Determination of Water Resources Class, Reserve and Resource Quality Objectives for Secondary Catchments A5 – A9 and Secondary Catchment B9

Internal Draft Report submitted to Myra Consulting

Contents

1. GROUNDWATER STATUS QUO

1.1. APPROACH TO STATUS QUO ASSESSMENT

1.1.1. Overview and Data Sources

The delineation of groundwater resource units depends on the hydrogeological characteristics of the area (amongst other factors), and it is practical to consider the status quo for groundwater resources in respect of groundwater resource units. As such, the hydrogeological characteristics of the area, the delineation of resource units (or rather groundwater units of analysis) and status quo of groundwater units (of analysis) are presented together in this report. Section 1.2 includes an overview of the geology and hydrostratigraphy of the study area, followed by the delineation of groundwater resource units (GRUs) (1.3). The groundwater status quo assessment (section 1.4) includes a description of key groundwater characteristics (recharge, discharge, groundwater use and groundwater quality) across the groundwater resources units, followed by a detailed status quo and trend analysis of groundwater level and groundwater quality per groundwater resource unit (section 0 onwards).

All available point data (borehole geology, abstraction, groundwater level, groundwater quality) was collated (Refer to Information & Gap Analysis Report), and interrogated for the trend analysis, and points with sufficient time-series including recent data are analysed to provide a current status quo. Sources of data used to populate the tables included in the trend analysis per GRU include:

- National Groundwater Archive
- GRIP data (2011)
- HYDSTRA database
- WMS datasets
- WARMS data
- Point data extracted from various reports assessing the response to bulk abstraction (i.e. municipal monitoring reports)
- Data from DWS project All Towns Reconciliation project
- Various reports

The trend analysis (section 0 onwards) is presented in a standard table format per groundwater resources unit (GRU). The datasets collated contain long term DWS-owned monitoring boreholes. These boreholes are dispersed, and are capable of illustrating the background trends in particular locations or aquifers. Given the predominance of disperse abstraction, this data is likely to be sufficient for an indication of regional trends and typical water levels and water qualities in particular aquifers and locations. This will form a valuable basis for future phases of the project. The existence of additional data not yet incorporated in the trend analysis is mentioned in the status quo assessment where this is known. Additional monitoring data (i.e. illustrating the response to bulk point abstraction at municipal wellfields) will be sought where necessary for prioritised GRUs.

1.1.2. Theoretical background for groundwater level trend analysis

Under natural conditions an aquifer is in a state of dynamic equilibrium: wet and dry years balance out, aquifer discharge equals the recharge, and the groundwater levels (equivalent to the stored volume) are constant over the long-term. When an aquifer is pumped this equilibrium is disturbed, and "water withdrawn artificially from an aquifer is derived from a decrease in storage in the aquifer, a reduction in the previous discharge from the aquifer, an increase in the recharge, or a combination of these changes" (Theis, 1940). On pumping, water levels will therefore decline, natural discharge may decline, and recharge may increase. Over time (and with the same rate of pumping), a new dynamic equilibrium will form in response to the changes fluxes (i.e. new discharge mechanisms to abstraction, reduced discharge and or enhanced recharge). Once the new dynamic equilibrium is formed, there is no further loss from storage i.e. groundwater levels no longer decline in response to abstraction.

The time taken to reach this new dynamic equilibrium (the "response time") can vary from relatively short to hundreds of years, depending on the aquifer parameters and location of abstraction compared to aquifer boundaries (Sophocleous 2000; Bredehoeft and Durbin, 2009). The magnitude of storage depletion (water level change before new equilibrium is met), is also dependent on the aquifer parameters and location of abstraction.

If the abstraction can be met by changes in the aquifer fluxes (reduced discharge, enhanced recharge) and a new equilibrium can be established (halting water level decline), then the abstraction can be considered maintainable (note, not sustainable) (Delvin and Sophocleous, 2005; WRC, 2016). If "sustainable groundwater use" is defined as groundwater use that is socially, environmentally (ecologically), and economically acceptable, then abstraction of a maintainable yield is not necessarily sustainable. A critical step from quantification of a maintainable aquifer yield to quantification of sustainable groundwater use, is to determine the volume contribution from each source under the new dynamic equilibrium (projected reduced discharge, enhanced recharge, impact on storage / groundwater levels), and then take a socio-economic-environmental decision as to whether this is acceptable (Sophocleous, 2000, Alley and Leake, 2004, WRC, 2016). Projection of the impact of pumping on storage / water levels can be completed (for simple situations) with analytical models that derive a characteristic water level decline over time when pumped ("pump curves", Kruseman and de Ridder, 1991). Determination of the impact on natural discharge or enhanced recharge generally requires a numerical model to be setup for the aquifer in question to simulate the abstraction and impacts on flow regime.

Not all abstraction can be maintained. Abstraction from groundwater without an active flow regime (fossil groundwater) simply harvests stored groundwater and groundwater levels continue to fall. "Runaway" drawdown, in which the rate of decline of groundwater level increases over time, is an indication that the abstraction rate cannot be met by changes in the aquifer fluxes (it is not maintainable).

The above-mentioned theory is relevant to the status quo trend analysis. Water level decline is to be expected in response to pumping. Groundwater level decline (alone) is not an indication of abstraction rates being too high or not maintainable, and certainly not an indication of un-sustainability (using the definition of sustainable groundwater use mentioned above). Water level decline is simply a reflection of the aquifer transitioning to a new dynamic equilibrium after commencement of pumping. Water level analysis using numerical / analytical equations to determine whether abstraction yields are maintainable, and to determine the maximum drawdown that is to be expected under the abstraction conditions, is not possible within this regional study. Barring this level of detail, some comments on monitored water level decline and what it might represent are nevertheless possible through comparing the shape of the water level decline by eye to characteristic pump curves, and through consideration of rainfall changes.

1.2. DESCRIPTION OF STUDY AREA

1.2.1. Location and Drainage Regions

The Limpopo and the small northern section of the Olifants WMAs, catchments A5-9 and B9, occupies the north-western part of the Limpopo Province, forming the project area. The Limpopo River watercourse forms the northern boundary of the WMA, and indeed of the country (DWAF, 2003a). The major tributaries, from the upstream end, are the Matlabas River, Mokolo River, Lephalala River, Mogolakwena River, Sand River and the Nzhelele, Nwanedi, Mutale, Levuvhu and Shinhwedzi Rivers (Figure 1). All of these rivers flow towards the Limpopo River in the north. The Limpopo River flows eastwards and eventually mouths in the Indian Ocean in Mozambique.

The WMA's do not include the total catchment area of the Limpopo River, since the upper tributaries (the Marico and Crocodile Rivers) are included in the Crocodile West and Marico WMA. The study area includes a total of 76 quaternary catchments.

Table 1 lists the sub-areas (secondary drainage area) tertiary drainages, quaternary catchments together with the main tributaries for the Limpopo WMA.

Table 1. Drainage description of the project area.

WMA	Sub-Area	Tertiary Drainage	Quaternary Catchments	Description
Limpopo	***Lephalala (A5)***	**A50**	A50A,B,C,D,E,F	Lephalala (Upper)
			A50G,H	Lephalala (Lower)
			A50J	Soutkloof
	Mogalakwena (A6)	**A61**	A61A,B,C	Nyl (Upper)
			A61D,E	Nyl (Middle)
			A61F,G	Mogalakwena (Upper)
			A61H,J	Sterk
		A62	A62A,B,C,D,E,F,G,H,J	Mogalakwena (Middle)
		A63	A63C	Doringfonteintjiespruit
			A63A,B,D	Mogalakwena (Lower)
			A63E	Kolope
	Sand (A7)	**A71**	A71A,B,C,D	Sand (Upper)
			A71E,F,G	Hout
			A71H,J,K	Sand (Lower)
			A71L	Kongoloops/Soutsloot
		A72	A72A,B	Brak
	Nzhelele (A8)	**A80**	A80A,B,C	Nzhelele (Upper)
			A80D,E,F,G	Nzhelele (Lower)
Olifants	***Nwanedi (A8)***	**A80**	A80H,J	*Nwanedi*
	Mutale (A9)	**A92**	A92A,B,C,D	Mutale
	Levuvhu (A92)	**A92**	A92A,B, C,D	Upper Levuvhu
			A92E,F,G	Middle Levuvhu
			A92H,J,K	Lower Levuvhu
	Shingwidzi (B9)	**B90**	B90A,B,C,D	Upper Shingwedzi
			B90E,F,G	Middle Shingwedzi
			B90H,J,K	Lower Shingwedzi

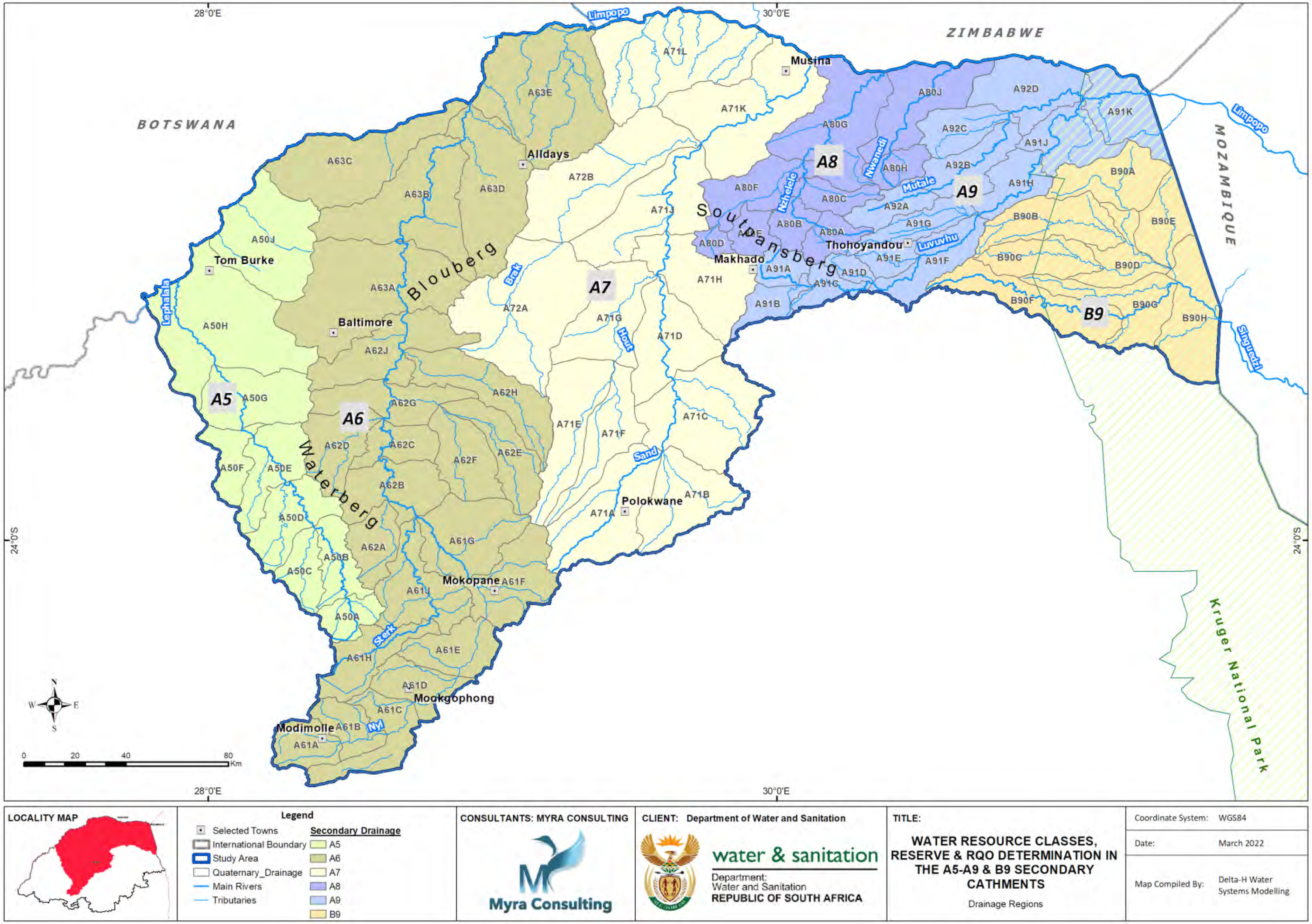


Figure 1. Regional secondary drainage region of the study area.

1.2.2. Topography

The study area is characterised by mostly flat laying terrain with elevations of approximately 800 mamsl. Local granitic inselburgs occur due to the more resistant Matlala, Mashashane and Moletsi granite intrusions with elevation ups to 1300mamsl. The Waterberg in the south and Soutpansberg in the north-east form topographical elevated mountainous areas with elevation up to 1700mamsl. The average altitude in the central part of the study area is between 400 and 800 m and between 1 200 and 2 000 m along the Soutpansberg, Blouberg and Waterberg mountain ranges(refer to Figure 1).

1.2.3. Climate

The climate is typically of South African Bushveld and Highveld, characterised by warm wet summers month between October and march with most rainfall occurring as thundershowers, and cool dry winters with cold nights and mist occurring at the mountainous areas. Some orogenic rainfall does occur as cloud area accreted onto the Soutpansberg and Tzaneen mountain range. In terms of climate, the study area is characterised by semi-arid temperatures in the south becoming arid in the northern portions. The mean annual temperature ranges between 16°C in the south to more than 22°C in the north with an average of 20°C for the catchment as a whole. Seasonal rainfall is characteristic of the area with mean annual rainfall of 300 mm to 700 mm per annum (mm/a) (DWAF, 2003b) with the greatest part of the study area receiving only 300mm/a. . The Soutpansberg and Blouberg mountains experience precipitation of between 500 and 600mm/a with the escarpment up to 1000mm/a. In general, the rainfall decreases from the southern part of the study area to the drier northern parts, where the lowest MAP of about 350 mm occurs along the lower part of the Limpopo River valley (Figure 2). The mean annual evaporation varies from 1400 to 1700 mm/a, exceeding more than half of the amount of precipitation.

1.2.4. Geology

The geomorphology features found in the study area are the results of geological evolution of the Swazian aged Greenstone belts and granites forming the Kaapvaal Craton, collision between the Kaapvaal and Zimbabwean cratons forming the Limpopo Mobile Belt, granite and basaltic intrusions, sedimentary deposition forming the Blouberg, Waterberg, Soutpansberg and Karoo groups. The study area is delineated by the Archaean Basement rocks, Bushveld Complex, Karoo Supergroup, and the Waterberg, Blouberg and Soutpansberg groups. The geological sequencing is shown in Table 2 and illustrated in Figure 3.

Table 2. Geological sequences in the region.

Era	Lithostratigraphy Unit	Rock Types
Cenozoic (<65 Ma)	Quaternary deposits	Sand, soil, alluvial, calcrete
Mesozoic (250 – 65 Ma)	Karoo Supergroup	Sandstone, shale, mudstone, coal, intrusive dolerite
Mokolian (2050-1000 Ma)	Blouberg Formation	Sandstone, feldspathic granulestone, breccia, conglomerate, quartzite and gneiss
	Waterberg Group	Granulestone, conglomerate and sandstone
	Soutpansberg Group	Basalt, andesite, shale, greywacke, conglomerate and lava
Vaalian (2650 – 2050 Ma)	Bushveld Igneous Complex	Gabbro norite
	Transvaal Supergroup	Quartzite, dolomite, chert,
Swazian (>3100 Ma)	Archaean Granitiods Intrusion	Granitic rock
	Archaean Greenstone Belt	Gneiss, schist, quartz-carbonate rock, amphibolite, komatiite and basalt
	Goudplaats-and Houriver gneiss	Gneiss (basement rock)

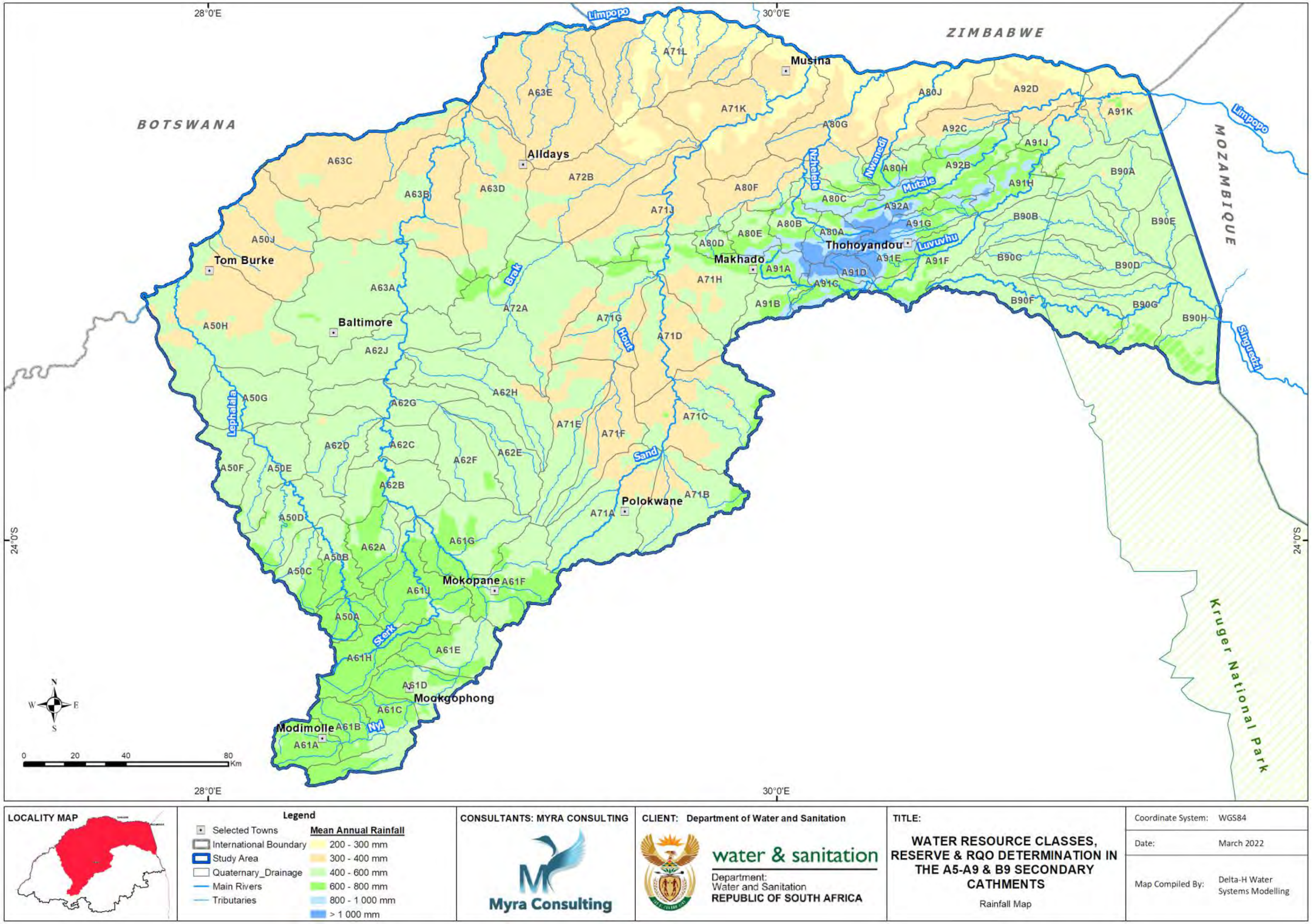


Figure 2. Regional precipitation of the project area.

1.2.4.1. *Basement rocks from the Limpopo Mobile Belt*

The term Kalahari Craton was recently introduced (Johnson et al, 2006) for the discussion of the Kaapvaal and Zimbabwean Craton together with the Limpopo Mobile Belt (LMB), a gneissic zone, as a whole formational event describing the evolutionary stages of the Limpopo Mobile belt welded onto the stable Kaapvaal and Zimbabwean Craton creating a large stable region on which various geological events and features occurred. The evolution of Southern Africa can be regarded as subsequence of accretion onto the stable Kaapvaal Craton during both extensional and compression tectonic periods (Patridge and Maud, 1987). With the occurrence of the accretion of the Limpopo Mobile Belt onto the Kaapvaal craton (approximately 3.1 Ga) and Zimbabwean Craton, the study area is characterized by granitoid-greenstone rock formations together with rocks of sedimentary an volcanic origin. The study area falls within the southern marginal zone of the Limpopo Mobile belt in the north-eastern section of the Kaapvaal Craton and is mostly underlain by Precambrian crystalline basement rocks (granite, gneiss, greenstones, etc.). Typical characterisation of the gneisses is that they are either fine grained to Pegmatoidal, and homogenous or layered (Brandl, 1986, 1987; Du Toit et al., 1983; Anhaeusser,1992; Brandl and Kröner, 1993). All these formations are consequently overlain by quaternary deposits formed from erosional sequences of the pre-existing formations.

Towards the northeast the study area is underlain by the mega shear zone known as the Limpopo Mobile Belt, which strikes east to northeast and separates the Kaapvaal Craton from the Zimbabwean Craton. The resulting Limpopo Mobile Belt consists of three main crustal zones, namely the Northern Marginal Zone, the Central Zone and the Southern Marginal Zone, which lie parallel to one another in an ENE direction.

The Southern Marginal Zone is bounded by down faulted basins containing upper Karoo strata and the Soutpansberg Mountains consisting of Soutpansberg Group rocks, while to the south the northward dipping Hout River Shear Zone forms the boundary of the Limpopo Mobile Belt. To the southwest the Limpopo Mobile belt is truncated by large E-W trending faults with younger Waterberg Group strata and the northern lobe of the Bushveld Complex on the down faulted side of the faults (e.g. Melinda Fault). The associated Palala Shear zone is regarded as the southern boundary of the Central zone of the Limpopo Mobile Belt.

The LMB consists of gneissic, granites, granulites, serpentenites, metapelites and horneblende gneisses with infolded supra crustal rocks such as the Houtriver-Goudplaats gneisses and the Beit Bridge Complex, which have undergone high grade granulite metamorphism. The Beit Bridge Complex consists of metaquartzites, calcsilicates, amphibolite, meta-pelites and pink hornblende gneisses The Bandelierskop Complex is infolded into the basement of the Houtriver-Goudplaats gneisses and consists of ultramafic peridotite, pyroxenite lavas, mafic granulite, amphibolite, metapelite, pelitic gneisses, magnetite, quartzite and meta quartzite). A number of massive, unfoliated granite intrusions occur as batholiths, plutons and stocks in the study area. These granitic intrusions form prominent topographical features that can be seen north of Polokwane. The Rhenosterkoppies and Pietersburg Greenstone Belts occur towards the southwest and north of Polokwane. They are composed largely of extrusive mafic and, to lesser extents, ultramafic and felsic rock.

1.2.4.2. *Diabase dykes and sills*

Tre number of diabase dykes and sills are found throughout the project area. Dyke swarms crop more densely in the north-eastern domain of the Kaapvaal than elsewhere on the craton and northeast-trending diabase dykes are dominant in the project area. Due to their orientation and these northeast-trending dykes are associated with 2.7 Ga Ventersdorp Supergroup trends (Uken & Watkeys, 1997), which formed either in response to the Limpopo orogeny (Burke et al.) or by crustal extension due to mantle plume activity (Hatton, 1995). Later Karoo dolerites sporadically cut through the older dykes, but usually follow the same intrusion paths as their Archaean predecessors. The Houtrivier Shear Zone was probably one of the controls of the dyke emplacement in the area, because many more dykes are observed north of the Hout River Shear(in the South Marginal Zone) than south of it.

1.2.4.3. *Bushveld Complex*

The study area is also bounded by the northern limb of the Bushveld Complex. This intrusive complex is intruded into basement rocks and comprises of the lower Rustenburg Layered suite and the Lebowa Granite Suite above. The layered rocks of the Bushveld Complex are believed to be the result of slow cooling during crystallization (gravitational crystals settling) of magma. Bowen (1928) described these as accumulative rocks. These accumulative rocks consists of two classes of materials; cumulus grains that form from settling and become packed and intercumulus liquid filling up the spaces between the cumulus grains that cements them together (Jackson, 1967). These rocks are characterised by large homogenous rocks with igneous lamination. The formation of the rocks in the Bushveld Intrusive Complex is formed through the processes of fractional crystallization and mineralization in a magma chamber, which follows Bowen's reaction series. Gabbro Norite rocks characterise Bushveld Complex.

1.2.4.4. *Southpansberg, Waterberg and Blouberg formations*

The Soutpansberg formation forms the large east-west trending mountain range in the project area. The Blouberg and Waterberg formation are located south, west and north in the study area where they form local recharge areas. The Soutpansberg, Waterberg and Blouberg formations are considered to be between 1700 and 2000 Ma old, forming part of the Palaeoproterozoic age (Barker et al., 2006).The Blouberg Formation consists completely of clastic sedimentary rocks deposited nonconformably over the granulite-grade gneisses of the Limpopo Mobile Belt with a maximum thickness of 1400m (Jansen, 1975; Bumby et al., 2001a). However, only sequences of less than 300 metres are found at outcrop. The Blouberg formation consists of two members, a lower and upper member. The 600 metre thick lower member consists of cross-bedded coarse arkoses and stone and channel fills of feldspathic granulestone (Wentworth, 1922) in association with depositional events in braided river and stream systems. The upper member consists of coarse, feldspathic sedimentary breccia and conglomerate. The cobbles and boulders consist of quartzite and foliated feldspathic gneiss. The formation event of this upper layer is interpreted as the deposition of alluvial fans. The sediments of the Blouberg Formation are characterised by overturned sediments with steeply dipping bedding planes dipping in a northerly direction (Bumby et al., 2001a). However, the lower member of the formation is characterised by southwards dipping planes. The sandstones are often feldspathic, consisting of subangular grains of quartz with minor K-feldspar and opaque minerals. The Soutpansberg Formation rests unconformably on the Archaean granulite-grade gneiss as well as on the Blouberg formation with a maximum thickness of 5000 m (Barker, 1979 and Brandl,1999). According to Barker (1979) the Soutpansberg formation comprises of both volcanic basalt and andesites and sedimentary rock successions that is subdivided onto six successions.

1.2.4.5. *Other geological formations (Transvaal and Karoo Supergroup)*

A small extent (area) of the study area is charactered by the Transvaal and Karoo supergroups. The Transvaal Super Group rocks occur in the south central part of the study area with the strata dipping towards the Bushveld Complex. The most significant lithology in terms of groundwater potential is the Chuniespoort Group consisting of cherts, dolomites and subordinate limestone. Karoo Super Group rocks consisting of shale, shaley sandstone conglomerate with coal in places, occur in several localities throughout the Limpopo WMA but are prominent west of Lephalale and north of Alldays.

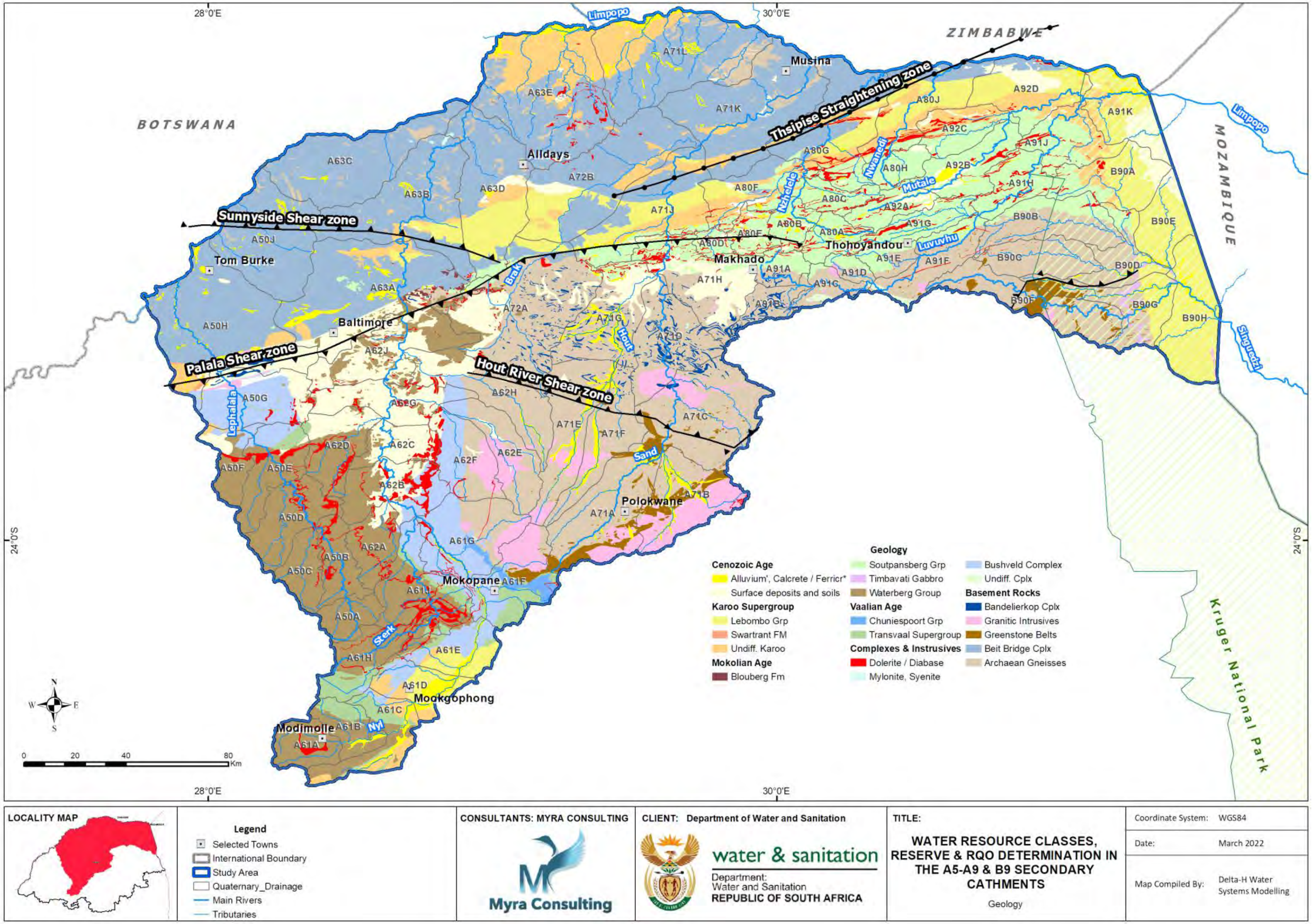


Figure 3. Regional geology.

1.2.5. Aquifer Types

Some of the greatest groundwater needs in South Africa occur in the Limpopo and Olifants WMAs and groundwater is the only dependable source of water for many users. Groundwater is available and widely used throughout the study area, but in varying quantities depending upon the hydrogeological characteristics of the underlying aquifer. The study area is dominated by Intergranular and fractured aquifer systems with borehole yields between 0.1 and > 5 l/s (Figure 4) (Du Toit, 2003). The dominant rock types in the study area are the Goudplaats-, Hout River-, Alldays- and Sand River Gneiss as well as the Beit Bridge complex including the number of granitic intrusions. These rocks form the major subgroups of the Basement Crystalline Complex as they form part of the Achaean eon 3.1 to 2.5 Ga. Aquifers are developed within the weathered overburden and fractured bedrock of these hard crystalline or re-crystallised rocks of igneous or metamorphic origin. Crystalline rocks are characterised by very low primary porosity (fresh or unweathered crystalline rocks contain virtually no water), and almost all groundwater movement and storage in these rocks takes place via fractures, faults, weathered zones and other secondary features that enhance the aquifer potential only locally. Intrusive batholiths and fractured contact zones can displace the host rocks during intrusion in order to create space for the ascending magma. These 10 to 100 metres wide zones are highly productive and can yield in boreholes in excess of 30 l/s (Du Toit, 2001).

A number of exceptionally high yielding areas within the crystalline basement aquifer system occur in the Dendron (Mogwadi), Vivo, Baltimore and Tolwe regions (Figure 4). These aquifers have provided for large scale irrigation for the last few decades.

The southwest of the study area is dominated by the Waterberg Group sandstones and the Karoo Super Group rocks which are classified as a fractured aquifer with expected borehole yields between 0.1 and > 2 l/s (Figure 4). Primary aquifers (or intergranular aquifers) occur throughout the study area and exist in the vicinity of drainage channels where alluvial material overlies or replaces the weathered overburden creating a distinct intergranular aquifer type. The elongated alluvial aquifers follow rivers (so called valley trains), sand rivers or drainage lines with limited width and depth, which typically vary according to the topography and climate.

The mountainous area east of Mokopane are also of special interest as far groundwater is concerned as this area consists primarily of dolomite and has considerable groundwater resources. The karst aquifer with excepted yields of more than > 5l/s is however heavily exploited, within quaternary catchment A61F (DWAF, 2004)

Three main types of aquifer occur within the study area, namely

- Intergranular (alluvial aquifer),
- Intergranular (“primary” or weathered sandy aquifers) and fractured (“secondary” aquifers), and
- Karst aquifer system.

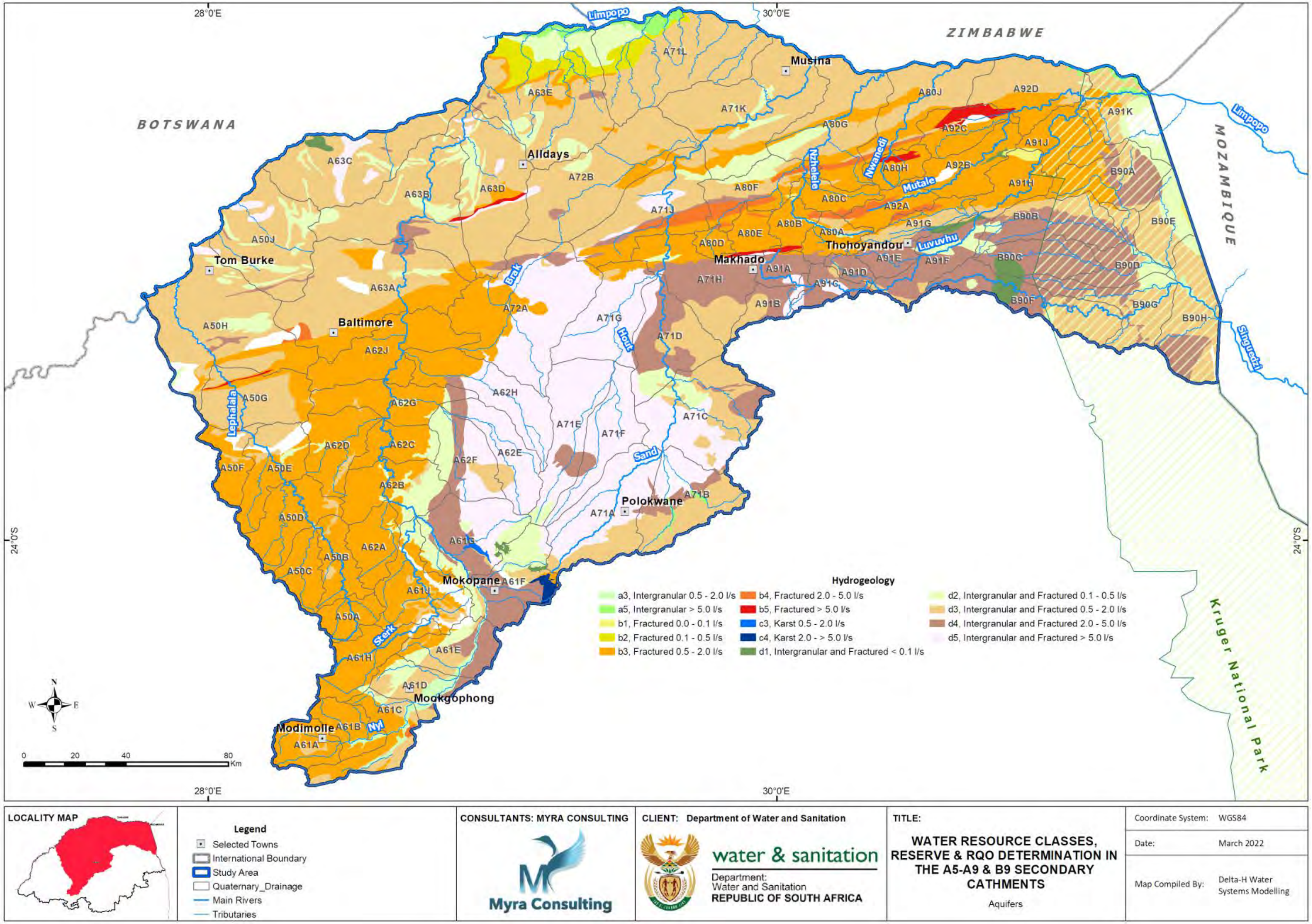


Figure 4. Aquifer type and yield.

Intergranular aquifer (alluvial aquifer)

An alluvial aquifer is described as "an aquifer comprising unconsolidated material deposited by water, typically occurring adjacent to rivers and buried palaeochannels." (DWS, 2011). The distribution of alluvial deposits (aquifers) is determined by the river gradient, geometry of the channel, fluctuation of stream power as a function of decreasing discharge downstream due to evaporation and infiltration losses, as well as rates of sediment input due to erosion (Moyce et al., 2006). The most predominant alluvial aquifer system is the Limpopo River. The geomorphology of the Limpopo River is characterised by 100 m to 66 500 m wide alluvial deposits ranging in thickness between 5 and 10 m, as well as rocky outcrops and floodplains in the upper and middle reaches and extensive floodplains further downstream (Boroto and Görgens, 2003). The aquifers comprise mainly unconsolidated Quaternary sequences of clay, sand and gravel beds (CSIR, 2003; Gomo and van Tonder, 2013), and are sources of groundwater abstraction for multiple communities due to their high permeabilities (Owen and Madari, 2010) and good water quality (CSIR, 2003; Moyce et al., 2006). The alluvial aquifers along the Limpopo River are considered to have the potential for high yields, whereas those along tributaries such as the Luvuvhu River display much lower potential due to limited aquifer extent and less than optimum hydraulic characteristics (CSIR, 2003)

Intergranular and fractured aquifer system

An aquifer system in crystalline material such as the norites and pyroxenites of the Bushveld Igneous Complex as well as the Basement Complex rocks comprise of (a) an in-situ weathered overburden or saprolite (often collectively with the soil zone referred to as regolith), partially replaced or overlain by alluvial or hill wash material, (b) an unweathered and intact rock matrix with negligible matrix porosity and permeability, and (c) planes of discontinuity in the rock matrix, including layers/reefs, faults and joint planes (collectively here referred to as fractures in the hydrogeological meaning). The fractured bedrock comprising of the intact rock matrix and fractures is commonly referred to as saprock. The degree/intensity of chemical weathering or more specifically the spatial and depth variations thereof, control the geometry of the shallow weathered aquifer profile. The weathered overburden is considered to have low to moderate transmissivity, but high storativity. The weathered aquifer is recharged by rainfall or by leakage from perennial and non-perennial surface water drainages and dams. Direct recharge from rainfall is limited, as the mafic rocks of the BIC tend to weather to a swelling clay rich soil (black turf), which has low permeability and considered to reduce infiltration unless preferential flow paths are opened by vertical desiccation cracks. The dominant rock types in the study area are the Goudplaats-, Hout River-, Alldays- and Sand River Gneiss as well as the Beit Bridge complex including the number of granitic intrusions.

With the presence of the Karoo Supergroup located in the weathered zone of the Karoo sediments hosts the unconfined or semi-confined shallow weathered Karoo aquifer or hydro-stratigraphic zone. Due to direct rainfall recharge and dynamic groundwater flow through the unconfined aquifer in weathered sediments, the water quality is expected to be generally good, but in the absence of an overlying confining layer also vulnerable to pollution. Localised perched aquifers may occur on clay layers or lenses. Water intersections in the weathered aquifer are mostly above or at the interface to fresh bedrock (sandstone or sills), where less permeable layers of weathering products and capillary forces limit the vertical percolation of water and promote lateral water movement. Groundwater flow is governed by secondary porosities like faults, fractures, joints, bedding planes or other geological contacts (including coal seams), while the rock matrix itself is considered impermeable. Geological structures are generally better developed in competent rocks like sandstone, which subsequently show better water yields than the less competent silt- or mudstones and shales. Not all secondary structures are water bearing due to e.g. compressional forces by the neo-tectonic stress field overburden closing the apertures.

Karst aquifer

The kart / dolomitic aquifer consists of chert-rich dolomite and chert breccias with boreholes yields exceeding 5 l/s. Water bearing properties of the dolomite stem from carbonate dissolution along structural and lithological discontinuities (such as faults, fractures, and joints). Storativity of South African dolomite aquifers generally vary between 1 and 5 % but this property depends greatly on the extent of weathering and dissolution. Transmissivities can be several hundred m^2/day or more. The aquifer can be regarded as a water-table aquifer with mostly unconfined conditions. Groundwater levels varies, however typically shallow in natural conditions, and generally show an immediate response to rainfall. The karst aquifer system is limited to the Malmani Dolomites found around Mokopane area (DWS and WGS, 2011).

1.2.6. Transboundary Aquifers (TBAs)

Two international transboundary aquifers[1] occur in the study area namely the AF9 – Tuli Karoo Sub-Basin and the AF8 – Limpopo Basin and the (Figure 5). A summary of the characteristics of the aquifers is provided below:

- AF9 – Tuli Karoo Sub-Basin
    - The predominant lithology is crystalline rocks – volcanic and basement rocks with sedimentary rocks - sandstones and extensive sands - alluvial deposits along the major drainage channels.
- AF8 – Limpopo Basin
    - The predominant lithology is crystalline rocks – granitic basement.

A comprehensive description of the Limpopo TBAs is generally lacking due to the lack of data from adjacent countries. These two specific TBAs have generally low transmissivities with a slow rate of groundwater movement. In addition groundwater occurs within disconnected "pockets" determined by geology and weathering processes (e.g. basement aquifers) (Cobbing et al., 2008). The impression of a large interconnected and high yielding shared aquifer resources are, therefore not the case for these two TBAs. However, the Limpopo River alluvial aquifer might be of more importance to the four countries sharing the resource. The seasonal flow regime of the Limpopo River is characterised by wet season runoff that recharges the alluvial aquifer; surface flows decline during the dry winter months, reducing to dislocated pools of standing water connected by sub-surface flows. At this stage the AF8 and AF9 TBAs is not believed to be at risk of competition for water between South African and neighbouring countries. In addition these TBAs north of the Limpopo River will be excluded from the study area purely based on the basis and methodology applied to delineate of the groundwater resource units.

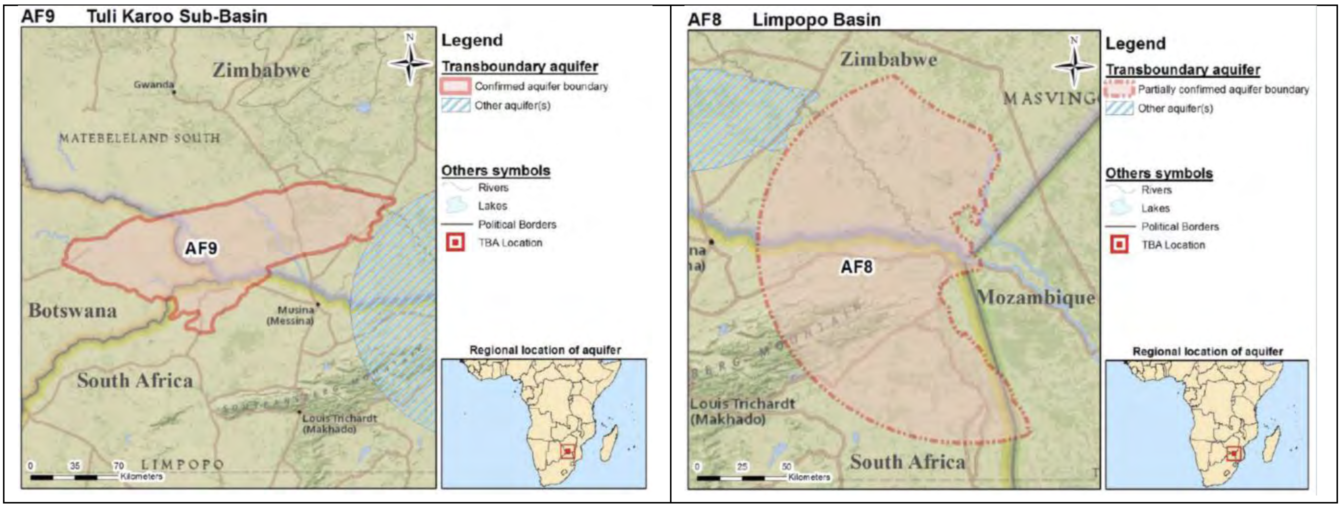


Figure 5. Transboundary aquifers of the study area.

[1] Transboundary Water Assessment Programme (TWAP) – www.geftwap.org

1.2.7. Strategic Water Source Areas – Groundwater (SWSA-gws)

There are 57 nationally strategic SWSA-gw which cover about 11% of South Africa, with 37 of these being nationally strategic (Le Maitre, et al., 2019). Groundwater source area can therefore be defined as an area with high groundwater availability and where this groundwater forms an important resource. A strategic groundwater source area can therefore be defined as an area with a high source of groundwater and where this groundwater forms a nationally important resource. The study area hosts 6 SWSA-gw areas (Figure 6) of which all except the Blouberg groundwater resource area is considered of National importance.

1.3. Delineation of Groundwater Resource Units

1.3.1. Overview

It is practical to consider the status quo for groundwater resources in respect of groundwater resource units (termed groundwater units of analysis or GUAs). As such, the hydrogeological characteristics of the area, the delineation of groundwater units of analysis, and status quo of GUAs are presented together in this report.

Quaternary catchments are used as the primary delineation of water resource units in RDM assessments. The delineation of groundwater resource units depends on the hydrogeological characteristics of the area (e.g. aquifer types and flow regimes), and due to the nature of groundwater flows, hydraulic boundaries for groundwater flow are often different to that of surface water systems. Although the hydraulic boundaries may differ, the delineation should consider that a Class, Reserve and RQOs must be set for each unit, and therefore linkages with other components have to be considered, and each unit will have to be managed. The delineation of GUAs presented in this section therefore considers the following physical, management and functional criteria together:

- Surface water divides on a quaternary and secondary level
- Geological structures (i.e. fault, hydrostratigraphy or lithological contact zones)
- River systems
- Recharge and discharge zones and groundwater flow regimes
- Zones of groundwater use
- Groundwater management (size and extent of units)

1.3.2. Groundwater regions

The groundwater divisions as proposed by Vegter (2000) are primarily based on geology and not hydraulic units as such. As a result the delineated regions group similar geological rocks that has uniform water bearing properties. A comparison of the borehole information of the groundwater regions within the study area after Vegter (2000) is provided in Table 3. The regions were adapted in this study to isolate the Nyl River Flats more distinctly from the larger Waterberg regions Figure 7. In addition the dolomites found at Mokopane (in the old Eastern Bankenveld) was renamed as Mokopane dolomites. From the results, the variability between delineated groundwater regions is clear. As expected the Mokopane dolomite region have above average transmissivity and yields, while lower transmissivities and yields are associated with the Karoo- and Soutpansberg Strata. The variability in groundwater potential is also evident between the crystalline basement complexes, where the Houdenbrak Granulite-Gneiss has higher average yields compared to the Limpopo Granulite-Gneiss Belt.

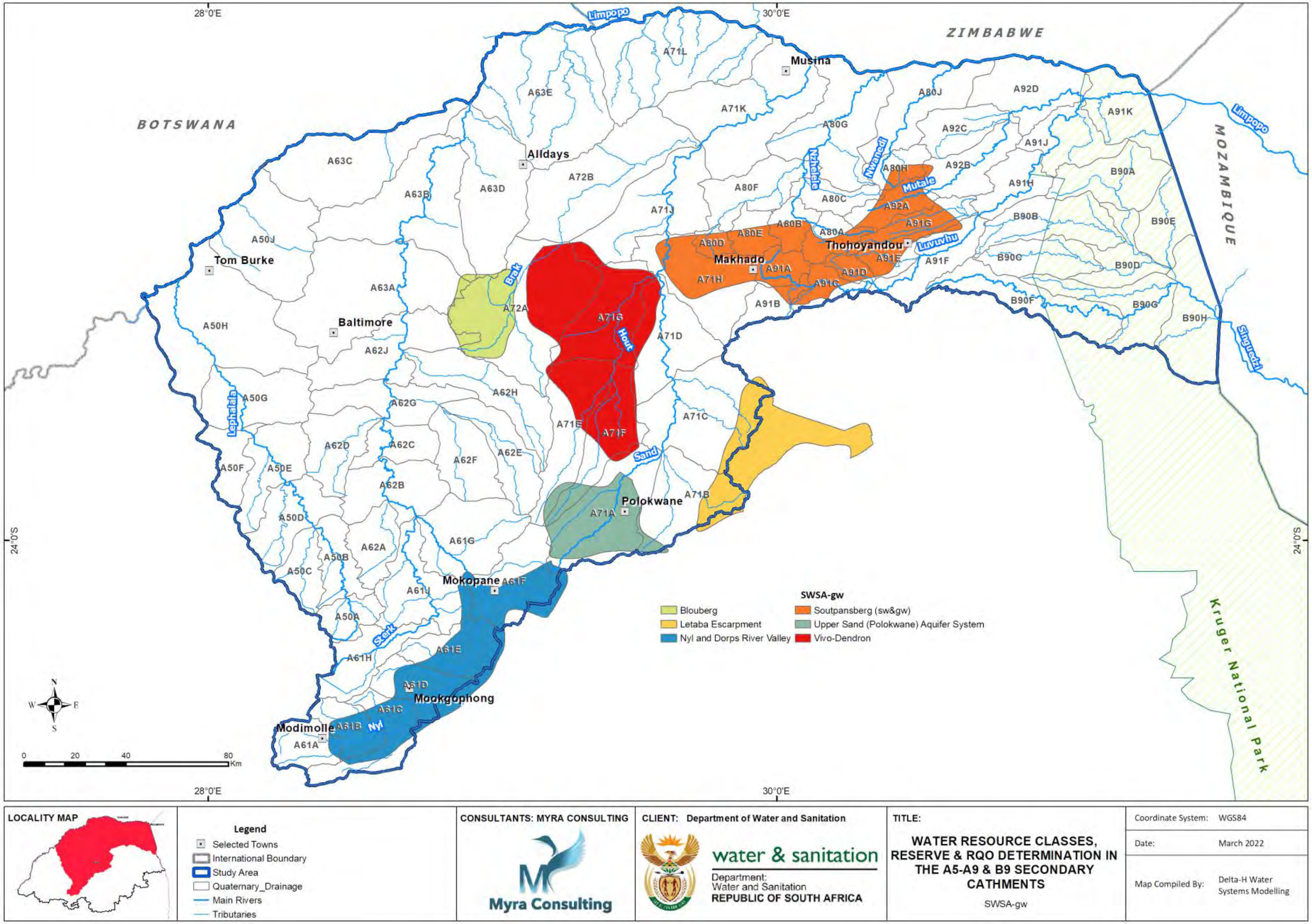


Figure 6. SWSA-gw for the study area.

Table 3: Comparison of hydrogeological parameters for the delineated groundwater regions.

Groundwater Region	Info	BH Depth	Water Level	Water Strike	Transmissivity	Rec. Yield	Blow Yield
		(mbgl)			(m²/day)	(l/s for 24hrs)	(l/s)
Granulite-Gneiss Plateau	N	1050	1136	278	149	76	208
	Min	-	<1	<1	0.1	0.02	<0.01
	Max	250	78.5	160	960	12	40
	Mean	59.5	15.2	37.3	39.7	1.3	3.2
Houdenbrak Granulite-Gneiss	N	1363	1567	430	255	97	299
	Min	-	<1	<1	0.3	0.01	<0.01
	Max	300	93.6	204	640	11	99
	Mean	61.8	24.8	43.1	33.4	1.2	2.5
Koedoesrand Bushveld Cpx	N	274	204	183	40	65	88
	Min	-		2	0.2	0.05	<0.01
	Max	290.5	115	289	527	7	27
	Mean	54.4	18.0	50.2	51.7	1.0	2.1
Limpopo Granulite-Gneiss Belt	N	1443	1297	654	93	79	355
	Min	<1	<1	<1	0.1	0.04	<0.01
	Max	335	200	306	387	15	30
	Mean	50.5	24.0	49.4	37.5	1.1	1.7
Limpopo Karoo Basin	N	338	201	165	1	1	100
	Min	<1	<1	6	12.4	0.8	<0.01
	Max	259	66	259	12.4	0.8	0.7
	Mean	34.6	17.4	43.2	12.4	0.8	1.1
Mokopane Dolomites	N	195	172	130	20	21	94
	Min	<1	2	5	4	0.05	0.1
	Max	238	122	149	500	6.6	36
	Mean	59.6	20.1	41.7	112.3	1.6	8.2
Northern Lebombo	N	118	99	121	none	none	102
	Min	<1	<1	4	none	none	<0.01
	Max	137.5	54	114	none	none	15
	Mean	45.9	13.7	29.9	none	none	1.9
Northern Limb Bushveld Cpx	N	610	580	244	124	57	133
	Min	<1	<1	2	0.1	0.01	<0.01
	Max	204	92	150	380	11.0	15
	Mean	54.4	15.5	42.8	52.8	1.0	1.7
Nyl River Flats	N	526	405	299	14	13	194
	Min	<1	<1	<1	0.4	0.06	<0.01
	Max	281	90	192	68	3.6	28
	Mean	57.8	15.8	44.2	24.1	1.4	2.1
Soutpansberg Hinterland	N	777	664	399	80	58	264
	Min	<1	<1	<1	0.2	0.02	<0.01
	Max	340	137	266	925	15	60
	Mean	64.1	22.5	47.8	68.2	1.2	3.0
Soutpansberg Trough	N	792	746	263	154	64	214
	Min	<1	<1	2	0.2	0.02	<0.01
	Max	340	140	340	428	11	49
	Mean	63.4	15.1	44.6	16.6	0.8	2.7
Waterberg Karoo Coal Basin	N	58	32	61	none	none	21
	Min	<1	6	3	none	none	<0.01
	Max	300	160	258	none	none	9
	Mean	69.9	34.4	88.9	none	none	0.7
Waterberg Plateau	N	1005	778	560	122	69	288
	Min	<1	<1	2	0.1	0.02	<0.01
	Max	291	220	257	800	0.3	38
	Mean	64.3	19.6	51.0	43.1	0.5	1.6

NOTE: Borehole depth and water levels based on integrated GRIP and NGA databases. Min value not statistical meaningful, reported as <1mbgl).
Water Strike and Blow Yield based on NGA database.
Transmissivity and Rec. Yield based on GRIP database.
Major River based on perennial river flow as indicated on the report maps.

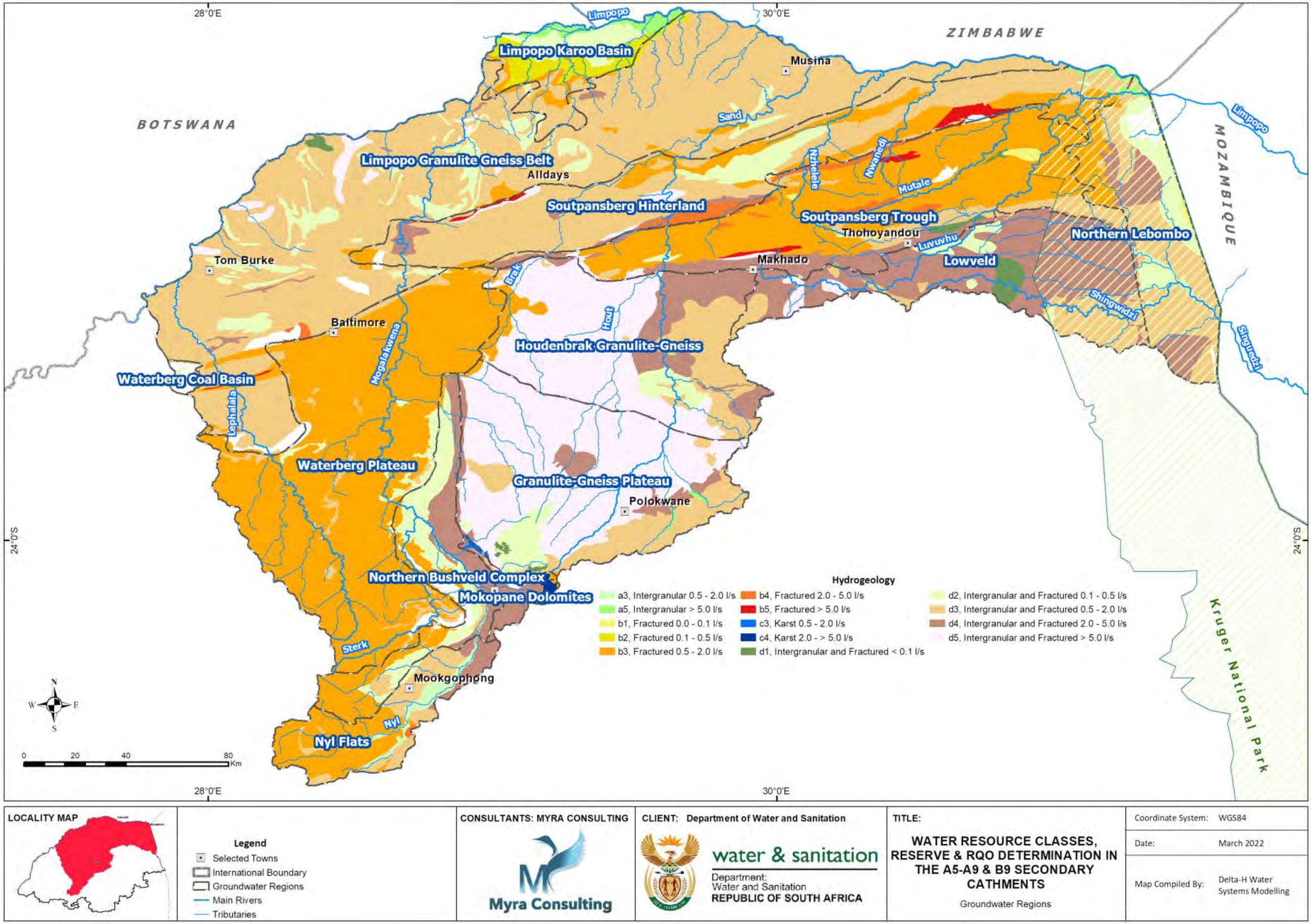


Figure 7. Groundwater regions (adapted from Vegter, 2000).

