5 CONCLUSION AND RECOMMENDATIONS

Good successes were obtained by employing methods suggested by Taylor, Dijon, Larrson (1981) and other authors. Potentially high yielding sites were identified at positions where shear zones could be identified and where recharge should be optimal. Thereafter drilling positions were pin-pointed at positions in the field where jointing is most prominent. During this project boreholes were mostly sited by geological interpretation and field mapping and little geophysical work was done.

The high fluoride values are however characteristic of granitic areas. It was therefore accepted that the ground water from the granite had a high fluoride content and that the high nitrogen content can be solved by better sanitation practices. Solutions to the fluoride problem can also be found, and if possible the most practical solution should be domestic, self sustainable and easy-to-use.

5.1. DRILLING OF NEW BOREHOLES

Most of the boreholes drilled, were drilled into hard rock granite covered with a thin layer of alluvium or colluvium and a thin weathered layer. Casing was installed at average depths of 12 to 18 metres. Major water strikes were recorded at an average depth of 69 metres with an average yield of 2.25 litres per second. Boreholes sited on major joint sets had striking depths of 100 metres and deeper.

Penetration rates in shear zones are much higher than those next to the shear zones where jointing is not as prominent. At surface it may seem as if the joints are in a compressive stress regime but at depth it seems as if the stress regime changes and the compressive stress lessens with the joints being more open. Due to the fact that this phenomena can not fully be identified with normal percussion drilling it was decided to drill a core borehole.

One core borehole was completed and preliminary results confirm that the jointing is vertical and little horizontal faulting could be identified. Shearing planes could be identified and secondary mineralization could also be identified and this confirms the theory that the joints tend to be more open at depth. To speculate on the theory why the granites tend to be in a less compressive stress field in depth is not appropriate at this stage.

5.2 PUMP TESTING

The boreholes were all evaluated according to the Rule of Thumb method, the Recovery method and the FC_Method. Generally the boreholes have a poor recovery and the calculations were done on extrapolated recovery periods (Table 12).

Table 12. Sustainable Yields

Regional Borehole number	PHYS	S.W.L. (m)	Pump depth (m)	Blow yield (l/s)	Production recommendation (l/s @ 24hrs)			
					Rule of thumb	Recovery	F.C-method	Average
H06 0881	1	7.5	45	4.1	1.58	1.13	1.38	1.36
H06 0882(A)	4	2.35	27	6	2.97	0.35	3.89	2.4
H06 0882(B)	4	1.69	32	3	1.65	-	2.35	1.85
H06 1043(A)	4	3.25	45	3	0.55	-	1.68	1.12
H06 1043(B)	4	3.58	68	3	-	-	0.3	0.3
H06 0907	5	2.43	56	1.8	0.4	0.31	0.65	0.45
H06 0910(A)	7	2.05	60	25	-	0.6	1.69	1.15
H06 0910(B)	7	3.63	86	25	-	0.9	1.95	1.43
H06 1028	10	5.48	64	3	0.64	0.66	0.28	0.53
H06 1496	11	2.43	96	3	0.39	0.39	0.32	0.37
H06 1038	14	10.28	93	36	2.4	1.1	1.11	1.54
H06 1448	19	22.6	58	3.6	1.4	1.25	0.51	1.05
H06 1049	20	3.2	64	12	1.11	-	1.25	1.18
H06 1054	21	0	80	6	3.81	3.82	2.49	3.37
H06 1420	22	11.68	46	3.6	1.21	1.21	1.33	1.25

The static water level is quite close to the surface except for borehole H06 1448. This borehole was drilled into a weathered aquifer and sited on a geophysical anomaly. It is suspected that the borehole's geohydrological conditions differ from the boreholes situated on the fractures.

All the boreholes had blow yields ranging from 1.8 to 36 l/s, and with little exception all the boreholes had a much lower constant discharge. The average blow yield was 8.6 l/s and the average constant discharge rate was 4.8 l/s. The recommended yield for sustainable use, is much lower with an average recommended yield of 1.3 l/s. The average recommended yield is 85 % less than the average blow yield and 73 % less than the constant discharge. Therefore no conclusions can be made using the blow yields or even the constant discharge rate. For example borehole H06-1038 had a very high blow yield of 36 l/s, but due to the poor recovery could only be recommended for sustainable yield of 1.54 l/s, which is only 4.3 % of the measured blow yield.

5.3 AQUIFER TYPES IDENTIFIED

According to the pump test results, taking into account the blow yield, recommended yield and the geology, three major aquifer types could be identified:

1) Fractured aquifers associated with major structures.
2) Fracture aquifers associated with dykes.
3) Weathered aquifers resulting from weathering of major structures.

