Appendix D : Groundwater Report

DEVELOPMENT OF INTERNAL STRATEGIC PERSPECTIVES

GROUNDWATER OVERVIEW FOR MIDDLE VAAL CATCHMENT MANAGEMENT AREA

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1 Groundwater Issues in the Middle Vaal

The following is a brief description of the major groundwater issues in the Middle Vaal Water Management Area (WMA). The issues are discussed in terms of the three sub-catchments within the WMA namely, the Middle Vaal (C224 & C25), Sand/Vet (C43,C42 & C41) and Rhenoster/ Vals (C70 & C60).

1.1 Availability of groundwater information in the catchment area

The following data sources with regard to groundwater are available:

- NGDB database
- WARMS database with verification information this includes data of water abstraction for towns and agriculture.
- Catchment Management Strategy (CMS) Phase 1 and 2 studies in Klerksdorp goldfields (KOSH) area
- Ventersdorp surveys and other related projects regarding this dolomitic compartment
- Wesselsbron survey done by DWAF
- GH Reports, WRC projects and related MSc Thesis's, the Catchment Management Strategy (CMS) of the Sand/Vet
- Geohydrological maps

Data is readily available where there are active mining activities due to the management and control structures in place in these areas. Data are also generated in these areas due to the fact that these areas are targeted by DWAF as areas of concern with regard to quality and quantity of groundwater. The focus of the CMS studies are also in these areas. There is however less data available on groundwater in the Sand/Vet catchment than the Schoon Spruit/ Koekemoer Spruit catchments. This can be contributed to two factors: at the time of CMS development in the Sand/Vet groundwater was not considered to be "public water" as is now the case under the New Water Act of 1998, and the impacts on groundwater is less pronounced than in the KOSH area due to the nature of the aquifers in the Sand/Vet catchments.

Data on agricultural use is very poor, except in specific areas under stress which were targeted by DWAF e.g. Ventersdorp and Wesselsbron. Groundwater is utilized by agriculture for small scale irrigation (< 1ha) feedstock watering and household use throughout the WMA but limited data is available on abstraction volumes and quality of these points. With regard to larger scale irrigation from groundwater the data should become available once the WARMS database's data is verified.

Some data on abstraction for domestic supply in towns, where the bulk water supply is from groundwater or it is augmented with groundwater, is also available on the WARMS database. The largest gap on data for groundwater use and resources is in the Renoster/Vals sub-catchments. There is little mining or industrial development in these catchments and the only data available is from the WARMS database. No studies targeted at groundwater have been initiated in this area.

1.2 Overview of groundwater resources and use throughout the catchment area

1.2.1 Industrial and mining

In the Middle Vaal sub-catchment mining plays a major role in the economic development of the area, especially in the KOSH area. Gold mining has taken place in this area since the late 19th century. The impacts from the gold mining activities on groundwater has only been recognised as early as 1960 when localised dewatering became an issue at Stilfontein Gold Mine. Only more recently has the impacts on the quality of the groundwater and the interaction with the Vaal River become a concern. Due to the characteristics of the underlying geology the relationship with the surface water resources play a significant role (See Section 4).

There are five major gold mines active in the area and several diamond mine activities (varying from small scale one man operations to larger scale operations). Groundwater is abstracted for different uses at these mines (Darcy, 2002).

The largest volumes are abstracted at Stilfontein Gold Mine's Margaret Shaft. Although Stilfontein's underground operations has ceased for more than ten years pumping at Margaret shaft continues for the safety of the downgradient mines. The volume of water abstracted daily is estimated at 32 Ml/d. The water is utilized by a number of users: at DRD – North West Operations for process water (7 Ml/d), water supply to a number of private plots north of Stilfontein where the cone of depression influence the local groundwater levels, and most recently Mine Waste Solutions use the water at the Chemwes plant for the reworking of the old Stilfontein tailings dams (18 Ml/d). Any excess is discharged to the Koekemoer Spruit. Groundwater is also abstracted from other operating shafts in the KOSH mining area for safety and the water is utilized as process water.

