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

WP10197

Groundwater Options Report

Original

FINAL REPORT

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Report no.: P WMA 04/B50/00/8310/10

Prepared by:

aurecon

Contact person:
WP Comrie
Aurecon Centre,
Lynnwood Bridge Office Park,
4 Daventry Str, 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

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.... 3-11-2011 ....

W.P. COMRIE (Date)

Water Unit Manager

.... 3-11-2011 ....

J BEUMER (Date)

Study Leader

Approved for the Department of Water Affairs:

.... 17-11-2011 ....

T NDITWANI (Date)

Chief Water Resource Planner: NWRP (North)

.... 21/11/2011 ....

J.A. VAN ROOYEN (Date)

Director NWRP

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.

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

Abstraction
The removal of water from a resource e.g. the pumping of groundwater from an aquifer.

Alluvial Aquifer
An aquifer formed of unconsolidated material deposited by water, typically occurring adjacent to river channels and in buried or paleo channels.

Aquifer
An aquifer is defined as a saturated permeable geological formation or group of formations that is permeable enough to yield economic quantities of water.

Baseflow
Sustained low flow in a river during dry or fair weather conditions, but not necessarily all contributed by groundwater: includes contributions from delayed interflow and groundwater discharge.

Basic Human Needs
The minimum amount of water to satisfy basic water requirements; currently at 25 litres per person per day.

Borehole
Is an artificially drilled hole into an aquifer for the purpose of abstracting groundwater for use, or monitoring of quality and water levels.

Catchment
The area from which any rainfall will drain into the watercourse, contributing to the runoff at a particular point in a river system; synonymous with the term river basin.

Confined Aquifer
An aquifer overlain by a confining layer of significantly lower hydraulic conductivity in which groundwater is under greater pressure than that of the atmosphere.

Drawdown
It is the distance between the static water level and the surface of the cone of depression.

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.

Evapotranspiration
The loss of moisture from the combined effects of direct evaporation from land and sea and transpiration from vegetation.

Fractured Aquifer
An aquifer that owes its water-bearing properties to fracturing caused by folding and faulting.

Groundwater
Water found in the subsurface in the saturated zone below the water table or piezometric surface, i.e. the water table marks the upper surface of groundwater systems.

Groundwater Flow
The movement of water through openings and pore spaces in rocks below the water table, i.e. saturated zone.

Groundwater Resource Unit
A groundwater body that has been delineated or grouped into a single significant water resource on one or more characteristics that are similar across that unit; also referred to as groundwater unit.

Groundwater Table
It is the surface between the zone of saturation and the zone of aeration; the surface of an unconfined aquifer.

Harvest Potential
Maximum amount of groundwater that can be abstracted per square kilometre per annum without depleting the aquifers.

Hydraulic Conductivity
Measure of the ease with which water will pass through earth material: defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d)

Hydraulic Gradient
The slope of the water table or piezometric surface. It is ratio of the change of hydraulic head divided by the distance between the two points of measurement.

Interflow
The rapid flow of water along essentially unsaturated paths, water that infiltrates the subsurface and moves both vertically before discharging into other surface water bodies.

Internal Strategic Perspective (ISP)
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**.**

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.

Permeability
It is related to hydraulic conductivity, but is independent of the fluid density and viscosity and has the dimensions L^2. Hydraulic conductivity is therefore used in all calculations.

Porosity
It is the percentage of the bulk volume of a rock that is occupied by interstices, whether isolated or connected.

Pumping Tests
Are conducted to determine aquifer or borehole characteristics.

Primary Aquifer
An aquifer in which water moves through the original interstices of the geological formation.

Quaternary Catchment
A fourth order catchment in a hierarchal classification system in which a primary catchment is the major unit.

Recharge
Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation.

Reserve
The quantity and quality of water required to supply basic needs of people to be supplied with water from that resource, and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of water resources.

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.

Resource Unit
Areas of similar physical or ecological properties that are grouped or typed to simplify the Reserve determination process.

Secondary Aquifer
An aquifer in which water moves through secondary openings and interstices, which developed after the rocks were formed i.e. weathering, fracturing or faulting equivalent to ‘fractured aquifer’.

Semi-confined Aquifer
An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur also referred to as a leaky aquifer.

Static Water Level
It is the level of water in a borehole that is not being affected by withdrawal of groundwater.

Total Dissolved Solids (TDS)
It is a term that expresses the quantity of dissolved material in a sample of water

Unconfined Aquifer
An aquifer with no confining layer between the water table and the ground surface where the water table is free to fluctuate.

List of Abbreviations & Acronyms

CMA	Catchment Management Agency
CMC	Catchment Management Committee
CME	Compliance Monitoring and Enforcement
DPLG	Department of Provincial and Local Government
DWA	Department of Water Affairs
DWAF	Former Department of Water Affairs and Forestry
EMF	Environmental Management Framework
EMP	Environmental Management Plan
EWR	Ecological Water Requirements (Ecological Component of the Reserve)
GDP	Gross Domestic Product
GIS	Geographical information System
GRDM	Groundwater Resource Directed Measures
GRIP	Groundwater Resource Information Project
IB	Irrigation Board
IDP	Integrated Development Plan
IAP	Invasive Alien Plants
ISP	Internal Strategic Perspective
IWRM	Integrated Water Resources Management
IWRMP	Integrated Water Resources Management Plan
LNW	Lepelle Northern Water Board
MAR	Mean Annual Runoff
MINWAC	Mining & Industry Water Action Committee
NGA	National Groundwater Archive
NRF	National Research Foundation
NWA	National Water Act (Act 36 of 1998)
NWRS	National Water Resource Strategy
OWAAS	Olifants Water Availability Study
RO	Regional Office
RWQO	Resource Water Quality Objectives
SALGA	South African Local Government Association
SDF	Strategic Development Framework
URV	Unit Reference Value
VAC	Visual Absorption Capacity
VAPS	Vaal Augmentation Planning Study
WAAS	Water Availability Assessment Study
WARMS	Water Use Authorisation & Registration Management System
WCDM	Water Conservation /Demand Management
WFGDS	Water for Growth & Development Strategy
WMA	Water Management Area
WMP	Water Management Plan
WMS	Water Management System
WQMP	Water Quality Management Plan
WQT	Water Quality Time Series Model
WSDP	Water Services Development Plan
WUA	Water User Association
WWTW	Waste Water Treatment Works

Measurements

l/uso	litres per unit sent out (electricity)
Mm^3	million cubic metres
mg/l	milligrams per litre
mS/m	milli-Siemens per metre (electrical conductivity)

Table of Contents

List of Tables

List of Figures

Appendices

A – DWA Water quality substances and criteria of concern for drinking purposes.

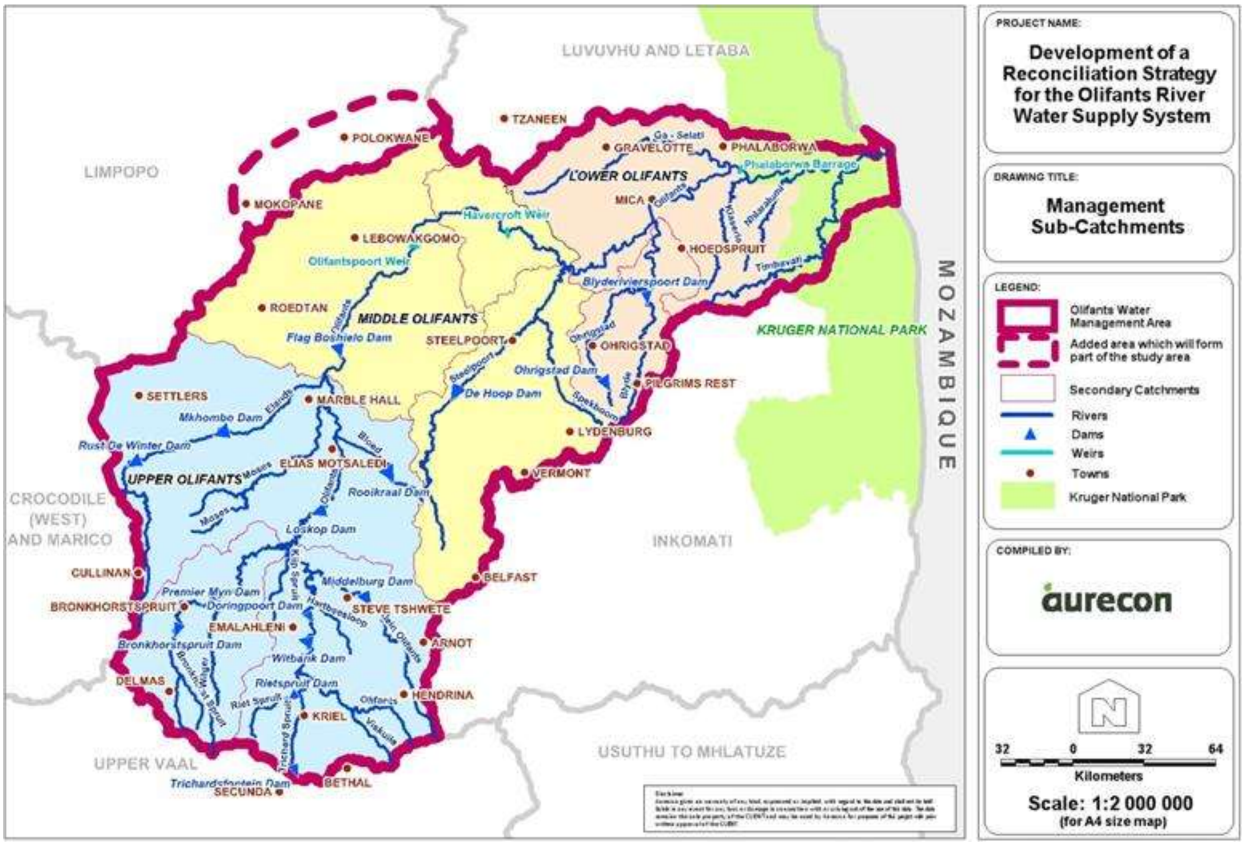
1. INTRODUCTION

The study area consists of the Olifants River Catchment and its immediate supply zone. Hence, the urban areas of Polokwane and Mokopane have been included in the study area. This study area is collectively referred to as "the catchment" in this report.

1.1. BACKGROUND

The Olifants River Catchment is located within the provinces of Gauteng, Mpumalanga and Limpopo and covers an area of approximately 54 550 km^2. The catchment has been divided into three sub-catchments, namely the Upper Olifants, Middle Olifants (incorporates the Steelpoort River), and the Lower Olifants. In the western part of the catchment the topography is characterised by gently sloped hills before the Olifants River cuts through the Drakensberg mountains to enter the relatively featureless Lowveld region. As a consequence of the topography, the climate experienced differs distinctly throughout the catchment, varying from cool in the highveld region of the catchment, through temperate in the central parts to sub-tropical east of the escarpment and lowveld region. The mean annual precipitation falls within the range of 700 mm in the highveld region, reaching 1 000 mm in the mountains and reducing to 500 mm in the lowveld region. The potential evaporation is well in excess of the rainfall.

Figure 1.1: Map indicating the location of the Olifants River Catchment



The Olifants River is fed by a number of tributaries of which the most significant on the left bank are the Wilge, Elands and Ga-Selati Rivers and the Steelpoort, Blyde, Klaserie and Timbavati Rivers on the right bank. The Olifants River flows directly from South Africa into

Moçambique where it joins the Limpopo River. Developments in South Africa directly impact upon the water quality and quantity flowing across the border into Moçambique.

Economic activity in the Olifants catchment is diverse and ranges from mining, power generation, metallurgic industries and irrigation in the Upper sub-catchment, to irrigation, dry land, subsistence agriculture and ecotourism in the middle and lower sub-catchments. Approximately 5% of the Gross Domestic Product (GDP) of South Africa is generated within the Olifants catchment with the largest economic sectors inclusive of mining, manufacturing, power generation, government and agriculture. Coal is the dominant mineral mined in the catchment.

The Upper Olifants sub-catchment is predominately urbanised with the majority of the urban population concentrated in the Emalahleni (formerly Witbank) and Middelburg areas. The land is extensively mined for its rich coal deposits which are exported through Richards Bay and also used locally in the coal-fired power stations. Much of the central and north western areas of the sub-catchment are largely undeveloped, with scattered rural settlements. The predominant land uses in the Middle Olifants sub-catchment include agriculture and extensive irrigation exploits. A number of platinum and chrome mines have also been developed in this area. Agriculture is the predominant land use, although vanadium and chrome mining also occur, along the rural Steelpoort river. The Lower Olifants sub-catchment is rural in character, with the main urban centre being Phalaborwa. Eco-tourism is a prominent industry in the sub-catchment with a number of game parks and the Kruger National Park in the area. The main mining activities in this sub-catchment consist of copper and phosphorus excavations.

