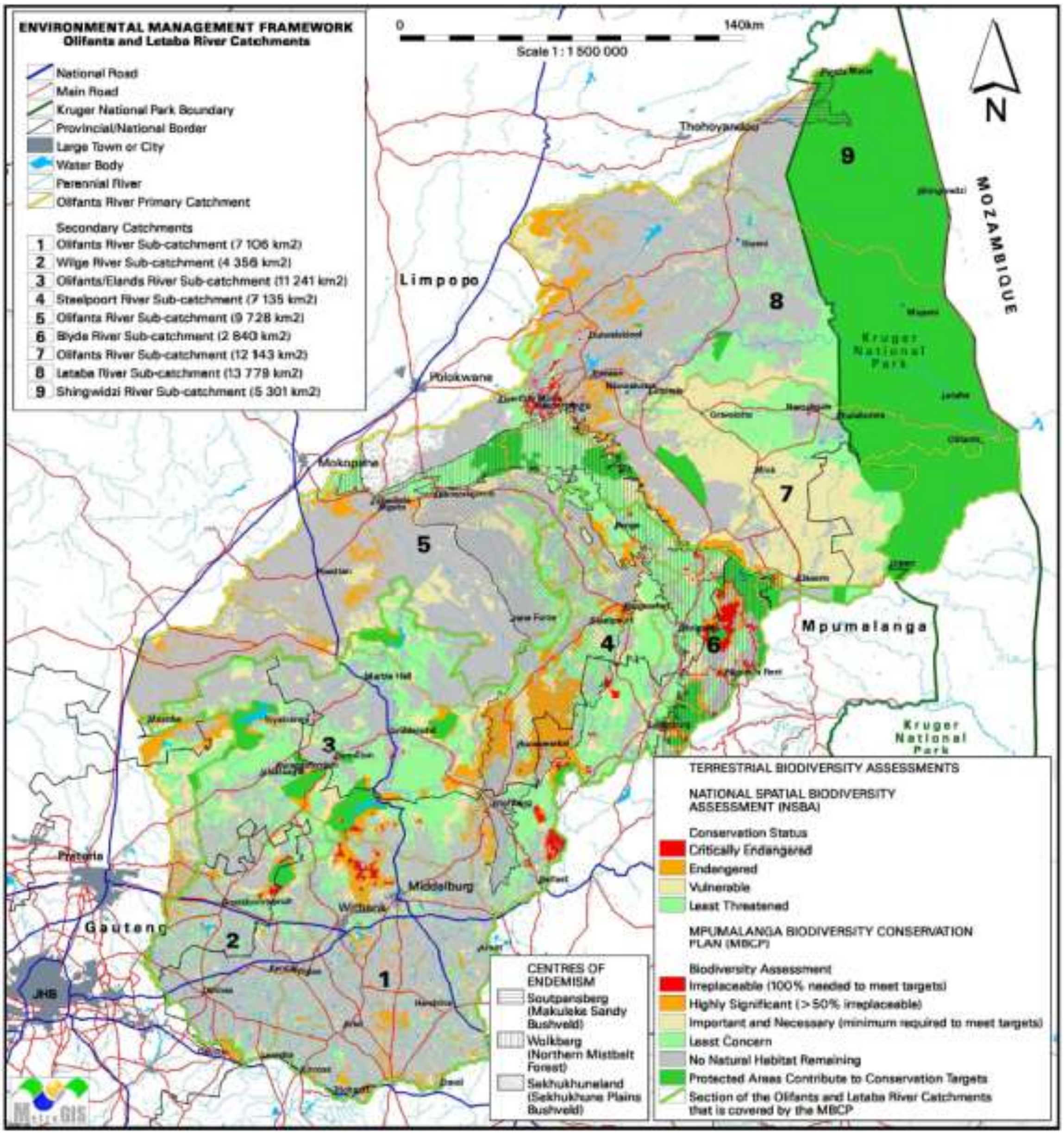


Figure 4.4: Threatened Ecosystems (Source: DEAT, 2009)

The **Wolkberg Centre** is extremely rich floristically. More than 40 species or endemic/near endemic to the dolomites and more than 90 to the quartz- and shale-derived substrates occur in the area. These figures are conservative, with more taxa likely to be added as knowledge of the flora improves.

The three families with the largest number of endemics on the quartzitic and related rock types are the Asteraceae, Iridaceae and Liliaceae. The asteraceous genus *Helichrysum,* with 10 species being the most prolific in producing endemics. *Gladiolus* has more than ten species endemic to the region as a whole. The Liliaceae is the family with the largest number of dolomite endemics to the region as a whole, followed by the Euphorbiaceae, Lamiaceae and Acanthaceae. For mosses, the Wolkberg Centre is one of the main southern African centres of diversity and a secondary centre of endemism.

Significantly, nearly all the endemics (notably the quartzitic ones) are grassland species. Most of the taxa endemic to the Wolkberg Centre appear to be palaeoendemics. The Wolkberg Centre, especially the arid dolomite areas, shares many species with the adjacent Sekhukhuneland Centre, several of which are endemic to the combined region.

The vegetation of the Sekhukhuneland Centre has never been studied in detail. It is usually mapped as Mixed Bushveld. However, floristically the bushveld of Sekhukhuneland Centre is quite unique and certainly deserves recognition as a separate type. The *Kirkia wilmsii*, a species that is relatively rare in other parts of the Mixed Bushveld is a characteristic tree of this area. Vegetation differences between the north- and south-facing aspects of the mountains are often striking. Intriguing vegetation anomalies associated with heavily eroded soils are present throughout the region.

The flora of the Sekhukhuneland Centre is still poorly known, with many apparently endemic species awaiting formal description. Families particularly rich in Sekhukhuneland Centre endemics include the Anacardiaceae, Euphorbiaceae, Liliaceae, Lamiaceae and Vitaceae. A still-to-be-described monoptypic genus of the Alliaceae is endemic also. The area around Burgersfort is reputed to have the highest concentration of *Aloe* species in the world. The Leolo Mountains harbour relic patches of Afromontane Forest, Fynbos-type vegetation and several Sekhukhuneland Centre endemics. There are also some rare wetlands in the summit area.

The Kruger to Canyons Biosphere reserve falls within the study area (**Figure 4.5**).

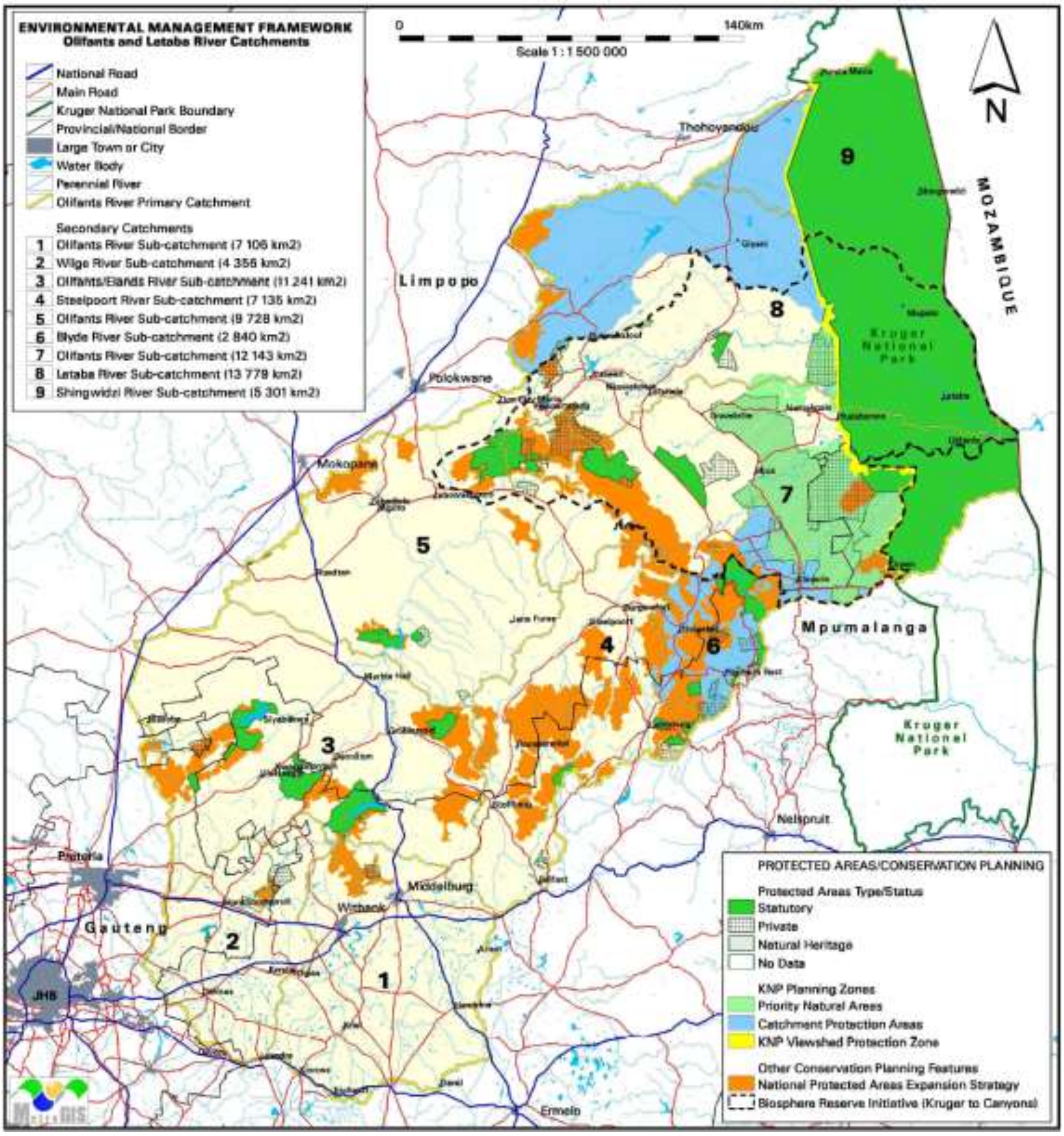


Figure 4.5: Protected Areas and Conservation Planning (DEA, 2009)

4.5 AQUATIC ECOLOGY

The upper reaches of the Olifants River Catchment are characterised mainly by mining, agricultural and conservation activities (DEAT, 2005). Over-grazing and highly erodible soils result in such severe erosion, in parts of the middle section that, after heavy rains the Olifants River has a red-brown colour from all the suspended sediments. The description of the Olifants River System aquatic ecology is as follows (DEAT, 2005):

- The Steelpoort River is in a fair to unacceptable ecological state;
- overgrazing, and dryland cultivation throughout the area surrounding the Spekboom, Steelpoort, Beetgekraal, and Waterval Rivers including within the riparian zone, leads to erosion, which causes high silt levels in the rivers;
- high silt levels in the aforementioned rivers, increases the risk of flooding and leads to the smothering of in-stream habitats and fish gills resulting in loss of invertebrate and fish species;

- runoff from mines and other activities lowers the water quality in the Steelpoort River;
- on the Olifants River the riparian vegetation is overgrazed and over utilised. As a result, riverbanks are collapsing due to erosion and sedimentation occurs in the riverbed;
- downstream of the Rust de Winter Dam, on the Elands River, flow is extremely regulated with very infrequent releases which has a severe impact on in-stream biota because the river is often dry;
- artificial flow regimes in the Elands River caused by ecologically insensitive releases of water from the Rhenosterkop Dam change the riverbed, causes erosion and results in undesirable habitat conditions for in-stream biological communities;
- the Olifants River, upstream of the Flag Boshielo Dam, is impacted by agricultural activities, runoff from commercial agricultural areas contains agro-chemicals, which cause eutrophication or contamination of water, either of which can impair the health of invertebrates and fish;
- riparian vegetation on both the Elands River and the Olifants River is in a very degraded state due to overgrazing and over utilization and as a result, riverbanks are collapsing due to erosion, and sedimentation occurs in the riverbed;
- alien vegetation along the banks of the Olifants and Elands River include Eucalypts (Eucalyptus spp.) Sesbania (Sesbania punicea) and Seringa (Melia azedarach);
- mining, predominantly for coal, and other industrial activities around the Wilge, Bronkhorstspruit, Klein Olifants and Olifants Rivers are the main contributors to poor in-stream and riparian habitat conditions where acid leachate from mines is a primary contributor to poor water quality and instream conditions;
- in some parts around the above mentioned rivers, access roads, mostly related to mining and industrial activities, have resulted in severe disturbance of riparian habitats, and increased erosion of both land and riverbed;
- the riparian vegetation around the Wilge, Bronkhorstspruit, Klein Olifants and Olifants Rivers is under pressure from overgrazing in some parts, and alien plants such as wattles that occur within the riparian zone, competing with indigenous vegetation and reducing available water;
- water quality in the Olifants River is negatively impacted by the high acidity and high concentrations of dissolved salts in some of the tributaries, especially the Klip River;
- the Klipspruit receives mine effluent and a long term management plan will be required to cope with the problem, because contaminant loads inherited from mining activities are likely to persist for many years;
- intensive irrigation of crops (including fruit trees) extends from the Loskop Dam to Marble Hall and the heavy abstraction of water that this causes may reduce the water available for ecological functioning downstream;
- commercial agricultural activities reach up to the riverbanks of the Olifants River downstream of the Loskop Dam and the clearing of ground cover associated with these activities increases the potential for erosion as well as sedimentation in the river channel; seasonal and ecologically insensitive releases from, or retention in, the Loskop Dam have an adverse impact on in-stream biological communities and cause erosion of the riverbed, through scouring; and
- the quality of the water in the Witbank Dam is poor, affecting the rivers downstream.

4.6 ECOLOGICAL RESERVE

A preliminary estimate of the Reserve was determined by the DWA using the Desktop methodology for the water balances and a preliminary Reserve was determined for the Olifants WMA. The river was classified using a preliminary classification system available at the time of the study. Once a classification system has been formally established, the preliminary classification will be revised to fit in with the new system. The final determination and decisions about the Reserve will be taken during the IWRM process, which will balance ecology, economics, social impacts in an integrated way. During this process, the ecological management class and the schedule for the implementation of the Reserve will be determined (DWA, 2004).

4.7 MUNICIPAL AREAS AND TOWNS

The Olifants WMA falls within three provinces viz Gauteng, Mpumalanga, and the Limpopo Province (**Figure 4.6**).

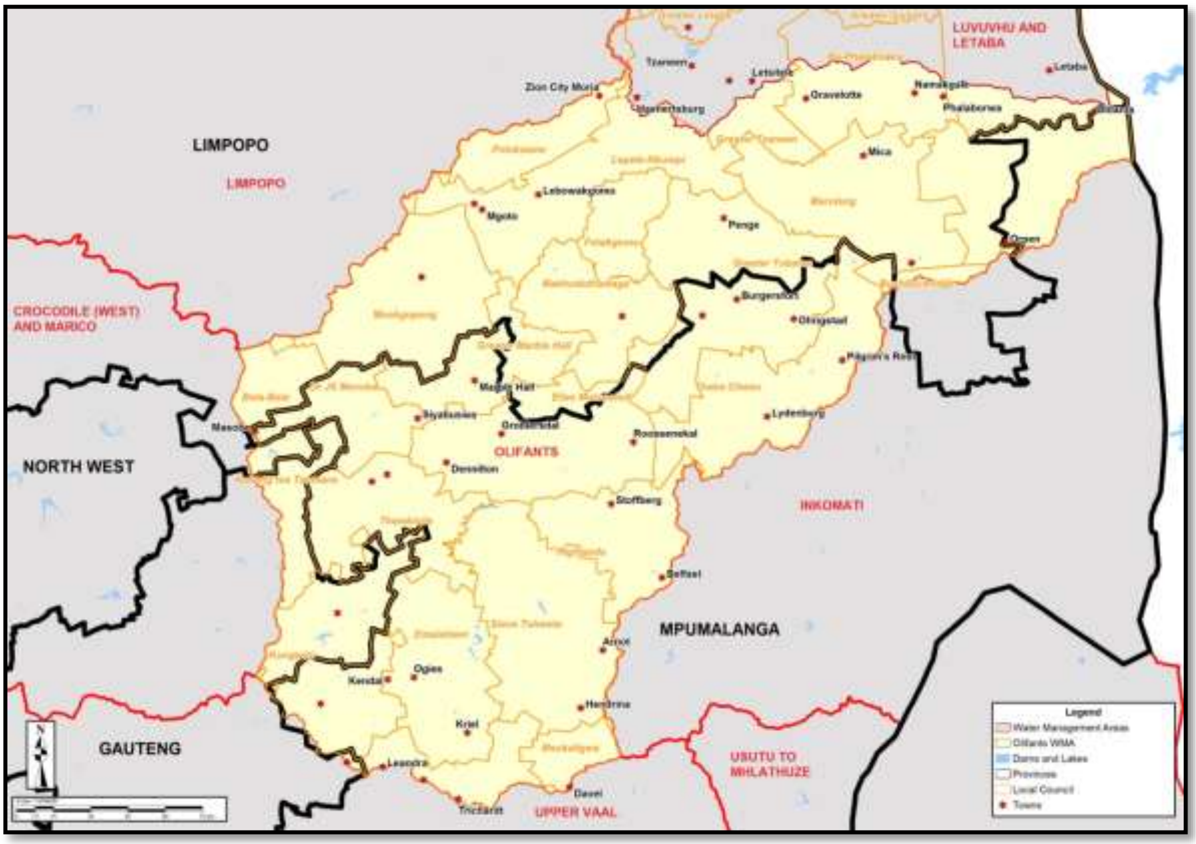


Figure 4.6: Municipalities in the Olifants WMA

The major urban areas include Emalahleni and Steve Tshwete in the Upper Olifants Sub-area and Phalaborwa in the Lower Olifants Sub-area. The Middle Olifants and Steelpoort Sub-area are largely undeveloped with scattered rural settlements (DWA, 2004).

5. WATER USERS IN THE STUDY AREA

5.1 INTRODUCTION

Water quality is always assessed in terms of fitness for use, i.e. there must be a user in order to determine whether the water is usable or not. The water user data for the Olifants River System is not currently collected and maintained in a central database (DWA, 2004). In terms of water quality the system is not necessarily under stress and the aim of this study is to focus on doing a more technical water quality assessment.

5.2 AGRICULTURE: IRRIGATION

Irrigation is the largest water use sector in the Olifants WMA, especially in the Middle Olifants sub-area where extensive irrigation takes place from Loskop Dam (DWA, 2004). There is extensive irrigation that takes place along the Olifants River, in the Blyde River catchment and in the upper reaches of the Ga-Selati catchment.

Irrigation water users may experience a range of impacts as a result of changes in water quality (DWAF: Irrigation, 1996). This study focuses on specific constituents, for which there is available information and gives a broad overview of the fitness-for-use of the available water for irrigation.

5.3 AGRICULTURE: LIVESTOCK WATERING

Livestock is an important water user in the WMA. Livestock is a basic source of work and income for many of the poorer people living in the catchment. The population in the Middle Olifants, Lower Olifants Sub-area and Steelpoort Sub-areas is largely rural settlements which depend on livestock as a source of food and income.

Livestock does not use a significant amount of water and will not influence the quantity of water used in the catchment. However, the catchment should have operating rules that ensure that there is sufficient water supply for livestock watering. Albeit that livestock are more resilient to a poor water quality than humans and do adapt with time to a gradual change in water quality, the water quality requirements of livestock must be taken into consideration.

The potable quality of water for livestock may be defined according to the palatability of the water which would affect intake and hence production, as well as its degree of contamination with pathogenic micro-organisms of a wide variety, algae and/or protozoa, hydrocarbons, pesticides and salts such as nitrates, sulphates, fluoride and the salts of heavy metals (DWAF: Livestock, 1996). To address all of these water quality requirements would need a more extensive water quality source of data which is not available, as well a detailed study of the types, location, feed, etc. of animals in the catchment. This study is taking into consideration a broad overview of a water quality assessment for livestock watering.

Constituents of concern, which have a toxicological effect, include arsenic, copper, fluoride, molybdenum, nitrite, sodium, toxic algae, cadmium, mercury, lead, selenium, pathogens and pesticides. Constituents that are of concern but unlikely to result in toxicosis due to a low order of toxicity or a low occurrence in the aquatic environment, are aluminium, calcium, chloride, chromium, cobalt, iron, manganese, nickel, sulphate, vanadium and zinc. The primary water quality constituents of concern regarding palatability are the total dissolved solids (TDS), chloride and sulphate. Other water quality constituents which may be implicated include nitrates and high concentrations of heavy metals (DWAF: Livestock, 1996). Where possible as many of these constituents have been included in the water quality assessment done in this study.

5.4 POWER GENERATION

The second largest water user located in the WMA is power generation. There are six active Eskom coal fired power stations located in the Upper Sub-area (DWA, 2004). The electricity demand is projected by Eskom to grow faster than originally estimated. The utilisation and capacity of these power stations is to be increased resulting in an increase in the water requirements. The water requirements are however met with water transfers from outside the WMA. The management of the supply to these stations is carried out at the national level and does not impact on this WMA (DWA, 2004)

5.5 DOMESTIC

The Upper Olifants Sub-area is the most urbanised of the four sub-areas with the majority of the urban population located in Emalahleni and Steve Tshwete. The population in the Middle Olifants and Steelpoort Sub-areas is largely undeveloped with scattered rural settlements. The Lower Olifants Sub-area is also rural in character with the main urban centre being Phalaborwa.

The use of water in the domestic environment is common to all consumers and probably provides the widest direct experience of the effects of water quality. The term “domestic water”, as used in this study, refers to water which is used in the domestic environment, this includes water for (DWAF: Domestic, 1996):

- drinking;
- food and beverage preparation;
- hot water systems;
- bathing and personal hygiene;
- washing, for example, dishes; and,
- laundry.

Therefore certain constituents, such as dissolved organic carbon, total hardness and corrosion represent aggregates of constituents which interact to cause a particular water quality effect. Some constituents are used to characterise a water source, such as those that play a role in causing water quality-related problems, whereas other constituents are associated with site-specific water quality problems (DWAF: Domestic, 1996).

This study does not focus on acutely toxic water quality problems but views constituents that give a broad based overview of the fitness-for-use of the surface water in the Olifants River Catchment.

5.6 INFORMAL DOMESTIC

Informal domestic use refers to water that is not formally treated in a treatment works. The water is used mainly for drinking and cooking. It is normally not used for cleaning or bathing because the water is not piped but carried to the place of use. This use of water mainly occurs along the rivers because of the distance to transport the water. Other informal water use is from wells or boreholes.

When accessing water quality information in the water quality assessment and eventually in the implementation of mitigating actions it must be assumed that the water used for informal domestic use is not treated with any disinfectant (jik, chlorine etc.) before use.

The extent of informal water use is not very well known and needs to be investigated further. In the interim, when evaluating the water quality of water use requirements, the informal water use sector’s needs are to be taken into consideration.

5.7 INDUSTRIAL AND MINING

There is extensive coal mining activities in the sub-area both for export through Richards Bay and for use in the 6 active coal fired power stations in the Upper Olifants sub-area (DWA, 2004). The presence of coal also led to the establishment of the steel manufacturing industries located in Emalahleni and Steve Tshwete. There are a number of platinum and chrome mines being developed in the Middle Olifants Sub-area. The mines have increased the water requirements in the area both due to direct water use and the influx of people into the area to work on the new mines. There is vanadium and chrome mining and mineral processing taking place in the Steelpoort Sub-area. There is also mining in the Lower Olifants sub-area, with the main mining activity being the copper and phosphorus mining taking place in the vicinity of Phalaborwa (DWA, 2004).

The strength of the manufacturing industry can be attributed to the relatively cheap supply of coal which particularly contributes to the success of the metallurgic industry in the Emalahleni and Steve Tshwete areas. Ecotourism is also an important industry in the WMA, with a number of private game parks and conservancies and the Kruger National Park (KNP) located in the Lower Olifants sub-area.

The water quality requirements of industry are difficult to represent as a “general” water user because each manufacturing process or each industrial activity often has very specific water quality requirements. According to the DWA Industrial Water Quality Guidelines, the water requirements for industry can be broken down into four process types which include cooling, steam production, process water (solvent, diluent, carrier), product water (as in beverages), utilities (domestic, fire protection) and wash. However, in the catchment most industries receive water from the municipalities therefore if an industry has special water quality requirements, it pre-treats the water. The main constituents that influence industrial water quality include chloride, total dissolved substances (electrical conductivity), chemical oxygen demand, alkalinity, Silica for descaling (iron and steel industry), etc (DWAF: Industrial, 1996)

5.8 RECREATION

The use of water for recreational purposes is one of the 11 water uses regulated in terms of the National Water Act, 1998 (Act 107 of 1998) NWA (Section 21 j). Recreational use can take many forms and only occasionally has any direct impact on the water resource. Most obvious are activities such as power-boating, sailing and swimming which can have quality / pollution impacts (DWA, 2004). Far more significant in terms of both quantity and quality is the release of water to allow for canoeing and other water sports downstream (The Olifants, Dusi and Fish River canoe marathons being prime examples).

Other recreational activities include fishing and different types of boating. However, if the water is suitable for domestic, ecological and irrigation use, it will more than likely be suitable for basic water contact recreational use, such as boating and swimming.

5.9 RESERVE

The Reserve mainly focuses on only water for “drinking” and water for the ecology of the river. Water quality requirements included in the Reserve are for “drinking” and ecology. This study looks at some of the basic constituents that will give a good assessment of the water quality for these two water uses. The DWA Water Quality Guidelines for Aquatic Environments were used for the purpose of the Ecological Reserve.

5.10 INTERNATIONAL

The Olifants WMA falls within the Limpopo River Basin, which is shared by South Africa, Botswana, Zimbabwe and Moçambique. As the Olifants River flows directly from South Africa into Moçambique, where it joins the Limpopo River, developments in South Africa directly impact upon Moçambique.

Joint utilization of the water resources of the Olifants River is facilitated through the bilateral Joint Water Commission between South Africa and Mocambique. International co-operation with respect to the use and management of the watercourses in the Limpopo River Basin was overseen by the Limpopo Basin Permanent Technical Committee (LBPTC) with membership by South Africa, Botswana, Zimbabwe and Moçambique. The LBPTC was replaced by the Limpopo Water Course Commission, established in November 2003.

6. POTENTIAL CONTAMINATION SOURCES

6.1 SETTLEMENTS

The Upper Olifants Sub-area is the most urbanised of the four sub-areas with the majority of the urban population located in Witbank and Middelburg with the rest of the study area being largely rural.

Poor water quality in dense settlements has a wide range of significant impacts on human health, social development, environment and down-stream use values. This is usually as a result of low standards of water supply and poor sanitation which is a feature of almost all developing areas such as is in many of the urban areas of the Olifants River Catchment. The diseases that arise as a result of inadequate water services contribute to a large proportion of infant and child death and too many of the diseases in adults (DWAF, October 2001).

As urban areas become denser and heavily populated, the pollutant loads are likely to increase, thereby increasing the risk of disease and the provisions for the removal of waste water need to be comprehensive and less simple. More importantly, these services must be operated effectively in order to ensure that they do not fail (DWAF, October 2001).

Although most waterborne diseases are caused by germs being transmitted by the faecal-oral route, there are secondary longer term waterborne diseases that can result from water polluted by dense settlements further downstream, as a wide variety of pathogenic viruses, protozoa, and bacteria may be transmitted by water (DWAF, October 2001).

Most pollution from dense settlements occurs where the demand for the resource is greatest. With this goes opportunity costs or the cost of not being able to undertake a certain economic activity in the future associated with the environmental degradation. The typical types of environmental impact arising from dense settlement pollution are sedimentation, faecal pollution and Eutrophication. The impacts of sedimentation, faecal pollution and Eutrophication on the economic activities of downstream users can be dramatic. Irrigated agriculture for example is frequently confronted with lower plant yields because the pollution in the water settles on leaves and reduces photosynthesis. The presence of nutrients such as nitrogen and phosphorous can also stimulate plant growth, even if unwanted, for example, during a fruit development period (DWAF, October 2001).

Pollution from dense settlements also causes blockages in irrigation equipment that not only affects production but can be costly to remove and to control. Irrigation with contaminated water reduces the market value of a number of irrigated crops, such as vegetables and fruits that are not cooked before they are consumed (DWAF, October 2001).

The economic impact of pollution from dense settlements on aquatic environments will be felt most through the reduction in amenity value and the value of the resource as a tourist destination. As South Africa's tourism and leisure industry is set to grow and is proffered as a vehicle for future economic growth, these impacts will be increasingly severe (DWAF, October 2001).

Livestock farmers also suffer economic costs when pollution from dense settlements is inadvertently ingested by their stock. Apart from the palatability effects, there are a number of diseases that can be spread through contaminated water. Apart from the impacts on stock production, the market value of livestock is greatly reduced due to the presence of pollution from dense settlements (DWAF, October 2001).

Human consumption of contaminated water is highly costly in terms of disease costs, lost productivity costs and mortality costs. Water service providers therefore are particularly vigilant about treating water to acceptable portable standards. The cost of treatment increases dramatically with the presence of pollution from dense settlements (DWAF, October 2001).

6.2 WASTE DISPOSAL

All urban areas have waste disposal sites, which for the same reasons as mentioned above for sewage works, are often poorly managed. There is often no groundwater monitoring boreholes at most of the solid waste facilities. There is some runoff during high rainfall periods. Leachate collection systems are poor or non-existent and the site is often located in flood plains, or on top of important groundwater resources.

Urban development results in an increased production of waste, creating a need for additional and improved waste-management facilities. Although techniques for containing waste are available, and are being applied to new facilities, older waste repositories had no structured lining systems, and they have released contaminated leachate into adjacent water resources (DEAT, 2007).

6.3 SEWAGE WORKS

Wastewater treatment works form an important part of water resources management (WRM). Effluent treatment prevents pollution of water resources and allows the integration of treated effluent into the water supply system (DWAF, 1991). In the Olifants WMA, only major urban centres have advanced wastewater treatment works with smaller settlements using pit latrines, tanks or stabilisation ponds (DWAF, 1991).

Most municipalities with their limited budgets and other resources are not managing WWTWs as they should be and therefore have a serious water quality impact on the receiving surface water resources.

Industries, also discharge their waste to the local municipal sewage works with very little pre-treatment and as a result are responsible for a large percentage of the volume of effluent and waste load which is discharged by the sewage works. Ineffective municipal by-laws and the fact that such activities are a major source of employment and income to the area makes it very difficult for the local authorities to take action resulting in poor water quality effluents being discharged from the sewage works.

6.4 AGRICULTURE

The impact of agricultural drainage as a result of agricultural activities has a significant impact on water quality. This includes irrigation return flows and seepage, which may contain salts that include nutrients (fertilizers), other agro-chemicals (including herbicides and pesticides) and runoff or effluent from animal husbandry locations such as feedlots, piggeries, dairies, or chicken farms, which also contribute to contamination (DEAT, 2007).

6.5 INDUSTRY AND MINING

The water quality in the Upper Sub-area of the WMA is dominated by the intensive coal mining activities. The mining is currently located in the Witbank and Middelburg Dam Catchments as well as the Spookspruit and Klipspruit Catchments. Currently the coal mining activities in the Wilge Catchments are low and the water quality is still fit for use in this catchment. The water quality in terms of salinity has deteriorated in the Witbank and Middelburg Dams over time. The deterioration in these dams has been managed with the introduction of the controlled release schemes in these catchments. The acidic decants and seepage from many of the old underground mine workings in Klipspruit catchment are collected and neutralised at the Brugspruit WTW before discharging to the Brugspruit (a tributary of the Klipspruit). A White Paper was produced describing a phased approach for the management of water quality in the Klipspruit. The water quality in the Loskop Dam is being maintained at a satisfactory level by the water in the Wilge River (DWA, 2004) which has not been significantly impacted by activities in the catchment.

Mine water is generally high in dissolved solids with sulphate the dominant or indicator anion and calcium and magnesium the cations. Some of the waters contain high sodium particularly in the Middelburg Dam catchment (DWA, 2004). The information collected during the Loskop Dam Study indicated that at 1995 development levels, the coal mines generate some 8 million m^3 of excess mine water during an average rainfall year.

Mining can result in change of pH (acidity of the water), increased salinity, increased metal content, and increased sediment load. Industrial contributions are more varied, depending on the industrial process, but can include poisonous and hazardous chemicals, nutrients, elevated salinity and increased sediment (DEAT, 2007).

There are manufacturing and metallurgic industries in the Emalahleni and Steve Tshwete areas. Ecotourism is also an important industry in the WMA, with a number of private game parks and conservancies and the Kruger National Park (KNP) located in the Lower Olifants sub-area.

Waste disposal from industry and mining also results in an increased production of waste, creating a need for additional and improved waste-management facilities. Although techniques for containing waste are available and are being applied to new facilities, older waste repositories (industry and mining) and landfill sites (domestic) had no structured lining systems and they have released contaminated leachate into adjacent water resources (DEAT, 2007).

7. AVAILABILITY OF DATA/DATA COLLECTION

7.1 INTRODUCTION

The water quality of a natural stream is determined by the concentration of the different chemical variables of the water body. The change in the concentration of these different variables is the result of a number of random processes, including rainfall, runoff, anthropogenic activities, geology etc. Water quality is therefore rarely static, but changes over time and location. The measurement of the concentration of these different chemical variables is the data required to complete a water quality assessment.

The water quality assessment, however, does not focus on the instantaneous concentration as it is seldom that the instantaneous concentration has an impact on the water user. Rather the overall difference in the magnitude of the concentration and range of concentration over a period of time must be used as a measurement of the water quality status. For this reason individual water quality measurements (or data) are of little use to water quality managers, and regular measurements over a number of years are required.

The source, number and frequency of measurements are important in the overall evaluation of the water quality and decision making.

7.2 WATER QUALITY DATA USED

The data used for the water quality assessment was obtained from the DWA. This data was used to determine the history and trends of the water quality over a period of time and to assess the present or current water quality status. Only stations which fell within the Olifants Water Management Area were reviewed. Most of the data available was up to 2005, except for the Middle Olifants Catchment area which had data up to 2007. **Table 7.1** presents a list of the monitoring stations which were reviewed.

Table 7.1: List of DWA Water Quality Monitoring Stations

Area	Monitoring Station	Date of first Sample	Date of last Sample	No of Samples
Witbank Dam Catchment	B1R001Q01	1972/01/04	2005/05/27	808
	Rietspruit	1997/10/02	2005/05/27	461
	Rietspruit Dam	1998/07/27	2005/05/27	299
	Tweefontein	1997/10/02	2005/05/27	442
	Bethal Road Bridge	1997/10/02	2005/05/27	382
	B1H020	1990/05/01	2005/05/27	926
	B1H006	1982/10/13	2005/05/17	684
	B1H019	1990/05/09	2005/05/27	951
	B1H017	1990/01/02	2005/05/17	871
	B1H021	1990/07/02	2005/05/27	1043
	B1H018	1991/05/27	2005/05/27	925

Area	Monitoring Station	Date of first Sample	Date of last Sample	No of Samples
	B1H005	1979/11/20	2005/05/27	1057
	Duvha Road Bridge	1997/10/02	2005/05/27	299
Wilge River and Loskop Dam Catchment	B2H003	1983/05/03	2005/05/18	507
	B2H004	1984/10/27	2005/05/18	786
	B2H007	1985/08/26	2005/05/18	787
	B2H010	1983/07/29	2005/05/17	241
	B2H014	1991/01/30	2005/05/17	490
	B2H015	1994/01/05	2005/05/04	425
	B1H002	1979/05/05	2005/05/16	790
	B3R002	1972/08/31	2005/04/15	864
Middelburg Dam Catchment	B1H012	1993/11/16	2005/05/27	960
	B1H015	1983/02/01	2005/05/13	994
	B1H004	1966/04/18	2005/05/16	838
	B1R002Q01	2002/08/07	2003/08/27	48
Middle Olifants Catchment	B3R001Q01	1968/03/19	2007/02/13	211
	B3R005Q01	1983/04/05	2007/05/10	295
	B3H021	1994/01/06	2007/02/27	292
	B3H007	1992/08/19	2007/02/28	484
	B3H017	1993/09/01	2007/02/28	386
	B3H001	1976/10/12	2007/02/16	583
	B5R002	1998/07/01	2007/03/27	152
	B5H004	1993/09/01	2007/05/11	381
	B3H002	1998/12/15	2004/10/13	299

Figure 7.1 shows the location of the DWA water quality stations that were used for the analysis.

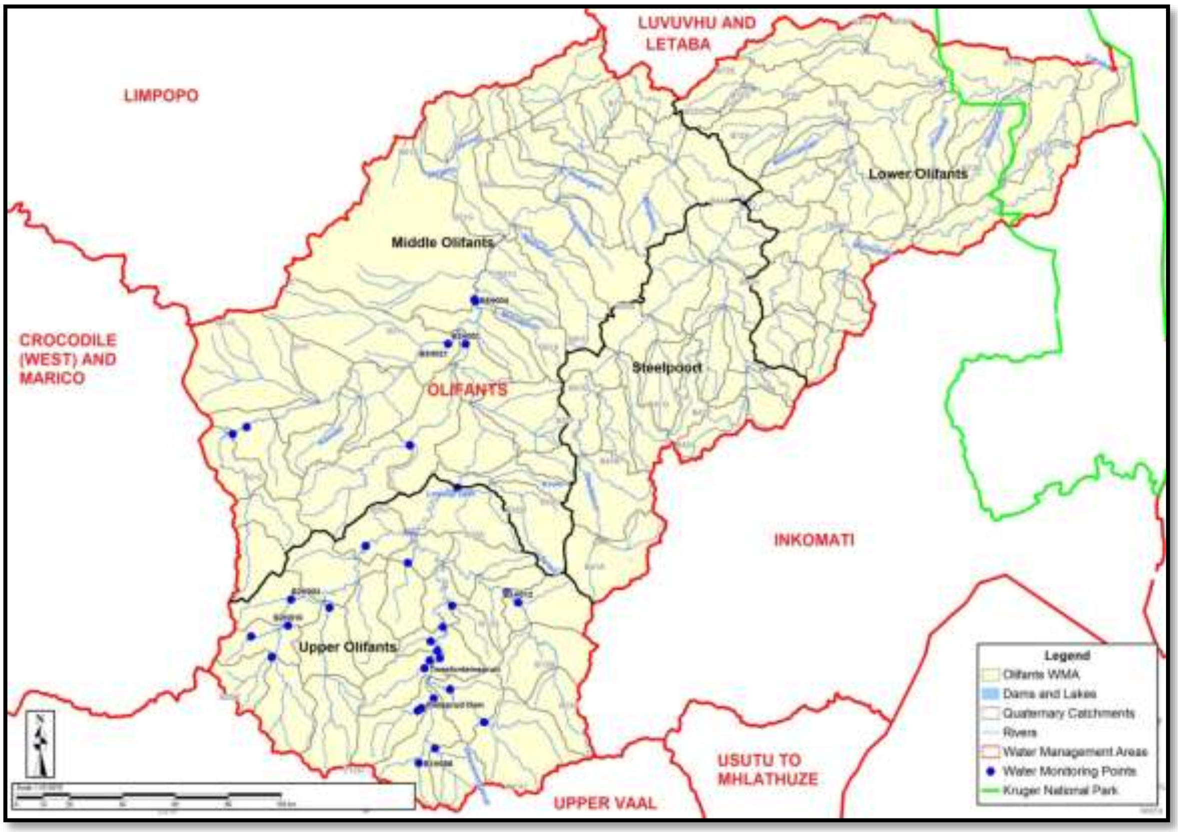


Figure 7.1: DWA Monitoring Stations

7.3 PREPARATION OF THE WATER QUALITY DATA

To determine the status of the water quality of the Olifants River System, the data has to be assessed in an unbiased manner for all the purposes for which the water is being used. This followed a basic systematic approach of:

1. Filtering of data to remove bias, a process of selecting a single measurement of the water quality for each month over the period of review; and,
2. Checking of the completeness of data (sufficient data to present a statistically sound view of the water quality status of the water body).

