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GROUNDWATER RESOURCES OF THE T60 DRAINAGE REGION

(T&P Report No. 990200 – Draft Ver. 2)

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TABLE OF CONTENTS

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS

PAGE

1.0 INTRODUCTION

The introduction of the RDP water supply programme has resulted in the identification of the need in many instances for substantial augmentation of domestic water supply schemes serving large rural populations in the Eastern Cape Region. Water resources with adequate yield assurances are required for upgrading of the water supplies in the T60 tertiary drainage region.

The general level of knowledge regarding the water resources of the T60 catchment is limited. The aim of this study is to provide planners with an information base from which strategies for the sustainable and efficient utilisation of the water resources can be formulated, as well as for establishing water management areas and a catchment development strategy plan, as stipulated by the new Water Act.

The scope of this study is to provide a broad evaluation of the current status and potential for development of the water resources of the T60 catchment, as well as the existing and future water requirements of all user sectors.

Toens and Partners were appointed by the Department of Water Affairs and Forestry to conduct the groundwater component of the 'Eastern Pondoland' or T60 Drainage Basin Study, under the supervision of the Lead Consultants, Uhlmann, Witthaus and Prins (UWP) Consulting Engineers.

2.0 TERMS OF REFERENCE (TOR)

Toens and Partners were instructed by UWP to commence the groundwater study on the 8th March 1999 (Telefax No. 19278BS 1/9-UF-98), in accordance with our project proposal dated the 25th January 1999 (**Appendix 1**).

The purchase of the Landsat imagery and remote sensing for the groundwater study was approved on the 10/04/1999. Toens and Partners were also requested to conduct a satellite remote sensing study aimed at mapping the extent of soil erosion in the study area.

3.0 DEFINITION OF THE STUDY AREA

The study area encompasses the T60 Tertiary Drainage Region (**Figure 1**), which is located in the most north-eastern, coastal portion of the Wild Coast District of the Eastern Cape Province (formerly part of the Transkei). This area is also known as the Pondoland coast.

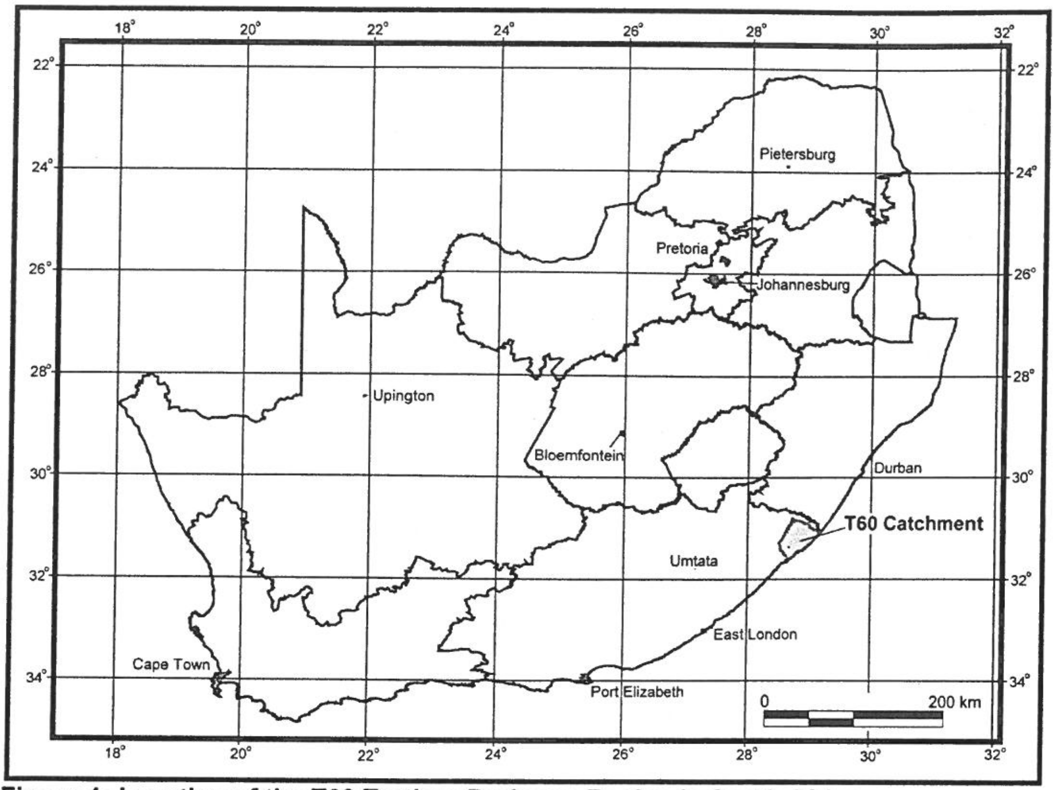

Figure 1: Location of the T60 Tertiary Drainage Region in South Africa

4.0 PHYSICAL CHARACTERISTICS

4.1 PHYSIOGRAPHY

The physiography of the T60 catchment is variable and is strongly controlled by the underlying geological formations with different resistance to weathering and erosion. The ground elevation rises in a series of 'steps' from the coastline to a maximum of 1245 m.amsl in the north-western portion of the study area (**Figure 2**). The digital elevation model (DEM) shows two major physiographic regions, namely:

4.1.1 Coastal Plateau

The coastal belt is generally 10-20km wide and comprises a relatively flat, gentle seaward-sloping peneplain, lying between 0 and 400 m.amsl. The drainage channels are often linear and tend to follow the dominant fracture systems, especially the NW trend (i.e. **Figure 2** – the Mtentu River). This region is underlain by sandstone of the Msikaba Formation. Where rivers cut across the Msikaba sandstones, major steep sided gorges have been formed. The shape of the coastline is controlled by geological structures. The coastal zone between the Mkozi River and Port St. Johns is low-lying, commonly less 200 m.amsl, and

6.0 PREVIOUS GEOHYDOGEOLOGICAL INVESTIGATIONS

A number of geohydrological investigations have been conducted that fall within or cover a portion of the T60 drainage region. Consultants carried out most of the work on behalf of the Government. This section outlines the nature and scope of these studies, while the pertinent geohydrological information is referenced within the relevant chapters of this report. Groundwater investigations in adjoining, hydrogeologically similar areas are also included.

The following important geohydrological reports were reviewed during this study:

- **Northern Zone – Village Water Supply Study** (SRK, 1991)

  Steffen, Robertson & Kirsten carried out a study of the groundwater resources of the so-called 'Northern Zone' for the former Department of Agriculture and Forestry (DAF) of the then Transkei. Their study area covered most of the T60 catchment, extending from Port Edward in the north to the Mtafufu River in the south (i.e. the districts of Bizana, Lusikisiki, Flagstaff, Tabankulu, Mount Ayliff, Qumbu, Mount Frere, Mount Fletcher and Matatiele). The investigation served as a pilot project to assess the feasibility of establishing small-scale water supply schemes to service villages and to assess the willingness of the communities to accept the responsibility for maintaining their schemes. Villages with severe water supply shortfalls were targeted. The project commenced in August 1989. During this study some 77 exploration boreholes were drilled. They concluded that handpump-based groundwater supply schemes presented a practical and cost effective (i.e. R10,650/scheme at 1990 prices, excluding consultant fees) method of supplying water to small rural communities. They found that many communities were in favour of taking responsibility for the operation and maintenance of their water-supply scheme, with some form of 'assistance' from Government.

- **Natal Sandstones – Hydrogeological Investigation** (SRK, 1993)

  Steffen, Robertson & Kirsten conducted an investigation on behalf of the former Department of Agriculture and Forestry to determine the groundwater potential of the sandstone of the Msikaba Formation. The project formed part of the 'Transkei National Ground Water Plan' and commenced in 1986. The investigation was completed in 1993, after a number of lengthy delays. SRK's exploration drilling in the Msikaba sandstone led them to conclude that the groundwater potential of this unit is low.

- **DWAF's Hydrogeological Characterisation and Mapping Programme for the Kwazulu-Natal Province:**

  The Directorate: Geohydrology (DWAF) subdivided the Kwazulu-Natal Province into 11 hydrogeological 'mapping-units', as part of their national groundwater characterisation and mapping programme. During 1994 to 1995, groundwater consultants were appointed to evaluate the groundwater resources within each of the mapping-units. This information is presently being used to compile the following 1:500,000 scale hydrogeological maps: Durban (2928) and Vryheid (2730), as well as portions of Nelspruit (2928) and Kroonstadt (2726).

Three of the mapping-units, namely units 4, 6 and 10, share a common boundary with the northern edge of the T60 drainage region and are thus directly relevant to this study.

Mapping-Unit 4 (Davies, Lynn & Partners, 1995)

The study area is located on the South Coast of Kwazulu-Natal between Durban and Port Edward and extends inland as far as Harding-Ixopo. They found that the rocks of the Msikaba Formation are most favourable for groundwater development, whilst the Dwyka Group and Precambrian basement rocks exhibit exceptionally poor hydrological properties. They state that the potential for groundwater development in Unit 4 is largely determined by the rate of recharge.

Mapping-Unit 10 (Groundwater Development Services, 1995a).

The investigation encompassed the area between the towns of Harding, Kokstad, Matatiele, Donnybrook and Underberg, and shares a common boundary with Unit 4 to the west. The hydrogeological assessment of the Ecca and Beaufort Group rocks, as well as the Karoo dolerite intrusives are of relevance to this study. The highest percentage of boreholes yielding more than 3 l/s were located in the Vryheid sandstones of the Ecca Group, while the dolerite intrusions yielded the highest success rate in the yield range of less than 1 l/s. GDS concluded that the groundwater resources of the area are capable of meeting the entire rural community's water needs.

Mapping-Unit 6 (Groundwater Development Services, 1995b)

The investigation covered a 4-5km wide strip of the coast extending from the Mtunzini River in the north to the Mtamvuna River in the south, near Port Edward. Particular attention was paid to the alluvial and estuarine sediments, as well as the beach and aeolian deposits – which cover almost 30% of the unit. It was found that the coastal quaternary aquifers, if properly developed, generally yield in excess of 10 l/s. GDS found that these primary, 'strip' aquifers are not currently being exploited.

- **1:500,000-scale Queenstown Hydrogeological Map** (Smart, 1998)

  The methodology and results of the Queenstown (3126) mapping programme are of direct relevance to this study. This regional geohydrological study covers almost the entire T60 drainage region, except for the Bizana area to the north of latitude 31°S.

7.0 RECONNAISSANCE HYDROCENSUS

Mr. B. Malghas of Kei Water Solutions in Umtata conducted a 6-day reconnaissance hydrocensus of specific areas of hydrogeological data deficiency, which were identified during the literature review and evaluation of the groundwater GIS database. The original objectives of the hydrocensus were to:

- Locate and collect geohydrological and construction information from borehole and springs; e.g. depth, collar height, position, usage, geology, position of borehole in relation to prominent geological structures.
- Obtain water quality and chemistry data from boreholes and springs within different lithological formations and climatic zones.
- Assess the usage and protection-status of springs/seeps.
- Evaluate the degree of groundwater usage and perceptions towards groundwater in the area.
- Verify, where possible, documented borehole information with field observations.

The inaccessibility of the terrain, the scarcity and poor operational status of boreholes in these areas yielded very limited useful results. Water samples for quality testing could not be collected from inoperative boreholes. The local inhabitants could not supply any geohydrological or construction details on their boreholes. The boreholes and springs inventoried during the study are summarized in **Table 2**, while their positions are indicated in **Figure 15**. The numerous seeps along the many deeply incised river valleys have not been indicated.

The following general observations were made during the hydrocensus:

- Most of the public boreholes are not in operation, due either to broken equipment and/or having "dried-up" or collapsed. Operational boreholes are used mainly for domestic water supply purposes.
- The waterlevel dipmeter could not be used because the equipped boreholes (i.e. handpumps and windpumps) are sealed and any open boreholes are either fitted with welded-caps or are filled with stones.
- Some areas visited did not have any boreholes because the area is extremely rugged and inaccessible to drilling-rigs, i.e. the areas to the south of Lusikisiki where people rely solely on springs and river water.
- Springs are widely used for potable drinking-water.

- The groundwater quality as indicated by the Electrical Conductivity (EC) values are relatively low (<100 mS/m), falling within the acceptable limits stipulated by DWAF.
- The majority of the people in the area do not have access to drinking water within 200m of their dwellings (as stipulated by the RDP regulations).

7.1 SPRINGS AND SEEPS

Springs are commonly located at the contact between dolerite intrusions and the host rocks, especially in the Magusheni area. In the coarse-grained quartzitic sandstone of the Msikaba Formation, water seeps from fault zones, bedding-plane joints and other zones of hydraulic discontinuity. The sustainable flow of these springs is proportional to the geographic extent of the effective catchment area, permeability of the aquifer and rates of recharge. Most of the springs in the areas visited are inaccessible since they are situated on steep hillsides and at the base of river gorges.

- Springs are common and are used for drinking water purposes. The communities of Sikombe, Kwanyana and Mtolane depend largely upon springs and resort to water from the Bizane and Mnyameni Rivers during the dry seasons only.
- Many of the 'springs' are seasonal with the exception of a few (i.e. SP1 close to Mnyameni River mouth – **Figure 15**) and people have to rely on perennial rivers like Bizane, Msikaba and Mtentu for their dry-season water supplies.
- Springs can be developed to serve small communities where both surface water reticulation and borehole drilling are not economically viable, especially in the rugged and inaccessible terrain.
- The springs are not developed to enhance their yield or protected to avoid contamination of the resource.

7.2 GROUNDWATER WATER QUALITY

- The electrical conductivity (EC) of the spring water in the areas inventoried varies between 4–20 mS/m, irrespective of lithology, which is indicative of the regular recharge and short residence time of water beneath the surface. This water is for all intents and purposes an 'attenuated' rainwater. Spring water emanating nearer to the coast has a higher EC, in the range of 30–37 mS/m. This is probably due to the influence of wind-borne salts and the NaCl content of the rainwater, which decreases with distance inland.
- The water quality deteriorates during the dry season due to lower recharge and animal fecal contamination.