1.3.3. Delineation results

Due to the size of the project area, it is not feasible to determine a Groundwater Reserve for the entire area. In addition, the first step in the RDM Classification process as outlined under Chapter 3 of the NWA, is the demarcation of the units of analysis (UA), of which is to be classified, a Reserve assessment undertaken and Resource Quality Objectives (RQOs) set.

In this study the quaternary catchments were used as the primary delineation, while the GUAs were based on a single or a combination of quaternary catchments. The following aspects were considered:

- Although surface water and groundwater divides do not always correspond, groundwater must be considered in terms of an integrated water resource.
    - The study area is drained by 8 major rivers flowing into the Limpopo River. As a result the study area is easily divided into 8 sub-catchments. Considering that the groundwater component of the (ecological) Reserve is determined by calculating the groundwater contribution to baseflow it makes sense to follow the hydrological approach.
    - Regionally the groundwater mimics the surface topography. Figure 8 shows the very good correlation (R^2=1.0) between absolute surface and groundwater table elevations in metres above mean sea level (mamsl) for the project area.
        - The data presented is based on water levels obtained from the GRIP and NGA dataset.
- Identification and recognition of aquifer type and groundwater regimes within each sub-catchment.

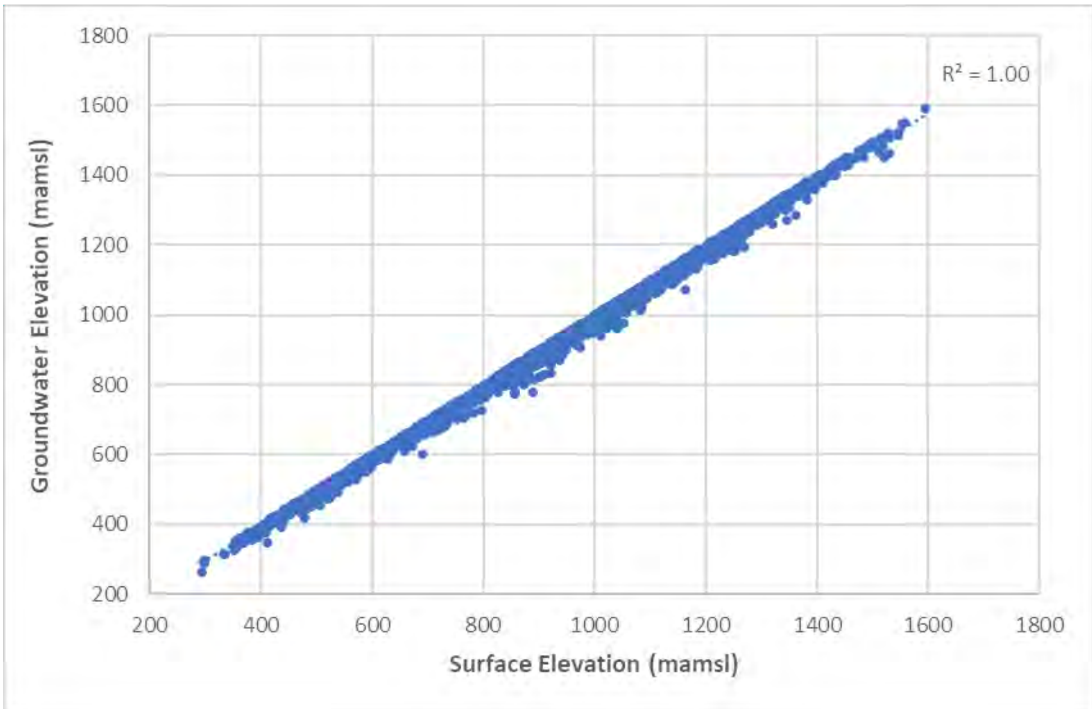


Figure 8. Correlation between surface topography and groundwater elevations for the study area.

A summary of the delineated GUA within each sub-catchment is provided in Table 4. All GUAs coincide with the sub-catchments except for A63/A71-3, which straddle the Mogalakwena- and Sand River sub-catchments. The tributaries draining the associated quaternary catchments drain directly into the Limpopo River. These catchments also straddle the Limpopo Karoo Basin, so as a result they were delineated as a single GUA.

The delineated resource units generally combine a couple of quaternary catchments so that the integration of surface water and groundwater systems can be achieved (Figure 9).

Table 4. Description of delineated groundwater units of analysis.

Drainage system	GUA	Nr of Quats.	Catchments	Name	Geology
Lephalala	A50-1	6	A50A,B,C,D,E,F	Upper Lephalala	Waterberg Group
	A50-2	1	A50G	Middle Lephalala	Bushveld Complex
	A50-3	1	A50H	Lower Lephalala	Basement Complex
Upper Mogalakwena	A61-1	5	A61A,B,C,D,E	Nyl River Valley	Bushveld Complex, Lebombo Group
	A61-2	2	A61H,J	Sterk	Bushveld Complex, Waterberg Group
	A61-3	3	A61F,G	Upper Mogalakwena	Bushveld- and Basement Complex, Dolomites
Middle- and Lower Mogalakwena	A62-1	3	A62A,B,C,D	Klein Mogalakwena	Bushveld Complex, Waterberg Group
	A62-2	2	A62E,F	Matlala	Bushveld- and Basement Complex,
	A62-3	3	A62G,H,J	Steilloop	Waterberg Group
	A63-1	3	A63A,B,D	Lower Mogalakwena	Basement Complex, Karoo Super Group, Lebombo Group
Upper Sand	A71-1	2	A71A,B	Upper Sand	Basement Complex, Alluvium
	A71-2	3	A71C,D,H	Middle Sand	Basement Complex
	A71-3	4	A71E,F,G	Hout	Basement Complex
Lower Sand	A71-4	2	A71J, A72B	Sandbrak	Basement Complex, Karoo Super Group, Lebombo Group
	A71-5	1	A71K	Lower Sand	Basement Complex, Karoo Super Group
Limpopo Tributary	A63-3/A71-6	2	A63E, A71L	Limpopo Tributary	Basement Complex, Karoo super Group
Kalkpan	A50-4/A63-2	2	A63C, A50J	Kalkpan/Maasstroom	Basement Complex
Nzhelele	A81-1	6	A80A, B,C,D,E,F	Nzhelele	Soutpansberg Group, Karoo Super Group, Lebombo Group, Basement Complex
Lower Nzhelele	A81-2	1	A80G	Lower Nzhelele	Soutpansberg Group, Karoo Super Group, Basement Complex
Nwanedi	A81-3	2	A80H,J	Nwanedi	Soutpansberg Group, Karoo Super Group, Basement Complex
Upper Luvuvhu	A91-1	7	A91A,B,C,D,E,F,G	Upper Luvuvhu	Soutpansberg Group, Basement Complex
Mutale /Luvuvhu	A91-2	7	A91H,J,K, A92A,B,C,D	Mutale /Luvuvhu	Soutpansberg Group, Basement Complex
Shingwedzi	B90-1	8	A90A,B,C,D,E,F,G,H	Shingwedzi	Basement Complex, Soutpansberg Group

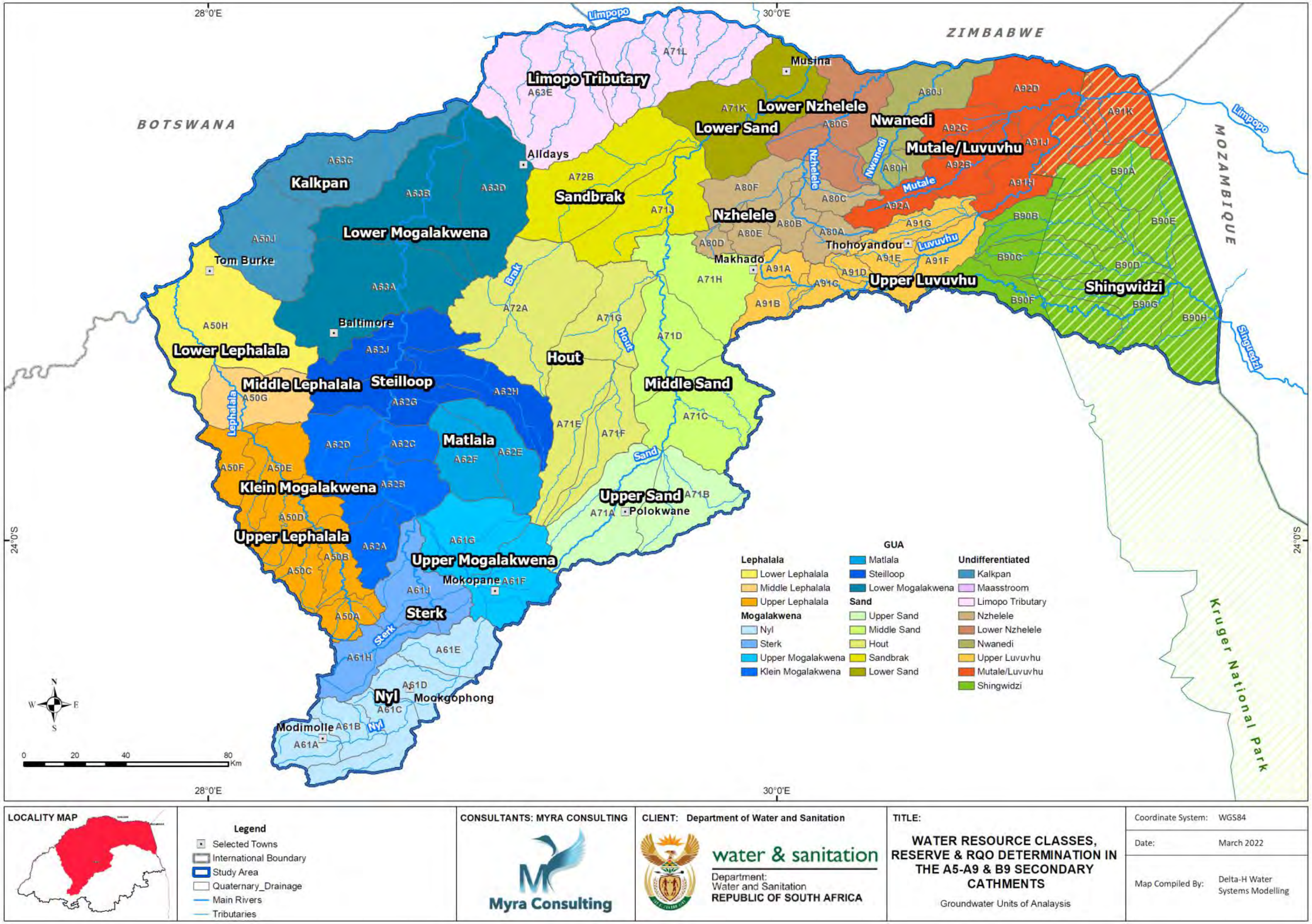


Figure 9. Delineated groundwater units of analysis.

1.4. REGIONAL GROUNDWATER DESCRIPTION

1.4.1. Groundwater levels and flow direction

Average water levels for the study area are 20 metres below groundwater level (mbgl). The deepest average water strikes are observed within the Waterberg Karoo Coal Basin, i.e. 89 mbgl, with all other geological setting similar with an average of approx. 40 mbgl (Table 3). This is also reflected in the groundwater levels, as the Waterberg Karoo Coal Basin has an average water level of 34 mbgl, whereas the other geological setting of approx. 15-20 mbgl. The deeper water recorded water strikes and water levels may be as a result of deep drilling into the underlying confined Waterberg Group strata. The reflection of shallow water levels and water strikes observed at the other geological setting could imply that the weathered aquifer system is targeted, rather than the deeper aquifer systems.

Based on the hydrographs (obtained from the HYDSTRA data) majority of groundwater levels indicate a decrease in groundwater levels. Recharge events are observed for most monitoring boreholes, with groundwater levels recovering to long-term average levels (during periods of above average rainfall). Aecom (2015) provided a series of groundwater level heat maps for certain periods from 1960 to present which shows the areas affected by (over) abstraction over the Limpopo WMA over time.

A large scale groundwater contour map based on the latest HYDSTRA groundwater levels is shown in Figure 10. Regionally groundwater levels mimic surface topography and shallow groundwater flow is from higher lying ground towards surface drainages. The main flow direction is towards (and along) the Limpopo River towards the north and northeast.

1.4.2. Recharge

The nationally available recharge dataset, GRAII (DWAF, 2004) is shown in in Figure 10, and summed in Table 5 (per GUA). The recharge distribution is largely controlled by the precipitation distribution, which in turn is related to the topography. At the broadest scale, areas of high rainfall largely correspond (at least in the theoretical datasets) to areas of high recharge. In certain areas the correlation is not direct and the underlying geology, and aquifer type, influences the recharge.

A study from Sorensen et al., (2021) investigated statically the response of groundwater levels over time (hydrographs) with geomorphological conditions within the Mogalakwena and Sand River catchments (see chapters 1.1, 2.3, 1.1 and 2.5). The study found rainfall and aridity are driving factors for groundwater level responses with either a string or subdued reflection from rainfall (recharge) with seasonal fluctuations observed, however some boreholes only showed rainfall response to large recharge events. Groundwater abstraction has an impact on correlation of rainfall, recharge and groundwater responses such as at clustered groundwater abstraction sites (well fields) used for large scale water supply and should be taken with consideration within such areas.

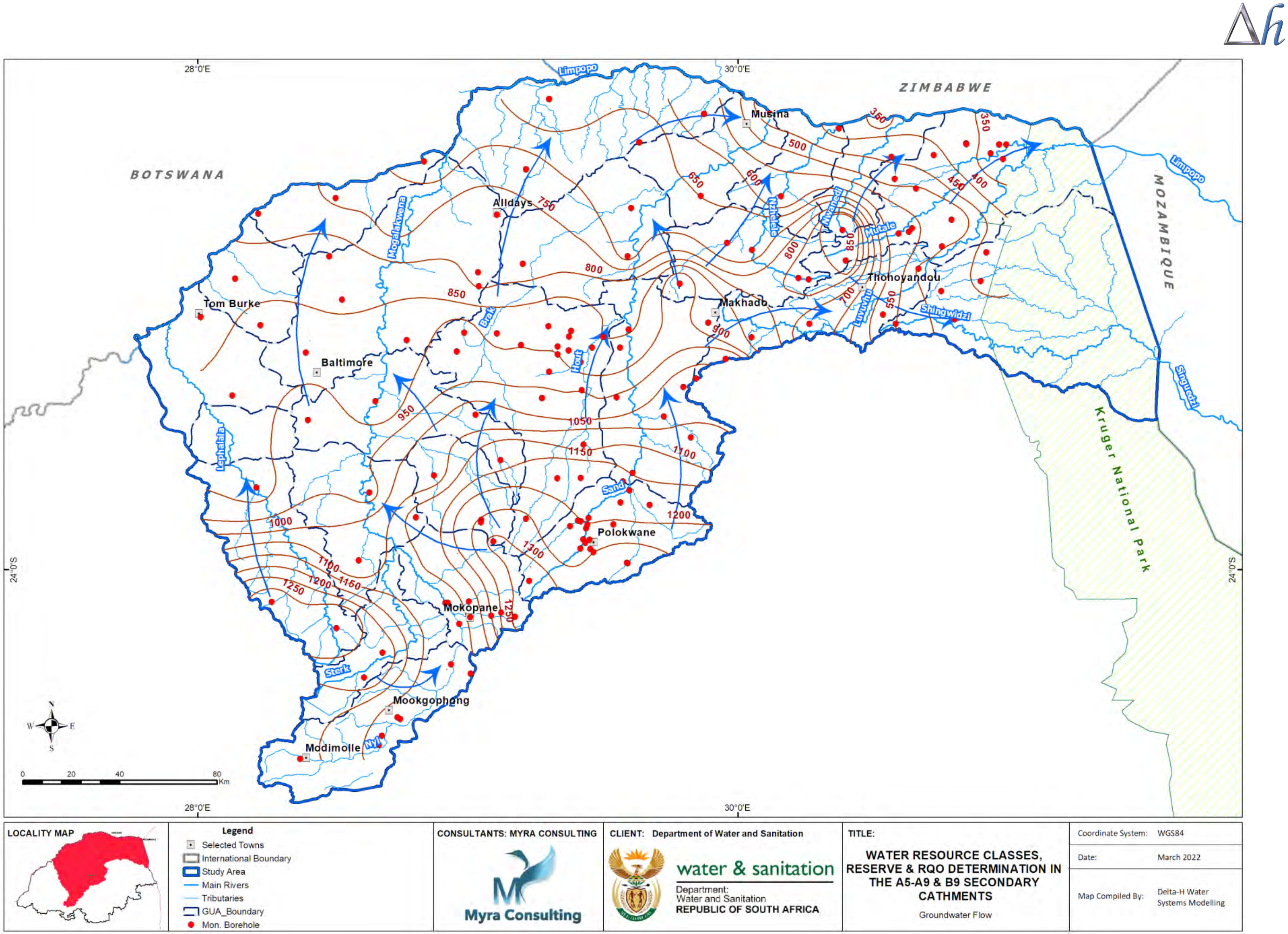


Figure 10. Regional groundwater levels and flow direction.

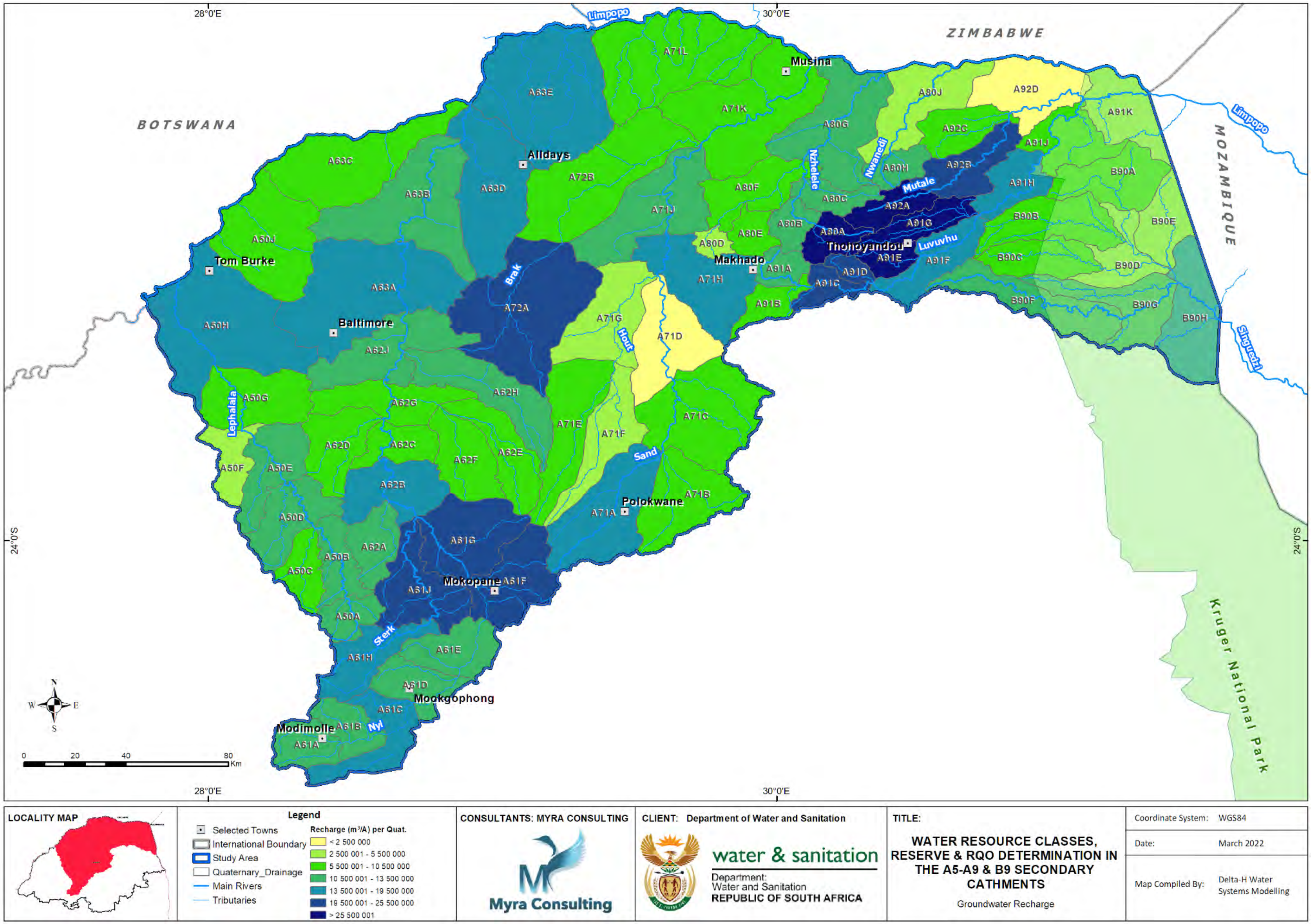


Figure 11. Groundwater recharge per quaternary catchment.

Table 5. Groundwater recharge estimates per GUA.

Description	GUA	Area (km²)	GRA II		Vegter (1995)
			(Wet) Mm³	(Dry) Mm³	Mean Mm³
Upper Lephalala	A50-1	2 704	62.6	44.5	140.4
Middle Lephalala	A50-2	821	9.2	6.3	3.2
Lower Lephalala	A50-3	1 943	15.1	9.9	2.6
Nyl River Valley	A61-1	2 333	62.1	44.7	113.2
Sterk	A61-2	1 403	42.4	30.7	54.6
Upper Mogalakwena	A61-3	1 716	43.2	30.9	28.4
Klein Mogalakwena	A62-1	2 125	42.0	29.5	62.8
Matlala	A62-2	1 240	17.8	12.2	12.2
Steilloop	A62-3	2 428	31.6	21.6	13.4
Lower Mogalakwena	A63-1	4 751	43.5	29.4	10.8
Maasstroom	A63-2	1 318	8.1	5.3	4.5
Upper Sand	A71-1	2 026	26.7	18.3	10.9
Middle Sand	A71-2	3 235	27.9	19.0	17.2
Hout	A71-3	4 359	35.4	24.2	18.7
Sandbrak	A71-4	2 716	21.9	14.5	5.4
Lower Sand	A71-5	1 669	9.5	6.1	0.9
Limpopo Tributaries	A63-3/71-3	3 750	23.3	15.0	3.0
Kalkpan	A50-4/A63-2	2 572	16.98	11.24	29.00
Nzhelele	A81-1	1 837	71.7	52.7	116.2
Lower Nzhelele	A81-2	1 228	11.8	7.8	1.7
Nwanedi	A81-3	1 133	15.2	10.5	10.2
Upper Luvuvhu	A91-1	2 098	170.2	131.9	451.1
Mutale/Luvuvhu	A91-2	3 838	113.5	83.7	94.8
Shingwedzi	B90-1	5 301	70.5	48.4	40.4

1.4.3. Discharge

One groundwater discharge mechanism is through discharge to surface water, as groundwater contribution to baseflow (river baseflow, springs and seeps). The available baseflow information for the region is a national dataset derived from the GRAII assessment at quaternary catchment scale (DWAF, 2004), shown in (Figure 12). The distribution of groundwater contribution to baseflow closely correlates with the distribution of recharge. Rainfall has a dominant control on recharge, and aquifers with high recharge, can also be reasonably expected to have high groundwater discharge, given a state of dynamic equilibrium in the long term.

This dataset is often the only or major (natural) discharge considered from groundwater. It is simply the only one for which there is a spatial dataset available. Interflow between aquifers, direct evapotranspiration, are discharge mechanisms for which there is not readily available spatial data at regional scale. A widely applied equation for groundwater availability equates availability to recharge minus use (existing abstraction and groundwater contribution to baseflow) minus the reserve. This equation simply yields un-quantified groundwater discharge. All natural discharge (and some enhanced recharge) may be available, or only a small portion of it, depending on the ability to capture this yield (section 1.1.2).

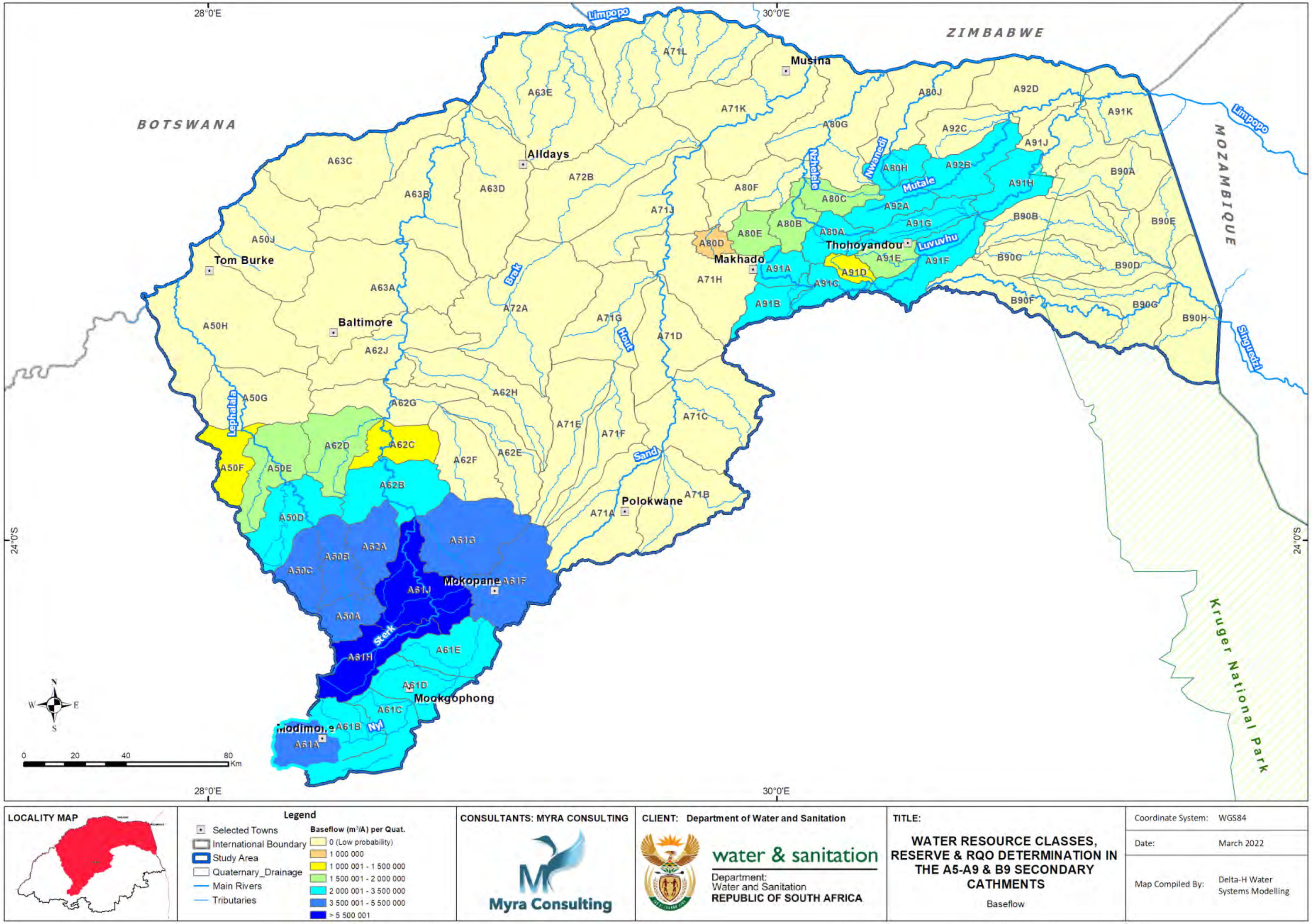


Figure 12. Baseflow distribution, per quaternary catchment.

1.4.4. Groundwater use

The sum of registered groundwater use (WARMS) per GUA is shown in Table 6 and to assess the current exploitation of the units the volumes was compared to recharge as well as the harvest and exploitation potential.

Groundwater Availability (DWAF, 2004b GRA II)

The volume of water that may be abstracted from a groundwater resource based on the concept of an 'exploitability factor' and yield (borehole) distribution which relates to the **Groundwater Exploitation Potential (GEP)**. The volume of water that may be abstracted from a groundwater resource may ultimately be limited by anthropogenic, ecological and/or legislative considerations, which ultimately is a management decision that will reduce the total volume of groundwater available for development – referred to as the **Utilisable Groundwater Exploitation Potential (UGEP)**, which accounts for the Reserve by prescribing a fixed-level below which the groundwater level may not decline.

The **Groundwater Harvest Potential** is aimed at providing estimates on a national scale of the annual maximum volume of groundwater that can be abstracted from a unit area on a sustainable basis.

A map showing the distribution of registrations is in Figure 13. This map also illustrates a density function which sums the groundwater registration (l/s) per km^2, emphasising clustered use and high registrations. The three largest groundwater use sectors are large scale irrigation from farmlands, water services to communities and towns/cities and mining, as illustrated in Table 7.

Groundwater use in terms of distribution, is significantly higher along the Nyl river system, following downgradient northwards the sand river system. Large clusters of groundwater use is observed at the Bela-Bela/Modimolle towns, Polokwane and downgradient from Albasini dam (farm land irrigation). Widespread groundwater use is mostly associated with local communities and irrigation use. Groundwater use clustering is less in the central west and far east (Kruger National park). Using the present groundwater utilisation data and comparing it with the exploitable volumes shows that the Lephalala (A50-3), Upper Mogalakwena (A61-3), Upper Sand (A71-1; A71-2), Sandbrak (A71-4), Nzhelele (A81-2), Nwanedi (A81-3) and Levuvhu (A91-1) GUAs are heavily exploited while the Lower Sand and Limpopo Tributaries (comprising of abstraction from the Limpopo Alluvial Aquifers) exceed the exploitation potential.

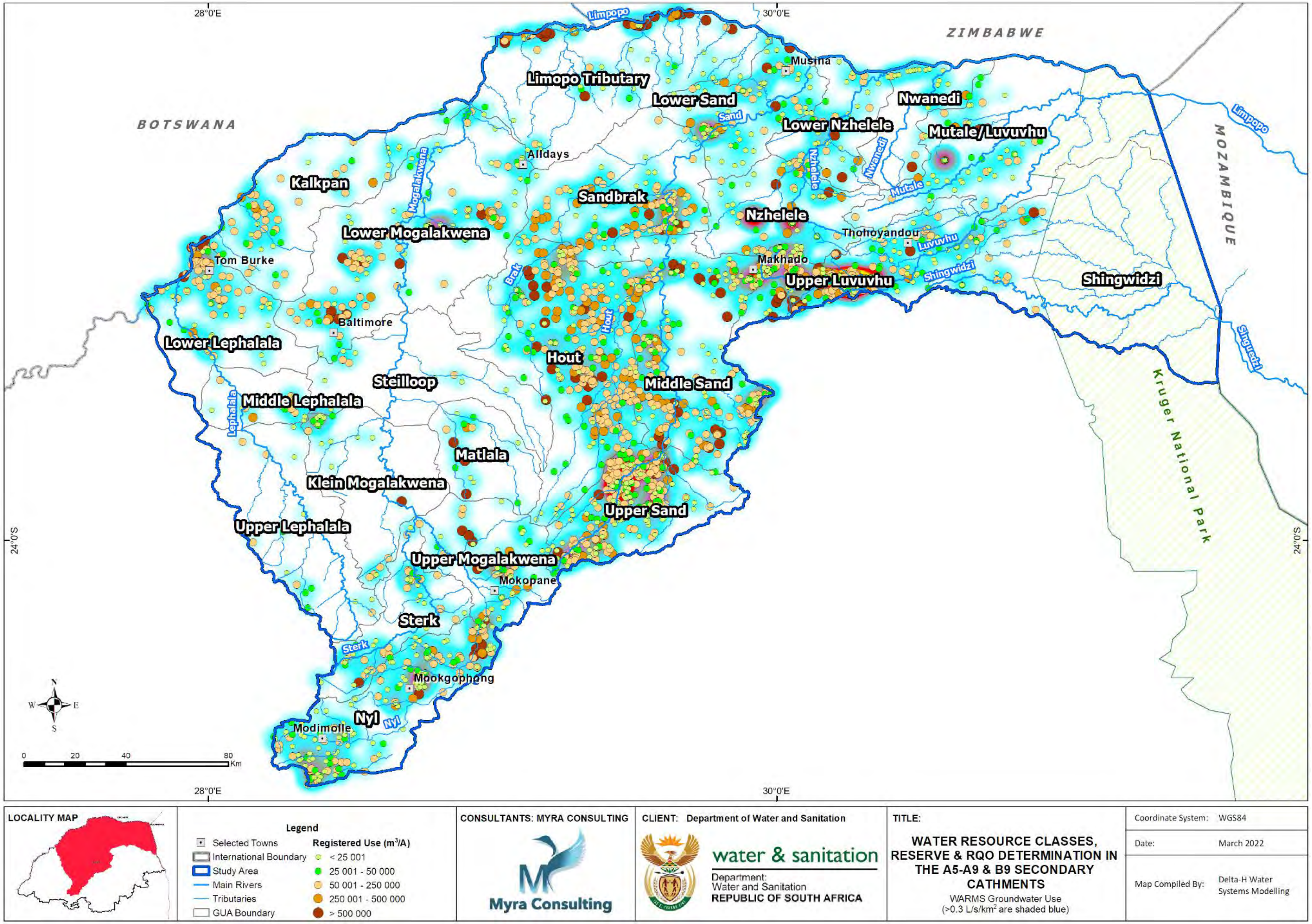


Figure 13. Map showing distribution of registered groundwater abstraction (points) and groundwater use >0.3 L/s/km² shaded.

Table 6. Groundwater use (WARMS) compared to the exploitation potential of the GUA.

Drainage system	GUA	Groundwater Use (Mm^3/a)	Harvest Potential (Mm^3/a)	Groundwater Exploitation Potential (Mm^3/a)	Utilisable Groundwater Exploitation Potential (Mm^3/a)	Exploit % (Use vs. GEP)
Lephalala	A50-1	0.71	34.35	249.83	40.83	0.3%
	A50-2	1.29	5.82	11.30	6.06	11.4%
	A50-3	11.55	12.17	20.77	10.30	55.6%
Upper Mogalakwena	A61-1	15.17	42.01	102.19	15.93	14.8%
	A61-2	4.14	20.37	94.69	8.94	4.4%
	A61-3	12.49	10.85	18.15	8.07	68.8%
Middle- and Lower Mogalakwena	A62-1	1.75	26.03	193.56	26.77	0.9%
	A62-2	3.82	14.30	29.93	15.35	12.7%
	A62-3	1.01	21.48	140.09	48.07	0.7%
	A63-1	15.98	37.48	73.42	33.99	21.8%
Upper Sand	A71-1	37.65	21.11	45.27	11.46	83.2%
	A71-2	40.63	31.10	74.53	25.81	54.5%
	A71-3	44.82	46.68	119.67	16.95	37.5%
Sandbrak	A71-4	19.39	17.41	27.73	14.25	69.9%
Lower Sand	A71-5	13.97	5.32	8.33	4.21	167.7%
Limpopo Tributaries	A63-3/71-3	46.97	16.87	19.89	9.35	236.1%
Kalkpan	A50-4/A63-2	5.83	27.79	27.15	15.77	21.5%
Nzhelele	A81-1	8.40	14.76	55.13	33.61	15.2%
	A81-2	5.50	5.24	9.81	5.68	56.0%
Nwanedi	A81-3	5.97	5.01	11.92	6.40	50.1%
Levuvhu	A91-1	61.10	27.15	102.65	66.75	59.5%
Mutale /Levuvhu	A91-2	3.70	27.65	82.35	49.14	4.5%
Shingwidzi	B90-1	2.24	47.32	82.22	31.89	2.7%

Table 7. Groundwater use (WARMS) per groundwater use sector.

Groundwater Use Sector	Registered Use (Mm^3/a)
Agriculture: Aquaculture	0.35
Agriculture: Irrigation	284.01
Agriculture: Wearing Livestock	2.13
Industry (Non-Urban)	5.41
Industry (Urban)	4.89
Mining	19.99
Power Generation	0.004
Recreation	0.06
Schedule 1	0.60
Water Supply Service	46.66
TOTAL	**364.09**

1.4.5. Groundwater quality

The median groundwater quality for selected parameters was calculated for each GUA, as shown in Table 8. Even though the groundwater quality will be discussed in more detail in the following sections, a short discussion is provided here. Approximately 2100 groundwater quality samples were collated from the available databases (e.g. GRIP and WMS). Major elements (pH, EC, Ca, Mg, Na, K, SO_4 Cl, NO_3 as N and F) were compared to the water quality guidelines for acceptable drinking water specified by the Department of Water and Sanitation, inclusive of three water quality classes. The most noticeable elements of concern for water consumption is nitrate (measured as nitrogen (N), with some exceedances observed for fluoride, and sodium.

According to Marais (1999), the single most important reason for groundwater sources in South Africa being declared unfit for drinking is nitrate levels exceeding 10 mg/l (as N). The main inputs of nitrate to groundwater in rural environments are derived from anthropogenic activities such as inappropriate on-site sanitation and wastewater treatment, improper sewage sludge, drying and disposal, and livestock concentration at watering points near boreholes. However, the extensive occurrence of nitrate in groundwater in uninhabited regions may suggest non-anthropogenic sources possibly related to evaporative enrichment of dry and wet deposition, biogenic point sources through N-fixing organisms, or to a geogenic origin (Tredoux and Talma, 2006). Several samples show major ion concentrations (i.e. Na and F) with elevated salts. This can mostly be related to evaporative concentration of elements in discharge areas or due to low recharge values as well as long residence times for selected samples. The occurrence of fluoride is primarily controlled by geology and climate. Therefore, there are no preventative measures under the given spatial limits of water supply to avoid contamination.

The spatial distribution of the collated (last analysed) Electrical Conductivity (EC) concentrations (in mS/m) is shown in Figure 14. While it may not reflect a specific point in time it does provide an overall indication of the salt loads for comparison purposes. The EC intervals is based on the DWAF (1996) domestic use water quality classification/guideline. Most notable hotspots occur in the Steilloop GUA as well as Lower Lephalala GUA, Upper Mogalakwena GUA, Hout GUA along the Brak River and the Mutale/Luvuvhu GUA.

Table 8. Median water quality for selected parameters (in mg/l) per GUA, compared to DWAF drinking water guidelines (red text exceeds Class III).

GUA	GUA	Parameter	pH	EC (mS/m)	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I			5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II			4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III			3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
Lephalala	A50-1	Median	7.8	143.0	738.2	90.5	38.0	170.1	2.8	25.7	175.9	0.6	1.6
		N	5	5	4	5	5	5	5	5	5	1	5
	A50-2	Median	8.1	127.0	993.7	72.0	48.7	137.8	2.9	39.4	157.8	115.1	1.2
		N	61	65	56	67	67	67	67	67	67	11	64
	A50-3	Median	8.1	125.2	952.5	69.3	58.5	103.2	9.0	30.5	107.0	48.9	1.0
		N	45	45	33	47	47	47	47	47	47	13	45
Upper Mogalakwena	A61-1	Median	7.8	37.5	133.8	28.2	11.5	34.7	1.3	11.2	16.8	0.9	0.3
		N	19	20	7	21	21	21	21	17	20	13	20
	A61-2	Median	8.1	58.0	469.5	51.8	19.0	24.2	1.2	12.1	21.3	-	0.4
		N	5	5	5	5	5	5	5	5	5	0	4
	A61-3	Median	8.1	106.7	865.8	60.0	69.6	60.3	2.0	30.2	75.3	76.0	0.3
		N	132	124	121	135	134	134	128	130	124	12	123
Middle- and Lower Mogalakwena	A62-1	Median	8.1	109.5	761.0	74.4	39.2	89.7	1.9	12.1	123.9	63.5	0.6
		N	130	143	131	153	152	153	150	136	153	21	147
	A62-2	Median	8.1	124.5	943.4	54.9	38.0	149.0	8.7	26.5	172.2	59.1	0.6
		N	143	137	144	155	155	154	154	155	155	11	148
	A62-3	Median	8.1	116.0	865.6	57.3	47.1	130.9	8.5	24.6	164.0	35.9	0.4
		N	155	158	149	170	171	171	171	169	170	18	150
	A63-1	Median	8.1	120.6	884.8	70.6	58.8	97.8	2.5	25.3	119.1	83.4	0.4
		N	127	128	123	140	139	140	137	127	141	15	132
Upper Sand	A71-1	Median	8.1	87.5	650.8	41.0	35.6	86.5	6.2	26.1	68.5	24.9	0.4
		N	178	180	167	204	201	203	203	198	204	32	179
	A71-2	Median	8.1	125.3	962.7	57.3	54.4	129.5	7.6	34.8	122.7	44.9	0.3
		N	156	143	136	164	165	164	164	150	166	29	142
	A71-3	Median	8.1	109.6	826.0	47.8	46.4	111.5	10.0	27.7	140.5	23.8	0.3
		N	320	322	347	389	387	386	385	384	389	39	287
Sandbrak and Lower Sand	A71-4	Median	7.7	110.0	541.5	66.1	45.0	99.1	2.8	30.1	109.0	34.7	0.5
		N	3	3	2	3	3	3	3	3	3	1	3
	A71-5	Median	8.2	177.5	1330.0	102.0	82.0	159.4	5.1	104.8	223.8	36.2	0.8
		N	4	4	3	4	4	4	4	4	4	1	4
Limpopo Tributaries	A63-3/71-3	Median	8.1	131.4	964.6	95.4	79.6	37.6	1.6	41.0	76.7	-	0.5
		N	2	2	2	2	2	2	2	2	2	0	2
Kolope	A50-4/A63-2	Median	7.4	102.0		75.6	60.9	69.2	10.1	16.9	74.5	81.4	0.2
		N	1	1	0	1	1	1	1	1	1	1	1
Nzhelele	A81-1	Median	7.8	54.7	409.9	29.6	25.3	30.4	0.7	7.9	34.6	3.1	0.2
		N	142	141	132	146	145	142	120	104	137	10	106
	A81-2	Median	8.0	177.0	1178.1	73.9	63.1	140.0	1.3	60.3	208.2	-	0.4
		N	15	15	14	15	15	15	15	15	15	0	15
Nwanedzi	A81-3	Median	7.8	70.0	485.9	18.3	20.2	54.9	1.5	16.8	57.0	16.6	0.2
		N	52	53	45	53	54	53	51	40	52	7	47
Levuvhu	A91-1	Median	8.0	56.3	453.7	42.0	29.2	23.7	1.0	7.3	29.4	10.9	0.2
		N	288	275	262	329	332	329	282	265	328	62	221
Mutale /Levuvhu	A91-2	Median	7.9	49.1	378.0	24.1	20.0	38.4	0.9	7.1	38.0	8.4	0.2
		N	228	239	213	257	254	251	227	179	257	28	174
Shingwidzi	B90-1	Median	8.1	121.1	939.6	67.8	59.6	103.1	2.2	14.3	102.4	71.5	0.4
		N	150	138	124	159	161	160	156	151	161	36	134

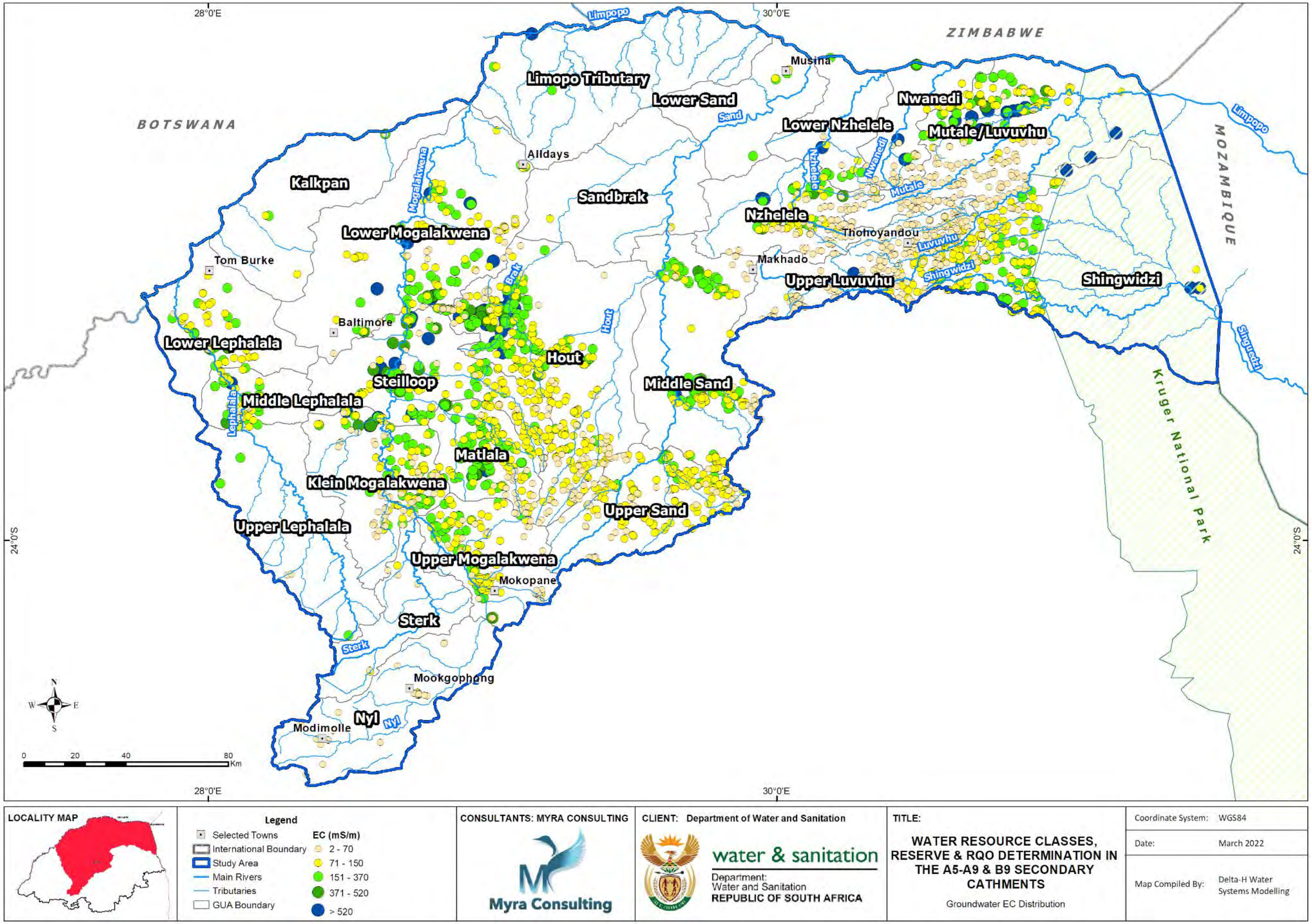


Figure 14. Spatial distribution of groundwater EC concentration (GRIP dataset).

2. GUA STATUS QUO ASSESSMENT

2.1. LEPHALALA RIVER

The upper Lephalala River is relatively undeveloped and travers's large wilderness areas. The runoff originates in the upper reaches, and most of the surface water use is found in these upper catchments, where the large number of farm dams supports a significant amount of irrigation. Lower down in the catchment irrigators make use of water from alluvial aquifers. The only other significant water use is the rural water use, and it is assumed that this is sourced from groundwater. Communities in the catchment are located in the lower reaches and they rely mainly on the groundwater resource. In this assessment four GUAs have been delineated for the Lephalala drainage area, namely A50-1 (Figure 16), A50-2 (Figure 17), A50-3 (Figure 18) and A50-4 (Figure 19). A summary of the borehole information for the region is shown in Table 9.

Table 9. Borehole information for the Lephalala drainage region.

Description	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Upper Lephalala	A50-1	N	355	214		2	174
		Mean	68.0	24.4		1.1	1.6
Middle Lephalala	A50-2	N	208	159	31	52	72
		Mean	51.1	18.2	60.3	0.9	2.6
Lower Lephalala	A50-3	N	455	404	60	73	154
		Mean	64.5	24.8	40.4	1.1	2.0
Kalkpan	A50-4/A63-2	N	768	641	1	1	149
		Mean	42.4	23.2	14.7	0.4	1.75

2.1.1. Groundwater recharge

The low and variable rainfall together with evaporation rates considerably exceeding rainfall result in a low expectation of natural recharge to groundwater over most of the area. As a result the recharge vary spatially from as high as 18 mm/a in the higher lying areas to less than 2 mm/a in the lower parts of the catchment. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 10.

Table 10. Recharge estimation (Lephalala).

Description	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Upper Lephalala	A50-1	A50A	654.1	298	11.35	8.28	42.16
		A50B	599.0	406	12.05	8.64	29.31
		A50C	593.0	362	10.36	7.40	24.96
		A50D	558.2	637	12.57	8.89	17.86
		A50E	517.0	629	10.95	7.63	13.61
		A50F	495.8	372	5.35	3.70	12.51
Middle Lephalala	A50-2	A50G	435.3	821	9.20	6.26	3.19
Lower Lephalala	A50-3	A50H	407.2	1945	15.11	9.91	2.56
Kalkpan	A50-4/A63-2	A50J	391.1	1255	8.84	5.91	4.09
		A63C	377.7	1323	8.14	5.32	4.54

2.1.2. Groundwater Use

The groundwater use for the Lephalala GUAs is summarised in Table 11. The present WARMS groundwater use data was compared to the 2015 Limpopo (WMA) North Reconciliation Strategy (LNRS) estimated 2020 use. The majority of groundwater use is lower down the catchment closer to the confluence of the Limpopo River (i.e, A50-3 and A50-40).

Table 11. Groundwater use (per annum) as registered per catchment for each Lephalala GUA.

GMA Description	GUA	Quat	WARMS: Use Mm³	LNRS 2020 Mm³
Upper Lephalala	A50-1	A50A	0.107	0.159
		A50B	0.115	0.199
		A50C	0.235	0.193
		A50D	0.108	0.303
		A50E	0.122	0.255
		A50F	0.136	0.106
Middle Lephalala	A50-2	A50G	1.290	3.120
Lower Lephalala	A50-3	A50H	11.552	3.786
Kalkpan	A50-4	A50J	4.254	1.009
	A50-4/A63-2	A63C	1.579	0.502

2.1.3. Groundwater quality

Regional water quality in the Upper Lephalala is subject to considerable variation due to the extensive use of groundwater, various lithologies and groundwater-surface water interaction. Groundwater samples indicate a variety of water types (e.g. Ca/Mg-HCO_3, Na-HCO_3 and Na-Cl) (Figure 15). A high percentage of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl and Ca/Mg-Cl type water present.

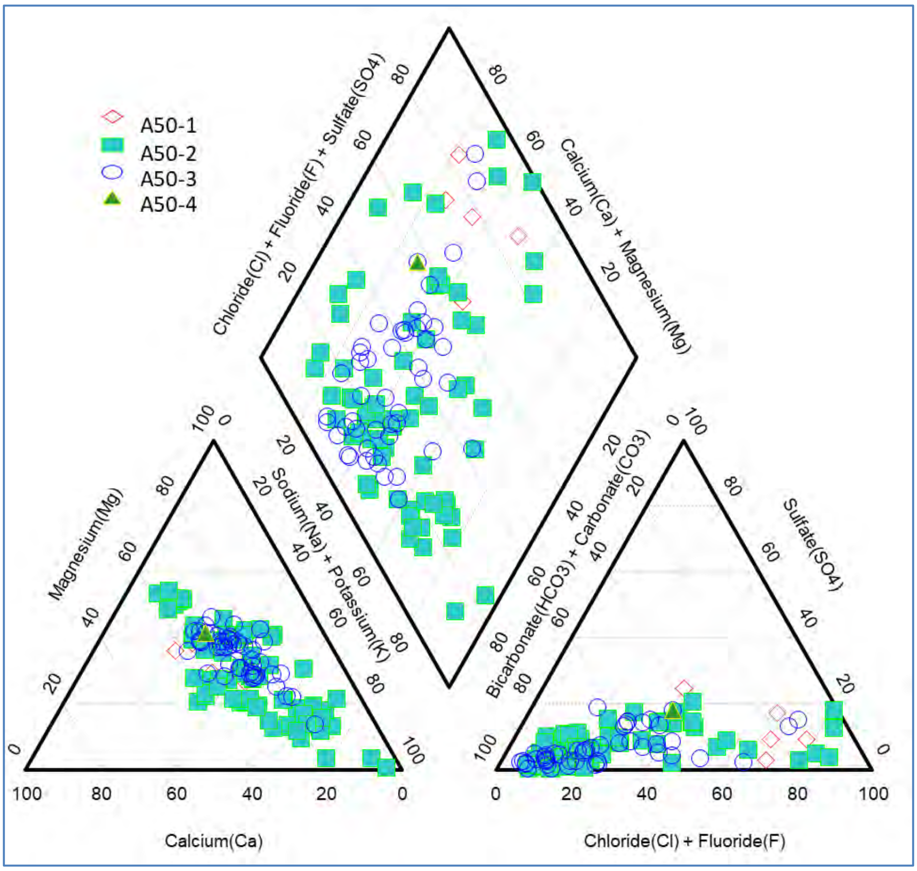


Figure 15 . Piper diagram for the Upper Lephalala drainage region.

Groundwater quality in the Lephalala is considered to be acceptable to marginal water quality. The most notable elements of concern include NO_3 as N and fluoride with average concentrations above the recommended drinking limit (Table 12).

Table 12. Groundwater quality for the Lephalala region (All units in mg/l, EC in mS/m) (red text exceeds Class III)

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A50-1	N	5	5	4	5	5	5	5	5	5	1	5
	Median	7.7	143	738	90.5	38.0	170.1	2.7	25.6	175.9	0.57	1.6
A50-2	N	61	65	56	67	67	67	67	67	67	11	64
	Median	8.0	127	993	72.0	48.7	137.7	2.9	39.4	157.76	115.1	1.2
A50-3	N	45	45	33	47	47	47	47	47	47	13	45
	Median	8.1	125	952	69.2	58.5	103.19	8.9	30.4	107.00	48.9	0.9
A50-4/A63-2	N	1	1	0	1	1	1	1	1	1	1	1
	Median	7.4	102	-	75.6	60.9	69.20	10.1	16.8	74.48	81.4	0.2

2.1.4. Groundwater contribution to baseflow

Effluent conditions are expected in the upper reaches while seasonal alternating effluent / influent conditions can occur along the lower reaches of the Lephalala River. It is expected that surface-groundwater exchange between the alluvium and the Lephalala River occurs on a far shorter time scale in comparison to the interaction between the regional and alluvial aquifers. Regional aquifers of the lower catchment show marginal gradients towards the Lephalala River course and exchange water with the river only indirectly via the alluvial deposits. However, in the upper reaches of the catchment a higher gradient towards the River course is observed and where the alluvium is lacking the surface-groundwater exchange is directly from the regional aquifer to the River. Comparison of groundwater contribution to baseflow estimates for the Lephalala drainage region are summarised in Table 13.

Table 13. Groundwater contribution to baseflow estimates.

Description	GUA	Quat	Hughes Mm^3/a	Shultz Mm^3/a	Pitmann Mm^3/a	GRA II (WR2005) Mm^3/a	Maint. Low flow Mm^3/a
Upper Lephalala	A50-1	A50A	11.19	3.48	8.97	4.22	3.01
		A50B	11.81	3.87	10.72	5.44	3.07
		A50C	10.27	3.42	9.45	4.82	1.25
		A50D	6.71	0.36	2.87	2.12	2.98
		A50E	4.86	0.33	2.58	1.88	0.42
		A50F	2.39	0.18	1.49	1.04	0.23
Middle Lephalala	A50-2	A50G	-	-	-	-	0.02
Lower Lephalala	A50-3	A50H	-	-	-	-	0.04
Kalkpan	A50-4/A63-2	A50J	-	-	-	-	0.72
		A63C	-	-	-	-	0.84

2.1.5. Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 14, Table 15, Table 16 and Table 17.

Table 14. Summary information for GUA: A50-1.

