DEVELOPMENT OF INTERNAL STRATEGIC PERSPECTIVES

GROUNDWATER OVERVIEW FOR LOWER VAAL CATCHMENT MANAGEMENT AREA

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1 Overarching Issues

The following is a brief description of the major groundwater issues in the Lower Vaal Water Management Area (LVWMA). For more detailed information please refer to the references and data sources referred to in Section 1.

1.1 Availability of groundwater information in the catchment area

The following data sources with regard to groundwater are available:

- NGDB database
- WARMS data base
- DWAF Geohydrology Northern Cape
- GH Reports
- 1: 5000 000 Geohydrological maps and brochures
- Consultants reports and other academic reports

The NGDB is heavily populated with groundwater data for the WMA. There are over 400 points currently being monitored throughout the Northern Cape (including the Lower Vaal WMA). Most of the data are related to water supply and irrigation schemes, and ambient water quality monitoring.

The WARMS database contains valuable information with regard to large-scale abstraction for water supply schemes and irrigation. Verification of data still has to be performed.

The geohydrology offices in the Northern Cape have good data on groundwater utilization and the natural quality of groundwater due to the close relationship with ongoing water supply projects and other groundwater investigations. Another vast source of information is from GH reports (more than 500) and the 1: 500 000 geohydrological maps completed for the region by the Geohydrology Directorate.

Several consultant reports and academic reports are also available. PD Toens and Associates have been involved in ongoing monitoring of groundwater resources in the Northern Cape for a number of years.

1.2 Overview of groundwater resources and use throughout the catchment area

1.2.1 Industrial and mining

There are quite a number of mining operations in the LVWMA. These activities vary from base-metal mining; diamond mining and even limited gold mining in the Kalahari greenstone belt. Groundwater use at most of these sites is limited and should any seepage occur into opencast pits or underground workings, the water is usually pumped and utilized in processes to minimize use of other water sources. This pumping often causes localized dewatering but the only mine where this effect is pronounced is ISCOR’s Sishen Mine. The following is a brief description of the main mining activities with some description of impacts on the groundwater regime.

The North Cape manganese deposits lie to the north and west of Kuruman. They are known to cover an area of at least 1 100 km^2 and are the largest manganese deposits in the world. It is estimated that more than 80% of the worlds known manganese reserves are situated in the North Cape Deposits. They stretch from Black Rock in the north to Postmasburg in the south and effectively form two distinct ore bodies namely the Kalahari Manganese Field and the Postmasburg Manganese Field.

The first and most famous manganese mine was established in 1926 in the Kalahari Manganese Fields and known as the open cast Black Rock mine. Unfortunately all operations ceased by the early 1930's. In 1934 operations re-started under the name of Assmang. The Smartt mine was opened in 1954, which was followed soon after, by the Hotazel Mine and many others (http://www.dwaf.gov.za/orange).

ISCOR's Sishen Mine was established in 1953 and is situated in the Northern Cape approximately 280 km north-west of Kimberley. It is one of the seven largest open cast mines in the world with an open pit of approximately 11 km long, 1.5 km wide and almost 400 m deep. The haematite ore at Sishen occurs in beds of varying thickness. Interbedded impurities, such as shales occur as bands in laminated ores, with iron enrichment at the contact zones.

Although the Sishen Mine can utilise Vaal River water via the 700mm diameter Vaal-Gamakara pipeline, it currently makes use of groundwater abstracted directly from the mining area (http://www.dwaf.gov.za/orange). Approximately 1.5 million m^3 of water is abstracted monthly from the mine of which approximately 0.9 million m^3 is used for the mining operations or the towns housing the mine employees and their families (Dingleton, Kathu and Sesheng). The remainder is distributed to other mines in the area including Hotazel and Olifantshoek via the Vaal-Gamagara pipeline. It is anticipated that the groundwater will gradually be depleted and that Sishen Mine will eventually have to import water.

Assmang operate the Beeshoek iron ore operations, located near Sishen. Both Beeshoek North and South mines are opencast operations. The ore is mined from various different pits. The run-of-mine product is processed by a crushing, washing and screening plant.

