DETERMINATION OF THE GROUNDWATER COMPONENT OF THE RESERVE: LIMPOPO WATER MANAGEMENT AREA

INCEPTION REPORT

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1. INTRODUCTION

Water resources in South Africa are managed according to the principles that underpin the National Water Act (NWA) (Act No. 36 of 1998), namely sustainability and equity. The goals of sustainability and equity are thus the guiding objectives of the National Water Act, but are accompanied by the fundamental tenets of water management in this country. Resource Directed Measures can be regarded as a resource based tool to protect and conserve water and hence strives to ensure water resources are afforded a level of protection that will assure a sustainable level of utilization for the future. To this end, RDM comprises three main interrelated components, namely:

- Resource Classification (i.e. Aquifer systems and classification and delineation of resource units)
- Reserve Quantification (i.e. Basic Human Needs requirements and the Ecological Reserve)
- Resource Quality Objectives (RQOs)

In order to support the process of water use licensing while at the same time giving effect to the Reserve, the Department of Water Affairs appointed Water Geosciences Consulting to undertake a Groundwater Resource Directed Measures (GRDM) assessment in the Limpopo Water Management Area (WMA).

The Limpopo WMA is the northern most water management area in the country and represents part of the South African portion of the Limpopo Basin which is also shared by Botswana, Zimbabwe and Mozambique (Figure 1). Groundwater plays a pivotal role in the Limpopo WMA, and constitutes the only dependable source of water for many users, especially for rural water supplies as well as industrial and mining development. Due to the variability with respect to the importance, sensitivity as well as demand and current use of groundwater, the confidence levels required in the GRDM results will vary with resultant differing levels of RDM determinations required.

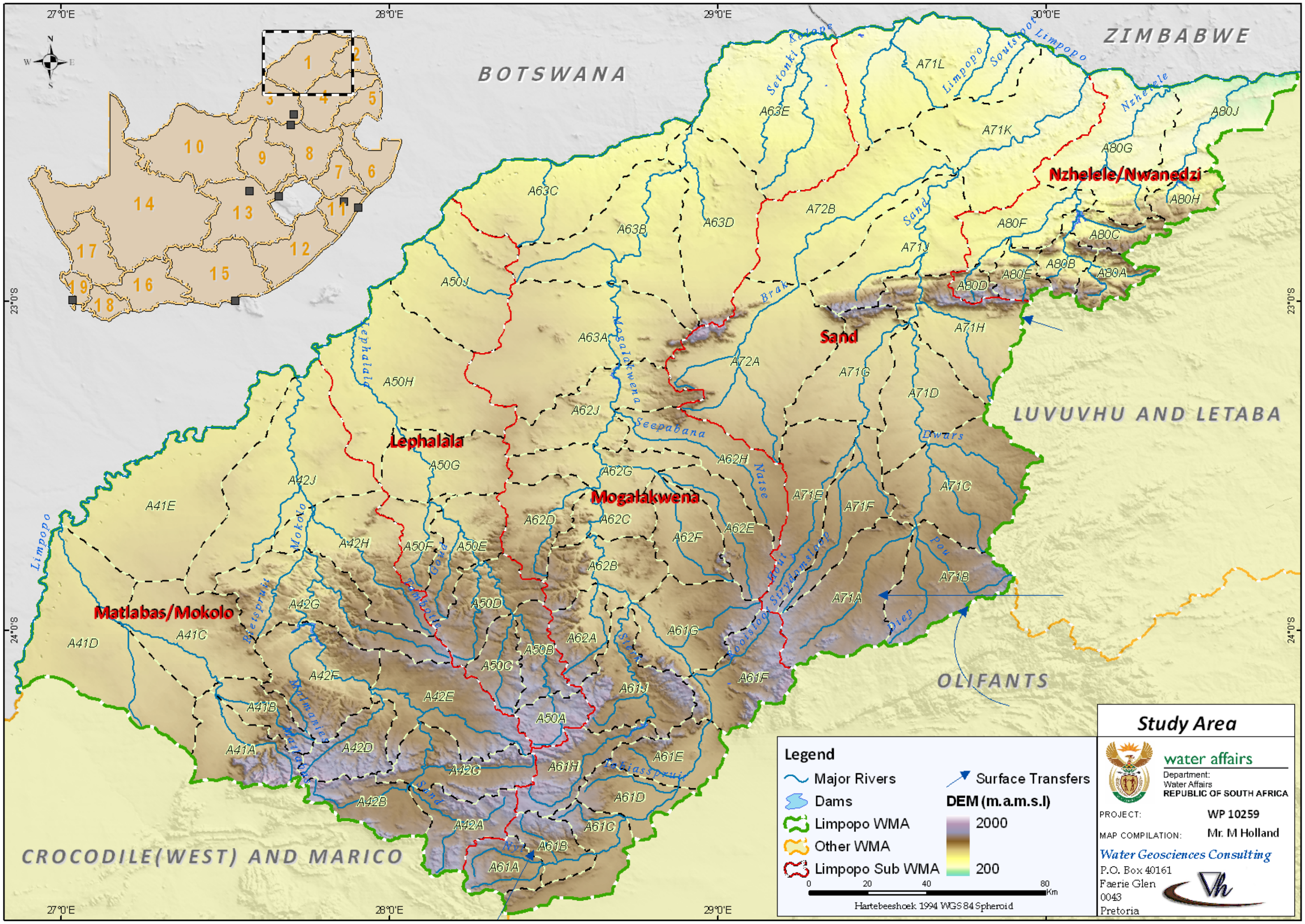

Figure 1. Location of the Limpopo Water Management Area (1).

2. STUDY OBJECTIVES

The **Primary Objective** of the study is to implement an intermediate GRDM assessment yielding results at medium levels of confidence for the Limpopo WMA, taking into account water resource management aspects raised in relevant sources:

- The Limpopo WMA is experiencing an over-exploitation of groundwater resources in a number of catchments. Licensing and water demand management measures should be implemented to address the water deficit and to provide for the component of the Reserve.
- Population growth and the resultant increase in water requirements in the main industrial and mining towns and in new mining developments.
- Water quality may be impacted upon by coal mining in the Mokolo catchment.
- The impacts of mining and industries (water quantity and quality) must be addressed.
- Further resource development, with a mainly surface water focus, is planned through the construction of new dams and/or increasing the capacity of existing dams. An expensive exercise that is unlikely to be funded by irrigation farming.
- Water for rural development and poverty relief (such as additional irrigation rights for resource-poor farmers) will have to be sourced through re-allocation from existing users.
- Increased transfers between WMA's that must be reserved in a particular WMA.

In conclusion, it is apparent that existing deficits and future water requirements are primarily being addressed through further surface water resource development and water transfer between water management areas. Aspects that must be considered with respect to groundwater development and utilization:

- Describe aquifer systems and applicable aquifer classification systems, their nature and characteristics.
- List all groundwater users such as towns, rural communities, etc. and their respective groundwater use characteristics.
- Comment on spatial coverage of existing boreholes and their main uses (i.e. for domestic, agricultural, etc. purposes).
- Describe the characteristics/nature of the groundwater resource (i.e. both quantity and quality aspects).
- Describe potential pollution sources and their likely impact on the groundwater resources, together with their vulnerability to contamination.
- Where relevant/applicable, describe surface water/groundwater interaction in parts of the catchments underlain by major aquifers. Groundwater contribution to baseflow needs to be qualified for the different geological environments.

2.1 Secondary Objective

A secondary objective will be to ensure the transfer of technical skills to historically disadvantaged individuals and to enhance their marketability as prospective professional hydrogeologists. Ms. Ndivhuwo Netshiendeulu and Mr. Manelisi Ndima of the RDM office have enrolled for Masters Degrees in Hydrogeology at the University of Free State (Institute for Groundwater Studies). It is expected that they will conduct their research in the Limpopo WMA. According to early discussions Ndivhuwo will be assessing the problem of elevated nitrates in the Limpopo WMA, while Manelisi will focus on recharge estimations and more importantly mechanisms of recharge in fractured rock.

2.2 Project Phases

In correspondence with the proposal submitted during the tender process and in terms of the appointment. The GRDM assessment will consist of the following phases:

- **Phase 1: Inception**
    - Literature Review (identify and review all relevant information).
    - Identification of role players who can provide expert knowledge of the area
    - Project Plan (scheduled tasks and activities required)
    - Database (containing all collected geohydrological and related data – preliminary)
    - Inception report
- **Phase 2: Study Implementation (Refer to section 5)**
    - Description of the study area (including field verification process)
    - Delineation of groundwater resource units
    - Preliminary water resource classification
    - The quantification/determination of the groundwater Reserve
    - Setting of preliminary Resource Quality Objectives (RQO's)
    - Recommendations for a Groundwater monitoring programme to support the RQO's
- **Phase 3: Project Termination**

Once all the objectives have been achieved the client will terminate the project. The project team, and in particular the project manager, will then:

- Supply delivery dates of final documents and products
- Close all contracts
- Complete and submit all reports
- Submit final accounts and financial report

3. PRELIMINARY DESCRIPTION OF STUDY AREA

3.1 Physical characteristics

The Limpopo WMA occupies the north-western part of the Limpopo Province. The Limpopo River watercourse forms the northern boundary of the WMA, and indeed of the country (DWAF, 2003a). The major tributaries, from the upstream end, are the Matlabas River, Mokolo River, Lephalala River, Mogolakwena River, Sand River and the Nzhelele and Nwanedi Rivers (refer to Figure 1). All of these rivers flow towards the Limpopo River in the north. The Limpopo River flows eastwards and eventually mouths in the Indian Ocean in Mozambique. The Limpopo WMA comprises an aerial extent of approximately 60 000 km^2 and consists of sixty eight quaternary catchments (Midgely et al. 1994). Table 1 lists the sub-areas (secondary drainage area) tertiary drainages, quaternary catchments together with the main tributaries for the Limpopo WMA.

