

REPUBLIC OF BOTSWANA



MINISTRY OF MINERAL RESOURCES AND WATER AFFAIRS

DEPARTMENT OF WATER AFFAIRS

**CONSOLIDATED EMERGENCY  
WATER SUPPLY PROGRAMME**

**GROUP I VILLAGES**

**Seolwane, Tobane, Mogapi,**

**Kgagodi / Mogapinyana,**

**Diloro**

**FINAL REPORT**

**Volume I**

**March 1989**



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## SUMMARY

The project has been undertaken as part of the Consolidated Emergency Village Water Supply Programme instituted and supervised by the Department of Water Affairs. The five study villages, designated Group I, are Seolwane, Tobane, Mogapi, Kgagodi/Mogapinyana and Diloru in Central District, Botswana. Each of these villages currently have inadequate water supplies and a number of investigations to identify new groundwater resources have previously been undertaken with minimal success.

The study has examined the present supply situation in each village and has completed geophysical surveys and exploratory drilling and testpumping programmes in order to locate and evaluate new groundwater sources to satisfy a projected ten year (1998) water demand. The overall approach to the study has been much more flexible than during any previous investigation and considerable success has been achieved. New sources have been located within relatively close proximity for the villages of Seolwane and Tobane and an area having sufficient potential for a wellfield-type development has been identified as a suitable source of supply for Kgagodi/Mogapinyana, Diloru and Mogapi by more substantial pipeline water transfer. Evaluation of the groundwater resource and recommendations for its development have also been made in relation to each new potential source.

This report incorporates the results of the hydrogeological studies for the Group I villages of Seolwane, Tobane, Mogapi and Kgagodi/Mogapinyana/Diloru. Each village or village group is discussed separately and recommendations for future development made.

The report is presented in three volumes. Volume I comprises the main report, Volume II an album of maps, site plans and data analysis plots and Volume III the project data base.

**SECTION I**

## 1. INTRODUCTION

Under the auspices of the Consolidated Emergency Village Water Programme (C.E.P) initiated in early 1988 by the Department of Water Affairs, a number of local specialist Consultancy Companies have been engaged to undertake groundwater resources evaluation studies for rural village water supply purposes. Each consultant has been allocated a group of five villages in the same geographical area and has been given the task of identifying and supervising the development of adequate water supplies for present and future village demand. This should be either a localised individual village source or collectively as a village group via piped water transfer from a more distant source. The projected planning horizon for development purposes has been taken as 10 years (1998).

The approach envisaged by the Department of Water Affairs to the problems of rural village water supply is one of flexibility, especially in the more difficult groundwater areas. As such the consultants are expected to examine all possible alternatives and not be solely limited to the search areas for new supply points. Such an approach will therefore also involve the re-evaluation of existing sources such that optimum utilization of a scarce resource is achieved.

The five Group I villages allocated to Wellfield Consulting Services Pty Ltd (WCS) are situated northeast of Palapye in Central District. They are Seolwane, Tobane, Kgagodi/Mogapinyana and Diloru. The general programme proposed in the Terms of Reference for the study was a short Desk Study resulting in an Inception Report, to be followed by a field geophysical investigation phase and resultant exploratory drilling and aquifer testing activities. Thus, following contract signing at the end of May 1988, a detailed Inception Report presenting all available data relating to the five villages indicated above and formulating a field programme strategy was presented to Department of Water Affairs by the end of June 1988. The time schedule of the proposed study programme as presented in the Inception Report is indicated in Fig I.1. This programme was discussed with and agreed by the Department of Water Affairs and the field investigations began in July 1988. The study was substantially completed by December 1988.

Of particular significance is that the Inception Report proposed the grouping of the villages of Mogapi, Kgagodi / Mogapinyana and Diloru into a single study unit due, substantially, to the failure of previous village - specific investigations. During the course of the present project however, it has been found more appropriate to divide the above mentioned villages into two study units. This has resulted in a reporting format comprising four village groupings - Seolwane, Tobane, Mogapi and Kgagodi / Mogapinyana / Diloru.