Pering Mine is a lead (Galena) and zinc (Sphalerite) mine that is located in the southwestern portion of the North West Province close to the border with the Northern Cape Province. The nearest town, Reivilo is 20 km south west of the mine. Vryburg is 70 km north east of the mine. The majority of the mine’s 191 employees and seventeen contractors come from Reivilo (including Boipelo), which is part of the Greater Taung Municipality and of Greater Taung and Kuruman. The mine is an open pit, truck and shovel operation. Lead (Galena) and zinc (Sphalerite) concentrates are produced by means of a conventional crushing, milling and flotation process from a low grade Mississippi type ore body. The Pering Mine ore body is rapidly approaching depletion after being in operation since late 1986. It is estimated that 8 million m^3/annum of groundwater is abstracted at Pering (Van Dyk, 2003).

The Finsch diamond mine, located 160 km north west of Kimberley, is one of De Beers’ seven South African operations. Discovered in 1961 during exploration for asbestos, the deposit was first developed as an open pit. Since 1991, production has come from the underground mine beneath the old pit. Finsch is a classic diamondiferous kimberlite pipe, which has a surface expression of around 17.9ha. The country rocks consist of banded ironstones overlying dolomites and limestones, the pipe itself consisting of weathered kimberlite (yellow ground) to a depth of around 100m with unweathered material (blue ground) beneath. Pumping controls groundwater seepage from the overlying strata of dolomite and limestone. No volumes are available.

Smaller mining operations include a limestone quarry at LimeAcres, Kalahari Goldridge Mine (opencast mine with heap leach extraction) near Mmabatho and several diamond diggings in alluvial deposits along the Vaal and smaller tributaries. The diamond diggings have little impact on water quality; huge amounts of water are abstracted locally during the processing of the diggings and surface environment and drainage patterns are altered. Currently the Kalahari Goldridge mine supply its own water by circulating water from the pit and sludge lagoons as well as from boreholes (Total 120 Ml/year). It is estimated that the mining activities will affect the boreholes and that an additional amount of 30- 50 Ml/month will be needed in the next 5 years (Africon, 2002).

1.2.2 Agriculture

As previously stated in the ISP document agriculture plays a major role in terms of economic development in the WMA. Almost every farm unit in the WMA is dependent on groundwater for domestic use and stock watering. There are however no abstraction volumes available but in terms of quantities of water, stock farming has a relatively small influence on the regional groundwater resource.

Large-scale irrigation is developed where aquifer types are suitable. The lithologies from which abstraction for irrigation takes place vary between dolomitic/karstic aquifers, weathered granite and quartzite and at contact or faulting zones (see Section 2).

Table 1 gives estimated annual abstraction volumes for the large-scale irrigation areas with the associated geological lithologies.

Problems encountered at these irrigation areas are over utilisation of the resources with the associated lowering of water tables. Disputes regarding water allocation have become a major concern of the regional DWAF management (Van Dyk, 2003).

Table 1: Estimated abstraction volume for irrigation in the WMA from groundwater resources with associated geological formations (DWAF, 2003)

Name	**Estimated abstraction**	**Geological Formation**
	million m^3/annum	
Coetzersdam/ Louwna	40	Weathered pegmatite granite (Zz)
Kuruman	5	Dolomite (Va)
Sishen	17	Dolomite (Va)
Bestwood	1	
Tosca	18	Contact banded iron /dolomite (Va)
Pering/ Lykso	8	Dolomite (Va)
Kudumane	2	Dolomite (Va)
Danielskuil	1	Dolomite (Va)
Stella	1	Contact zone (Zk and Zz)
Sannieshof	2	Weathered lava (Rk)
Ottosdal	2	Weathered lava (Rk)
Delareyville	5	Contact lava (R-val) and granite (Zz)
Totals	**102**	

1.2.3 Domestic

Several local municipalities are dependent on groundwater as a source of bulk supply. The water is supplied from boreholes within the municipal grounds. The main aquifers exploited are from dolomites and weathered fractured crystalline rocks such as andesitic lavas and granites. Some of the towns water supply is augmented by surface water supply e.g. Vryburg. The total population dependant on the source in urban areas is estimated to be 140 000 residents. Table 2 is a breakdown of groundwater consumption estimated for 1996 (Africon, 2002).