Table 1. Drainage description of the Limpopo WMA.

WMA	Sub-Area	Tertiary Drainage	Quaternary Catchments	Description
Limpopo	*Matlabas/Mokolo (A4)*	**A41**	A41A,B,C,D	Matlabas
			A41E	Steenbokpan
		A42	A42A,B,C,D,E,F	Mokolo (Upper)
			A42G, H, J	Mokolo (Lower)
	Lephalala (A5)	**A50**	A50A,B,C,D,E,F	Lephalala (Upper)
			A50G,H	Lephalala (Lower)
			A50J	Soutkloof
	Mogalakwena (A6)	**A61**	A61A,B,C	Nyl (Upper)
			A61D,E	Nyl (Middle)
			A61F,G	Mogalakwena (Upper)
			A61H,J	Sterk
		A62	A62A,B,C,D,E,F,G,H,J	Mogalakwena (Middle)
		A63	A63C	Doringfonteintjiespruit
			A63A,B,D	Mogalakwena (Lower)
			A63E	Kolope
	Sand (A7)	**A71**	A71A,B,C,D	Sand (Upper)
			A71E,F,G	Hout
			A71H,J,K	Sand (Lower)
			A71L	Kongoloops/Soutsloot
		A72	A72A,B	Brak
	Nzhelele/Nwanedzi (A8)	**A80**	A80A,B,C	Nzhelele (Upper)
			A80D,E,F,G	Nzhelele (Lower)
			A80H,J	Nwanedi

In terms of climate, the Limpopo WMA is characterised by semi-arid temperatures in the south becoming arid in the northern portions. Seasonal rainfall is characteristic of the area with mean annual rainfall of 300 mm to 700 mm per annum (DWAF, 2003b), occurring mainly in the summer months. In general, the rainfall decreases from the southern part of the WMA (average about 650 mm) to the drier northern parts, where the lowest MAP of about 350 mm occurs along the lower part of the Limpopo River valley. For a small portion in the Soutpansberg the MAP is 1 000 mm and higher.

The topography is generally flat to rolling, with the Waterberg in the south and Soutpansberg in the north-east as main topographic features. The average altitude in the central part of the Limpopo WMAs project area is between 400 and 800 m and between 1 200 and 2 000 m along the Soutpansberg, Blouberg, Buffelshoek and Waterberg mountain ranges (Photo 1). Grassland and sparse bushveld shrubbery and trees cover most of the terrain, which is also known for its splendorous Boabab trees (DWAF, 2003b).

Photo 1. The Waterberg formation forms part of the Blouberg Mountain Range (Picture by Theo Rossouw).

3.2 Geology

The Limpopo River WMA is underlain by a wide variety of different lithologies. The geology of the Limpopo WMA is summarized in this section from the Limpopo Water Resources

Situation Assessment Report (DWAF, 2003a) and the Limpopo WMA Internal Strategic Perspective (ISP) (DWAF, 2004).

In the north, the Limpopo Mobile Belt occurs with its southern margin bounded by down faulted basins containing upper Karoo strata and the Soutpansberg Mountains consisting of Soutpansberg Group rocks (Figure 2). Some Ecca shales also lie unconformably on the Limpopo Mobile Belt gneisses.

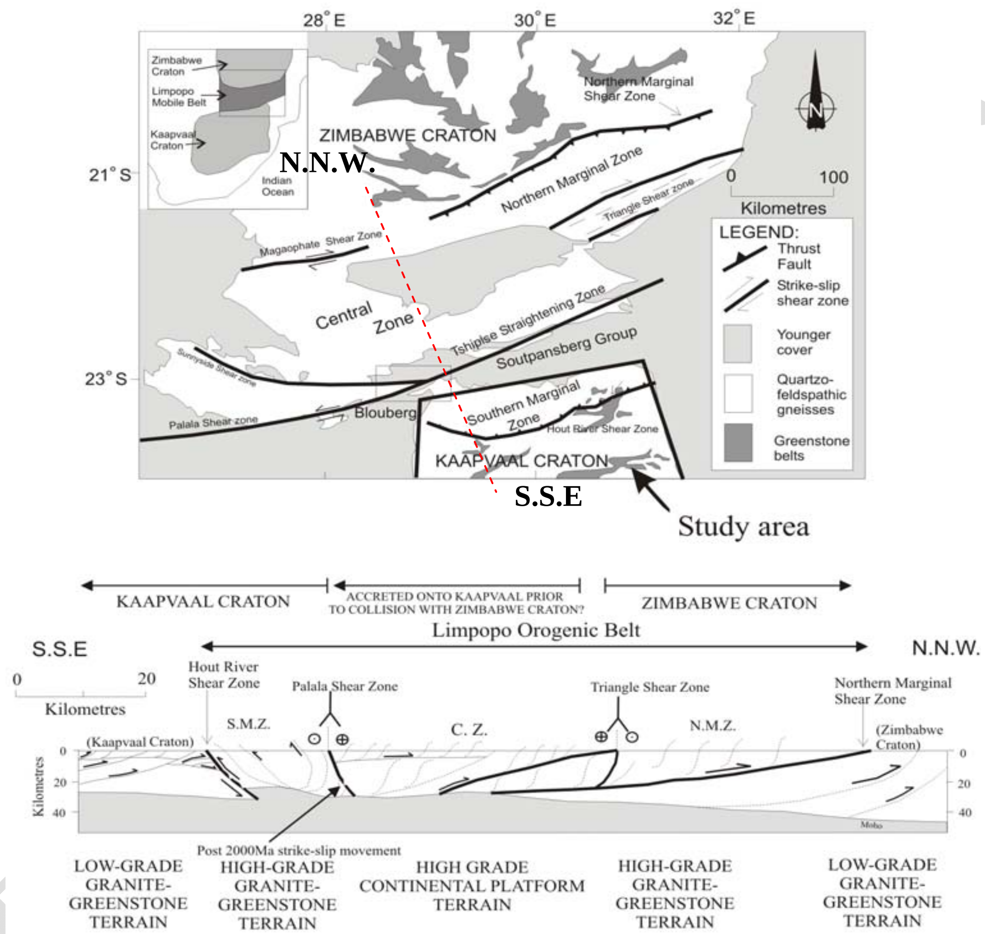

Figure 2. Generalised map of the Limpopo Mobile Belt showing the main features and subdivisions (Bumby & van der Merwe, 2004).

To the south west the Limpopo Mobile belt is truncated by large E-W trending faults with Waterberg Group strata and the northern lobe of the Bushveld Complex on the down faulted side of the faults. The Waterberg sandstone overlies predominantly Nebo Granite of the Lebowa Granite Suite and covers most of the western quadrant of the WMA. The south central part of the WMA is underlain by basement gneisses i.e. the Houtriver and Goudplaats gneisses intruded by younger granite plutons.