GUA	Upper Lephalala A50-1
Description	The main aquifer types include are the fractured Waterberg Group aquifers (Predominately) and Intergranular Alluvial aquifers. The Waterberg formation, located from Welgevoden northwest to Berglus-Onskuld-Indenburg area, is associated with steep topography and shows generally poor capability to produce huge amounts of groundwater. Recharge to the aquifer, often discharged on the steep slopes, provides baseflow to the rivers. A weathered zone aquifer is found only where deep weathering occurs and provides groundwater storage that feeds the underlying fractured aquifer. Alluvial aquifers are recharged during periods of high stream-flows as well as during the rainfall season. The alluvium appears to be better developed along the lower reaches of the Lephalala River with a thickness of approximately 5 m. The GUA lower lying areas is characterised by rocks from the Karoo supergroup and Bushveld Complex, forming typical fractured aquifer systems. The groundwater use is associated with irrigation, schedule 1, recreational and livestock watering use.
Catchments	A50A,B,C,D,E,F
Map	

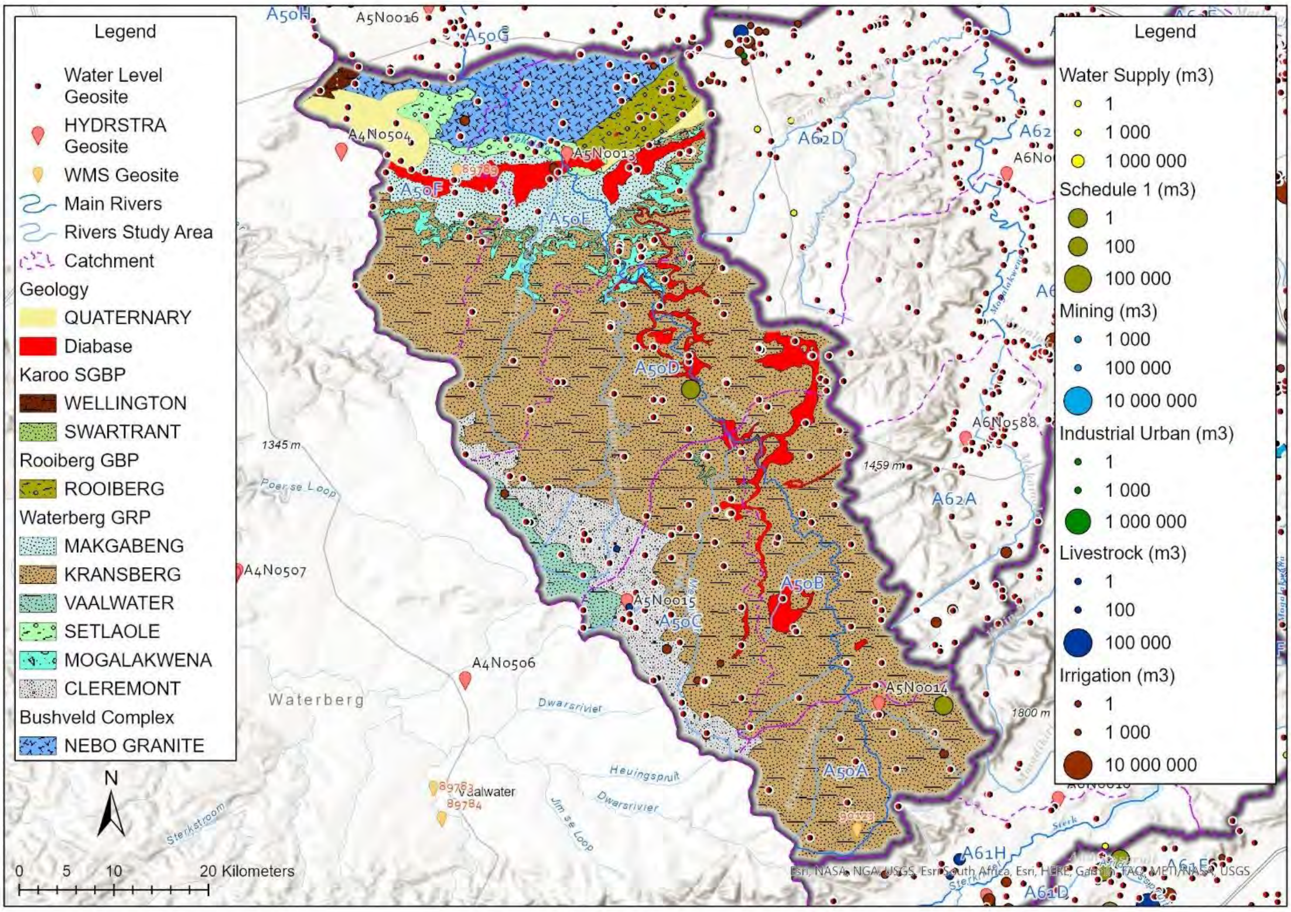


Figure 16 Map showing the GUA A50-1 with geology, groundwater use and geo-sites.

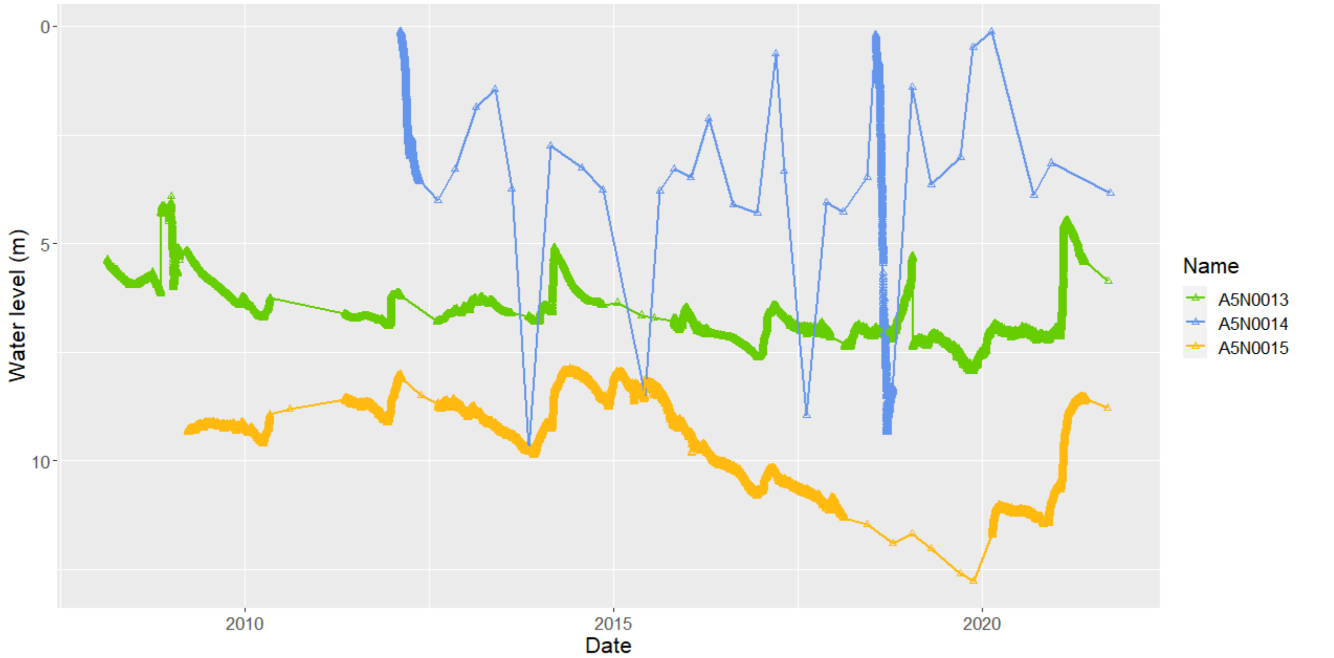
Water Use Schemes (after DWAF, 2015, Recon Study)

Scheme Name	Village/Settlement	Catchment
Modimolle LM Farms Supply	Farms Modimolle LM	A50B
Rietbokvalley Supply	Rietbokvalley	A50A, B

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A5N0013	2008/02/21	2021/09/17	3425	7.95	3.92	6.56	4.03
A5N0014	2007/10/26	2021/09/29	2801	10.45	0.12	3.72	10.33
A5N0015	2009/03/26	2021/09/14	3672	12.76	7.88	9.47	4.88

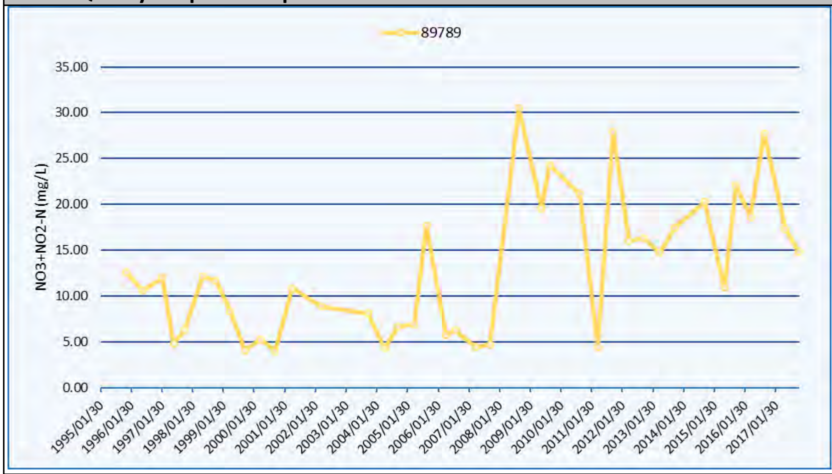
Water Level Graphs

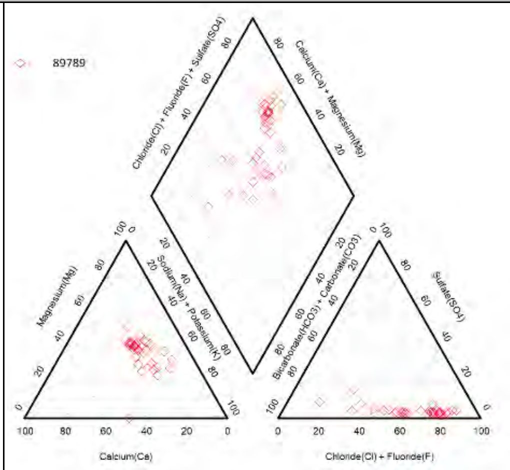


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89789	1995/11/30	2017/10/30	39	30.50	3.96	11.67	Yes

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the three stations show a fluctuation of between 4 and 10 m. A significant response in water levels can be attributes to groundwater recharge events is observed for boreholes in the upper Lephalala catchment (A50A), while a more subtle response is observed at stations lower down the catchment (A50C and A50E). The overall trend indicates a slight lowering of groundwater levels.

The nitrate concentration graph show significant fluctuations in observations, however an overall increasing trend is observed since 2008. The groundwater signature is dominated by Cl-anion water facies, indicating mineralised (evolved) groundwater. Only one long term DWS groundwater quality monitoring station is active for the GUA.

Table 15. Summary information for GUA: A50-2.

GUA	Middle Lephalala A50-2
Description	The main aquifer types include intergranular and fractured aquifer system from the Bushveld Complex. The middle reaches of the Lephalala drainage area is underlain by Ingenious rock that comprise of deeper fractured (i.e. secondary) aquifers overlain by a weathered horizon of variable thickness. Thick, weathered aquifer zones are expected in areas where the bedrock has been subjected to intense fracturing. The Lephalala River section is characterised by intergranular Alluvial aquifers. Alluvial aquifers are recharged during periods of high stream-flows as well as during the rainfall season. The alluvium appears to be better developed along the lower reaches of the Lephalala River with a thickness of approximately 5 m. Groundwater use is associated with Irrigation, industrial (urban) and recreations use.
Catchments	A50G
Map	

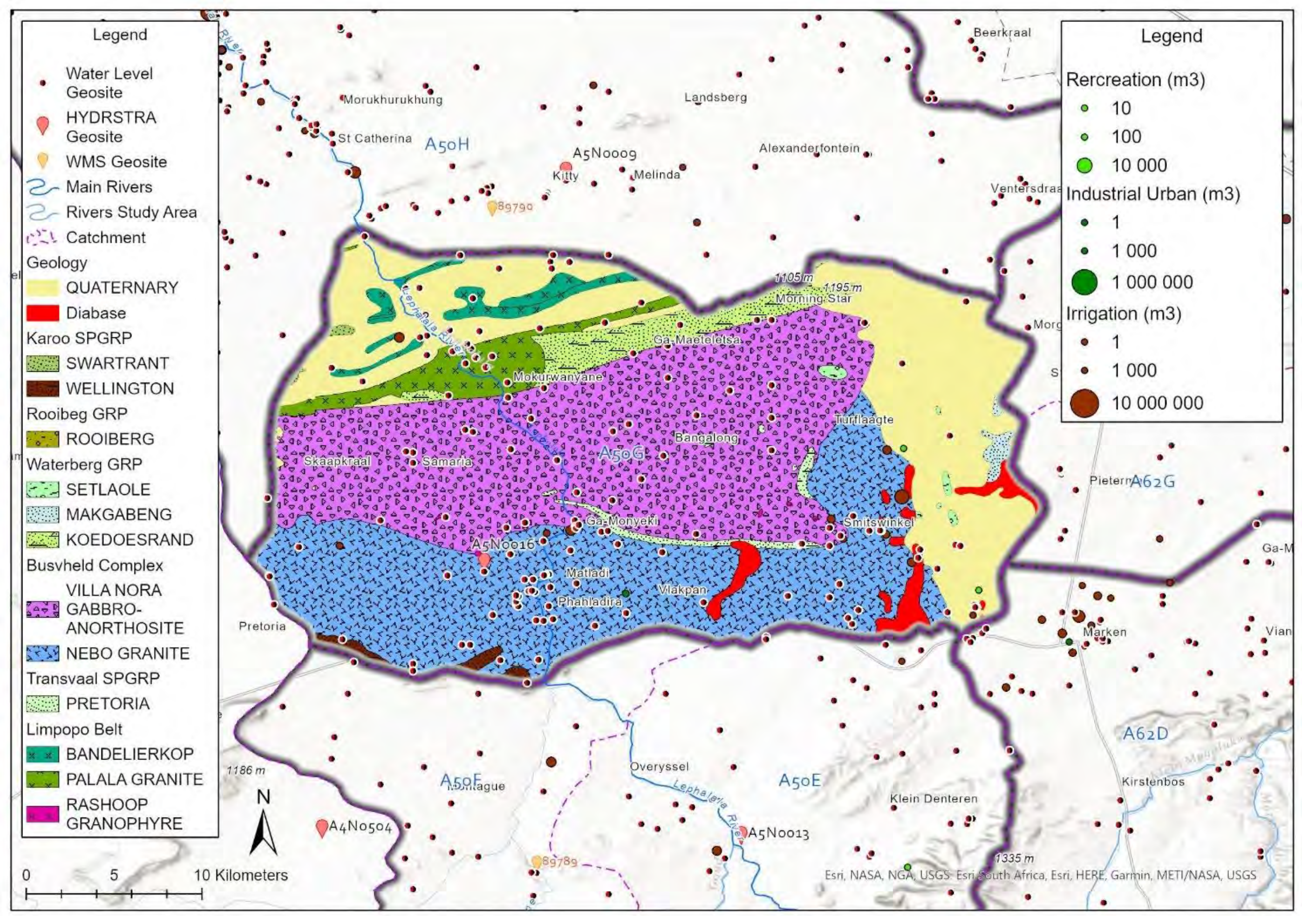


Figure 17 Map showing GUA A50-2 with geology, groundwater use and geo-sites.

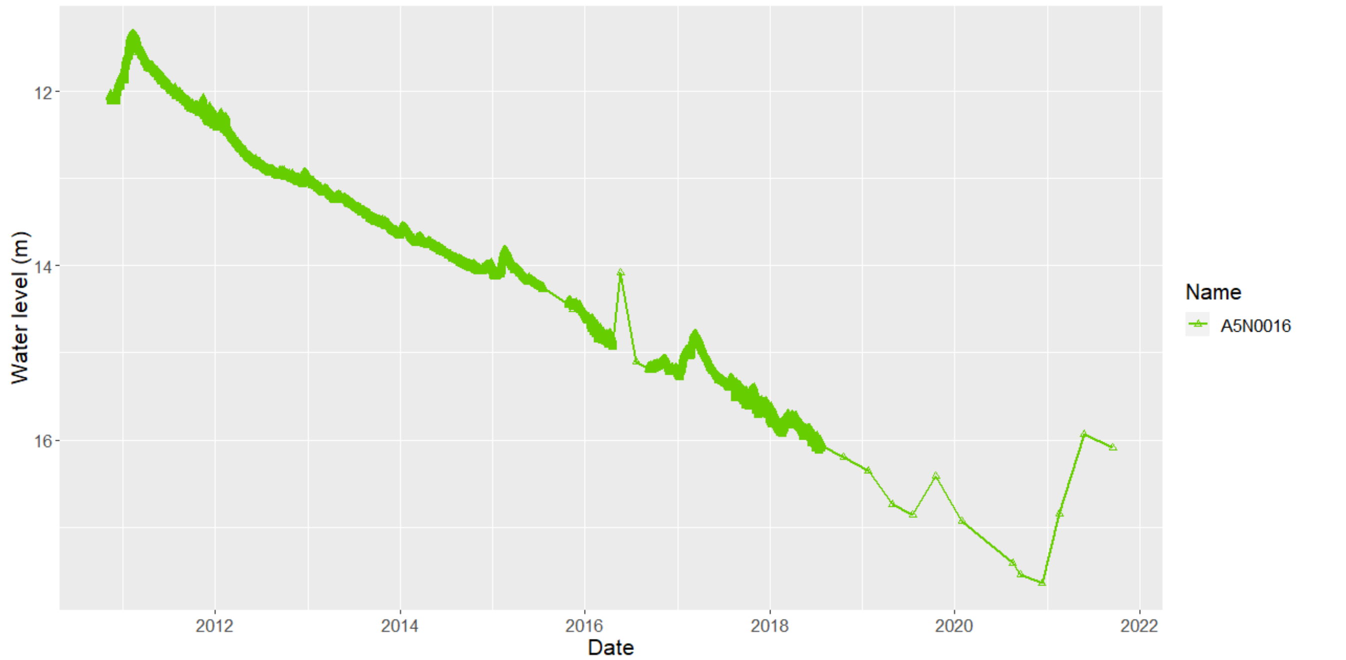
Water Use Schemes (after DWAF, 2015, Recon Study)

Scheme Name	**Village/Settlement**	**Catchment**
Mmaletswai RWS	Dipompopong, Ditaung, Ga-Maeteletsa, Ga-Mocheko, Hlagalakwena, Keletse le Mma, Kiti, Mmaletswai, Mokuruanyane Abbottspoort, Mokuruanyane Martinique, Mokuruanyane Neckar, Motsweding, Reabetswe	A50G, H
Ga-Phahladira Cluster	Ga-Phahladira Settlement	A50G

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A5N0016	2010/11/11	2021/09/17	4634	17.64	11.34	13.80	6.31

Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)
none
Water Quality Graph and Piper Plot
None
Comments
One water level monitoring station is located within the GUA (i.e. A5N0016). The observed hydrograph shows a fluctuation of between 11 and 18 m. The groundwater levels observed during 2010 was approx. 12 mbgl with the latest recording at 16 mbgl during 2021.

Table 16. Summary information for GUA: A50-3.

GUA	Lower Lephalala A50-3
Description	The main aquifer types include the intergranular and fractured aquifer system from the Basement Complex and Intergranular Alluvial aquifers. The lower reaches of the Lephalala drainage area, from Melinda-Alexanderfontein area north to Tom-Burke-Limpopo River, is underlain by basement aquifers that comprise of deeper fractured (i.e. secondary) aquifers overlain by a weathered horizon of variable thickness. Thick, weathered aquifer zones are expected in areas where the bedrock has been subjected to intense fracturing. Recharge to the aquifer, often discharged on the steep slopes, provides baseflow to the rivers. A weathered zone aquifer is found only where deep weathering occurs and provides groundwater storage that feeds the underlying fractured aquifer. Alluvial aquifers are recharged during periods of high stream-flows as well as during the rainfall season. The groundwater use is associated with irrigation, industrial, recreation and schedule I water use.
Catchments	A50H
Map	

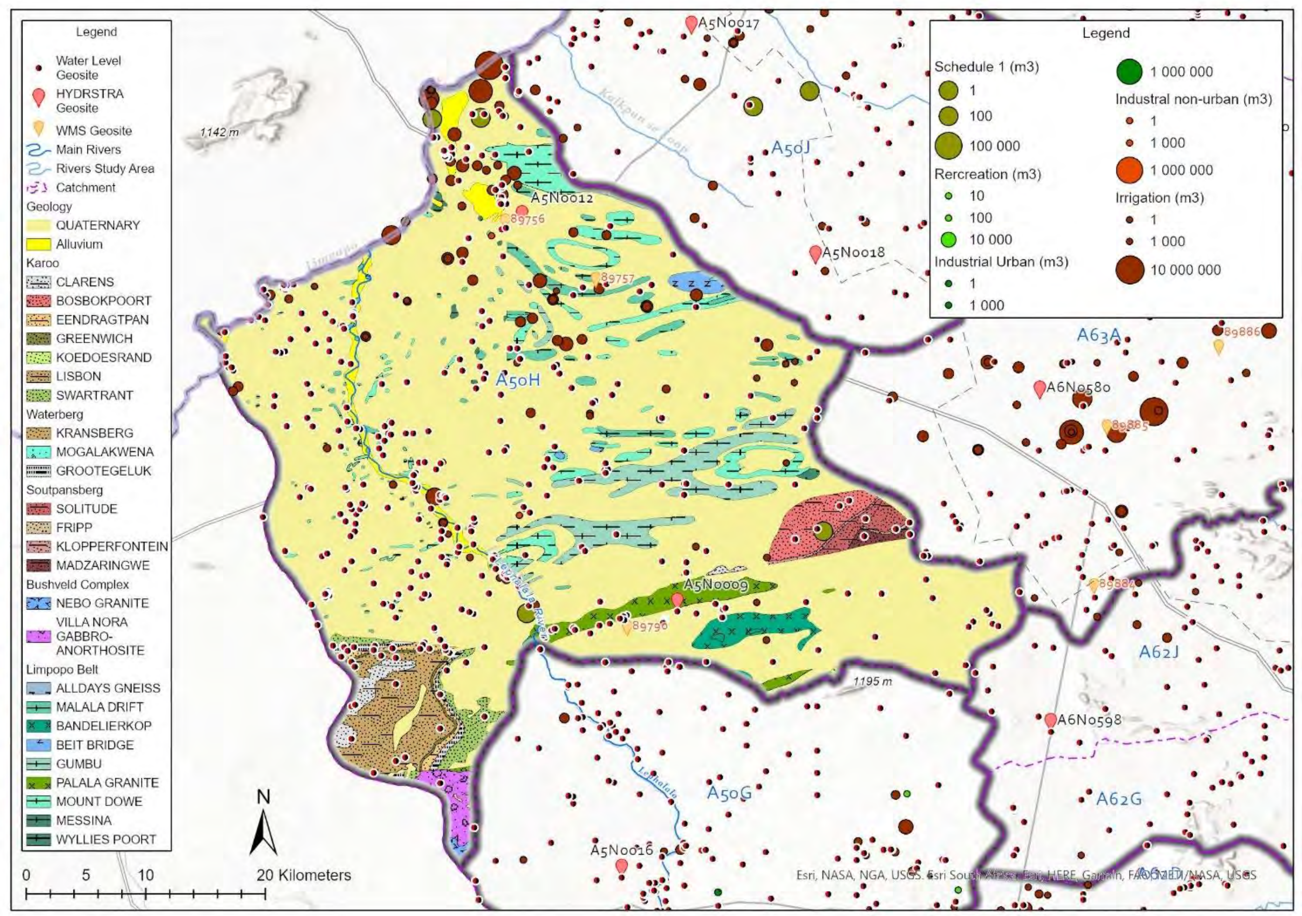


Figure 18 Map showing GUA A50-3 with geology, groundwater use and geo-sites.

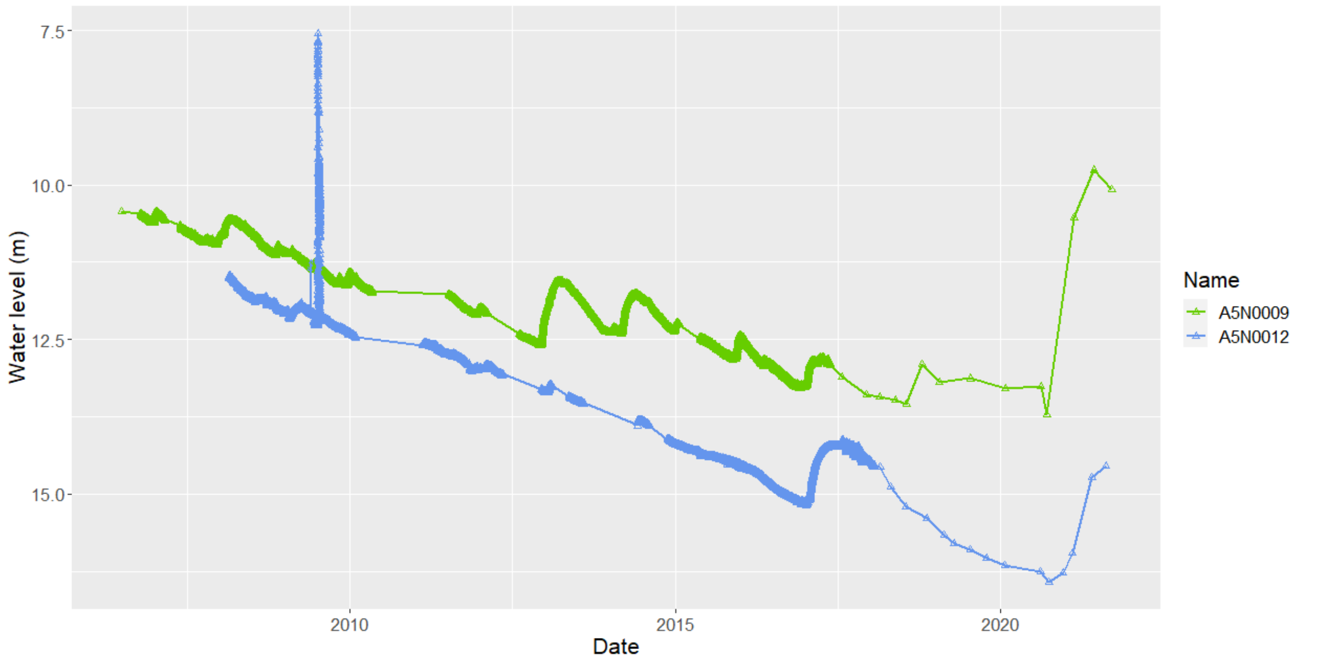
Water Use Schemes (after DWAF, 2015, Recon Study)

Scheme Name	Village/Settlement	Catchment
Ga-Seleka RWS	Botshabelo, Ga – Seleka, Kauletsi, Lebu, Madibaneng, Moong, Monwe, Mothlasedi, Sefithlogo, Tom Burke, and Tshelamfake	A50H
Marnitz Supply	Marnitz	A50H
Witpoort RWS	Botsalanong, Kgobagodimo, Kopanong, Lerupurupurung, Letlora, Mongalo, Segale, Senoela, Thabo Mbeki, Tlapa le Borethe and the Witpoort CBD	A50H
Tom Burke Supply	Tom Burke	A50H
Mmaletswai RWS	Dipompopong, Ditaung, Ga-Maeteletsa, Ga-Mocheko, Hlagalakwena, Keletse le Mma, Kiti, Mmaletswai, Mokuruanyane Abbottspoort, Mokuruanyane Martinique, Mokuruanyane Neckar, Motsweding, Reabetswe	A50, H

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A5N0009	2006/06/28	2021/09/17	2867	13.72	9.76	11.84	3.96
A5N0012	2008/02/20	2021/08/18	2525	16.42	7.55	13.43	8.87

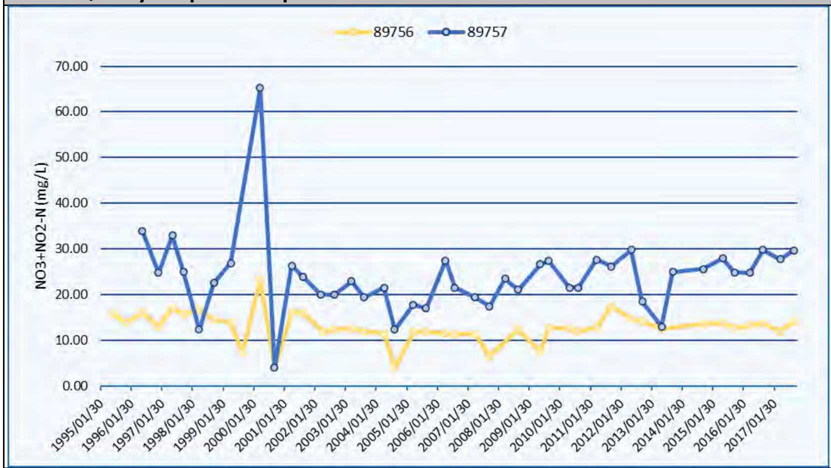
Water Level Graphs

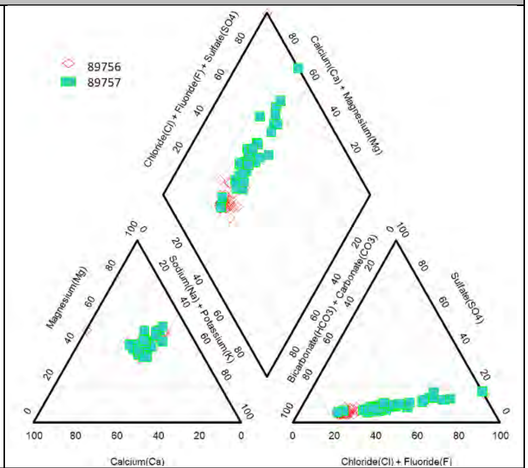


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89756	1995/06/28	2017/09/20	42	23.24	3.97	12.80	Yes
89757	1996/06/11	2017/09/20	40	65.25	3.97	24.32	Yes

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the two stations show a fluctuation of between 4 and 9m. A subtle response in water levels as a result of groundwater recharge is observed for boreholes in the Lower Lephalala catchment (A50H). Apart from the seasonal fluctuations in groundwater levels, the overall trend suggest a lowering of the water table. However, a distinct recharge period in the last year or so years have resulted in an increase of the water levels.

The nitrate concentration graph show a strong fluctuation in observations, especially during beginning of 2000, however an overall slight increase in nitrate concentrations are observed at station 89757. The groundwater signature is dominated by both HCO_3 and Cl-anion water facies, indicating freshly recharged groundwater undergoing mineralisation.

Table 17. Summary information for GUA: A50-4/A63-2.

GUA	Kalkpan A50-4/A63-2
Description	The GUA is underlain by basement aquifers, from Orleans-California area north to the Limpopo River, that comprise of deeper fractured (i.e. secondary) aquifers overlain by a weathered horizon of variable thickness. Thick, weathered aquifer zones are expected in areas where the bedrock has been subjected to intense fracturing. Recharge to the aquifer, often discharged on the steep slopes, provides baseflow to the rivers. A weathered zone aquifer is found only where deep weathering occurs and provides groundwater storage that feeds the underlying fractured aquifer. Alluvial aquifers are recharged during periods of high stream-flows as well as during the rainfall season. Borehole yields generally range between 0.1 – 2 l/s. Hydrogeological findings by Bush (1989) in the Swartwater area revealed that 66 % of boreholes surveyed had yields below 1 l/s. Vegter (2000) indicated that only 19 % of boreholes recorded yielded more than 1 l/s in an area east of Beauty. The groundwater use is associated with irrigation and schedule I use.
Catchments	A50J
Map	

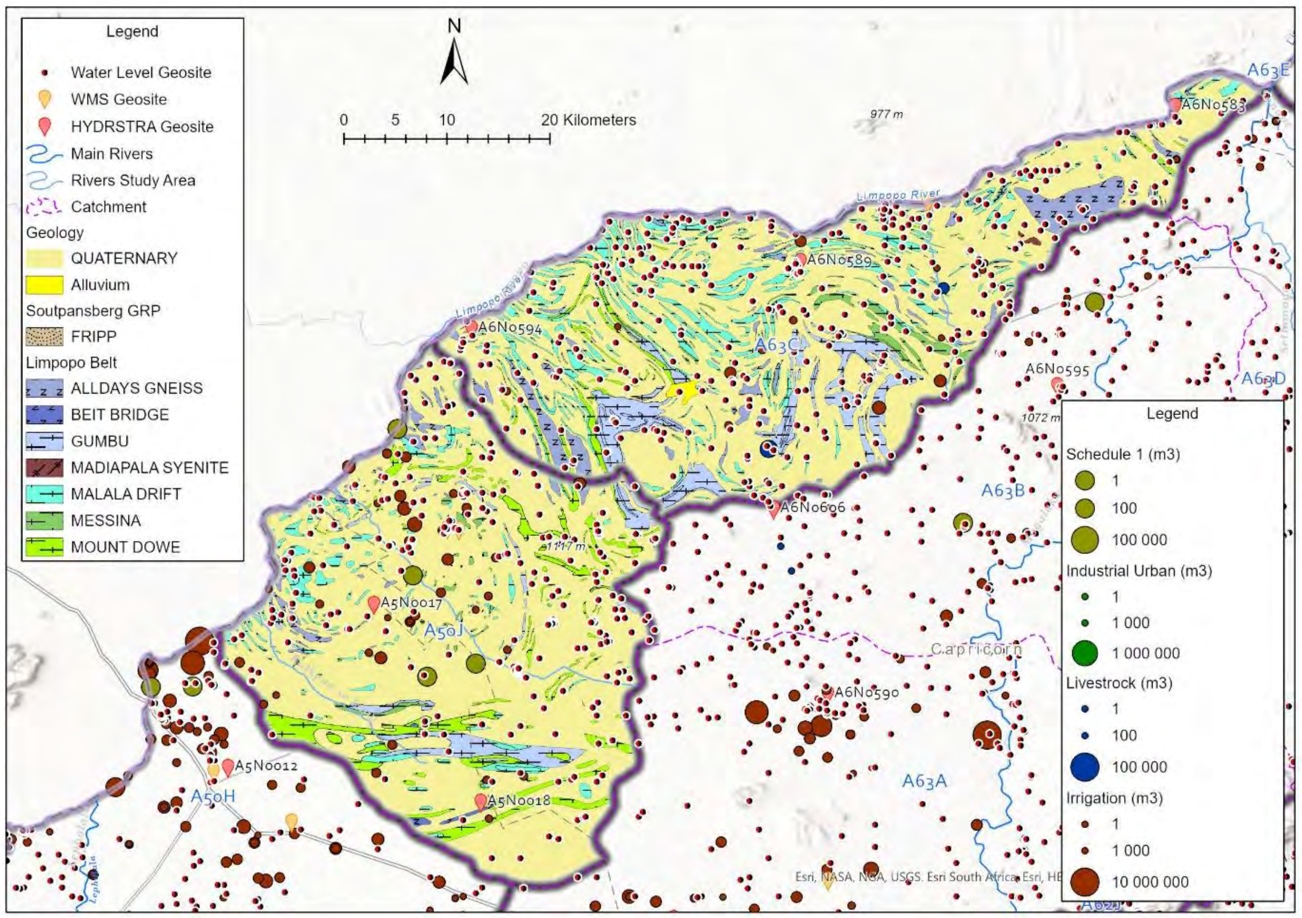


Figure 19 Map showing GUA A50-4 with geology, groundwater use and geo-sites.

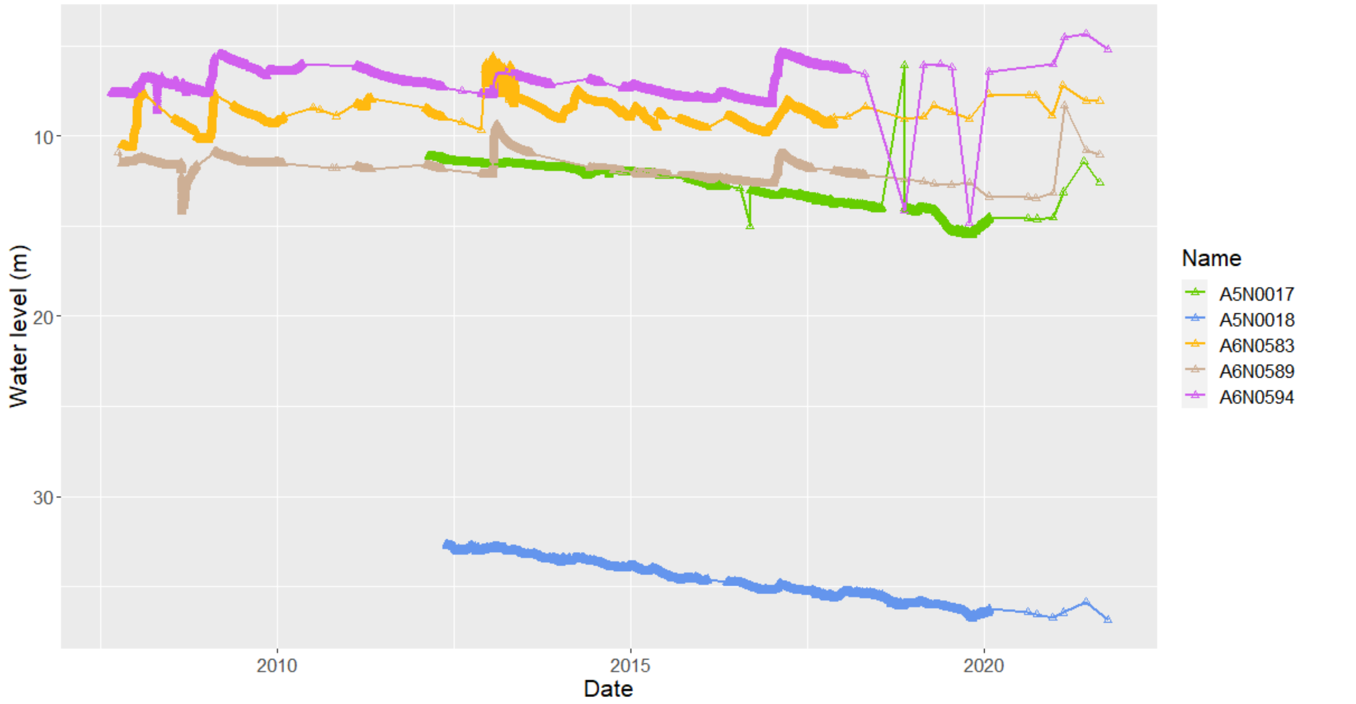
Water Use Schemes (after DWAF, 2015, Recon Study)

Scheme Name	Village/Settlement	Catchment
Zwartwater Supply	Zwartwater	A50J
Maasstroom Supply	Maasstroom	A63C

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A5N0017	2012/02/23	2021/08/18	3996	15.53	11.09	12.78	4.44
A5N0018	2012/05/23	2021/09/30	4011	36.84	32.65	34.59	4.19
A6N0583	2007/10/22	2021/08/19	3718	10.67	5.56	8.74	5.11
A6N0589	2007/10/04	2021/08/19	3457	14.19	8.31	11.75	5.88
A6N0594	2007/08/29	2021/09/30	2920	14.81	4.34	6.95	3.00

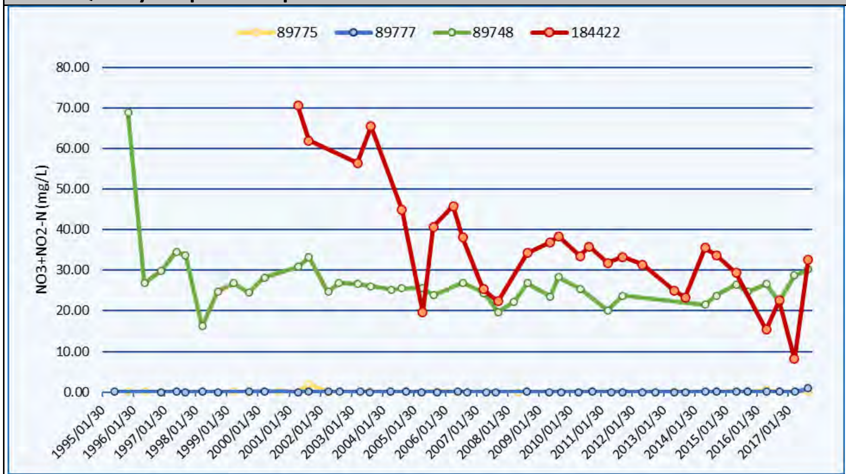
Water Level Graphs

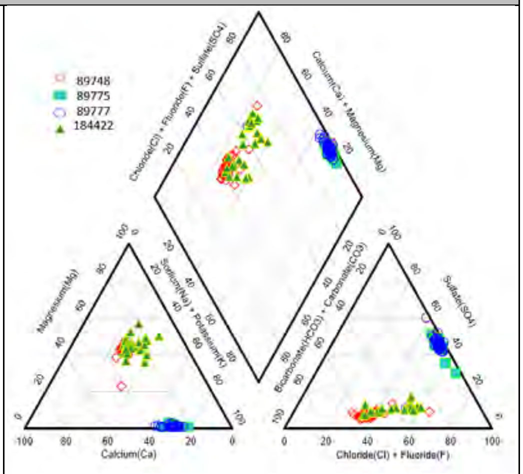


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89748	1995/11/29	2017/09/19	38	68.89	16.18	25.84	Yes
184422	2001/05/10	2017/09/19	28	70.56	8.12	33.62	Yes
89748	1995/11/29	2017/09/19	38	68.89	16.18	25.84	Yes
184422	2001/05/10	2017/09/19	28	70.56	8.12	33.62	Yes

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the two stations show a fluctuation of approx. 4 m. No clear response from groundwater recharge events or surface-groundwater interaction is observed for stations A5N0017 and A5N0018, showing limited fluctuations overtime. However, stations A6N0583, A6N0589 and A6N0594 indicate strong seasonal and recharge events. The overall trend indicates a decrease in groundwater levels overtime.

The nitrate concentration graph shows significant fluctuations in observations; however, an overall decreasing trend is observed. The nitrate concentrations are highly elevated for stations 89748 and 184422. Stations 89775 and 89777 is well below any target values. The groundwater signature is dominated by both HCO_3 and Cl-SO_4 anion water facies, indicating freshly recharged groundwater undergoing mineralisation with potential anthropogenic impacts or reflection from the river systems.

2.2. NYL AND UPPER MOGALAKWENA

The Mogalakwena River is known as the Nyl River in its upper reaches. The Nyl River originates north of Bela-Bela at an altitude of about 1 500 m. At Mokopane the name changes and it becomes the Mogalakwena River (DWA, 2003a). The river flows northwards and joins the Limpopo River at an altitude of about 625 m. The upper Mogalakwena catchment is densely populated. As a result groundwater resource development occurred mainly to allow irrigation and to meet domestic and urban water needs. Several Platinum mines were developed and utilise local groundwater resources and limited surface water resources. Numerous well-fields were developed to meet consumers' needs. Two Subterranean government water control areas occur within the upper Mogalakwena drainage region namely, Nyl River Valley and Dorpsrivier. The groundwater resource had been and still is extensively utilised in the region for municipal, irrigation and mining purposes. The Nylsvley wetland in the upper reaches of the Mogalakwena River catchment is home to a large number of bird species and is a registered RAMSAR site. The 16,000-ha Nyl River Flood-plain that stretches over 70 km from Modimolle to Mokopane forms part of South Africa's largest flood-plain.

In this assessment three GUAs have been delineated for the Upper Mogalakwena drainage area, namely A61-1 (Figure 21), A61-2 (Figure 22) and A61-3 (Figure 23). A summary of the borehole information for the region is shown in Table 18. According to the pumping tests conducted in the Upper Mogalakwena, there are vast differences in the transmissivities of the groundwater UA's. Most notably is the high transmissivities observed in the Dorps River Valley A61-3 GUA. A number of large yielding aquifers including the Chuniespoort Group dolomites occur within the Upper Mogalakwena drainage region.

Table 18. Borehole information for the Upper Mogalakwena drainage region.

Description	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Nyl River Valley	A61-1	N	673	530	16	16	218
		Mean	56.6	16.0	22.2	0.95	2.1
Sterk	A61-2	N	252	152	4	6	119
		Mean	57.1	16.5	6.6	0.25	1.8
Upper Mogalakwena	A61-3	N	535	554	121	58	168
		Mean	59.5	16.3	65.9	0.6	4.3

2.2.1. Groundwater recharge

Mean annual precipitation varies from 600 mm in the Nyl River valley and Mokopane to about 450 mm north of Doorndraai dam (**Error! Reference source not found.**). The Upper Mogalakwena ranges from 12 mm/a to more than 20 mm/a. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 19.

Table 19. Recharge estimation.

Description	GUA	Quat	MAP (mm)	Area (km^2)	GRA II (Wet) Mm^3	GRA II (Dry) Mm^3	Vegter (1995) Mean Mm^3
Nyl River Valley	A61-1	A61A	629.1	381	11.86	8.57	27.75
		A61B	629.1	362	10.89	7.86	24.86
		A61C	632.7	587	16.44	11.83	18.57
		A61D	630.2	456	12.37	8.91	22.27
		A61E	624.6	547	10.57	7.57	19.76
Sterk	A61-2	A61H	636.0	585	18.94	13.74	29.66
		A61J	630.7	818	23.46	17.01	24.97
Upper Mogalakwena	A61-3	A61F	597.2	789	22.40	16.07	14.08
		A61G	584.8	927	20.80	14.82	14.28

2.2.1. Groundwater Use

The groundwater use for each of the GUA associated with the Nyl and Upper Mogalakwena River system is summarised in Table 20. The present WARMS groundwater use data was compared to the 2015 Limpopo (WMA) North Reconciliation Strategy (LNRS) estimated 2020 use.

Table 20. Groundwater use (per annum) as registered per catchment for each GUA

GMA Description	GUA	Quat	WARMS: Use Mm^3	LNRS 2020 Mm^3
Nyl River Valley	A61-1	A61A	1.384	2.650
		A61B	0.274	0.644
		A61C	2.449	3.219
		A61D	2.930	3.705
		A61E	8.137	9.401
Sterk	A61-2	A61H	2.785	2.616
		A61J	1.564	1.777
Upper Mogalakwena	A61-3	A61F	3.222	5.082

2.2.2. Regional groundwater quality

Regional water quality in the Nyl and Upper Mogalakwena is subject to considerable variation due to the extensive use of groundwater, various lithologies and groundwater-surface water interaction. Groundwater samples indicate a variety of water types (e.g. Ca/Mg-HCO_3, Na-HCO_3 and Na-Cl) (Figure 20). A high percentage of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl and Ca/Mg-Cl type water present.

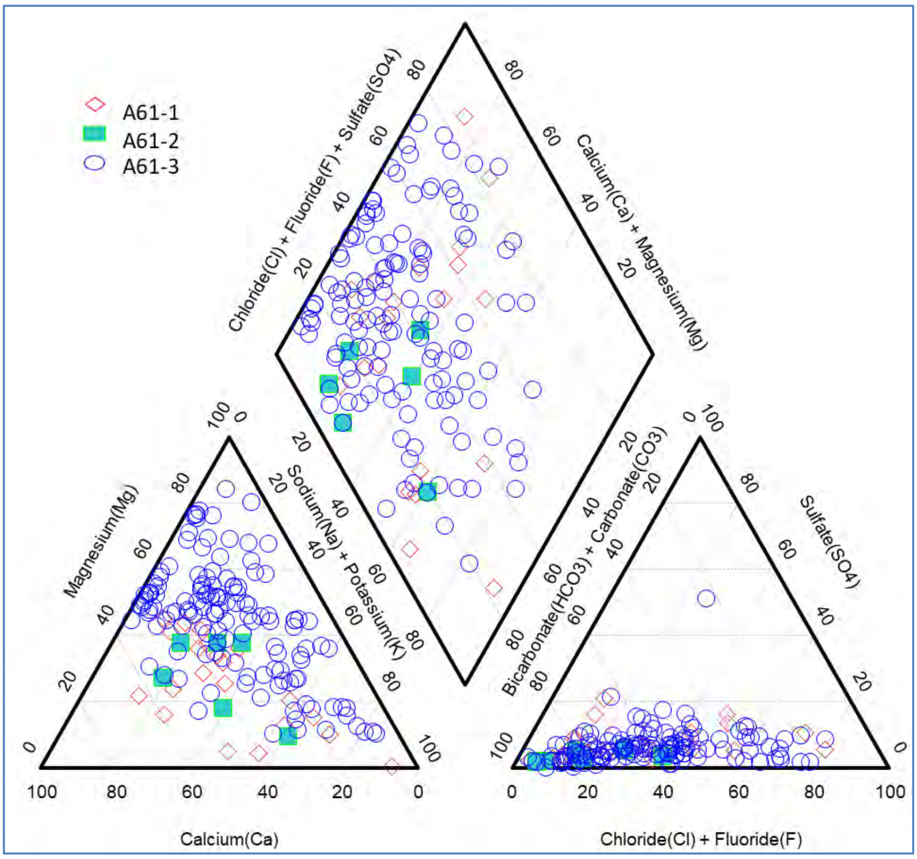


Figure 20. Piper diagram for the Nyl and Upper Mogalakwena drainage region.

Groundwater quality in the Nyl and Upper Mogalakwena is considered to be acceptable to marginal water quality. The most notable elements of concern include NO_3 as N with average concentrations above the recommended drinking limit (Table 21).

Table 21. Groundwater quality for the Nyl and Upper Mogalakwena region (All units in mg/l, EC in mS/m) (red text exceeds Class III)

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A61-1	N	19	20	7	21	21	21	21	17	20	13	20
	Median	7.8	37	133	28.1	11.5	34.7	1.3	11.2	16.7	0.9	0.31
A61-2	N	5	5	5	5	5	5	5	5	5	0	4
	Median	8.1	58	469	51.8	19.0	24.2	1.2	12.1	21.2	-	0.39
A61-3	N	132	124	121	135	134	134	12	130	124	12	123
	Median	8.1	106	865	59.9	69.6	60.3	1.9	30.2	75.3	75.9	0.80

2.2.3. Groundwater contribution to baseflow

The Upper Mogalakwena River stretch can be classified into a continuous interaction bedrock system (Waterberg Group) in the upper reaches, while the middle (Nyl River Valley) and low reaches (Dorps River Valley) can be classified as a porous media (alluvial sediments). The Nyl river valley can be regarded as a gaining river while in the lower reaches seasonal alternating effluent / influent conditions can be experienced.

Apart from exceptionally wet periods, flow in the river is sustained mainly by groundwater. Groundwater is generally toward the main River channel; however, intermittency implies local inversions from effluent to influent conditions by secondary permeability variations in the underlying lithology. Numerous seasonal and some perennial springs occur in the dolomitic formations, which contribute significantly, to the baseflow component of the Dorps River (A61G). However, some springs occurring in the lower Dorps River catchment have been effected by the abstraction from boreholes. Comparison of groundwater contribution to baseflow estimates for the Upper Mogalakwena drainage region are summarised in Table 22.

Table 22. Groundwater contribution to baseflow estimates.

Description	GUA	Quat	Hughes Mm^3/a	Shultz Mm^3/a	Pitmann Mm^3/a	GRA II (WR2005) Mm^3/a	Maint. Lowflow Mm^3/a
Nyl River Valley	A61-1	A61A	6.98	1.80	6.48	3.77	0.89
		A61B	5.84	1.20	5.43	2.83	0.50
		A61C	8.31	1.11	7.63	3.37	0.54
		A61D	6.54	1.11	5.47	3.08	1.27
		A61E	7.30	1.11	6.56	3.25	0.61
Sterk	A61-2	A61H	11.99	6.12	10.76	6.83	1.72
		A61J	15.95	7.74	14.97	9.15	2.28
Upper Mogalakwena	A61-3	A61F	6.51	2.64	6.15	5.16	1.57
		A61G	7.17	2.97	7.05	4.87	1.69

2.2.4. Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 23, Table 24 and Table 25.

Table 23. Summary information for GUA: A61-1.

GUA	Nyl River Valley A61-1
Description	The GUA is characterised by the Waterberg Plateau (mountainous region) from the Waterberg Group, located from Modimolle to Rooipoort area, comprising of sedimentary and metamorphic rocks, with associated elevation up to 1500 mamsl. The Waterberg formation (Upper Nyl River Valley) is associated with steep topography and shows generally poor capability to produce huge amounts of groundwater. A weathered zone aquifer is found only where deep weathering occurs and provides groundwater storage that feeds the underlying fractured aquifer. Flat laying areas are associated with the Springbok flats consisting mostly of extrusive rocks. The Nyl Flats form a large alluvial system following the Nyl (small) River. Alluvial aquifers are recharged during periods of high stream-flows as well as during the rainfall season. The total alluvial thickness varies from 10 to 24 m and is used in conjunction with the underlying weathered and fractured bedrock aquifers. Due to its limited extent and saturated thickness these aquifers are also vulnerable to over-abstraction during periods of drought when there is little or no recharge. Higher recharge rates are associated with the Nyl Flats' alluvial system, being a intergranular aquifer system, relative to the fracture aquifers from the Waterberg system. Borehole yields generally range between 0.1 – > 5 l/s. The groundwater use is associated with irrigation, water service supply, schedule I, mining, industrial and livestock watering uses. A large number of villages (schemes) are associated with the GUA.
Catchments	A61A,B,C,D,E
Map	

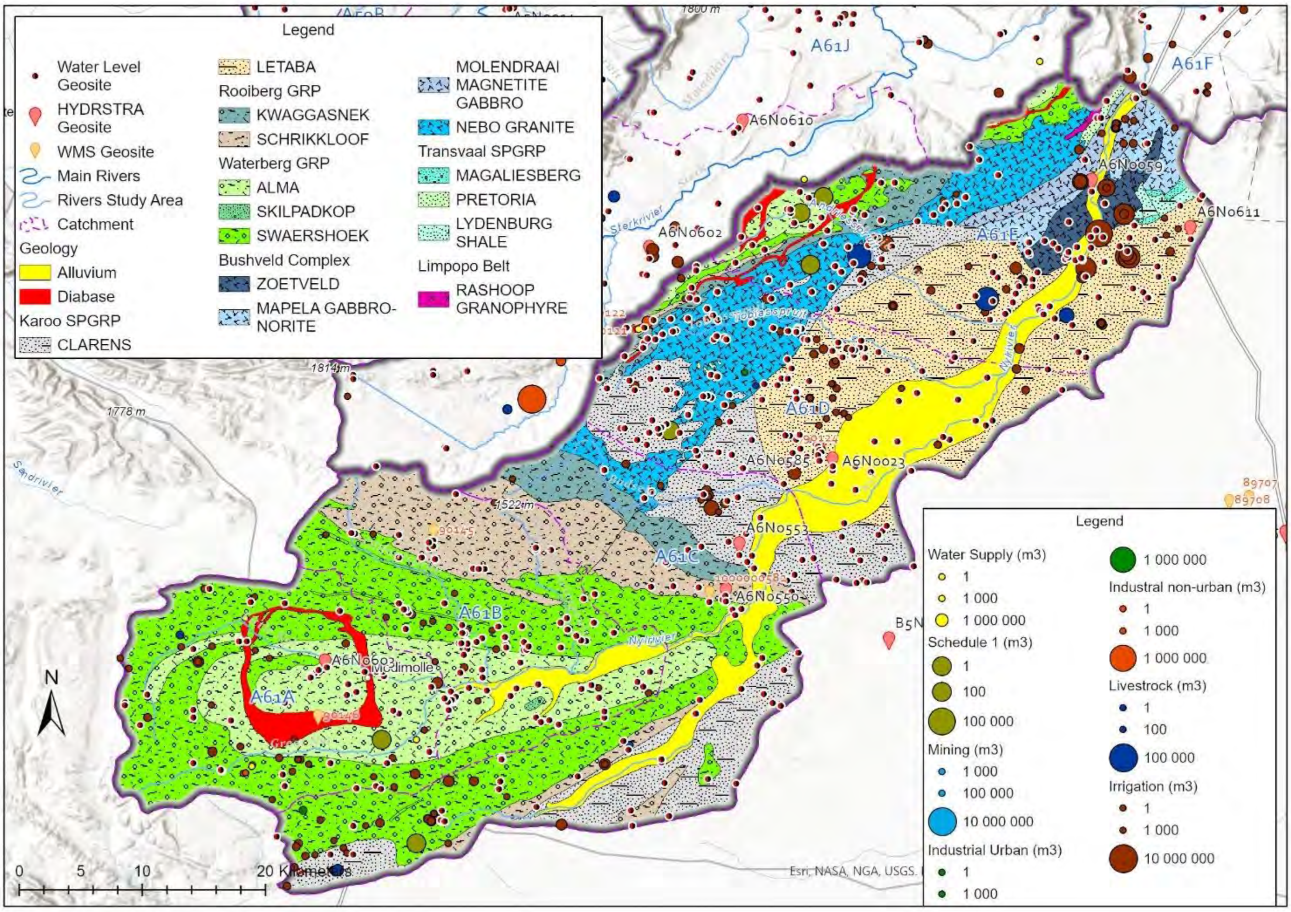


Figure 21 Map showing GUA A61-1 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

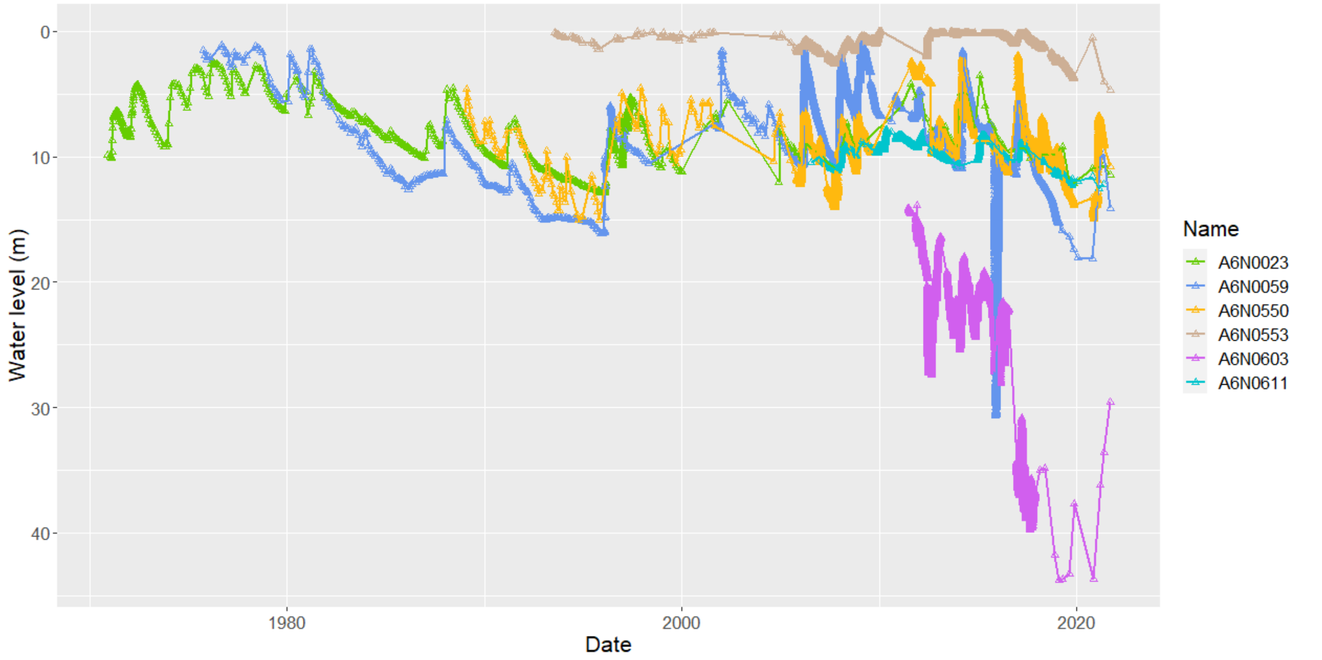
Scheme Name	**Village/Settlement**	**Catchment**
Bakenberg RWS	Bakenberg Basogadi, Bakenberg Kwanaite, Bakenberg Matlaba, Bakenberg Mautjana, Bakenberg Mmotong, Bakenberg Mothwathwase, Basterspad, Bohwidi, Buffelhoek, Claremont, Dikgokgopeng, Diphichi, Galakwenastroom, Ga-Masipa, Good Hope, Harmansdal, Jakkalskuil, Kabeane, Kaditshwene, Kgopeng, Kromkloof, Lesodi, Leyden, Lusaka Ngoru, Mabuladihlare 1,Makekeng, Malapila, Mamatlakala, Marulaneng, Matebeleng, Mphelelo, Nelly, Paulos, Pudiyakgopa, Raadslid, Ramosesane, Rantlakane, Sepharane, Skilpadskraal,Skrikfontein A, Skrikfontein B, Taolome, Van Wykspan, Vlakfontein, Vlakfontein 2, Wydhoek and Good Hope East	A61G,J, A62A,B,C,F

Mapela RWS	Danisane, Ditlotswane, Ga-Chokoe, Ga-Magongoa, Ga-Mokaba, Ga-Molekana, Ga-Pila Sterkwater, Ga-Tshaba, Hans, Kgobudi, Kwakwalata, Lelaka, Maala Parekisi, Mabuela, Mabusela, Mabusela Sandsloot, Machikiri, Magope, Malokongskop, Masahleng, Masenya, Masoge, Matlou, Matopa, Mesopotania,, Millenium Park, Mmahlogo, Mmalepeteke, Phafola, Ramorulane, Rooiwal, Seema, Sekgoboko Sekuruwe, Skimming, Tshamahansi, Witrivier, Fothane, Mohlotlo Ga-Malebana, Mohlotlo Ga-Puka	A61F,G,A62B,F , A71B
Modimolle Urban RWS	Modimolle (previously called Nylstroom), the outlying informal settlement area of Phagameng, the rural areas of Diflymachineng, Kokanja Retirement Village and Resort	A61A,B
Mogalakwena LM Farms Supply	Farms Mogalakwena LM	A61E
Mogwadi Wurthsdorp GWS	Matima, Ga-Madikana, Koniggratz, Mogwadi, Mohodi, Wurthsdorp	A61E, A71E, A71G, A72A
Mokopane RWS	Madiba, Madiba East, Mzumbana North, Mzumbana South, Maribashoop/Oorlogsfontein plots, Masodi, Madiba, Madiba East, Mzumbana North, Mzumbana South, Maribashoop/Oorlogsfontein plots, Masodi, and Sekgakgapeng	A61E,F,G,H,J
Moletje South GWS	Boetse, Diana, Ga-Kgasha, Ga-Madiba, Ga-Mangou, GaMatlapa, Glen Roy, Jupiter, Mandela Park, Manyapye, Mapateng, Matlaleng, Maune, Mohlonong, Montwane 1, Montwane 2, Moshate, Naledi, Ngopane, Sebora, Sefahlane, Segoahleng, Sepanapudi, Utjane, Chebeng, Doornspruit, Ga-Mapangula, Makweya, Newlands, Pax College, Sengatane, Setotolwane College, Vaalkop 1 and Vaalkop 3 Venus and Waterplaats	A61F,G,A62E,F , A71E, F
Mookgophong RWS	Mookgopong (Naboomspruit), Mookgopong Phomolong, Phomolong Squatter Settlement and Rietbokvalley	A61C,D
Weenen Supply	Weenen	A61F

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A6N0023	1970/11/24	2021/09/20	513	12.86	2.52	8.05	10.34
A6N0059	1975/09/29	2021/09/20	15128	30.64	0.30	8.13	30.34
A6N0550	1989/01/06	2021/09/16	11515	15.06	1.96	8.78	13.10
A6N0553	1993/07/20	2021/09/16	3698	4.71	0.00	0.90	4.71
A6N0585	2007/01/30	2021/09/20	4059	55.71	12.01	19.26	43.70
A6N0603	2011/06/22	2021/09/16	14416	43.74	13.84	23.65	29.90
A6N0611	2006/07/18	2021/05/25	4125	12.56	7.82	9.72	4.74

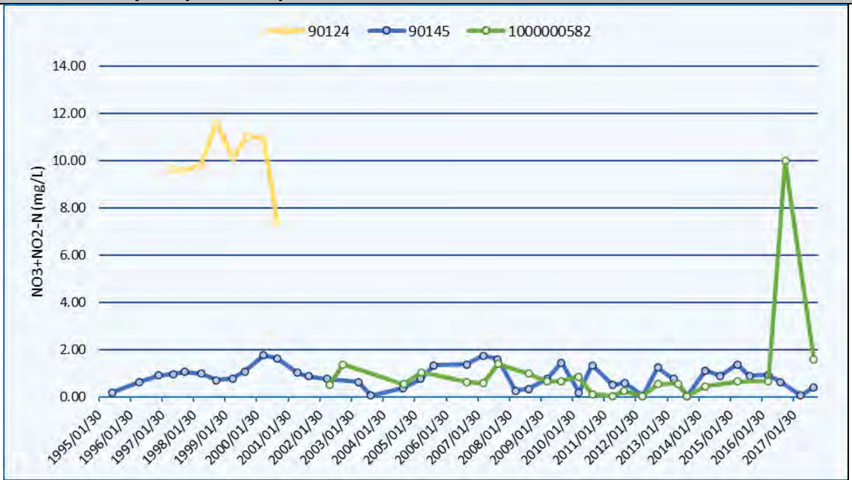
Water Level Graphs

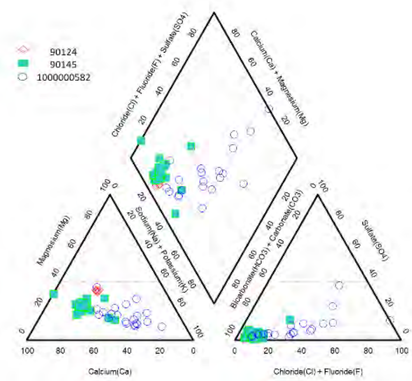


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
90124	1997/06/05	2000/09/20	8	11.61	7.46	9.99	Yes
90145	1995/07/07	2017/09/19	41	1.77	0.03	0.82	No
1000000582	2002/05/22	2017/09/19	21	10.00	0.03	0.62	No

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the three stations show a fluctuation of between 4 and 30 m. Since the high recharge event during 1997 a slight decrease in groundwater levels is observed. Station A6N0603 show a less pronounced recharge effect with a strong decreasing trend. A larger number (relative to the GUA) of registered groundwater users is observed in close approximation of station A6N0603. There are two main interrelated factors which control the general trend of groundwater-level fluctuations in the area, namely recharge and abstraction. A well-identified seasonal water-level fluctuation is observed over most stations.

