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RESERVE DETERMINATION FOR THE POMFRET - VERGELEGEN DOLOMITIC AQUIFER, NORTH WEST PROVINCE

PART OF CATCHMENTS D41C, D, E and F

GROUNDWATER SPECIALIST REPORT

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CSIR ENVIRONMENTEK

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1 INTRODUCTION

Due to the current stress placed upon the Tosca - Vergelegen dolomitic aquifer, from intense abstraction by irrigation farmers, a Reserve Determination has been requested by the Regional Department of Water Affairs and Forestry (DWAF).

This report presents the results of a preliminary, intermediate reserve determination for the Pomfret - Vergelegen dolomitic aquifer, in the North West Province. The approach is based on the Department Water Affairs and Forestry (DWAF, 1999) Resource Directed Measures (RDM) guidelines for Intermediate Reserve Determination (IRD).

2 STUDY AREA

The study area is defined as the sub-outcrop boundary of the Campbell Group of dolomites (Figure 1). The study area occupies part of quaternary catchments D41C, D, E, F and lies within the Lower Vaal Water Management Area, in the North West Province. The main focus of the Reserve Determination is on the dolomitic aquifer, which is currently overutilized due to the abstraction of groundwater for agricultural activities. Due to the nature of the dolomitic aquifer, and the fact that the quaternary catchment boundaries do not form groundwater divides, the entire dolomitic aquifer was selected as the boundary of the study area.

2.1 Resource Units

Three Resource Units (RUs) are defined within the Pomfret - Vergelegen dolomitic aquifer, identified from observed aquifer characteristics, from drilling logs, water level response, aquifer tests and the presence of regional dolerite dykes, which divide the area into three major compartments (Figure 1). These include:

RU 1 – Tosca - Vergelegen dolomitic aquifer (bounded on the west by the Grassbank dyke and on the south by the Quarreefontein dyke).
RU 2 – Dolomitic aquifer, area of post Karoo dolerite intrusives (dyke swarms)
RU 3 – Pomfret dolomitic aquifer

A fourth Resource Unit was identified as the overlying, low yielding, Kalahari Group aquifer (RU4). This unit is only used extensively close to the Molopo river due to the good quality water available above the Budin clay formation. Away from the river very little groundwater is available in this formation.

For the purpose of calculating the available groundwater resource, RUs 1 and 3 have been further subdivided into two areas, (i) banded ironstone overlying dolomite, and (ii) outcrop and sub-outcrop dolomite (Figure 1).

2.2 Geohydrological Response Units

Within the three dolomitic Resource Units (RU1-3), smaller geohydrological response units exist, typically formed by the intrusion of dolerite into the dolomitic aquifer forming small compartments, which may act as isolated units. Where possible, reference is made to these response units.

3 DATA SOURCES

Information used in the determination of the groundwater component of the Reserve was obtained from:

- the DWAF National Groundwater Database (NGDB);
- Smit, PJ., 1977. Die Geohidrologie in the opvanggebied van die Moloporivier in the Noordelike Kalahari. PhD Thesis, Univ Free State.
- DWAF report, GH2986. Groundwater conditions in the Pomfret Mining Area – Molopo, 1967.
- CSIR report EMI-C 91179, Geohydrological and Geophysical Investigation in the Tosca-Vergelee area, 1991.
- DWAF report, GH3767. Grondwater ondersoek vir Suid-Afrikaanse Weermag Pomfret, Distrik Vryburg, 1992.
- DWAF report, GH3813. Geohydrological investigation for SADF Pomfret. District Vryburg, Drainage Region D410, 1993.
- DWAF Regional Database (Kimberley) - data of groundwater and irrigation monitoring in the area during 2001 and 2002.

4 BACKGROUND

4.1 Climatic Conditions

The study area is characterised by a low annual rainfall, varying between 107 – 928 mm/a, with an average rainfall of 385 ± 153 mm/a (average of Pomfret [station 0504050X] and Vergelegen [station 0505347 6] records). Historical records of annual rainfall is shown in Figure 2. Approximately 83-85% of the rain occurs during the summer months of October to March (Figure 3).

Evaporation in the area is high, between 2050 – 2250 mm/a (WRC, 1994). As such only a small percentage of rainwater is available to recharge groundwater.

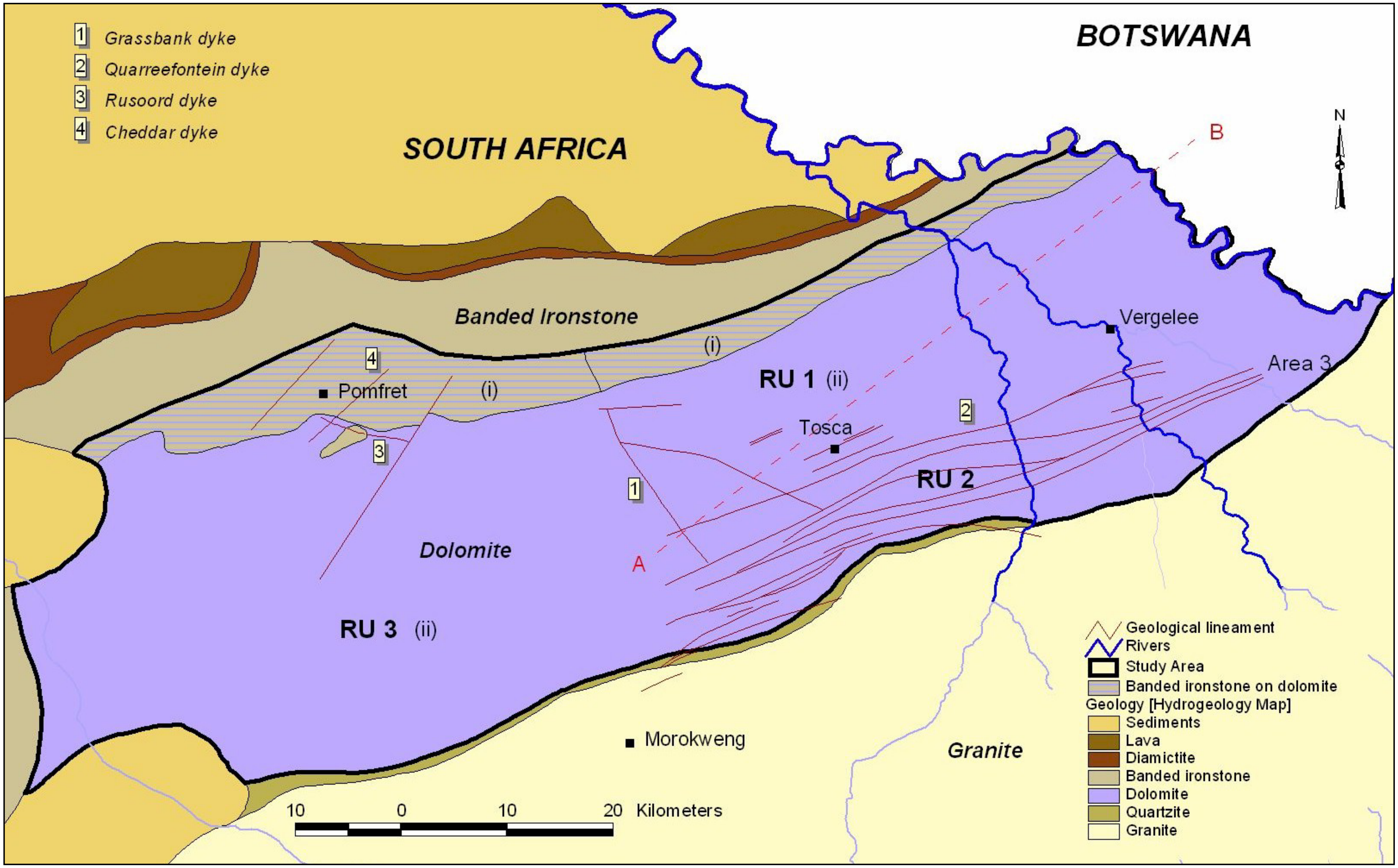

Figure 1 Pomfret - Vergelegen dolomitic aquifer (study area), sub-outcrop geology, with Kalahari sands removed.