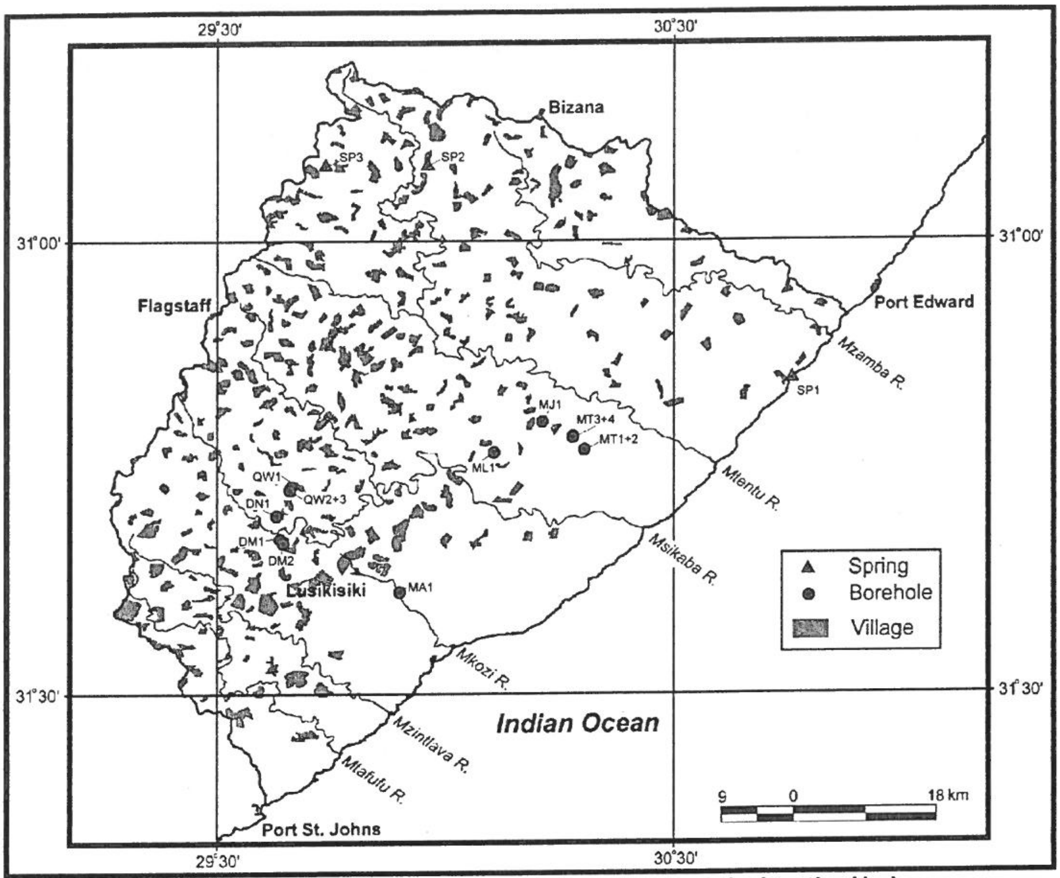

Figure 15: Location of Boreholes and Springs inventoried during the Hydrocensus

TABLE 2: Summary of Boreholes and Springs Inventoried

Map Ref No.	Village	Bore Number	Borehole Status	Depth (m)	EC (mS/m)	Equipment	Water Usage
3129BC	Lusikisiki-Dumisa, Gunyeni and Qawukeni - Great Places.	DM1	WP broken	no access	-	Windpump	Domestic
		DM2	WP broken	no access	-	Windpump	-
		DN1	WP broken	no access	-	Windpump	-
		QW2		no access	-		-
		QW1	WP broken	100	-	Windpump	Domestic
		QW3		no access	-	-	-
		MA1	WP broken	no access	-	Windpump	Domestic
3129BB	Kanyayo	MJ1	sealed	no access	-	-	-
		MT4	Dry	no access	-	-	-
		MT3	-	no access	19	handpump	Domestic
		MT2	-	no access	-	handpump	Domestic
		MT1	-	no access	16	handpump	Domestic
		ML1	-	no access	15	handpump	Domestic
3029DC	Magusheni, KuGwabeni	Sp3	-	-	-	-	Domestic
		Sp2	-	-	-	-	Domestic
3130AA & AB	Xolobeni, Sikombe, Kwanyana & Mtolane	Sp1	-	-	-	-	Domestic

greatest. This local 'thickening' of the shallow, phreatic aquifer beneath major drainage channels often equates to zone of enhanced transmissivity (i.e. permeability x saturated thickness).

- Many river courses are controlled by geological structures (**Chapter 5.6**), where faults, fracture zones and dykes are more easily eroded.
- Enhancement of near-surface fractures in steep-sided river valleys due to differential overburden stresses created by terrain effects.

8.1.5 Contact between Lithostratigraphic Units

Yield analysis of boreholes drilled within 500m of the contact between the Msikaba-Dwyka and Dwyka-Ecca rocks would, tentatively, indicate that they represent favourable groundwater drilling targets. Toens and Partners (1997) tested the Dwyka-Ecca contact in an area to the south of Peddie and obtained borehole yields in the excess of 5 l/s.

Table 8: Yield Statistics of Boreholes drilled into a Litho-stratigraphic contact.

Lithostratigraphic Contact	Borehole Yield (l/s) Statistics			
	Number	Median	Mean	Standard Deviation
Dwyka-Ecca Group	8	1.95	3.05	2.85
Dwyka-Msikaba Fm	5	0.75	2.60	2.74
(boreholes within 500m of mapped lithological contact)				

SRK (1993) tested the water-yielding potential of the Dwyka-Misikaba lithostratigraphic contact at two localities, and obtained borehole yields of 5.6 and 6.8 l/s in this zone. SRK concluded that their test drilling of the Dwyka-Msikaba contact was not able to fully quantify its true potential due to their inability to drill deep boreholes to penetrate the Msikaba sandstones beneath the Dwyka rocks.

8.2 GROUNDWATER EXPLORATION DRILLING TARGETS

The groundwater drilling targets commonly associated with higher yielding boreholes within each of the lithostratigraphic units are summarised in **Table 9**.

Sophisticated exploration techniques are not commonly used in many groundwater community water supply investigations due to budgetary constraints, which contributes to the all too often poor drilling results obtained.

The scarce but valuable geohydrological information being gathered during these ad-hoc investigations needs to be collated and scientifically interpreted to provide a clearer indication of favourable drilling targets in the eastern Karoo Basin. This research will lead to a better conceptualisation of groundwater occurrence and thereby improve the exploration drilling success rates and average borehole yields. Specific research aimed at assessing the water-bearing capacity of the Dwyka–Ecca and Msikaba-Dwyka contacts, drilling of deeper boreholes to intercept regional fracture systems or the Msikaba sandstones underlying the Dwyka diamictite, and the assessment of new geophysical and remote-sensing techniques are required.

Table 9: Groundwater Drilling-Targets within each Lithostratigraphic Unit.

LITHOLOGICAL UNIT	AQUIFER DESCRIPTION	DRILLING TARGETS
Pre-Cambrian Basement Gneiss and Granite	Secondary, fractured and intergranular.	Faults, Fracture-zones, Weathered 'basins'.
Msikaba Formation (Natal Group)	Secondary, fractured.	Faults, Dolerite dykes, Fracture-zones, Msikaba-Dwyka contact.
Dwyka Group	Secondary, fractured.	Fracture-zones, Dolerite dykes, Dwyka-Ecca contact.
Ecca Group	Secondary, fractured.	Dolerite dykes-sills, Lithological contacts, Fracture-zones, Faults Dwyka-Ecca Contact.
Beaufort Group	Secondary, fractured.	Dolerite dykes-sills, Lithological contacts, Fracture-zones, Faults.
Karoo Dolerite Intrusions	Secondary, fractured, minor intergranular.	Weathered/jointed zones, Fissured dolerite, Fractured/brecciated contacts.
Cretaceous Semi-Consolidated and Quaternary Unconsolidated Deposits	Primary, intergranular.	Medium to coarse grained sand and gravel-rich zones. Composite alluvial – weathered bedrock aquifer.

Unfortunately, the Karoo rocks of the Eastern Cape have acquired the stigma of being 'low-yielding'. Borehole yields in the Central and Western Karoo Basin are thought to be 'somewhat higher-yielding', but the analysis of private drilling results (i.e. boreholes sited mainly by dowsers, drilled to shallow depths within a limited drilling budget) conducted by farmers in these areas do not vindicate this statement. Woodford and Chevallier (1999) examined the yields of some 2500 private boreholes drilled into the Beaufort rocks within an 11,600 km^2 area between Loxton and Victoria West. A mean and median borehole yield of 2.4 l/s (standard deviation of 4.3) and 1.3 l/s, respectively, was obtained. This is similar to the results presented for the Beaufort rocks in **Table 4**. Woodford and Chevallier scientifically sited 39 boreholes on regional lineaments in the same area, with a mean and median yield of 6.3 l/s (standard deviation of 8.8) and 2.3 l/s. Note that these statistics also include observation boreholes that are not necessarily sited with the aim of maximising yield.

In the Western Karoo Basin, the groundwater abstraction schemes supplying the larger towns, such as Beaufort West, De Aar, Middelburg and Graaff-Reinet, are only 'successful' because of the thousands of scientifically sited exploration boreholes drilled at significant cost by the Department of Water Affairs and

Forestry. During these geohydrological investigations it was accepted that a certain number of exploration boreholes had to drilled in order to obtain a single high-yielding production borehole (i.e. > 3 l/s), required for the establishment of large-scale abstraction wellfields. The results of the exploration and drilling techniques employed were continually evaluated and refined, which in turn led to improved borehole success rates. No such effort has been launched in the Eastern Cape, except for the Queenstown area.

The present approach to rural community groundwater supply needs to re-assessed, if the groundwater resources of the Eastern Karoo Basin are to be utilised to their full potential. For instance, where individual boreholes are drilled in geohydrologically unfavourable sites (i.e. on summit hills) for ease of access by foot and equipped with either handpumps or windpumps. Groundwater supply projects are often planned, financed and executed with the forgone conclusion that the borehole yields will be low. High-yielding groundwater abstraction schemes should be investigated where feasible, either as a sole-source supply or as part of a surface-water reticulation scheme. The cost-benefits of developing such groundwater schemes needs, as was conducted in the Western Karoo, to carefully assessed in relation to water-demand and alternative sources of water.

8.3 BOREHOLE YIELD STATISTICS PER HYDROTECTONIC DOMAIN

The T60 drainage region was subdivided into 12 hydrotectonic domains (**Figure 18**) based upon the nature and occurrence of the following:

- Lithology
- Dolerite Sills
- Geometry and density of geological lineaments.
- Climate (MAP) and physiography (i.e. river density, geomorphology).

The main characteristics of each hydrotectonic domain are summarised in **Table 10**, while the results of the borehole yield analysis within each domain are contained in **Table 11**.

No borehole information is available for domains 5 and 12. Domains 1, 6 and 9 show relatively higher borehole yields, again showing the dominant influence of the Ecca shale and associated dolerite intrusions. However, boreholes in Domain 3, also containing Ecca shale, are relatively low yielding. A reason for these lower than expected yields in domain 3 may be due to the low lineament density, particularly in the vicinity of the boreholes, and the rugged, deeply incised nature of the area. Boreholes in Domain 4 are low yielding, which may not be a true reflection of the yield potential of this well fractured, sandstone-rich zone.

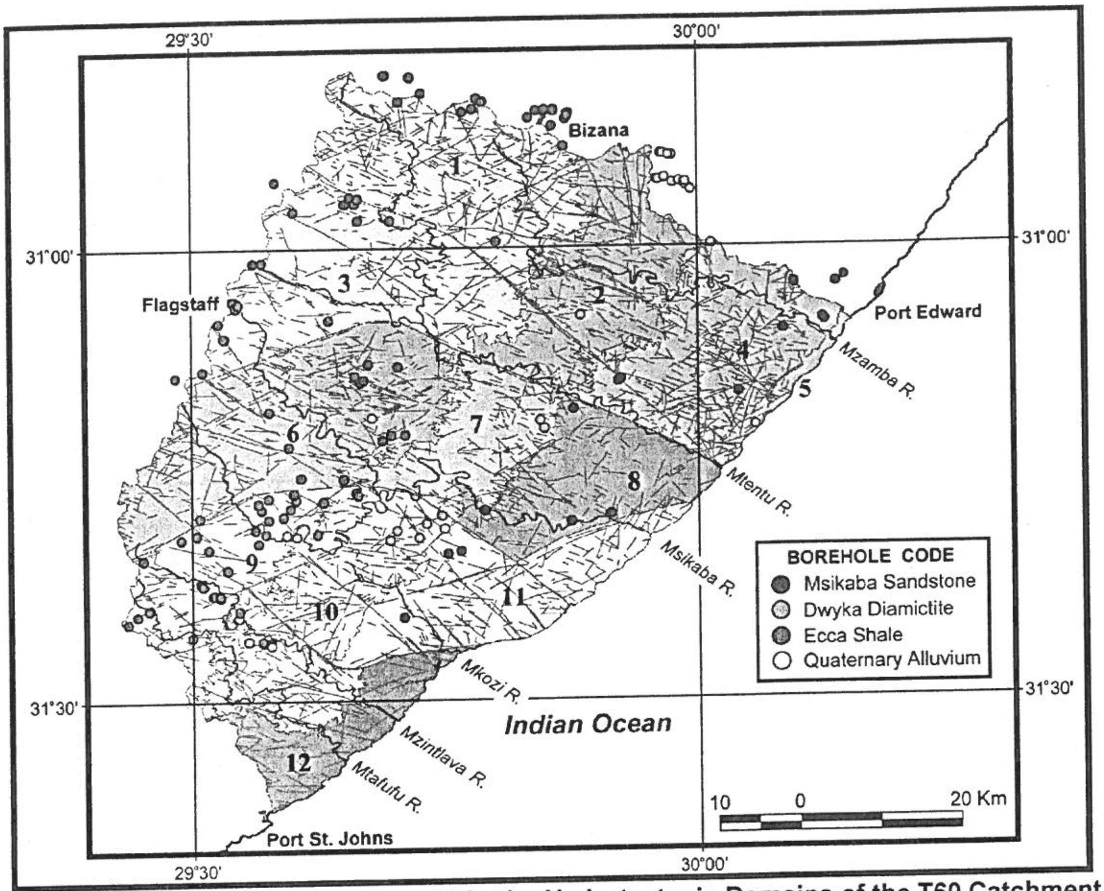

Figure 18: Borehole Distribution within the Hydrotectonic Domains of the T60 Catchment

Table 10: Summary of Geological Classification Criteria per Hydrotectonic Domain

HYDRO-TECTONIC DOMAIN	CLASSIFICATION CRITERIA		
	Predominant Lithology	Sills	Lineaments
1	Ecca	abundant	High density, complex 'knots'; NW, NE, EW and NS lineaments.
2	Dwyka	none	Mostly high density, complex 'knots', regional NW-NNW and N-S lineaments, including the Ntlakwe-Bongwan Fault system.
3	Ecca	abundant	Low density; E-W, NE and regional NW lineaments.
4	Msikaba	none	Mostly high density; complex 'knots';, NE, WNW, regional NW and NS Lineaments. Major regional lineament, controlling Mtentu River course forms southern boundary.
5	Basement – Unconsolidated Deposits	none	Overburden restricts mapping, anticipated to be similar to Domain 4, with E-W to NE faulting.
6	Ecca	abundant	High density; dominant NE, WNW –NW lineaments.
7	Dwyka	none	Moderate to low density; short lineaments of NW to WNW orientation.
8	Msikaba	none	Low density, short lineaments of WNW to NW, and minor of NE orientation.
9	Ecca	abundant	Low density, NE and WNW-NW trending lineaments.
10	Dwyka	Minor	Moderate density, complex 'knots'; regional NE and NW, with minor E-W trends.
11	Msikaba	none	Dense, NW and ESE lineaments. Egosa Fault forms southern boundary.
12	Ecca	abundant	Moderate density; regional WNW to NW, ENE to E-W (faults) trending lineaments. Egosa Fault forms the northern boundary.

Table 11: Borehole Yield Statistics per Hydrotectonic Domain

Hydotectonic Domain	Statistics					
	Number	Min	Max	Median	Mean	Std. Deviation
1	14	0.22	10.00	1.41	3.03	3.52
2	11	0.10	5.60	0.49	1.59	2.11
3	11	0.05	1.80	0.55	0.77	0.69
4	6	0.10	0.72	0.12	0.22	0.25
5	0	-	-	-	-	-
6	11	0.32	3.00	1.20	1.66	0.95
7	2	2.80	6.80	-	-	-
8	4	0.25	6.90	-	2.05	3.24
9	23	0.19	5.00	1.25	1.46	1.06
10	9	0.04	4.43	0.96	1.73	1.74
11	3	0.03	0.30	-	0.12	0.15
12	0	-	-	-	-	-

8.4 BOREHOLE YIELD STATISTICS PER QUATERNARY CATCHMENT

The borehole yield statistics per quaternary catchment are presented in **Table 12**, which may not be the most appropriate geohydrological unit for classification, but is required to ensure compatibility and integration of the groundwater study with the other water resource components of the T60 Basin Study.

Table 12: Borehole Yield statistics per Quaternary Catchment

Quaternary Catchment	Total No. Bores	No. Dry Bores (%)	Yield (l/s) Statistics			
			Median	Mean (Std Dev)	Max	Min
T60A	38	14 (37)	0.67	2.34 (3.12)	10.0	0.10
T60B	16	5 (31)	0.38	0.95 (0.86)	2.00	0.05
T60C	3	2 (75)	-	-	9.90	9.90
T60D	5	1 (20)	0.14	0.17 (0.09)	0.30	0.10
T60E	7	2 (29)	1.14	1.69 (1.22)	3.00	0.55
T60F	30	7 (23)	1.26	1.67 (1.04)	5.00	0.16
T60G	13	4 (31)	0.50	2.01 (2.84)	6.90	0.04
T60H	2	0 (0)	-	0.04 (-)	0.04	0.03
T60J	18	6 (33)	0.88	1.51 (1.45)	4.43	0.20
T60K	4	2 (50)	0.90	0.90 (-)	1.00	0.80

In order to obtain a more hydrogeologically representative median borehole yield for each quaternary catchment (**Table 13**), a weighted-average median yield was calculated according to the percentage outcrop area of the three major lithological units, the Msikaba Formation, Dwyka and Ecca Group. The influence of the numerous dolerite intrusives in the Ecca shales are integrated into the yield statistics of this lithological unit (see **Table 3**). This yield information will be used to assess the groundwater development potential per quaternary catchment (**Chapter 11.3**).

