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DEPARTMENT OF WATER AND SANITATION
CHIEF DIRECTORATE: WATER ECOSYSTEMS

THE DETERMINATION OF WATER RESOURCE CLASSES AND ASSOCIATED RESOURCE QUALITY OBJECTIVES IN THE INKOMATI WATER MANAGEMENT AREA









RESOURCE QUALITY OBJECTIVES: GROUNDWATER

Report Number: RDM/WMA05/00/CON/CLA/0514

JANUARY 2015

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REFERENCE

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R 9	RDM/WMA05/00/CON/CLA/0315	The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area: **Close out report**

DEPARTMENT OF WATER AND SANITATION
CHIEF DIRECTORATE: WATER ECOSYSTEMS

THE DETERMINATION OF WATER RESOURCE CLASSES AND ASSOCIATED RESOURCE QUALITY OBJECTIVES IN THE INKOMATI WATER MANAGEMENT AREA

RESOURCE QUALITY OBJECTIVES: GROUNDWATER

Report Number: RDM/WMA5/00/CON/CLA/0514

Approved for IWR Water Resources by:

…………………………………….. | ***29 May 2015***
Delana Louw | Date
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During the course of the study the demarcations of the Water Management Area changed. This resulted in the Inkomati Water Management Area changing to the Inkomati-Usuthu Water Management Area. These changes are reflected in the text of the following reports although the title of the study and associated maps, headers and footers were left unchanged and conform to the original report format:

- R 5: RDM/WMA05/00/CON/CLA/0414 - The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area: **Resource Quality Objectives: Rivers and Wetlands.**
- R 6: RDM/WMA05/00/CON/CLA/0514 - The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area: **Resource Quality Objectives: Groundwater.**
- R 7: RDM/WMA05/00/CON/CLA/0115 - The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area: **Implementation report.**
- R 8: RDM/WMA05/00/CON/CLA/0215 - The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area: **Main report.**
- R 9: RDM/WMA05/00/CON/CLA/0315 - The determination of water resource classes and associated resource quality objectives in the Inkomati Water Management Area: **Close out report.**

EXECUTIVE SUMMARY

INTRODUCTION

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study during 2013 for the provision of professional services to undertake the determination of Water Resource Classes and associated Resource Quality Objectives (RQOs) in the catchments of the Inkomati. IWR Water Resources was appointed as the Professional Service Provider (PSP) to undertake this study.

This task forms ***part*** of Step 6, i.e. the development of RQOs and provision of numerical limits for the Groundwater component of the study area. This step is closely linked to the next step where the class configuration and RQOs are gazetted and implemented. The results of Step 6 are documented in this report. The information generated during Step 1, 3, 4 and 5 forms the basis of the RQOs.

The study area comprises the Komati, Crocodile East and Sabie-Sand river catchments. These three major tributaries of the international Inkomati River Basin are operated largely independently of each other and are therefore described in this section as separate entities.

DESCRIPTION OF GROUNDWATER RESOURCES

The catchments of the Inkomati are predominantly (> 60%) underlain by igneous and metamorphic crystalline basement rocks comprising of the Northern Basement Rocks (i.e. Nelspruit Suite) and the Barberton Supergroup. The Inkomati aquifers comprise of five groundwater regions as defined by Vegter (2000) and are predominantly characterised by their geological settings. Within each of these regions a number of aquifer types can be differentiated namely:

- Intergranular (weathered) and Fractured Aquifers.
- Fracture Aquifer.
- Intergranular (alluvial) aquifers.

Based on the borehole yield classification insignificant to minor aquifers are present in large parts of the Inkomati. Moderate intergranular aquifer zones are associated with river courses, valleys or open plains and although not specifically mapped, they do occur locally throughout the Inkomati. The Malmani dolomite formations cutting across the Inkomati forms a moderate Karst aquifer.

The delineation of groundwater units (GUs) are based on hydrogeological criteria and might not necessarily correlate to quaternary surface water catchments or surface water units of analysis. A total of nineteen GUs were delineated.

Based on the collated borehole datasets obtained from the National Groundwater Archive (NGA) average water levels range from 7 to 25 m below surface with average borehole yields of 0.4 to 3.1 l/s.

The 'Great Escarpment' is an important recharge area and groundwater provides significant baseflow to the head waters of surface drainages. The lower reaches of the Inkomati lack on the other hand groundwater baseflow and many major rivers have a low probability of being groundwater-fed.

Mean annual groundwater recharge varies from 100 to 150 mm in the higher rainfall areas along the central escarpment regions to 10 to 25 mm in the low rainfall and lower lying easternmost portion of the Inkomati. The average annual groundwater recharge for the entire Inkomati based on the Groundwater Resource Assessment Phase II (GRA II) dataset is estimated to be more than 1 500 Mm^3/a, equating to recharge percentages between 5 and 10% of the mean annual precipitation for the area.

According to the Inkomati ISP groundwater use amounts to 27.5 Million m^3/a based on the Water Use Authorisation and Registration Management System (WARMS) database (2004), while estimated use based on the GRA II dataset amount to only 13.3 Million m^3/a (DWAF, 2004a). The current study approach took also cognisance of the GRA II and WARMS 2013 datasets to achieve a more balanced estimate of groundwater use. The total groundwater use for the Inkomati was subsequently estimated to 52.3 Mm^3/a.

Approximately 800 groundwater quality samples (latest analysis per station) were collated from the NGA and Water Management System (WMS) datasets. A deterioration of the groundwater quality (salinity) in the Inkomati from west to east, following essentially the average annual rainfall, is obvious. Several samples show major ion concentrations (i.e. Mg, Na, Cl, and F) and subsequently electric conductivities elevated to Class II drinking water qualities. This can mostly be related to evaporative concentration of elements in discharge areas or low recharge values, while the occurrence of fluoride is primarily controlled by geology.

Historical mining activities have resulted in the presence of abandoned adits, shafts, mine reside deposits and other infrastructure scattered across the area, although the impact of these on groundwater quality is thought to be rather local in nature. Other potential threats to groundwater quality include sub-standard sewage treatment plants and agricultural activities. Due to the growing population, the increase in the use of septic tanks, pit and bucket latrines, poses a direct risk to the groundwater quality in terms of nitrate and bacterial or viral concentrations.

GROUNDWATER CLASSIFICATION

The Komati sub-catchment comprises of seven GUs. Groundwater use is substantially higher within the lower parts of the Komati sub-catchment with a registered groundwater use of over 6 Mm^3/a. These volumes need to be verified with follow-up studies but may well relate to either an over registration or wrongly entered information into WARMS. The aquifers of the Komati sub-catchment are by far not utilised to their potential. Overall groundwater quality in the Upper Komati sub-catchment is regarded as good with most samples complying with the recommended drinking water quality standards. Coal mining poses a threat to the quality of the groundwater if compliance to environmental legislation is not enforced. Groundwater level fluctuations from the observed hydrographs vary between 1 and 3 m. No declining trend due to abstraction is observed from the hydrographs.

The Crocodile sub-catchment comprises of six GUs. Groundwater use is dominated by irrigation and forestry. Numerous rural communities occur within the region dependant on groundwater for water supply. Groundwater use in relation to recharge and available resources is minimal throughout the sub-catchment. The overall groundwater quality in the Crocodile sub-catchment is regarded as good with most samples complying with the recommended drinking water quality standards. Slightly elevated sulphate concentrations compared to the population are seen in some samples. These locally impacted groundwater quality might be related to the industrial activities occurring along the Elands River. Groundwater level fluctuations from the observed hydrographs vary between 1 and 4 m. No declining trend due to over abstraction is observed from the hydrographs.

The Sabie-Sand sub-catchment comprises of five GUs. Groundwater use is predominantly for domestic use specifically in the Middle Sabie and Bushbuckridge areas. The aquifers of the Sabie-Sand sub-catchment are by far not utilised to their potential. The upper Sabie-Sand sub-catchment provides a groundwater contribution to surface flow from springs and seeps along the escarpment, as well as from the dolomitic formation which extends across the headwaters of the of the Sabie River. The overall groundwater quality in the Sabie-Sand sub-catchment is regarded as good with most samples complying with the recommended drinking water quality limits. A slightly poorer water quality is observed in the Lower Sabie-Sand region, mainly due to elevated Electrical Conductivity (EC), Total Dissolved Salt (TDS), Sodium and Chloride values. This can again be related to evaporative concentration of elements in discharge areas, and low recharge values. Although not yet above recommended drinking water guideline limits, elevated Nitrate concentrations within suggest potential anthropogenic influences on the groundwater quality related to inappropriate on-site sanitation, wastewater treatment including sewage sludge disposal or livestock concentration (animal feedlots) at watering points near boreholes. Water levels show a general seasonal fluctuation and no declining trend due to abstraction is observed from the hydrographs.

In summary, groundwater use in relation to recharge and available resources (harvest potential) is minimal throughout Inkomati. Numerous groundwater level monitoring dataset depict and increasing trend suggesting that the system is no under significant stress due to (over)abstraction. Increasing domestic and other industries water requirements could be met from groundwater. The groundwater quality of the Inkomati is generally of potable use; however, some boreholes do show elevated nitrate concentrations.

RESOURCE QUALITY OBJECTIVES

The groundwater RQOs and appropriate numerical limits are based on what information is available and estimations using hydrogeological reasoning. It is understood that the Inkomati is not regarded as a high groundwater priority area and the status quo was largely based on a desktop assessment. Where available, existing monitoring networks were taken into account in setting the RQOs. Although, the Resource Unit Prioritisation Tool can be applied for rivers, wetlands and estuaries, currently no methodology exists for prioritising groundwater Resource Units. As a result no official criteria and rating guideline was applied for the Inkomati RQO but prioritisation was based on the following main indicators:

- Importance for users.
- Threat posed to users/receptors.
- Practical considerations.
- Level of surface water – groundwater interaction.

The relevant RQO parameters used included water level, baseflow and water quality. The setting of water quantity related RQOs (i.e. water level and baseflow) is aimed at maintaining water levels within natural seasonal fluctuations ensuring sufficient yield for all users and to improve or maintain groundwater discharge to support low flow river requirements. The setting of water quality related RQOs is aimed at maintaining the groundwater quality in relation to its background/present level, or ensuring compliance with water quality standards for domestic use, as this is the more stringent requirement for the variety of users in the GU.

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ACRONYMS

AMD	Acid Mine Drainage
BHN	Basic Human Need
CD: WE	Chief Directorate: Water Ecosystems
DWA	Department of Water Affairs (Change after 2008)
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water Affairs and Sanitation (Change after May 2014)
GRA II	Groundwater Resource Assessment Phase II
GRDM	Groundwater Resource Directed Measures
GU	Groundwater Unit
GW	Groundwater
HP	Harvest potential
ISP	Internal Strategic Perspective
MAP	Mean Annual Precipitation
mbs	Metres below the surface
NGA	National Groundwater Archive
PSP	Professional Service Provider
RQOs	Resource Quality Objectives
SI	Stress Index
TDS	Total Dissolved Solids
UGEP	Utilisable Groundwater Exploitation Potential
WARMS	Water Use Authorisation and Registration Management System
WMA	Water Management Area
WMS	Water Management System

1 INTRODUCTION

1.1 BACKGROUND

The Chief Directorate: Water Ecosystems (CD: WE) of the Department of Water and Sanitation (DWS) initiated a study during 2013 for the provision of professional services to undertake the determination of water resource classes and associated Resource Quality Objectives (RQOs) in the catchments of the Inkomati. IWR Water Resources was appointed as the Professional Service Provider (PSP) to undertake this study which is managed by Rivers for Africa for IWR Water Resources.

1.2 STUDY AREA OVERVIEW

The study area comprises the Komati, Crocodile East and Sabie-Sand river catchments, as shown in Figure 1.1. These three major tributaries of the international Incomati River Basin are operated largely independently of each other and are therefore described in this section as separate entities.

1.3 INTEGRATED STEPS APPLIED IN THIS STUDY

The integrated steps for the National Water Resource Classification System, the Reserve and RQOs (DWA, 2013a) are supplied in Table 1.1.

Table 1.1 Integrated study steps

Step	Description
1	Delineate the units of analysis and Resource Units, and describe the status quo of the water resource(s).
2	Initiation of stakeholder process and catchment visioning.
3	Quantify the Ecological Water Requirements and changes in non-water quality ecosystem.
4	Identification and evaluate scenarios within the Integrated Water Resource Management process.
5	Evaluate the scenarios with stakeholders and determine Water Resource Classes.
6	**Develop draft RQOs and numerical limits.**
7	Gazette and implement the class configuration and RQOs.

This task forms ***part*** of Step 6, i.e. the development of RQOs and provision of numerical limits for the Groundwater component of the study area. This step is closely linked to the next step where the class configuration and RQOs are gazetted and implemented. The results of Step 6 are documented in this report. The information generated during Step 1, 3, 4 and 5 forms the basis of the RQOs.

1.4 LITERATURE AND DATA

The following reports and datasets were consulted for the determination of the Status Quo and the classification of groundwater resources in the Inkomati:

- Inkomati WMA. Overview of Water Resources Availability and Utilisation (DWAF, 2003).
- Inkomati (WMA). Internal Strategic Perspective (DWAF, 2004a).
- Komati Catchment Ecological Water Requirement study; Groundwater Scoping Report (AfriDev, 2005).
- Inkomati Groundwater Reserve Determination (AGES, 2007).
- Desktop Geohydrological Assessment of the Sudwala/Pilgrim's Rest Dolomites (WGC, 2008).

- Comprehensive Groundwater Reserve Determination study for the Inkomati WMA (AGES, 2010).
- Inkomati Water Availability Assessment (DWAF, 2009).

Data Collation:

- 1:250 000 geological maps (Council for Geoscience).
- 1:500 000 Nelspruit and Phalaborwa geological maps (Council for Geoscience).
- Groundwater Resources Information (Groundwater Resource Assessment Phase II - GRA II) Project (DWAF, 2004b) – Quaternary Scale.
    - Recharge; Baseflow; Groundwater/harvest potential.
- Groundwater Use (GRA II and Water Use Authorisation and Registration Management System - WARMS 2013).
- Inkomati Water Availability Assessment (as part of this project).
- Vegter (1995) groundwater map set (borehole yield prospect).
- Regional groundwater quality and water level data from the National Groundwater Archive (NGA - DWS).
- Groundwater Regions (Vegter, 2000).

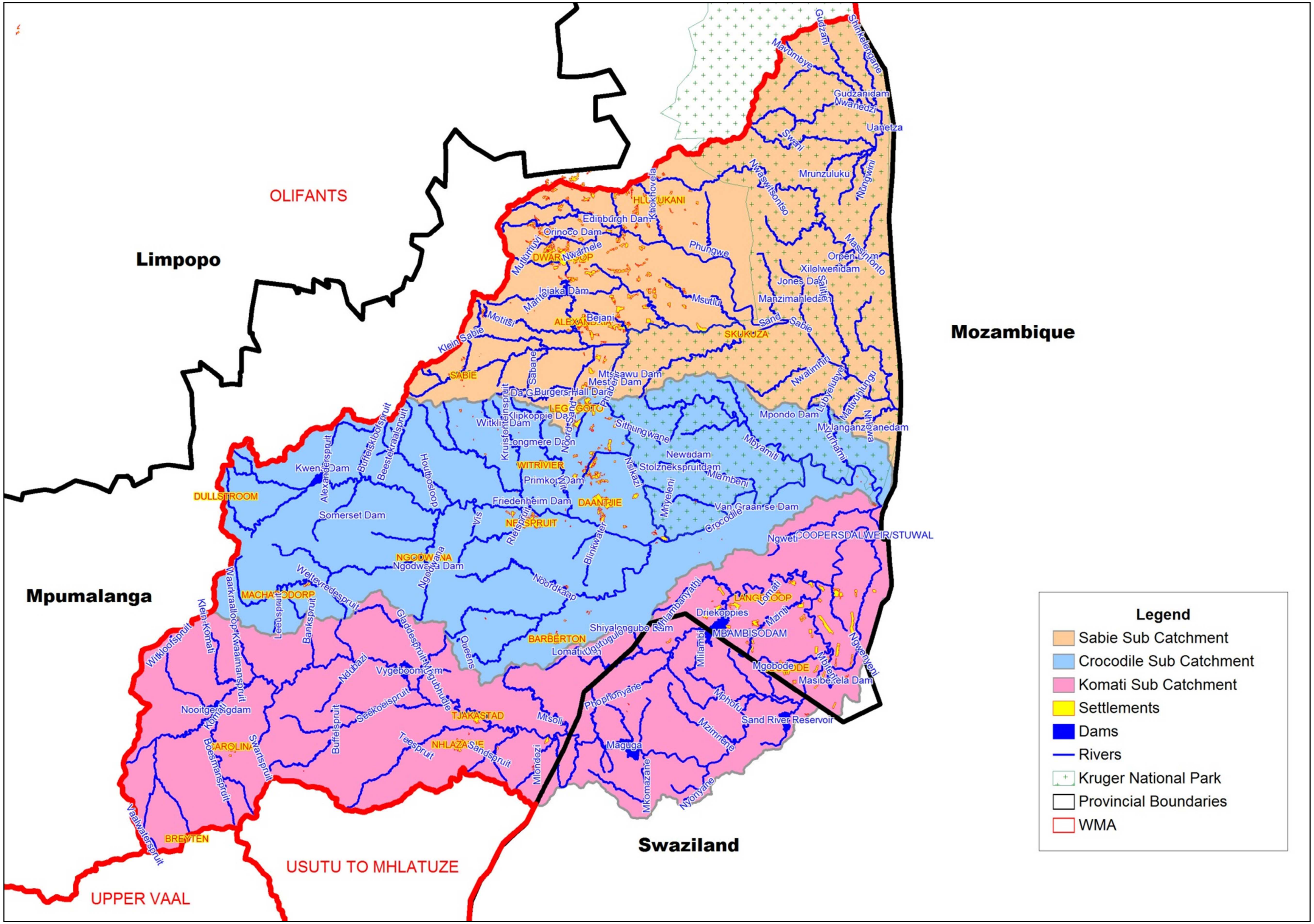


Figure 1.1 Study area – Catchments of the Inkomati (DWA, 2013a)

1.5 PURPOSE AND OUTLINE OF THIS REPORT

The purpose of this document is to provide a summary of the narrative and numerical RQOs for Groundwater in the Inkomati Catchment.

The report outline is provided below.

Chapter 1: Introduction
This Chapter provides general background to the project Task.

Chapter 2: Description of Groundwater Resources
This chapter provides a description of the geological setting and groundwater resources of the Inkomati. The chapter also presents the results of the collated borehole information.

Chapter 3: Groundwater Classification
The chapter present the results of the groundwater classification in terms of groundwater use, groundwater quality, and water levels.

Chapter 4: Resource Quality Objectives
This chapter describes the approach and prioritisation of GU in order to set groundwater descriptive and numerical RQOs.

Chapter 5: References

Chapter 6: Appendix A: Report Comments
Comments from the Client are listed.

2 DESCRIPTION OF GROUNDWATER RESOURCES

2.1 GEOLOGY

The understanding of the geological setting and its influence on the groundwater occurrence is one of the first steps in identifying potential aquifers and significant groundwater resources. It also forms the basis for the delineation of aquifers.

The Inkomati is predominantly (> 60%) underlain by igneous and metamorphic crystalline basement rocks comprising of the Northern Basement Rocks (i.e. Nelspruit Suite) and the Barberton Supergroup (Figure 2.1). These basement rocks form weathered and fractured aquifers with complex hydrogeology and perceived low exploitation potential of groundwater due to historically low drilling success rates or high frequency of low yielding boreholes. However, scientifically sited boreholes using appropriate groundwater exploration and interpretation methods showed to yield considerable amounts of groundwater (Sami *et al*., 2002). The remainder of the Inkomati comprise of the following major geological groups:

- Karoo Supergroup
  - The Ecca Group is represented by the Dwyka and Vryheid formations in the south-western parts (near Carolina) of the Inkomati. These formations consist mainly of shales, sandstones and coal beds. Dolerite sills intrude these formations.
  - The eastern edge of the Inkomati is represented by the basalts of the Lebombo Group.
- Transvaal Supergroup
  - The Pretoria Group overlies the crystalline igneous and metamorphic Basement rocks unconformably and is characterised by shales, mudrock and quartzites. The Malmani dolomite Subgroup occurs at the base of the Pretoria Group. The weathering resistant Transvaal Supergroup forms the “Great Escarpment”.