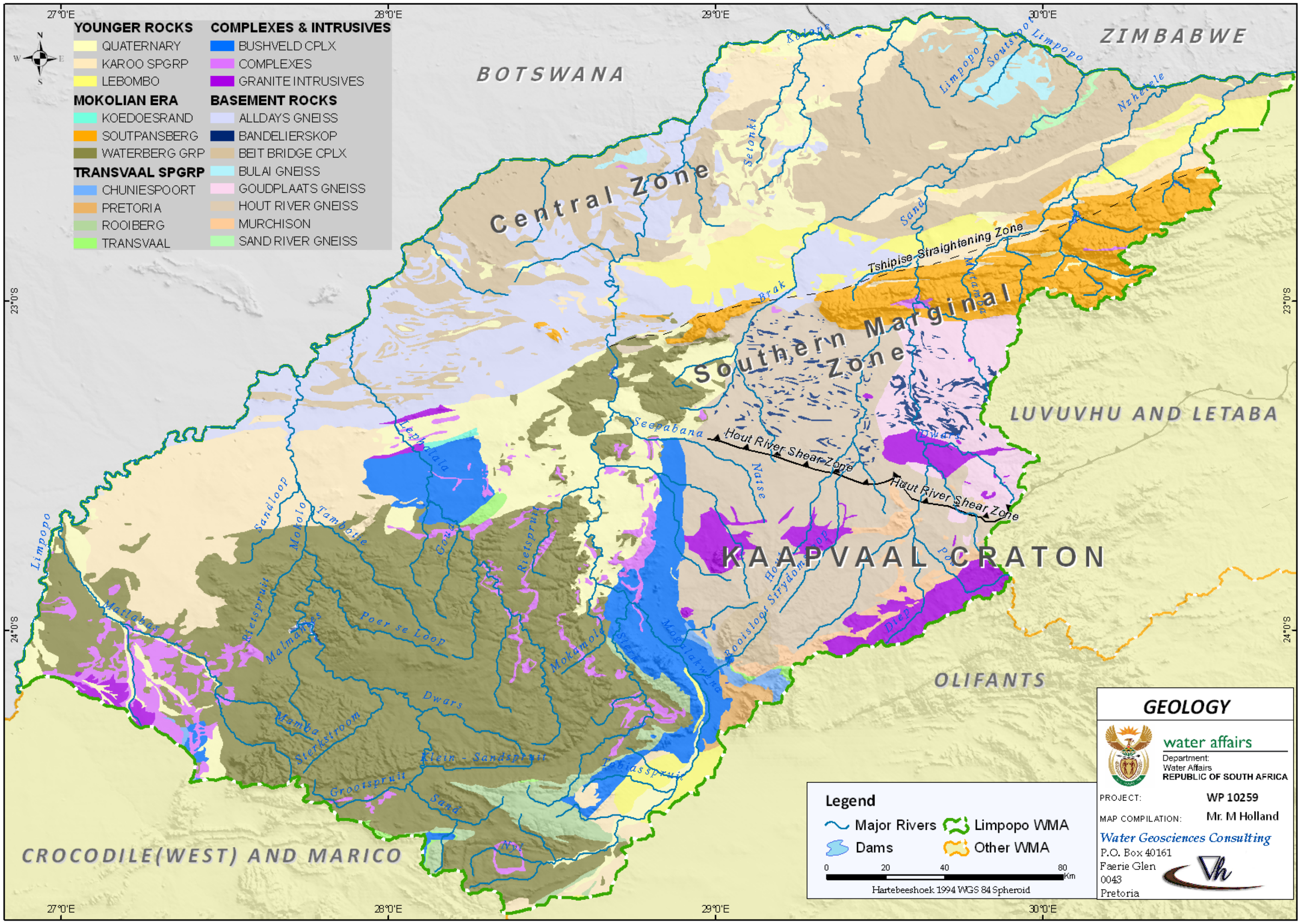

Figure 3. Simplified Geology of the Limpopo WMA.

Infolded into the basement are the low-grade metamorphic greenstone sequences, such as the Pietersburg Group and the high grade metamorphic Sandriver gneisses and the Bandelierskop Complex. The south western quadrant of the study area is dominated by the northern lobe of the Bushveld Complex, which is intrusive into Transvaal Super Group strata and overlain by Waterberg sandstones. Karoo Super Group strata are preserved south of the Zebedelia fault in the Springbok flats basin and in the extreme west overlying Bushveld Complex and Waterberg Group strata (Figure 3).

3.3 General Hydrogeology

The Limpopo WMA is dominated by Intergranular and fractured aquifer systems. The dominant rock types in the study area are meta-arenaceous rocks (quartzite and gneiss) with migmatites and gneissoid rocks with zenoliths. Within these rock types borehole-yields between 0.5 and > 5 l/s can be expected (Du Toit, 2003). The Goudplaats-, Hout River-, Alldays- and Sand River Gneiss as well as the Beit Bridge complex including the number of granitic intrusions form the major subgroups of the Basement Complex as they form part of the Achaean eon 3.1 to 2.5 Ga (Petzer, 2009). Basement aquifers are developed within the weathered overburden and fractured bedrock of these hard crystalline or re-crystallised rocks of igneous or metamorphic origin. Crystalline rocks are characterised by very low primary porosity (fresh or unweathered crystalline rocks contain virtually no water), and almost all groundwater movement and storage in these rocks takes place via fractures, faults, weathered zones and other secondary features that enhance the aquifer potential only locally (Lloyd, 1999).

Perhaps one of the most differentiating structural features of the study area is the high frequency and orientation of dyke swarms. The Achaean lithologies have been intensively intruded by NE striking dykes (Stettler, et al. 1989). Depending on their permeabilities dykes can therefore act either as conduits or as barriers promoting or retarding respectively the passage of ground-water to areas of lower elevation.

Intrusive batholiths and fractured contact zones can displace the host rocks during intrusion in order to create space for the ascending magma. These 10 to 100 metres wide zones are highly productive and can yield in boreholes in excess of 30 l/s (Du Toit, 2001).

The mountainous area east of Mokopane are also of special interest as far groundwater is concerned as this area consists primarily of dolomite and has considerable groundwater resources. The aquifer is however is heavily exploited, within quaternary catchment A61F (DWAF, 2004).

Although geology is still recognized as the major controlling factor of hydrogeology in most cases, in crystalline rock terrain, geology is not greatly important since most of these rocks depend on a number of factors to fracture and decompose. As such, neo-tectonics, climate, susceptibility to weathering and rock structure are often more important in accounting for differences in borehole yield than the rock type. This fact will certainly influence the delineating of resource units and must be taken into consideration.

Primary aquifers exist in the vicinity of drainage channels where alluvial material overlies or replaces the weathered overburden and creates a distinct intergranular aquifer type. The elongated alluvial aquifers follow rivers (so called valley trains), sand rivers or drainage lines with limited width and depth, which typically vary according to the topography and climate.

3.3.1 Groundwater Use

According to the Limpopo Water Resources Availability and Utilisation report (DWAF, 2003b) nearly 40% of the yield from local water resources in the water management area is from groundwater. This amounts to 98 million m^3/a, however, more recent work suggest that the use is much larger than previously thought (DWAF, 2004). According to the ISP of the Limpopo WMA, groundwater is the only remaining water resource in the WMA which is not fully utilised and is generally under-utilised. However, large abstractions of groundwater from deeply weathered and fractured Hout River gneiss (and granite intrusives) as well as the Chuniespoort dolomites towards the north- and south-east of the WMA for large scale irrigation may lead to over-exploitation (Figure 4).

The distribution of boreholes obtained from the National groundwater Archive and the Limpopo Groundwater Resources Information Project (GRIP) is illustrated in Figure 4. It is noted that the accuracy and reliability of the data is variable but nevertheless provides baseline data on which the GRDM assessment can be based.

3.3.2 Recharge

Overall groundwater recharge is approximately 702 million m^3/a assuming recharge being 2% of mean annual precipitation (DWAF, 2004). The distribution of recharge based on the GRA II dataset is presented in Figure 5.

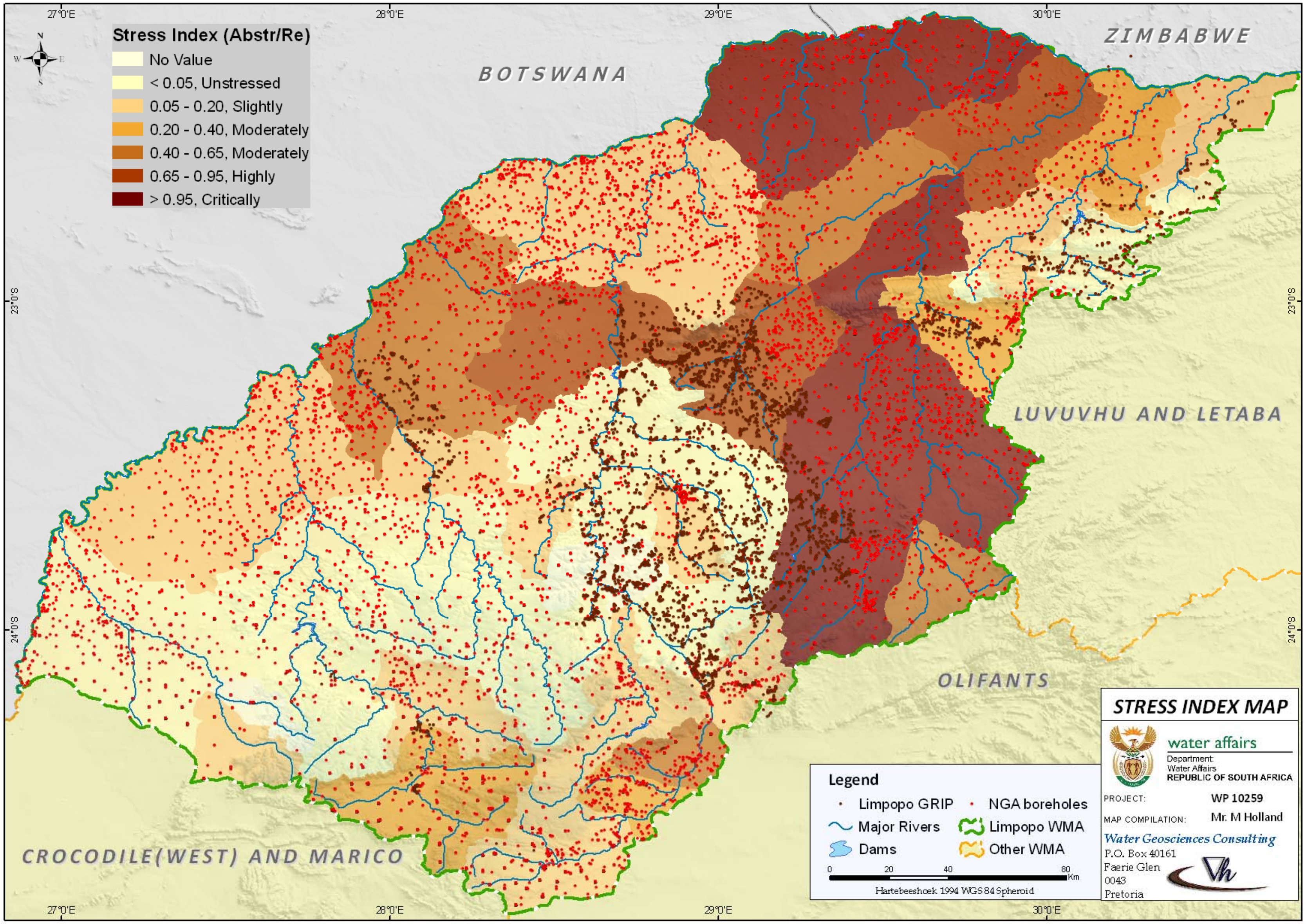

Figure 4. Distribution of boreholes in the Limpopo WMA as well as stress index values based on quaternary drainage regions.

