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DWAF Water Resource Study in Support of the ASGISA EC Mzimvubu Development Project

Groundwater Assessment

VOLUME 3 OF 5

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DWA WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

LIST OF STUDY REPORTS

REPORT	DWA report number
Summary Report	P WMA 12/000/00/3609
Existing water supply infrastructure assessment	P WMA 12/000/00/3609 Volume 1 of 5
Agricultural assessment and irrigation water use	P WMA 12/000/00/3609 Volume 2 of 5
Groundwater assessment	**P WMA 12/000/00/3609 Volume 3 of 5**
Water resources assessment	P WMA 12/000/00/3609 Volume 4 of 5
Assessment of potential for pumped storage and hydropower schemes	P WMA 12/000/00/3609 Volume 5 of 5
Rainwater Harvesting	P WMA 12/000/00/3609
An assessment of rain-fed crop production potential in South Africa's neighboring countries	P RSA 000/00/12510

Title	***Groundwater Assessment***
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DWAF WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

GROUNDWATER ASSESSMENT

EXECUTIVE SUMMARY

The Mzimvubu River catchment area is one of the poorest and least developed parts of South Africa. Development of the area, with the express purpose of accelerating the social and economic upliftment of the people in the region, was therefore identified as one of the priority initiatives of the Eastern Cape Provincial Government. Harnessing the still largely unexploited water resources of the region could offer some of the best opportunities to achieve such development. The Department of Water Affairs, in partnership with the Eastern Cape Provincial Government, undertook to investigate the potential for further water resources development in the area.

This report describes the assessment of the groundwater resources in the Mzimvubu catchment.

It is intended to provide an overview of the regional groundwater situation based on a preliminary assessment and the use of existing data and information only. This would then form the basis for possible detailed groundwater potential assessments which would involve more accurate analytical and numerical groundwater Reserve quantifications. The current approach was to focus mainly on the following items in order to obtain a regional comparative indication of broad groundwater potential between quaternary catchments in the study area:

- *Allocatable groundwater per quaternary catchment;*
- *Groundwater Reserve as a percentage of recharge, and*
- *Stress Index as defined by the Groundwater Resource Directive Measures (GRDM).*

Information for the assessments was drawn from the following available documentation:

- *Mzimvubu Catchment Development Study – Preliminary Groundwater Assessment*
- *The Groundwater Resource Directed Measures Manual and its associated software as published by DWAF and the WRC, February 2006;*
- *Latest NGDB geosite data – assuming conservative full-time abstraction volumes per borehole at 1 ℓ/s; and*
- *GRDM database data for population figures, baseflow, recharge and rainfall assuming potable groundwater use at 60 ℓ/c/d.*

The following three maps were produced through this process:

- *Groundwater Reserve as a percentage of recharge;*
- *Quaternary catchment Stress Index; and*
- *Allocatable groundwater per quaternary catchment.*

Given the preliminary and desk-top nature of the work, it should be noted that the maps are therefore not a quantitive reflection of actual groundwater potential or availability, but rather intended as a reflection of the broad groundwater situation and variations in groundwater potential across the catchment.

The preliminary assessments indicate that none of the quaternary catchments are currently stressed and that allocatable groundwater volumes are significant, resulting in groundwater being feasible for further development in most parts of the study area. Groundwater potential was preliminary defined as Very High at the town of Cederville and as High at the towns of Matatiele, Qumbu and Tsolo. Of the remaining 14 towns within the catchment, a total of 8 were defined as having medium or moderate groundwater potential, while the remaining 6 towns were defined as having low potential to rely on groundwater as a sustainable water source for municipal water supply.

The following groundwater occurrences can be described for the study area:

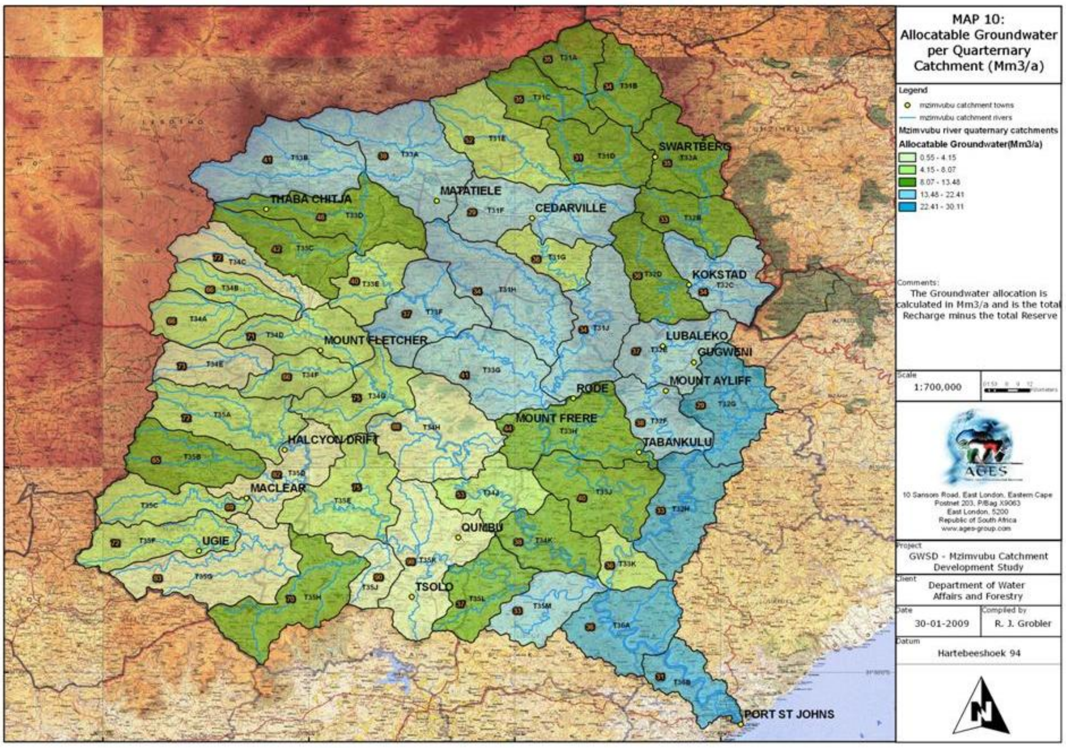
- *Aquifers associated with dolerite intrusion;*
- *Aquifers associated with fracturing unrelated to dolerite intrusion; and*
- *Intergranular aquifers.*

The expected median of the borehole yield class is described as 0.5 ℓ/s to 2 ℓ/s, although occasional higher yielding boreholes can be expected in ideally sited locations. Median borehole yields in quaternary alluvium deposits in the Cedarville and Matatiele region is known to be between 2 ℓ/s and 5 ℓ/s.

Groundwater quality data is insufficient to delineate potential based on expected water classes.

A summary of the provisional assessments of the groundwater potential for the main towns is given in Table 1 on page iv. The term "Stress Index" should not be misinterpreted as implicating that any of the quaternary catchments within the Mzimvubu catchment are currently stressed.

A groundwater potential definition without accurate regional water balance and Reserve determination information, however, is incomplete and cannot be used for final regional water resource management application and planning. It is therefore recommended that a numerical groundwater balance and flow model be applied for the Mzimvubu catchment in further studies.



MAP 10 **Allocatable groundwater per quaternary catchment (Mm^3/a)**

Table 1 Preliminary groundwater potential assessment per town located within the Mzimvubu River catchment

MZIMVUBU CATCHMENT DEVELOPMENT STUDY - TOWN SURVEY - GROUNDWATER POTENTIAL ESTIMATES & PRELIMINARY GROUNDWATER RESERVE IN APPLICABLE QUATERNARY CATCHMENTS									
							ASSOCIATED QUATERNARY CATCHMENT STATUS		
PROVINCE	DISTRICT MUNICIPALITY	LOCAL MUNICIPALITY	TOWN	AQUIFER TYPE median yield class	TOWN GROUNDWATER POTENTIAL ESTIMATE	EXISTING GROUNDWATER USE	RESERVE %	STRESS INDEX %	ALLOCATABLE GROUNDWATER (Mm^3/a)
EASTERN CAPE	Alfred Nzo	Matatiele	Matatiele	Intergranular & fractured 0.5 - 2.0 l/s	HIGH	YES	44 - 53	1.5 - 3.0	4 - 8
	Alfred Nzo	Umzimvubu	Mt Frere	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	YES	53 - 75	0.5 - 1.5	4 - 8
	Alfred Nzo	Matatiele	Cedarville	intergranular & fractured 2.0 - 5.0 l/s	VERY HIGH	YES	29 - 36	1.5 - 3.0	13 - 22
	Alfred Nzo	Umzimvubu	Mt Ayliff	Intergranular & fractured 0.5 - 2.0 l/s	LOW	YES	53 - 75	3.0 - 4.4	4 - 8
	OR Tambo	Mhlantlo	Tsolo	Intergranular & fractured 0.5 - 2.0 l/s	HIGH	YES	75 - 98	0.5 - 1.5	0.6 - 4
	OR Tambo	Mhlantlo	Qumbu	Intergranular & fractured 0.5 - 2.0 l/s	HIGH	YES	75 - 98	0.5 - 1.5	0.6 - 4
	OR Tambo	Ntabamkulu	Tabankulu	Intergranular & fractured 0.5 - 2.0 l/s	LOW	YES	53 - 75	0.5 - 1.5	4 - 8
	OR Tambo	Port St Johns	Port St John:	Fractured 0.5 - 2.0 l/s	LOW	NO	29 - 36	0.5 - 1.5	22 - 30
	Ukhahlamba	Elundini	Ugie	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	NO	53 - 75	0.5 - 1.5	4 - 8
	Ukhahlamba	Elundini	Maclear	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	NO	53 - 75	0.5 - 1.5	4 - 8
	Ukhahlamba	Elundini	Mt Fletcher	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	YES	36 - 44	0.5 - 1.5	13 - 22
	Ukhahlamba	Senqu	Rode	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	YES	53 - 75	0.5 - 1.5	4 - 8
	Alfred Nzo	Matatiele	Thaba Chitja	Intergranular & fractured 0.5 - 2.0 l/s	LOW	NO	29 - 36	3.0 - 4.4	8 - 13
	Alfred Nzo	Umzimvubu	Gugweni	Intergranular & fractured 0.5 - 2.0 l/s	LOW	YES	36 - 44	3.0 - 4.4	13 - 22
	Alfred Nzo	Umzimvubu	Lubaleko	Intergranular & fractured 0.5 - 2.0 l/s	LOW	YES	36 - 44	3.0 - 4.4	13 - 22
	Ukhahlamba	Elundini	Halcyon Drift	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	Not Known	75 - 98	0.5 - 1.5	0.6 - 4
KZN	KZN	Greater Koksta	Swartberg	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	Not Known	29 - 36	1.5 - 3.0	13 - 22
	KZN	Greater Koksta	Kokstad	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	YES	29 - 36	3.0 - 4.4	8 - 13

Reserve is indicated by the percentage of the recharge that is required to satisfy Reserve demand. The stress index is calculated by dividing the current abstraction with recharge. The groundwater allocation is calculated in Mm^3/a and is the total recharge minus the total reserve.

Notations and terms

Advection is the process by which solutes are transported by the bulk motion of the flowing groundwater.

Anisotropic is an indication of some physical property varying with direction.

Cone of depression is a depression in the groundwater table or potentiometric surface that has the shape of an inverted cone and develops around a borehole from which water is being withdrawn. It defines the area of influence of a borehole.

A *confined aquifer* is a formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.

The *darcy flux*, is the flow rate per unit area (m/d) in the aquifer and is controlled by the hydraulic conductivity and the piezometric gradient.

Dispersion is the measure of spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.

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

Effective porosity is the percentage of the bulk volume of a rock or soil that is occupied by interstices that are connected.

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

A *fault* is a fracture or a zone of fractures along which there has been displacement.

Hydrodynamic dispersion comprises of processes namely mechanical dispersion and molecular diffusion.

Hydraulic conductivity (**K**) is the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured perpendicular to the area [L/T]. Hydraulic conductivity is a function of the permeability and the fluid's density and viscosity.

Hydraulic gradient is the rate of change in the total head per unit distance of flow in a given direction.

Heterogeneous indicates non-uniformity in a structure.

Karstic topography is a type of topography that is formed on limestone, gypsum, and other rocks by dissolution, and is characterised by sinkholes, caves and underground drainage.

Mechanical dispersion is the process whereby the initially close group of pollutants are spread in a longitudinal as well as a transverse direction because of velocity distributions.

Molecular diffusion is the dispersion of a chemical caused by the kinetic activity of the ionic or molecular constituents.

Observation borehole is a borehole drilled in a selected location for the purpose of observing parameters such as water levels.

Permeability 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 the calculations.

Piezometric head (ϕ) is the sum of the elevation and pressure head. An unconfined aquifer has a water table and a confined aquifer has a *piezometric surface*, which represents a pressure head. The piezometric head is also referred to as the hydraulic head.

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

Pumping tests are conducted to determine aquifer or borehole characteristics.

Recharge is the addition of water to the zone of saturation; also, the amount of water added.

Sandstone is a sedimentary rock composed of abundant rounded or angular fragments of sand set in a fine-grained matrix (silt or clay) and more or less firmly united by a cementing material.

Shale is a fine-grained sedimentary rock formed by the consolidation of clay, silt or mud. It is characterised by finely laminated structure and is sufficiently indurated so that it will not fall apart on wetting.

Specific storage (S_0), of a saturated confined aquifer is the volume of water that a unit volume of aquifer releases from storage under a unit decline in hydraulic head. In the case of an unconfined (phreatic, watertable) aquifer, *specific yield* is the water that is released or drained from storage per unit decline in the watertable.

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

Storativity is the two-dimensional form of the specific storage and is defined as the specific storage multiplied by the saturated aquifer thickness.

Total dissolved solids (TDS) is a term that expresses the quantity of dissolved material in a sample of water.

Transmissivity (T) is the two-dimensional form of hydraulic conductivity and is defined as the hydraulic conductivity multiplied by the saturated thickness.

An *unconfined, watertable or phreatic aquifer* are different terms used for the same aquifer type, which is bounded from below by an impermeable layer. The upper boundary is the watertable, which is in contact with the atmosphere so that the system is open.

Vadose zone is the zone containing water under pressure less than that of the atmosphere, including soil water, intermediate vadose water, and capillary water. This zone is limited above by the land surface and below by the surface of the zone of saturation, that is, the water table.

Water table is the surface between the vadose zone and the groundwater, that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

LIST OF ABBREVIATIONS

Abbreviation	Description
DWAF	Department of Water Affairs and Forestry
EC	Electrical conductivity
EIA	Environmental impact assessment
EMPR	Environmental management programme report
GRDM	Groundwater resource directive measures
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MBGL	Meter Below Ground Level
MBGL	Meter Below Ground Level (i.e. depth)
NEMA	National Environmental Management Act
NGDB	National Groundwater Database
NGA	National Groundwater Archive
NWA	National Water Act
RGFB	Regional Groundwater Flow Balance Model
TDS	Total Dissolved Solids
TWQR	Target Water Quality Range
WMA	Water Management Area

DWAF WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

GROUNDWATER ASSESSMENT

TABLE OF CONTENTS

Page

1 INTRODUCTION 1
1.1 BACKGROUND 1
1.2 TERMS OF REFERENCE 1
1.3 STUDY AREA 2

2 METHODOLOGY 6
2.1 INFORMATION SOURCING 6
2.2 DATA SOURCING 7
2.3 DATA PROCESSING 7
2.4 INCEPTION PHASE 7
2.5 PRELIMINARY GROUNDWATER POTENTIAL ASSESSMENT 8
2.5.1 Groundwater Assessment based on available data 8
2.5.2 Groundwater assessment based on GRDM outputs 9

3 SITE DESCRIPTION 10
3.1 LAND USE 10
3.2 TOPOGRAPHY 11
3.3 SURFACE WATER AND DRAINAGE 12
3.4 CLIMATE 16
3.5 GEOLOGY 16
3.6 HYDROGEOLOGY 20

4 RESULTS 22
4.1 PREVIOUS STUDIES 22
4.1.1 Lusikisiki Groundwater Feasibility Study (SRK Consulting, 2007) 22
4.1.2 Mthatha River Basin Study (FST Consulting Engineers, 2001) 23
4.2 PROJECT INCEPTION REPORT – AGES-BKS (2008) 27
4.2.1 Inception Phase - Background 27
4.2.2 Inception Phase - Groundwater component 28
Task 8.4: Field verification 33
4.3 GROUNDWATER DATA 33
4.3.1 NGDB data application 34
4.3.2 GRIP EC data application 36
4.4 PRELIMINARY GROUNDWATER POTENTIAL ASSESSMENT 36
4.4.1 Groundwater flow model methodology 36
4.4.2 Quaternary level groundwater potential assessment – GRDM 37
4.4.3 Town-based groundwater potential assessment 38

5 SUMMARY & CONCLUSIONS.. 40

6 RECOMMENDATIONS... 44

7 REFERENCES.. 46

List of Figures

Figure 1 Mzimvubu River catchment locality map 4
Figure 2 Mzimvubu River quaternary catchments 5
Figure 3 Mzimvubu River catchment vegetation 10
Figure 4 Mzimvubu River catchment terrain 13
Figure 5 Mzimvubu River catchment digital terrain model (CSIR) 14
Figure 6 Mzimvubu River catchment: Rivers and dams 15
Figure 7 Karoo Supergroup stratigraphy. Tankard (1982) 17
Figure 8 Different styles of dolerite intrusion associated with different stratigraphical elevations in the Karoo Supergroup. (Smart, 1998) 18
Figure 9 Mthatha River catchment study boundary 24

List of Tables

Table 1 Preliminary groundwater potential assessment per town located within the Mzimvubu River catchment ...……………………………………………..........……..40

1 INTRODUCTION

Africa Geo-Environmental Services (Pty) Ltd (AGES) was appointed as part of the BKS project team for geohydrological inputs during the *Mzimvubu River Catchment Development Study*. The dynamic nature of the project has resulted in numerous changes in scope of work and approaches since AGES's appointment in 2007. The initial focus for groundwater inputs was developed around the requirement stated by the client, that the availability of water would need to be investigated or confirmed to support/enable development opportunities identified by the Eastern Cape Provincial Government. Such a focus would require a groundwater potential and reserve determination approach, based on reliable groundwater data and involving desk-top study as well as actual fieldwork for verification. The final scope of work and terms of reference was concluded at the beginning of 2009, when the instruction was given to AGES to only summarise work done to date without groundwater balance and reserve determination outputs, for the study to be concluded as a Preliminary Groundwater Assessment of the Mzimvubu River catchment.

1.1 BACKGROUND

The Mzimvubu River catchment, located in the north eastern region of the Eastern Cape Province, has been referred to as one of the poorest parts of South Africa and therefore in dire need for development. Unemployment in the area is amongst the highest in the country, there is little primary economic activity and a large proportion of the households are dependent on the income of family members who work elsewhere as migrant workers. As a consequence, it has been recognized by the National Government as one of the priority areas for upliftment under the ASGISA initiative. The Eastern Cape Provincial Government, in close collaboration and with the support of the Department of Water Affairs and Forestry (DWAF), has initiated a priority programme to stimulate meaningful economic and social development in the region (BKS, Bid Document 2007).

The main primary sectors in which potential for economic development may exist have been identified as agriculture, and in particular irrigation (commercial and small scale); forestry; hydropower and tourism. Potential may also exist for mining of heavy metals in some of the dune sands along the coast. Other needs are for improved water supply and sanitation services as well as the possible transfer of water from the Mzimvubu River to other catchments where it could be beneficially utilised.

In all of the above, the availability of water is an important factor and in many cases the key determinant. (BKS, Bid Document 2007)

1.2 TERMS OF REFERENCE

The evaluation of groundwater resource availability requires an initial baseline assessment of the use, aquifer distribution and the location of groundwater recharge zones, as well as potential contamination sources. The baseline information is used to evaluate the groundwater potential of the catchment as well as management units on the basis of their geology and geohydrology.

The initial focus of groundwater inputs would have involved a desktop-level assessment of aquifer potential and further field inspections where the information warrants it. The end product was intended to be an assessment of available data and literature on the groundwater potential in the catchment and the distribution of groundwater use and potential contamination sources. From this information, an assessment would have been made of the current groundwater balance at a quaternary catchment-level using an analytical, spreadsheet-based model. The identification of major aquifer zones and stressed areas would have been one of the important outputs of the study.

Inputs given during the study's Inception Phase were in line with this approach.