The nitrate concentration graph show some fluctuation however is generally at low levels. Station 90124 shows the highest level of nitrate values, however recordings have ceased since 2001. The groundwater signature is dominated by both HCO_3 water facies, indicating freshly recharged groundwater that had limited time for mineralisation to occur.

Table 24. Summary information for GUA: A61-2.

GUA	Sterk A61-2
Description	The GUA is characterised by the Waterberg Plateau (mountainous region) from the Waterberg Group, from Paardeplaats northeast to Koelmansrus and north to Leyden areas, comprising of sedimentary and metamorphic rocks, with associated elevation up to 1800 mamsl. A weathered zone aquifer is found only where deep weathering occurs and provides groundwater storage that feeds the underlying fractured aquifer. Rocks form the Bushveld Complex and Limpopo Belt is found in the far northeaster areas of the GUA. The groundwater use is associated with irrigation, livestock watering, industrial and water supply uses.
Catchments	A61H,J
Map	

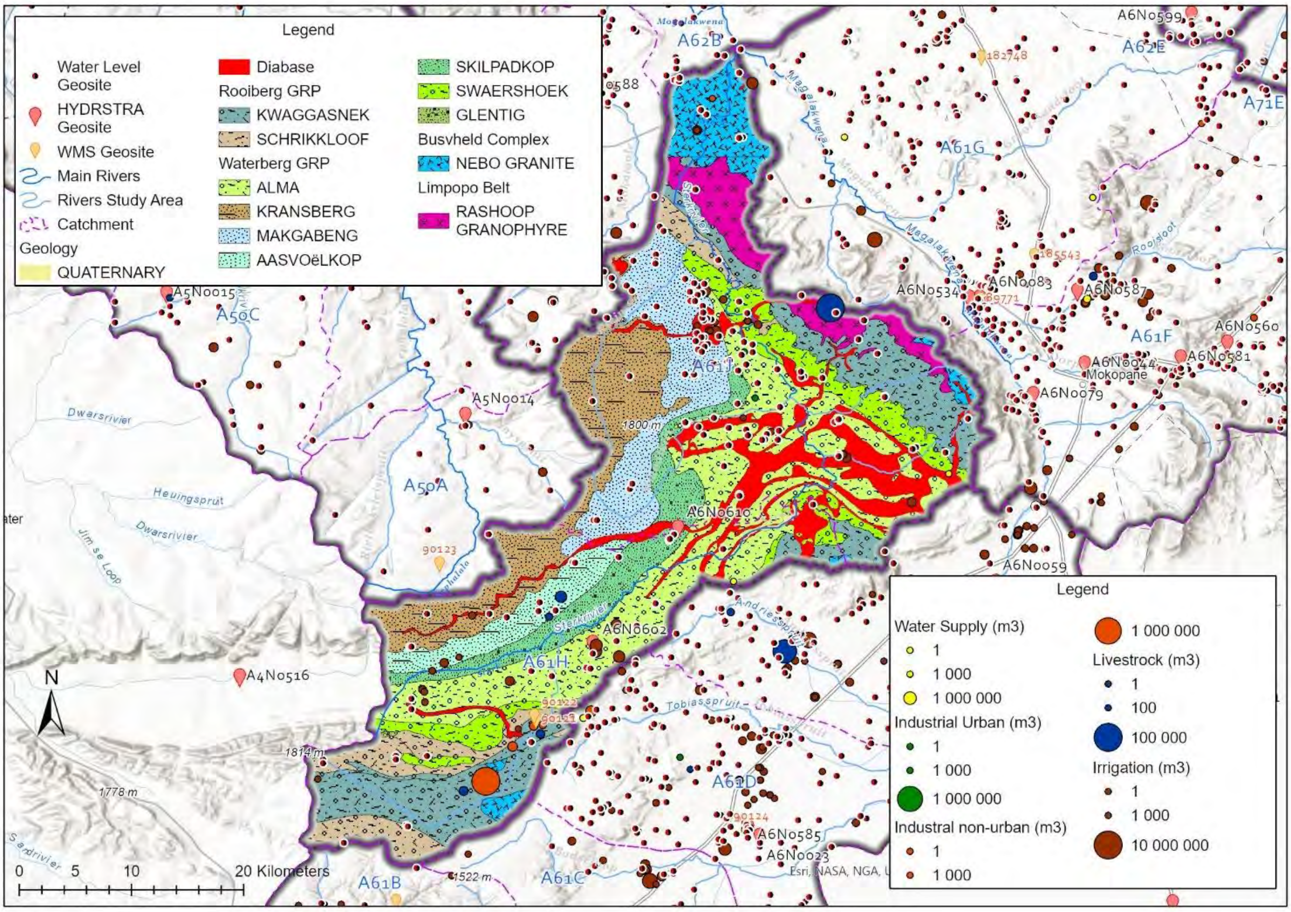


Figure 22 Map showing GUA A61-2 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

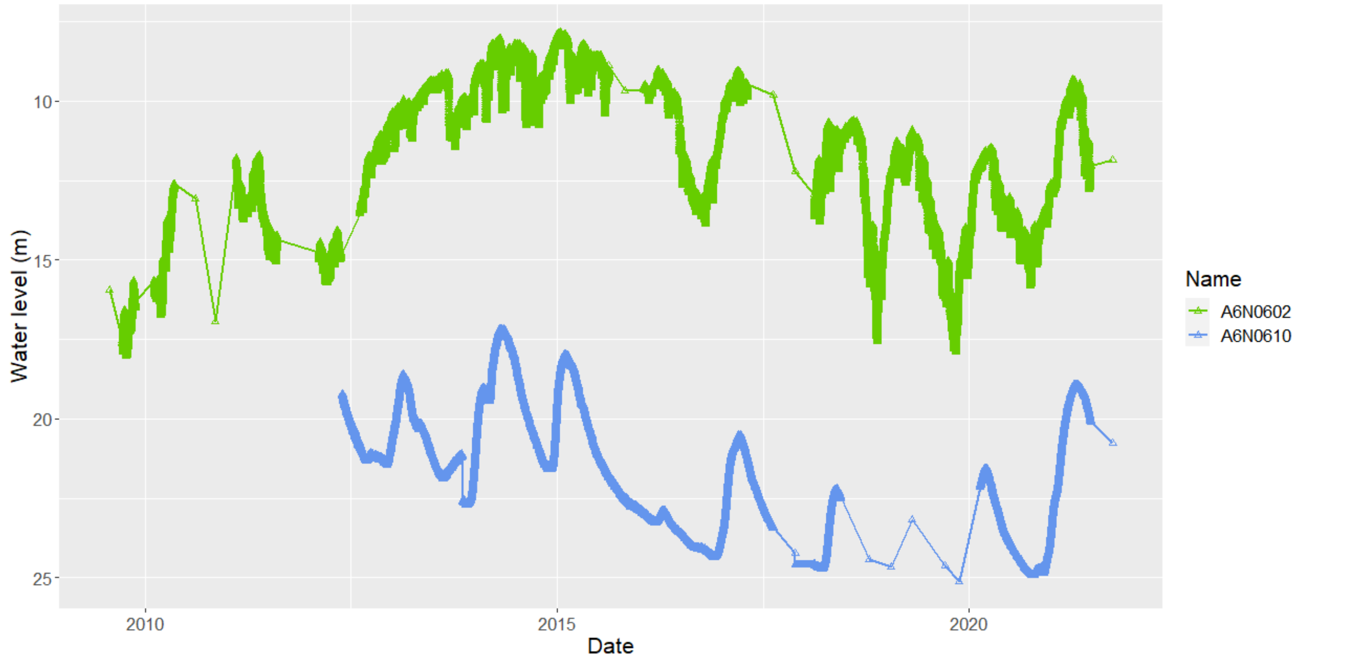
Scheme Name	Village/Settlement	Catchment
Bakenberg RWS	Bakenberg Basogadi, Bakenberg Kwanaite, Bakenberg Matlaba, Bakenberg Mautjana, Bakenberg Mmotong, Bakenberg Mothwathwase, Basterspad, Bohwidi, Buffelhoek, Claremont, Dikgokgopeng, Diphichi, Galakwenastroom, Ga-Masipa, Good Hope, Harmansdal, Jakkalskuil, Kabeane, Kaditshwene, Kgopeng, Kromkloof, Lesodi, Leyden, Lusaka Ngoru, Mabuladihlare 1,Makekeng, Malapila, Mamatlakala, Marulaneng, Matebeleng, Mphelelo, Nelly, Paulos, Pudiyakgopa, Raadslid, Ramosesane, Rantlakane, Sepharane, Skilpadskraal,Skrikfontein A, Skrikfontein B, Taolome, Van Wykspan, Vlakfontein, Vlakfontein 2, Wydhoek and Good Hope East	A61G, A61J, A62A, A62B, A62C, A62F
Mokopane RWS	Madiba, Madiba East, Mzumbana North, Mzumbana South, Maribashoop/Oorlogsfontein plots, Masodi, Madiba, Madiba East, Mzumbana North, Mzumbana South, Maribashoop/Oorlogsfontein plots, Masodi, and Sekgakgapeng	A61E, A61F, A61G, A61H, A61J

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)

A6N0602	2009/07/28	2021/09/29	9612	18.03	7.83	11.68	10.20
A6N0610	2012/05/24	2021/09/29	9025	25.11	17.15	21.12	7.96

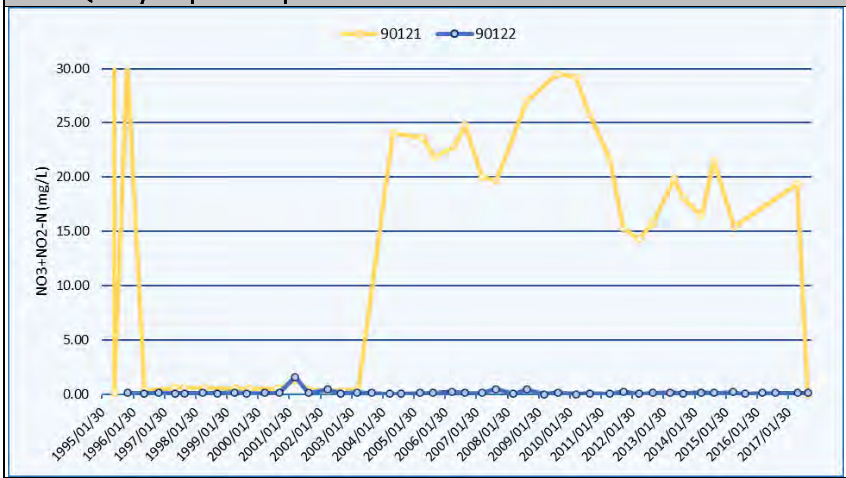
Water Level Graphs

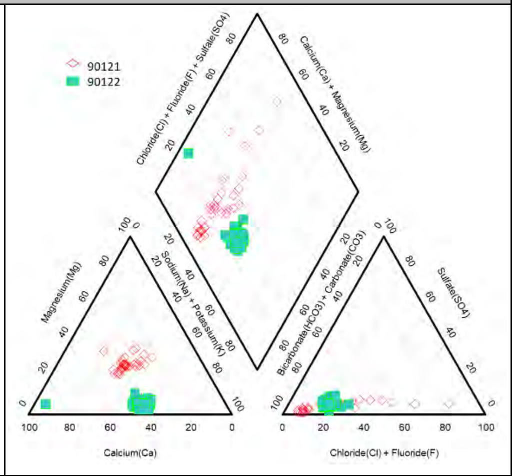


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
90121	1995/06/21	2017/09/14	37	99.51	0.05	16.42	Yes
90122	1995/11/27	2017/09/14	37	1.60	0.01	0.12	No

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the two stations show a fluctuation of between 8 and 10 m. A significant response in water levels as a result of seasonal fluctuations and recharge events are observed for the monitoring boreholes. Station A6N0602 shows an overall increase in groundwater levels, especially from 2013 to 2015.

The nitrate concentration graph (of station 90121) show significant fluctuations in observations. Station 90122 show low levels of nitrate concentrations. The groundwater signature is dominated by HCO_3 anion water facies, indicating freshly recharged groundwater.

Table 25. Summary information for GUA: A61-3.

GUA	Upper Mogalakwena A61-3
Description	The GUA is characterised by the Waterberg Plateau (mountainous region) from the Bushveld, Basement complex and Transvaal Supergroup comprising of ingenuous, sedimentary, dolomitic and metamorphic rocks, with associated elevation up to 1500 mamsl. Fractured rocks of the Bushveld complex owe their groundwater potential largely to fracturing. Its groundwater potential is generally good with water occurring in deeply (up to 55 m in places) weathered and fractured basins occurring in these mafic rocks. A weathered zone aquifer is found only where deep weathering occurs and provides groundwater storage that feeds the underlying fractured aquifer. Alluvial aquifers are recharged during periods of high stream-flows as well as during the rainfall season. The total alluvial thickness varies from 10 to 24 m and is used in conjunction with the underlying weathered and fractured bedrock aquifers. Due to its limited extent and saturated thickness these aquifers are also vulnerable to over-abstraction during periods of drought when there is little or no recharge. Higher recharge rates are characterised with the alluvial system, being a intergranular aquifer system, and karst aquifer, relative to the fracture aquifers from the Waterberg group system. Borehole yields generally range between 0.1 – > 5 l/s however are much larger within the karts aquifer system (>5l/s). The karst aquifer system is used for water supply to Mokopane and surrounding water users. The groundwater use is associated with irrigation, livestock watering, water supply, schedule I, mining and industrial uses. A large number of village (schemes) occur within the GUA.
Catchments	A61H,J
Map	

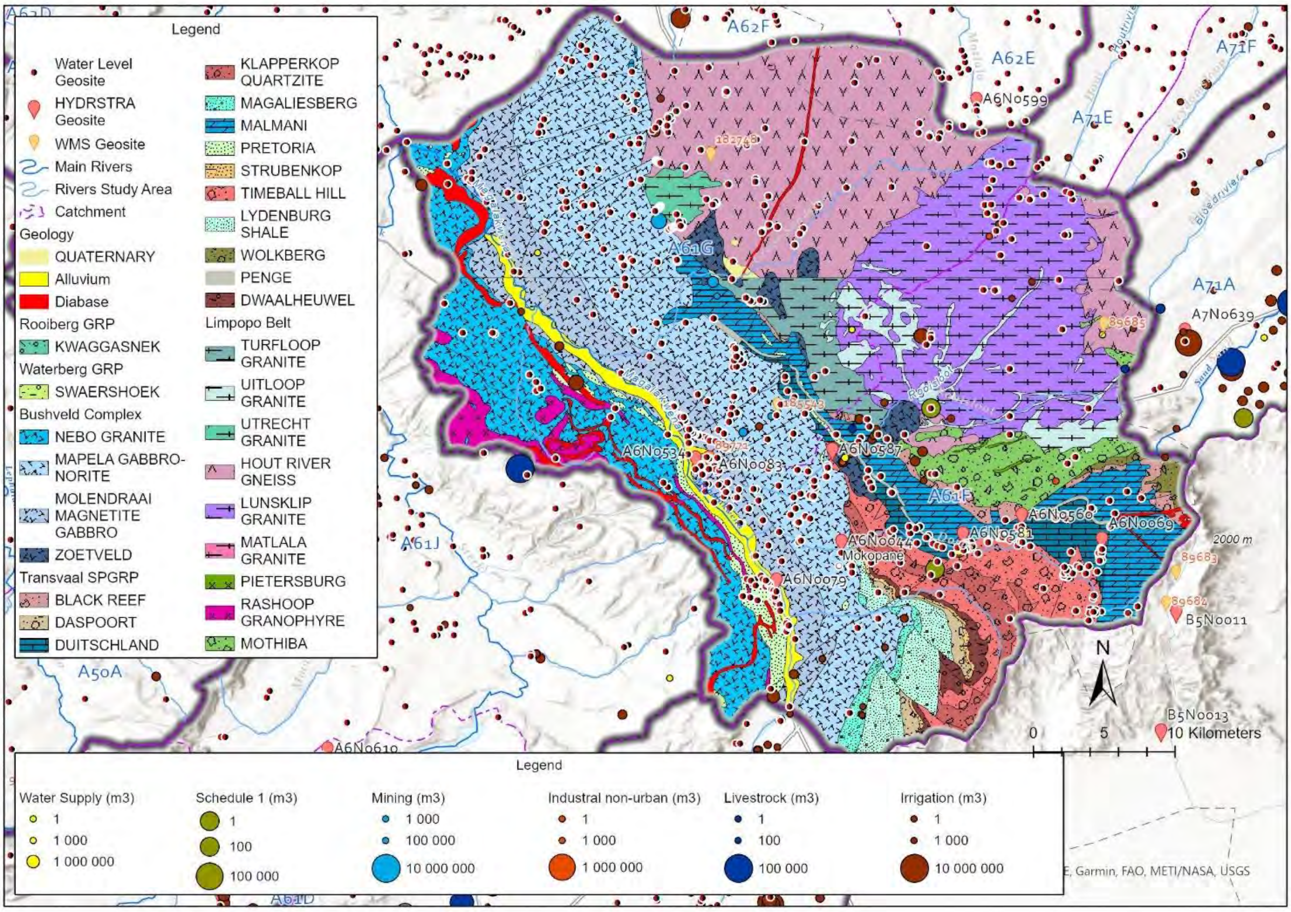


Figure 23 Map showing GUA A61-3 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

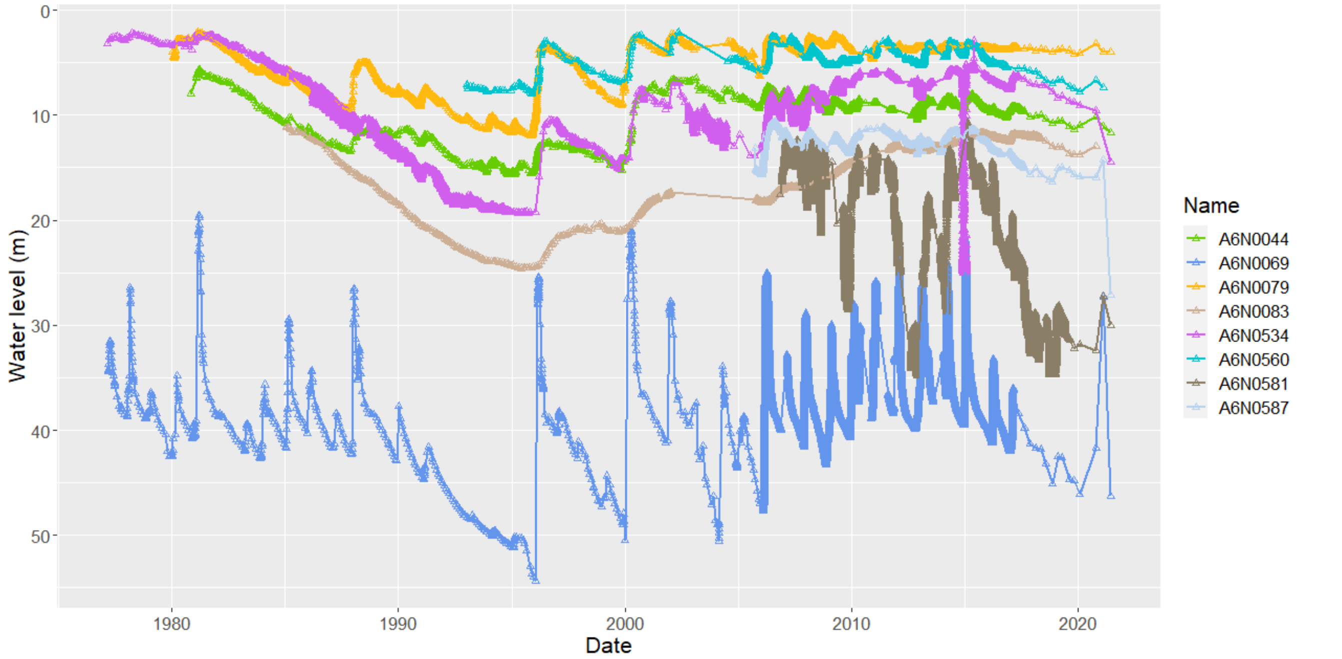
Scheme Name	Village/Settlement	Catchment
Bakenberg RWS	Bakenberg Basogadi, Bakenberg Kwanaite, Bakenberg Matlaba, Bakenberg Mautjana, Bakenberg Mmotong, Bakenberg Mothwathwase, Basterspad, Bohwidi, Buffelhoek, Claremont, Dikgokgopeng, Diphichi, Galakwenastroom, Ga-Masipa, Good Hope, Harmansdal, Jakkalskuil, Kabeane, Kaditshwene, Kgopeng, Kromkloof, Lesodi, Leyden, Lusaka Ngoru, Mabuladihlare 1,Makekeng, Malapila, Mamatlakala, Marulaneng, Matebeleng, Mphelelo, Nelly, Paulos, Pudiyakgopa, Raadslid, Ramosesane, Rantlakane, Sepharane, Skilpadskraal,Skrikfontein A, Skrikfontein B, Taolome, Van Wykspan, Vlakfontein, Vlakfontein 2, Wydhoek and Good Hope East	A61G, A61J, A62A, A62B, A62C, A62F

Mokopane RWS	Madiba, Madiba East, Mzumbana North, Mzumbana South, Maribashoop/Oorlogsfontein plots, Masodi, Madiba, Madiba East, Mzumbana North, Mzumbana South, Maribashoop/Oorlogsfontein plots, Masodi, and Sekgakgapeng	A61E, A61F, A61G, A61H, A61J

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A6N0044	1980/11/02	2021/06/08	3258	15.69	5.68	8.97	10.01
A6N0069	1977/03/08	2021/06/09	13435	54.34	19.53	36.92	34.81
A6N0079	1980/01/10	2021/06/08	3252	11.96	2.13	3.63	9.83
A6N0083	1985/01/17	2020/10/14	5792	24.59	11.11	14.50	13.48
A6N0534	1977/03/02	2021/06/08	7546	25.02	2.22	8.21	22.80
A6N0560	1993/01/06	2021/02/10	3270	7.96	2.09	4.19	5.87
A6N0581	2006/11/07	2021/06/09	20067	34.77	10.68	20.77	24.09
A6N0587	2005/10/04	2021/06/09	4698	27.14	10.66	12.53	16.48

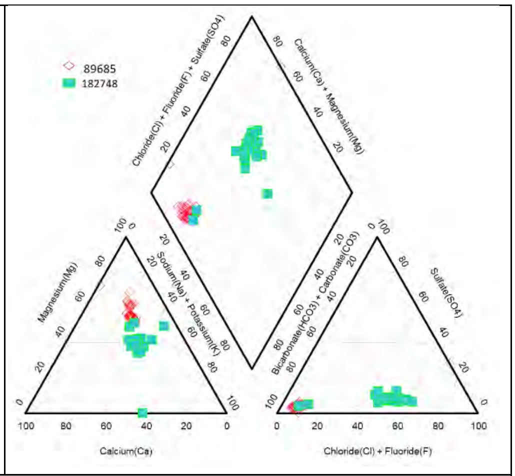
Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89685	1997/05/26	2017/09/11	38	2.11	0.03	0.29	No
182748	2000/05/04	2017/09/13	34	16.06	0.19	3.97	Yes

Water Quality Graph and Piper Plot



Comments
The observed hydrographs for each of the stations show a fluctuation of between 6 and 35 m. A significant response in water levels is observed at station A6N0069. Station A6N0069 is located within the karts aquifer system and could indicate strong correlation with groundwater recharge events, such as rainfall, associated with the high recharge zones of the dolomitic rocks. Apart from the observed seasonal fluctuations decreasing trend is observed up to 1997 followed by an increase up to 2016. Since 2017 the a slight decreasing groundwater level trend have been observed. The nitrate concentration graph (of station 182748) indicate elevated nitrate with a distinct decrease since 2005. Low levels of nitrate concentrations are observed at station 89685. The groundwater signature is dominated by both HCO_3 and Cl-anion water facies, indicating freshly recharged groundwater undergoing mineralisation.

2.3. MIDDLE AND LOWER MOGALAKWENA

The Middle- and Lower Mogalakwena catchment have limited surface water resources but large groundwater resources which have already been extensively exploited by the irrigation sector. High rural population densities occur in the middle part of the Mogalakwena catchment which should be able to source their water from groundwater while larger requirements may require transfers in from the Olifants WMA since there is little scope for further development of the local surface water resources.

In this assessment five GUAs have been delineated for the Middle and Lower Mogalakwena drainage area, namely A62-1 (Figure 25), A62-2 (Figure 26), A62-3 (Figure 27), and A63-1 (Figure 28). There are vast differences in the transmissivities of the GUA's (Table 26). Most notably is the high transmissivities observed in A62-2 and A63-1. The high yielding boreholes associated with A62-2 is located along the contact zones of the batholiths which intruded the older Hout River Gneiss. In GUA A63-1, Tolwe and Baltimore is known for its large scale irrigation from boreholes.

Table 26. Borehole information for the Middle and Lower Mogalakwena drainage region.

Description	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Klein Mogalakwena	A62-1	N	470	405	80	50	**150**
		Mean	62.0	17.4	50.4	0.4	1.4
Matlala	A62-2	N	395	413	65	47	43
		Mean	59.0	13.6	75.8	1.3	2.2
Steilloop	A62-3	N	509	393	67	56	128
		Mean	65.1	17.5	27.3	0.8	2.0
Lower Mogalakwena	A63-1	N	973	877	108	57	255
		Mean	59.2	24.2	59.9	1.2	2.9

2.3.1. Groundwater recharge

Mean annual precipitation varies from 600 mm in the south to less than 400 mm in the north (**Error! Reference source not found.**). In lower lying areas the low and variable rainfall together with evaporation rates (2 000 mm) considerably exceeding rainfall result in a low expectation of natural recharge to groundwater. Recharge vary spatially from as high as 18 mm/a in the Waterberg region to less than 3 mm/a at the confluence with the Limpopo River. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 27.

Table 27. Recharge estimation (Middle- and Lower Mogalakwena).

Description	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Klein Mogalakwena	A62-1	A62A	610.2	428	11.07	7.98	24.85
		A62B	528.7	710	14.20	9.96	14.94
		A62C	478.3	385	6.53	4.50	11.30
		A62D	488.8	603	10.15	7.02	11.71
Matlala	A62-2	A62E	460.4	621	8.59	5.88	5.64
		A62F	478.1	620	9.18	6.33	6.58
Steilloop	A62-3	A62G	437.3	627	8.25	5.63	4.60
		A62H	439.3	871	10.94	7.45	5.25
		A62J	450.1	930	12.44	8.50	3.59
Lower Mogalakwena	A63-1	A63A	433.1	1928	18.20	12.36	1.81
		A63B	393.9	1505	11.35	7.61	4.29
		A63D	412.3	1319	13.99	9.43	4.72

2.3.2. Groundwater Use

The groundwater use for each of the GUA associated with the Middle and Lower Mogalakwena River system is summarised in Table 28. The present WARMS groundwater use data was compared to the 2015 Limpopo (WMA) North Reconciliation Strategy (LNRS) estimated 2020 use.

Table 28. Groundwater use (per annum) as registered per catchment for each GUA.

GMA Description	GUA	Quat	WARMS: Use Mm^3	LNRS 2020 Mm^3
Klein Mogalakwena	A62-1	A62A	0.577	0.866
		A62B	0.523	1.685
		A62C	0.001	0.693
		A62D	0.648	1.208
Matlala	A62-2	A62E	0.106	2.214
		A62F	3.709	5.672
Steilloop	A62-3	A62G	0.003	1.199
		A62H	0.798	2.941
		A62J	0.211	1.057
Lower Mogalakwena	A63-1	A63A	11.003	20.900
		A63B	1.171	2.793
		A63D	3.808	4.952

2.3.3. Groundwater quality

Groundwater samples in the Middle and Lower Mogalakwena drainage region indicate a variety of water types (e.g. Ca/Mg-HCO_3, Na-HCO_3 and Na-Cl) (Figure 24). A high percentage of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl and Ca/Mg-Cl type water present.

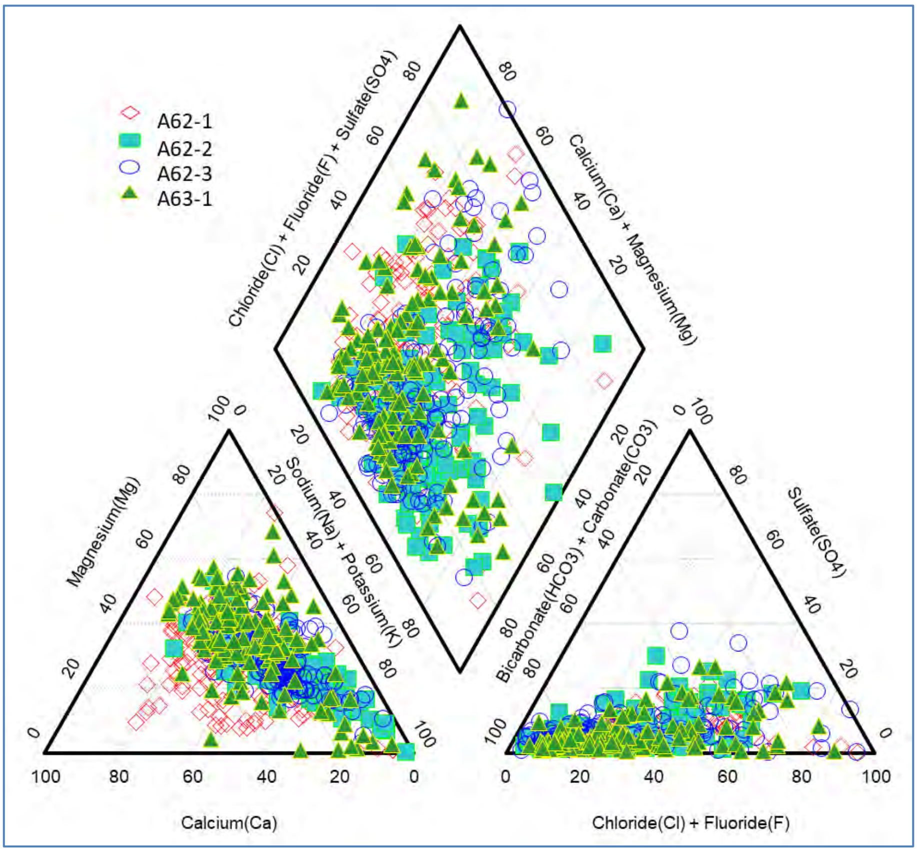


Figure 24 Piper diagram for the Middle- and Lower Mogalakwena drainage region.

Groundwater quality in the Middle- and Lower Mogalakwena region is considered to be moderate to poor. The most notable elements of concern include NO_3 as N with average concentrations above the maximum allowable recommended drinking limit (Table 29). In addition, high (not exceeding thought) ion concentrations (e.g. Mg and Cl) and subsequently electric conductivities (EC) beyond acceptable limits. This can mostly be related to evaporative concentration of elements in discharge areas or due to low recharge values as well as long residence times for selected samples.

Table 29. Groundwater quality for the Middle- and Lower Mogalakwena region (All units in mg/l, EC in mS/m). (red text exceeds Class III).

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A62-1	N	130	143	131	153	152	153	150	136	153	21	147
	Median	8.0	109	760	74.4	39.2	89.7	1.9	12.1	123.9	63.4	0.62
A62-2	N	143	137	144	155	155	154	154	155	155	11	148
	Median	8.1	124	943	54.8	38.02	149.0	8.7	26.5	172.1	59.0	0.61
A62-3	N	155	158	149	170	171	171	171	169	170	18	150
	Median	8.1	116	865	57.2	47.10	130.9	8.5	24.5	163.9	35.9	0.36
A63-1	N	127	128	123	140	139	140	137	127	141	15	132
	Median	8.08	120.60	884.79	70.60	58.80	97.83	2.54	25.31	119.07	83.4	0.44

2.3.4. Groundwater contribution to baseflow

The Middle Mogalakwena River stretch can be classified into a localized interacting weathered hard rock system (Bushveld Complex) in the upper reaches, while the Waterberg Group will be in continues interaction with the river and probability of baseflow is regarded as high. In the lower reaches alluvium replaces the weathered material and can be classified as a porous media with a semi-pervious layer. In both cases seasonal alternating effluent / influent conditions can be experienced. Comparison of groundwater contribution to baseflow estimates for the Middle- and Lower Mogalakwena drainage region are summarised in Table 30.

Table 30. Groundwater contribution to baseflow estimates.

Description	GRU	Quat	Hughes Mm^3/a	Shultz Mm^3/a	Pitmann Mm^3/a	GRA II (WR2005) Mm^3/a	Maint. Low flow Mm^3/a
Klein Mogalakwena	A62-1	A62A	8.24	3.72	7.58	4.52	3.46
		A62B	4.71	0.48	2.27	2.44	1.27
		A62C	1.82	0.27	1.12	1.11	0.49
		A62D	3.08	0.39	1.75	1.82	1.45
Matlala	A62-2	A62E	-	-	-	-	0.34
		A62F	0.02	-	-	-	0.41
Steilloop	A62-3	A62G	-	-	-	-	0.14
		A62H	0.01	-	-	-	0.40
		A62J	0.05	-	-	-	0.24
Lower Mogalakwena	A63-1	A63A	0.08	-	-	-	0.03
		A63B	-	-	-	-	0.02
		A63D	-	-	-	-	0.37

2.3.5. Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 31, Table 32, Table 33 and Table 34.

Table 31. Summary information for GUA: A62-1

GUA	Klein Mogalakwena A62-1
Description	The main aquifer types include the Fractured aquifers associated with the Waterberg Formation, ranging from Duikerfontein north to Kirstenbos, and Granitic Intrusive rocks, northern extent of the GUA at Marken. area The Waterberg formation is associated with steep topography and shows generally poor capability to produce huge amounts of groundwater. Recharge to the aquifer, often discharged on the steep slopes, provides baseflow to the rivers. A weathered zone aquifer is found only where deep weathering occurs and provides groundwater storage that feeds the underlying fractured aquifer. The Bushveld rocks, located towards the east of the GUA at Gooedehoop area, forms fractured aquifers owing their groundwater potential largely to fracturing. Intergranular Alluvial aquifers (limited to the main river stems) recharge during periods of high stream-flows as well as during the rainfall season. The groundwater use is associated with irrigation, water supply, livestock watering, industrial and some aquacultural use. A large number of villages (schemes) are associated with the GUA.
Catchments	A62A,B,C,D,E
Map	

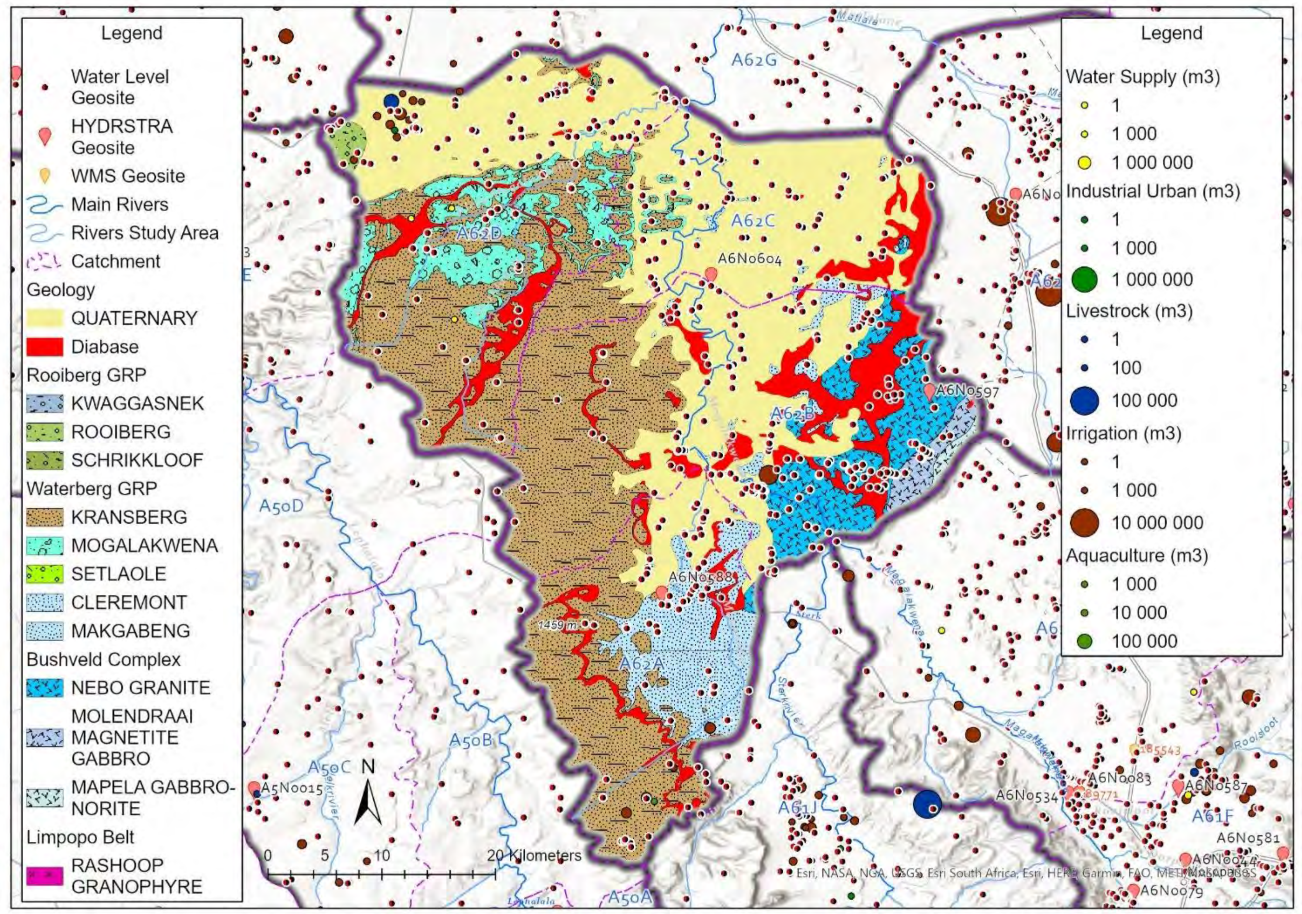


Figure 25 Map showing GUA A62-1 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

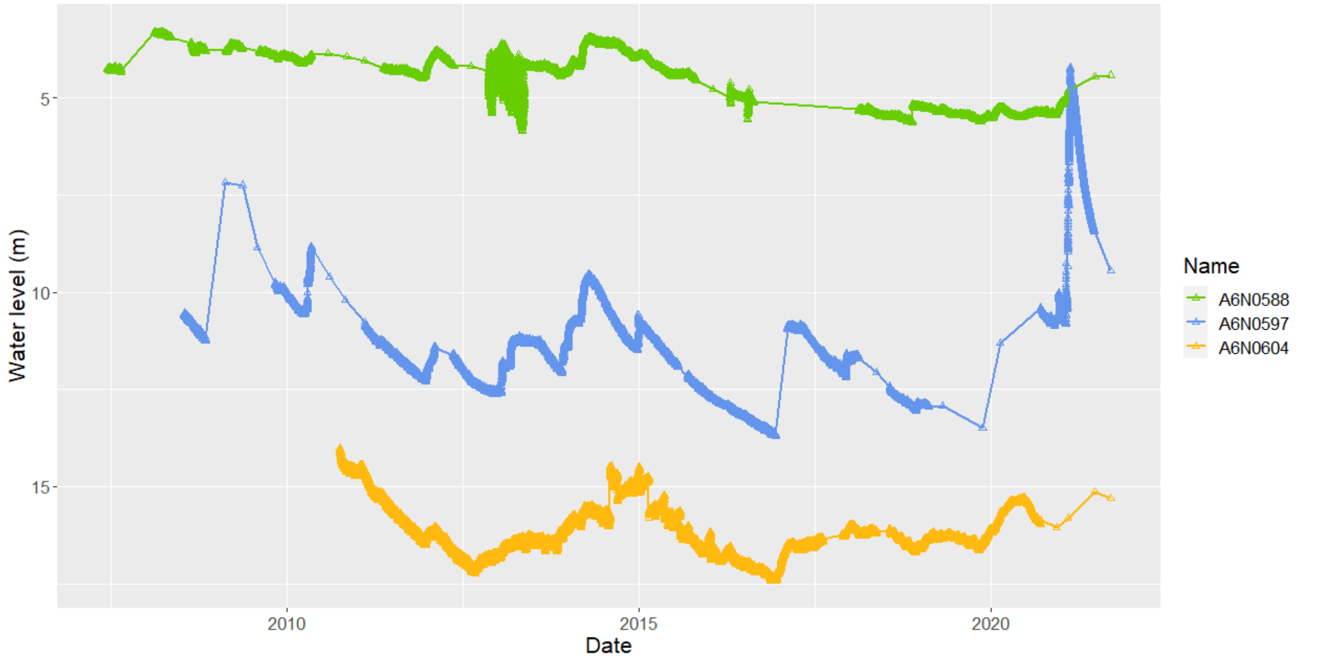
Scheme Name	**Village/Settlement**	**Catchment**
Aganang East GWS	Chloe A, Chloe B, Damplats, Eerste Geluk, Ga-Ngwetsana, GaRamoshwane, Kgabo Park, Preezburg, Ramatlwane, Rampuru, Rapitsi, Ga-Mmabasotho, Ga-Modikana, Ga-Phago, Ga-Piet, GaRankhuwe, Kalkspruit 1, Lehlohlong, Vischkuil, Wachtkraal and Ga-Nonyane	A62E A62H A71E A71F
Bakenberg RWS	Bakenberg Basogadi, Bakenberg Kwanaite, Bakenberg Matlaba, Bakenberg Mautjana, Bakenberg Mmotong, Bakenberg Mothwathwase, Basterspad, Bohwidi, Buffelhoek, Claremont, Dikgokgopeng, Diphichi, Galakwenastroom, Ga-Masipa, Good Hope, Harmansdal, Jakkalskuil, Kabeane, Kaditshwene, Kgopeng, Kromkloof, Lesodi, Leyden, Lusaka Ngoru, Mabuladihlare 1,Makekeng, Malapila, Mamatlakala, Marulaneng, Matebeleng, Mphelelo, Nelly, Paulos, Pudiyakgopa, Raadslid, Ramosesane, Rantlakane, Sepharane, Skilpadskraal,Skrikfontein A, Skrikfontein B, Taolome, Van Wykspan, Vlakfontein, Vlakfontein 2, Wydhoek and Good Hope East	A61G A61J A62A A62B A62C A62F
Bakone GWS	Bakone, Boratapelo, Dibeng, Ga-Ramakara, Madietane, Manamela 2, Mpone Ntlolane 1, Mpone Ntlolane 3, Nokayamatlala, Ntlolane 2, Phetole, Phofu, Ramalapa 1, Semaneng	A62E A62F

	and Taung.	
Biesjeskraal WS	Moepelfarm	A62D
Daggakraal WS	Daggakraal	A50D A62B
Ga Mokobodi GWS	Ga-Lepadima, Ga-Mokobodi, Ga-Phaka, Ga-Ramakadi-Kadi, Goedgevonden, Hwibi, Juno, Moetagare, Schoongelegen, Tibana, Ga-Mabitsela, Ga-Ramotlokana, Leokaneng, Mamehlabe, Pinkie, Rozenkranz and Ngwanallela	A62E A62F A62G A62H
Ga Rawesi GWS	Uitkyk 2, Mesehleng 1, Mesehleng 2, Mokudung, Kgokonyane, Nonono, Setlaole, Ga-Masekwa, Rotlokwa, Ga-Rawesi, Murasie, Ga-Letswalo, Lekiting, Aurora, Ga-Ngwepe and Schoongezicht	A62E A62G A62H A72A
Glen Alpine GWS	Mattanau, Breda, Duren, Galakwena, Ga-Tlhako, Khala, Lennes, Monte Christo, Polen, Preezburg, Rebone, Setuphulane, Sodoma, Taueatswala, Thabaleshoba, Tipeng, Uitzicht, Sterkwater	A62D A62G A62H A62J
Houtrivier RWS	Koloti, Kamape 1, Komape 2, Komape 3, Mabukelele, Madikote, Mamadila, Moshate, Ramagaphota, Cristiana, Ga-Kgoroshi, GaSetshaba, Helena, Kalkspruit, Magongoa, Vlaklaagte and Waschbank	A62E A62H A71E A71F
Mapela RWS	Danisane, Ditlotswane, Ga-Chokoe, Ga-Magongoa, Ga-Mokaba, Ga-Molekana, Ga-Pila Sterkwater, Ga-Tshaba, Hans, Kgobudi, Kwakwalata, Lelaka, Maala Parekisi, Mabuela, Mabusela, Mabusela Sandsloot, Machikiri, Magope, Malokongskop, Masahleng, Masenya, Masoge, Matlou, Matopa, Mesopotania,, Millenium Park, Mmahlogo, Mmalepeteke, Phafola, Ramorulane, Rooiwal, Seema, Sekgoboko Sekuruwe, Skimming, Tshamahansi, Witrivier, Fothane, Mohlotlo Ga-Malebana, Mohlotlo Ga-Puka	A61F A61G A62B A62F A71B
Marken Supply	Marken	A62D
Moletje South GWS	Boetse, Diana, Ga-Kgasha, Ga-Madiba, Ga-Mangou, GaMatlapa, Glen Roy, Jupiter, Mandela Park, Manyapye, Mapateng, Matlaleng, Maune, Mohlonong, Montwane 1, Montwane 2, Moshate, Naledi, Ngopane, Sebora, Sefahlane, Segoahleng, Sepanapudi, Utjane, Chebeng, Doornspruit, Ga-Mapangula, Makweya, Newlands, Pax College, Sengatane, Setotolwane College, Vaalkop 1 and Vaalkop 3 Venus and Waterplaats	A61F A61G A62E A62F A71E A71F
Rebone RWS	Bavaria, Breda, Blinkwater, Chipana, Dipere, Duren, Ga-Chere, Galakwena, Galelia, Ga-Monare, Ga-Mushi, Ga-Nong, Ga – Tlkako, Grasvlei, Ham 1, Hlogoyanku, Khala, Lekhureng, Lennes, Makobe, Mathekga, Matjitjileng, Mattanau, Monte Christo, Polen, Preezburg, Moshuka, kidikitlana, Rebone, Rapadi, Segole 1, Segole 2, Seirappes, Senita, Setophulane, Sodoma, Sterkwater, Taueatswala, Tennerif, Thabaleshoba, Tiberius, Tipeng, Uitzicht, Vergenoeg and Vianna	A62C A62D A62F A62E A62G A62H
Uitspan Supply	Uitspan	A62D

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A6N0588	2007/01/30	2021/09/13	2360	5.85	3.30	4.54	2.55
A6N0597	2008/07/17	2021/09/13	6444	13.69	4.21	11.39	9.48
A6N0604	2010/10/06	2021/09/13	3205	17.42	14.00	16.12	3.42

Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)							
Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
none							

Water Quality Graph and Piper Plot

none

Comments

The observed hydrographs for each of the three stations show a fluctuation of between 3 and 10 m. A response in water levels as a result of recharge observed for these monitoring boreholes. Apart from the observed seasonal fluctuations decreasing trend is observed up to 2016 followed by an increase up to 2021. Station A6N0588 is located close to a non-perennial river bed, and could explain the shallow groundwater table associated with the borehole observations. A prominent groundwater recharge events is clearly observed during 2014/15.