The second largest abstraction of groundwater is from "scavenger" boreholes on the northern banks of the Vaal River on Anglogold's property. These boreholes serve as a barrier for polluted groundwater emanating from tailings and waste rock deposits in a high permeability zone of the dolomites. This water is utilised in the gold recovery processes. Some small-scale abstraction is also done for the purpose of irrigation at recreational and sports parks on the mine properties.

Skeat mine located north-west of Klerksdorp is totally dependent on groundwater. Process water is abstracted from old underground shafts and domestic water is abstracted from boreholes. The numerous diamond diggings and mines utilize large amounts of water from alluvial type aquifers in the catchment. There have been claims that the activities from the diggers have an impact on the aquifers yields but up to date these claims have not been substantiated by proper investigations.

The groundwater use in the Free State Goldfields differs from KOSH due to the difference in geology and aquifer types. The history of gold prospecting and mining in the Free State goes back to the late 19th century when gold was discovered and mined near Vredefort, but it took a considerable time before any substantial gold deposits were found in the north-western Free State - development only started after 1948.

Although mining has reduced significantly from the boom in the 1980s there are still five major mining houses involved in gold mining today and two diamond mines. Due to the large quantities of water present in the mined Witwatersrand rocks, a large quantity of water (120 -150 Ml/d) is pumped to the surface for accessibility each day (Cogho et al., 1992). This groundwater however has average conductivities of 500 mS/m and cannot be used for drinking or irrigation purposes. A small portion is diluted with potable water and used as process water and the remainder is pumped to evaporation areas and pans. This has a negative impact on the localized shallow aquifers in the area (see Section 1.3). The yields of the shallow aquifers are very low and thus little abstraction takes place for other uses by the mines. Both in the KOSH and Free State Goldfields areas the only industrial activities utilizing groundwater is related to the mining industry.

In the Renoster/Vals catcments there are little or no mining and industrial activities impacting on groundwater. Some diamond mining development is currently taking place north of Kroonstad and the industries (mainly food processing) at Viljoenskroon that utilize groundwater as a source.

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 and stock watering use. No numbers are available on the total abstraction volumes for this use. There are only two areas where large-scale irrigation takes place from groundwater resources. This is in the Ventersdorp dolomitic compartment and from the Karoo aquifers north of Wesselsbron. The Ventersdorp compartment has been studied in several investigations since its declaration as a Government Subterranean Water Control Area and the latest figures on irrigation volumes are 40.9Mm3/a for irrigation and 1.3Mm3/a for mining activities. (S Veltman, 2003)

A study undertaken during 2002 by DWAF has indicated that there is large-scale irrigation from groundwater resources north of Wesselsbron but no current volumes of abstraction have been calculated (Hohne, 2002).

1.2.3 Domestic

As previously discussed groundwater is utilized for individual domestic use in most rural and farming areas. Very few towns are solely dependent on groundwater as resource in the WMA due to the excellent surface water bulk supply network. Towns that are dependent (partially or completely) on groundwater in the Middle Vaal sub-catchment are: Ventersdorp, Hartbeesfontein, Coligny, Leeudoringstad, Makwassie, Hartbeesfontein, Dominiumville and several rural/ tribal villages in the Ventersdorp municipal area.

Towns in the Sand/Vet catchment that utilize groundwater include: Bultfontein, Marquard, Verkeerdevlei and Paul Roux. And in the Renoster/Vals catchment are: Petrus Steyn, Steynsrus and Edenville.

Private boreholes in urban areas are often utilized for garden irrigation and domestic uses such as filling of swimming pools, etc. No data is available on the abstraction volumes or number of boreholes in use in urban areas.