7.4 CALCULATIONS

7.4.1 Statistics

The statistical parameters for the data sets were calculated by making use of the relevant functions in Excel.

8. FITNESS FOR USE CLASSIFICATION

8.1 INTRODUCTION

To answer the questions “what is the water quality” and “how has the water quality changed” non-parametric statistics are used to calculate the variability, which is a measure of how water quality may differ over time. Non-parametric statistics depend on equally spaced (over time) data, which then allows the calculation of the percentage of time for which a value was not exceeded. The 75th percentile value thus refers to a value that was not exceeded for 75 percent of the data points. The interquartile range (the values between the 25th percentile and the 75th percentile) indicate the central tendency, as the values fall between these two values for 50 percent of the time. The 95th percentile is an indication of the variability.

The current water quality was based on the calculation of the median, 75th percentile and the 95th percentile.

Except for extreme cases, the instantaneous value is not significant, rather it is the long term exposure that will determine the effect on a user. For this reason it is necessary to develop a set of water quality guidelines that can be used in conjunction with the statistical parameters to determine fitness for use.

The water quality guidelines as developed by the DWA, South Africa (DWAF, 1996 - South African Water Quality Guidelines Volumes 1 to 7 (second edition)) were used as the main set of criterion for the evaluation process.

Water quality guidelines have been set for each of the major categories of water use. This makes it possible to have more than one guideline for each of the water quality variables (depending on how many water uses are affected or for how many variables a water use has had water quality guidelines set for it).

The guidelines provide a “description” of the impact that the water quality will have on the “usability” of that water. This “description” is a set of cut-off values, for each of the different fitness-for-use categories.

The process to determine the water quality status followed the following steps:

1. Selection of the variables of concern,
2. Determining a set of water user specific guidelines unique to the catchment and study,
3. The evaluation of the data against this set of guidelines,
4. The interpretation of the evaluated data against a set of criteria to determine overall status of the water quality, and
5. The interpretation of the water quality trends.

8.2 VARIABLES OF CONCERN

The objective of the study is not to perform an in-depth analysis of water quality in the study area, but rather to provide a broad overview of the current water quality situation. For this reason only a few indicator variables were chosen.

Total Dissolved Solids (TDS)
The total dissolved solids (TDS) are a measure of the quantity of various inorganic salts dissolved in water. The TDS concentration is directly proportional to the electrical conductivity (EC) of water. Normally at a ratio of TDS: EC of 6.5:1. Since EC is much easier to measure than TDS, it is routinely used as an estimate of the TDS concentration (DWAF: Domestic, 1996). Electrical Conductivity (EC): is used as an indicator of the salinity of the water. This affects both domestic use as well as irrigation. The aquatic ecosystem is only affected if the salinity deviates to a large extent from the natural background value.

pH
The pH of natural waters is a measure of the acid-base equilibrium of various dissolved compounds, and is a result of the carbon dioxide-bicarbonate-carbonate equilibrium which involves various constituent equilibriums, all of which are affected by temperature. Conditions which favour production of hydrogen ions result in a lowering of pH, referred to as an acidification process. Alternatively, conditions which favour neutralisation of hydrogen ions result in an increase in pH, referred to as an alkalinisation process. The pH of water does not have direct consequences on the use except at extremes. The adverse effects of pH result from the solubilisation of toxic heavy metals and the protonation or deprotonation of other ions (DWAF: Ecosystems, 1996). pH: is used as an indicator of characteristics such as the acidity or alkalinity of the water, which in turn is an indication of possible aggressive or corrosive properties. Health impacts are normally limited to irritation of mucous membranes or the eyes when swimming. The aquatic ecosystem is only affected by significant deviations from the natural background value.

Chloride (Cl)
Chloride (Cl): is an indicator of the nature of the salinity. It is an indicator of salty taste, and also corrosivity with respect to household appliances and irrigation equipment. In some water bodies' sulphate has the same effect as chloride and the two should be assessed in conjunction with each other.

Effects on the aquatic ecosystem as a result of salinity will be detected long before chloride in itself becomes problematic, and chloride can therefore be ignored when assessing water quality in this respect. Some crops, specifically deciduous trees such as citrus, are sensitive to chloride as it builds up in the leaves and causes leave sclerosis. This is probably the most sensitive use with respect to chloride.

Nitrite (NO_2)/Nitrate (NO_3)
Nitrogen refers to all inorganic nitrogen forms present in water, that is, ammonia, ammonium, nitrite and nitrate. Ammonia (NH_3) and Ammonium (NH_4) are the reduced forms of inorganic nitrogen and their relative portions in water are governed by water temperature and pH. Nitrite (NO_2) is the inorganic intermediate and nitrate (NO_3) the end product of the oxidation of organic nitrogen and ammonia. Nitrate is the more

stable of the two forms, and usually, by far, the more abundant in the soil and water environment. In view of their co-occurrence and rapid interconversion, nitrite and nitrate are usually measured and considered together (DWAF: Irrigation, 1996). Nitrate/Nitrite (NO_3/NO_2): has a health effect on humans, and is also an indication of contamination from human activities in the catchment, notably the discharge of treated waste water. Nitrite has a toxic effect on aquatic organisms, particularly those organisms that breathe under water.

Ammonia (NH_3)
Total Ammonia is used as an indicator of the presence of Ammonia which is highly toxic to aquatic life even in low concentrations, and is therefore difficult to measure. Ammonia has no effect on human consumption or on irrigation in the concentrations in which it occurs in rivers and streams. Ammonia is broken down to Nitrate/Nitrite by bacteria that occur naturally in water bodies.

Phosphate (PO_4)
Phosphorus can occur in numerous organic and inorganic forms, and may be present in waters as dissolved and particulate species. Elemental phosphorus does not occur in the natural environment. In unimpacted waters Phosphorus is readily utilized by plants and converted into cell structures by photosynthetic action. Phosphorus is considered to be the principle nutrient controlling the degree of eutrophication in aquatic ecosystems. Natural sources of phosphorus include the weathering of rocks and the subsequent leaching of phosphate salts into surface waters, in addition to the decomposition of organic matter. In South Africa, phosphorus is seldom present in high concentrations in unimpacted surface waters because it is actively taken up by plants. Elevated levels of phosphorus may result from point-source discharges such as domestic and industrial effluents and from diffuse sources (non-point sources) in which the phosphorus load is generated by surface and subsurface drainage. Non-point sources include atmospheric precipitation, urban runoff, and drainage from agricultural land, in particular from land on which fertilizers have been applied.

Phosphorus concentrations are usually determined as orthophosphates, total inorganic phosphate or total dissolved phosphorus (which includes organically bound phosphorus and all phosphates). The dissolved forms are measured after filtering the sample through a prewashed 0.45 µm filter. Concentrations of particulate phosphorus can be calculated from the difference between the concentrations of the total and dissolved fractions (DWAF: Ecosystems, 1996). Phosphate (PO_4): has no direct effect on the use of water, but is an indicator of contamination from activities in the catchment such as waste water discharge and fertilisers from agricultural activities

Sulphate (SO_4)
Sulphate is a naturally occurring substance that contains sulphur and oxygen. It is present in various mineral salts that are found in soil. Sulphate may be leached from the soil and is commonly found in most water supplies. Magnesium, potassium and sodium sulphate salts are all soluble in water. Calcium and barium sulphates are not very easily dissolved in water.

There are several other sources of sulphate in water. Decaying plant and animal matter may release sulphate into water. Numerous chemical products including ammonium sulphate fertilizers contain sulphate in a variety of forms. Human activities such as the combustion of fossil fuels and sour gas processing release sulphur oxides to the atmosphere, some of which is converted to sulphate.

Sulphate is generally considered to be non-toxic. The consumption of drinking water containing high amounts of magnesium or sodium sulphate may result in intestinal discomfort, diarrhoea and consequently dehydration. This laxative effect is often observed when someone drinks water that contains greater than 500 milligrams per litre (mg/L) of sulphate. Over time, individuals appear to develop a tolerance to higher concentrations of sulphate. Diarrhoea and dehydration are often observed when individuals accustomed to drinking water with low concentrations of sulphate consume water with high amounts of sulphate. It is not advisable to use water that contains high concentrations of sulphate for infant feeding.

8.3 FITNESS-FOR-USE CATEGORIES

Water quality does not suddenly change from "good" to "bad". Instead there is a gradual change between categories and this is reflected by the fitness-for-use range which is graded to indicate the increasing risk of using the water.

Water quality criteria are discrete values that describe a specific effect as a result of a particular set of conditions. These criteria are then used to develop guidelines, which describe the effect on a user who is exposed to an ever increasing concentration or changing value.

Water quality criteria are used to describe the fitness-for-use. The fitness-for-use range can be divided into four sections which are classified as four categories, ranging from "ideal" to "unacceptable". These categories are described as:

Ideal : the user of the water is not affected in any way;
Acceptable : slight to moderate problems are encountered;
Tolerable : moderate to severe problems are encountered; and
Unacceptable : the water cannot be used under normal circumstances.

The fitness-for-use range is colour coded for ease of interpretation of information during the assessment of the water quality (**Table 8.1**).

Table 8.1: Colour codes assigned to fitness for use ranges

Fitness for use range	Colour code
Ideal	**Blue**
Acceptable	Green
Tolerable	Yellow
Unacceptable	**Red**

8.4 IDENTIFICATION OF FITNESS-FOR-USE

Water quality guidelines describe the fitness-for-use of the water. The biological, chemical or physical data is analysed and the results are compared against the guidelines to assess the water quality of a resource.

It is therefore necessary that water quality guidelines be identified for each water use and for each variable of concern. The basis of these guidelines can be found in the South African Water Quality Guidelines, Volumes 1 to 7 (DWAF: Domestic, 1996), (DWAF: Ecosystems, 1996), (DWAF: Irrigation, 1996) and (DWAF: Livestock, 1996).

The DWA water quality guidelines make provision for five water use categories, namely domestic, recreation, industrial, agricultural (irrigation, livestock watering, and aquaculture) and the aquatic ecosystem.

For the purposes of this study only three out of the five water use categories have been taken into account, namely domestic use, agricultural use (irrigation and livestock watering) and the aquatic ecology, as the other are not relevant to the catchment in the study area.

The guidelines provide a description of the effect that changes in water quality will have on the use and not an interpretation of whether this is acceptable or not. From these guidelines the cut-off values for the different fitness-for-use categories have been set.

The water quality guidelines identified for the abovementioned water uses for the variables of concern are summarised in **Table 8.2** and **Table 8.3**.

8.5 COMBINED FITNESS-FOR-USE CLASSIFICATION

The cut-off values for the fitness for use categories are per user and per variable and can be used to assess the fitness for use of the water in the Olifants River System for individual uses or user categories such as domestic, agriculture, industry, recreation and the aquatic ecosystem.

In order to determine the fitness for use of the water resource in Olifants River System as a whole, the different fitness for use categories for different users affected by the same variable were reconciled.

This was done by selecting the most stringent value, in other words the value for the most sensitive use to water quality deterioration, for each cut-off value in order to arrive at the management levels or combined fitness-for-use.

The summary of the combined fitness-for-use values are given in **Table 8.4**.

Table 8.2: User Specific Guidelines: Domestic

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
DOMESTIC (SA)					
Electrical Cond.	mS/m	< 70.00	70.00 to 150.0	150.0 to 370.0	> 370.0
pH (lower range)	pH units	> 5.00	5.00 to 4.50	4.50 to 4.00	< 4.00
(upper range)		< 9.50	9.50 to 10.00	10.00 to 10.50	> 10.50
Nitrate / Nitrite	mg/l N	< 6.00	6.00 to 10.00	10.00 to 20.00	> 20.00
Ammonia	mg/l	< 1.00	1.00 to 2.00	2.00 to 10.00	> 10.00
Chloride	mg/l	< 100.0	100.0 to 200.0	200.0 to 600.0	> 600.0
Phosphate	mg/l P				
Sulphate	mg/l	< 200.0	200.0 to 400.0	400.0 to 600.0	> 600.0

Table 8.3: User Specific Guidelines: Agriculture & Ecology

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
AGRICULTURE: Irrigation (SA)					
Electrical Cond.	mS/m	< 40.00	40.00 to 270.0	270.0 to 540.0	> 540.0
pH (lower range) **(upper range)**	pH units	> 6.50 < 8.40			< 6.50 > 8.40
Nitrate / Nitrite	mg/l N				
Ammonia	mg/l				
Chloride	mg/l	< 100.0	100.0 to 175.0	175.0 to 700.0	> 700.0
Phosphate	mg/l P				
Sulphate	mg/l				
AGRICULTURE: Livestock Watering (SA)					
Electrical Cond.	mS/m	< 154.0	153.0 to 308.0	308.0 to 462.0	> 462.0
pH	pH units				
Nitrate / Nitrite	mg/l N	< 100.0	100.0 to 250.0	250.0 to 400.0	> 400.0
Ammonia	mg/l				
Chloride	mg/l	< 1000.	1000. to 1750.	1750. to 2000.	> 2000.
Phosphate	mg/l P				
Sulphate	mg/l	< 1000.	1000. to 1250.	1250. to 1500.	> 1500.
ECOLOGICAL (SA)					
Electrical Cond.	mS/m				
pH	pH units				
Nitrate / Nitrite	mg/l N				
Ammonia	mg/l	< 0.27	0.27 to 0.58	0.58 to 3.85	> 3.85
Chloride	mg/l				
Phosphate	mg/l P	< 0.01	0.01 to 0.03	0.03 to 0.25	> 0.25

Table 8.4: Combined Fitness-for-Use Categories

Variable	Units	Ideal	Acceptable	Tolerable	Unacceptable
Electrical Cond.	mS/m	< 40.00	40.00 to 150.0	150.0 to 310.0	> 310.0
pH (lower range)	pH units	> 5.00	5.00 to 4.50	4.50 to 4.00	< 4.00
(upper range)		< 8.40	8.50 to 9.50	9.50 to 10.00	> 10.00
Ammonia	mg/l	< 0.20	0.20 to 1.00	1.00 to 2.00	> 2.00
Chloride	mg/l	< 100.0	100.0 to 175.0	175.0 to 600.0	> 600.0
Sulphate	mg/l	< 200.0	200.0 to 250.0	250.0 to 400.0	> 400.0
Nitrate / Nitrite	mg/l N	< 6.00	6.00 to 10.00	10.00 to 20.00	> 20.00
Phosphate	mg/l P	< 0.01	0.01 to 0.03	0.03 to 0.25	> 0.25

The explanation of how the cut-off values for the water quality variables for each of the variables are were decided on as follows:

Electrical Conductivity (EC):
The agricultural guideline for irrigation is the most stringent. The ideal range in this guideline falls between 0 and 40 mS/m. Except that domestic use has a lower "unacceptable" limit than irrigation.

pH:
The fitness for use for the pH category simply represents a combination of all the user-specific guidelines to form the most stringent.

Nitrate and Nitrite:
Nitrate/Nitrite concentrations are important in domestic and for irrigation use. However, it is more stringent for domestic use.

Ammonia:
There are guidelines for ammonia in the domestic and ecological user groups. It is, however, more stringent in ecological use. It is also an existing variable within the existing data and gives a good indication of water quality for domestic use.

Chloride:
The most stringent guideline is for agricultural irrigation, although there are also guidelines for domestic use. This guideline will be carried over to the fitness-for-use categories because it is necessary to protect the crops farmed from toxic levels of chloride.

Phosphorous:
The only guideline for phosphorous is in the ecological user group.

Sulphate:
Domestic use has strict requirements for sulphate concentrations and determined the combined fitness for use guidelines.

Each water quality variable was then assessed over the long term in accordance with **Table 8.5** and accordingly categorised.

Table 8.5: Water Quality Assessment Category

Fitness for use range in which the variable falls			Water quality assessment category	Colour code
Median	75th percentile	95th percentile		
Ideal	Ideal	Ideal	Ideal	Blue
Ideal	Ideal	Acceptable	Acceptable	Green
Ideal	Acceptable	Acceptable		
Acceptable	Acceptable	Acceptable		
Ideal	Ideal	Tolerable		

Fitness for use range in which the variable falls			Water quality assessment category	Colour code
Median	75th percentile	95th percentile		
Ideal	Acceptable	Tolerable	Tolerable	Yellow
Acceptable	Acceptable	Tolerable		
Acceptable	Tolerable	Tolerable		
Tolerable	Tolerable	Tolerable		
Any other combination			**Unacceptable**	**Red**

For instance, if the median is in the ideal range, the 75th percentile is in the acceptable range and the 95th percentile is in the tolerable range, then the water quality assessment category is “tolerable”.

This methodology thus tests a set of data in a consistent and unbiased manner, taking into consideration the water quality, of each of the variables of concern, for the full range of fitness-for-use (median, the 75th and the 95th percentiles) of the water for a specific resource. In this methodology the full time span of the water quality of the resource is checked in an acceptable scientific manner in the same way one sample would be checked for fitness-for-use.

9. RESULTS OF WATER QUALITY STATISTICAL ANALYSIS

9.1 SAMPLING SITES USED

Only the monitoring stations in the Olifants Water management area were used for the water quality assessment.

9.2 WATER QUALITY SITUATION IN THE OLIFANTS RIVER SYSTEM

Table 9.1 is the water quality assessment of the fitness-for-use of the water resources using the median values. The assessment indicates that most of the resources show a water quality that is “ideal” for use in the Olifants River System. The phosphates levels in the Olifants River System are within acceptable ranges. The only cause for concern is the pH values at station B1H004 in the Middelburg Dam Catchment which is in the unacceptable range.

Table 9.1: Water Quality Assessment: Median

Area	Monitoring Point	EC	NO_3/NO_2	PO_4	NH_3	pH	Cl	SO_4
Witbank Dam Catchment	B1R001Q01	48.65	0.14	0.01		7.80	16.30	143
	Rietspruit	48				7.91	44.00	53
	Rietspruit Dam	29.35				8.24	26.00	33.42
	Tweefontein	82.3				7.88	82.00	77
	Bethal Road Bridge	60.8				7.71	24.00	61.2
	B1H020	111.05	0.042	0.015	0.045	7.76	44.40	381.8
	B1H006	25.90	0.090	0.015	0.042	7.70	11.5	21.2
	B1H019	78.35	0.046	0.0120	0.04	7.640	20.693	237.68
	B1H017	58.95	0.01	0.019	0.01	8.33	24.75	47.10
	B1H021	45.25	0.28	0.09	0.041	8.23	22	67.8
	B1H018	33	0.01	0.022	0.01	8.11	19.10	31.4
	B1H005	63.25	0.158	0.014	0.04	7.97	20.10	179
	Duvha Road Bridge	52.55				8.07	22.00	50.8
Wilge River and Loskop Dam Catchment	B2H003		0.09	0.02	0.01	8.17	10.40	
	B2H004		0.12	0.01	0.05	8.19	6.50	
	B2H007		0.60	0.01	0.04	8.17	6.60	
	B2H010		0.01	0.02	0.05	8.23	12.22	
	B2H014		0.10	0.01	0.01	8.04	8.00	
	B2H015		0.07	0.01	0.01	7.83	8.00	
	B1H002	54.3	0.23	0.01	0.05	7.39	10.00	379.89
	B3R002	27.8	0.11	0.01	0.05	7.40	14.10	63
Middelburg Dam Catchment	B1H012	76.1	0.04	0.01	0.04	7.96	20.53	288.8
	B1H015	50.7	0.08	0.01	0.04	7.94	14.40	159.35
	B1H004		1.27	0.01	0.12	3.96	41.85	
	B1R002Q01	44						134
Middle Olifants Catchment	B3R001Q01		0.01	0.01	0.01	7.67	12.36	
	B3R005Q01		0.08	0.01	0.05	8.09	17.30	
	B3H021		0.18	0.03	0.01	8.31	179.25	
	B3H007		0.07	0.02	0.01	7.95	9.40	
	B3H017		0.15	0.01	0.04	7.87	13.14	
	B3H001		0.33	0.01	0.04	8.06	45.85	

Area	Monitoring Point	EC	NO_3/NO_2	PO_4	NH_3	pH	Cl	SO_4
	B5R002		0.08	0.02	0.02	8.11	37.22	
	B5H004		0.16	0.01	0.02	8.11	33.45	
	B3H002	131.85						431.64

(See **Table 8.5** for reference to colours)

Table 9.2 is the water quality assessment of the fitness-for-use of the water resources in the study area based on the 75th percentile values. The assessment indicates that most of the values of the different variables show a water quality that is "ideal" or "acceptable" for use in the area that it occurs. However station B1H004 in the Middleburg Dam Catchment can be highlighted as showing periods of time that the ammonia levels of that water resource as to be "unacceptable".

Table 9.2: Water Quality Assessment: 75th Percentile

Area	Monitoring Point	EC	NO_3/NO_2	PO_4	NH_3	pH	Cl	SO_4
Witbank Dam Catchment	B1R001Q01	58.5	0.239	0.017		8.05	21.72	167.15
	Rietspruit	76.3				8.16	66.00	100.4
	Rietspruit Dam	41.2				8.59	35.75	38.2
	Tweefontein	122.6				8.24	138.00	233
	Bethal Road Bridge	75.9				8.10	30.00	86
	B1H020	151.27	0.074	0.0215	0.068	8.06	55.95	684
	B1H006	28.1	0.2	0.023	0.06	8.15	13.5	25.154
	B1H019	106.125	0.084	0.018	0.049	7.91	26.775	475.95
	B1H017	67.80	0.055	0.031	0.045	8.47	32.70	59
	B1H021	60.32	0.738	0.18	0.093	8.54	32.87	98
	B1H018	42.4	0.073	0.033	0.048	8.28	27	44.54
	B1H005	87.02	0.343	0.025	0.064	8.20	26.40	301
	Duvha Road Bridge	62.85				8.48	27.00	93.25
Wilge River and Loskop Dam Catchment	B2H003		0.160	0.025	0.059	8.31	12.03	
	B2H004		0.269	0.019	0.067	8.34	9.20	
	B2H007		0.830	0.018	0.060	8.30	8.30	
	B2H010		0.120	0.025	0.093	8.35	14.13	
	B2H014		0.226	0.022	0.045	8.18	10.11	
	B2H015		0.143	0.020	0.041	7.98	10.17	
	B1H002	109.5	0.417	0.019	0.070	7.86	12.42	854.1
	B3R002	33.1	0.206	0.015	0.070	7.77	16.50	82
Middelburg Dam Catchment	B1H012	112.1	0.100	0.017	0.059	8.20	25.00	
	B1H015	61.8	0.138	0.016	0.060	8.09	16.49	
	B1H004							
	B1R002Q01	47						134
Middle Olifants Catchment	B3R001Q01		0.059	0.019	0.070	7.91	15.83	
	B3R005Q01		0.140	0.020	0.078	8.22	27.03	
	B3H021		0.649	0.041	0.052	8.45	246.92	
	B3H007		0.183	0.023	0.040	8.09	13.31	
	B3H017		0.249	0.018	0.093	8.02	15.54	
	B3H001		0.535	0.022	0.060	8.33	72.19	
	B5R002		0.171	0.024	0.045	8.27	67.87	
	B5H004		0.262	0.021	0.058	8.22	63.47	
	B3H002	156.45						431.64

(See **Table 8.5** for reference to colours)

Table 9.3 is the water quality assessment of the fitness-for-use for the study area based on the 95th percentile values. Again a number of the values of the different variables show a water quality that is an “ideal” or “acceptable” water quality for use.

However, phosphate levels in the study area ranges from acceptable to ”tolerable”. Station B1H004 in the Middleburg Dam Catchment can be highlighted as showing periods of time that the ammonia levels of that water resource as to be “unacceptable”.

Table 9.3: Water Quality Assessment: 95th Percentile

Area	Monitoring Point	EC	NO_3/NO_2	PO_4	NH_3	pH	Cl	SO_4
Witbank Dam Catchment	B1R001Q01	70.23	0.442	0.030	0.112	8.300	35.60	216.5
	Rietspruit	151.4				8.510	96.20	420
	Rietspruit Dam	56.45				9.030	45.00	59
	Tweefontein	239.7				9.009	224.10	356
	Bethal Road Bridge	140				8.738	48.00	291.8
	B1H020	284	0.1708	0.0517	0.4284	8.35	80	1582.95
	B1H006	32.25	0.4385	0.053	0.12	8.44	17.2	34.2
	B1H019	162	0.20035	0.0340	0.10455	8.223	42.225	846.46
	B1H017	76.400	0.2954	0.0816	0.093	8.72	41.14	78.58
	B1H021	91	1.905	0.711	0.324	9.1121	45.88	265
	B1H018	57.940	0.2197	0.06425	0.086	8.49	41.275	77.55
	B1H005	136.935	0.921	0.0586	0.130	8.48	35.8	632
	Duvha Road Bridge	114.2				8.931	35.90	193
Wilge River and Loskop Dam Catchment	B2H003		0.353	0.050	0.110	8.460	16.07	
	B2H004		0.489	0.034	0.103	8.510	13.50	
	B2H007		1.717	0.031	0.090	8.510	11.67	
	B2H010		0.314	0.047	0.357	8.494	16.73	
	B2H014		0.371	0.047	0.080	8.364	12.51	
	B2H015		0.276	0.043	0.067	8.185	13.48	
	B1H002	250.5	0.957	0.039	0.266	8.370	17.90	1423.3
	B3R002	43.60	0.760	0.036	0.121	8.118	22.53	123
Middelburg Dam Catchment	B1H012	182.4	0.283	0.036	0.104	8.740	36.90	1042
	B1H015	73.3	0.276	0.026	0.104	8.290	21.78	257.62
	B1H004		6.938	0.054	7.318	7.611	90.31	
	B1R002Q01	65.95						205
Middle Olifants Catchment	B3R001Q01		0.221	0.038	0.186	8.187	21.45	
	B3R005Q01		0.312	0.034	0.133	8.375	36.77	
	B3H021		1.305	0.093	0.103	8.636	423.92	
	B3H007		0.391	0.050	0.072	8.269	21.39	
	B3H017		0.495	0.031	0.286	8.190	18.78	
	B3H001		0.970	0.065	0.110	8.533	131.45	
	B5R002		0.288	0.054	0.090	8.412	79.10	
	B5H004		0.484	0.039	0.137	8.376	76.09	
	B3H002	206						1393.75

(See **Table 8.5** for reference to colours)

Table 9.4 is the concluding water quality assessment, as calculated by using the median, 75th and 95th percentiles data sets in the water quality assessment methodology as set out in **Table 8.4**, presenting the “overall” fitness-for-use of the Cl of the water quality resources within the study area. **Table 9.5**, **Table 9.6** and **Table 9.7** present the same for pH, EC and sulphates.

The water in the study Olifants River system generally presents no problem with respect to irrigation, urban use and industrial use except pH levels at station B1H004 in the Middelburg Dam Catchment. The EC levels are slightly high but are within the acceptable and tolerable ranges. The sulphate levels range between ideal and unacceptable. The main cause for concern in the Witbank Dam Catchment is the high levels of sulphates at stations B1H020, B1H019, B1H005 and the Rietspruit. The same applies for stations B1H012 in the Wilge River and Loskop Dam Catchment and station B3H002 in the Middle Olifants Catchment.

Table 9.4: Concluding Cl Water Quality Assessment

Area	Monitoring Point	Cl			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
Witbank Dam Catchment	B1R001Q01	B	B	B	B
	Rietspruit	B	B	B	B
	Rietspruit Dam	B	B	B	B
	Tweefontein	B	B	Y	G
	Bethal Road Bridge	B	B	B	B
	B1H020	B	B	B	B
	B1H006	B	B	B	B
	B1H019	B	B	B	B
	B1H017	B	B	B	B
	B1H021	B	B	B	B
	B1H018	B	B	B	B
	B1H005	B	B	B	B
	Duvha Road Bridge	B	B	B	B
Wilge River and Loskop Dam Catchment	B2H003	B	B	B	B
	B2H004	B	B	B	B
	B2H007	B	B	B	B
	B2H010	B	B	B	B
	B2H014	B	B	B	B
	B2H015	B	B	B	B
	B1H002	B	B	B	B
	B3R002	B	B	B	B
Middelburg Dam Catchment	B1H012	B	B	B	B
	B1H015	B	B	B	B
	B1H004	B	B	B	B
Middle Olifants Catchment	B3R001Q01	B	B	B	B
	B3R005Q01	B	B	B	B
	B3H021	Y	Y	Y	Y
	B3H007	B	B	B	B
	B3H017	B	B	B	B
	B3H001	B	B	G	G
	B5R002	B	B	B	B
	B5H004	B	B	B	B

(See **Table 8.5** for reference to colours)

Table 9.5: Concluding pH Water Quality Assessment

Area	Monitoring Point	pH			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
Witbank Dam Catchment	B1R001Q01	B	B	B	B
	Rietspruit	B	B	G	G
	Rietspruit Dam	B	G	G	G
	Tweefontein	B	B	G	G
	Bethal Road Bridge	B	B	G	G
	B1H020	B	B	B	B
	B1H006	B	B	B	B
	B1H019	B	B	B	B
	B1H017	B	B	B	B
	B1H021	B	B	G	G
	B1H018	B	B	B	B
	B1H005	B	B	B	B
	Duvha Road Bridge	B	B	G	G
Wilge River and Loskop Dam Catchment	B2H003	B	B	B	B
	B2H004	B	B	B	B
	B2H007	B	B	B	B
	B2H010	B	B	B	B
	B2H014	B	B	B	B
	B2H015	B	B	B	B
	B1H002	B	B	B	B
	B3R002	B	B	B	B
Middelburg Dam Catchment	B1H012	B	B	B	B
	B1H015	B	B	B	B
	B1H004	R	B	B	R
Middle Olifants Catchment	B3R001Q01	B	B	B	B
	B3R005Q01	B	B	B	B
	B3H021	B	B	B	B
	B3H007	B	B	B	B
	B3H017	B	B	B	B
	B3H001	B	B	B	B
	B5R002	B	B	B	B
	B5H004	B	B	B	B

(See **Table 8.5** for reference to colours)

Table 9.6: Concluding EC Water Quality Assessment

Area	Monitoring Point	EC			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
Witbank Dam Catchment	B1R001Q01	G	G	G	G
	Rietspruit	G	G	Y	Y
	Rietspruit Dam	B	G	G	G
	Tweefontein	G	G	Y	Y
	Bethal Road Bridge	G	G	G	G
	B1H020	G	Y	Y	Y
	B1H006	B	B	B	B
	B1H019	G	G	Y	Y
	B1H017	G	G	G	G

Area	Monitoring Point	EC			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
	B1H021	G	G	G	G
	B1H018	B	G	G	G
	B1H005	G	G	G	G
	Duvha Road Bridge	G	G	G	G
Wilge River and Loskop Dam Catchment	B2H003				
	B2H004				
	B2H007				
	B2H010				
	B2H014				
	B2H015				
	B1H002	G	G	Y	Y
	B3R002	B	B	G	G
Middelburg Dam Catchment	B1H012	G	G	Y	Y
	B1H015	G	G	G	G
	B1H004				
	B1R002Q01	G	G	G	G
Middle Olifants Catchment	B3R001Q01				
	B3R005Q01				
	B3H021				
	B3H007				
	B3H017				
	B3H001				
	B5R002				
	B5H004				
	B3H002	G	Y	Y	Y

(See **Table 8.5** for reference to colours)

Table 9.7: Concluding SO4 Water Quality Assessment

SO_4					
Area	Monitoring Point	Median	75th Percentile	95th Percentile	Concluding Water Quality Category
Witbank Dam Catchment	B1R001Q01	B	B	G	G
	Rietspruit	B	B	R	R
	Rietspruit Dam	B	B	B	B
	Tweefontein	B	G	Y	Y
	Bethal Road Bridge	B	B	Y	G
	B1H020	Y	R	R	R
	B1H006	B	B	B	B
	B1H019	G	R	R	R
	B1H017	B	B	B	B
	B1H021	B	B	Y	G
	B1H018	B	B	B	B
	B1H005	B	Y	R	R
	Duvha Road Bridge	B	B	B	B
Wilge River and Loskop Dam Catchment	B2H003				
	B2H004				
	B2H007				

SO_4					
Area	**Monitoring Point**	**Median**	**75th Percentile**	**95th Percentile**	**Concluding Water Quality Category**
	B2H010				
	B2H014				
	B2H015				
	B1H002	Y	R	R	R
	B3R002	B	B	B	B
Middelburg Dam Catchment	B1H012	Y	B	R	R
	B1H015	B	B	Y	G
	B1H004				
	B1R002Q01	B	B	Y	G
Middle Olifants Catchment	B3R001Q01				
	B3R005Q01				
	B3H021				
	B3H007				
	B3H017				
	B3H001				
	B5R002				
	B5H004				
	B3H002	R	R	R	R

(See **Table 8.5** for reference to colours)

During the late 1990s there was a sudden increase in the electrical conductivity of the water in the Loskop Dam. This was maintained until 2005/2006, after which there has been a gradual reduction in electrical conductivity. This can possibly be related to the neutralisation of acid mine drainage water in the catchment, which was discontinued around 2005 (**Figure 9.1**).

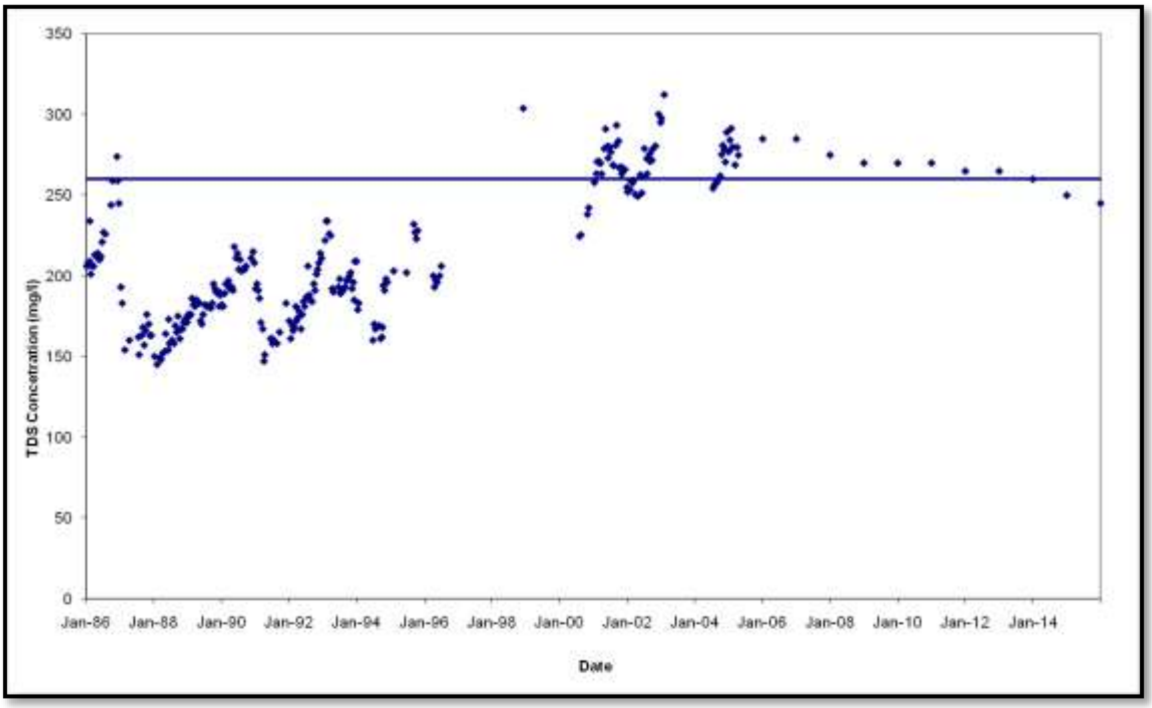


Figure 9.1: Electrical Conductivity Trend in the Loskop Dam

The results for the nutrients are presented in **Table 9.8, Table 9.9**, and **Table 9.10**.

Table 9.8: Concluding NO3/NO2 Water Quality Assessment

Area	Monitoring Point	NO_3/NO_2			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
Witbank Dam Catchment	B1R001Q01	B	B	B	B
	Rietspruit				
	Rietspruit Dam				
	Tweefontein				
	Bethal Road Bridge				
	B1H020	b	b	b	b
	B1H006	b	b	b	b
	B1H019	b	b	b	b
	B1H017	b	b	b	b
	B1H021	b	b	b	b
	B1H018	b	b	b	b
	B1H005	b	b	b	b
	Duvha Road Bridge				
Wilge River and Loskop Dam Catchment	B2H003	B	B	B	B
	B2H004	B	B	B	B
	B2H007	B	B	B	B
	B2H010	B	B	B	B
	B2H014	B	B	B	B
	B2H015	B	B	B	B
	B1H002	B	B	B	B
	B3R002	B	B	B	B
Middelburg Dam Catchment	B1H012	B	B	B	B
	B1H015	B	B	B	B
	B1H004	B	B	R	R
Middle Olifants Catchment	B3R001Q01	B	B	B	B
	B3R005Q01	B	B	B	B
	B3H021	B	B	B	B
	B3H007	B	B	B	B
	B3H017	B	B	G	G
	B3H001	B	B	B	B
	B5R002	B	B	B	B
	B5H004	B	B	B	B

(See **Table 8.5** for reference to colours)

Table 9.9: Concluding PO4 Water Quality Assessment

Area	Monitoring Point	PO_4			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
Witbank Dam Catchment	B1R001Q01	B	G	G	G
	Rietspruit				
	Rietspruit Dam				
	Tweefontein				
	Bethal Road Bridge				
	B1H020	G	G	Y	Y
	B1H006	G	G	Y	Y
	B1H019	G	G	Y	Y

Area	Monitoring Point	PO4			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
	B1H017	G	Y	Y	Y
	B1H021	G	G	Y	Y
	B1H018	G	Y	Y	Y
	B1H005	G	G	Y	Y
	Duvha Road Bridge				
Wilge River and Loskop Dam Catchment	B2H003	G	G	Y	Y
	B2H004	G	G	Y	Y
	B2H007	G	G	Y	Y
	B2H010	G	G	Y	Y
	B2H014	G	G	Y	Y
	B2H015	G	G	Y	Y
	B1H002	G	G	Y	Y
	B3R002	G	G	Y	Y
Middelburg Dam Catchment	B1H012	G	G	Y	Y
	B1H015	G	G	G	G
	B1H004	G	G	Y	Y
Middle Olifants Catchment	B3R001Q01	G	G	Y	Y
	B3R005Q01	G	G	Y	Y
	B3H021	G	Y	Y	Y
	B3H007	G	G	Y	Y
	B3H017	G	G	Y	Y
	B3H001	G	G	Y	Y
	B5R002	G	G	Y	Y
	B5H004	G	G	Y	Y

(See **Table 8.5** for reference to colours)

Table 9.10: Concluding NH3 Water Quality Assessment

Area	Monitoring Point	NH_3			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
Witbank Dam Catchment	B1R001Q01				
	Rietspruit				
	Rietspruit Dam				
	Tweefontein				
	Bethal Road Bridge				
	B1H020	B	B	G	G
	B1H006	B	B	B	B
	B1H019	B	B	B	B
	B1H017	B	B	B	B
	B1H021	B	B	G	G
	B1H018	B	B	G	G
	B1H005	B	B	G	G
	Duvha Road Bridge				
Wilge River and Loskop Dam Catchment	B2H003	B	B	B	B
	B2H004	B	B	B	B
	B2H007	B	B	B	B
	B2H010	B	B	B	B
	B2H014	B	B	B	B
	B2H015	B	B	B	B

Area	Monitoring Point	NH_3			Concluding Water Quality Category
		Median	75th Percentile	95th Percentile	
	B1H002	B	B	B	B
	B3R002	B	B	B	B
Middelburg Dam Catchment	B1H012	B	B	B	B
	B1H015	B	B	B	B
	B1H004	B	R	R	R
Middle Olifants Catchment	B3R001Q01	B	B	B	B
	B3R005Q01	B	B	B	B
	B3H021	B	B	B	B
	B3H007	B	B	B	B
	B3H017	B	B	G	G
	B3H001	B	B	B	B
	B5R002	B	B	B	B
	B5H004	B	B	B	B

(See **Table 8.5** for reference to colours)

The phosphates levels are slightly high and are within acceptable and tolerable ranges. The NO_3/NO_2 and NH_3 at station B1H004 are within unacceptable ranges.