1.2. PURPOSE OF THIS REPORT

The Olifants River Catchment is currently one of South Africa's most stressed catchments as far as surface water quantity (due to high demand) and water quality is concerned. Although groundwater is also under stress in certain areas, it is important to evaluate the contribution that undeveloped groundwater resources can make. The objective of this report is to investigate and weigh up various groundwater options, and possible conjunctive utilisation with surface water, taking into account the yields, water quality, costs (infrastructure and operating), groundwater surface water interaction, Reserve requirements, and environmental impacts.

2. METHODOLOGY

All the available reports were studied and form the base of this report. The report Volume 4 of 12 of the Assessment of Water Availability in The Olifants WMA, titled “Groundwater and Groundwater Quality Analysis” of SATAC (2008) contains much information on groundwater and is used for this strategy. Other baseline reports are the “Groundwater Reserve Determination for the Olifants Catchment” by SRK (2009), the “Olifants Water Management Area Internal Strategic Perspective” Appendix A on groundwater by BKS, GMKS, Thlou and Matji (DWAF (ISP), 2004) and the “Mpumalanga Groundwater Master Plan” by DWA (2008). The most recent geohydrological information on the various aquifers and their possible future sources of supply from previous reports are summarised. Sustainable volumes of available groundwater, and existing and potential schemes utilising the available groundwater, are identified in the Summary Report. The required evaluation and calculations for feasible existing and potential schemes are based on the available information.

Both over- and under-exploitation of groundwater resources are investigated. Management and control measures for over-exploitation must be considered for implementation. In areas of over-exploitation the determined preliminary Reserve of the Olifants WMA need to be protected. The potential of under-exploited resources to augment water supplies in areas of over exploitation by transfer schemes are considered.

Groundwater resources with unacceptable drinking water quality such as high natural fluorides or high nitrates may be usable as such for irrigation or can be used conjunctively with surface water to reduce the parameter levels to acceptable levels. The mining sector plays an important role in the Olifants River Catchment and both dewatering and decanting water sources are evaluated. Mines should be encouraged to use groundwater as supply to mining operations, thus intercepting mine water inflow, the need to dewater, and acid mine drainage. Treated decant water can be reused by mines or utilized by Eskom and when treated to potable quality, by the municipalities. The treatment or recycling of groundwater contaminated by coal discards or ash dumps must be considered.

Possible increases in the groundwater resource as a result of mining activities (e.g. higher recharge potential) are briefly evaluated. Mines should be encouraged to use this water rather than drawing on surface water sources and then getting flooded and pumping dirty water back into the system.

The conjunctive use with surface water can reduce the salinity and reduce the cost of treatment for selected uses. The groundwater options will vary for the different sub-catchments and the most favourable option for each sub-catchment are described in the report. Cost estimates for the implementation of options need to be done and take account parameters such as yield, storage, water quality.

3. GENERAL GEOLOGY

The Olifants catchment WMA covers a total area of 54 550 km^2. The catchment has been sub-divided into 3 sub-areas as follows:

- The Upper Olifants, covering an area of 12 250 km^2, and incorporating quaternary catchments B11A – K, B21A – E, B20A – J, and B32A
- The Middle Olifants, covering an area of 22 550 km^2, and incorporating quaternary catchments B31A – J, B32A – J, B41A – K, B42A – H, B51A – J, B71A – F
- The Lower Olifants, covering an area of 12 600 km^2, incorporating quaternary catchments B60A – J, B72A – K, B73A – J.

The subdivision of the WMA is shown in **Figure 1.1.** The general geology is discussed according to the occurrence of lithological units in the Olifants WMA. The distribution of the lithologies across the quaternary catchments is shown in **Figure 3.1** (DWAF ISP, 2004).

3.1. KAROO SUPERGROUP

The Karoo Supergroup consists of the following lithological units:

- Basalt
- Intercalated arenaceous and argillaceous strata
- Tillite

The basalt is the youngest lithology and covers the older formations in the Springbok Flats and Kruger National Park. The arenaceous and argillaceous strata are present in the Witbank, Kriel, Hendrina, near Marble Hall and Springbok Flats area. The tillite is the oldest formation and is only present north-west of Witbank.

3.2. PRINCIPALLY ARENACEOUS STRATA

The Waterberg Group's arenaceous strata consist mainly of sandstone and quartzite which occurs in the Bronkhorstspruit and Middelburg areas.

Arenaceous strata belonging to the Pretoria Series form a broad hemisphere from south of Lydenburg to north of Lebowakgomo. The strata consist mainly of sandstone and shale inter-bedded.

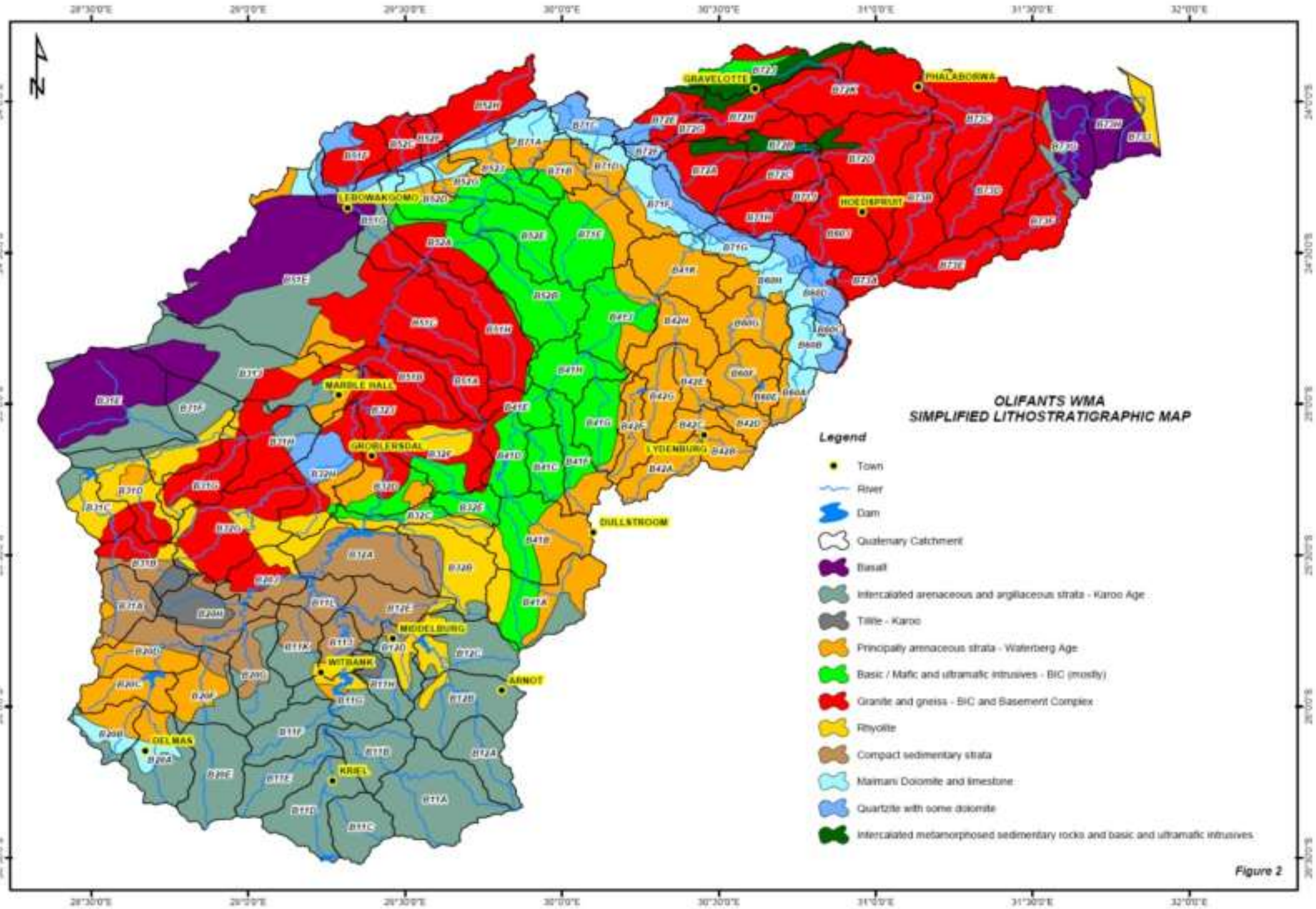


Figure 3.1: Distribution of the lithological units in the WMA

3.3. BUSHVELD IGNEOUS COMPLEX (BIC)

The basic/mafic and ultramafic intrusives mostly belongs to the BIC. Norite and Gabbro underlie 5 800 km^2 of the Sub-area and outcrop over wide arch sub-paralleling the eastern escarpment. Structural features are evident in the landscape of deep valleys and rugged mountains.

3.4. GRANITE AND GNEISS

Nebo granite and gneiss belonging to the BIC is widespread in the Middle WMA covering an area of 6 630 km^2. The Nebo granite is characterised by shallow weathering and extensive areas of sub-outcrop. Fracturing is extensive and numerous regional and sub-regional structures traverse the granite.

Basement granite underlies most of the Lower Olifants WMA. The granite from the Basement Complex covers an area of 9 200 km^2.

3.5. RHYOLITE

The rhyolite and felsite lavas are part of the Transvaal Super group and these lavas are particularly fine grained and marginally porous. They form outcrops totalling 2 675 km^2 around the granite as shown on **Figure 3.1**. Weathering is reported to be extremely limited and usually felsite and rhyolite sub-outcrop.

3.6. COMPACT SEDIMENTARY STRATA

Compact sedimentary strata consisting of sandstone and quartzite belonging to the Waterberg Group and covering an area of 3 275 km^2, stretching from east of Pretoria to north and east of Witbank.

3.7. MALMANI DOLOMITE AND LIMESTONE

Dolomite lithology is present in all the Olifants WMA sub-areas.

In the Upper Olifants an eastern extension of the extensive hemispherical dolomite outcrop stretching from the North West Province and through Gauteng occurs in the Bapsfontein-Delmas area. The dolomite strikes NW – SE and dips to the NE at 15°. The dolomite is dark grey to grey, massive and characterised by the occurrence of chert rich and chert poor horizons. The dolomites are intruded by mainly NW – SE striking dolerite dykes.

In the Middle Olifants dolomite forming part of the Chuniespoort Group occur west of Groblersdal and Marble Hall. Malmani Dolomite occurs along the escarpment and forms a wide arc as shown on Map 2. The Malmani dolomite along the escarpment extends into the Lower Olifants.

3.8. BASIC AND ULTRAMAFIC INTRUSIVES

These include the greenstones, intercalated metamorphosed sedimentary rocks and basic and ultramafic intrusives occurring in the area around Gravelotte as shown on **Figure 3.1.**

4. GEOHYDROLOGY

The availability of groundwater resources for abstraction is controlled by the aquifer characteristics of permeability and storage. The aquifers in the Olifants River Catchment are divided into three main types namely, inter-granular and fractured, fractured and karst or only fractured (GMKS, Tlou and Matji and Wates, Meiring and Barnard, 2004). The highest yields are available in the fractured karst (dolomite) aquifer yielding 0.1 – 50 ℓ/s. Favourable resources are also available in the deep weathered Karoo basalt and valley areas underlain by norite and gabbro of the Bushveld Igneous Complex yielding up to 5 ℓ/s. Low yields can be expected in the Karoo siltstone, shale and mudstones, the Nebo granite, as well as the Waterberg sandstone and quartzite yielding in the order of 0.5 ℓ/s. The aquifers associated with the various formations are shown in **Figure 3.1** and a summary of the hydrogeological characteristics of the various formations is shown in **Table 4.1.**

4.1. KAROO AGE SILTSTONE AND SANDSTONE

The aquifers in these formations are inter-granular and fractured. Although groundwater occurrence are wide spread the yields are generally low and below 5 ℓ/s. Boreholes selected scientifically on contact zones with the dolerite sills and dykes or fault zones are more successful and yields between 0.5 and 2.0 ℓ/s are present. Generally the boreholes are between 30 and 60m deep and the water level between 5 and 20 m below ground level.

4.2. DELMAS DOLOMITE

The dolomites are intruded by numerous dykes striking SW-NE with subordinate NW-SE and N_S trends. As in other dolomite areas the dykes are assumed to compartmentalise the dolomite. However, because of weathering to a depth of 30 m the compartmentalising effect is not evident in the areas where the water level is shallower than 30 m below ground level. Borehole yields of more than 50 ℓ/s are reported with the general yield in the order of 25 ℓ/s. borehole depths vary from 100 to 250 m with an average of 150 m depth. The water levels recorded during census vary from about 4 m to 70 m below ground level.