1.3 Groundwater quality in the catchment area

1.3.1 Natural

From the 2002 Wesselsbron survey it was found that the occurrence of natural pans and the resulting evaporation from these pans result in slightly increased salinity of the natural groundwater. Electrical conductivities are normally in the range of 100 –200 mS/m but in the vicinity of the pans the values increase to about 300 mS/m. Figure 1 shows the documented total dissolved solids for the area as mapped by Simonic (1999).

The poor quality groundwater that is abstracted from the deep mining areas in the Free State Goldfields are another example of natural occurring poor quality water. The water originates in the Ecca formations and is of typical Na-Cl type water, found in marine depositional sediments with high salinity (500mS/m).

1.3.2 Point and diffusive pollution

There are several sources of point and diffuse groundwater pollution in the WMA. Most of these sources are related to mining activities.

In the Middle Vaal sub-catchment the following sources contribute to the degradation of the groundwater quality. Gold mining activities related to groundwater pollution in the KOSH area include: Acid mine/ rock drainage (both in the mine workings and on surface at waste rock dumps); waste deposits such as tailings dams and waste rock dumps; recirculation of process water between metallurgical plants, tailings dams and underground; return water dams; incidents such as pipe bursts and other spills at gold metallurgical plants; decant and abandoned mines (Darcy, 2002).

Water quality is typical higher than normal salinity with a Ca-Mg-Na-SO_4 or carbonate rich character. The pH's is normally in the neutral range due to the neutralizing effect of the dolomitic geology. Some enrichment is found in metals such as Fe, Mn and Al but is restricted due to the neutral ph of the water.

The old Vierfontein colliery is currently decanting into the Vierfontein Spruit, which flows north into the Vaal River east of Orkney, the quality of which is characterised with high in salinity and sulfate values. The volume decanting has not been accurately measured up to date. Abandoned mines and tailing deposits is another uncontrolled source of diffuse pollution in the area.