Some groundwater utilisation for small rural settlements, takes place in the western portion of the WMA from primary or porous aquifers from the Kalahari group, but the quality and yields are often variable and not good.

Groundwater Utilisation of local municipalities		
Town	**Residents**	**Annual Abstraction 1996 Million m^3**
Bankara Bodulong	5520	0.19
Danielskuil	2700	0.12
Dibeng	300	0.01
Groenwater	300	0.01
Holpan	100	0.00
Jennhaven	200	0.01
Kathu	5192	0.64
Kono	200	0.01
Kuruman+WW	11000	2.02
Majeng	300	0.01
Postmasburg	32100	0.86
Schmidtsdrift	500	0.01
Amalia		0.21
Schweizer Reneke		0.90
Gamotlatla		0.04
Lichtenburg		4.20
Itsoseng		2.20
Ottosdal	18000	0.88
Sannieshof	15000	0.25
Stella		0.12
Vryburg	20000	4.38
Delarey	20000	1.80
Reivilo	5000	0.10
Setla-Kgobi North		0.37
Setla-Kgobi South		0.60
Ganyesa/Kudumane		2.30
Total	**136412**	**33.24**

Table 2: Groundwater utilization for domestic use – Local Municipalities

1.3 Groundwater quality in the catchment area

1.3.1 Natural

The natural occurring water quality in the WMA is generally good in the dolomitic/karstic and fractured/crystalline aquifers. In the western portion of the WMA in the Kalahari group primary (sand/gravel) aquifers and clay formations the quality is often naturally poor with TDS values ranging from 1500 mg/l and higher (See Figure 1).