Table 4.1: Summary of Typical hydrogeological Characteristics (Source: Olifants River Internal Strategic Perspective)

Lithology	Area within Catchment (km^2)	Average Borehole Yield (ℓ/s)	Average Range of Depth of Water Level (mbgl)	Typical Borehole Depth (m)	Aquifer Type	Groundwater Quality DWA Class
Karoo age siltstone and sandstone	7 250	,0.5 0.5 – 2 along dyke contacts	5-20	30-60	Inter-granular and fractured	0-1 Occasionally 2
Delmas dolomite	210	0.1 - > 50	3-68	100-250	Fractured and karst	0 Pockets of NO_3 due to agriculture
Pretoria Group quartzite and shale (Bronkhorstspruit area)	1 230	< 0.5 – 2	20-30	40-100	Inter-granular and fractured (shale) Fractured (Quartzite)	0
Waterberg Sandstone and Quartzite	3 275	< 0.5 Occasionally > 3	<10 - > 40	40-120	Fractured	0
Nebo granite	6 630	< 0.5 Up to 2 in fracturing	10-20	40-100	Inter-granular and fractured	0-1 Isolated NO_3 in settlements Isolated F
Rhyolite and felsite	2 675	< 0.1 Occasionally < 0.5	10-50	70-150	Fractured	0
Basalt (Springbok flats) and KNP	2 730	2 – 5 Sometimes > 10	10-50	50- > 150	Inter-granular and fractured	NO_3 problem in Springbok Flats
Clarens SST	2 830	1-2	10-20	30-70	Inter-granular and fractured	0
Mudstone and shale (Irrigation) Sandstone (Ecca)Norite and gabbro		>0.5	10-20	802-120	Inter-granular and fractured	2 or 3
Norite and gabbro	5 800	0.5 – 2 Occasionally > 5	10-20	30-80	Inter-granular and fractured	0 or 1 Isolated NO_3 in settlements
Pretoria Group quartzite and shale Escarpment areas	6 200	0.5 – 2 Occasionally up to 5	<10 - > 40	40-150	Fractured	0
Dolomite	1 615	< 1 - > 5 Potentially > 20	0 - >50	30-250	Fractured and karst	Pristine in many areas
Black reef quartzite	2 120	0.5 – 2 > 5 in dolomite	10-30	50-100	Fractured	0 Pristine in many areas
Granite (Lowveld)	9 200	0.5 – 2	5-15	30-80	Inter-granular and fractured	1 Isolated NO_3 in settlements

4.3. PRETORIA GROUP QUARTZITE AND SHALE

The Pretoria Group formations present around Bronkhorstspruit are classified as inter-granular and fractured aquifers on the 1:500 000 Hydrogeological Map 2526, and are mainly associated with structural features in the bedrock. Groundwater occurrences are generally present but limited with yields between 0.1 and 2.0 ℓ/s. The higher yields are normally obtained from boreholes scientifically sited. Drilling varies between 40 and 100 m depth and water levels between 20 and 30 m below ground level.

4.4. WATERBERG SANDSTONE AND QUARTZITE

The Waterberg formations are present east of Pretoria to north and east of Witbank. Groundwater occurs mainly in the fractured rock mass. Yields in boreholes are generally limited and below 0.5 ℓ/s. However, scientifically sited boreholes on fault and fracture zones can yield higher than 3 ℓ/s. Water levels and drilling depth vary with the topographically location of the boreholes. Depths vary between 40 and 120 m while water levels vary between 10 to more than 40 m below ground level.

4.5. NEBO GRANITE

The Nebo granite and gneiss occur widespread in the central part of the Olifants River Basin. Groundwater occurrence are mainly associated with the weathered zone and fractured rock and structural features. Although groundwater is generally present in the weathered formation the yields is below 0.5 ℓ/s. However, scientifically sited boreholes on structural features can yield 2 ℓ/s and more. The water levels vary between 10 and 20 m below ground level while boreholes are 40 to 100 m deep.

4.6. RHYOLITE AND FELSITE

The rhyolite and felsite formation occur around the edge of the Nebo granite and Bushveld Igneous Complex as shown on Map 2. Groundwater is totally limited and generally yields less than 0.5 ℓ/s. Borehole depths vary between 70 and 150 m while the water levels vary between 10 to 50 m below ground level.

4.7. KAROO BASALT

The basalt formation covers a large part of the Springbok Flats and the Kruger National Park in the Lower Olifants. Groundwater occurs in the weathered and well developed fractured rock. It is known that the contact zone between the basalt and the underlying sandstone is well fractured and a good aquifer. The average yield is 2 to 5 ℓ/s but yields of 10 ℓ/s and more are common. Water levels range between 10 and 20 m below ground level. Depending on the depth of weathering the depth of drilling vary between 50 and more than 150 m.

4.8. KAROO SANDSTONE, MUDSTONE AND SHALE

Rocks of the Clarens, Irrigasie and Ecca Formations of the Karoo Supergroup occur immediately south of the basalt formation in the Springbok Flats. The Clarens Sandstone is fractured and weathered to greater than 50 m and yields of between 1 and 2 ℓ/s can be expected from boreholes 30 to 70 m deep. Mudstone belonging to the

Irrigasie and shale, sandstone and shale belonging to the Ecca Formation underlies the Clarens sandstone. Groundwater in the weathered and fractured rock is poorly developed and yields is normally less than 0.5 ℓ/s. Boreholes are 80 to 120 m deep and water levels 20 to 30 m below ground level.

4.9. NORITE AND GABBRO

The norite and gabbro belonging to the Bushveld Igneous Complex is present over a wide arch sub-paralleling the eastern escarpment. Groundwater occurs in the weathered and fractured rock and borehole yields of between 0.5 and 2 ℓ/s are common. Scientifically sited boreholes along dyke contact zones and other structural features can yield more than 5 ℓ/s. It is known that north-south deep weathering occurs in the norite and gabbro north of Pretoria, giving higher yields. Boreholes average between 30 and 80 m deep and water levels between 10 and 20 m below ground level.

4.10. PRETORIA GROUP QUARTZITE AND SHALE

The Pretoria Group strata occurs from south of Lydenburg to north of Lebowakgomo and the aquifers is located in the fractured sandstone and on the sandstone shale contacts. Generally borehole yields are between 0.5 and 2 ℓ/s but can be up to 5 ℓ/s south of Lydenburg, Dullstroom and east of Orighstad.

Water levels depend on topography and vary between less than 10 m and more than 40 m below ground level. Boreholes can be 150 m deep but generally are between 40 and 70 m deep. Many perennial rivers have their source in the area around Machadodorp-Dullstroom-Bambi Motel. This area must at all costs be protected as any development will impact on the river flows, like the Elands, Sabie, Maritie, Blyde and Treur Rivers.

4.11. MALMANI DOLOMITE ALONG THE ESCARPMENT

The Malmani Dolomite outcrops east of the Pretoria Group along the escarpment. As expected in dolomite terrain the groundwater occurs in the karst zones and zones of fracturing and solutional weathering. The dolomite form extensive areas of rugged terrain and are mostly undeveloped. As known in dolomite the yields can be significant and more than 5 ℓ/s. As result of the topography the water levels vary from seepage to more than 50 below ground level. There is a great potential for development of this resource. The source of the Ngodwana River, a tributary of the Elands, with its confluence just below the SAPPI Pulp and Paper Mill and its primary source of water, is a dolomitic spring. The catchment of this spring should be determined and protected.

4.12. BLACK REEF QUARTZITE

The Black Reef Quartzite underlies the Malmani Dolomite and is a fractured aquifer with the potential to yield between 0.5 to 2 ℓ/s or more. To the north and north-west of Lebowakgomo yields of 0.1 to 0.5 ℓ/s are reported from boreholes 50 to 100 m deep and water levels between 10 and 30 m below ground level.

4.13. GRANITE

The Lower Olifants is mostly underlain by granite rock. Aquifer in the granite is weathered and fractured and is present on the contact zones with intrusions. Boreholes yields are generally between 0.5 and 2 ℓ/s with yields of 5 ℓ/s and more occur in aquifers around Phalaborwa, Gravelotte and east of Hoedspruit. Boreholes vary between 30 and 80 m deep and water levels between 5 and 15 m below ground level.

5. GROUNDWATER QUALITY

Groundwater quality is generally good in the Olifants WMA but one of the activities that impact on the quality is the coal mining in the Upper Olifants Catchment as discussed by Hodgson and Krantz (1998). Groundwater quality is also impacted by nitrate from agriculture and sanitary systems and DWAF (ISP) (2004) mention the impacts in the different aquifers. The aquifers impacted by nitrate are shown in **Table 4.1.** Fluoride is a natural occurring element whose presence above the allowable drinking water limit makes the water unacceptable for human usage.

SATAC (2008) did an assessment of the groundwater quality in the Olifants River Catchment. All the available borehole data was obtained from the Department of Water Affairs National Groundwater Data Base (NGA) and shown in **Figure 5.1.** As stated in the report there were data of 6 966 data points in the NGA of which only 4 058 boreholes were used in the chemical data base as shown in **Figure 5.2.** The data base contained little data in the Delmas, Witbank and Middelburg areas. The data were historical and recent data archived in the data base. The absence of chemical data in the Witbank Middelburg area is confirmed by groundwater quality data used by SRK (2009) in their report. The data available is limited and mostly historical and it is recommended that a the a data acquisition strategy like the Groundwater Resource Information Project (GRIP) that were done in the Limpopo and Eastern Cape be conducted in the Gauteng and Mpumalanga Provinces in order to supply reliable present data on quality and quantity.

DWA's classification of water quality and criteria of concern for drinking water purposes were applied to the data in order to establish the status of water quality as shown in **Table 5.1**. The classification is based on the content range of main inorganic substances and total coliforms in the water as shown in **Appendix A.**

Table 5.1: DWA classification of water quality and criteria of concern for drinking water

Water quality class	Description	Drinking health effects
Class 0	Ideal water quality	No effects, suitable for many generations.
Class 1	Good water quality	Suitable for lifetime use. Rare instances of sub-clinical effects.
Class 2	Marginal water quality, water suitable for short-term use only	May be used without health effects by majority of users, but may cause effects in some sensitive groups. Some effects possible after lifetime use.
Class 3	Poor water quality	Poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available.
Class 4	Unacceptable water quality	Severe acute health effects, even with short-term use.

Each borehole was subjected to the classification and if one or more parameters fell into Class 4 the quality was Class 4. The remaining boreholes were then sorted into Class 3, Class 2, Class 1 and the rest falling into Class 0. The data distribution is shown in **Figure 5.3**. The biggest contributors to poor quality groundwater are Nitrate, Fluoride, EC, Sodium, Magnesium and Sulphate. The data showed that only 28% of the boreholes sampled have long term drinking water quality. Short term drinking water quality totalled 28% of the boreholes, while unacceptable drinking quality water is present in 44% of the boreholes. It was concluded that the data base is biased as the majority of boreholes are derived from investigations in problem polluted areas such as the Springbok Flats, with the minority of samples collected in the general catchment area. It could be assumed that the areas (except the Witbank area) not sampled represent acceptable groundwater quality.

5.1. ELECTRICAL CONDUCTIVITY

The classification and distribution of EC values in the Olifants Catchment is shown in Map 5.4. The SATAC (2008) study showed that about 21,5 % of all the samples fall into Class 2, 3 and 4 while 78.5 % is class 1 and 0. The Class 2 to 4 boreholes are mainly located in the Springbok Flats in quaternary catchments B51 and B52 as well as a large number in catchment B73. Herholdt (2008) confirmed that high TDS values were recorded for surface water in the Selati catchment. The high EC values are mainly due to pollution from irrigation areas, sanitation at villages and to a minor extend mining activities.

5.2. NITRATE

The nitrate concentration distribution in groundwater is shown in **Figure 5.5.** The high nitrate values in Springbok Flats located in sub-catchments B31 and B51 has been the subject of a number of previous studies Verhoef (1973), Grobler (1976) and Tredoux (1993). Tredoux's distribution correlates perfectly with that shown in **Figure 5.5**. He noted that the distribution further correlates with the distribution of Jurassic basalt rocks of the Letaba Formation which forms part of the Karoo Sequence in the area. The black turf top soil of the area is the area with the higher nitrate values as noted by Verhoef (1973). The transformation from pasture to arable land is also considered a big cause for the increased nitrate pollution of the groundwater. It is concluded that the elevated nitrate concentrations in boreholes is due to anthropogenic activities such as feedlots, kraals, pit latrines, fertilisers or other sources.

The scattered high nitrate values over the other areas and specifically sub-catchments B51, B52, B71 and B41 is also due to anthropogenic activities as mentioned above. Numerous villages are located throughout these areas and it is known that a high percentage of village boreholes are polluted by nitrate mainly as result of pit latrines or uncontrolled feedstock drinking around hand pumps or leaking water reticulation pipes.

5.3. FLUORIDE

The fluoride concentration distribution in groundwater is shown in **Figure 5.6**. Fluoride is a natural occurring element and is the residual fractions of the late or final stages of magmatic evolution and is therefore associated with the Lebowa granite Suite. The occurrence of fluoride or fluorspar minerals is discussed in the Mineral Resources of the Republic of South Africa (Geological Survey, 1976). Boreholes in the granite display values up to 14 mg/ℓ according to Barnard (2000). High values up to 8 mg/ℓ are also reported in the Letaba Formation in deeper boreholes on the margins of the formation. High fluoride values are also indicated in the Lower Olifants Catchment scattered over the area. According to Bond (1945) high fluoride values are known to occur sporadic and inconsistent in the granite rocks of the area.