Table 13: Weighted Median Borehole Yield per Quaternary Catchment

Quaternary Catchment	Lithology Weighted Median Bore Yield (ℓ/s)	% Area		
		Msikaba Formation	Dwyka Group	Ecca Group
T60A	0.80 (0.67)	23	40	37
T60B	1.20 (1.17)	0	0	100
T60C	0.87 (0.74)	10	42	48
T60D	0.51 (0.48)	90	10	0
T60E	1.20 (1.17)	0	0	100
T60F	1.07 (0.99)	0	21	79
T60G	0.55 (0.39)	46	54	0
T60H	0.57 (0.55)	85	6	9
T60J	0.86 (0.71)	7	48	45
T60K	1.15 (1.11)	3	5	92

Note: (0.67) – Median Borehole Yield from **Table 4**, after Smart (1988).

8.5 GROUNDWATER LEVEL AND YIELD VARIATIONS WITH BOREHOLE DEPTH

The average depth of boreholes drilled in the study area is 62.4 metres **(Table 14)**, while the average groundwater-level is 15.4 m below ground surface.

The majority of the boreholes intercepted a single 'measurable' water-strike, whilst the higher yielding boreholes commonly show multiple water interceptions with drilling depth (**Figure 19**).

The median and average depth of the first, measurable water-strike is 27 and 31 metres below ground-level, respectively - or more importantly, 11 and 19 metres below the groundwater-level, respectively. The second and third water strikes normally occurs at each 10m incremental depth of drilling below this datum.

Table 14: Statistics of Waterlevels, Depth of Water Interceptions and Borehole Depths in the T60 Catchment

Parameter	Statistics					
	Number	**Min**	**Max**	**Median**	**Mean**	**Std. Deviation**
Drill Depth (m)	93	15.85	15.0	-	62.4	28.45
Waterlevel (mbgl)	63	0.100	65.00	-	15.4	12.71
1st Water Strike						
(mbgl)	35	6.0	114.0	27.0	30.7	22.59
(mbwl)	32	1.0	102.0	10.6	18.6	20.57
2st Water Strike						
(mbgl)	17	6.0	89.0	34.0	40.7	21.74
(mbwl)	17	4.1	84.0	23.1	28.0	20.51
3st Water Strike						
(mbgl)	8	23.0	70.0	45.5	46.3	16.40
(mbwl)	8	8.9	67.0	33.5	36.5	18.40
4st Water Strike						
(mbgl)	6	24.0	74.0	49.5	51.2	18.81
(mbwl)	6	9.9	74.0	46.5	47.0	23.90
NOTE: mbgl – metres below ground-level. Mbwl – metres below static groundwater-level.						

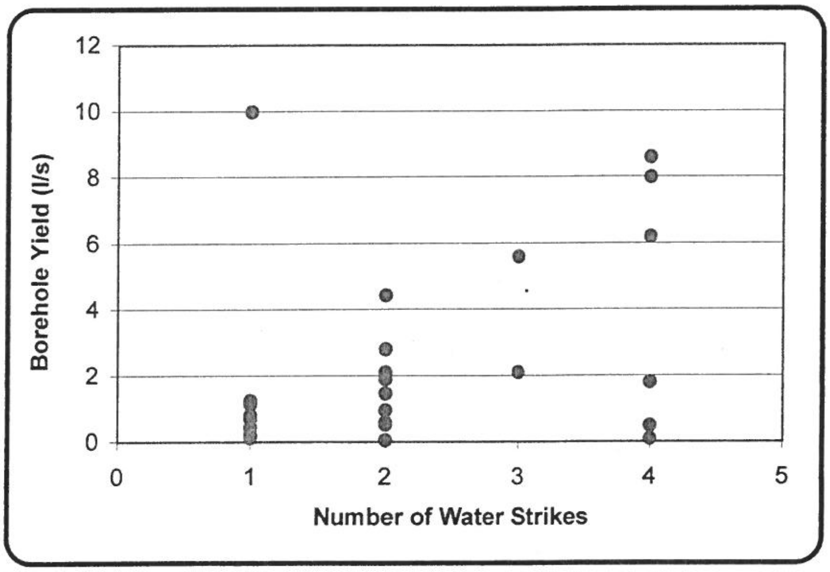

Figure 19: Borehole Yield versus number of Water-strikes

The probability of striking water bearing fractures with drilling depth below the ground surface and regional waterlevel are indicated in **Figure 20**.

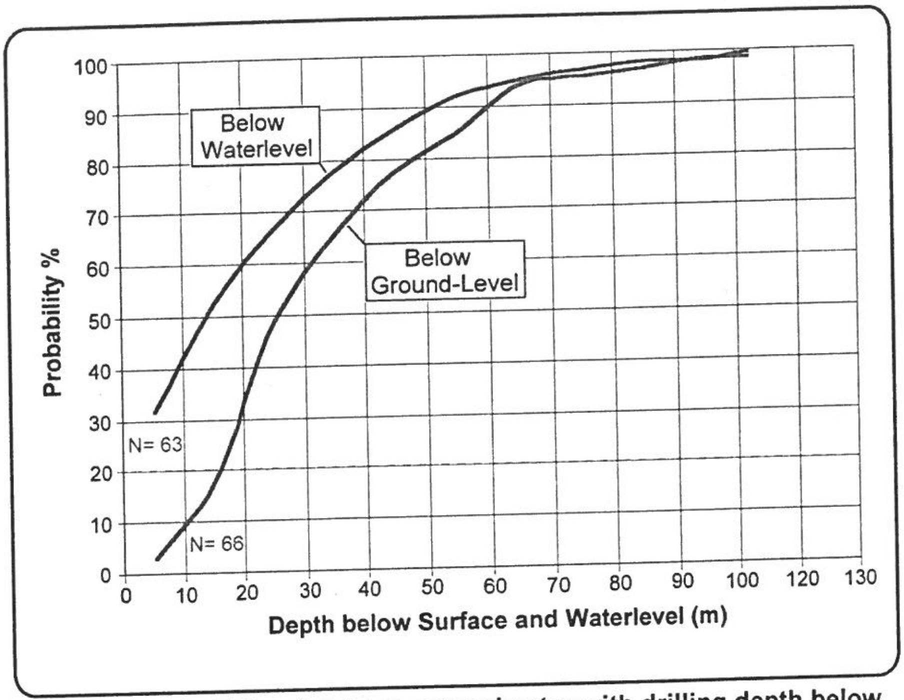

Figure 20: Probability of striking groundwater with drilling depth below the surface and below the regional waterlevel

The general trend is a decrease in the likelihood of intercepting water-bearing fractures with depth below the surface or regional waterlevel. The probability graph flattens rapidly after about 55m and 65m below the regional waterlevel and ground surface, respectively – indicating a sharp decline in the number of water bearing fractures below these depths. **Figure 20** shows that 50% of the water-strikes occur within the first 15m of drilling below the regional waterlevel. These graphs only reflect the general drilling conditions related to the near-surface zone, where the influence of weathering and horizontal fracture enhancement by erosional unloading are dominant. It is likely that boreholes correctly sited on regional fracture systems of tectonic origin will show less frequent, higher yielding water-strikes, which are independent of drilling depth.

The relationship between the yield of individual water-interceptions and drilling depth could not be assessed due to a lack of reliable water-strike yield information in the study area. Smart (1998) produced a graph of mean yield of water strikes in relation to depth below surface (**Figure 21**), which shows no significant variation in individual water-strike yields with depth.

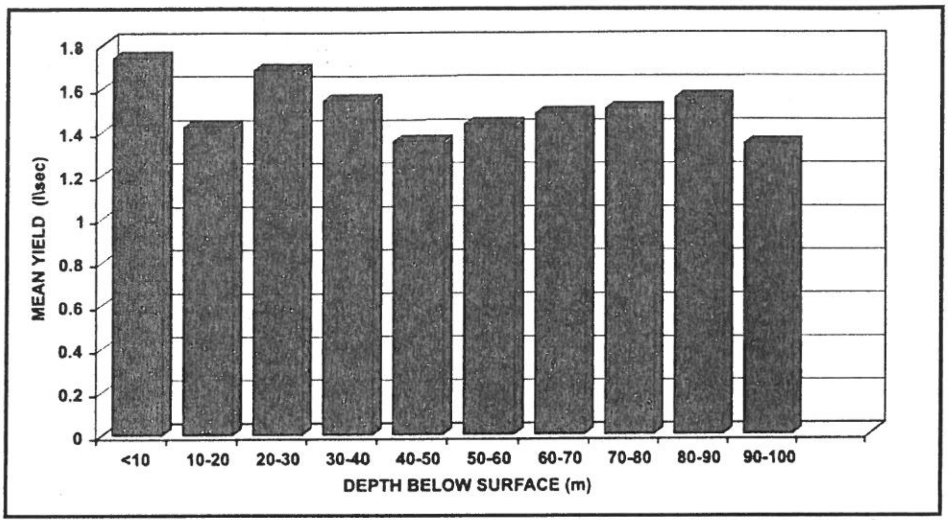

Figure 21: Mean Borehole Yields obtained at Water-Strikes in relation to Depth below the Surface (Smart, 1998).

8.6 SPRINGS AND SEEPS

The concept of springs and seeps needs to be understood by water planners, as the two sources have different potential for development as a water supply, namely:

Seeps represent the attenuated discharge of infiltrated rainwater from the vadose zone or from a locally "perched"-aquifer, before it actually reaches the main groundwater body (**Figure 22**). They tend to show marked seasonal fluctuations in yield (i.e. are directly correlated to local rainfall variability), and their water chemistry is similar to that of rainwater (i.e. electrical conductivity or EC < 20 mS/m) – see **Table 15** and **Figure 23**.

The springs in the area tend to emanate in the lower-lying areas, especially in the deeply incised valleys, along bedding-planes, intrusive contacts and other structural features – where the groundwater phreatic- or piezometric-level intersects the surface (**Figure 22**). The chemistry of the spring-water therefore reflects that of the local shallow aquifer (EC 20-70 mS/m) or in more rare cases a deeper-seated aquifer (>500 mS/m). The yield of a spring is more regular than that of a seep, i.e. seasonal fluctuations in flow are not as marked, because the spring is linked to a relatively large groundwater storage reservoir. Springs are therefore more favourable for development as community water supplies.

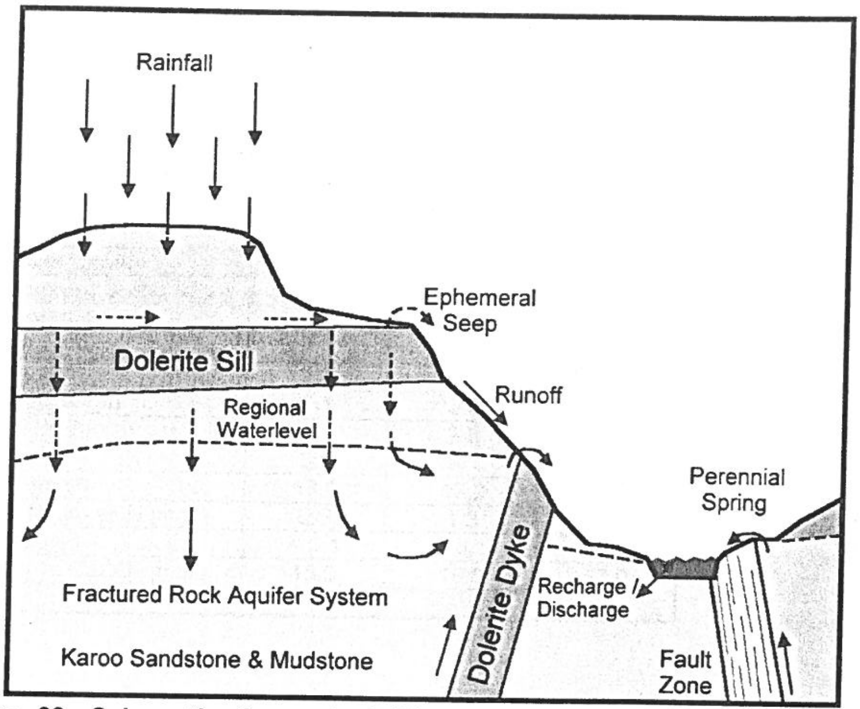

Figure 22: Schematic Conceptual Diagram indicating the occurrence and hydrological significance of springs and seeps in the study area.

It is the author's opinion that the electrical conductivity, as well as other macro-chemical and isotopic constituents, of this water may be used to obtain a first-order approximation of the sustainability of the resource (i.e. spring versus seep). The nature and degree of correlation between the rate of flow (l/s) and local rainfall (mm) will provide a more reliable definition between the two types, as well as quantitative estimates of the long-term sustainable yield of the supply. Such applied research would greatly enhance our understanding and selection of 'true' springs suitable for community water supply - especially in this area where they form an important freshwater resource for cost-effective, small-scale development, but have the stigma of being 'unreliable'

Smart (1998) states that springs are important sources of water in areas of high rainfall and found that they commonly develop along:

- Dykes intersecting drainage features.
- Contact of dolerite sills and sheets.
- Basal contacts of fractured sandstones with an underlying less permeable mudrock horizon.
- Weathered basins, usually dolerite sills.

The yield and sustainability of a spring depends upon the interplay between the rate of aquifer recharge, aquifer storage capacity, piezometric pressure at the spring and permeability of the formation or fracture.

Table 15: Chemistry of 'Fresh' Springs sampled during the Hydrocensus

	Spring Number		
	TPS-1	**TPS-2**	**TPS-3**
Latitude	31.91601	31.15164	30.91555
Longitude	29.61855	30.13133	29.72909
Date Sampled	26/5/199	27/5/99	28/5/99
Conductivity (mS/m)	6	18	18
Total Dissolved Solids (mg/l)	38	115	115
pH (Laboratory)	6.1	6.0	7.1
Sodium (mg/l)	5.1	28.0	13.0
Calcium (mg/l)	2.7	1.7	11.0
Magnesium (mg/l)	2.1	3.3	7.2
Sulphate (mg/l)	0.2	9.8	2.1
Chloride (mg/l)	5.0	34.0	13.0
Alkalinity (mg/l)	17.0	17.0	52.0
Nitrate + Nitrite as N (mg/l)	0.6	1.3	3.4
Fluoride (mg/l)	< 0.1	< 0.1	<0.1
Hardness as $CaCO_3$ (mg/l)	15.0	18.0	57.0

Gevers (1941) describes the occurrences of highly mineralised springs (1400 mS/m) in the vicinity of Port St. Johns and along the banks of the Umtamvuna River to the east of Bizana. Cones of travertine of varying proportions have built-up around their orifices. Gevers concluded that the springs represent highly concentrated Dwyka groundwater that originates from shallow depths. He based this assertion on the normal temperature of the Umtamvuna spring water of 20.1 – 21.0 °C (air-temperature of 22°C). The Port St. Johns springs are rich in H_2S, while those along the Umtamvuna River contain CO_2 and no H_2S. The Umtamvuna springs rise along the Ntlakwe-Bongwan Fault system. Further to the north, at the Bongwan Railway Siding, the CO_2 exhalations represent the only commercially exploited natural sources of CO_2 gas in South Africa. Gevers postulated that the gases were not of volcanic origin, but that they resulted from the reaction of acidic (H_2S) groundwater with crystalline limestone at depth. The source of this limestone is uncertain, although Gevers points to carbonate-rich xenoliths in the underlying granite basement, some distance to the east (Marble Delta). Gevers claims that the sulphuric acid in the groundwater could be generated by the oxidation of pyrite within the overlying Ecca shales.