9.3 TREND ANALYSIS

Time series plots for all variables can be found in **Appendix A**. A summary is presented in **Table 8.16.** An upward trend is depicted in red, a downward trend in blue while a static condition is shown in green.

Table 9.11: Summary of Trend Analysis

Area	Monitoring Point	EC	NO_3/NO_2	PO_4	NH_3	pH	Cl-	SO_4
Witbank Dam Catchment	B1R001Q01	R	B	R	B	G	R	R
	Rietspruit	B				G	B	R
	Rietspruit Dam	G				G	R	R
	Tweefontein	R				G	R	R
	Bethal Road Bridge	R				G	R	R
	B1H020	R	G	G	B	G	B	R
	B1H006	R	B	R	G	G	B	R
	B1H019	B	G	G	G	G	B	B
	B1H017	G	B	G	G	G	G	G
	B1H021		G	R	G	G	R	G
	B1H018	G	G	G	B	G	B	R
	B1H005	R	B	G	G	G	R	R
	Duvha Road Bridge	R				G	G	R
Wilge River and Loskop Dam Catchment	B2H003		R	G	G	G	R	
	B2H004		R	G	B	G	B	
	B2H007		B	G	B	G	B	
	B2H010		B	R	R	G	R	
	B2H014		R	R	G	G	R	

Area	Monitoring Point	EC	NO_3/NO_2	PO_4	NH_3	pH	Cl-	SO_4
	B2H015		G	R	G	G	R	
	B1H002	B	B	G	G	G	R	G
	B3R002	R	B	G	B	G	R	R
Middelburg Dam Catchment	B1H012	B	G	G	G	G	R	B
	B1H015	R	B	R	G	G	R	R
	B1H004		G	R	B	R	B	
	B1R002Q01	R						R
Middle Olifants Catchment	B3R001Q01		B	G	R	G	R	
	B3R005Q01		B	G	G	G	R	
	B3H021		B	G		G	R	
	B3H007		B	G	G	G	R	
	B3H017		G	R	G	G	R	
	B3H001		R	G	G	G	G	
	B5R002		B	G	R	G	R	
	B5H004		B	G	G	G	G	
	B3H002Q01	R						R

10. EUTROPHICATION ASSESSMENT

10.1 INTRODUCTION

Eutrophication is the enrichment of a water body with mineral and organic nutrients, normally plant nutrients. Although it is a natural ageing process of a water body it is accelerated by anthropogenic activities (DWAF, 2003). Eutrophication can, therefore, be an indicator of the negative impacts of human activities upstream of the site. Eutrophication is also monitored because it causes many other types of problems to water users and water infrastructure. **Table 10.1** shows the description of the trophic classification.

Table 10.1: Description of Trophic Classification

State	Description
Oligotrophic	Low in nutrients and not productive in terms of aquatic animal and plant life.
Mesotrophic	Intermediate levels of nutrients, fairly productive in terms of aquatic animal and plant life and showing emerging signs of water quality problems.
Eutrophic	Rich in nutrients, very productive in terms of aquatic animal and plant life and showing increasing signs of water quality problems.
Hypertrophic	Very high nutrient concentrations where plant growth is determined by physical factors. Water quality problems are serious and can be continuous.

The assessment of eutrophication was not the main focus of this study but to address concerns raised the status of the eutrophication within the Olifants River system and was included in this report.

10.2 SOURCE OF EUTROPHICATION DATA

The DWA initiated a National Eutrophication Monitoring Programme (NEMP) in 2002 and has been conducting annual assessments of the eutrophication in a number of dams based on the Annual Eutrophication Monitoring Programme (DWAF, October 2006).

The project is currently being managed by the DWA but due to insufficient resources to effectively implement the monitoring programme, the information is not always complete.

10.3 VARIABLES OF CONCERN

The NEMP uses specific cut-off chlorophyll concentrations to characterize the trophic status of a monitoring site. The trophic status is an indication of the extent of eutrophication in a water resource (DWAF, October 2006). **Table 10.2** shows the method used to determine the trophic status statistics.

Table 10.2: Method Used to Determine the Trophic Status Statistics

Statistic	Unit	Current Trophic Status			
Mean annual chlorophyll *a*	µg/ℓ	0<x≤10	10<x≤20	20<x≤30	>30
		Oligotrophic (low)	**Mesotrophic (moderate)**	**Eutrophic (significant)**	**Hypertrophic (serious)**
		Current nuisance value of algal bloom productivity			
% of time chlorophyll *a* >30 µg/ℓ		0	0<x≤8	8<x≤50	>50
		negligible	**moderate**	**significant**	**serious**
		Potential for algal and plant productivity			
Mean annual Total phosphorus	mg/ℓ	x≤0.015	0.015<x≤0.047	0.047<x≤0.130	>0.130
		negligible	**moderate**	**significant**	**serious**

10.4 SAMPLING SITES USED

There are 104 NEMP national monitoring sites in 15 Water Management Areas (WMAs). Monitoring sites within the Olifants WMA were increased from 5 to 14 impoundments (DWA, 2006). Of these 14 registered sites only 9 were functional for the NEMP during 2005.

10.5 RESULTS OF EXISTING STUDIES

10.5.1 Annual NEMP Reports

The trophic status of the dams in the study area is generally of except for Bronkhorstspruit which was hypertrophic for both 2005 and 2006. The dominant algal species is *Ceratium*. The results of the 2005 and 2006 annual assessment can be seen in **Table 10.3** and **Table 10.4** respectively.

Table 10.3: Eutrophication for 2005 (DWAF, October 2006)

Site Description	No. of samples	Trophic status, algal productivity and severity of potential problems	Types of Problems
Blyderivierpoort Dam	Chl a: 1	Oligotrophic, Negligible Productivity& Unknown potential of productivity.	Not Available
Bronkhorstspruit Dam	Chl a:22 TP: 21	Hypertrophic, Serious Productivity & Significant potential of productivity.	Not Available
Buffelskloof Dam	Chl a:14 TP: 17	Oligotrophic, Negligible Productivity & Moderate potential of productivity.	Not Available
Flag Boshielo Dam	Chl a: 4 TP:12	Mesotrophic, Negligible Productivity & Significant potential of productivity.	Not Available
Loskop Dam	Chl a: 13 TP:6	Oligotrophic, Negligible Productivity & Moderate potential of productivity.	Not Available
Middelburg Dam	Chl a: 21 TP:20	Oligotrophic, Negligible Productivity & Moderate potential of productivity.	Not Available
Ohrigstad Dam	Chl a: 2 TP:3	Oligotrophic, Negligible Productivity & Moderate potential of productivity.	Not Available
Olifants River	Chl a: 12	Oligotrophic, Negligible Productivity & Unknown potential of productivity.	Not Available
Phalaborwa Barrage	TP:1	Unknown trophic status, Unknown Productivity & Significant potential of productivity.	Not Available
Rhenosterkop Dam	TP:1	Unknown trophic status, Unknown Productivity & Significant potential of productivity.	Not Available
Rust de Winter Dam	TP:5	Unknown trophic status, Unknown Productivity & Moderate potential of productivity.	Not Available
Tonteldoos Dam	Chl a: 11 TP:18	Oligotrophic, Negligible Productivity & Moderate potential of productivity.	Not Available
Vlugkraal Dam	Chl a: 7 TP:19	Oligotrophic, Negligible Productivity & Moderate potential of productivity.	Not Available
Witbank Dam	TP:14	Unknown trophic status, Unknown Productivity & Significant potential of productivity.	Not Available

Table 10.4: Eutrophication for 2006 (DWAF, June 2007)

Site Description	No. of samples	Trophic status, algal productivity and severity of potential problems	Types of Problems
Blyderivierpoort Dam	Alg-id:1 Chl a: 1 TP:2	Oligotrophic, Negligible Productivity& Moderate potential of productivity.	Not Available
Bronkhorstspruit Dam	Alg-id:21 Chl a:24 TP: 24	Hypertrophic, Serious Productivity & Significant potential of productivity.	Cyanobacteria: Anabaena Other Algae: Ceratium Aquatic plants: None
Buffelskloof Dam	Alg-id:10 Chl a:6 TP: 16	Oligotrophic, Negligible Productivity & Moderate potential of productivity.	Cyanobacteria: Anabaena Other Algae: Ceratium Cyclotella Melosira Aquatic plants: None
Flag Boshielo Dam	Alg-id:13 Chl a: 7 TP:20	Oligotrophic, Negligible Productivity & Moderate potential of productivity.	Cyanobacteria: Anabaena Anabaenopsis Cylindrospermopsis Other Algae: Melosira Nitzchia Aquatic plants: None
Loskop Dam	Alg-id:14 Chl a: 11 TP:7	**Oligotrophic**, Negligible Productivity & Moderate potential of productivity.	Cyanobacteria: Merismopedia Microcysts Other Algae: Ceratium Flagilaria Melosira Nitzchia Aquatic plants: None
Middelburg Dam	Alg-id:15 Chl a: 17 TP:18	**Oligotrophic**, Negligible Productivity & Moderate potential of productivity.	Cyanobacteria: Anabaenopsis Microcysts Other Algae: Ceratium Asterionella Cryptomonas Flagilaria Melosira Nitzchia Aquatic plants: None
Ohrigstad Dam	Alg-id:17 Chl a: 3 TP:12	**Oligotrophic**, Negligible Productivity & Moderate potential of productivity.	Cyanobacteria: Anabaena Microcystis Cylindrospermopsis Other Algae: Ceratium

Site Description	No. of samples	Trophic status, algal productivity and severity of potential problems	Types of Problems
			Cosmarium Flagilaria Melosira Monoraphidium Nitzchia Aquatic plants: None
Olifants Rivier	TP:20	**Oligotrophic**, Negligible Productivity & Unknown potential of productivity.	Not Available
Phalaborwa Barrage	TP:1	**Unknown** trophic status, Unknown Productivity & Significant potential of productivity.	Not Available
Rhenosterkop Dam	Alg-id:9 Chl a: 1 TP:7	**Unknown** trophic status, Unknown Productivity & Significant potential of productivity.	Cyanobacteria: Microcystis Other Algae: Ceratium Cyclotella Euglena Flagilaria Melosira Monoraphidium Nitzchia Aquatic plants: None
Rust de Winter Dam	Alg-id:10 Chl a: 1 TP:2	Unknown trophic status, Unknown Productivity & Moderate potential of productivity.	Cyanobacteria: Cylindrospermopsis Microcystis Other Algae: Ceratium Cyclotella Flagilaria Melosira Nitzchia Aquatic plants: None
Tonteldoos Dam	Alg-id:15 Chl a: 19 TP:22	**Oligotrophic**, Negligible Productivity & Moderate potential of productivity.	Cyanobacteria: Anabaenopsis Merismopedia Microcystis Oscillatoria Other Algae: Ceratium Cyclotella Euglena Flagilaria Mallomonas Nitzchia Aquatic plants: None
Vlugkraal Dam	Alg-id:16 Chl a: 13	**Oligotrophic**, Negligible Productivity & Moderate potential of	Cyanobacteria: Anabaenas

Site Description	No. of samples	Trophic status, algal productivity and severity of potential problems	Types of Problems
	TP:20	productivity.	Cylindrospermopsis Merismopedia Microcystis Oscillatoria Other Algae: Ceratium Cyclotella Euglena Navicula Flagilaria Mallomonas Nitzchia Aquatic plants: None
Witbank Dam	TP:12	**Unknown** trophic status, Unknown Productivity & Significant potential of productivity.	Not Available

According to the findings of the NEMP for both 2005 and 2006, the Loskop dam is in an Oligotrophic state. However according to the Olifants River forum media release in April 2010, there was evidence of progressive eutrophication of the Loskop dam and the Olifants River (http://www.orf.co.za). A total of 54 dominant algae species from sampling sites in the upper catchment and Loskop dam were analysed. The two species that occurred at all the sampling sites were *Melosira granulate* (consistent with eutrophic waters) and *Spirogyra reinhardi* (an indicator of eutrophic waters and tolerant of high levels of heavy metal pollution). There was also a decrease in the variety of algae normally found in freshwater.

10.6 CURRENT EUTROPHICATION STATUS

Impoundments in the WMA have not previously experienced serious eutrophication except for the Bronkhorstspruit Dam which previously was classified as a mesotrophic system and has moved into a hypertrophic state.

The Olifants River and the Loskop Dam are also a cause for concern as they are progressing towards eutrophication.

11. ECOLOGICAL ASSESSMENT

11.1 INTRODUCTION

Rivers in both rural and urban settings are complex, multifunctional ecosystems that have developed their own self-sustaining balance. Modification of a particular function over another may cause an imbalance that, in the case where it persists, may eventually lead to degradation of the aquatic environment and ecology (DEAT, March 2005). Environmental awareness has led to a scientific approach whereby the state of the river is improved in terms of physical characteristics, chemical quality, ecological diversity and aesthetic appearance is determined. The “health” of the river gives a good indicator, measurement, as to how the ecosystem is responding to disturbances (DEAT, March 2005). The ecological status of a river, therefore, is indication of the river’s overall condition and includes the assessment of all of the features and characteristics of a river and its riparian areas. An ecological assessment determines a river ability to support a natural array of species (DEAT, March 2005).

11.2 SOURCE OF ECOLOGICAL DATA

The main focus of the water quality assessment, in this report, is on the chemical water quality status of the catchment. However, work has been done by then Department of Environmental Affairs and Tourism (DEAT), now DEA, on the ecological status of the Olifants River System in conjunction with DWA and CSIR. It is, therefore, logical to include the findings of this study into this report with the intent to compare the outcomes of the River Health Programme (RHP) for the Olifants River System with the outcomes of the Water Quality “chemical” assessment done in this report. If the outcomes of the two studies do not support each other, there should be a logical explanation why (approach, methodology or most importantly as a result of “insufficient” data).

11.3 RIVER HEALTH CATEGORIES

A river health categorisation is used to provide a simplified user-friendly key to a much more intricate and complex process of assessing the Ecostatus of a river. Each river health category relates to a level of ecosystem health, which in turn relates to the potential of the river to support a particular range of ecosystem services. The river health categories and their relation to the water resource classification system as proposed by the DWA are presented in **Table 11.1** (DEAT, March 2005):

Table 11.1: River Health Indicators

RIVER HEALTH CATEGORISATION		WATER RESOURCE CLASSIFICATION SYSTEM	
CATEGORY	**DESCRIPTION**	**PROPOSED**	**DESCRIPTION**
Natural	No or negligible modification of in stream and riparian habitats and biota.	Natural	Human activity has caused no or minimal changes to the historically natural structure and functioning of biological communities, hydrological characteristics, chemical concentrations and the bed, banks and channel of the resource.
Good	Ecosystem essentially in good state; biodiversity largely intact.	Moderately used or impacted	Resource conditions are slightly to moderately altered from the Natural class due to the impact of human activity and water use.
Fair	Sensitive species may be lost, with tolerant or opportunistic species dominating.	Heavily used or impacted	Resource conditions are significantly changed from the Natural class due to human activity and water use, but are nonetheless ecologically sustainable.
Poor	Mainly tolerant species present or alien species invasion; disrupted population dynamics; species are often diseased.	Unacceptably degraded resources	Due to over-exploitation, these rivers are already in a state that is ecologically unsustainable.

11.4 STATE OF THE OLIFANTS RIVER SYSTEM

The Olifants River and some of its tributaries, notably the Klein Olifants River, Elands River, Wilge River and Bronkhorstspruit, rise in the Highveld grasslands.

The upper reaches of the Olifants River Catchment are characterised mainly by mining, agricultural and conservation activities. Over-grazing and highly erodable soils result in such severe erosion, in parts of the middle section that after heavy rains the Olifants River has a red-brown colour from all the suspended sediments.

Thirty large dams in the Olifants River Catchment include the Witbank Dam, Renosterkop Dam, Rust de Winter Dam, Blyderivierspoort Dam, Loskop Dam, Middelburg Dam, Ohrigstad Dam, Flag Boshielo Dam and the Phalaborwa Barrage. In addition, many smaller dams in this catchment have a considerable combined capacity.

The Olifants River meanders past the foot of the Strydpoort Mountains and through the Drakensberg, descending over the escarpment. The Steelpoort and Blyde tributaries, and others, join the Olifants River before it enters the Kruger National Park and neighbouring private game reserves. Crossing the Moçambique border, the Olifants River flows into the Massingir Dam (DWA, 2007).

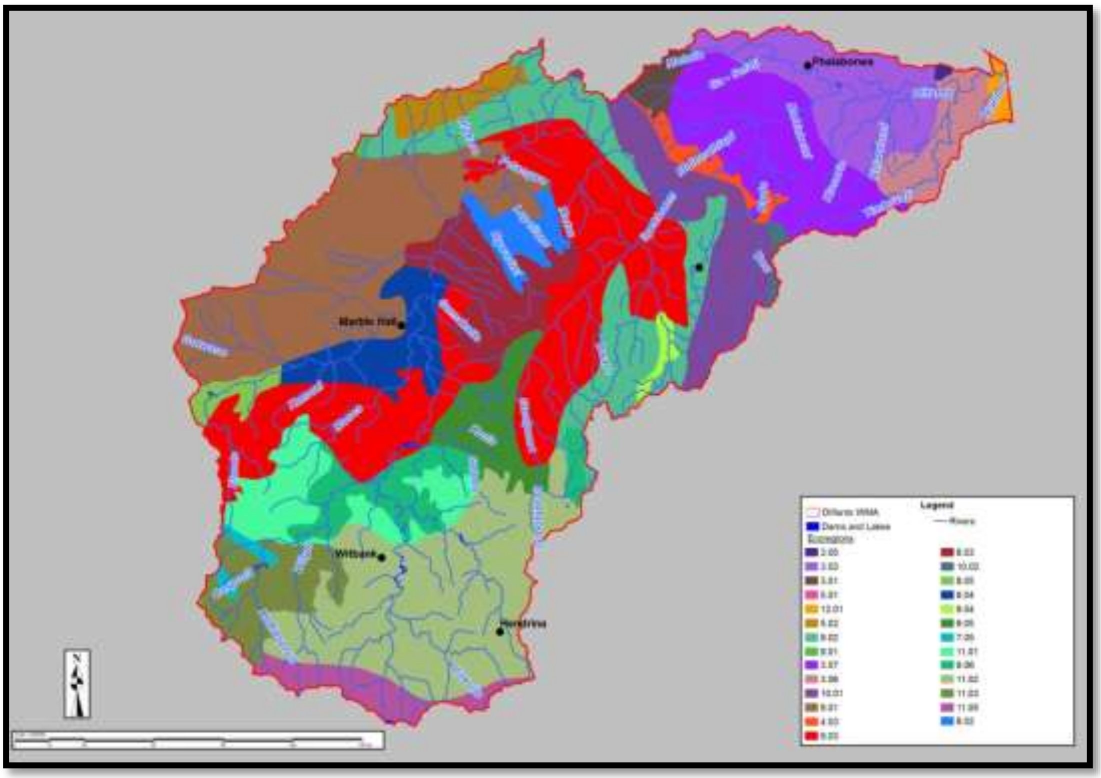


Figure 11.1: Olifants River Catchment

11.4.1 Ecoregions 11.02, 11.03 & 11.05

This is an area of flat grasslands with rolling rocky zones on top of the escarpment. Sandstone and shale harbor rich coal deposits, covered by deep, red to yellow sandy soils. Wetlands that overlie these deposits are threatened by potential mining activities (DWA, 2007).

The Wilge, Bronkhorstspruit and Klein Olifants Rivers are tributaries of the Olifants River that, together with the Olifants River, originate in the Highveld grasslands in these areas belong in this ecoregion. The river structure varies from a narrow channel with no definite riparian zone up to a 20-30 m wide channel with well-defined riparian habitat. The Witbank and Doringpoort Dams are in this section of the Olifants River (**Figure 11.2**).

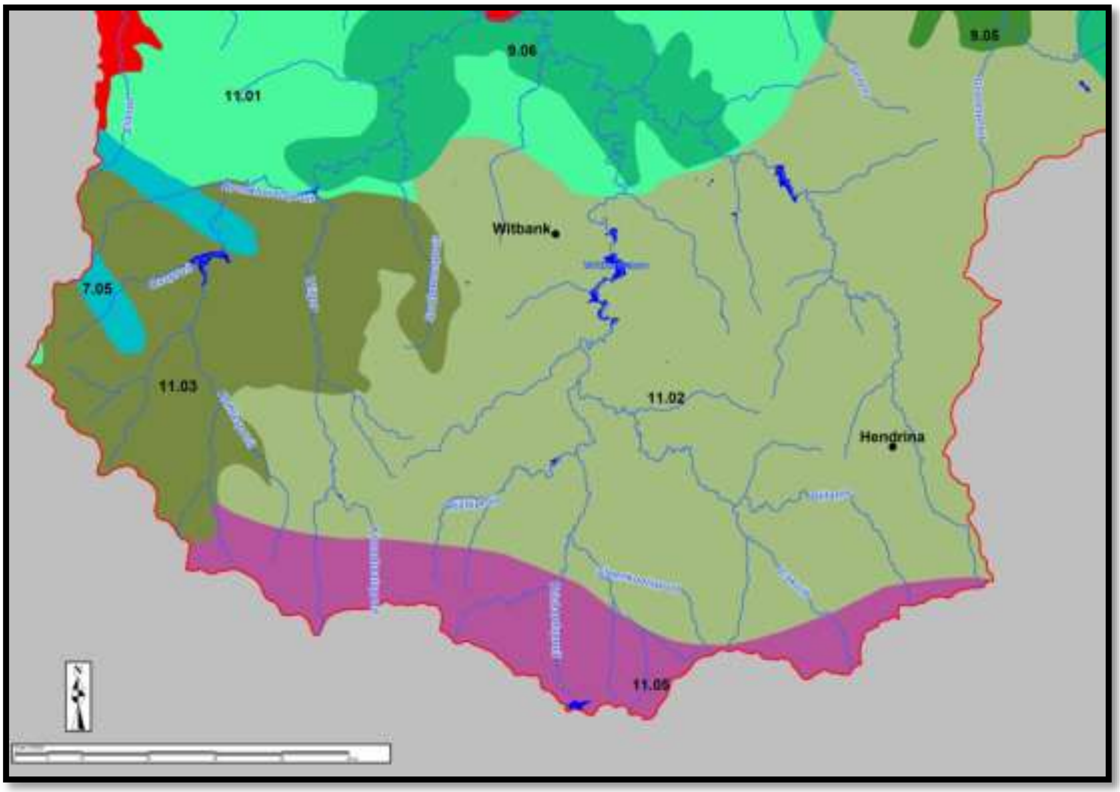


Figure 11.2: Ecoregions 11.02, 11.03 & 11.05 in the Olifants River System

The in-stream and riparian habitats in these ecoregions show a **fair** to **unacceptable** state, with the general condition being **poor** and **fair** in ecoregions 11.02 and 11.03 respectively. Biological communities also reflect **fair** to **unacceptable** health, with the streams in ecoregion 11.03 in a slightly better state than those in ecoregion 11.02.

11.4.2 Ecoregions 7.05, 9.03 & 9.06

This section of the Olifants River Catchment extends from the Highveld Plateau (7.05), descending the Drakensberg Escarpment (9.06) and bordering on the Bushveld Basin (9.03). Conglomerates, granites and quartzites predominate, as do shallow, rocky, sandy soils, across the ecoregions.

The confluence of the Olifants and Klein Olifants Rivers takes place in ecoregion 9.06 (**Figure 11.3).** From here the Olifants River flows in a north-westerly direction where it joins the Wilge River, upstream of the Loskop Dam. The Loskop Dam is situated at the lower end of a scenic gorge with high aesthetic value. The river varies from a single channel to multiple channels with afforested islands. Riverbanks are steep in some areas. Riparian vegetation is sparse, comprised of a few grasses and reeds. Rapids and pools are common, as are boulders and large rocks in the riverbed. Floodplains are narrow.

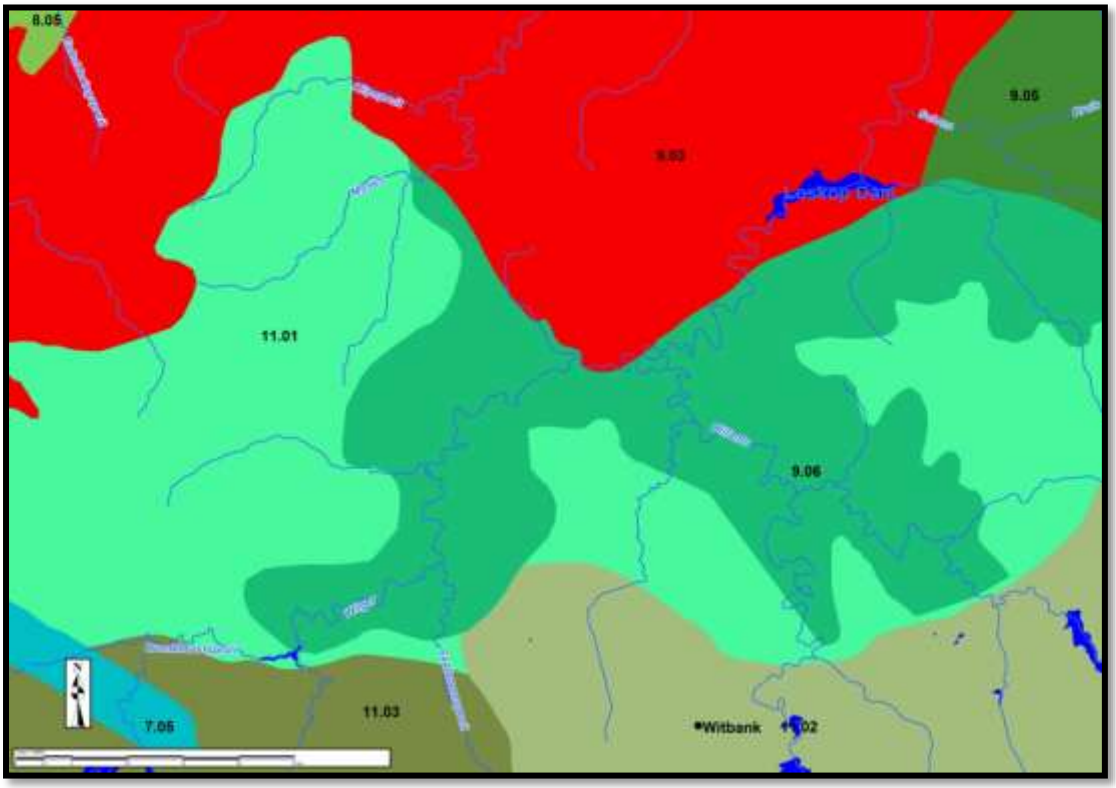


Figure 11.3: Ecoregions 7.05, 9.03 & 9.06 in the Olifants River System

Ecoregion 7.05 & 9.06: This section of the Bronkhorstspruit is **good** to **fair**. The Wilge is in an overall **good** state and the state of the Klein Olifants is **fair**. The riparian habitats and vegetation of the Olifants River in this section are generally in **good** health. In-stream conditions are more variable, ranging from **good** to **fair**.

Ecoregion 9.03: This includes the Olifants River downstream of the Loskop Dam and the Moses River. In-stream habitat is in a **fair** state; fish **fair** to **poor** health, and invertebrates reflect **good** health. Riparian habitats and vegetation are in **fair** condition.

11.4.3 Ecoregion 8.01 & 8.04

This is an area of middle slopes (800-1 500 m) with mixed bushveld overlying shallow coarse sandy soils on mudstone, sandstone and shale.

The Rust de Winter Dam is situated in the Elands River, which rises east of Bronkhorstspruit. The Olifants River meanders from the Loskop Dam through relative flat landscape past Groblersdal and Marble Hall to the Flag Boshielo Dam, at the confluence of the Elands and Olifants Rivers. The riverbed is sandy due to alluvial deposits. From the Flag Boshielo Dam, the Olifants River flows through the Springbok Flats, which forms part of the Bushveld Basin (**Figure 11.4**).

The river is steep with many riffles in ecoregion 8.01, becoming gentler with a sandy soft bed in ecoregion 8.04 (DEAT, 2007).

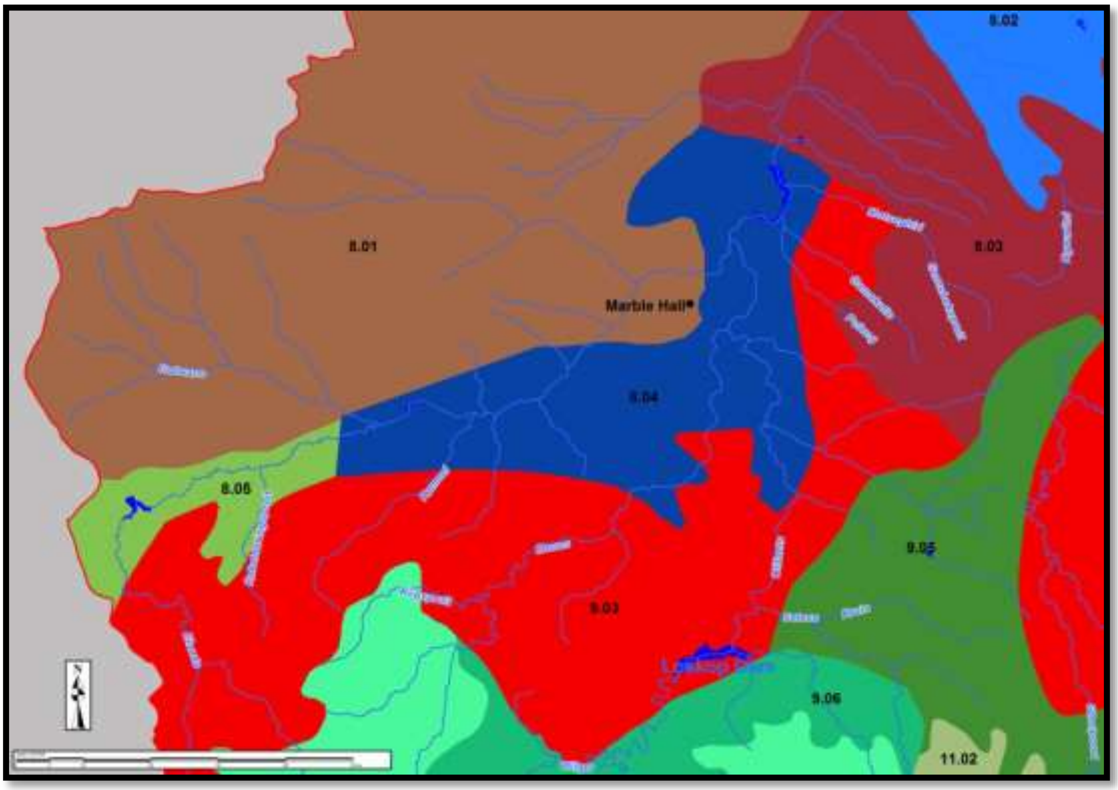


Figure 11.4: Olifants River System in Ecoregions 8.01 & 8.04

River habitats in this region are in a **poor** to **unacceptable** state. The exception is upstream of the Rust de Winter Dam where the Elands River is in a **fair** condition. In-stream biota in the Olifants River is **fair** to **poor,** with the riparian vegetation being in a **poor** state. For the Elands River the riparian vegetation is **fair**, but in-stream biota varies from **fair** to **unacceptable.** The worst part is immediately downstream of Rust De Winter Dam, where the river is often dry because releases from the dam are insufficient or non-existent.

11.4.4 Ecoregion 9.02 & 9.03

The Olifants River in this region is characterized by a single channel. After passing south of the foothills of the Strydpoort Mountains, the Olifants River converges with the Mohlapitse River (DEAT, 2007). The source of the Mohlapitse River is in the Wolkberg Wilderness Area as shown in **Figure 11.5.**

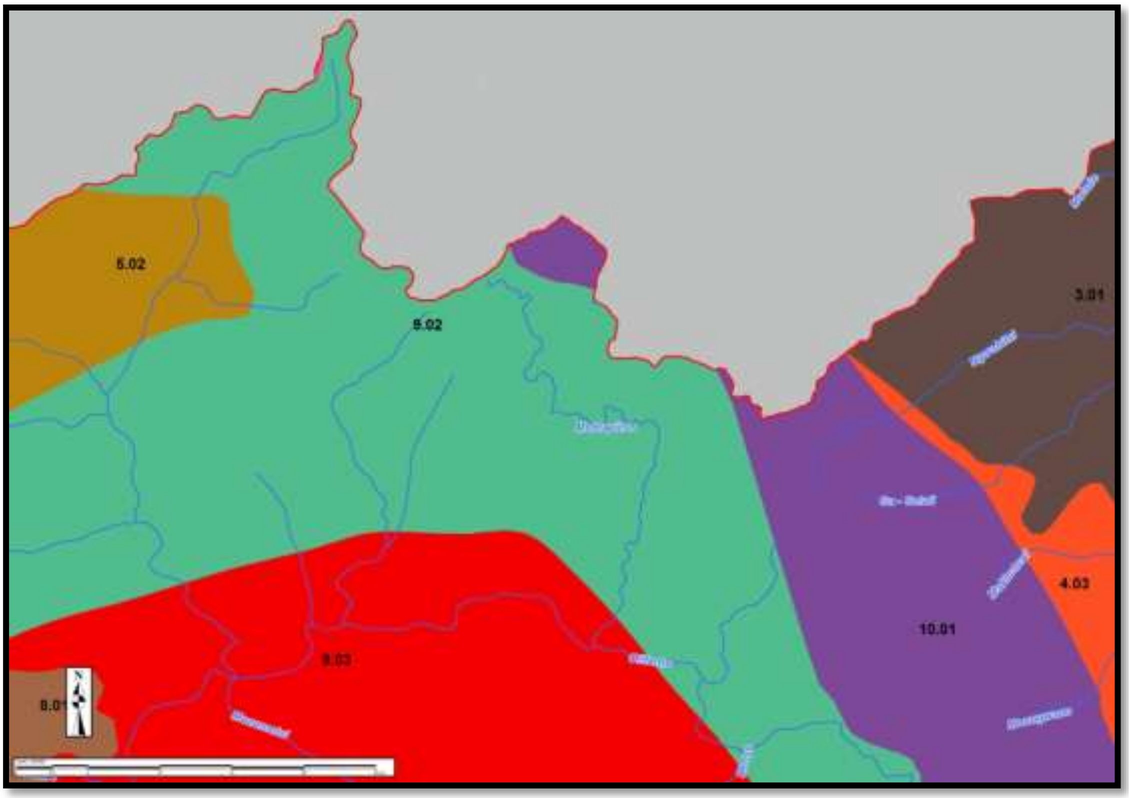


Figure 11.5: Olifants River System in Ecoregions 9.02 & 9.03

The ecological state of the Tongwane and upper Mohlapitse Rivers is **natural**. Habitat conditions in the lower parts of the Mohlapitse River are more impacted, being **fair**, with invertebrates, fish and riparian vegetation reflecting **natural**, **good** and **fair** health respectively. For both the Olifants and Steelpoort Rivers in this region, the biological indicators reflect a predominantly **poor** state with river habitats being in an **unacceptable** state (DEAT, 2007).

11.4.5 Ecoregion 9.02 & 9.03

These ecoregions span the escarpment. Ecoregion 9.02 is situated on the Highveld Plateau and the upper slopes of the escarpment, and is characterized by highveld grasslands. Ecoregion 9.03 is on the lower slopes, and sees the conversion to mixed bushveld.

The Spekboom and Steelpoort Rivers, tributaries of the Olifants River, arise in these ecoregions. The Spekboom has its source in the mountains near Lydenburg. It joins the Waterval River and flows in a northerly direction to the confluence with the Steelpoort River, north-west of Burgersfort. From here, the Steelpoort River flows in a north-easterly direction and converges with the Olifants River in the Drakensberg near Kromellenboog (**Figure 11.6**).

The river is steep, high lying, with riffles, rapids, and waterfalls in ecoregion 9.02. Wetlands and small gorges are also abundant. In 9.03 the river has a gentler slope, with predominantly sandy beds DEAT, 2007).

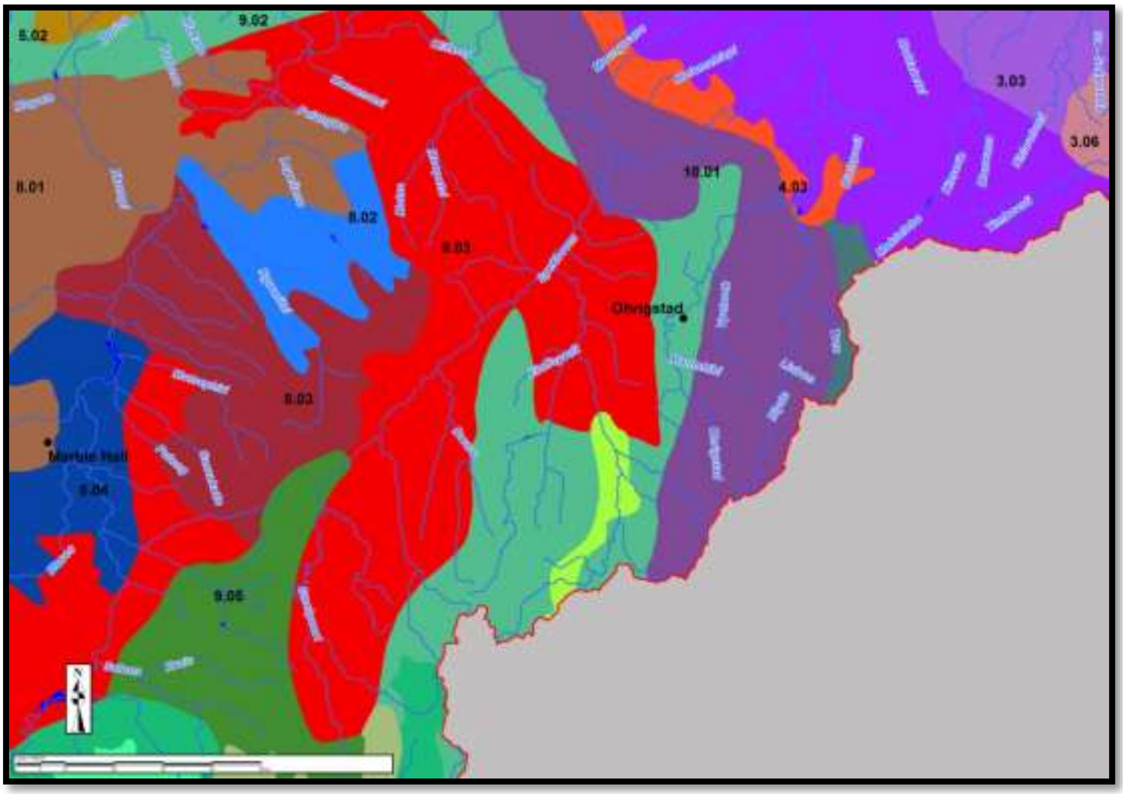


Figure 11.6: Olifants River System in Ecoregions 9.02 & 9.03

Ecoregion 9.02: The Spekboom River is in a **good** state, with riparian vegetation slightly more impacted and reflecting **fair** health. The overall state of the Beetgekraal River is **fair**, with fish and invertebrates being **good**.