Based on numerous changes in scope of the overall project, groundwater inputs were put on hold for a significant part of the project in the light of uncertainties in terms of requirements and deliverables. At a meeting held with BKS on the 5th of February 2009, it was concluded that the final scope of work – based on which the final report must be rendered, will take note of the following:

- No catchment based analytical groundwater reserve determination will be carried out;
- Limited desktop level GRDM software outputs can be used for basic indication of groundwater characteristics throughout the study area;
- No actual fieldwork and verification will be required as the available NGDB data is acceptable for the amended scaled-down scope for preliminary groundwater assessment;
- Available hydrocensus data sourced as part of the Eastern Cape Groundwater Resource Information Project (GRIP) can be incorporated for the assessment of groundwater dependency at towns throughout the catchment as well as groundwater assessment;
- Preliminary delineation of higher groundwater potential areas should be carried out within the framework of the limited scope of work;
- Previous studies in and in close proximity to the Mzimvubu River catchment should be referenced where applicable; and
- Recommendations from this report should guide future phases of the catchment development study in terms of groundwater potential further work required.

1.3 STUDY AREA

It was stated at the onset of the project that the investigation of water resources will be restricted to the Mzimvubu River catchment, with consideration only of the water resource situation in adjoining catchments. It was further noted that a wider approach will be taken with respect to development options outside the catchment, but which may benefit from water from the Mzimvubu River. This definition resulted in the adjacent Mthatha River catchment as well as the Lusikisiki area becoming part of the study area at the initial stages of the project. The final study boundary was however re-defined at a later stage in the project and confirmed to only include the Mzimvubu River catchment boundary. Reference is still, however, made in this report to work done in the adjacent catchments.

The Mzimvubu River basin is situated in the previously designated Transkei region of the Eastern Cape Province (**Figure 1**). Its catchment boundary is contained within the Mzimvubu to Keiskamma Water Management Area (WMA) No 12, and it has a total catchment size of approximately 19 800 km^2.

This area includes tertiary catchments of T31, T32, T33, T34, T35, and T36. The primary drainage region incorporates the following main river systems: Mzimvubu, Tsitsa, Tina, Kinira and Mzintlava Rivers and the entire catchment expanse consists of 51 quaternary catchments (**Figure 2**). A significant section of the north-eastern part of the catchment lies within Kwazulu Natal while most of the catchment falls within the Eastern Cape Province.

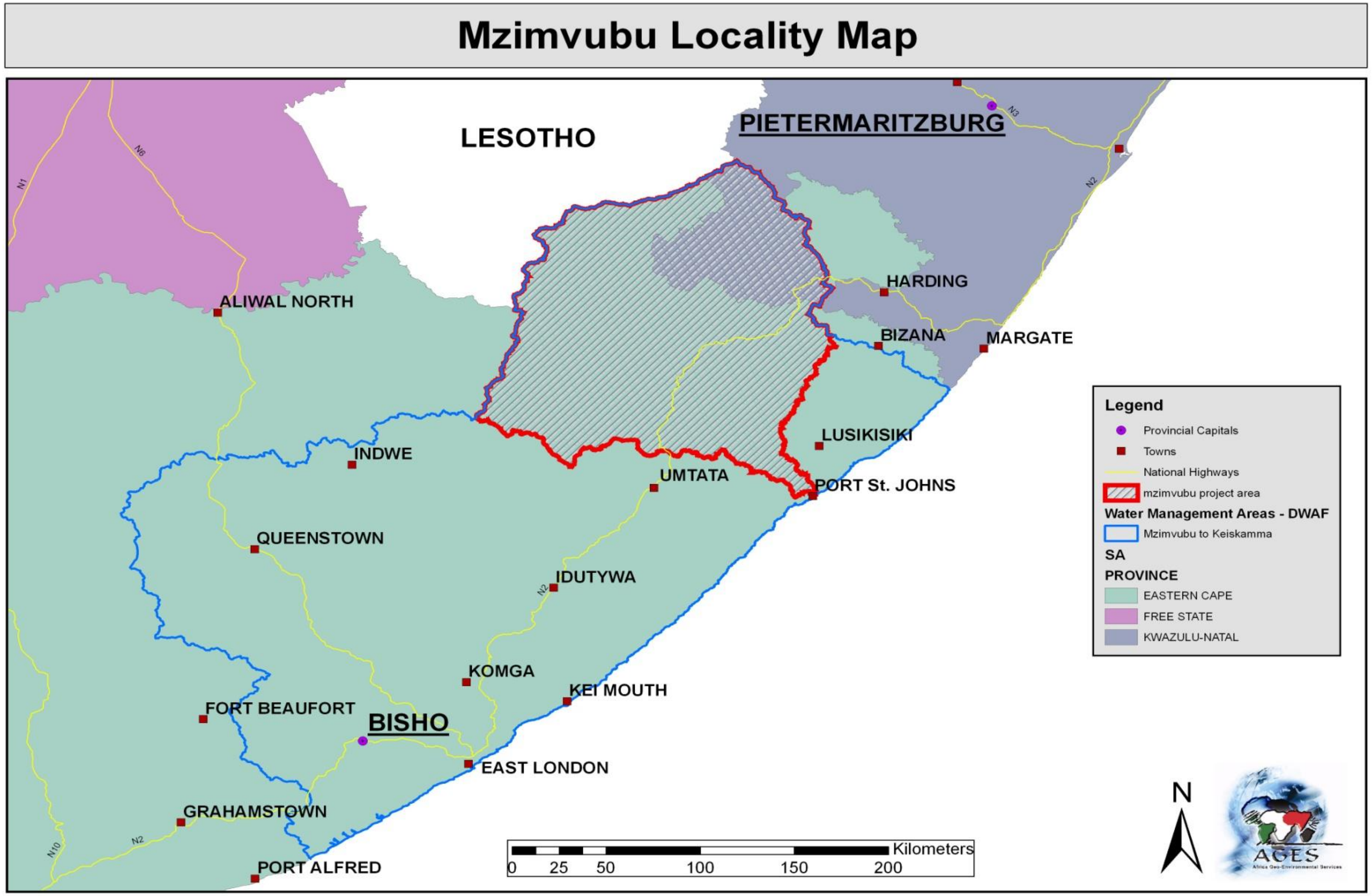


Figure 1 Mzimvubu River catchment locality map

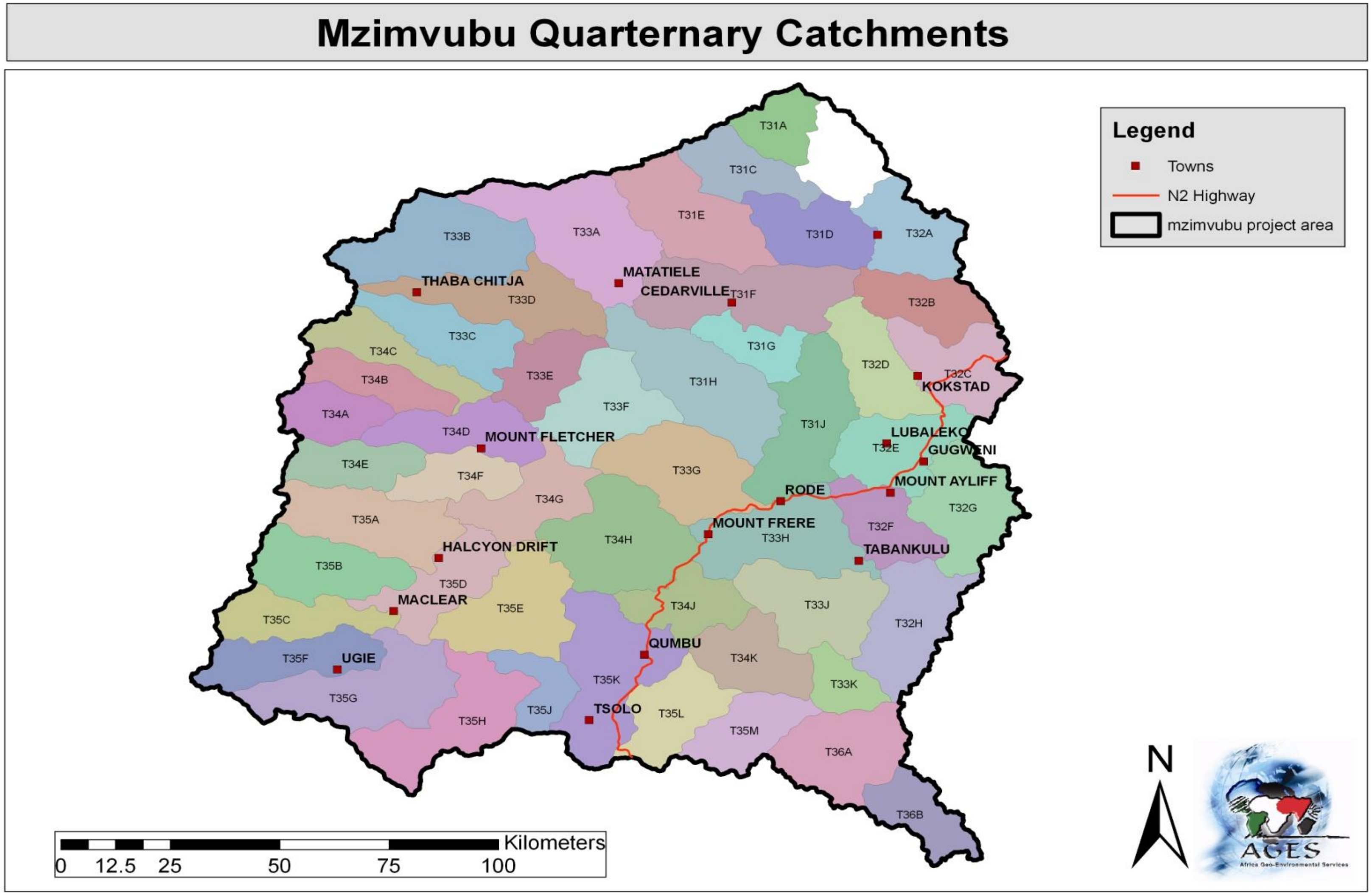


Figure 2 Mzimvubu River quaternary catchments

2 METHODOLOGY

Due to the project's scope of work having changed from the initial groundwater reserve determination approach, towards the final scope, which entailed only a summary of groundwater data sourced with preliminary groundwater potential definition, the following methodology description is based only on actual work carried out for the preliminary groundwater assessment.

2.1 INFORMATION SOURCING

The initial scope of work required the following information to be sourced:

- Current groundwater usage;
- Historical rainfall data;
- Status of General Authorisation levels;
- National Groundwater Database data from the NGDB dataset and local DWAF office;
- GIS spatial data;
- Hydro-census data from the GRIP EC programme;
- Water Use License information applicable to groundwater sources for the Mzimvubu River catchment (registrations, authorisations, water users associations);
- Municipality water supply schemes (information and contact details) for the catchments;
- Data and information from DWAF research drilling and pump testing programmes;
- *Lusikisiki Study* and *Umtata River Catchment Study* ;
- Pending applications as per WARMS;
- Land use and type distribution clarification;
- Departments of Agriculture and DWAF information pertaining to agricultural activity, land use potential and planned redistribution and agricultural schemes and forestry;
- Surface / groundwater interaction quantification through workshops with team; and
- Groundwater dependant ecosystem identification and quantification.

Due to the scope of work and deliverables having been changed by the client, only the information relevant to the requirements of the current study were sourced and referenced. This entailed mainly all obtainable groundwater data as well as recently completed studies in the adjacent catchments.

2.2 DATA SOURCING

Groundwater data was primarily sourced from the existing National Groundwater Database (NGDB). The NGDB is presently populated with in excess of 225 000 borehole records across the country. The spatial distribution of borehole records and some metadata on this database are also available. Numerous new developments and changes to the NGDB have been taking place over the last year. The transformation of the NGDB towards the National Groundwater Archive (NGA) has been the most prominent of these. The GRIP EC project was implemented by DWAF for the main purpose of populating the then NGDB (now NGA). Data is obtained in spreadsheet format from the DWAF Port Elizabeth offices. Historical data from numerous local groundwater development and sanitation projects were incorporated from the AGES internal dataset into the GRIP database as part of the initial stages of the GRIP project.

2.3 DATA PROCESSING

Groundwater data is obtained from the NGDB in spreadsheet format and then processed into spreadsheet-type tables for application in the GIS as shape files as well as for statistical evaluations. GRIP data is obtained through a data-dump process from the GRIP Data Tool, which renders the data in spreadsheet-type tables for processing into shape files in the GIS or tables for statistical analyses. Due to the GRIP EC data still being in the process of being captured, the dataset for the study area was seen as incomplete and could therefore not be used for groundwater assessment purposes as part of this study.

2.4 INCEPTION PHASE

This Inception Report is prepared as follow-up to the proposal submitted to the Department of Water Affairs and Forestry (DWAF). BKS lead the study, together with FST Consulting Engineers. Other sub-consultants were included as part of the study team. The study area was sub-divided into quaternary catchments. There was some delay in the execution of the work mainly due to DWAF and the Study Team awaiting the appointment of PSPs by ASGISA. It was foreseen that there will be substantial interaction between this study team and the study team to be appointed by ASGISA. BKS, (2008).

The Inception Phase concentrates on gathering and reviewing of available data and reports, and expanding on finer detail of the different tasks and sub-tasks as included in the project proposal.

This phase included the following:

- Review the findings of relevant water resources evaluations and planning studies;
- Review details of relevant system model applications;

- Assessment and evaluation of data required for the Water Resources Yield Model;
- Drafting of an Inception Report; and
- Firming up on the proposal budget. BKS, (2008).

The Groundwater Assessment was defined as Task 8 of the study and detailed based on the initial scope of work and the assessment methodology is detailed as part of the inception report. This is described in Chapter 4 of this report, as part of the results of the overall study.

2.5 PRELIMINARY GROUNDWATER POTENTIAL ASSESSMENT

Groundwater potential definition without accurate regional water balance and reserve determination information is incomplete and cannot be used for final regional water resource management application and planning. It is therefore crucial for the reader to realise that this report aims to report only on available information in terms of existing borehole data, with reference to work carried out in other studies in similar geohydrological conditions. A first level assessment of allocatable groundwater and groundwater reserve as well as stress indexes per quaternary catchment is given by using the DWAF developed GRDM manual and software (Parsons, 2006). AGES is currently involved in several groundwater reserve determination studies where the GRDM approach is further enhanced with numerical flow balance modelling, developed and applied by AGES, which results in accurate groundwater balance figures. It will therefore be the main and most important recommendation from this report that a numerical groundwater balance and flow model be applied for the *Mzimvubu River Catchment Development Study* in the next phase of the project.

2.5.1 Groundwater Assessment based on available data

Based on desktop study results and limited available groundwater information, only preliminary groundwater potential zonation can be carried out. The data that can be used usually include information such as borehole yields, lithological drilling logs, pump testing data and water chemistry results. The information is evaluated and a groundwater development potential map is compiled purely based on borehole yield potential and groundwater quality. This can be used as a planning tool for groundwater source development and planning purposes only once a regional groundwater water balance has been carried out as recommended in this report. It has been found that the zone of highest potential can be delineated according to the geometry and occurrence of higher potential geological structures and formations.

2.5.2 Groundwater assessment based on GRDM outputs

Four levels of GRDM determination are recognised, with each expected to yield a greater level of confidence in the results. For the purpose of the preliminary groundwater assessment of this study, only a desktop level determination was carried out.

The following general features characterise the differences between the four levels: Parsons, (2006)

Desktop: These determinations are done using readily available data and information; extrapolate the results from previous more detailed and localised assessments; have low intensity information requirements; take a matter of hours to complete; and yield results of very low confidence; usually the first step in any GRDM process and is a useful planning tool.

Rapid: Similar to desktop determinations, but include a short field trip to assess present state; typically used to assess individual licence applications with low impact, in unstressed catchments and/or catchments of low ecological importance and sensitivity; should take less than two weeks to complete.

Intermediate: These determinations yield results of medium confidence; require field investigations by experienced specialists and should take about two months (but <6 months) to complete; used to assess individual licences for moderate impacts in relatively stressed catchments.

Comprehensive: Comprehensive GRDM determinations aim to produce high confidence results and are based on site-specific data collected by a team of specialists; used for all compulsory licensing exercises, as well as for individual licence applications that could have a large impact in any catchment, or a relatively small impact in ecologically important and sensitive catchments. It should take less than two years to complete. Due to lack of long-term geohydrological data sets, GRDM assessments will only rarely be done at this level. Parsons, (2006)

Outputs generated for the purpose of the preliminary groundwater assessment approach of the study focussed mainly on the following to get a regional comparative indication of broad groundwater potential between quaternary catchments in the study area:

- Allocatable groundwater per quaternary catchment;
- Reserve as a percentage of recharge; and
- Stress Index as defined by the GRDM.

3 SITE DESCRIPTION

The Mzimvubu River catchment boundary falls within the following four District Municipalities; Alfred Nzo, Ukhahlamba, Sisonke and OR Tambo and stretches across ten Local Municipalities. The largest urban settlement in the basin is the town of Kokstad, with numerous smaller towns scattered through out, serving as growth points and governmental service centres. The majority of the population reside in small rural villages scattered through out the catchment as is typical of the former Transkei. The natural veld in the Mzimvubu River basin varies between lush coastal tropical forest type near the coast and along watersheds, false grassland and karroid types in the deeper river valleys, with temperate and transitional forest and scrub type further away from the coast and areas of pure grassland (**Figure 3**).

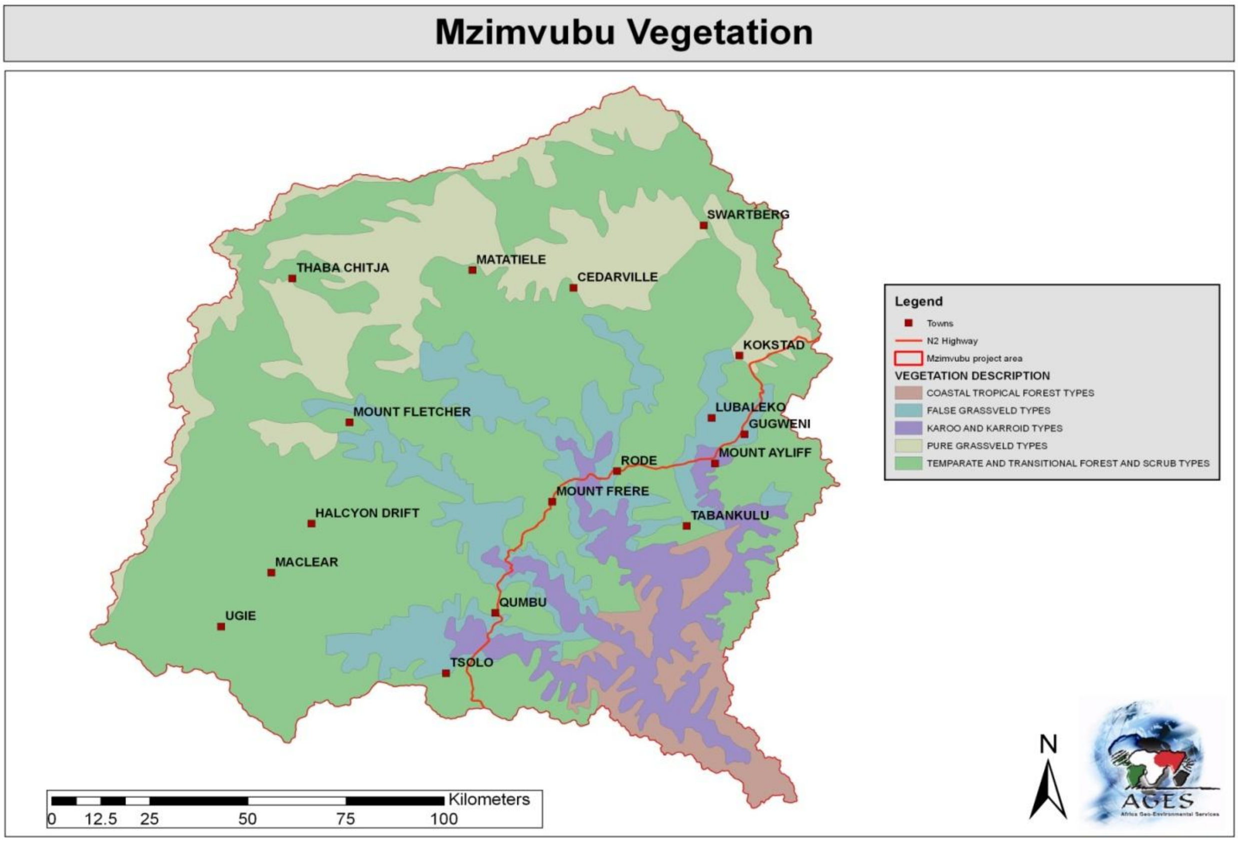


Figure 3 Mzimvubu River catchment vegetation

3.1 LAND USE

Land use is diverse across the catchment but in general the area is largely under developed with minimal large income generating developments. The Mzimvubu River catchment is considered to be one of South Africa's largest undeveloped river catchments and it has been described as the river system in the Eastern Cape with the greatest potential for associated development through utilisation of its resources (EC State of the

Environment Report 2004). Surface waters, groundwater, rain water and springs are the main sources of water available to rural dwellers in the Transkei region (Faniran, Ngceba, Bhat and Oche 2001).