Table 16: Chemistry of the hyper-saline Insunka Spring

Parameter	Insunka Spring, Port St. Johns
Latitude	31.60917
Longitude	29.48306
Date Sample	17/11/94
pH (Lab)	7.6
EC (mS/m)	4 500
TDS (mg/l)	28 800
Sodium (mg/l)	11 700
Calcium (mg/l)	108
Magnesium (mg/l)	117
Potassium (mg/l)	384
Chloride (mg/l)	9 990
Sulphate (mg/l)	7 402
Alkalinity $CACO_3$ (mg/l)	5 794
Ammonia as N (mg/l)	2.35
Nitrate as N (mg/l)	1.69
Phosphate (mg/l)	<0.1
Iron as Fe (mg/l)	<0.05
Manganese as Mn (mg/l)	<0.05
Fluoride as F (mg/l)	1.32
(Source DWAF)	

8.7 GROUNDWATER QUALITY

The chemistry of natural groundwater is commonly controlled by the soluble products of rock weathering, as well as recharge and rates of flow in the aquifer. It is often significantly altered by pollution.

The severe lack of groundwater chemistry data makes it impossible to even analyse the distribution of salinity in the study area. The following hydrochemical information was located and used for this study (**Figure 23**):

- 18 boreholes with full macro-chemistry, 9 of which actually fall within the T60 drainage region (source DWAF National Groundwater Chemistry Database),
- 4 springs with full macro-chemistry, 3 of which were analysed during this study (**Tables 15** and **16**).
- 13 boreholes with electrical conductivity information, 3 of which were collected during this study (**Table 2**).

Groundwater Development Services (1995a) collected groundwater samples from 128 boreholes and springs in the Ecca and Beaufort Group rocks in Mapping Unit 10, to the north of the T60 catchment. The electrical conductivity (EC) of the groundwater varied between 60 and 300 mS/m, with only one sample exceeding 300 mS/m (TDS > 2000 mg/l). They found elevated fluoride (> 1.5 mg/l) concentrations in groundwater from the Ecca shale (4 samples).

8.7.1 Regional Water Quality Trends

Smart (1998) states that the electrical conductivity (EC) of the groundwater in the area between latitude 31° - 33°S and longitude 26° - 30.5°E, rarely exceeds 300 mS/m, which is the maximum acceptable limit for human consumption (DWAF, 1993). Smart's regional salinity map indicates that the EC of groundwater in the T60 drainage region is generally below 70 mS/m, although localised values in excess of 1000 mS/m occur in the vicinity of Port St. Johns (**Table 16**). This water is emanating along regional faults as springs and probably represents the leakage from a deeper, artesian aquifer system. The scant EC information tends to confirm this assessment (**Figure 23**), although groundwater with EC's of 150-160 mS/m occur to the west of Lusikisiki. These elevated salinity values are 'anomalous' and may be associated with water emanating from the saturated alluvial deposits in the area.

Smart (1998) states that local quality variations do occur, with the result that the general trends depicted on his generalised EC map may differ significantly from that found at a particular locality in the field.

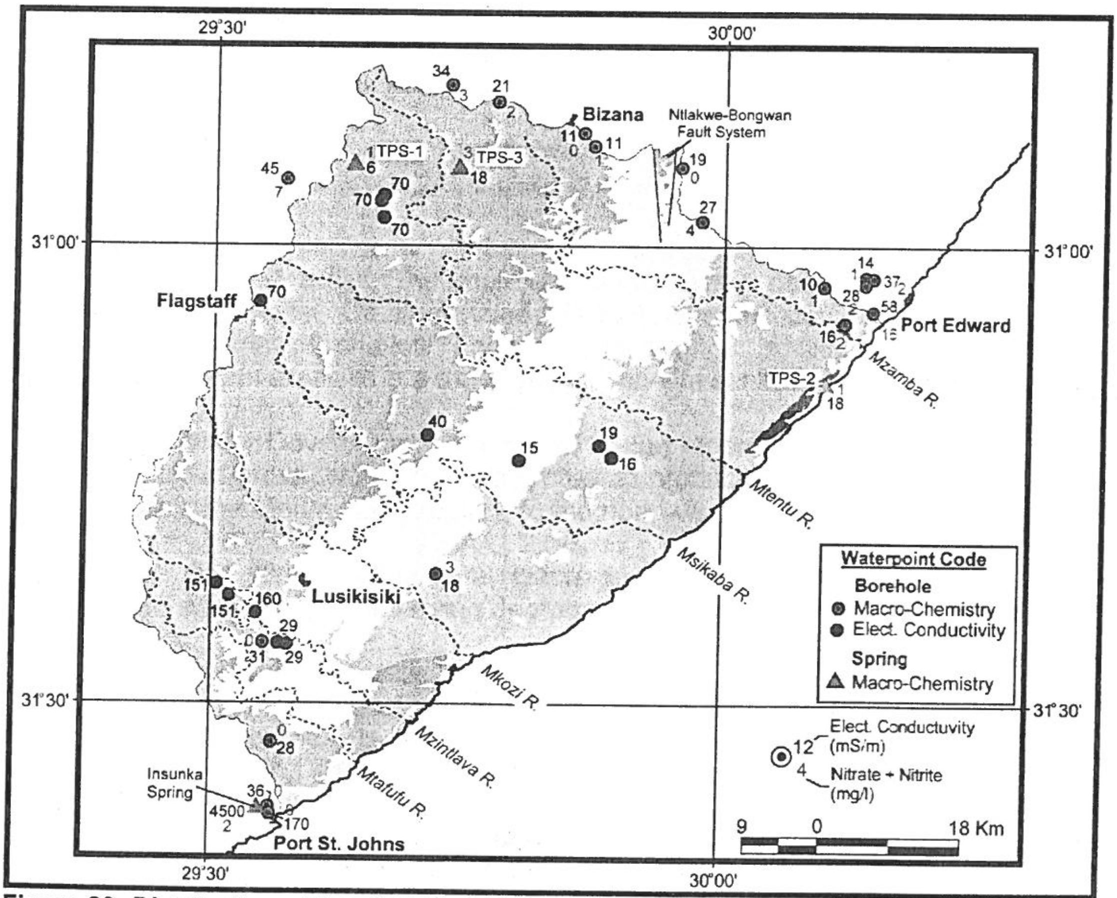

Figure 23: Distribution of Boreholes and Springs with water chemistry information

The characteristic trend of groundwater quality in the Karoo rocks, i.e. increasing salinity with increasing aridity, is apparent in **Figure 23**. The groundwater EC increases from between 10-20 mS/m along the Coastal Plateau to between 40-160 mS/m in the interior. Higher EC's along the coastline are probably due to the influx of wind-borne salts from the sea or the mixing with a deeper, more saline groundwater rising along the numerous coastal faults.

The groundwater in the Dwyka Group is commonly more saline than that in the Ecca (Toens and Partners, 1997). The few groundwater salinity measurements available in the Dwyka rocks of the study area do not show this relationship.

The groundwater quality of the study area is generally potable and within DWAF's recommended drinking-water health standards (DWAF, 1993). The macro-chemical analyses of the groundwater, although limited in number, do not indicate any constituents that are in excess of the maximum recommended limits for domestic consumption. However, elevated nitrate levels (**Figure 23**), are a cause for concern and are probably related to point source pollution of the groundwater resource. Regardless of the above, it is imperative that no groundwater resource be developed prior to thorough chemical and bacteriological analysis of the water.

8.7.2 Possible Sources of Groundwater Pollution

The natural quality of groundwater may be altered by anthropogenic contamination in many ways, including some of the most basic human activities.

Human and animal faecal contamination is the most common sources of pollution in these rural areas, the main pollutants being pathogens (indicators total Coliform, Faecal Colliform and Faecal Streptococci) and nitrate. Faecal contamination of shallow aquifers and springs is likely to be a problem, particularly in areas where the density of on-site sanitation facilities is high.

Groundwater Development Services (1995a) report E.Coli counts of up to 2500 per litre of groundwater in an unprotected production borehole, south of Donny Brook in the Mount Curry district, to the north-west of the study area.

Cattle dips, uncontrolled rural waste-dumps and poorly managed municipal landfill sites are all to a varying degree potential sources of potential pollution

Human and stock activities in the proximity of boreholes and springs are the most common source of localised or "point-source" groundwater pollution, especially where the borehole is improperly constructed. The need to insert adequate lengths of casing and to grout the annulus between the casing and the formation is important, but often overlooked. The construction of a sanitary apron, allowing for proper drainage away from the immediate surroundings of the pump installation, and fencing to keep animals away from the water source, especially springs, is rarely practised.

Unsealed, abandoned boreholes, commonly as a result of unsuccessful drilling or failure of the pump equipment, may constitute a health hazard, as they frequently become convenient receptacles for the disposal of wastes. Borehole and dug-wells represent a direct and rapid path whereby pollutants can enter the aquifer.

A detailed description and evaluation of the potential pollution hazards in the T60 basin is beyond the scope of this study.

areas such as Lusikisiki, where many of the exploration targets are narrow linear features "hidden" from sight by overburden and where budget constraints restrict the drilling of only one exploration borehole per drill-site. Should drilling reveal that a borehole is not optimally sited on the geological structure, then the borehole can be artificially "connected" to the fracture-zone via hydraulic-fracturing, up to a distance of 50m.

10.0 EXISTING GROUNDWATER USAGE AND CONSUMPTION

Groundwater is used for domestic and livestock watering purposes. The main groundwater source in the study area are the perennial springs and ephemeral seeps (i.e. only flowing during the wet season) (**Chapter 8.6**). The springs tend to emanate in the lower-lying areas, especially in the deeply incised valleys, along bedding-planes, intrusive contacts and other structural features – where the groundwater-level intersects the surface. The majority of the springs used for domestic supply have not been protected (i.e. fenced-off, cement-lined) or developed (i.e. deepened to increase yields), and pose a health hazard, especially during the dry season when both the inhabitants and their stock place pressure on these water resources.

Relatively few boreholes have been drilled in the study area, the majority of those included in the borehole GIS were drilled by or on behalf of the former 'Transkei' Government Department of Water Affairs (T-boreholes). Many of these boreholes are not in use or the pump-equipment, mainly windpumps and hand-pumps, are out of order. A number of the T-boreholes have not been equipped for production purposes due to their low yields.

The existing annual groundwater abstraction is estimated per quaternary catchment using the following information:

- existing geohydrological reports,
- the borehole GIS database,
- a limited reconnaissance hydrocensus within specified hydrogeological domains in the study area,
- population census (1996) per village, and
- digital topocadastral information (i.e. perennial rivers, location of villages) captured at a scale of 1/50 000.

The information was spatially processed in the GIS to estimate the annual groundwater consumption per Quaternary catchment using the following methodology:

1. The total number of inhabitants per Quaternary catchment was calculated using the individual village population information (**Village Population**).

2. An additional 10% of the Village Population was added to each Quaternary catchment in order to take into account the number of people residing outside of the main villages (**Rural Population**).

3. The degree unto which groundwater is being utilised within a particular area was assessed by considering the availability (i.e. distance from user) of alternative sources of water, as follows (**Figure 26**):

   - It was assumed that village and rural inhabitants within 500m of perennial rivers obtained at least 80% of their water needs from this source (i.e groundwater 20%).
   - Due to the high density of perennial rivers and the scarcity of mapped dams and earth-lined impoundments, outside of the surface-water supply schemes, the latter were excluded from the analysis.
   - Village and rural inhabitants within a reticulated Surface-Water Supply Scheme and within 500m of a perennial river were assumed to obtain 5% and 10% of their water requirements from groundwater, respectively. The higher percentage usage of groundwater by rural inhabitants being due to the limited effectiveness of the reticulation network in these areas. The assumption being that the reticulated water is used mainly for drinking purposes and that the rivers are used for washing etc.
   - Village and rural inhabitants within a reticulated Surface-Water Supply Scheme and further than 500m from a perennial river are estimated to obtain 10% and 20% of there water requirements from groundwater, respectively. The assumption being that the purified water is used mainly for drinking purposes and that additional water is obtained from a nearby groundwater source.
   - Both village and rural inhabitants situated outside of Surface-Water Supply-Schemes and further than 500m from a perennial river, obtain about 80% of their water needs from a groundwater source.

   This model assumes that the choice of water supply utilised is based purely upon the distance between the user and the available water resources. During the hydrocensus (**Chapter 7.0**), many of the inhabitants expressed the opinion that the river-water may be polluted by upstream users and that they preferred to use the spring-water for drinking purposes. The river-water being used more for the washing of clothes, stock-watering etc. Many of the springs are located along the banks of the perennial rivers and thus groundwater usage in the areas within 500m of perennial rivers will be underestimated, particularly if there is a perception of varying water quality between the two sources. The large groundwater base-flow component of the MAR points to the likelihood that a significant percentage of the groundwater recharged from rainfall enters these river systems via seeps and springs.

4. The average per capita water consumption is assumed to vary between 15 and 25 l/day.

5. It is assumed that livestock obtain approximately 30% of their water needs from a groundwater resource. There is no large-scale groundwater abstraction for irrigation or forestry.

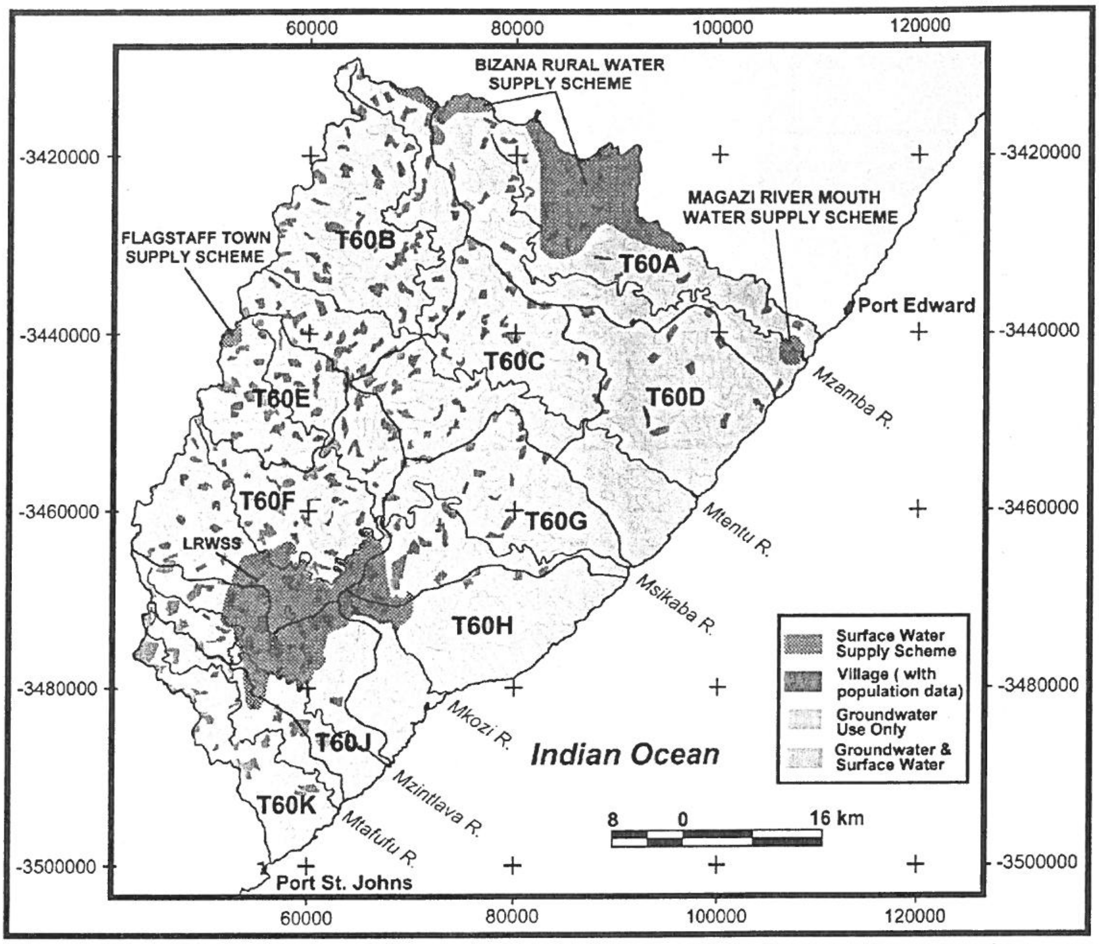

Figure 26: **GIS spatial-model used to estimate Groundwater Consumption per Quaternary catchment**

The estimated annual volumes of groundwater consumed per Quaternary Catchment are presented in **Table 17**. The total groundwater consumption for the T60 drainage region is estimated at between 2 - 3 x 10^6 m^3 per annum, and rises to $6x10^6$ m^3 per annum if a daily per capita consumption of 60 litres is assumed. The groundwater consumption is the highest in the interior (T60B, T60F, T60A and T60C) where the majority of the population resides. The lower population density along the coast results in lower groundwater usage in these catchments.