2.2 GROUNDWATER REGIONS AND AQUIFERS

The Inkomati aquifers comprise of five groundwater regions as defined by Vegter (2000) and are predominantly characterised by their geological settings (Figure 2.2):

1. **Eastern Highveld** – Comprised of the rocks belonging to the Karoo Supergroup.
2. **Eastern Bankeveld** – Comprised of the gently westerly dipping mainly sedimentary rocks of the Transvaal Supergroup including the Malmani dolomites.
3. **North-eastern Middelveld** – Comprised of the rugged mountainous region of the more basic igneous and metamorphic Barberton Supergroup.
4. **Lowveld** – Comprised of the Northern Basement rocks (granites and gneisses), most notably the Nelspruit Suite.
5. **Northern Lebombo**– Comprised of the Lebombo Group, including basalts and rhyolite-dacite. These rocks are tilted in a general easterly or seaward direction.

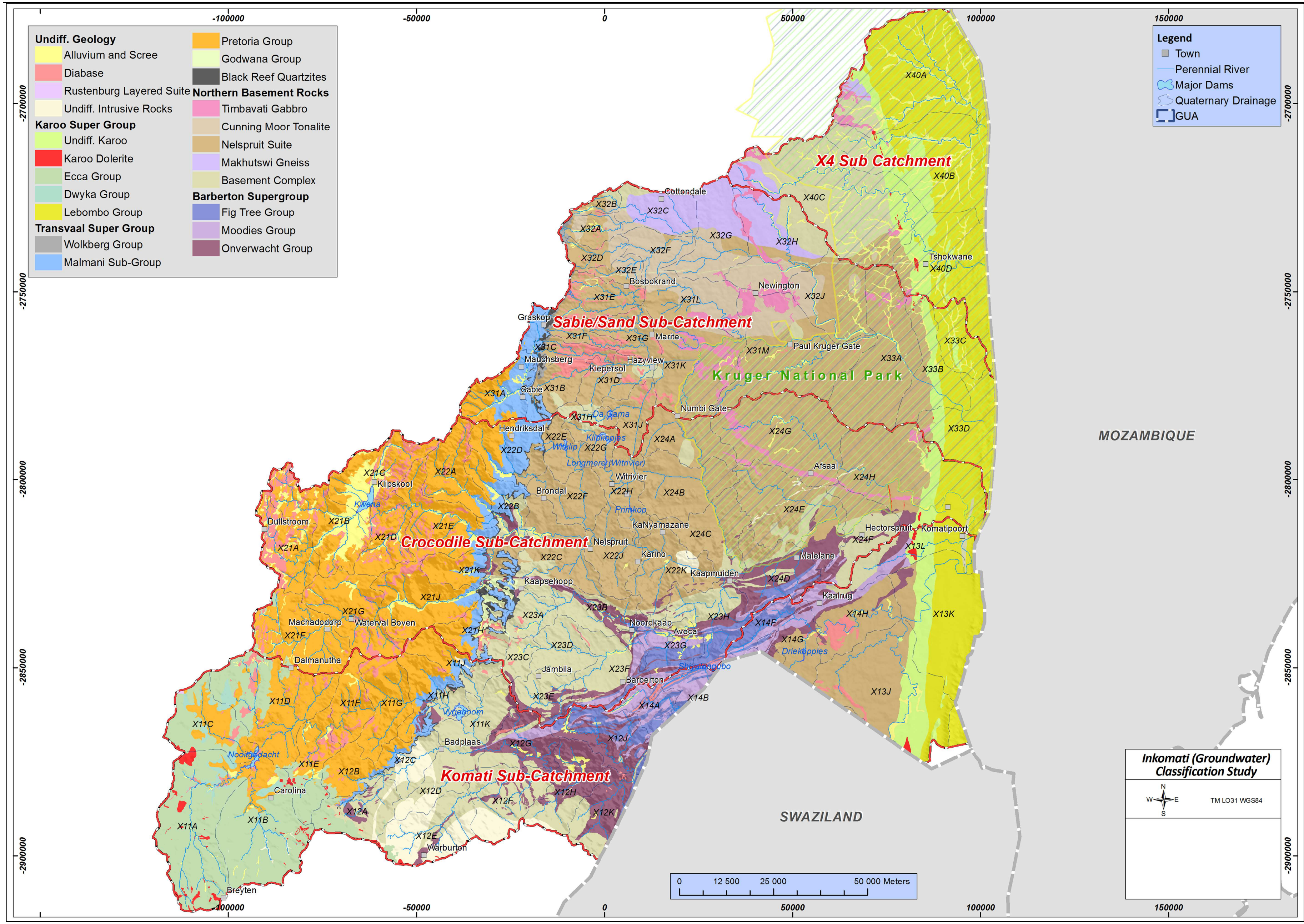


Figure 2.1 Simplified geology of the Inkomati(showing the 4 secondary drainage regions)

Within each of these regions a number of aquifer types can be differentiated (Figure 2.2):

- **Intergranular (weathered) and Fractured Aquifers**
  - The weathered/fractured aquifer type is characterised by an almost continuous regolith overlying the fresh (un-weathered) bedrock. The overlying regolith, i.e. unconsolidated material derived from prolonged *in-situ* decomposition of the bedrock, has a thickness from negligible to a couple of tens of meters. The regolith usually has a high porosity and a low permeability due to clay-rich material (Acworth, 1987). When saturated, this layer constitutes the reservoir of the aquifer. The situation allows for circumstances where the intergranular regolith serves primarily as a storage function while the water is transmitted mainly through the underlying fractured bedrock.
  - By far the greatest portion of the study area is underlain by Intergranular and Fractured aquifers associated with the igneous and metamorphic Basement rocks as well as the sedimentary rocks of the Transvaal- and Karoo Supergroup.
  - It must be emphasised that in the case of a very thin or absent weathered zone or if the water level occurs in the underlying bedrock, it can be characterised as a fractured aquifer only. This may be the case for the topographical higher lying areas along the escarpment and in the mountainous Barberton terrain.
- **Fractured Aquifers**
  - The fractured aquifer type is characterised by an intact and relatively un-weathered matrix with a complex arrangement of interconnected fracture systems.
  - Fractured aquifers may occur throughout the Inkomati on a local scale, but based on the published hydrogeological maps it is mostly limited to the quartzites and dolerite sills of the Transvaal- and Karoo Supergroup (Figure 2.2).
- **Intergranular (alluvial) aquifers**
  - Intergranular (alluvial) aquifers overlie or replace the weathered overburden and are found along watercourses, valleys and wide open plains. Tey comprise of sand deposits of unconsolidated clayey silts and forms primary aquifers of high yielding potential, but are typically limited in extent. The spatial extent varies according to the topography and climate (especially run-off).
  - It is an important local, major aquifer and exists in equilibrium with surface water, adjacent groundwater systems and ecosystems along the rivers. Towards the eastern and central regions (along the 'great escarpment') a close inter-dependence exists between groundwater and surface water.

2.3 BOREHOLE YIELD AND AQUIFER RATING

The published Hydrogeological Map Series by DWA indicate median borehole yields (excluding dry boreholes) in l/s from <0.1 to > 5l/s for various aquifer types. These borehole yields can be classified into four categories of aquifer rating as outlined in Table 2.1 (DWA, 2013b):

Table 2.1 Borehole yield classes and associated aquifer ratings (DWA, 2013b)

Borehole yield class (l/s)	Aquifer rating
<0.1 to 0.5	Insignificant
>0.5 to 2.0	Minor
>2.0 to 5.0	Moderate
>5.0	Significant

The above aquifer rating for the Inkomati is presented in Figure 2.2, which shows that insignificant to minor aquifers are present in large parts of the Inkomati. Moderate intergranular aquifer zones are associated with river courses, valleys or open plains and although not specifically mapped, they do occur locally throughout the Inkomati study area. The Malmani dolomite formations cutting across the Inkomati forms a moderate Karst aquifer. The dolomitic rocks of the Inkomati have been described as "Escarpment Dolomite", distinctly different in terms of weathering and morphology from the dolomites in e.g. the Gauteng area (Martini and Kavalieris, 1976). Although dolomitic formations can be regarded as a significant aquifer, according to the Inkomati Internal Strategic Perspective (ISP) the Escarpment dolomite is not the generally high-yielding aquifer that dolomite is elsewhere in the country due to the prevailing and past geomorphic conditions in this region (DWAF, 2004a). However, scientifically sited boreholes could yield considerable larger amounts of groundwater and merits further investigations. Other moderate aquifers are associated with the intergranular and fractured aquifer type occurring as higher yielding areas within the minor classification. These regions may be attributed to more locally well-developed weathering and fractured zones, while the development of these aquifers was based on detailed exploration methods.

2.4 DELINEATION OF GROUNDWATER UNITS

The delineation of groundwater units (GUs) are based on hydrogeological criteria and might not necessarily correlate to quaternary surface water catchments or surface water units of analysis.

However, it must be kept in mind during the delineation of groundwater units of analysis, that a Class, Reserve and RQOs have to be set for each unit; linkages with other components have to be considered; and that each unit will have to be managed. As a result, the delineation is largely based on management considerations while attention is given to hydrogeological criteria. Although previous groundwater reserve studies for the Inkomati (AGES 2007; 2010) identified groundwater target areas (based on quaternary drainages), no GUs were delineated. As a result, the current delineation of GUs for the Inkomati was based on the following criteria:

- Surface water units of analysis as part of this project.
- The four main Inkomati sub-catchments were considered, namely the Komati, Crocodile, Sabie-Sand and the undeveloped X4 sub-catchment in the Kruger National Park.
- The quaternary drainage areas were considered as the basis of delineation.
    - o Quaternary drainage areas with similar hydrogeological characteristics were grouped into one GU. The dolomites were a far as possible grouped into separate GU, while including the quaternary drainage areas contributing to its run-off.
- Hydrogeological criteria (including geology, geomorphology and topography).

A total of nineteen GUs were delineated as described in Table 2.1 and illustrated in Figure 2.3.

Table 2.2 Description of delineated groundwater units for the Inkomati

Sub-catchment	GUs	Area Km^2	No of Quats	Predominant Geology (rock type)	Aquifer rating
Komati	GU1-1	1,588	3	Karoo Supergroup (Vryheid Formation).Sandstone, shale and coal seams. Intrusive Dykes.	Insignificant to Minor
	GU1-2	1,278	4	Pretoria Group (Lydenburg Shale). Shale, mudrock and quartzites. Malmani Sub-Group Dolomites.	Minor
	GU1-3	451	2	Pretoria Group (Lydenburg Shale). Shale, mudrock and quartzites. Malmani Sub-Group Dolomites.	Minor to Moderate (dolomites)

Sub-catchment	GUs	Area Km^2	No of Quats	Predominant Geology (rock type)	Aquifer rating
	GU1-4	585	3	Karoo Supergroup (Vryheid Formation). Sandstone, shale and coal seams. Intrusive Dykes. Pretoria Group (Lydenburg Shale) Shale, mudrock and quartzites. Basement Complex.	Minor to Moderate (dolomites)
	GU1-5	2,511	10	Basement Complex (Granite, Gneiss). Onverwacht Group (Ultramafic, and mafic lavas). Fig Tree Group (Pyroclastic rocks, greywacke).	Minor
	GU1-6	1,471	4	Basement Complex (Nelspruit Suite). Porphyrytic granite. Moodies Group (Sandstone, quartzite, shale, conglomerate). Karoo Supergroup (Basalts, diamictite, mudrock and Sandstone).	Minor
	GU1-7	908	2	Karoo Supergroup (Basalts, diamictite, mudrock and Sandstone).	Insignificant to Minor
Crocodile	GU2-1	1,174	4	Pretoria Group (Shale, siltstone and quartzites). Diabase (Intrusive). Alluvium and Scree.	Minor to Moderate (alluvial aquifers)
	GU2-2	744	2	Pretoria Group (Shale, siltstone and quartzites). Alluvium.	Minor to Moderate (alluvial aquifers)
	GU2-3	1,926	7	Malmani Sub-Group Dolomites. Pretoria Group (Shale, siltstone and quartzites). Diabase (Intrusive). Alluvium.	Minor to Moderate (dolomites/ alluvium)
	GU2-4	2,483	10	Basement Complex (Nelspruit Suite). Porphyrytic granite, and granodiorites.	Insignificant to Minor
	GU2-5	1,942	9	Kaap Valley Tonalite (Horneblende, biotite tonalite). Moodies Group (Subgreywacke, quartzite, shale, conglomerate). Fig Tree Group (Greywacke and shale).	Minor to Moderate (intergranular aquifers)
	GU2-6	2,177	4	Basement Complex (Nelspruit Suite). Porphyrytic granite and granodiorites. Moodies Group (Subgreywacke, quartzite, shale, conglomerate). Fig Tree Group (Greywacke and shale).	Minor to Moderate (intergranular aquifers)
Sabie-Sand	GU3-1	887	5	Malmani Sub-Group Dolomites. Basement Complex (Nelspruit Suite). Porphyrytic granite, and granodiorites. Pretoria Group (Shale, siltstone and quartzites). Diabase (Intrusive)	Minor to Moderate (dolomites)
	GU3-2	1,367	6	Basement Complex (Nelspruit Suite). Porphyrytic granite, and granodiorites. Timbavati gabbro. Cunning Moor Tonalite.	Minor to Moderate (intergranular aquifers)
	GU3-3	1,072	7	Basement Complex (Nelspruit Suite) Porphyrytic granite, and granodiorites. Makhutswi Gneiss. Cunning Moor Tonalite.	Insignificant to Minor
	GU3-4	2,153	4	Basement Complex (Nelspruit Suite). Porphyrytic granite, and granodiorites.	Minor to Moderate (intergranular

Sub-catchment	GUs	Area Km^2	No of Quats	Predominant Geology (rock type)	Aquifer rating
				Cunning Moor Tonalite. Alluvium.	aquifers/alluvium)
	GU3-5	844	3	Karoo Supergroup (Basalts, diamictite, mudrock and Sandstone).	Insignificant to Minor
X4	GU4-1	3,197	4	Basement Complex (Gneiss). Karoo Supergroup (Basalts, diamictite, mudrock and Sandstone). Alluvium.	Insignificant to Moderate (alluvium)

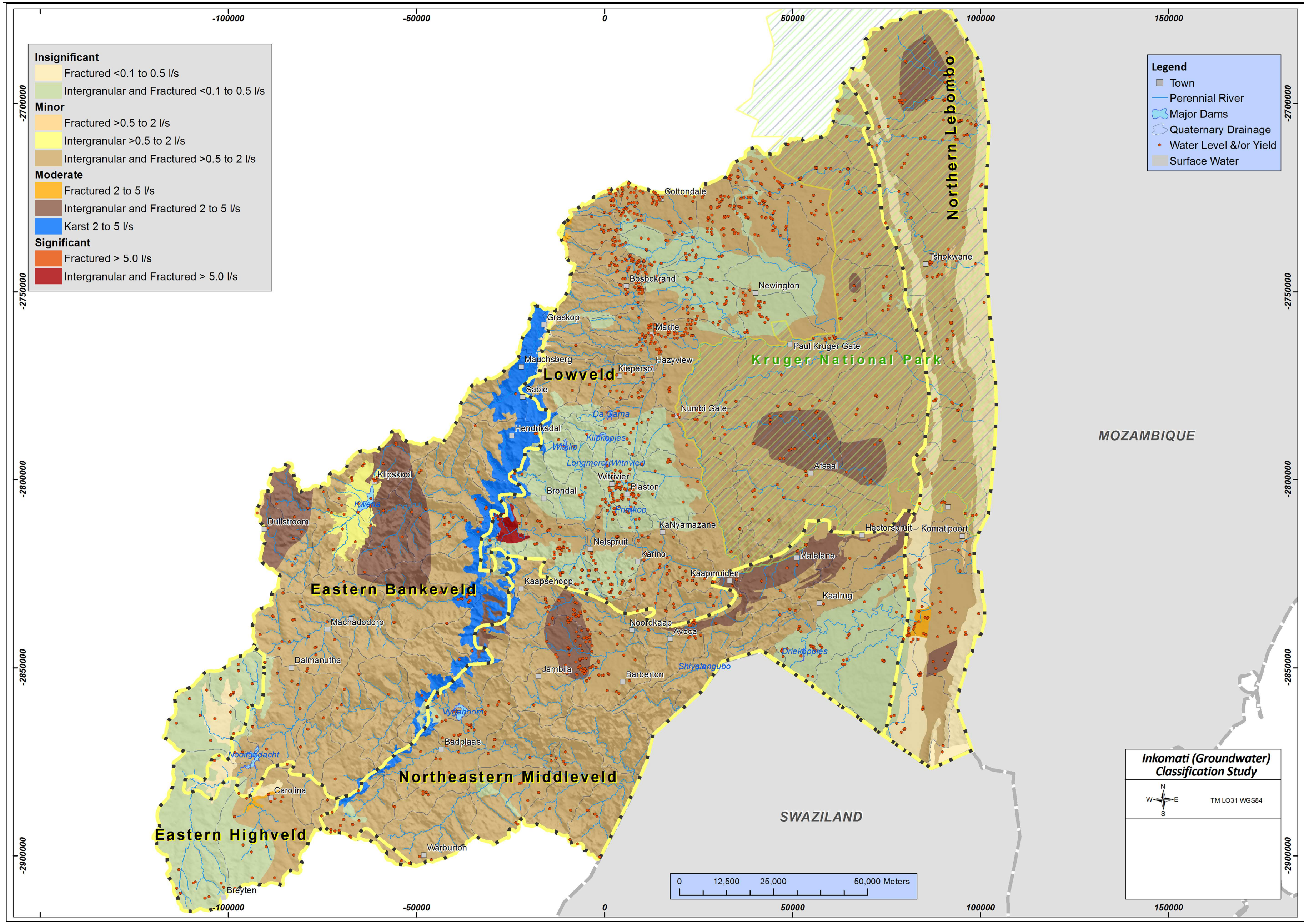


Figure 2.2 Groundwater regions and aquifer yields for the Inkomati

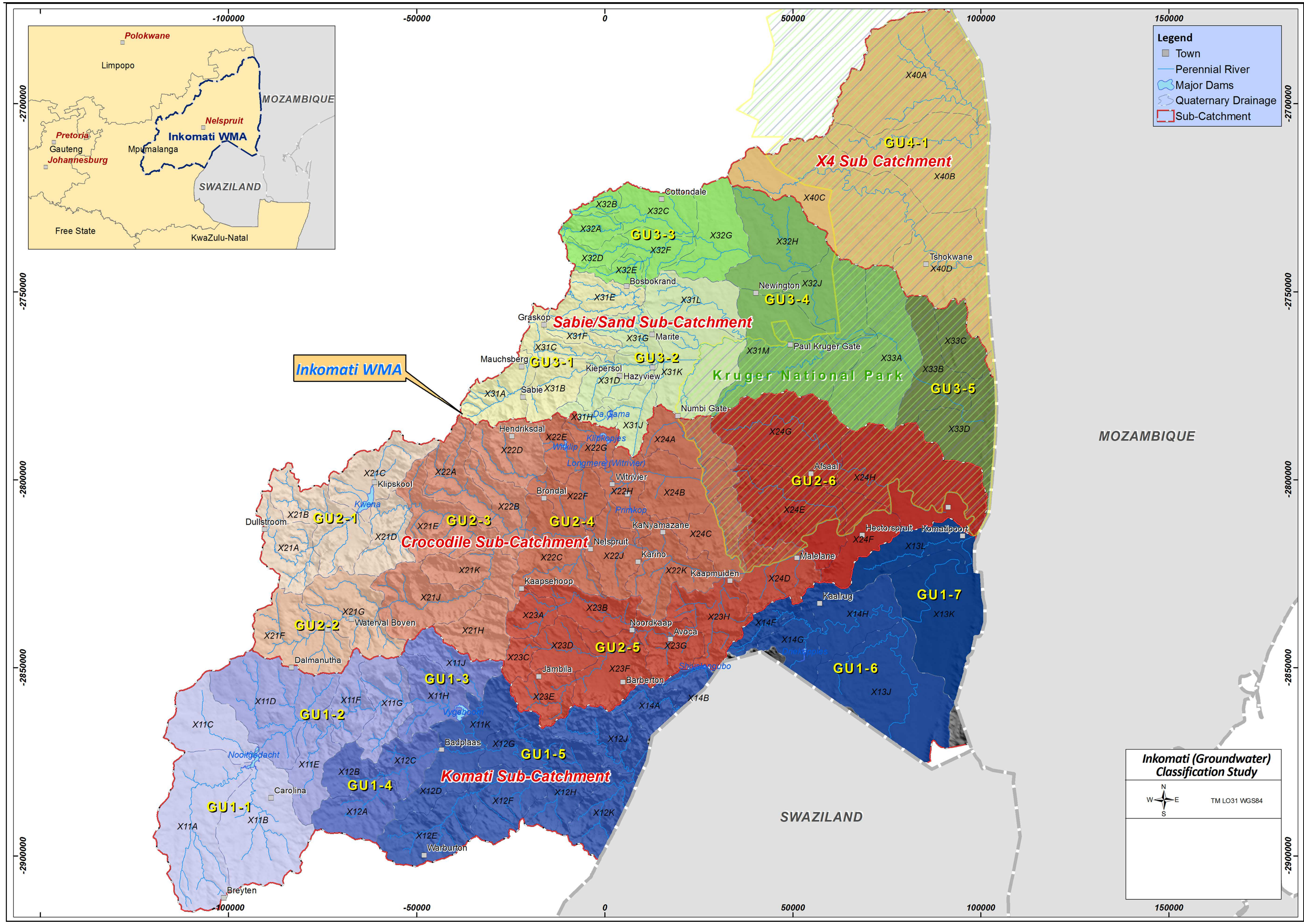


Figure 2.3 Delineated groundwater units for the Inkomati

2.5 STATUS QUO

2.5.1 Water level, borehole depth and yields

A summary of the water level, borehole depth and yields obtained from the NGA for each GU is shown in Table 2.3.