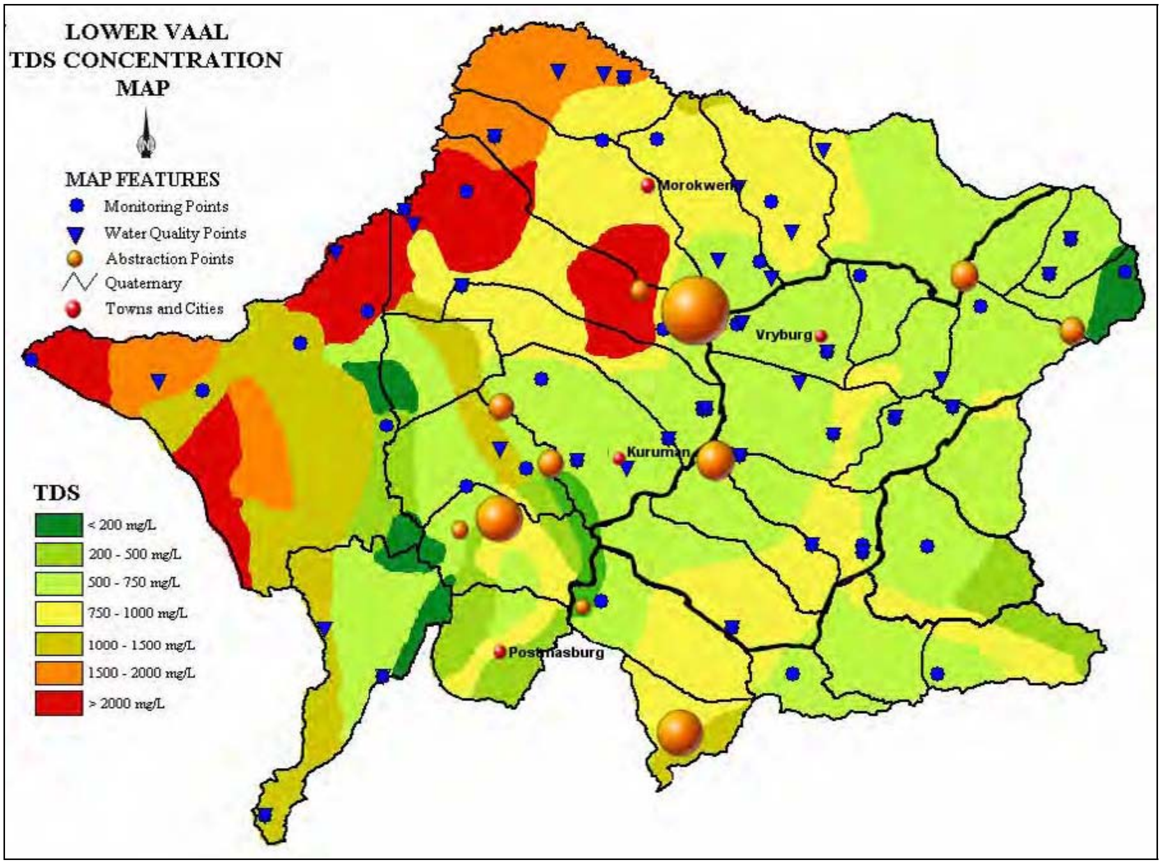

Figure 1: Total dissolved solids for the WMA with main abstraction and water quality monitoring points.

1.3.2 Point and diffusive pollution

Agricultural activities are a source of diffuse water contamination. The contribution of each farm on a local scale is often fairly small but the contribution on a catchment scale needs to be included in assessing any pollution situation. Most findings regarding this issue can only be assessed in a generic way due to the lack of data in the WMA. Nitrates are the contaminant of most concern, since they are very soluble and do not bind to soils, nitrates have a high potential to migrate to groundwater. Because they do not evaporate, nitrates/nitrites are likely to remain in water until consumed by plants or other organisms. Generally on a local scale the areas of intense cultivation are the major contributors in terms of inorganic nitrates. The primary inorganic nitrates, which may contaminate drinking water, are potassium nitrate and ammonium nitrate both of which are widely used as fertilizers. Feedlots contribute to the organic nitrates in groundwater and can be far more problematic. For most farming activities organic nitrate is not a serious problem in South Africa. Other contaminants of concern are pesticides and herbicides. The contribution of these to groundwater contamination is very difficult to quantify on catchment scale. Site-specific data relating to likely loading/application volumes and history, soil profiles and local geohydrology are required.

During 2003 a study was funded by the WRC (Ellington, 2003), which investigated the effects of the high density cultivation at the Vaalharts surface water irrigation scheme on the underlying aquifer. The scheme was established during the 1930's, although it was only firmly established during the 1950's. The irrigated area is 32000ha, comprising of the North and West Canal areas. Water is furrowed to the Scheme from the Vaal River at Warrenton.

The aims of the project were to construct a suitable conceptual model for the Vaalharts Irrigation Scheme and the aquifer underlying it. In order for the conceptual model to have basis, the characteristics of the aquifer needed to be studied. Seventeen boreholes were drilled by DWAF during 2003 within the North Canal area to gain access to the groundwater and cement the construction of the conceptual model. The final aim of the project was to determine the impact of the irrigation on the aquifer underlying the Vaalharts Irrigation scheme.

Based upon literature and studies conducted during this project, it was found that the TDS of the groundwater has increased at a rate of 13 mg/l/annum. The leaching addition of approximately 100000 t/annum was found to be the main source of this TDS increase. Simultaneously, the main contributor to the salt load within the Vaalharts Irrigation Scheme was found to be the incoming canal water from the Vaal River at Warrenton. Whereas fertilizers contribute only 50000 t/annum, the incoming Vaal River water contributes 130000 t/annum of salts. These salts are moving towards the Harts River at a rate of approximately 5Mm^3/annum. The path towards the Harts River, however sees the rainfall having a dilution effect on the concentration, and thereby reducing the groundwater TDS concentrations on its path towards the Harts River, and therefore too the concentration of salts entering the Harts river.

Similar studies should be considered to determine the effects of high groundwater abstraction and salination of underlying soils and aquifers, in areas where groundwater is utilized for high-density cultivation.