A prominent feature is the extent of dryland cultivation and the large number of scattered rural villages. These villages are concentrated in the former Transkei area and occupy about 2% of the land area of the basin. The majority of the land is communal and most of the agricultural activity in the former Transkei is based on subsistence dry farming cultivation and rearing of livestock. There are no major irrigation schemes within the region. A large portion of the basin can be classified as degraded, mainly as a result of overgrazing that has caused severe soil erosion. Commercial farming mostly occurs outside the former Transkei in areas such as Kokstad, Maclear, Matatiele and Ugie, where irrigated pasture for dairy farming is common practice. Water is a constraint for agricultural production in particular the impact that irrigated agricultural practices are having on water resources (EC State of the Environment Report 2004).

Commercial forestry contributes significantly to the Gross Geographic Product (GGP) of the basin and occurs predominantly in the south-west. Mineral wealth is considered as lacking and to date there is no major mining activity in the basin except for a single quarry. The invasive alien plants, other than forestry, has been estimated to occupy an equivalent area of 22 600 ha in the basin and is believed to reduce the mean annual run-off by 36 million m^3 (Sellick 2005). A significant number of wetlands occur in the basin, mostly in the northern portion in KwaZulu-Natal. These wetlands are important to the ecology and in the hydrological cycle. Despite the natural beauty of the basin, only 5 nature reserves are found in the basin and the estuary is considered an area of relatively high conservation importance.

A tenth of the total population (1 031 700 persons) are considered to be urbanised with most of the remaining people living in a large number of small scattered rural villages throughout the river basin. The two largest urban centres are Kokstad and Mount Frere, which account for about 41% of the urban population. The lack of strong economic stimulants in the basin area is responsible for the lack of development and thus the strong focus on subsistence farming (EC State of the Environment Report 2004).

3.2 TOPOGRAPHY

The Mzimvubu River basin discharges into the Indian Ocean and is bound in the south by the Mthatha and Mbashe river catchments, in the west by the Orange River basin and in the north-east by the Umzimkulu and Mtamvuna river catchments. In the east the catchment is bordered by the Pondoland Coastal catchments. The river basin shares an international border to the north with Lesotho along the Drakensberg escarpment. The Mzimvubu River and its four main tributaries, the Tsitsa, Tina, Kinira and Mzintlava all have their headwaters in the Drakensberg Mountains. The Mzimvubu River basin has a total catchment area of 19 852 km^2.

The topography of the Mzimvubu River basin varies from predominantly hilly around the coast and escarpment with numerous rivers draining deep valleys, to a less mountainous undulating central area (**Figure 4**). The study area exhibits morphological elements of typical hillslope development under semi-humid conditions, with the majority of the slopes classified as moderate to steep as seen in the digital terrain model, Figure 5 (CSIR data). The main stem and the tributaries descend through the escarpment and flow through deep river valleys incised into the coastal belt before discharging into the Indian Ocean at Port St Johns, in the OR Tambo District Municipality. The river estuary has been given a fairly high conservation importance rating, placing it in the upper 15% of South African estuaries.

3.3 SURFACE WATER AND DRAINAGE

The Mzimvubu River basin is drained by several river systems, the Mzimvubu River being the largest of them and extending from the Lesotho Highlands to the Indian Ocean. The Mzimvubu River has four main tributaries, the Tsitsa, Tina, Kinira and Mzintlava, all having their headwaters in the Drakensberg Mountains (**Figure 5**).

The catchment is believed to be one of the areas of highest mean annual runoff in South Africa, with a natural mean annual run-off of 2 900 million m^3. Despite the large population, the Mzimvubu River basin is one of South Africa's basins with the lowest total water requirements. This can largely be attributed to the relatively high rainfall and the generally low level of development and economic activity.

There are no significant high capacity dams in the catchment. A number of smaller capacity dams are stretched across the north eastern section and this correlates with the dominant type of land use, that of agriculture. Crystal Springs in T32C, Roodeberg Dam in T32B and Mountain Dam in T33A are the three largest dams in the catchment and have capacities of just over 1 million m^3 (Midgley, Pitman and Middleton 1990). The Bon Accord, Hopewell and Poortije dams are also significant surface water bodies in terms of their capacity (**Figure 6**). There therefore remains a significant potential for water source development.

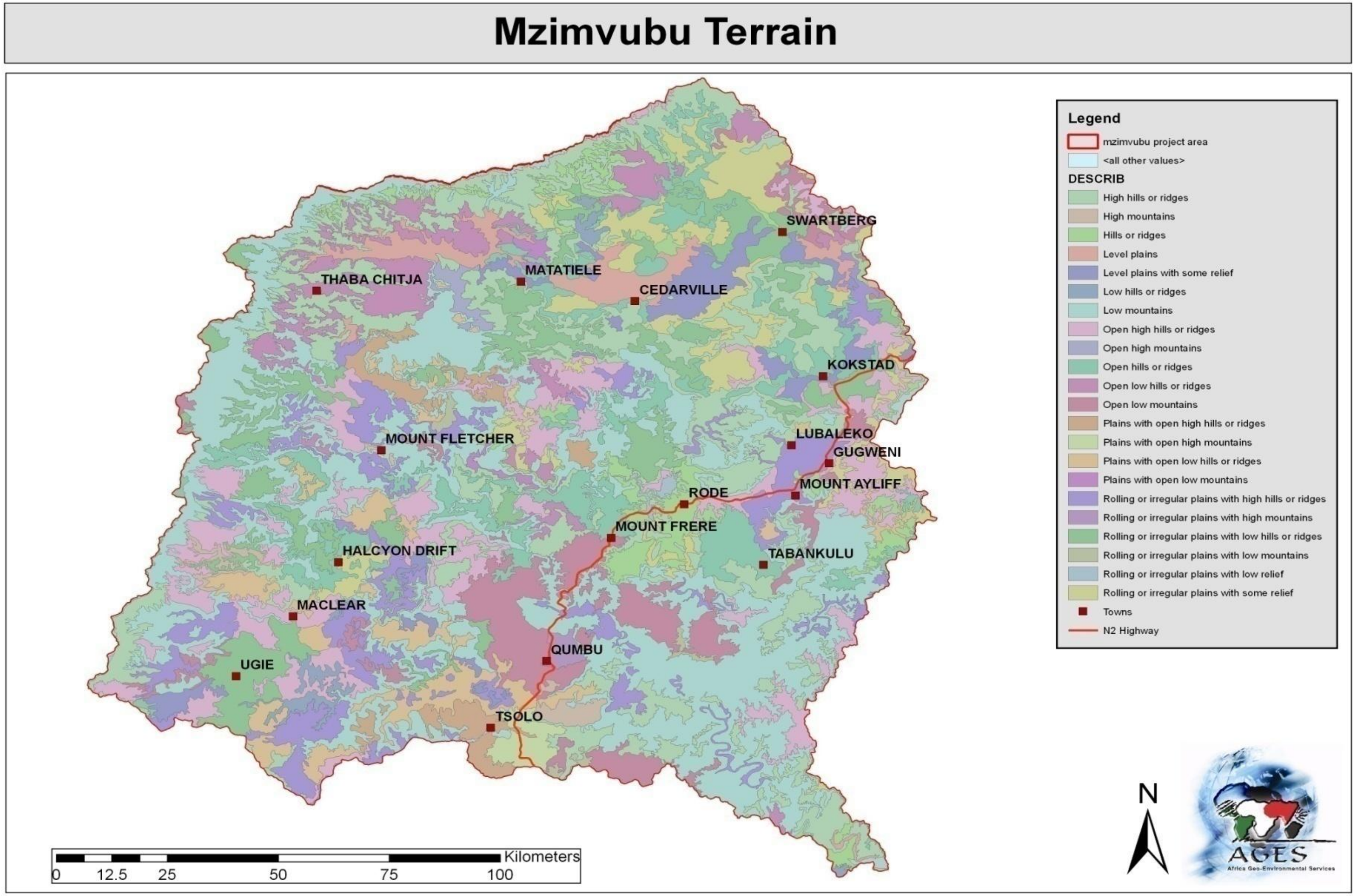


Figure 4 Mzimvubu River catchment terrain

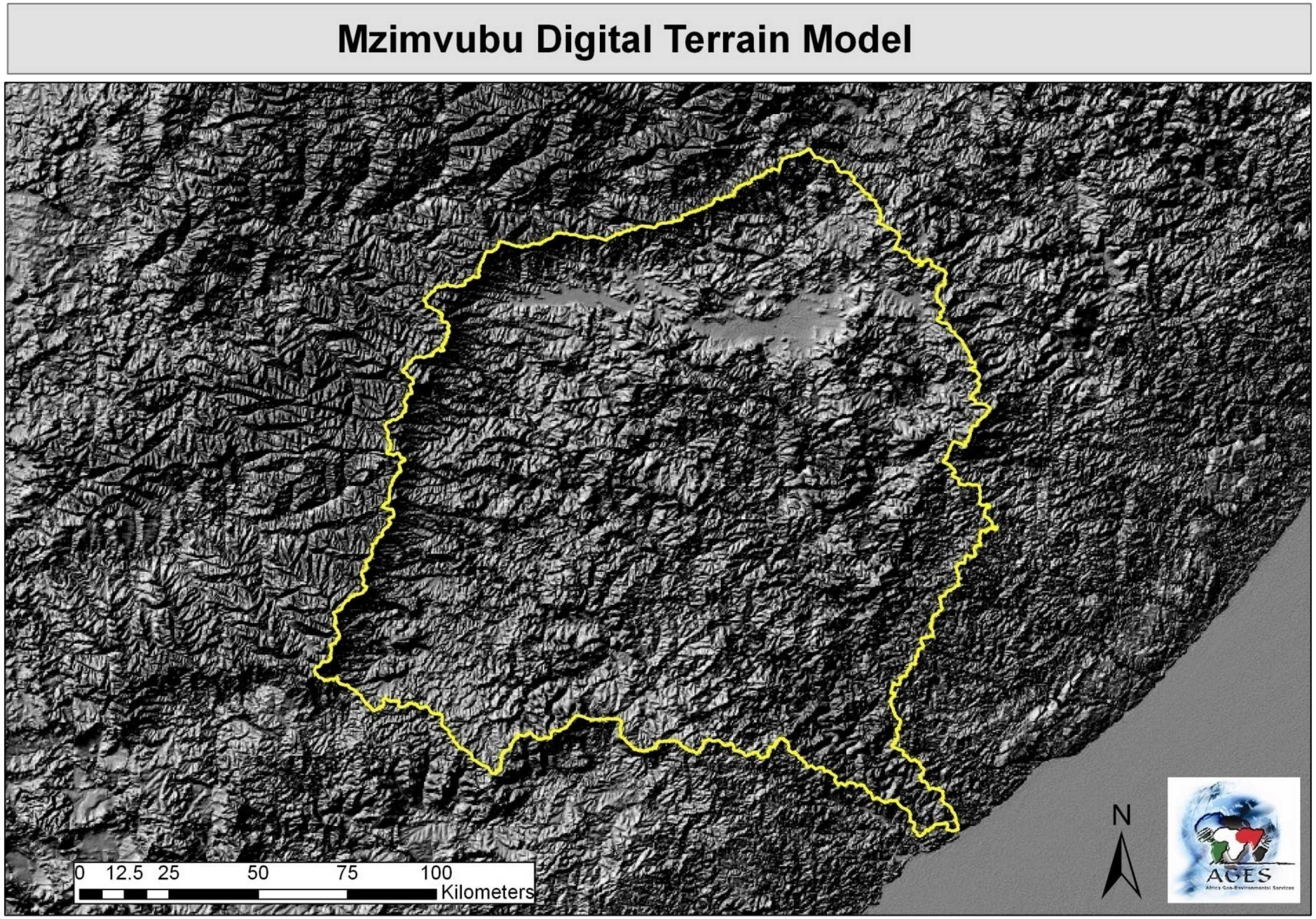


Figure 5 **Mzimvubu River catchment digital terrain model (CSIR)**

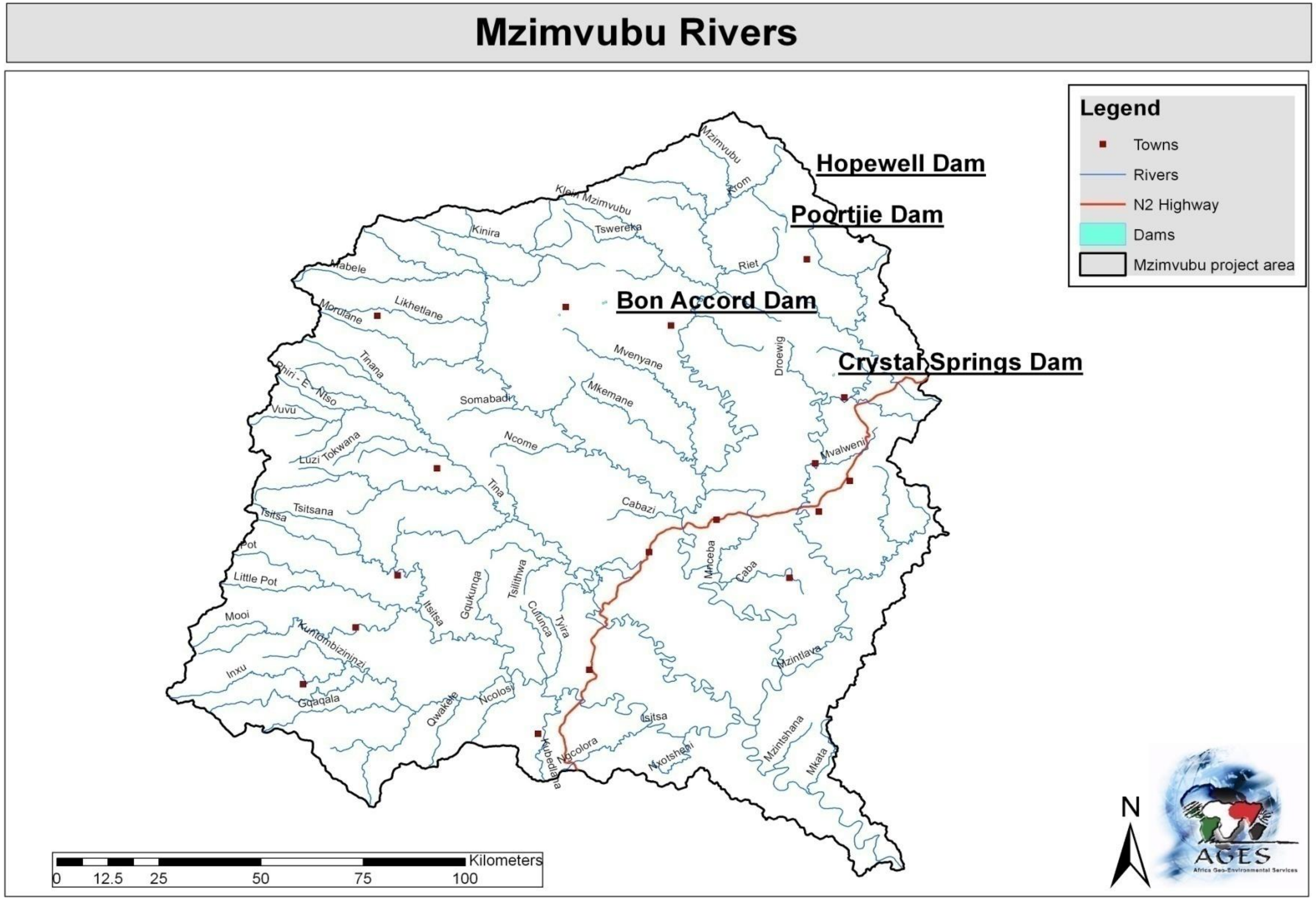


Figure 6 **Mzimvubu River catchment: Rivers and dams**

3.4 CLIMATE

The climate and temperature variations in the Mzimvubu River basin are closely related to elevation and proximity to the coast. The basin has a mild, temperate climate along the coast to more extreme conditions occurring inland. In general, rainfall increases from the west to the east and from inland to the coast with a mix of some local troughs and peaks in between. The mean annual precipitation (MAP) along the coast is 1 224 mm, 685 mm in the centre of the basin and 820 mm along the portions of the escarpment[1]. Most of the rainfall occurs during the summer months (November-March) with the peak of the rainy season in January. There is less variance in the mean annual evaporation (MAE) as it tends to increase slightly from the east to the west and from the coast to the interior. The MAE is 1 573 mm and highest during the summer months (October-January), peaking in December with an average of 183 mm[2].

3.5 GEOLOGY

In general the geology of the study area represents a layered stratigraphical sequence of Karoo Supergroup formations from the Lesotho highlands in the northwest, to Port St Johns in the southeast along the coast at the Mzimvubu River mouth. The regional geology is indicated in **Map 1** in **Appendix A**.

Alluvium associated with the tributaries of the Mzimvubu River occurs in small quantities along valleys with the exception of a large accumulation of alluvium found to the north and north west of Cedarville in quaternary catchments T31F and T31D as well as alluvium associated with the Mabele River in quaternary catchments T33A and T33B. These open flat valleys in the northern central part of the catchment, can also clearly be seen in the digital terrain model presented in Figure 5. Along the north, northwest and western Mzimvubu River secondary catchment boundary, deposition of basaltic lava with subordinate tuff and conglomerate is found originating from extensive magma intrusion and lava flows that occurred during the early stages of the break-up of Gondwanaland in the Mid-Jurassic time period. The basaltic lava constitutes the uppermost part of the Karoo stratigraphical sequence in the study area.

Figure 7 gives a graphical representation of the sequence of formations as they occur in the study area. The Mzimvubu River catchment is unique in the sense that the full stratigraphical sequence is represented from the mountains in the north-west towards sea-level in the south-east.

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1 Rainfall data was sourced from DWAF – Water Resource Information System from weather stations 0178881W, 0129068W and 0177552W

2 Evaporation data was sourced for station 01807526 in Kokstad

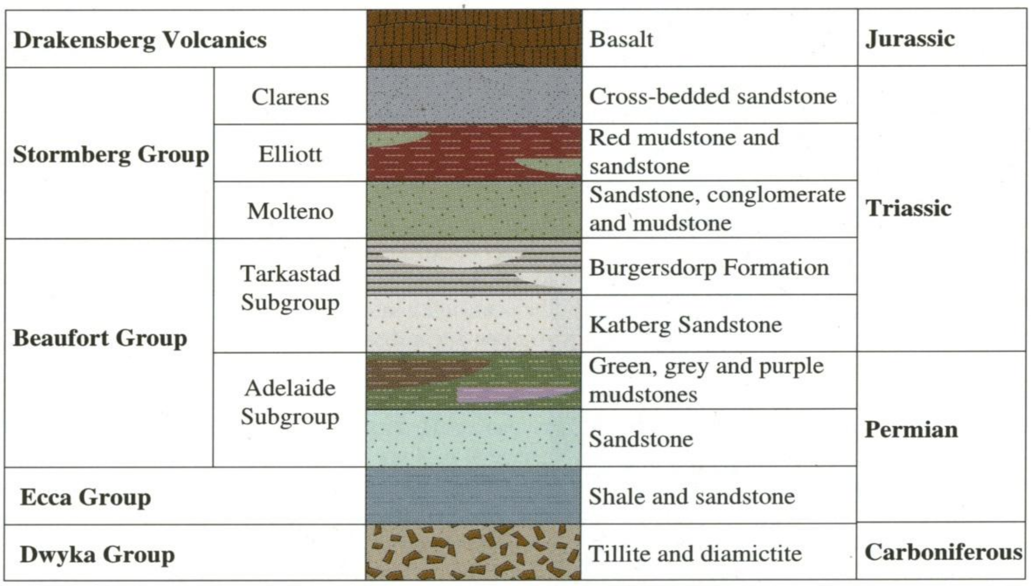


Figure 3–1 The Karoo Supergroup. [Adapted from Tankard *et al.* (1982).]

Figure 7 Karoo Supergroup stratigraphy. Tankard (1982)

Underlying the basaltic lava's, moving southeast from the Lesotho mountains, a small portion of the surface area of the Mzimvubu River catchment is underlain by the Clarens formation consisting of pale orange to pink fine-grained sandstone. Further southeast and below the Clarens formation, the study area is underlain by the Elliot formation constituted by brownish-red and grey mudstone-sandstone. This is underlain by the Molteno formation, consisting of grey mudstone, shale, gritty sandstone and occasional coal seams. Below the Molteno formation lies the Burgersdorp and Katberg formations belonging to the Tarkastad subgroup of the Beaufort group. The Burgersdorp formation consists of brownish-red and grey mudstone sandstone, while the Katberg formation consists predominantly of sandstone with subordinate brownish-red and grey mudstone. The Tarkastad subgroup can be found in the central part of the study area.