Table 17: Estimated Annual Volumes of Groundwater Consumed per Quaternary Catchment

Quaternary Catchment	Population (Rural + Village)	Domestic Use (m^3/yr)[1]	Domestic Use (m^3/yr)[2]	Livestock Use (m^3/yr)[3]	TOTAL GROUNDWATER USAGE (m^3/yr)
T60A	71,175	125,644	209,407	126,000	251,644[1] - 335,407[2]
T60B	122,680	350,479	584,131	125,100	475,579[1] - 709,231[2]
T60C	47,970	141,377	235,628	86,100	227,477[1] - 321,728[2]
T60D	20,542	52,876	88,127	96,900	149,776[1] - 185,027[2]
T60E	41,271	114,528	190,880	46,800	161,328[1] - 237,680[2]
T60F	85,288	205,011	341,685	109,800	314,811[1] - 451,485[2]
T60G	51,539	128,627	214,378	85,200	213,827[1] - 299,578[2]
T60H	10,826	10,040	16,733	77,700	87,740[1] - 94,433[2]
T60J	49,353	62,926	104,877	69,900	132,826[1] - 174,777[2]
T60K	46,389	107,335	178,892	57,900	165,235[1] - 236,792[2]
TOTAL	**547,033**	**1,298,843**	**2,164,738**	**881,400**	**2,180,243[1] - 3,046,138[2]**

Note:

1 – assuming a per capita consumption of 15 *l*/day.
2 – assuming a per capita consumption of 25 *l*/day.
3 – assuming 30% of total livestock consumption.

11.0 GROUNDWATER RESOURCE POTENTIAL OF THE T60 TERTIARY DRAINAGE REGION

This chapter deals with the regional groundwater resources of the T60 Tertiary catchment in terms of the potential volumes of water available (Exploitation Potential) and the potential to abstract this water via boreholes (Development Potential). The groundwater resource assessment is presented per Quaternary catchment to facilitate the comparison and integration of this information with that of the surface water resources. The hydrological information for each Quaternary catchment is summarised in **Table 18**.

Table 18 : Hydrological Characteristics of T60 Quaternary Catchments

Quaternary Catchment	1	2	3	4	5
	Area Km^2	**Mean Annual Precipitation (mm)[A]**	**Mean Annual Volume Ppt (x10^6 m^3/year)**	**Mean Annual Runoff (x10^6 m^3/year)[A]**	**Mean Annual Baseflow (x10^6 m^3/year)[B]**
T60A	548.462	873	478.8	72.08	35.107
T60B	530.063	896	474.9	75.68	36.357
T60C	364.611	952	347.1	62.86	29.216
T60D	416.025	1072	446.0	102.93	43.920
T60E	198.885	885	176.0	28.09	13.852
T60F	465.743	940	437.8	79.28	37.776
T60G	361.548	1116	403.5	100.51	43.180
T60H	323.452	1277	413.1	124.66	52.121
T60J	294.739	1101	324.5	77.5	34.812
T60K	243.210	1075	261.5	59.6	27.086

Note: Source of Information [A] – UWP Consulting Engineers (1999)
[B] – Water Systems Management (1999).

11.1 AQUIFER RECHARGE

Aquifer recharge refers to the amount of rainwater that infiltrates into the vadose zone and then actually enters into the main underlying aquifer system. The average groundwater-level in the study area is in the order of 15 m.bgl and therefore the calculated volumes of recharged rainwater already accounts for evapotranspiration losses.

The annual volumes of rainwater recharge within each Quaternary catchment was estimated using the 1'x1' raster data of mean annual rainfall or MAP (**Chapter 4.2**). The following methods were applied in a GIS to simulate the mean annual volumes of recharge:

(a) A fixed recharge rate (R_e) of 5% of MAP (**Figure 27**).

(b) A variable recharge rate (**Figure 28**), where R_e increases with increasing MAP: $R_e(\%)$ = [MAP (mm) / 10 000].

(c) Recharge volumes estimated in (b) above, are re-calculated to provide an upper (**Figure 29**) and lower limit (**Figure 30**), according to the variation in the annual rainfall (**Figure 6**).

The results a simulations (a), (b) and (c) are presented in **Table 19**, columns 9, 10, 11 and 12, respectively.

The river base-flow per Quaternary catchment (**Table 18**) makes up some 45-50% of the mean annual runoff (MAR), which is considered to be abnormally high. Estimates of mean annual recharge using a rate of 5% is commonly used in the drier Central and Western Karoo Basin and is considered to be a conservative estimate for the T60 drainage region. Groundwater Development Services (1995b) obtained a similar recharge rate of 4.9% (49 mm/yr) for an area where the MAP is 1000 mm, using river base-flow data. The mean annual base-flow per Quaternary catchment exceeds these volumes of recharge (**Table 19**, Col. 9), by between 30 and 150% - which is physically impossible and further points to a flaw in the river base-flow data.

The mean annual recharge estimates using a variable recharge rate (**Table 19**, Col. 10) are considered to represent a maximum figure for the study area. The 'true' mean annual recharge probably lies between these two extremes (i.e. Cols. 9 and 10 in **Table 19**), and is probably in the order of the lower estimate of recharge (Column 12, **Table 19**)

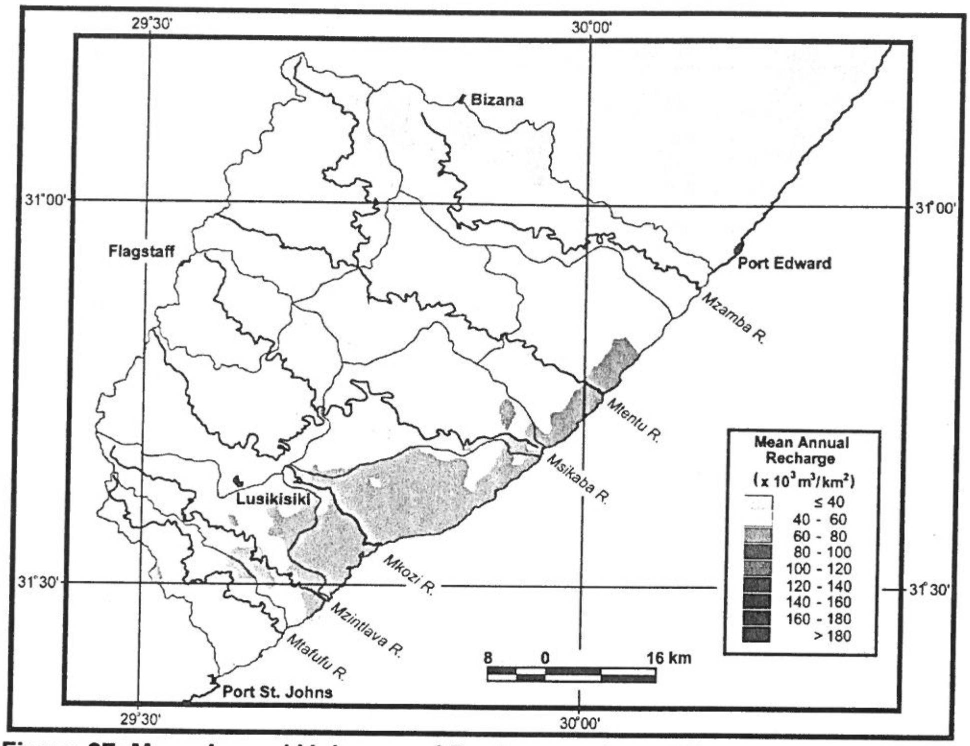

Figure 27: Mean Annual Volumes of Recharge using a 5% recharge rate.

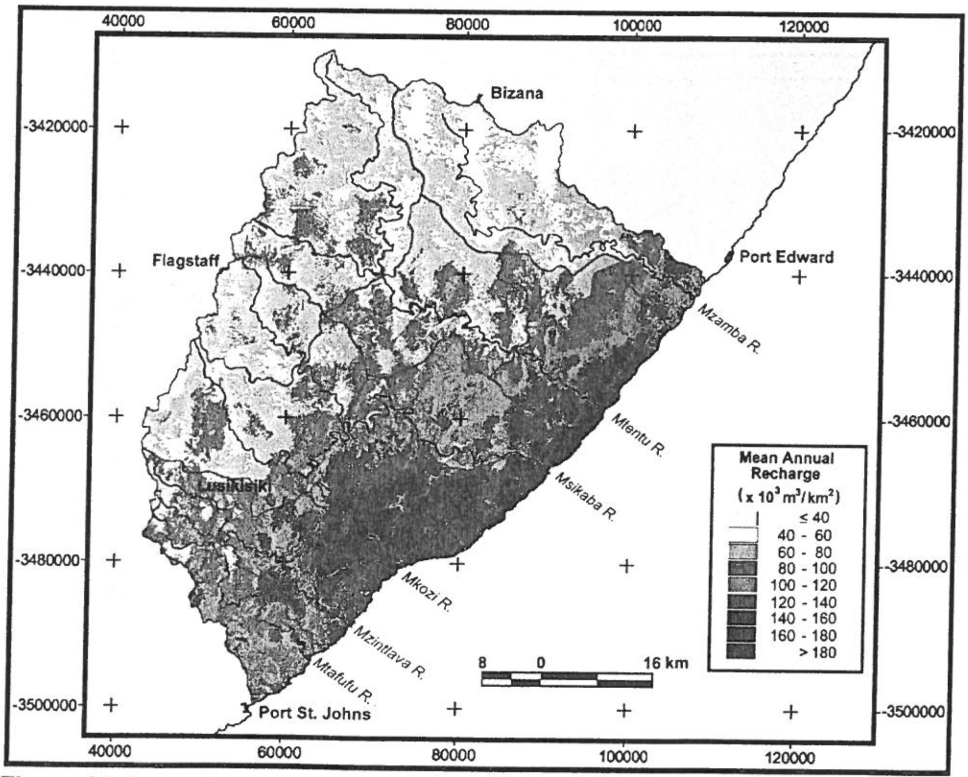

Figure 28: Mean Annual Volumes of Recharge using a variable recharge rate

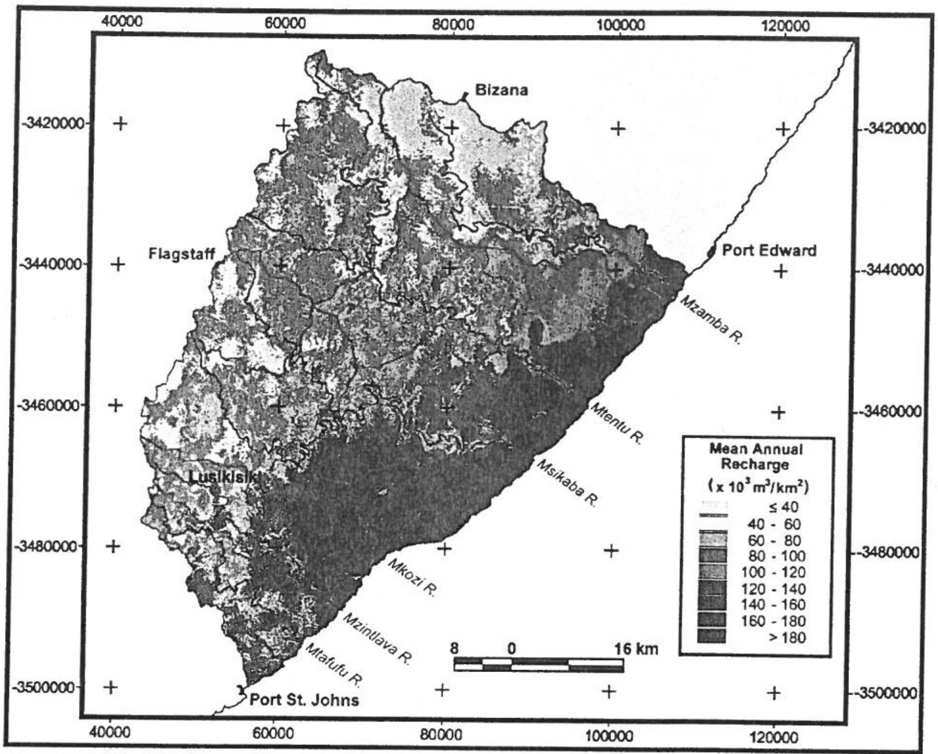

Figure 29: Upper Limit of Mean Annual Volumes of Recharge (variable rate)

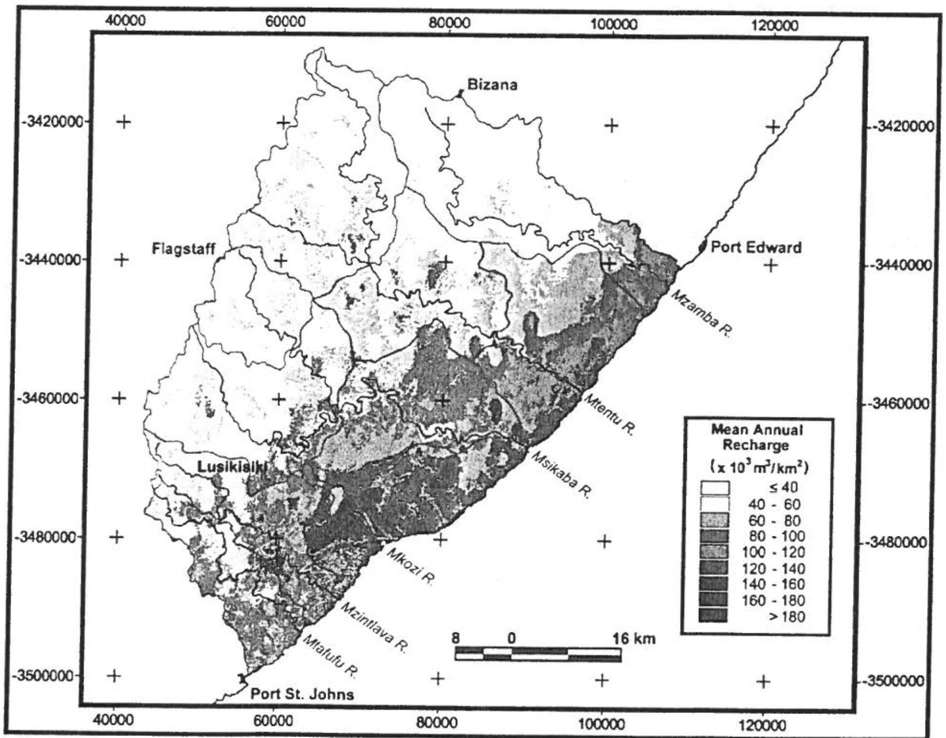

Figure 30: Lower Limit of Mean Annual Volumes of Recharge (variable rate)

Table 19 : Groundwater Recharge and Exploitation Potential of the T60 Quaternary Catchments

Quaternary Catchment	6 Harvest Potential (x10^6 m^3/year)	7 Exploitation Potential (x10^6 m^3/year)	8 Existing Groundwater Consumption (x10^6 m^3/year)	9 Annual Recharge 5% (x10^6 m^3/year)	10 Annual Recharge Variable (x10^6 m^3/year)	11 Upper Annual Recharge Variable (x10^6 m^3/year)	12 Lower Annual Recharge Variable (x10^6 m^3/year)
T60A	18.868	13.208	0.335	23.742	37.869	46.003	29.395
T60B	7.209	3.604	0.709	23.547	37.051	45.129	28.871
T60C	8.874	4.437	0.321	17.268	28.501	34.348	22.616
T60D	36.035	18.017	0.185	22.114	44.934	52.239	36.461
T60E	2.705	1.352	0.237	8.744	13.664	16.692	10.614
T60F	6.334	3.167	0.451	21.692	36.625	44.186	29.005
T60G	18.562	5.569	0.299	19.992	40.343	47.216	33.439
T60H	25.433	12.717	0.094	20.479	48.741	55.467	40.890
T60J	6.025	3.012	0.175	16.157	32.299	37.839	26.706
T60K	3.827	1.914	0.237	12.930	23.916	28.186	19.618
TOTAL	**133.872**	**66.997**	**3.043**	**187.152**	**343.943**	**407.305**	**277.615**

Note:

6 Source: after Seymour and Seward (1996)

7 Source: CCWS-DWAF project in progress by Water Systems Management (1999). The Groundwater Exploitation Potential estimates represent a refinement of the Harvest Potential, where the Harvest Potential assessments are re-adjusted using the "average" borehole yield per catchment.