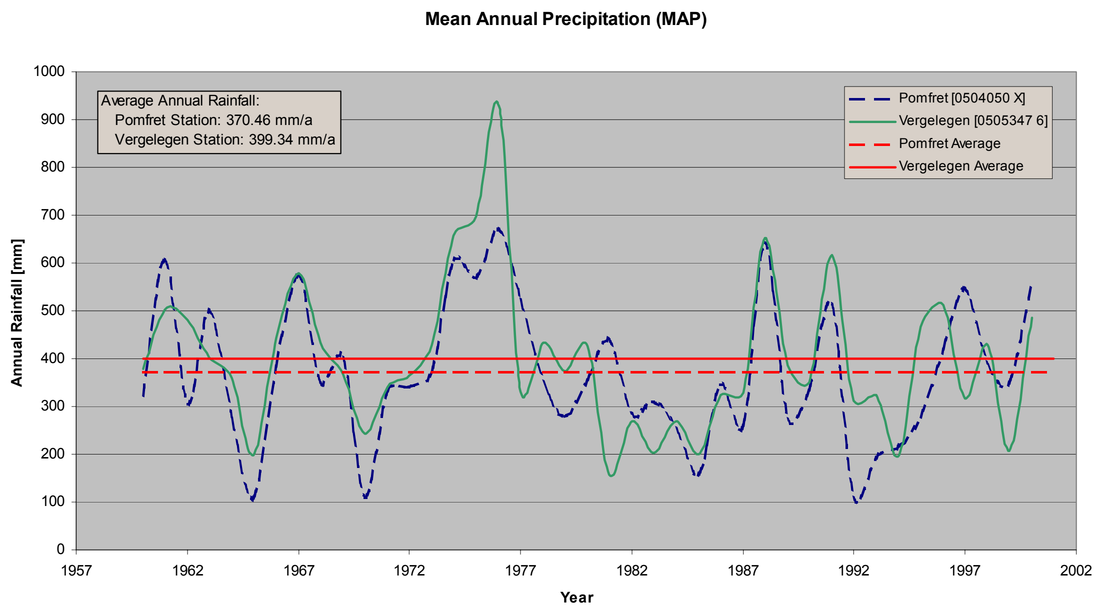

Figure 2 Annual distribution of rainfall for stations Pomfret and Vergelegen.

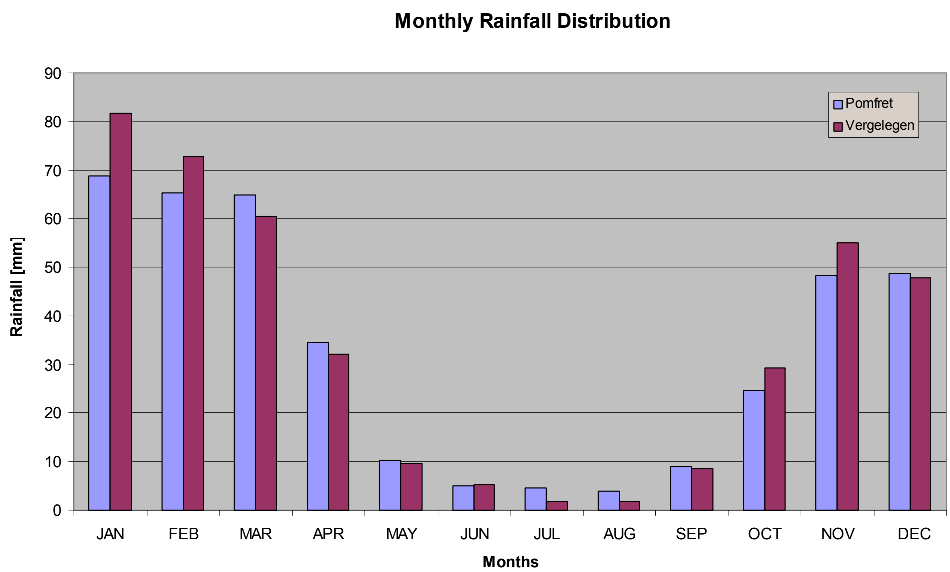

Figure 3 Monthly rainfall distribution for stations Pomfret and Vergelegen.

4.2 Land Use

The low rainfall in the Molopo district results in semi-arid conditions, characterised by tropical bush and savanna types (Bushveld) vegetation and continental red and brown shifting sands (WRC, 1994). The main activity within the area is stock watering and agriculture. Typical crops include paprika and maize. Small scale, subsistence, farming has taken place in this area for a number of decades, however, only over the past 10 years has the irrigation potential of the area been realised, resulting in a rapid increase in the land under irrigation (Section 8.1.1). Groundwater is the sole source of water for both agricultural and domestic requirements. As such irrigation farming has placed a considerable strain on the dolomitic aquifer and subsequently the Kalahari Group aquifer.

5 GEOLOGY

5.1 Regional Geology

The stratigraphic succession of the area is given in Table 1 (SACS, 1980). The sub-outcrop geology is shown in Figure 1, while the outcrop geology is shown in Figure 5.

Table 1 Stratigraphy and lithological explanation.

Sequence	Group	Formation	Description
	Kalahari	Gordonia Eden Budin Wessels	Red brown aeolian sand Calcareous sandstone and clay Red clay Sandstone and gravels
Post Karoo			Dolerite dykes and sills
Griqualand West		Makganyene	Diamictite
	Griquatown	Asbestos Hills	Banded ironstone, including jaspilite and chert
	Campbell	Ghaap Plateau Schmidtsdrift	Dolomite chert limestone Dolomite and shale
		Vryburg	Quartzite
Archaean			Granite

5.2 Local Geology

The full geological succession given in Table 1 is represented within the study area. The Archaean granites form the basement of the area, outcropping to the south of the study area. The granites are overlain by quartzites of the Vryburg formation which reach thicknesses of only tens of meters. The dolomites of the Campbell Group reach thickness of 900-1650 m and are a significant water bearing formation. The dolomites are overlain in the north of the study area, by banded ironstone of the Asbestos Hills formation. Intruded into these rocks are dolerite sills and dykes. This package of rocks dips at approximately 10° into a northwesterly direction. Large north-south trending faults are present within the area.

An era of intense weathering and erosion followed the deposition of the Griqualand West Sequence, carving a north-east trending U-shaped valley into the dolomite. The thickness of the valley increases towards the Molopo river where a depth in excess of 150 meters is reached. This valley is filled with younger (Quaternary – Tertiary) clastic and clayey fluvial sediments of the Kalahari Group. At the base of the valley gravels and sandstones of the Wessels formation were deposited. These gravels are poorly sorted and range in size from less than 1 mm to 25 mm. On top of the gravels red-brown clay of the Budin formation were deposited, followed by fine grained sandstone of the Eden formation. The sequence is covered by red-brown aeolian sand which covers most of the area. The thickness of Kalahari sands varies across the area from less than 15 m near the dolomitic and granitic outcrops in the west, to up to 120 m of thickness to the northeast of Vergelee, in proximity to the Molopo river (Figure 4).