Continuing southeast and underlying the Tarkastad subgroup is the undifferentiated Adelaide subgroup with grey and brownish-red mudstone and subordinate sandstone. Although the subdivision of the Adelaide subgroup has not been mapped east of 28° longitude, the Middleton formation has been identified as far east as Mount Ailiff. A thickness of 1 650 m is estimated for the Adelaide subgroup near 31° latitude (GSSA, 1983). The Adelaide subgroup rests conformably on the Ecca Group, which in the project area consists of dark-grey shale with subordinate mudstone and sandstone. In the southeast the project area is underlain to a smaller extent by the Dwyka group consisting of Tillite and near Port St John's, at the Mzimvubu River mouth, a small part of the catchment area is underlain by Natal Group light grey quartzitic sandstone.

Throughout the project area hypabassal dolerite intruded into the host Karoo sedimentary rock during Jurassic time periods, creating dykes (vertical structures), sills (horizontal structures) and large sheets. The dolerite in the project area is associated with the same volcanic event that formed the Basaltic lava on the northeast boundary of the Mzimvubu River catchment. There are a great number of dyke intrusions across the whole of the study area with a predominantly west-northwest, east-southeast strike. **Map 1** in **Appendix A**.

Figure 8 graphically represents different styles of dolerite intrusion throughout the upper part of the Karoo sequence as it occurs in the Mzimvubu River catchment. Special reference is made to the type of dolerite intrusion in the Beaufort Group of the Karoo Sequence where dolerite intrusion in the form of conical sub-vertical sheets have resulted in numerous dolerite intrusions that can be seen in Map 1 as circular intrusions popularly referred to as ring-structures. These structures are most prominent around the towns of Qumbu and Tsolo and to the north in the vicinity of Matatiele and Cederville.

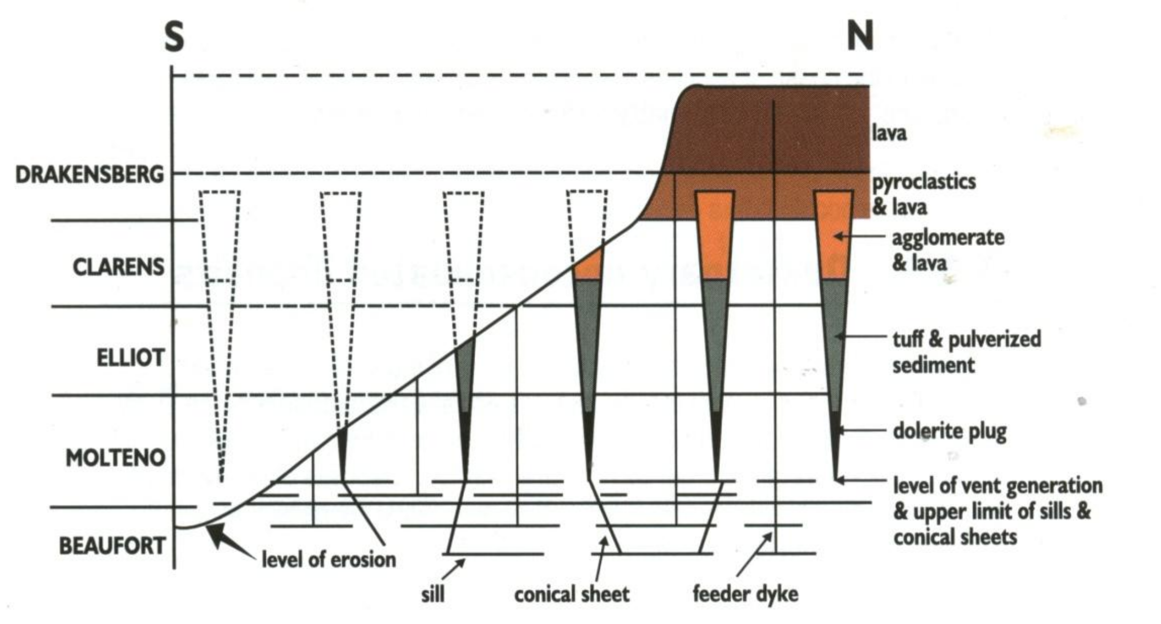


Figure 8 Different styles of dolerite intrusion associated with different stratigraphical elevations in the Karoo Supergroup. (Smart, 1998)

In the project area three main categories of dolerite intrusion are recognized, namely vertical dykes, sills and sheets of varying inclination and curvature, (see Map 1). Dolerite sheets, which approximately conform to bedding dip, are termed sills. Dolerite dykes of the study area usually range between 1 and 10 m wide and can be tens of kilometres long. Their orientations vary but with a WNW strike direction being more prominent over much of the area. ENE as well as NS trending dykes are also common. Sills and sheets are usually between a few meters and 100 m thick, but can be well in excess of this in some instances.

The following types of intrusion are found in the different formations in the study area:

Adelaide subgroup	-	Dykes and sills
Katberg formation	-	Dykes and sheets
Burgersdorp formation	-	Dykes, ringsheets and sheets
Molteno formation	-	Mainly dykes

Sills in the Karoo formations are sheetlike forms of dolerite intrusions that tend to follow the bedding planes of the formations concordantly. These structures, whose thickness vary from less than a metre to hundreds of metres, represent the dominant form in which dolerite is emplaced in the Karoo Supergroup It is thus important to know how the sills were emplaced and how they may influence the geohydrology of the Karoo Supergroup.

It is generally assumed that linear dolerite dyke intrusions must be younger than the ring dykes and sills and evidence exists where dykes cut the latter structures. The linear dykes are also usually thinner than ring dykes and are confined to the Ecca and Beaufort Groups. There is indication that the magmatic activity at the time the linear dykes intruded, was less than when the ring dykes and sills intruded.

The insight into the intrusion of linear dykes is fairly limited at the moment. It is however known that linear dykes are usually associated with linear conduits that feed magma to the earth’s surface.

The baking and metamorphosing of the host rocks were not the only effects that the intrusion of dolerites had on the Karoo sediments. Other effects, particularly mechanical deformation, may also have influenced the geohydrological properties of the rocks. This may be a further indication that the dykes intruded by matrix melting. Observations have shown that the intrusion of dolerites caused two types of bending in the host rocks of the Karoo formations. The first type is where the surrounding rocks were bended concavely by an intruding linear dyke. It is not difficult to see that this type of bending was caused by frictional forces that existed between the dolerite and the surrounding rock. The bending is consequently usually restricted to relatively small distances (20 m) on both sides of the dyke. This type of bending, nevertheless, can fracture the host rock considerably near the dyke.

The second type of bending that can be observed quite often in the Karoo formations is where the host rock was bended in the form of an arch. A preliminary attempt to explain this type of bending quantitatively, has shown that the simplest explanation is to assume that the dolerite intruded as a laccolith. Laccolithic intrusions will cause two sets of fractures in the overburden – one that opens downwards and the other that opens upwards. The fractures that open upwards should be free from dolerite, and thus form receptacles for groundwater unless closed later by other processes. Such areas will clearly be ideal recharge areas, or even form aquifers on their own if they did not develop too deeply within the earth's surface. Rocks bended by laccoliths can therefore play a prominent role in the geohydrological behaviour of aquifers. Due to the horizontally layered nature of Karoo formations, the assumption can be made that the multiple layers in the overburden will slide across one another during the intrusion of a laccolith. The Karoo formations are highly stratified with alternating layers of partially bonded sandstones, mudstones, siltstones and shales, each with its own elastic modulus. It will therefore be difficult for the layers to simply slide across one another, without weakening or fracturing their contact planes when displaced by a laccolith. The intrusion of laccoliths may thus have been responsible, or at least have contributed, to the existence of another major feature of Karoo formations bedding parallel fractures, (AGES, *Mhlontlo Feasibility Study*, 2002).

3.6 HYDROGEOLOGY

Groundwater potential assessments and aquifer types occurring in the study area must be viewed in the light of the type of dolerite intrusion, as well as the geological formation present. This needs to be combined with a future regional water balance and groundwater reserve figures before groundwater availability and potential can be accurately defined.

The presence of abundant dykes and sheets indicate that significant regional structural disturbances must have taken place during intrusions. It is however expected that drilling of boreholes associated with dolerite intrusions in the Burgersdorp formation in the Qumbu area will be lower yielding than boreholes drilled in the same formation towards the west in the Queenstown area. Yields exceeding 3 ℓ/s are seldom found. Clay products from intense weathering can cause reduced fracture transmissivities at shallow depths, (AGES, 2002).

Dykes are generally long and abundant in the study area. This correlation could indicate that the abundance and length of dyke intrusions reflect the degree of associated structural disturbance and fracturing which could result in higher borehole yields. Assuming the study area is subject to regional compression from the south-east, dykes with a north-west trend will be in tension and associated fractures more open as a result. This could predict high potential in areas where this trend is more prominent.

The 1:500 000 DWAF hydrogeological maps describe the groundwater potential and character of the study area based on the geological formations found. Areas underlain by the Tarkastad sub-group are described as predominantly argillaceous while the Katberg and Molteno formations are described as argillaceous and arenaceous in approximately equal proportions. All lithologies underlying the study area are described as having groundwater occurring intergranular and in fracture zones, with predominantly fractured aquifers to be found associated with the small section of Natal Group sedimentary rocks near the Mzimvubu River mouth. The expected median of the borehole yield class is described as 0.5 ℓ/s to 2 ℓ/s although occasional higher yielding boreholes can be expected in ideally sited locations. Median borehole yields in Quaternary alluvium deposits in the Cedarville and Matatiele region, is known to be between 2 ℓ/s and 5 ℓ/s.

For the bulk of the study area groundwater occurs in dual porosity aquifers, comprising large, but infrequent principle transmissive fractures with relatively low storage capacity, and secondary but numerous microfissures with high storativity but lower transmissivity. The microfissures are usually concentrated towards the surface (usually first 30 m) and results in a higher storage capacity than deeper lying rocks. The upper and lower zones are hydraulically linked. The deeper fractures often have a high transmissivity but lower storativity than the shallow zone fractures.

The following groundwater occurrences can be described for the study area:

- Aquifers associated with dolerite intrusion;
- Aquifers associated with fracturing unrelated to dolerite intrusion; and
- Intergranular aquifers.

Static groundwater levels range from being very close (1 to 2 m) to the surface to approximately 50 m below surface throughout the study area.

Groundwater quality data is insufficient, by far to delineate potential based on expected water classes. The 1:500 000 hydrogeological maps and descriptions of the area describe the groundwater as a Calcium Magnesium Bicarbonate water with sodium enrichment which is most prevalent in the Burgersdorp formation in the study area. These waters are indicative of active groundwater circulation with sodium and chloride enrichment occurring through ionic exchange in the groundwater flow paths. Groundwater conductivities (EC) are expected to generally range between 70 and 300 mS/m in the study area, while higher EC values (higher than 1 000 mS/m) have been noted in faulted Dwyka and Natal Group sandstone and also possibly alluvium associated with the Mzimvubu River near the river mouth at Port St Johns.

4 RESULTS

4.1 PREVIOUS STUDIES

4.1.1 Lusikisiki Groundwater Feasibility Study (SRK Consulting, 2007)

SRK Consulting was appointed by the Department of Water Affairs and Forestry to investigate the potential for groundwater as a supplementary water source for rural villages in the vicinity of the town of Lusikisiki, located directly north east of the Mzimvubu River catchment.

The study area included the town of Lusikisiki, and stretched from Port St Johns in the south to the Mkambati nature reserve in the northeast. The methodology included:

- Desk study;
- Hydrocensus;
- Target area selection;
- Geophysical exploration;
- Borehole Drilling; and
- Aquifer testing.

From the above information, the groundwater potential of the area was described in terms of the groundwater exploration potential (GEP – refers to the ease of drilling a successful borehole) and the groundwater development potential (GDP – refers to the possibility of finding a sustainable groundwater source). The GEP focuses on the available structures and geological targets, while the latter also takes into account aspects such as recharge (calculated from rainfall and topography). (SRK, 2007).

A set of groundwater potential maps were generated with the following main conclusions reached based on results of the study:

- The Natal Group Sandstone was considered to have the highest groundwater potential, but drilling should still be concentrated on dolerite dykes, faults and major lineaments. High yielding boreholes in excess of 10 ℓ/s can be expected where dykes are targeted, but lower yields (< 2 ℓ/s) can also be encountered where only lineaments are drilled;
- The Dwyka Group formations were considered to have the second highest groundwater potential and again high borehole yields in excess of 5 ℓ/s can be expected where dolerite dykes are targeted; and
- The Ecca Group was considered to have the lowest groundwater potential and is also the most difficult to investigate because of the presence of dolerite sheets. The sheets cover the Ecca Group area and make groundwater exploration extremely difficult.

The NGS and the Dwyka Group were therefore considered as areas of high groundwater potential and can be targeted for future groundwater exploration projects. (SRK, 2007).

These formations only cover a very small percentage of the study area near the Mzimvubu River mouth and Port St Johns, where elevated EC values predict marginal to poor water quality which influences groundwater potential.

The assessment of the potential targets for future drilling were done on the basis of establishing moderate to high yielding boreholes that can be used as part of a comprehensive water supply scheme and not as part of individual village water supply. Based on the results of the Lusikisiki Groundwater Feasibility Study, the following target areas were considered the most significant:

- Dolerite dykes occurring in the Natal Group Sandstone, Dwyka Group formations and to a lesser extend, the Ecca Group; and
- Lineaments proved successful in the Dwyka Group and to a lesser extent the NGS.

Based on the results of the investigation, the following targets did not yield any significant results:

- Dolerite sheets (shallow dipping to horizontal) in the Ecca Group; and
- Small-scale lineaments in the NGS (SRK, 2007).

4.1.2 Mthatha River Basin Study (FST Consulting Engineers, 2001)

To initiate the participation process that must underpin the establishment of a Catchment Management Agency, DWAF: Eastern Cape Region started in 1999 with a process for the development of the Mthatha Catchment Management Strategy (MCMS) for the water resources of the Mthatha River catchment. Part of this process included the need to establish a Catchment Management Forum representing stakeholders in the catchment with a view of involving them in the development of the MCMS. Numerous meetings were held since its inception in April 2001 (Smit, 2003).

The Mthatha River catchment is one of the many catchments making up the Mzimvubu to Keiskamma Water Management Area (12). The catchment is made up of three secondary catchments and covers a total area of approximately 5 500 km². These are the Mtata River catchment represented by the area marked T20 in **Figure 9**, the Mngazi River catchment known as T70 and the Xora River catchment known as T80 (Smit, 2003).

This report dealt with the geology and geohydrology of the Mthatha River Basin, as described in a Inception Report that was presented in August 1999. The scope of work for both the geology and geohydrology consisted of remote studies comprising desktop investigation plus the use of air photo interpretation and backed by the most recent geological and geohydrological publications. Fieldwork was limited as a result of budgetary constraints. The information provided, albeit limited, was nonetheless an important overview of both the geology and geohydrology of the Basin.

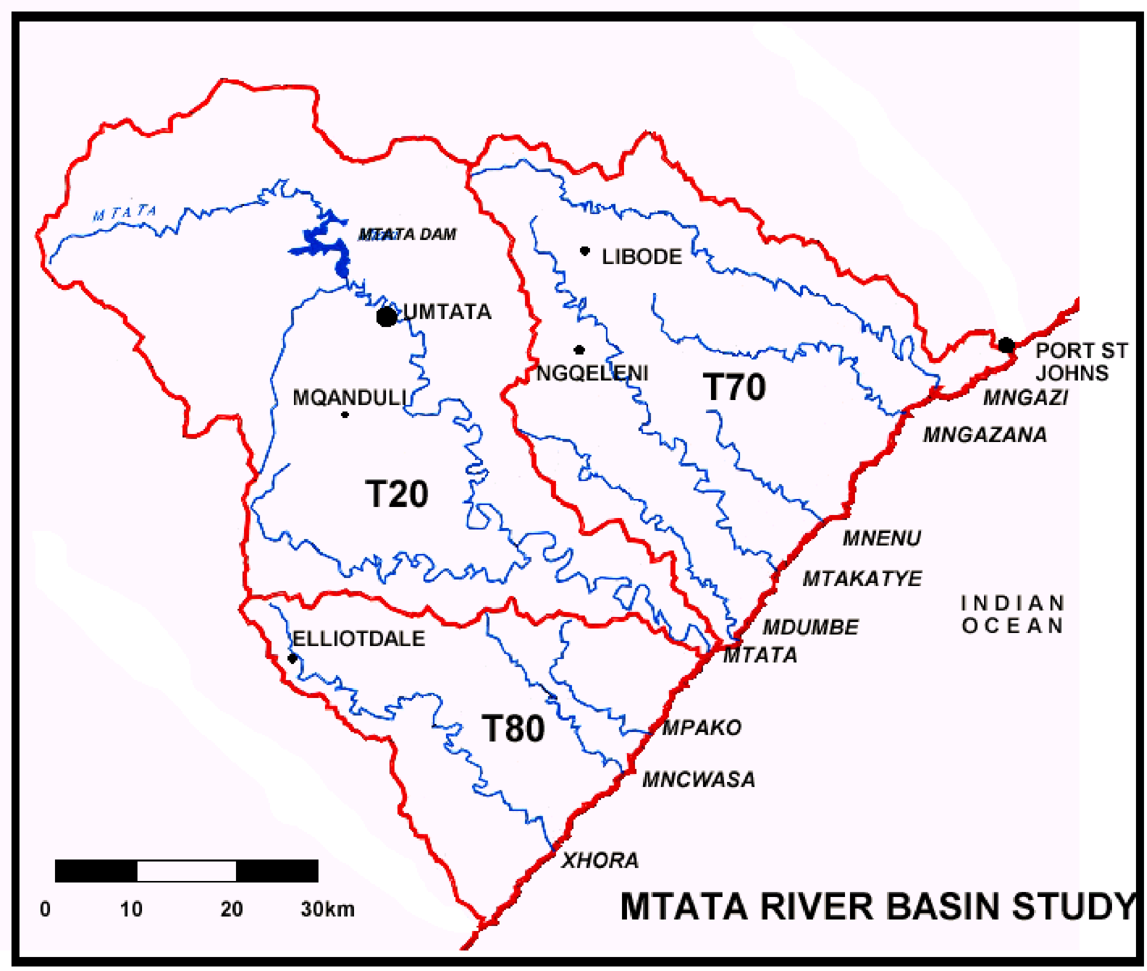


Figure 9 Mthatha River catchment study boundary

Sedimentary strata belonging to the Karoo Sequence and the Cretaceous System underlie the area covered by the Mtata River Basin. The Karoo Sequence comprises the Dwyka Formation, the Ecca Group, the Beaufort Group and the Molteno Formation. Cretaceous rocks occupy very small areas and are represented by the Mgazana Formation (conglomerates with fossiliferous lenses). Dykes and sills of dolerite have intruded all the pre-Cretaceous strata. Quaternary alluvium and sand cover the older rocks in places. Structurally, the geological strata comprise a gently dipping inland area and a more complicated coastal strip with a number of prominent faults. The only potential economic deposits in the Transkei area are dimension stone, copper and nickel, coal and heavy-mineral sands. None of these is being exploited at present (FST Consulting Engineers, 2007).

Structurally, the area can be divided into a gently dipping inland area with few major faults, and a coastal area with numerous faults striking east-west near the coast and then curving north-east to south-west inland. Downthrows to the east and south result in strata dips of 200 or more. Information for 123 boreholes recorded on the fifteen 1:50 000 topographic map sheets covering the catchments was obtained from the National Groundwater Data Base (NGDB) of the Department of Water Affairs and Forestry (DWAF). Information for the position of a further 177 boreholes was obtained from the Directorate Water Services Macro Planning and Information Systems Data Base (PISDB). It was noted that 30 boreholes (24% of the total records) were drilled to a depth of less than 60 m (FST Consulting Engineers, 2007).

The Mthatha River basin is typified by secondary aquifers, i.e. aquifers developed within secondary features associated with weathering, jointing, and fracturing of the Karoo rocks. The fractured dyke and sill contacts are of particular importance to groundwater occurrence in this area since they represent zones where secondary porosity and permeability are often well developed over extensive areas compared to the host rock (FST Consulting Engineers, 2007).

Primary aquifers, associated with unconsolidated deposits, are absent with the possible exception of a small-localized area of alluvium at the mouth of the Mthatha River.(FST Consulting Engineers, 2007).

Secondary aquifer characterization was described as follows in the report:

- The Dwyka Group formation is a poor aquifer due to the low permeability associated with its fine grained, compact and massive nature. Failure in this formation is greater than 50% and where successful, the yields amount to less than 0,7 ℓ/s.
- In the Ecca Group the average yield is 0,8 ℓ/s with a failure rate of 45%. The high failure rate is considered to be the result of unscientific siting. More recent work indicates blow yields in excess of 10 ℓ/s. Investigations indicate that the best yields are on sandstone/shale contacts and in the brecciated contact zones alongside dolerite sills and dykes. All aquifers are confined and the groundwater is often brackish, particularly along the coast.
- The Beaufort Group occupies 59% of the study area, and of this 37% is arenaceous (mostly sandstone) and 63% is argillaceous (FST Consulting Engineers, 2007).