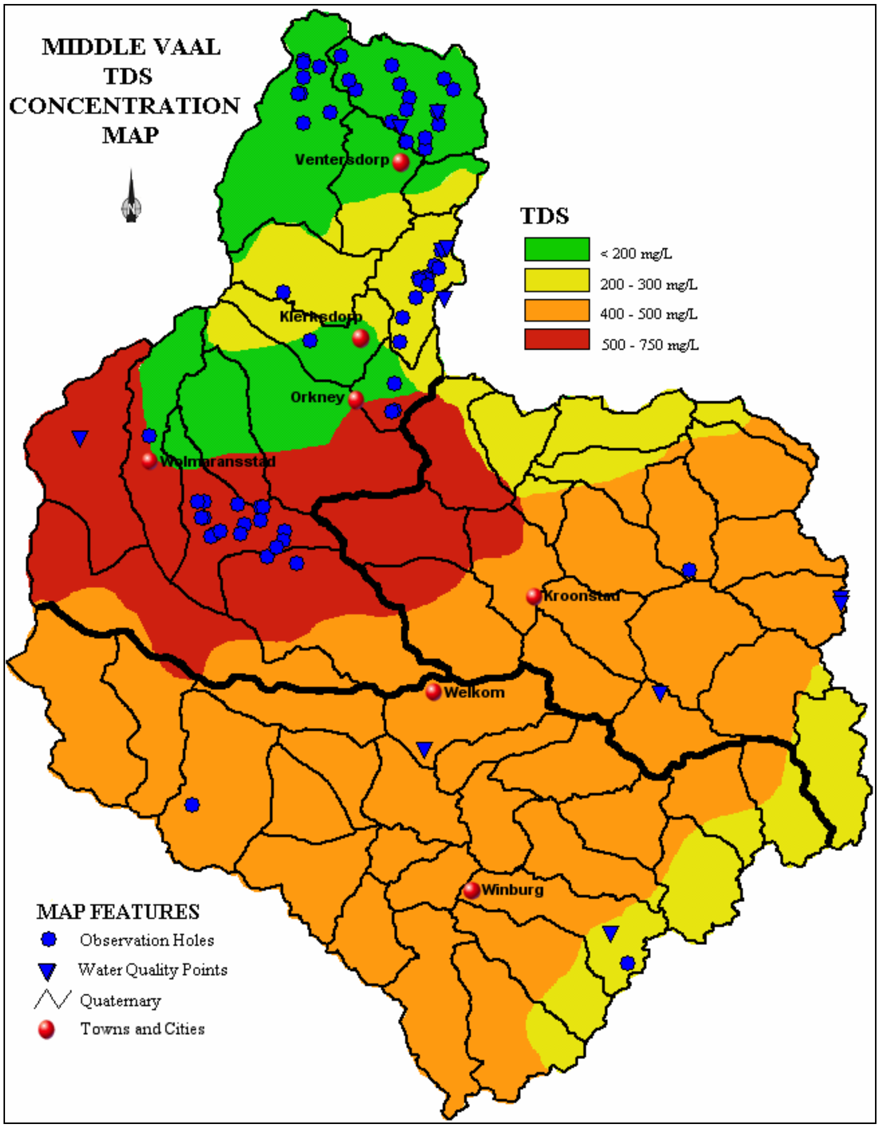

Figure 1 **Total dissolved solids**

The characteristics of the dolomitic aquifers in the KOSH area is the cause that the impacts on the groundwater regime differs from the impacts found in the Free State Goldfields. The higher permeability allows for more drainage of water from unlined surface water bodies such as tailings and associated return water dams and other process water dams. Less evaporation areas are thus found in the KOSH area. Formation of sinkholes is another negative impact associated with the pollution of the groundwater, dissolution by low pH source water and fluctuations in waterlevels leads to the formation of sinkholes.

The Groundwater/ surface water interaction between the dolomites is another matter of concern and the volume of water contributed to the Vaal River has been estimated at 73.1 Ml/day with the enormous associated salt load to the river system (IWQS, 1995). (As part of the second phase CMS study a detailed water and salt balance will be compiled for the Middle Vaal sub-catchment.)

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 real data in the WMA.

Nitrates are the contaminant of most concern (Conrad et al, 1999), 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. Where feedlots are operated the contribution of organic nitrates to groundwater contamination can be far more problematic, but for most farming activities organic nitrate is not a severe 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 and site specific data relating to likely loading/application volumes and history, soil profile and local geohydrology are required.

In the Sand/Vet sub-catchment activities associate with gold mining also have the largest impact on the groundwater quality. The impacts are mostly the same as described above with the exceptions of the large evaporation pans and areas, the water quality (Na- Cl – type) of the deep aquifers and the shallow low yielding Karoo aquifers underlying the mining activities, which keep the pollution localized surrounding the sources. Although a definite connection between the pans and the groundwater has not been proven the evaporation pans and areas are also associated with localized groundwater pollution. The water is typical of a SO_4, Na, Ca – Cl type with associated low pH which cause metals to be mobilized in the groundwater. The groundwater pollution together with contaminated run-off contributes to the salination of the Sand River in the area.

Activities related to urban areas can also result in localized or even diffuse pollution of groundwater. In the Welkom area poor management of sewage treatment works contribute to the groundwater pollution by discharging raw sewage directly in into evaporation pans. Other sources of pollution are landfill sites, on-site sanitation (especially in informal settlements) and spills resulting from accidents or leaking underground tanks.

In Renoster/Vals catchment the only definite problem that was identified is the localized groundwater pollution from food manufacturing factories. The issues relating to urban and agricultural activities can also apply here.

1.4 Groundwater management and monitoring requirements in the catchment area

1.4.1 Current groundwater monitoring

There are three levels of groundwater monitoring in the Middle Vaal WMA. There is the National monitoring network, Regional networks and compliance monitoring (Veltman, 2003). There may be some overlapping between the three levels of monitoring but each level serves a different purpose. Most of the monitoring points in the catchments are shown on Figure 1.