8 (estimation - see **Chapter 10.0**).

9 Annual volumes of groundwater recharge assuming a 5% rate of recharge, based upon Schulze et al (1997) 1x1' grid of Mean Annual Precipitation (mm).

10 Annual volumes of groundwater recharge assuming a variable rate of recharge, based upon Schulze et al (1997) 1x1' grid of Mean Annual Precipitation (mm). Recharge Rate = MAP(mm)/10 000.

11 Upper recharge estimate using a variable recharge rate, where the Schulze et al (1997) 1x1' grid of Coefficient of Variation (%) of Annual Precipitation.

12 Lower recharge estimate using a variable recharge rate, where the Schulze et al (1997) 1x1' grid of Coefficient of Variation (%) of Annual Precipitation.

11.2 GROUNDWATER EXPLOITATION POTENTIAL

The exploitation potential is defined for the purposes of this study as the volumes of groundwater per Quaternary catchment that are potentially available for abstraction on a long-term sustainable basis (i.e. without 'aquifer-mining' taking place). The maximum sustainable yield of an aquifer is therefore equal to the average volumes of recharge to the system.

Seymour and Seward (1996) produced a national map indicating what they termed the groundwater 'Harvest Potential'. The harvest potential is defined as 'the maximum volume of water that is available for abstraction on a sustainable basis, without exhausting the resources'. These estimates are based upon the volumes of groundwater held in storage and the volumes of rainfall recharge. The annual groundwater harvest potential per Quaternary catchment is presented in **Table 19**, col. 6.

Water Systems Management (1999) refined the annual groundwater harvest potential estimates, using the 'average' borehole yield for each Quaternary catchment – which they refer to as the exploitation potential (**Table 19**, col. 7). This recognises the fact that, in many portions of the country, the low aquifer permeability is the main factor limiting the volumes of groundwater that can be abstracted. This is certainly the case in the T60 drainage region, where a lack of drilling targets, low exploration budgets and limited terrain accessibility further restrict the exploitable potential of the groundwater resources. In this document, the term 'groundwater development potential' is used to take into consideration these restrictions on the utilisation of the resource.

11.3 GROUNDWATER DEVELOPMENT POTENTIAL

The groundwater development potential per Quaternary catchment is estimated as follows:

- Calculation of the annual volumes of groundwater that could theoretically be abstracted from a regular 1 x 1 km grid of production borehole pumping at the lithology-weighted median catchment borehole yield (**Chapter 8.4**) for 12 hours per day (**Table 20**, Col. 13). A median borehole yield of 0.5 l/s was used for the Msikaba Formation, instead of the 0.14 l/s obtained for the T60 catchment.
- A similar calculation was performed using the lithology-weighted mean catchment borehole yield (**Table 20**, col. 14).
- In order to assess the relative availability of drilling-targets within each Quaternary catchment, the 'structural-density' was estimated as a percent of the total catchment area using:

  (a) the outcrop of dolerite sills, and
  (b) geological lineaments, buffered by 50m (i.e. allowing a zone of influence).

- The terrain accessibility was estimated as a percentage of the total Quaternary catchment area, using a slope (°) raster-dataset created from a 30x30m DEM of the T60 catchment. It was assumed that areas with slopes in excess of 12.5° are inaccessible to drilling-rigs (**Table 20**, col. 16).
- The drilling target density and terrain accessibility raster-datasets were then spatially integrated to define the density of accessible 'structural' drilling targets (**Figure 31**), as a percentage of the Quaternary catchment area (**Table 20**, col. 17).
- The initial estimates of 'mean' and 'median' annual volumes of abstractable groundwater were adjusted according to the relative density of accessible drilling targets within each Quaternary catchment (**Table 20**, cols. 18 and 19)

Terrain accessibility is an important factor limiting the development of groundwater in the study area, which is poorly served by tarred-roads. Access to villages from the tarred-roads is by a network of rural roads, which are generally in a poor condition. The villages are commonly situated on the crests of hills and ridges, below which the land slopes steeply to the river valley. Many communities are only accessible by 'paths' and cannot be reached by two-wheel drive vehicles.

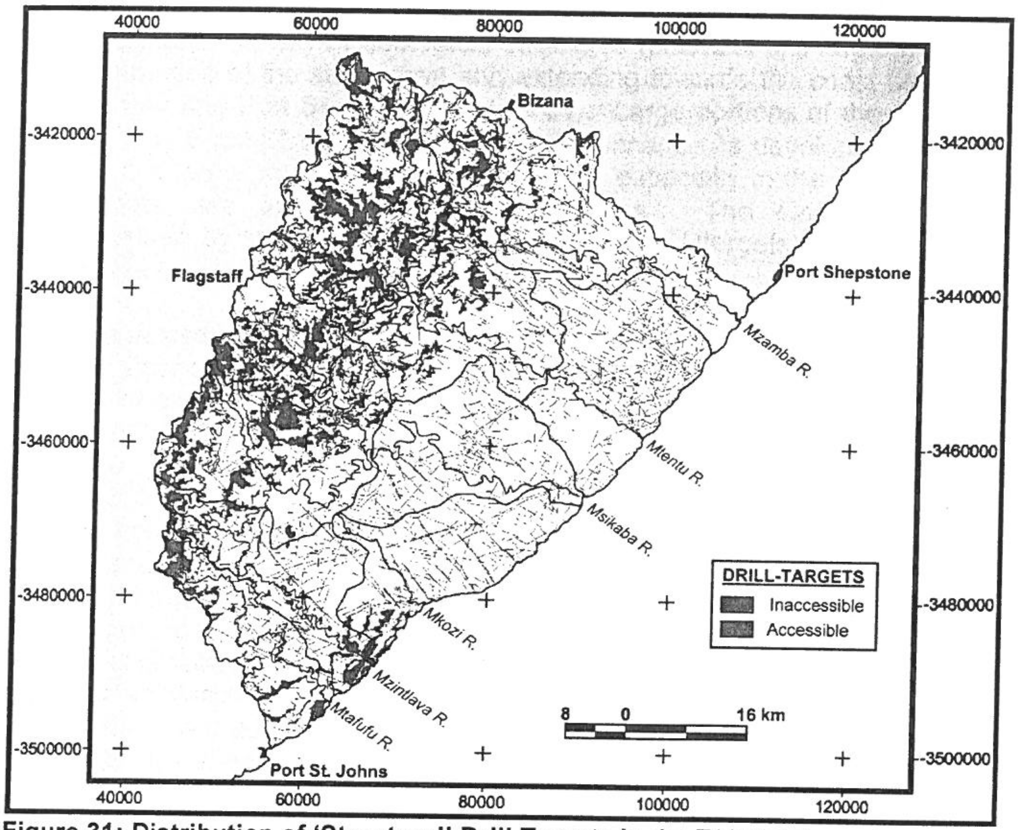

Figure 31: Distribution of 'Structural' Drill Targets in the T60 Catchment.

Table 20: Groundwater Development Potential of the T60 Quaternary Catchments

Quaternary Catchment	13 "Median" Annual Abstraction ($x10^6$ m^3/year)	14 "Mean" Annual Abstraction ($x10^6$ m^3/year)	15 Structural Density (%)	16 Terrain Accessibility (%)	17 Density of Accessible Drill Targets (%)	18 Adjusted "Median" Annual Abstraction ($x10^6$ m^3/year)	19 Adjusted "Mean" Annual Abstraction ($x10^6$ m^3/year)
T60A	6.844 (546)	13.546	16.9	69.9	23.7	1.623	3.213
T60B	9.991 (528)	14.819	41.2	56.7	41.7	4.163	6.175
T60C	5.015 (364)	9.800	19.0	50.1	19.4	0.971	1.897
T60D	3.323 (414)	5.673	9.1	88.0	16.1	0.536	0.914
T60E	1.589 (198)	5.557	44.6	55.6	46.1	0.733	2.564
T60F	7.826 (463)	13.102	31.1	64.6	24.4	1.912	3.202
T60G	3.106 (359)	7.634	7.1	70.7	10.4	0.324	0.796
T60H	2.886 (322)	4.657	11.2	82.4	14.1	0.406	0.655
T60J	3.965 (293)	8.049	22.5	67.9	27.8	1.103	2.238
T60K	4.383 (242)	6.689	23.8	51.8	26.9	1.180	1.801
TOTAL	**48.926 (3729)**	**89.526**		**66.5**		**12.510**	**23.456**

Note: ( ) – Number of production boreholes required (Column 13).

Note the higher density of geological structures (potential drill targets) along the western portion of the study area and extending towards the coast between the Mkozi River and Port St. Johns (**Figure 31**). Large portions of these areas are underlain by Ecca Shales, which will further enhance its development potential. However, a large proportion of these targets, especially in the T60E and T60B catchments, are inaccessible to drilling rigs. The Coastal Plateau is characterised by a lower density of structural drill targets, which are mostly accessible for exploration drilling.

The unadjusted 'mean' annual volume of abstractable groundwater (89.5x10^{6} m^{3}) for T60 drainage region is higher than Water Systems Management's (1999) equivalent exploitation potential (**Table 19**, col. 7). The 'accessibility' adjusted estimates of the <u>total volumes of groundwater</u> that can be <u>feasibly abstracted</u> from the T60 catchment are extremely low and reflect the present 'ad-hoc' approach to groundwater exploration in the Eastern Karoo Basin (**Chapter 8.2**) – ranging between <u>12.5 - 23.5 x 10^{6} m^{3}/annum</u>. Approximately 3.0x10^{6} m^{3}/annum of this groundwater is presently being utilised (**Chapter 10.0**). It is the author's opinion that, with an improved understanding of the occurrence of groundwater in the region and with the appropriate scientific exploration techniques, a far greater volume of groundwater could be abstracted on a sustainable basis from the study area via high-yielding boreholes. This is conservatively estimated at 62.0x10^{6} m^{3} per annum or a third of the lowest estimate of rainfall recharge. The groundwater quality is moderate to good (**Chapter 8.7**) and is not expected to place any restrictions on the development potential of the study area.

The spatial variability of the groundwater development potential in the T60 catchment is depicted in **Figure 32**, according to the following qualitative ranking system: inaccessible; low-, moderate-, high- and very high- development potential. The average groundwater development potential for each Quaternary catchment is presented in **Table 21**, scaled from low potential (≤ 1) to very high potential (> 3).

<u>Table 21</u>: Average Groundwater Development Potential between Quaternary Catchments

Quaternary Catchment	Average Groundwater Development Potential
T60A	1.64 (1.95)
T60B	1.74 (1.99)
T60C	1.14 (1.75)
T60D	2.15 (2.28)
T60E	1.79 (1.94)
T60F	1.74 (1.99)
T60G	1.34 (1.75)
T60H	1.98 (2.07)
T60J	1.48 (1.75)
T60K	1.32 (1.67)

Note: ( ) Bracketed Values, excludes areas of inaccessible terrain.
<u>Ranking</u>: ≤ 1 : Low 1 – 2 : Moderate 2 – 3 : High > 3 : Very High Potential

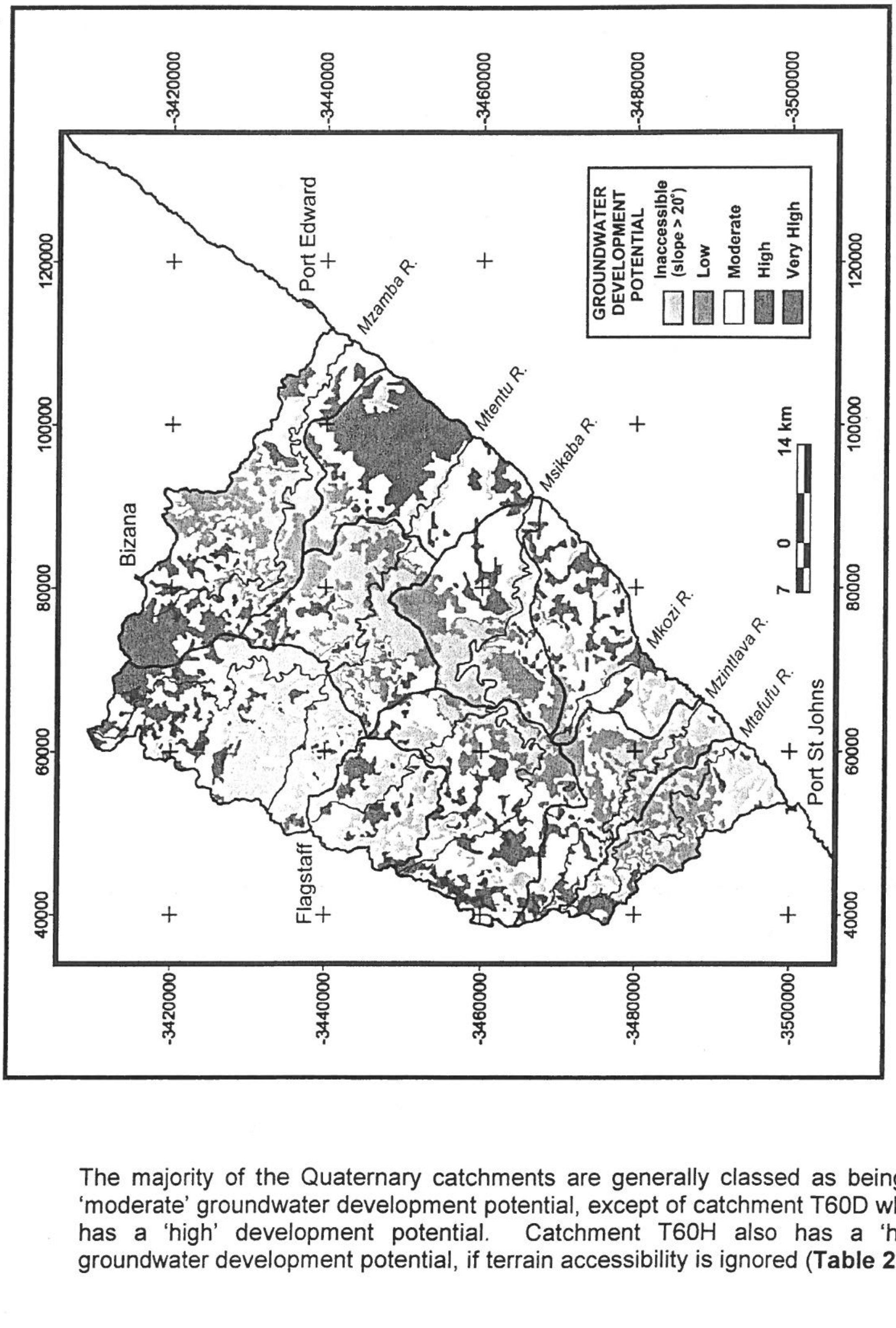

Figure 32: Groundwater Development Potential of the T60 drainage region

The majority of the Quaternary catchments are generally classed as being of 'moderate' groundwater development potential, except of catchment T60D which has a 'high' development potential. Catchment T60H also has a 'high' groundwater development potential, if terrain accessibility is ignored (**Table 21**).