The average yield of boreholes (75% in the Ecca and 8% in the Dwyka) is 0,5 ℓ/s with 18% exceeding 1,1 ℓ/s. The average failure rate is 36% with the most favourable aquifers found to be associated with the Tarkastad Subgroup. The average borehole depth is 60 m to 70 m. Best water strike occurrences were in the Ecca Group. All aquifers are confined and the water quality is mostly suitable for human consumption. Development potential is described as moderately good to locally poor (FST Consulting Engineers, 2007)

According to the published 1:500 000 Hydrogeological Map of Queenstown 3126, groundwater occurrence throughout the catchment comprises intergranular storage within the near surface weathered horizon, with deeper fractured flow. The groundwater rest level or piezometric surface is usually within the weathered horizon. Yields of boreholes are reported to average between 0,5 – 2 ℓ/s throughout the area (FST Consulting Engineers, 2007).

Records of borehole water levels seem to indicate values ranging from 6 m to 49 m (average 20 m) in the Tarkastad Subgroup and less than 10 m in the Adelaide Subgroup. In each case the static water level is above the strike level thereby confirming that the aquifers are confined. It may be speculated that regionally, the groundwater flow direction will follow the topography and flow will be from west to east towards the coast. It is also speculated that locally groundwater flow will be towards the drainages, and that groundwater flow forms an important component to base flow in rivers. Once a hydro census has been undertaken and reliable water level data are available, the groundwater flow directions, hydraulic gradients and impact/contribution to the surface water regime will be known in greater detail (FST Consulting Engineers, 2007).

It is generally accepted that the ground water recharge can be estimated as being between 2% and 5% of average annual precipitation. This would amount to an annual global groundwater recharge for the study area of 90 to 245 million m^3/a, a substantial amount of potentially exploitable groundwater, a portion of which contributes to base flow in the rivers (FST Consulting Engineers, 2007).

It was stated in the report that from simplistic calculation, albeit in the absence of confirmatory fieldwork, that groundwater resources could make a valuable contribution to the water supply needs of the catchment. The current status of groundwater exploitation is, however, unknown and would have to be confirmed by a hydro-census. The desk study and photo geological interpretation has confirmed that the groundwater resources of the Mthatha River Basin are sufficiently widespread to be able to play an important role for future water supply development. A careful development strategy is required which must consider the following:

- The application of sound scientific methods to site boreholes;
- Use of rotary air percussion boreholes drilled under the supervision of a qualified scientist and constructed in accordance with the latest technical specifications;
- Quantification of all aquifers to ensure sustainability; and
- Long-term monitoring (FST Consulting Engineers, 2007).

The report concluded that water supply schemes of various sizes can be supported as follows:

- Primary point-source supply is feasible throughout the study area;
- Small reticulation schemes from boreholes producing in excess of 3 ℓ/s for villages of up to 3 000 people; and
- Medium reticulation schemes in areas where groundwater development potential is moderate or high i.e. up to 10 ℓ/s for basic supply to 10 000 people.

The report further concluded with the recommendation that the findings of the study be confirmed, updated, quantified and given more substance by undertaking the following investigations:

- Carrying out of a hydrocensus to confirm the existing level of groundwater use and to identify areas of over and under utilization of available groundwater resources;
- Carrying out of a groundwater sampling programme to provide a spread of quality data throughout the catchment;
- Drilling of exploratory boreholes to obtain high quality geological and hydrogeological data; and
- Controlled pumping tests on key boreholes to obtain hydraulic parameters to assist in the identification and management of the various aquifers.

It was stated that only when such data are available can the preliminary findings as discussed in the report be confirmed, the groundwater resources quanitified and development and management strategies properly planned (FST Consulting Engineers, 2007).

4.2 PROJECT INCEPTION REPORT – AGES-BKS (2008)

4.2.1 Inception Phase - Background

As part of the Inception phase it was stated that the water resources of the Mzimvubu River catchment need to be considered during the investigation of the various proposed development options and depending on the impact of the development; the present state of the water resource; the ecological sensitivity and the importance of the water resources to determine the level of Reserve determination are as follows: BKS, (2008)

- Rivers (main stem and tributaries) - all developments, but especially large dam developments should consider the ecological Reserve on a Comprehensive level of detail. Results from previous Rapid III level studies could be utilised as an initial estimate of the Reserve;
- Estuary - the Mzimvubu River estuary is still in a fairly natural state due to limited dam developments in the catchment. Large dams and changes to the flow regime of the river will have an impact on this state, especially due to no or fewer floods entering the estuary, thus the estuary should be considered on a Comprehensive level of detail. No previous studies have been conducted on the estuary;
- Groundwater - large-scale afforestation development could impact negatively on the groundwater contribution to surface flow, thus impacting on the low flows in the rivers and wetlands. The groundwater component should be investigated on an intermediate level of detail, especially in areas where afforestation is planned. Only *ad hoc*, low confidence groundwater Reserve determinations have been conducted for the Mzimvubu River catchment; and

- Wetlands - developments could impact on the functioning of wetlands or lead to the destruction of wetlands. The wetlands should thus be assessed on a desktop level as to their distribution, health, function, importance, sensitivity and present state. The priority wetlands where development will impact should be identified for which the Reserve should be determined at a higher level of detail (BKS, 2008).

4.2.2 Inception Phase - Groundwater component

The following was reported as part of the groundwater component of the Inception phase of the project. This was based on the initial planning to render quaternary-based groundwater Reserve figures for detailed groundwater potential assessments. It is included in this report for reference in future implementation phases of the *Mzimvubu River Catchment Development Study*.

The evaluation of groundwater resource availability requires an initial baseline assessment of the use, aquifer distribution and the location of groundwater recharge zones, as well as potential contamination sources. The baseline information will be used to evaluate the groundwater potential of the catchment as well as management units on the basis of their geology and geohydrology. This study will involve an assessment of aquifer potential and further field inspections where the information warrants it. The end product will include an assessment of available data and literature on the groundwater potential in the catchment and the distribution of groundwater use and potential contamination sources. From this information, an assessment will be made of the current groundwater balance at a quaternary-catchment level using an analytical, spreadsheet-based model. The identification of major aquifer zones or stressed areas will be one of the important outputs of the study (BKS, 2008).

Africa Geo-Environmental Services (Pty) Ltd (AGES) would primarily be responsible for executing the bulk of this task with appropriate interaction with some of the other study team members. Both BKS and FST have worked closely with AGES in other study areas, including the Olifants River and the Crocodile (West) River catchments.

Koos Vivier from AGES was the task leader for the groundwater task. Site related inputs and data sourcing, as well as meetings and sessions in the Eastern Cape, were done by local staff of the AGES office in East London. Jan Myburgh was in charge of the East London team.

The task team has commenced with data sourcing and have obtained the following information:

- Historical data from numerous local groundwater development and sanitation projects;
- Data from the EC GRIP programme – AGES is currently active at several towns in the study area;

- Mthatha River Basin Study ;
- Lusikisiki Feasibility Study;
- Rainfall data; and
- Satellite images –DWAF needs to submit letter of appointments in order to obtain the data

Task 8.1: Data gathering

Resource Units are characterised, and levels of confidence defined, based on the GRDM principles. Special attention must be given to gaps in information in priority and high confidence level Resource Units. Additional information requiring specialist studies would be defined and implemented in coordination with the team and client (BKS, 2008).

The following information is seen as necessary for the groundwater component of the Reserve determination and catchment development study:

- Current groundwater usage;
- Historical rainfall data;
- Status of General Authorisation levels;
- National Groundwater Database data from the NGDB dataset and local DWAF office;
- GIS spatial data;
- Hydrosensus data from GRIP EC programme to be obtained;
- Water Use License information applicable to groundwater sources for the Mzimvubu River catchment (Registrations, Authorisations, Water Users Associations);
- Municipality Water Supply Schemes (Information and contact details) for the catchments;
- Data and information from DWAF research drilling and pump-testing programmes. Lusikisiki study and Umtata River catchment study;
- Pending applications as per WARMS;
- Land use and type distribution clarification;
- Department of Agriculture and DWAF information pertaining to agricultural activity, land use potential and planned redistribution and agricultural schemes and forestry;
- Surface / groundwater interaction quantification through workshops with team;
- Groundwater dependant ecosystem identification and quantification.

Task 8. 2: Classification of groundwater sub-units

The main aim of classification of groundwater resources is to assess its current status in relation to its natural state (reference conditions) and define the future desired state. According to the GRDM manual, a number of factors can be included in assessing the current use. These include recharge, groundwater use and contamination or expected contamination status. The sustainability of groundwater resources and current stress levels will be determined by the deviation from the reference conditions and the current status of the water resource. In classifying the water resources, approaches followed on other recent DWAF Reserve determination projects will be followed. The suggested process of Resource Classification will include but will not be limited to the following:

- Delineate area;
- Delineate Resource Units;
- Determine current water use;
- Determine strategic water use;
- Delineate areas of common groundwater use;
- Indicate the level of importance of various uses, ascribed by the stakeholders;
- Delineate areas of multiple groundwater use;
- Identify conflicting and non-conflicting multiple uses;
- Describe the reference conditions of the Resource Units;
- Describe the present status of preliminary groundwater Resource Units;
- Indicate the vulnerability of the Resource Units with respect to:
    - Ecological dependency
    - Inherent contamination vulnerability
    - Inherent drought vulnerability
    - Over-exploitation risk
    - Current degree of impact
- Assign a Present Ecological Status Category (PESC);
- Describe the desired groundwater status;
- Assign a Desired Ecological Status Category (DESC); and
- Map DESC to Ecological class – Natural, Good, Fair.

The above classification system takes into account the present ecological state and the desired ecological state and these are integrated to management class.

The delineation of resource units will be based on eco-regions, i.e. areas of similar physical (similar geologic, vegetation or hydrological characteristics) and ecological properties. Areas of groundwater dependence will also be considered. Since the National Water Act deals with water resources as unitary body (water cycle), the assessment of interdependency of other components of the water cycle, e.g. wetlands and rivers, will also be undertaken (BKS, 2008).

Task 8.3: Groundwater Reserve: Quality and quantity

AGES has developed a model termed the Regional Groundwater Flow Balance Model (RGFB) that can be used to determine the groundwater balances on a number of quaternary catchments while accounting for variable recharge from rainfall. The variability in rainfall and hence recharge was identified as one of the factors that influence sustainability of groundwater supply, that cannot be managed.

The purpose of the model is to simulate groundwater flow balances on a quaternary sub-catchment scale on monthly time steps. The output should provide statistical changes in groundwater volume based on rainfall recharge variations, which yields assurance levels for groundwater volume calculations.

The model was developed to simulate each catchment as a cell. Inflow and outflow components are calculated that must balance between time steps. The model was applied by AGES with success in the *Crocodile River West Catchment Study*.

The analytical model is a differentiation of the steady-state, basic case. Distinction is made between natural and unnatural inflow and outflow components. Also between outflow components that are lost (e.g. evapotranspiration by alien vegetation) and outflow components where groundwater is used (e.g. basic human need Reserve). Groundwater Loss Components (GLC) are less valuable than Groundwater Use Components (GUC). This is due to the fact that it is more sensible to use groundwater for basic human need purposes than to lose it to alien vegetation. Hence if one has the option to prioritise outflow, all outflow components are not considered of the same importance level.

It is the purpose of the model to calculate the volume of groundwater in storage given that the volume of water required by natural systems is allocated for.

The various groundwater flow components are described by the following:

1. **The groundwater inflow from natural systems ($+Q_{GINS}$).**

$+Q_R$ = Recharge from rainfall $[L.T^{-1}]$

2. **The groundwater inflow from unnatural systems ($+Q_{GIUNS}$).**

$+Q_{DS}$ = Inflow from Dam Seepages $[L.T^{-1}]$

$+Q_{IRR}$ = Return recharge from irrigation $[L.T^{-1}]$

3. Groundwater loss components ($-Q_{GLC}$).

$-Q_{AVEG}$	=	Alien vegetation	$[L.T^{-1}]$
$-Q_{EVAP}$	=	Evaporation losses	$[L.T^{-1}]$
$-Q_{MDW}$	=	Mine dewatering	$[L.T^{-1}]$

4. Groundwater use by natural systems ($-Q_{GUNS}$)

$-Q_{SF}$	=	Spring flow	$[L.T^{-1}]$
$-Q_{BF}$	=	Base flow	$[L.T^{-1}]$
$-Q_{WLD}$	=	Wetland fed by groundwater	$[L.T^{-1}]$
$-Q_{RVEG}$	=	Riparian vegetation	$[L.T^{-1}]$

5. Groundwater use by unnatural systems ($+Q_{GUUNS}$)

$-Q_{BH}$	=	Abstraction from boreholes	$[L.T^{-1}]$
$-Q_{BHN}$	=	Allocation for basic human needs and communities	$[L.T^{-1}]$
$-Q_{IR}$	=	Abstraction for irrigation	$[L.T^{-1}]$

6. Volume of groundwater in storage (GV_{ST})

$+GV_{ST}$	=	Volume of groundwater in storage	$[L^3]$

In a natural, steady-state situation, the groundwater balance equation for the model is given by:

$$Q_{GINS} = Q_{GUNS} \quad (2)$$

In an unnatural groundwater system, the groundwater flow balance is given by:

$$GV_{ST} = Q_{GINS} + Q_{GIUNS} - Q_{GLC} - Q_{GUUNS} - Q_{GUNS} \quad (3)$$

From which follows:

$$GV_{ST} = Q_R + Q_{DS} - Q_{BH} - Q_{BHN} - Q_{IR} + Q_{IRR} - Q_{MDW} - Q_{AVEG} - Q_{WLD} - Q_{RVEG} - Q_{SF} - Q_{BF} \quad (4)$$

It is evident that the groundwater use by natural systems ($-Q_{GUNS}$) is last in the flow sequence. This is because unnatural groundwater use such as from boreholes and shafts can take water below and before it has the opportunity to flow to a natural system. The flow sequence is important, because base flow is the last component to receive groundwater. When outflow exceeds inflow in any given time step, water would be taken firstly from storage, then from spring flow and then from base flow. A supplementary conservative assumption is made that base flow is constant (i.e. a minimum base flow component is allocated) and if outflow exceeds inflow, water would be taken mainly from storage until the head declines to the defined dead storage level.

The groundwater balance from (4) is calculated for monthly time steps (Δt) to yield a monthly groundwater balance at a 95 % assurance level.

The model output is put into perspective for the groundwater component of the Reserve.

Task 8.4: Field verification

Once groundwater data has been gathered, it will be essential to carry out field verification in the following areas:

- Zones where gaps in data is noted. These will typically include areas where no borehole data is available or where groundwater use is not known
- Zones delineated as sensitive "hot spots" based on groundwater- surface water interaction, groundwater prominence, pollution potential and current/future development

Field verification will be preceded by Google image flyovers and remote sensing to prevent unnecessary field verification if resolution and image quality permits.

Inputs during groundwater-related field verification will typically include:

- Hydrocensus – borehole/spring identification and site observations relating to hydrogeology and use;
- Water quality analyses through selective groundwater sampling; and
- Water use – quantification and verification of use.

Task 8.5: Water balance

The input and output parameters of the model link to a MS-Access database. The input is obtained from the data base, used in the model and the output is stored back in the data base.

It can therefore be used as a groundwater accounting system to determine the volume of groundwater available if for example an additional Water Use License is granted or alien vegetation is cleared (AGES-BKS, 2008).

4.3 GROUNDWATER DATA

Two borehole information data-sets were used to obtain additional desktop information on the project area and confirm the findings of the investigation. These data-sets are known as the National Groundwater Data Base (NGDB) and the DWAF initiated, Groundwater Resource Information Project (GRIP) data-set.

The latest (October 2008) NGDB dataset was used and is defined as an Accuracy 2 dataset. The Class 2 accuracy relates to accuracy of geosites to within 100 m. The majority of sites have a much higher accuracy.

The GRIP project was launched in the Eastern Cape to provide the necessary information towards ensuring the sustainable use, development, management and regulation of groundwater in the Eastern Cape Province. The project plan has been defined to deliver the following overall project objectives:

- To develop systems, tools and procedures for collection, verification, processing, assessment and capturing of hydrogeological data for the Eastern Cape;
- To prioritize areas for hydrogeological data in terms of demand of services, data and knowledge gaps, resource protection and sensitivity;
- To conduct a hydrocensus of priority wards within the Eastern Cape;
- To process, assess, evaluate and capture geohydrological data;
- To render groundwater information to DWAF, Water Services Authorities and all institutions involved in water supply and management in the Eastern Cape Province;
- To support the full implementation of the regional and national groundwater databases; and
- To render information on groundwater use for verification, registration and authorisation.

The GRIP data that could be used in the GIS analysis for the Mzimvubu River catchment was updated in March 2009. The GRIP data itself originates from two surveys respectively: The ward-based hydrocensus, as well as a more specific town survey that was completed in 10 of the 18 towns located in the Mzimvubu River catchment. The GRIP EC project was suspended by DWAF due to budget constraints and only processing and capturing of data is still in progress. Most of the ward-based data has not been captured at the writing of this report, so it could not be used for reference.

4.3.1 NGDB data application

A total of 1 905 NGDB borehole sites fall within the Mzimvubu River catchment boundary. Four maps were produced, using relevant borehole and groundwater data from the NGDB dataset as follows:

MAP 2: NGDB geo-site localities

MAP 2 gives a geographical representation of the distribution and location of the 1 905 boreholes that have been captured in the NGDB within the Mzimvubu River catchment. Evident from the distribution is the tendency of the boreholes to be located near towns or villages. Borehole frequency is higher in rural township areas where communities rely on groundwater as their sole water source in most cases. The much lower frequency of boreholes in the KZN part of the study area can be ascribed to the fact that this area is covered by commercial farming activity, implicating that less hydrocensus surveys were carried out here in the past. It does not necessarily imply that there are less boreholes and groundwater abstraction in these areas. Borehole distribution is also not related to geology but rather based on demand and accessibility for drilling rigs to communal land.

MAP 3: NGDB Borehole yields

A distribution of boreholes for which yield information has been recorded in the NGDB is depicted in **MAP 3**. A total of 746 boreholes are displayed with borehole yield ranges shown (estimated abstraction rates). Yields reported range between zero to more than 15 ℓ/s. Yield information is not available throughout the catchment, and is especially limited towards the coast and in commercial farming areas in KZN. Higher yielding boreholes occur throughout the study area with no specific pattern or tendency to be noted. Slight clustering of higher yielding holes is noted in the vicinity of the towns of Matatiele and Qumbu.

MAP 4: NGDB Borehole depths

A total of 1 419 boreholes had borehole depths available from the NGDB dataset and are displayed in **MAP 4**. Depth range is indicated by dot colouring from yellow to green to blue, with small dark blue dots indicating boreholes from which depth records could not be obtained or are in question. Borehole depths are in excess of 150 m in certain places with the majority of boreholes ranging between 30 m and 100 m depths.

MAP 5: NGDB Borehole localities in relation to Geology

All 1 905 NGDB boreholes are displayed on the backdrop of 1: 250 000 Geological maps that cover the Mzimvubu River catchment in **Map 5**. Several borehole clusters are visible in the GIS representation. These clusters of higher borehole frequency are noted as:

1. In the south, close to the coast, associated with the Ecca and Dwyka Group formations
2. In the vicinity of the towns of Tsolo and Qumbu associated with the the Burgersdorp and Katberg formations and associated dolerite intrusion
3. In the vicinity of the town of Mount Fletcher, associated with the Molteno formations and numerous dolerite intrusions
4. In the vicinity of the town of Mt Ayliff, associated with the Adelaide formations and extensive dolerite intrusions.

Based on the scale of the assessment and accuracy of data, it is not possible to find any relation between exact borehole localities and dolerite intrusions, but it is evident on a regional scale that a higher frequency of boreholes are present where dolerite intrusion is most prominent and extensive. This includes dolerite sheets and dykes.

4.3.2 GRIP EC data application

MAP 6: Provincial coverage of GRIP survey to date

MAP 6 outlines the extent of progress of the hydro-census survey thus far over the Eastern Cape Province on the 2nd of March 2009. Wards and municipalities are highlighted in colours identifying the level of progress made in outlined areas. A total of 6 District Municipalities, 36 local municipalities and 613 Wards are covered by the GRIP survey in the Eastern Cape. Up to the 2nd of March 2009 a total of 200 wards have been completely surveyed.

MAP 7: Wards and towns covered by the GRIP survey in the Mzimvubu River catchment

As indicated in **Map 7**, a total of 114 wards covered during the GRIP survey fall within the Mzimvubu River catchment. 26 of these wards are in the final stages of completion. A complete hydro-census has been conducted for 15 of these wards.