Table 32. Summary information for GUA: A62-2

GUA	Matlala A62-2
Description	The GUA is characterised by intergranular alluvial aquifers, recharged during periods of high stream-flows as well as during the rainfall season. The igneous and metamorphic rocks occurring in the eastern portions of the Matlala area especially the Hout River Gneiss have good water bearing potential. Thick, weathered aquifer zones are expected in areas where the bedrock has been subjected to intense fracturing. The Basement is represented in the eastern sector of the Mogalakwena drainage region. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. The basement aquifer system (Limpopo Belt) is located to the east of the GUA, range from Ga-Manou north to Ga-Ramela area, whereas the fractured aquifer form the Bushveld rocks in located towards the west of the GUA. The groundwater use is associated with irrigation and industrial uses.
Catchments	A62E, F

Map

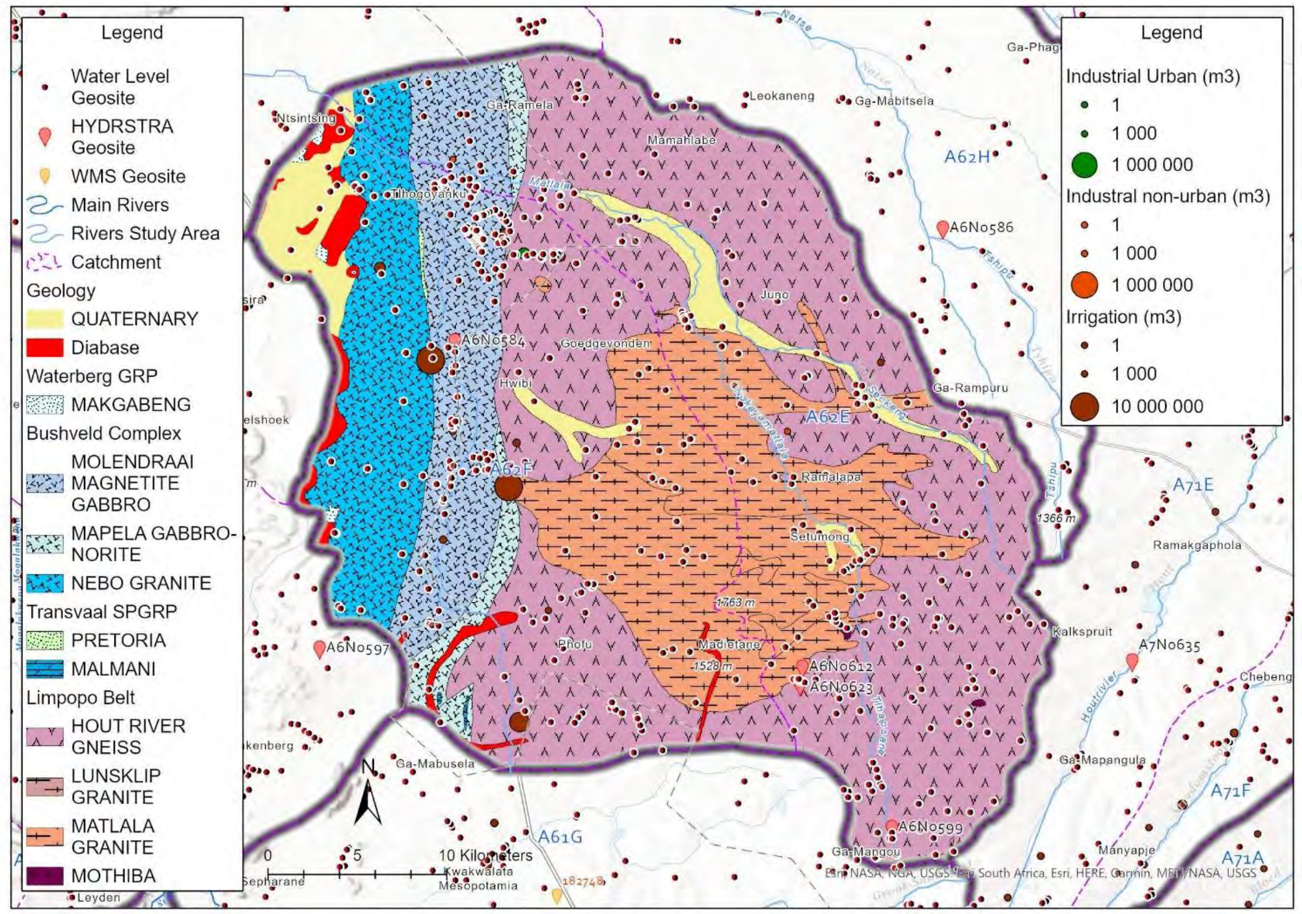


Figure 26 Map showing GUA A62-2 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

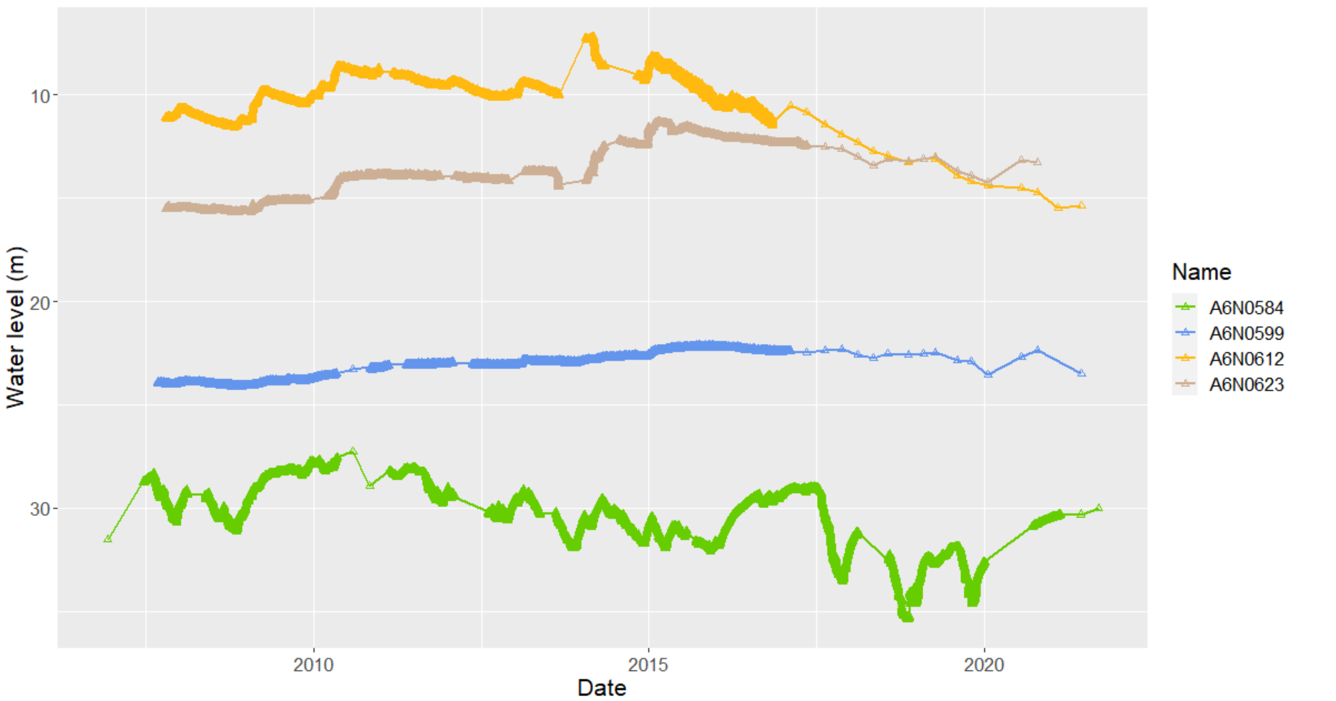
Scheme Name	Village/Settlement	Catchment
Aganang East GWS	Chloe A, Chloe B, Damplats, Eerste Geluk, Ga-Ngwetsana, GaRamoshwane, Kgabo Park, Preezburg, Ramatlwane, Rampuru, Rapitsi, Ga-Mmabasotho, Ga-Modikana, Ga-Phago, Ga-Piet, GaRankhuwe, Kalkspruit 1, Lehlohlong, Vischkuil, Wachtkraal and Ga-Nonyane	A62E A62H A71E A71F
Bakenberg RWS	Bakenberg Basogadi, Bakenberg Kwanaite, Bakenberg Matlaba, Bakenberg Mautjana, Bakenberg Mmotong, Bakenberg Mothwathwase, Basterspad, Bohwidi, Buffelhoek, Claremont, Dikgokgopeng, Diphichi, Galakwenastroom, Ga-Masipa, Good Hope, Harmansdal, Jakkalskuil, Kabeane, Kaditshwene, Kgopeng, Kromkloof, Lesodi, Leyden, Lusaka Ngoru, Mabuladihlare 1,Makekeng, Malapila, Mamatlakala, Marulaneng, Matebeleng, Mphelelo, Nelly, Paulos, Pudiyakgopa, Raadslid, Ramosesane, Rantlakane, Sepharane, Skilpadskraal,Skrikfontein A, Skrikfontein B, Taolome, Van Wykspan, Vlakfontein, Vlakfontein 2, Wydhoek and Good Hope East	A61G A61J A62A A62B A62C A62F
Bakone GWS	Bakone, Boratapelo, Dibeng, Ga-Ramakara, Madietane, Manamela 2, Mpone Ntlolane 1, Mpone Ntlolane 3, Nokayamatlala, Ntlolane 2, Phetole, Phofu, Ramalapa 1, Semaneng and Taung.	A62E A62F

Ga Mokobodi GWS	Ga-Lepadima, Ga-Mokobodi, Ga-Phaka, Ga-Ramakadi-Kadi, Goedgevonden, Hwibi, Juno, Moetagare, Schoongelegen, Tibana, Ga-Mabitsela, Ga-Ramotlokana, Leokaneng, Mamehlabe, Pinkie, Rozenkranz and Ngwanallela	A62E A62F A62G A62H
Ga Rawesi GWS	Uitkyk 2, Mesehleng 1, Mesehleng 2, Mokudung, Kgokonyane, Nonono, Setlaole, Ga-Masekwa, Rotlokwa, Ga-Rawesi, Murasie, Ga-Letswalo, Lekiting, Aurora, Ga-Ngwepe and Schoongezicht	A62E A62G A62H A72A
Aganang LM Farms supply	Farms Aganang LM	A62F
Houtrivier RWS	Koloti, Kamape 1, Komape 2, Komape 3, Mabukelele, Madikote, Mamadila, Moshate, Ramagaphota, Cristiana, Ga-Kgoroshi, GaSetshaba, Helena, Kalkspruit, Magongoa, Vlaklaagte and Waschbank	A62E A62H A71E A71F
Mapela RWS	Danisane, Ditlotswane, Ga-Chokoe, Ga-Magongoa, Ga-Mokaba, Ga-Molekana, Ga-Pila Sterkwater, Ga-Tshaba, Hans, Kgobudi, Kwakwalata, Lelaka, Maala Parekisi, Mabuela, Mabusela, Mabusela Sandsloot, Machikiri, Magope, Malokongskop, Masahleng, Masenya, Masoge, Matlou, Matopa, Mesopotania,, Millenium Park, Mmahlogo, Mmalepeteke, Phafola, Ramorulane, Rooiwal, Seema, Sekgoboko Sekuruwe, Skimming, Tshamahansi, Witrivier, Fothane, Mohlotlo Ga-Malebana, Mohlotlo Ga-Puka	A61F A61G A62B A62F A71B
Moletje South GWS	Boetse, Diana, Ga-Kgasha, Ga-Madiba, Ga-Mangou, GaMatlapa, Glen Roy, Jupiter, Mandela Park, Manyapye, Mapateng, Matlaleng, Maune, Mohlonong, Montwane 1, Montwane 2, Moshate, Naledi, Ngopane, Sebora, Sefahlane, Segoahleng, Sepanapudi, Utjane, Chebeng, Doornspruit, Ga-Mapangula, Makweya, Newlands, Pax College, Sengatane, Setotolwane College, Vaalkop 1 and Vaalkop 3 Venus and Waterplaats	A61F A61G A62E A62F A71E A71F
Rebone RWS	Bavaria, Breda, Blinkwater, Chipana, Dipere, Duren, Ga-Chere, Galakwena, Galelia, Ga-Monare, Ga-Mushi, Ga-Nong, Ga – Tlkako, Grasvlei, Ham 1, Hlogoyanku, Khala, Lekhureng, Lennes, Makobe, Mathekga, Matjitjileng, Mattanau, Monte Christo, Polen, Preezburg, Moshuka, kidikitlana, Rebone, Rapadi, Segole 1, Segole 2, Seirappes, Senita, Setophulane, Sodoma, Sterkwater, Taueatswala, Tennerif, Thabaleshoba, Tiberius, Tipeng, Uitzicht, Vergenoeg and Vianna	A62C A62D A62F A62E A62G A62H

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A6N0584	2006/12/07	2021/09/13	7246	35.39	27.28	30.35	8.11
A6N0599	2007/09/05	2021/06/10	1879	24.14	22.10	23.07	2.04
A6N0612	2007/10/18	2021/06/10	3805	15.46	7.17	9.79	8.29
A6N0623	2007/10/18	2020/10/16	3416	15.70	11.27	13.18	4.43

Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2	Min NO_3+NO_2	Median NO_3+NO_2	Exceed Drinking

				conc. (mg/L)	conc. (mg/L)	conc. (mg/L)	Water guideline
none							
Water Quality Graph and Piper Plot							
none							
Comments							
The observed hydrographs for each of the four stations show a fluctuation of between 2 and 8 m. Seasonal fluctuations and a response to significant recharge events are observed for stations A6N0584, A6N0623 and A6N0612. However station A6N0599 shows limited fluctuations. Station A6N0599 is located close to the Tlhapsana river system whereas the other station are not in close approximation of a perennial river and could explain difference in water level response. Stations A6N0584 and A6N0612 shows a decline in groundwater levels.							

Table 33. Summary information for GUA: A62-3

GUA	Steilloop A62-3
Description	The igneous and metamorphic rocks occurring in the eastern portions of the GUA especially the mafic rocks (gabbro, norite, etc.) of the Bushveld Complex and the Hout River Gneiss have good water bearing potential. Thick, weathered aquifer zones are expected in areas where the bedrock has been subjected to intense fracturing. The Basement is represented in the eastern sector of the Mogalakwena drainage region. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. The fractured aquifers associated with the Bushveld rocks is located at the south and central part of the GUA whereas the Waterberg Group at the western portion of the GUA. The GUA is characterised by intergranular alluvial aquifers, recharged during periods of high stream-flows as well as during the rainfall season. The groundwater use is associated with irrigation, industrial and water supply uses. A large number of villages (schemes) are associated with the GUA.
Catchments	A62G,H,J
Map	

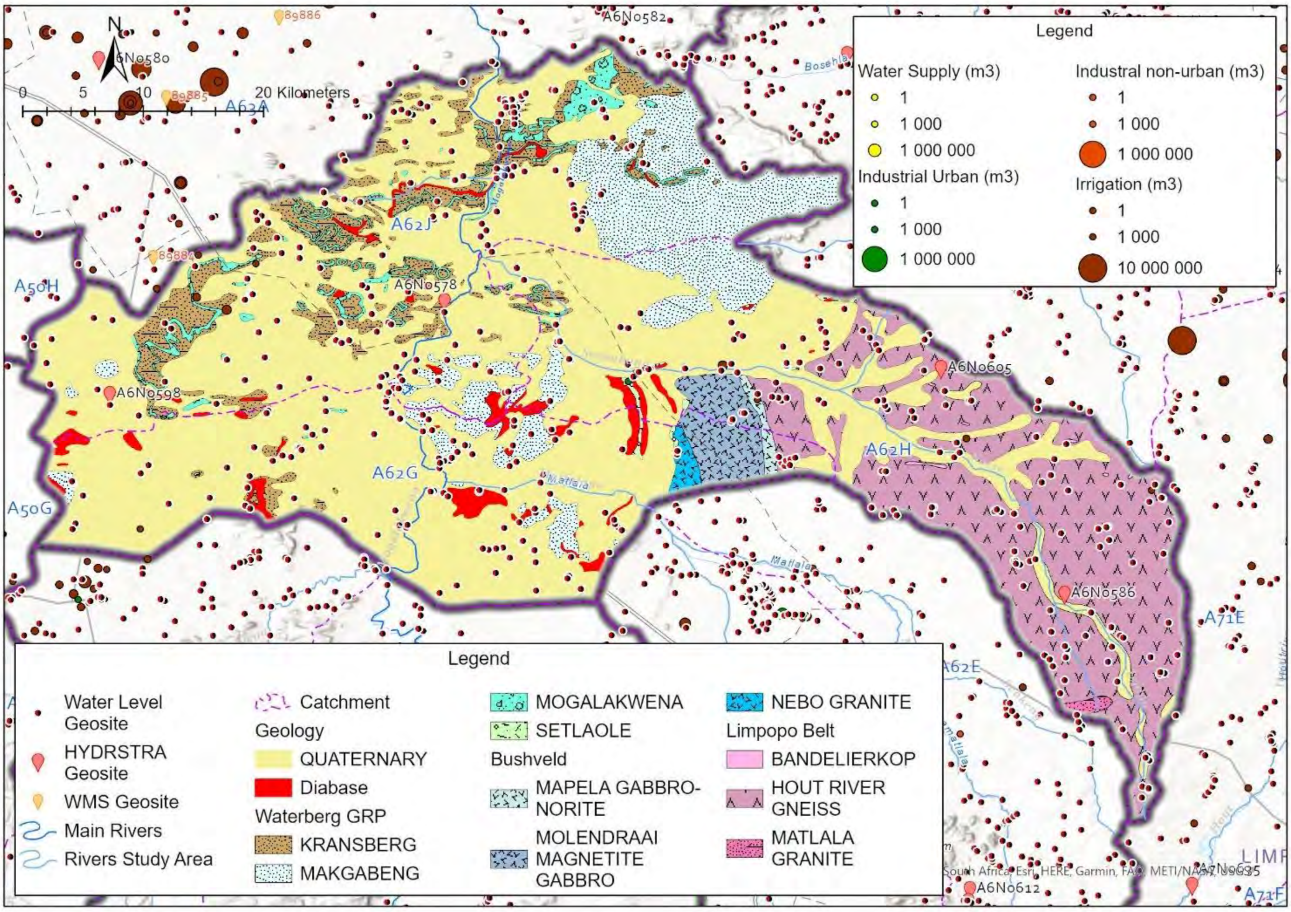


Figure 27 Map showing GUA A62-3 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

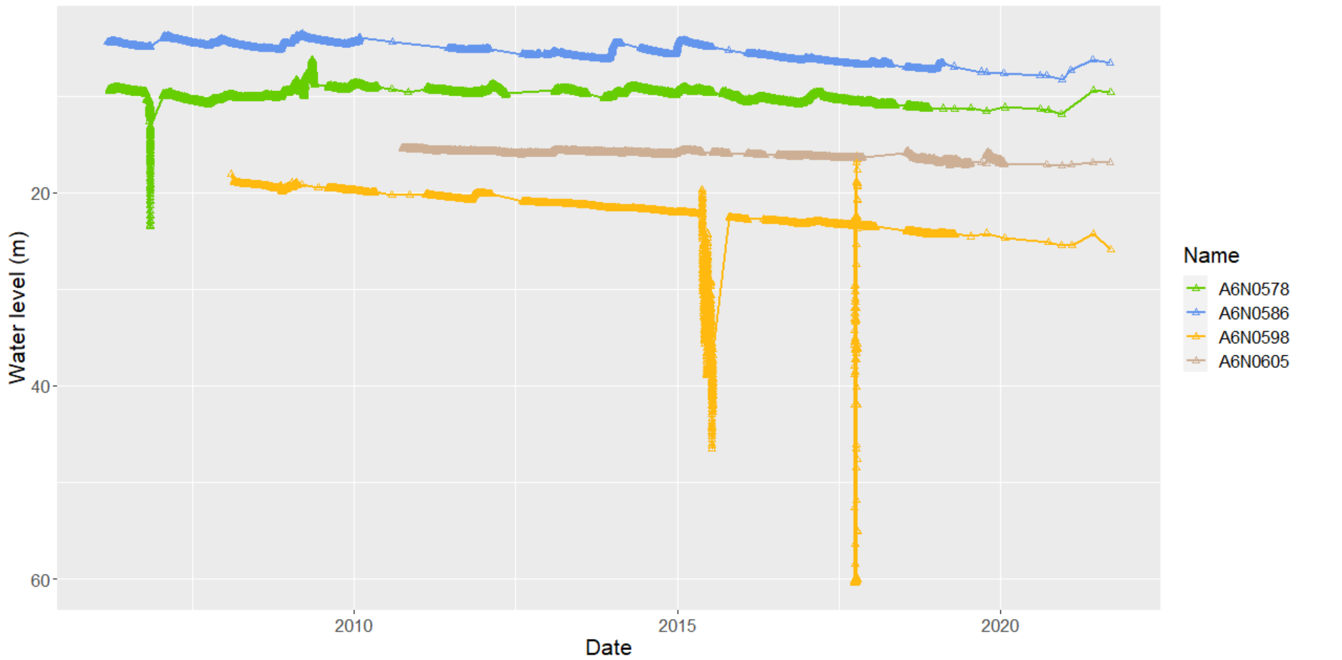
Scheme Name	**Village/Settlement**	**Catchment**
Aganang East GWS	Chloe A, Chloe B, Damplats, Eerste Geluk, Ga-Ngwetsana, GaRamoshwane, Kgabo Park, Preezburg, Ramatlwane, Rampuru, Rapitsi, Ga-Mmabasotho, Ga-Modikana, Ga-Phago, Ga-Piet, GaRankhuwe, Kalkspruit 1, Lehlohlong, Vischkuil, Wachtkraal and Ga-Nonyane	A62E A62H A71E A71F
Aganang North GW	Ga-Maboth, Ga-Mantlhodi, Ga-Mosehlong, Ga-Motlakgomo, Kanana, Mohlajeng, Ga-Kolopo, Ga-Maribana, Ga-Phagodi, Marowe, Modderput, Sekuruwe 2, Ga-Moropa, Ga-Mankgodi, GaKeetse, Ga-Dikgale, Uitkyk and Terbrugge	A62H A71E A72A
Blouberg LM Farms Supply	Blouberg LM Farms Supply	A62J
Ga Mokobodi GWS	Ga-Lepadima, Ga-Mokobodi, Ga-Phaka, Ga-Ramakadi-Kadi, Goedgevonden, Hwibi, Juno, Moetagare, Schoongelegen, Tibana, Ga-Mabitsela, Ga-Ramotlokana, Leokaneng, Mamehlabe, Pinkie, Rozenkranz and Ngwanallela	A62E A62F A62G A62H
Ga Rawesi GWS	Uitkyk 2, Mesehleng 1, Mesehleng 2, Mokudung, Kgokonyane, Nonono, Setlaole, Ga-Masekwa, Rotlokwa, Ga-Rawesi, Murasie, Ga-Letswalo, Lekiting, Aurora, Ga-Ngwepe and Schoongezicht	A62E A62G A62H A72A

Glen Alpine GWS	Mattanau, Breda, Duren, Galakwena, Ga-Tlhako, Khala, Lennes, Monte Christo, Polen, Preezburg, Rebone, Setuphulane, Sodoma, Taueatswala, Thabaleshoba, Tipeng, Uitzicht, Sterkwater	A62D A62G A62H A62J
Houtrivier RWS	Koloti, Kamape 1, Komape 2, Komape 3, Mabukelele, Madikote, Mamadila, Moshate, Ramagaphota, Cristiana, Ga-Kgoroshi, GaSetshaba, Helena, Kalkspruit, Magongoa, Vlaklaagte and Waschbank	A62E A62H A71E A71F
Lephalale LM Farms Supply	Farms Lephalale LM	A62J
Rebone RWS	Bavaria, Breda, Blinkwater, Chipana, Dipere, Duren, Ga-Chere, Galakwena, Galelia, Ga-Monare, Ga-Mushi, Ga-Nong, Ga – Tlkako, Grasvlei, Ham 1, Hlogoyanku, Khala, Lekhureng, Lennes, Makobe, Mathekga, Matjitjileng, Mattanau, Monte Christo, Polen, Preezburg, Moshuka, kidikitlana, Rebone, Rapadi, Segole 1, Segole 2, Seirappes, Senita, Setophulane, Sodoma, Sterkwater, Taueatswala, Tennerif, Thabaleshoba, Tiberius, Tipeng, Uitzicht, Vergenoeg and Vianna	A62C A62D A62F A62E A62G A62H
Silwermyn / Kirstenspruit GWS	Driekoppies, Silwermyn, De Villiersdale 1, De Villiersdale 2, Swarts, Non-Parella, Mons, De Villiersdale, Thabanantlhana, De La Roche, Kirstenspruit, Grootdraai, Vergelegen, Ga-Mankgodi, Papegaai, Sebotlana, Madibeng, Ga-Ntshireletsa and Nieuwe Jerusalem	A62H A62J A63A A72A
Taaiboschgroet	Simpson, Grootpan, Sais, Slaaphoek, Donkerhoek, Voorhout, Royston, Juniorsloop, Berseba, Wegdraai, Ga-Raphokola, Gideon, Thlonasedimong, Eldorado, Fonteine Du Champ, Esaurinca, Louisenthaal, The Grange, Longden, Taaiboschgroet, De Vrede, Kromhoek, Pax, Johannesburg, Lovely, Burgerregt, Edwinsdale, The Glen and Glenferness	A63A A63B A63D A72A

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A6N0578	2006/03/17	2021/09/17	3824	14.95	6.17	9.81	8.87
A6N0586	2006/03/09	2021/09/13	3509	8.23	3.50	5.33	4.73
A6N0598	2008/02/06	2021/09/17	4713	28.40	16.20	21.58	12.2
A6N0605	2010/09/30	2021/09/13	1801	17.16	15.30	15.98	1.86

Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
none							

Water Quality Graph and Piper Plot

none

Comments

The observed hydrographs for each of the four stations show a fluctuation of between 2 and 12 m. Irregular fluctuation observed at station A6N0598 can be attributed to suspect measurements. As a result the fluctuation at station A6N0598 is approx. 7m. Overall a decreasing trend is observed in the groundwater levels. Some increase in groundwater levels can be attributes to groundwater recharge.

Table 34. Summary information for GUA: A63-1

GUA	Lower Mogalakwena A63-1
Description	The GUA is characterised by intergranular alluvial aquifers, recharged during periods of high stream-flows as well as during the rainfall season. The igneous and metamorphic rocks, basement rocks form the Limpopo Belt, occurring in the northern portions of the Lower Mogalakwena area especially gneiss from the and the Alldays Gneiss have good water bearing potential. Thick, weathered aquifer zones are expected in areas where the bedrock has been subjected to intense fracturing. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. The weathered and fractured aquifer systems associated with the Soutpansberg mountainous area, associated with basalts, are associated with the Beerkraal area, Waterberg sedimentary rocks at the Papagaai area and Blouberg sedimentary rocks associated with the Blouberg Mountains form the southern portion of the GUA . The Karoo Supergroup rocks, located in a small portion close to Doornfontein, Towle and Wegdraai areas, central part of the GUA, form intergranular and fractured aquifer systems with high groundwater yields. The groundwater use is associated with irrigation, water supply, livestock watering and schedule I uses. Large number of communities rely on groundwater as main water use.
Catchments	A63A,B,D
Map	

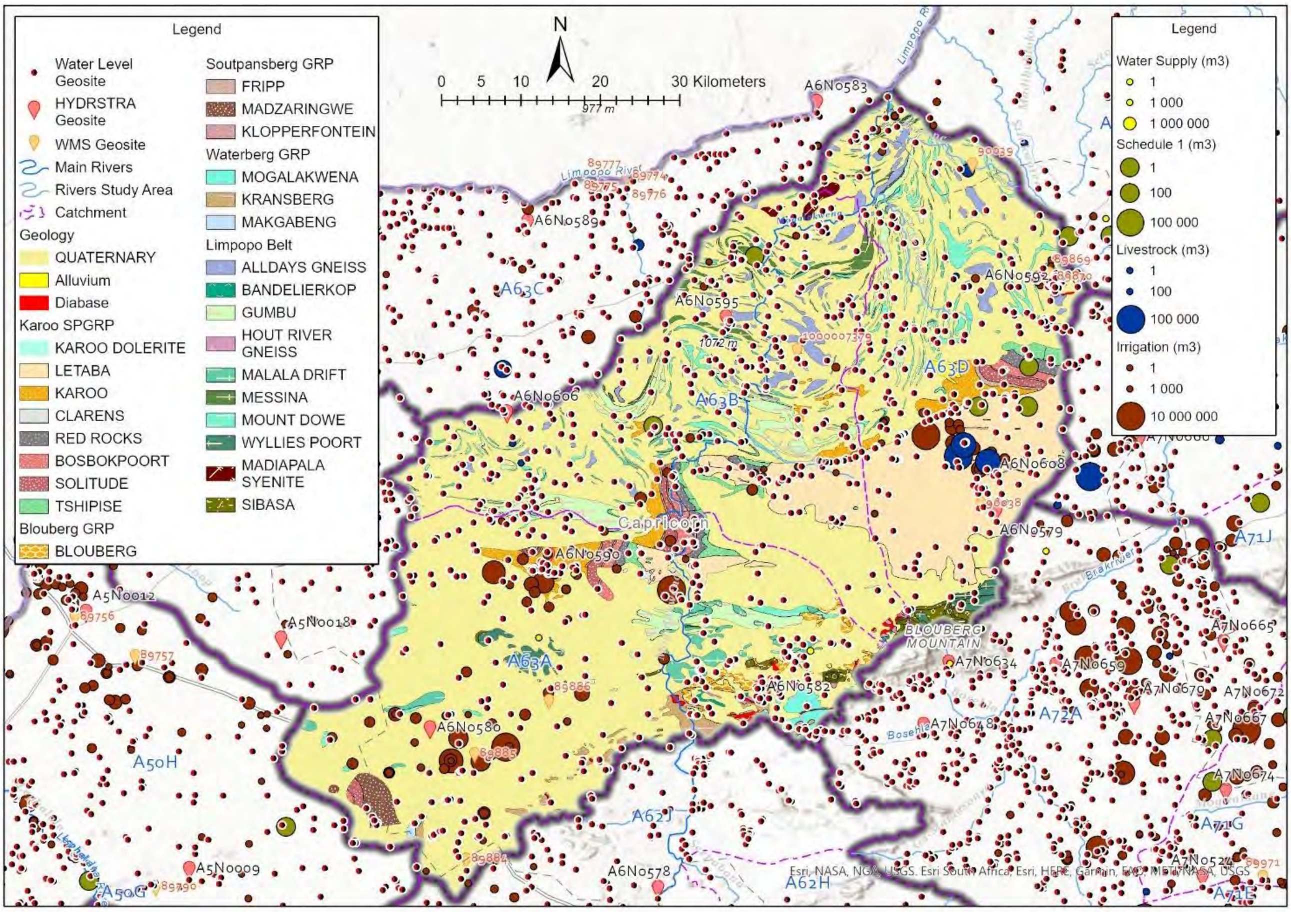


Figure 28 Map showing GUA A63-1 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

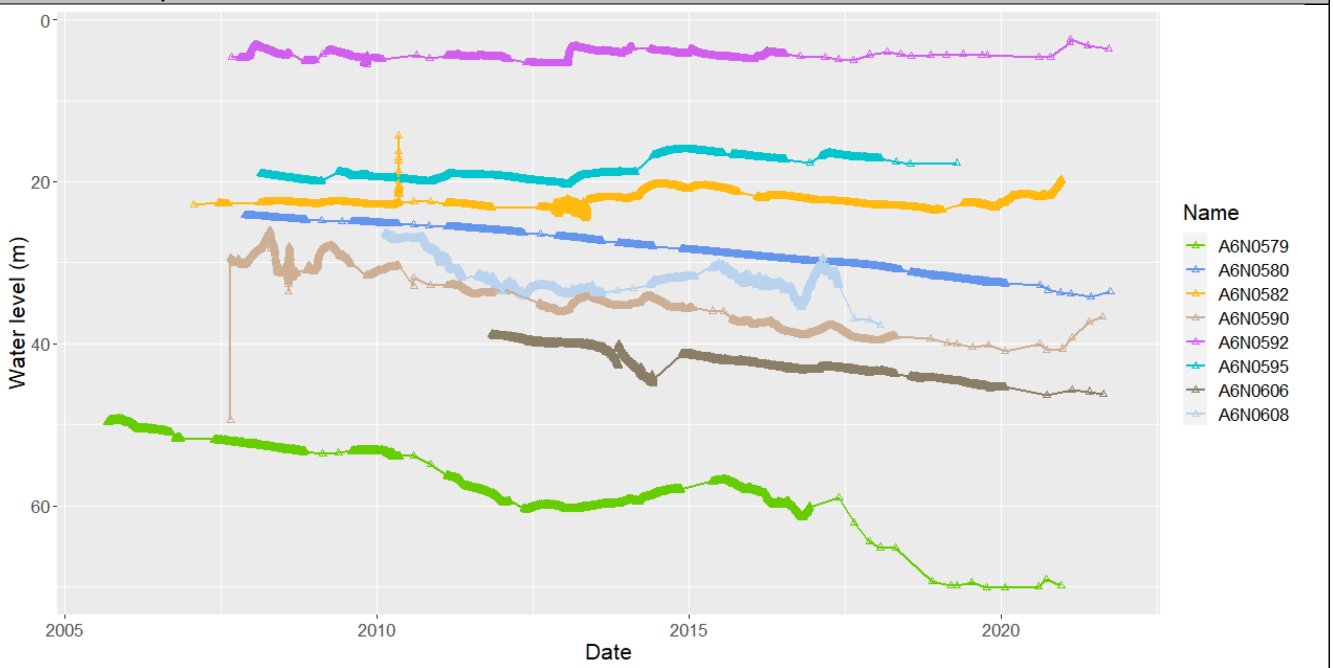
Scheme Name	**Village/Settlement**	**Catchment**
Alldays BS	Alldays BS	A63D A63E
Archibald GWS	Archibald, Genua, Letswatla, Borwalathoto, Thorp	A63A A63B
Avon GWS	Avon, Bul Bul, Dantzig 2, Ga-Kibi, Indermark, Innnes, Puraspan, Sewale North and The Glade	A63D A72A
Baltimore Supply	Baltimore	A63A
Gorkum GWS	Berg-en-Dal, Ga-Mamoleka, Gorkum, Varedig, Sekhung and Morotsi	A63A A63B A72A
Silwermyn / Kirstenspruit	Driekoppies, Silwermyn, De Villiersdale 1, De Villiersdale 2, Swarts, Non-Parella, Mons,	A62H A62J

GWS	De Villiersdale, Thabanantlhana, De La Roche, Kirstenspruit, Grootdraai, Vergelegen, Ga-Mankgodi, Papegaai, Sebotlana, Madibeng, Ga-Ntshireletsa and Nieuwe Jerusalem	A63A A72A
Taaiboschgroet	Simpson, Grootpan, Sais, Slaaphoek, Donkerhoek, Voorhout, Royston, Juniorsloop, Berseba, Wegdraai, Ga-Raphokola, Gideon, Thlonasedimong, Eldorado, Fonteine Du Champ, Esaurinca, Louisenthaal, The Grange, Longden, Taaiboschgroet, De Vrede, Kromhoek, Pax, Johannesburg, Lovely, Burgerregt, Edwinsdale, The Glen and Glenferness	A63A A63B A63D A72A
Thalahane GWS	Kgatalala, Buffelshoek and Thalahane	A63A A63B A63D A72A
Ga-Hlako RWS	Bodie, Brodie Hill, Dithabaneng, Ga-Hlako, Ga-Mabeba, GaMaboth, Gamakgwata, Ga-Malokela, Ga-Mampote, Ga-Maselela, Ga-Mokopane, Kobe, Kutumpa, Kwaring, Manye, Manye extension, Miltonduff 1, Mokumuru, Mongalo, Sesalong, Udney 1, Werden	A72A A63A

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A6N0580	2007/11/20	2021/09/30	6801	34.21	24.15	28.26	10.06
A6N0582	2007/01/25	2020/12/18	3924	24.47	14.28	22.25	10.19
A6N0590	2007/08/29	2021/08/13	9259	49.52	26.12	34.44	7.00
A6N0595	2008/02/20	2019/04/16	2956	20.38	15.96	18.49	4.42
A6N0606	2011/11/03	2021/08/19	6461	46.31	38.78	42.36	7.53
A6N0579	2005/09/08	2020/12/15	7548	70.11	49.25	56.21	20.86
A6N0592	2007/09/04	2021/09/20	2133	5.49	2.44	4.34	3.05
A6N0608	2010/02/15	2018/01/22	7421	37.74	26.34	31.59	11.41

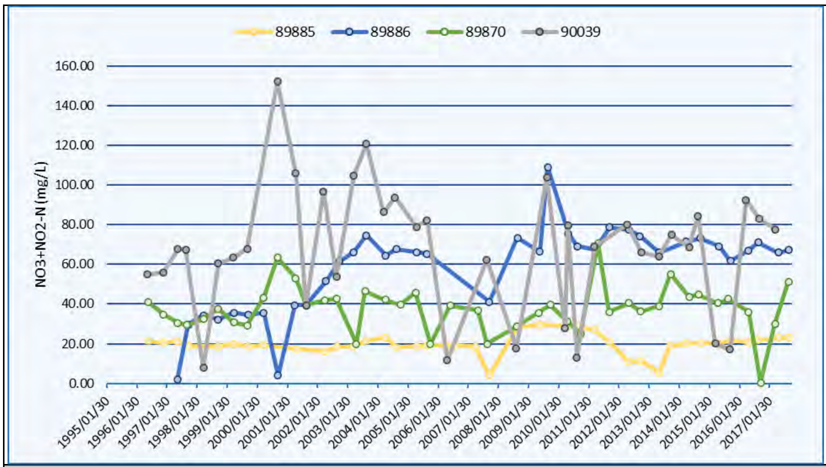
Water Level Graphs

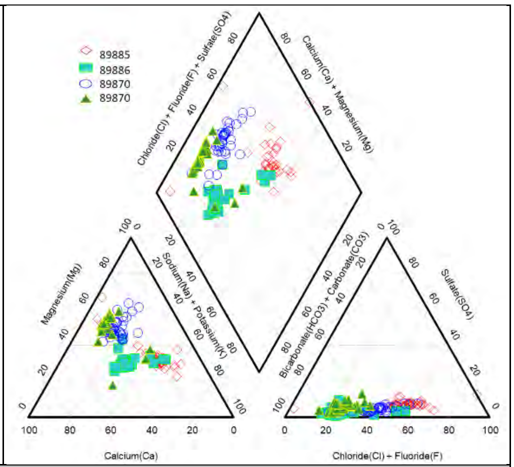


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89885	1996/06/11	2017/09/20	39	29.70	3.92	19.83	Yes
89886	1997/06/04	2017/09/20	37	109.00	1.80	66.15	Yes
89870	1996/06/11	2017/09/12	42	70.62	0.47	39.17	Yes
90039	1996/06/05	2017/04/10	38	152.15	7.80	68.35	Yes

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the stations show a fluctuation of between 3 and 21 m. The overall trend for most monitoring stations indicate a decrease in water levels. A significant decrease of approx. 21 m is observed at station A6N0579. Monitoring stations A6N0592, A6N0595 and A6N0582 show limited water level fluctuations and an overall increasing trend.

Nitrate concentrations is elevated for all monitoring stations. The nitrate concentration graph show significant fluctuations at stations 89886 and 90039. Stations 89885 and 89870, indicate fairly constant nitrate concentrations over the time period.

The groundwater signature is dominated by both HCO_3 and Cl-anion water facies, indicating freshly recharged groundwater undergoing mineralisation.

2.4. UPPER SAND

The Sand River originates south of Polokwane and drains the eastern part of the Limpopo WMA. The River traverses semi-arid terrain before passing through the gorge at the Soutpansberg mountains. The catchment has exceptional groundwater reserves which have been heavily exploited. The water requirements are large compared to the rest of the study area, with irrigation the largest water user. One Subterranean government water control areas occur within the drainage region namely, Dendron-Vivo (Houdenbrak). In this assessment three GUAs have been delineated for the Upper Sand drainage area, namely A71-1 (Figure 30), A71-2 (Figure 31) and A71-3 (Figure 32). The area is characterised by high transmissivities and as a result has good groundwater potential (Table 35).

Table 35. Borehole information for the Upper Sand drainage region

Drainage system	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Upper Sand	A71-1	N	454	565	105	59	121
		Mean	53.4	16.0	32.4	1.4	4.9
Middle Sand	A71-2	N	777	633	126	53	222
		Mean	54.6	25.7	32.0	1.3	2.4
Hout	A71-3	N	736	1004	175	80	163
		Mean	66.3	25.1	52.7	1.5	2.8

2.4.1. Groundwater recharge

The climate of the Upper Sand is semi-arid with mean annual rainfall spatially varying between 350 mm and 700 mm (**Error! Reference source not found.**). The flat and almost featureless plateau can be described as an extremely old erosion surface underlain by crystalline bedrock into which several mature rivers have incised themselves. Low and variable rainfall together with evaporation rates (2000 mm) considerably exceeding rainfall result in a low expectation of natural recharge to groundwater. Recharge vary from approximately 10 mm/a to less than 3 mm/a north of Mogwadi. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 36.

Table 36. Recharge estimation (Upper Sand).

GMA	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Upper Sand	A71-1	A71A	468.3	1144	16.71	11.48	5.18
		A71B	450.4	882	9.99	6.81	5.70
Middle Sand	A71-2	A71C	417.8	1331	10.43	7.04	4.95
		A71D	390.0	892	2.39	1.60	3.33
		A71H	490.8	1012	15.07	10.40	8.91
Hout	A71-3	A71E	420.8	893	6.38	4.31	4.86
		A71F	400.2	683	4.29	2.88	3.67
		A71G	427.2	875	4.80	3.26	4.59
		A72A	464.5	1908	19.96	13.72	5.55

2.4.2. Groundwater Use

The groundwater use for each of the GUA associated with the Upper Sand River system is summarised in Table 37. The present WARMS groundwater use data was compared to the 2015 Limpopo (WMA) North Reconciliation Strategy (LNRS) estimated 2020 use.

Table 37. Groundwater use (per annum) as registered per catchment for each GUA.

GMA Description	GUA	Quat	WARMS: Use Mm^3	LNRS 2020 Mm^3
Upper Sand	A71-1	A71A	32.032	47.470
		A71B	5.620	13.217
Middle Sand	A71-2	A71C	18.898	25.263
		A71D	6.510	6.000
		A71H	15.210	3.762
Hout	A71-3	A71E	9.705	8.723
		A71F	6.294	7.752
		A71G	12.571	11.127
		A72A	16.248	24.017

2.4.3. Groundwater quality

Groundwater samples in the Upper Sand region vary from a Na-HCO_3 to a Na-Mg-HCO_3 and Na-Cl water type. A high percentage of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl type water present (Figure 29).

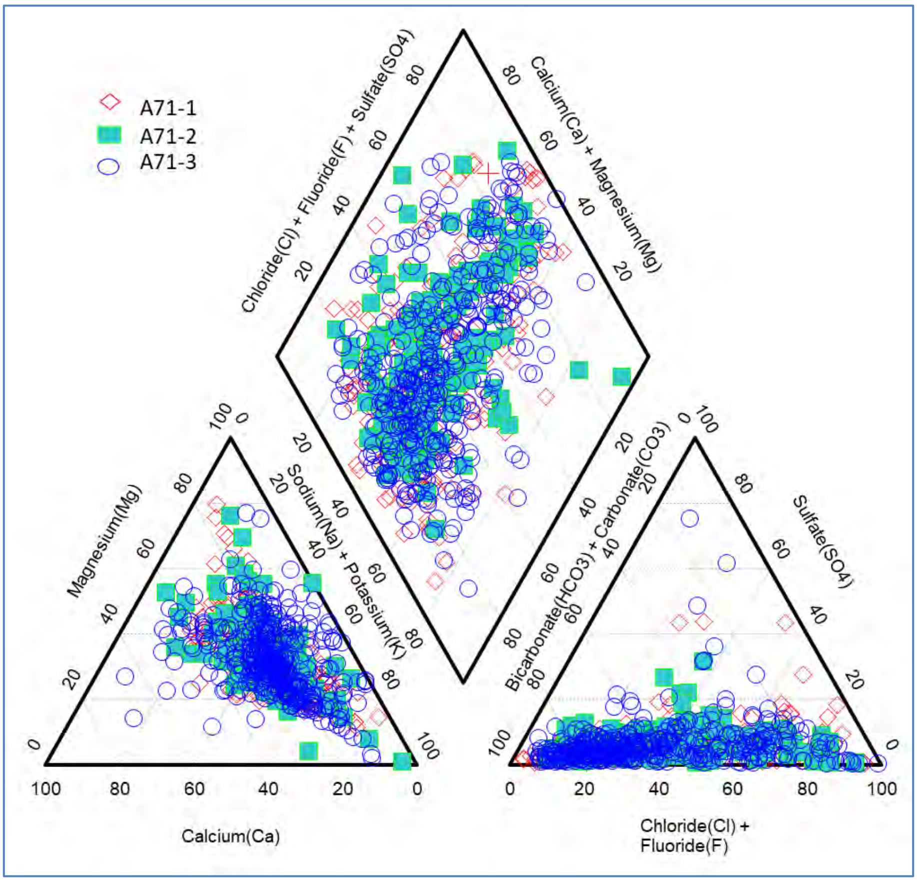


Figure 29. Piper diagram for the Upper Sand drainage region.

Groundwater quality in the Upper Sand region is considered to be marginal to poor with the most notable elements of concern include NO_3 as N with average concentrations above the maximum allowable recommended drinking limit in the (Table 38). In addition, some samples showed elevated major ion concentrations (e.g. Cl). This can mostly be related to evaporative concentration of elements in discharge areas or due to low recharge values as well as long residence times for selected samples.

Table 38. Groundwater quality for the Upper Sand region (All units in mg/l, EC in mS/m). (red text exceeds Class III)

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A71-1	N	178	180	167	204	201	203	203	198	204	32	179
	Median	8.1	87	650	40.9	35.6	86.4	6.2	26.0	68.4	24.9	0.4
A71-2	N	156	143	136	164	165	164	164	150	166	29	142
	Median	8.0	125	962	57.2	54.4	129.5	7.6	34.8	122.7	44.9	0.3
A71-3	N	320	322	347	389	387	386	385	384	389	39	287
	Median	8.1	109	826	47.7	46.4	111.4	9.9	27.6	140.4	23.8	0.3

2.4.4. Groundwater contribution to baseflow

Alluvium is present to various degrees in all the major surface water drainage courses grading from clay through sand to pebbles and in places is covered superficially by deposits of calcrete. In general, the thickness and lateral extent of the alluvium increases down-gradient towards the north. The porous nature of the alluvium makes this a natural repository for groundwater recharged periodically from ephemeral flows in the drainage courses. However, the natural groundwater-surface water interaction has been modified by the artificial recharge of treated sewage effluent that is continuously being discharged from the municipal sewage treatment works into the Sand River. This effluent is either abstracted directly from the Sand River by some riparian farmers downstream for irrigation purposes or it serves as a source of recharge of the groundwater stored in the alluvium. Comparison of groundwater contribution to baseflow estimates for the Upper Sand drainage region are summarised in Table 39.

Table 39. Groundwater contribution to baseflow estimates.

Description	GRU	Quat	Hughes Mm^3/a	Shultz Mm^3/a	Pitmann Mm^3/a	GRA II (WR2005) Mm^3/a	Maint. Low flow Mm^3/a
Upper Sand	A71-1	A71A	0.13	-	-	-	0.03
		A71B	0.01	-	-	-	0.42
Middle Sand	A71-2	A71C	0.01	-	-	-	0.24
		A71D	-	-	-	-	0.12
		A71H	0.19	-	-	-	0.75
Hout	A71-3	A71E	-	-	-	-	0.37
		A71F	-	-	-	-	0.23
		A71G	-	-	-	-	0.02
		A72A	0.34	-	-	-	0.06

2.4.1. Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 40, Table 41 and Table 42.

Table 40. Summary information for GUA: A71-1

GUA	Upper Sand A71-1
Description	The GUA is characterised by intergranular and fractured aquifer system associated with the Limpopo Mobile Belt. The groundwater potential of the Hout River Gneiss is in general moderate to good with yield between 0.5 to 2.0 L/s. High yielding boreholes in the Hout River Gneiss appear to be related to pegmatite occurrences in the area. Groundwater in the gneisses is also obtained in deep basins of weathering and transitional zones between weathered and solid gneiss. The groundwater potential of granite intrusive (batholiths), forming distinct inselbergs is generally poor, however boreholes located along the contact zones of these batholiths provide the highly productive boreholes. Associated with the Sand River is a intergranular alluvial aquifer system. Due to its limited extent and saturated thickness these aquifers are also vulnerable to over-abstraction during periods of drought when there is little or no recharge. The river section is characterised by a two-layers intergranular and fractured aquifer with groundwater yield above 5L/s. The groundwater is associated with irrigation, water supply, schedule I, mining, industrial, livestock watering and aquacultural uses.
Catchments	A71A,B
Map	

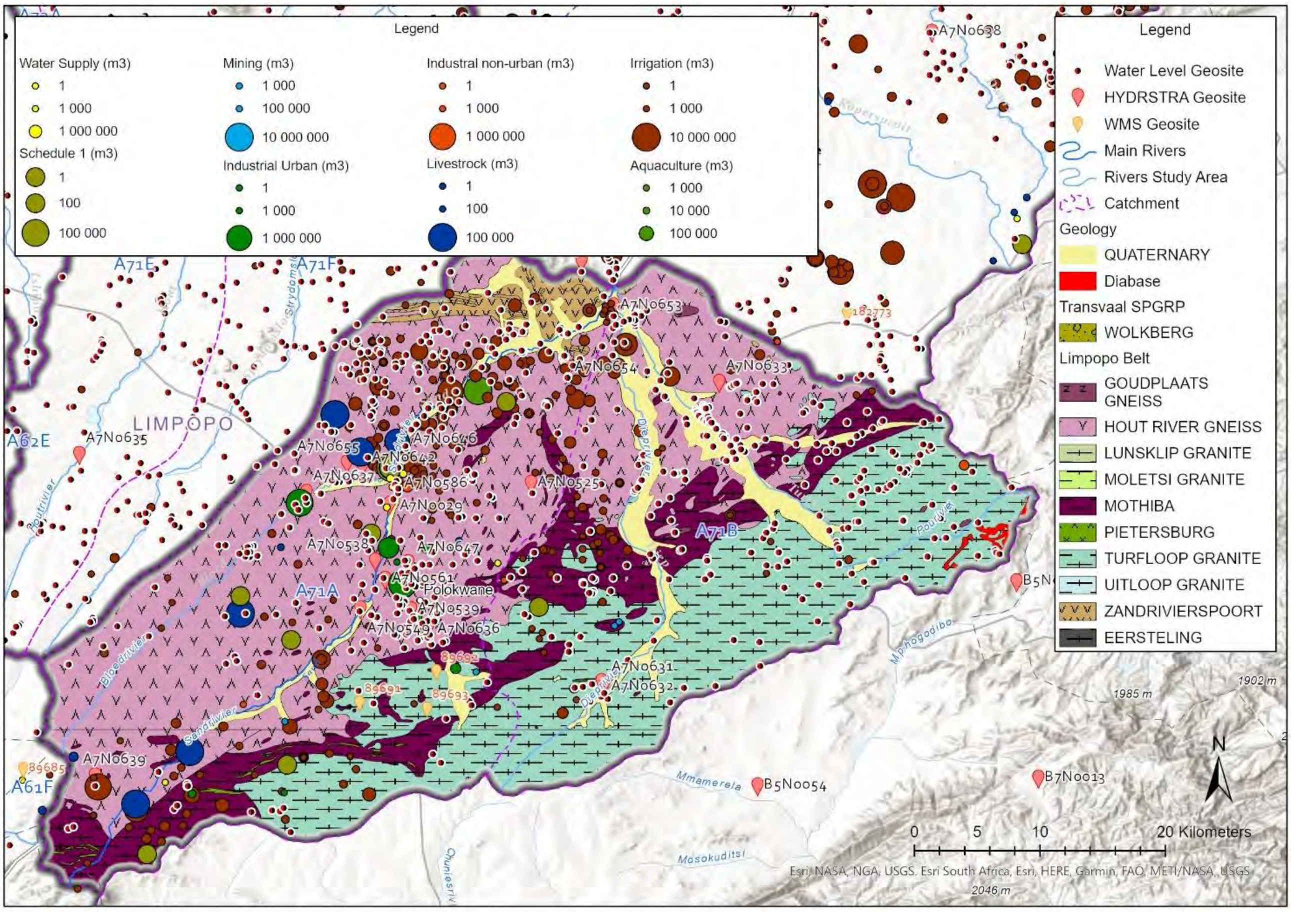


Figure 30 Map showing GUA A71-1 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

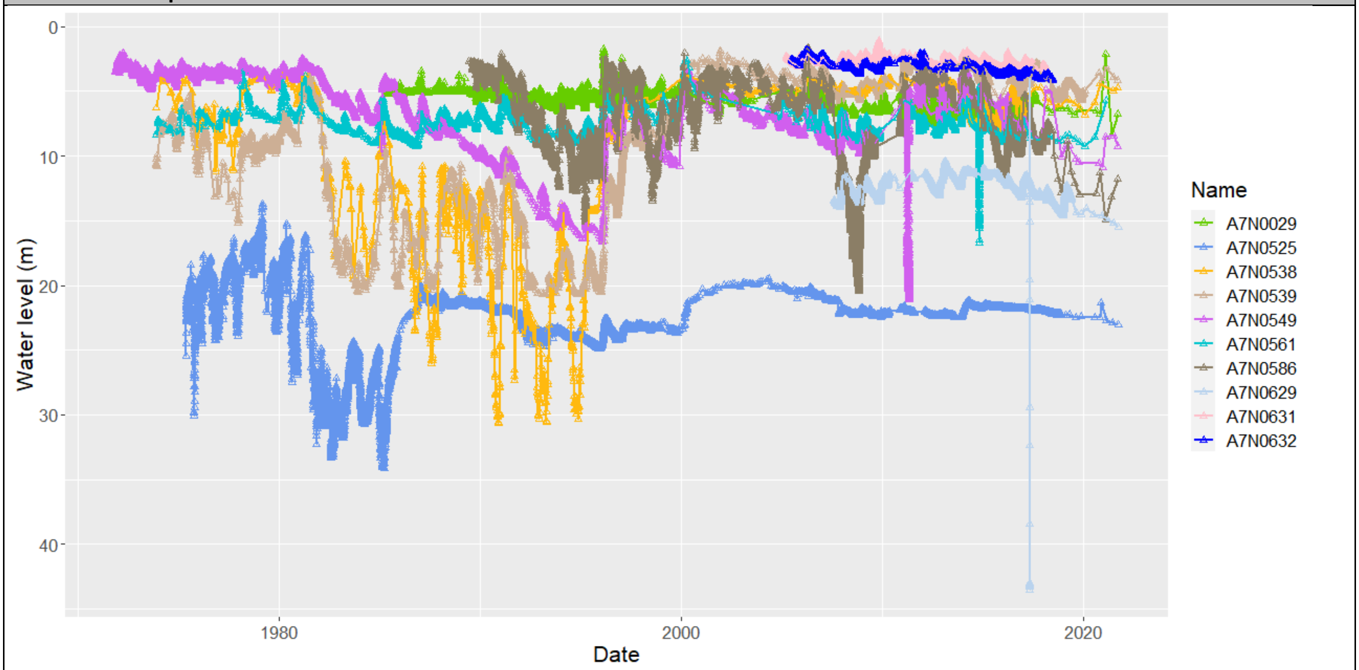
Scheme Name	Village/Settlement	Catchment
Badimong RWS	Badimong, Bergvley, Ga-kole, Ga-Mailula, Ga-Makgoba, GaMamphaka, Ga-Moropo, Ga-Silwane, Katzenstren, Kgatla, Kgwara, Komaneg, Lebowa, Leswane, Masealama, Melkboom, Mongwaneng, Moshate, Thema, Thune, Tsware	A71B
Laaste Hoop RWS	Laaste Hoop Ward 7, Maboi, Manthorwane, Mogoloe, Tsatsaneng	A71B
Mankweng RWSS	Ga-Magowa, Ma-Makanye, Ga-Ramogale, Ga-Thoka, Makgwareng, Mankweng A, Mankweng B, Mankweng C, Mankweng D, Mankweng unit E, Mankweng unit F, Mankweng unit G, Moshate, Tsatsaneng, University of the North	A71B
Mapela RWS	Danisane, Ditlotswane, Ga-Chokoe, Ga-Magongoa, Ga-Mokaba, Ga-Molekana, Ga-Pila Sterkwater, Ga-Tshaba, Hans, Kgobudi, Kwakwalata, Lelaka, Maala Parekisi, Mabuela, Mabusela, Mabusela Sandsloot, Machikiri, Magope, Malokongskop, Masahleng, Masenya, Masoge, Matlou, Matopa, Mesopotania,, Millenium Park, Mmahlogo, Mmalepeteke, Phafola, Ramorulane, Rooiwal, Seema, Sekgoboko Sekuruwe, Skimming,	A61F A61G A62B A62F A71B

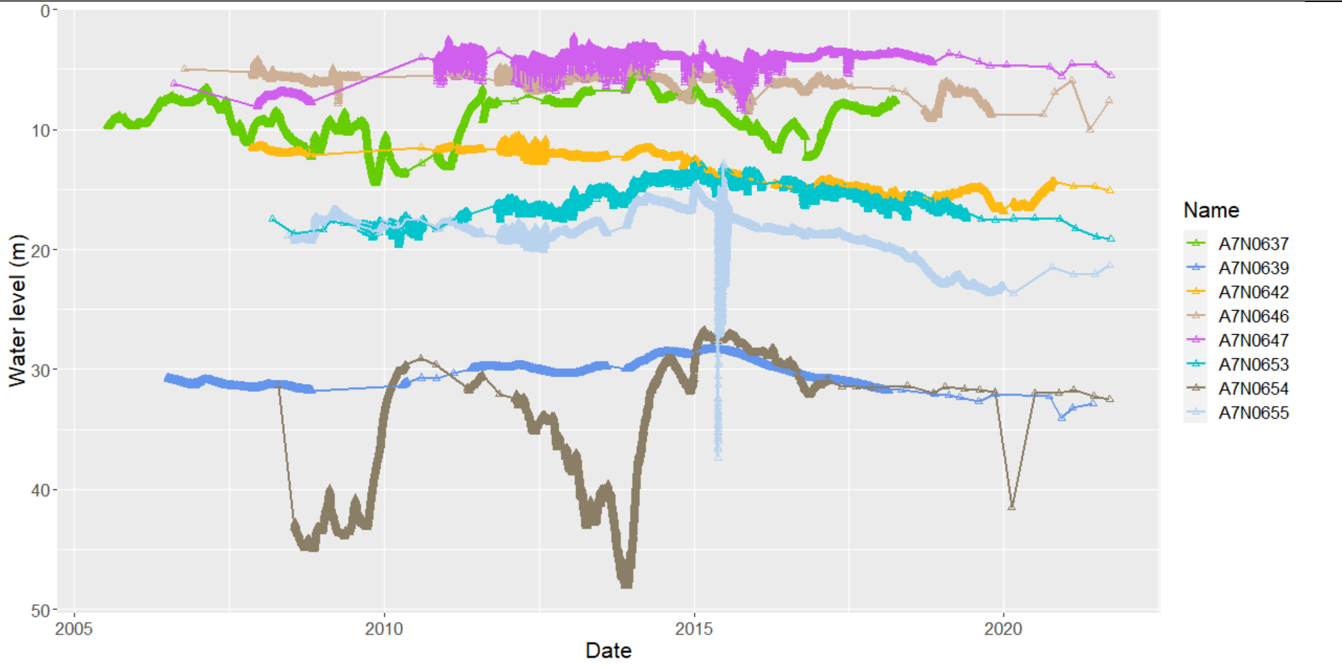
	Tshamahansi, Witrivier, Fothane, Mohlotlo Ga-Malebana, Mohlotlo Ga-Puka	
Moletje East Regional Groundwater SS	Chokoe, Ga-Mabotsa, Hlahla, Kobo, Mabitsela, Mabotsa 1, Mabotsa 2, Makibelo, Mashita, Masobohleng, Matikireng, Ramongwane 1, Ramongwane 2, Semenya, Setati	A71A A71E A71F
Mothapo RWSS	Cottage, Ga-Mothiba, Makotopong 1, Makotopong 2, NobodyMothapo, Nobody-Mothiba and Ntshichane	A71B
Olifants-Sand RWSS	Bloedrivier, Bergnek Greenside, Kgohlwane, Mabotsa, Makgove, Mokgokong, Pietersburg, Seshego, Sepanapudi, Toska, Mashinini, Seshego, Toska Mashinini, Zone 6, Perskebult Ext 1&2, Polokwane, Montinti Park, Dalmada S/H, Doornbult S/H, Elmadal S/H, Geluk S/H, Ivydale, Mooifontein S/H, Myngenoeg S/H, Palmietfontein S/H A, B &C, Tweefontein S/H, Roodepoort S/H, Polokwane SDA3	A71A A71B A71F
Segwasi RWSS	Jack and Mohlakeng	A71B

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A7N0029	1985/04/15	2021/09/13	2597	8.41	1.70	6.16	6.71
A7N0525	1975/05/07	2021/09/23	2871	34.13	13.74	22.03	20.39
A7N0538	1973/11/12	2021/09/13	4866	30.63	3.31	5.42	27.32
A7N0539	1973/11/13	2021/09/13	4656	20.71	1.89	4.39	18.82
A7N0549	1971/11/05	2021/09/13	6521	21.09	2.07	7.15	19.02
A7N0561	1973/11/12	2021/02/15	3746	16.74	2.57	7.65	14.17
A7N0586	1989/06/05	2021/09/13	9169	20.48	1.69	7.39	18.79
A7N0629	2007/07/31	2021/09/23	4028	19.56	4.01	12.23	15.55
A7N0631	2005/03/14	2018/02/08	2038	3.47	1.08	2.65	2.39
A7N0632	2005/06/20	2018/06/18	1890	4.13	1.83	3.08	2.30
A7N0633	2006/03/13	2021/09/17	7429	19.96	12.21	15.44	7.74
A7N0636	2005/02/25	2017/04/21	6964	11.11	4.08	7.59	7.03
A7N0637	2005/07/14	2018/04/03	8691	14.49	5.11	9.07	9.38
A7N0639	2006/07/04	2021/06/08	3541	34.08	28.25	30.20	5.83
A7N0642	2007/11/10	2021/09/17	5612	16.81	10.47	13.45	6.34
A7N0646	2006/10/10	2021/09/13	4240	10.05	4.16	6.09	5.89
A7N0647	2006/08/10	2021/09/23	3804	8.42	2.25	4.24	6.16
A7N0653	2008/03/11	2021/09/23	4654	19.63	12.75	15.62	6.88
A7N0654	2008/04/16	2021/09/15	14951	48.03	26.76	34.95	21.27
A7N0655	2008/06/11	2021/09/17	8195	37.34	12.83	18.78	24.51

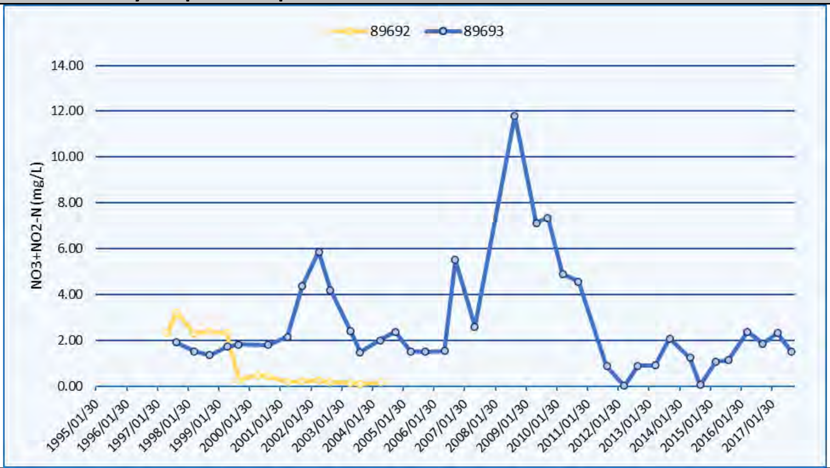
Water Level Graphs

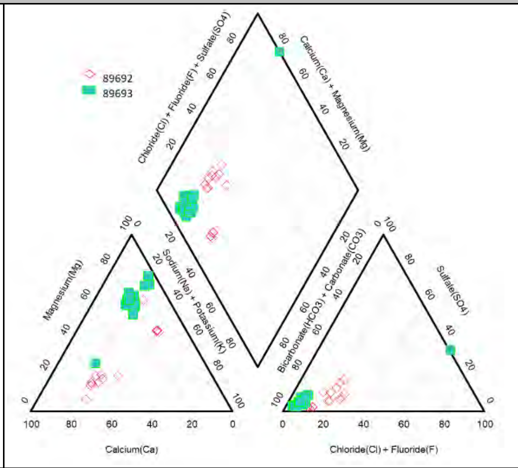




Available monitoring locations for trend analysis -Water Quality (Chemistry)							
Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89692	1997/05/26	2004/04/30	15	3.203	0.09	0.25	No
89693	1997/09/15	2017/09/18	34	11.80	0.03	1.85	Yes

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the stations show a fluctuation of between 2 and 27 m. Declining groundwater levels is observed at specific monitoring stations e.g. A7N0586 and A7N0549, overall groundwater levels appear to have recovered back to long term averages due to above average rainfall in late 1990s and early 2000's.