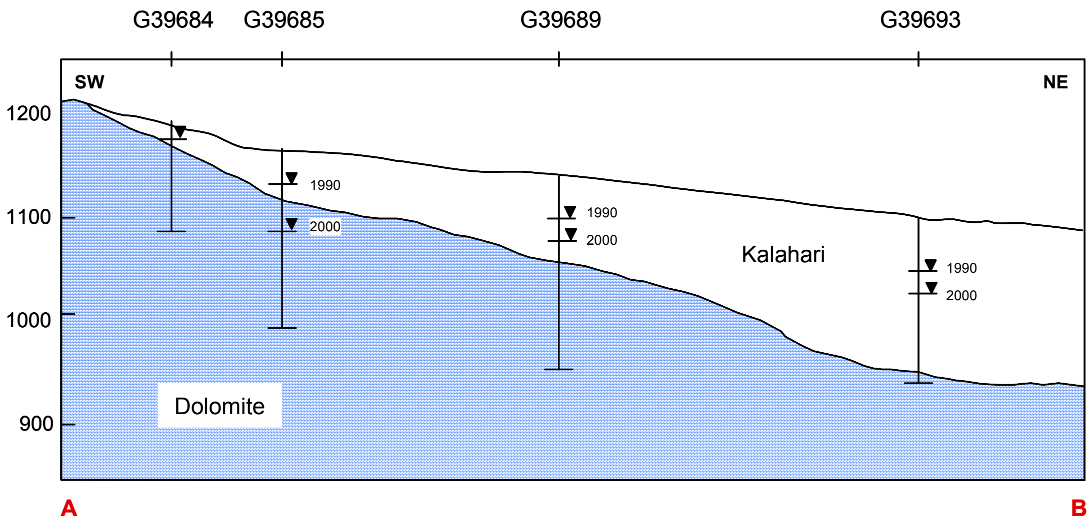

Figure 4 Cross section through the Tosca dolomitic aquifer (See Figure 1).

Along the Molopo river and tributaries, very recent river deposits are present. The channel of the Molopo river meandered within a 4 km wide band from the present channel to build up a riverbed deposit up to 30 m in depth. These deposits consist of gravels of 1 to 10 mm, sandbars and fine grained sand and to a lesser extend silt.

6 GEOHYDROLOGY

As mentioned in Section 2.1, four Resource Units are defined within the study area, three within the Pomfret - Vergelegen dolomitic aquifer. These three RU1-3, are based on the local and regional geological and geohydrological conditions.

Resource Unit 1, referred to as the Tosca - Vergelegen dolomitic aquifer, is bound by the Grassbank and Quarreefontein dykes to the west and south (Figure 1). Groundwater occurrence is mainly within fault zones where fracturing, weathering and leaching have developed. The fault zones are meters to 10's of meters in extent and stretch linearly north-south for kilometers. The brecciated fault zones consist of fractured dolomite, fractures, small solution cavities and Mg-rich wad material. Borehole yields within RU1 range between 0.01-126 l/s with an average yield of 6.32 l/s. In the northern part of the Resource Unit, the dolomite is overlain by banded ironstones (Figure 1). Due to the shallow dip of these formations, the majority of boreholes drilled into the banded ironstones, penetrate the underlying dolomite formation. The water levels within RU1 vary between 5-10 m below ground level (mbgl) in the west to 50-60 mbgl north-east at the Molopo river.

Resource Unit 2 consists of an area of east - west trending dykes, which have formed numerous small compartments within the dolomite. The groundwater occurrence is mainly along fracture zones associated with dolerite dykes, typically on the southern side of dykes.

Borehole yields within RU2 are typically low, ranging between 0.01-44 l/s with an average yield of 2.4 l/s. Water levels range between 15 to 25 mbgl.

To the west and south-west the north-south Grassbank dyke, dolomite outcrops within RU3, referred to as the Pomfret dolomitic aquifer. Groundwater occurs in similar fractured and weathered geological features. Groundwater levels are shallow at around 10 mbgl, with less dyke occurrence and compartmentalization. In RU3 groundwater occurs more in weathered zones and less in fractured zones, with good recharge due to calcrete cover and little sand cover. Borehole yields vary between 0.01-75 l/s with an average yield of 3.9 l/s. In the northern part of the Resource Unit, the dolomite is overlain by banded ironstones (Figure 1). Due to the shallow dip of these formations, the majority of boreholes drilled into the banded ironstones, penetrate the underlying dolomite formation. Water levels in the dolomitic aquifer vary between 10-70 mbgl.

The shallow water level in the dolomites results in a moderate to high vulnerability. With increasing thickness of Kalahari sands overlying the dolomites, this vulnerability is dramatically reduced. According to the Parsons (WRC, 1995a) '*Classification of Aquifers in South Africa*' the Pomfret - Vergelegen dolomitic aquifer is classified as a sole source aquifer. Defined as "an aquifer which is used to supply 50% or more of domestic water, and for which there are no reasonably available sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial." As a 'Sole Source Aquifer', with a 'moderate to high aquifer vulnerability', a 'strictly non-degradation' level of protection is required for the aquifer (WRC, 1995a).

Covering approximately 80% of the study area is the Kalahari Group (RU4) consisting of gravels, sandstone, clay and sand. The Kalahari Group was originally saturated to the clays of the Budin Formation. In the Eden sandstones water to sustain stock watering is intersected. Along the Molopo river thicker saturation of the sandstones is present. The presence of the Budin clay formation, which acts as an aquiclude or confining layer, is not continuous throughout the study area, resulting in some hydraulic connection between the dolomitic aquifer and the weak, overlying Eden Formation aquifer. This is evident from the fact that regional water levels within the Kalahari Group aquifer have also been impacted through over abstraction, resulting in a decline in the regional water level of 10-20m. From a use perspective the Kalahari Group aquifer may seem insignificant due to the low transmissivities, resulting in low yields. However, the storage capabilities of the Kalahari aquifer in combination with the high yielding underlying dolomites, is of particular significance. From aquifer testing it is estimated that the storage capabilities of the Kalahari Group aquifer are at least twice that of the dolomite.

Three main, geologically controlled, aquifers are therefore present within the Pomfret - Vergelegen dolomitic aquifer. These include:

(i) Brecciated and leached zones along faults, a high yielding aquifer within the area.

(ii) Fracture zones associated with the intrusion of post-Karoo dolerite dykes and sills. Along these sills and dykes relatively high yielding fractures are intersected. The extent of these fracture zones and possible compartmentalization impede the long-term, sustainable, yield from these zones. Pump testing and water level response to abstraction indicate recovery loss after pump testing resulting in long-term water level declines.

(iii) Transition zone between the dolomite, shale bands and the banded ironstone.

6.1 Recharge

According to Vegter (WRC, 1995b), groundwater recharge within the catchment varies from 3 to 12 mm per annum. Recharge software developed by the Institute for Groundwater Studies (IGS) (van Tonder, 2000) was used to assess recharge for each of the resource units. The software makes use of three recharge methods, the Chloride method (Bredenkamp et al., 1995), Vegter's Recharge map (WRC, 1995b) and the Harvest Potential map (DWAF, 1996). The results of each of these methods is given in Table 2.

Table 2 Calculated recharge figures as a percentage of Mean Annual Precipitation.