Within the Mzimvubu River catchment a total of 228 boreholes (geosites) have been captured and processed in a database with all relevant information linked. 435 geosites have been identified in the hydrocensus field survey thus far and are being processed for final capturing.

4.4 PRELIMINARY GROUNDWATER POTENTIAL ASSESSMENT

Based on the current, amended scope of work, the aim of this report is to define the generalized regional groundwater potential to establish a groundwater potential determination framework for future, more detailed groundwater potential assessments which will need to involve accurate analytical and possibly numerical groundwater Reserve determinations on a quaternary catchment basis. It is proposed for this to be carried out in the next phase of the study as detailed in the following paragraph.

4.4.1 Groundwater flow model methodology

AGES has developed a groundwater flow model approach to simulate the potential groundwater flow directions and velocities, inflow rates, water balance and depth to groundwater. The model is developed based on the site specific physical boundaries and hydrogeological zones. The model input parameters are; piezometric heads, hydraulic conductivity, recharge and sink/s (boreholes, wetlands etc). The models are developed according to the geology and provision is made for an upper weathered layer and preferential pathways, as well as possible compartments formed by dolerite dykes and fault zones.

The data obtained from existing data bases, e.g. the National Groundwater Data Base (NGDB) and GRIP EC, as well as technical reports are used to build on. The groundwater flow balance is a good barometer that indicates the sensitivity of a specific water use and ultimately presents data that can be used to define groundwater potential to a very high level of accuracy based on the groundwater Reserve and not just based on exploration and borehole yield potential.

4.4.2 Quaternary level groundwater potential assessment – GRDM

Following a project management meeting held on the 27th of August 2008 in East London, it was proposed that AGES give a first level assessment (desk top level) of the groundwater potential and character per quaternary catchment for the whole Mzimvubu River catchment area.

Preliminary water balance assessments per quaternary catchment were done using the following:

- The Groundwater Resource Directed Measures Manual and its associated software as published by DWAF and the WRC, February 2006;
- Latest NGDB geo-site data – assuming conservative full-time abstraction volumes per borehole at 1 ℓ/s; and
- GRDM database data for population figures, baseflow, recharge and rainfall
- Assuming potable groundwater use at 60 ℓ/c/d.

The following three maps were produced through this process and are given in **Map 8**, **Map 9**, and **Map 10** respectively:

1. Groundwater Reserve as a Percentage of Recharge – Map 8;
2. Quaternary Catchment Stress Index – Map 9; and
3. Allocatable Groundwater per Quaternary Catchment – Map 10.

It is crucial to note that the brief from the client was to indicate, on a preliminary assessment basis, the differences in groundwater character between the quaternary catchments within the Mzimvubu River catchment. Maps 8, 9 and 10 are therefore not a quantitative reflection of actual groundwater potential or availability, but intend to give the reader an indication of the change in groundwater character across the catchment.

A generalised conclusion can be made from Maps 8 and 10 that groundwater potential, based on allocatable volumes and preliminary reserve estimates, increases towards the east of the Mzimvubu River catchment.

Taking current abstraction into account, it can be noted in Map 8, that the general trend for groundwater potential to increase towards the east, is no longer relevant as some of the catchments have a higher dependency from groundwater. The term “Stress Index” must not be misinterpreted as implicating that any of the quaternary catchments within the Mzimvubu River catchment are currently stressed. It merely indicates differences between different catchments. Preliminary indication is that none of the quaternary catchments are currently stressed and allocatable groundwater volumes are significant, resulting in groundwater being a feasible water source in most of the quaternary catchments in the study area.

4.4.3 Town-based groundwater potential assessment

Following the Project Management Meeting held on the 27th of August 2008 in East London, it was proposed that AGES give a first level assessment summary of groundwater potential at all the town localities within the project area for incorporation into the so called *All Towns Reconciliation Strategy*.

Preliminary groundwater potential per town located within the catchment was assessed using the following information:

- GRIP hydrocensus data;
- AGES internal database and local knowledge & experience; and
- Published DWAF Hydrogeological maps.

Map 11 was produced indicating the preliminary groundwater potential at each of the towns located within the Mzimvubu River catchment. This is a preliminary holistic approach towards expressing groundwater potential at each town, taking note of hydrogeological setting, existing groundwater use, borehole yield potential, water quality and groundwater prominence. The potential however does not take into account what the stress index and allocatable groundwater component in the applicable quaternary catchments are. It is recommended that this be carried out as part of the detailed groundwater model that is listed as the most important recommendation for the next phase of the project.

A summary of the applicable data used in the temporary assessment of groundwater potential per town, is given in **Table 1** for reference.

Groundwater potential was preliminary defined as Very High at the town of Cederville and as High at the towns of Matatiele, Qumbu and Tsolo. Of the remaining 14 towns within the catchment, a total of 8 were defined as having medium or moderate groundwater potential, while the remaining 6 towns were defined as having low potential to rely on groundwater as a sustainable water source for municipal water supply. This preliminary estimate will however have to be verified through more detailed assessments in the next phase of the project and in the light of regional water balance calculations.

Table 2 Preliminary groundwater potential assessment per town located within the Mzimvubu River catchment

MZIMVUBU CATCHMENT DEVELOPMENT STUDY - TOWN SURVEY - GROUNDWATER POTENTIAL ESTIMATES & PRELIMINARY GROUNDWATER RESERVE IN APPLICABLE QUATERNARY CATCHMENTS									
							ASSOCIATED QUATERNARY CATCHMENT STATUS		
PROVINCE	DISTRICT MUNICIPALITY	LOCAL MUNICIPALITY	TOWN	AQUIFER TYPE median yield class	TOWN GROUNDWATER POTENTIAL ESTIMATE	EXISTING GROUNDWATER USE	RESERVE %	STRESS INDEX %	ALLOCATABLE GROUNDWATER (Mm^3/a)
EASTERN CAPE	Alfred Nzo	Matatiele	Matatiele	Intergranular & fractured 0.5 - 2.0 l/s	HIGH	YES	44 - 53	1.5 - 3.0	4 - 8
	Alfred Nzo	Umzimvubu	Mt Frere	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	YES	53 - 75	0.5 - 1.5	4 - 8
	Alfred Nzo	Matatiele	Cedarville	intergranular & fractured 2.0 - 5.0 l/s	VERY HIGH	YES	29 - 36	1.5 - 3.0	13 - 22
	Alfred Nzo	Umzimvubu	Mt Ayliff	Intergranular & fractured 0.5 - 2.0 l/s	LOW	YES	53 - 75	3.0 - 4.4	4 - 8
	OR Tambo	Mhlantlo	Tsolo	Intergranular & fractured 0.5 - 2.0 l/s	HIGH	YES	75 - 98	0.5 - 1.5	0.6 - 4
	OR Tambo	Mhlantlo	Qumbu	Intergranular & fractured 0.5 - 2.0 l/s	HIGH	YES	75 - 98	0.5 - 1.5	0.6 - 4
	OR Tambo	Ntabamkulu	Tabankulu	Intergranular & fractured 0.5 - 2.0 l/s	LOW	YES	53 - 75	0.5 - 1.5	4 - 8
	OR Tambo	Port St Johns	Port St John	Fractured 0.5 - 2.0 l/s	LOW	NO	29 - 36	0.5 - 1.5	22 - 30
	Ukhahlamba	Elundini	Ugie	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	NO	53 - 75	0.5 - 1.5	4 - 8
	Ukhahlamba	Elundini	Maclear	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	NO	53 - 75	0.5 - 1.5	4 - 8
	Ukhahlamba	Elundini	Mt Fletcher	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	YES	36 - 44	0.5 - 1.5	13 - 22
	Ukhahlamba	Senqu	Rode	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	YES	53 - 75	0.5 - 1.5	4 - 8
	Alfred Nzo	Matatiele	Thaba Chitja	Intergranular & fractured 0.5 - 2.0 l/s	LOW	NO	29 - 36	3.0 - 4.4	8 - 13
	Alfred Nzo	Umzimvubu	Gugweni	Intergranular & fractured 0.5 - 2.0 l/s	LOW	YES	36 - 44	3.0 - 4.4	13 - 22
	Alfred Nzo	Umzimvubu	Lubaleko	Intergranular & fractured 0.5 - 2.0 l/s	LOW	YES	36 - 44	3.0 - 4.4	13 - 22
	Ukhahlamba	Elundini	Halcyon Drift	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	Not Known	75 - 98	0.5 - 1.5	0.6 - 4
KZN	KZN	Greater Koksta	Swartberg	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	Not Known	29 - 36	1.5 - 3.0	13 - 22
	KZN	Greater Koksta	Kokstad	Intergranular & fractured 0.5 - 2.0 l/s	MEDIUM	YES	29 - 36	3.0 - 4.4	8 - 13

Reserve is indicated by the percentage of the recharge that is required to satisfy Reserve demand. The stress index is calculated by dividing the current abstraction with recharge. The groundwater allocation is calculated in Mm^3/a and is the total recharge minus the total reserve.

5 SUMMARY & CONCLUSIONS

- Africa Geo-Environmental Services (Pty) Ltd (AGES) was appointed as part of the BKS project team for geohydrological inputs during this study.
- The dynamic nature of the project has resulted in numerous changes in scope and approaches since AGES's appointment in 2007. The initial focus for groundwater inputs was developed around the requirement stated by the client, that the availability of water would need to be investigated or confirmed to support identified development opportunities through a groundwater potential and reserve determination approach.
- The final scope of work and terms of reference was concluded at the beginning of 2009, when the instruction was given to AGES to only summarise work done to date without groundwater balance and reserve determination outputs, for the study to be concluded as a Preliminary Groundwater Assessment of the Mzimvubu River catchment based on available data.
- It was stated at the onset of the project that the investigation of water resources will be restricted to the Mzimvubu River catchment, with consideration only of the water resource situation in adjoining catchments.
- The Mzimvubu River basin is situated in the previously designated Transkei region of the Eastern Cape Province and its catchment boundary is contained within the Mzimvubu to Keiskamma Water Management Area (WMA) No 12.
- Land use is diverse across the catchment but in general the area is largely under-developed with minimal large income-generating developments. The Mzimvubu River catchment is considered to be one of South Africa's largest undeveloped river catchments.
- Due to the scope of work and required deliverables having been changed by the client, only the information relevant to the requirements of the current study were sourced and referenced. This mainly entailed all obtainable groundwater data as well as recently completed studies in the adjacent catchments.
- Groundwater data was primarily sourced from the existing National Groundwater Database (NGDB).
- The GRIP EC project was implemented by DWAF for the main purpose of populating the then NGDB (now NGA).
- Due to the GRIP EC data still being in the process of being captured, the dataset for the study area was seen as incomplete and could therefore not be used for groundwater assessment purposes as part of this study.
- A total of 1 905 NGDB borehole sites fall within the Mzimvubu River catchment boundary. Four maps were produced, using relevant borehole and groundwater data from the NGDB dataset.

- Borehole frequency is higher in rural township areas where communities rely on groundwater as their sole water source in most cases. A much lower frequency of boreholes in the KZN part of the study area can be ascribed to the fact that this area is covered by commercial farming activity.
- Borehole yields reported range between zero to more than 15 ℓ/s while borehole depths are in excess of 150 m in certain places with the majority of boreholes ranging between 30 m and 100 m depths.
- Several borehole clusters are visible throughout the study area, associated with specific geological formations and numerous dolerite intrusions.
- Based on the scale of the assessment and accuracy of data, it is not possible to find any relation between exact borehole localities and dolerite intrusions, but it is evident on a regional scale that a higher frequency of boreholes are present where dolerite intrusion is most prominent and extensive. This includes dolerite sheets and dykes.
- A first-level assessment of allocatable groundwater, groundwater Reserve percentages as well as stress indexes per quaternary catchment has been given by using the DWAF developed GRDM manual and associated software.
- Based on desktop study results and limited available groundwater information, only preliminary groundwater potential zonation could be carried out. This can be used as a planning tool for groundwater source development and planning purposes only once a regional groundwater water balance has been carried out as recommended in this report. It has been found that the zone of highest potential can be delineated according to the geometry and occurrence of higher potential geological structures and formations.
- Four levels of GRDM determinations are recognised, with each expected to yield a greater level of confidence in the results. For the purpose of the preliminary groundwater assessment of this study only a desktop level determination was carried out. This determination was done using readily available data and information; extrapolate the results from previous more detailed and localised assessments; have low intensity information requirements; and yield results of very low confidence and is a useful planning tool.
- In general the geology of the study area represents a layered stratigraphical sequence of Karoo Supergroup formations from the Lesotho highlands in the northwest, to Port St Johns in the southeast along the coast at the Mzimvubu River mouth.
- All lithologies underlying the study area are described as having groundwater occurring intergranular and in fracture zones, with predominantly fractured aquifers to be found associated with the small section of Natal Group sedimentary rocks near the Mzimvubu River mouth. The expected median of the

borehole yield class is described as 0.5 ℓ/s to 2 ℓ/s although occasional higher yielding boreholes can be expected in ideally sited locations. Median borehole yields in quaternary alluvium deposits in the Cedarville and Matatiele region, is known to be between 2 ℓ/s and 5 ℓ/s.

- Groundwater quality data is by far too insufficient to delineate potential based on expected water classes. Groundwater conductivities (EC) are expected to generally range between 70 mS/m and 300 mS/m in the study area, while higher EC values (higher than 1 000 mS/m) have been noted in faulted Dwyka and Natal Group sandstone and also possibly alluvium associated with the Mzimvubu River near the river mouth at Port St Johns.
- SRK Consulting was appointed in 2007 by the Department of Water Affairs and Forestry to investigate the potential for groundwater as a supplementary water source for rural villages in the vicinity of the town of Lusikisiki. The groundwater potential of the area was described in terms of the groundwater exploration potential and the groundwater development potential. The Natal Group Sandstone was considered to have the highest groundwater potential while the Dwyka Group formations were considered to have the second highest groundwater potential with high borehole yields in excess of 5 ℓ/s to be expected where dolerite dykes are targeted. The Ecca Group was considered to have a lower groundwater potential in relation to the other formations in the Lusikisiki study.
- Due to these formations (Natal Group and Dwyka Formation) only covering a very small percentage of the study area near the Mzimvubu River mouth and Port St Johns, where elevated EC values predict marginal to poor water quality, its significance to the groundwater potential in the Mzimvubu River study is little.
- FST Consulting Engineers carried out a water feasibility study in the adjacent Mthatha River catchment in 2001. The scope of work consisted of remote studies comprising desktop investigation plus the use of air photo interpretation and backed by the most recent geological and geohydrological publications. The Dwyka Group formation was defined as a poor aquifer due to low permeability while the Ecca and Beaufort Groups were seen as of higher potential based on recent work indicating blow yields in excess of 10 ℓ/s. The most favourable aquifers were found to be associated with the Tarkastad Subgroup. Groundwater recharge was estimated as being between 2% and 5% of average annual precipitation. It was stated that groundwater resources could make a valuable contribution to the water supply needs of the catchment. The report concluded that water supply schemes of various sizes can be supported from groundwater.
- Preliminary water balance assessments per quaternary catchment were done as part of the AGES study using the Groundwater Resource Directed Measures Manual and its associated software as published by DWAF.

- The following maps were produced through this process:
    - Groundwater Reserve as a percentage of recharge
    - Quaternary catchment Stress Index
    - Allocatable groundwater per quaternary catchment
- A generalised conclusion was made that groundwater potential, based on allocatable volumes and preliminary Reserve estimates, increases towards the east of the Mzimvubu River catchment.
- Taking current abstraction into account, it was noted that the general trend for groundwater potential to increase towards the east, is no longer relevant as some of the catchments have a higher dependency from groundwater.
- Groundwater potential was preliminary defined as Very High at the town of Cederville and as High at the towns of Matatiele, Qumbu and Tsolo. Of the remaining 14 towns within the catchment, a total of 8 were defined as having medium or moderate groundwater potential, while the remaining 6 towns were defined as having low potential to rely on groundwater as a sustainable water source for municipal water supply.

6 RECOMMENDATIONS

- A groundwater potential definition without accurate regional water balance and Reserve determination information is incomplete and cannot be used for final regional water resource management application and planning. It is therefore crucial for the reader to realise that this report aims to report only on available information in terms of existing borehole data, with reference to work carried out in other studies in similar geohydrological conditions
- AGES is currently involved in several groundwater reserve determination studies where the GRDM approach is further enhanced with numerical flow balance modelling, developed and applied by AGES. This approach results in accurate groundwater balance figures for groundwater use planning and future water use licensing.
- It is the main recommendation from this preliminary assessment study that a numerical groundwater balance and flow model be applied for this study in the next phase of the project
- Groundwater potential assessments and aquifer types occurring in the study area must be viewed in the light of the type of dolerite intrusion that occurs in different parts of the study area as well as the geological formation present. This needs to be combined with future regional water balance and groundwater Reserve figures before groundwater availability and potential can be accurately defined
- It is crucial to note that the brief from the client was to indicate, on a preliminary assessment basis, the differences in groundwater character between the quaternary catchments within the Mzimvubu River catchment. Maps shown are therefore not a quantitative reflection of actual groundwater potential or availability, but aim to give the reader an indication of the differences in groundwater character across the catchment.
- The term "Stress Index" must not be misinterpreted as implicating that any of the quaternary catchments within the Mzimvubu River catchment are currently stressed. It merely indicates differences between different catchments.
- Preliminary indication is that none of the quaternary catchments are currently stressed and allocatable groundwater volumes are significant, resulting in groundwater being a feasible water source in most of the quaternary catchments in the Mzimvubu River catchment study area.
- The preliminary groundwater potential estimate given for the 18 towns located within the Mzimvubu River catchment will have to be verified and quantified through more detailed assessments in the next phase of the project in the light of regional water balance calculations.

- Available GRIP EC data must be incorporated into this study dataset once captured.
- It must be motivated for DWAF to complete the GRIP hydrocensus in the Mzimvubu River catchment to ensure a complete and comprehensive dataset for application in the regional groundwater flow balance.
- Focus must be placed to obtain groundwater information in commercial farming areas in KZN where little or no information is currently available, especially in the high groundwater potential areas near Cedarville and Matatiele.
- Information relating to possible studies carried out in the Ukhahlamba District, where numerous boreholes have been developed in the Molteno Group formations, must be sourced.
- High borehole yield potential and poor water qualities reported at the faulted Dwyka and Ecca formations near Port St Johns must be investigated as a possible future water supply option in the densely populated area of the catchment.
- In the central part of the catchment extensive dolerite intrusion and possible high potential associated with ring-type intrusions at greater depths than 200 m, must be investigated as this was well researched and proven in the Queenstown area west of the Mzimvubu River catchment.

7 REFERENCES

AGES (2002) Mhlontlo Local Municipality Feasibility Study, 2002.

AGES (2007) The Assessment of Water Availability in the Crocodile (West) River Catchment by Means of Water Resource Related Models in Support of the Planned Future Licensing Process. AGES report no AS-R-2007-01-31.

BKS (2008) Mzimvubu Catchment Development Project – Inception report, Rossouw JD, February 2008.

Faniran, J. A., Ngceba, F. S., Bhat, R. B. and Oche, C. Y. (2001) An assessment of the water quality of Insinuka springs in the Transkei region of the Eastern Cape, Republic of South Africa. Water SA Vol 27 No 2.

FST (2001) Mtata River Basin Study, Volume 2, Geology and Geohydrology, FST Consulting Engineers, 2001.

Midgley, D. C., Pitman, W. V. and Middleton, B. J. (1990) Surface Water Resources of South Africa. WRC Report No 298/5.1/94. Volume V.

Parsons (2006) Groundwater Resource Directed Measures; GRDM Manual; February 2006.

Sellick E. C. H. (2005) DWAF – Mzimvubu River Basin, water utilization opportunities. Report No: P WMA 12/000/00/0505.