Ecoregion 9.03**:** The ecological state of the Steelpoort River is **fair** to **unacceptable**. The Spekboom River is generally in a **good** state. The habitats and riparian vegetation of the Waterval River are **fair**, while fish populations are **good** and invertebrates reflect a **natural** state of health.

11.4.6 Ecoregions 10.01

This area lies in the upper slopes of the Drakensberg Mountains and the grasslands are interspersed with patches of afro-montane forest. The Steelpoort River joins the Olifants River where it meanders through the mountainous landscape of the Drakensberg. The stony riverbed varies between 50 and 80 m wide at the confluence with deep alluvial sands and silt deposits. In some areas the river forms secondary channels, floodplains and woody islands.

The Ga-Selati and Makhutswi Rivers arise near Leydsdorp. From here the rivers flow in an easterly direction (DEAT, 2007). The Ohrigstad River joins the Blyde River at the Blyderivierspoort Dam in the Blyderivierspoort Nature Reserve as shown in **Figure 11.7**.

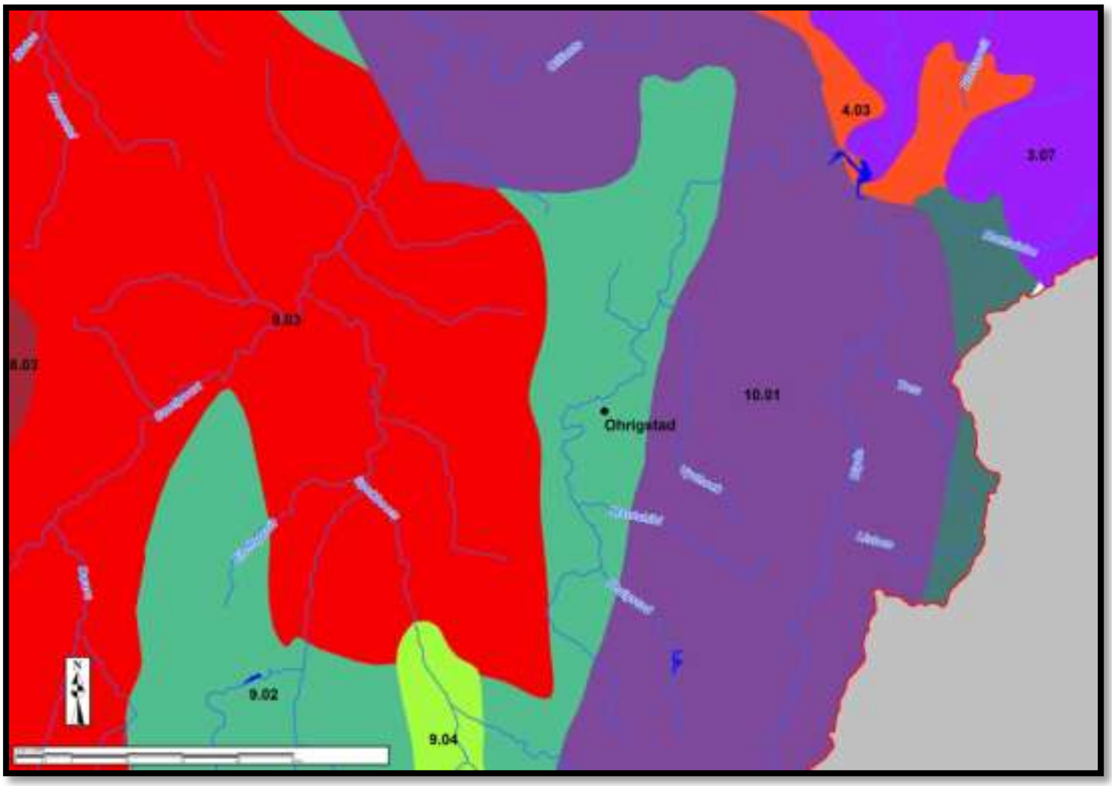


Figure 11.7: Olifants River System in Ecoregions 10.01

The Ga-Selati, Makhutswi, Blyde and Treur Rivers, as well as the Belvedere Creek are in **good** to **natural** ecological states. The present ecological state of the Spekboom River is slightly lower with the riparian habitats (**good** to **fair**) and fish (**poor**) being the worst components for this river. The Ohrigstad River has the lowest ecological state of the rivers in this region, with its overall condition being **fair** to **poor**. At places the state of in-stream and riparian habitats are **unacceptable** (DEAT 2007).

11.4.7 Ecoregions 3.03 & 3.06

Mopane bushveld characterises ecoregion 5.02 and in ecoregion 5.07, sweet lowveld bushveld is dominant, on shallow clayey soils overlying a variety of geological types including mudstone, sandstone and shale.

The first stretch of the Olifants River in this section is a broad, sandy channel with large trees, like wild figs and mahogany, on the banks. The river changes as it flows eastwards through the Kruger National Park, forming several channels with permanent reed-grown islands. Dominant tree species on the islands are Common Cluster (*Ficus sycomores*) and Jakkalsbessie (*Diospyros mespiliformis*). The Letaba River joins the Olifants River west of the Olifants Rest Camp. A narrow gorge forms where the Olifants River flows through the Lebombo Mountains. **Figure 11.8** shows the section of the Olifants River System in ecoregions 3.03 and 3.06.

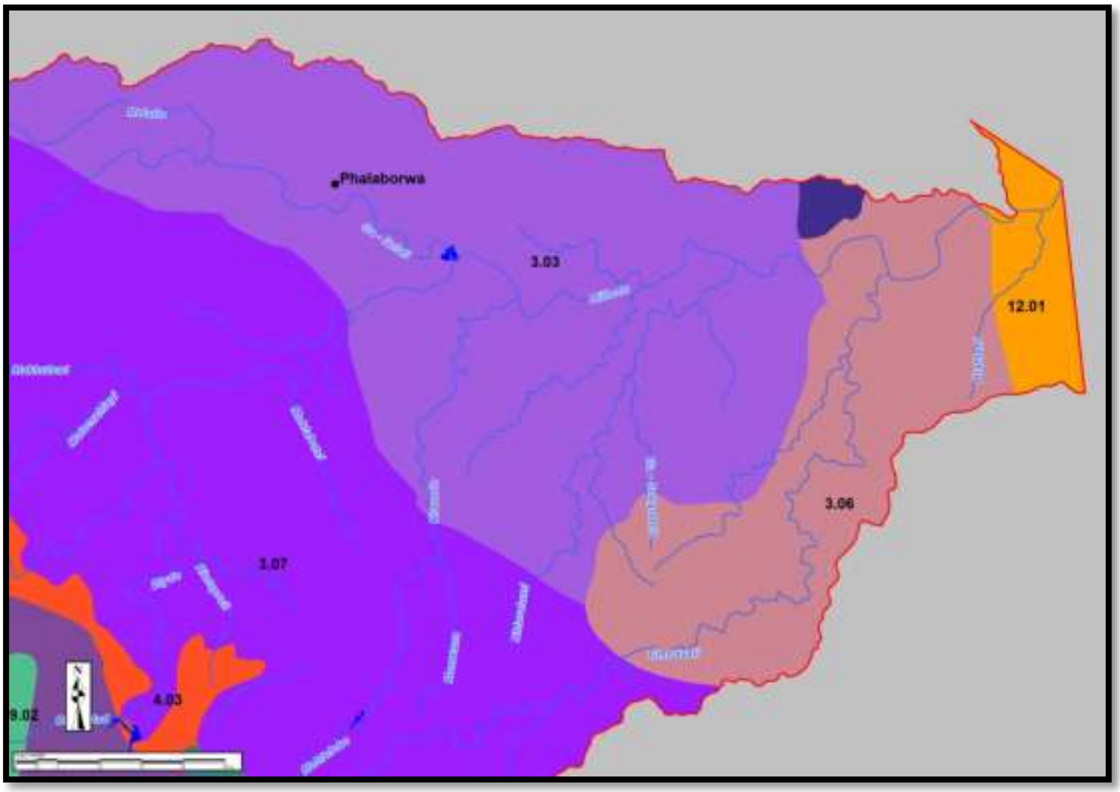


Figure 11.8: Olifants River System in Ecoregions 3.03 & 3.06

Ecoregion 3.03: The Olifants River is generally in a **fair** state with fish and invertebrates occasionally reflecting **poor** conditions. The Ga-Selati is generally in a fair state with the state of fish and riparian vegetation being poor (DEAT, 2007).

Ecoregion 3.06: In this region the Olifants River in general is in a fair state with good riparian vegetation (DEAT, 2007).

11.5 CONCLUSION

The Olifants System experiences extreme demand for natural resources, and associated land modification and pollution. Thus river ecosystems in this area are generally in a fair to poor condition. Exceptions are the Tongwane, upper Mohlapitse, and most of the Blyde Rivers, where a natural state prevails, and the lower reaches of the Olifants River, which is protected by conservation activities.

In the upper parts of the catchment mining-related disturbances are the main causes of impairment of river health. There is also an extensive invasion by alien vegetation, and to a lesser extent alien fauna. Ecologically insensitive releases of water and sediment from storage dams are another major cause of environmental degradation downstream, which is particularly relevant in the middle and lower parts of the catchment.

12. DISCUSSION

There is a lot of mining, predominantly for coal, and other industrial activities around the Wilge, Bronkhorstspruit, Klein Olifants and Olifants Rivers, which are the main contributors to poor in-stream and riparian habitat conditions where acid leachate from mines is a primary contributor to poor water quality and instream conditions. Other water uses include domestic, livestock watering and, power generation.

Water quality is determined by the activities on the catchment, the landuse and the geology. Water quality guidelines published by the Department were used to develop combined guidelines for the study area based on Domestic, Agriculture and Aquatic Ecosystem water guidelines.

The water quality in the study area generally presents no problem with respect to irrigation, urban use and industrial use, with the exception of the Middelburg Dam (station B1H004) is under pressure as reflected by the pH, levels of ammonia as well as nitrite/nitrate levels. The low pH levels may be due to acid rain as a result of mining activities in the study area. The high levels of ammonia and nitrate/nitrite levels may be due to use of fertilisers and is an important indicator of faecal pollution as a result of poor sewage treatment (WHO, 1996).

The sulphate levels range between ideal and unacceptable with a considerable number of stations showing sulphate levels within unacceptable ranges (stations B1H020, B1H019, B1H005 in the Witbank Dam Catchment, stations B1H012 in the Wilge River and Loskop Dam Catchment and station B3H002 in the Middle Olifants Catchment). The results also show an upward trend in sulphates for most stations except stations B1H019, BH017, BH021, BH002 and BH012. The high levels of sulphates may be due to use of ammonium sulphate fertilisers as well as mining activities in the area.

The phosphates are slightly high but within the acceptable and tolerable ranges. This may be due to domestic and industrial effluents or surface and subsurface drainage, nutrients in the irrigation return flows, wash-off and return flows from settlements. Phosphorous loads in water may result from drainage from agricultural land on which fertilizers have been applied. High levels of phosphates lead to eutrophication. Although the chlorides are generally within the ideal range, trend analysis shows that they are on an upward trend. This may be due to the various mining activities in the area.

The EC values are also slightly high, but within acceptable and tolerable ranges. The trends analysis also shows EC as being in an upward trend for most of the stations. This may also be attributed to the various mining activities in the study area.

Most of the dams in the Olifants River System are oligotrophic, except for the Bronkhorstspruit Dam which is in a hypertrophic state. However according to the Olifants River Forum, the Olifants River and the Loskop Dam are fast approaching eutrophic states. This may be due to the substantial sewage treatment plant return flow volumes in the Klipspruit, Witbank Dam and Witbank and Middelburg Dam to Loskop Dam catchments. The return flows contribute to the base flow into Loskop Dam and have been cited as a cause of eutrophication in the upper reaches of the Loskop Dam and the Klein Olifants River (DWA, 2004).

13. CONCLUSION

The water quality in the Olifants River System is generally fit for use, with the exception of the Middelburg Dam (Station B1H004) where the pH, nitrite/nitrate and ammonia levels are within the unacceptable range. Some stations (stations B1H020, B1H019, B1H005 in the Witbank Dam Catchment, stations B1H012 in the Wilge River and Loskop Dam Catchment and station B3H002 in the Middle Olifants Catchment) have sulphate levels that are within unacceptable ranges. The phosphates are slightly high throughout the study area.

Despite the fact that the water quality is generally such that it is fit for use, there are a significant number of localised water quality problems, especially in the upper parts of the catchment and around Phalaborwa. Most of these have to do with pollution or poor on-site management of water, and can (and should) be addressed at source.

An exception to this is the question of acid mine drainage in the coal mining area. This is a large-scale problem that will have to be addressed by desalinating the water. This will on the one hand present an additional source of water in the urbanised and industrialised upper part of the catchment, while on the other hand will prevent the water quality in the Loskop Dam from deteriorating to the point where the fitness for use to downstream users is compromised.

14. BIBLIOGRAPHY

Ashton PJ. 2010. The demise of the Nile crocodile (Crocodylus niloticus) as a keystone species for aquatic ecosystem conservation in South Africa: The case of the Olifants River Aquatic Conservation: Marine and Freshwater Ecosystems 20: 489–493 (2010)

Aurecon Group (2010): Development of a Reconciliation Strategy for the Olifants River Water Supply System: WP10197: Summary Report for the Department of Water Affairs

Botha PJ. 2006. The Current Nile Crocodile Population in the Loskop Dam. Mpumalanga Tourism and Parks Agency: Nelspruit, South Africa.

Botha PJ. 2010a. Monitoring the Nile Crocodile Population in the Olifants River and Selected Tributaries During 2005 and 2009. Report on the Co-operative Project between the Department of Water Affairs and Mpumalanga Tourism and Parks Agency, South Africa.

DEAT. (2007). The Olifants River System. State-of-Rivers Report.

Driescher AC. 2008. A water quality study of Loskop Dam and the upper catchment of the Olifants River. Unpublished MSc thesis, University of the Free State: Bloemfontein, South Africa.

DWAF. 2006.Raising of Flag Boshielo Dam: Observations on Nile Crocodile Deaths at Main Spillway. Olifants River Water Resources Development Project Phase 1. Report No. 20/2/ B501-11/G/1/29. Directorate Civil Design, Department of Water Affairs and Forestry, Pretoria, South Africa.

DWA (2010). Water Resource Planning Systems Series: Water Quality Planning Sub-Series No. WQP 2.0: Resource Directed Management Of Water Quality Planning Level Review Of Water Quality In South Africa

DWAF. (October 2006). Annual Assessment Report - National Eutrophication Monitoring Programme, 2005, Ginkel, C.E. Mphumbude P. Internal Report No. N/0000/00/DEQ/0706 for the Department of Water Affairs and Forestry, South Africa.
DWAF (2004). Olifants Water Management Area Internal Strategic Perspective

DWAF. (June 2007). Annual Assessment Report - National Eutrophication Monitoring Programme, 2006, van Ginkel, C.E. Internal Report No. N/0000/00/DEQ/0307 for the Department of Water Affairs and Forestry, South Africa.

DWAF. (2006). Best Practice Guideline G3. Water Monitoring Programme, Pulles, Howard and de Lange Inc.

DWAF. (September 2007). Developement of a Decision Support System and Execution of the 2006/2007 annual operating analysis, September 2007, WRP H.S. Swart: Great Marico River System: Development of Operating Rules and Drought Management Plans, DWAF Report PWNA 03/000/00/4807.

DWAF. (2003). Development of a Strategy to Control Eutrophication in South Africa, 2003, Walmsley, R.D. Department of Water Affairs and Forestry. Water Quality Management Series U 2.1.

DWAF. (January 2009). Inception Report: Updating of the Hydrology and Yield Analysis fo the Marico River Catchment, January 2009, WRP & DMM. Final, Report No. DWAF P WMA 03/000/00/5008.

DWA (October 2009). Environmental Management Framework for the Olifants and Letaba Rivers Catchment Area (OLEMF)

DWAF. (2005). Policy for Resource Directed Water Quality Management. Water Resource Planning Systems, 2005, Insight Modelling Services, CSIR Environmentek, Sub-Series No. WQP 1.5. Ver 2.24.

DWAF. (1996). South African Water Quality Guidelines (second edition). 1996, CSIR Environmental Services, Holmes, S.Volume 5: Agricultural Use: Livestock Watering.
DWAF. (October 2001). The National Costs of Pollution from Settlements, October 2001, Danced.: Managing the Water Quality Effects of Settlements: Water Quality Management Series.

DWAF: Aquaculture. (1996). South African Wate Quality Guidelines (second edition). Volume 6: Agricultural Water Use: Aquaculture.

DWAF: Domestic. (1996). South African Wate Quality Guidelines (second edition). Volume 1: Domestic Water Use.

DWAF: Ecosystems. (1996). South African Wate Quality Guidelines (second edition). Volume 7: Aquatic Ecosystems.

DWAF: Industrial. (1996). South African Wate Quality Guidelines (second edition). Volume 3: Industrial Water Use.

DWAF: Insight Modeling. (Feb 2005). Policy for Resource Directed Water Quality Management. Water Resource Planning Systems, Sub-Series Nol WQP 1.5. Version 2.24. Pretoria.

DWAF: Irrigation. (1996). South African Wate Quality Guidelines (second edition). Volume 4: Agricultural Water Use: Irrigation.

DWAF: Livestock. (1996). South African Wate Quality Guidelines (second edition). Volume 5: Agricultural Water Use: Livestock Watering.

DWAF: Recreational. (1996). South African Wate Quality Guidelines (second edition). Volume 2: Recreational Water Use.

Jacobsen NHG. 1984. The distribution and status of crocodile populations in the Transvaal outside the Kruger National Park. Biological Conservation 29: 191–200.

Joubert SCJ. 2007. The Kruger National Park: A History. 3 Volumes. High Branchings (Pty): Johannesburg, South Africa.

NWA. (August 1998). National Water Act, 1998 (Act 36 of 1998) as published in the Government Gazette No. 1091 on 26 August 1998.

Oberholster PJ, Myburgh JG, Ashton PJ, Botha A-M. 2010. Responses of phytoplankton upon exposure to a mixture of acid mine drainage and high levels of nutrient pollution in Lake Loskop, South Africa. Ecotoxicology and Environmental Safety 73: 326–335.

Simberloff D. 1998. Flagships, umbrellas, and keystones: is single-species management passe´ in the landscape era? Biological Conservation 83: 247–257.

Swanepoel DGJ. 1999. Movements, nesting and the effects of pollution on the Nile crocodile Crocodylus niloticus in the Olifants River, Kruger National Park. Unpublished MSc thesis, University of Natal, Pietermaritzburg, South Africa.

Swanepoel DGJ. 2001. The Raising of the Arabie Dam Wall and the Impacts on the Nile Crocodile Population.Unpublished Report No. P.RSA/00/0699. Department of Water Affairs and Forestry, Pretoria, South Africa.

Van Vuuren L. 2009. Experts unite to save abused river from extinction. Water Wheel 8: 14–17.

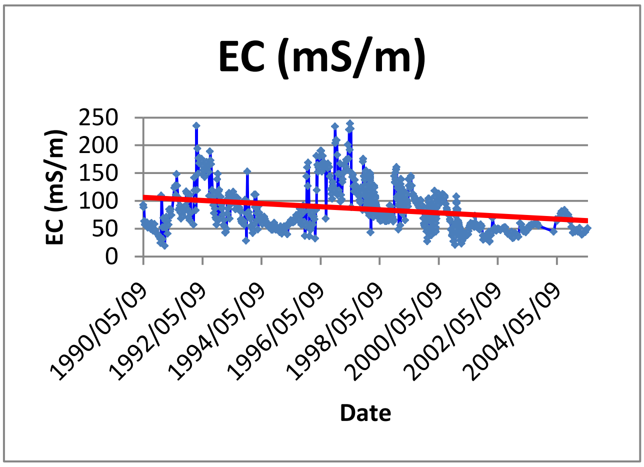
WHO (2006) Ammonia: Background document for development of WHO Guidelines for Drinking-water Quality

WRC (2005) *Survey of Certain Persistent Organic Pollutants in Major South African Waters:* WRC Report No. 1213/1/05.