Resource Unit	Recharge (1) [% of MAP]		
	Cl Method	Vegter	Harvest Potential
RU 1	0.13 – 9.2	0.75 – 3.0	6 - 53
RU 2	0.05 – 4.0	0.75 – 3.0	6 - 53
RU 3	0.20 – 7.2	0.81 – 3.2	6 - 57

(1) Rainfall figures for Vergelegen (399 mm/a) have been used for RU1 and RU2, while figures from Pomfret (371 mm/a) have been used for RU 3.

The chloride concentrations in groundwater were used to determine more accurate recharge figures for the study area (Bredenkamp et al., 1995). Based on the chloride concentration in each borehole, a recharge figure was therefore calculated. A spatial plot of these results highlighted areas of higher recharge, as shown in Figure 5. These areas coincide with existing structural features, such as lineaments, outcrop areas and alluvial channels, likely areas of recharge. The proposed recharge areas also coincide well with existing conceptual models and understanding of the dynamics of the dolomitic aquifer. The following recharge figures (Table 3) were obtained for each of the Resource Units.

Table 3 Calculated recharge figures using Chloride method.

Resource Unit	Response Unit	% Recharge 5^{th} – Mean – 95^{th}	Percentage of boreholes giving a % Recharge of				
			< 1%	> 1%	> 2%	> 5%	> 10%
RU 1	(i)	0.18 – 1.06 – 4.45	41.67	58.3	33.3	0.0	0.0
	(ii)	0.25 – 1.41 – 4.22	38.06	61.9	33.6	2.2	0.0
RU 2	-	0.12 – 0.51 – 2.05	81.11	17.8	5.6	0.0	0.0
RU 3	(i)	0.54 – 1.70 – 4.94	26.32	73.7	44.7	5.3	0.0
	(ii)	0.26 – 0.93 – 4.89	52.38	47.6	31.0	4.8	0.0

These recharge figures correspond well with those previously reported on by Smit (1977), who gave recharge figures in outcrop areas of 2.2 – 3.8%. According to Smit, no recharge to groundwater occurs in areas where the thickness of the Kalahari sand is greater than

15m, due to the high evaporation. In areas where the Kalahari sand is < 15m recharge to groundwater varies between 0.26 – 0.8%, with an average of 0.5% (Smitt, 1977).

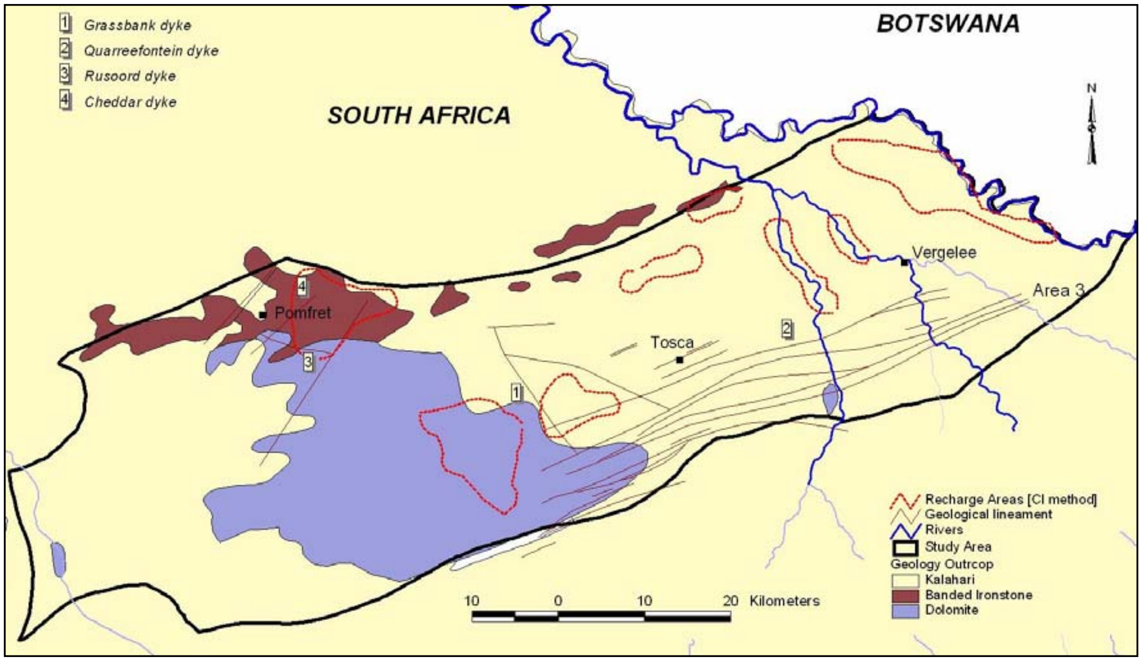

Figure 5 Areas of highest recharge, based on Cl values for existing boreholes.

Based on the results of the Chloride recharge method, the following areas of recharge to the dolomitic aquifer are proposed (Figure 5):

- Recharge through geological lineaments (faults, not dykes)
- Recharge through shallow outcrop and suboutcrop of dolomite (southwestern area)
- Recharge through banded ironstone formation (northern border of study area).
- Recharge through the alluvial channels of the Molopo river and tributaries.

Figure 5 indicates areas (in red) of highest recharge values, based on groundwater Chloride concentrations, of existing boreholes. As such the demarcation of these high recharge areas are based on the presence of existing boreholes and may actually extend further that indicated. The conceptual model of significant recharge along faults is supported by age determinations of groundwater which indicated young waters, i.e. more recent recharge (< 500 years) associated with faults, and older water (> 5000 years) associated with dykes (Duvenhage and Meyer, 1991).

Due to the variance in recharge figures obtained from the Chloride, Vegter and Harvest Potential methods and the medium confidence associated with the results, professional judgement, based on experience within the catchment, has also been used in quantifying the reserve (Table 8).

6.2 Baseflow

The Molopo river, although considered a 4th order river, is a non-perennial river. The river used to flow after heavy rainfall events, however the building of dams (Disaneng and recently the Modimola) upstream has impeded river flow. Although no official gauging station exists on the river, it is reported that before 1980 runoff only occurred every 2-3 years. Since 1980 flow in this section of the Molopo river only occurred 5 times, after severe heavy precipitation in 1988, ’91, ’96, 2000 and 2001. The baseflow index for the study area is given as negligible (WRC, 1995b). As such, there is no groundwater component to surface flow in this area. Instead the Molopo river acts as a ‘water loss’ river, recharging groundwater during runoff events.

6.3 Groundwater Quality

Groundwater quality data from the DWAF NGDB, for 316 samples is available for the study area. A summary of groundwater quality per Resource Unit is given in Table 4.

Table 4 Groundwater quality for Resource Units 1-3.