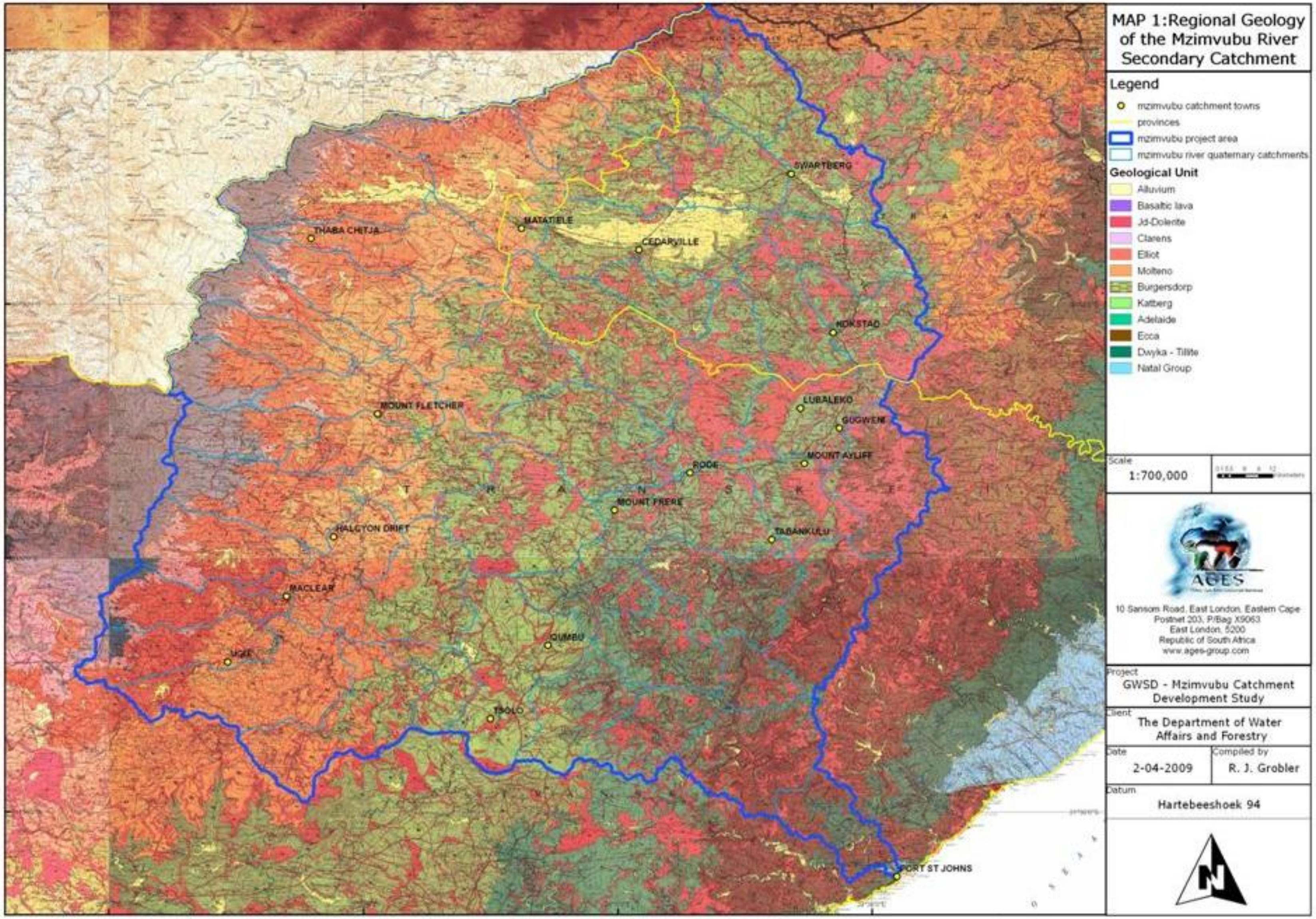
Smart (1998) An Explanation of the 1: 500 000 General Hydrogeological Map Queenstown 3126, The Department of Water Affairs & Forestry, Smart MC, 1998.

Smit (2003) Catchment Management Forums in the Eastern Cape Province of South Africa, Smit, Tim, July 2003.

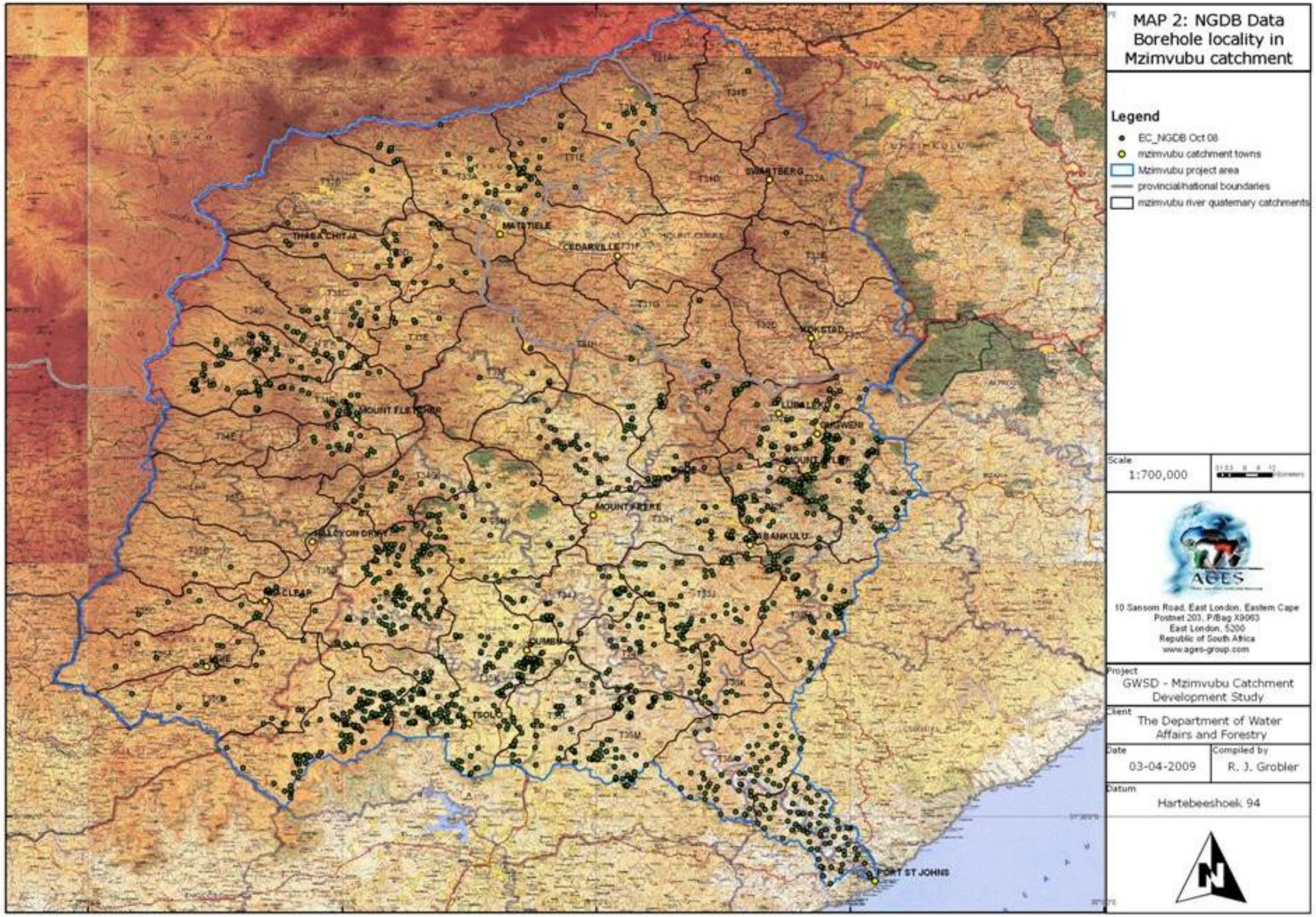
SRK (2007) Lusikisiki Groundwater Feasibility Study, SRK Consulting, 2007.

APPENDIX A

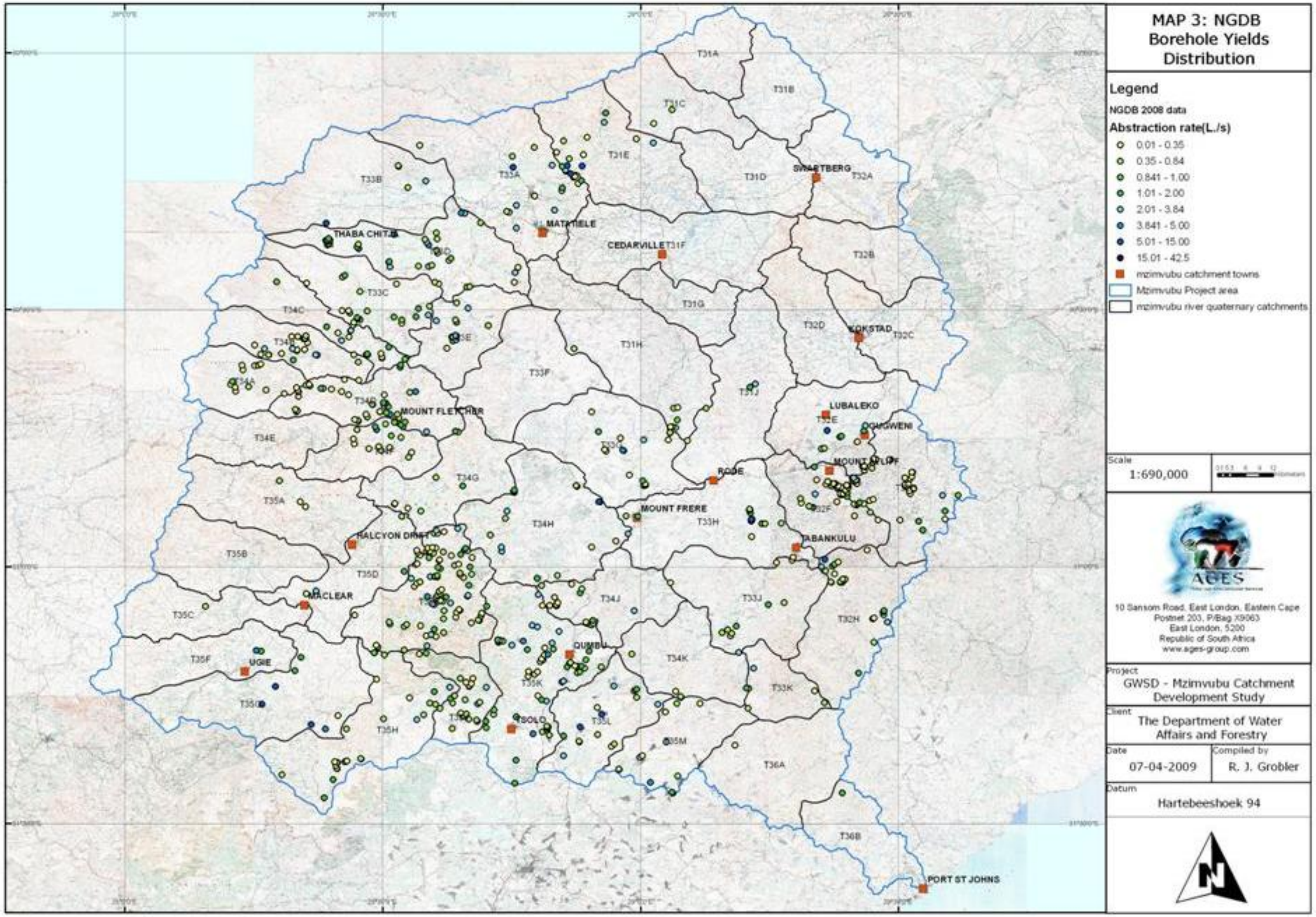
MAPS



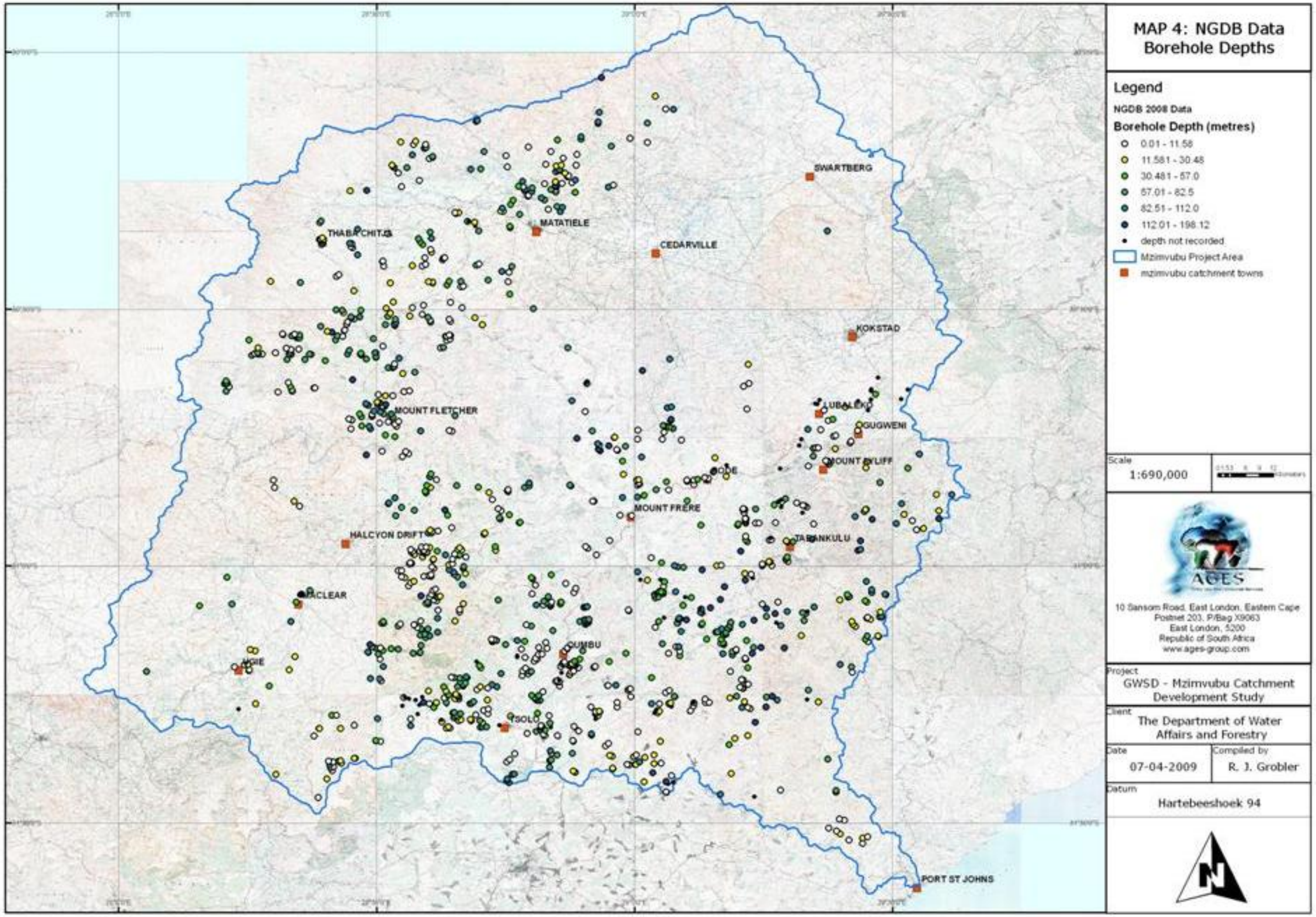
MAP 1 **Regional geology of the Mzimvubu River secondary catchment**



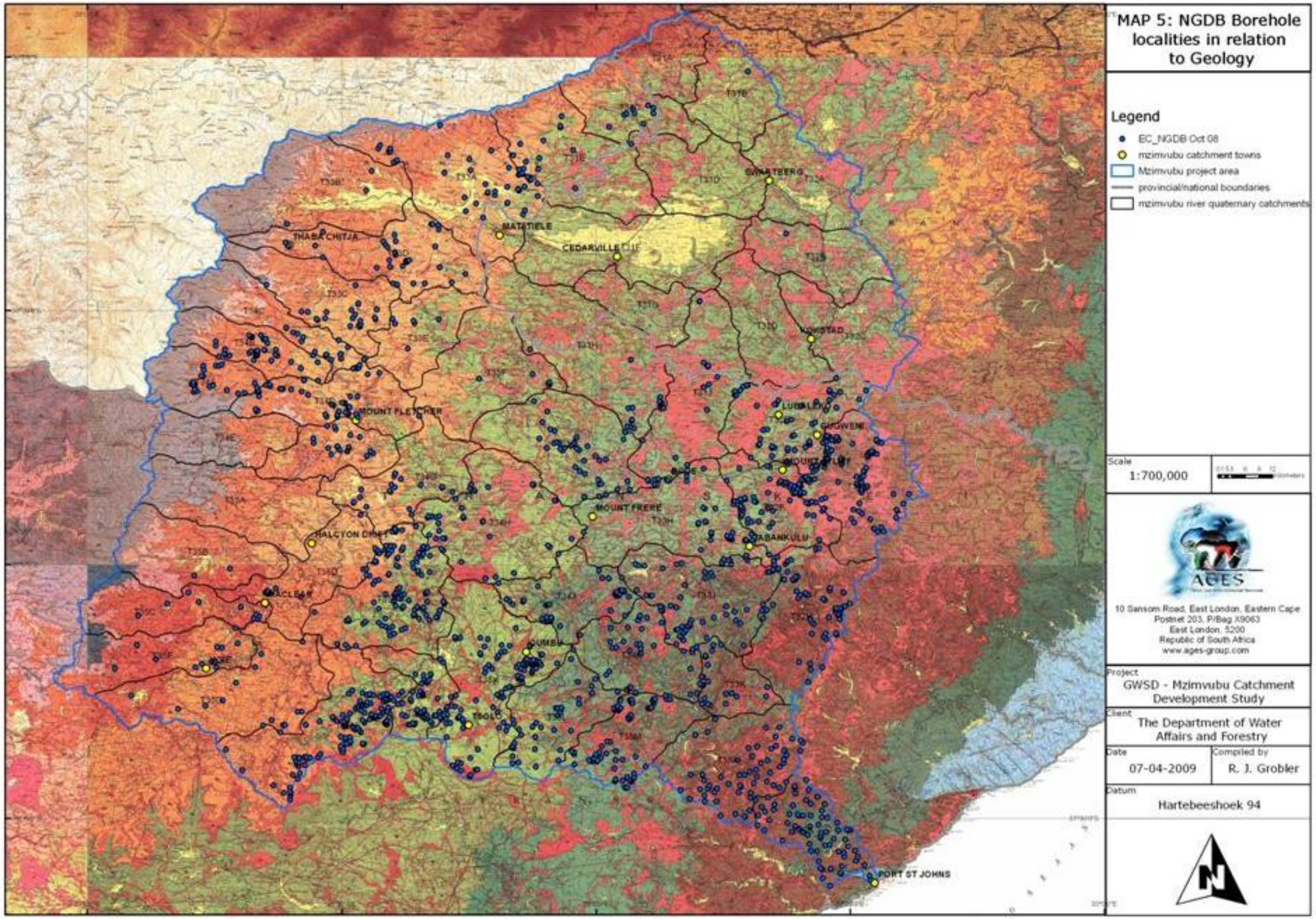
MAP 2 NGDB data borehole locality in the Mzimvubu River catchment