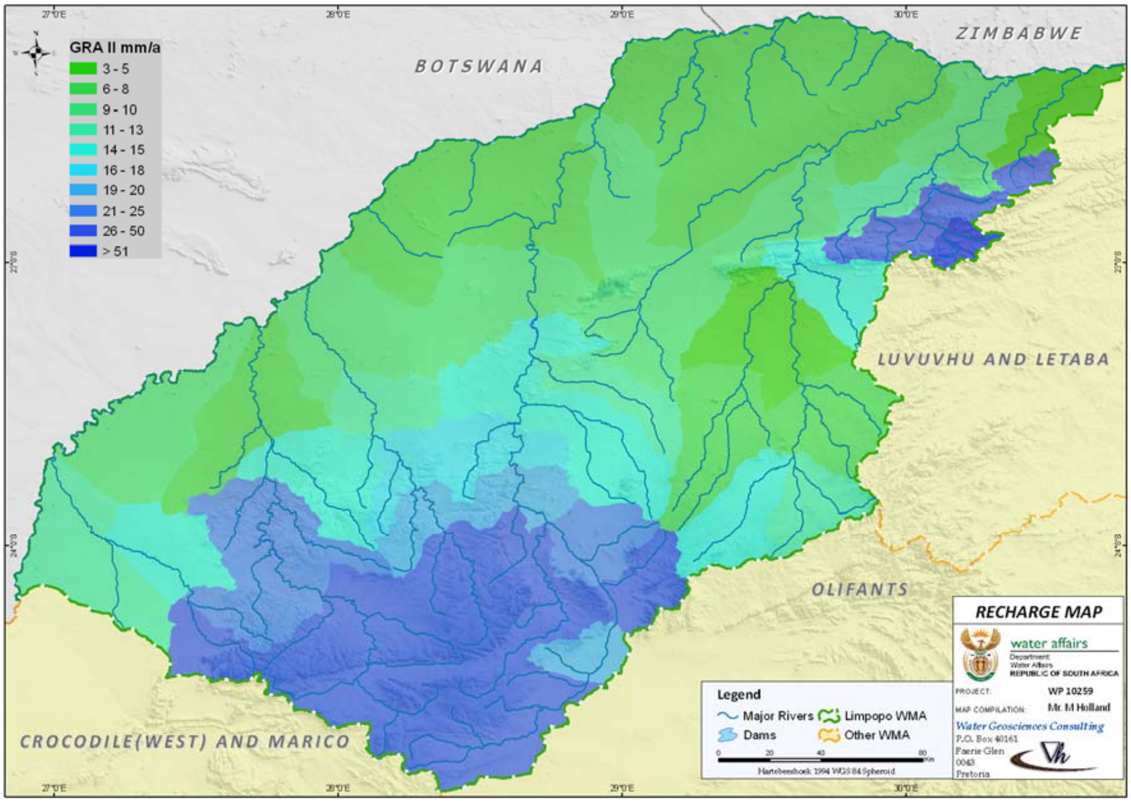

Figure 5. Recharge map based on values obtained from the GRA II dataset.

3.4 Land Use

Parts of the Limpopo WMA are heavily populated and widespread rural communities are a feature of the area which includes the old Lebowa and part of the old Venda. Hunters and cattle herders lived in the region since early times and these activities still thrive in the water management area today. Recent developments include large expansions in mining activities with respect to the platinum group metals, mainly in the vicinity of the Bushveld Igneous Complex.

Small areas of commercial forest are found in the high rainfall parts of the Soutpansberg near Makhado. Most of the water management area remains under natural vegetation, however, with livestock and game farming as main activities. Irrigation developments occur at various locations in the water management area, such as the Waterberg area, the Sand River catchment and along the Limpopo River, with much of the water being supplied from farm dams and groundwater. Approximately 700 rural villages are scattered throughout the WMA, more notably in the central parts, with little local economic activity to support these population concentrations (Figure 6).

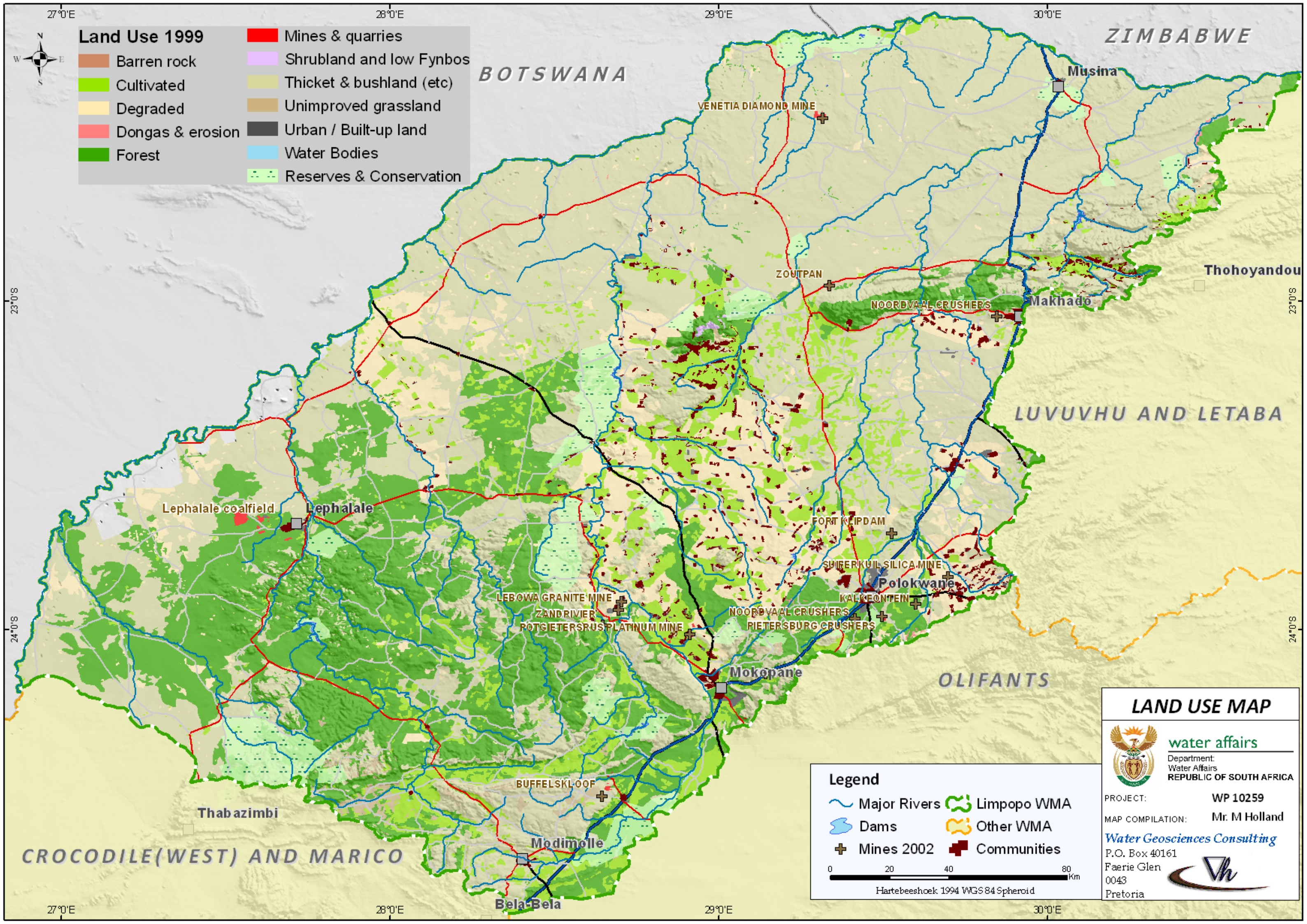

Figure 6. General land use map of the Limpopo WMA.

Polokwane is the largest urban centre in the WMA, and Musina, Makhado, Mokopane, Mookgopong and Modimolle as main towns. According to the latest demographic data from the Department of Water Affairs 1.7 million people live in the Limpopo WMA.

Table 2 provides a summary of the major water user's and potential water supply issues within each sub-area of the Limpopo WMA.

Table 2. Summary of major land use activities according to secondary drainage.