The national monitoring network or ZQM network has the purpose of measuring ambient groundwater quality and samples for macro chemical analyses are taken once every six months. There is 7 ZQM monitoring boreholes located in the Middle Vaal WMA.

On regional level or level 2 there are the following boreholes for the purpose of resource management:

- Schoonspruit dolomitic compartment (9 quality, 3 monthly; 15 WL, monthly; 3rainfall data loggers, 1 rainfall sampler, yearly for Cl, H-isotope, O-isotope)
- Wesselsbron (8 quality, monthly; 14 WL, monthly, 2 rainfall data loggers)
- KOSH (7 WL orphimedes; 11 quality, monthly; 4 WL, monthly, 2 rainfall samplers)

For the purpose of compliance monitoring there are site-specific boreholes at mines and municipalities (solid waste sites). The positions and number of boreholes is depended on the individual permits or licenses at the sites.

1.4.2 Management

Regarding management of groundwater resources the following structures or projects are in place or are being developed:

Catchment Management Strategies (CMS):

- Schoon/ Koekemoer Spruit catchments are currently in the second phase of CMS development and specific groundwater issues will be addressed.
- Sand/Vet catchments are in the implementation phase of the CMS with an established Catcment Management Committee. There is however a lack of adequate groundwater management options in the current CMS.

Water user Associations:

- Ventersdorp Dolomite WUA is currently waiting for approval from the Minister.

Licenses (permits) are currently under review to address site specific groundwater issues

Reserve Determinations that are completed or underway for the purpose of licence applications include: C60G (rapid), C24F (preliminary) and C24C (preliminary).

1.4.3 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.

Emerging farmers can also benefit by the exploitation of groundwater for irrigation and livestock farming and the WUAs could play an active role in this regard.

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).

Exploitable aquifers are found in four major Geological Supergroups: The Karoo Supergroup, Transvaal Supergroup, Ventersdorp Supergroup and the Witwatersrand Supergroup (see Figure 2). There are also limited aquifers found in alluvial deposits along streams and rivers.

Karoo sediments of the Ecca and Beaufort Groups, which consist of mainly sandstones, mudstones and shales, cover a large portion of the WMA. The aquifers are secondary aquifers with water associated with fracturing of the porous medium. Groundwater is often associated with dolerite intrusions and the yields are very variable between 0.1 – 10l/s depending on the type and fracturing of the sediments. Yields are normally higher in the Beaufort group than in the Ecca (Barnard, 2000).

Ventersdorp group lavas outcrops at some places in Goldfields area and the Transvaal, Ventersdorp, Witwatersrand groups and some basement rocks represent the majority of aquifers in the KOSH area. The most significant aquifer in the region is the Malmani dolomite, which forms part of the Chuniespoort Group of the Transvaal Sequence. Although this aquifer extent in terms of outcrop region is small, as a resource this is the most important groundwater related body in the area. This represents the most southerly extent of an arc of dolomite outcrop, which extends as far north as Johannesburg and constitutes one of the most extensive and heavily utilised groundwater resources within South Africa. Although the dolomite has a relatively low primary permeability, the development of karstic features due to the preferential solution along discontinuities such as joints, faults and bedding planes has served to develop the secondary permeability of the rock mass, particularly in chert-rich units such as the Monte Christo and the Eccles Formations. Groundwater movement within the dolomite aquifer in this area is known to be associated by north-south trending joints and faults which have experienced preferential solution and flow takes place towards the Vaal River and points of abstraction such as Margaret Shaft at Stilfontein Gold Mine.

Other lower yielding aquifers are found in the Timeball shales and Hekpoort andesites from Pretoria group. The Ventersdorp andesites (lavas) and Witswatersrand quartzites can, where weathered, be aquifers or sometimes be seen as aquicludes. Some basement granites represent aquifers in the Hartbeesfontein area.