Table 2.3 Water level and borehole statics for the Inkomati per GU

Sub-catchment	GU	Predominant aquifer	Parameter	Water Level (mbs[1])	Yield (l/s)	Borehole depth (m)
Komati	GU1-1	Karoo rocks	N	10	n.a[2].	3
			Mean	13.5	n.a.	68
	GU1-2	Malmani Dolomites Pretoria Group	N	5	6	6
			Mean	7.2	1.2	37
	GU1-3	Malmani Dolomites Pretoria Group	N	3	4	5
			Mean	14.0	1.4	76
	GU1-4	Karoo Basement Complex	N	13	5	13
			Mean	13.8	0.4	37
	GU1-5	Barberton Basement	N	56	27	59
			Mean	13.0	3.1	49
	GU1-6	Nelspruit Suite Basement	N	44	8	40
			Mean	24.8	1.7	93
	GU1-7	Karoo rocks	N	8	10	10
			Mean	23.6	2.2	79
Crocodile	GU2-1	Pretoria Group Alluvium and Scree	N	11	7	12
			Mean	24.1	2.3	63
	GU2-2	Pretoria Group Alluvium	N	8	8	8
			Mean	16.2	1.6	74
	GU2-3	Malmani Sub-Dolomites Pretoria Group Alluvium	N	29	17	24
			Mean	18.3	2.7	63
	GU2-4	Basement Complex	N	116	100	115
			Mean	23.8	0.8	73
	GU2-5	Barberton Basement	N	59	91	110
			Mean	20.3	2.2	43
	GU2-6	Basement Complex	N	71	83	83
			Mean	13.0	1.7	54
Sabie-Sand	GU3-1	Malmani Dolomites Basement Complex Pretoria Group	N	11	1	11
			Mean	18.7	2.6	90
	GU3-2	Basement Complex	N	97	13	95
			Mean	12.6	1.1	64
	GU3-3	Basement Complex	N	223	10	209
			Mean	16.0	1.7	69
	GU3-4	Basement Complex	N	98	44	97
			Mean	16.9	1.9	60
	GU3-5	Karoo rocks	N	31	40	40
			Mean	8.2	1.5	50
X4	GU4-1	Basement Complex Karoo rocks	N	174	176	182
			Mean	15.4	1.5	52
Inkomati	**Total**		**N**	**1069**	**651**	**1123**
			Mean	**16.7**	**1.7**	**61**

Lowest value in sub-catchment
Highest Value in sub-catchment

1 Metres below the surface.
2 Not available.

From the available ~ 4900 geo-sites only ~2500 sites contain information on either water level or yield. From these geo-sites only ~1000 sites have a coordinate accuracy of less than 1km. The results from Table 2.3can be summarised as follows:

- **Komati sub-catchment**
  - Average water levels range from 7 to 25 m below surface; with the deepest water levels found in the Nelspruit Suite basement (GU1-6) and Karoo (basalt) (GU1-7) aquifers.
  - Highest borehole yields are associated with the Barberton basement aquifer (GU1-5), while yields below the population (Inkomati) average are found in GU1-2 to GU1-4. It must be noted that a limited number of boreholes with yield data were available for these GUs and might distort the assessment.
  - The deepest average borehole depth is found in the Nelspruit Suite basement- (GU1-6) and the Karoo- (basalt) (GU1-7) aquifers. Drilling depths below the population (Inkomati) average are found in GU1-2, GU1-4 and GU1-5.
- **Crocodile sub-catchment**
  - Average water levels range from 13 to 24 m below surface, while the deepest water levels are found in the Pretoria Group- (GU2-1) and the Basement (GU2-5) aquifers respectively.
  - Highest borehole yields are associated with the Malmani dolomites (GU2-3), while yields above the population (Inkomati) average are also found in GU2-1 to GU2-5. The lowest borehole yields are associated with the basement complex (GU2-4) aquifer.
  - Average borehole depths range from 43 to 74 m below surface.
- **Sabie-Sand sub-catchment**
  - Average water levels range from 8 to 19 m below surface, which is considerably shallower than in the Komati- and Crocodile sub-catchments.
  - Borehole yields are unfortunately also generally lower compared to the Komati- and Crocodile sub-catchment. The Basement (GU3-3 and GU3-4) aquifers have a higher average yield in comparison to the Karoo (GU3-5) aquifers.
  - Average borehole depths range from 50 to 90 m below surface. Despite shallower water levels compared to the Komati- and Crocodile sub-catchments, the drilling depths are on average deeper than the these sub-catchments.
- **X4 sub-catchment**
  - Average water levels are 15 m below surface with an average borehole yield of 1.5 l/s, which is lower than the total population (Inkomati) average.

2.5.2 Groundwater Resources

Groundwater resources were assessed on a national scale during the GRA II project (DWAF 2004a) and the data are used in Groundwater Resource Directed Measures (GRDM) datasets at quaternary catchment scale. The results from the following datasets were populated for each GU and are summarised in Table 2.4 to Table 2.7:

- Groundwater contribution to River baseflow.
- Recharge.
- Harvest Potential.
- Utilisable Groundwater Exploitation Potential (UGEP).

Table 2.4. Summary of groundwater resources for the Komati sub-catchment (in Mm^3/a)

GUs	Quat	Area (Km^2)	Baseflow	Recharge (Wet)	Recharge (Dry)	Harvest Potential	UGEP (Wet)	UGEP (Dry)
GU1-1	X11A	672	7.21	30.79	22.67	13.67	8.63	5.67
	X11B	597	6.96	30.33	22.54	12.49	9.24	6.16

GUs	Quat	Area (Km^2)	Baseflow	Recharge (Wet)	Recharge (Dry)	Harvest Potential	UGEP (Wet)	UGEP (Dry)
	X11C	319	3.68	17.57	13.04	6.45	5.49	3.68
	Total	**1587**	**17.84**	**78.68**	**58.25**	**32.60**	**23.36**	**15.51**
GU1-2	X11D	590	23.59	32.17	24.11	8.59	3.52	0.00
	X11E	241	9.97	14.31	10.77	3.57	2.01	0.48
	X11F	183	7.54	13.06	10.00	2.03	2.44	1.08
	X11G	264	17.25	29.39	22.87	3.03	5.55	2.59
	Total	**1278**	**58.35**	**88.93**	**67.74**	**17.22**	**13.52**	**4.15**
GU1-3	X11H	265	17.17	34.11	27.14	7.46	7.08	4.11
	X11J	186	11.98	27.20	22.18	5.03	6.52	4.41
	Total	**451**	**29.14**	**61.32**	**49.32**	**12.49**	**13.60**	**8.52**
GU1-4	X12A	244	13.94	18.74	14.29	9.74	2.51	0.85
	X12B	155	12.05	12.65	9.72	2.81	2.01	0.71
	X12C	186	8.03	17.32	13.53	7.66	2.87	1.37
	Total	**585**	**34.02**	**48.71**	**37.54**	**20.21**	**7.39**	**2.93**
GU1-5	X11K	211	10.00	24.93	19.54	7.69	4.01	2.02
	X12D	223	7.54	17.29	13.40	9.48	3.67	2.18
	X12E	333	11.50	25.80	20.20	14.05	5.30	3.23
	X12F	313	10.85	26.89	21.00	13.04	6.36	4.08
	X12G	239	3.42	21.70	17.02	4.53	6.94	5.18
	X12H	286	9.41	29.19	23.06	7.14	7.87	5.49
	X12J	296	5.77	43.10	35.89	4.74	13.68	11.02
	X12K	286	9.37	31.18	24.43	5.21	7.22	5.01
	X14A	141	0.00	26.69	22.51	2.18	8.07	6.56
	X14B	185	0.00	34.76	29.22	1.50	5.51	4.49
	Total	**2511**	**67.85**	**281.52**	**226.28**	**69.55**	**68.62**	**49.26**
GU1-6	X13J	828	0.00	34.49	25.18	10.75	13.47	10.39
	X14F	117	4.62	22.17	18.60	1.82	6.83	5.57
	X14G	204	6.15	12.70	9.97	3.20	2.03	1.06
	X14H	360	3.19	14.87	11.21	5.31	4.73	3.37
	Total	**1509**	**13.96**	**84.24**	**64.96**	**21.09**	**27.07**	**20.40**
GU1-7	X13K	621	6.86	13.79	9.64	8.96	5.67	4.49
	X13L	286	2.83	7.08	5.01	3.56	3.12	2.38
	Total	**907**	**9.69**	**20.87**	**14.65**	**12.53**	**8.79**	**6.86**

Table 2.5 Summary of groundwater resources for the Crocodile sub-catchment (in Mm^3/a)

GUs	Quat	Area (Km^2)	Baseflow	Recharge (Wet)	Recharge (Dry)	Harvest Potential	UGEP (Wet)	UGEP (Dry)
GU2-1	X21A	265	2.69	17.49	13.21	3.01	6.39	4.59
	X21B	378	4.01	22.02	16.35	4.22	8.07	5.52
	X21C	311	3.21	20.57	15.50	3.49	7.83	5.52
	X21D	219	2.04	13.36	9.98	2.48	5.47	3.90
	Total	**1173**	**11.95**	**73.44**	**55.03**	**13.20**	**27.76**	**19.53**
GU2-2	X21F	397	3.17	22.55	16.96	4.43	7.71	5.46
	X21G	347	4.24	22.43	17.08	3.90	8.94	6.51

GUs	Quat	Area (Km^2)	Baseflow	Recharge (Wet)	Recharge (Dry)	Harvest Potential	UGEP (Wet)	UGEP (Dry)
	Total	**744**	**7.41**	**44.99**	**34.04**	**8.33**	**16.65**	**11.97**
GU2-3	X21E	345	3.59	44.27	34.29	4.59	18.06	13.72
	X21H	229	5.70	34.86	28.55	7.33	12.99	10.21
	X21J	355	6.45	41.18	32.49	4.45	15.62	11.74
	X21K	245	4.16	36.75	29.99	5.76	14.39	11.43
	X22A	251	4.28	40.14	32.38	3.28	16.64	13.06
	X22B	227	4.36	34.68	27.72	4.61	12.11	9.49
	X22D	274	3.84	43.22	36.02	6.40	15.43	12.39
	Total	**1926**	**32.39**	**275.10**	**221.45**	**36.42**	**105.25**	**82.03**
GU2-4	X22C	366	7.51	28.48	22.57	7.30	9.38	7.55
	X22E	153	3.90	21.76	18.08	2.51	6.92	5.70
	X22F	212	2.05	15.67	12.48	3.38	5.14	4.19
	X22G	107	3.02	14.74	12.22	1.73	4.83	3.94
	X22H	200	2.09	13.76	10.90	3.23	4.07	3.31
	X22J	240	2.56	15.30	11.72	3.84	4.63	3.66
	X22K	335	3.55	24.17	18.75	5.30	8.02	6.39
	X24A	249	2.52	10.57	7.88	3.82	4.08	2.96
	X24B	335	2.46	15.01	11.19	5.30	5.13	3.89
	X24C	286	1.35	14.73	10.99	4.51	5.20	3.82
	Total	**2483**	**31.02**	**174.20**	**136.77**	**40.92**	**57.40**	**45.41**
GU2-5	X23A	127	1.71	20.73	17.07	5.53	6.82	5.47
	X23B	229	3.18	15.74	12.23	5.62	5.44	4.10
	X23C	81	3.34	13.09	10.84	3.51	4.39	3.55
	X23D	182	2.43	18.15	13.97	7.88	6.07	4.56
	X23E	180	3.18	18.52	15.10	5.72	6.01	4.70
	X23F	310	1.63	25.96	19.73	8.86	9.13	6.73
	X23G	225	2.24	19.31	15.05	3.58	6.56	4.98
	X23H	306	1.92	25.47	19.68	4.96	9.63	7.40
	X24D	302	2.08	19.29	14.66	4.70	7.03	5.22
	Total	**1942**	**21.71**	**176.27**	**138.34**	**50.36**	**61.08**	**46.71**
GU2-6	X24E	526	0.00	18.10	13.14	6.41	7.64	5.55
	X24F	262	0.00	8.86	6.48	3.34	3.72	2.75
	X24G	620	0.00	15.44	11.06	7.48	6.73	4.81
	X24H	770	0.00	15.80	11.14	8.39	5.79	4.10
	Total	**2178**	**0.00**	**58.20**	**41.82**	**25.62**	**23.87**	**17.21**

Table 2.6 Summary of groundwater resources for the Sabie-Sand sub-catchment (in Mm^3/a)

GUs	Quat	Area (Km^2)	Baseflow	Recharge (Wet)	Recharge (Dry)	Harvest Potential	UGEP (Wet)	UGEP (Dry)
GU3-1	X31A	230	2.14	65.72	55.36	5.32	28.82	24.11
	X31B	195	1.81	55.26	46.48	3.63	23.95	20.22
	X31C	154	1.44	45.93	38.87	3.04	20.77	17.56
	X31E	214	1.92	55.83	46.76	3.38	21.72	18.15
	X31F	94	1.88	25.93	22.00	1.48	10.72	9.09

GUs	Quat	Area (Km^2)	Baseflow	Recharge (Wet)	Recharge (Dry)	Harvest Potential	UGEP (Wet)	UGEP (Dry)
	Total	**887**	**9.19**	**248.67**	**209.47**	**16.86**	**105.98**	**89.13**
GU3-2	X31D	192	0.77	20.82	16.55	3.06	9.44	7.63
	X31G	169	1.65	17.70	14.20	2.66	8.36	6.78
	X31H	60	0.60	10.11	8.40	0.96	4.51	3.78
	X31J	154	1.57	14.49	11.35	2.43	6.31	5.04
	X31K	488	0.00	16.27	11.99	6.57	7.96	6.01
	X31L	304	0.00	10.02	7.53	3.94	4.96	3.96
	Total	**1367**	**4.59**	**89.40**	**70.03**	**19.62**	**41.53**	**33.20**
GU3-3	X32A	112	0.00	13.11	10.62	1.84	5.68	4.60
	X32B	55	1.07	5.89	4.63	0.90	2.27	1.76
	X32C	233	0.52	7.36	5.54	3.48	3.63	2.86
	X32D	100	1.47	13.16	10.68	1.60	5.29	4.29
	X32E	78	0.95	7.08	5.56	1.30	3.56	2.83
	X32F	157	0.76	5.00	3.72	2.49	2.76	2.20
	X32G	336	0.99	8.02	5.87	4.08	4.70	3.76
	Total	**1072**	**5.77**	**59.61**	**46.63**	**15.69**	**27.90**	**22.31**
GU3-4	X31M	709	0.00	13.74	9.80	8.52	6.21	4.45
	X32H	488	0.00	9.84	7.14	5.86	4.59	3.39
	X32J	355	0.00	6.35	4.54	4.13	2.64	1.88
	X33A	600	0.00	11.19	7.88	5.97	4.38	3.08
	Total	**2153**	**0.00**	**41.13**	**29.37**	**24.48**	**17.82**	**12.81**
GU3-5	X33B	310	0.00	4.47	3.13	2.77	1.64	1.15
	X33C	183	0.00	1.64	1.14	1.62	0.46	0.32
	X33D	350	0.00	4.84	3.24	3.14	1.24	0.84
	Total	**843**	**0.00**	**10.95**	**7.51**	**7.53**	**3.34**	**2.31**

Table 2.7 Summary of groundwater resources for the X4 sub-catchment (in Mm^3/a)

GUs	Quat	Area (Km^2)	Baseflow	Recharge (Wet)	Recharge (Dry)	Harvest Potential	UGEP (Wet)	UGEP (Dry)
GU4-1	X40A	924	0.00	12.59	8.76	8.11	4.60	3.20
	X40B	743	0.00	9.38	6.32	6.51	3.22	2.21
	X40C	941	0.00	16.58	11.93	10.26	6.85	4.92
	X40D	589	0.00	6.01	4.09	5.10	1.71	1.17
	All	**3197**	**0.00**	**44.56**	**31.09**	**29.98**	**16.38**	**11.50**

Baseflow

Figure 2.4 illustrates the probability of groundwater contributions to baseflow in a river. The 'Great Escarpment' is an important recharge area and groundwater provides significant baseflow to the head waters of surface drainages. The lower reaches of the Inkomati lack on the other hand groundwater baseflow and many major rivers have a low probability of being groundwater-fed. The aquifers of the Barberton lithologies and the Pretoria Group show generally higher baseflow values than the Karoo Supergroup aquifers. There is little or no contribution of the Lebombo Group to the baseflow component of rivers.

Groundwater Recharge

The distribution of groundwater recharge based on the GRA II dataset is presented in Figure 2.5. Mean annual groundwater recharge varies from 100 to 150 mm in the higher rainfall areas along the central escarpment regions to 10 to 25 mm in the low rainfall and lower lying easternmost portion of the study area. The average annual groundwater recharge for the entire study area based on the GRA II dataset is estimated to be more than 1500 Mm^3/a, equating to recharge percentages between 5 and 10% of the mean annual precipitation for the area. However, recharge may be significant lower in areas covered with basement rocks, where the contribution of rainfall to the groundwater recharge is estimated as less than 3%.