Sub-Area	**Tertiary Drainage**	**Major Water Users**	**Comment (ISP) (DWAF, 2004)**
Matlabas	**A41**	Irrigation	Largely undeveloped
Mokolo	**A42**	Lephalale Town Rural Settlements Grootgeluk Colliery Matimba Power Station Irrigation	Mokolo Area is approximately in balance. (Additional water requirements from groundwater). The quality of the water resource could be affected by the various land uses. New open cast coal mining activities near the town of Lephalale.
Lephalala	**A50**	Large Scale Irrigation Rural Settlements	The Lephelala Area is stressed. Groundwater will be the primary source of water for the scattered rural settlements. No mining or industrial activities in this area.
Mogalakwena	**A61/A62/A63**	Irrigation Mining/Industrial Urban Rural Settlements	Mining activities could pose serious pollution risks, more especially to groundwater. Groundwater use in the Area is large. In sourcing additional groundwater, care must be taken not to over-exploit the resource on a local scale.
Sand	**A71/A 72**	Irrigation Mining/Industrial Urban Rural Settlements	The surface water resource of the Area is very limited, urban requirements are supplied mostly from transfers into the Area. Large irrigation requirement is supplied mostly from groundwater (sustainability of the resource have been raised). Groundwater pollution in this area is widespread (more specifically nitrate).
Nzhelele	**A80**	Irrigation Rural Settlements Holiday Resort Forestation	Increased rural requirements should be sourced from groundwater. No new allocations are possible to the irrigation. Groundwater quality might be impacted from agricultural activities in areas where application of fertilizers is poorly managed.
Nwanedzi	**A80**	Irrigation Mining (small scale) Rural Settlements	There is extensive use of groundwater but still potential for further use. The risks of groundwater pollution by mining effluent and acid mine drainage must be understood. Prevention measures must be put in place, and monitoring programmes be established and maintained

4. INCEPTION TASKS COMPLETED

4.1 Literature Review

A number of literature sources have been acquired and reviewed by the project team thus far. This task will be ongoing and it is expected that further literature and knowledge will be gained as the project evolves. A number of GH (previous geohydrological directorate) reports which were summarised in Haupt (1995) have been collected from the Water Affairs library.

4.1.1 Desktop Reserves completed

A number of desktop groundwater Reserve determinations on quaternary scale as part of the water use licensing and registration process have been completed in the Limpopo WMA. According to recent information obtained from the RDM Office about sixty two percent of the quaternary catchments (42) in the Limpopo WMA have a desktop Reserve in addition to a rapid Reserve determination conducted by Water Geosciences consulting on the Mokolo catchment (A42) (WGC, 2008). A summary of the available results for the desktop including the Rapid Reserve is summarised in Table 3. These Reserves gives an indication of the current state of the groundwater system catchments in the Limpopo WMA (by looking at the PESC) and highlight some of the catchments with a high groundwater contribution to baseflow relative to recharge (e.g. Mokolo catchment). In most instances the Basic Human Needs (BHN) component comprise of a small percentage of the determined Reserve. Recharge of these Reserves is based on the GRA II datasets as illustrated in Figure 5 and requires authentication during this study. The results of the desktop/rapid Reserves will serve only as a reference and holds little value in terms of higher level Reserve quantification.

Table 3. Summary of the available desktop and rapid Reserves completed in the Limpopo WMA.

Sub-Area	Quaternary Catchments	Quaternary catchment	PESC#	Annual recharge (Mm^3/a)	GW contribution to Baseflow*	BHN (Mm^3/a)	Reserve (%)$
Matlabas/ Mokolo (A4)	A41A,B,C,D,E	A41A	B	19.1	3.1	0.2	17%
	A42A,B,C,D, E,F,G,H,J	A42A	C	16.1	4.1	0.4	28%
		A42B	C	16.9	8.2	0.3	50%
		A42C	C	21.8	4.0	0.2	19%
		A42D	B	17.0	9.2	0.1	55%
		A42E	C	22.5	8.2	0.3	38%
		A42F	B	22.3	2.5	0.4	13%
		A42G	A	25.3	2.7	0.3	12%
		A42H	A	15.6	0.6	0.2	6%
		A42J	A	13.2	0.4	0.0	3%
Lephalala (A5)	A50A,B,C,D, E,F, G,H,J	A50C	C	15.2	2.7	0.3	19%
Mogalakwena (A6)	A61A,B,C,D, E,F,G,H,J	A61A	C	11.8	5.8	0.2	50%
		A61C	C	19.5	0.5	0.5	5%
		A61D	B	16.0	1.3	0.1	9%
		A61E	C	10.6	0.6	0.1	7%
		A61H	D	18.9	1.7	0.1	9%
		A61J	D	23.5	2.3	0.2	11%
	A62A,B,C,D, E,F,G,H,J	A62E	B	8.6	0.3	0.6	11%
		A62F	B	9.1	0.4	0.4	9%
		A62G	C	13.0	0.5	0.1	5%
	A63A,C,B,D,E	A63B	D	11.1	0.0	0.2	2%
		A63C	A	16.0	0.8	0.2	6%
Sand (A7)	A71A,B,C,D, E,F,G,H,J,K,L	A71A	C	16.0	0.3	1.1	9%
		A71B	C	9.3	0.4	1.2	18%
		A71E	B	6.3	0.4	0.5	14%
		A71H	B	14.3	0.8	0.7	10%
	A72A,B	A72A	B	19.0	1.1	0.9	11%

* = Based on the Maintenance Low Flow of the IFR requirement from Baseflow
# = Present ecological status category (e.g. A=unmodified or D=largely modified)
$ = Reserve (BHN & Baseflow) as a percentage of Recharge

4.2 Data acquisition (GIS)

One of the main tasks during the Inception Phase of the GRDM assessment was the acquisition of data. The spatial characterisation of datasets and maps generated with GIS will greatly enhance the project team's ability to describe conditions prevailing in the Limpopo WMA. The following datasets were sourced thus far but it is expected that more site specific datasets will be introduced during the latter stages of the project:

- Limpopo GRIP datasets including the Nation Groundwater Archive have been acquired and entered into ArcGIS geodatabases (consists of yield, logs, chemical- and pumping test data).

- o GRAII datasets.
- o WARMS (Water Authorisation and Management systems).
- o All base map shapefiles (e.g. rivers, dams, roads, catchments etc.)

Other datasets include:

- o Regional hydrogeological maps (1: 500 000) and explanation booklets (Haupt, 1995; Du Toit, 2003).
- o Published geological maps (1: 250 000 series).
- o Topographic 1: 50 000 maps
- o ASTER lineaments (1:50 000) (Limpopo regional office).

4.2.1 Monitoring Data

All HYDSTRA (groundwater level) datasets for the Limpopo WMA have been sourced and is illustrated in (Figure 7) together with the Limpopo regional office's continues logger locations. These datasets are vital to describe the aquifers response to rainfall and will receive much attention in the GRDM assessment. Although the locations of the Water Management System Chemistry Data (monitoring points), rainfall- and river gauging stations are shown in Figure 7, this datasets still needs to be sourced.

4.3 Identification of project role players

The following persons have been notified and consulted with this far:

- Limpopo Regional Office (Department of Water Affairs).
  - o Willem du Toit
  - o Heyns Verster
  - o Piet Lubbe
  - o Celia Mashaba (DWA Capricorn manager)
- GRIP and other consultants
  - o Khulani GeoEnviro Consultants (Moropa Madisha).
  - o VSA Leboa (Reinhardt Weidemann).
  - o WSM Leshika (Carel Haupt).

The experience and knowledge of these individuals on the occurrence, development and management of groundwater within the Limpopo WMA will be of great value to the project. The following role players and Water Service Authorities were identified but still needs to be notified of the GRDM assessment:

- Selected mining houses.
- Waterberg-, Vhembe- and Capricorn District Municipalities
  - o Includes community borehole managers (e.g. Satellite- and camp managers)

A list of role players and knowledge gained will be updated continuously.