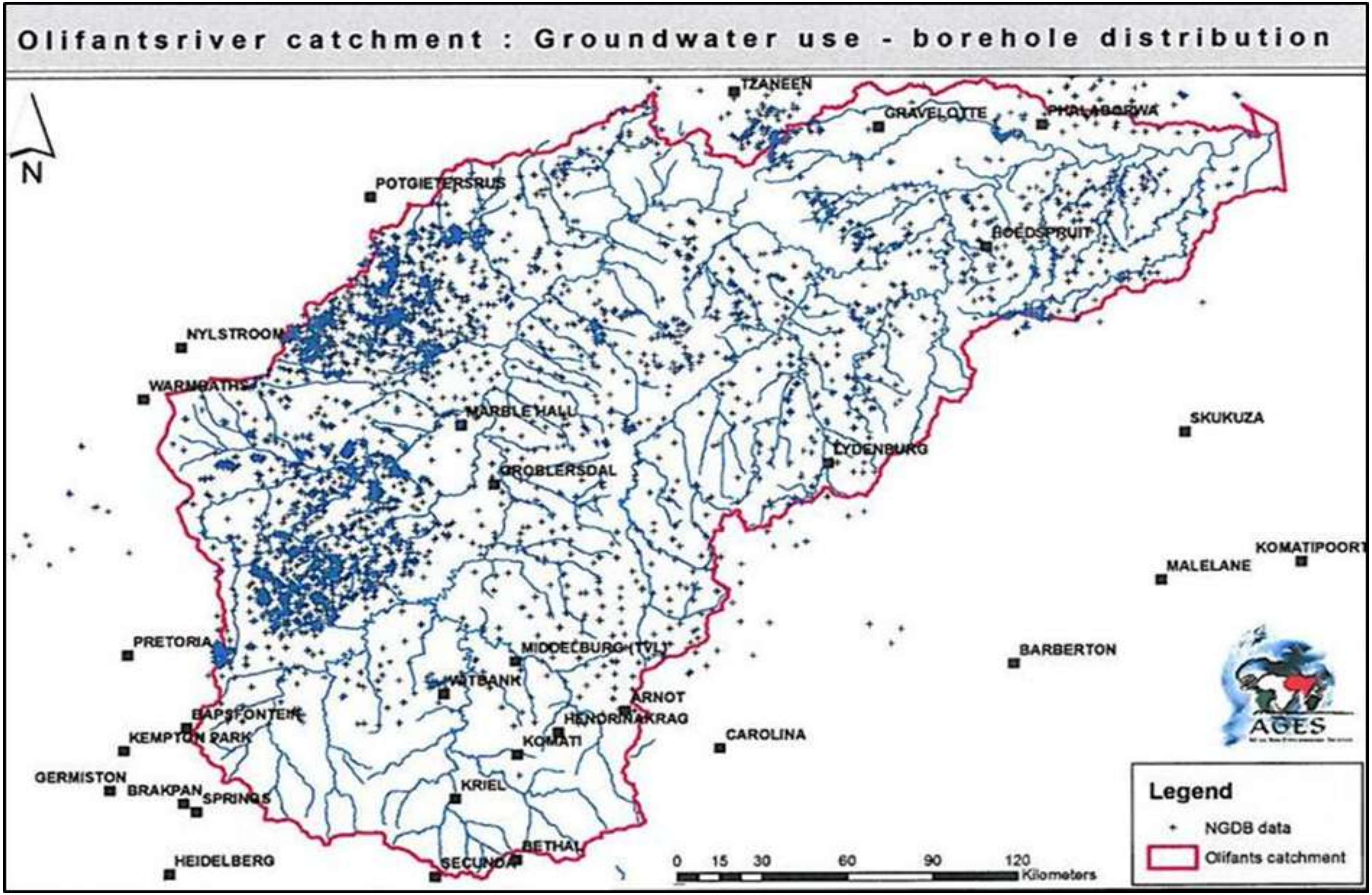


Figure 5.1: Distribution of all boreholes throughout the WMA (Source: AGES 2009)

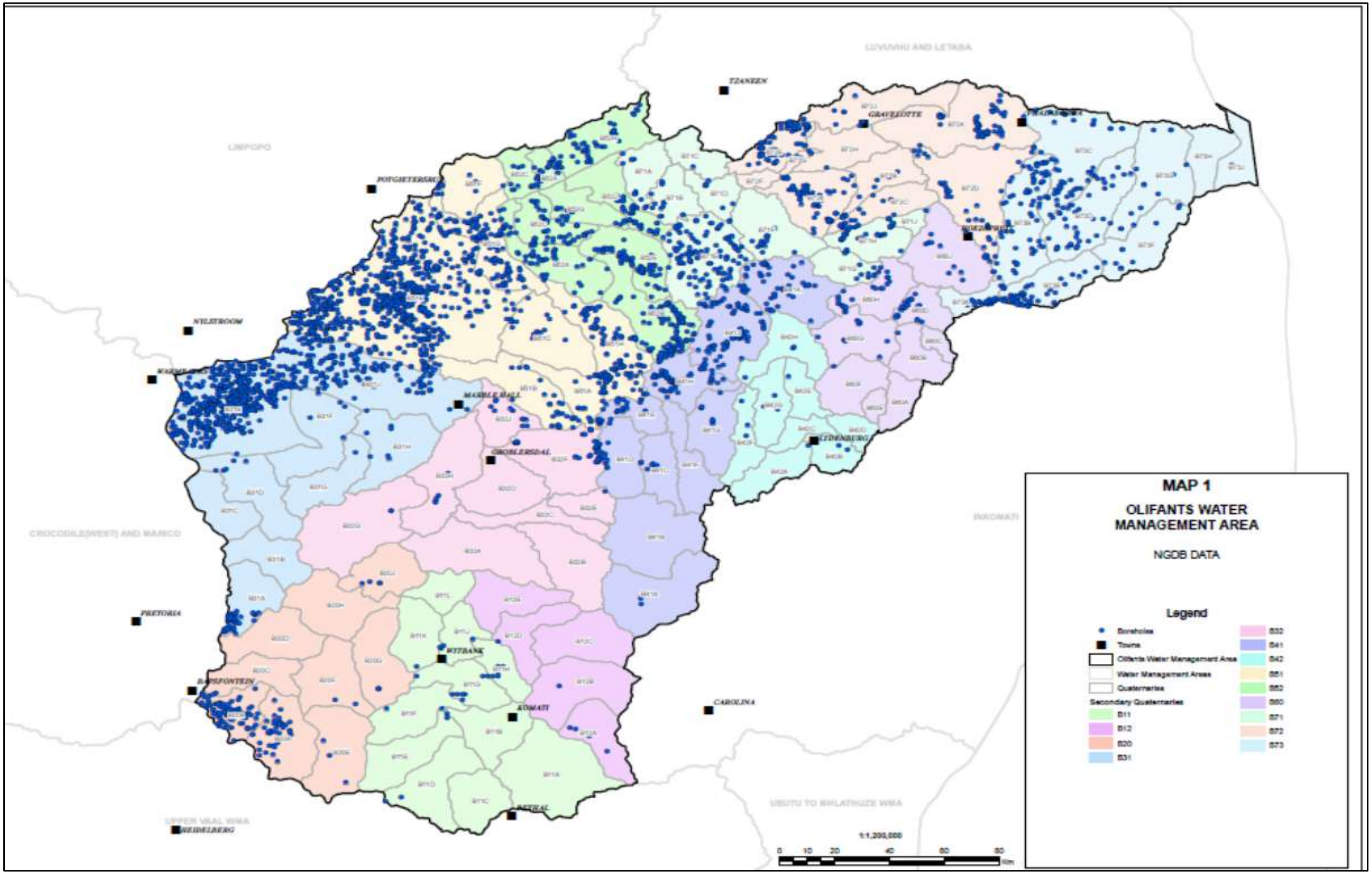


Figure 5.2: Distribution of boreholes with chemical data throughout the WMA

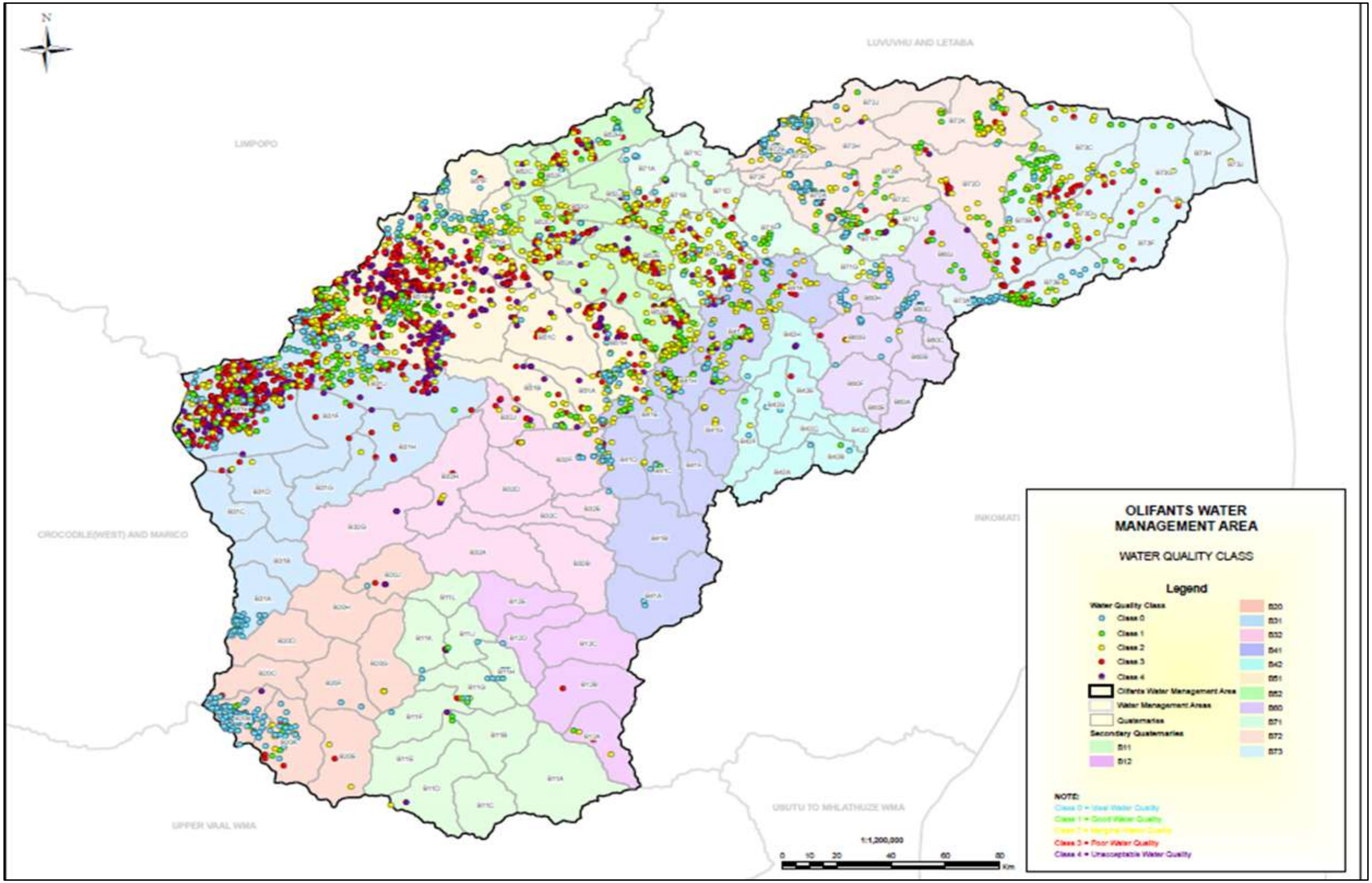


Figure 5.3: Distribution of Water Class in the WMA (SATAC, 2008)