The comprehensive groundwater reserve determination for the Inkomati(AGES, 2010) determined a lower groundwater recharge volume of around 1300 Mm^3/a for the study area. However, the groundwater recharge was calculated in this assessment as a percentage of rainfall that is assumed to reach the aquifer on a monthly basis and the standard deviation for a 95% assurance level was used to obtain a range within which the monthly rainfall-recharge is sampled (AGES, 2010). In the absence of more detailed groundwater recharge studies, the latter values are used in the setting of a management class.

Groundwater Availability (GRA II)

The volume of water that may be abstracted from a groundwater resource may be limited by anthropogenic, ecological and/or legislative considerations and the definition of the so called **Utilisable Groundwater Exploitation Potential (UGEP)** is ultimately a management decision that will reduce the total volume of groundwater available for development. It is likely that, with an adequate and even distribution of production boreholes in accessible portions of most catchments or aquifer systems, these volumes of groundwater may be annually abstracted on a sustainable basis.

The **Groundwater Harvest Potential (HP)** is aimed at providing preliminary estimates on a national scale of the annual maximum volume of groundwater that can be practically abstracted (taking technical constraints into account) from a unit area on a sustainable basis. The spatial distribution of the Inkomati groundwater harvest potential is shown in Figure 2.6. It must be emphasised that the volumes of groundwater estimated under the various exploitation scenarios are for planning purposes only. While they give an indication of the general availability and distribution of groundwater resources, detailed studies are still required to identify, develop and exploit site specific groundwater abstraction schemes.

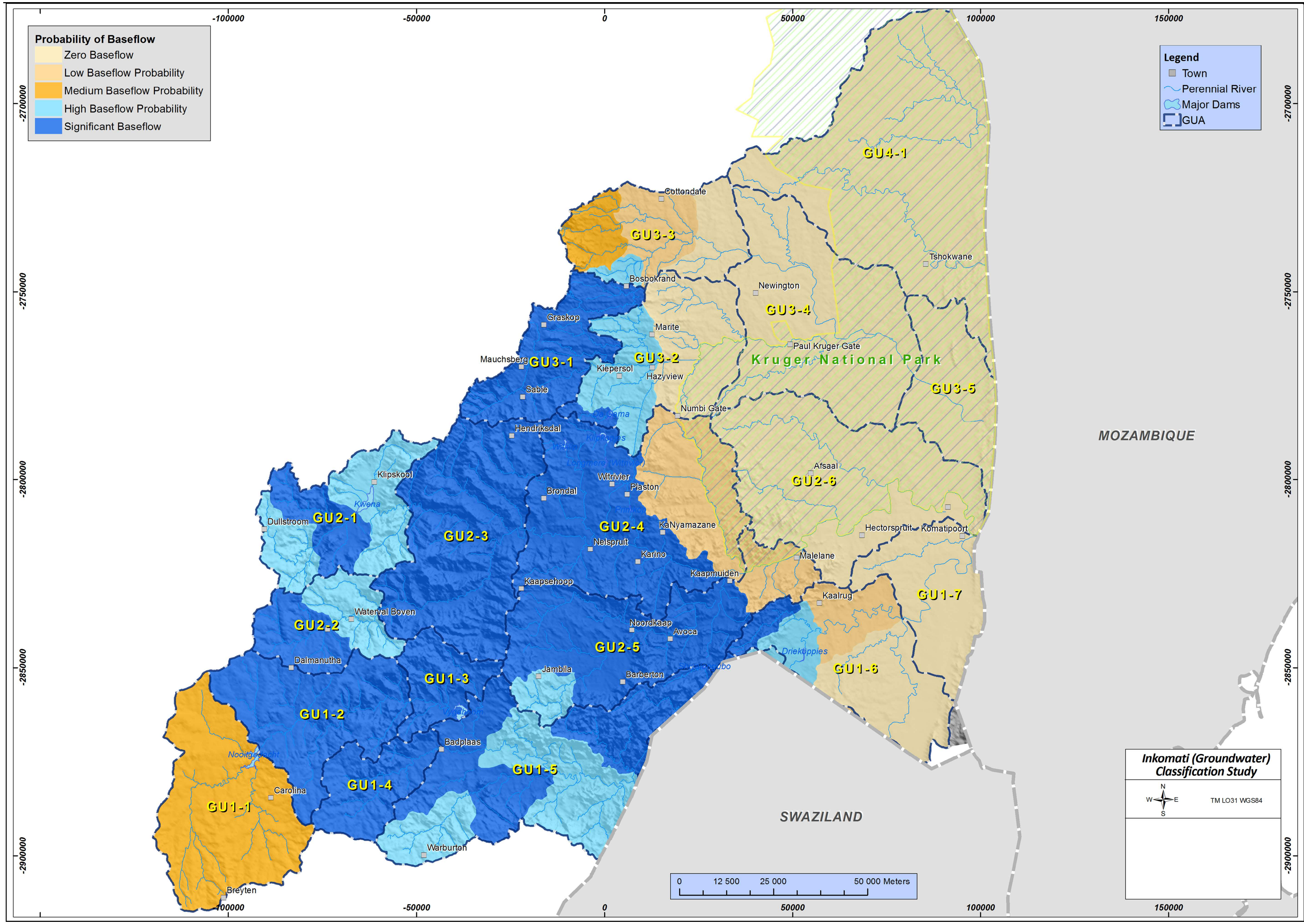


Figure 2.4 Groundwater contribution to baseflow probability

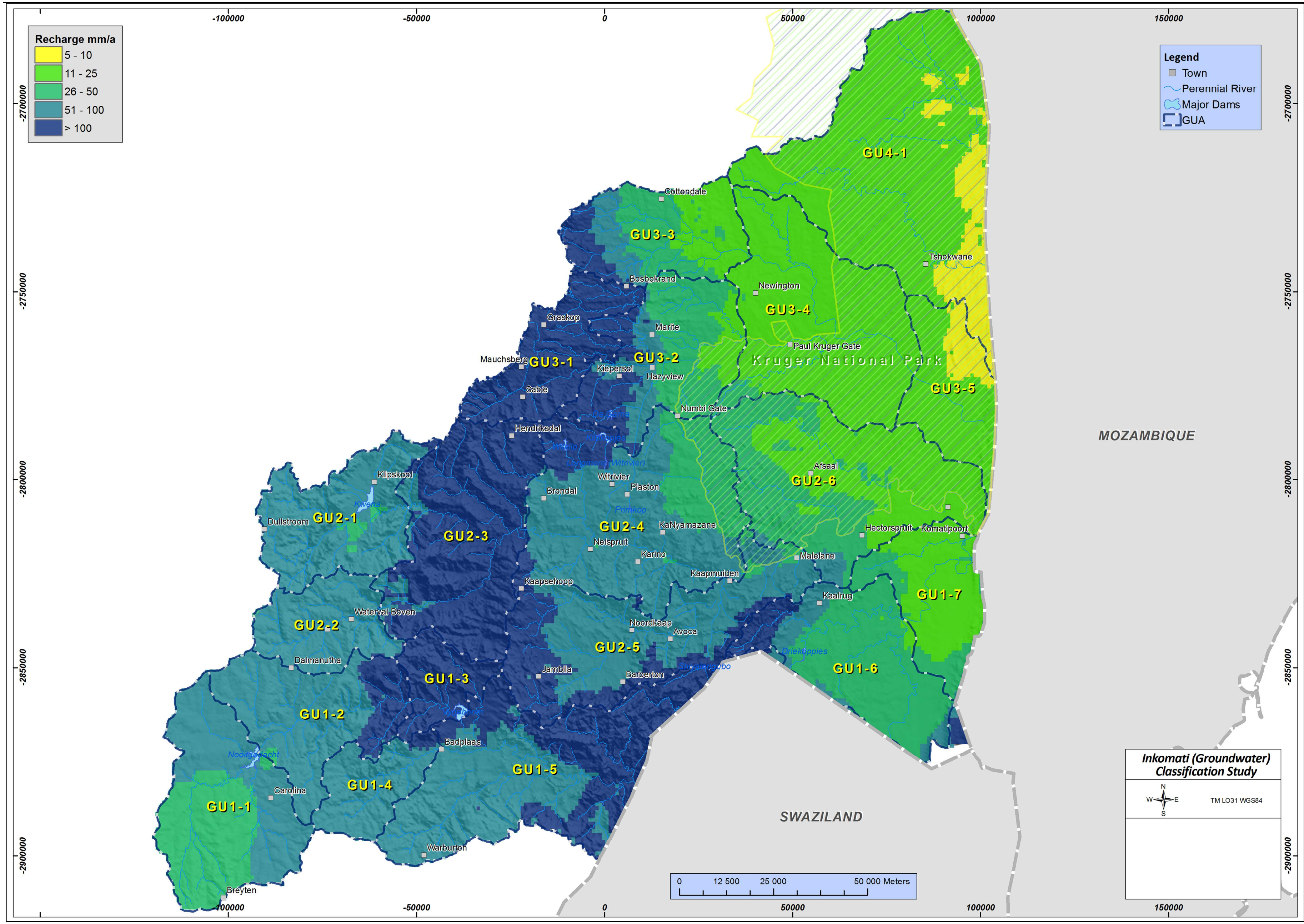


Figure 2.5 Recharge distribution map based on values obtained from the GRA II dataset

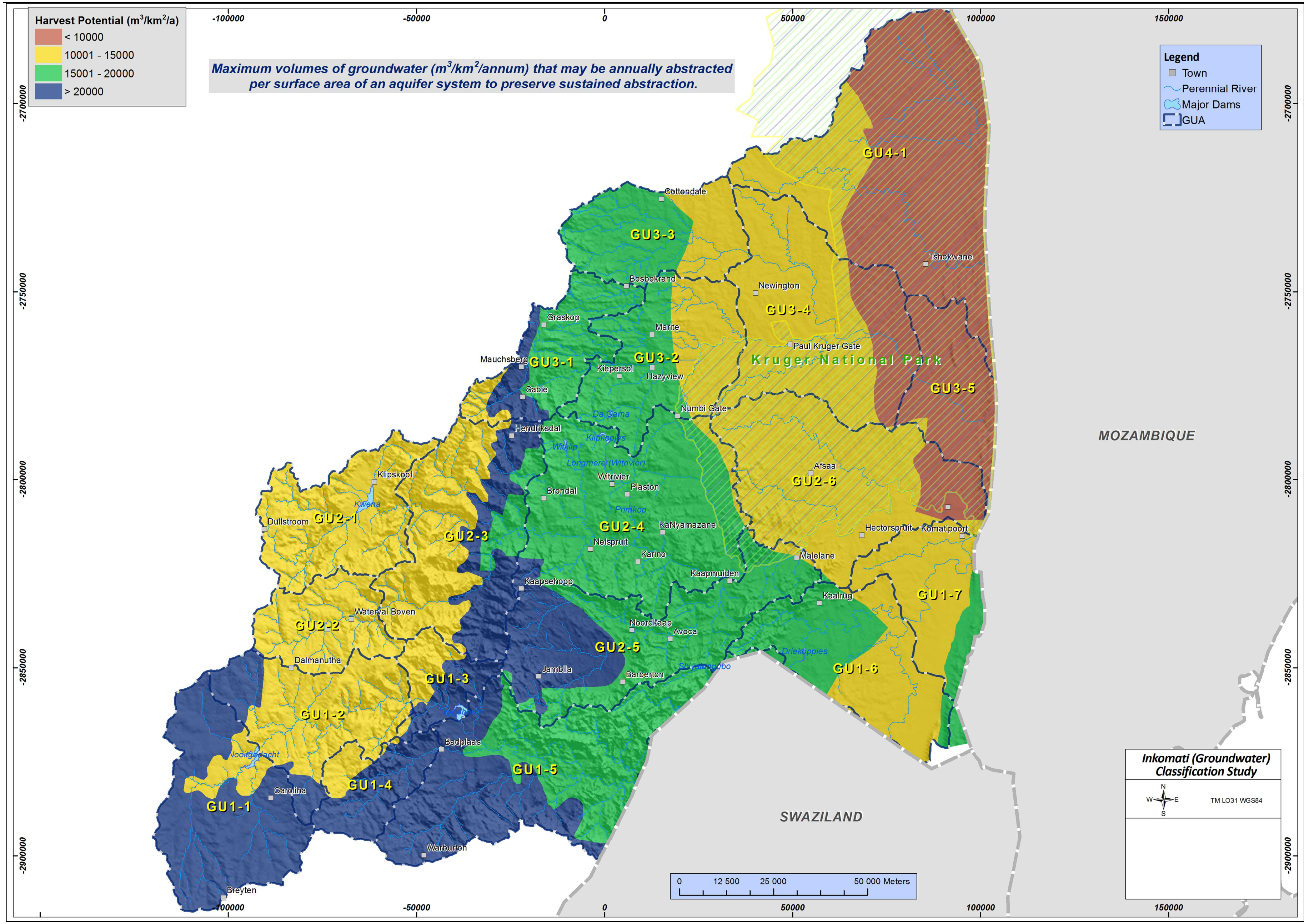


Figure 2.6 Groundwater harvest potential map of the Inkomati

2.5.3 Groundwater Use

Most of the groundwater use in the Inkomati is for rural domestic supplies, as well as for game and livestock watering in its drier parts. However groundwater abstraction for irrigation purposes should not be underestimated.

According to the Inkomati ISP groundwater use amounts to 27.5 Million m^3/a based on the WARMS database (2004), while estimated use based on the GRA II dataset amount to only 13.3 Million m^3/a (DWAF, 2004a). The latter use figure can be broken down into 68 % for rural water supply, 12 % for the mining industry and 12 % for agricultural use. Based on the results of the Comprehensive Groundwater Reserve Determination for the Inkomati by AGES (2010), a significantly higher groundwater use figure was estimated. The study was based on the distribution of NGA boreholes and associating them with a specific use (agriculture irrigation, forestry, mining or domestic water supply). It was further assumed in the assessment by AGES (2010) that of the 70440 ha of farm land are under irrigation, with groundwater resources accounting for 10 % or 70.4 Mm^3/a of farm irrigation. Similarly groundwater use was assumed to be relevant for 1% of the forestry surface area and amounted to 3.9 Mm^3/a. The total groundwater use for the Inkomati was subsequently estimated to 114.9 Mm^3/a and includes the Basic Human Need (BHN) community water allocation of 18.9 Mm^3/a.

In view of several far reaching assumptions in the specialist Groundwater Reserve studies by AGES (2010), the current study approach took also cognisance of the GRA II and WARMS 2013 datasets to achieve a more balanced estimate of groundwater use. It must be emphasized that the 'WARMS' dataset is based on actual current reporting of groundwater use and arguably provides the best available water use dataset on a catchment scale to establish the groundwater stress index required for the classification process. A summary of the various groundwater use datasets per GU is shown in Table 2.8.

Table 2.8 Summary of the groundwater use estimates for each of the Inkomati GUs (in m^3/a)

Sub-catchment	GUs	WARMS	GRA II	AGES (2010)*	Revised GW[1] Use[#]
Komati	GU1-1	2,712,265	406,200	1,242,432	2,712,265
	GU1-2	524,105	49,600	2,316,184	871,203
	GU1-3	452,656	12,700	1,036,012	701,304
	GU1-4	129,198	12,500	435,940	195,570
	GU1-5	1,272,365	30,000	2,500,108	1,858,673
	GU1-6	7,351,154	1,992,300	1,450,516	8,064,320
	GU1-7	3,080,995	381,700	6,244,388	3,539,513
Crocodile	GU2-1	781,994	1,634,600	2,606,128	2,013,346
	GU2-2	987,474	195,100	363,448	987,474
	GU2-3	169,708	111,100	1,782,836	1,215,650
	GU2-4	4,679,017	1,168,000	9,950,008	8,305,594
	GU2-5	3,387,769	1,464,200	6,925,312	4,890,928
	GU2-6	748,485	25,600	4,535,156	2,036,529
Sabie-Sand	GU3-1	2,744,067	855,700	583,416	3,002,219
	GU3-2	2,274,679	1,785,000	5,854,292	4,301,823

Sub-catchment	GUs	WARMS	GRA II	AGES (2010)*	Revised GW[1] Use[#]
	GU3-3	3,845,298	2,633,900	3,934,948	5,818,181
	GU3-4	297,077	410,200	1,702,020	1,370,892
	GU3-5			110,376	55,188
X4	GU4-1	17,719	103,400	1,505,844	376,461
Total		**35,456,025**	**13,271,800**	**55,079,364**	**52,317,133**

* The estimated Irrigation use by AGES (2010) was regarded as an overestimate and was reduced by 50%.
# The final revised groundwater use estimate is based on a combination of the AGES (2010) reported volumes and the WARMS.
1 Groundwater.

2.5.4 Groundwater Quality

Approximately 800 groundwater quality samples (latest analysis per station) were collated from the NGA and Water Management System (WMS) datasets. Major elements and selected metals were compared to the water quality guidelines as specified by DWAF (1996) (Table 2.9).

The general groundwater mineralisation in the Inkomati is based on average Electrical Conductivities between 10 mS/m and 235 mS/m low to acceptable. A deterioration of the groundwater quality (salinity) in the WMA from west to east, following essentially the average annual rainfall, is obvious. While the higher rainfall areas in the west have usually a Total Dissolved Solids(TDS) content of less than 300 mg/l, the TDS content in the more arid areas in the east (i.e. GU 1-7; GU3-4 and GU3-5) rises to more than 1000 mg/l (Table 2.9) or poor water quality.

Several samples show major ion concentrations (i.e. Mg, Na, Cl, and F) and subsequently electric conductivities elevated to Class II drinking water qualities. This can mostly be related to evaporative concentration of elements in discharge areas or low recharge values, while the occurrence of fluoride is primarily controlled by geology. Therefore, there are no preventative measures under the given spatial limits of water supply to avoid exceedance of applicable drinking water limits in certain regions except treatment.

Historical mining activities have resulted in the presence of abandoned adits, shafts, mine reside deposits and other infrastructure scattered across the area, although the impact of these on groundwater quality is thought to be rather local in nature. Current mining activities, including the reprocessing of old waste dumps, present a possible threat to local groundwater resources if applicable environmental legislation is not enforced. Other potential threats to groundwater quality include sub-standard sewage treatment plants and agricultural activities. In general, the risk of regional pollution of aquifers is far lower compared to urbanized areas like Gauteng, but it should be emphasised that the sustainability of rural water supply (without sophisticated treatment) depends on unpolluted water resources, which are difficult to remediate once contaminated. The water quality in the rural settlements ranges already from good to poor, due to elevated nitrate concentrations. Due to the growing population, the increase in the use of septic tanks, pit and bucket latrines, poses a direct risk to the groundwater quality in terms of nitrate and bacterial or viral concentrations.