This report (3 volumes) thus presents the study results and recommended groundwater development strategies related to the C.E.P. Group I villages of Seolwane, Tobane, Mogapi, Mogapinyana / Kgagodi / Diloru.

ACTIVITIES AND MANPOWER ALLOCATIONS

	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
Mobilisation																						
Seolwane																						
Tobane																						
Mogapi, Mogapinyana - Diloru																						
Borehole Drilling & Construction																						
Test Pumping Supervision																						
Progress Report (PR)			PR		PR		PR		PR		PR			PR			PR					
Draft Report																						
Final Report																						
<u>Personnel Schedule</u>																						
J.L. Farr (Project Leader)																						
R. Gumirehete (Team Leader)																						
K. Laletsang (Junior Consultant)																						
M. Mabe (Junior Consultant)																						

(from Inception Report, June 1988)

SECTION II

## GENERAL DESCRIPTION OF THE PROJECT AREA

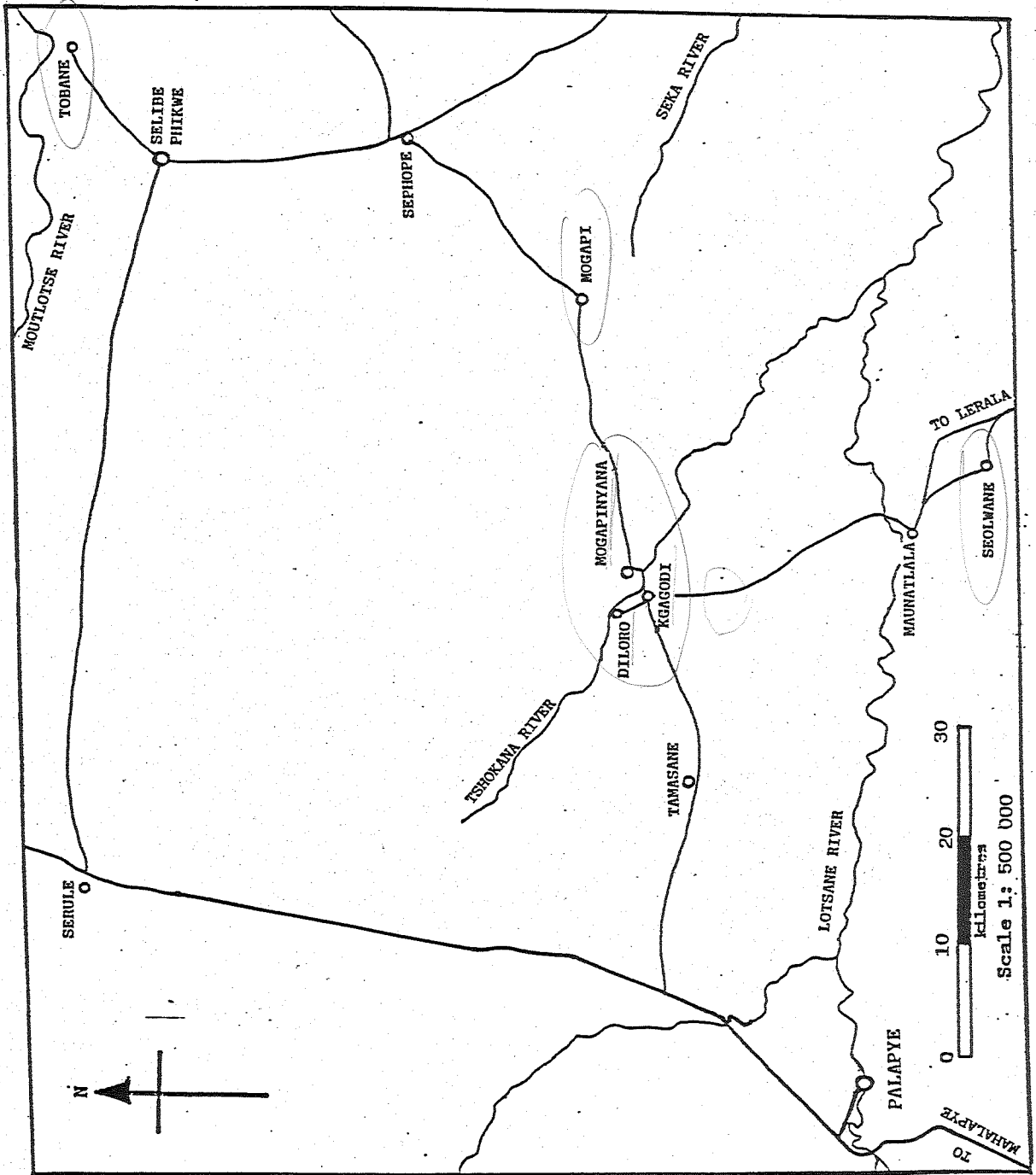
### 1. Location

The five villages of Seolwane, Tobane, Mogapi, Mogapinyana /Kgagodi and Diloru are situated to the northeast of Palapye in Central District, some 270 kilometres north of Gaborone. A main gravel road runs northeast through the area, connecting Palapye with Sefophe (89 kms) and hence by tar road to Selibe Phikwe (28 kms) and Bobonong (48 kms). Three of the villages, Mogapi, Mogapinyana / Kgagodi and Diloru are situated along this gravel road. Seolwane lies approximately 32 kilometres to the south of Mogapinyana / Kgagodi on a poor gravel/sand road while Tobane lies some 16 kilometres on a good gravel road to the north east of Selibe Phikwe adjacent to the Motloutse River. The distance between the two most outlying villages (Seolwane and Tobane) is approximately 116 kilometres, while the distance from Mogapinyana / Kgagodi to the regional centre of Palapye is 80 kilometres.

The disposition of the Group One villages in relation to other regional localities and access routes is indicated on Map II.1.

### 2. Physiography

The study area encompassing all the five villages is situated some 200 kilometres to the east of the main Kalahari Basin watershed with regional topographic gradient being gently southeastwards towards the Limpopo River valley. Within the area the topography is broadly undulating with kopjies and inselbergs forming isolated elevations on the wide pediment surfaces of the interfluvial areas between the Motloutse River and its tributaries in the north and the Lotsane River and its tributaries in the south. General elevations are in the range of 853 metres above mean sea level. The area is bordered to the south by the higher elevations of the Tswapong Hills, the ridges of which trend northwest / southeast and form a much more rugged topography some 300 - 400 metres above the level of the general plain.