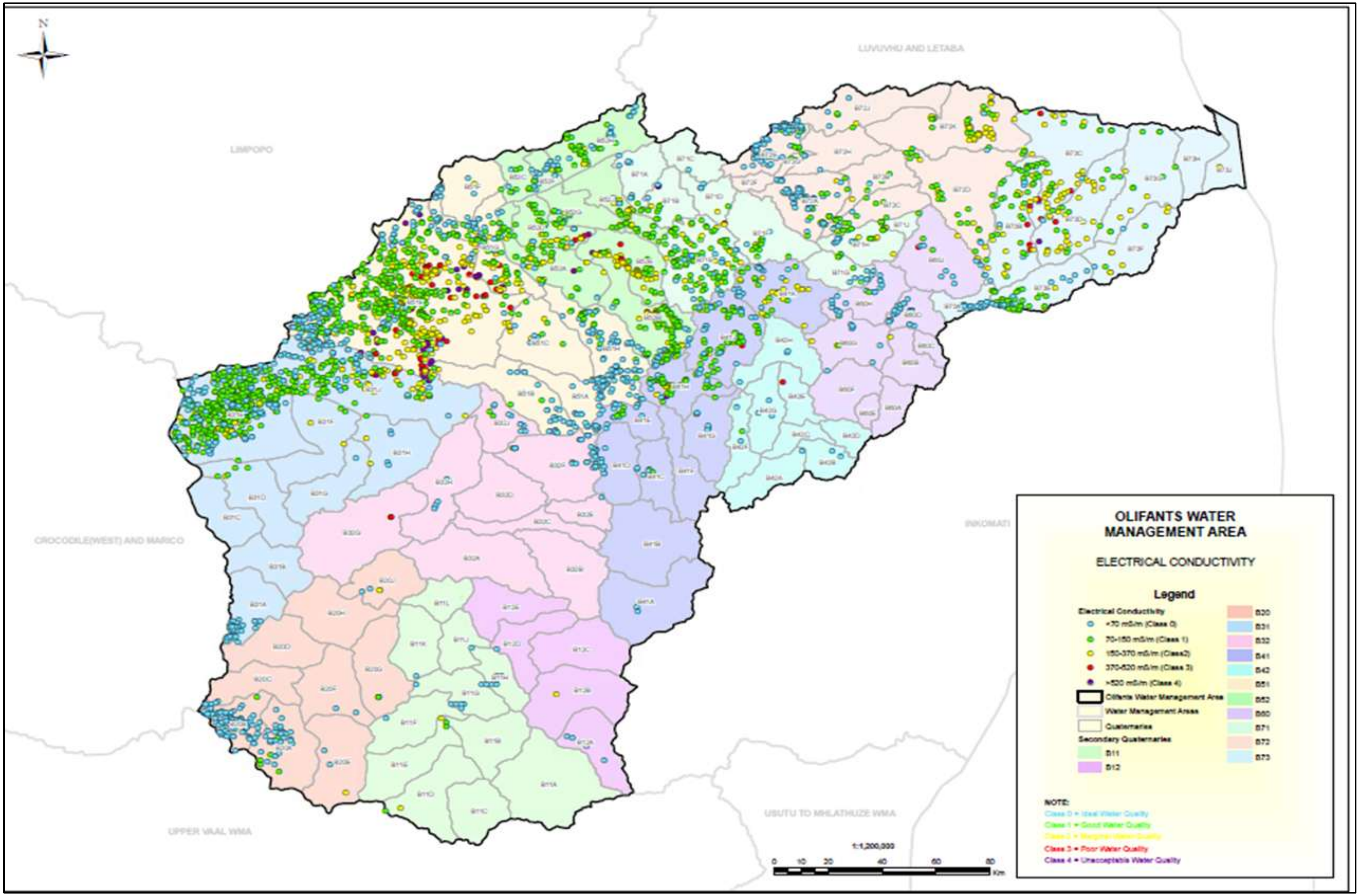


Figure 5.4: Distribution of EC values throughout the WMA (SATAC, 2008)

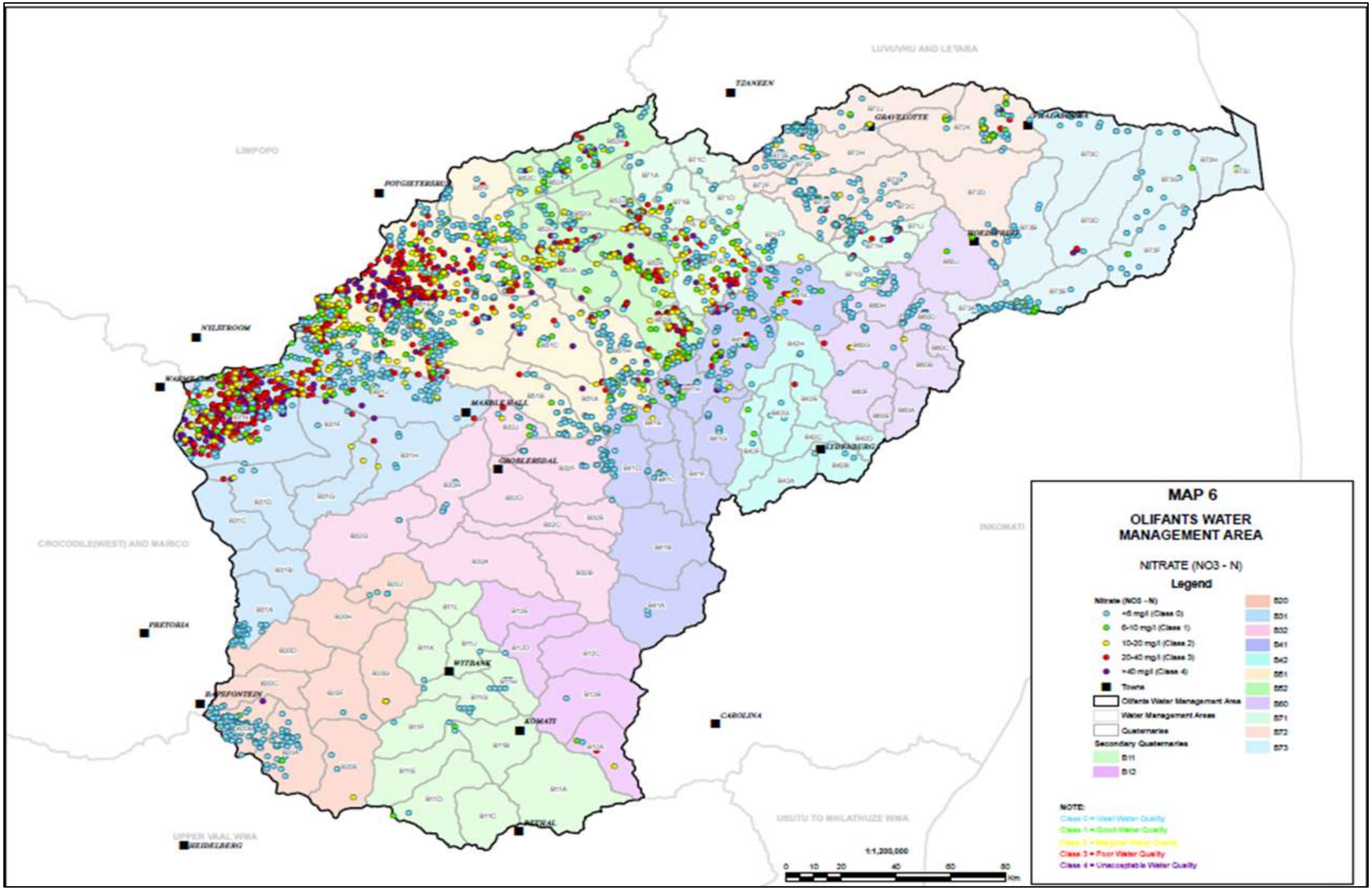


Figure 5.5: Distribution of Nitrate Values throughout the WMA (SATAC, (2008)

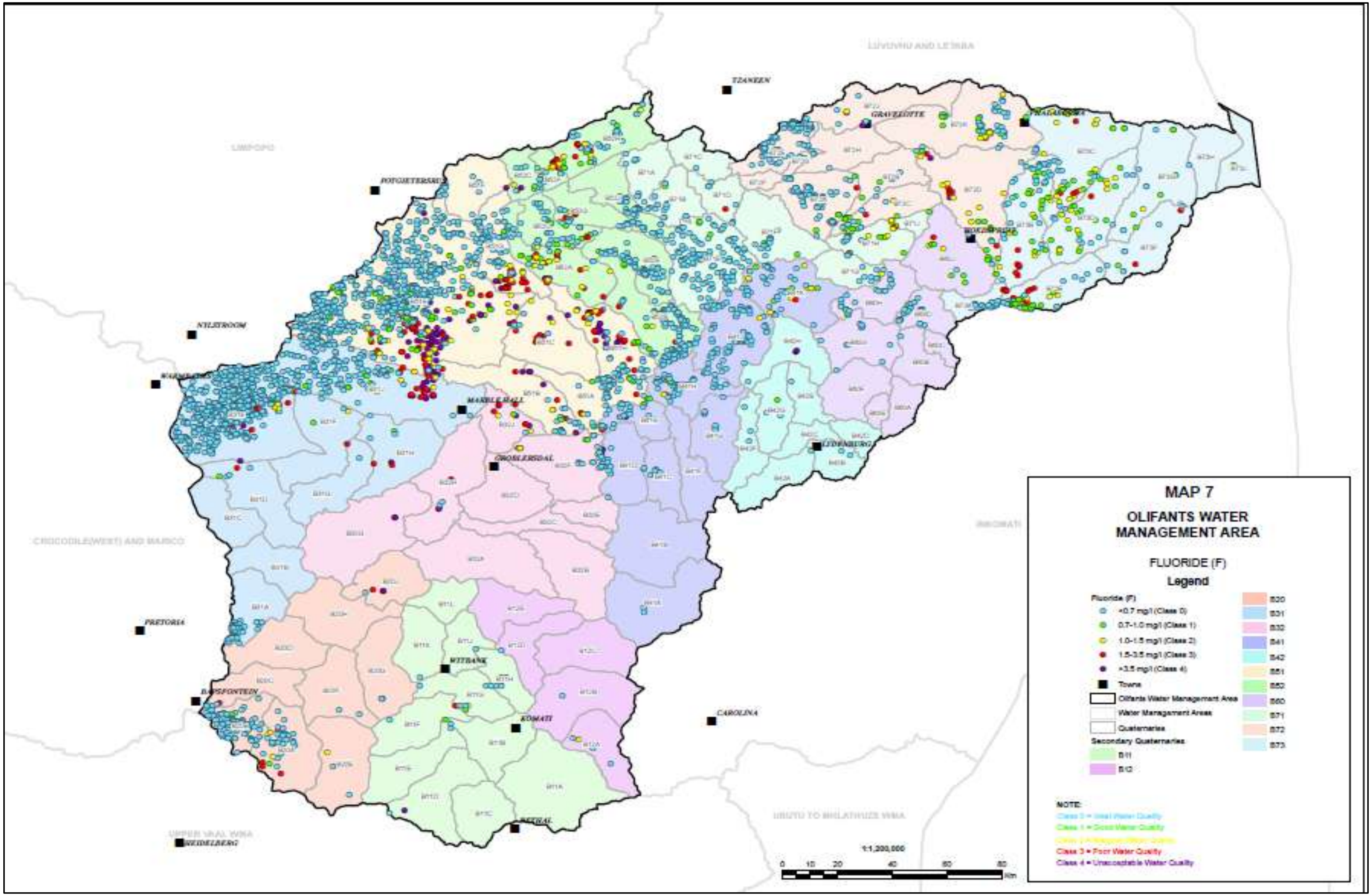


Figure 5.6: Distribution of Fluoride throughout the WMA (SATAC, 2008)

6. GROUNDWATER USE

Groundwater is available throughout the Olifants WMA only varying in quantities depending upon the hydrogeological characteristics of the underlying formations. The groundwater use in the various sub-catchments therefore varies very much with the groundwater availability. Groundwater in high yielding areas is mainly used for irrigation, whereas in low yielding areas it is mainly for domestic and livestock watering.

The concept that water abstracted from the alluvial river beds does not constitute groundwater, but rather from part and parcel of the river flow, has been established in the Crocodile (West) - the concept is however not well known nor well publicised. The KNP officials have complained that releases from the Blydepoort Dam, do not reach the KNP. At a guess it is probably extracted as 'groundwater' downstream. This aspect MUST receive attention.

Anecdotal evidence shows that many irrigation schemes, where surface water is the primary source, groundwater is utilised as well. Although outside the Olifants Catchment, an example of the Letsitele area will be mentioned. During the droughts of a few years ago, one farmer claimed that they have lost 25% of their orchards but without groundwater they would have lost 75%. This implies the infrastructure was available and is utilised from time to time. It is imperative that the volumes be determined as well as the abstraction points, i.e. real or perceived groundwater being used.

6.1. GROUNDWATER RESOURCE ASSESSMENT

AGES (2009) reported that 5690 boreholes were available on the DWA NGA with yield information. Yields are reported to vary from 0 to 20 ℓ/s with an average yield of approximately 2 ℓ/s. However, they pointed out that these yields does not represent sustainable yield but mainly blow yields. The average yield data of 2 ℓ/s was used to get a broad estimation of the annual abstraction across the Olifants WMA by assuming a 2 to 6 hour pumping per day. This gave a usage of between 30 million m^3/a and 90 million m^3/a. Based on these volumes calculated they conclude that the groundwater resources in the Olifants WMA is underutilised.

The Groundwater Yield Model (GYM) has been developed by AGES and aims to quantify the groundwater balance on quaternary catchment scale based on assurance levels. In the steady state system, the inputs to the groundwater from recharge will equate the outputs from the groundwater to surface water system in the form of base flow and losses to evapo-transpiration. The overall results of the GYM indicated that there is a surplus of groundwater in the four sub-areas due to inflow exceeding outflow. The total volume of groundwater recharge is calculated to be in the order of 860 million m^3/a and the groundwater component of base flow is 45 million m^3/a for the Olifants WMA.