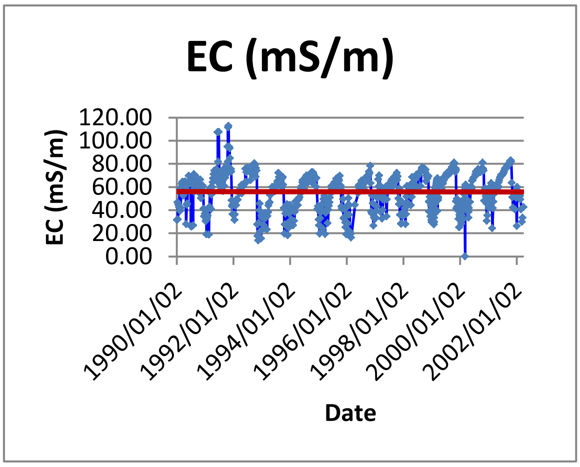
APPENDIX A: TREND GRAPHS

Witbank Dam Catchment

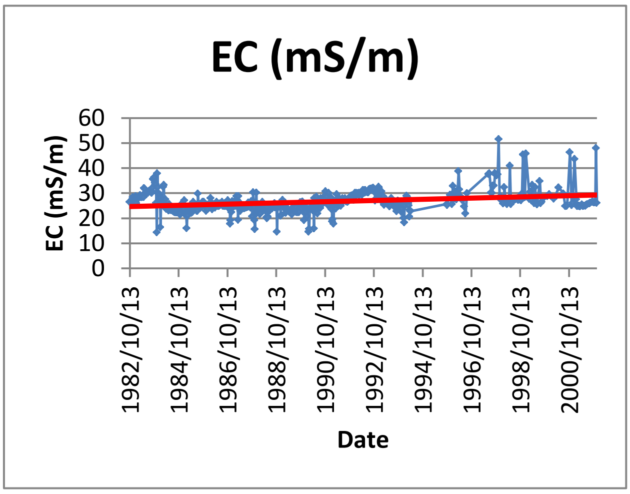
B1H019



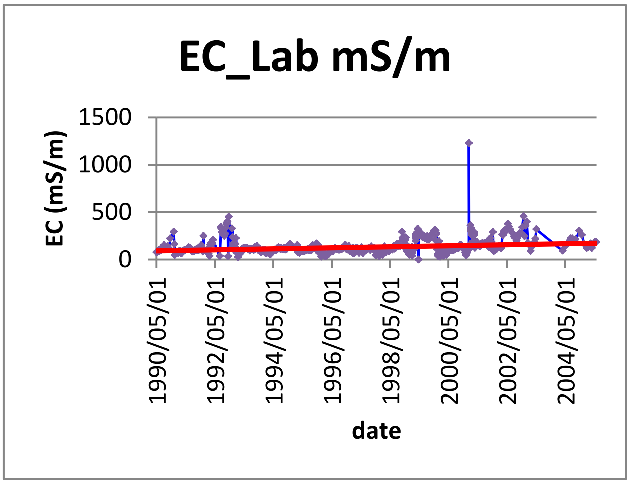
B1H017



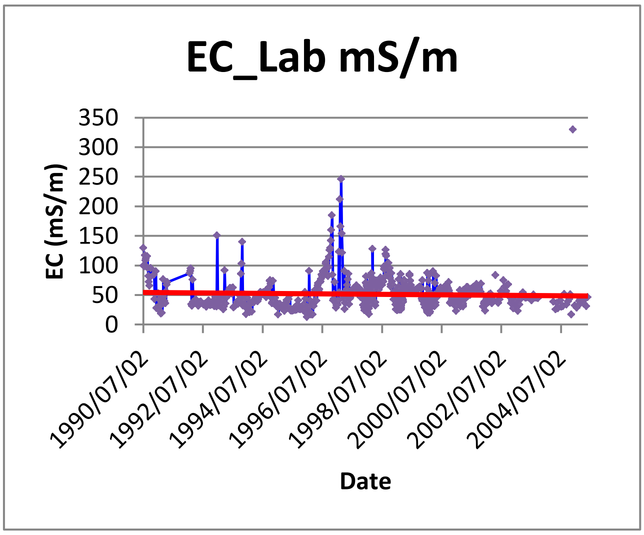
B1H006



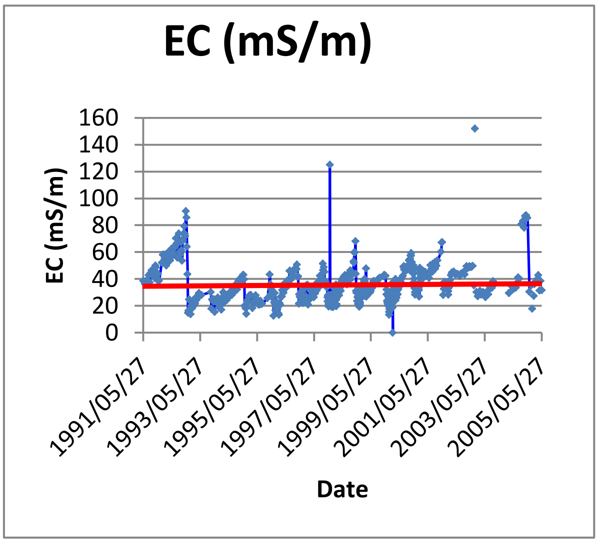
B1H020



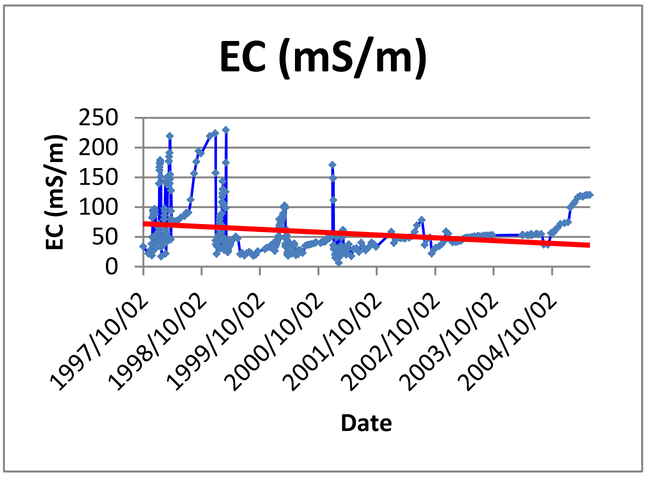
B1H021



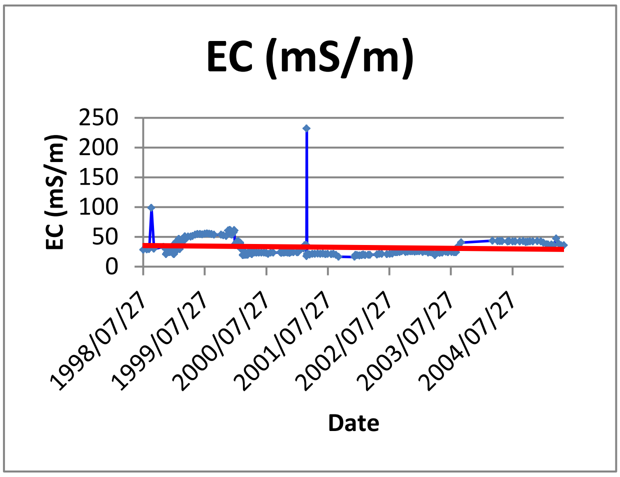
B1H018



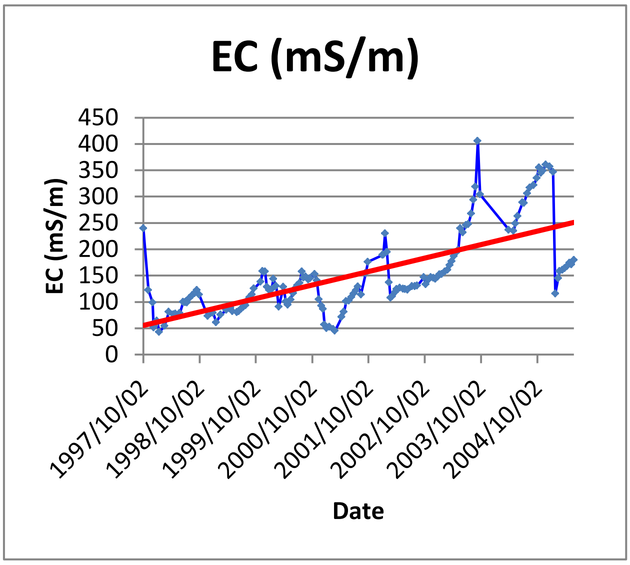
Rietspruit



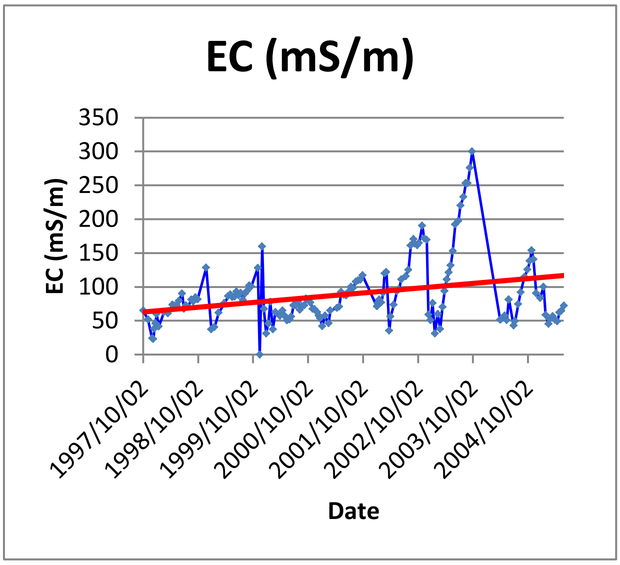
Rietspruit Dam



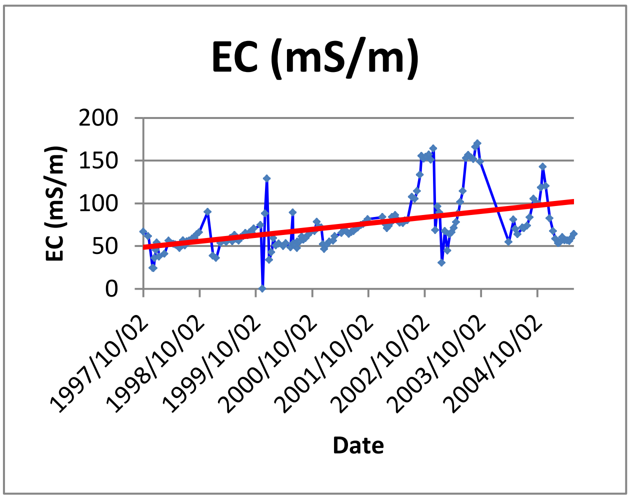
Tweefontein



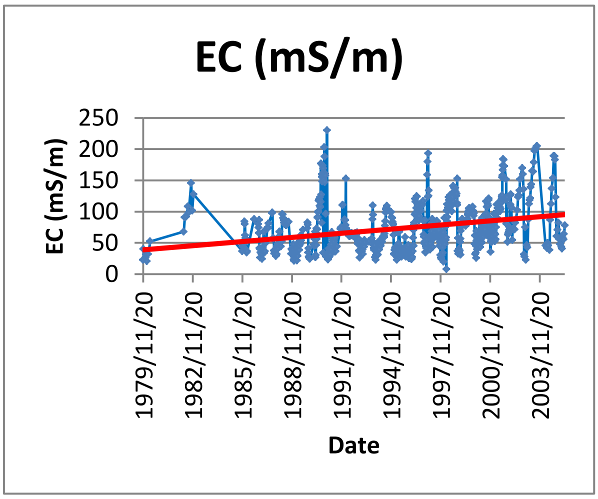
Bethal Ridge Road



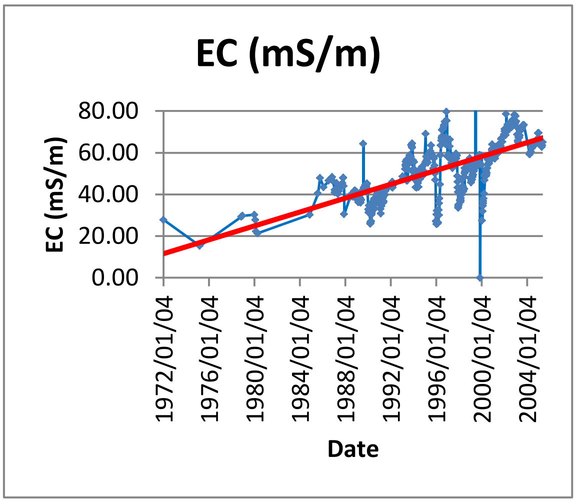
Duvha Road Bridge



B1H005

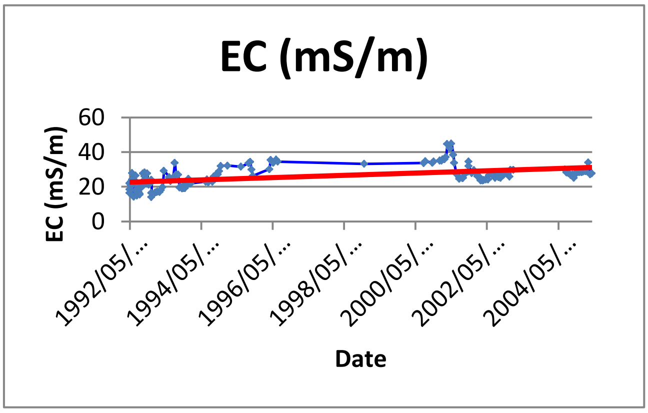


R001Q01

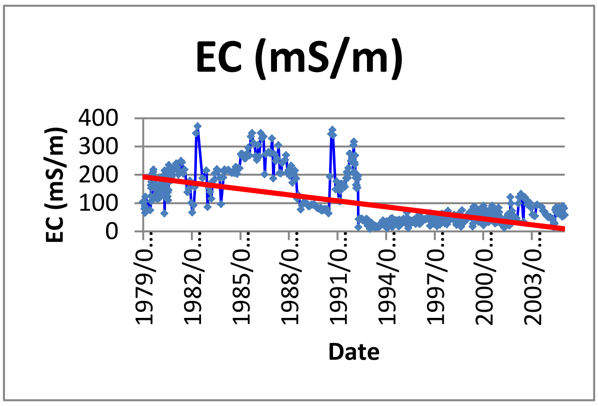


Wilge River and Loskop Dam

B3R002

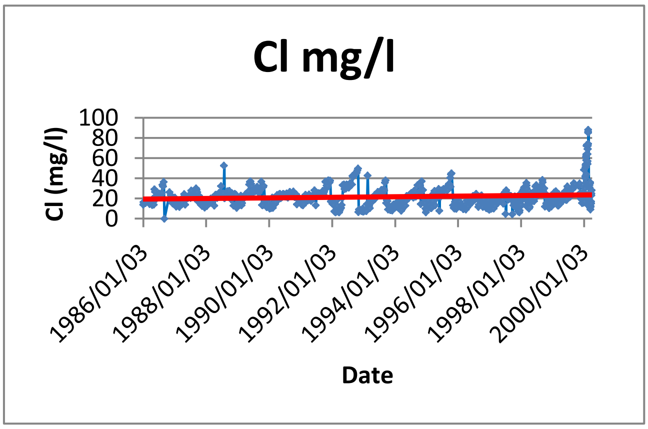


B1H002

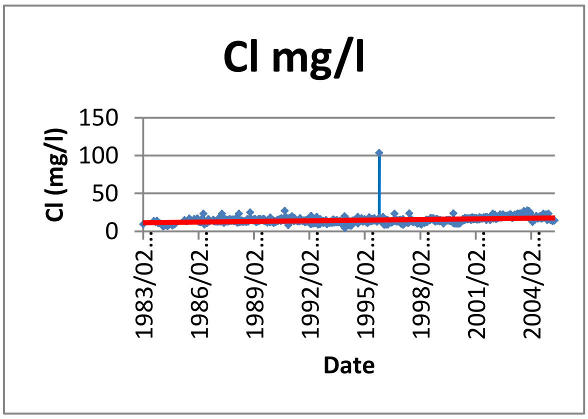


Chlorides: Middelburg Dam Catchment

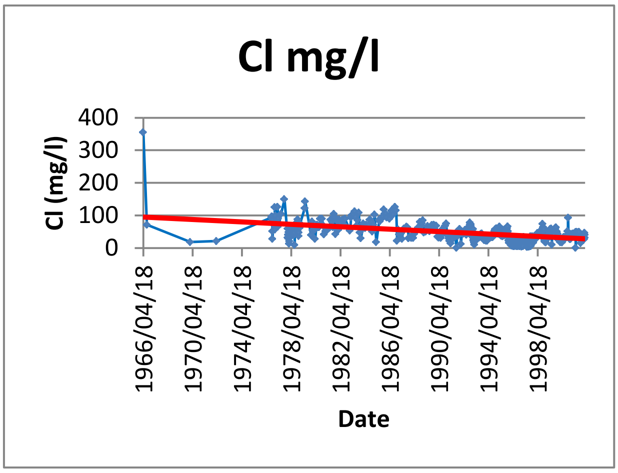
B1H012



B1H015

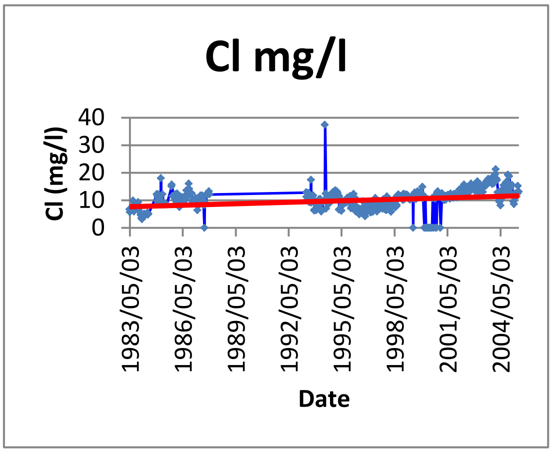


B1H004

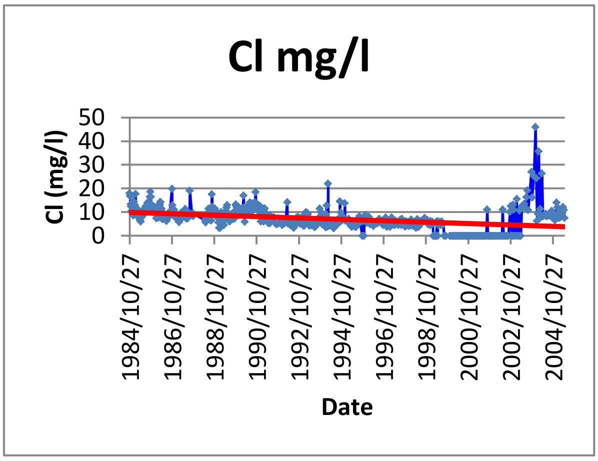


Wilge and Loskop Dam Catchments

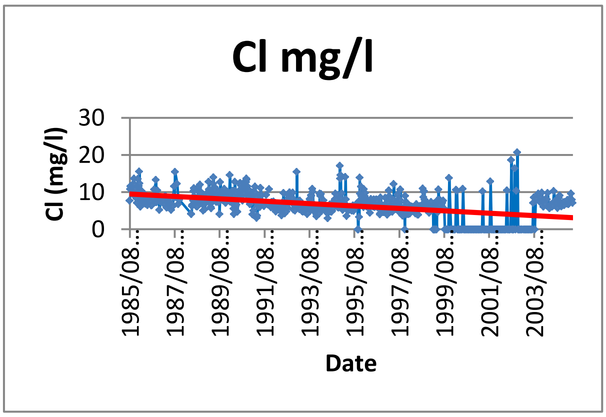
B2H003



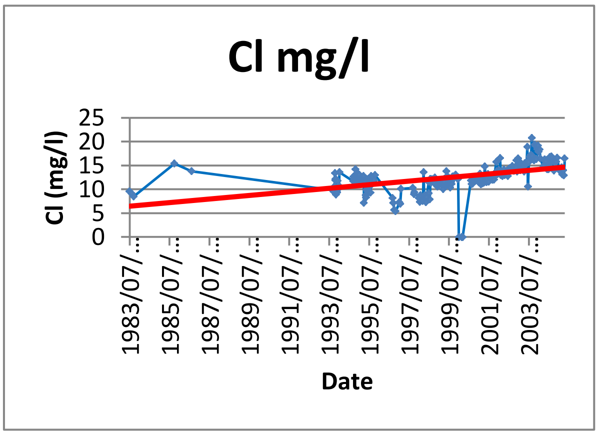
B2H004



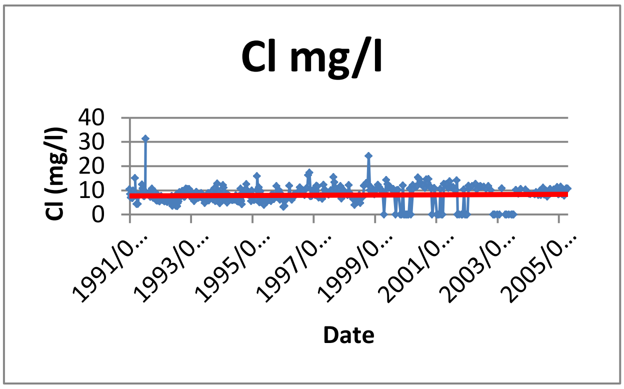
B2H007



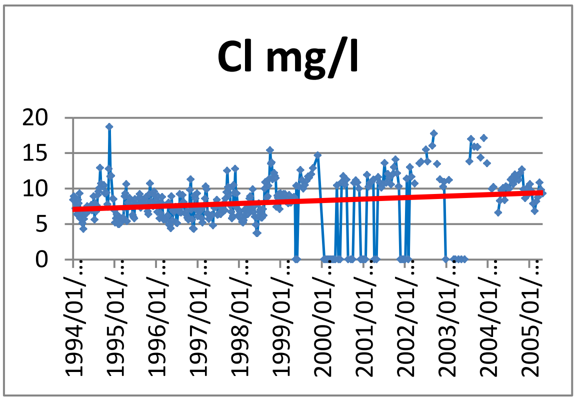
B2H010



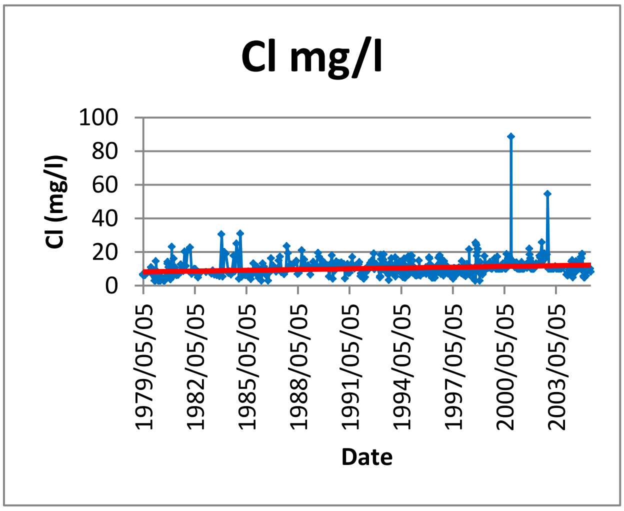
B2H014



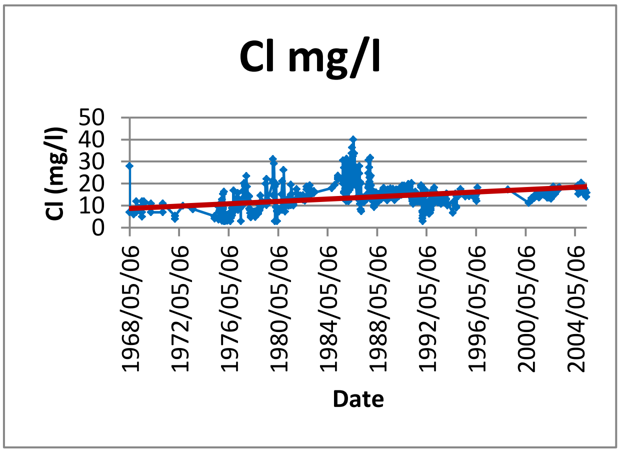
B2H015



B1H002

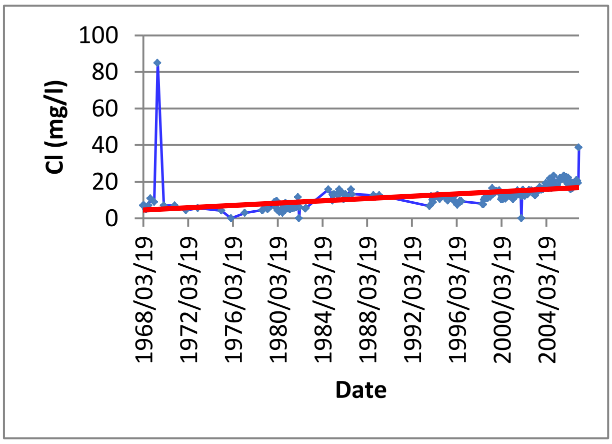


B3R002

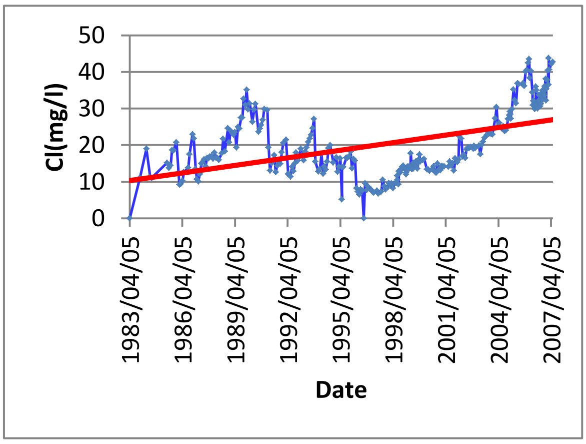


Middle Olifants Catchment

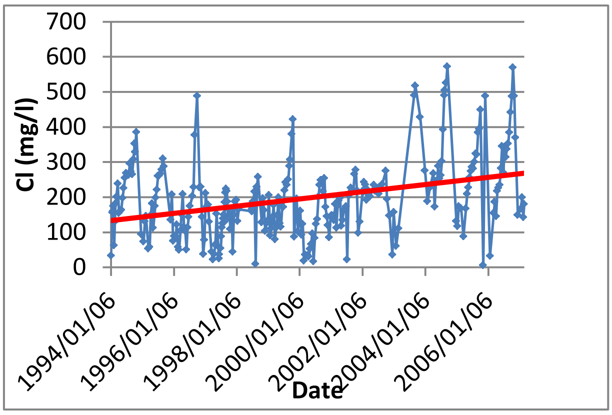
B3R001



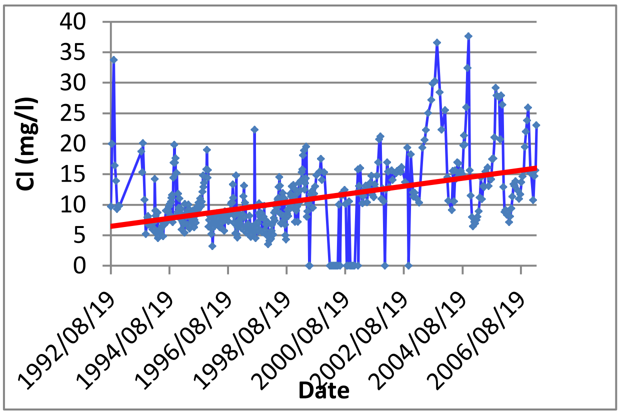
B3R005



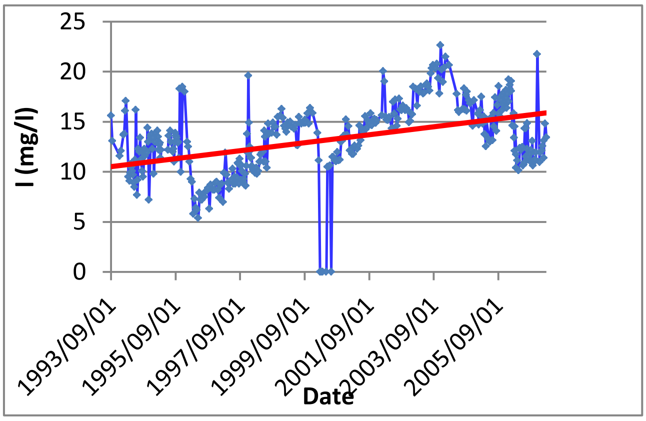
B3H021



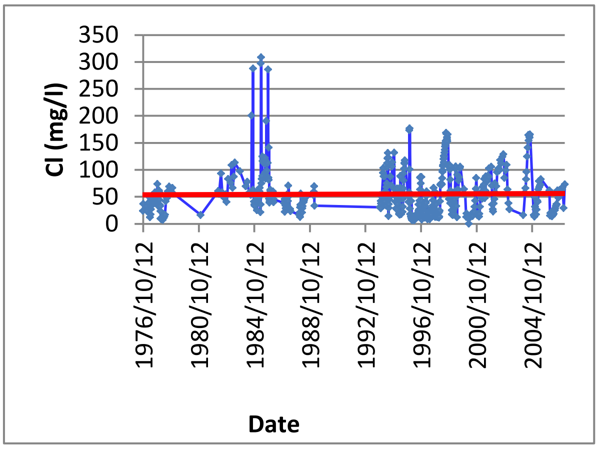
B3H007



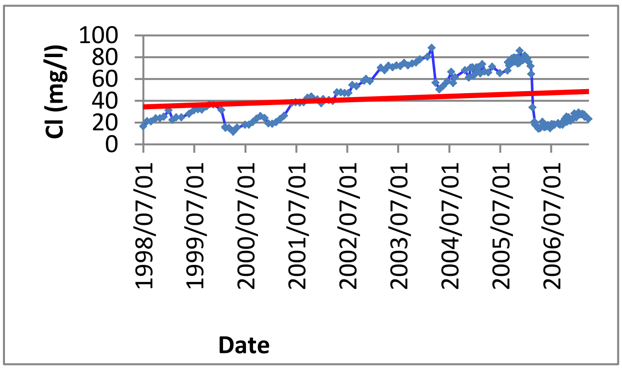
B3H017



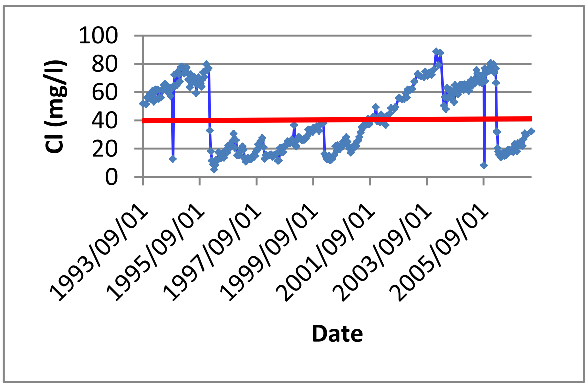
B3H001



B5R002

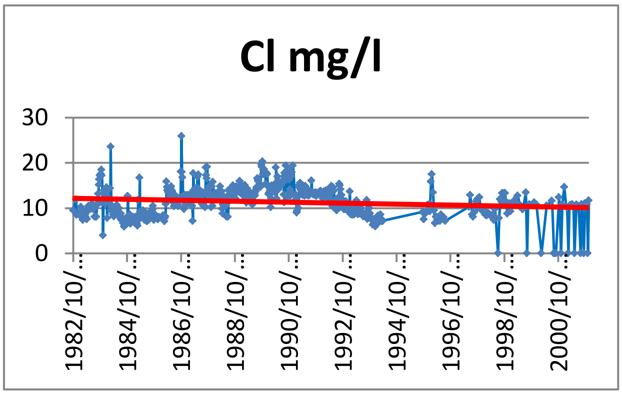


B5H004

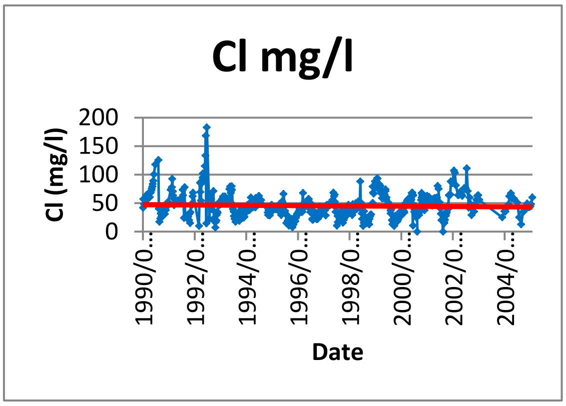


Witbank Dam Catchment

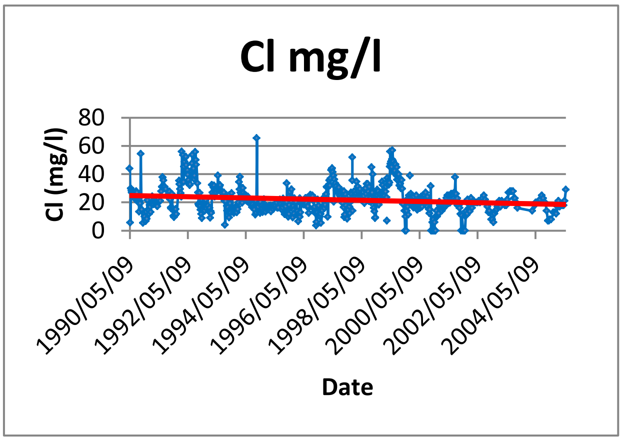
B1H006



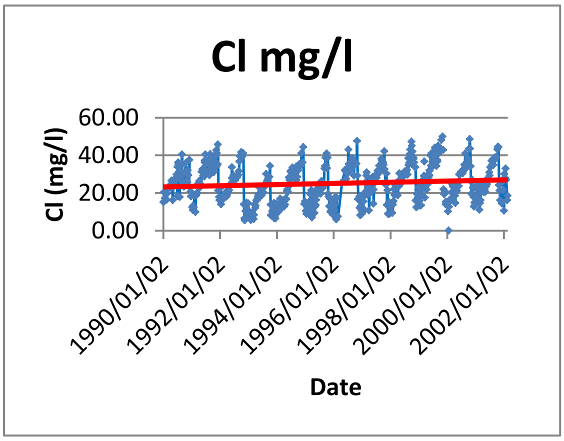
B1H020



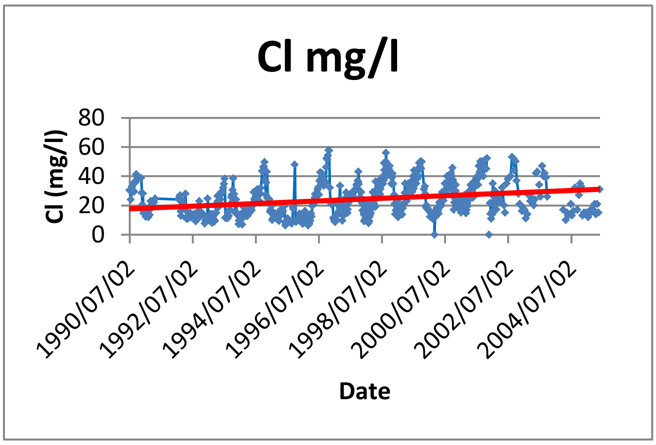
B1H019



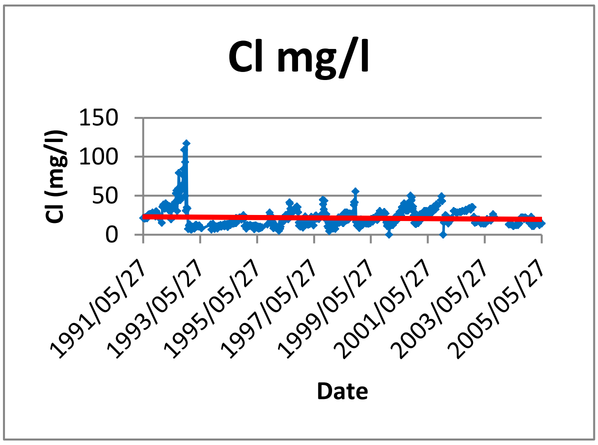
B1H017



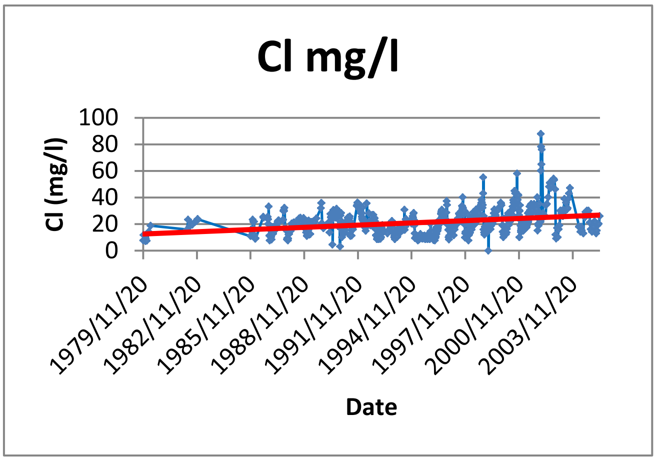
B1H021



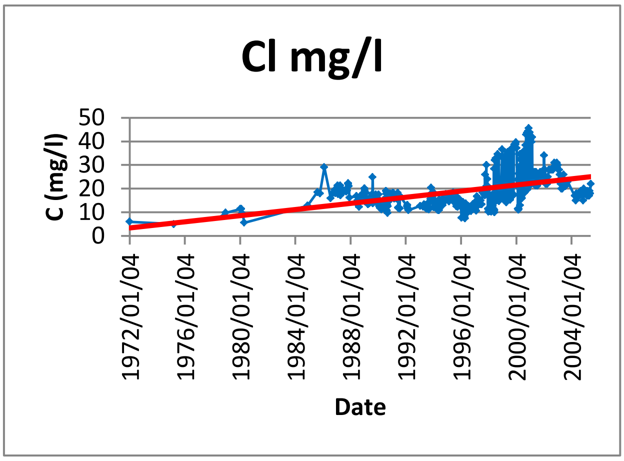
B1H018



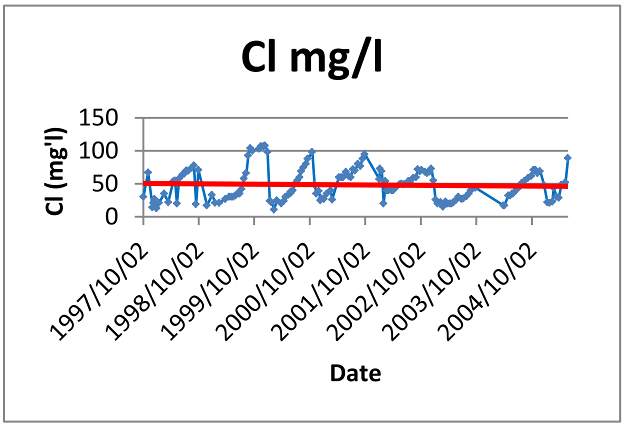
B1H005



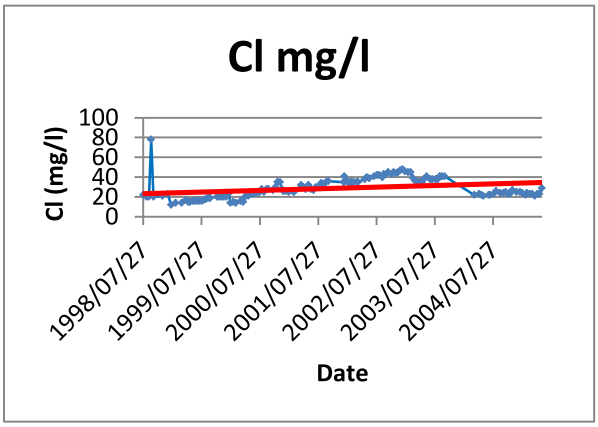
B1R001



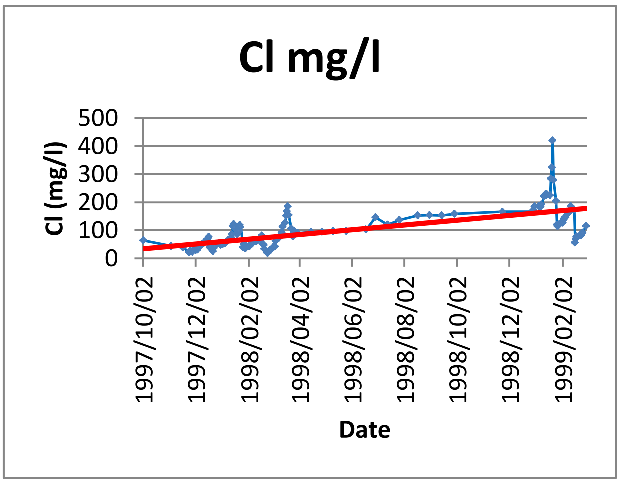