The water-yielding capacity of boreholes have been categorised by DWAF, as part of its regional groundwater mapping programme, in terms of their development potential (**Table 22**)

Table 22: Borehole Development Potential according to Yield

Borehole Yield Range (l/s)	Description	Development Potential
> 3.0	High Yield	Suitable for supply of medium to large-scale water schemes supporting small towns and/or small to medium scale irrigation schemes.
> 0.5 - ≤ 3.0	Moderate Yield	Suitable for reticulation schemes for villages, clinics and schools.
> 0.1 - ≤ 0.5	Low Yield	Primary water supply abstracted using handpumps or windpumps for non-reticulated community and domestic / stock watering purposes.
≤ 0.1	Very Low	Suitable for marginal supply for domestic and domestic stock-watering only.

According to this classification, the majority of the boreholes in the T60 catchment can be described as 'low to moderate yielding', suitable only for non-reticulated and small-scale reticulated village supply.

11.4 COSTS OF GROUNDWATER DEVELOPMENT

The total cost of developing a groundwater resource is difficult to assess and will depend upon many factors, i.e. the required exploration technique(s), drilling-methods, drilling depth, borehole construction, borehole yields, water quality treatment, pump equipment, reticulation pipelines etc.

The cost of establishing and maintaining a groundwater supply scheme may, in certain parts of the T60 region, prove to be a factor limiting its development. The present groundwater development costs are relatively high in terms of the poor drilling success rates and low sustainable yields of the boreholes. The 'sustainability' of these water supplies are severely restricted by a lack of maintenance of the boreholes, pump equipment and reticulation networks. Furthermore, no groundwater monitoring or management programmes are put in place to ensure the long-term sustainability of the supply, which is crucial given the 'invisible' nature of the resource. The present ad-hoc nature of the existing groundwater supply 'schemes' makes it difficult to implement any feasible cost recovery systems, so urgently required to ensure a long-term self-sustaining water supply scheme. Cost reductions can be achieved through better integration of the groundwater development strategies within the overall strategic planning of the region's water resources.

A simple GIS raster-model was created to estimate the relative costs (R/m^3) of developing and abstracting groundwater within the study area, for the following exploitation scenarios:

(i) individual boreholes (≤ 0.5 l/s) to be equipped with windpumps or handpumps (*local supply scenario*), and
(ii) engine-driven borehole wellfields, with borehole yields in excess of 2.5 l/s (*regional supply scenario*).

The following raster-based (100x100m cell-size), GIS approach was applied to obtain groundwater development cost estimates for the T60 drainage region:

1. The percentage of 'dry' boreholes were estimated for each of the major lithological units (**Chapter 8.1.1**):

Msikaba Formation	± 15% (i.e. 1 in 6.6 boreholes are dry).
Dwyka Group	± 33%
Ecca Group	± 25%

2. The percentage of 'wet' boreholes yielding 2.5 l/s and more were estimated for the major lithological units (**Chapter 8.1.1**):

Msikaba Formation	± 10% (i.e. 1 in 10 boreholes yield ≥ 2.5 l/s)
Dwyka Group	± 25%
Ecca Group	± 20%

3. The number of exploration boreholes required per lithological unit to establish a single production borehole yielding ≥2.5 l/s was estimated using items 1 and 2 above:

Msikaba Formation	± 12 exploration boreholes
Dwyka Group	± 6 exploration boreholes
Ecca Group	± 4 exploration boreholes

4. The number of exploration boreholes required per lithological unit to establish a single production borehole yielding between 0.1 and 0.5 l/s were estimated:

Msikaba Formation	± 1.5 exploration boreholes.
Dwyka + Ecca Group	± 2 exploration boreholes.

5. The number of exploration boreholes required to establish a given production yield within each of the lithological units were adjusted to take into account areas of higher groundwater development potential (**Figure 32**). If a cell coincided with a zone of 'high' or 'very high' groundwater development potential then the number of exploration boreholes required was lowered by 1 or 2 boreholes, respectively. Likewise, the number of exploration boreholes required was increased by 1 if a cell coincided with a zone of 'low' potential.

6. An optimum drilling depth below the groundwater-level of 50m was estimated from **Figure 20**.

7. The 'regional groundwater-levels' in the study area were approximated by fitting a curved surface through all the cells in a 30x30m DEM which coincide with the course of a perennial river. The assumption being that the regional groundwater-level intersects the ground surface along the course of the perennial rivers, which accounts for the numerous springs along these rivers and the large base-flow component of the MAR.

8. The required borehole drilling depths were estimated by integrating the optimum drilling depth (item 6) with the 'regional groundwater-level' raster dataset (item 7).

9. The inaccessible portions, i.e. terrain with slopes in excess of 20°, of the study area were excluded from the analysis.

10. The costs of drilling an exploration borehole (diameter 165mm) to the required depth (Item 8) was estimated, assuming the following:
    - All boreholes are equipped with 18m of steel casing, costing R120/m.
    - Drilling costs of R110 per metre at depths of up to 80 m.bgl, increasing to R140/m over the depth range of 80 to 150m.bgl and R180/m for depths in excess of 150m.bgl.

11. The exploration costs (remote-sensing, field mapping, geophysical surveys etc.) were assumed to be in the order of R4 500 per exploration borehole.

12. The yield assessment costs (pump-testing and evaluation) were estimated at:
    - 0.5l/s Production borehole – R17 000 per production borehole.
    - 2.5l/s Production borehole – R24 000 per production borehole.

13. The total cost of establishing a production borehole of the required yield was estimated by integrating:

    [No. Expl. Boreholes (Item 4 & 5) x Drill Costs (Item 10)] + Exploration Costs (Item 11) + Yield Assessment Costs (Item 12)

14. The following pumping equipment and costs thereof were assumed:
    - 0.5 l/s Production Borehole: Windpump.
      * R20 000 - pumping head less than or equal to 120m.
      * R30 000 – pumping head greater 120m.
    - 2.5 l/s Production Borehole: Mono-pump and diesel engine.
      * R25 000 - pumping head less than or equal to 120m.
      * R37 000 – pumping head greater 120m.

15. The total 'capital' costs per production borehole were estimated by summing Items 13 + 14.

16. The annual maintenance costs were estimated as follows:
    [(Item 13) / 20 yrs] + [(Item 14) / 5 yrs]

17. The following 'operating' costs per production borehole were assumed:
    - Windpump – R0.10 per m^3 of groundwater abstracted.
    - Diesel Mono Pump – R2.00 per m^3 of groundwater abstracted.

    The operating cost of a diesel-engine pump was obtained from the average fuel and operator salary costs of 9 rural groundwater supply schemes in the Northern Cape Province (range R1.00 - 3.50/m^3). Similarly, an average cost of R0.68/m^3 was obtained from 4 village supply schemes, which use electrically driven pumps.

18. An average 'scheme life' of 20 years was assumed, with high-yielding and low-yielding production boreholes operating at 60% and 70%, respectively, of their maximum capacity on a continual basis (i.e. a 2.5 l/s production borehole pumping continuously at 1.5 l/s for 20 years).

19. The cost of developing groundwater (R/m^3) per exploitation scenario for the study area was estimated by integrating Items 15, 16, 17 and 18 (**Figures 33** and **34**).

This provides a first order estimate of the average 'costs' of developing the groundwater resources of the T60 catchment for regional water resources planning purposes. Note that reticulation costs have not been included. In general, it can be concluded that:

- The average cost of developing a cubic metre of groundwater is R2.18 (range R2.08 - 2.56) and R0.45 (range R0.35 – 0.84) for high- and low- yielding production borehole abstraction scenarios, respectively. In general, the cost of developing a high-yielding borehole is some 5 times greater than that of a low-yielding borehole.

- The cost of developing a low-yielding production borehole in the Msikaba Formation is uniformly low (R0.30-0.40/m^3) – **Figures 33** and **8**. In contrast, it is the most costly (R2.30-2.50/ m^3) lithological unit in which to develop high-yielding production boreholes (**Figure 34**).

- It is most costly to develop low-yielding production boreholes in the Dwyka rocks and heavily dissected areas underlain by Ecca shales (**Figure 33** and **8**). The Ecca and a large portion of the Dwyka rocks are more favourable for the development of high-yielding production boreholes (**Figure 34**).

- **Figure 35** indicates that it is 5 to 6 times more costly (red zone) to develop high-yielding production boreholes in the Msikaba sandstones than it is to develop low-yielding production boreholes.

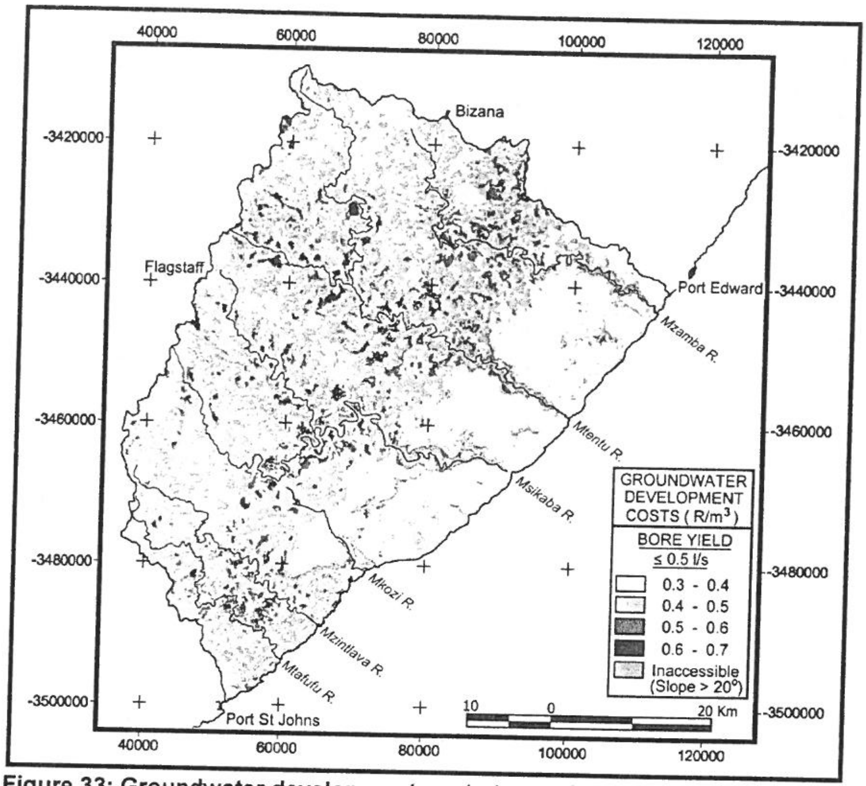

Figure 33: Groundwater development costs to establish a borehole yielding ≤ 0.5 l/s.

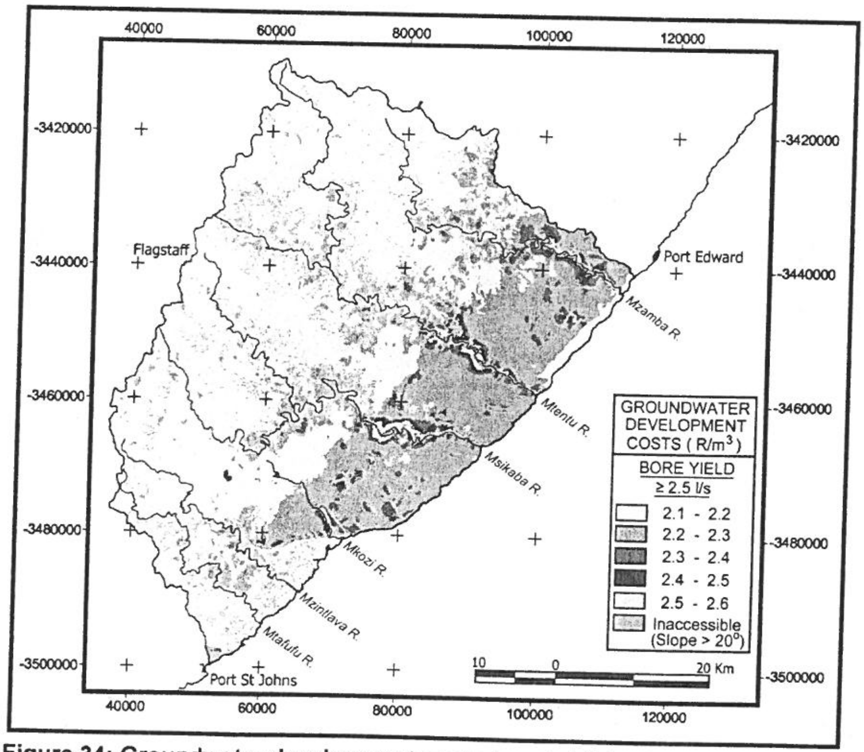

Figure 34: Groundwater development costs to establish a borehole yielding ≥ 2.5 l/s.

The average groundwater development costs for establishing high- and low-yielding production boreholes within each Quaternary catchment are summarised in **Table 23**, where it is evident that:

- It is more cost effective to develop low-yielding (< 0.5 l/s) rather than high-yielding (≥ 2.5 l/s) production boreholes in all catchments (**Figure 35**).
- The average cost of developing high- and low-yielding production boreholes does not vary significantly between the Quaternary catchments (i.e. R0.08).
- Individual, low-yielding production boreholes can be most cost effectively developed in catchments T60H and T60D.
- Wellfields of high-yielding production boreholes can be most cost effectively developed in catchments T60B, T60E and T60F.
- Catchments T60D and T60H should receive the highest priority for groundwater development, due to their high groundwater potential and reasonable development costs.
- Catchment T60C has the lowest groundwater development potential due mainly to the rugged terrain and predominance of Dwyka rocks.

Note that, although the above cost estimates indicate that it is some 5 times more costly to develop high-yielding production boreholes, there would be significant long-term 'savings', not accounted for in these estimates, related to the design (reticulation), operation, maintenance, monitoring and management of such abstraction schemes or wellfields.

The groundwater resources of the T60 basin should be developed within existing or as an integral part of future surface-water supply schemes, where they can be utilised to:

- augment supplies during droughts / floods (emergency-standby role),
- to span periods of peak water demand (intermittent usage), or
- to gradually increase the capacity of the scheme (continuous usage).

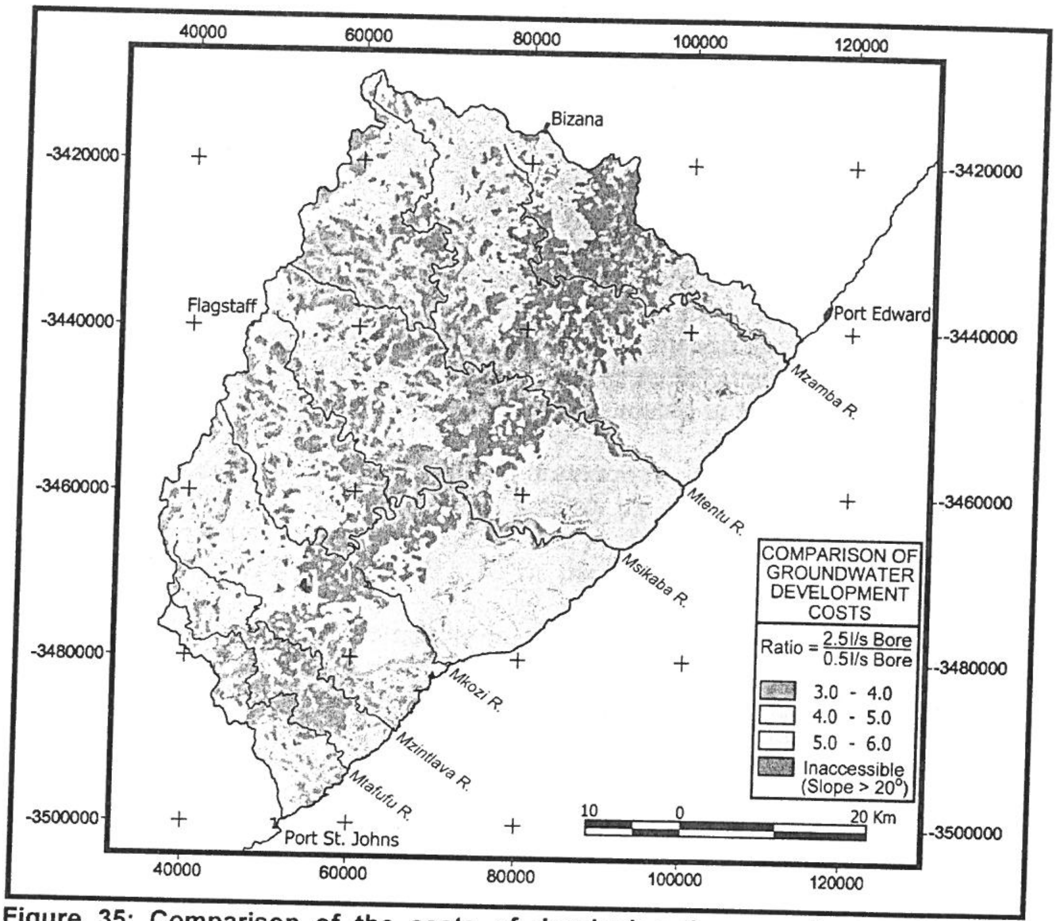

Figure 35: Comparison of the costs of developing the groundwater resources using 2.5 l/s and 0.5 l/s production boreholes (i.e. ratio of Figures 34/33).