AGES calculated that evapo-transpiration losses account for up to 500 million m^3/a or 70% of the groundwater flow losses. The biggest water users are the community water supply at 79 million m^3/a (10%) and irrigation at 72 million m^3/a (8%). They estimate the inflow from dam seepage as high as 47 million m^3/a, which is more than base flow. In **Figure 6.1** they showed the quaternary catchments that are potentially stressed due to over abstraction, as well as quaternary catchments that have a positive water balance and potential to be further developed.

Six areas were identified as stressed aquifer units and termed “hotspots” and is shown in **Figure 6.2.** At these hotspots, groundwater is over-utilised on a local scale. The following are the hotspots:

1. The Delmas Dolomite Aquifer (B20A and B20B), where irrigation in the order of 6 million m^3/a is abstracted from a spatial limited aquifer. Sinkhole formation increased tremendously in the last number of year with loss of land use (Jasper Muller and Associates, 2005).
2. Similar to Delmas is the Zebediela Dolomite Aquifer (B51E and B51G) where 3 million m^3/a are abstracted also from a spatially limited aquifer.
3. The Springbok Flats Karoo Aquifer (B51E) where irrigation in the order of 8 – 12 million m^3/a was abstracted for irrigation. Various studies were done between 1984 and 1994 investigating the over-abstraction of recharge (Timmerman,1984; Zwartz,1987; Nel, 1992 and Fayazi,1994)
4. Witbank-Middelburg-Kriel Karoo Coal Aquifers (B11K, B11J, B11H and B12D) where water quality is more affected than quantity.
5. Steelpoort mining and community water supply aquifer areas (B41J and B41K) where groundwater quantity and quality is affected.
6. Kruger National Park and Bushbuckridge Catchments (B73J, B73H and B73F) where groundwater sustains community water requirements and riparian vegetation.

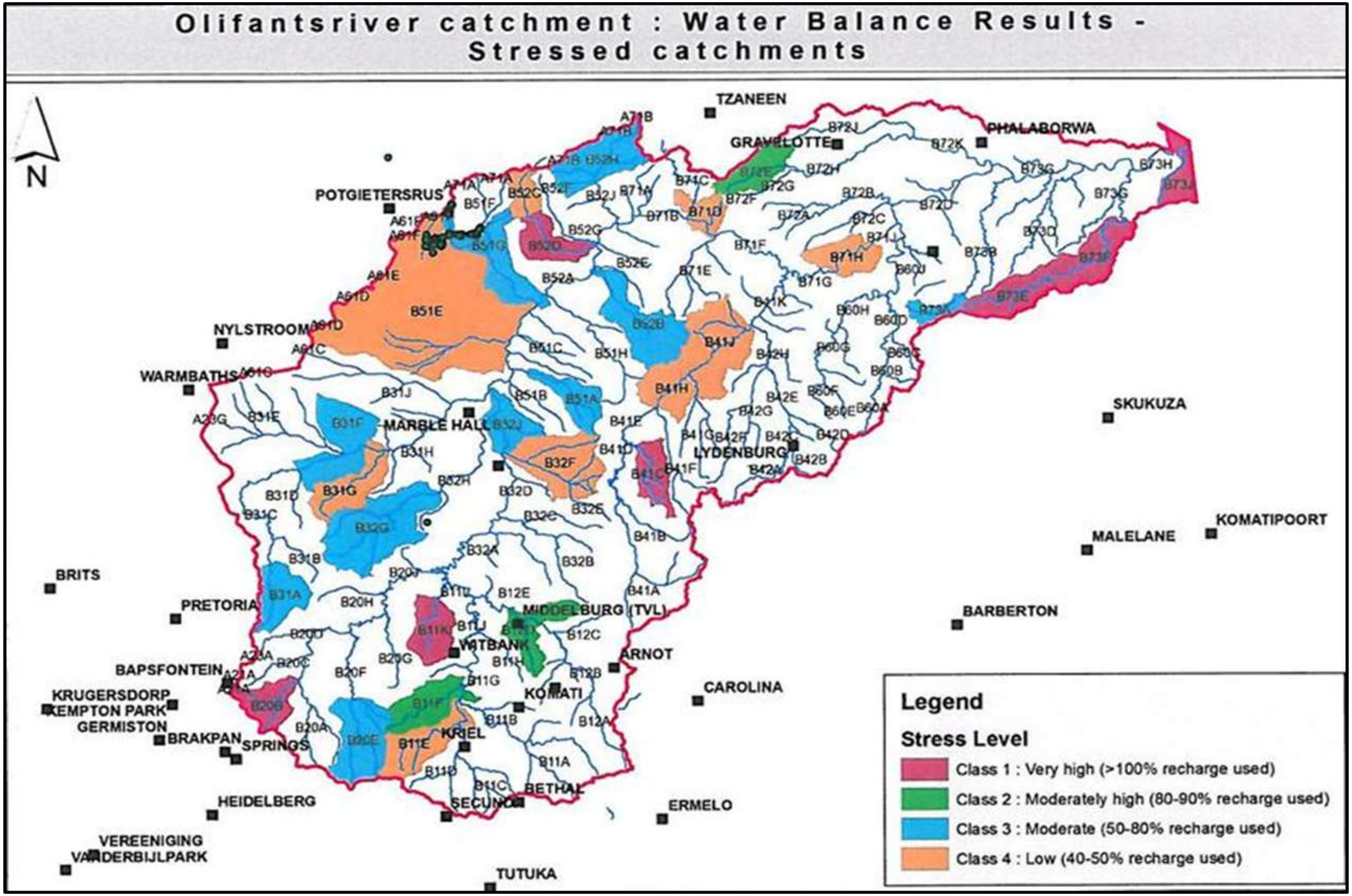


Figure 6.1: Map indicating stressed quaternary catchments (Source: AGES, 2009)

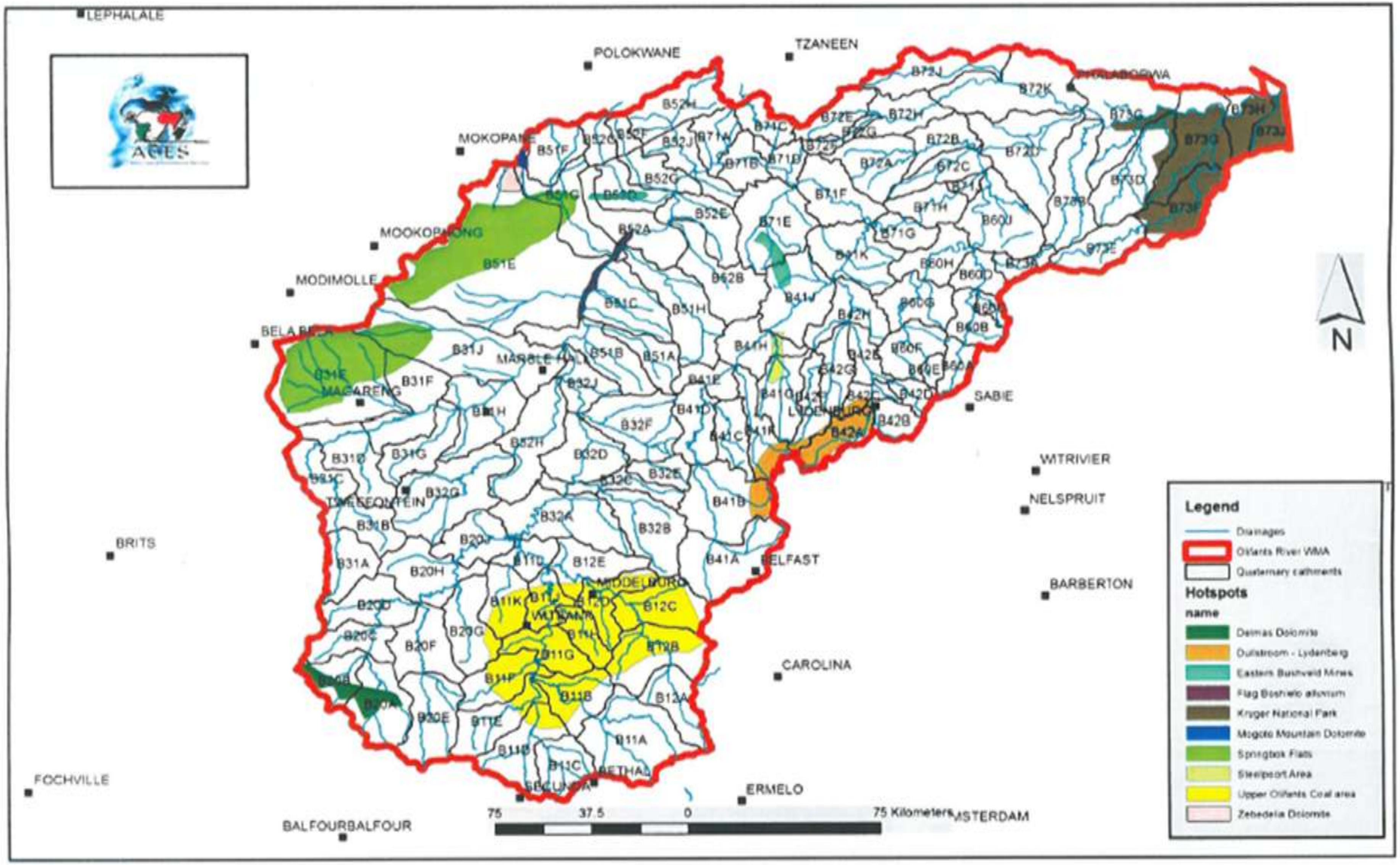


Figure 6.2: Hotspot quaternary catchments in the Olifants WMA (Source: AGES, 2009)

6.2 GROUNDWATER RESERVE

The Groundwater Component of the Reserve Determination Study for the Olifants River Catchment, WMA was undertaken and reported by SRK Consulting (Pty) Ltd (2009). Due to the large extent (54 000 km^2) of the Olifants River Catchment and the availability of data, a rapid assessment was done instead of an intermediate scale. A limited hydro census was conducted in order to address spatial concerns with data as well as to gain an indication of the variation in water usage across the WMA. In addition samples were taken for chloride analysis to aid in quantifying recharge using the chloride mass balance method.

The groundwater usage by sector, based on the 2008 updated WARMS database is shown in **Table 6.1**. According to this data the agricultural sector is the largest groundwater user with the mining sector second and the industrial usage the lowest. This data does not include community water supply which according to AGES (2009) is the largest groundwater users in the WMA. It is also known that in the past farmers registered more groundwater volume than they need to ensure that if DWA reduce the allocation they will still have enough supply. However, since payment for registered water use came in place they started to reduce the registered allocation. We are not sure where we are in the process.

Table 6.1: Registered groundwater users by sector (2008), (SRK Consulting, 2009)

WARMS Registered Users	Mm^3/a
Agriculture / aquaculture	0.04
Agriculture: Irrigation	110.87
Agriculture: Livestock watering	2.37
Industrial	4.30
Mining	30.63
Water Supply and Schedule 1	20.65
Total Usage (Mm^3/a)	**168.87**

SRK (2009) concluded that approximately 269.3 million m^3/a of groundwater is abstracted across the WMA of which only 168.87 is registered. The result of the Groundwater Resource Directed Measures (GRDM) employed estimates an additional 1 250 million m^3/a can be allocated for use without impacting on the current groundwater reserve requirement of 495 million m^3/a. However based on the quantification of the Reserve and available groundwater for additional use no further groundwater allocations can be made in:

- The Delmas Dolomite area
- The Springbok Flats
- The Zebediela Dolomite
- The Babsfontein Dolomite.

The dolomite compartment, on which Babsfontein is located, is already over-abstracted and this area must be approached with caution. This is much in line with the hotspots delineated by AGES (2009).

6.3 GROUNDWATER AVAILABILITY

Groundwater recharge estimates since 1980 were made by the Department of Water Affairs (DWA) and various consultants and is reported by SRK (2009) in **Table 6.2**. The exploitable or available yield has been estimated to vary from 70 to 469 million m^3/a. Various approaches and techniques were used to estimate and quantify the recharge, usage and groundwater surface water interaction. DWA initiated the Groundwater Resource Assessment Phase 2 (GRAII) project, aimed at quantifying the groundwater resources of South Africa on a national scale. Storage, recharge, aquifer thickness and depth were used to determine the exploitation potential per quaternary catchment.