Rietspruit



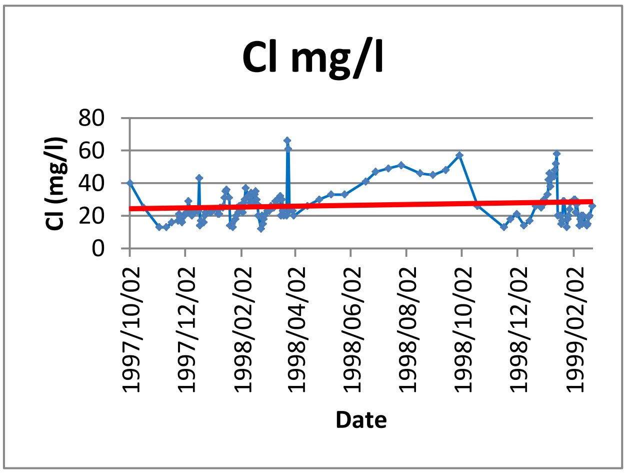
Rietspruit Dam



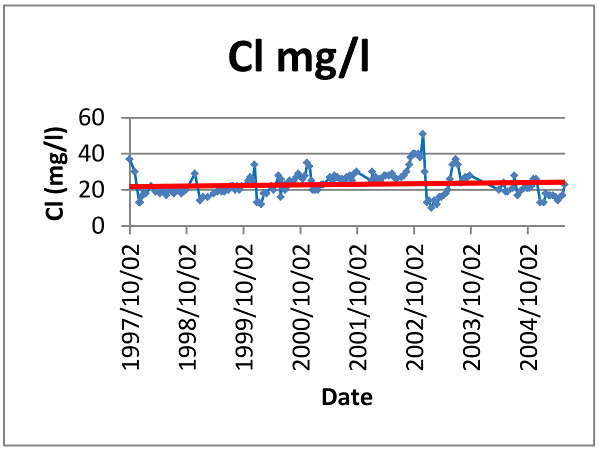
Tweefontein



Bethal Road Bridge

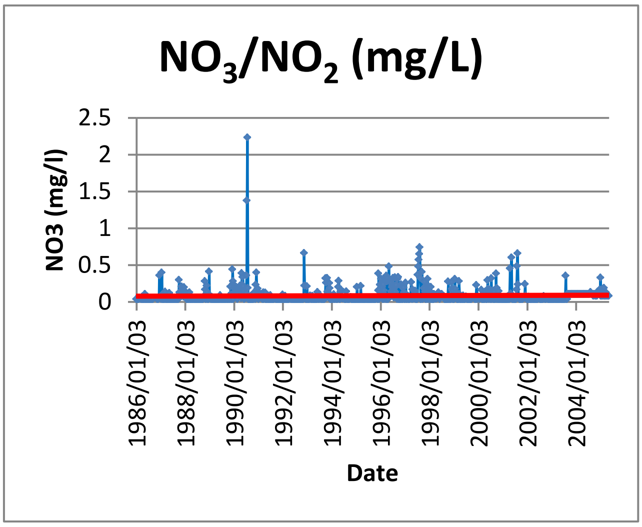


Duvha Road Bridge

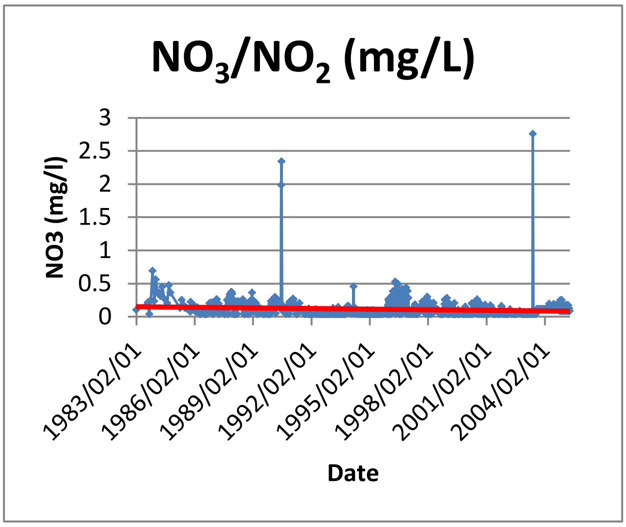


NO_2/NO_3:Middelburg

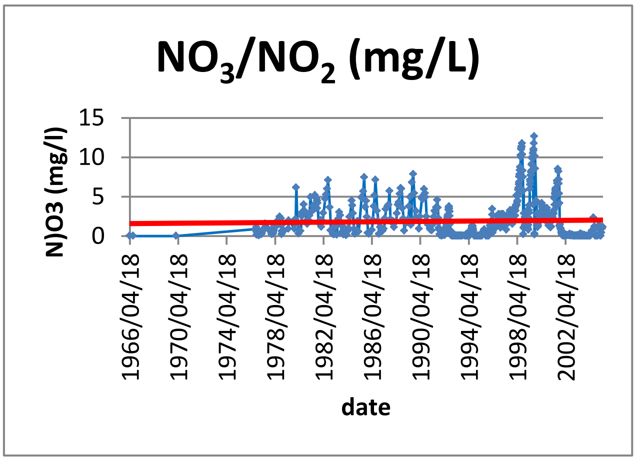
B1H012



B1H015

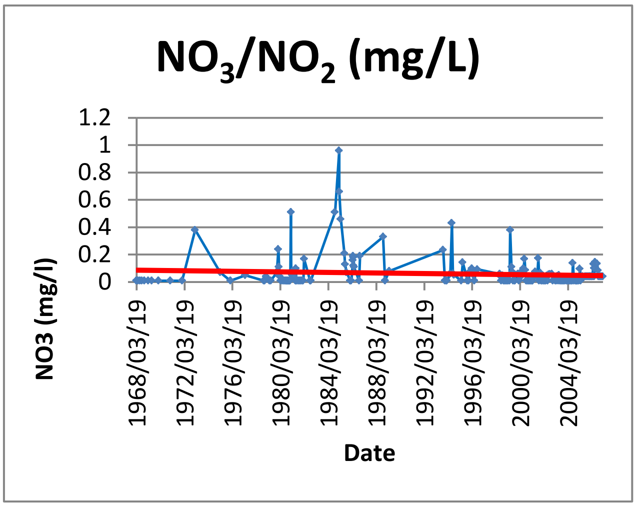


B1H004

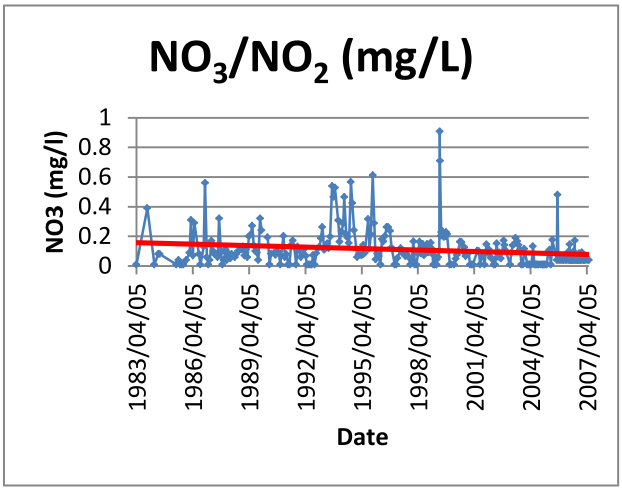


Middle Olifants

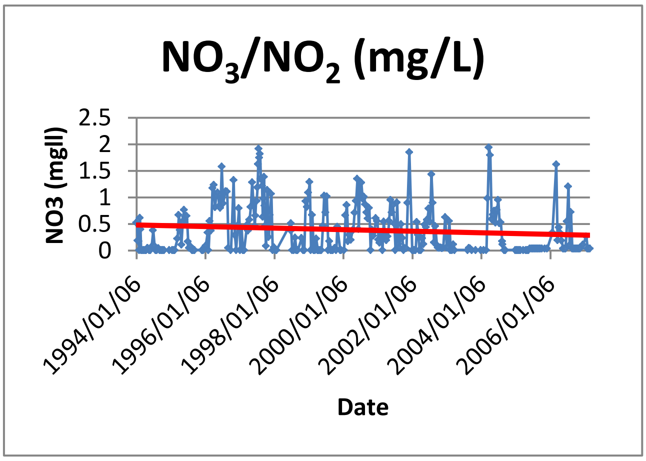
B3R001



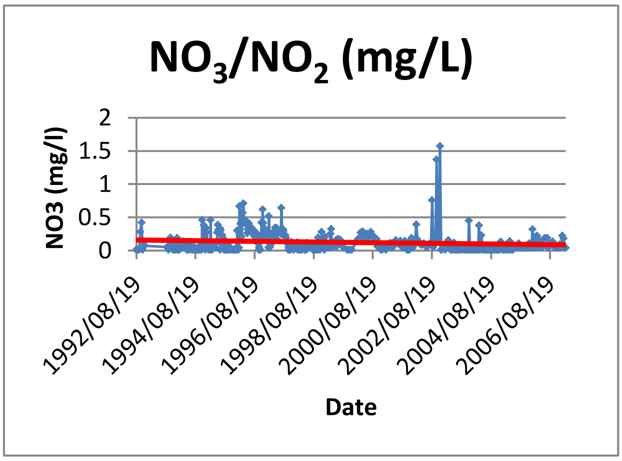
BR005



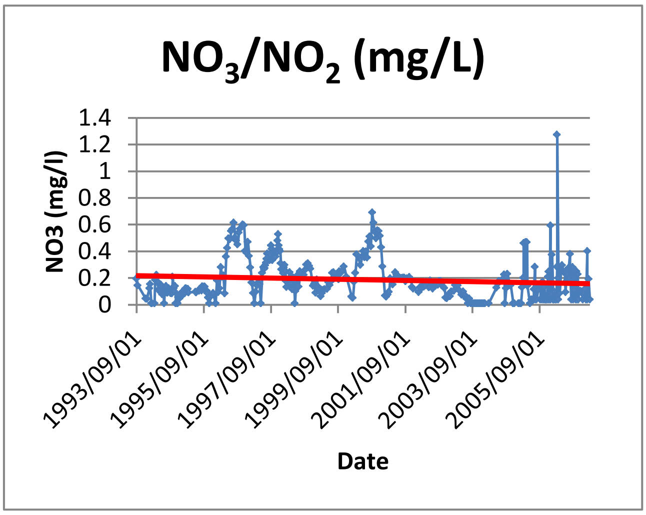
B3H021



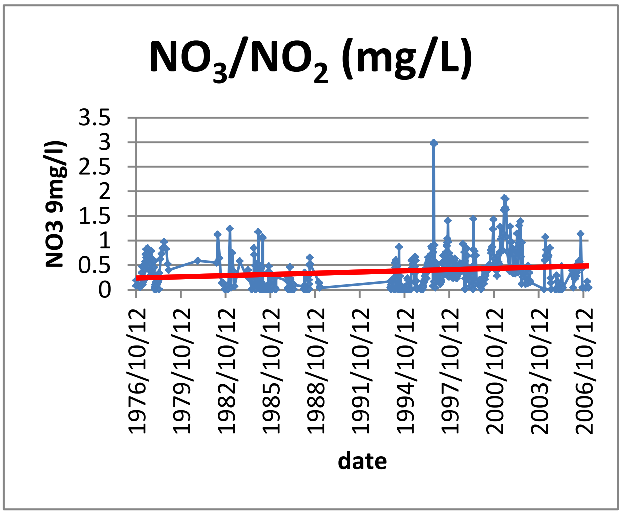
B3H007



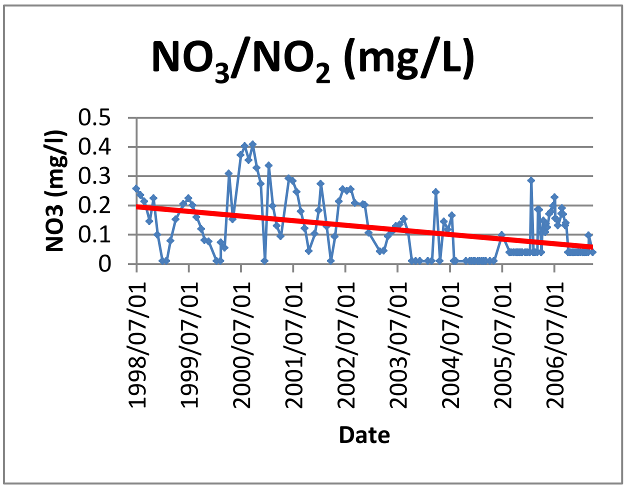
B3H017



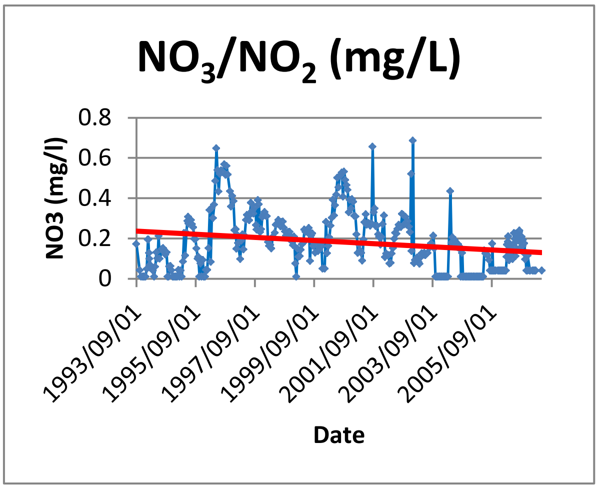
B3H001



B5R002

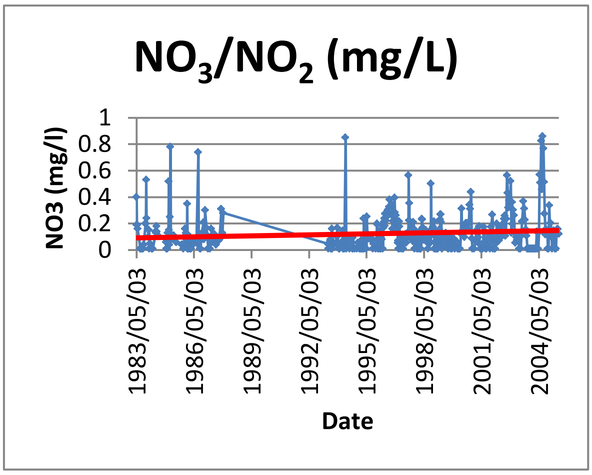


B5H004

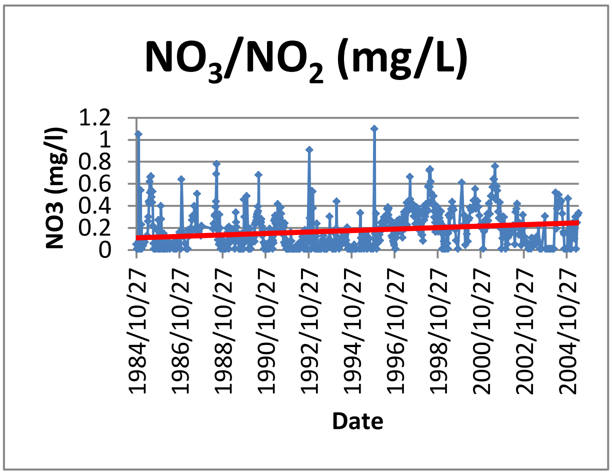


Wilge River and Loskop Dam Catchment

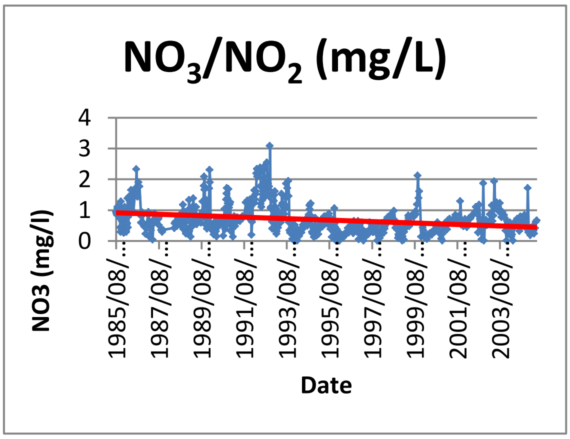
B2H003



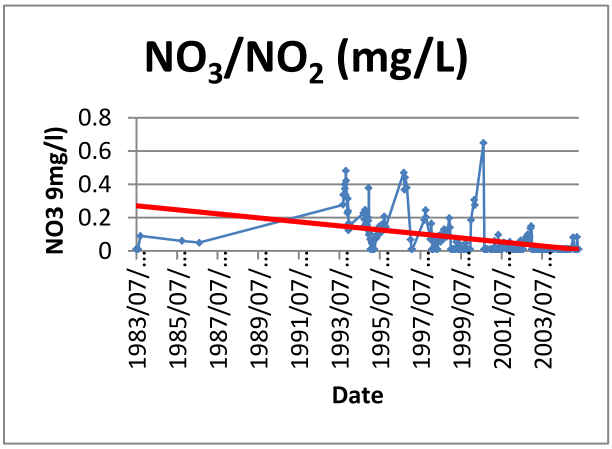
B2H004



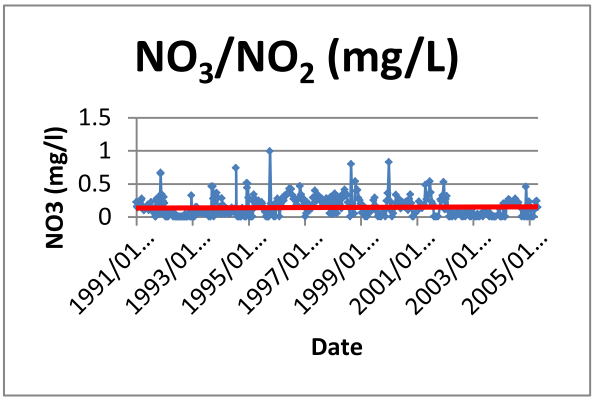
B2H007



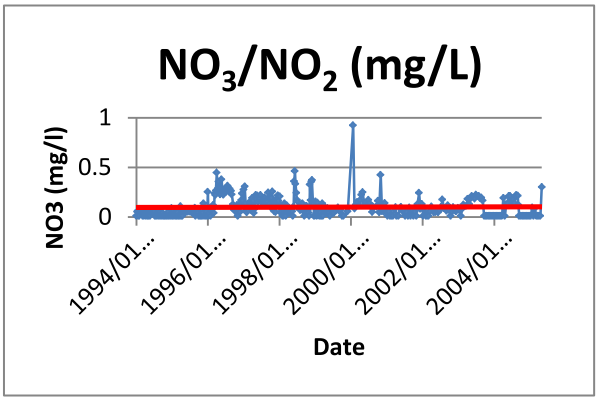
B2H010



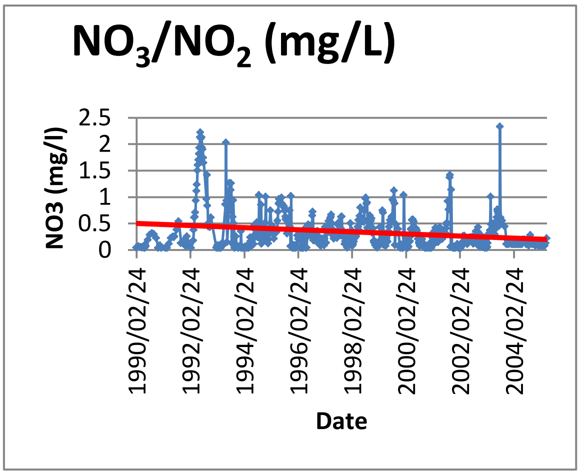
B2H014



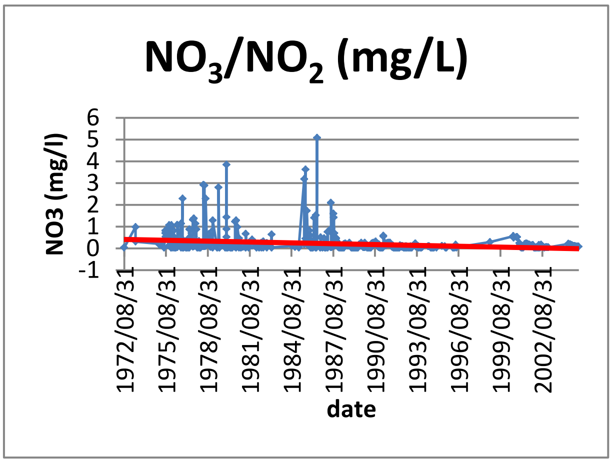
B2H015



B1H002

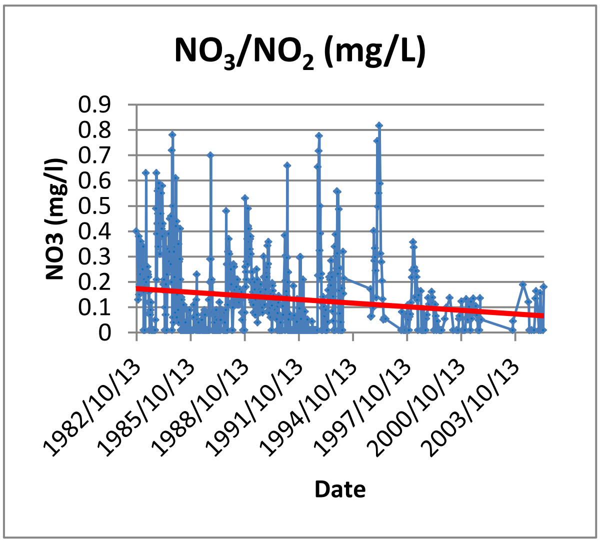


B3R002

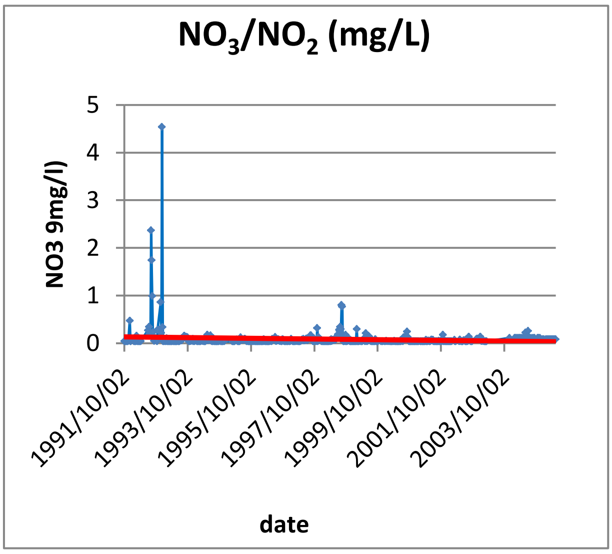


Witbank Dam Catchment

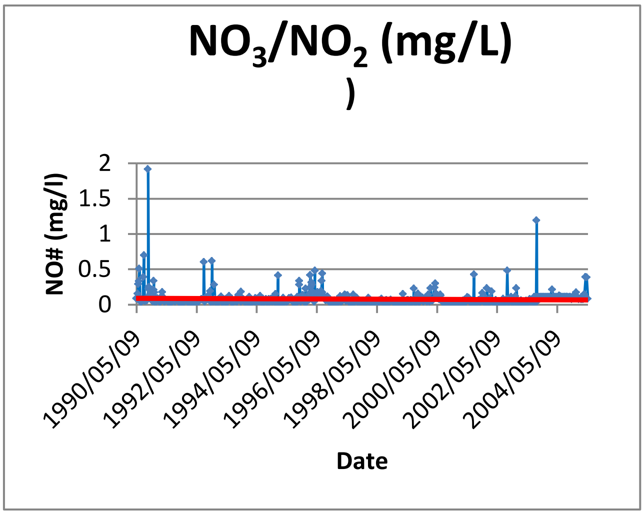
B1H006



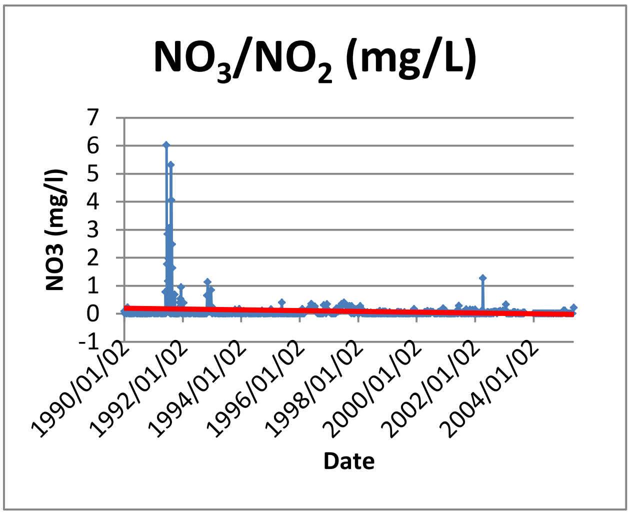
B1H020



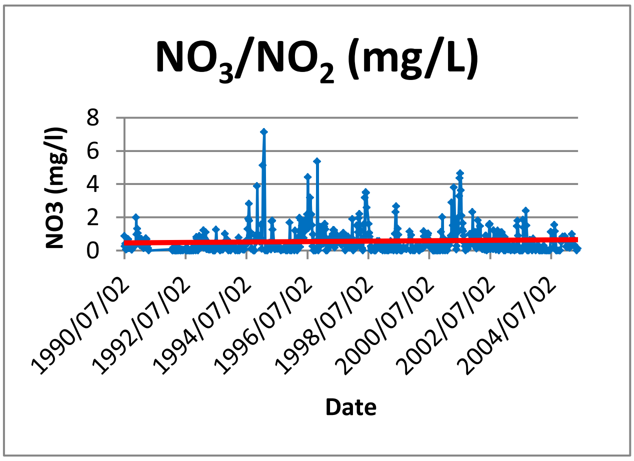
B1H019



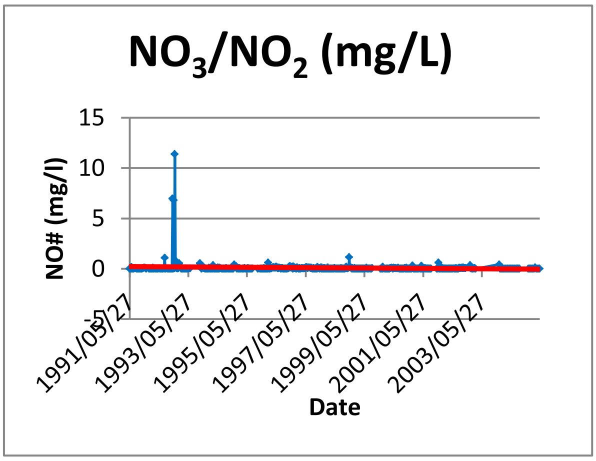
B1H017



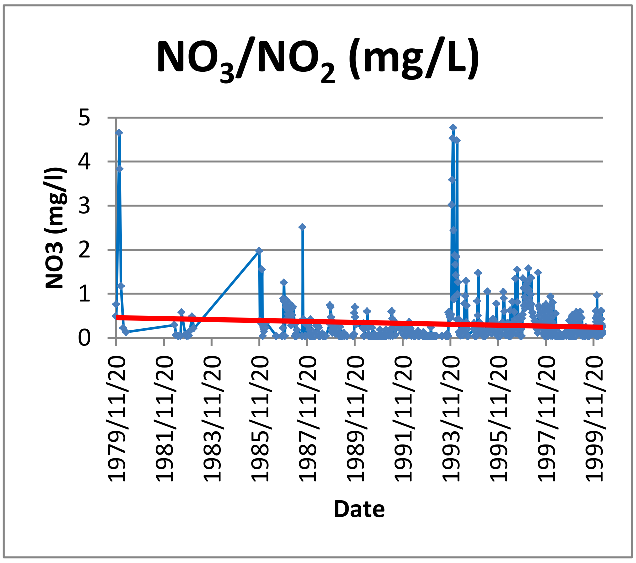
B1H021



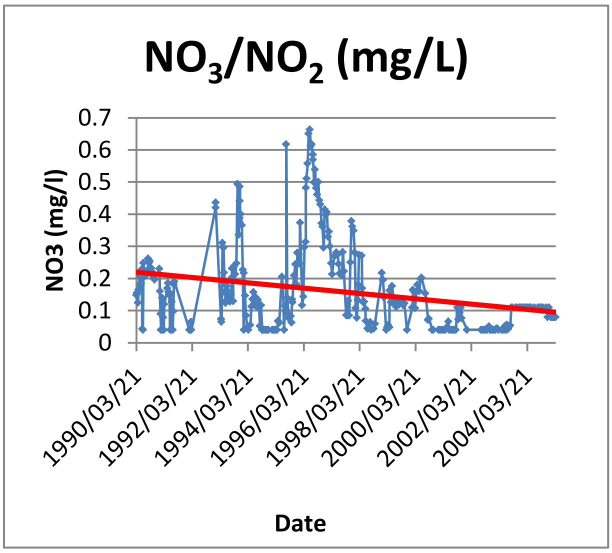
B1H018



B1H005

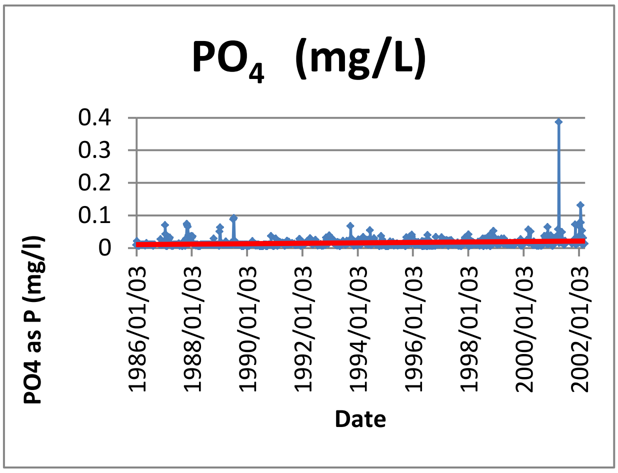


B1R001

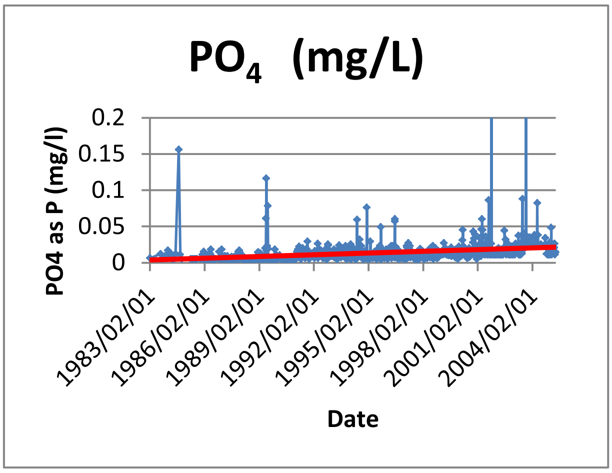


PO_4:Middelburg Dam Catchment

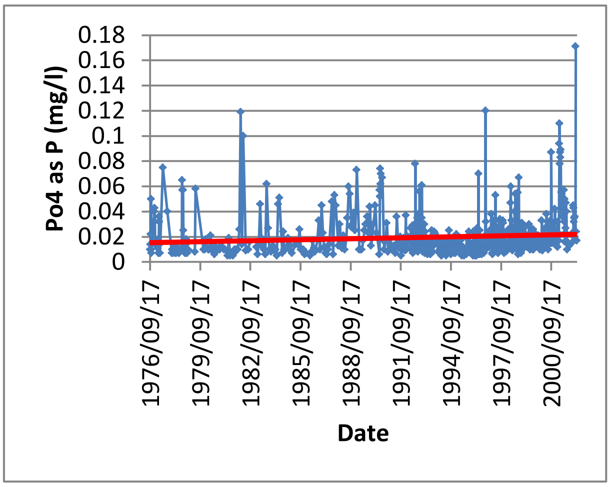
B1H012



B1H015

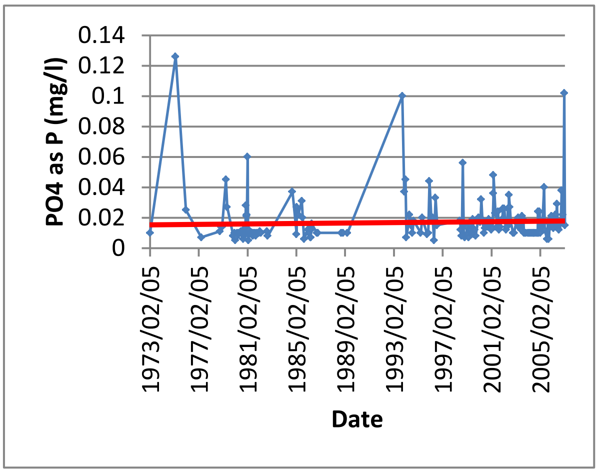


B1H004

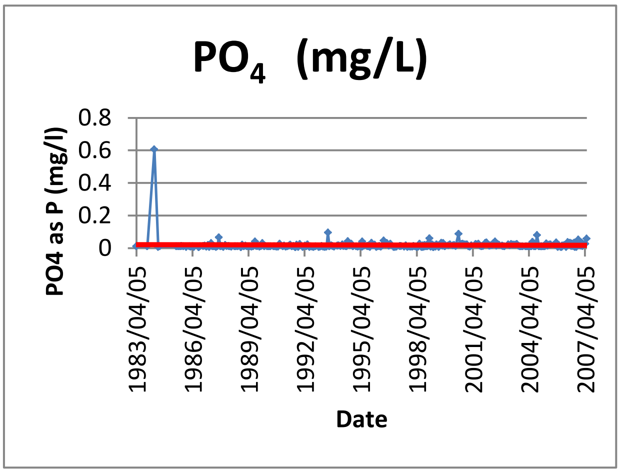


Middle Olifants catchment

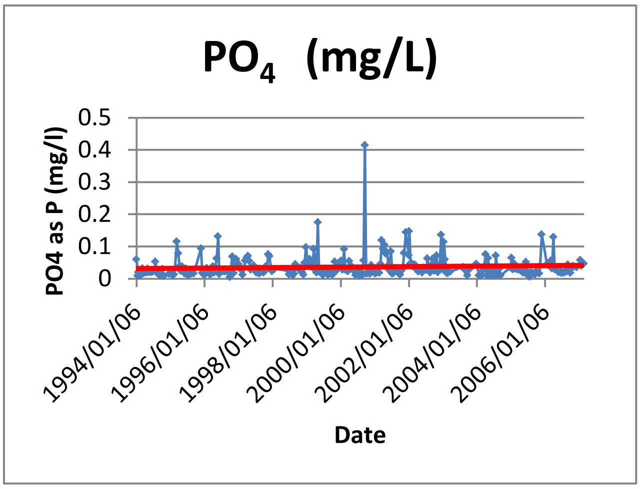
B3R001



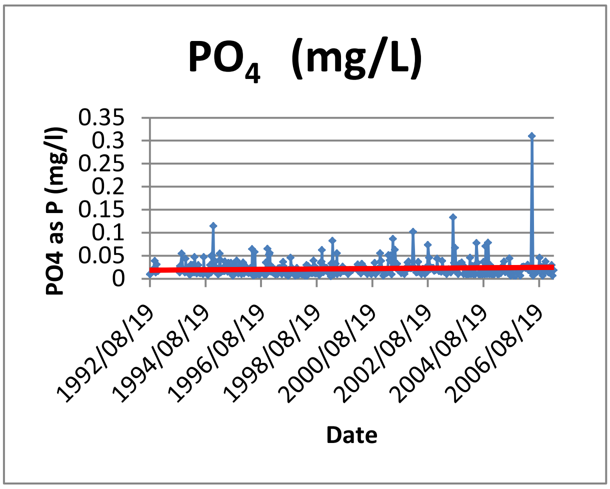
B3R005



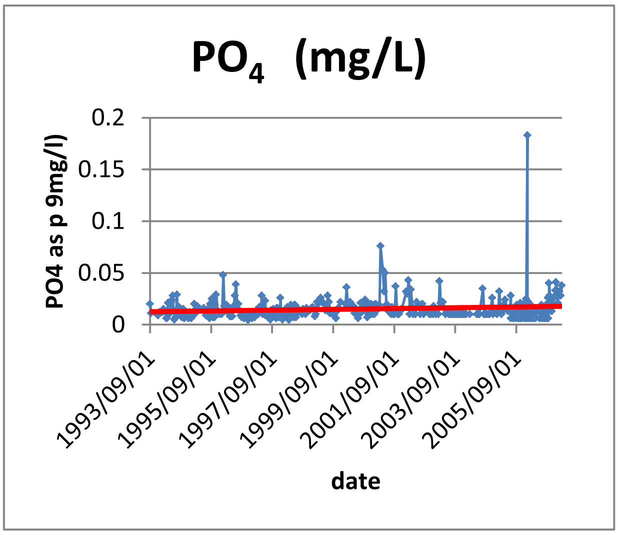
B3H021



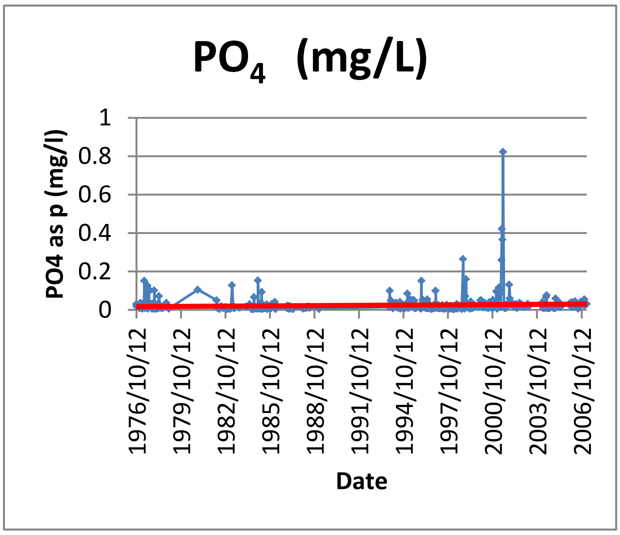
B3H007



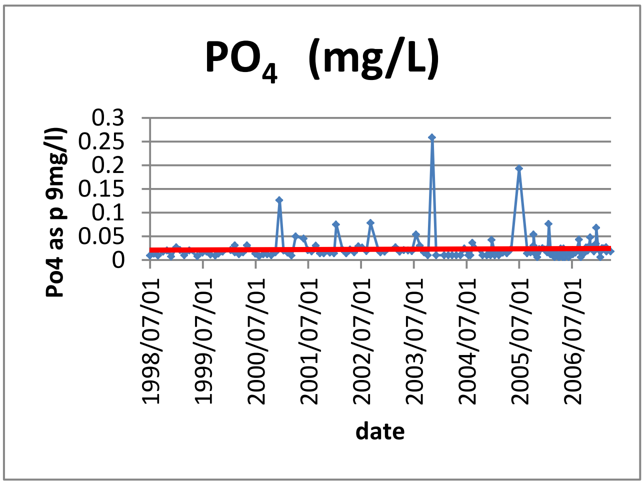
B3H017



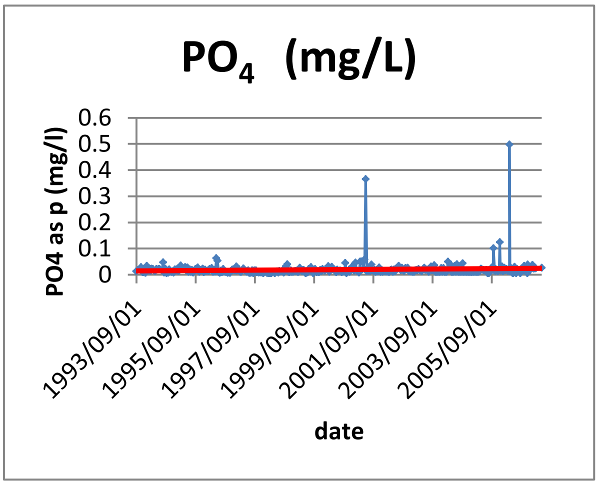
B3H001



B5R002

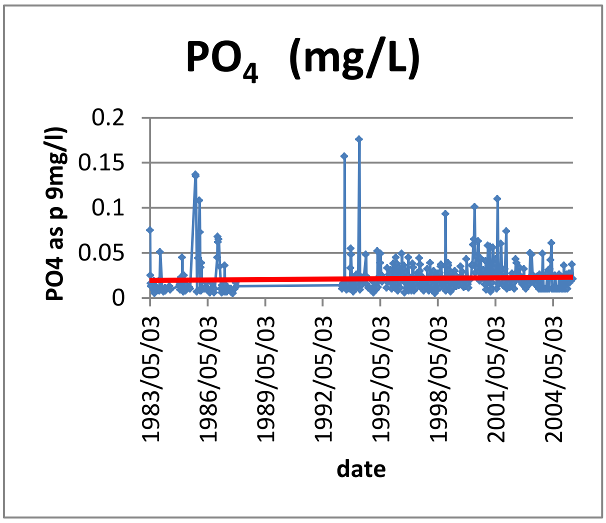


B5H004

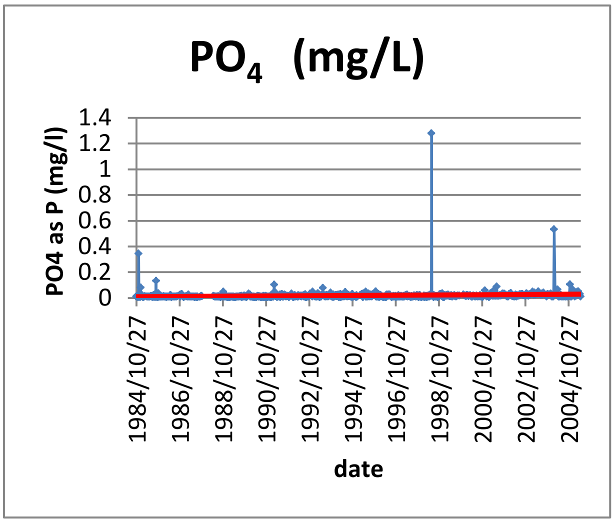


Wilge River and Loskop Dam Catchment

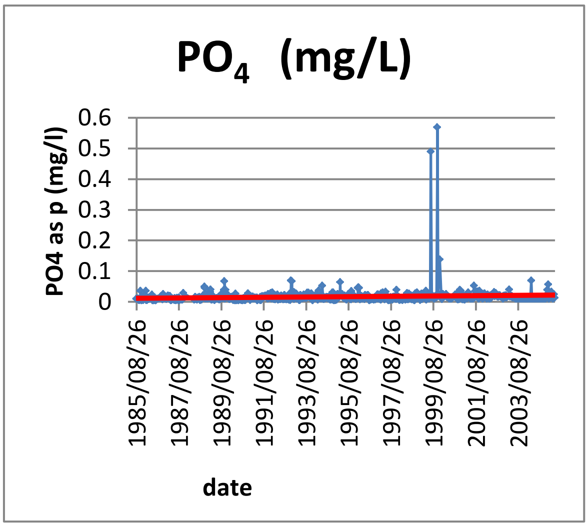
B2H003