Chemical Parameter		Resource Unit			(SABS 241:1999)		
		RU 1	RU 2	RU 3	Class 0	Class I	Class II
pH		7.3 - 7.8 - 8.3	7.3 - 7.7 - 8.4	7.2 - 7.7 - 8.4	6 – 9	5 – 9.5	4 - 10
Electrical Conductivity	mS/m	47 - 81 - 182	75 - 115 - 304	57 - 86 - 199	< 70	70 - 150	150 - 370
Calcium as Ca	mg/l	10 - 66 - 112	28 - 76 - 191	23 - 72 - 165	< 80	80-150	150-300
Magnesium as Mg	mg/l	28 - 57 - 87	37 - 71 - 179	26 - 55 - 131	< 30	30-70	70-100
Sodium as Na	mg/l	11 - 34 - 105	27 - 73 - 332	8 - 30 - 120	< 100	100-200	200-400
Total Alkalinity	mg/l	128 - 310 - 439	140 - 299 - 452	142 - 284 - 430	-	-	-
Chloride as Cl	mg/l	19 - 62 - 348	40 - 163 - 714	17 - 58 - 314	< 100	100-200	200-600
Sulphate as SO_4	mg/l	4 - 11 - 61	7 - 38 - 199	4 - 53 - 151	< 200	200-400	400-600
Nitrate as NO_x	mg/l	0.1 - 3.5 - 29	0.2 - 12 - 75	0.1 - 2.3 - 116			

* Values given as the 5th – median – 95th percentiles

It is evident from this summary that the groundwater of RU1 and RU3 are very similar in quality, generally low in total dissolved solids, while RU2 has an elevated salt content for all major cations and anions. More saline, higher TDS, groundwaters are therefore associated with the east-west dolerite dykes, as one would expect from the difference in ages of the groundwater (Section 6.1). The groundwater type varies considerably throughout the area from a Ca,Mg-HCO_3 type water to a Mg, Na-Cl type. The dominant cations are however Mg and Ca and dominant anions, HCO_3 and Cl. All groundwater quality samples have been plotted on the Piper Diagram (Figure 6), and show the spatial variation in groundwater quality within the study area, from low TDS waters typical of recharge areas, to high TDS groundwater.

Elevated concentrations of F and NO_3, often associated with pollution, are present in RU2 and RU3. The origin of the F could be from weathering of the dolerite intrusions or from the proximity to the granites. The elevated NO_3 in these units with there shallow water levels may be the result of local pollution from human and animal excreta and fertilizer application.

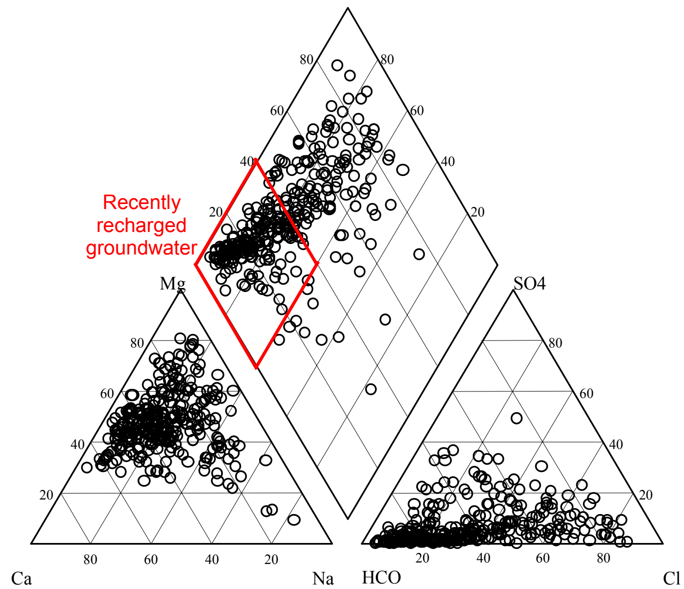

Figure 6 Piper diagram of groundwater quality of the Pomfret - Vergelegen dolomitic aquifer.

7 REFERENCE CONDITIONS

7.1 Resource Units 1 and 2

RU1 and RU2 represent the Tosca – Vergelegen dolomitic aquifer, and the area of dolomite to the south which has been intruded by post-Karoo dolerite. For the purpose of reporting, RU1 and RU2 are combined in this section.

7.1.1 Groundwater levels

Regional water level records for 2 periods (1977 and 1990) were available to assess the reference conditions of the groundwater resource within the eastern part of the Pomfret - Vergelegen dolomitic aquifer (RU1 and RU2). During the 2 years prior to the 1974 hydrocensus, investigations in the area provided a data set of water levels (mamsl) (Figure 7(a)).

During 1990 a similar hydrocensus was conducted where 351 boreholes were located (Duvenhage & Meyer, 1991). Water level measurements were possible at 198 boreholes. The water levels in the northwest vary between 5 to 10m below surface, gradually deepening to 50 and 60 m to the north-east at the Molopo river (Figure 7(b)).

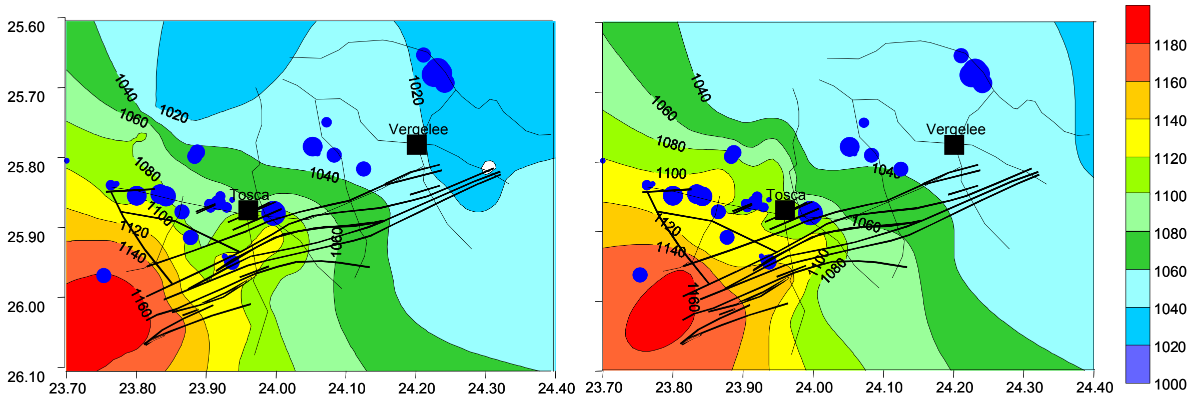

Figure 7 Groundwater level elevation contours (mamsl) (1977 (a) left and 1990 (b) right).

To assess how representative the water levels for 1977 and 1990 are as reference conditions, the precipitation for those years was compared with the average. It is evident that the pre-1974 water levels were measured in a period of average to below average rainfall (Figure 2) while the 1990 water levels were measured following high rainfalls in 1988.

Only minor changes in groundwater levels are evident between 1977 and 1990. The most striking being elevated water levels along the Molopo river and elevated water levels along the dyke swarms parallel to the Quarreefontein dyke. As such the groundwater levels in 1990 are still considered to be unimpacted, reference conditions. From both maps (Figure 7) the northeast gradient of groundwater levels towards the Molopo river is evident with the dyke swarms possibly impeding groundwater flow from the south and southwest.

7.2 Resource Unit 3

Resource Unit 3 represents the Pomfret dolomitic aquifer and overlying banded ironstone formation. Groundwater is encountered within the banded ironstones, the dolomite/shale contact and within fractures, brecciation zones and solution cavities within the dolomites.

7.2.1 Groundwater levels

The dolomitic aquifer in the region of Pomfret is characterized by at least 13 compartments, bounded by dolerite dykes (van Dyk, 1993). Very little information on the reference conditions of water levels within these compartments is available. Different piezometric water levels are encountered in the three different aquifers in this RU. Water levels in the banded ironstone aquifer vary between 30-60m, water levels in the dolomite/shale transition zone vary between 40-70m while the water levels in the dolomitic aquifer vary between 10-30m below surface.

As in the Tosca - Vergelegen aquifer, the gradient of groundwater levels are towards the Molopo river, however the abstraction of groundwater from compartments 3 and 5 has resulted in a groundwater sink to the east of Pomfret.