2-2  
*[Handwritten signature]*

Regional Location Map

Rainfall in the area is highly seasonal, falling mainly during the months of October to March and averaging 400 millimetres per annum. Areal variation is small and rainfall events usually occur as localised, high intensity short duration storms. Mean annual temperature across the area is around 21°C with a low in winter (July - Aug) and a high of 31°C in summer (Dec to Jan).

The area is bordered to the north and to the south by two major easterly flowing drainage systems. In the north there is the Motloutse with its main tributaries, the Letlhakane and the Thune, and in the south the Lotsane and its main tributary, the Tshokana. Both systems are ephemeral and only flow under high rainfall conditions into the Limpopo to the east. Major drainage directions generally transect regional geological trends and are as a result of superimposition from an earlier erosion surface.

Four phases of morphological evolution have been recognised (Key 1978). The summit levels of the Tswapong Hills in the south are regarded as outliers of the African (or Early Tertiary) cycle. Evidence of an earlier cycle is given by the almost constant height of the kopjies and inselbergs rising from the relatively featureless plain, which is itself a part of the extensive Late Tertiary peneplain of eastern Botswana. A polycyclic Quaternary phase is confined to the drainage courses of the area.

### 3. Regional Development

#### 3.1 Economic Activities

Botswana by tradition rely mainly for income on cattle rearing and to a lesser extent on crop farming. However, arable farming is generally on a subsistence level with only a small number of farmers selling surplus sorghum and millet to the Botswana Agricultural Marketing Board. Arable farming areas are usually located some distance from the villages and are restricted to well fenced fields with crop production being limited to the higher rainfall season and being exclusively rainfed. Unfortunately no soil conservation methods are practised and much soil is lost by erosion exacerbated by overgrazing in the dry season. Such occurrence is especially prevalent in the valley areas where most of the better farming land is situated.