The nitrate concentration graph (89693) show a significant increase (> 10 mg/l) in observations during from 2008 to 2010 followed by a decreasing trend to around 2 mg/l, currently.

The groundwater signature is dominated by HCO_3 anion water facies, indicating freshly recharged groundwater that had limited time to undergo mineralisation.

Table 41. Summary information for GUA: A71-2

GUA	Middle Sand A71-2
Description	The groundwater potential of the Hout River Gneiss, Limpopo Mobile Belt, is high with yielding values > 5 l/s. The thickness of the regolith is typically between 15 and 50 metres below surface. Alluvial aquifers are recharged during periods of high stream-flows as well as during the rainfall season. Due to its limited extent and saturated thickness these aquifers are also vulnerable to over-abstraction during periods of drought when there is little or no recharge. Borehole yields generally range between 0.1 – > 5 l/s fir the GUA. Fractured rocks associated with the Karoo Supergroup is located furthest reaches towards the north of the GUA, close to the Sandsloot River. The groundwater use is associated with irrigation, water supply, industrial, schedule I, mining and livestock watering.
Catchments	A71C,D,H
Map	

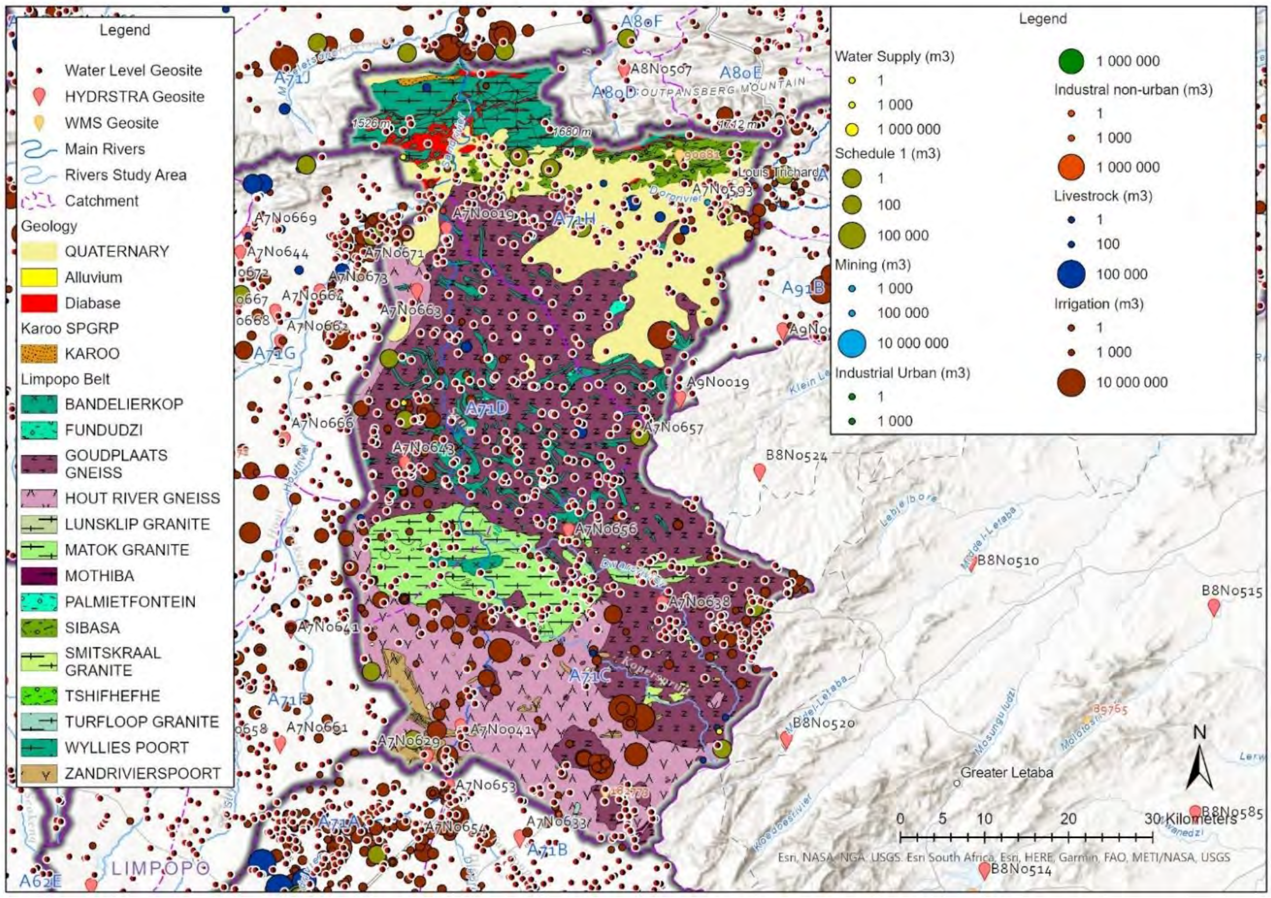


Figure 31 Map showing the distribution of GUA A71-2 with geology, wate use and geo-sites

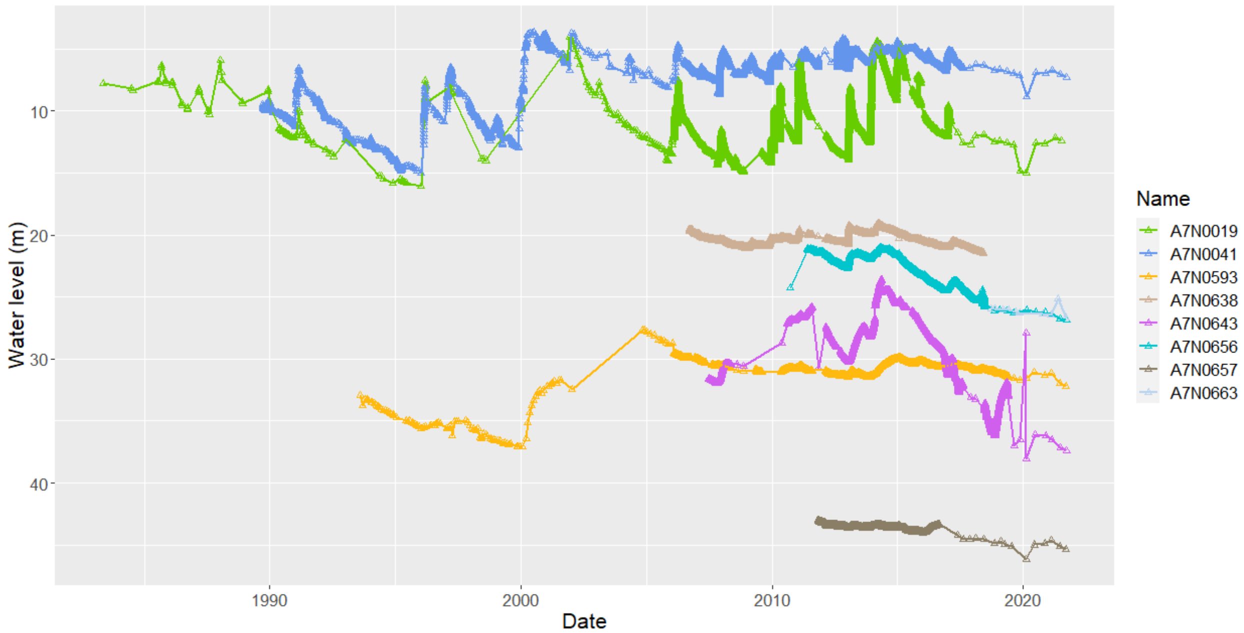
Water Use Schemes (after DWAF, 2015, Recon Study)

Scheme Name	**Village/Settlement**	**Catchment**
Alexandra Scheme	Alexandra Scheme	A71H A80D
Bandelierkop Supply	Bandelierkop Supply	A71D
Botlokwa GWS	Ga-Phasha, Makgato, Mangata, Matseke, Mphakane, Ramatjowe, Sekakene, St Brendans Mission School	A71C
Makhado Air Force Base Supply	Makhado Air Force Base	A71D A71H
Makhado RWSS	Tshikota, Louis Trichardt, Tshikota Squatter	A71H
Molemole LM Farms Supply	Molemole LM Farms Supply	A71D
Nthabiseng RWS	Capricorn Park, LCHMorebeng, Nthabiseng	A71C
Ramakgopa GWS	Eisleben, Mokganya, Ramakgop	A71C
Rietgat GWS	Rietgat (ZZ2)	A71C
Sinthumule/Kuta ma RWSS	Diiteleni, Midorini, Tshikhodobo, Dzumbathoho, Zamenkom, Tshikwarani B, Makhita, Tshikwarane, Raphalu, Ha-Manavhela, Muduluni, Muraleni Block B, Muraleni Block C, Ha-Madonga, Ravele, Ha Mamburu, Gogobole, Tshiozwi, Ha-Ramahantsha, Ramakhuba, Madombidzha Zone 1, Madombidzha Zone 2, Madombidzha Zone 3, Rathidili, Ha-Magau, Mutavhani, Raliphaswa, Siyawoodza, Moebani and Mutayhani	A71D A71G A71H

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A7N0019	1983/05/17	2021/07/12	10010	16.02	4.00	10.91	12.02
A7N0041	1989/09/20	2021/09/23	3361	14.99	3.63	6.05	11.36
A7N0593	1993/08/10	2021/09/16	2054	37.11	27.64	30.67	9.47
A7N0638	2006/09/12	2018/05/30	2399	21.47	19.05	20.37	2.41
A7N0643	2007/06/27	2021/09/23	10817	38.07	23.61	28.85	14.46
A7N0656	2010/09/20	2021/09/20	4308	26.84	21.04	22.67	5.80
A7N0657	2011/11/02	2021/09/14	998	45.39	43.01	43.54	2.38
A7N0663	2018/09/18	2021/09/14	10	26.67	25.15	26.11	1.52

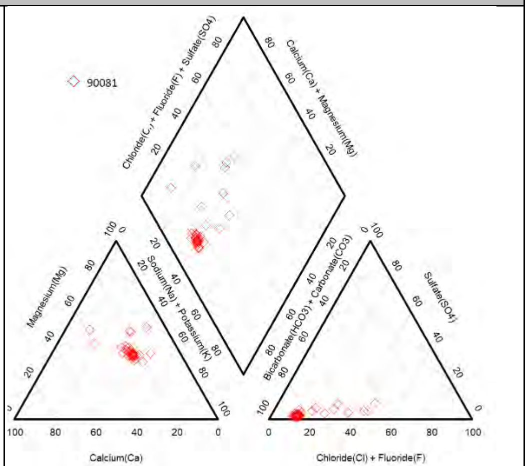
Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
90081	1995/06/23	2017/04/19	40	18.80	0.03	6.56	Yes

Water Quality Graph and Piper Plot



Comments

The observed hydrographs for each of the stations show a fluctuation of between 2 and 15 m. A response in water levels as a result of recharge events is observed for these monitoring boreholes. The majority of water levels are deeper than 20 m.

A decrease in groundwater levels have been observed up to the late 1900's, following a recharge event resulting in a slight recovery of the groundwater levels. An overall decrease in the groundwater levels since the recharge event can be observed.

The nitrate concentration graph show extreme fluctuations from 2012 to 2017 (exceeding 10 mg/l). The groundwater signature is dominated by HCO_3 anion water facies, indicating freshly recharged groundwater that had limited time to undergo mineralisation.

Table 42. Summary information for GUA: A71-3

GUA	Hout A71-3
Description	Borehole yields generally range between 0.1 – > 5 l/s.. The groundwater potential of the Hout River Gneiss is in general moderate to good yielding > 5 l/s. High yielding boreholes in the Hout River Gneiss appear to be related to pegmatite occurrences in the area. Water in the gneisses is also obtained in deep basins of weathering and transitional zones between weathered and solid gneiss. Deep weathering in excess of 40m is not uncommon in the gneiss. The thickness of the regolith in the generally extends to between 15 and 50 metres below surface. Below the weathered zone is a zone of fracturing, which according to geohydrological studies done by Dziembowski (1976) and Jolly (1986) in the Dendron/Mogwadi area may extend to depths greater than 120 m. The groundwater potential of granite intrusive (batholiths), forming distinct inselbergs is generally poor, however boreholes located along the contact zones of these batholiths provide the highly productive boreholes. Intergranular and fractured rocks from the Karoo supergroup is located in the west, close to Bodi are, with yields below 2L/s. The Blouberg Mountains, Soutpansberg and Waterberg Group form the sedimentary rocks towards the north of the GUA, with yields ranging from 0.5L/s to above 5L/s. The groundwater use is associated with irrigation, water supply, schedule I, industrial and livestock watering.
Catchments	A71E,F,G,A72A
Map	

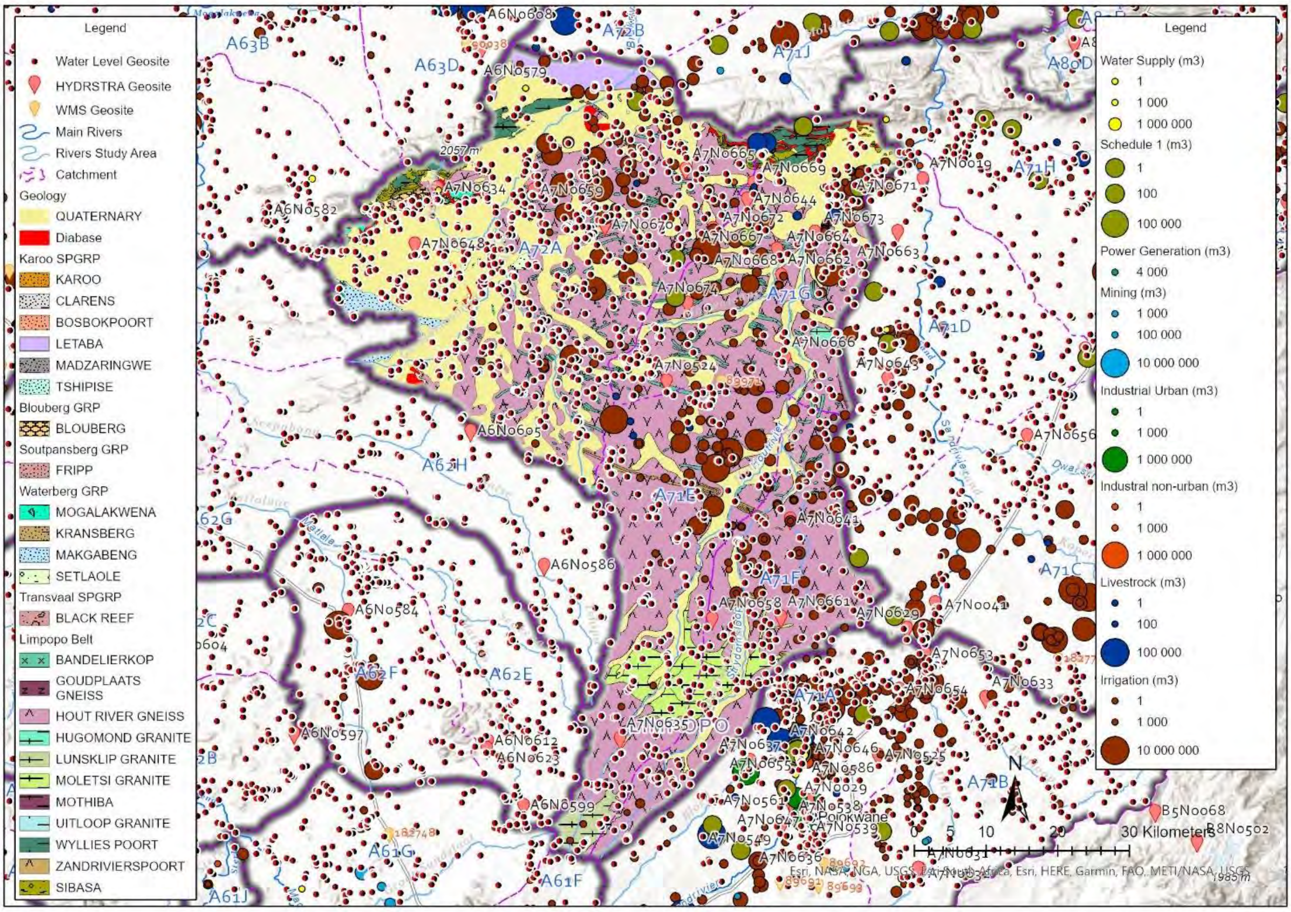


Figure 32 Map showing GUA A71-3 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

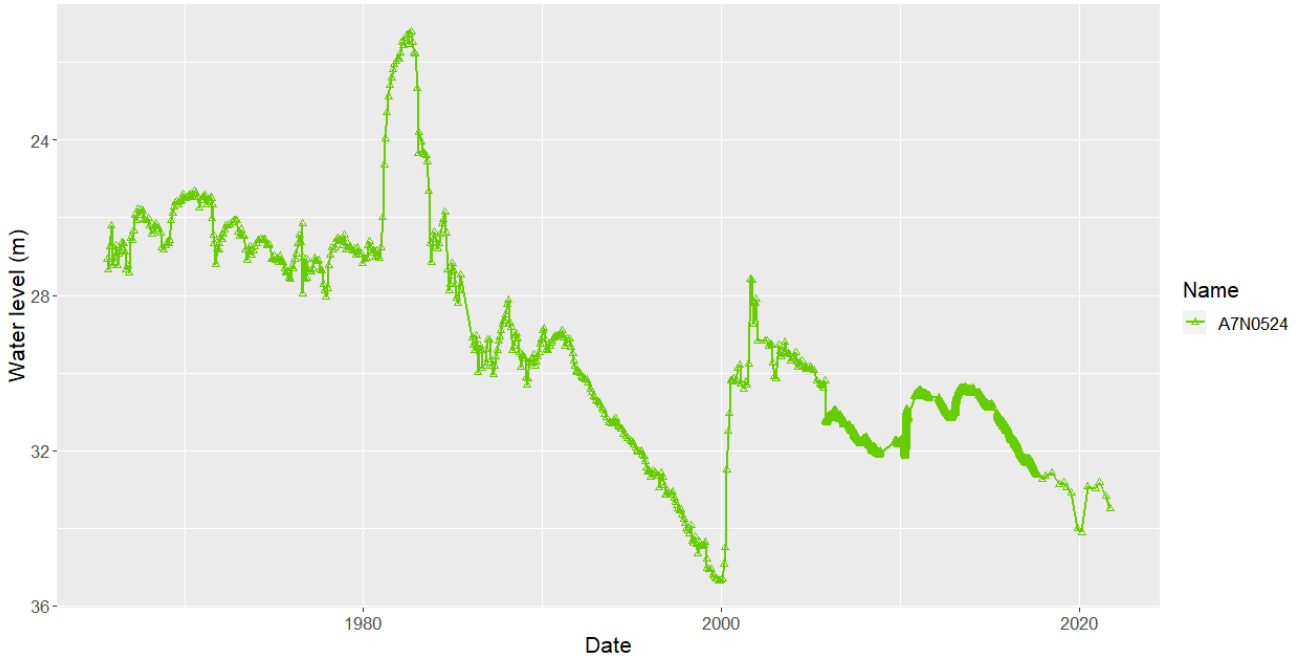
Scheme Name	Village/Settlement	Catchment
Aganang East GWS	Chloe A, Chloe B, Damplats, Eerste Geluk, Ga-Ngwetsana, GaRamoshwane, Kgabo Park, Preezburg, Ramatlwane, Rampuru, Rapitsi, Ga-Mmabasotho, Ga-Modikana, Ga-Phago, Ga-Piet, GaRankhuwe, Kalkspruit 1, Lehlohlong, Vischkuil, Wachtkraal and Ga-Nonyane	A62E A62H A71E A71F
Aganang North GWS	Ga-Maboth, Ga-Mantlhodi, Ga-Mosehlong, Ga-Motlakgomo, Kanana, Mohlajeng, Ga-Kolopo, Ga-Maribana, Ga-Phagodi, Marowe, Modderput, Sekuruwe 2, Ga-Moropa, Ga-Mankgodi, GaKeetse, Ga-Dikgale, Uitkyk and Terbrugge	A62H A71E A72A
Buysdorp Scheme	Buysdorp Scheme	A71G A72A
Houtrivier RWS	Koloti, Kamape 1, Komape 2, Komape 3, Mabukelele, Madikote, Mamadila, Moshate, Ramagaphota, Cristiana, Ga-Kgoroshi, GaSetshaba, Helena, Kalkspruit, Magongoa, Vlaklaagte and Waschbank	A62E A62H A71E A71F

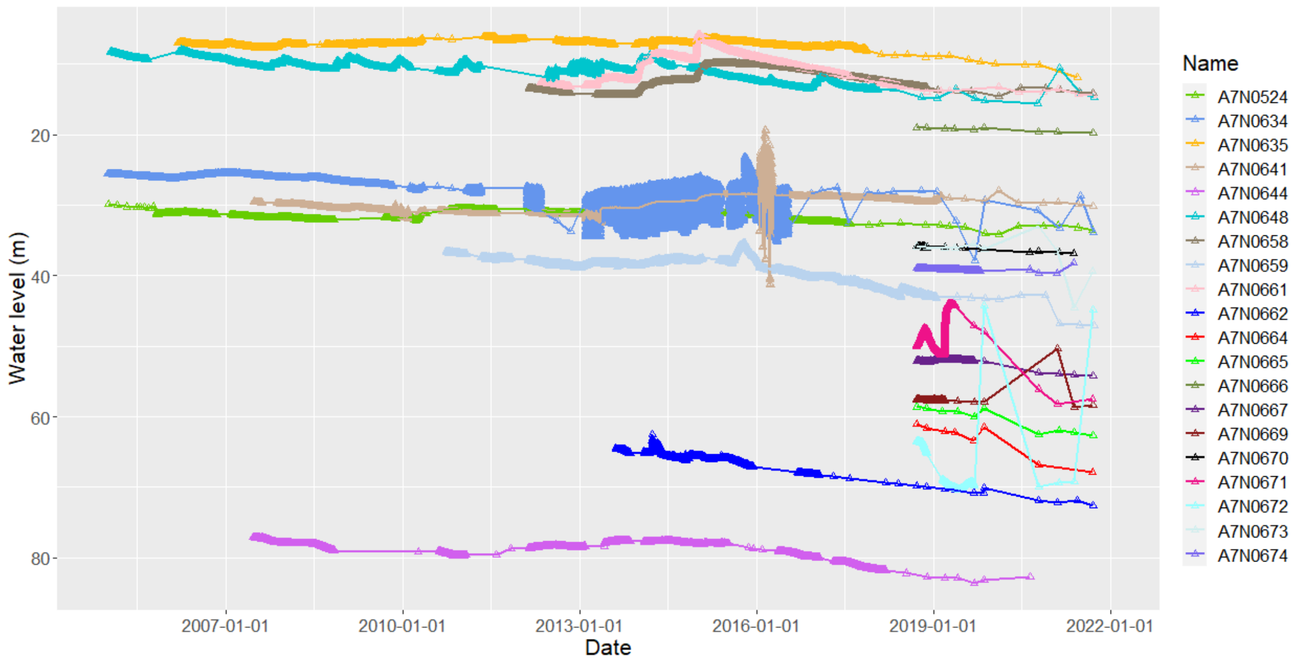
Makgalong A & B GWS	Makgalong A and Makgalong B	A71E
Mogwadi Wurthsdorp GWS	Fatima, Ga-Madikana, Koniggratz, Mogwadi, Mohodi, Wurthsdorp	A61E A71E A71G A72A
Molemole West Individual GWS	Ga-Mollele, Schellenburg A, Schellenburg B, Ga-Broekmane, GaMokwele, Brilliant, Koekoek, Ga-Poopedi, Bouwlust, Brussels, Ga-Mokgehle, Schoonveld 1, Schoonveld 2, Reinland, Ga-Kgare, Ga-Sako, Sakoleng, Overdijk West, Ga-Madikana, Wurthsdorp, Mogwadi, Fatima, Mohodi and Koniggratz	A71G A72A
Moletje East Regional Groundwater SS	Chokoe, Ga-Mabotsa, Hlahla, Kobo, Mabitsela, Mabotsa 1, Mabotsa 2, Makibelo, Mashita, Masobohleng, Matikireng, Ramongwane 1, Ramongwane 2, Semenya, Setati	A71A A71E A71F
Moletje North Groundwater SS	Ditengteng, Kgoroshi (Mphela), Kgoroshi (Thansa), and Mahwibitswane, Manamela	A71E A71F
Moletje South GWS	Boetse, Diana, Ga-Kgasha, Ga-Madiba, Ga-Mangou, GaMatlapa, Glen Roy, Jupiter, Mandela Park, Manyapye, Mapateng, Matlaleng, Maune, Mohlonong, Montwane 1, Montwane 2, Moshate, Naledi, Ngopane, Sebora, Sefahlane, Segoahleng, Sepanapudi, Utjane, Chebeng, Doornspruit, Ga-Mapangula, Makweya, Newlands, Pax College, Sengatane, Setotolwane College, Vaalkop 1 and Vaalkop 3 Venus and Waterplaats	A61F A61G A62E A62F A71E A71F
Olifants-Sand RWSS	Bloedrivier, Bergnek Greenside, Kgohlwane, Mabotsa, Makgove, Mokgokong, Pietersburg, Seshego, Sepanapudi, Toska, Mashinini, Seshego, Toska Mashinini, Zone 6, Perskebult Ext 1&2, Polokwane, Montinti Park, Dalmada S/H, Doornbult S/H, Elmadal S/H, Geluk S/H, Ivydale, Mooifontein S/H, Myngenoeg S/H, Palmietfontein S/H A, B &C, Tweefontein S/H, Roodepoort S/H, Polokwane SDA3	A71A A71B A71F
Sinthumule/Kuta ma RWSS	Diiteleni, Midorini, Tshikhodobo, Dzumbathoho, Zamenkom, Tshikwarani B, Makhita, Tshikwarane, Raphalu, Ha-Manavhela, Muduluni, Muraleni Block B, Muraleni Block C, Ha-Madonga, Ravele, Ha Mamburu, Gogobole, Tshiozwi, Ha-Ramahantsha, Ramakhuba, Madombidzha Zone 1, Madombidzha Zone 2, Madombidzha Zone 3, Rathidili, Ha-Magau, Mutavhani, Raliphaswa, Siyawoodza, Moebani and Mutayhani	A71D A71G A71H

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A7N0524	1965/09/10	2021/09/14	2547	35.35	21.21	31.29	14.14
A7N0634	2004/12/01	2021/09/20	8866	37.79	23.18	27.28	14.62
A7N0635	2006/03/09	2021/06/10	1899	11.85	6.03	7.06	5.82
A7N0641	2007/06/27	2021/09/16	5204	41.22	19.26	29.71	21.96
A7N0644	2007/05/31	2021/02/08	4226	82.68	77.01	78.69	5.67
A7N0648	2005/01/18	2021/09/23	5677	15.53	7.94	10.66	7.59
A7N0658	2012/02/20	2021/09/16	4625	14.59	9.77	12.04	4.82
A7N0659	2010/09/29	2021/09/21	7158	47.05	35.27	39.02	11.78
A7N0661	2012/05/07	2021/09/15	6943	14.36	5.79	10.34	8.57
A7N0662	2013/08/13	2021/09/15	2842	72.67	62.45	66.01	10.22
A7N0664	2018/09/18	2021/09/14	8	67.87	61.03	63.31	6.84
A7N0665	2018/09/21	2021/09/15	10	62.72	58.57	60.41	4.15
A7N0666	2018/09/18	2021/09/15	9	19.74	19.00	19.30	0.74
A7N0667	2018/09/18	2021/09/15	481	54.23	51.78	51.99	2.45
A7N0669	2018/09/18	2021/09/14	306	58.59	50.31	57.63	8.28
A7N0670	2018/09/21	2021/05/20	241	36.86	35.77	35.90	1.09
A7N0671	2018/09/18	2021/09/14	2851	58.14	35.16	48.14	22.98
A7N0672	2018/09/18	2021/09/15	1940	70.31	44.19	68.30	26.12
A7N0673	2018/09/18	2021/09/14	10	44.57	32.94	36.91	11.63
A7N0674	2018/09/21	2021/05/20	481	39.67	38.20	39.12	1.47

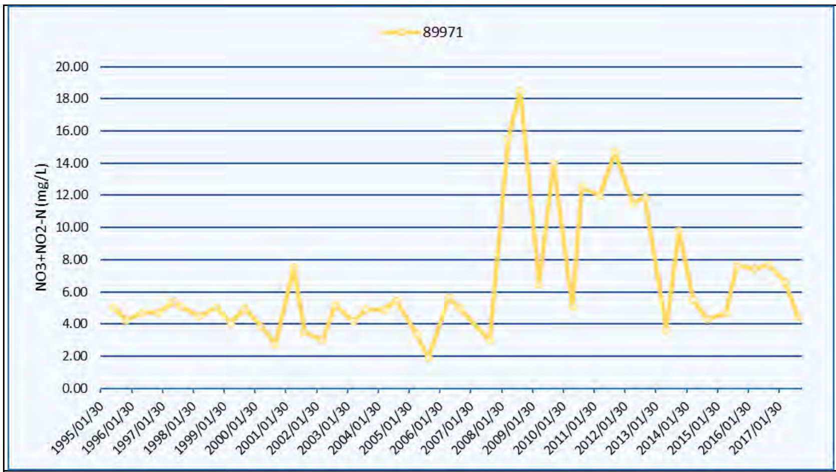
Water Level Graphs

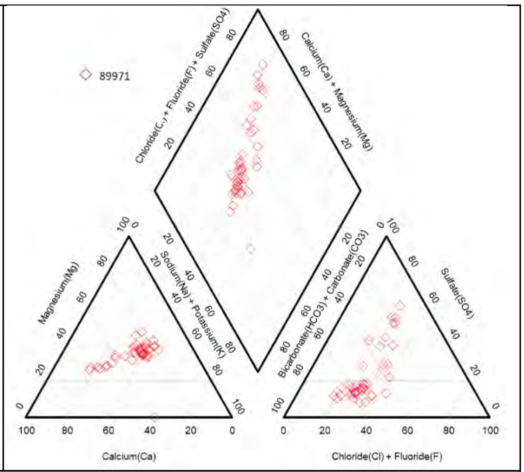




Available monitoring locations for trend analysis -Water Quality (Chemistry)							
Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89971	1995/06/23	2017/09/11	45	18.50	1.89	5.04	Yes

Water Quality Graph and Piper Plot





Comments
The observed hydrographs for each of the stations show a fluctuation of between 1 and 26 m. Station A7N0524 has the longest available data since 1956 and indicates show an overall decline in groundwater levels. Groundwater recharge events are evident during the 1980's and early 2000's, resulting in a recovery of the groundwater levels. The other stations indicate similar groundwater levels trends as A7N0524, however with a subdued reflection. A decline in groundwater levels is further observed at specific monitoring stations e.g. A7N0586 and A7N0549, overall groundwater levels appear to have recovered back to long term averages due to above average rainfall in late 1990s and early 200's. A well-identified seasonal groundwater level fluctuation is observed over most stations. The nitrate concentration graph show a sudden increase in early 2008 (exceeding 10 mg/l). A gradual decrease in this trend was observed since 2010 to concentrations of around 4 mg/l. The groundwater signature shows a mixed anion signature, indicating freshly recharged groundwater undergoing mineralisation with potential anthropogenic impacts.

2.5. LOWER SAND AND LIMPOPO TRIBUTARIES

The Lower Sand River passes through the gorge at the Soutpansberg Mountains before flowing north-east towards its confluence with the Limpopo River. Smaller urban centres (e.g. Musina) and numerous mining activities (e.g. Venetia diamond Mine) obtain water supplies from locally developed groundwater sources along the Limpopo River. Quaternary catchment A63E and A71L do not drain towards the Sand River but towards the Limpopo River via a number of smaller tributaries. Quaternary catchment A71L has the lowest rainfall and highest MAE of all of the catchments in the Sand River drainage area (tertiary catchment A71). The majority of water usage comes from the primary aquifer or directly from river flow. Numerous coalfields are being explored along the Limpopo River and north of the Soutpansberg. In this assessment the Lower Sand River have been delineated in two GUAs, namely A71-4 and A71-5, while quaternary catchment A71L have been grouped with A63E to form a separate GUA, namely A63/71-3 (Table 43).

Table 43. Borehole information for the Lower Sand and Limpopo Tributary drainage region

Drainage system	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Sandbrak	A71-4	N	360	240	3	4	150
		Mean	59.4	27.0	3.3	0.3	1.3
Lower Sand	A71-5	N	290	166	3	3	114
		Mean	46.9	24.5	3.5	0.7	1.4
Limpopo Tributaries	A63-3/71-3	N	562	348	2	2	161
		Mean	39.1	19.6	38.2	1.4	1.3

2.5.1. Groundwater recharge

The Lower Sand receives on average 350 mm rainfall per annum making it one of the arid areas in the Limpopo WMA (**Error! Reference source not found.**). Recharge are considered to be low over most of the area however, recharge can be slightly higher in the fault zones, and significantly higher in the alluvial area where no surface runoff is evident. Recharge vary from approximately 8 mm/a to less than 2 mm/a in the northeast. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 44.

Table 44. Recharge estimation (Lower Sand and Limpopo Tributary).

GMA	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Sandbrak	A71-4	A71J	396.1	1162	12.80	8.57	3.23
		A72B	343.9	1554	9.05	5.96	2.14
Lower Sand	A71-5	A71K	304.7	1668	9.47	6.12	0.95
Limpopo Tributaries	A63-3/71-3	A63E	357.9	1992	13.72	8.99	2.17
		A71L	287.8	1765	9.57	6.02	0.86

2.5.2. Groundwater Use

The groundwater use for each of the GUA associated with the Lower and Limpopo River system is summarised in Table 45. The present WARMS groundwater use data was compared to the 2015 Limpopo (WMA) North Reconciliation Strategy (LNRS) estimated 2020 use.

Table 45. Groundwater use (per annum) as registered per catchment for each GUA.

GMA Description	GUA	Quat	WARMS: Use Mm³	LNRS 2020 Mm³
Sandbrak	A71-4	A71J	13.921	16.519
		A72B	5.472	3.622
Lower Sand	A71-5	A71K	13.970	4.877
Limpopo Tributaries	A63-3/71-3	A63E	24.340	4.931
		A71L	22.631	0.589

2.5.3. Groundwater quality

A limited number of groundwater samples are available for the Lower Sand drainage region. Based on the piper diagram the main water types vary from a Ca/Mg-HCO_3, to a Na-Cl dominance (Figure 33). Na-Cl water type is a result of prolonged residence and fluid-rock interaction times in the subsurface in areas of discharge (i.e. alluvium along rivers) or areas of low recharge.

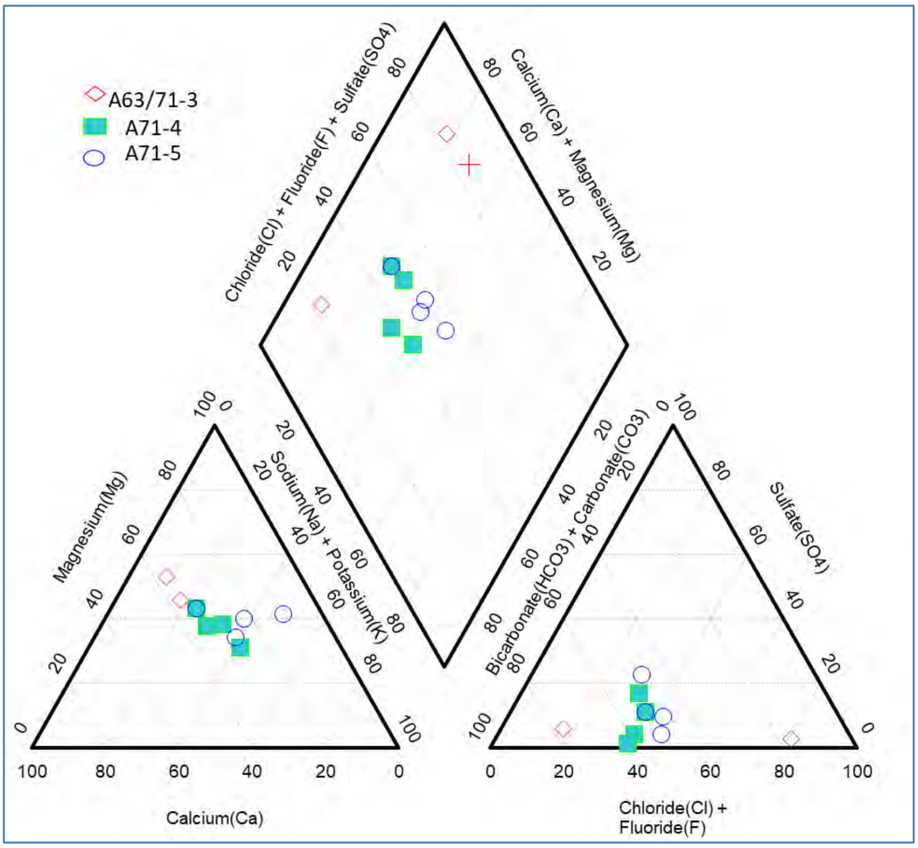


Figure 33. Piper diagram for the Lower Sand and Limpopo Tributary drainage region.

Groundwater quality in the Lower Sandriver and Limpopo Tributary region is considered to be marginal to poor with the the most notable elements of concern include NO_3 as N with average concentrations above the allowable recommended drinking limit (Table 46). In addition, several samples show elevated salt content and ion concentrations (e.g. Mg and EC) beyond acceptable limits. This can mostly be related to evaporative concentration of elements in discharge areas or due to low recharge values as well as long residence times for selected samples. It should be noted, a limited number of water sample (statistical population) was available for interpretation.

Table 46. Groundwater quality for the Lower Sand region (All units in mg/l, EC in mS/m).

GUA Para-meter		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A71-4	N	3	3	2	3	3	3	3	3	3	1	3
	Median	7.7	110	541	66.1	45.0	99.1	2.7	30.1	109.0	34.70	0.46
A71-5	N	4	4	3	4	4	4	4	4	4	1	4
	Median	8.1	177	1329	102.0	81.9	159.3	5.1	104.7	223.8	36.19	0.8
A63-3/71-3	N	2	2	2	2	2	2	2	2	2	0	2
	Median	8.1	131	964	95.3	79.6	37.5	1.6	41.0	76.6		0.5

2.5.4. Groundwater contribution to baseflow

The Lower Sand and Limpopo Tributaries have a low probability of groundwater contribution to baseflow. According to baseflow data in the GRA II dataset groundwater baseflow to surface water courses does not exist in the area, hence, natural recharge must be lost through riverine vegetation and spring discharge.

2.5.4.1.1.Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 47, Table 48 and Table 49.

Table 47. Summary information for GUA: A71-4

GUA	Sandbrak A71-4
Description	The main aquifer types include the Fractured aquifers associated with the Soutpansberg Group and Karoo Supergroup. The Soutpansberg Group does not possess any primary porosity and groundwater occurrences are controlled by geological structures. In general groundwater yields are low. The stratified rocks of the Karoo can generally be regarded as being of low groundwater potential away from structures with the inter-bedded sandstones having a moderate potential. Intergranular Alluvial aquifers (Limited to the main river stems) are recharged during periods of high stream-flows as well as during the rainfall season, The depths of the alluvium generally decrease away from the river. Intergranular and fractured associated with the Beit Bridge Complex cover large parts of the area with moderate groundwater potential and boreholes yield between 0.5 and 2 l/s. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. Although dykes have intruded the host rock extensively they are generally poor water suppliers. The groundwater use is associated with irrigation, water supply, schedule I, recreation, mining, industrial and livestock uses.
Catchments	A71J and A72B
Map	

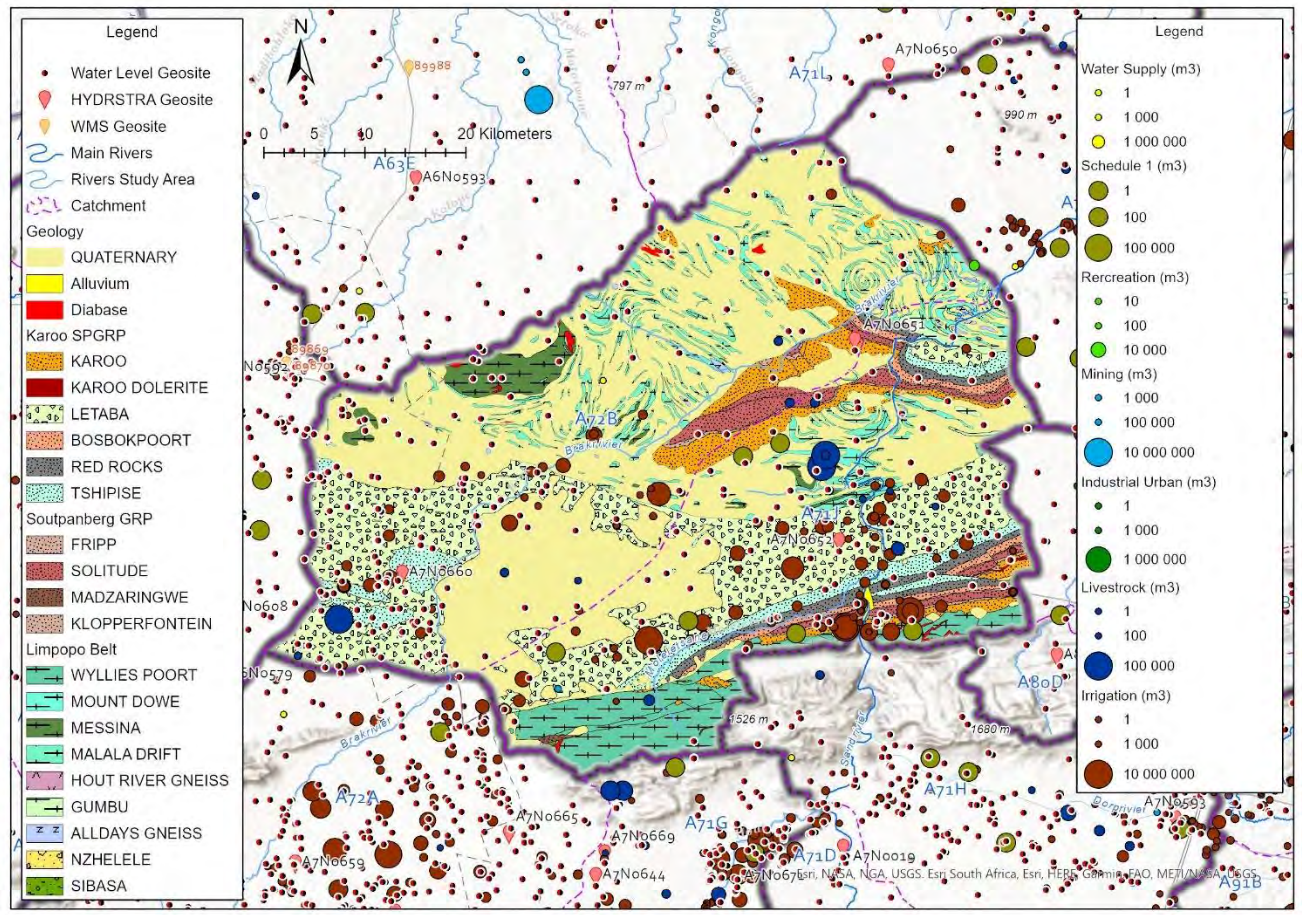


Figure 34 Map showing GUA A71-4 with geology, groundwater use and geo-sites.

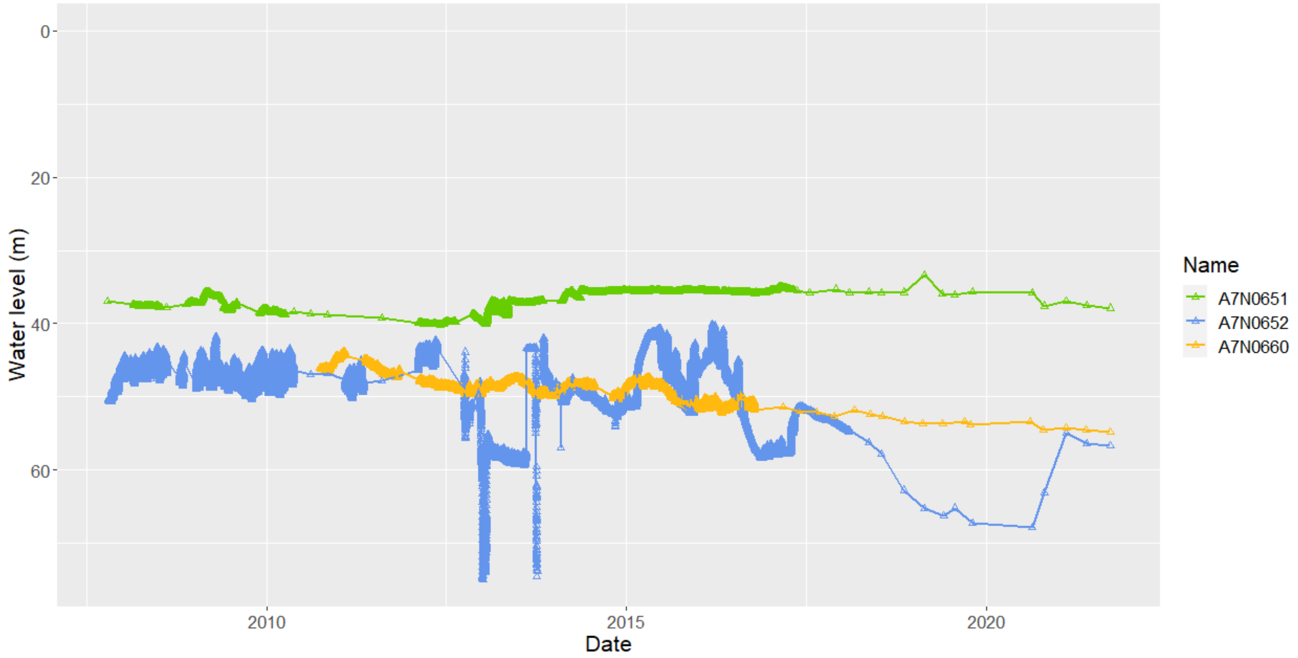
Water Use Schemes (after DWAF, 2015, Recon Study)

Scheme Name	Village/Settlement	Catchment
Mapela RWS	Danisane, Ditlotswane, Ga-Chokoe, Ga-Magongoa, Ga-Mokaba, Ga-Molekana, Ga-Pila Sterkwater, Ga-Tshaba, Hans, Kgobudi, Kwakwalata, Lelaka, Maala Parekisi, Mabuela, Mabusela, Mabusela Sandsloot, Machikiri, Magope, Malokongskop, Masahleng, Masenya, Masoge, Matlou, Matopa, Mesopotania,, Millenium Park, Mmahlogo, Mmalepeteke, Phafola, Ramorulane, Rooiwal, Seema, Sekgoboko Sekuruwe, Skimming, Tshamahansi, Witrivier, Fothane, Mohlotlo Ga-Malebana, Mohlotlo Ga-Puka	A61F A61G A62B A62F A71B
Musina LM Farms Supply	Farms Musina LM	A71J
Waterpoort Supply	Waterpoort	A71H A71J

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A7N0651	2007/10/18	2021/09/21	4236	40.17	33.35	36.76	6.82
A7N0652	2007/10/23	2021/09/21	16696	76.91	40.12	50.31	36.79
A7N0660	2010/09/29	2021/09/20	7400	54.89	43.87	48.63	11.02

Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
none							

Water Quality Graph and Piper Plot

none

Comments

The observed hydrographs for each of the stations show a fluctuation of between 2 and 36 m. Stations A7N0652 and A7N0660 show a declining groundwater level trend since the onset of monitoring in 2007. Some response in water levels as a result of recharge is evident. The average groundwater levels depths range from to 40 to 50 mbgl.

Table 48. Summary information for GUA: A71-5

GUA	Lower Sand A71-5
Description	The main aquifer types include with the Intergranular and fractured associated with the Beit Bridge Complex cover large parts of the area with moderate groundwater potential and boreholes yield between 0.5 and 2 l/s. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. Although dykes have intruded the host rock extensively they are generally poor water suppliers. The Fractured aquifers associated Soutpansberg Group and Karoo Supergroup. The Soutpansberg Group does not possess any primary porosity and groundwater occurrences are controlled by geological structures. In general groundwater yields are moderate, ranging from 0.5L/s to 2.0L/s. Alluvial aquifers (Limited to the main river stems) are recharged during periods of high stream-flows as well as during the rainfall season, The depths of the alluvium generally decrease away from the river.
Catchments	A71K

Map

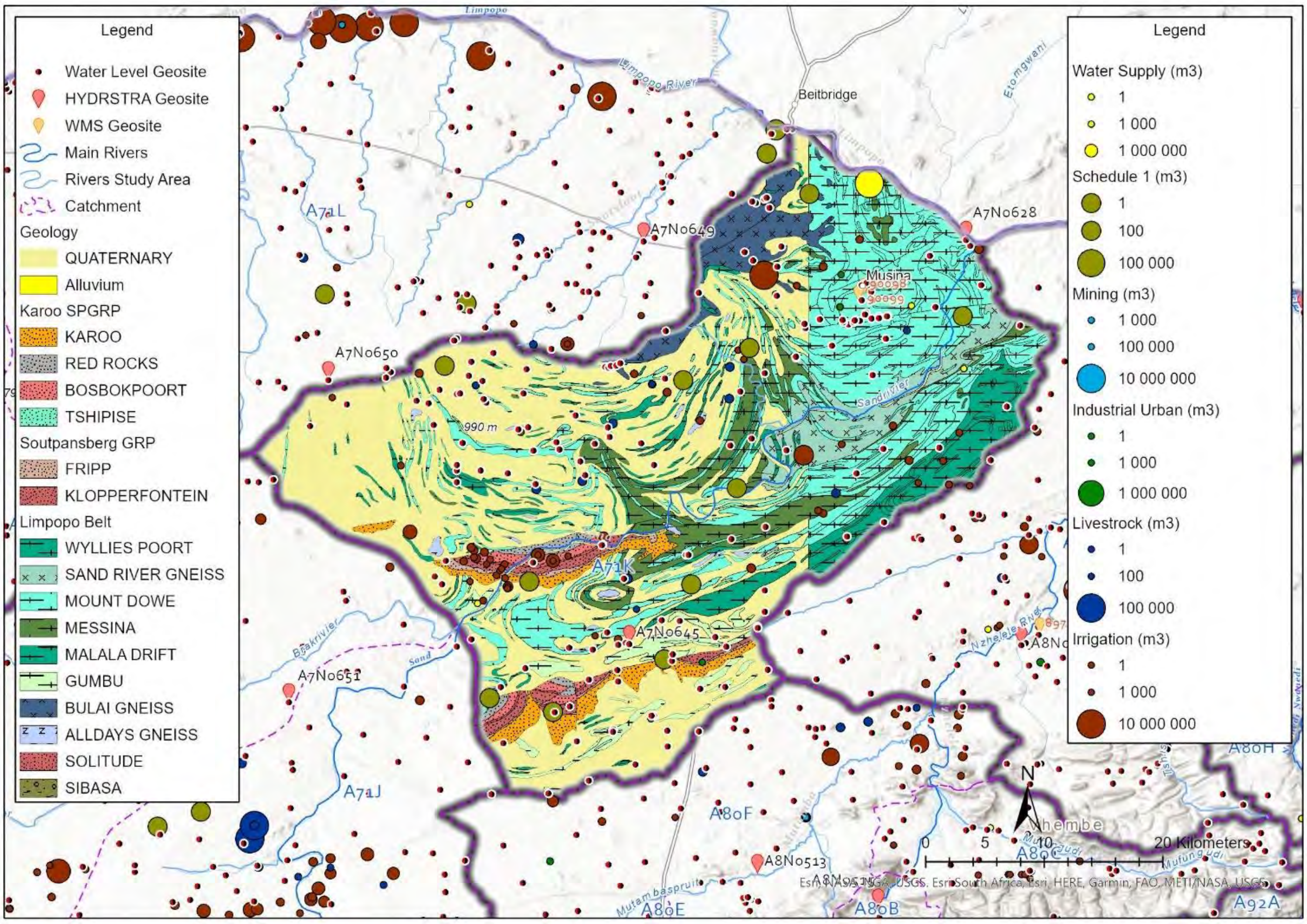


Figure 35 Map showing GUA A71-5 with geology, groundwater use and geo-sites.

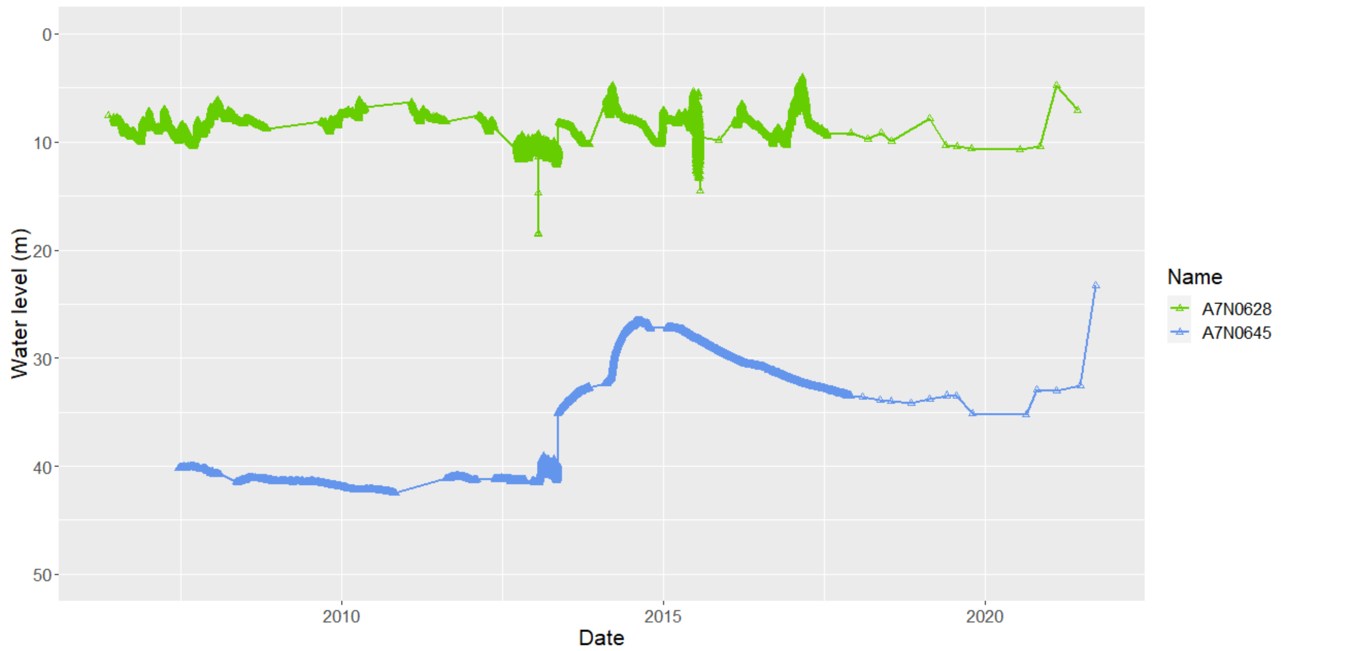
Water Use Schemes (after DWAF, 2015, Recon Study)

Scheme Name	Village/Settlement	Catchment
Mopane Supply	Mopane	A71K
Musina RWS	Musina (Messina), Harper, Harper Industrial, Lost City (Cambell), Musina Military Base, Nancefield	A71K A71L A80G

Available monitoring locations for trend analysis – Water Levels

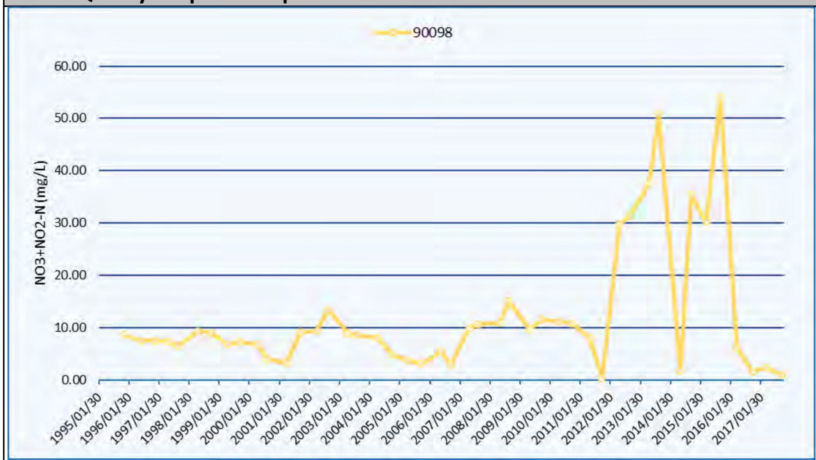
Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A7N0628	2006/05/19	2021/06/09	6328	22.34	4.04	8.46	18.29
A7N0645	2007/05/15	2021/09/21	10652	40.14	23.30	36.18	16.84

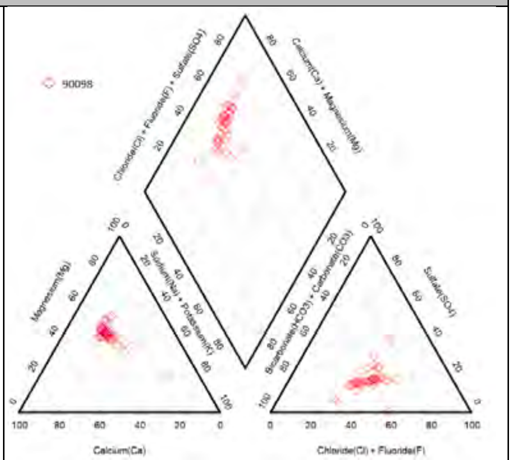
Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)							
Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
90098	1995/11/28	2017/10/12	45	54.01	0.295	8.536	Yes

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the stations show a fluctuation of between 16 and 18 m. Groundwater level monitoring stations show a significant response to recharge events with variable (and seasonal) fluctuations.