Activities related to urban areas can also result in localized or even diffuse pollution of groundwater. Poor management of sewage treatment works can contribute to the groundwater pollution as can landfill sites, on-site sanitation (especially in informal settlements) and spills resulting from accidents or leaking underground tanks.

There are many impacts on the environment dealing with the water quality and waste disposal from metal mining. As described in Section 1.2.1, mining activities in the WMA covers a range of metal and diamond ores. The following is a brief generic description of possible effects from metal mining that could occur, due to the lack of more site-specific data.

These adverse water quality impacts are caused primarily by land disposal practices that fail to contain wastes, by run-on and run-off controls that are inadequate to prevent surface water from flowing through impoundments, or by groundwater infiltrating surface impoundments. Open-pit and underground mining methods can also cause disturbances that can lower the water table in an area, causing water shortages, land subsidence and fracturing. However due to the low rainfall in some of the areas the impacts on the groundwater quality are less than expected and very localized. The volume of solid waste generated, including tailings from processing, is one of the main pollution concerns in the mining industry. The overburden (waste-to-ore) ratio for surface mining of metal ores generally ranges from 2:1 to 8:1, depending on local conditions. The ratio for solid wastes from underground mining is typically 0.2:1. Where concentration or other processing of the ore is done on site, the tailings generated also have to be managed.

Ores with a low metal content, say, less than 0.4%, generate significant quantities of tailings. In certain mines where ores have high sulphur content, drainage from mine workings and waste heaps can become highly acidic and can contain high concentrations of dissolved heavy metals. This acid mine drainage (AMD) can have a pH of 3 or lower; sulphate levels of 800 – 1800 mg/l; copper levels up to 50 mg/l; iron levels up to 1000 mg/l; lead levels up to 12mg/l; zinc levels up to 1700 mg/l; and cadmium levels of several milligrams per liter, depending on the contents of the ore. Effluent from tailings ponds may contain concentrations of chromium of several milligrams per liter. Base metal mining tailings decant may contain high concentrations of thiosalts. Chemicals used in flotation and other metal concentration processes could create toxicity problems when released in effluents. Surface runoffs may also pose significant environmental problems through erosion and carryover of tailings and other mining residues.

As discussed in Section 1.2.1 impacts on groundwater quality from the diamond mining industry in the WMA is negligible.

1.4 Groundwater management and monitoring requirements in the catchment area

1.4.1 Current groundwater monitoring and management

There are a total of approximately 180 monitoring points throughout the Lower Vaal WMA (See Table 3). The monitoring points serve all two of the levels of groundwater monitoring namely level 1 or national monitoring network and level 2 or regional. Some points are shown of Figure 1. The monitoring includes water levels and ambient water quality. There are automatic data loggers at some stations. The aim is to expand the network but the required equipment and personnel is currently not available. The required expansion as well as reporting and individual user reporting could be solved with the establishment and involvement of WUAs.

Table 3: Groundwater monitoring points in the WMA (DWAF, 2003)

Place	W / sample	Waterlevel	Orphimedes	Thalimedes
Barkly West	1			
Bestwood	20	19		
Boshoff	1			
Christiana	2			
Danielskuil	8	5		
Delareyville	1			
Ganspan	2	3	1	
Gerdau	1			
Ghaapplato	28	29	3	1
Griekwastad	7	7		
Groenwater/Skeyfontein	2			
Hartsvalleiskole	2			
J/Kemp Vaalharts Irrig	1			
Jan Kempdorp	1			
Kathu	9	8		
Koopmansfontein	1			
Kudumane	1			
Kuruman	18	18	6	5
Lichtenburg	1			
Majeding	1			
Majeng	2			
Manyeding Oog	1			
Niekerkshoop	4	1	1	
Peringmyn		5	1	
Peringmyn Scheurfontein	1		5	1
Postmasburg	5	5		
Sannieshof	1			
Schmidsdrif	3	3		
Schweizer Reneke	2			
Sishen	1	3	3	
Stella	1			
Taung	1			
Taung Dry Harts	1			
Ulco	1			
Vryburg	1			
Witsand	1		3	
Witsand	11	3		
Total	**145**	**109**	**23**	**7**

The main challenges facing DWAF in this WMA is with regard to the management and allocation of the groundwater resources at the high-abstraction irrigation areas. Constitutions have been drawn up, and are awaiting approval by the minister, for the following Water User Associations (WUAs): Stella, Coetsersdam/ Louwna, Tosca and Molopo.