Table 2.9 Summary of the average groundwater quality estimates for each of the Inkomati GUs (in mg/l)

GUs	Parameter	pH	EC (Ms/m)	TDS[1]	Alkalinity as $CaCO_3$	Ca	Mg	Na	K	Cl	SO_4	Nitrate as N	Ammonia as N	PO_4 as P	F	Fe	Mn	Al
GU1-1	N	6	6	5	6	6	6	5	5	6	5	6	5	5	6	1	1	1
	Mean	7.6	34.0	251.4	135.1	28.6	8.5	23.9	3.6	10.7	9.1	2.3	0.03	0.02	0.3	0.011	0.002	0.021
GU1-2	N	3	3	3	3	3	3	3	3	3	3	3	3	3	3			
	Mean	8.0	23.0	188.7	111.8	20.2	10.2	11.0	0.6	3.4	2.8	0.5	0.05	0.07	0.3			
GU1-3	N	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1
	Mean	7.4	11.7	111.0	45.8	7.7	4.2	6.5	1.2	28.1	4.8	0.4	0.03	0.01	0.6	0.003	0.001	0.026
GU1-4	N	4	4	4	4	4	4	4	4	4	4	4	4	4	4			
	Mean	7.2	16.7	115.8	58.6	8.7	8.4	6.8	0.5	5.4	3.0	2.2	0.11	0.02	0.1			
GU1-5	N	29	29	29	29	29	29	29	29	29	29	29	29	29	29	2	2	2
	Mean	7.8	57.3	448.3	202.9	27.5	27.6	53.6	3.1	58.9	11.6	3.9	0.05	0.02	0.8	0.065	0.002	0.041
GU1-6	N	52	52	52	52	52	52	52	52	52	52	52	52	52	52	1	1	1
	Mean	8.3	155.4	1058.8	299.7	63.3	54.3	193.2	4.9	340.0	17.2	4.4	0.17	0.03	0.5	0.006	0.815	0.035
GU1-7	N	10	10	10	10	10	10	10	10	10	10	10	10	10	10			
	Mean	8.0	149.7	1098.6	343.9	65.5	51.9	183.8	2.5	285.8	42.7	10.5	0.04	0.03	0.6			
GU2-1	N	3	3	3	3	3	3	3	3	3	3	3	3	3	3	1	1	1
	Mean	7.6	22.9	183.1	107.3	19.0	13.3	5.8	0.7	4.1	4.2	1.0	0.04	0.02	0.2	0.039	0.006	0.040
GU2-2	N	3	3	2	3	3	3	2	3	2	3	3	3	3	3	1	1	1
	Mean	8.2	30.6	186.5	107.2	17.3	11.5	4.4	2.4	3.8	6.5	0.3	0.03	0.03	1.2	0.017	0.019	0.014
GU2-3	N	11	11	10	11	11	11	10	10	11	10	11	10	10	11			
	Mean	7.7	47.9	351.9	108.5	36.1	22.3	28.6	1.0	68.9	40.7	1.0	0.02	0.01	0.2			
GU2-4	N	24	24	22	24	24	24	23	23	24	22	23	23	23	23	6	6	4
	Mean	7.9	52.2	451.9	204.9	28.1	18.7	63.8	3.1	37.1	14.0	2.4	0.07	0.02	1.1	0.008	0.024	0.029
GU2-5	N	34	34	34	34	34	34	34	34	34	34	34	34	34	34			
	Mean	8.0	58.6	479.5	246.9	27.6	34.8	50.4	1.6	25.0	25.9	2.8	0.03	0.03	0.5			
GU2-6	N	41	41	39	40	40	40	40	40	40	40	39	39	39	39	3	3	3
	Mean	8.5	108.0	887.3	420.8	35.7	37.8	162.9	1.6	128.4	9.5	0.8	0.06	0.02	1.0	0.074	0.004	0.173
GU3-1	N	22	22	22	22	22	22	22	22	22	22	22	22	22	22	3	3	3
	Mean	7.5	20.1	161.6	76.1	14.0	9.1	12.5	2.9	12.0	11.3	1.5	0.03	0.03	0.4	0.037	0.004	0.011
GU3-2	N	143	143	143	143	143	143	143	143	143	143	143	143	143	143	41	41	41
	Mean	7.8	72.0	492.3	189.3	34.0	26.1	70.2	2.1	83.9	9.5	7.9	0.03	0.03	0.6	0.024	0.012	0.043
GU3-3	N	300	300	299	300	300	300	299	299	300	299	300	299	299	300	74	75	76

GUs	Parameter	pH	EC (Ms/m)	TDS[1]	Alkalinity as $CaCO_3$	Ca	Mg	Na	K	Cl	SO_4	Nitrate as N	Ammonia as N	PO_4 as P	F	Fe	Mn	Al
	Mean	7.9	72.7	529.5	213.0	35.2	23.2	82.3	2.7	80.9	12.4	7.2	0.05	0.04	0.7	0.025	0.036	0.055
GU3-4	N	124	124	123	124	124	124	124	124	124	124	123	123	123	124	29	30	30
	Mean	8.2	197.0	1447.0	536.5	58.7	76.5	270.4	4.2	332.5	25.3	5.1	0.10	0.02	0.8	0.037	0.027	0.059
GU3-5	N	11	11	11	11	11	11	11	11	11	11	11	11	11	11	3	3	3
	Mean	8.6	221.5	1559.8	516.8	75.9	65.4	325.6	1.6	445.4	12.6	0.2	0.22	0.02	1.3	3.607	0.017	0.500
GU4-1	N	70	70	63	70	70	70	69	69	70	69	64	63	63	70	10	10	11
	Mean	8.5	235.3	1743.2	560.8	65.8	84.7	341.1	4.2	450.8	30.9	6.5	0.07	0.03	1.1	0.489	0.004	0.370
Drinking Water Quality Limits - DWAF (1996)																		
Class 1		5-6 or 9-9.5	70-150	450-1000		80-150	30-70	100-200	25-50	100-200	200-400	6-10			0.7-1	0.1-0.2	0.05-0.1	0-0.15
Class 2		4-5 or 9.5-10	150-370	1000-2400		150-300	70-100	200-600	50-100	200-600	400-600	10-20			1-1.5	0.2-2	0.1-1	0.15-0.5
Class 3		3.5-4 or 10-10.5	370-520	2400-3400		>300	100-200	600-1200	100-500	600-1200	600-1000	20-40			1.5-3.5	2-10	1-5	>0.5

1 Total Dissolved Solids.

3 GROUNDWATER CLASSIFICATION

3.1 BACKGROUND

The description of the Water Resource Class is listed below:

- **Class I (Minimally used):** The configuration of the Ecological Categories of the water resources within the catchment results in an overall water resources condition that is minimally altered from its pre-development condition.
- **Class II (Moderately used):** The configuration of Ecological Categories of the water resources within the catchment results in an overall water resource condition that is moderately altered from its pre-development condition.
- **Class III (Heavily used):** The configuration of Ecological Categories of the water resources within the catchment results in an overall water resource condition that is significantly altered from its pre-development condition.

There are a set of guidelines and procedures for determining the different classes of water resources.

Defining stress

The concept of stressed water resources is addressed by the NWA, but is not defined. Part 8 of the Act gives some guidance by providing the following qualitative examples of 'water stress':

- Where demands for water are approaching or exceed the available supply.
- Where water quality problems are imminent or already exist.
- Where water resource quality is under threat.

The groundwater stress index reflects water availability versus water used. Groundwater use should include water utilised by current water users, water required to sustain the Reserve as well as for BHN. The Stress Index for an assessment area is defined as follows:

$$SI(\%) = \frac{gwUse}{Recharge} \times 100$$

Where:

gwUse = Current groundwater use

Recharge = Recharge (as a volume)

In calculating the Stress Index, the variability of annual recharge is taken into account in the sense that not more than 65% of average annual recharge can be allocated on a catchment scale).

Present Category	Description	Compliance (Spatial/Temporal)
I	Minimally used	≤20%
II	Moderately used	20% – 65%
III	Heavily used	> 65%

A guide for quantifying groundwater use is documented below.

Activity	Percentage of recharge
Stock watering, farm domestic water supply, rural water supply.	Use ranges between 5% and 20% of recharge.
Small-scale irrigation, rural water supply, water supply for villages and small towns.	Use ranges between 20% and 40% of recharge.
Water supply for large rural communities, medium to large towns, large-scale irrigation.	Use ranges between 40% and 65% of recharge.

Baseline class

Defining the point at which a resource is no longer being used in a sustainable manner is generally very difficult. The level of sustainability probably fluctuates through time, and impacts from over-use could manifest themselves sometime after the impact was caused. The change from sustainable use to over-use is gradational, and not necessarily marked by some distinct change. Indicators of quantitative unsustainable groundwater use include:

- Land subsidence or sinkhole formation.
- Long-term declining water levels on a regional level.
- Long-term declining water quality levels.

A guide for assessing the status of groundwater units based on **observed impacts** resulting from groundwater abstraction is presented below.

Present Category	Generic description	Affected environment
Minimally used (I)	The water resource is minimally altered from its pre-development condition.	No sign of significant impacts observed.
Moderately used (II)	Localised low level impacts, but no negative effects apparent.	Temporal, but not long-term significant impact to: ▪ spring flow ▪ river flow ▪ vegetation ▪ land subsidence ▪ sinkhole formation ▪ groundwater quality
Heavily used (III)	The water resource is significantly altered from its pre-development condition.	Moderate to significant impacts to: ▪ spring flow ▪ river flow ▪ vegetation ▪ land subsidence ▪ sinkhole formation ▪ groundwater quality

Groundwater quality

Domestic use (human consumption) is considered by the authors as the highest beneficial use, with the supposedly most stringent quality requirements. It is assumed that any water resource, which is deemed fit for human consumption, also meets the requirements of aquatic ecosystems. While the water quality requirements of aquatic ecosystems might differ and are in fact for several elements even more stringent than for domestic use (e.g. Cd), the chosen approach avoids the pitfall of equating groundwater quality in the sub-surface to water quality discharging into a surface water body.

In other words, the methodology recognizes the processes occurring in discharge areas in general (e.g. evapotranspiration) and the enhanced microbiological and chemical reactions (e.g. Redox or cation exchange reactions) in the hyporheic zone specifically), without trying to quantify them by setting only domestic use requirements for the groundwater resource itself.

It is therefore recommended to use the South African Water Quality Guidelines Vol. 1 – Domestic use (DWAF, 1996), or the national drinking water standard (SANS 241: 2011) for the present status category assessment of a water resource.

Present Category	Description	Compliance (Spatial/Temporal)
I	DWS class 0 or 1 or natural background.	95%
II	DWS class 2 (95 % compliance) or natural background (75 % compliance).	75%
III	DWS class 3 or 4 or natural background (<75 % compliance).	<75%

3.2 KOMATI SUB-CATCHMENT

3.2.1 Groundwater Stress Index (SI)

The Komati sub-catchment comprises of seven GUs and can be divided into two distinct sections: Komati West, comprising the area upstream of Swaziland, and Komati East, comprising the area downstream of Swaziland. Groundwater use in relation to recharge and available resources is generally limited throughout the upper Komati sub-catchment, namely GU1-1 through to GU1-5 (Table 3.1). Groundwater use is substantially higher within the lower parts of the Komati sub-catchment with a registered groundwater use of over 6 Mm^3/a for GU1-6, more specifically quaternary catchment X14H. These volumes need to verified with follow-up studies but may well relate to either an over registration or wrongly entered information into WARMS. Beyond this outlier, the aquifers of the Komati sub-catchment are by far not utilised to their potential.

Table 3.1 Groundwater availability and stress index for the Komati sub-catchment

Description	GUs	Quat	Area (Km^2)	MAP[1] WR90 (mm/a)	Harvest potential (HP)	Recharge (Mm^3/a)	GW use (Mm^3/a)	GW use as % of HP	SI (GW use as % of recharge)
Komati Highveld	GU1-1	X11A	672	726	13.67	24.36	0.33	2%	1%
		X11B	597	726	12.49	22.93	0.83	7%	4%
		X11C	319	726	6.45	13.12	1.56	24%	12%
Upper Komati	GU1-2	X11D	590	781	8.59	25.97	0.51	6%	2%
		X11E	241	781	3.57	11.38	0.02	1%	0%
		X11F	183	781	2.03	9.49	0.15	7%	2%
		X11G	264	890	3.03	20.58	0.20	6%	1%
Escarpment Komati	GU1-3	X11H	265	890	7.46	21.55	0.44	6%	2%
		X11J	186	890	5.03	15.75	0.26	5%	2%
Middle Komati West	GU1-4	X12A	244	896	9.74	15.35	0.08	1%	0%
		X12B	155	896	2.81	10.30	0.04	2%	0%
		X12C	186	896	7.66	13.28	0.08	1%	1%
Middle Komati	GU1-5	X11K	211	890	7.69	16.73	0.82	11%	5%
		X12D	223	896	9.48	14.19	0.29	3%	2%

Description	GUs	Quat	Area (Km^2)	MAP[1] WR90 (mm/a)	Harvest potential (HP)	Recharge (Mm^3/a)	GW use (Mm^3/a)	GW use as % of HP	SI (GW use as % of recharge)
		X12E	333	896	14.05	20.72	0.09	1%	0%
		X12F	313	896	13.04	21.69	0.13	1%	1%
		X12G	239	896	4.53	16.90	0.05	1%	0%
		X12H	286	1135	7.14	26.31	0.05	1%	0%
		X12J	296	1135	4.74	29.62	0.16	3%	1%
		X12K	286	1135	5.21	27.93	0.08	2%	0%
		X14A	141	713	2.18	8.89	0.09	4%	1%
		X14B	185	713	1.50	11.39	0.09	6%	1%
Lower Komati	GU1-6	X13J	828	713	10.75	20.68	0.70	7%	3%
		X14F	117	713	1.82	6.89	0.07	4%	1%
		X14G	204	713	3.20	6.00	0.62	19%	10%
		X14H	360	713	5.31	8.67	6.68	126%	77%
Lower Komati East	GU1-7	X13K	621	713	8.96	10.25	2.56	29%	25%
		X13L	286	713	3.56	5.17	0.98	28%	19%

1 Mean Annual Precipitation.

3.2.2 Groundwater Quality

Overall groundwater quality in the Upper Komati sub-catchment (GU1-1 to GU1-5) is regarded as good with most samples complying with the recommended drinking water quality standards (Table 3.2). Towards the lower Komati sub-catchment (GU1-6 to GU1-7) the groundwater quality decrease slightly with a number of samples exceeding the guideline limits. This can mostly be related to evaporative concentration (elevated Na and Cl) of elements in discharge areas or due to low recharge values as well as long residence times for selected samples. The most notable elements of concern include NO_3 as N with average concentrations above the recommended drinking limit for GU 1-7. Although based on the results the groundwater quality in the Upper Komati (Highveld area) is generally good, coal mining poses a threat to the quality of the groundwater in GU1-1 if compliance to environmental legislation is not enforced.

Table 3.2 Groundwater quality classification for the Komati sub-catchment

GU	EC (Ms/m)	TDS	Ca	Mg	Na	Cl	SO_4	NO_3 as N	F	No of Samples	Class 0 or 1	Class 2	Class 3 or 4
GU1-1	34.0	251.4	28.6	8.5	23.9	10.7	9.1	2.3	0.3	6	57%	43%	-
GU1-2	23.0	188.7	20.2	10.2	11.0	3.4	2.8	0.5	0.3	3	100%	-	-
GU1-3	11.7	111.0	7.7	4.2	6.5	28.1	4.8	0.4	0.6	2	100%	-	-
GU1-4	16.7	115.8	8.7	8.4	6.8	5.4	3.0	2.2	0.1	4	100%	-	-
GU1-5	57.3	448.3	27.5	27.6	53.6	58.9	11.6	3.9	0.8	29	79%	3%	17%
GU1-6	155.4	1058.8	63.3	54.3	193.2	340.0	17.2	4.4	0.5	52	33%	50%	17%
GU1-7	149.7	1098.6	65.5	51.9	183.8	285.8	42.7	10.5	0.6	10	20%	40%	40%

Class 0 or 1 Class 2 Class 3 or 4

3.2.3 Groundwater level trends

A summary of the available water level monitoring station which cover in most cases the last decade are provided in Table 3.3. Selected water level trends are shown in Figure 3.2. Generally, groundwater levels fluctuate according to the characteristics of precipitation events (i.e. amount, duration, and intensity) and various hydrogeological variables (i.e. topography, thickness of the unsaturated zone, and matrix composition of saturated and unsaturated materials). Groundwater level fluctuations from the observed hydrographs vary between 1 and 3 m. No declining trend due to abstraction is observed from the hydrographs. However, a couple of datasets (i.e. X1N0001 and X1N0013) show a distinct decline in water levels which were considered to be faulty readings or wrongfully captured datasets. This should be highlighted to DWS.

Table 3.3 Water level monitoring stations for the Komati sub-catchment

GU	Station	Range start	Range end	Comment
GU1-5	X1N0001	May-01	Sep-14	Seasonal fluctuation approx. 2 m*
	X1N0002	May-01	Sep-14	Seasonal fluctuation approx. 1 m
	X1N0003	May-01	Sep-14	Seasonal fluctuation approx. 2 m*
	X1N0004	May-01	Sep-14	Seasonal fluctuation approx. 2 m*
	X1N0005	Dec-04	Sep-14	Seasonal fluctuation approx. 3 m*
	X1N0006	May-01	Sep-14	Seasonal fluctuation approx. 1.5 m
GU1-6	X1N0007	Dec-03	Sep-14	Seasonal fluctuation approx. 2 m
	X1N0008	Blocked		
	X1N0009	Nov-03	Sep-14	Poor dataset
	X1N0011	Nov-03	Sep-14	Seasonal fluctuation approx. 2 m (Increasing trend)
	X1N0013	May-01	Sep-14	Seasonal fluctuation approx. 3 m*

* Datasets needs to be re-checked with DWS (appear to have faulty readings).

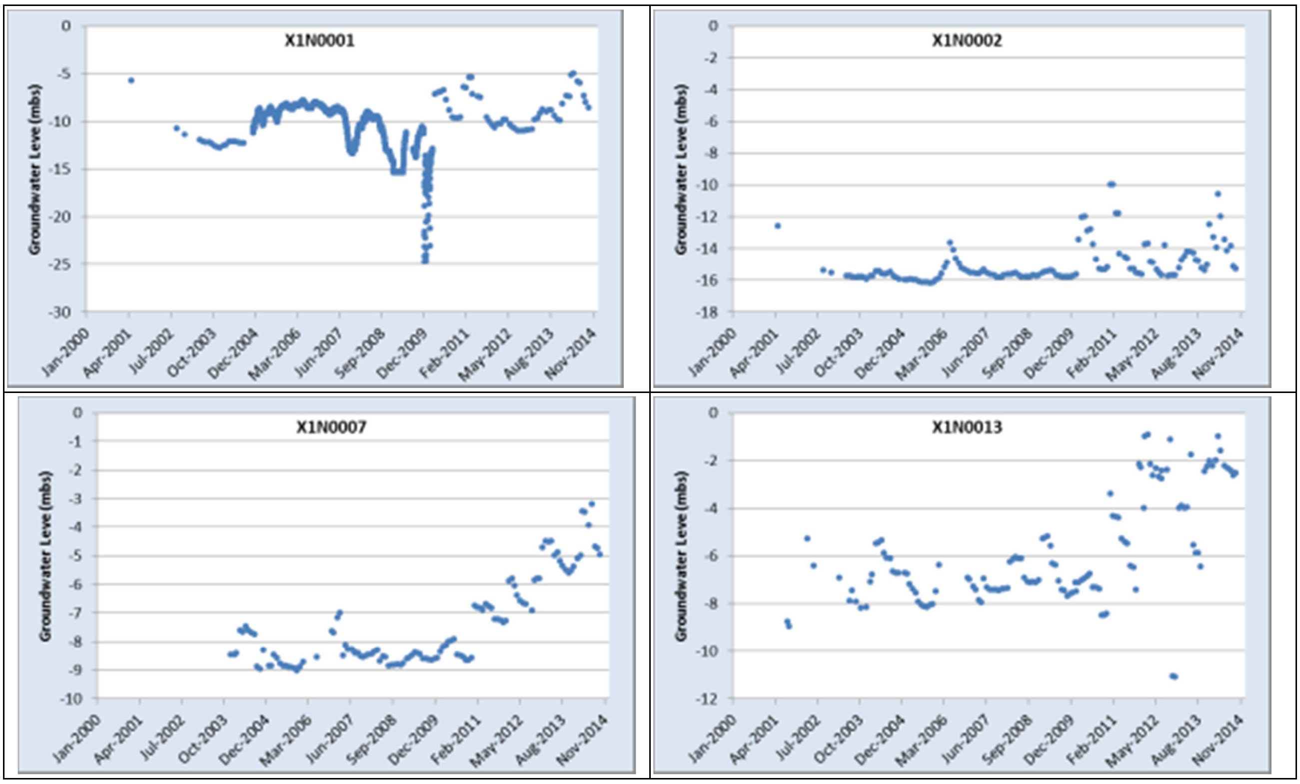


Figure 3.1 Selected water level monitoring trends for the Komati sub-catchment

3.3 CROCODILE SUB-CATCHMENT

3.3.1 Groundwater SI

The Crocodile sub-catchment comprises of six GUs and is dominated by irrigation and forestry. Numerous rural communities occur within the region, especially within GU2-4 and GU2-5 (Middle Crocodile and Barberton region). Total groundwater use is estimated at 19.45 Mm^3/a, which exceeds usage in the other sub-catchments. Large industries, namely the Sappi paper mill at Ngodwana (Elands catchment) and the sugar mills at Malelane and Komatipoort, occur within the sub-catchment.