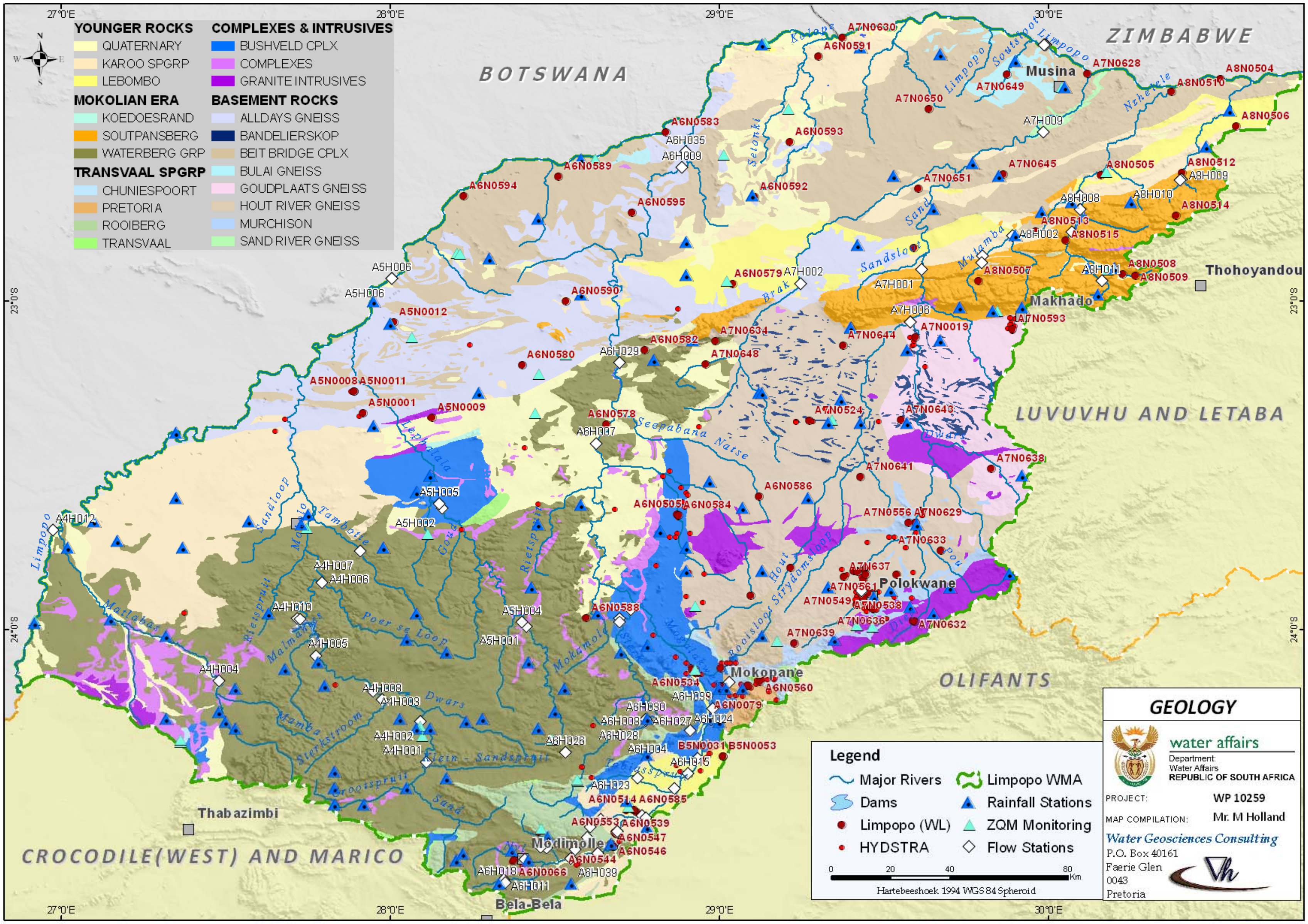

Figure 7. Monitoring station locations.

5. GRDM ASSESMENT

5.1 Background

The Limpopo WMA is described as a '*water stressed region that lacks baseflow*' due to over-exploitation of the groundwater resources and prolonged drought periods*.* A stressed catchment implies PESC (present ecological status class) levels of C to D and above for most indicators. It is understood that, due to the variability of groundwater use and differing levels of stress, that the study can only support high confidence level results (i.e. requiring a comprehensive GRDM assessment) in areas where site-specific, representative and detailed data is available. In addition, not all aquifer systems are adequately covered with respect to both regional and site-specific groundwater monitoring data and groundwater quality indicators are seldom measured in monitoring programmes. This study will identify 'hot spot' areas, in a geohydrological context, with monitoring protocols designed accordingly.

5.1.1 Key aspects facing the project team

Data integrity, reliability and representivity are key requirements of the GRDM methodology:

- The accuracy of the available yield and the potential of the different aquifers based on current usage, recharge, storage, climate patterns and predicted climate change are dependent on the reliability of the available input data.
- The present spread of groundwater and flow gauge data may be inadequate to evaluate regional or aquifer specific-patterns of recharge and discharge.
- In addition, the density and representivity of data may be inadequate to interpret regional patterns of seasonal fluctuations, surface-groundwater interactions, spring discharge, environmental dependency and response to climate variations.
- Municipal use and groundwater usage for small town supplies are variably monitored and there are issues of consistency, reliability, frequency of measurement and routine interpretation of the data. Private use may be significant and unmonitored. It is not possible to make sustainable or defensible licensing decisions based on incomplete or inadequate records, point source data, and irregular time series data.

This study allows for a hydrocensus with regard to groundwater quality, abstraction and discharge for different aquifers to verify existing data. The current estimates of groundwater usage will also be verified.

Assumptions underlying the GRDM Methodology include:

- Resilient groundwater systems can recover from perturbations.
- Groundwater resources can be developed without depleting the Reserve.

- The resource and/or Reserve are not impacted if groundwater levels do not decline (long-term) and ambient groundwater quality remains within natural limits.
- Sustainable abstraction rate is a function of long-term annual recharge while aquifer storage acts as buffer during dry periods.
- Recharge and abstraction are relatively evenly distributed throughout significant water resources.
- Validity of GRDM assessment monitored every 5 years using monitored data.
- GRDM assessment carried out by qualified personnel and subject to formal review.

5.2 Technical Approach

The assessment is to be based on the methods described by Parsons and Wentzel (2007). However, the underlying assumptions of the GRDM methodology (described in section 5.1.1) will be taken into account. The project team aims to evaluate the applicability of the GRDM methodology and to propose improvements where applicable. The following common steps of the GRDM assessment are proposed for the Limpopo Reserve determination.

5.2.1 Detailed description of study area

A detailed hydrgeological description will be included to support subsequent sections on the delineation of groundwater resource units, etc. The geohydrological description will refer to the status of the identified water resources with reference to:

- Identifying the ambient conditions (reference conditions where possible) for the resource units
- Observed impacts due to abstraction (water use), impacts on groundwater quality, etc.
- Groundwater – surface water interactions will be addressed by identifying and characterising potential interactions in association with surface water Reserve teams.

Figure 8 illustrates whether the baseflow in a river is likely to be fed by groundwater. If the river has a low probability of being groundwater-fed, then no further assessment of baseflow is required. According to Sophocleous (2002) perennial streams are primarily gaining, ephemeral streams are generally losing and intermittent streams might either gain or lose water depending on the season.

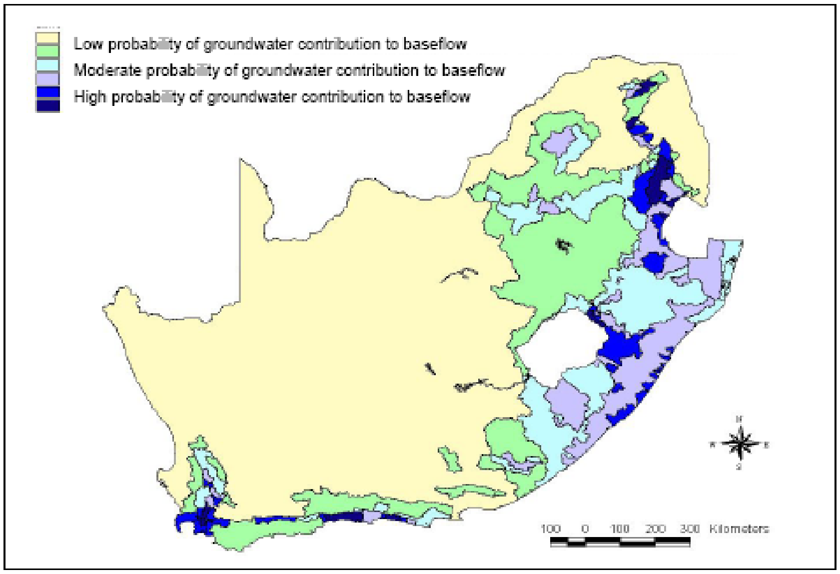

Figure 8. National scale map showing the relative probability of groundwater contributing to baseflow (Parsons and Wentzel, 2007)

Based on Figure 8 the Limpopo WMA generally lacks baseflow however, areas where baseflow is significant a two tiered classification scheme comprises a geological classification of the river-aquifer setting (Figure 9) followed by a hydraulic classification of the interaction (Figure 10) will be applied. The approach combines and extends the hydraulic classification by Vegter and Pitman (2003) with geological features similar to the method of the Environment Agency (2002).

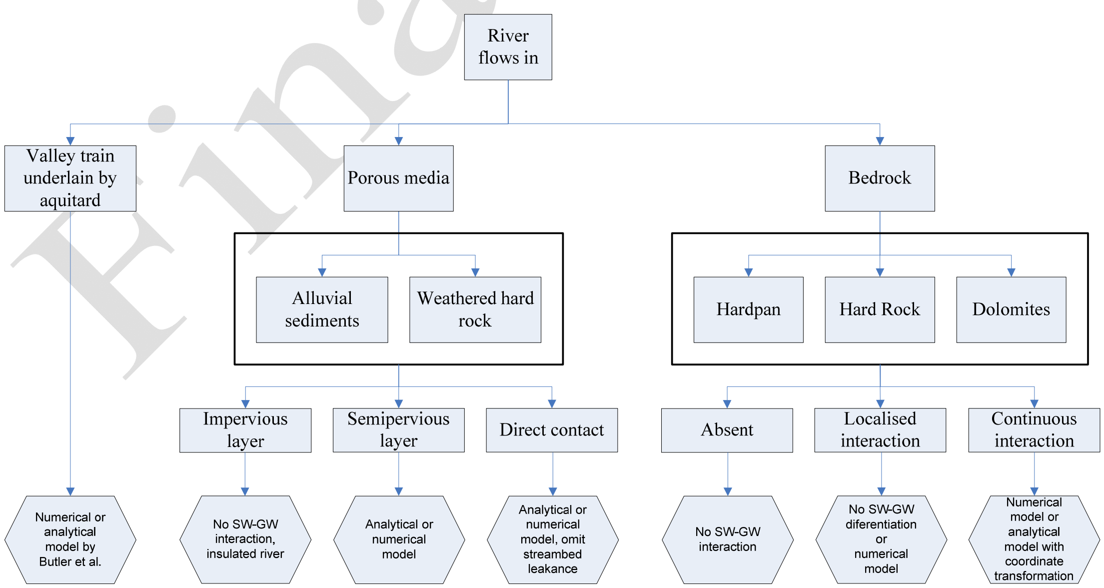

Figure 9. Primary geological classification scheme for surface-groundwater interaction assessments.