Table 6.2: Various Groundwater Abstraction/Availability Estimates (SRK, 2009)

Year	Exploitable/Available Yield Mm^3/a	Abstraction Mm^3/a
1980		170
1995	180	100,6
2000 (DWAF)	99	
2001 (Seward)		183,3
2003 (Van Vuuren)	287,4	
2007 (AGES)	70	217
2007 (GRAII)	468,9	100,5

AGES (2009) was appointed as an associate by the SATAC Consortium in 2007 to assess the groundwater availability by means of water resource related models. They developed the Groundwater Yield Model (GYM) and used it to quantify the groundwater balance on quaternary scale based on assurance levels. Their results are presented in **Table 6.3** indicating a recharge of 860 million m^3/a, and a base flow of 690 million m^3/a for the Olifants WMA. They estimate that the evapo-transpiration losses account for up to 70% or in the order of 500 million m^3/a of the recharge.

SRK (2009) was appointed by DWA: Chief Directorate Resource Directed Measures to determine the groundwater component of the Reserve for the Olifants River Catchment at an Intermediate Level. This level of determination can be defined as yielding results of medium to high confidence which is required for assessing individual licenses for moderate impacts in relatively stressed catchments. Their results are summarised in **Table 6.3** indicating a recharge of 2 015.35 million m^3/a in the Olifants WMA and a base flow of 467.18 million m^3/a.

Table 6.3: Recharge and Usage estimates by AGES (2009) and SRK (2009)

	Surface Area	Recharge	Farming Livestock	Irrigation Boreholes	Mining De-water	Industrial Use	Community Supply	Base Flow	Groundwater ET losses
	Km^2	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a
SRK	54 726	2 015.35	2.4	110.87	30.63	4.3	20.65	467.18	
AGES	54 552	864	40	83	26		80	690	646

AGES (2009) showed a groundwater usage of about 229 million m^3/a based on the figures in **Table 6.3**. They concluded that at least 70 million m^3/a of additional groundwater resources (**Table 6.4**) can be developed in the quaternary catchments that are not stressed. SRK (2009) calculated that currently 269.3 million m^3/a of groundwater is abstracted across the Olifants River catchment. Using the GRDM they calculated that an additional 1 250 million m^3/a (**Table 6.4** can be allocated for use without impacting on the current usage.

Table 6.4: Groundwater Usage and Availability

	Total Usage Mm^3/a	Available Mm^3/a
SRK	269,33	1 250
AGES	229	70

However, the approach and results from the two studies vary considerable and it is difficult to decide if under or over-estimation has played a role in the estimates. SRK is presently carrying out a validation study of their data which will place more confidence on using their results. A conservative approach is recommended and for the purpose of this study we accepted the AGES (2008) estimate of 70 million m^3/a for modelling purposes.

Groundwater is the only source of water supply in many places, especially rural areas, where it is used mainly for domestic and stock watering purposes. DWA published General Hydrogeological Maps at the scale of 1:500 000 covering the whole country. The four maps Johannesburg, Polokwane, Phalaborwa and Nelspruit were used to compile a hydrogeological yield map of the Olifants WMA shown in **Figure 6.3**. The map display the principal groundwater occurrence in the various aquifer types across the WMA calculated from the borehole yields on the National Groundwater Data Base (NGA). It is clear from the map that almost 80% to 90% of boreholes in aquifers across the WMA yield less than 2 ℓ/s. The map confirm the previous conclusions that the higher yielding aquifers are the karst and fractured karst aquifers in the Delmas and Escarpment area and the Intergranular and Fractured aquifers in the Springbok Flats and Hoedspruit areas. Generally groundwater can only be used for domestic and stock watering and supply for small villages supplied by well fields. The Springbok Flats, Delmas and Zebediela areas are stressed and the only potential aquifer for development is the karst or dolomite aquifers of the Eastern Escarpment.

7. GROUNDWATER OPTIONS

In the Olifants WMA Strategies (DWAF ISP, 2004) it is stated that there is still further development potential of the groundwater resources. The Management of Groundwater Resources (DWA, 2008) must be considered when evaluating the available options. In the Mpumalanga Groundwater Master Plan (DWA, 2008) it is mentioned that in the Middelburg Region Most settlements were successfully served from groundwater but since the surface water distribution network was installed, groundwater use fell into total disuse. However, detailed studies will be required at the local level to determine the sustainable yield of any groundwater resources that are to be exploited in the future. Three groundwater development options are considered to improve the available water resources in the future. The options considered are:

- The management and control of over-exploited groundwater resources;
- The development of under-exploited groundwater resources;
- Conjunctive use of groundwater and surface water.

7.1. MANAGEMENT AND CONTROL OF OVER-EXPLOITED GROUNDWATER RESOURCES

The six stressed areas previously mentioned in **Section 6.1** need immediate attention. If the groundwater resources in these areas are not protected and exploitation reduced, a point will be reached where the communities will demand import of water to solve imbalance. The following groundwater regulation and management actions are urgently required:

- Comprehensive groundwater Reserve determinations of the catchments need to be done to establish the maximum volume available for allocation.
- Compulsory Water User Licence A required from every groundwater user.
- Validation and accounting of the groundwater use in these catchments by detail hydro census.
- A hydrocensus in unimpacted areas around the Witbank Coals fields, to establish baseline water quality, is imperative. Many geohydrological reports done for EIAs, mentions ‘elevated iron’ or elevated ‘sulphate’, however, the baseline has not been established. Without the baseline as a reference this statement is baseless.
- Control drilling for groundwater supply in these catchments by requiring registration of all new boreholes.
- Monitoring of representative aquifers by drilling of monitoring boreholes, equipping with automatic monitoring systems.

These management actions must be developed in co-operation with the local water users associations to ensure sustainable of the resources.

7.2. THE DEVELOPMENT OF UNDER-EXPLOITED GROUNDWATER RESOURCES

According to AGES (2009) overall the available groundwater resources within the Olifants catchment are underutilised although this clearly depends both on the groundwater occurrence and the demand. Even weaker groundwater occurrence areas can often provide more than the basic human (BHN) need of 25 ℓ per head per day, where groundwater is the main source for rural supplies. It is however necessary that boreholes drilled in the general weaker aquifers to be sited outside settlements and away from pollution sources, using the most modern exploration techniques, including geophysics.

7.2.1. The Escarpment Dolomite Aquifer

The exploitation potential of the Escarpment Dolomite Aquifer, shown in **Figure 7.1**, was investigated by AGES (2009). The water balance model they developed for this relatively-unexploited dolomite in the northern escarpment area of the Olifants River WMA indicated that the groundwater balance in the dolomite aquifers is positive (60 – 90 million m^3/a) and can be used for future development as a regional groundwater resource. The relief is mountainous and they noticed the presence of springs which are evidence of base flow at the surface and drain into the Olifants River via a number of non-perennial stream channels. It would be prudent to identify strategic springs and start monitoring these immediately.

The dolomite aquifer fell into Resource Unit 15 of the reserve study by SRK (2009). They calculated the abstraction along the escarpment at 3.5 million m^3/a. The recharge was estimated at 127,35 million m^3/a which is 10% of the Mean Annual Precipitation (MAP). This classified the aquifer as unstressed or low level of stress. This is in agreement with the AGES study that a potential resource exists for future development. The relief is mountainous and the population is sparse. A detail study will be required to investigate the best localities for development and areas (communities) that will benefit from supply from this resource.

Ideally DWA would want to refer to Water Resource Classification (RQO) as preliminary, in instances where there is no official Water Resource Classification set for a catchment. The following Resource Quality Objectives (RQO) is required to prevent the degradation or to maintain reasonably healthy resource sustainability:

- A high base flow component exists for this area and groundwater levels in response to abstraction in close proximity of these streams will need to be monitored;
- Production boreholes must not exceed recommended sustainable yields;
- Water levels in high abstraction boreholes need to be monitored; and
- Due to the sensitivity of this area and the rich biodiversity the highest level of environmental management will be required for development. The development cost will need to take into account that the relief is mountainous and sites selected for development will need detail investigation. Access for drilling equipment and pipeline routes will have to be planned. All different options for water supply need to be investigated to develop this available groundwater resource.

7.2.2. Dolomite Recharge at the Proposed Godwinton Weir

As stated in the previous section relief in the Escarpment Dolomite Formation is mountainous and the presence of springs is evidence of base flow at the surface and drain into the Olifants River via a number of non-perennial stream channels. The construction of a weir on the farm Godwinton in the Olifants River is proposed to recharge surface water back into the dolomite formation where it can be abstracted for bulk supply to areas with low water resources. The locality of the weir (shown in **Figure 7.2**) is about 25 to 30 kilometres downstream from where the Olifants River enters the dolomite formation in the escarpment. The river bed level falls about 50 m over this rich, indicating the weir height required to inundate the full stretch.

The proposed weir will block the river flow and push water back upstream, providing an opportunity for recharge to take place into structural features in the dolomite. On the geological map (**Figure 7.2**) a number of northeast-southwest striking structural features are shown upstream and downstream of the proposed weir. Some of the structures are known to be diabase dykes while the blue lines represent aeromagnetic lineaments. However when the Google map of the area is studied, **Figure 7.3,** numerous structural features can be identified similar to the structures on the geological map. There are structures upstream, downstream of the proposed weir and also structures striking northeast-southeast across the river.

It is known that the dolomite rock formation host numerous karst structures and voids and can therefore store large volumes of water. Production sites can be selected where recharged groundwater can be abstracted to supply areas with low water resources. These sites can only be selected after a detail study is done of the recharge around the weir. The study will include a detail structural study of the areas around the proposed weir site. It will further involve drilling of boreholes for monitoring piezometric levels before weir construction and after weir completion. Based on the data gathered during wet and dry seasons the recharge zones should be delineated. It is possible that the natural flow of an existing spring may increase and can be captured as another option.

The Artificial Recharge Strategy (DWA, 2007) did a theoretical artificial recharge storage potential study for the Olifants WMA. They indicate low recharge potential in the Escarpment Dolomite and the Godwinton Weir recharge is therefore a new area of recharge that must be considered and added as an additional option to their list. Once a detail study of the structural features in the area has been done the theoretical artificial recharge storage potential can be estimated. Important in the study is that the guidelines formulated in the Dolomite Management Guidelines (DWA, 2006) be implemented.