The nitrate concentration graph show a sudden increase in observations during 2012 followed by a decreasing trend to around 2 mg/l, currently. The groundwater signature is dominated by a mix between HCO_3 , Cl and SO_4 anion water facies, indicating groundwater undergoing mineralisation.

Table 49. Summary information for GUA: A63-3/71-3

GUA	Limpopo Tributary Sand A63-3/71-3
Description	The main aquifer types include the Fractured aquifers associated with the Karoo Supergroup and Soutpansberg Group. The stratified rocks of the Karoo and Soutpansberg can generally be regarded as being of low groundwater potential away from structures with the inter-bedded sandstones having a moderate potential, with yield ranging from 0.1L/s to 2.0L/s. Intergranular Alluvial aquifers from the Limpopo River are recharged during periods of high stream-flows as well as during the rainfall season and is associated with high yielding potential, above 5L/s. The depths of the alluvium generally decrease away from the river. Intergranular and fractured associated with the Beit Bridge Complex cover large parts of the area with moderate groundwater potential and boreholes yield between 0.5 and 2 l/s. Groundwater use is associated with irrigation, water supply, schedule I, mining, industrial and livestock watering uses.
Catchments	A63E, A71L
Map	

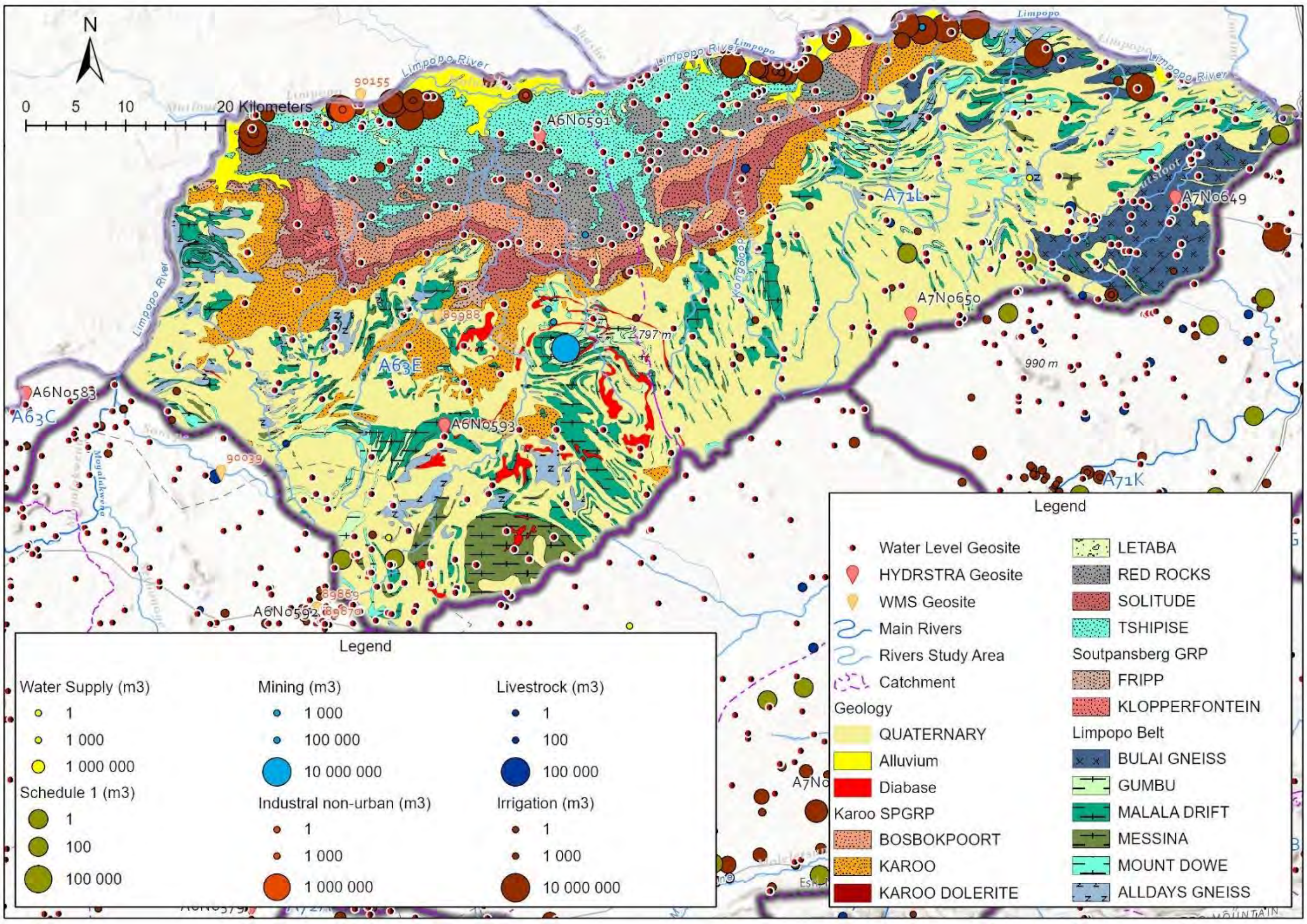


Figure 36 Map showing GUA A63/71-3 with geology, groundwater use and geo-sites.

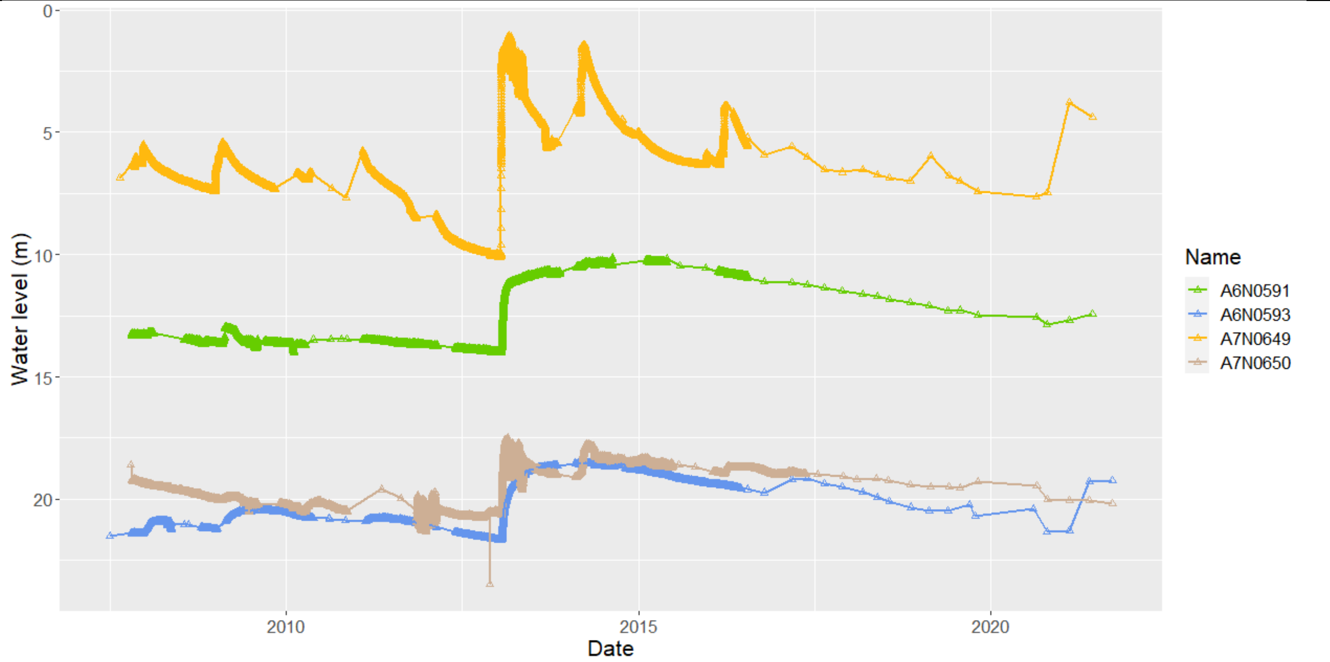
Water Use Schemes (after DWAF, 2015, Recon Study)

Scheme Name	**Village/Settlement**	**Catchment**
Alldays BS	Alldays	A63D A63E
Makhado LM Farms Supply	Farms Makhado LM	A63E
Musina RWS	Musina (Messina), Harper, Harper Industrial, Lost City (Cambell), Musina Military Base, Nancefield	A71K A71L A80G

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A6N0591	2007/08/08	2021/06/09	2079	13.00	10.11	12.55	2.89
A6N0593	2007/07/03	2021/09/20	2739	21.67	18.51	20.06	3.16
A7N0649	2007/08/23	2021/06/09	7937	10.13	1.04	6.21	9.09
A7N0650	2007/10/18	2021/09/21	2727	23.47	17.48	19.43	5.99

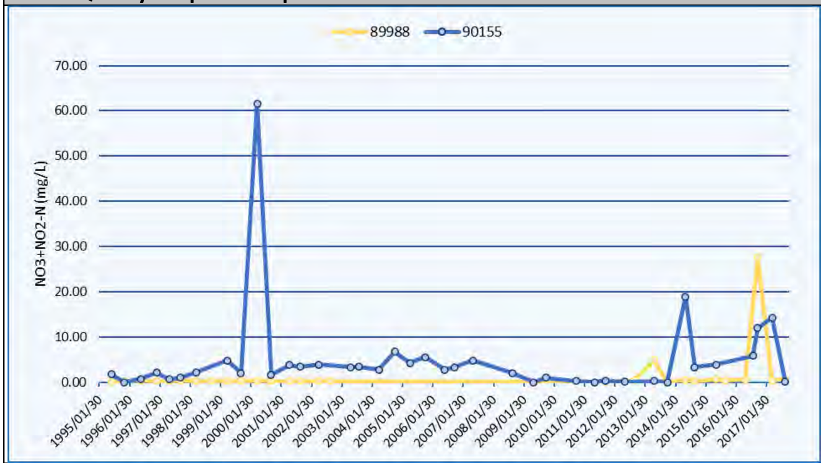
Water Level Graphs

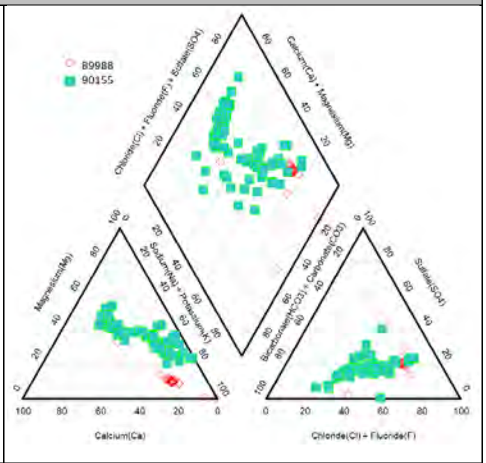


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89988	1995/06/26	2017/09/12	28	27.59	0.03	0.28	Yes
90155	1995/06/26	2017/09/12	37	61.61	0.01	2.76	Yes

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the stations show a fluctuation of between 3 and 10 m. A well-identified seasonal as well as response to significant recharge events can be inferred from the groundwater level fluctuation observations. Groundwater levels show a decreasing trend during poor recharge seasons.

The nitrate concentration graph show a some fluctuations exceeding 10 mg/l but are for most part around 2 mg/l. The groundwater signature is dominated by a mix between HCO_3 , Cl and SO_4 anion water facies, indicating groundwater undergoing mineralisation.

2.6. NZHELELE

The Nzhelele River comprises a perennial reach upstream of the Nzhelele Dam with considerable water abstraction. The upper reaches, which flow through forestry areas and steep mountainous areas, have several red data species. The waterfalls along several of the river reaches in the mountainous areas create breaks which prevent migration of fish species. Numerous flow dependent species occur in the upper Nzhelele and its tributaries. Although the groundwater is used extensively in certain areas, any additional water requirements for domestic use will have to be sourced from groundwater and groundwater still has potential for future use. In this assessment the Nzhelele have been delineated in two GUA, namely A81-1 (Figure 38) and A81-2 (Figure 39).

Table 50. Borehole information for the Nzhelele drainage region.

Drainage system	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Nzhelele	A81-1	N	387	293	72	38	**138**
		Mean	61.9	19.8	14.2	0.7	2
Lower Nzhelele	A81-2	N	190	122	14	13	106
		Mean	50.9	18.6	7.1	0.6	1.5

2.6.1. Groundwater recharge

The upper reaches of the drainage region drains the mountainous region to the south and has a relatively high rainfall (**Error! Reference source not found.**). For a small portion in the Soutpansberg the MAP is 1 000 mm and higher. In comparison the plains north of the Soutpansberg have a relatively low rainfall of only 300 mm per annum. Recharge vary from approximately 18 mm/a to less than 2 mm/a in the northeast. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 51.

Table 51. Recharge estimation (Nzhelele).

GMA	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Nzhelele	A81-1	A80A	938.0	287	26.11	20.40	48.27
		A80B	659.3	251	12.11	8.85	18.22
		A80C	576.3	294	11.26	8.00	13.48
		A80D	621.9	128	4.59	3.30	16.30
		A80E	622.3	247	9.79	7.01	16.23
		A80F	388.1	630	7.78	5.18	3.70
Lower Nzhelele	A81-2	A80G	332.6	1230	11.84	7.76	1.72

2.6.1. Groundwater Use

The groundwater use for each of the GUA associated with the Nzhelele River system is summarised in Table 52. The present WARMS groundwater use data was compared to the 2015 Limpopo (WMA) North Reconciliation Strategy (LNRS) estimated 2020 use.

Table 52. Groundwater use (per annum) as registered per catchment for each GUA.

GMA Description	GUA	Quat	WARMS: Use Mm³	LNRS 2020 Mm³
Nzhelele	A81-1	A80A	1.282	0.388
		A80B	1.471	0.407
		A80C	1.477	0.317
		A80D	0.030	0.455
		A80E	1.235	1.563
		A80F	2.901	0.843
Lower Nzhelele	A81-2	A80G	5.495	3.151

2.6.2. Groundwater quality

Based on the piper diagram the main water types for the Nzhelele region vary from a Ca/Mg-HCO_3, to a Na-Cl dominance (Figure 37). A number of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl and Ca/Mg-Cl type water present.

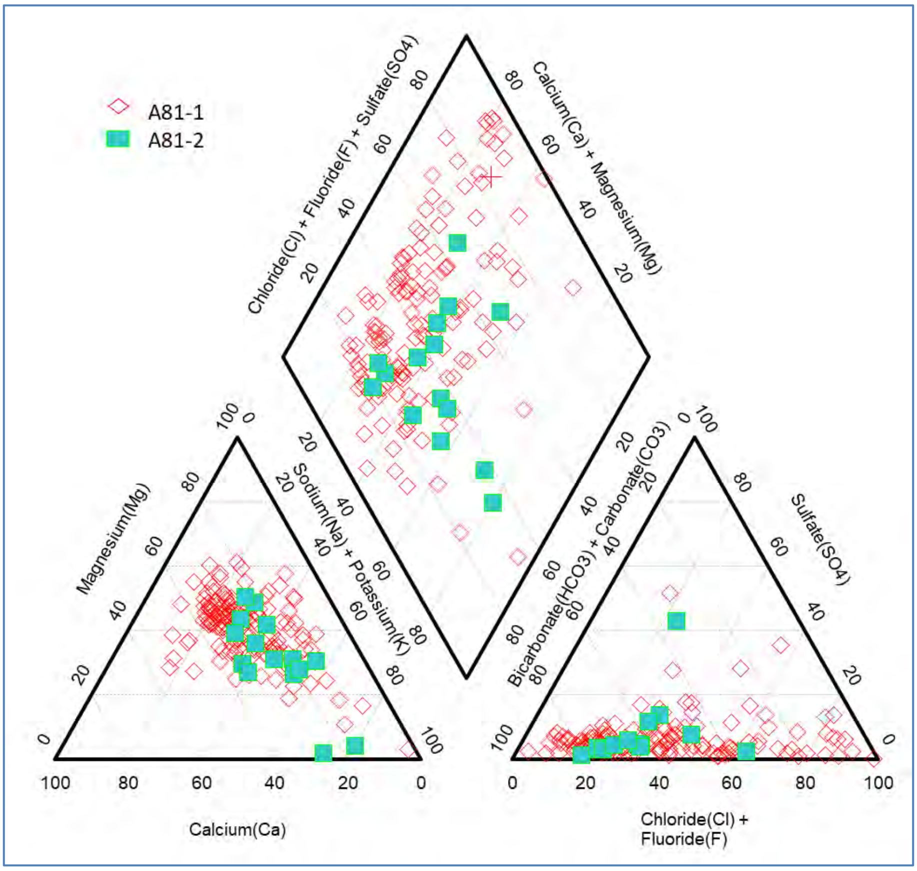


Figure 37. Piper diagram for the Nzhelele drainage region.

Groundwater quality in the Nzhelele region is considered to be acceptable for drinking water with limited exceedances observed (Table 53). Some elevated salts (chloride) are observed for the Nwanedi region.

Table 53. Groundwater quality for the Nzhelele zi region (All units in mg/l, EC in mS/m).

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A81-1	N	142	141	132	146	145	142	120	104	137	10	106
	Median	7.8	54	409	29.6	25.3	30.4	0.6	7.8	34.5	3.1	0.2
A81-2	N	15	15	14	15	15	15	15	15	15	0	15
	Median	7.9	177	1178	73.8	63.0	139.9	1.3	60.3	208.2		0.3

2.6.3. Groundwater contribution to baseflow

In the upper catchments groundwater contributes to base flow via sub surface seepage and springs. The probability of baseflow diminishes down-gradient towards the northeast. Comparison of groundwater contribution to baseflow estimates for the Nzhelele drainage region are summarised in Table 54.

Table 54. Groundwater contribution to baseflow estimates.

Description	GUA	Quat	Hughes Mm^3/a	Shultz Mm^3/a	Pitmann Mm^3/a	GRA II (WR2005) Mm^3/a	Maint. Low flow Mm^3/a
Nzhelele	A81-1	A80A	15.60	2.62	8.90	2.30	4.80
		A80B	4.66	1.23	3.31	1.98	1.24
		A80C	3.18	0.96	2.70	1.81	0.38
		A80D	1.98	0.57	1.43	0.99	0.52
		A80E	3.86	1.14	2.77	1.84	1.01
		A80F	-	-	-	-	0.01
Lower Nzhelele	A81-2	A80G	-	-	-	-	0.02

2.6.4. Summary

The following tables provide a summary for each of the GUA, as illustrated in Table 55 and Table 56.

Table 55. Summary information for GUA: A81-1

GUA	Nzhelele A81-1
Description	The Souptpansberg Mountain range forms prominent elevated topography, associated with higher recharge in comparison the lower laying areas. The main aquifer types include the Fractured aquifers from the Soutpansberg Group and Karoo Supergroup. The Soutpansberg Group does not possess any primary porosity and groundwater occurrences are controlled by geological structures. In general groundwater yields are moderate with yields up to 5L/s. The Karoo supergroup, located towards the north, has low groundwater potential with yield up 0.5L/s. to The Intergranular and fractured associated with the Limpopo Belt, granite-gneissic rocks, cover the central and southern portion of the GUA with moderate groundwater potential and boreholes yield between 0.5 and 2 l/s. Alluvial aquifers is mainly bound to the main river systems and the depths of the alluvium generally decrease away from the river. The groundwater use is associated with irrigation, water supply, schedule I, recreation, industrial and livestock watering uses.
Catchments	A80A, B,C,D,E,F

Map

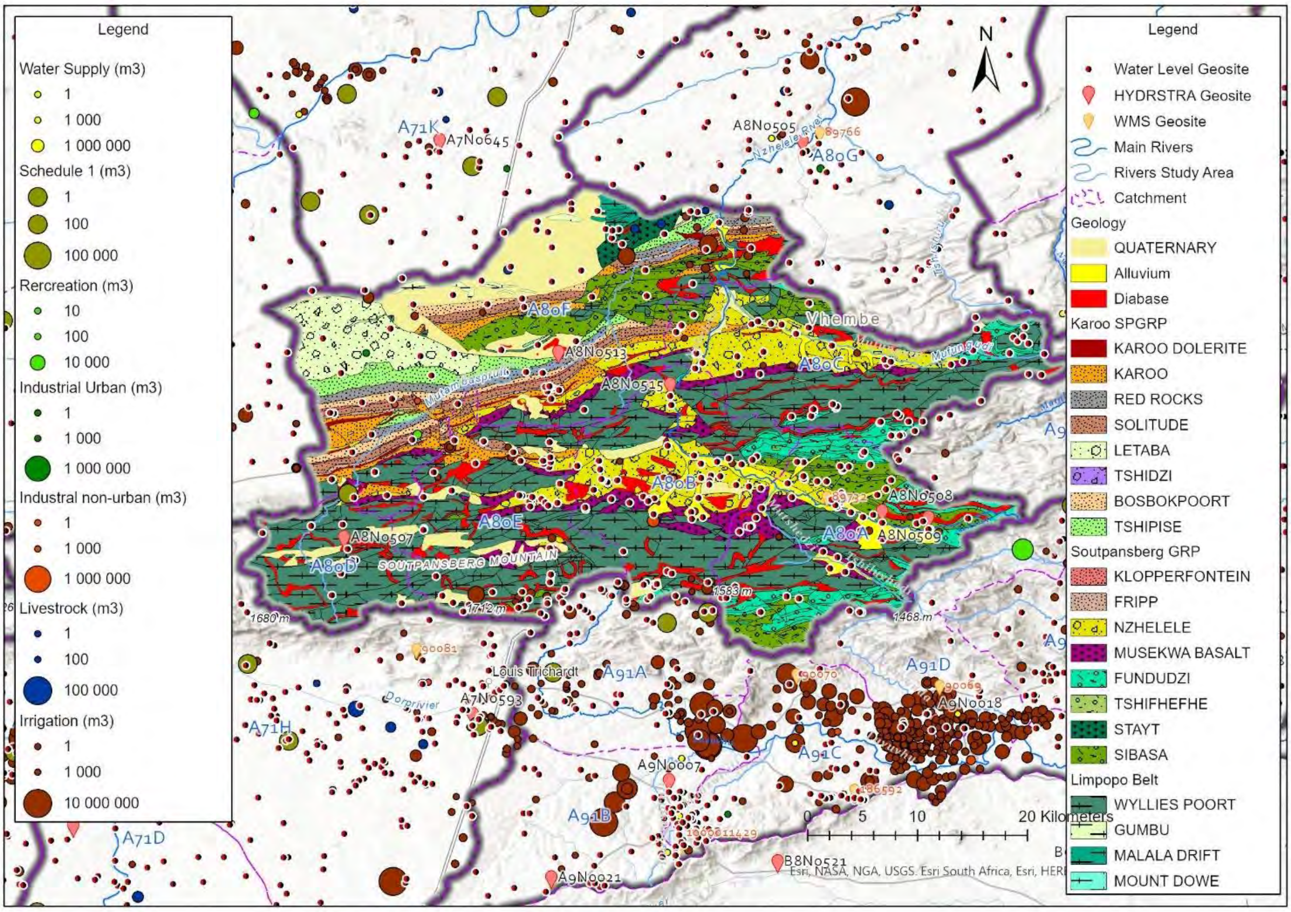


Figure 38 Map showing GUA A81-1 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

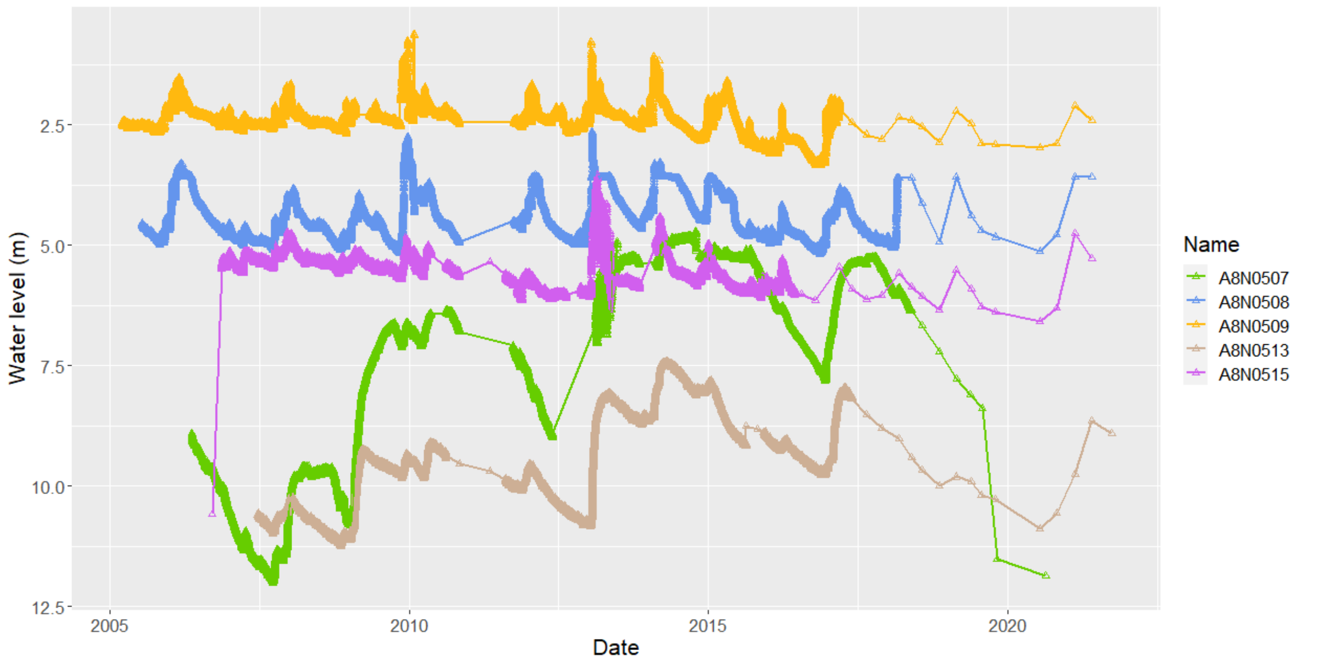
Scheme Name	Village/Settlement	Catchment
Alexandra Scheme	Alexandra	A71H A80D
Matshavhawe / Kunda RWS	Khunda, Matshavhawe, Manyuwa, Piesanghoek	A80A A80B
Mutale Main RWS	Dzamba Tshiwisa, Dzata Ruins, Dzumbama, Fefe, Gogogo, Goma, Gundani, Gwagwathini, Ha-Mabila, Helala, Khakhu Thondoni, Luheni, Madatshitshi, Madzororo, Mafhohoni, Mafhohoni, Mafhohoni South, Maname, Mavhode, Mavhuwa, Mazwimba, Mphagane, Mufongodi, Mufulwi, Ngalavhani, Mufulwi, Ngalavhani, Sheshe, Thonoda Lusidzana, Thononda, Tsaanda, Tsaanda 2 Tshiedeulu Thembaluvhilo, Tshiendeulu, Tshilimbane, Tshilovi, Tshitandani, ZTshixwandza and Tshumulungwi.	A80A A80B A80C A80G A80H
Nzhelele North RWS	Afton, Dolidoli, Garasite, Khomela, Maangani, Makushu, Mangwele, Maranikhwe, Mudimeli, Musekwa, Musekwa Korporasi, Natalie, Ndouvhada, Ngonavhanyai, Pfumembe, Pfumembe Tsha Fhasi, Phembani, Sane, Straighthardt, Tshitwi	A80B A80C A80E A80F A80G A80H A80J
Nzhelele RWS	Divhani, Domboni, Dopeni, Dzanani, Fondwe, Ha Matsa, HaFunyufunyu, Ha-Makatu, Ha-	A80A A80B

	Mandiwana Dzanani, Ha-Manngo, Ha-Maphaha, Ha-Mapila, Ha-Matidza, Ha-Matshareni, HaMphaila, Ha-Rabali, Khalavha, Lutomboni, Luvhalani, Magoloni, Makanga, Makhavhani, Makungwi, Malamba, Mamuhohi, Mamuhoyi, Mamvuka, Maname Paradise, Mandala A, Mandala B, Mandala Tshantha, Manyii, Manyuwa, Mapakophele, Matanda Zone 2, Matsa, Matsa A, Matsa B, Matserere, Mauluma, Mavhunga, Mbadoni, Mudunungu, Musanda Thondoni, Mutavhani, Posaito, Raliphaswa, Ramavhoya, Shanzha, Siloam, Siyawoadza, Thembaluvhilo, Thondoni, Tshatharu, Tshavhalovhedzi, Tshiheni, Tshikhalani, Tshikhalani East, Tshikhudo, Tshikuwi, Tshirolwe Ext 2, Tshirolwe Ext1, Tshisinisa, Tshiswenda, Tshitasini, Tshithuni Tshafhasi, Tshithuthuni, Tshituni, Tshituni B, Tshituni Tshantha, Tshivhambe, Tshivhilidulu, Vhutuwangazebu	A80E A80F
Tshifire Murunwa RWS	Dzumbathoho, Phadzima, Mazhazhani, Mazuwa, Gudumabama, Maelula, Vuvha, Matakani, Mazhazhani, Mazuwa, Murunwa, Tshedza Tshihalwe, Tshifudi B, Tshifudi A, Tshidzini Tshifudi, Tshidzini, Phaswana, Mutshetshe, Mushiru, Mushiro Mahagala, Musenga, Mubvumoni South, Mubvomoni North, Masiwane, Manzemba, Lukalo, Ha-Lambani Tshantha, Tshitavha, Begwa, Buluni, Dimani	A80A

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A8N0507	2006/05/19	2020/08/18	7049	12.01	4.72	7.38	7.30
A8N0508	2005/07/19	2021/05/25	2350	5.18	2.64	4.41	2.54
A8N0509	2005/03/16	2021/05/25	2121	3.35	0.62	2.41	2.73
A8N0513	2007/06/21	2021/09/22	3811	11.25	7.41	9.42	3.83
A8N0515	2006/09/20	2021/05/25	2075	10.58	3.55	5.50	7.03

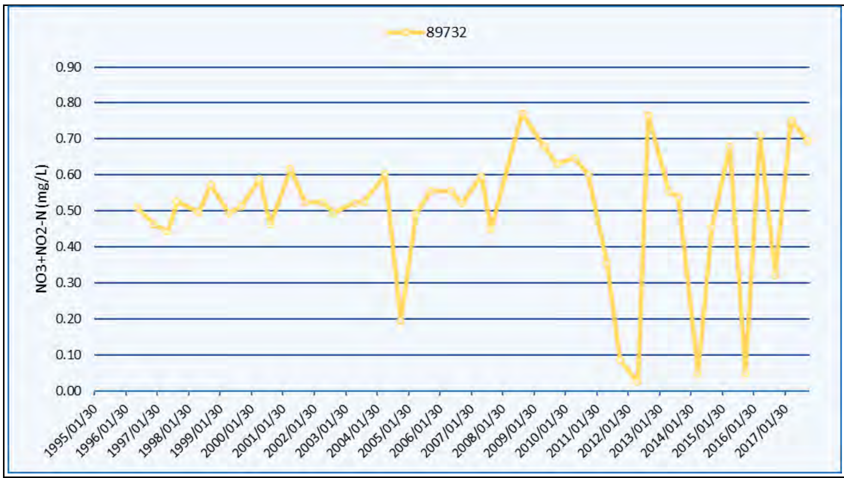
Water Level Graphs

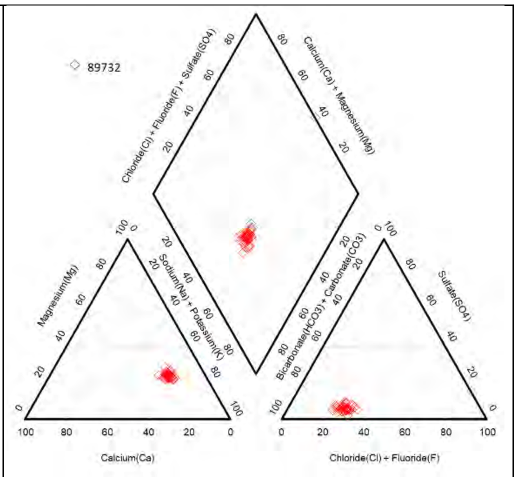


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89732	1996/06/06	2017/10/20	40	0.77	0.03	0.53	No

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the three stations show a fluctuation of between 2 and 7 m. A strong seasonal fluctuation is observed. Some stations (i.e. A8N0507) show a decreasing groundwater level trend.

The nitrate concentration graph show significant fluctuation but values remain less than 1 mg/l.

The groundwater signature is dominated by HCO_3-anion water facies, indicating freshly reached groundwater with limited time to undergo mineralisation.

Table 56. Summary information for GUA: A81-2

GUA	Nzhelele A81-2
Description	The main aquifer types include the Fractured aquifers from the Soutpansberg Group and Karoo Supergroup. The Soutpansberg Group does not possess any primary porosity and groundwater occurrences are controlled by geological structures. In general groundwater yields are moderate with yields up to 5L/s. The Karoo supergroup, located towards the north, has low groundwater potential with yield up 0.5L/s. The Intergranular Alluvial aquifers (Limited to the main river stems) are recharged during periods of high stream-flows as well as during the rainfall season. It is an important local, major aquifer and exists in equilibrium with surface water, adjacent groundwater systems and ecosystems along the rivers. The depths of the alluvium generally decrease away from the river. The Intergranular and fractured associated with the Limpopo Belt, granite-gneissic rocks, has moderate groundwater potential and boreholes yield between 0.5 and 2 l/s. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. The groundwater use is associated with irrigation, water supply, industrial and livestock watering uses.
Catchments	A80G

Map

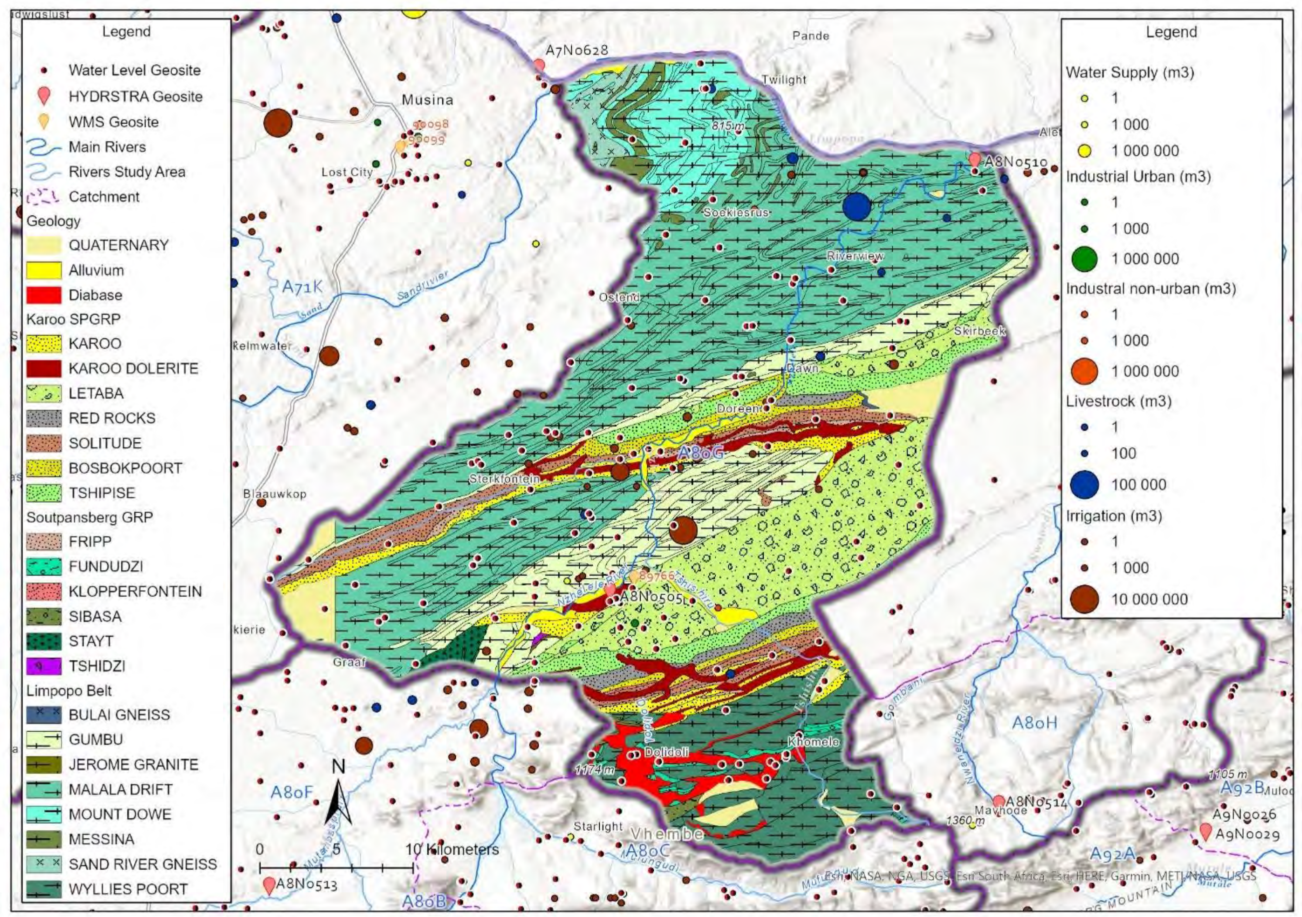


Figure 39 Map showing the distribution of GUA A81-2 with geology, wate use and geo-sites

Water Use Schemes (after DWAF, 2015, Recon Study)

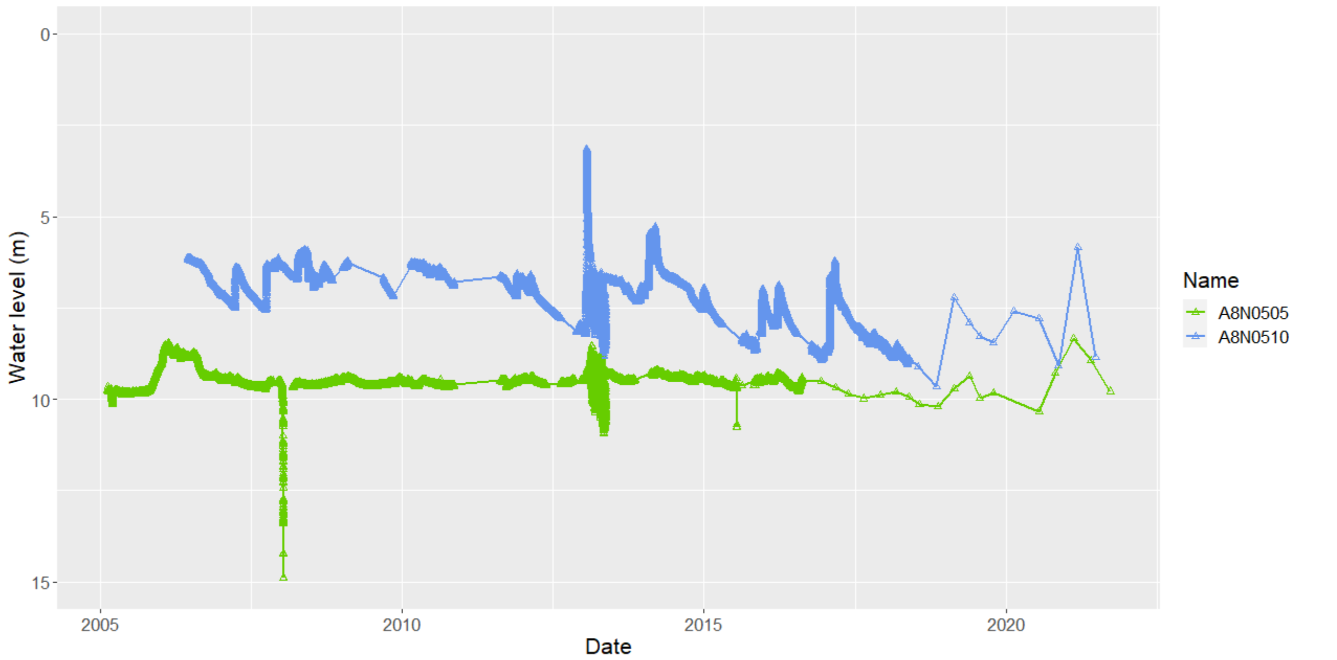
Scheme Name	**Village/Settlement**	**Catchment**
Musina RWS	Musina (Messina), Harper, Harper Industrial, Lost City (Cambell), Musina Military Base, Nancefield	A71K A71L A80G
Mutale Main RWS	Dzamba Tshiwisa, Dzata Ruins, Dzumbama, Fefe, Gogogo, Goma, Gundani, Gwagwathini, Ha-Mabila, Helala, Khakhu Thondoni, Luheni, Madatshitshi, Madzororo, Mafhohoni, Mafhohoni, Mafhohoni South, Maname, Mavhode, Mavhuwa, Mazwimba, Mphagane, Mufongodi, Mufulwi, Ngalavhani, Mufulwi, Ngalavhani, Sheshe, Thonoda Lusidzana, Thononda, Tsaanda, Tsaanda 2 Tshiedeulu Thembaluvhilo, Tshiendeulu, Tshilimbane, Tshilovi, Tshitandani, ZTshixwandza and Tshumulungwi.	A80A A80B A80C A80G A80H

Nzhelele North RWS	Afton, Dolidoli, Garasite, Khomela, Maangani, Makushu, Mangwele, Maranikhwe, Mudimeli, Musekwa, Musekwa Korporasi, Natalie, Ndouvhada, Ngonavhanyai, Pfumembe, Pfumembe Tsha Fhasi, Phembani, Sane, Straighthardt, Tshitwi	A80B A80C A80E A80F A80G A80H A80J
Tshipise Resort Supply	Tshipise Reserve	A80G

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A8N0505	2005/02/16	2021/09/22	2451	15.01	8.34	9.55	6.67
A8N0510	2006/06/15	2021/06/24	3742	9.64	3.16	7.19	6.48

Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
none							

Water Quality Graph and Piper Plot

none

Comments

The observed hydrographs for each of the three stations show a fluctuation of approx. 6m. A strong seasonal fluctuation is observed. especially seen at station A8N0505. A slight decreasing groundwater level trend is observed for station A8N0505.

2.7. NWANEDI

The Nwanedi River catchment is a small catchment in the north-eastern corner of the Limpopo WMA. The drainage region has high rainfall in the upper reaches of the catchment and is semi-arid in the central and lower reaches of the catchment. Although the groundwater is used extensively in certain areas, any additional water requirements for domestic use will have to be sourced from groundwater and groundwater still has potential for future use. In this assessment the Nwanedi drainage region have been delineated as A81-3 (Figure 41).

Table 57. Borehole information for the Nwanedi drainage region

Drainage system	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Nwanedi	A81-3	N	142	115	5	33	60
		Mean	60.9	15.3	114.3	1.0	3.4

2.7.1. Groundwater recharge

Recharge vary from approximately 18 mm/a to less than 2 mm/a in the northeast. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 51.

Table 58. Recharge estimation (Nwanedi).

GMA	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Nwanedi	A81-3	A80H	620.6	266	10.75	7.72	8.90
		A80J	292.1	870	4.43	2.82	1.26

2.7.2. Groundwater Use

The groundwater use for each of the GUA associated with the Nwanedi River system is summarised in Table 52. The present WARMS groundwater use data was compared to the 2015 Limpopo (WMA) North Reconciliation Strategy (LNRS) estimated 2020 use.

Table 59. Groundwater use (per annum) as registered per catchment for each GUA.

GMA Description	GUA	Quat	WARMS: Use Mm^3	LNRS 2020 Mm^3
Nwanedi	A81-3	A80H	4.848	0.064
		A80J	1.121	1.375

2.7.3. Groundwater quality

Based on the piper diagram the main water types for the Nwanedi region vary from a Ca/Mg-HCO_3, to a Na-Cl dominance (Figure 40). A number of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl and Ca/Mg-Cl type water present.

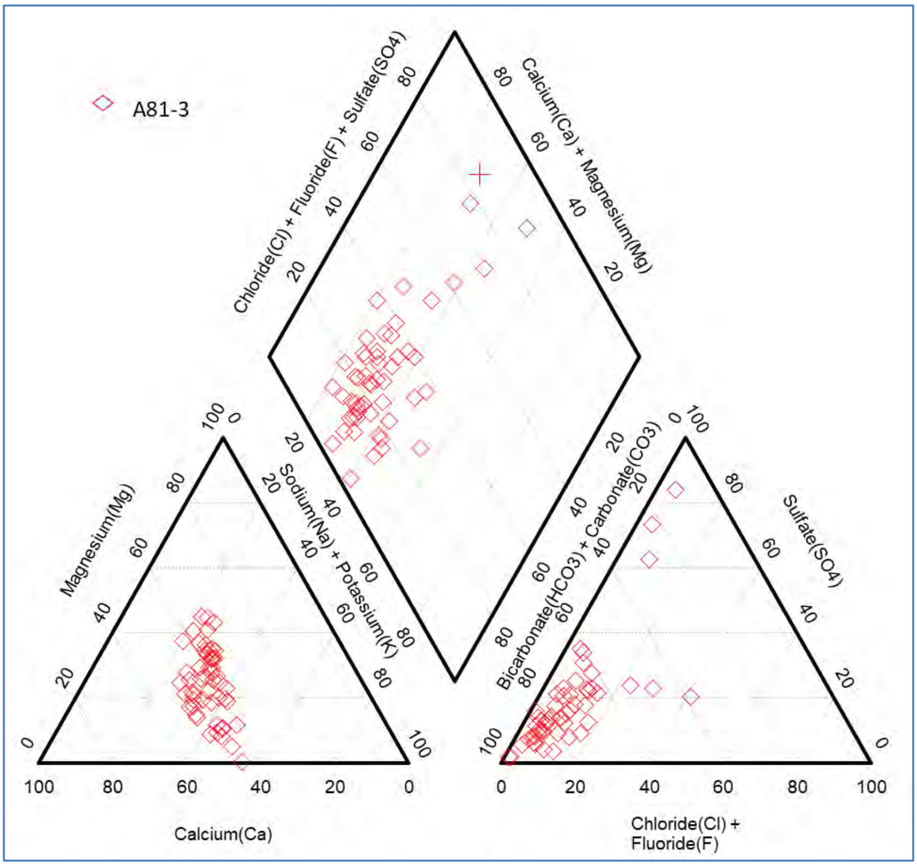


Figure 40. Piper diagram for the Nwanedi drainage region.

Groundwater quality in the Nwanedi region is considered to be poor with the most notable elements of concern include NO_3 as N with average concentrations above the recommended drinking limit (Table 53).

Table 60. Groundwater quality for the Nwanedi region (All units in mg/l, EC in mS/m).

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A8-3	N	52	53	45	53	54	53	51	40	52	7	47
	Median	7.8	69	485	18.2	20.2	54.8	1.4	16.7	57.0	16.6	0.25

2.7.4. Groundwater contribution to baseflow

In the upper catchments groundwater contributes to base flow via sub surface seepage and springs. The probability of baseflow diminishes down-gradient towards the northeast. Comparison of groundwater contribution to baseflow estimates for the Nwanedi drainage region are summarised in Table 54.

Table 61. Groundwater contribution to baseflow estimates.

Description	GUA	Quat	Hughes Mm^3/a	Shultz Mm^3/a	Pitmann Mm^3/a	GRA II (WR2005) Mm^3/a	Maint. Low flow Mm^3/a
Nwanedi	A81-3	[1]A80H	9.00	2.91		2.41	1.08
		A80J					0.01

2.7.5. Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 62.

Table 62. Summary information for GUA A80-3.

GUA	Nwanedi A81-3
Description	The main aquifer types include the Fractured aquifers from the Soutpansberg Group. The main aquifer types include the Fractured aquifers from the Soutpansberg Group and Karoo Supergroup. The Soutpansberg Group does not possess any primary porosity and groundwater occurrences are controlled by geological structures. In general groundwater yields are moderate with yields up to 2L/s. The Intergranular Alluvial aquifers (Limited to the main river stems) are recharged during periods of high stream-flows as well as during the rainfall season. It is an important local, major aquifer and exists in equilibrium with surface water, adjacent groundwater systems and ecosystems along the rivers. The depths of the alluvium generally decrease away from the river. The Intergranular and fractured associated with the Limpopo Belt, granite-gneissic rocks, has moderate groundwater potential and boreholes yield between 0.5 and 2 l/s. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. The groundwater use is associated with irrigation, water supply, industrial and livestock watering uses
Catchments	A80H,J
Map	

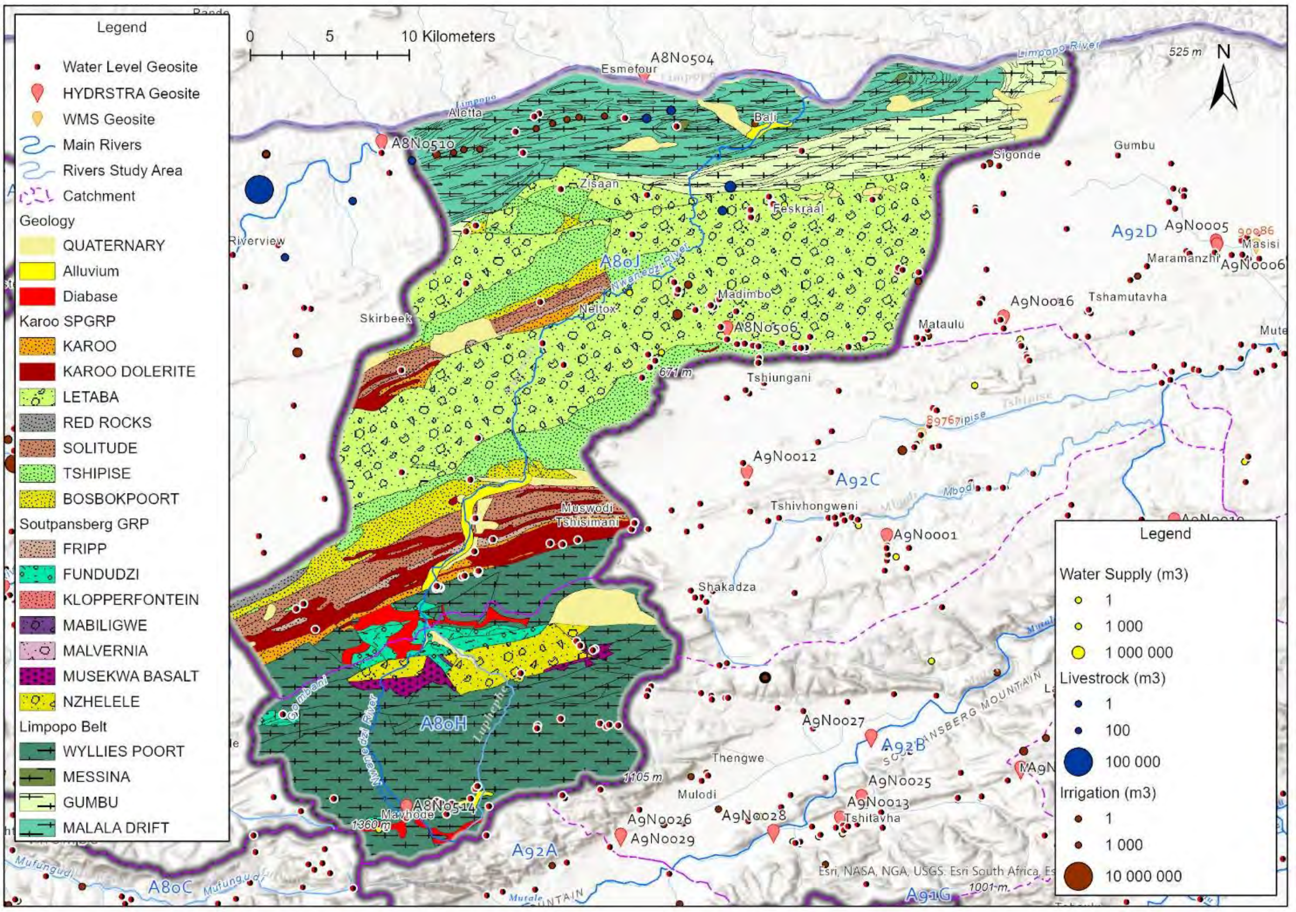


Figure 41 Map showing the distribution of GUA A81-3 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

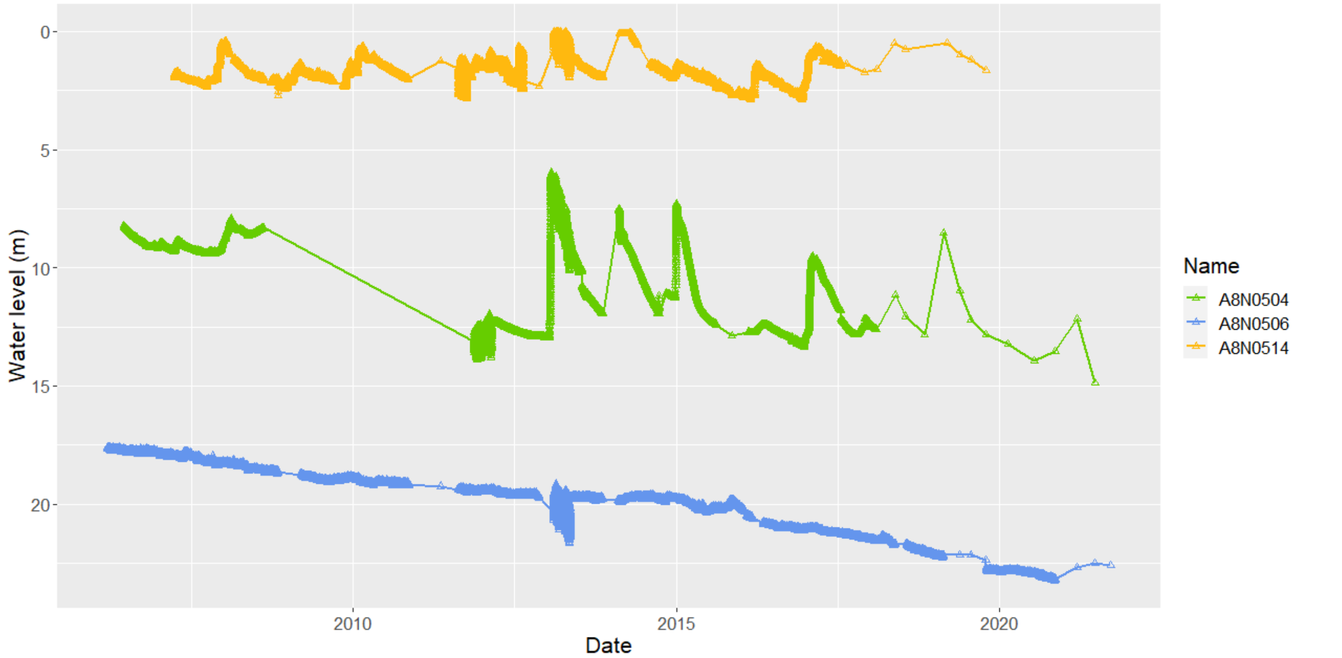
Scheme Name	Village/Settlement	Catchment
Luphephe / Nwandedzi North	Bale, Bale North, Malale, Mapakoni, Masea, Matshakatini, Matshena, Tshamutumbu Police Station and Tshiungani.	A80J
Luphephe / Nwanedi Main RWS	Folovhodwe, Gumela, Musunda, Muswodi Dipeni, Muswodi Tshisimani, Nwanedi Nature Resort, Tshikotoni and Tshitanzhe.	80H A80J
Mutale Main RWS	Dzamba Tshiwisa, Dzata Ruins, Dzumbama, Fefe, Gogogo, Goma, Gundani, Gwagwathini, Ha-Mabila, Helala, Khakhu Thondoni, Luheni, Madatshitshi, Madzororo, Mafhohoni, Mafhohoni, Mafhohoni South, Maname, Mavhode, Mavhuwa, Mazwimba, Mphagane, Mufongodi, Mufulwi, Ngalavhani, Mufulwi, Ngalavhani, Sheshe, Thonoda Lusidzana, Thononda, Tsaanda, Tsaanda 2 Tshiedeulu Thembaluvhilo, Tshiendeulu, Tshilimbane, Tshilovi, Tshitandani, ZTshixwandza and Tshumulungwi.	A80A A80B A80C A80G A80H
Nzhelele North RWS	Afton, Dolidoli, Garasite, Khomela, Maangani, Makushu, Mangwele, Maranikhwe, Mudimeli, Musekwa, Musekwa Korporasi, Natalie, Ndouvhada, Ngonavhanyai,	A80B A80C A80E A80F

	Pfumembe, Pfumembe Tsha Fhasi, Phembani, Sane, Straighthardt, Tshitwi	A80G A80H A80J

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A8N0504	2006/06/14	2021/06/24	6894	14.86	5.97	10.71	8.89
A8N0506	2006/03/16	2021/09/22	5067	23.25	17.56	19.93	5.69
A8N0514	2007/03/27	2019/10/18	2815	2.87	0.00	1.67	2.87

Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
none							

Water Quality Graph and Piper Plot

none

Comments

The observed hydrographs for each of the three stations show a fluctuation of between 3 and 9 m. A significant response in water levels as a result of recharge/rainfall is observed for station A8N0504 and A8N0514, while a more subtle response is observed at station A8N0506. A decreasing trend in the groundwater levels are observed (at station A8N0504 and A8N0506) which is more pronounced at A8N0506.