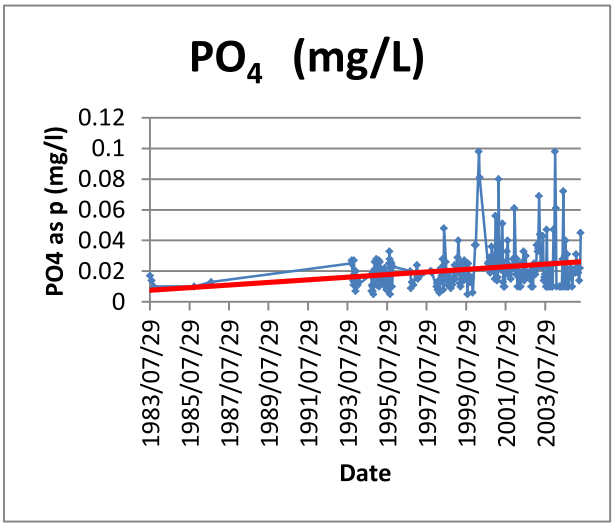
B2H004



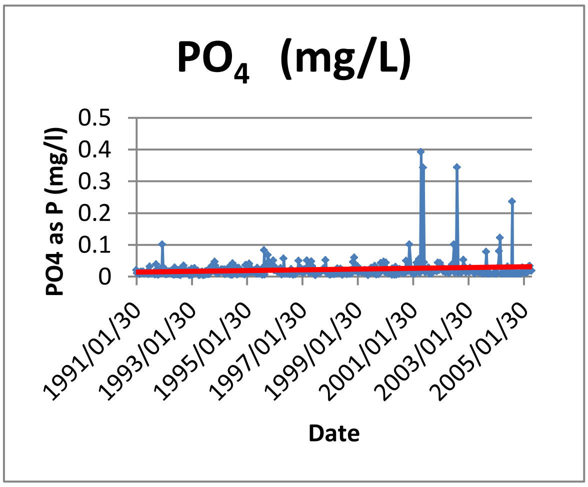
B2H007



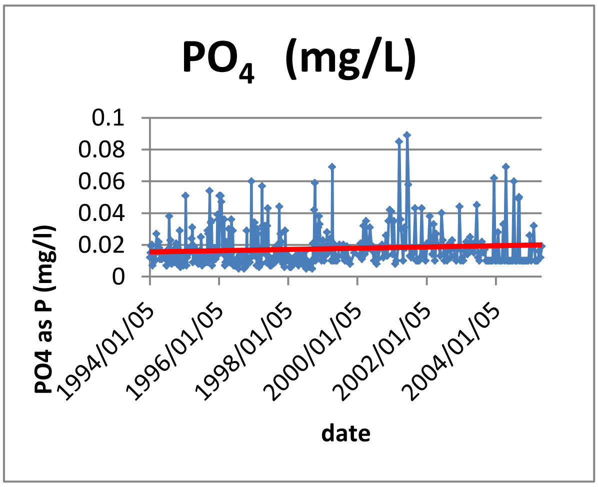
B2H010



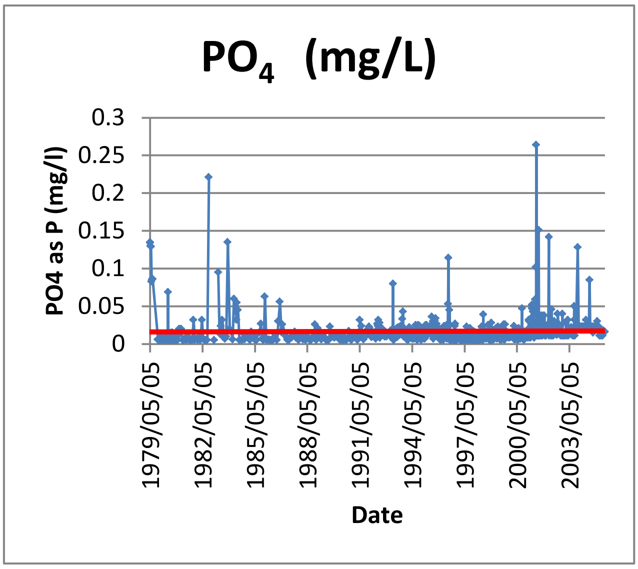
B2H014



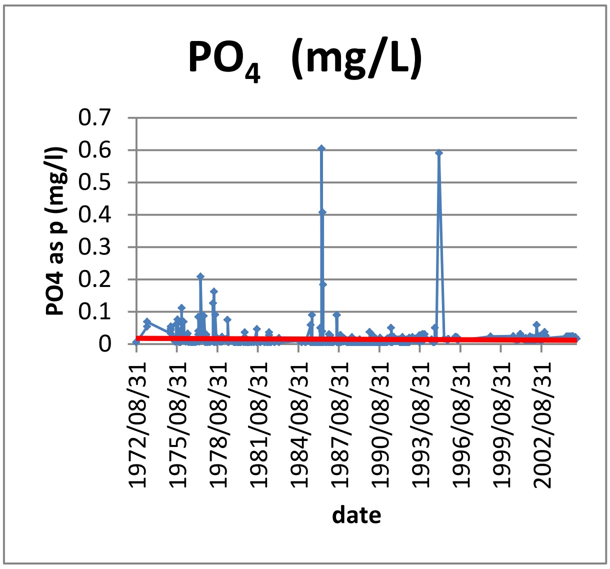
B2H015



B2H002

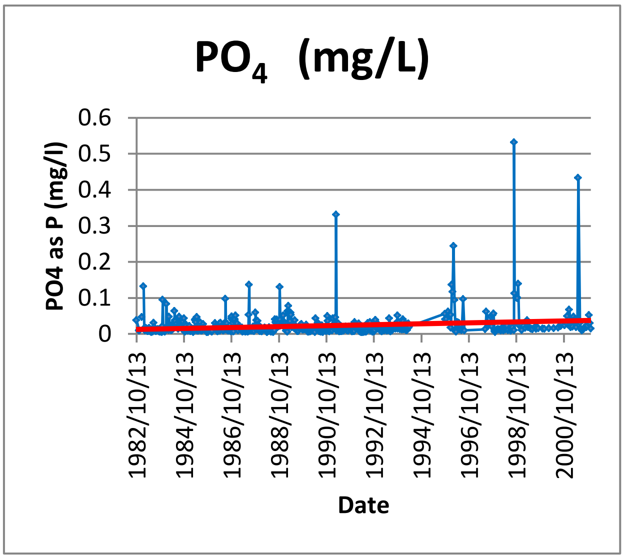


B3R002

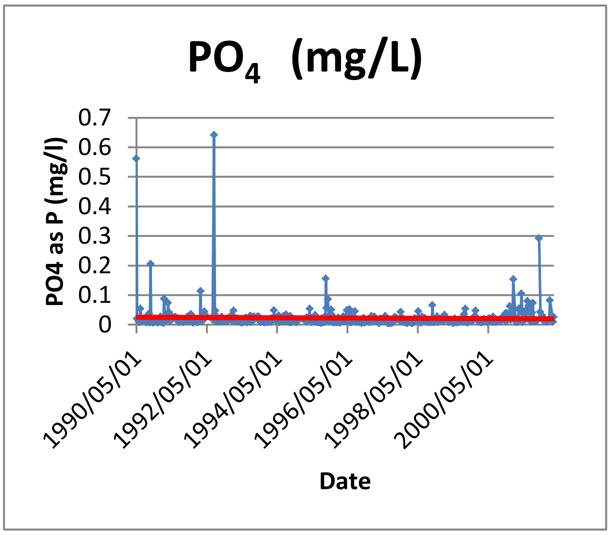


Witbank Dam Catchment

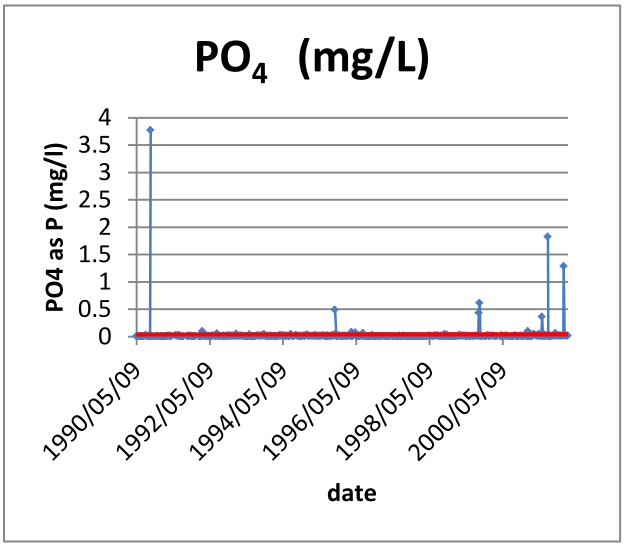
B1H006



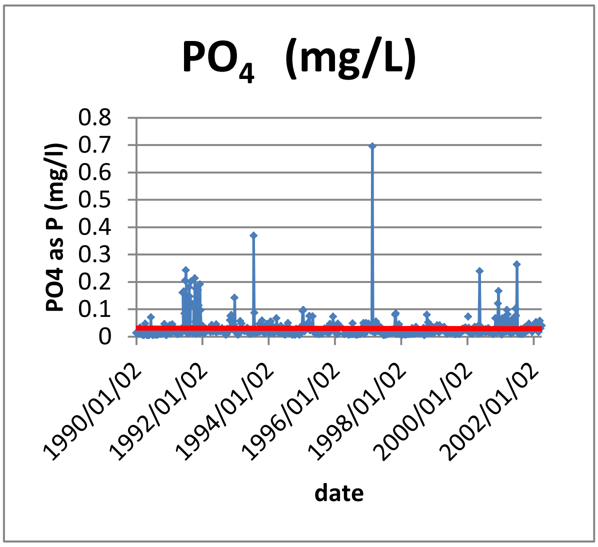
B1H020



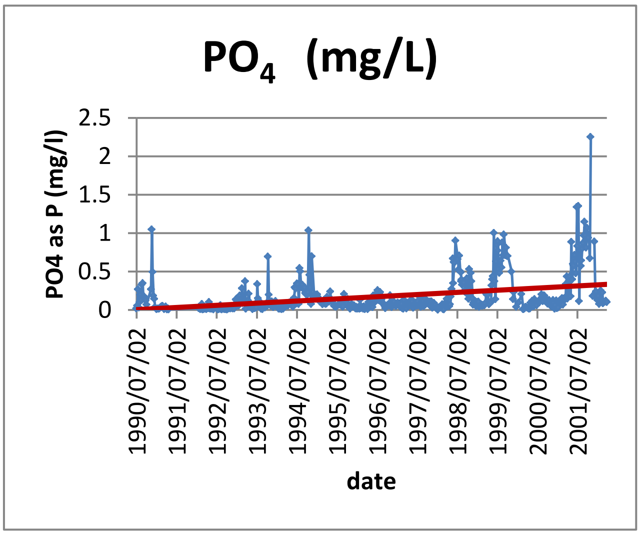
B1H019



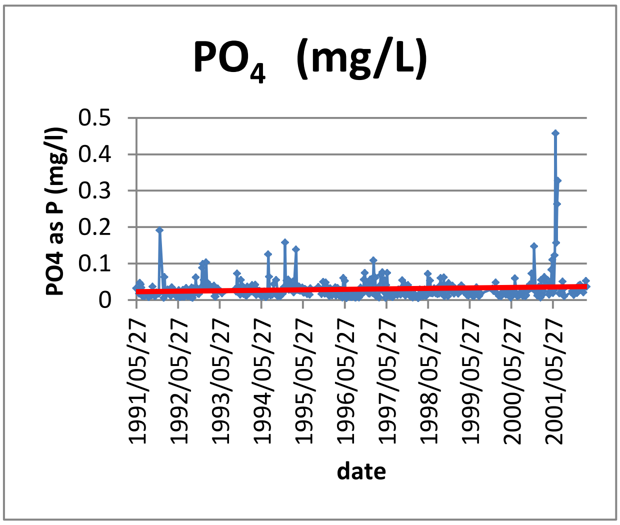
B1H017



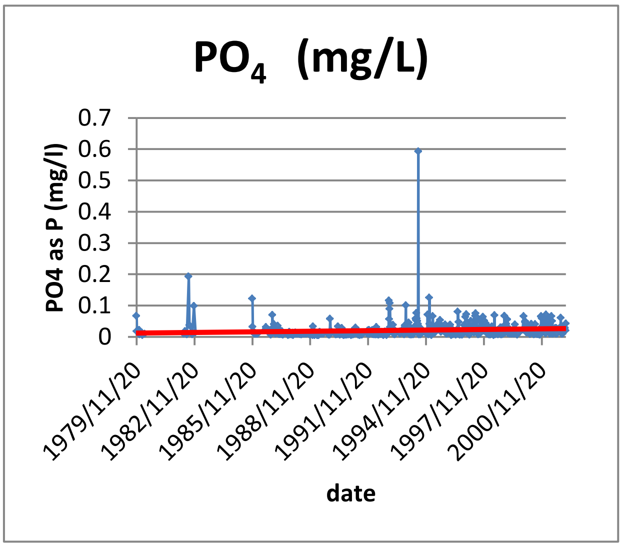
B1H021



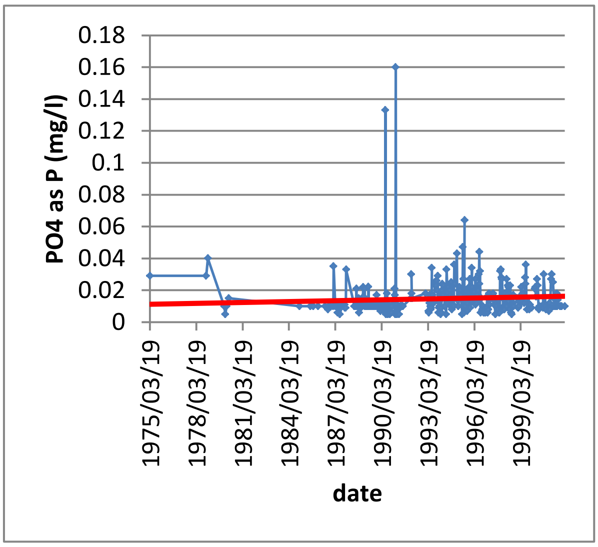
B1H018



B1H005

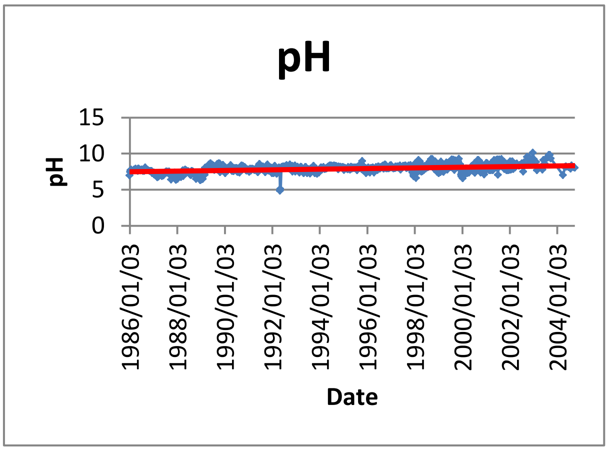


B1R001

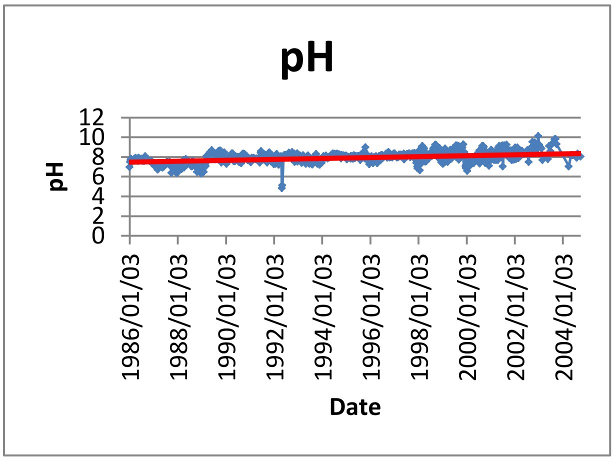


pH: Middelburg

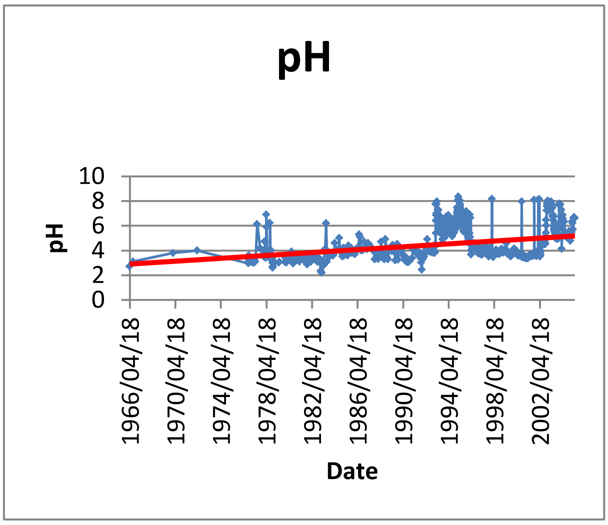
B1H012



B1H015

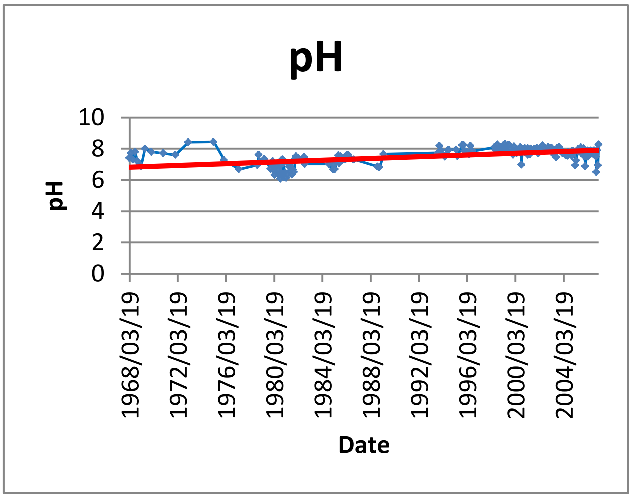


B1H004

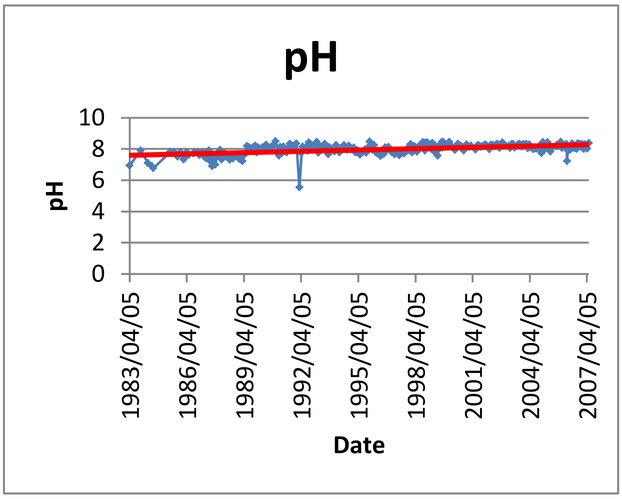


Middle Olifants catchment

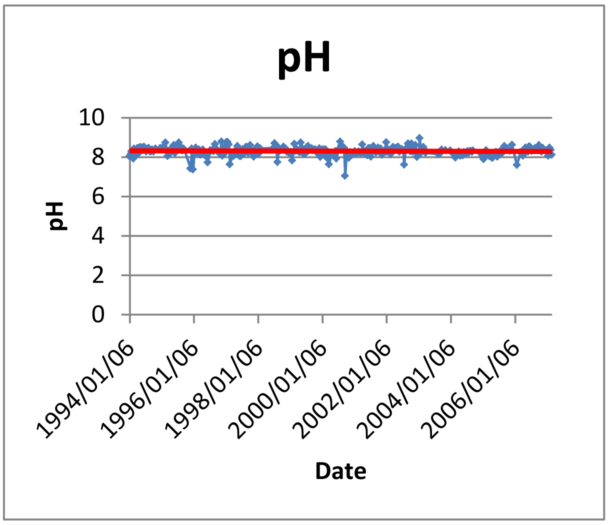
B3R001



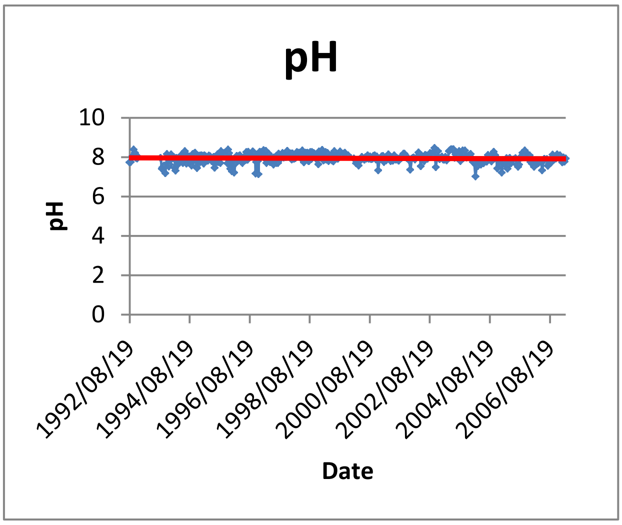
B3R005



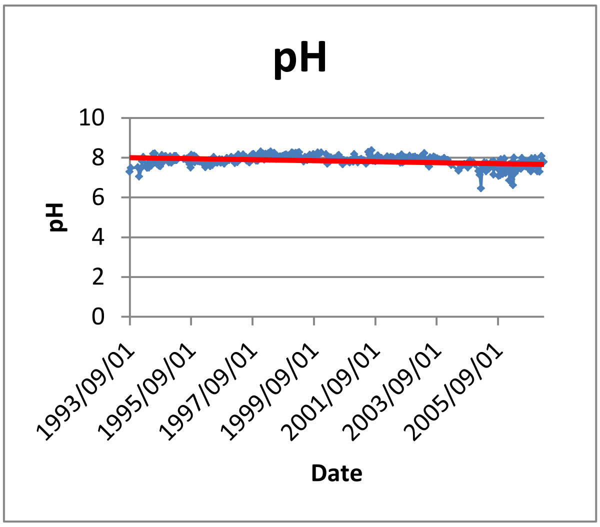
B3H021



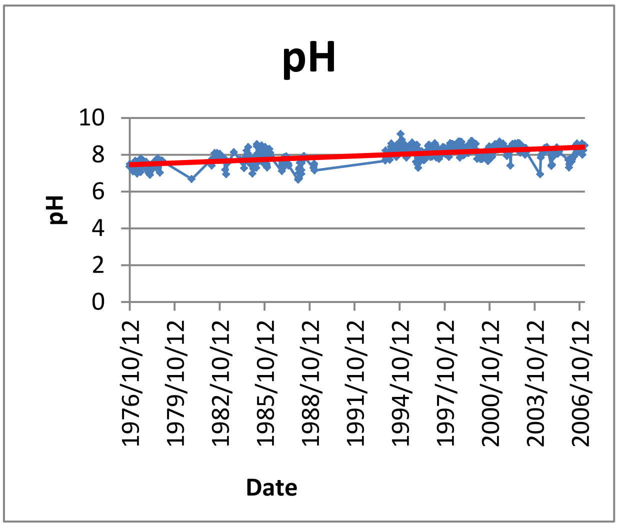
B3H007



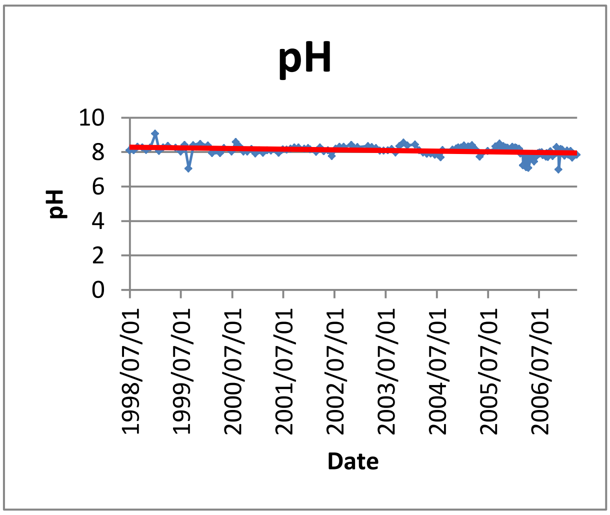
B3H017



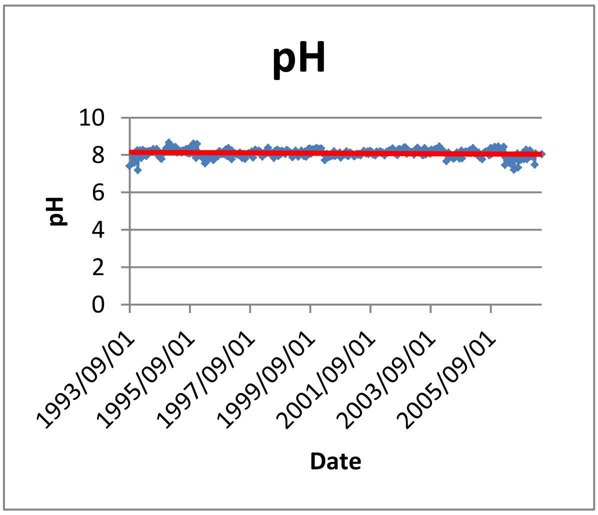
B3H001



B5R002

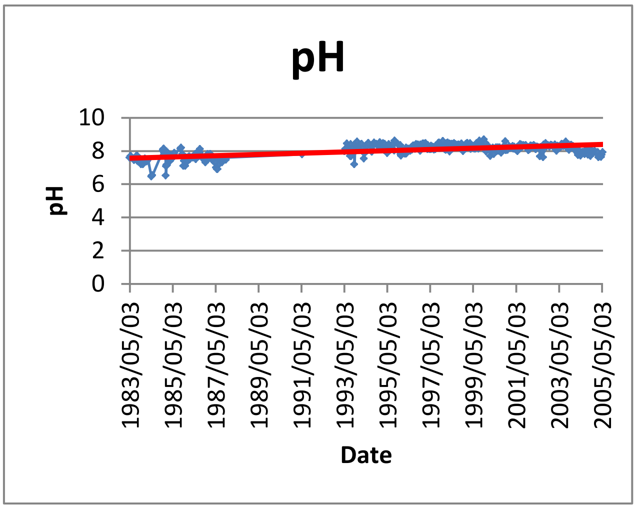


B5H004

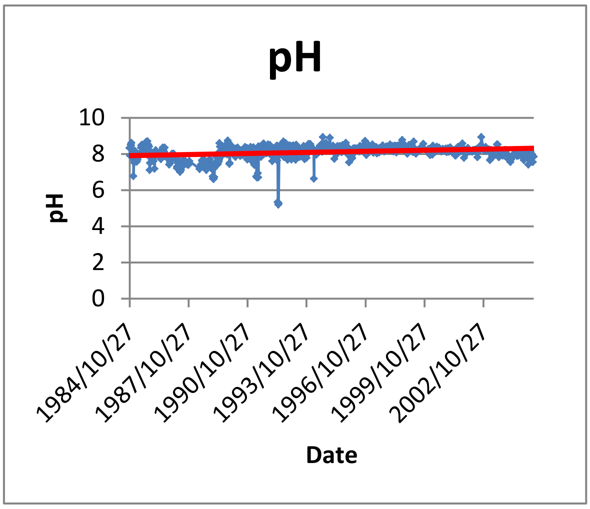


Wilge River and Loskop Dam Catchment

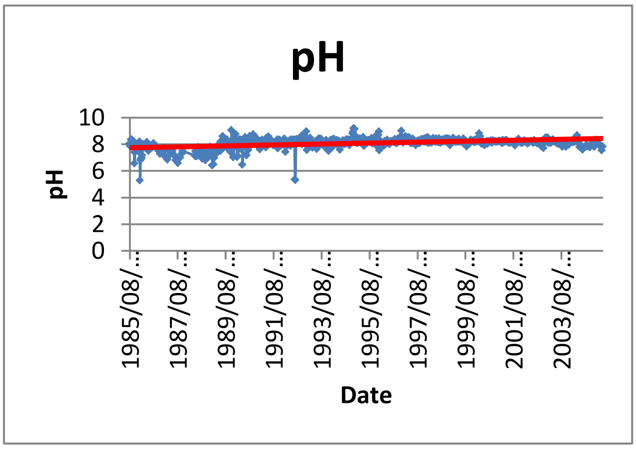
B2H003



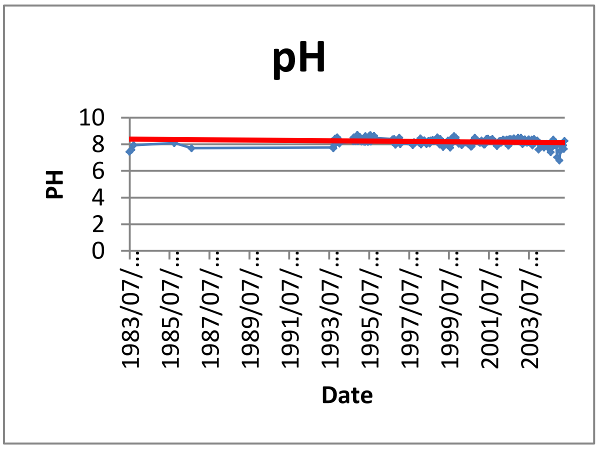
B2H004



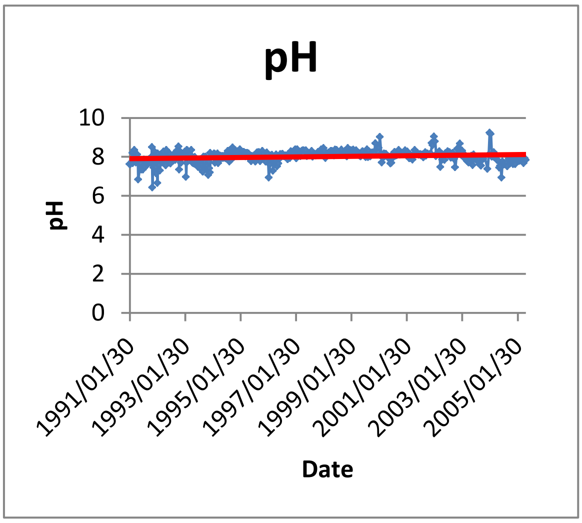
B2H007



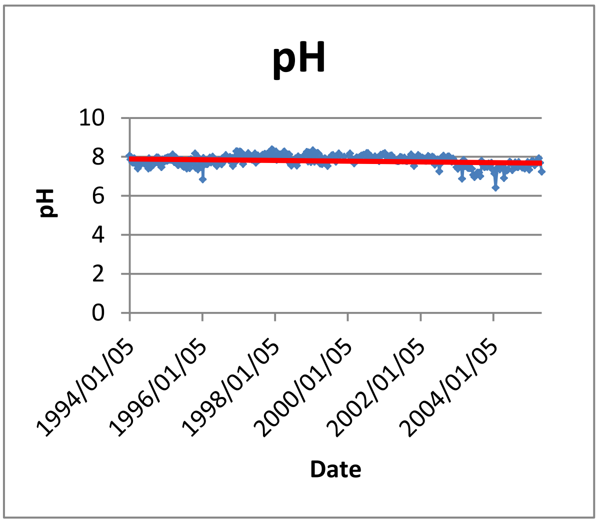
B2H010



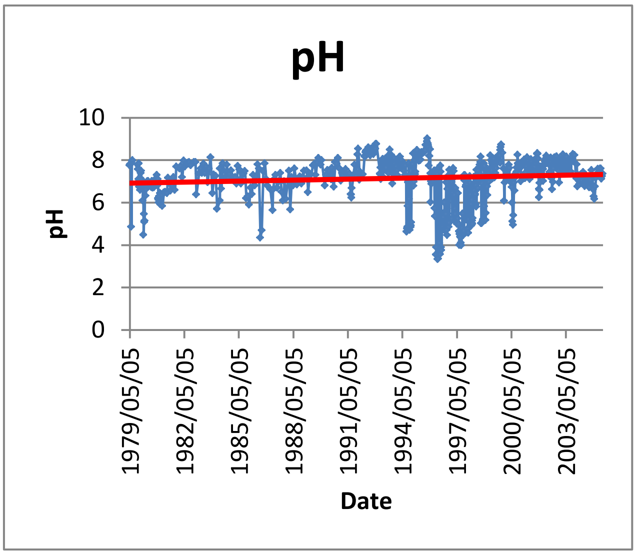
B2H014



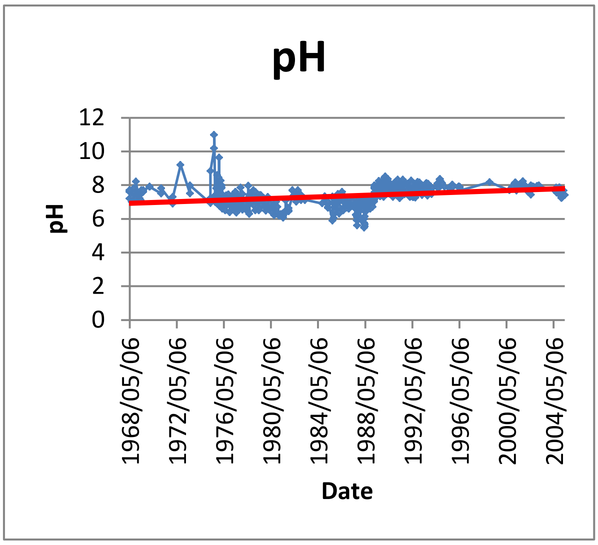
B2H015



B2H002

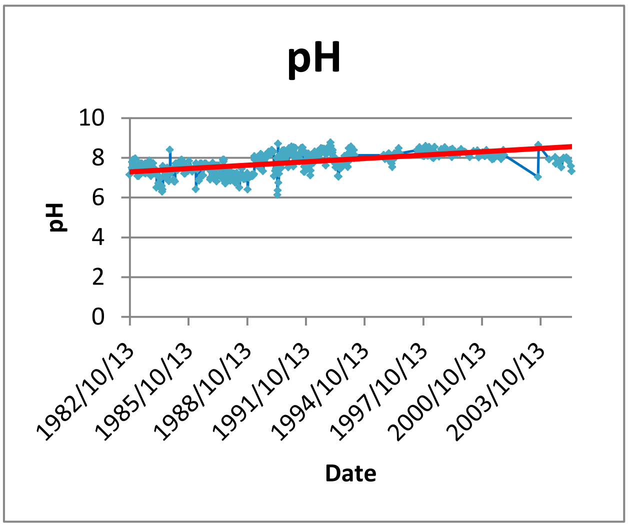


B3R002

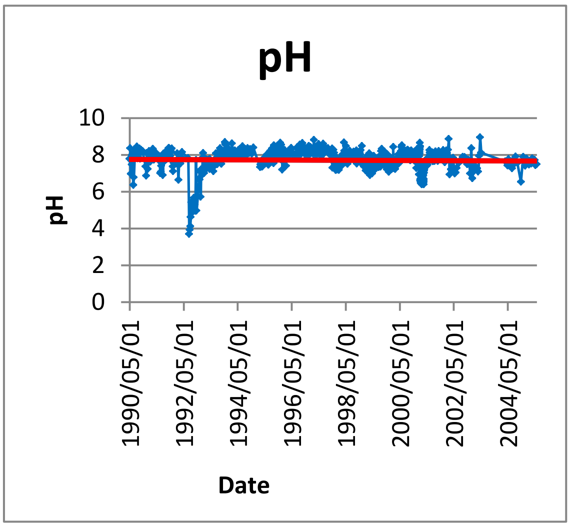


Witbank Dam Catchment

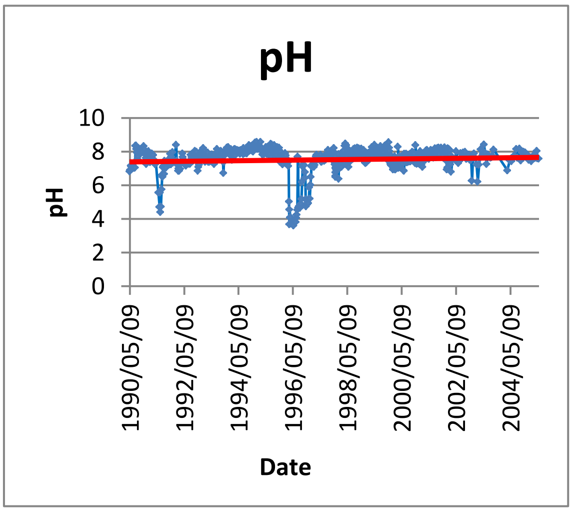
B1H006



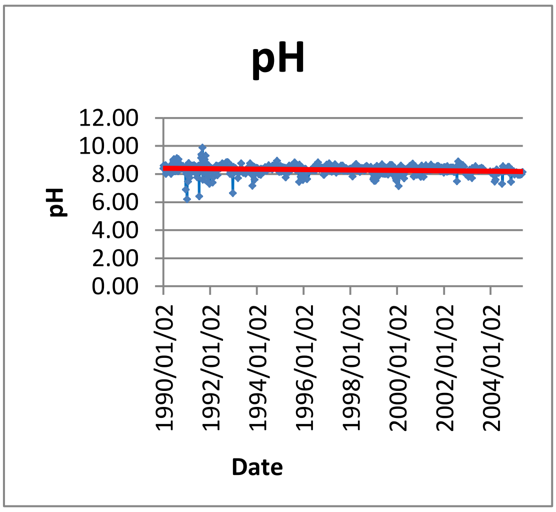
B1H020



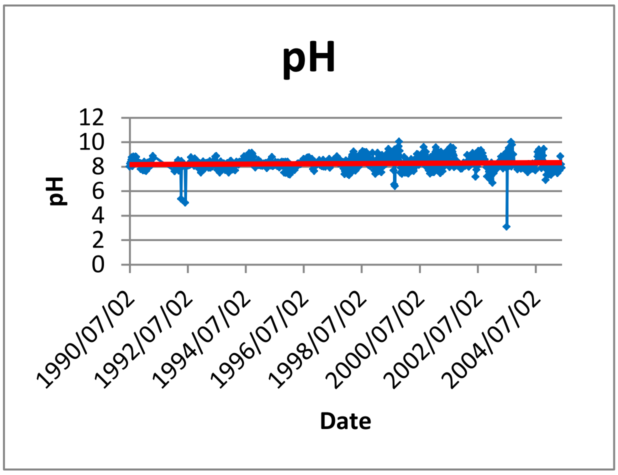
B1H019



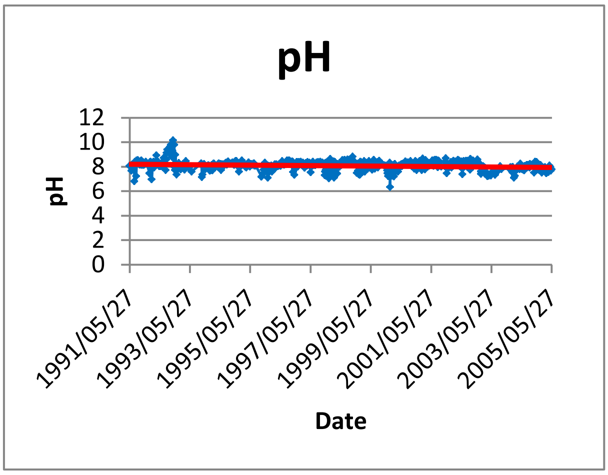
B1H017



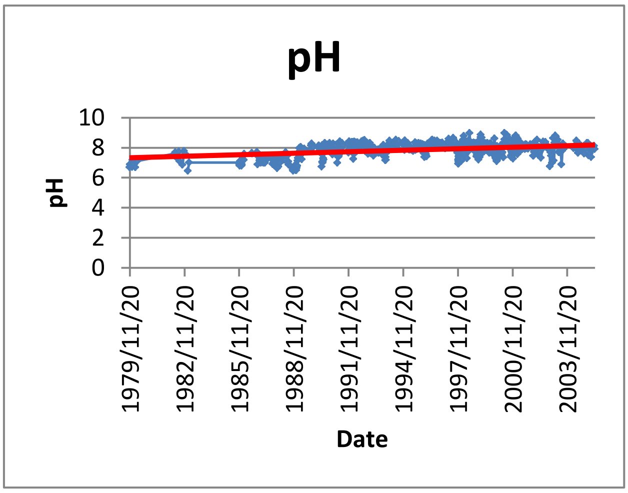
B1H021



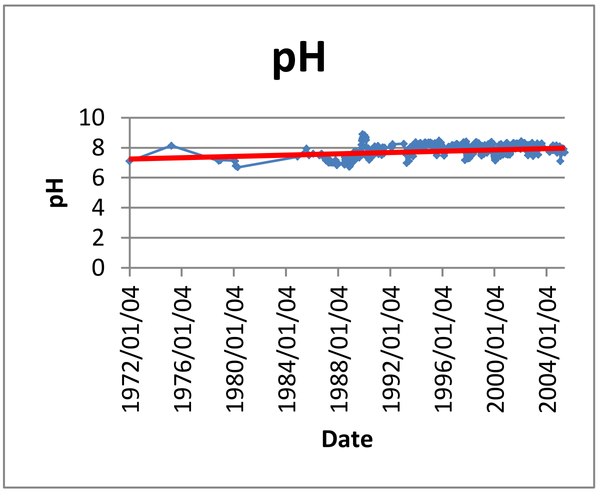
B1H018



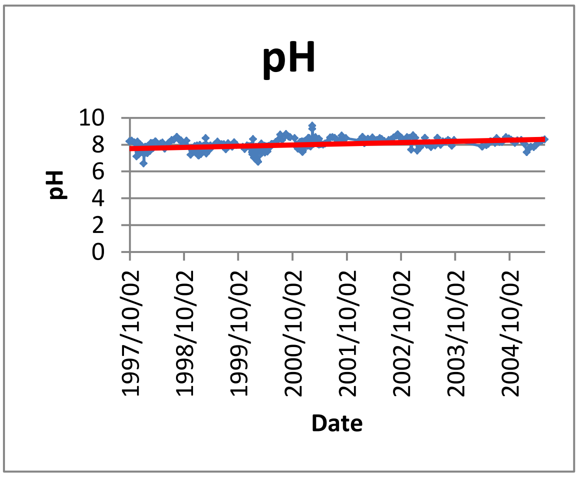
B1H005



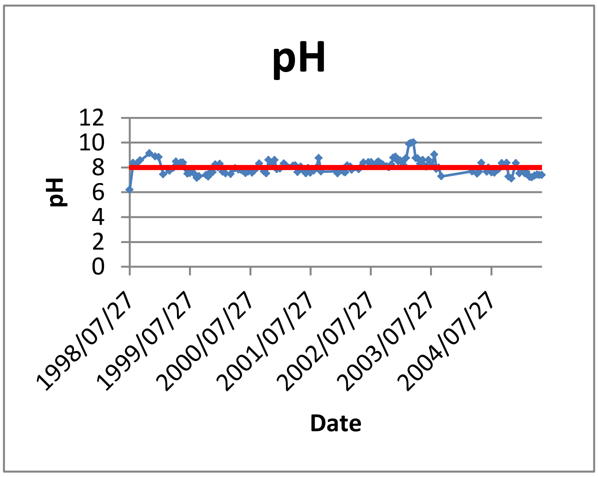
B1R001



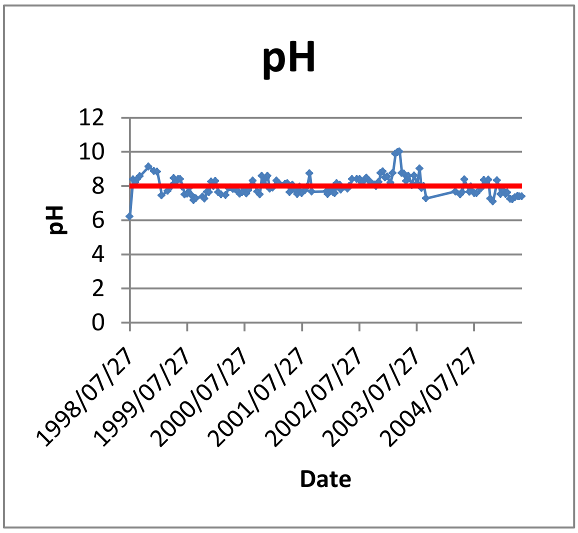
Rietspruit



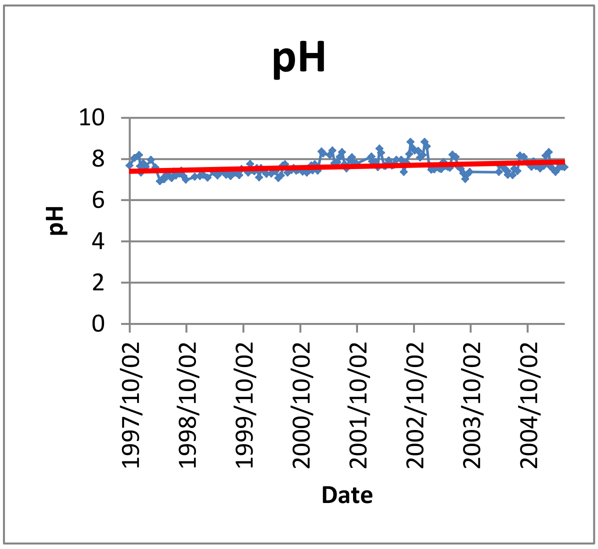
Rietspruit Dam



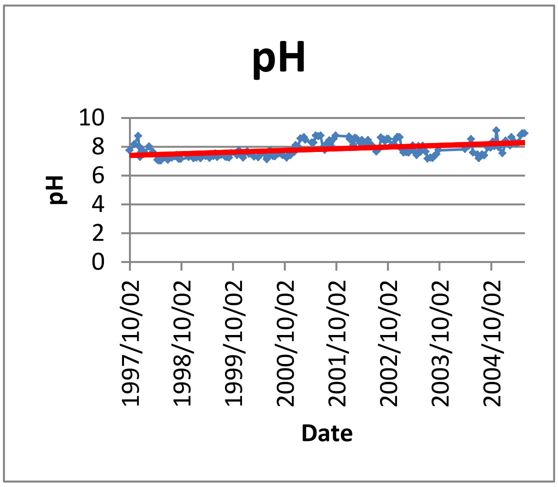
Rietspruit Dam



Bethal Road Bridge