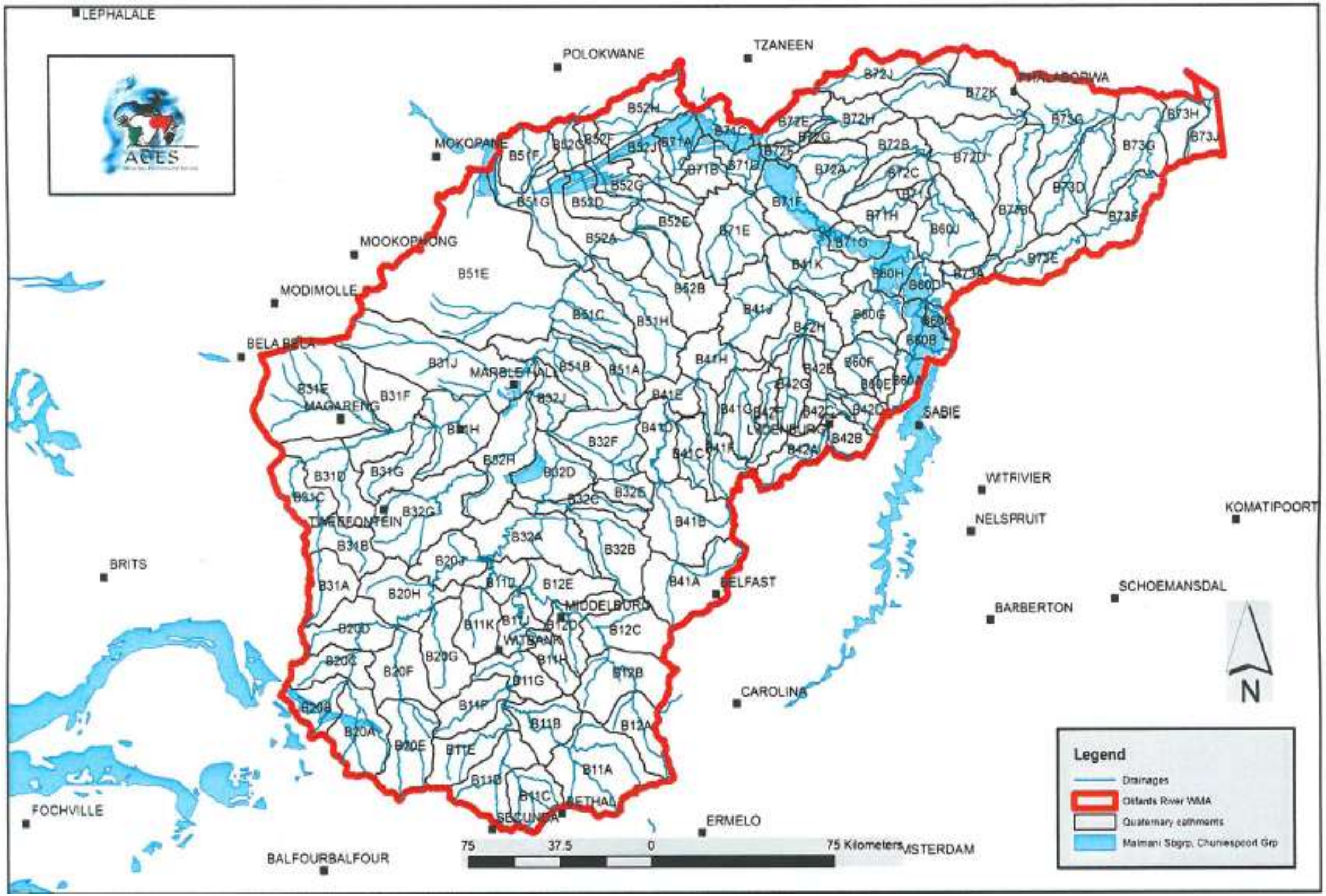
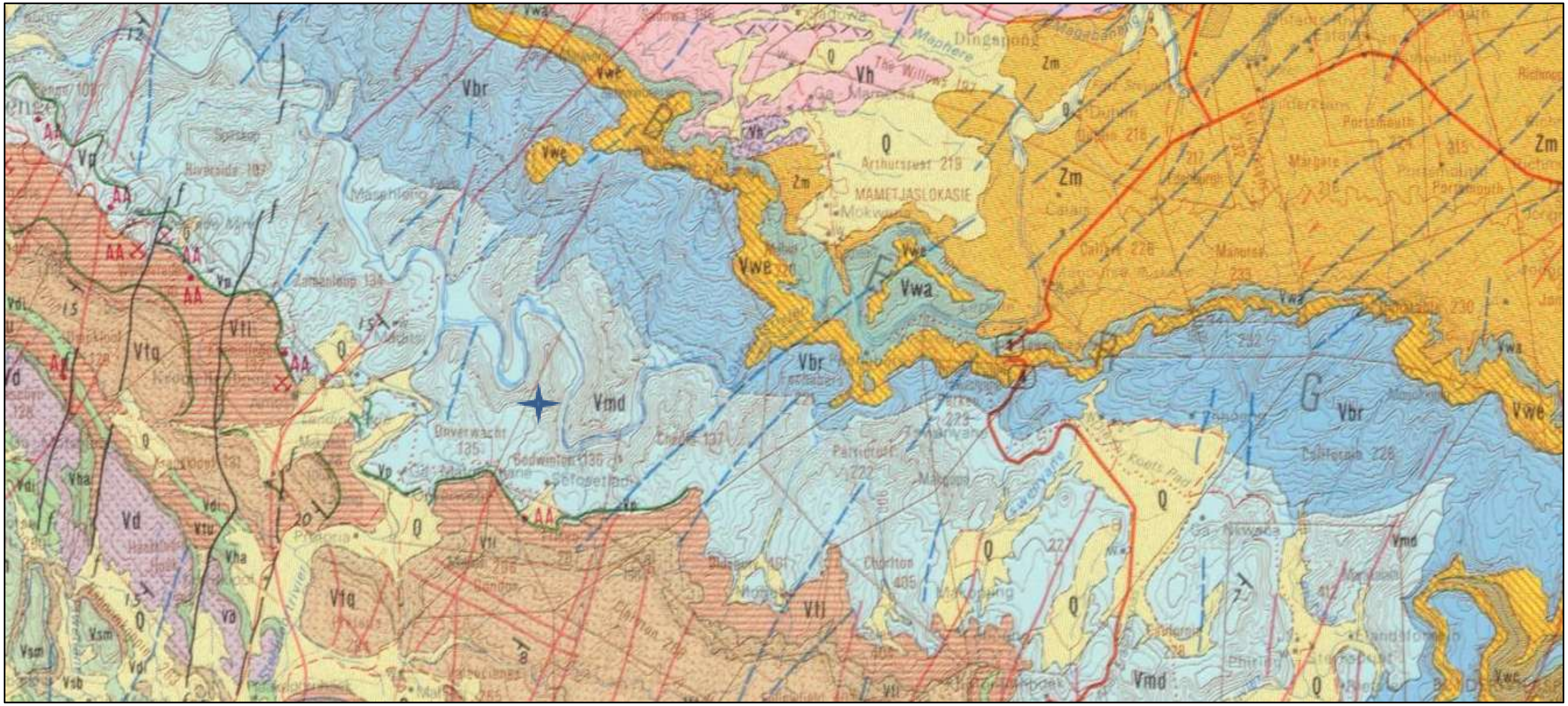


Figure 7.1: Map showing the locality of the Northern Dolomite Escarpment (AGES, 2009)



Locality of the Weir in the Olifants River

Figure 7.2: Locality of the proposed Godwinton Weir on the Geological Map of the Area

Figure 7.3: Google Map showing some of the Main Structural Features around the Proposed Godwinton Weir

7.3. GROUNDWATER-SURFACE WATER RECHARGE

Potential applications for groundwater recharge, which include utilising rainwater supplies, reclaimed mine water, and treated waste water, is discussed in Task 5 by Aurecon (2010). These potential applications need to be evaluated against the DWA (2006) Artificial Recharge Strategy guidelines. The potential area investigated into direct aquifer recharge includes underground storage at mines where water is currently being pumped out for purification and reuse purposes. The two potential mining areas where rainfall and surface water run-off recharge groundwater are rehabilitated open-pit coal mines and areas where long-wall mining occurred. The water quality of the water supplies for the recharge, however, needs to comply with DWA and the SANS 241 Drinking Water Standards if utilised for potable purposes.

Hodgson and Krantz (1998) did some studies of the water recharge characteristics for opencast mining. They calculated the average recharge onto rehabilitated spoils is 10% for run-off and 8% for seepage. The recharge depends on the top soil cover and the vegetation coverage which differ between mines. The evapotranspiration properties of the soil and vegetation differ also between mines. The former open pits that are now rehabilitated were protected by berms and cut-off trenches to divert run-off away from the pits. These berms and trenches need to be rehabilitated to increase run-off across the rehabilitated spoils for increased recharge. The development and potential of these water resources need further study.

Water storage in underground mines is discussed by Hodgson and Krantz (1998) for shallow and deep underground coal mines. They state that most shallow underground mines are full of water and recharge into these mines is estimated up to 15% of rainfall. It is known that high extraction underground mining results in the collapse of overlying strata, usually with impacts such as dewatering of adjacent aquifers. All these mines have problems to dispose of the water because of the quality and water is stored underground. Preventing pyrite oxidation by maintaining alkaline conditions ensures a stratified water column, with best water quality at the top. Considerable volumes of water are therefore available but the quality requires treatment.

7.4. CONJUNCTIVE GROUNDWATER SURFACE WATER USE

Groundwater resources with unacceptable drinking water quality such as high natural fluorides or nitrates are usable as such for irrigation or stock watering or can be used conjunctively with surface water to reduce the parameter levels to acceptable level. Using the contaminated resources for agriculture can release good quality for domestic use. The conjunctive use with surface water can reduce the salinity of groundwater resources and reduce the cost of treatment for selected uses. Groundwater can replace surface water use in agricultural to make it available for domestic use. A detail investigation is required to select the areas where conjunctive use with groundwater resources can be implemented.

8. CONCLUSIONS

The following conclusions are made:

- The availability of groundwater resources for abstraction is controlled by the aquifer characteristics of permeability and storage. The aquifers in the Olifants River Catchment are divided into three main types namely, inter-granular and fractured, fractured and karst or only fractured. All aquifers are capable of providing more than the basic human (BHN) need of 25 ℓ per head per day.
- Groundwater quality is impacted by mining, agriculture and sanitation as indicated by high EC and nitrate content. Natural occurrence of high fluoride also impact on water quality for human consumption.
- Groundwater data is limited in the Gauteng and Mpumalanga Provinces as no GRIP project has been implemented to update the present quality and quality groundwater data.
- The following six stressed areas were identified during groundwater resource investigations:
  - Delmas Dolomite Aquifer;
  - Zebediela Dolomite Aquifer;
  - Springbok flats Karoo Aquifer;
  - Highveld Coal Mining Area;
  - Steelpoort Mining and Community Supply Aquifers; and
  - Kruger National Park and Bushbuckridge areas.
- Groundwater recharge was determined using the Groundwater Yield Model (864 million m^3/a) and the GRDM software (2 015.2 million m^3/a). The more conservative values must be used until SRK's validations of their estimates are available and a comprehensive groundwater reserve is determined.
- Both recharge calculations indicated that additional groundwater resources are available for development.
- Three groundwater development options are considered to improve the available water resources in the future. The options considered are:
  - The management and control of over-exploited groundwater resources;
  - The development of under-exploited groundwater resources; and
  - Conjunctive use of groundwater and surface water.

9. RECOMMENDATIONS

The following recommendations are made:

- The NGA borehole data that was available for the studies does not seem to be sufficient and should be updated with data from mine EMPs and additional hydro census investigations.
- It is recommended that a GRIP project be implemented to update the present groundwater data in terms of quality and quantity in the Gauteng and Mpumalanga Provinces.
- No further groundwater allocations are recommended in any of the six stressed areas identified.
- The implementation of management and control measures for over-exploited groundwater resources must receive urgent attention from the department.
- It is recommended that a detail study of the Northern Dolomite Escarpment be done to select potential sites for development of this under-exploited groundwater resource. Once potential sites are selected the water demand centres must be determined as well as the costs for development.
- The interaction between groundwater and surface water in the vicinity of the Northern Dolomite Escarpment should be investigated.
- The construction of the proposed Godwinton Weir in the Olifants River where it flows through the Escarpment Dolomite, can recharge the dolomite formation upstream and downstream from the weir. Detail studies of the structural features in the vicinity of the proposed weir are recommended. The effect of such a recharge scheme on flows in the Olifants river must be assessed, as the lower Olifants river is already stressed.
- The real potential of the groundwater surface water recharge of rehabilitated opencast mines as well as undermined areas must be investigated further. Such an investigation must review all past and present studies in this field in order to identify areas with this highest potential for development.
- The various conjunctive uses of groundwater-surface water need further investigation to identify areas where any of the applications can be applied to improve the development and use of the water resources in the Olifants WMA.

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APPENDIX A

Substance	Unit of Measure	Substance range per class of water – health effects				
		Class 0	Class 1	Class 2	Class 3	Class 4
Group A : Substances which are general indicators of water quality						
Electrical Conductivity (EC) Total dissolved salts (TDS)	mS/m mg/l	<70 <450	70-150 450- 1000	150- 370 1000-2400	370-520 2400- 3400	>520 >3400
Feacal coliforms	Counts/100 ml	0	0-1	1-10	10-100	>100
pH Value (increasing acidic) (increasing alkaline)	pH units	7-5 7-9.5	5-4.5 9.5-10	4.5-4 10-10.5	4-3 10.5-11	<3 >11
Turbidity	NTU	<0.1	0.1-1	1-20	20-50	>50
Group B : Substances which are commonly present at concentrations which may lead to health problems						
Nitrate & Nitrite	mg/l N mg/l NO3	<6 <26	6-10 26-44	10-20 44-89	20-40 89-177	>40 >177
Fluoride	mg/l F	<0.7	0.7-1.0	1.0-1.5	1.5-3.5	>3.5
Sulphate	mg/l SO4	<200	200-400	400-600	600-1000	>1000
Chloride	mg/l Cl	<100	100-200	200-600	600-1200	>1200
Arsenic	mg/l As	<0.010	0.01-.05	0.05-0.2	0.2-2.0	>2.0
Total coliforms	Counts/100 ml	0	0-10	10-100	100-1000	>1000
Group C : Substances which occur less frequently at concentrations of real concern to health						
Cadmium	mg/l Cd	<0.003	.003-0.005	0.005-0.020	0.020-0.050	>0.050
Copper	mg/l Cu	<1	1-1.3	1.3-2.0	2.0-15	>15
Group D : Substances which may commonly be present at concentrations of aesthetic or economic concern in domestic water sources						
Manganese	mg/l Mg	<0.1	0.1-0.4	1.0-4.0	4.0-10.0	>10.0
Zinc	mg/l Zn					
Iron	mg/l Fe	<0.01	0.01-0.2	2.0-5.0	5.0-10.0	>10.0
Potassium	mg/l K	<25	25-50	50-100	100-500	>500
Sodium	mg/l Na	<100	100-200	200-400	400-1000	>1000
Calcium	mg/l Ca	0-80	80-150	150-300	>300	
Magnesium	mg/l Mg	<70	70-100	100-200	200-400	>400
Total Hardness as CaCO3	mg/l CaCO3	<200	200-300	300-600	>600	

Water quality class	Description	Drinking health effects
Class 0	Ideal water quality	No effects, suitable for many generations.
Class 1	Good water quality	Suitable for lifetime use. Rare instances of sub-clinical effects
Class 2	Marginal water quality, water suitable for short-term use only	May be used without health effects by majority of users, but may cause effects in some sensitive groups. Some effects possible after lifetime use.
Class 3	Poor water quality	Poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available.
Class 4	Unacceptable water quality	Severe acute health effects, even with short-term use.

DWA Water quality substances and criteria of concern for drinking purposes.