5.3.1 Fractured aquifers associated with major structures.

Boreholes H06-1043, -0907, -1054, and -1420 were drilled in this aquifer type. The aquifer is typically a major structure not associated with dykes and could not be identified with simple geophysical techniques. These boreholes had an average blow yield of 3.6 l/s and an average recommended yield of 1.5 l/s, almost 42% of the measured blow yield. Borehole H06-1054 is an artesian well with a yield of 0.5 l/s, and recovered in 10 minutes and have a recommended yield of 3.37 l/s, almost 56 % of the measured blow yield. Boreholes sited only on structural geological mapping and which did not intersect any dolerite, generally had a better recovery than those boreholes which intersected doleritic material. Borehole H06-1420 could be fitted on a leaky aquifer or recharge boundary. An T-early value of 14.79 and a T-late value of 7.64 were calculated. An very low S-value of 10^{-5} were estimated. The FC-method was used to calculate T-values and estimate the S-value. The S-value estimation could be wrong.

5.3.2 Fractured aquifers associated with dyke material.

It may be difficult to identify these aquifers by geophysical means, although they are associated with intrusions. The boreholes situated on these aquifers are H06-1038, -0910 and -1049 associated with dykes and H06-1496 associated with the plate like dyke intrusion. These boreholes tend to have excellent blow yields especially those associated with the dykes, with an average blow yield of 24 l/s. The average recommended yield, however is 1.38 l/s, only 6% of the measured blow yield. The recovery period for these boreholes is poor, indicating a poor S-value. H06-1038 could be fitted on a barrier boundary or a typical fractures de-watered curve. It had a T-early of 9.80 and a T-late of 3.5, with an estimated S-value of 10^{-3}.

5.3.3 Weathered aquifers resulted from the weathering of major structures.

These aquifers can be located with the aid of geophysics and were identified during the geophysical investigation. Boreholes associated with the weathering due to structural features include H06-0881, -0882, -1448 and -1028. Generally these boreholes had a fair recovery with good recommended yields. The four boreholes had an average blow yield of 4.18 l/s and an average recommended yield of 1.34 l/s. These boreholes therefore had an average recommended yield of 32% of the measured blow yield. The boreholes also had a fair recovery indicating a marginal S-value. H06-0882 could be fitted on an unconfined delayed yield or double porosity aquifer. It had a T-early of 100.46 and a T-late of 28.80 with an estimate S-value of 10^{-4}.

5.4 CHEMICAL ANALYSIS

There is some correlation between the aquifer type and water quality. The aquifer types associated with fracturing and little weathering tend to have higher fluoride values. The lower fluoride values in the weathered aquifers may be attributed to the ion absorption capacity of the clays in the weathered material where the fluoride is absorbed by the clay minerals.

5.5 WATER BALANCE

A water balance model based on recharge was designed to give the end user a management guideline on the aquifer use. However, to get a workable answer certain assumptions were made and to demonstrate the influence or sensitivity of the parameters two scenarios were investigated. Firstly, looking at a more conservative scenario using Vegters' very low recharge value and a low MAP and in the second scenario more favourable conditions with much higher recharge and MAP values were used (Table 13).

Table 13. Assumptions made during calculations of water balance.

Influence factor	Scenario 1	Scenario 2
Average width of Ngwaritsi channel (m)	10	5
Effective hydraulic conductivity between river and aquifer (m/d)	0.001	0.001
Δd wet season (m) - Figure 11	0.5	2
Δd dry season (m) - Figure 11	-5	-2
Dry season days (days)	275	180
Wet season days (days)	90	185
Mean annual rainfall (mm)	519	720
Recharge (%)	2.31	4
Evapotranspiration (m^3/y)	-200000	-100000
Outflow to springs (m^3/y)	-200000	-100000
Outflow to weir (m^3/y)	-200000	-100000
Number of Hand pumps at 0.1 l/s	20	20
Number of Motorised pumps at 1.0 l/s	10	10

The effective hydraulic conductivity between the river and the aquifer was taken as an estimate and the average width of the Ngwaritsi River was estimated.

It is estimated that there are approximately 20 hand pumps, yielding 0.1 l/s for 24 hours, therefore abstracting 63 000 m^3 /y. It is also estimated that there are 10 motorised pumps, yielding 1 l/s for 24 hours, abstracting 315 000 m^3 /y. The total abstraction will then be in the order of 378 000 m^3 /y.

According to Scenario 1 there are 128 000 m^3/y remaining in the study area (aquifer) which can support 40 additional hand pumps or 4 additional motorised pumps. If the more favourable scenario is taken into account 1 300 000 m^3/y are still available and an additional 41 motorised pumps can be supported.

The value of the ground water can also be calculated. If the estimated cost of an alternative surface water supply source is R10.00/m^3 and the cost of the ground water supply is R3.00/m^3, the value of the ground water can be calculated as the difference in cost multiplied by the volume abstracted. Therefor if a total of 506 000 m^3/y is abstracted, the value of the ground water can be estimated at almost R 3 500 000 per year.