Sixty six applications have been received for new license applications which entails an approximate 10 million m^3/annum additional abstraction from the resource. Currently the Harvest Potential maps (Vegter, 1996) are used when making recommendations with regard to allocations. In areas where over exploitation of the aquifer is taking place (e.g. Tosca), drastic measures such as reversing of water rights are necessary. This is causing many legal complications for management in the regional DWAF office.

The following reserves have been requested and completed: C91E, D41B, C32B, D41C, C31E, C31F, C91A, C91C, D41L, D56B, D41C+D, D41C+D and D41F.

1.4.2 Current (quality and quantity) requirements

No formal quality and quantity requirements have been set to date but DWAF is in the process of addressing the issue.

1.5 Poverty eradication and the role groundwater can play in the catchment

Often groundwater is an inexpensive resource to develop for domestic water supply for communities that are located far from existing surface water bulk supply systems. However cognizance has to be taken of the groundwater quality and exploitability when the level of sanitation is considered. DWAF Geohydrology is actively involved in water supply schemes for domestic use from groundwater resources in the WMA.

Emerging farmers can also benefit by the exploitation of groundwater especially in areas where potential for irrigation development from groundwater resources in the WMA is high. However, careful consideration needs to be taken of existing water rights and the possible over allocation of the resource.

In order to aid the government's initiative with regard to mineral development especially for small-scale mining operations, DWAF could play an active role in the water licensing process.

2 Groundwater according to geolithological units and catchments associated or enclosed with the units (1: 1000 000 geology)

The Lower Vaal WMA is underlain by diverse lithologies. Several broad lithostratigraphic units fall within the boundaries. A simplified geological map of the WMA is presented in Figure 2. From oldest to youngest, the units which are important in terms of groundwater occurrence comprise the following:

- **Swazian:** The oldest formations are the meta-sediments from the Kraaipan Group (Zk) which consist mainly of quartzite, chert, slate, phyllite and schist. The unnamed basement granite and gneiss (Zz) covers a large portion to the north east of the WMA. The rocks are the products of high-grade metamorphism.
- **Randuim:** Overlying the granite and gneiss are the quartzites, conglomerates, lavas and sediments of the Dominion Group (Rd). The Klipriviersberg Group (Rk) consisting of well jointed basaltic lava covers a large area to the east.
- **Vaaluim:** Lithologies of this age vary between meta-argillaceous rocks (slate, siltstone and dolomite of the Vryburg Group (Vry)); dolomites, limestones and related sedimentary rocks (often iron or manganiferous ore bearing, e.g. banded iron formations) of the Ghaap (Va) and Chuniespoort Groups (Vh); meta arenaceous quartzite from the Volop Group (Vv), basal diamictite, and basaltic and adensitic lava interbedded with chert and jasper from the Postmasburg and Pretoria Groups (Vp).
- **Carboniferous-Permian:** Karoo Sequence represented by the Ecca Group and Dwyka Formation (C-Pd), comprises of thick successions of sedimentary rocks covers a portion of the area to the south-east. Sedimentary rocks range from mudrocks through coarser varieties (sandstones, conglomerates) to diamictites and rhythmites (pleistocene

deposits). Karoo or Jurassic dolerite is fairly common throughout the sequence and also frequently intrudes older rocks.

- **Tertiary-Quaternary:** Undifferentiated inland deposits of unconsolidated to semi-consolidated sediments including sands, calcrete, aeolianite, gravel, clay and silcrete make up the Kalahari Group (T-Qk) to the north-west and far west of the WMA.