3 Riverbed Sand Aquifers (summarized from Driscoll, 1986)

Very few riverbed sand aquifers are found in the WMA and no data is available on the characteristics or exploitability. However the general characteristics of riverbed sand aquifers can be summarized as:

- Coarse gravels and sands are more typical of alluvial deposits. However, flood plains consist mainly of fine silt.
- 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. Therefore boreholes drilled into these aquifers are almost always successful.

4 Ground Water/Surface Water Linkage

This area exhibits certain regions where there is pronounced interaction between surface and groundwater. The two regimes are therefore well-linked and should be integrated to manage any water related issues in these catchments.

Ways in which groundwater and surface waters interact (streams and rivers particularly) include:

- Decant from mines. Examples include the water being fed from the south into the Vaal from the decanting and partially flooded Vierfontein coal mine.
- Pumpage from mines into surface water. The most pronounced of these is probably the Stilfontein mine water, which is pumped from Margaret shaft into the Koekemoer Spruit. Winde (2001) explains in detail how the pumping influences the flow, temperature, and hydrochemical interactions and consequent contaminant transport within this Spruit.

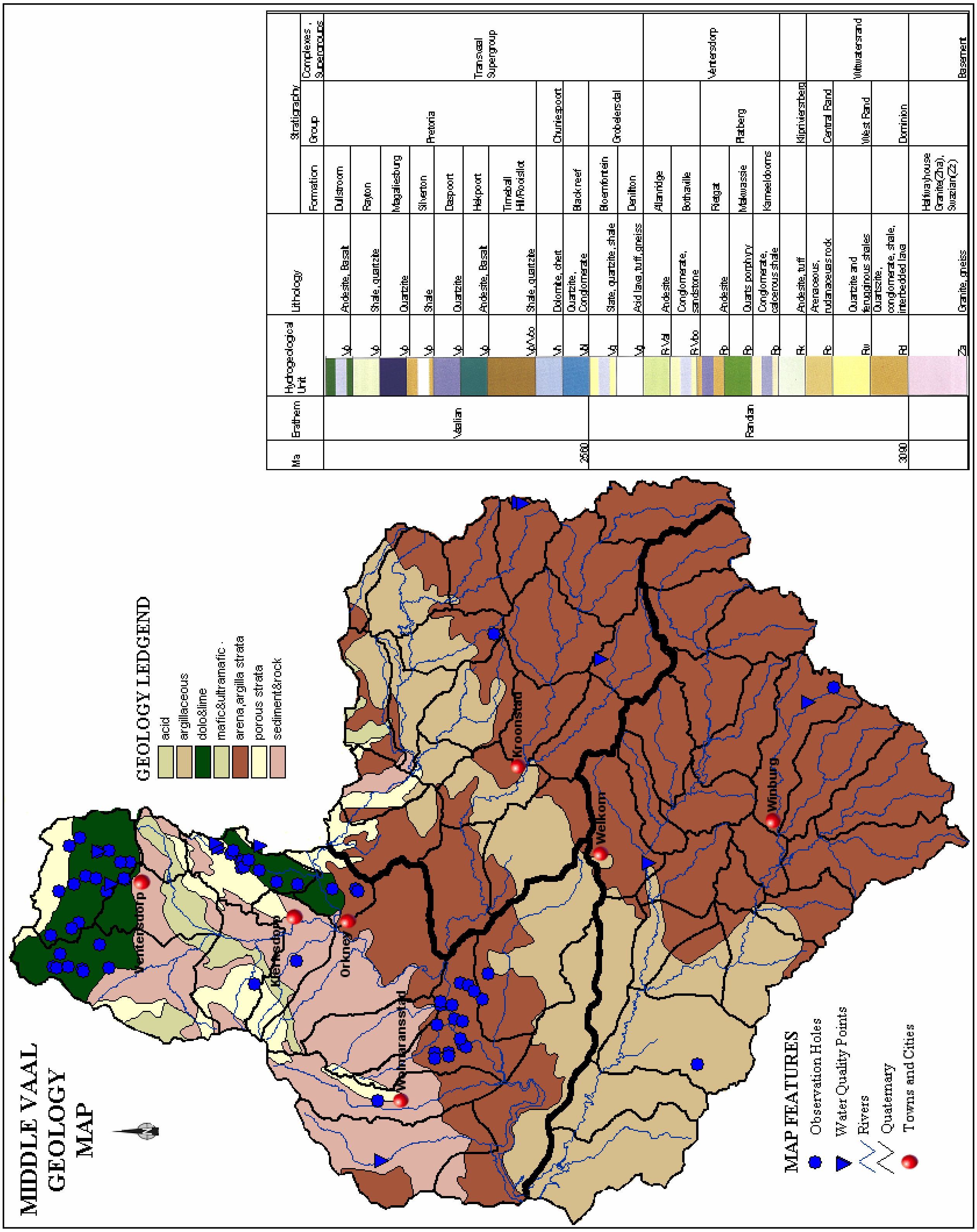

Figure 2 Middle Vaal Geology

- Recirculation of water in the mines overlain by dolomite. In the northerly KOSH mines this is a particular problem leading to heightened salination and increased pumping with the associated costs. This circulation is also suspected of increasing the dissolution of subsurface dolomites and may lead to sinkhole formation.

- Eye flows. Two separate types of eye flow are important. Firstly the eye's below the mining areas are important in the overall seepage of groundwater, much of it with elevated sulphates and TDS into the Vaal river. Observed yields of the "eye" is reported to fluctuate considerably with season and available records indicate that the flow in recent years has ranged between a maximum of 23 775 m^3/day in April 1989 and 3 583 m^3/day in November 1989 (L & W Environmental 1993).