Cattle rearing, from which most of the regions' rural income is derived, is undertaken in the traditional cattle post style. Such cattle posts are widely scattered over the area with cattle being grazed freely and supplied with water from water points (wells or boreholes) usually adjacent to the cattle kraals themselves. In the specific study areas numerous cattle posts are located at Kgophathata, 16 kilometres south-west of Mogapi, where cattle are watered from seasonal handdug wells along the Kgophathata and Tshokana Rivers.

Industrial and commercial activities are concentrated in the main regional centres of Palapye and Selibe Phikwe, although a certain amount of general retail trading does take place in a number of the larger villages of the area.

### 3.2 Population Distribution

The region is fairly well populated in comparison with much of the rest of Botswana. Large population concentrations are located in the regional centres of Palapye and Selibe Phikwe with the remainder of the population living in the numerous villages of the region. Population distribution does, to a degree, vary seasonally with a movement of people from the smaller villages to the arable lands during the growing season. The population of the larger villages is, however, rather more static due to the existence of government services and institutions such as schools, clinics and district authority offices. All the specific study villages have primary schools and clinics. A secondary school exists at Mogapi and a new secondary school is planned at Kgagodi / Mogapinyana under the Central Government's accelerated schools building programme.

Population data for the specific study villages has been obtained from the 1981 National Census and percentage growth calculated over the ten year period from the previous census (1971). Such growth rates have been used to estimate current (1988) and future (1998) population figures and, on a 30l/day/person basis, the present and future water demands for the villages. This data is summarised in Table II.1.

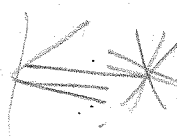


TABLE II.1

POPULATION AND WATER REQUIREMENTS

VILLAGE	1981 CENSUS	% INCREASE SINCE 1971	ESTIMATED POPULATION 1988	ESTIMATED DAILY WATER DEMAND (1988) (cu. metre)	ESTIMATED POPULATION 1998	ESTIMATED DAILY WATER DEMAND (1998) (cu. metre)
MOGAPI	1089	+ 190	2216	66.5	3707	111.2
MOGAPINYANA	596	+ 362	2251	67.5	7411	222.3
KGAGODI	933	+ 86	1939	58.2	2895	86.9
SEOLWANE	521	+ 331	1200	36.0	5666	170.0
TOBANE	696	+ 93	834	25.0	2261	67.8
* DILORO	186	+ 40	194	5.8	276	8.3

\* No data available for Diloro

\* 40% increase since 1971 was assumed as an average for similar - sized villages eg Mokokwane.

#### 4. Existing Water Resources

As stated previously (Section 2) all rivers in the region are ephemeral and hence no permanent surface water sources exist. The town of Selibe Phikwe is, however, supplied from the distant Shashe Dam by pipeline and a few smaller centres, such as Mmadinare, draw supplies from the major sand river storage of the Motloutse River.

The primary source of water for the population of the region is groundwater. Villages, dependent on their size, are supplied from groundwater either on a single borehole basis or by small reticulation systems fed by one or several boreholes. The more scattered rural population and some of the very small settlements draw water from individual boreholes or handdug wells sunk in shallow, waterberg valley deposits. These latter are highly susceptible to failure during extended dry periods causing considerable hardship to their dependent human and animal population.

A comprehensive inventory of present water sources and a general evaluation of the groundwater regime of the specific study villages is contained in the following sections.

#### 5. General Project Methodology

The investigation techniques used during the course of the project and which applied to each of the individual study villages either in their entirety or partly, are briefly outlined below. Detailed discussion of their application and results on a village by village basis is contained in Sections III - VI of this report.

##### 5.1 Desk Study

This work comprised study of aerial photography, topographic maps, geophysical maps and satellite imageries, borehole data and reports of previous work. Aerial photographs in particular were examined and structural features of hydrogeological significance were mapped. Initial target areas demarcated for detailed field survey for each of the villages were thus selected.