7.3 Resource Unit 4

Resource Unit 4 represents the shallow, Kalahari aquifer, which overlies the Pomfret - Vergelegen dolomitic aquifer. The thickness of the Kalahari Group varies from less than 5 m in the southwest of the study area to as much as 150 m in the northeast, adjacent to the Molopo river, as indicated in Figure 4. From the regional decline in the water level, abstraction from the underlying dolomites have resulted in water levels declining 10 to 20 m. Boreholes which penetrate the Budin formation into the underlying, often high yielding, Wessels gravels are impacted upon by changes in water levels in the underlying dolomitic aquifer.

7.3.1 Groundwater levels

The groundwater level in proximity to the Molopo river is approximately 50 mbgl. Away from the river water levels increase to between 70-90 mbgl. Since extensive abstraction commenced, the water levels in the shallow Kalahari boreholes, away from the river, decreased by between 10 and 20 meters.

8 PRESENT STATUS

8.1 Resource Units 1 and 2

An assessment of the current status of groundwater use and quality within the Pomfret - Vergelegen dolomitic aquifer was made with information gathered during the bi-annual observations by DWAF.

8.1.1 Groundwater usage

During the 1990 hydrocensus groundwater use was limited to human consumption and stock watering. There was no industrial use and only limited irrigation use on the farms Thornwick (close to Tosca) and Blackheath (on the Molopo river). The total irrigation of groundwater was less than 100 ha or equivalent to 0.77 Mm^3 per annum. The total stock consumption in the 220,000 ha was calculated as 60 l/d/stock unit at 12 ha per unit to be 0.5 Mm^3 per annum. Total human consumption was estimated at 0.5 Mm^3 per annum. The total water used in the area was therefore less than 1.8 Mm^3 per annum.

Since 1990 more high yielding boreholes were drilled and the irrigation potential was realized. There was a steady increase in irrigation and a survey in 1994 reported 22 center pivot systems irrigating 600 ha with 4.6 Mm^3/a of groundwater. In April 2001, 32 systems were irrigating 1182 ha with 9.1 Mm^3/annum. By January 2002, 40 systems were irrigating 1495 ha with 11.1 Mm^3 of water (Table 5). The human and stock demand is assumed constant. Calculations of groundwater usage made by the local irrigation farmers indicated that significantly more groundwater, 16-18 Mm^3 per annum, was being abstracted.

Table 5 Groundwater usage within the Tosca dolomitic aquifer.

Year	1990	1996	2001	2002
Irrigation systems	2	22	32	40
Irrigation area (ha)	100	600	1182	1495
Irrigation (Mm^3) *	0.77	4.6	9.1	11.1
Stock watering (Mm^3)	0.5	0.5	0.5	0.5
Human consumption (Mm^3)	0.5	0.5	0.5	0.5
Total (Mm^3)	1.8	5.6	10.1	12.1

* Assuming 7,700 m^3/ha

The above abstraction has lead to an alarming decline in the water levels in the area (Figure 8 and 9). Since April 2001 a regional water level monitoring network has been established, initially with bi-annual measurements. Currently 95 water levels are measured at quarterly intervals distributed over the area.

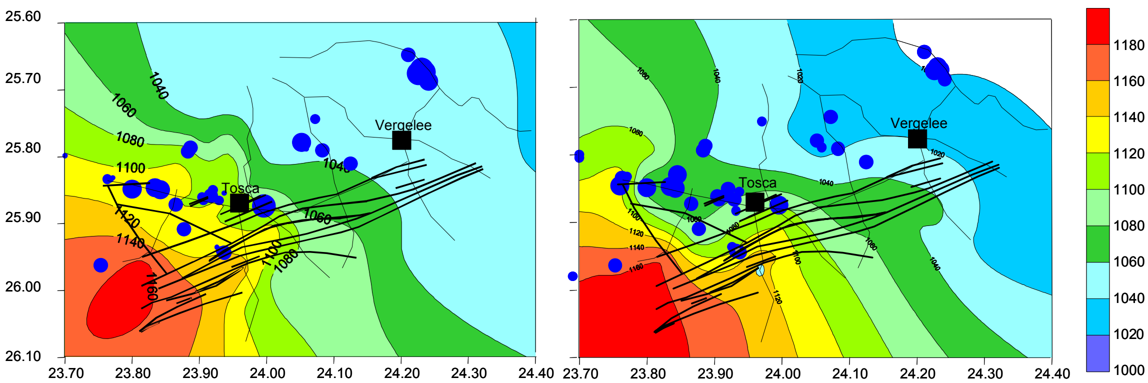

Figure 8 Groundwater level elevation contours (mamsl) (1990 and 2002).

The relative water level decline from 1990 to January 2002 is indicated in Figure 9. From this map it is evident that water levels have declined by up to 60m over the southwestern part of the Tosca dolomitic aquifer, and the southeastern part of the Pomfret dolomitic aquifer. This coincides with areas of intense pivot irrigation (blue circles, Figure 9).

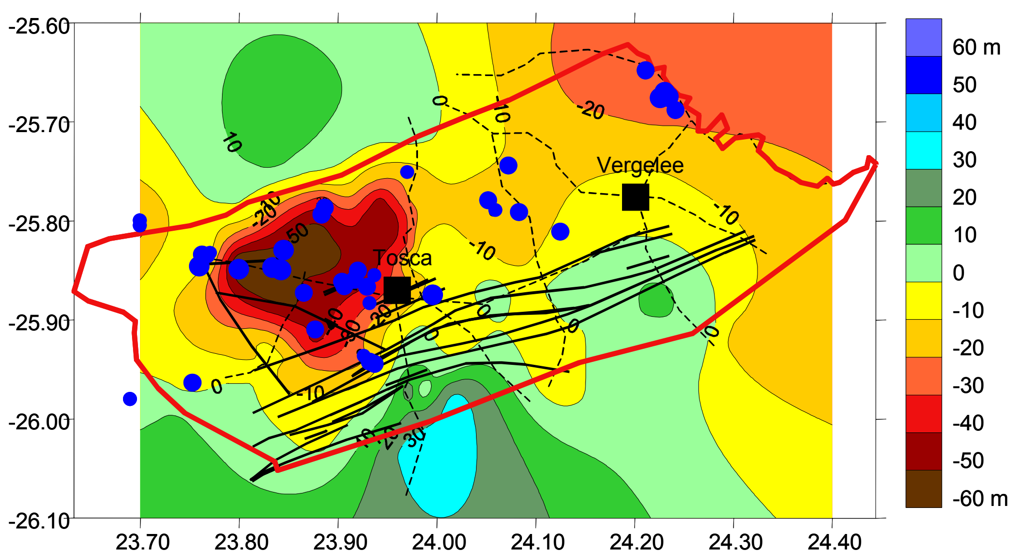

Figure 9 Variation in water levels between 1990 and 2002.

It is therefore evident from the above figures, that at some time between 1990 and present, the sustainable yield of the aquifer has been exceeded, resulting in the rapid decline in groundwater levels.

8.1.2 Groundwater contamination

Groundwater contamination of the dolomitic aquifer includes, elevated nitrate concentrations from fertilizer application and domestic sewage.

8.1.3 Potential or expected groundwater contamination

The potential or expected groundwater contamination is dependant upon the expected landuse impact and the vulnerability of the groundwater to contamination.

The vulnerability of groundwater to contamination in the dolomites varies from moderate to high. The dolomites of the Campbell Group are shown to be most vulnerable to pollution. However, the confined nature of the dolomitic aquifer limits the areas of potential contamination to those where the dolomite outcrops and the recharge areas along faults and dykes. Due to the importance of the dolomitic aquifer as a water supply source, this aquifer, and landuse activities on the dolomites, must be managed effectively to ensure that groundwater contamination does not occur.