2.8. UPPER LUVUVHU

The Upper Luvuvhu Rivers originate in the northern extremity of the Great Escarpment, flowing from the Nzhelele Nature Reserve thought the Albasini dam down into the Lower Luvuvhu River stretch. The drainage region has high rainfall in the upper reaches of the catchment and is semi-arid in the central and lower reaches of the catchment. The Luvuvhu/Mutale sub-area of the Luvuvhu/Letaba WMA forms part of the Limpopo River Basin, which is shared by South Africa, Botswana, Zimbabwe and Mozambique.

Groundwater use in the region is dominated by large scale irrigation and water supply services to local communities. Downstream of the Albasini Dam are high clustering of groundwater abstraction. Substantial quantities of groundwater are abstracted for irrigation purposes in the upper Luvuvhu River Catchment. In this assessment the Upper Luvuvhu drainage region have been delineated as A91-1 (Figure 43).

Table 63. Borehole information for the Upper Luvuvhu drainage region

Drainage system	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Upper Luvuvhu	A91-1	N	576	552	152	56	137
		Mean	61.8	16.4	17.2	0.9	2.9

2.8.1. Groundwater recharge

The upper reaches of the drainage region drains the mountainous region in the central section of thee GUA has a relatively high rainfall, with a MAP up to 1 500 mm and higher. In comparison the far east and west of the GUA relatively lower rainfall of only 450 mm per annum. Recharge vary from approximately 21 mm/a to less than 12 mm/a. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 64.

Table 64. Recharge estimation (Upper Luvuvhu).

GMA	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Upper Luvuvhu	A91-1	A91A	696	232	11.1	8.3	13.4
		A91B	620	275	8.0	5.8	14.8
		A91C	866	250	20.1	15.5	20.9
		A91D	1287	132	23.0	19.1	12.6
		A91E	1078	223	26.3	20.9	19.7
		A91F	662	580	14.6	10.5	22.7
		A91G	950	406	67.1	51.8	26.1

2.8.2. Groundwater Use

The groundwater use for each of the GUA associated with the Upper Luvuvhu River system is summarised in Table 65.

Table 65. Groundwater use as registered per catchment for each GUA.

GMA Description	GUA	Quat	WARMS: Use Mm^3
Upper Luvuvhu	A91-1	A91A	6.374
		A91B	11.689
		A91C	27.926
		A91D	10.445
		A91E	2.116
		A91F	1.770
		A91G	0.793

2.8.3. Groundwater quality

Based on the piper diagram the main water types for the Nzhelele and Nwanedi region vary from a Ca/Mg-HCO_3, to a Na-Cl dominance (Figure 42). A number of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl and Ca/Mg-Cl type water present.

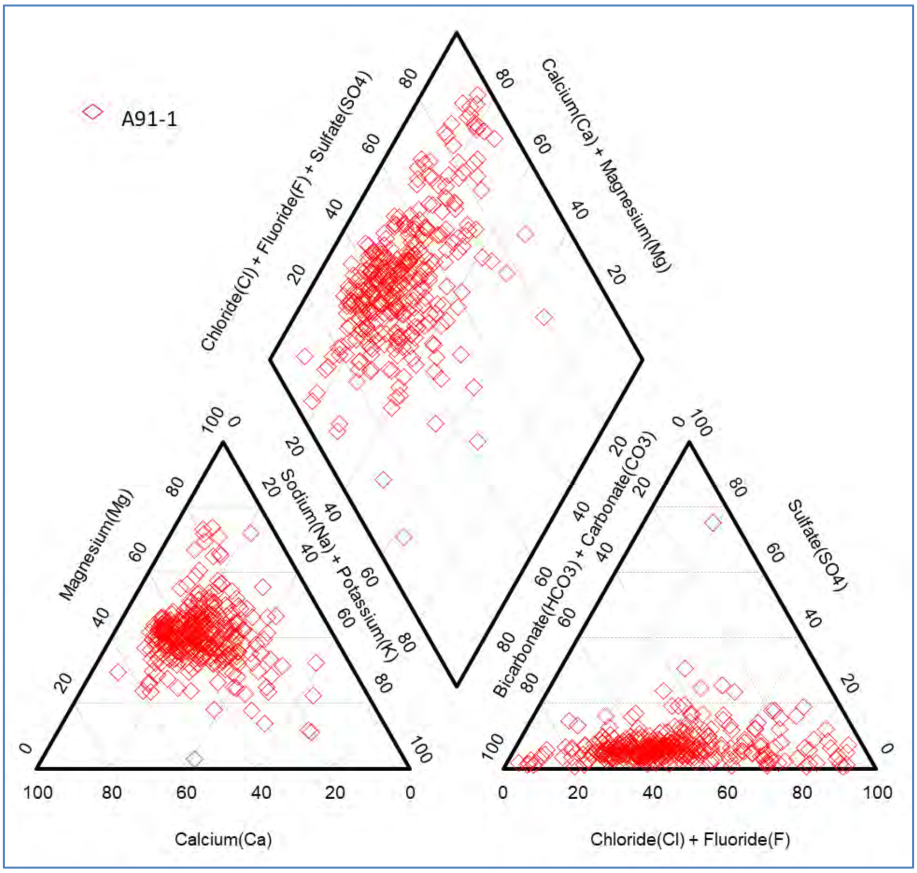


Figure 42. Piper diagram for the Upper Luvuvhu drainage region.

Groundwater quality in the Upper Luvuvhu region is considered to be acceptable to poor with some exceedances observed for NO_3 as N with average concentrations above the recommended drinking limit (Table 66).

Table 66. Groundwater quality for the Upper Luvuvhu region (All units in mg/l, EC in mS/m).

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A91-1	N	288	275	262	329	332	329	282	265	328	62	221
	Median	7.9	56	453	41.9	29.1	23.7	0.9	7.2	29.3	10.8	0.2

2.8.4. Groundwater contribution to baseflow

The Luvuvhu drainage region more specifically the Upper Luvuvhu stretch can be classified as a continuous interaction bedrock system (Great Escarpment rocks) with some trenches being porous media underlain by a semi-pervious layer. Along the lower reaches where the alluvium thinness or don exist at all the River stretch can be classified as localized interacting weathered hard rock system. The Great Escarpment Mountain range is an important area for groundwater recharge and drainage base flow. In the upper catchments groundwater contributes to base flow via sub surface seepage and springs. The probability of baseflow diminishes down-gradient towards the northeast. Comparison of groundwater contribution to baseflow estimates for the Upper Luvuvhu drainage region are summarised in Table 67.

Table 67. Groundwater contribution to baseflow estimates.

Description	GUA	Quat	Hughes Mm^3/a	Shultz Mm^3/a	Pitmann Mm^3/a	GRA II (WR2005) Mm^3/a
Upper Luvuvhu	A91-1	A91A	8.9	4.6	8.9	2.8
		A91B	6.9	3.9	8.2	3.1
		A91C	20.7	10.9	20.6	2.9
		A91D	23.6	11.6	18.0	1.1
		A91E	28.7	14.5	24.0	1.9
		A91F	6.5	1.1	3.1	3.0
		A91G	71.5	33.1	65.2	2.9

2.8.5. Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 68.

Table 68. Summary information for GUA: A91-1.

GUA	Upper Luvuvhu A91-1
Description	The main aquifer types include the Fractured aquifers associated with the Soutpansberg. The Soutpansberg Group, forming the elevated high and recharge region for he GUA, does not possess any primary porosity and groundwater occurrences are controlled by geological structures. In general groundwater yields are low, however structural dominated aquifers systems associated with lineaments yield high values (>5L/s). The Intergranular and fractured, Limpopo Belt rocks, consisting of granite-gneissic rocks has a moderate groundwater potential and boreholes yields between 0.5 and 2 l/s. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. Intergranular. The groundwater ruse is associated with water supply, schedule I, recreations, mining, industrial and irrigation uses.
Catchments	A91A,B,C,D,E,F,G
Map	

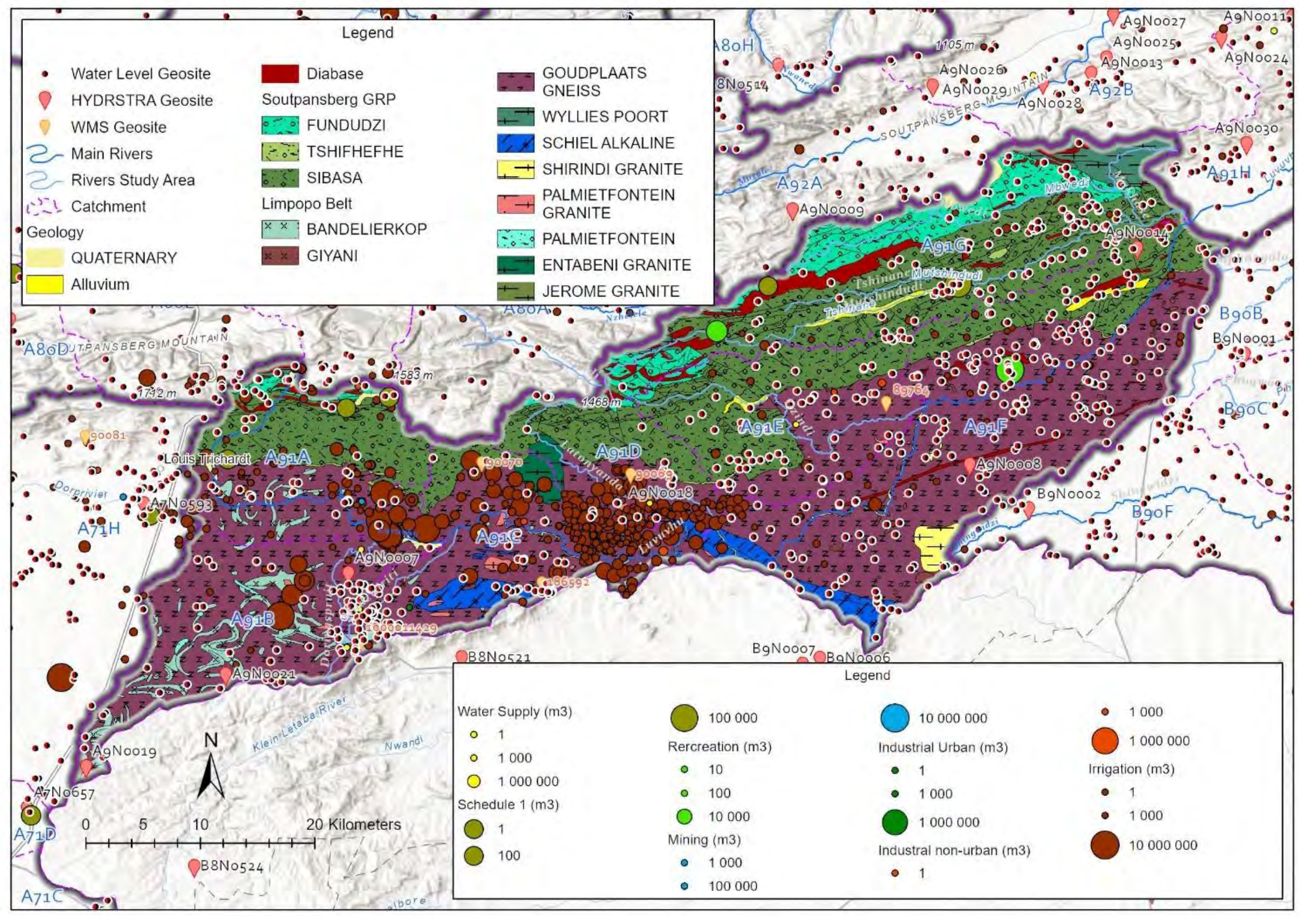


Figure 43 Map showing GUA A91-1 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

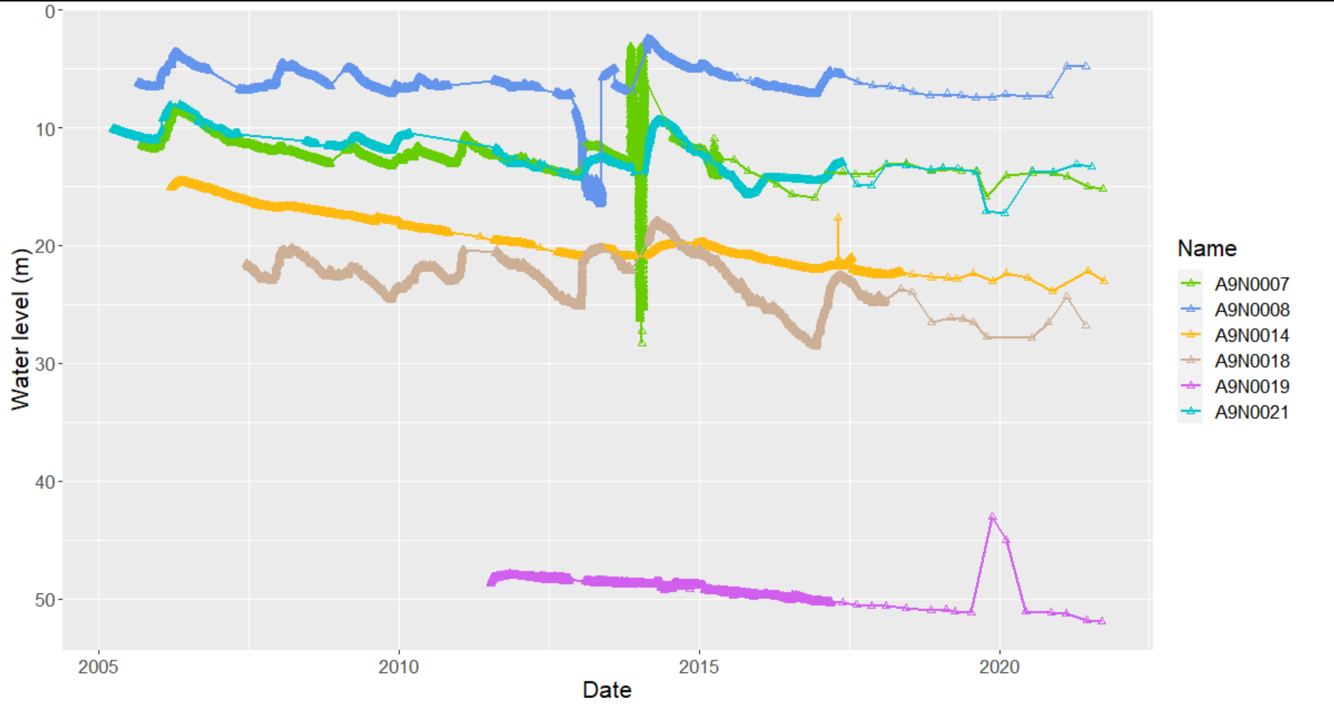
Scheme Name	**Village/Settlement**	**Catchment**
Elim/Vleifontein RWS	Elim/Vleifontein	A91B,C
Matshavhawe / Kunda RWS	Matshavhawe / Kunda	A91A
Mutale Mukuya RWS	Mutale Mukuya	A91D,E,F
Tshifire Murunwa RWS	Tshifire Murunwa	A91A,D,G
Levubu CBD	Levubu CBD	A91C,D
Middle Letaba RWS : Majosi	Majosi	A91B
Valdezia RWS	Valdezia	A91B,C
Vondo RWS	Vondo	A91E,F
Makhado RWS	Makhado	A91A,B,C

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A9N0007	2005/09/21	2021/09/21	5295	28.28	3.12	11.88	25.16
A9N0008	2005/09/01	2021/06/08	7100	16.51	2.45	6.19	14.06

A9N0014	2006/03/15	2021/09/29	7498	23.89	14.43	19.25	9.46
A9N0018	2007/06/20	2021/06/10	9625	28.59	17.96	22.69	10.63
A9N0019	2011/07/18	2021/09/14	2474	51.88	43.06	48.96	8.82
A9N0021	2005/03/30	2021/07/15	6180	17.24	7.99	12.15	9.25

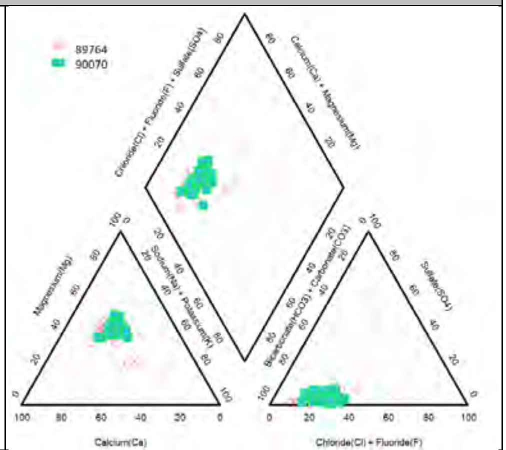
Water Level Graphs



Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89764	1995/01/30	2017/10/26	15	15.62	0.03	2.15	Yes
90070	1996/06/06	2017/10/10	42	6.85	0.86	3.08	Yes

Water Quality Graph and Piper Plot



Comments

The observed hydrographs for each of the stations show a fluctuation of between 9 and 25 m. Apart from the seasonal fluctuations in groundwater levels, an overall decreasing trend is observed since 2013.

Nitrate concentrations trend over the last few years seem to have stabilised below 5 mg/l. The groundwater signature is dominated by HCO_3-anion water facies, indicating fresher groundwater with limited evolution time to cause mineralisation in the groundwater signature.

2.9. MUTALE AND LOWER LUVUVHU

The Mutale and Lower Luvuvhu Rivers drains the most north-eastern part of the study area. The Mutale River originates at the Sacred Lake Funduzi and flows into the Luvuvhu River, which ends up in confluence with the Limpopo River. The Luvuvhu Rivers, flowing in an easterly direction through the Kruger National Park and into Mozambique before discharging into the Indian Ocean. In this assessment the Mutale and Lower Luvuvhu drainage region have been delineated as A91-2 (Figure 45).

Table 69. Borehole information for the Mutale and Lower Luvuvhu drainage region

Drainage system	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Mutale / Luvuvhu	A91-2	N	391	380	89	52	94
		Mean	73.4	14.2	17.6	0.9	3.6

2.9.1. Groundwater recharge

The higher elevation / mountainous area of the drainage region has a relatively high rainfall, with a MAP up to 1 000 mm and higher. In comparison the far north and east, lower laying in elevation, relatively lower rainfall of only 200 mm per annum. Recharge vary from approximately 16 mm/a to less than 3 mm/a. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 70.

Table 70. Recharge estimation (Mutale and Lower Luvuvhu).

GMA	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Mutale and Lower Luvuvhu	A91-2	A91H	722	450	15.94	11.65	22.17
		A91J	450	570	7.49	5.12	4.32
		A91K	373	669	4.00	2.53	2.48
		A92A	997	329	51.34	39.63	40.68
		A92B	711	565	25.43	18.56	19.54
		A92C	423	455	6.79	4.59	4.38
		A92D	301	805	2.47	1.58	1.22

2.9.2. Groundwater Use

The groundwater use for each of the GUA associated with the Mutale and Lower Luvuvhu River system is summarised in Table 71.

Table 71. Groundwater use as registered per catchment for each GRU

GMA Description	GUA	Quat	WARMS: Use Mm^3
Mutale and Lower Luvuvhu	A91-2	A91H	0.439
		A91J	0.092
		A91K	-
		A92A	0.223
		A92B	1.163
		A92C	1.599
		A92D	0.188

2.9.3. Groundwater quality

Based on the piper diagram the main water types for the Mutale/Lower Luvuvhu region vary from a Ca/Mg-HCO_3, to a Na-Cl dominance (Figure 44). A number of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl and Ca/Mg-Cl type water present.

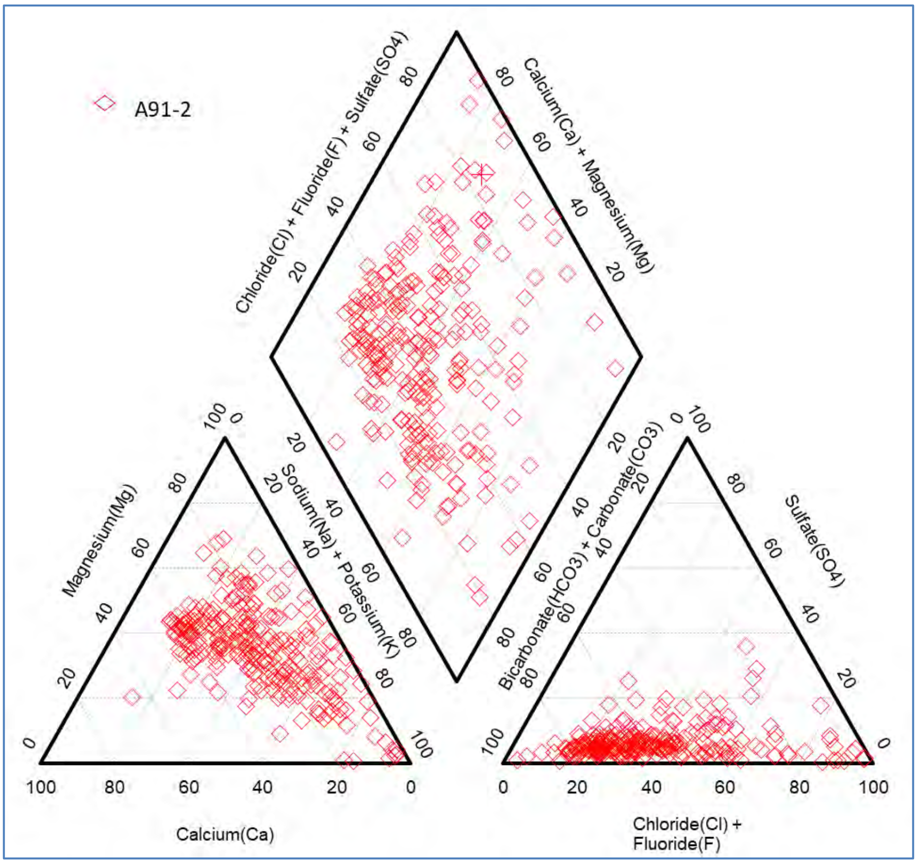


Figure 44. Piper diagram for the Mutale/Lower Luvuvhu drainage region.

Groundwater quality in the Mutale/Lower Luvuvhu region is considered to be acceptable water quality (Table 53).

Table 72. Groundwater quality for the Nzhelele and Nwanedi region (All units in mg/l, EC in mS/m).

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
A91-2	N	228	239	213	257	254	251	227	179	257	28	174
	Median	7.9	49	378	24.1	20.0	38.4	0.9	7.0	38.0	8.4	0.2

2.9.4. Groundwater contribution to baseflow

In the upper catchments groundwater contributes to base flow via sub surface seepage and springs. The probability of baseflow diminishes down-gradient towards the northeast. Comparison of groundwater contribution to baseflow estimates for the Mutale and Lower Luvuvhu drainage region are summarised in Table 73.

Table 73. Groundwater contribution to baseflow estimates.

Description	GUA	Quat	Hughes Mm^3/a	Shultz Mm^3/a	Pitmann Mm^3/a	GRA II (WR2005) Mm^3/a
Mutale and Lower Luvuvhu	A91-1	A91H	7.9	0.7	3.2	2.1
		A91J	-	-	-	-
		A91K	-	-	-	-
		A92A	60.4	27.1	56.1	2.5
		A92B	9.4	0.9	4.0	2.6
		A92C	-	-	-	-
		A92D	-	-	-	-

2.9.5. Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 74.

Table 74. Summary information for GUA: A91-2.

GUA	Mutale and Lower Luvuvhu A91-2
Description	The main aquifer types include the Fractured aquifers associated with the Karoo Group and Soutpansberg Group. The stratified rocks of the Karoo can generally be regarded as being of low groundwater potential away from structures with the inter-bedded sandstones having a moderate potential ranging from . Intergranular Alluvial aquifers (Limited to the main river stems) are recharged during periods of high stream-flows as well as during the rainfall season. It is an important local, major aquifer and exists in equilibrium with surface water, adjacent groundwater systems and ecosystems along the rivers. The depths of the alluvium generally decrease away from the river. The Intergranular and fractured (basement aquifers form the Limpopo Belt) consisting of granite-gneissic rocks has a moderate groundwater potential and boreholes yields between 0.5 and 2 l/s. Ground water is entrapped in small relatively shallow, locally developed basins and troughs revealing that mechanical and chemical weathering appear to be associated with surface drainage channels. The groundwater use is associated with irrigation and water supply uses.
Catchments	A91H,J,K,A92A,B,C,D

Map

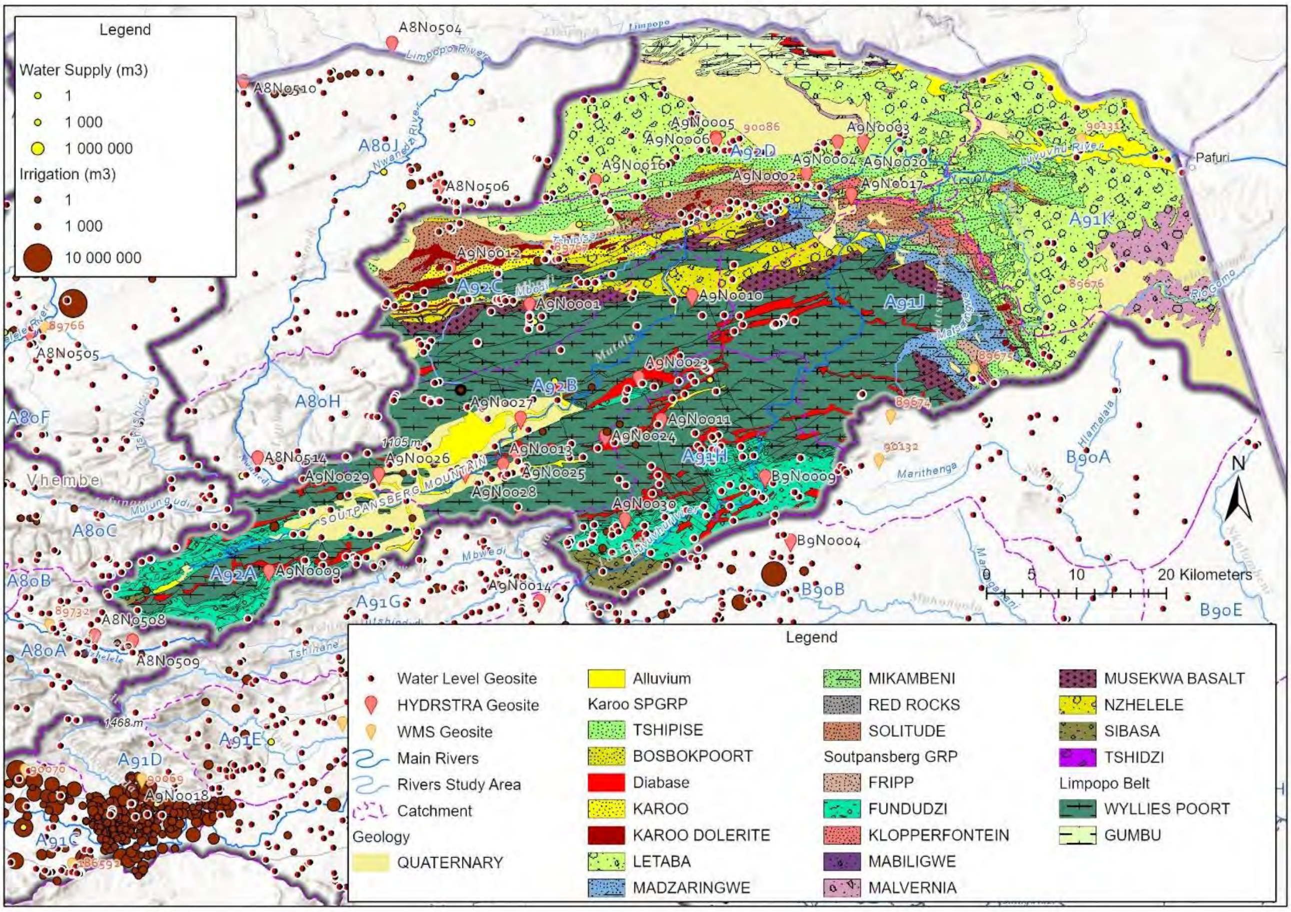


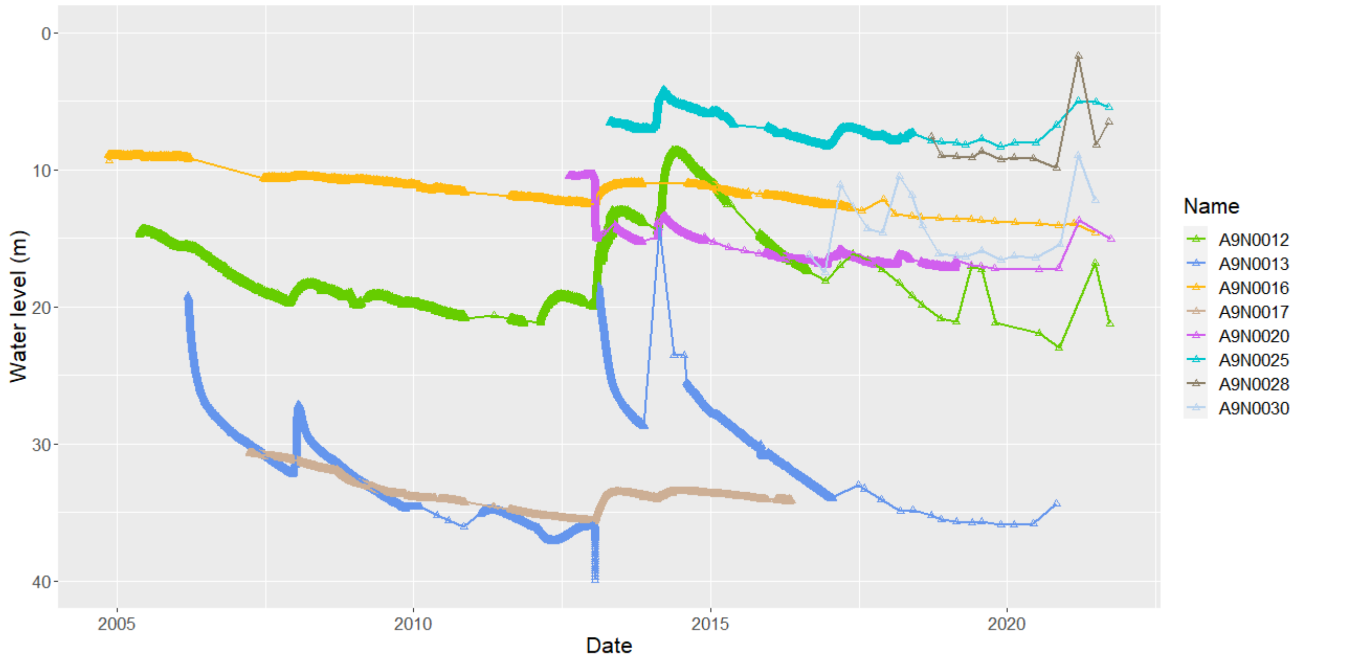
Figure 45 Map showing GUA A91-2 with geology, groundwater use and geo-sites.

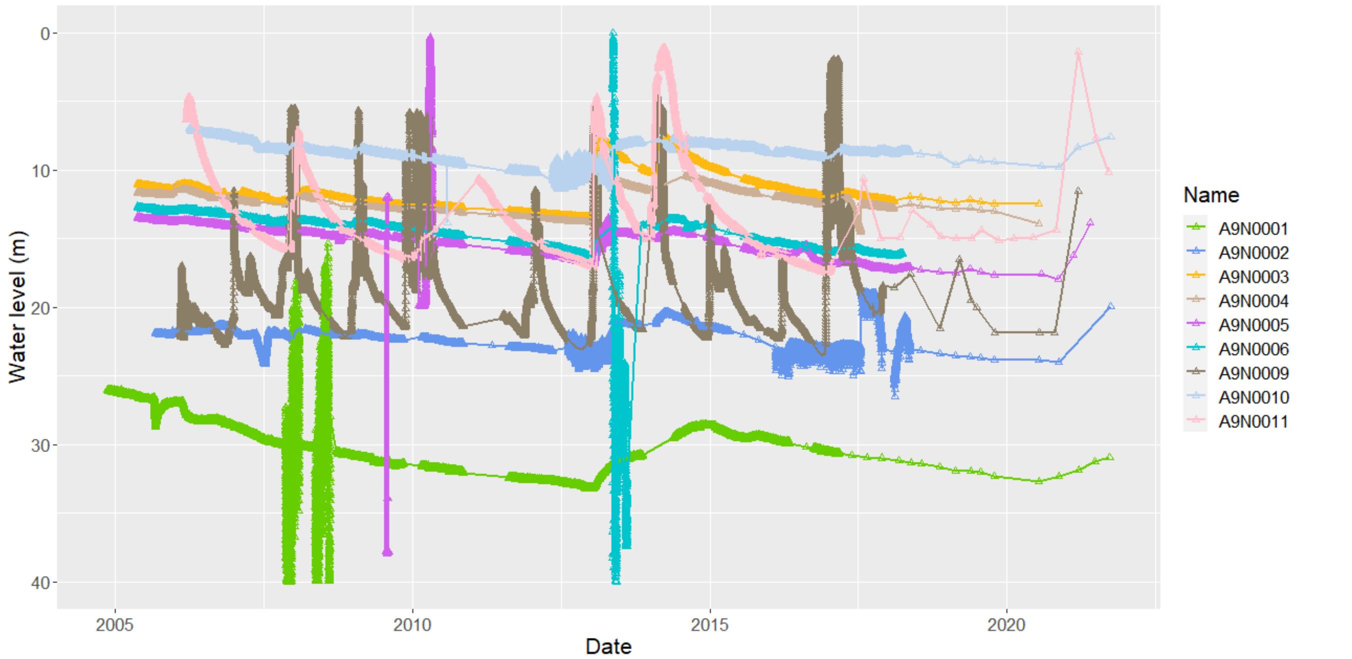
Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Fluctuation (min-max) (m)
A9N0001	2004/11/17	2021/09/22	8911	48.24	15.38	30.01	32.86
A9N0002	2005/09/06	2021/09/29	4738	26.50	18.85	22.07	7.64
A9N0003	2005/05/18	2020/07/14	5259	13.43	7.61	11.48	5.82
A9N0004	2005/05/18	2020/07/14	3861	14.48	10.06	12.15	4.42
A9N0005	2005/05/18	2021/05/26	4560	37.92	0.30	15.23	37.62
A9N0006	2005/05/18	2018/04/01	5209	55.23	0.01	14.75	55.22
A9N0009	2006/02/02	2021/03/12	13757	23.54	1.94	19.14	21.61
A9N0010	2006/04/03	2021/09/29	4192	13.82	6.88	8.66	6.95
A9N0011	2006/03/15	2021/09/16	13198	17.51	1.04	13.32	16.46
A9N0012	2005/05/19	2021/09/22	11444	22.97	8.54	16.88	14.43
A9N0013	2006/03/15	2020/10/29	14537	60.95	14.23	31.48	46.72
A9N0016	2004/11/11	2021/06/24	2785	14.56	8.84	11.09	5.72

A9N0017	2007/03/27	2016/05/11	4024	35.63	30.62	33.65	5.01
A9N0020	2012/08/14	2021/09/29	3569	17.26	10.29	15.41	6.97
A9N0025	2013/04/18	2021/09/16	3943	8.29	4.16	6.81	4.13
A9N0028	2018/09/19	2021/09/16	12	9.83	1.65	8.07	8.18
A9N0030	2016/08/31	2021/06/22	19	17.49	8.91	14.37	8.58

Water Level Graphs

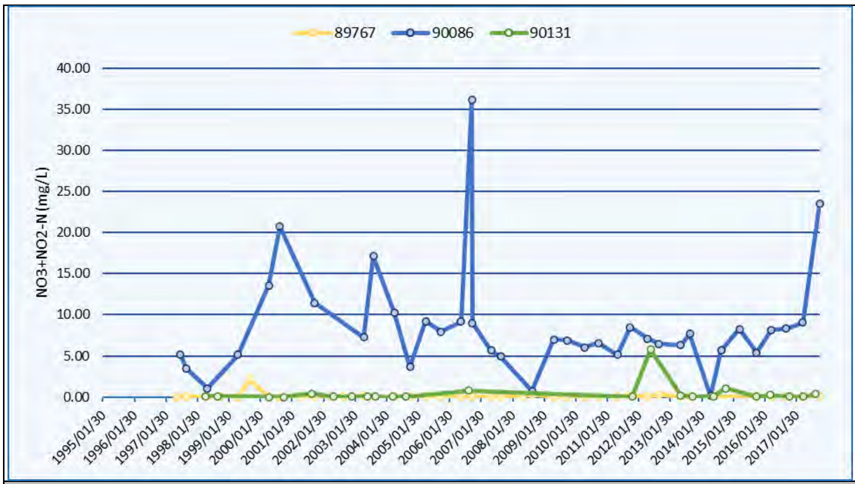


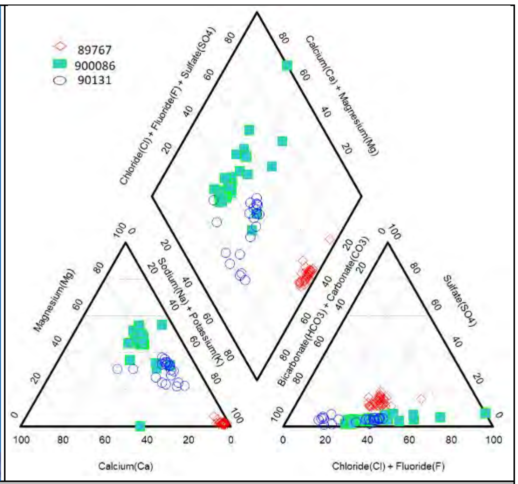


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
89767	1997/05/28	2017/10/23	20	2.17	0.01	0.05	No
90086	1997/07/14	2017/10/23	37	36.09	0.14	7.09	Yes
90131	1998/04/29	2017/09/05	16	5.76	0.02	0.06	No

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the three stations show a fluctuation of between 4 and 55 m. A well-identified seasonal as well as response to significant recharge events (i.e. 2012) can be inferred from the groundwater level fluctuation observations. Since this recharge event the overall trend is slightly decreasing with a recent rapid increase inf groundwater levels suggesting another significant recharge event.

The nitrate concentration graph show a some fluctuations exceeding 10 mg/l at station 90086 in the early 2000's but has since decreased to below 10 mg/l apart from the latest measurement. The nitrate concentrations at the other stations are low, with no noticeable fluctuation or exceedances over the monitoring period. The groundwater signature is dominated by both a HCO_3 and Cl-anion water facies, indicating freshly recharged groundwater undergoing evolution (mineralisation) in the groundwater and rock interactions.

2.10. SHINGWEDZI

The Shingwedzi sub-area is a head-water catchment, which drains into Mozambique. It is situated almost entirely within the Kruger National Park. The drainage region has high rainfall in the upper reaches of the catchment and is semi-arid in the central and lower reaches of the catchment. Limited number of groundwater users are observed for the Shingwedzi drainage region, mostly due to the large coverage of the Kruger National Park. In this assessment the Shingwedzi drainage region have been delineated as B90-1 (Figure 47).

Table 75. Borehole information for the Shingwedzi drainage region

Drainage system	GUA	Info	BH Depth (mbgl)	Water Level (mbgl)	Transmissivity (m^2/day)	Rec. Yield (l/s for 24hrs)	Blow Yield (l/s)
Shingwedzi	B90-1	N	356	365	86	43	144
		Mean	61.5	16.3	20.5	0.6	1.6

2.10.1. Groundwater recharge

The drainage region ‘s MAP ranges from up to 650 mm to as low as 400mm. Recharge vary from approximately 12 mm/a to less than 3 mm/a. Groundwater recharge volumes for each of the quaternaries constituting the unit of analysis and are summarised in Table 76.

Table 76. Recharge estimation (Shingwedzi).

GMA	GUA	Quat	MAP (mm)	Area (km^2)	GRA II		Vegter (1995)
					(Wet) Mm^3	(Dry) Mm^3	Mean Mm^3
Shingwedzi	B90-1	B90A	465	693	7.32	5.01	4.03
		B90B	470	754	8.54	5.88	6.99
		B90C	498	535	6.28	4.36	6.17
		B90D	471	447	4.57	3.14	3.77
		B90E	466	474	4.49	2.94	3.73
		B90F	539	819	11.37	7.99	6.96
		B90G	535	698	12.67	8.89	4.41
		B90H	538	890	15.26	10.18	4.30

2.10.1. Groundwater Use

The groundwater use for each of the GUA associated with the Shingwedzi River system is summarised in Table 77.

Table 77. Groundwater use (per annum) as registered per catchment for each GUA.

GMA Description	GUA	Quat	WARMS: Use Mm^3
Shingwedzi	B90-1	B90A	-
		B90B	1.614
		B90C	0.205
		B90D	-
		B90E	-
		B90F	0.422
		B90G	-
		B90H	-

2.10.2. Groundwater quality

Based on the piper diagram the main water types for the Shingwedzi region vary from a Ca/Mg-HCO_3, to a Na-Cl dominance (Figure 46). A number of samples relate to a fresh recharge type (Ca/Mg-HCO_3) water, while cation and anion exchange process may be occurring within the strata hence Na-Cl and Ca/Mg-Cl type water present. Some samples indicate sulphate enrichment as dominant anion water facies.

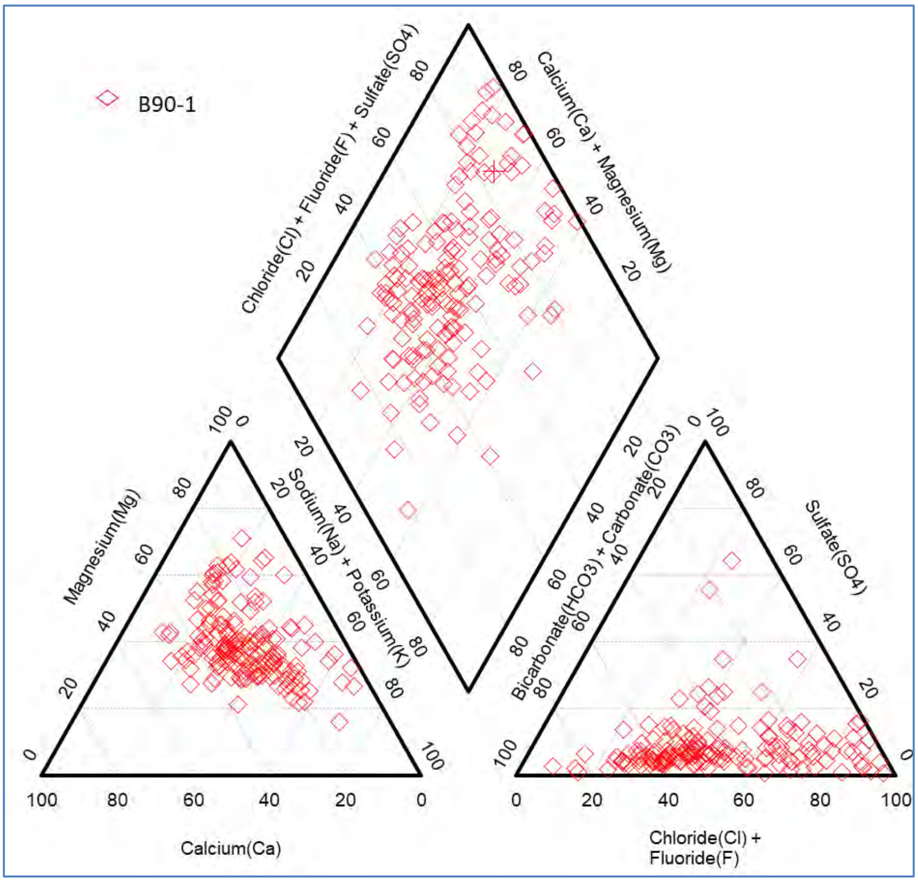


Figure 46. Piper diagram for the Shingwedzi drainage region.

Groundwater quality in the Shingwedzi region is considered to be poor with the most notable elements of concern include NO_3 as N with average concentrations above the recommended drinking limit (Table 53).

Table 78. Groundwater quality for the Shingwedzi region (All units in mg/l, EC in mS/m). (red text exceeds Class III)

GUA		pH	EC	TDS	Ca	Mg	Na	K	SO_4	Cl	NO_3 as N	F
DWAF Class I		5-6 or 9-9.5	70-150	450-1000	80-150	30-70	100-200	-	200-400	100-200	6-10	0.7-1
DWAF Class II		4-5 or 9.5-10	150-370	1000-2000	150-300	70-100	200-600	-	400-600	200-600	10-20	1-1.5
DWAF Class III		3.5-4 or 10-10.5	370-520	2000-3000	>300	100-200	600-1200	-	600-1000	600-1200	20-40	1.5-3.5
B90-1	N	150	138	124	159	161	160	156	151	161	36	134
	Median	8.0	121	939	67.8	59.5	103.1	2.2	14.3	102.4	71.4	0.3

2.10.3. Groundwater contribution to baseflow

The Shingwedzi GUA have a low probability of groundwater contribution to baseflow and no sustainable yield is derived from surface flow in the Shingwedzi catchment (DWA, 2014).

2.10.4. Summary

The following tables provide a summary for each of the GUA, as illustrate in Table 79.

Table 79. Summary information for GUA: B90-1.

GUA	Shingwedzi B90-1
Description	The main aquifer types include the Intergranular and fractured aquifer systems from the Karoo Supergroup (Letaba Group) and fractured basement aquifer associated with the Limpopo Belt as well as the Intergranular Alluvial aquifer. The stratified rocks of the Karoo supergroup can generally be regarded as being of low to moderate, ranging from 0.5L/s to 2.0L/s. Intergranular Alluvial aquifers (limited to the main river stems) are recharged during periods of high stream-flows as well as during the rainfall season. The depths of the alluvium generally decrease away from the river. The Intergranular and fractured (basement aquifers form the Limpopo Belt) consisting of granite-gneissic rocks has a moderate groundwater potential and boreholes yields between 0.5 and 2 l/s. The groundwater use is associated with irrigation and water supply uses.
Catchments	B90A, B,C,D,E,F,G

Map

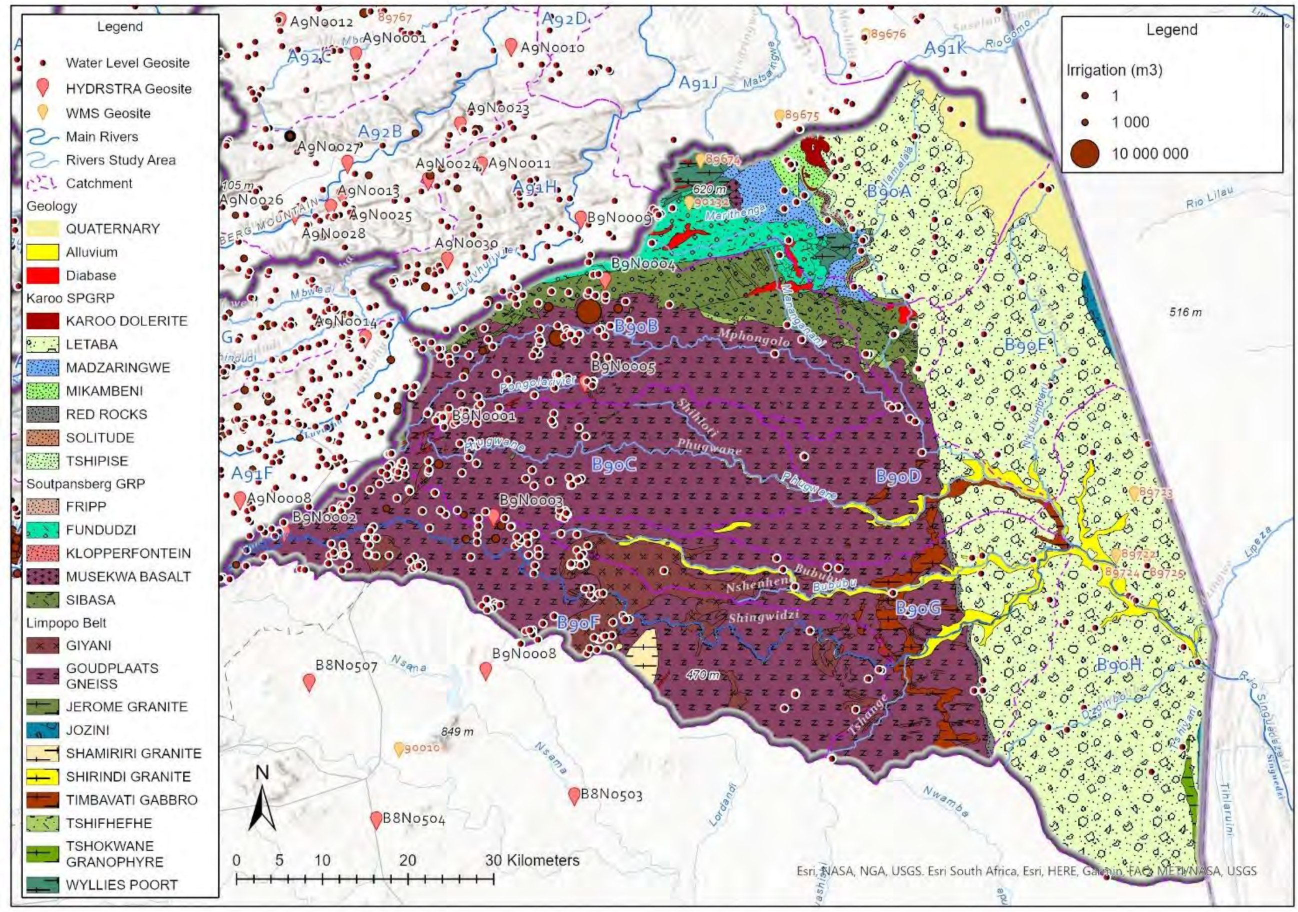


Figure 47 Map showing GUA B90-1 with geology, groundwater use and geo-sites.

Water Use Schemes (after DWAF, 2015, Recon Study)

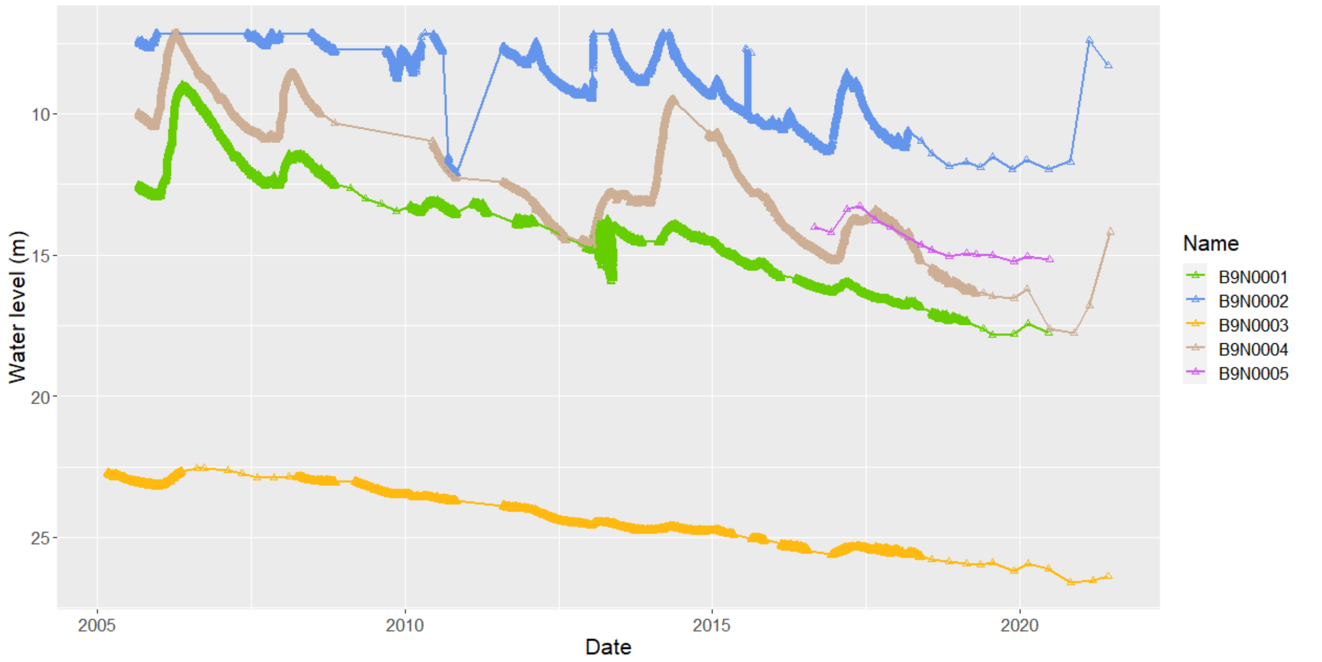
Scheme Name	Village/Settlement	Catchment
Malamulele West RWS	Malamulele	B90F
North Malamulele East RWS	Malamulele	B90A,B
Giyani System A/B & F1/F2	Giyani	B90F

Available monitoring locations for trend analysis – Water Levels

Name	Start Date	End Date	Count	Max water level (mbgl)	Min water level (mbgl)	Mean water level (mbgl)	Flux (min-max) (m)
B9N0001	2005/09/01	2020/06/19	4407	17.85	8.96	13.96	8.89
B9N0002	2005/09/01	2021/06/08	3097	12.11	7.14	8.95	4.97

B9N0003	2005/03/02	2021/06/08	2779	26.60	22.55	24.21	4.05
B9N0004	2005/09/01	2021/06/22	5940	17.76	7.14	12.20	10.62
B9N0005	2016/08/30	2020/06/26	16	15.22	13.27	14.49	1.95

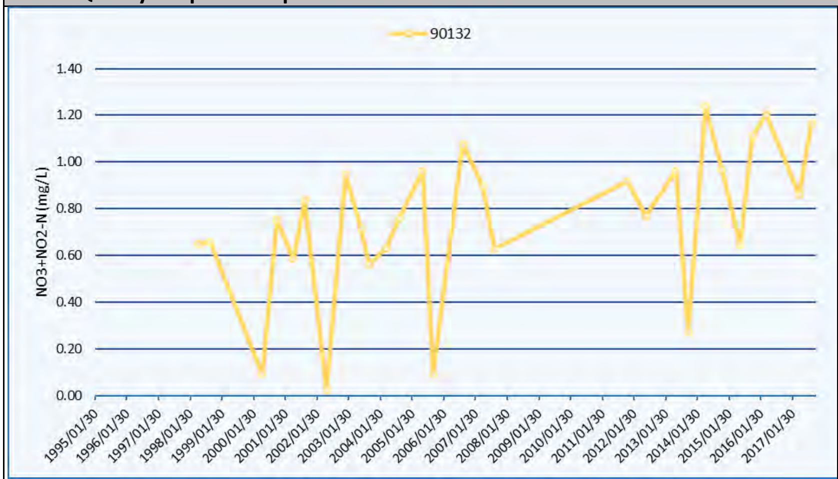
Water Level Graphs

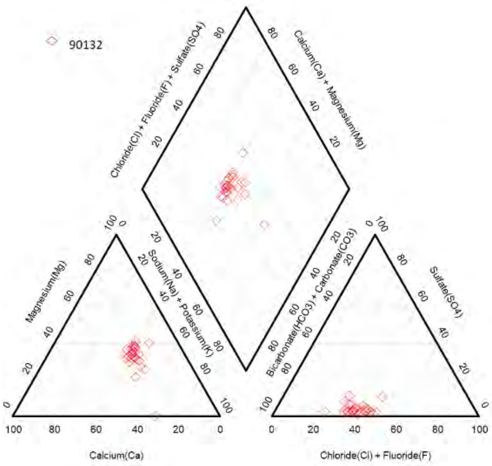


Available monitoring locations for trend analysis -Water Quality (Chemistry)

Name	Start Date	End Date	Count	Max NO_3+NO_2 conc. (mg/L)	Min NO_3+NO_2 conc. (mg/L)	Median NO_3+NO_2 conc. (mg/L)	Exceed Drinking Water guideline
90132	1998/04/29	2017/09/05	27	1.24	0.02	0.77	No

Water Quality Graph and Piper Plot





Comments

The observed hydrographs for each of the stations show a fluctuation of between 4 and 11 m. Apart from the seasonal fluctuations in groundwater levels, the overall trend shows a decrease in groundwater levels.
The nitrate concentration graph show a strong fluctuation in observations While an increase in nitrate concentrations are observed the levels are still below 2 ng/l. The groundwater signature is indicate a mix between HCO_3 and Cl-anion water facies, indicating freshly recharged groundwater undergoing mineralised (evolved groundwater).

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