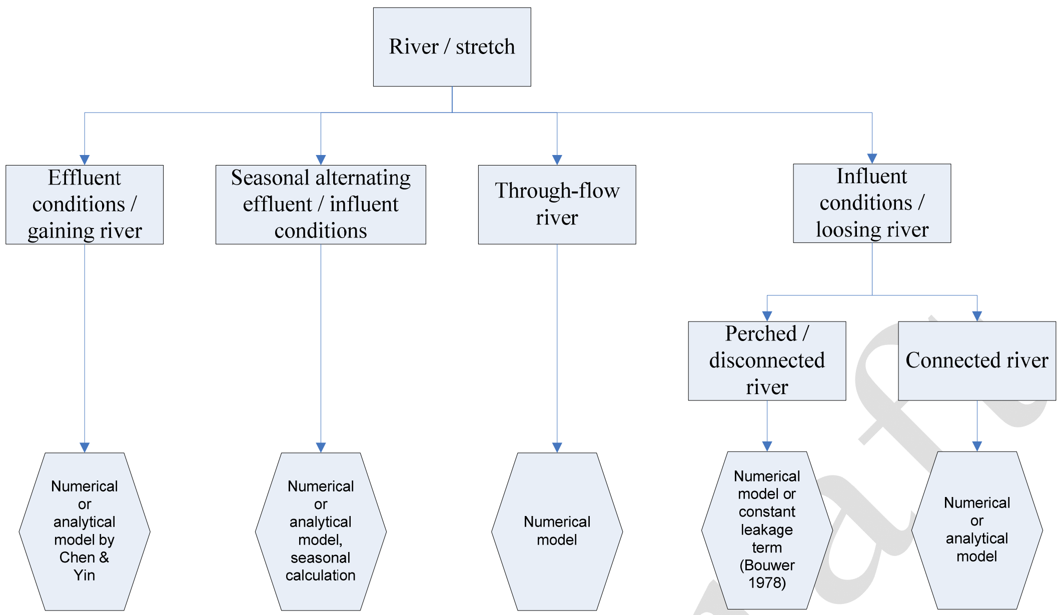

Figure 10. Secondary hydraulic classification scheme for surface-groundwater interaction assessments.

The primary geological classification (Figure 9) differentiates between rivers flowing in porous media or over bedrock. A third class accounts for valley trains underlain by aquitards, a typical situation of an alluvial aquifer along a river stretch underlain by impervious hardrocks. The porous media is further subdivided into alluvial sediments and weathered hard rock (residual soils) and the occurrence of any semi- or impervious layers noted. If an impervious layer impedes any surface-groundwater exchange, the river is insulated. The bedrocks on the other side are further subdivided into hard rocks, dolomites and hardpans. Surface-groundwater interaction is characterised as absent, localised (e.g. swallow holes, single major spring within a river) or continuous (diffuse gains/losses along river stretch). Following the conceptualisation of the geological setting the type of surface-groundwater interaction is classified in accordance to Vegter & Pitman (2003); i.e. based on the prevailing hydraulic gradient (Figure 10). The knowledge gathered in the project will be intuitively visualised in a hydrogeological map focussing on the above outlined river classification.

Fieldwork (hydrocensus), scheduled for approximately 2 months, is proposed to verify existing information. The fieldwork phase will be designed to inspect identified hotspots and verify critical parameters (e.g. water levels, hydrochemistry) characterising the groundwater resources. The fieldwork phase will also be designed to assist with the delineation and classification/categorization of the resource units.

5.2.2 Delineation of resource units

Delineation of significant (aerial extent) **groundwater resource units** (GRU) is based on quaternary catchment boundaries, aquifer type (primary, secondary or dolomitic) and other physical, management or functional criteria by project hydrogeologist.

- **Primary delineation**: Based on quaternary catchments, typically used for desktop or rapid assessments.
- **Secondary delineation**: Based on aquifer type (primary – secondary – dolomitic aquifers), sometimes re-grouped into a single unit.
- **Tertiary delineation**: No formal methodology, based on expert judgement and local knowledge.

Outcomes of phase:

- Delineation and description / justification for resource units (i.e. GRU and/or RU).
- Map showing extent of significant resource units (GRU/RU) in the study area.
- Consider other components of the water cycle (i.e. wetlands, rivers, etc.)
- GRDM assessment data sheet (list of each GRU/RU and its aerial extent).

The approach for delineation will probably vary between primary and secondary delineation approaches. However, as noted in section 3.3, basement lithologies have similar hydrogeological characteristics and delineation of groundwater resource units (secondary delineation) cannot only be based on lithology but should take into account amongst other, rock structure, climate and its susceptibility to weathering. It is expected that where data permits the delineation will be based on a tertiary delineation approach. A detailed hydrgeological description will be included to support subsequent sections on the delineation of groundwater resource.

5.2.3 Water resource classification

The purpose of the phase is to:

- Define a resource with regard to the current impact on the resource by considering a range of factors, incl. recharge, groundwater use, contamination or expected contamination status.
- Define a single Present Status Category (i.e. current state) for each RU and/or GRU
- Define the Water Resource Category (i.e. Natural, Good, Fair, Poor) for each RU and/or GRU.

Guideline tables and expert judgment for the Water Resource Classification / Categorization process will be used as developed for the GRDM process. A specific methodology to derive at the Management Class for a specific Resource Unit was as suggested in the tender document submitted. It is regarded as an Interim Resource Classification and is based on methods from Aller et al. (2005), Parsons and Conrad, (1998) and Parsons and Wentzel,

Key outcomes of phase will include:

- o A Present Status Category to each RU and/or GRU.
- o A Water Resource Category (i.e. Natural, Good, Fair, Poor) assigned to each RU and/or GRU.
- o GRDM Assessment Data Sheet – Record assigned category to each RU and/or GRU.

The classification process aims to define a resource in its natural state (reference conditions), determine/assess its current state and levels of its development and use, and define the future desired state of the resource - i.e. establishing a future management class for each Resource Unit. The above information is used in the RDM Classification Process to set the Management Class and Desired Status Category for each GRU / Resource Unit. The latter is not part of the Terms of Reference for the project.

5.2.4 Quantification of the groundwater Reserve

Where groundwater contributes or supports basic human needs or aquatic ecosystems, groundwater forms a component of the Reserve and hence has to be considered. However, groundwater also occurs in areas away from aquatic ecosystems and supports other components of the environment. In such instances, groundwater protection is affected through Resource Classification and Resource Quality Objectives (RQOs').

The outcome from this phase of the work is a quantification of groundwater (considering both quantity and quality) that can be abstracted from each RU ($GW_{allocation}$) with no significant impact on that unit's ability to sustain the Reserve and meet the RQO's. This quantity has to consider the impacts of groundwater abstraction on baseflow, i.e. the interception of groundwater which would have otherwise discharged into the surface water resource as well induced recharge from the surface water resource. In such an instance, the quality of groundwater required by sensitive groundwater dependent ecosystems will also have to be set. A crucial component that needs to be taken into account during this phase is to integrate data and results of the surface water Reserve studies. This task will mainly depend on proper communication with surface water specialists.

This can be done firstly by acquiring all data of surface water Reserve studies, comparison of desktop groundwater Reserve results, assessment of data and finally technical meetings between surface- and groundwater specialists.

Key outcomes of phase include:

- o Determine a quantity of groundwater (i.e. Groundwater Allocation) that can be abstracted from a RU / GRU without impacting the ability of the RU / GRU to sustain the Reserve (BHN & Ecological Reserve) and meet the RQO's.
- o GRDM assessment data sheet with recorded values of recharge, groundwater contribution to baseflow, BHN's etc.
- o Calculation of the Reserve as % of recharge and groundwater allocation per resource unit.
- o Scale the results to various appropriate units according to the management and administrative needs of DWA, e.g. to quaternary catchment level.
- o Compile a list of proposed groundwater utilisation license conditions that can be used to assist the Regional offices of the DWA to incorporate licensing conditions for ad hoc licenses to be issued.

5.2.5 Setting of preliminary Resource Quality Objectives (RQO's):

The purpose of this phase is to Set Resource Quality Objectives (RQO's) for each of the delineated resource units and to relate the RQO's to management objectives:

- o Select key measurable indicators as RQO's based on the conceptual understanding of the aquifer systems (including the groundwater dependent ecosystems in the study area) and the Reserve to be maintained.
- o Select practical, implementable and measurable indicators as RQO's that may include groundwater levels and gradients, guideline concentrations for the salinity, microbiological contamination, etc., limits on groundwater abstraction volumes, protection/exclusion zones around ecological sensitive areas or to limit impacts on the groundwater resource, etc.
- o Set level(s) at which RQO's must be maintained to protect and sustain the delineated water resource.
- o RQO's cannot be set at a level more stringent than reference or ambient conditions of a particular water resource.
- o Users of the resource will be tasked with monitoring of the resource against the set RQO's.

Resource quality refers to all aspects of a water resource including:

- o The quantity, pattern, timing, water level and assurance of in-stream flow including the environmental water requirements,

- The water quality, including the physical, chemical and biological characteristics of the water,
- The character and condition of the in-stream and riparian habitat,
- The characteristics, condition and distribution of the aquatic biota.

RQO's are defined to set aquifer management criteria and/or limits of acceptable impact, to set criteria to protect groundwater dependent ecosystems, etc. The RQO's are used to guide post GRDM aquifer management and monitoring activities.