Groundwater use in relation to recharge and available resources is minimal throughout the sub-catchment. Formal registered rural groundwater supply schemes occur in the Middle Crocodile River towards the east of Mbombela (Nelspruit), more specifically quaternary drainage X22K. The escarpment (and dolomites, GU2-3) provides a significant component of baseflow to the rivers in the sub-catchment and large scale groundwater development is expected to directly impact on available surface water resources. This is obviously more pronounced in drought respectively low flow periods, when abstractions could result in induced recharge (recharge of aquifers from rivers), thus directly impacting on the baseflow of rivers. However, abstractions further away (i.e. >1 km) from the main stem of a river are assumed to not impact directly and significantly on the low flow of the main river, as the non-perennial tributaries are considered to not contribute to the baseflow of the main river (DWAF, 2009). However, a potential delayed reduction of groundwater baseflow cannot be excluded and need to be assessed on a site specific scale.

Table 3.4 Groundwater availability and stress index for the Crocodile sub-catchment

Description	GUs	Quat	Area (Km^2)	MAP WR90 (mm/a)	HP	Recharge (Mm^3/a)	GW Use (Mm^3/a)	GW use as % of HP	SI (GW use as % of recharge)
Upper Crocodile	GU2-1	X21A	265	796	3.01	13.85	0.67	22%	5%
		X21B	378	796	4.22	18.81	0.45	11%	2%
		X21C	311	796	3.49	16.25	0.75	22%	5%
		X21D	219	796	2.48	10.95	0.14	6%	1%
Upper Elands	GU2-2	X21F	397	835	4.43	18.30	0.83	19%	5%
		X21G	347	835	3.90	17.51	0.16	4%	1%
Escarpment Dolomites	GU2-3	X21E	345	896	4.59	29.69	0.20	4%	1%
		X21H	229	955	7.33	21.19	0.08	1%	0%
		X21J	355	955	4.45	29.26	0.15	3%	1%
		X21K	245	955	5.76	22.78	0.11	2%	0%
		X22A	251	896	3.28	23.67	0.07	2%	0%
		X22B	227	896	4.61	21.24	0.46	10%	2%
		X22D	274	1070	6.40	25.58	0.15	2%	1%
Middle Crocodile	GU2-4	X22C	366	914	7.30	20.69	1.03	14%	5%
		X22E	153	1070	2.51	13.92	0.04	2%	0%
		X22F	212	914	3.38	11.41	1.19	35%	10%
		X22G	107	1070	1.73	9.39	0.11	6%	1%
		X22H	200	914	3.23	10.22	0.92	29%	9%
		X22J	240	914	3.84	12.75	0.81	21%	6%
		X22K	335	732	5.30	14.57	2.89	55%	20%
		X24A	249	732	3.82	7.57	0.40	11%	5%
		X24B	335	732	5.30	11.06	0.82	15%	7%
		X24C	286	732	4.51	10.49	0.09	2%	1%
Barberton Region	GU2-5	X23A	127	919	5.53	10.69	0.07	1%	1%
		X23B	229	919	5.62	12.38	0.65	12%	5%
		X23C	81	919	3.51	6.98	0.12	3%	2%
		X23D	182	919	7.88	12.89	0.17	2%	1%
		X23E	180	919	5.72	12.02	0.16	3%	1%
		X23F	310	919	8.86	20.29	2.41	27%	12%
		X23G	225	732	3.58	11.20	0.26	7%	2%
		X23H	306	732	4.96	14.59	0.66	13%	4%
		X24D	302	689	4.70	10.58	0.38	8%	4%

Description	GUs	Quat	Area (Km^2)	MAP WR90 (mm/a)	HP	Recharge (Mm^3/a)	GW Use (Mm^3/a)	GW use as % of HP	SI (GW use as % of recharge)
Lower Crocodile (Lowveld)	GU2-6	X24E	526	689	6.41	12.28	0.22	3%	2%
		X24F	262	689	3.34	5.76	0.72	22%	12%
		X24G	620	689	7.48	11.69	0.12	2%	1%
		X24H	770	689	8.39	12.78	0.98	12%	8%

3.3.2 Groundwater Quality

The overall groundwater quality in the Crocodile sub-catchment is regard as good with most samples complying with the recommended drinking water quality standards (Table 3.5). A slightly poorer water quality is observed in the Lowveld region (GU2-6), mainly due to elevated Total Dissolved Solids (TDS), Sodium and Chloride contents. This can again be related to evaporative concentration of elements in discharge areas along with low recharge values. The most notable elements of concern include Fluoride, which occurrence is in contrast to nitrate primarily controlled by the underlying geology and climate (further evaporative concentration). Therefore, there are no preventative measures under the given spatial limits of water supply to avoid exceedance of applicable limits.

Slightly elevated sulphate concentrations compared to the population are seen in samples collated from GU2-3. These locally impacted groundwater quality might be related to the industrial activities occurring along the Elands River at Ngodwana and need justify further investigations. Gold mining activities near Barberton (GU2-5) present inherently a possible threat to groundwater resources in the form of Acid Mine Drainage (AMD) with increased metal content. The impact of these mining activities on the groundwater quality is considered to be local in nature, but could spread off-site through surface run-off drainages or if best practices are not followed.

Table 3.5 Groundwater quality classification for the Crocodile sub-catchment

GU	EC (Ms/m)	TDS	Ca	Mg	Na	Cl	SO_4	NO_3 as N	F	No of Samples	Class 0 or 1	Class 2	Class 3 or 4
GU2-1	22.9	183.1	19.0	13.3	5.8	4.1	4.2	1.0	0.2	3	100%	-	-
GU2-2	30.6	186.5	17.3	11.5	4.4	3.8	6.5	0.3	1.2	3	67%	-	33%
GU2-3	47.9	351.9	36.1	22.3	28.6	68.9	40.7	1.0	0.2	11	82%	18%	-
GU2-4	52.2	451.9	28.1	18.7	63.8	37.1	14.0	2.4	1.1	24	42%	29%	29%
GU2-5	58.6	479.5	27.6	34.8	50.4	25.0	25.9	2.8	0.5	34	62%	29%	9%
GU2-6	108.0	887.3	35.7	37.8	162.9	128.4	9.5	0.8	1.0	40	25%	55%	20%

Class 0 or 1 Class 2 Class 3 or 4

3.3.3 Groundwater level trends

A summary of the available water level monitoring station which cover in most cases the last decade are provided in Table 3.6. Selected water level trends are shown in Figure 3.2. Groundwater level fluctuations from the observed hydrographs vary between 1 and 4 m. Apart from a slight decline in water levels over the monitoring period (Dec 2002 to Sep 2012) for X2N0025 no declining trend due to over abstraction is observed from the hydrographs. In contrast a couple of boreholes show an increase in water levels over the monitoring period.

Table 3.6 Water level monitoring stations for the Crocodile sub-catchment

GU	Station	Range Start	Range End	Comment
GU2-3	X2N0020	Decommissioned		
	X2N0021	Jul-02	Sep-14	Seasonal fluctuation approx. 2 m (Increasing trend)
	X2N0022	Jul-02	Sep-14	Seasonal fluctuation approx. 2 m (Increasing trend)
	X2N0023	Jul-02	Aug-11	Seasonal fluctuation approx. 1 m (Increasing trend)
	X2N0024	Jul-02	Sep-14	Seasonal fluctuation approx. 2 m (Increasing trend)
GU2-4	X2N0001	Decommissioned		
	X2N0002	Blocked		
	X2N0003	Blocked		
	X2N0004	Jul-02	Aug-05	Poor dataset
	X2N0005	Decommissioned		
	X2N0006	Decommissioned		
	X2N0007	Decommissioned		
	X2N0008	Decommissioned		
	X2N0009	Jul-02	Aug-05	Poor dataset
	X2N0010	Decommissioned		
	X2N0011	Jul-02	Aug-05	Poor dataset
	X2N0012	Jul-02	Aug-05	Poor dataset
	X2N0013	Jun-01	Sep-14	Seasonal fluctuation approx. 1m
	X2N0014	Decommissioned		
	X2N0015	Equipped		
	X2N0016	Dec-02	Sep-14	Seasonal fluctuation approx. 2 m (Increasing trend)
	X2N0017	Dec-02	Sep-14	Seasonal fluctuation approx. 2 m
	X2N0018	Dec-02	Sep-14	Seasonal fluctuation approx. 2 m
	X2N0019	Dec-02	Sep-14	Seasonal fluctuation approx. 2 m
	X2N0025	Dec-02	Sep-14	Seasonal fluctuation approx. 4 m (Decreasing trend)
	X2N0033	Blocked		
	X2N0034	Dec-02	Sep-14	Seasonal fluctuation approx. 1.5 m (Increasing trend)
	X2N0035	No Data		
	X2N0036	No Data		
GU2-5	X2N0027	Aug-01	Sep-14	Seasonal fluctuation approx. 1.5 m (Increasing trend)
	X2N0028	Aug-01	Sep-14	Seasonal fluctuation approx. 2 m
	X2N0029	Aug-01	Apr-14	Seasonal fluctuation approx. 1 m
	X2N0030	Apr-01	Sep-14	Seasonal fluctuation approx. 1 m
	X2N0031	Aug-01	Sep-14	Seasonal fluctuation approx. 1.5 m (Increasing trend)
GU2-6	X2N0032	Apr-01	Sep-14	Seasonal fluctuation approx. 1 m

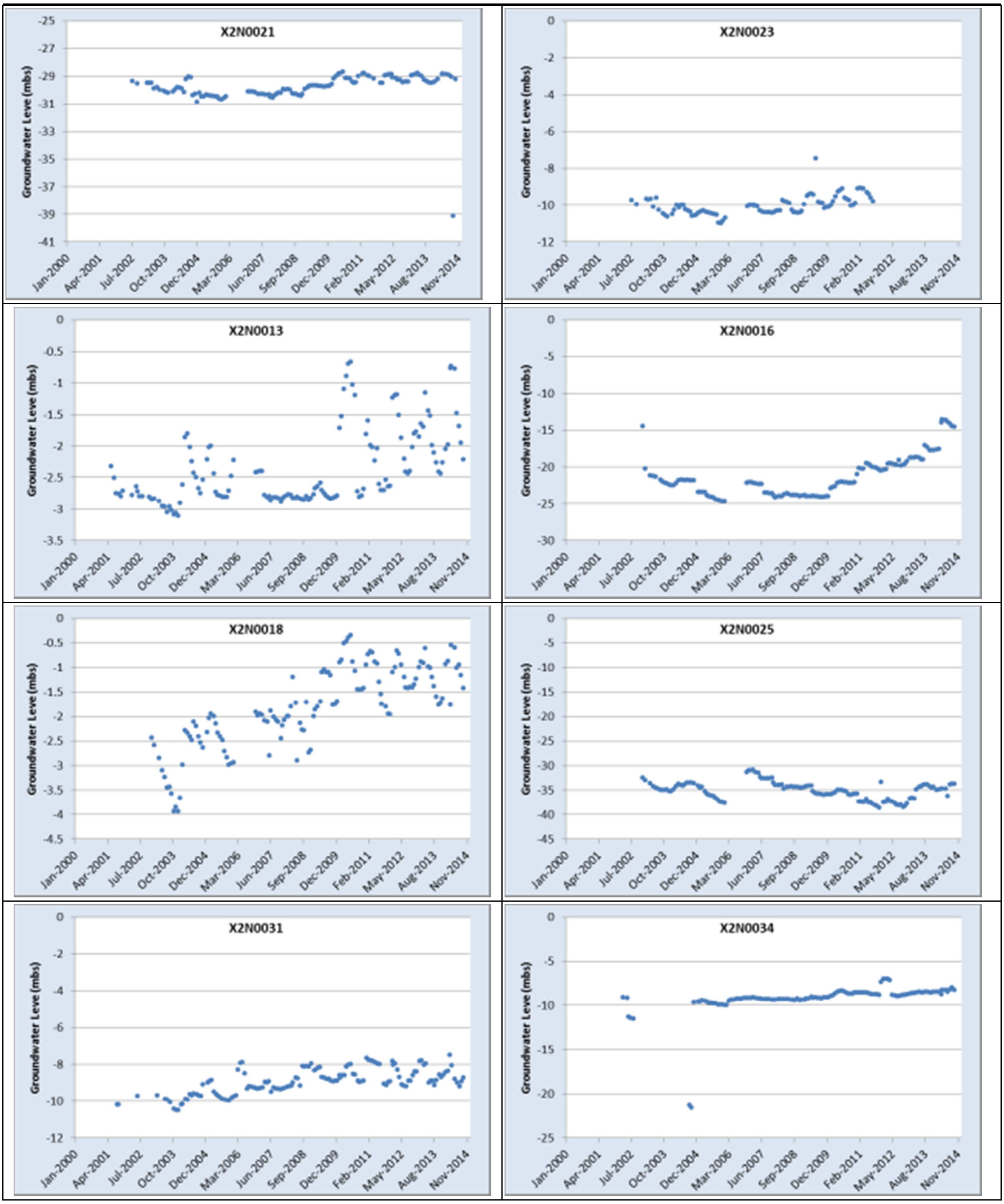


Figure 3.2 Selected water level monitoring trends for the Crocodile sub-catchment

3.4 SABIE-SAND SUB-CATCHMENT

3.4.1 Groundwater SI

The Sabie-Sand sub-catchment comprises of five GUs. Most domestic groundwater use occurs within this sub-catchment, specifically in the Middle Sabie (GU3-2) and Bushbuckridge areas (GU3-3 Upper Sand region). Groundwater use in the Upper Sabie is limited to water supply from a single spring, emanating rather concerning from an abandoned mine shaft (AGES, 2007). The volume of water registered for this use is 2Mm^3/a (WARMS 2013). Groundwater use in the remainder of the Sand-Sabie catchment (GU3-4 and GU-3-5) is limited to smaller rural domestic water supplies and is considered in relation to recharge and available resources minimal (Table 3.7). GU3-1 provides a groundwater contribution to surface flow from springs and seeps along the escarpment, as well as from the dolomitic formation which extends across the headwaters of the of the Sabie River.

Table 3.7 Groundwater availability and stress index for the Sabie-Sand sub-catchment

Description	GUs	Quat.	Area (Km^2)	MAP WR90 (mm/a)	HP	Recharge Mm^3/a	GW use Mm^3/a	GW use as % of HP	SI (GW use as % of recharge)
Upper Sabie	GU3-1	X31A	230	1224	5.32	39.15	2.33	44%	6%
		X31B	195	1224	3.63	32.54	0.11	3%	0%
		X31C	154	1224	3.04	25.80	0.11	4%	0%
		X31E	214	1130	3.38	26.11	0.37	11%	1%
		X31F	94	1130	1.48	11.66	0.08	5%	1%
Middle Sabie	GU3-2	X31D	192	1224	3.06	17.49	1.16	38%	7%
		X31G	169	1130	2.66	12.43	1.40	53%	11%
		X31H	60	1224	0.96	6.69	0.12	13%	2%
		X31J	154	1224	2.43	13.54	0.53	22%	4%
		X31K	488	772	6.57	12.58	0.58	9%	5%
		X31L	304	772	3.94	13.71	0.51	13%	4%
Upper Sand	GU3-3	X32A	112	978	1.84	7.40	0.50	27%	7%
		X32B	55	978	0.90	3.38	0.32	35%	9%
		X32C	233	978	3.48	6.52	0.91	26%	14%
		X32D	100	978	1.60	6.75	0.32	20%	5%
		X32E	78	978	1.30	4.68	2.36	182%	50%
		X32F	157	978	2.49	4.71	0.40	16%	8%
		X32G	336	682	4.08	5.48	1.02	25%	19%
Middle Sand	GU3-4	X31M	709	772	8.52	12.79	0.95	11%	7%
		X32H	488	682	5.86	7.21	0.28	5%	4%
		X32J	355	682	4.13	4.96	0.09	2%	2%
		X33A	600	572	5.97	7.85	0.05	1%	1%
Lower Sabie-Sand	GU3-5	X33B	310	572	2.77	3.24	0.02	1%	1%
		X33C	183	572	1.62	1.27	0.03	2%	2%
		X33D	350	572	3.14	3.92	0.00	0%	0%

3.4.2 Groundwater Quality

The overall groundwater quality in the Sabie-Sand sub-catchment is regarded as good with most samples complying with the recommended drinking water quality limits (Table 3.8). A slightly poorer water quality is observed in the Lower Sabie-Sand region (GU3-4 and GU3-5), mainly due to elevated Electrical Conductivity (EC), TDS, Sodium and Chloride values. This can again be related to evaporative concentration of elements in discharge areas, and low recharge values. Although not yet above recommended drinking water guideline limits, elevated Nitrate concentrations within GU3-2 and GU3-3 suggest potential anthropogenic influences on the groundwater quality related to inappropriate on-site sanitation, wastewater treatment including sewage sludge disposal or livestock concentration (animal feedlots) at watering points near boreholes.

Table 3.8 Groundwater quality classification for the Sabie-Sand sub-catchment

GU	EC (Ms/m)	TDS	Ca	Mg	Na	Cl	SO_4	NO_3 as N	F	No of Samples	Class 0 or 1	Class 2	Class 3 or 4
GU3-1	20.1	161.6	14.0	9.1	12.5	12.0	11.3	1.5	0.4	22	91%	-	9%
GU3-2	72.0	492.3	34.0	26.1	70.2	83.9	9.5	7.9	0.6	143	52%	29%	18%
GU3-3	72.7	529.5	35.2	23.2	82.3	80.9	12.4	7.2	0.7	300	53%	30%	17%
GU3-4	197.0	1447.0	58.7	76.5	270.4	332.5	25.3	5.1	0.8	124	8%	56%	35%
GU3-5	221.5	1559.8	75.9	65.4	325.6	445.4	12.6	0.2	1.3	11		45%	55%

Class 0 or 1 Class 2 Class 3 or 4

3.4.3 Groundwater level trends

A summary of the available water level monitoring station which cover in most cases the last decade are provided in Table 3.9. Selected water level trends are shown in Figure 3.3. Water levels show a general seasonal fluctuation and no declining trend due to abstraction is observed from the hydrographs. In contrast a couple of boreholes show an increase in water levels over the monitoring period (i.e. X3N0006 and X3N00010).