- The other important eye flow is the flow of the natural eyes such as the Schoonspruit eye. The flow from this eye is one of the controlling factors in the flows within the Schoonspruit. Kok (1972) reports that the flow from the Schoonspruit eye under natural conditions was approximately 32.63 Mm^3/year, while Polivka (1987) reports 55.4 Mm^3/year for all the springs around the Schoonspruit area. The surface water study elaborates on the influence of this eye on the Schoonspruit and its water users.

- Seepages into the streams. Hearne (1996) estimated that approximately 73.1 Ml/day of groundwater finds its way into the Vaal and its tributaries. This adds approximately 211 tonnes of dissolved solids and 121 tonnes of sulfate to the Vaal. The well field currently used by Vaal River Operations was established to reduce this impact.

- Surface/groundwater interactions are also important in the Stilfontein/Koekemoer spruit area, where leakage from the spruit in to dolomites has been reported (Darcy, 2002). The decrease in flow in this stream might lead to decreased infiltration and the water volumes currently anticipated may show a decrease.

- Natural groundwater flow towards rivers and streams. This base flow can be defined as the part of stream flow that is attributable to long-term discharge of groundwater to the stream. Based flow estimates per quaternary catchment as calculated by Van Tonder and Dennis (2003) are summarized in Table 1.

Table 1: Estimated base flow per quaternary catchment

Quaternary catchment	Base flow (Mm3/a)	Quaternary catchment	Base flow (Mm3/a)
C24A	3	C60A	4
C24B	2	C60B	4
C24C	14	C60C	3
C24D	1	C60D	2
C24E	2	C60E	2
C24F	5	C60F	2
C24G	2	C60G	2
C42A	3	C70A	3
C42B	3	C70B	3
C42C	4	C70C	3
C42D	2	C70D	2
C42E	3	C70E	2
C42F	3	C70F	2
C42G	2	C70G	3
C42H	1	C70H	1
C42J	3	C70J	2
C42K	2	C70K	3
C42L	1		

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