Table 23: Comparison of groundwater development potential and costs between Quaternary Catchments for establishing (i) low-yielding and (ii) high-yielding production boreholes

Quaternary Catchment	Groundwater Development Potential[A]	Single Borehole [$Q \leq 0.5$ l/s] (R/m^3)	Wellfield [$Q \geq 2.5$ l/s] (R/m^3)
T60A	1.64	0.46	2.18
T60B	1.74	0.45	2.13
T60C	1.14	0.48	2.17
T60D	2.15	0.40	2.24
T60E	1.79	0.45	2.13
T60F	1.74	0.45	2.14
T60G	1.34	0.46	2.22
T60H	1.98	0.41	2.23
T60J	1.48	0.45	2.15
T60K	1.32	0.46	2.15

Notes:
[A] – Average Groundwater Development Potential from **Table 21**.

12.0 CONCLUSION AND RECOMMENDATIONS

Groundwater in the T60 drainage region occurs mainly in shallow, weathered-fractured rock aquifers, where the average depth to the waterlevel is 15 metres below the ground surface. Borehole yields are generally higher in the Ecca shales and associated Karoo dolerite sills, while boreholes in the Dwyka rocks are low-yielding. Limited drilling evidence tends to indicate that, contrary to expectations, borehole yields in the Msikaba sandstone are low. There are indications of a deeper-seated, artesian aquifer system containing saline water. A number of semi- to unconsolidated, sandy primary aquifers of limited extent are likely to occur along the major river courses, especially towards the river-mouths and in estuaries. High borehole yields are anticipated at favourable locations.

The groundwater resources of the T60 drainage region are only being utilised at a fraction of their true potential, both actively via boreholes and passively from perennial springs or ephemeral seeps. The present groundwater consumption in the study area is estimated at 3.0×10^6 m^3 per annum.

In general, the groundwater quality is good and is suitable for domestic water supply purposes, although local variability is anticipated. Local point source pollution of the groundwater is likely in densely populated areas, due to anthropogenic activities, resulting in elevated nitrate levels and faecal bacterial counts.

The groundwater resources of the study area, as indicated by rainwater recharge, are high - in the order of $280\text{x}10^6$ m^3 per annum. However, much of this groundwater is 'lost' as base-flow to the many perennial rivers draining the T60 catchment, particularly during the dry season.

Presently, the low permeability of the shallow aquifers and the inaccessibility of the terrain limit the groundwater development potential of the T60 basin to between 12.5 - $23.5\text{x}10^6$ m^3 per annum. With the drilling of deeper and higher yielding production boreholes, it will be possible to abstract between 50.0 - $90.0\text{x}10^6$ m^3/year on a sustainable basis. The costs of exploring and developing such groundwater-supply schemes will be considerably higher (x5) than the existing 'ad-hoc', low-yielding groundwater supply 'schemes'. This will require Water Planners to re-assess groundwater's role within the overall strategy to develop the water resources of the region. The sustainability of these schemes will depend upon establishing appropriate groundwater monitoring and management programmes, which are to a large extent funded by revenue generated by the scheme itself. Lack of maintenance is the main cause of many water-supply schemes failing to deliver, rather than the groundwater 'drying-up'.

The following recommendations are made to improve the development and sustainable utilisation of the groundwater resources of the T60 drainage region:

- The development of the groundwater resources of the region should receive a high priority when compared to alternative sources, as it represents a ubiquitous, sustainable, relatively inexpensive and good quality source of water. In this regard, the following Quaternary catchments should be prioritised in their order of listing: T60D, T60H, T60E, T60F and T60B.
- Identification of high-yielding perennial springs and determining ways to incorporate them into the more 'formal' water-supply schemes (which includes protection from direct and indirect contamination).
- The many low-yielding springs and ephemeral seeps which emanate along the slopes of incised river gorges and along the rivers-banks – should be 'tapped' collectively using suitably located weirs along minor drainage tributaries.
- Springs are often not considered suitable for development as a water supply, because of their yield variability. In this regard, both direct and indirect methods of discerning between perennial springs and ephemeral seeps needs to be investigated.
- Research into the nature and mode of groundwater occurrence in the eastern Karoo Basin is required and should be formulated within the region's broader water resources planning.
- The general quality and detailed chemistry of the groundwaters in the T60 region are unknown – this issue should be addressed as part of a regional development plan.
- Prior to any groundwater exploration programme it important that a proper inventory of abandoned boreholes be carried out to assess the possibility of rehabilitating 'dry', but previously successful boreholes.
- The practical application and cost effectiveness of new remote-sensing and geophysical techniques should be assessed to improve borehole drilling success rates.
- Drilling success rates can be greatly improved by making use of 'hydraulic-fracturing' techniques on marginal yielding or "dry" boreholes. These methods have been shown to increase the yield of marginal boreholes by up to 300%. Low-yielding boreholes (<0.1 l/s) can thus be brought in production rather than abandoned.
- Stricter enforcement of existing guidelines and technical specifications for sanitary borehole construction and spring protection should be applied.

- Deeper exploration drilling, involving borehole depths of 250-300m, along selected regional geological structures should be considered with the aim of developing wellfields of high-yielding production boreholes as part of existing and future water supply schemes. In this regard, the groundwater potential of the Msikaba sandstone needs to be re-assessed – it is the authors opinion that this formation has a significantly higher potential than presently indicated.

- Implementation of appropriate maintenance, monitoring and management programmes for all groundwater supply schemes, which are initially operated by suitably qualified personal for a limited period of time (i.e. two years). Such a project team should consist of a hydrogeologist, civil engineer, technicians and locally based operators and foremen. The advantages of this approach are:

  1. Cost effective, sustainable and safe supplies of water for domestic use in these previously disadvantaged and remote areas.

  2. Expensive infrastructure installed by the Government will be properly managed and maintained.

  3. Scarce groundwater resources will be properly monitored and managed to ensure there long term sustainable utilisation.

  4. Previously disadvantaged communities will be empowered by:

     (a) the employment and training of community members as scheme operators and foremen,
     (b) the attendance of bi-annual management meetings by the Local Councils and their CEO's,
     (c) the holding of awareness and training workshops in the communities, and
     (d) District Councils and other Interested and Affected Parties can, at the same time, be informed and made aware of the need for the proper management and sustainable utilisation of scarce groundwater resources and expensive infrastructure.

  A successful working example of such a project is the Department of Housing and Local Government of the Northern Cape Province's management and monitoring programme of water supply schemes and groundwater resources in the rural areas of Namaqualand and Mier.

- A regional groundwater monitoring-programme should also be instituted to assess the *ambien*t waterlevel and water quality trends, away from the major groundwater supply-schemes. This data, along with that gathered at the local groundwater supply schemes, will provide more quantitative information on the aquifer dynamics (groundwater flow, recharge) and ultimately the sustainable yield of these resources.

APPENDIX 1

TERMS OF REFERENCE

LUSIKISIKI BASIN STUDY

TERMS OF REFERENCE

1. Background

Lusikisiki magisterial district is located in the most north-eastern, coastal part of the Wild Coast District of the Eastern Cape Province (formerly part of Transkei). This area is also known as the Pondoland coast and includes all river catchments between the Mntafufu and Mzamba Rivers (tertiary drainage region T600).

The introduction of the RDP water supply programme has resulted in the identification of the need in many instances for substantial augmentation of the domestic water supply schemes serving the large rural population in the region. In particular, water resources with adequate yield assurance are required for the upgrading of the water supply to the Lusikisiki magisterial district (213 000 people). The Wild Coast Spatial Development Programme has identified forestry and tourism as the drivers for economic development in the area. Agricultural developments for the production of sugar cane and tea may be viable. Furthermore, the riverine systems and the estuaries of the rivers in the area are in pristine condition. The Mkambati Nature Reserve (Msikaba River estuary) and the entire Pondoland coast are extremely environmentally sensitive. These are national assets and attractions for tourists.

The surface water resources in the area are largely under-utilised. Groundwater may have a potential for cost efficient water supply in certain areas of the district. Conjunctive use of run-of river and ground water may be economically viable in other areas. The economic viability of hydropower generation in the case of construction of dams in the area has not been investigated.

In general, the knowledge level about the water resources in the Pondoland area as well as many other Transkei catchments is very limited. In order to provide a planning tool for the sustainable development and efficient utilisation of the water resources in the area, it is recommended that a basin study be conducted. Such a study will further the aim of bringing the level of available information for the Transkei region in line with the rest of the catchments in South Africa. This study will also contribute valuable information for the establishment of a water management area and a catchment strategy as stipulated by the new Water Act.

The results of the study will be useful for other Government Departments and interested parties for the planning of various development initiatives.

2. Purpose of the Study

The study area is defined as the coastal river catchments between the Mntafufu and Mzamba Rivers (see attached locality map).

The study will provide a broad evaluation of the current state and the potential for development of the water resources in the area, as well as the present and potential water requirements for all user sectors. The Msikaba River catchment within which Lusikisiki lies will be given more detailed attention. Particular attention will be given to establishing the environmental water requirements for the Mkambati Nature Reserve which lies on the estuary of the Msikaba River.

A more specific output of the basin study will be a clear indication at a pre-feasibility level of detail, of a preferred source for augmentation of the domestic supply for the town of Lusikisiki and the surrounding rural areas as well as a recommendation for an implementation programme.

3. Proposed Scope of Work

The following activities are recommended to be undertaken during the course of this study (levels of detail – pre-feasibility for Msikaba River catchment and reconnaissance for the rest of the area) :

3.1 Background Information

- Assemble, collate and present in a suitable form existing information on the study area: climate, topography, demographics and socio-economic development, current and planned land use, institutional and legal aspects, natural resources, etc.
- Assessment of the accuracy and completeness of the existing information. Identification of gaps and further information required.
- Limited verification and patching of information, where necessary.

3.2 Domestic water supply situation

- Population and livestock distribution, present levels of service where this is known, existing projects and projects in process of implementation.
- Population growth and proposed future levels of service.
- Area planning and possible grouping of schemes.

3.3 Existing infrastructure

Existing road, rail and electricity infrastructure will be described. A description of the existing major water supply infrastructure, its operational condition and upgradability will be provided.

3.4 Agricultural developments and afforestation

- In general, this is to be limited to a broad overview of possible developments with reference to the effect of these developments on the runoff and water requirements. For the Msikaba catchment a more detailed assessment is required.
- Determine the extent of existing developments. Document all available information on development potential and identify information gaps. Study and review all development programmes proposed for the area (Wild Coast Spatial Development Initiative, for instance). Assess the feasibility of future developments taking into account available water resources, economic development potential and financial constraints. The assessment should include the effects of dryland farming, irrigation and commercial livestock farming as well as the effects of afforestation (planted forests) and invasive forests.

3.5 Water requirements

- Present and future water use by the various user sectors is to be assessed. Historical water use information should be presented where available and of use for future projections.
- Urban and industrial.
- Rural, domestic and livestock.
- Agricultural developments and afforestation.
- Hydropower generation (desktop evaluation of potential, feasibility and flows, only for proposed dams).
- Environmental and social requirements (the Reserve). IFR's are to be expressed as a percentage of natural annual flows.

3.6 Runoff hydrology, surface water resources and yield analysis

- In general the water resources assessments will be done primarily on the basis of WR90.
- In the case of the Msikaba River, the existing flow data collected by the former DAF of Transkei and by the DWAF prior to Transkei independence in 1968 will be reviewed, and if feasible will be used to determine more accurate Pitman Model parameters than obtainable from WR90. If flow records within the catchment are unsatisfactory then it may be necessary to calibrate a Pitman model for the catchment by making use of flow records for adjacent catchments and cross correlation.

Historical firm yield analysis will be applied for the calculation of the yields of proposed dams. Long term stochastic yield may be considered as an option.

- Floods for proposed dams and river abstractions will be estimated on the basis of TR137 for Msikaba River only.

3.7 Groundwater resources

- Studies for assessments of availability and assurance of groundwater resources will be undertaken on the basis of readily available information (borehole database) and previous experience in the area.
- A more detailed investigation may be required for the Lusikisiki water supply area only. The occurrence of aquifers, fractured rock and faults may have to be identified.

3.8 Reconciliation of supply and demand

- An assessment of the water balance in each catchment at 10 year intervals for the period until 2030 is to be undertaken and presented in a suitable form.

3.9 Water quality, sedimentation and return flows

- The river catchments of the study area are not presently included in any of the water quality monitoring systems and databases (HIS and POLMAN).
- Unless a monitoring programme is established by DWAF as a matter of priority then the consultant will be required to arrange that water samples from specific sites be tested during the course of the study and that the results be documented.
- Available sedimentation mapping and any other information on sedimentation such as the extent of erosion in the various catchments will be documented. This information will be used to predict the rate of sediment accumulation in new dams.
- The effect of return flows in the area is limited. Available information will be documented.

3.10 Development options for water supply to the Lusikisiki area

The various development options for the supply of water to Lusikisiki and surrounding villages are to be identified and described. This will involve:

- Review of previously identified schemes.
- Review, grouping and area planning.
- Shortlisting of options utilising all applicable criteria (technical feasibility, social and environmental acceptability, institutional and

operational viability, phased implementation, labour intensive construction, cost etc.)

3.11 Selection of preferred development option

- Conceptual design and sizing of competitive options, based on approved sizing criteria.
- Topographic surveys where required.
- Costing on the basis of cost models and cost functions agreed upon with the client. Recurrent annual costs will be calculated for each option.
- Economic evaluation will be done on the basis of discounted present cost and the unit reference value (URV) of water supplied by each option. The URV will be calculated for a period of time and discount rate as agreed with the client.
- A sensitivity analysis for various discount rates will be performed.

3.12 Environmental aspects

The purpose of this investigation will be to identify problematic areas and to provide a broad idea of the instream flow requirements for the rivers and the estuaries, to establish the river flows necessary to satisfy basic human needs and to provide a broad estimate of the Reserve. In the case of the Msikaba River a more detailed assessment of these water requirements is required. Results will be based on a desk study, existing information and limited site visits. No workshops are envisaged for this stage.

- Broad classification of rivers (possibly a group classification if rivers are similar).
- Broad estimate of the IFR for each river and estuary (based on D. Hughes planning estimate method) expressed as a percentage of the natural annual runoff.
- Assessment will be based on the Integrated Environmental Management (IEM) procedures as prescribed by the Environmental Conservation Act (1989) and more specifically the Regulations gazetted on 5 September 1998.
- More detailed assessment of the IFR and the Reserve for the Msikaba River (including its estuary) and the Mkambati Nature Reserve and of the impacts related to possible water resources developments for the Lusikisiki area will be undertaken. This could include assessment of the Preliminary Reserve as defined in the new Water Act and a scoping exercise to provide a broad assessment of the impacts of the more favourable dams identified.

3.13 Social aspects

For the schemes identified in the study the following will be established:

- Estimate number of people directly or indirectly affected by the developments.
- Estimate potential health and safety hazards.
- Estimate extent and value of physical assets that will be lost as a result of the development.
- Investigate and estimate the cost of mitigation measures.

3.14 Public involvement and community liaison

Public involvement and community liaison will be performed from the commencement of the study through the formation of a Stakeholders Liaison Committee. All affected communities and interested parties will be informed of the proposed developments and their inputs invited.