5.2.6 Recommendations for a groundwater monitoring programme (post GRDM)

The Monitoring programmes generally encompass two goals:

1) National scale monitoring: Long-term, standardized measurements and observations of groundwater in order to define status and trends of groundwater resources and to determine its "fitness of use".

2) Local scale monitoring: Monitoring could also be (based on availability of resources associated with a subsequent monitoring phase) of finite duration, intensive and site-specific in order to measure and observe the quality of groundwater resources in selected impacted groundwater sites at South Africa.

Similarly, groundwater monitoring programmes can be designed at regional or WMA level.In order to protect the aquifer systems or groundwater resources against specific contamination/pollution threats, a monitoring programme (i.e. a surveillance system of continuing observation, measurements and evaluations) at local scale is necessary. Data from national groundwater databases may not be relevant (or at the required detail) for groundwater monitoring at a local scale. Site-specific data will have to be generated for the development of conceptual models on local groundwater conditions.

Groundwater monitoring and sampling sites should be selected to be representative of geology, groundwater use, land-use, groundwater flow regimes, etc. Best practice guidelines for hard-rock environments (eg. ASTM) must be followed to ensure the representivity and reliability of samples collected. Care should be taken to ensure that the integrity of the data collected for groundwater monitoring purposes is maintained at all times.

Monitoring protocols, to generate data for compliance with RQO's, will be developed with due cognisance of the above and the current monitoring programmes exercised by the National and Regional Water Affairs office.

Such monitoring protocols will be developed taking into account the following:

Groundwater Databases:

- Most regional offices maintain their own local Excel databases for subsequent incorporation into the NGDB.
- Local municipalities and large commercial groundwater users maintain their own databases usually assisted by consulting groups.
- Groundwater data is stored in various databases such as the NGDB, WMS, HYDRAS and HYDSTRA as well as numerous geohydrological reports. As a result, groundwater databases and information systems need to be integrated to improve communication between water resource management institutions and water services authorities / providers.

Groundwater Monitoring Programmes:

- Most DWA Regional offices conduct their own regional groundwater monitoring programmes.
- Similarly, local municipalities also conduct local groundwater monitoring programmes assisted by various consulting groups and captured in different databases. There are limited interaction between such municipalities and DWA.
- Integration of the monitoring programmes, as well as the data and information generated, is limited.
- Adequate groundwater monitoring programmes is not in place for all aquifer systems.

Groundwater quality parameters and abstraction volumes are generally not collected during routine monitoring programmes. Such programmes must focus on the impacts associated with the varied groundwater uses.

6. PROJECT MANAGMENT

6.1 Project Team

The project team included in the tender document submitted to the Department of Water Affairs is summarised in Table 4. The team consists of experienced consultants from Water Geosciences Consulting and VSA Leboa. VSA Leboa can be considered one of the major contributors of the GRIP programme since its onset in the early 2000's. VSA's experience in groundwater exploration and water supply projects in the larger Limpopo can be of great use to the project to develop a good conceptual understanding of groundwater occurrence and aquifer characteristics. If deemed necessary by the project team specialists inputs will be sourced to ensure detailed knowledge relating to a specific field (e.g. hydrologists, ecologist) are available.

Table 4. Project Team.

Team member	Organisation	Key Function	Secondary Function
Rian Titus	WGC	Project Manager	Lead Hydrogeologist
Martin Holland	WGC	Task Leader	Hydrogeologist (GIS Specialist)
Kai Witthüser	WGC	Specialist Hydrogeologist	Modeling & Reporting Review
Karabo Lenkoe	WGC	Hydrogeologist	Literature Review, Data Management
Theo Rossouw	WGC	Hydrogeologist	Hydrocensus (GIS)
Neels Sonnekus	VSA Leboa	Hydrogeologist	Groundwater Exploration
Reinhardt Weidemann	VSA Leboa	Hydrogeologist	GRIP Consultant

6.2 Finances

A detailed description of the budget and time allocations for various tasks, for the entire project is summarized in Table 6. The proposed total expenditure for the entire project is R 1 334 528 (inclusive of disbursements and VAT). The percentage of the budget, allocated to HDI individuals, equal 52% (Table 5). The total monthly expenditure as well as the cumulative expenditure over the project period in illustrated in Figure 11.

Table 5. Time allocation and percentage of budget allocated to staff.

STAFF	Time Allocation (hrs)	Budget (excl. VAT)	% of Budget
Martin Holland	488	R 292 800	27
Karabo Lenkoe	784	R 352 800	33
Theo Rossouw	328	R 147 600	14
Rian Titus	256	R 192 000	18
Kai Witthueser	120	R 90 000	8
TOTAL Prof. Fees (Excl. Disbursements & VAT)		**R 1 075 200**	**100**

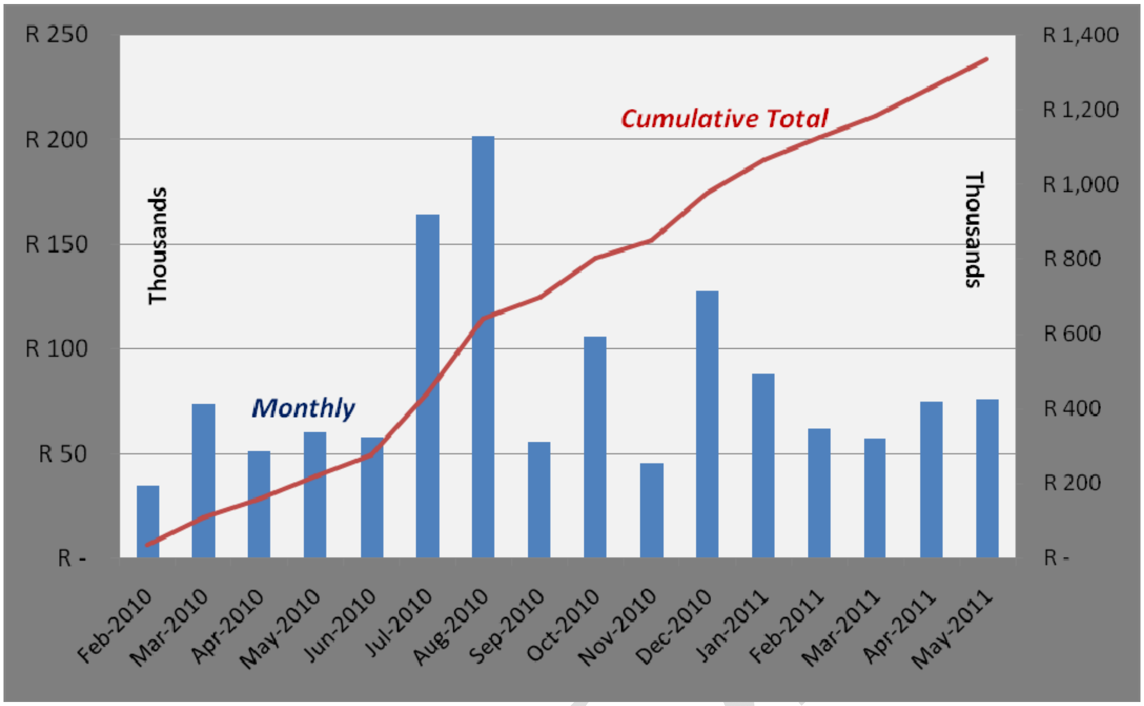

Figure 11. Total monthly expenditure as well as the cumulative expenditure over the project period.

Table 6. Project (budget) scheduling.

COST ESTIMATE																	
Tasks	**Feb-2010**	**Mar-2010**	**Apr-2010**	**May-2010**	**Jun-2010**	**Jul-2010**	**Aug-2010**	**Sep-2010**	**Oct-2010**	**Nov-2010**	**Dec-2010**	**Jan-2011**	**Feb-2011**	**Mar-2011**	**Apr-2011**	**May-2011**	**Totals**
1 PROJECT MANAGEMENT																	
SUB-TOTAL	R 7,340	R 6,940	R 7,340	R 6,940	R 7,340	R 3,520	R 3,920	R 6,940	R 3,920	R 3,520	R 3,920	R 3,520	R 3,920	R 6,940	R 3,920	R 6,940	R 86,880
2 PHASE 1: INCEPTION PHASE																	
SUB-TOTAL	R 21,520	R 66,560	R 21,520	R 0	R 0	R 0	R 0	R 0	R 0	R 0							R 109,600
3 PHASE 2: STUDY IMPLEMENTATION																	
SUB-TOTAL	R 0	R 0	R 16,416	R 52,984	R 44,776	R 160,856	R 192,320	R 48,776	R 96,656	R 41,936	R 118,280	R 84,080	R 52,616	R 29,728			R 939,424
4 PHASE 3: PROJECT TERMINATION																	
SUB-TOTAL	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 0	R 20,520	R 65,296	R 69,032	R 154,848
5 PHASE 4: CAPACITY BUILDING																	
SUB-TOTAL	R 5,472	R 0	R 5,472	R 0	R 5,472	R 0	R 5,472	R 0	R 5,472	R 0	R 5,472	R 0	R 5,472	R 0	R 5,472	R 0	R 43,776
TOTALS	R 34,332	R 73,500	R 50,748	R 59,924	R 57,588	R 164,376	R 201,712	R 55,716	R 106,048	R 45,456	R 127,672	R 87,600	R 62,008	R 57,188	R 74,688	R 75,972	R 1,334,528

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