Table 3.9 Water level monitoring stations for the Sabie-Sand sub-catchment

GU	Station	Range Start	Range End	Comment
GU3-1	X3N0011	Jul-07	Sep-14	Seasonal fluctuation approx. 1 m
GU3-3	X3N0001	Nov-02	Sep-14	Seasonal fluctuation approx. 1 m
GU3-3	X3N0002	Nov-02	Sep-14	Seasonal fluctuation approx. 1 m (Increasing trend)
GU3-3	X3N0003	Oct-03	Jun-08	Decommissioned
GU3-3	X3N0004	Oct-03	Sep-14	Seasonal fluctuation approx. 1 m (Increasing trend)
GU3-3	X3N0005	Oct-03	Sep-14	Data Gaps
GU3-3	X3N0006	Oct-03	Sep-14	Seasonal fluctuation approx. 2 m
GU3-3	X3N0007	Nov-02	Sep-14	Data Gaps
GU3-3	X3N0008	Nov-02	Sep-14	Seasonal fluctuation approx. 1 m (Increasing trend)
GU3-3	X3N0009	Nov-02	Sep-14	Seasonal fluctuation approx. 0.5 m (Increasing trend)
GU3-3	X3N0010	Nov-02	Sep-14	Seasonal fluctuation approx. 0.5 m (Increasing trend)

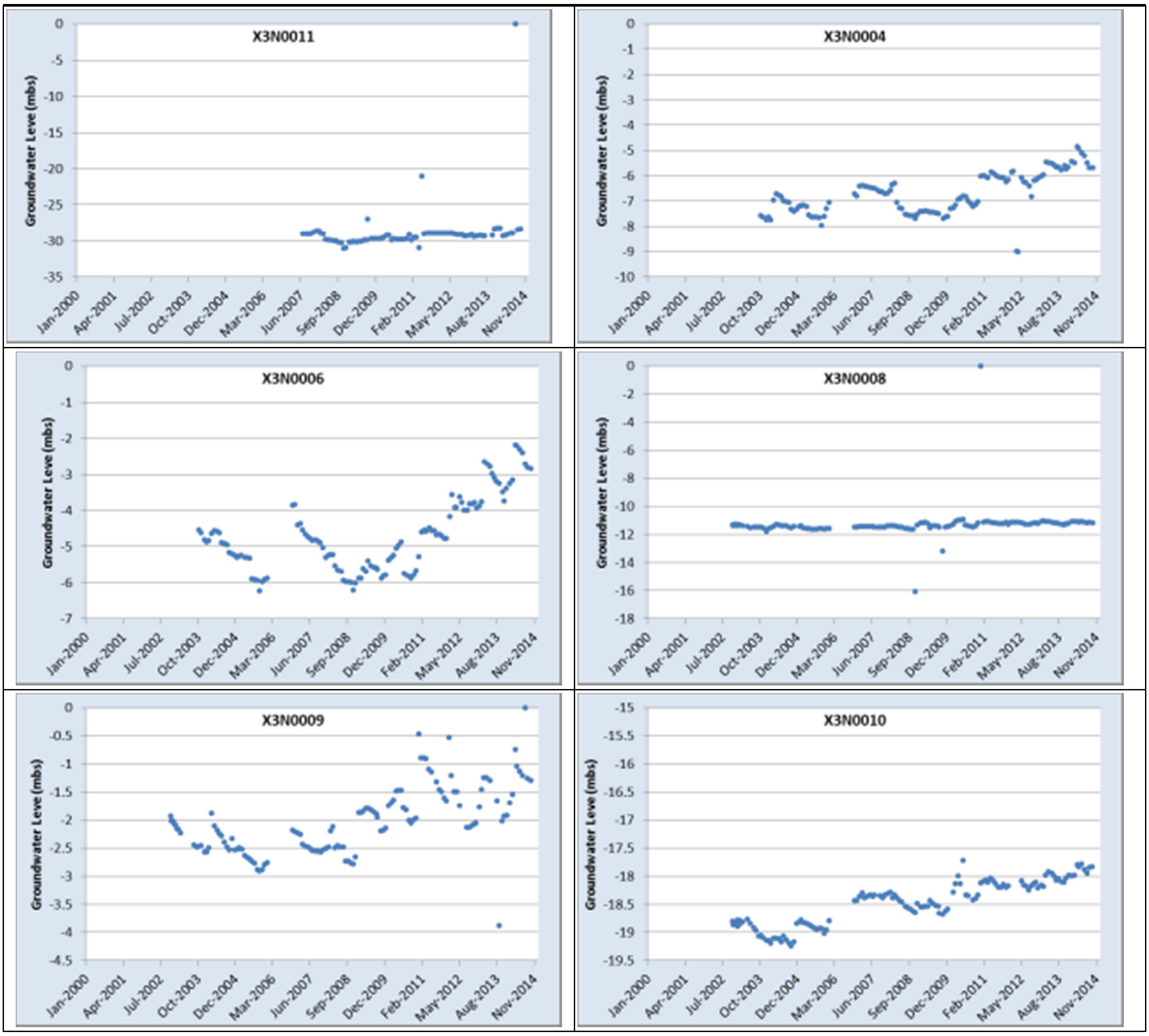


Figure 3.3 Selected water level monitoring trends for the Sabie-Sand sub-catchment

3.5 X4 SUB-CATCHMENT

3.5.1 Groundwater SI

The X4 (Northern Lebombo) sub-catchment comprises of a single GU, mainly due to the fact that the sub-catchment falls almost entirely within the Kruger National Park. Groundwater use is limited to supply to rest camps within the park and to selected watering holes (Table 3.10). However, groundwater abstraction for watering holes has been almost nullified due their negative influence on animal migration.

Table 3.10 Groundwater availability and stress index for the X4 sub-catchment

Description	GUs	Quat	Area (Km^2)	MAP WR90 (mm/a)	HP	Recharge Mm^3/a	GW use Mm^3/a	GW use as % of HP	SI (GW use as % of recharge)
X4 Northern Lebombo	GU4-1	X40A	924	587	8.11	9.59	0.10	1%	1%
		X40B	743	587	6.51	7.71	0.07	1%	1%
		X40C	941	587	10.26	10.89	0.15	1%	1%
		X40D	589	587	5.10	4.89	0.06	1%	1%

3.5.2 Groundwater Quality

A slightly poorer water quality is observed in this sub-catchment mainly due to elevated Electrical Conductivity (EC), TDS, Sodium, Chloride and Fluoride concentrations (Table 3.11). As before, this is attributed to evaporative concentration, low recharge values or the occurrence of Fluoride bearing minerals.

Table 3.11 Groundwater quality classification for the X4 sub-catchment

GU	EC (Ms/m)	TDS	Ca	Mg	Na	Cl	SO_4	NO_3 as N	F	No of Samples	Class 0 or 1	Class 2	Class 3 or 4
GU4-1	235.3	1743.2	65.8	84.7	341.1	450.8	30.9	6.5	1.1	70	6%	39%	56%

Class 0 or 1 Class 2 Class 3 or

3.6 SUMMARY

Groundwater use in relation to recharge and available resources (harvest potential) is minimal throughout Inkomati and is visualised in Figure 3.4. Numerous groundwater level monitoring dataset depict and increasing trend suggesting that the system is no under significant stress due to (over)abstraction. Increasing domestic and other industries water requirements could be met from groundwater.

The groundwater quality of the Inkomati is generally of potable use; however, some boreholes do show elevated nitrate concentrations. A deterioration of the groundwater quality (salinity) in the study area from west to east, following essentially the average annual rainfall, is evident which is related to evaporative concentration of elements in discharge areas or low recharge values.

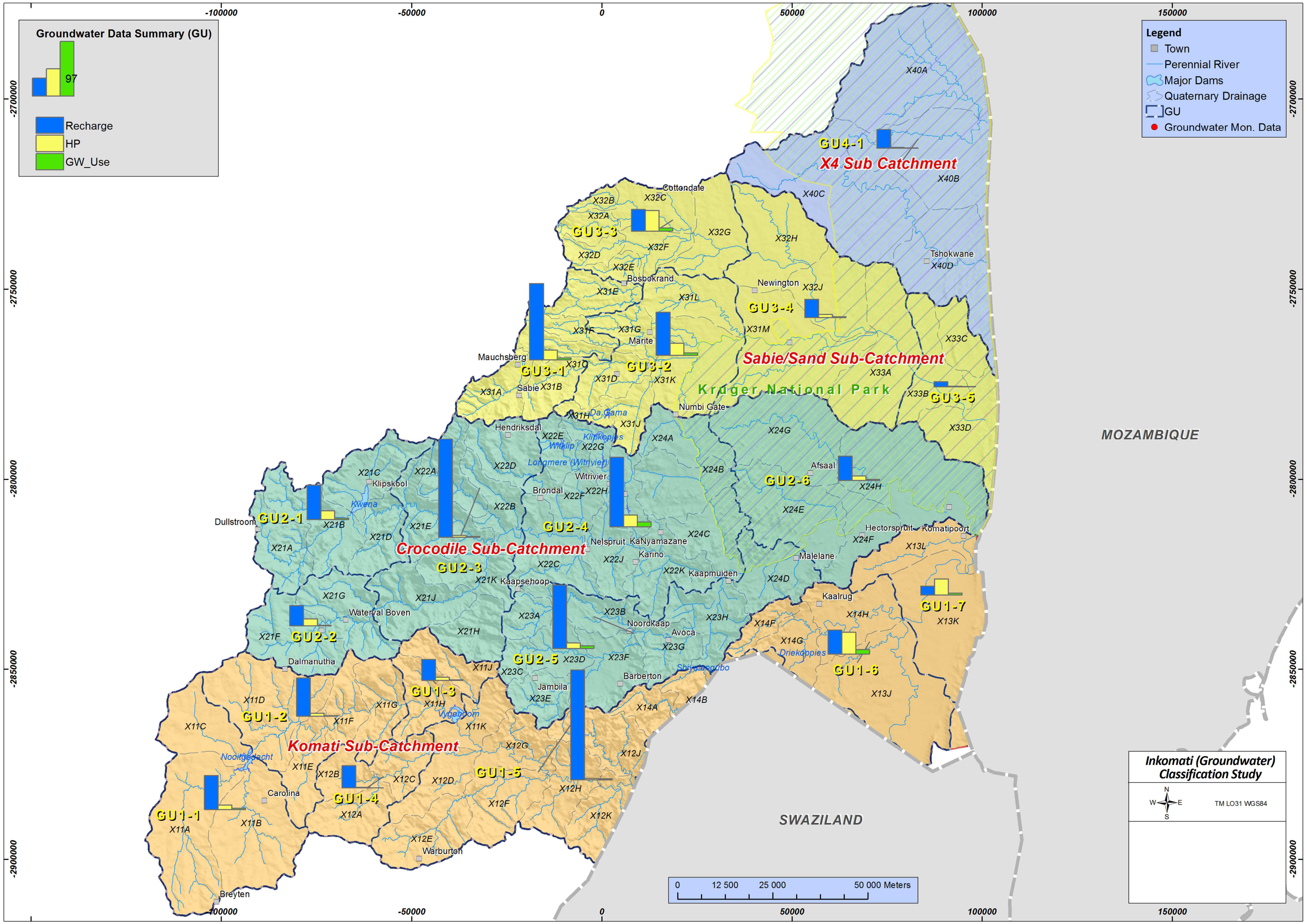


Figure 3.4 Groundwater use versus recharge and harvest potential

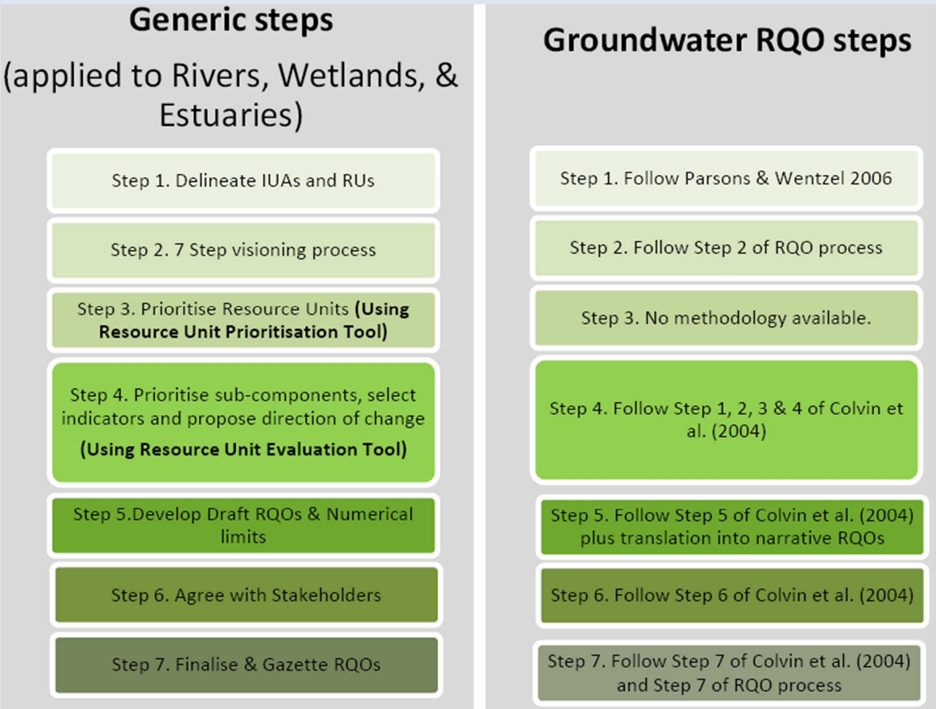
4 RESOURCE QUALITY OBJECTIVES

4.1 BACKGROUND

Resource Quality Objectives

RQOs must set objectives for the management of water resources in a catchment or other GUAs, (if applicable) and by its very nature be applicable on that scale. In general terms, RQOs establish clear goals relating to the quantity and quality of a water resource. They provide goals and objectives that frame the vision for sustainable use of a water resource, and hence form the basis for catchment decision-making and management. When setting RQOs, a balance must be found between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other.

Guidelines and methodologies are documented in Colvin *et al*. (2004) and Parsons and Wentzel (2007). A generic process to develop and implement RQOs has been developed in 2011 (DWA, 2011). In the process groundwater is dealt with separately as not only are the Resource Units completely different to the surface water systems, so are the variables of concern. These processes have been aligned with the above mentioned guidelines but the most notable difference is the description of RQOs as narrative and with attendant Numerical Limits.



Thehe National Water Resources Strategy (DWAF, 2004c) deals with RQOs for groundwater saying that "Resource Quality Objectives for groundwater resources are considered crucial for the effective protection of groundwater. Numeric or descriptive statements for a groundwater resource will be set in order to guide the use and management thereof, typically these will relate to - groundwater levels or gradients (time and locality specific); groundwater abstraction rates; groundwater quality; spring flow; and targets for the health and terrestrial ecosystems that are dependent on groundwater".

4.2 APPROACH AND PRIORITISATION

The process followed to develop groundwater RQOs can be summarised as follows:

- Collate and synthesize groundwater data (i.e. GRA II, DWS monitoring data and WARMS information) for each quaternary catchment in each groundwater unit in order to establish:
  - Borehole yields.
  - Groundwater levels.
  - Groundwater harvest and exploitation potential.
  - Existing groundwater (use) abstraction rates.
  - Groundwater quality.
  - Baseflow potential.
  - Recharge.

The groundwater RQOs and appropriate numerical limits are based on what information is available and estimations using hydrogeological reasoning. It is understood that the Inkomati is not regarded as a high groundwater priority area and the status quo was largely based on a desktop assessment. In many cases not sufficient monitoring was available or collated to derive detailed RQOs. Where possible existing monitoring networks were taken into account in setting the RQOs.

Although, the Resource Unit Prioritisation Tool can be applied for rivers, wetlands and estuaries, currently no methodology exists for prioritising groundwater Resource Units (DWA, 2011). As a result no official criteria and rating guideline was applied for the Inkomati RQO but prioritisation was based on the following main indicators.

- **Importance for users**: Some aquifers in the Inkomati provide significant services for the environment and other users. The importance for users was evaluated with respect to the current and possible future use by the different water sectors.
- **Threat posed to users/receptors**: Depending on the pattern and scale of groundwater abstraction as well as the land use within the resource units the different aquifers might be at risk of over-abstraction (indicated by aquifer stress and decline in water level) and or pollution (indicated by decline in water quality), both of were considered in the prioritisation.
- **Practical considerations**: RQOs can only be implemented and enforced if they can be measured. Hence, the focus was on identifying resource units with a sufficient groundwater monitoring network and existing baseline data to allow for comparison with data collected in the future. The spatial distribution of the DWS is shown Figure 4.1.
- **Level of surface water – groundwater interaction**: Depending on the aquifer type and its interaction with surface water bodies it has greater or lesser relevance for maintaining the hydrological integrity and water quality of the ecosystem. The aquifer types occurring in the GU and their contribution to surface water low flows were considered, as these could impact on possible management options.

A summary of the criteria's used for identifying groundwater priority areas is listed in Table 4.1 to Table 4.3. A number of water level monitoring boreholes occur throughout the Inkomati. However, the monitoring of groundwater quality (collated through the DWS WMS) is limited and should be expanded or, if possible, ceased monitoring sites should be re-instated. Figure 4.1 also shows the spatial distribution of nitrate concentrations from the collated status quo assessment indicating that numerous boreholes exceed the recommended drinking water quality limit of 11 mg/l (SANS 241: 2011).

Table 4.1 Priority groundwater units for the Komati sub-catchment

Description	GUs	Quat	Importance for users	Threat to posed users/receptors	Practical consideration	SW-GW Interaction	Over-riding indictors	Recommendation
Komati Highveld	GU1-1	X11B	Groundwater use is predominantly for mining, while some groundwater is used for forestry and domestic use.	High potential for AMD within the coal mining region.	No DWS water level monitoring. Limited quality data.	Medium baseflow probability.	Groundwater quality.	Establish appropriate monitoring protocols (water levels and quantity). Collate mine monitoring data. Increase groundwater allocation.
Escarpment Komati	GU1-3	X11H X11J	Groundwater use is predominantly for mining and forestry.	Groundwater abstraction within close proximity to major rivers is likely to impact on baseflow in the region.	No DWS water level monitoring. Limited quality data.	Significant source of baseflow.	Baseflow.	Establish appropriate monitoring protocols (water levels). Increase groundwater allocation. Potential large scale abstraction within the proximity of a river should be assessed based on the local aquifer characteristics.
Middle Komati	GU1-5	X12F X12H	Domestic groundwater use/rural water supply.	Risk of over-abstraction and or pollution.	Available DWS water level monitoring (X12H. Limited quality data.	High baseflow probability.	Groundwater use. Quality	Verify groundwater use volume. Expand monitoring programme. Collate mine monitoring data. Increase groundwater allocation.
		X12K	Groundwater use is predominantly for mining domestic use.	Potential for AMD within the gold mining region.	No DWS water level monitoring. Limited quality data.			
Lower Komati	GU1-6	X13J X14G X14H	Domestic groundwater use/rural water supply.	Risk of over-abstraction and or pollution.	Available DWS water level monitoring (X13J). Limited quality data.	High baseflow probability.	Groundwater use. Quality	Verify groundwater use volume. Expand monitoring programme. Increase groundwater allocation.

Table 4.2 Priority groundwater units for the Crocodile sub-catchment

Description	GUs	Quat.	Importance for users	Threat to posed users/receptors	Practical consideration	SW-GW Interaction	Over-riding indictors	Recommendation
Escarpment Dolomites	GU2-3	X21H X21J X21K	Groundwater use is predominantly for mining and forestry.	Groundwater abstraction within close proximity to major rivers is likely to impact on baseflow in the region/potential for AMD within the gold mining.	Available DWS water level monitoring (X21J). Limited quality data.	Significant source of baseflow.	Baseflow. Quality	Establish appropriate monitoring protocols (water levels). Set groundwater baseflow contribution protection zones. Increase groundwater allocation. Potential large scale abstraction within the proximity of a river should be assessed based on the local aquifer characteristics.
Middle Crocodile	GU2-4	X22H X22J X22K	Domestic groundwater use.	Risk of over-abstraction and or pollution.	Available DWS water level monitoring (X22J). Limited quality data.	Significant baseflow probability.	Groundwater use. Quality	Verify groundwater use volume/ Expand monitoring programme/ Increase groundwater allocation. Potential large scale abstraction within the proximity of a river should be assessed based on the local aquifer characteristics.
		X24A X24B X24C	Domestic groundwater use. Rural water supply.	Risk of over-abstraction and or pollution.	Available DWS water level monitoring. Limited quality data.	Medium baseflow probability.	Groundwater use. Quality	Verify groundwater use volume. Expand monitoring programme. Increase groundwater allocation.
Barberton Region	GU2-5	X23B X23F X23G	Groundwater use is predominantly for mining and rural water supply	High potential for AMD within the gold mining region.	No DWS water level monitoring.	Significant baseflow probability.	Quality	Establish appropriate monitoring protocols (water levels and quantity). Increase groundwater allocation. Potential large scale abstraction within the proximity of a river should be assessed based on the local aquifer characteristics.