8.1.4 Environmental impacts

The main environmental impact within RU1 is the current over utilization of the groundwater resulting in the decline of water levels and the potential dewatering of the compartment. Groundwater use within this compartment is not sustainable at the current pumping rates.

8.2 Resource Unit 3

8.2.1 Groundwater usage

Groundwater is the sole source of water in the Pomfret area for both domestic and agricultural purposes. As with the Tosca aquifer, the Pomfret aquifer is currently under considerable strain in supplying the required volumes of water for domestic and agricultural use. Groundwater abstraction from compartments 1-5 in the early 1990’s resulted in the complete dewatering of compartment 2, and a 56 m drawdown in water levels in compartment 5.

An estimation of water requirements, as indicated by van Dyk (DWAF, 1993), from groundwater for domestic purposes at that time was 3000 m^3/d. However, the as then, current demands on groundwater of 2000 m^3/d were already impacting significantly on groundwater levels. According to van Dyk (1993), the groundwater abstraction in 1993 in compartment 5 exceeded recharge by 270% and in compartment 6 by 200%. In compartments 8, 10, 11, 12, abstraction was less than recharge. In fact of the 7 compartments from which groundwater was abstracted in 1993, 5 compartments were abstracting more than 100% of recharge.

Calculations during 1997 indicated that 0.7 Mm^3 per annum is available from the Pomfret compartments. Water use at Pomfret has since declined due to the SADF withdrawing from the base resulting in actual abstraction being in line with this calculation. As a result water levels in the compartments have stabilized (pers comm., DWAF regional office).

The southern part of RU3, where the dolomites outcrop, is currently under utilized. This area lay within the old homeland of Bophuthatswana. As such, limited farming and drilling of boreholes has happened in this area. Compartmentalization of the dolomites could also however, impede abstraction of groundwater in this area when developed.

8.2.2 Groundwater contamination

Groundwater contamination of the dolomitic aquifer includes, elevated nitrate concentrations from fertilizer application and domestic sewage.

8.2.3 Potential or expected groundwater contamination

Due to the high vulnerability of the dolomitic aquifer, the potential for contamination is high. However, the confined nature of the dolomitic aquifer limits the areas of potential contamination to those where the dolomite outcrops and the recharge areas along faults and dykes.

8.2.4 Environmental impacts

The main environmental impact within RU3 is the current over utilization of the groundwater resulting in dewatering of compartments and the substantial decline in water levels. Groundwater use within certain identified compartments is not sustainable at the current pumping rates.

8.3 Resource Unit 4

8.3.1 Groundwater usage

Due to the low borehole yields within the Kalahari Group aquifer, groundwater use is limited to stock watering and domestic purposes. Based on a figure of 60 ℓ per stock unit per day, the estimated use of groundwater for stock watering from the Kalahari aquifer is 182,500 m^3/a. This could not be verified through actual monitoring of groundwater use.

8.3.2 Groundwater contamination

Elevated concentrations of nitrates and microbial contamination are encountered within RU4, resulting from the infiltration of contaminated water from feedlots, sewage systems such as French drains and soakaways, and fertilizer application.

8.3.3 Potential or expected groundwater contamination

The unconfined nature of the Kalahari Group aquifer results in a high potential for groundwater contamination.

8.3.4 Environmental impacts

Due to the limited aquifer potential of the Kalahari sands, the main environmental impacts are associated with overpumping of these shallow boreholes and as a result, the drop in water level below the borehole depth and/or the collapse of the borehole. The hydraulic connection between the underlying dolomitic aquifer and the Kalahari aquifer has resulted in a regional decline in groundwater levels within the Kalahari aquifer, due to over abstraction from the dolomites.

8.4 Summary

A summary of the Present Status Category for groundwater usage, contamination, potential for contamination and environmental impacts, is given in Table 6.

Table 6 Present Status Category for Resource Units 1-3.

Resource Unit	Groundwater (Present Status Category)			
	Usage	Contamination	Potential contamination *	Environmental Impacts
RU 1	C-F	B	B	C-F
RU 2	B	B	B	B
RU 3	B-F	B	B	B-F
RU 4	B	C	C	B-C

* Potential contamination category may increase with decreasing Kalahari thickness, due to high vulnerability of the dolomites.

9 RESERVE DETERMINATION

9.1 Management Class

Based on the present status category, the management class for the study area is set as a Class b, with the exception of areas of significant water level drawdown for which a management Class c is set. The present status category and the associated desired management class for each of the Resource Units within the Pomfret - Vergelegen dolomitic aquifer are given in Table 7.

Table 7 Present Status Category and Desired Management Class

Resource Unit	Present Status Category	Desired Management Class
RU 1	F	c
RU 2	B	b
RU 3	F	c
RU 4	C	b

9.2 Ecological Reserve

Since no groundwater contributes to surface water flow, through baseflow, there is no ecological reserve component defined for groundwater, only a groundwater quality component of the Reserve. The setting of only a groundwater quality reserve, does not however alleviate the current problems encountered regarding the over abstraction of groundwater and the long-term viability and protection of the groundwater resource. As such the groundwater resource has been quantified in this investigation, to ensure that groundwater abstractions do not exceed the recharge to the aquifer, and as such the sustainable yield of the dolomitic aquifer.

The quantity of groundwater available for use within each resource unit is assessed in Table 8. Recharge estimates have been used to calculate the total groundwater component available. According to the RDM Methodology (DWAF, 1999), after removing the annual low maintenance baseflow and the basic human needs requirements, the remaining water is available for allocation through abstraction. Since no baseflow requirements are set (no baseflow component), the critical component of the Reserve is the Basic Human Need Reserve. A conservative approach has been adopted in the calculation of recharge figures, due to limited data availability.

Three different methods, with varying levels of confidence, were used to calculate the quantity of groundwater recharging each of the Resource Units, and the resultant allocatable quantity of groundwater. These include:

- Method 1: Mean recharge figure applied to RU area
- Method 2: Varying recharge figures per estimated recharge areas

A range of available groundwater for the Pomfret - Vergelegen dolomitic aquifer is given as between 13.87 – 19.57 Mm^3/a. Due to the higher level of confidence, the volume of 19.57 Mm^3/a has been used in Table 8.

The calculation of the available groundwater resource within the Tosca - Vergelegen dolomitic aquifer (RU1) at 6.90 Mm^3/a indicates that currently the aquifer is being overpumped by 5.2 Mm^3/a (Table 5).

9.3 Basic Human Need Reserve

Population figures for each of the Resource Units were obtained from the regional office of the Department of Water Affairs and Forestry. The population of the study area is estimated at 14,500 people, split between the RUs as 4000 (RU1), 500 (RU2) and 10,000 (RU3). Based on a requirement of 25 litres per person per day (White Paper, 1994), the basic human need requirements are calculated as 0.133 Mm^3/a.

A more realistic figure of 200 litres per person has typically been applied in previous investigations by DWAF (van Dyk, 1993), since no alternate supply of water (i.e. surface water) is available for domestic purposes, however these required volumes can not be applied is setting the BHN Reserve.

9.4 Groundwater Quality Reserve

The groundwater quality reserve is set for Basic Human Needs, for a Class I Drinking Water (WRC, 1998). A Class I for drinking water ensures a ‘suitable quality for lifetime use’. A Class 0 can not be applied, as typically used in Reserve Determinations, due to the naturally elevated salt content of the groundwater in this region.