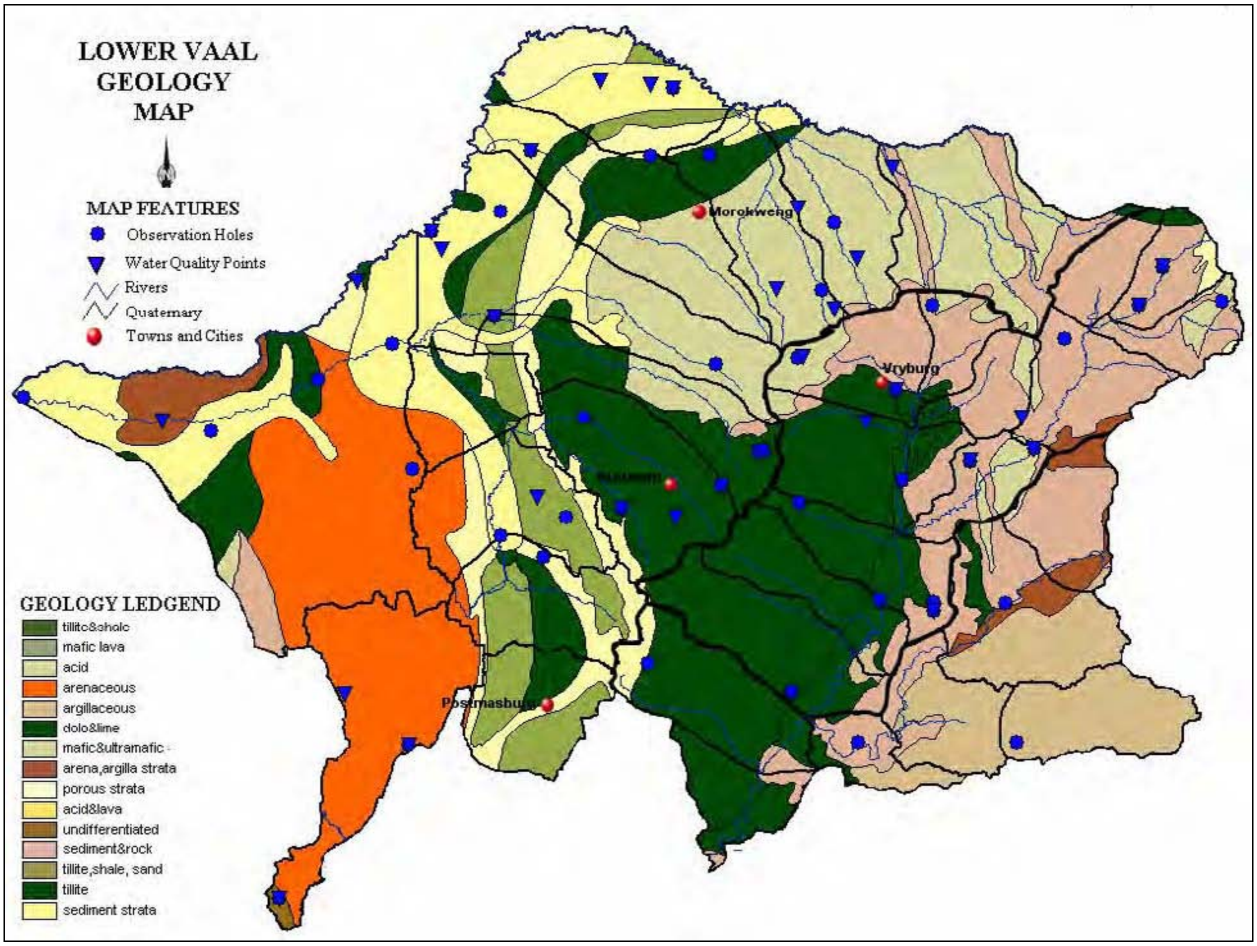

Figure 2: Generalised Geology of the WMA

Three aquifer types are present in the WMA: Intergranular and fractured, karstic and fractured. The following is a brief geohydrological description of the main exploitable aquifers in the WMA from the Vryburg and Kimberley geohydrological maps (DWAF, 2000).