## 5.2 Field Geophysical Survey

The following geophysical methods were utilised during the course of the Project:

### i) Magnetic Traversing

The traverses were run using a Geometrics G816 proton precision magnetometer with a vertical staff mounted sensor 2 metres off the ground. Generally station intervals were 10 metres, although a few lines were run at 20 metre intervals. Since the traverse lines were short and usually isolated from each other no base station readings were collected and hence no base correction to the total magnetic field carried out. Interpretation of the traverses was restricted to that of quantitative analyses only. Magnetic anomalies were further investigated by either an electromagnetic (EM) or a resistivity profiling survey, or both.

### ii) Electromagnetic Traversing

This work was undertaken using a 3.6 kHz single frequency horizontal loop Slingram portable unit. The transmitter-to-receiver separation was 60 metres, giving a penetration depth of about 30 metres below surface. Both In-phase (IP) and Out-phase (OP) quadrature readings were collected along the entire length of the traverse lines, most usually at 20 metre station intervals.

The aim of the EM survey was to discriminate between conductive and non-conductive zones at some 30 metre depth below surface. These zones were quantitatively interpreted from IP/OP profiles.

### iii) Resistivity Profiling

The resistivity traversing was carried out using a C.S.I.R 250 watt resistivity set. AB/2 spacing of 50 - 100 metres at a station interval of 10 metres was used to locate thick aquifers and to intercept fracture zones at depth. The apparent resistivity data was qualitatively analysed from the profiles.

#### iv) Vertical Electrical Sounding

The soundings were carried out at search sites of particular interest identified by magnetics and resistivity profiling. A Schlumberger array, expanding to a maximum AB/2 spacing of 500 metres, was employed to undertake surveys using the same resistivity set as above. The sounding curves were quantitatively interpreted by a discrete layer model programme operated in the field on a Hewlett Packard HP85 computer. Interpretations were further refined in the office on a Hewlett Packard HP9816 computer using the same ABEM programme as on the HP85.

### 5.3 Drilling and Testpumping Supervision

During the period of both the exploratory drilling and aquifer testing phases of the project, the contractors concerned were under the full time supervision of a qualified consultant. The purpose of this supervision was to instruct the contractors on the nature of the data to be collected during the respective operations and to ensure its accuracy and completeness. Data gathered during the drilling phase was of particular importance and was used by the on-site supervisor to determine the most appropriate exploratory borehole design such that successful sites could in future be utilized as production boreholes without the requirement for re-drilling. A discussion of drilling and testing methodology and its results is contained in Sections III - VI on a village by village basis.

SECTION III

SEOLVALE

## 1. Geology and Structure

The geology of the Seolwane area has been mapped by Jones (1966) and subsequently revised by Key (1977). Seolwane village is situated on the northern edge of the Tswapong Hills and the underlying geology comprises undifferentiated pink-grey gneisses. This unit extends for a considerable distance to the northeast but immediately to the southwest forms a major faulted contact with the overlying Palapye Group Formation (Lechana Fault Zone). South and west of the village a thick sandy alluvium has developed at the foot of the Tswapong Hills, grading into a scree and boulder alluvium immediately adjacent to the hill slopes. The Tswapong Hills themselves are composed of units of the Middle Precambrian Palapye Group of metasediments which form pronounced elevations and steep hill scarps. Intruded into all bedrock formations are a number of Post-Palapye Group mafic dykes. Table III.1 below indicates the geological sequence present in the area and a formation by formation lithological description follows.

TABLE III.1

<u>Age</u>	<u>Group</u>	<u>Formation</u>	<u>Brief Lithology</u>
Quaternary	-	-	Scree (Off Palapye Group)
"	-	-	Silty/Sandy Alluvium
"	-	-	Calcrete
Middle Precambrian	Palapye	Lotsane	Purplish siltstones and sandy shales
"	Palapye	Tswapong	Purplish red ferruginous quartzites
"	Palapye	Moeng	Grey, purplish and red shales with mica
"	Palapye	Selika	Massive poorly bedded ferruginous quartzite and minor conglomerates
Archean	(Basement)	G1 to G4	Undifferentiated gneisses with banding defined either by compositional layering, layered amphiboles and hornblende plagioclase

## The Archean Basement

The undifferentiated gneisses belong to the Limpopo Mobile belt system of rocks and these are commonly referred to as "The Basement Complex". This has been divided into a group of para-gneisses and ortho-gneisses. The former includes magnetic-quartzite and various para-gneisses. The ortho-gneisses consist of mafic to ultramafic intrusions and intrusive granitic rocks, concordant amphibolite bands are very common. Epidote, chlorite and quartz veins infill the abundant fractures.