10 RESOURCE QUALITY OBJECTIVES

The following Resource Quality Objectives (RQOs) or management actions for the Pomfret - Vergelegen aquifer are suggested.

- Water levels should not be allowed to further decline over the long-term within the Pomfret - Vergelegen aquifer. This must be managed by reducing abstraction from the aquifer, thereby allowing recovery of water levels.
- Unless boreholes of existing lawful users have collapsed or been destroyed, no new production boreholes should be drilled within areas of recharge, i.e. within faults zones and alluvial channels.
- No further boreholes should be allowed in currently overutilized dolomitic compartments, as this will lead to dewatering of the compartments in the short to medium term.
- Production boreholes should not be pumped at more than 60% of their tested sustainable yield, and should not be pumped continuously for more than 12 hours per day.
- Production boreholes should be spaced such, or pumped at a rate, that minimal interference between water level drawdown cones, occurs. The ‘safe’ distance between boreholes will vary depending on the aquifer dynamics, however, from available data, a preliminary estimate of 500 m between boreholes is suggested.

11 CONCLUSIONS

It can be concluded from available data, that both the Tosca - Vergelegen and Pomfret dolomitic aquifers are currently over utilized, with abstraction volumes exceeding recharge figures, resulting in the decline in groundwater levels, in particular in the areas of highest recharge, since these boreholes are the highest yielding boreholes. Unfortunately the areas of highest abstraction coincide with recharge areas, since high yielding boreholes are associated with geological features such as faulting and brecciation.

The four main areas of recharge to the Pomfret - Vergelegen dolomitic aquifer include:

- Recharge through geological lineaments (faults).
- Recharge through shallow outcrop and suboutcrop of dolomite.
- Recharge through banded ironstone formation.
- Recharge through the alluvial channels of the Molopo river and tributaries.

The main aquifers within the study area include:

- Brecciation along fault zones.
- Fracture zones associated with the intrusion of post-Karoo dolerite dykes and sills
- Transition zone between the dolomite and shale bands and the banded ironstone.

Since no groundwater quantity component of the ecological Reserve exists, only a groundwater quantity and quality component of the Basic Human Need Reserve is set. The groundwater quality is set as a Class 1 for drinking water. The groundwater quantity available for allocation has been calculated. It is estimated that 19.57 Mm^3/a recharges the Pomfret - Vergelegen dolomitic aquifer, of which 0.133 Mm^3/a must be maintained for BHN requirements. Due to the compartmentalization of the dolomitic aquifer, caution must be practiced in allocating this water for use, since each compartment has a limited quantity of groundwater available, depending on the size of the compartment. This is particularly the case in the Pomfret dolomitic aquifer.

Within the study area, RU1 (ii) and RU3 (i) are considered overutilized. RU3 (ii) is believed to be currently underutilized, since this area, due to it's inclusion in the previous homeland of Bophuthatswana, has not been developed for irrigation. Caution must however be taken in developing the groundwater in this area, as it represents one of the main recharge areas for the Pomfret - Vergelegen dolomitic aquifer.

12 RECOMMENDATIONS

The Pomfret - Vergelegen dolomitic aquifer is an important aquifer for both domestic and agricultural purposes, however the proper management of this aquifer is essential to ensure it's long-term sustainability. Factors which restrict the use of groundwater from this aquifer include low rainfall and high evaporation, resulting in low recharge figures for the area; the depth to groundwater; and the high potential vulnerability to pollution. From the Reserve Determination for the Pomfret - Vergelegen dolomitic aquifer, the following recommendations for groundwater management are made:

- The current over utilization of the aquifer must be immediately controlled and cut back, so as to ensure the long-term sustainability of the aquifer. This may be done by:
    - Discontinuing all unlawful groundwater uses in the area (post 1998);
    - Reducing the current volumes of groundwater abstracted by both lawful and unlawful groundwater users through a controlled cutback; and/or
    - Discontinuing all unlawful groundwater uses as well as reducing volumes abstracted by lawful water users.
- The actual volumes of groundwater abstracted from the aquifer for use, on a monthly basis must be quantified. This may involve the installation of flow metres on all abstraction boreholes.
- Continuous water level monitoring within the dolomitic aquifer is essential, to assess the response of the aquifer to the reduction of pumping. There are currently two boreholes installed, equipped with continuous water level loggers (since Oct/Nov 2001).
- Due to the conservative approach adopted in estimating the available groundwater, recharge values must be refined to improve upon the level of confidence for future evaluations. A rainfall collector is apparently in place to obtain more accurate Cl values for rainfall, the results of which should be available in November 2002.
- A quantitative 2D model for the Pomfret - Vergelegen aquifer must be created, to use as a decision support tool, to manage the aquifer, and assess the response of the aquifer to the reduced abstraction volumes.
- Continuation of the groundwater quality monitoring programme for the Pomfret - Vergelegen dolomitic aquifer at strategic boreholes within the area.

After implementing these recommendation, the Reserve should be re-evaluated after 5 years (2007), to assess the degree of recovery of the system and the potential for further licencing of groundwater use (if any).

It must be noted that if these RQOs and recommendations are not implemented within the Pomfret - Vergelegen dolomitic aquifer, the further unsustainable use of groundwater will result in the possible permanent, dewatering of the aquifer in the short to medium term.

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Table 8 Determination of the groundwater component of the Reserve.

BOUNDARIES AND TYPING			RECHARGE					Groundwater component of baseflow (Mm^3/a)	RESERVE			Allocatable (Mm^3/a)	CONFIDENCE
Resource Unit		Aquifer Type	Total Area (km^2)	% Recharge	MAP (mm/a)	Recharge (Mm^3/a)	Total Recharge (Mm^3/a)		Baseflow Required by IFR (Mm^3/a)	BHN Reserve (Mm^3/a)	Reserve as % of Recharge		
1	(i)	BIF/Dolomite	138	1.58	399	0.87	6.90	0	0	0.037	0.54	6.86	Medium
	(ii)	Dolomite	863	1.75		6.02							
2	-	Dolomite	624	0.69	399	1.72	1.72	0	0	0.005	0.29	1.72	Medium
3	(i)	BIF/Dolomite	254	2.08	371	1.96	10.95	0	0	0.091	0.83	10.86	Medium
	(ii)	Dolomite	1478	1.64		8.99							
TOTAL							*19.57*	*0*	*0*	*0.133*	*0.68*	*19.44*	*Medium*

Recharge: Water reaching the aquifer direct from precipitation and the infiltration of surface water.

Baseflow: Baseflow is that part of stream flow that comes from groundwater and shallow subsurface storage. During the dry season, the stream flow is composed entirely of baseflow. The specific component addressed by groundwater is the maintenance low flow in the dry season.

Groundwater component of the baseflow: This is the component of baseflow that comes from the aquifer adjacent to a surface water body and excludes interflow in the vadose zone or short-term storm events which saturates the subsurface soil and discharges to a surface water body before reaching the aquifer.

The Reserve: is the sum of the groundwater component of the base flow plus the BHN reserve expressed as a percentage of the Recharge.

IFR Requirement: The IFR requirement is based on the set class for the surface water IFR site, the set maintenance flows and the consequent low maintenance baseflows.

BHN: Basic Human Need, based on 1996 Population Census figures, with a 2.5% per annum growth rate, and 25 litres per person per day.

Note: The allocatable volume of groundwater for RU3 is divided between a number of compartments (at least 13). As such the available groundwater within each compartment should be used in license applications, rather than the total RU volume. Estimates of the allocatable groundwater per dolomitic compartment have been calculated in previous studies by the DWAF Regional Office.

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