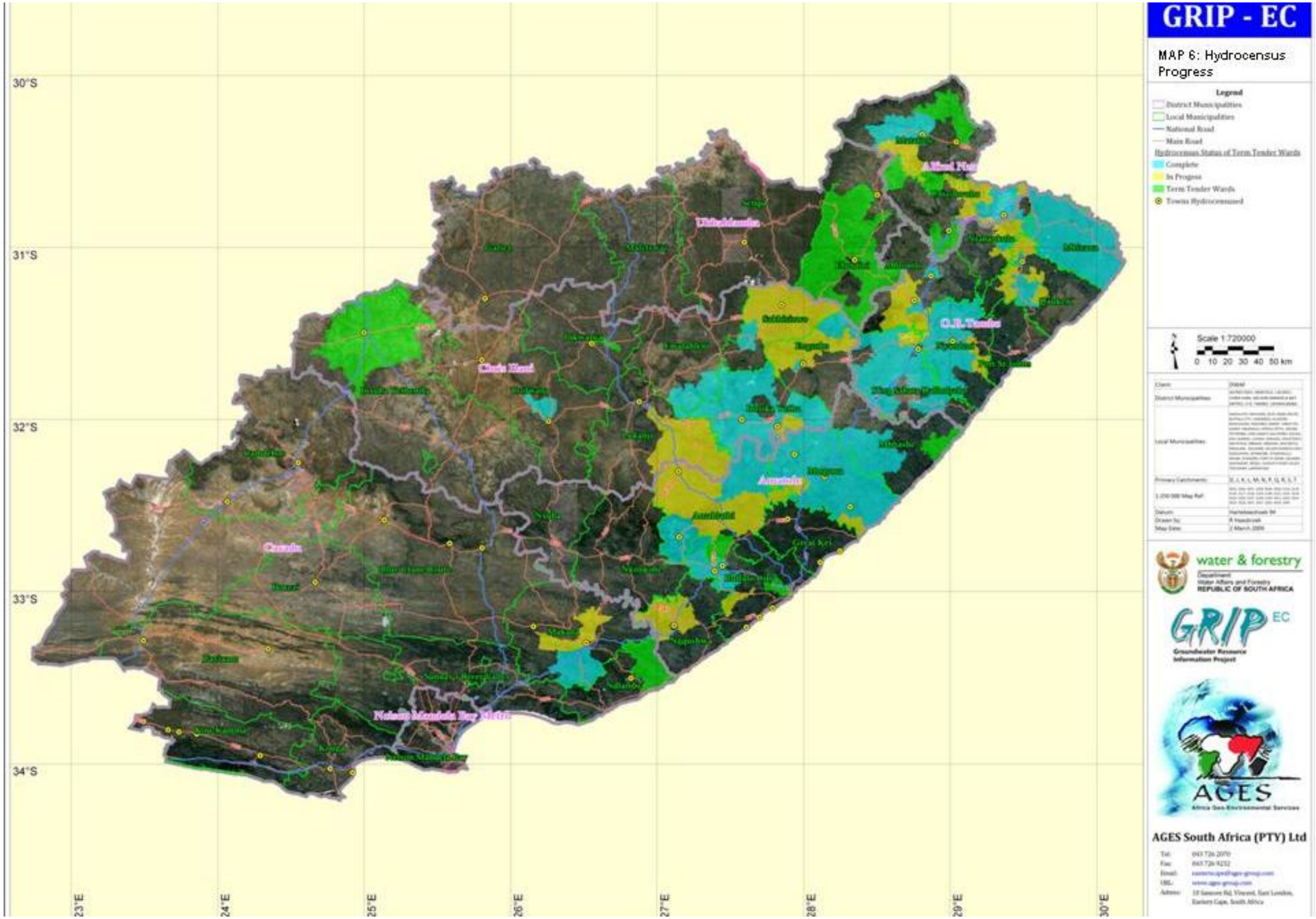
MAP 3 Borehole yields distribution



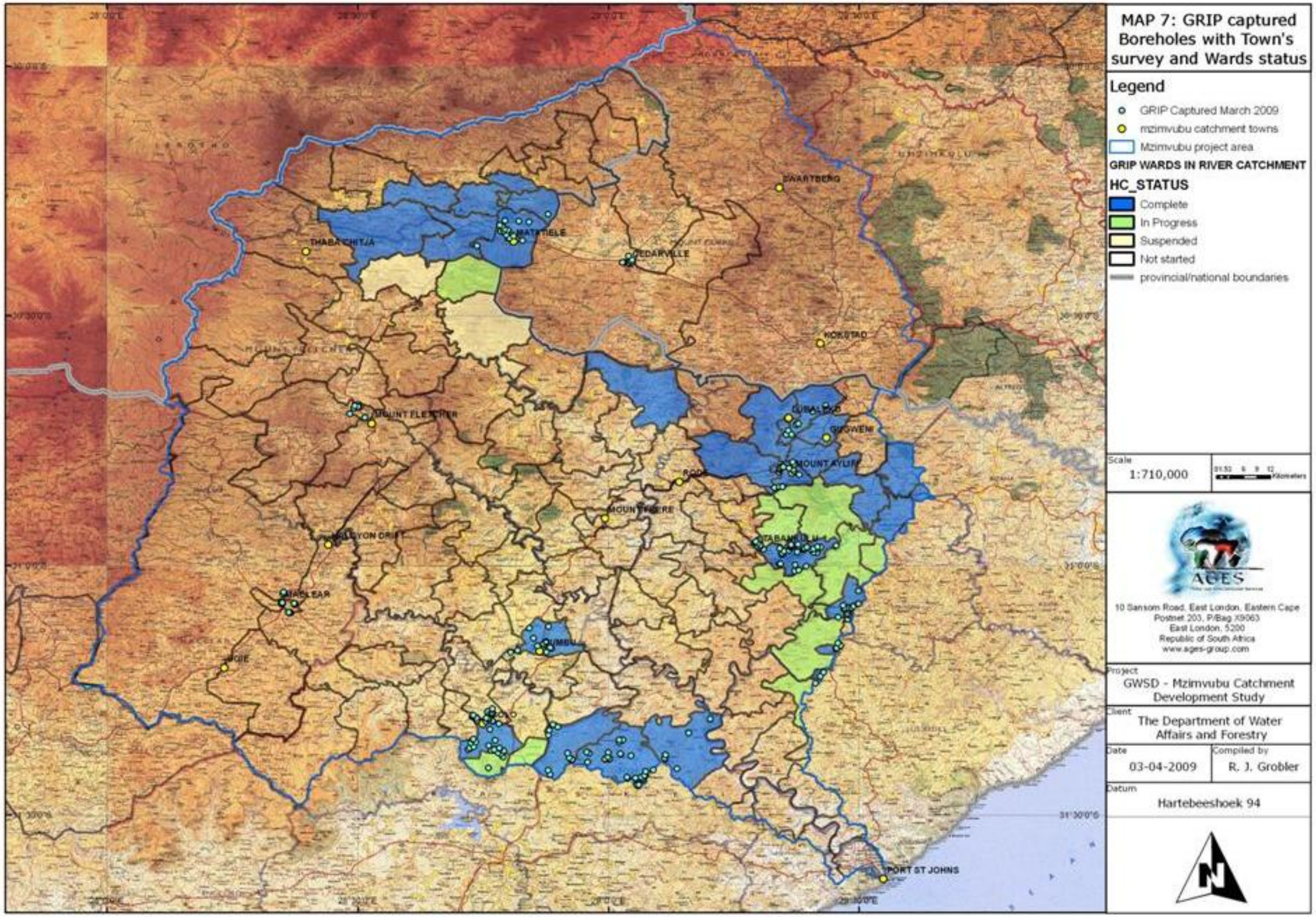
MAP 4 NGDB data borehole depths



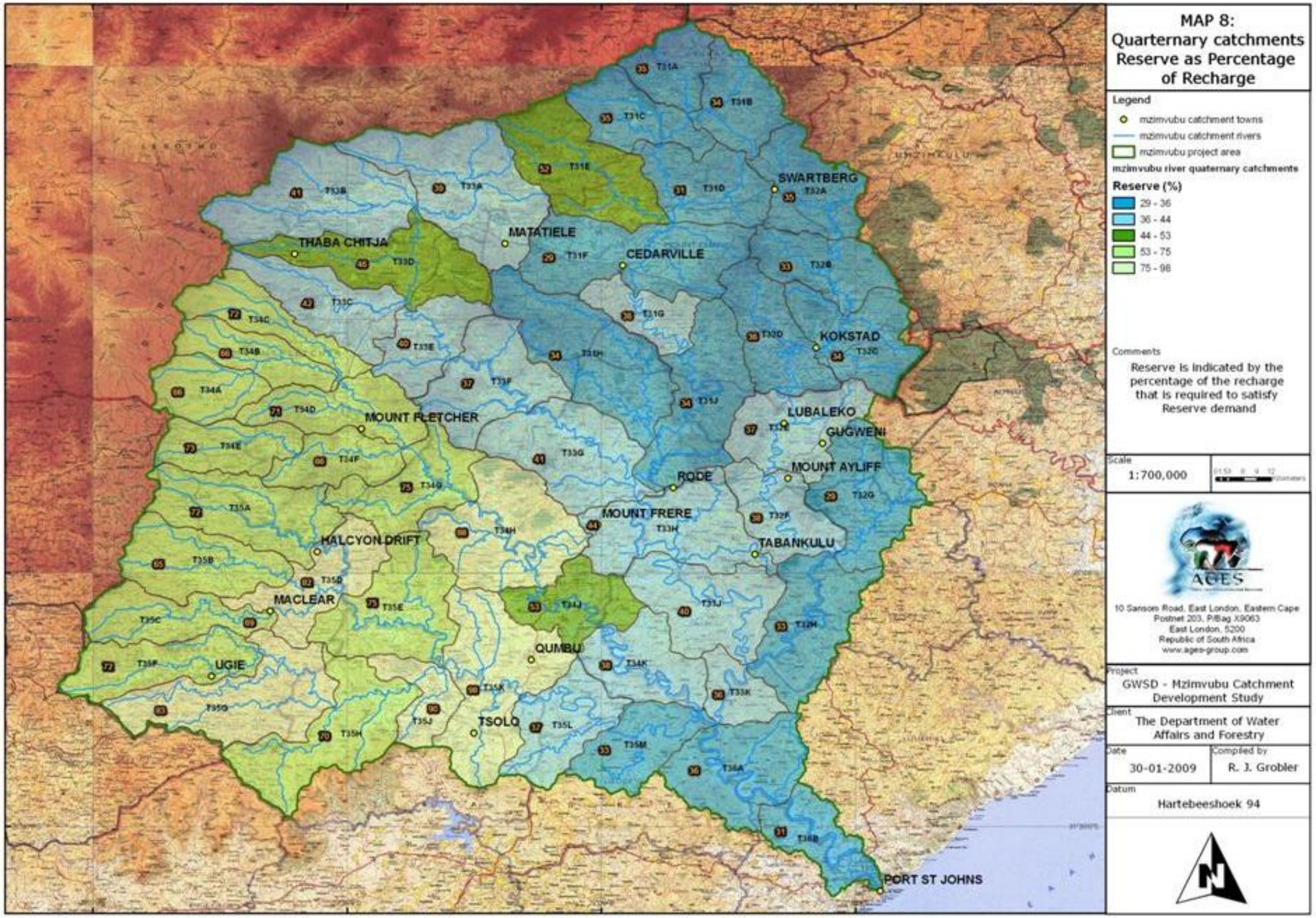
MAP 5 NGDB borehole localities in relation to geology



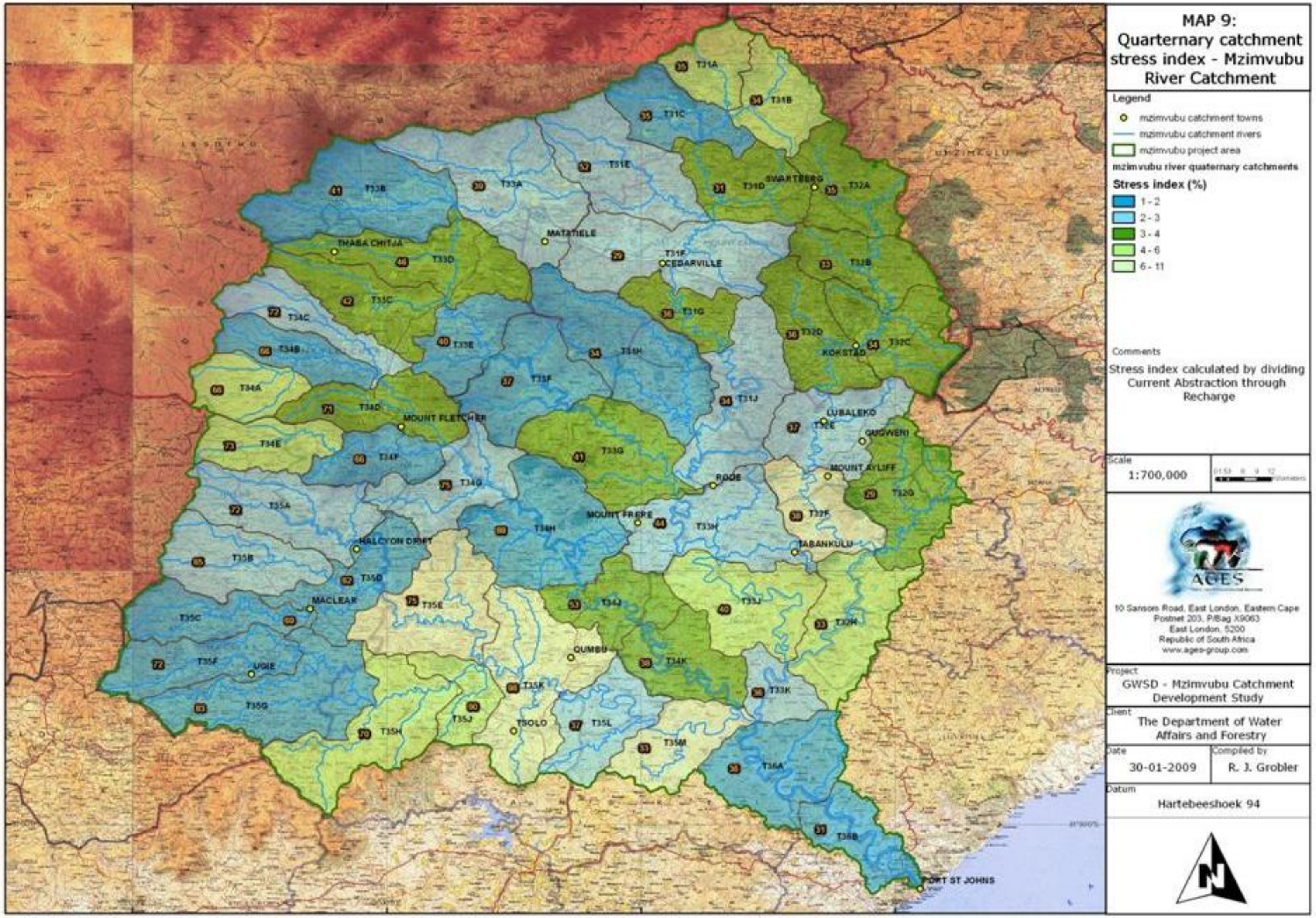
MAP 6 **Hydrocensus progress**



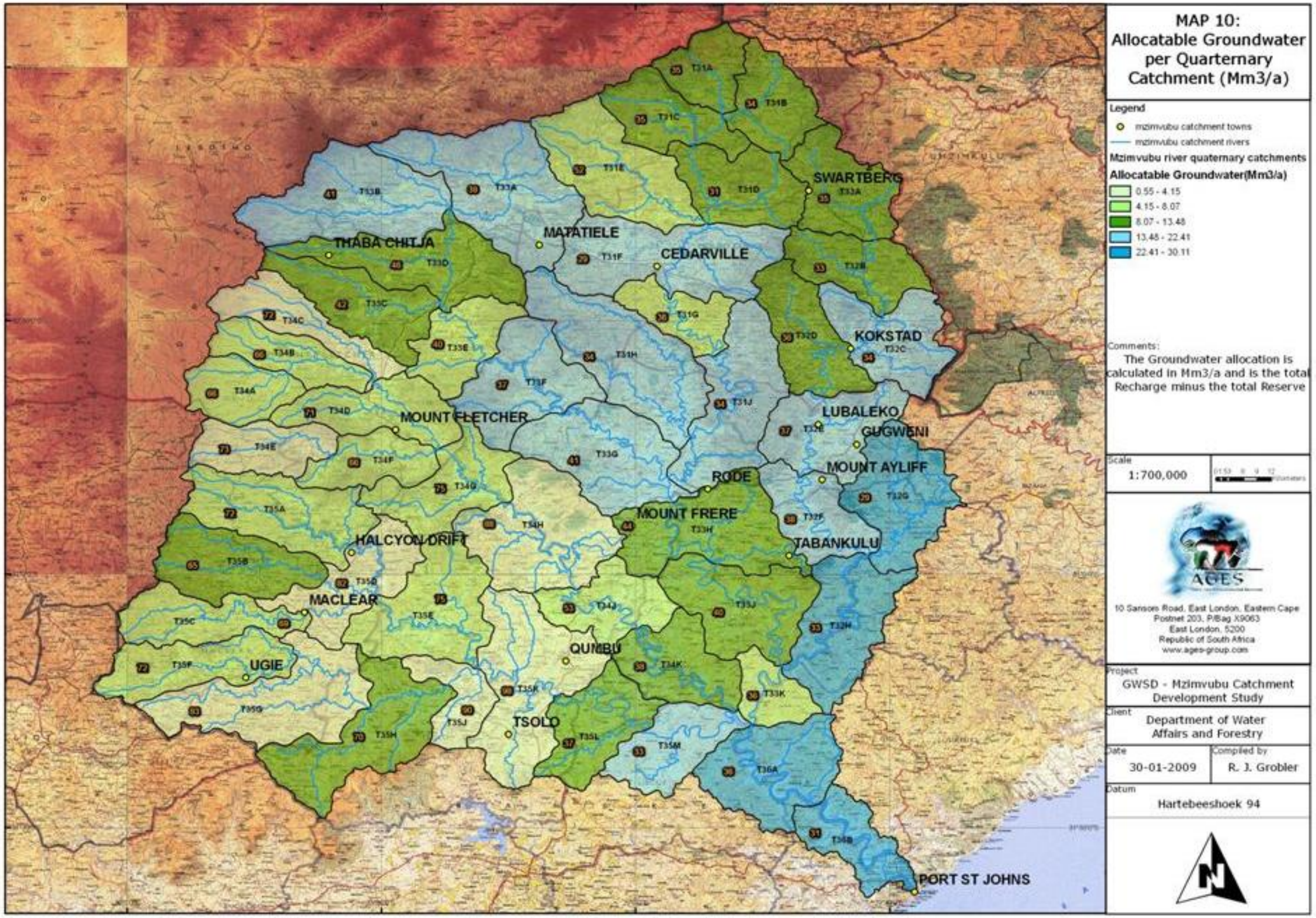
MAP 7 GRIP captured boreholes with town's surveys and ward status



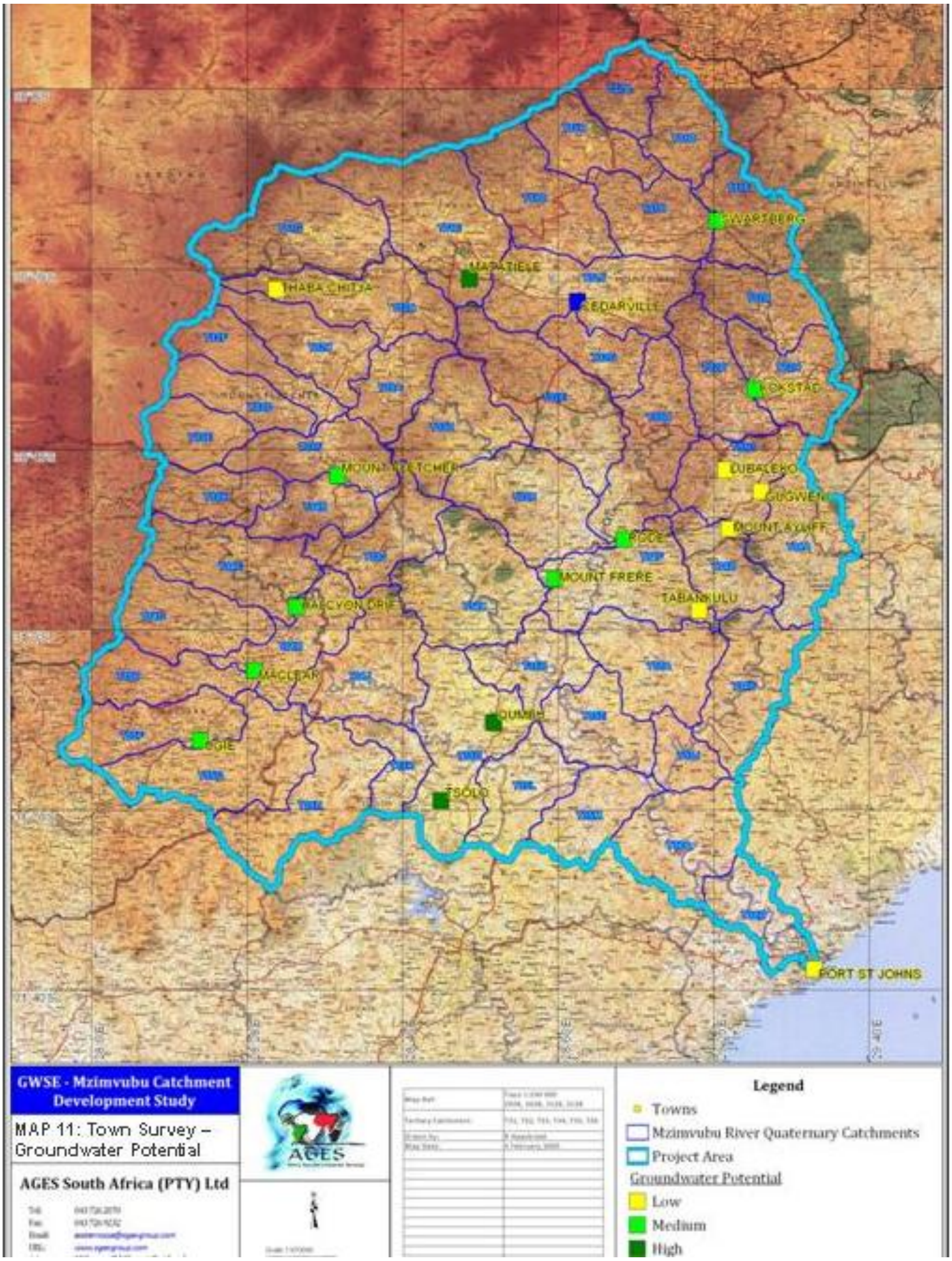
MAP 8 Quaternary catchments Reserve as percentage of recharge



MAP 9 Quaternary catchment stress index – Mzimvubu River catchment



MAP 10 Allocatable groundwater per quaternary catchment (Mm^3/a)



MAP 11 **Town survey – Groundwater potential**