The ability of granite and gneiss units to host groundwater is enhanced by the presence of fractures and dykes and the associated weathering. The aquifers can be divided into weathered, intermediate and fractured bedrock zones. Borehole yields vary across the unit depending on the waterbearing features. In the Louwna area the weathered pegmatitic granite yields are generally greater than 5 l/s as well as at the contact zone of the Kraaipan Group and the granite (Stella area). In the Delareyville area the contact between the Allanridge formation and the granites can be targeted for exploitable water. In the Schweiser Reneke area yields of up to 2l/s can be drilled in weathered ones of the granite.

Groundwater yields of 2 l/s – 5 l/s is found in fractured and weathered lavas of the Klipriviersberg formation (Sannieshof area).

The andesitic lava of the Allanridge formation can yield groundwater in excess of 2 l/s in fractures associated with faults or intrusions.

Solution cavities in dolomitic rocks of the Ghaap Group and Chuniespoort group often develop in association with diabase dykes and faults, contain large quantities of exploitable groundwater (yields > 5 l/s). Some dykes isolate compartments, which may be dewatered during overexploitation (e.g. Tosca). The contact between the banded iron formation and the dolomite is transitional with alternating shale and dolomite bands. This zone is a well-developed aquifer in association with faults and dykes.

Joints and fractures in the Volop quartzite and the whole of the Postmasburg Group can be targeted for boreholes with yields of up to 2 l/s. Yields in the Dwyka and Ecca sediments associated with fractures and intrusions, are not very high (0.1-0.5 l/s) and often the groundwater is associated with poor quality.

3 Riverbed Sand Aquifers

Little is known regarding true riverbed sand aquifers in the WMA. General characteristics of riverbed aquifers can be summarized as:

- Coarse gravels and sands are more typical of alluvial deposits. However, flood plains consist mainly of fine silt. Towards the end of a river's course, the river slows down dumping some of the heavier materials on these flood plains. Boreholes drilled into these types of formations normally have higher yields. It is important to note that borehole design is plays an important role in the yield of boreholes drilled into riverbed aquifers.
- Alluvial deposits grain size varies considerably, fine and coarse materials are intermixed. The hydraulic conductivities vary between 10^{-3} to 10^{3} m/d and their porosities vary between 25 – 70%. However, flood plain porosities usually range 35 – 50% and the hydraulic conductivities vary between $10^{-8} – 10^{-1}$ m/d.
- In general riverbed aquifers are high recharge areas and often recharge deeper underlying aquifers and are unconfined in nature.

The surface-water groundwater interaction is often intermittent (depending on the elevation of the water level, groundwater may recharge the surface water body or the surface water may recharge groundwater). This is normally dependent on the rainfall cycle (see Figure 3).

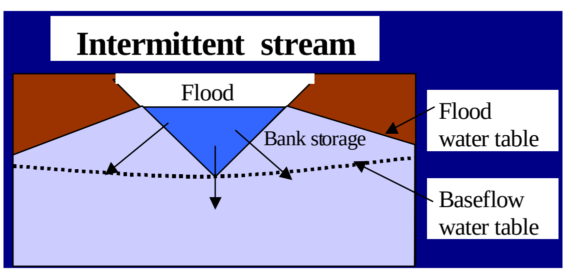

Figure 3 Intermittent interaction

The lower Vaal's gradient has lessened, suggesting that the suspended load and bedload are not only reduced in volume but are also smaller in particle size. As the river meanders back and forth sediments accumulate on the flood plains. Boreholes drilled here will almost always be successful because the sediments are of similar size and the river provides continuous recharge to the sediments. The design of boreholes along these rivers is extremely important to prevent clogging.

4 Groundwater-Surface Water Linkage

Groundwater-surface water interaction has not been studied sufficiently in the WMA. According to records documented by Van Tonder and Dennis (2003), under natural conditions there is seldom groundwater contributing to base flow in rivers. However observed surface water recharge in normally dry riverbeds. Current quality problems experienced in the Vaal and Orange rivers, waterlogging experienced with irrigation along these riverbanks indicate interaction. Therefore a study is currently motivated by DWAF Geohydrology to investigate Groundwater-surface water interaction in the Vaal and Orange rivers (Van Dyk, 2003).

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