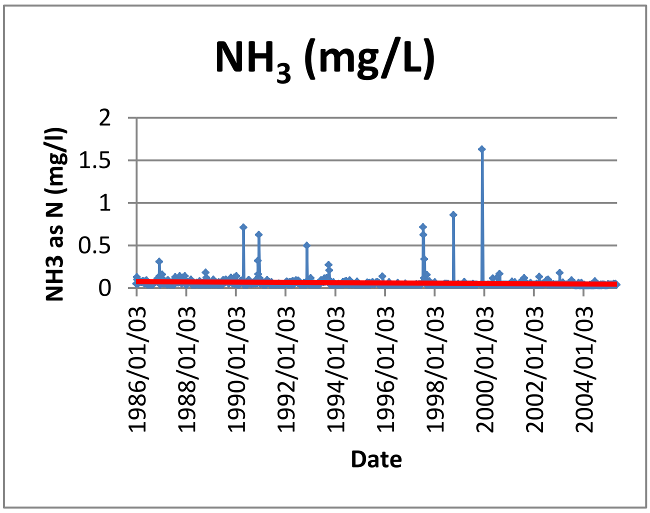


Duvha Road Bridge

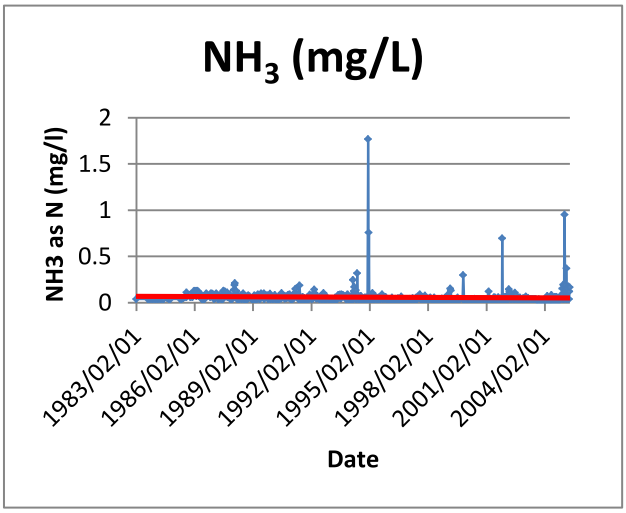


NH_3:Middelburg Dam Catchment

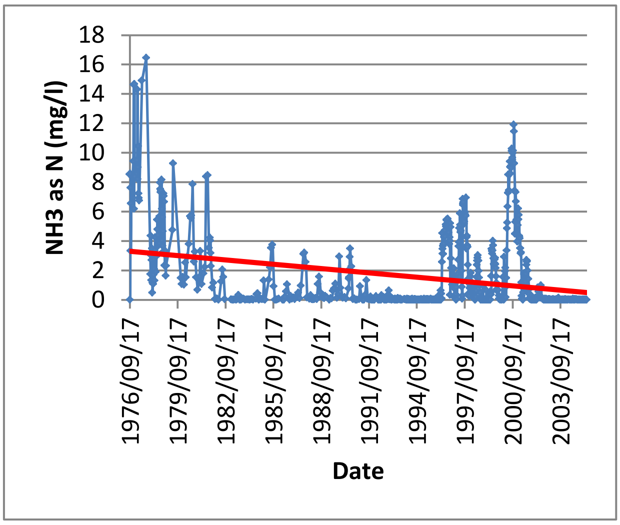
B1H012



B1H015

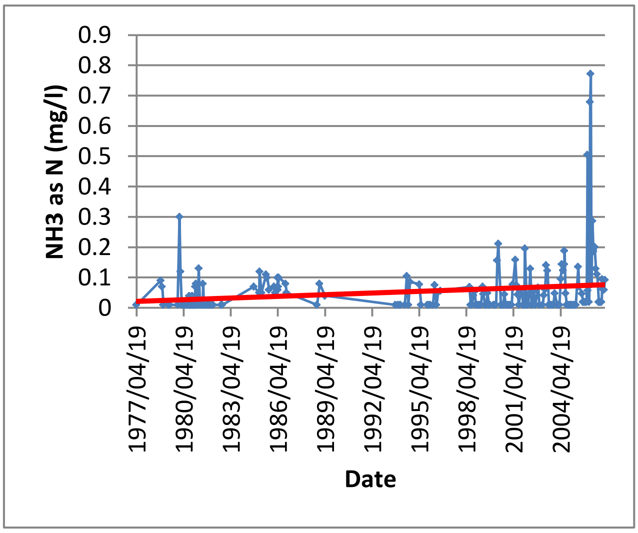


B1H004

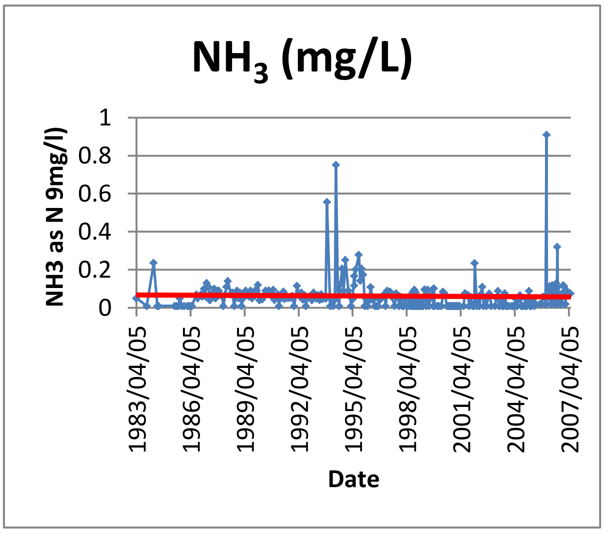


Middle Olifants catchment

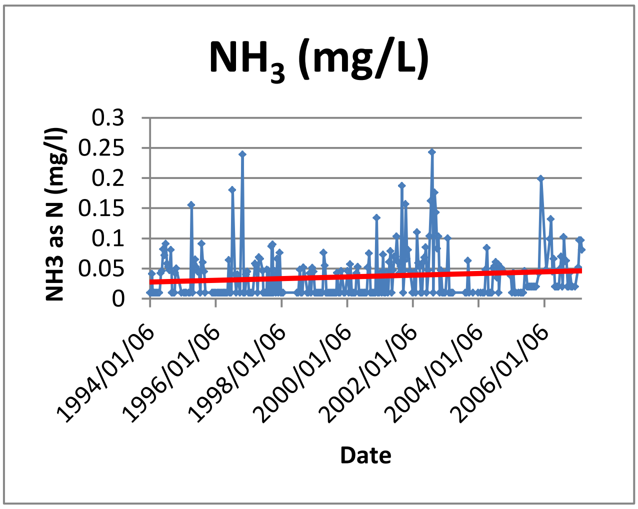
B3R001



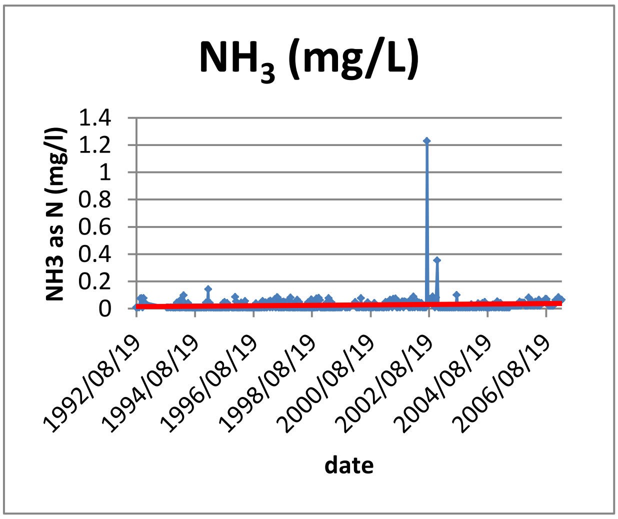
B3R005



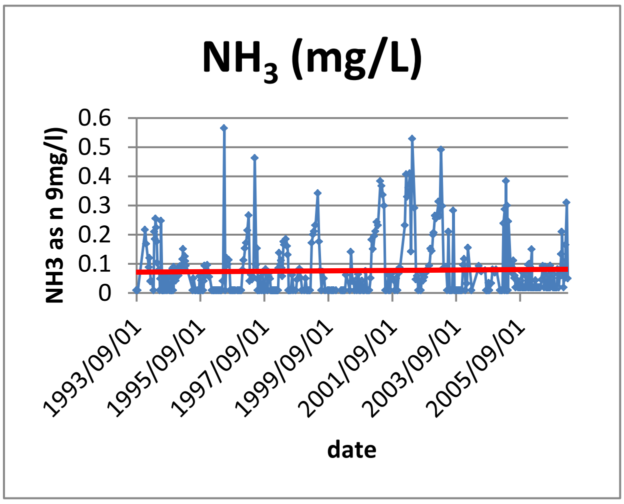
B3H021



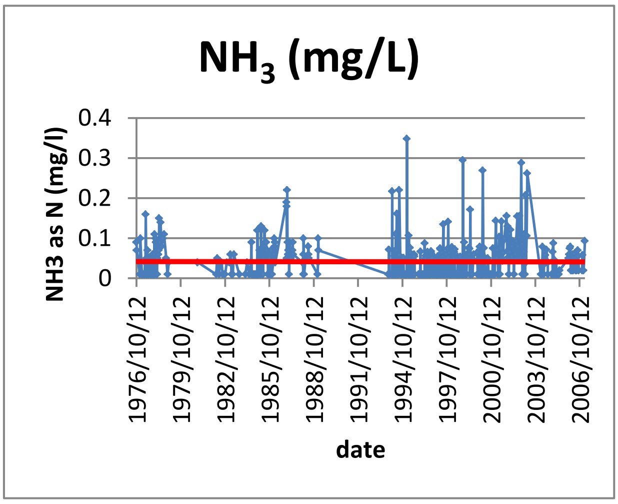
B3H007



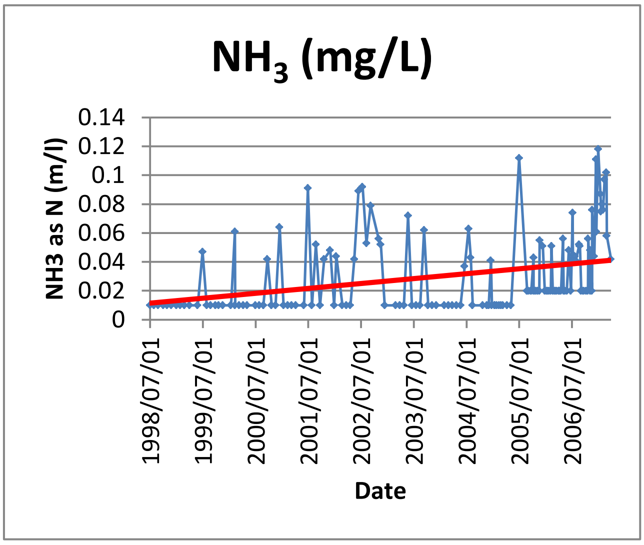
B3H017



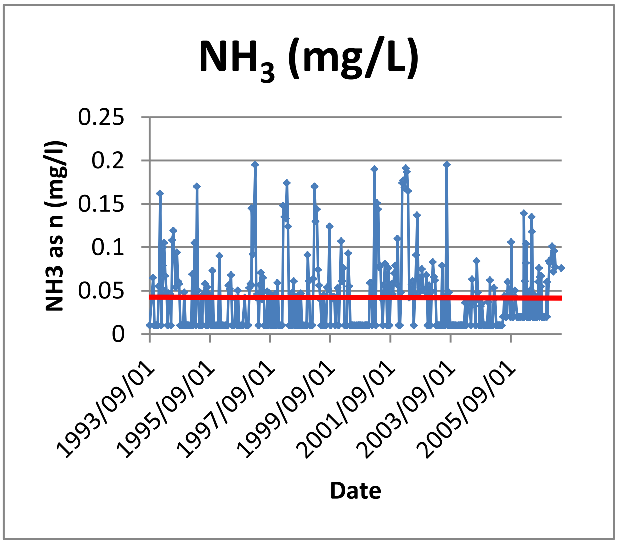
B3H001



B5R002

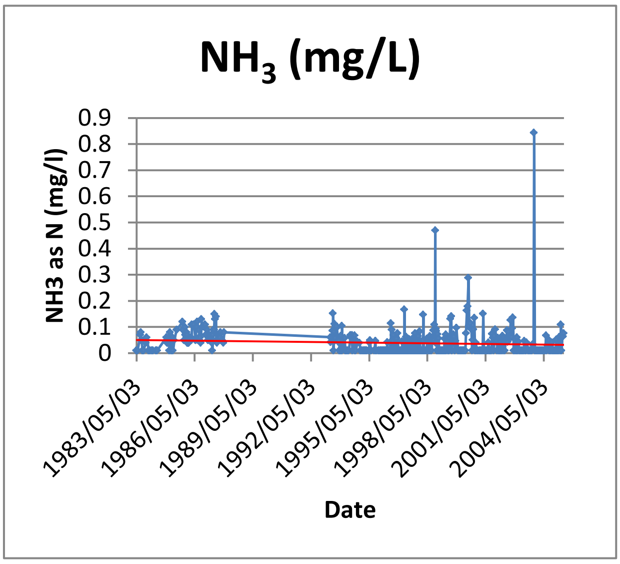


B5H004

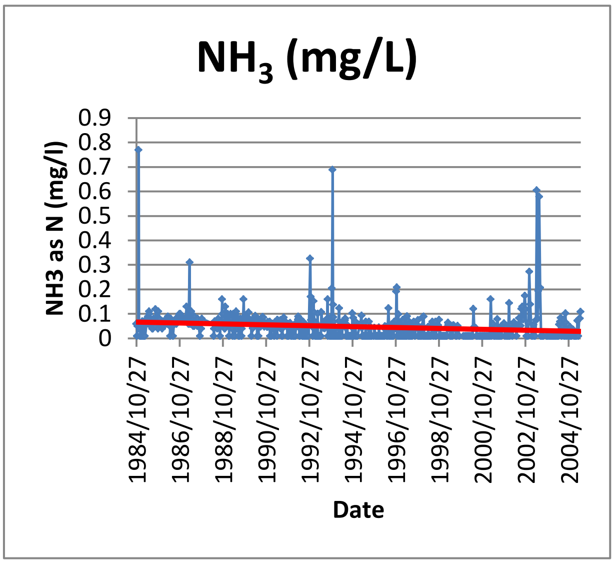


Wilge River and Loskop Dam Catchment

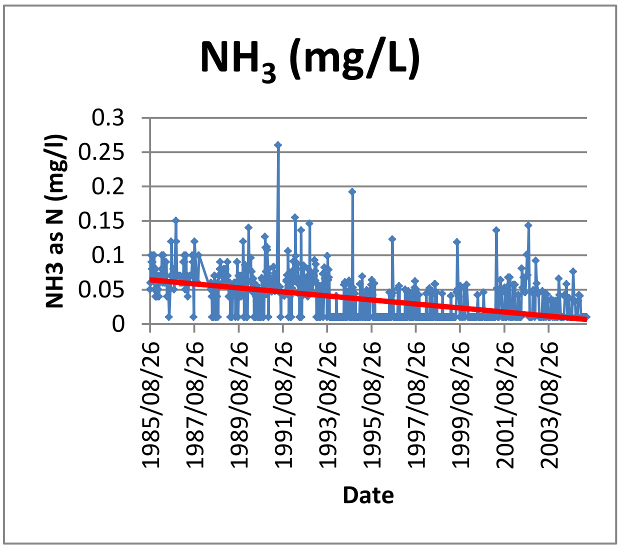
B2H003



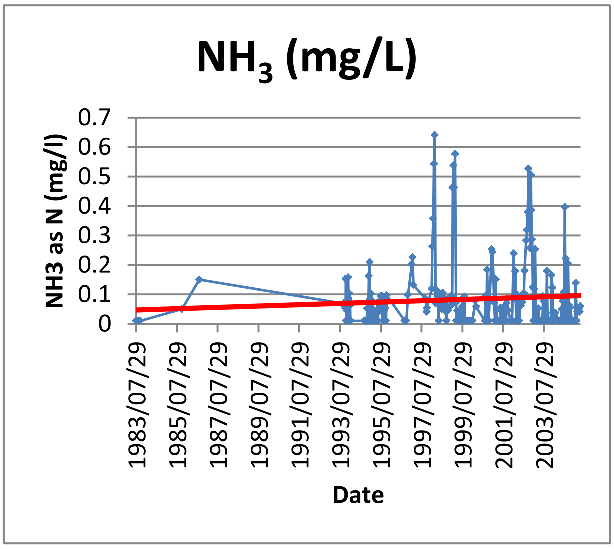
B2H004



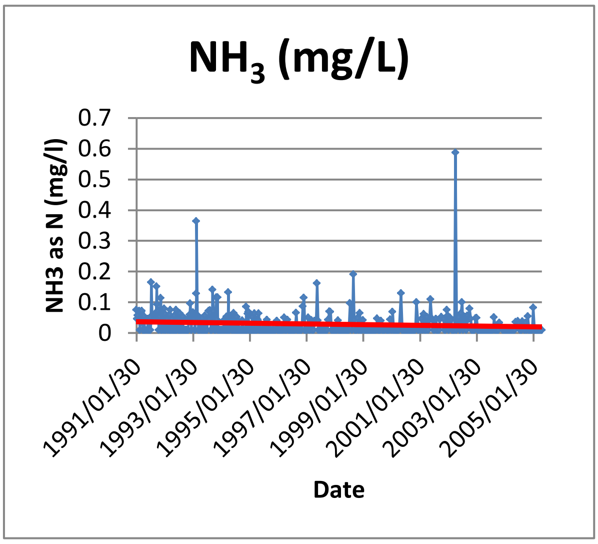
B2H007



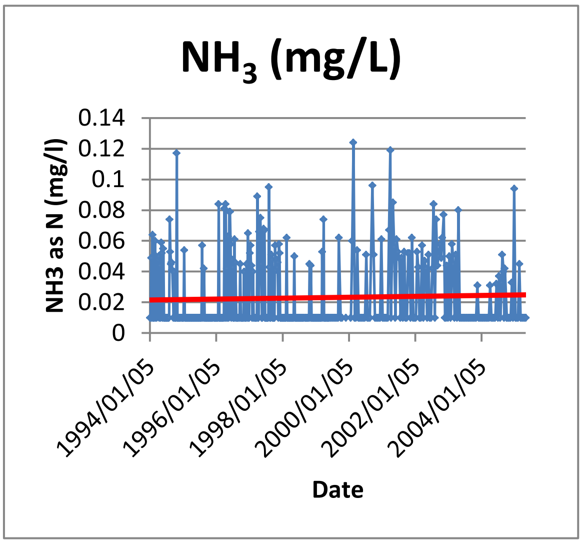
B2H010



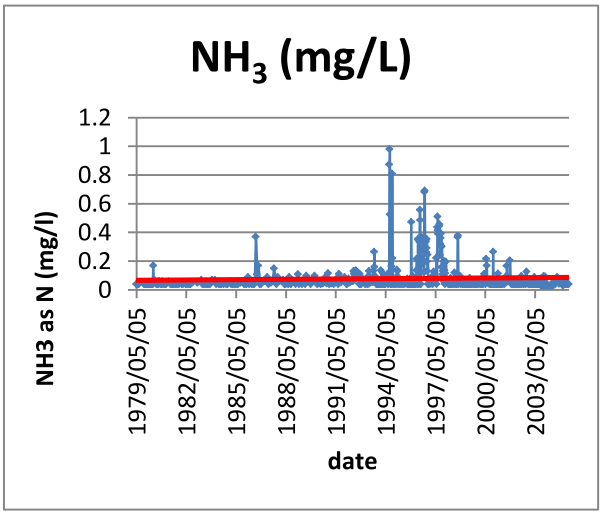
B2H014



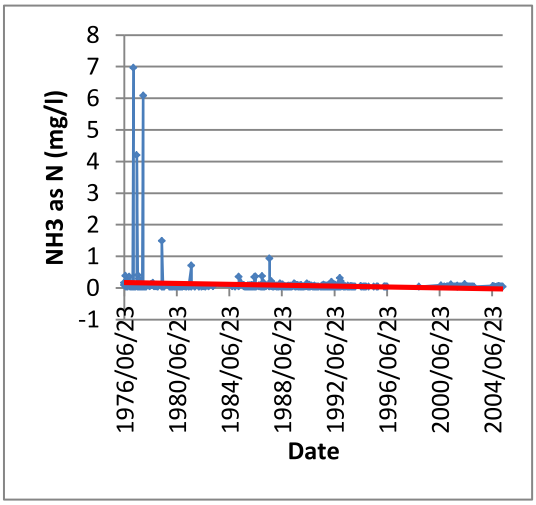
B2H015



B2H002

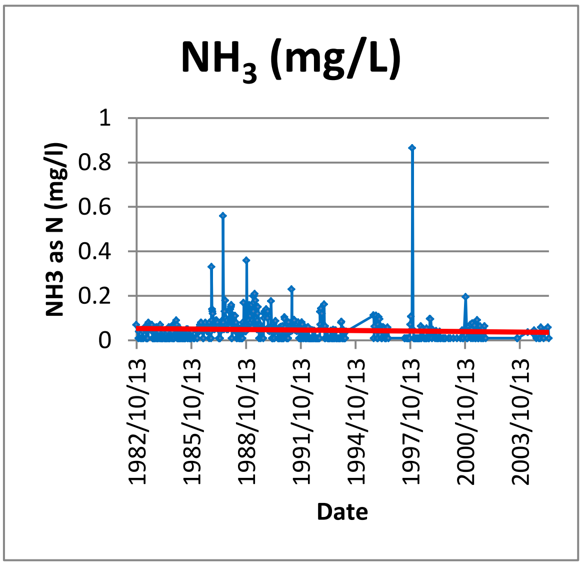


B3R002

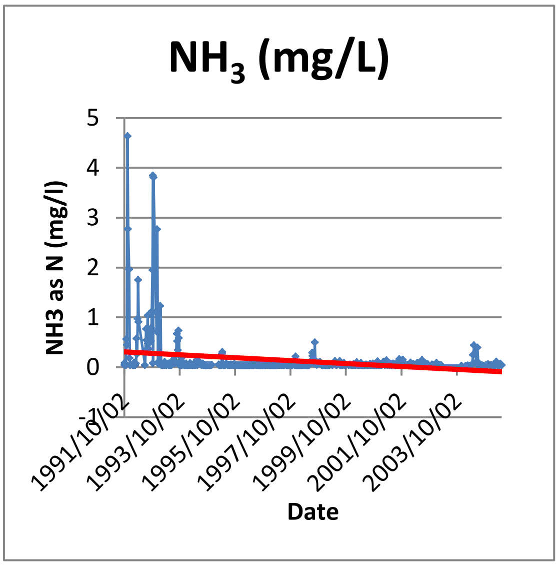


Witbank Dam Catchment

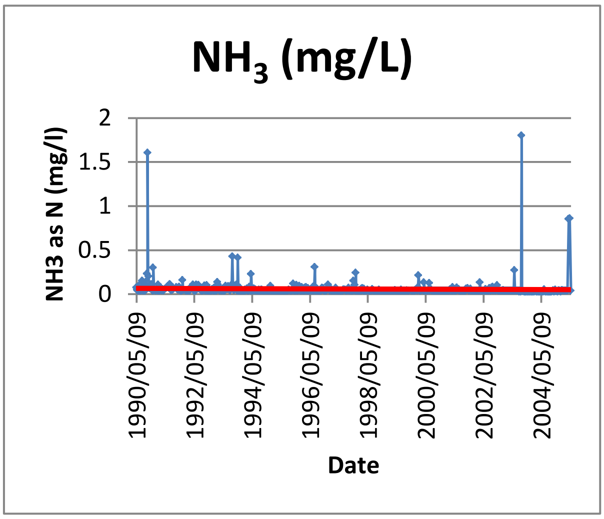
B1H006



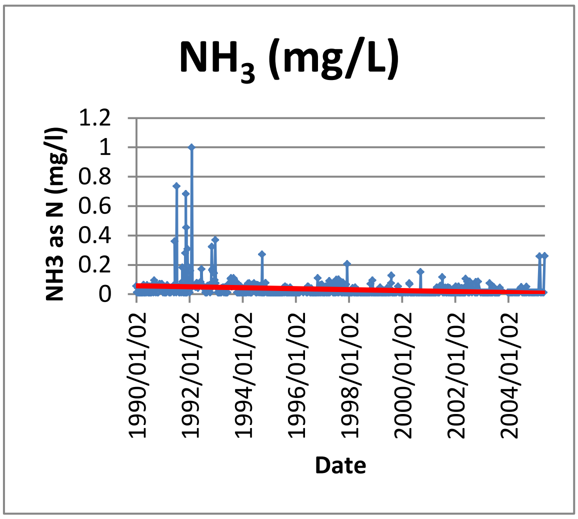
B1H020



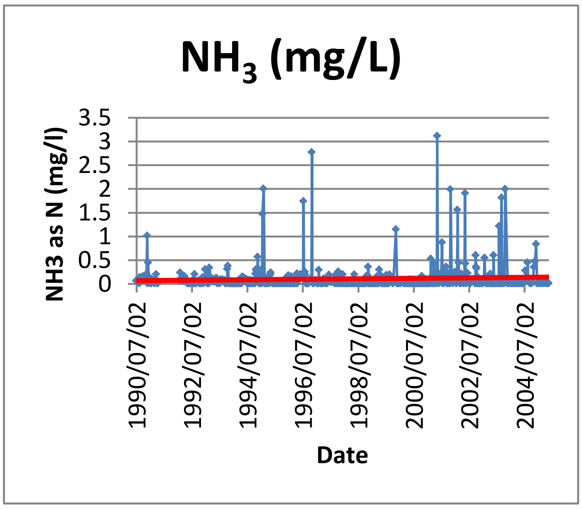
B1H019



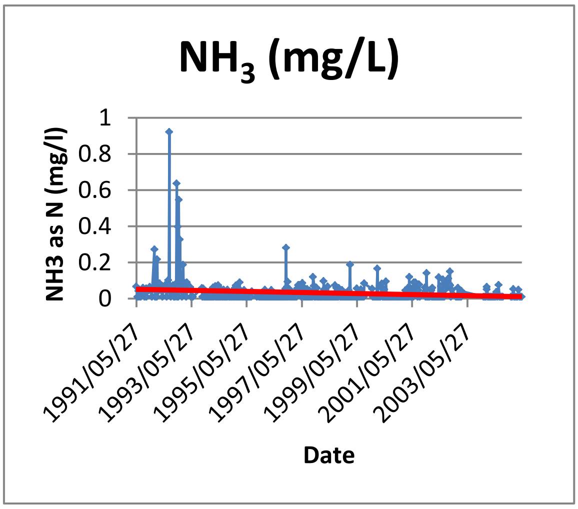
B1H017



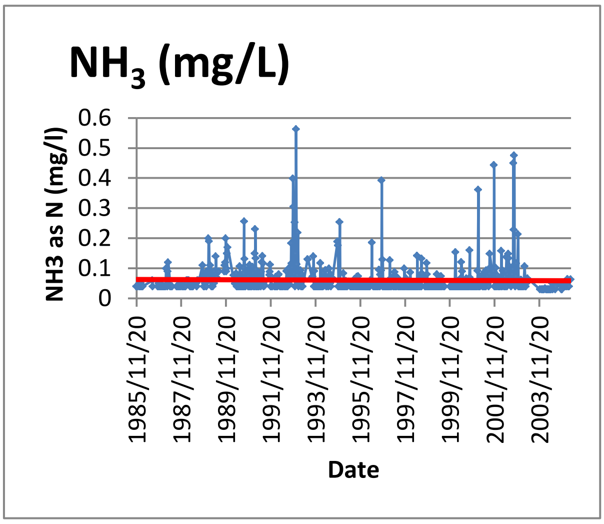
B1H021



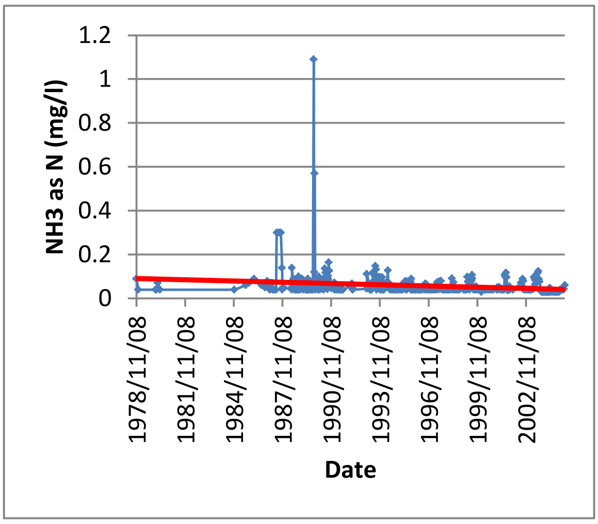
B1H018



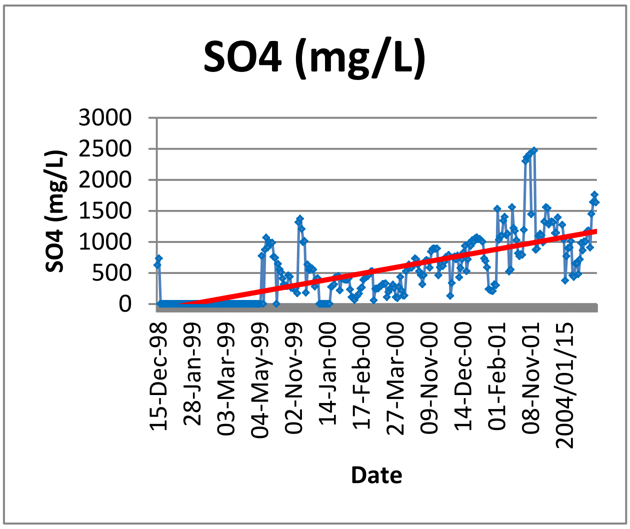
B1H005



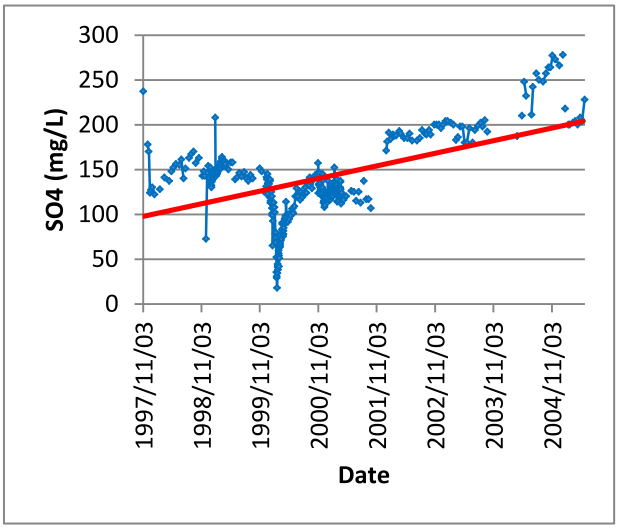
B1R001



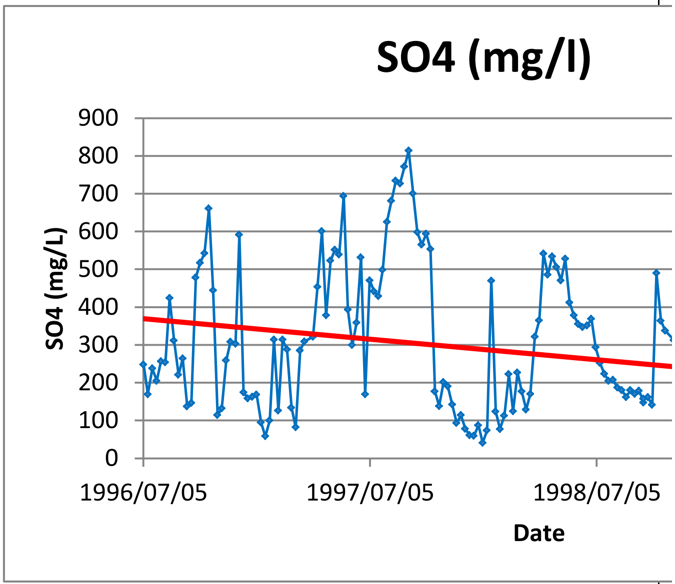
B3H002



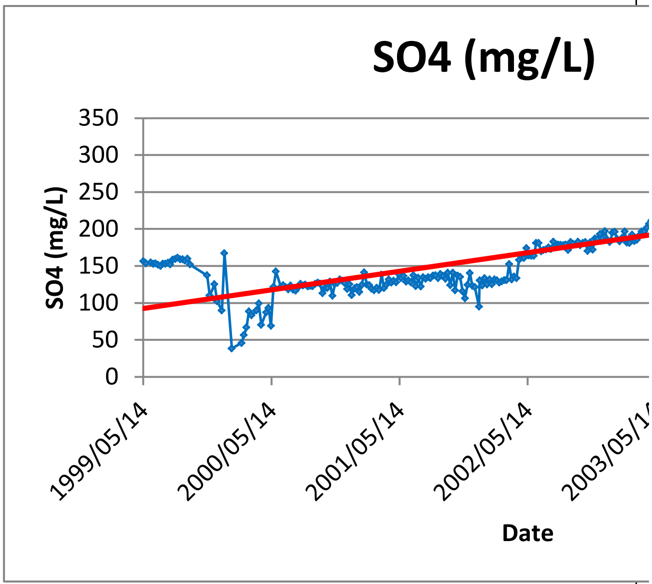
B1R002



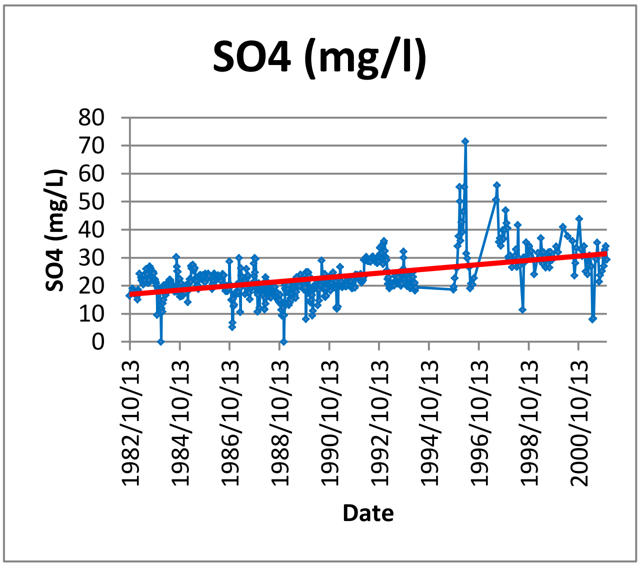
B1H012



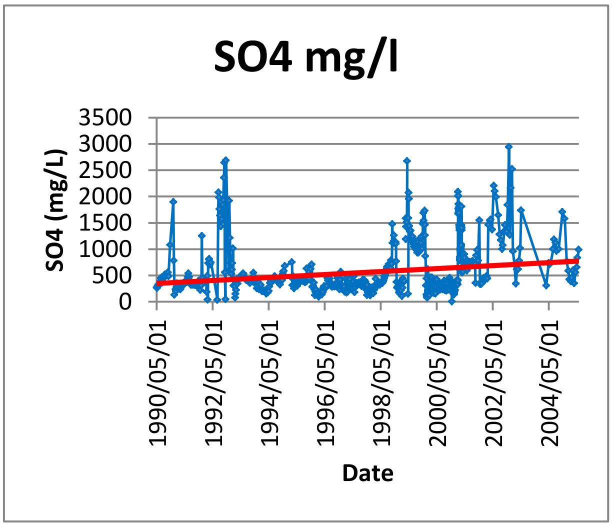
B1H015



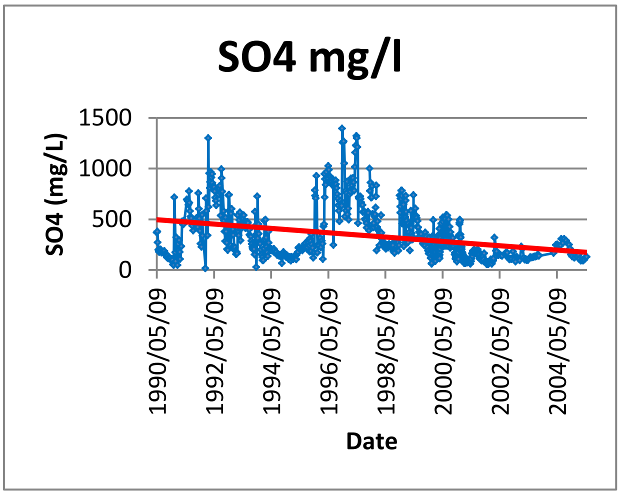
B1H006



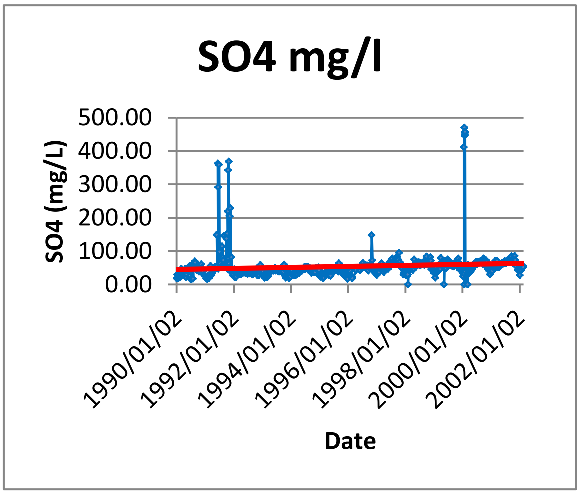
B1H020



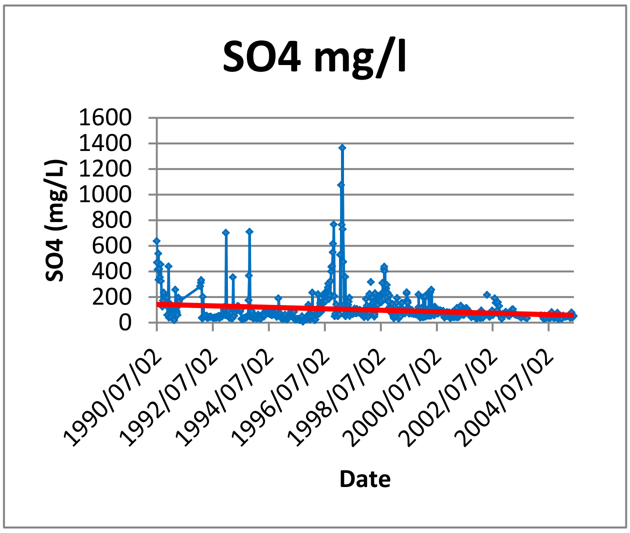
B1H019



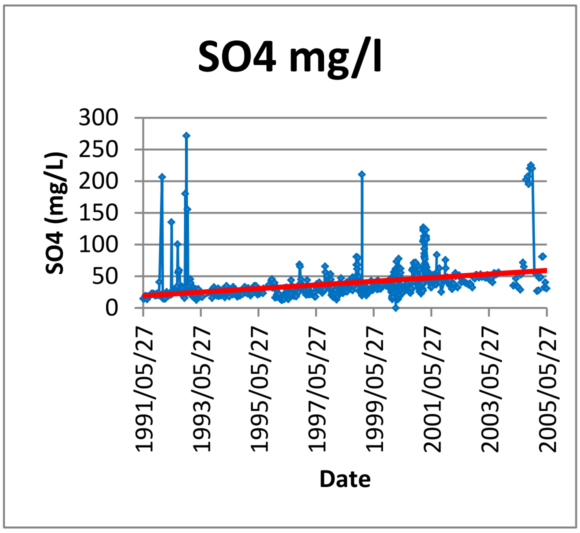
B1H017



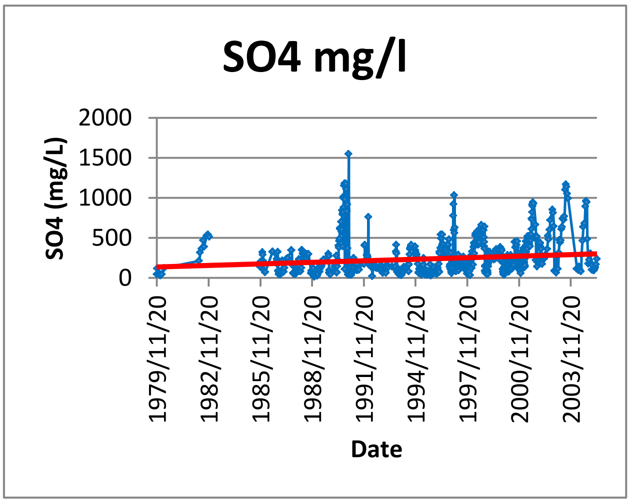
B1H021



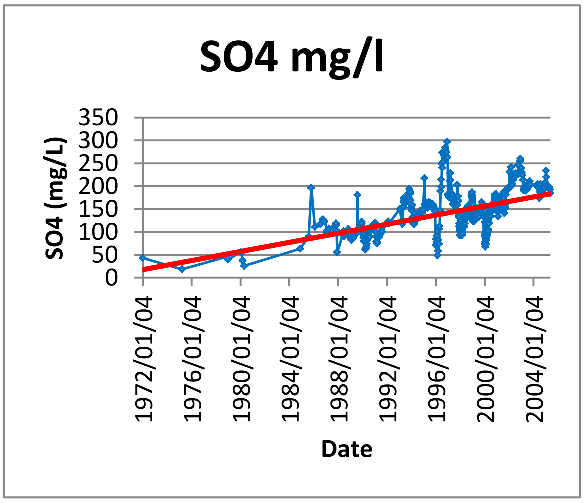
B1H018



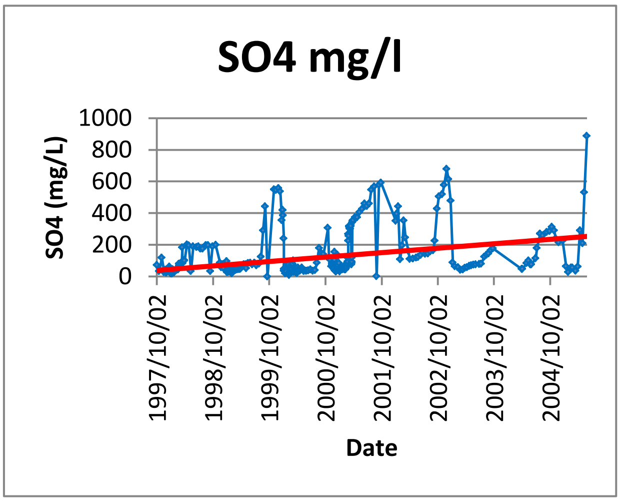
B1H005



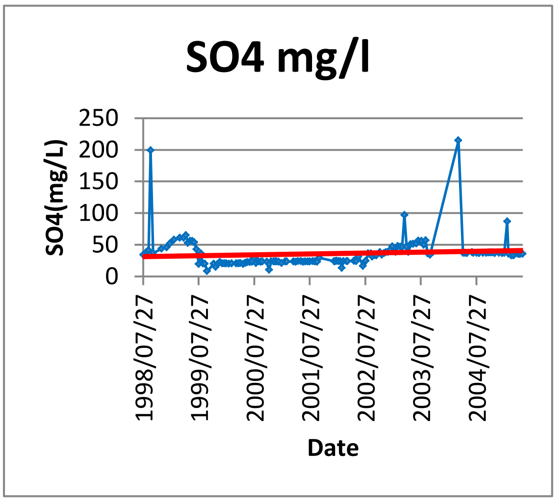
B1R001



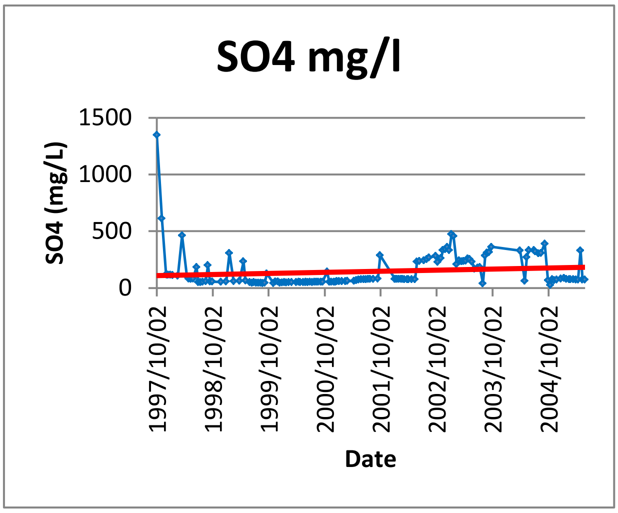
Rietspruit



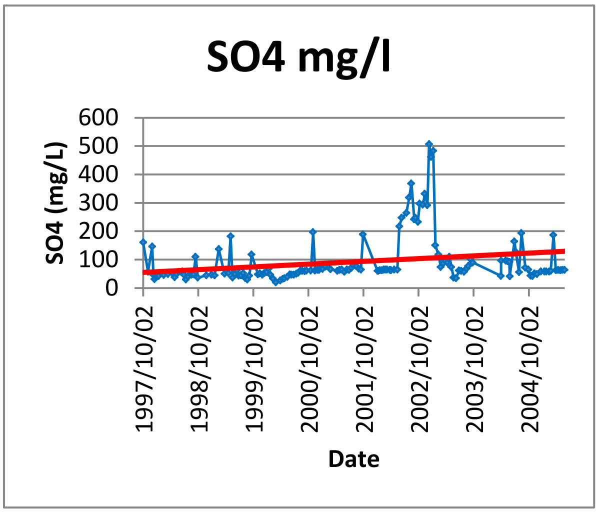
Rietspruit Dam



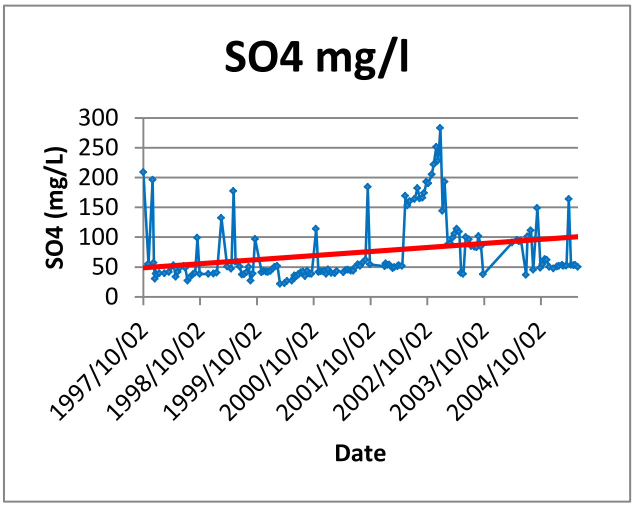
Tweefontein



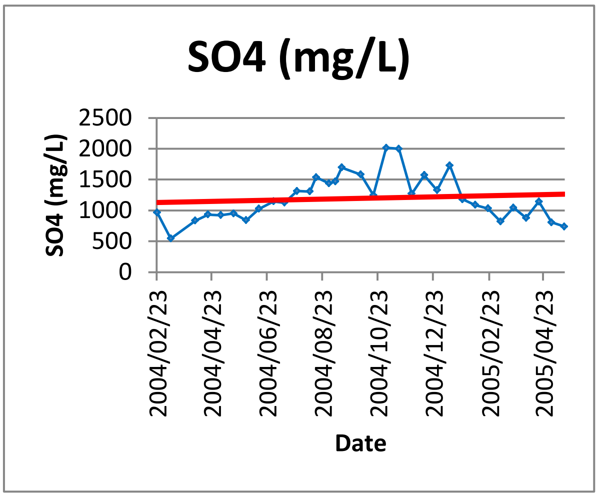
Bethal Road



Duvha Bridge



B1H002



B3R002