Table 4.3 Priority groundwater units for the Sabie-Sand sub-catchment

Description	GUs	Quat.	Importance for users	Threat to posed users/receptors	Practical consideration	SW-GW Interaction	Over-riding indictors	Recommendation
Upper Sabie	GU3-1	X31A	Domestic groundwater use. Rural water supply.	Groundwater abstraction within close proximity to major rivers is likely to impact on baseflow in the region. Risk of over-abstraction and or pollution.	No DWS water level monitoring. Quality data.	Significant baseflow probability.	Baseflow. Quality	Establish appropriate monitoring protocols (water levels). Set groundwater baseflow contribution protection zones. Potential large scale abstraction within the proximity of a river should be assessed based on the local aquifer characteristics.
Middle Sabie	GU3-2	X31G X31K X31L	Domestic groundwater use. Rural water supply.	Risk of over-abstraction and or pollution.	No DWS water level monitoring. Quality data.	Low to medium baseflow probability.	Groundwater use. Quality (some poor quality boreholes with elevated nitrates exist).	Verify groundwater use volume. Expand DWS water level monitoring.
Upper Sand	GU3-3	X32A X32B X32C X32D X32E X32F X32G	Domestic groundwater use. Rural water supply.	Risk of over-abstraction and or pollution.	Available DWS water level monitoring. Quality data.	Low to medium baseflow probability.	Groundwater use. Quality (some poor quality boreholes with elevated nitrates exist).	Verify groundwater use volume. Expand DWS water level monitoring.
Middle Sand	GU3-4	X31M X32H	Domestic groundwater use. Rural water supply.	Risk of over-abstraction and or pollution.	No DWS water level monitoring. Quality data.	Low baseflow probability.	Groundwater use. Quality (some poor quality boreholes with elevated nitrates exist).	Verify groundwater use volume. Expand DWS water level monitoring.

Figure 4.1 DWS Inkomati groundwater monitoring network

4.3 GROUNDWATER RQOs

Based on the prioritisation, an assessment of the 11 GUs resulted in the groundwater RQOs shown in Table 4.4 to Table 4.6. The relevant RQO parameters used included water level, baseflow and water quality. The setting of water quantity related RQOs (i.e. water level and baseflow) is aimed at maintaining water levels within natural seasonal fluctuations ensuring sufficient yield for all users and to improve or maintain groundwater discharge to support low flow river requirements. The setting of water quality related RQOs is aimed at maintaining the groundwater quality in relation to its background/present level, or ensuring compliance with water quality standards for domestic use, as this is the more stringent requirement for the variety of users in the GU.

Table 4.4 Summary of RQOs for Groundwater in the Komati River System

IUA	GUs	Component	Narrative RQO	Indicator/Measure	Numerical Criteria
X1-2 and X1-3	GU1-3	Quantity	Groundwater flow directions in the resource unit should not be reversed from it natural flow directions towards the drainage systems.	Continuous flow measurement at EWR G1.	19.9 % nMAR[1]
X1-6 and X1-5	GU1-5			Continuous flow measurement at EWR T1.	22.6 % nMAR[1]
X1-8 and X1-9	GU1-6			Continuous flow measurement at EWR K3 and EWR L1.	9.9 and 11.7 % nMAR[1]
X1-6 and X1-5	GU1-5	Aquifer	No negative trend between peak drawdowns during dry seasons.	Water level - Depth to Groundwater Level at active monitoring boreholes using Groundwater Monitoring Guidelines*.	Seasonal fluctuation to stay within natural range of 1 to 3 m^2.
X1-8 and X1-9	GU1-6				Seasonal fluctuation to stay within natural range of 2 to 3 m^2.
All	All prioritised GUs	Quality	Groundwater quality should be based on background groundwater quality. Sites that exceed the water use requirement# should not be allowed to deteriorate in water quality.	Background water quality per borehole/spring using Groundwater Monitoring Guidelines*. Bi-annual monitoring.	Water quality should not be allowed to deteriorate significantly form background water quality[3] (Refer to Table 2.9).
X1-1	GU1-1		Salinity levels should not increase. Concentrations must be maintained at levels to support domestic and ecological water users.	Salts - Electrical Conductivity. Bi-annual monitoring.	Electrical Conductivity ≤ 40 mS/m (based on quality dataset).
X1-6 and X1-5	GU1-5		Nitrate values in the GU must be maintained to support domestic water users.	Nutrients – Nitrate (as Nitrogen). Bi-annual monitoring.	Nitrate (as N)< 4 mg/l in recharge area (based on quality dataset).
X1-8 and X1-9	GU1-6		Nitrate values in the GU must be maintained to support domestic water users.	Nutrients – Nitrate (as Nitrogen). Bi-annual monitoring.	Nitrate (as N)< 5 mg/l in recharge area (based on quality dataset).

Table 4.5 Summary of RQOs for Groundwater in the Crocodile River System

IUA	GUs	Component	Narrative RQO	Indicator/Measure	Numerical Criteria
X2-2 and X2-4	GU2-3	Quantity	Groundwater flow directions in the resource unit should not be reversed from it natural flow directions towards the drainage systems.	Continuous flow measurement at EWR C3 and ER1.	30.1 and 4.97 % nMAR[1]
X2-7, X2-5, X2-6, X2-8 and X2-9	GU2-4			Continuous flow measurement at EWR C4.	9.07 % nMAR[1]
X2-10	GUA2-5			Continuous flow measurement at EWR C7.	6.18 % nMAR[1]
X2-2 and X2-4	GU2-3	Aquifer	No negative trend between peak drawdowns during dry seasons.	Water level - Depth to Groundwater Level at active monitoring boreholes using Groundwater Monitoring Guidelines*.	Seasonal fluctuation to stay within natural range of 1 to 2 m^2.
X2-7, X2-5, X2-6, X2-8 and X2-9	GU2-4				Seasonal fluctuation to stay within natural range of 1 to 4 m^2.
X2-10	GU2-5				Seasonal fluctuation to stay within natural range of 1 to 2 m^2.

All	All prioritised GUs	Quality	Groundwater quality should be based on background groundwater quality. Sites that exceed the water use requirement# should not be allowed to deteriorate in water quality.	Background water quality per borehole/spring using Groundwater Monitoring Guidelines*.	Water quality should not be allowed to deteriorate significantly form background water quality[3] (Refer to Table 2.9).
X2-2 and X2-4	GU2-3		Salinity levels should not increase.	Salts - Electrical Conductivity. Bi-annual monitoring.	Electrical Conductivity ≤ 55 mS/m (based on quality dataset).
X2-7, X2-5, X2-6, X2-8 and X2-9	GU2-4		Nitrate values must be maintained to support domestic water users.	Nutrients – Nitrate (as Nitrogen). Bi-annual monitoring.	Nitrate values in the recharge area should not increase to >3mg/l.
X2-10	GUA2-5				
X2-10	GUA2-5		Salinity levels should not increase. Concentrations must be maintained at levels to support domestic and ecological water users.	Salts - Electrical Conductivity. Bi-annual monitoring.	Electrical Conductivity ≤ 60 mS/m (based on quality dataset).

Table 4.6 Summary of RQOs for Groundwater in the Sabie-Sand River System

IUA	GUs	Component	NarrativeRQO	Indicator/Measure	Numerical Criteria
X3-1 and X3-2	GU3-1	Quantity	Groundwater flow directions in the resource unit should not be reversed from it natural flow directions towards the drainage systems.	Continuous flow measurement at EWR S1 and EWR S4.	12.88 and 14.35 % nMAR[1].
X3-2, X3-4, X3-3 and X3-6	GU3-2			Continuous flow measurement at EWR S5 and EWR S3.	28.32 and 9.71 % nMAR[1].
X3-7 and X3-8	GU3-3			Continuous flow measurement at EWR S7 and EWR S6.	11.14 and 13.38 % nMAR[1].
X3-1 and X3-2	GU3-1	Aquifer	No negative trend between peak drawdowns during dry seasons.	Water level - Depth to Groundwater Level at active monitoring boreholes using Groundwater Monitoring Guidelines*.	Seasonal fluctuation to stay within natural range of 1 m[2].
X3-7 and X3-8	GU3-3				Seasonal fluctuation to stay within natural range of 0.5 to 2 m[2].
All	All prioritised GUs	Quality	Groundwater quality should be based on background groundwater quality. Sites that exceed the water use requirement# should not be allowed to deteriorate in water quality.	Background water quality per borehole/spring using Groundwater Monitoring Guidelines*.	Water quality should not be allowed to deteriorate significantly form background water quality[3] (Refer to Table 2.9).
X3-1 and X3-2	GU3-1		Nitrate values must be maintained to support domestic water users.	Nutrients – Nitrate (as Nitrogen). Bi-annual monitoring.	Nitrate values in the recharge area should not increase to >2mg/l.
X3-2, X3-4, X3-3 and X3-6	GU3-2				Nitrate (as N) <8 mg/l in recharge area (based on quality dataset).
X3-7 and X3-8	GU3-3				
X3-4	GU3-4				Nitrate (as N) <6 mg/l in recharge area (based on quality dataset).

* - A Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa, DWAF (2008).
# - South African Water Quality Guidelines, DWAF (1996).
1 - %nMAR is flow required at the nodes expressed as a percentage of the natural Mean Annual Runoff, Low flows.
2 - Unlike in a dam, seasonal fluctuations of groundwater levels in an aquifer are dependent on the location of measurement (e.g. recharge versus discharge areas, with lower variations expected in the proximity of a discharge area like a river), the recharge rate (dependent amongst others on the properties of overlying soils at this point) as well as the

porosity of the aquifer as this point (with higher porosity aquifers showing lower variations). Delta H does therefore not support from a scientific point of view the concept of a single numerical fluctuation limits for GU, but included these figures on request of the client.

[3] - It is generally recognised that the groundwater chemistry evolves along a flow path, e.g. from a fresh low mineralised bicarbonate water in recharge areas to an older, higher mineralised water (water type dependent on amongst other factors the underlying geology) in discharge areas, where it is often undergoes additional concentration increases due to evapotranspiration. Additional factors influencing the groundwater quality over relatively short distances include the occurrence of preferential flow paths (along fractures) or the proximity to pollution sources. The background quality observed at one monitoring site is therefore not necessarily applicable as a background value for another monitoring location.)

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6 APPENDIX A: REPORT COMMENTS

Page &/ or section	Report statement	Comments	Changes made?	Author comment
Inkomati Infopack_NovSKDL_MH Date: 2014-11-14	Groundwater RQO A summary table of the proposed Inkomati RQO was presented for each GUA	Comments by Shane Naidoo RQOs for Baseflow, water quality and water quality was regarded as not being an RQO GUA was changed to GU	Minor changes was made to the narrative statement of the RQO	According to the understanding of what was required (based on previous gazetted templates i.e. Letaba) Delta-H revised the narrative groundwater RQOs for the Inkomati.
Inkomati_Infopack_Nov2014 Date: 2014-11-17	Groundwater RQO A updated summary table of the proposed Inkomati RQO was presented for each GUA	The updated groundwater RQO was still regarded as incorrect and was excluded from the submitted Inkomati_Draft RQOs report to stakeholders	During the stakeholder engagement meeting on the 24th November 2014 informal discussions with Adaroa Okonko, Nancy Motebe (NM) and Mohlapa Sekoele (MS) how to set the RQO was held.	Adaora Okonko (AO) sent through some example RQO tables that Delta-H should use. Delta-H revised the groundwater RQO and used a prioritisation approach to come up with RQO for identified GU
GroundwaterRQO_Inkomati_v01_Final_Draft Date: 2014-12-02	Groundwater report with updated RQO tables (based on Letaba templates and examples sent by AO)	E-mail comments from MS (2014-12-12) The deliverable is of an acceptable standard given the concerns raised on this component and the subsequent decision to remove the groundwater RQO's from the "stakeholder information pack" due to the RQOs for groundwater not meeting the department's requirements. 2. The water level data, where available, the fluctuations should be used for the numerical RQOs. 3. The water quality data can also be used where available from the WMS. 4. Abstraction needs to be removed because it cannot be measured. 5. The groundwater quality should be linked to the background quality and not drinking water quality. With reference to SANS 241- The DWS does not need to management GW in terms of drinking water quality standards – This was never accepted in other study areas, Unless the present condition is meeting SANS 241 6. The GUA not acceptable in terms of classification and RQOs procedures, indicate which IUA does each GUA correspond to 7. Please see the example on the attached template, if unclear please discuss with AO.	A meeting was arranged on the 13th of January 2015 to discuss comments	Delta-H revised the report based on examples (Table 16 and 15) sent by Adaroa Okonko

Page &/ or section	Report statement	Comments	Changes made?	Author comment
GroundwaterReportVer2 Date: 2015-01-15	Groundwater report with updated RQO tables (based on examples sent by AO)	E-mail comments from MS (2014-12-12) Where groundwater quality data is available for a groundwater resource unit, it should be added to protect the resource unit. The information on groundwater quality in the report should be on the template with the specific mentioned e.g. TDS, Sodium, Sulphate, Fluoride and Chloride for each GU. We want to see the numerical limits in the template as stated in the report. ▪ Link the groundwater unit to IUA . ▪ The foot notes can be in your technical document but will not be in the legal template. ▪ Have a look at the last template I sent to you. Thank you.		At this stage we refer to a table in the report (Table 2.9) which shows the average groundwater quality within each GU. It also shows the number samples taken. My question to AO is: ▪ how are we going to decide how many samples are representative of the background quality (some of the priority GUs have only 6 samples) ▪ which elements of concern without repeating the whole table will be prioritised. ▪ If an element of concern is highly elevated (i.e. Nitrate concentration in table below) it is not background value and should therefore not be included as its already anthropogenic influenced. ▪ Similar to the evaporative signature we see in the lower Sabie-Sand where average TDS values of over a 1000 mg/l is observed. Not so sure if you want to put this into an RQO as these exceed SANS:2011 and falls within Class 2 (DWAF, 1996) water quality guidelines. ▪ Further the samples stretch over a considerable time period with often ad-hoc sampling (I also show on a map (Figure 4.1) that there are only a couple of active WMS stations (hardly per GU). ▪ I believe the numerical limits should be determined for each groundwater application (or WUL).
GroundwaterReportVer4 Date: 2015-01-21	Groundwater report with updated RQO tables (based on Letaba templates and examples sent by AO)	Telephone discussion with AO (2014-01-23)	I added the numerical limits for the low flow requirements and added limits for nitrate and EC (for selected GUs).	
GroundwaterReportVer5 Date: 2015-01-26	Groundwater report with finalised RQO tables	Minor editorial comments		
Comments received from: Silo Kheva (NSP) – 5 May 2015				
		As I indicated in our last discussion, I have reservations about setting a numerical value of 1-3 m for groundwater level fluctuations within the Inkomati System. It appears to be two conservative for comfort. My reservation is based		We fully agree with this statement from Silo as explained in our Footnotes to the Groundwater RQO table. It reads: 2 - Unlike in a dam, seasonal fluctuations of groundwater levels in an aquifer are

Page &/ or section	Report statement	Comments	Changes made?	Author comment
		on the following:		dependent on the location of measurement (e.g. recharge versus discharge areas, with lower variations expected in the proximity of a discharge area like a river), the recharge rate (dependent amongst others on the properties of overlying soils at this point) as well as the porosity of the aquifer as this point (with higher porosity aquifers showing lower variations). **Delta H does therefore not support from a scientific point of view the concept of a single numerical fluctuation limits for GU, but included these figures on request of the client.**
		1. The monitoring data used (partly with other sources) only caters for the period between the year 2000 and now. This stems from the late development of the monitoring system in Mpumalanga. The PSP appears to have use what is available, and that is understandable. We have not gone through severe drought stresses during this period and to me this data mostly represents a 'wet' hydrological period. Though I do not have tangible proof it is my assertion that these water levels could reach below 3 m if the aquifers were to be subjected to a prolonged stresses.		The RQO state "Seasonal fluctuation to stay within natural range (i.e. 1 to 3 m). It should be made clear it only relates to the available water level monitoring points (because that is measured). Delta-H tried to avoid putting a numerical limit for groundwater level fluctuations. But rather referred to the seasonal fluctuation (i.e. natural change of water levels between rainfall- and dry periods) and not to an overall decline in water levels. Even if you have abstraction and an expected water level decline it should not impact on the natural (or seasonal) fluctuations (at the monitoring position and not the abstraction borehole). Groundwater is underutilised for large parts of the Inkomati WMA and should be promoted and developed. As a result there will be some drawdown but with monitoring (of both abstraction rates and water levels) it can be managed.
		2. Having drilled and pumped a few boreholes in the area north of Nelspruit (Nelspruit Granite Suite), I have observed slow aquifer responses typical of low transmissivity a feature that shows with a rapid decline in wellbore storage. One may argue that this good enough to set conservative RQOs. Yes but I would counter this by adding that the static water levels (swl) sit above the water strike positions in this area. In this case your initial drawdowns are merely a representation of your SWL and the pump intake level and this may not be fully representative of the stress on the		Agree with the last statement. Ideally the monitoring points (in relation to the position of the abstraction borehole) can be used to set a specific water level (critical) drawdown i.e. an early warning to reduce abstraction once the critical (management) water level is reached (at the designated monitoring position). Please note: these are ideal management initiative which must be set at local scale and not at WMA or even GU scale, and by acquiring much more data (if at all available).

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		aquifer. Depending on the elevation difference between the two positions (swl and pump intake) the water level could reach below 3 metres without negatively affecting the aquifer.		
		3. Thought characterised by low yield some aquifers have more than one water strike position occurring within a weathered zone of between 18 and 50 metres below ground level. Due to the secondary nature of the aquifer it is difficult to estimate the exact thickness of the saturated one. It depends of the terrain.		Agree.
		I am reasonably comfortable with numerical values on water quality. I suggest we consider adding Fe, Mn, Al values of Table 2.9 for the unit GU 1-2 to keep existing and potential mining operations on guard.		There was no analysis readily available for these parameters.
		Proposal: a. Run a geohydrological model (even at low confidence) and simulate water level drawdowns over a prolonged drought period while applying maximum abstraction. This should give an indicative idea of how much fluctuations could be tolerated. It will provide crucial scientific facts that could defend our position.		Not sure to what geohydrological model Silo refers to. We are aware of water balance models done by some consultants on WMA scale but we generally don't support this approach. Any form of modelling was never part of our scope.
		Based on the comments above received from the Regional Office, the DWS therefore requests you to: ▪ Run the geohydrological model to confirm whether the 1-3 m drawdown as indicated in the Template is reasonable or not. ▪ Consider adding Fe, Mn, Al values of Table 2.9 for the unit GU 1-2 to keep existing and potential mining operations on guard		No modelling was done (see also comments below). No data readily available for these parameters for GU 1-2. As with surface water quality, recommendations are made that if required, available information could be sourced from mining houses/consultants who worked in the area. This is beyond our scope (especially considering the stage of this project). We can however make sure this is in the implementation plan.
16 January 2015: Comments from Ms Adaora Okonkwo				
Section 4.3		Where groundwater quality data is available for a groundwater resource unit, it should be added to protect the resource unit. The information on groundwater quality in the report should be on the template with the specific mentioned e.g. TDS, Sodium, Sulphate, Fluoride and Chloride for each GU. We want to see the numerical limits in the template as stated in the report.	Yes	

Page &/ or section	Report statement	Comments	Changes made?	Author comment
Section 4.3, Tables 4.4 – 4.6		Link the groundwater unit to IUA.	Yes	
Section 4.3		The foot notes can be in your technical document but will not be in the legal template.	No	No change required in this document.