The Basement has been subjected to several generations of folding and faulting. Re-activation of some of the deformation probably gave rise to Palapye Group faulting systems.

## The Middle Precambrian Palapye Group

The Palapye Group has been subdivided into four formations as listed in Table III.1. The Selika and Tswapong Formations are predominantly arenaceous and the Moeng and Lotsane Formations are essentially argillaceous in character.

### Selika Formation

This unit comprises massive, poorly bedded ferruginous quartzites with quartz conglomerates. The formation outcrops south of Tswapong Hills.

### Moeng Formation

The Moeng Formation is composed of a sequence of soft brown, grey, red and purple shales, micaceous siltstones, thin limestones and minor quartzites. Although this sequence does not outcrop in the area borehole BH 5940 intercepted it at 14 m depth.

### Tswapong Formation

This formation, which overlies the Moeng Formation, outcrops in the east central and south-western portions of the area. It consists of a sequence of quartzites, conglomerates, grits and sandstones with a thin ironstone band near the base. The sequence tends towards a coarse grained ferruginous quartzite at its base.

### Lotsane Formation

This formation, which partially overlies the Tswapong Formation but oversteps onto the Basement Complex is developed to the west of Tamasane village. Outcrops are rare and most of the information has been derived from borehole data and road excavations. The unit consists of purplish, micaceous sandstone, siltstone and sandy shale. In general the formation becomes more sandy to the north west.

### Quaternary Deposits

These are the youngest deposits in the area. They include calcrete, sandy alluvium and scree (gravel and boulders) derived from Palapye Group Formations. Calcrete has been mapped north east of Seolwane at the confluence of Seolwane River and two minor streams. Sandy alluvium underlies most of the low land around the Tswapong Hills and the streams emanating from the hills. A considerable thickness of this material has been encountered along fault zones south west of Seolwane village in borehole numbers BH 5941 and BH 5943. Scree forms a very narrow restricted belt along the Tswapong Hill escarpment.

Archean Basement units in the Seolwane area exhibit an approximate north-south linear fabric which most probably reflects a regional D2 formation (Key 1977). This deformation produced major north-south trending synformal folds plunging southwards at shallow angles, later deformed by open asymmetric D3 folding on north-west - south-west trends. Palapye Group metasediments form an overlapping series of west-north-west, east-south-east striking units younging to the north-west and truncated on their northerly margin by the major regional Lechana Fault. Deformation and minor folding within the Palapye Group is thought to be as a result of such faulting. Prevailing fault attitudes in the area are north-west and south-east and most faults appear as shears, either original or reactivated. It is such shears and their intersections which have been regarded as primary groundwater targets (Inception Report, June 1988).

## 2. Hydrogeology

The groundwater potential of the Seolwane area has previously been investigated by Aqua Tech Groundwater Consultants (Aqua Tech 1985) and by Department of Water Affairs (DWA 1986). Under these programmes water supply boreholes were provided for the nearby villages of Mokokwane and Maunatlala. The area also falls within the scope of a regional hydrogeology study of the Palapye Group Formations currently being carried out by the Dept. of Water Affairs. During the period, 1985 - 87, two boreholes (BH 3784 and BH 2189) have also been cleaned and tested by DWA.

The hydrogeological environment of the area is one of secondary aquifers created by fracturing and fissuring with permeability enhanced by weathering processes. No primary aquifers exist except for the Quaternary alluvial and scree deposits at the foot of the Tswapong Hills. Groundwater levels in the basement formations are relatively shallow (less than 30m b.g.l.) and indicate a regional piezometric gradient in a northeasterly direction towards the Lotsane River. The Palapye Group metasediments of the Tswapong Hills form a surface and groundwater divide and local hydraulic gradients are steep. Groundwater emerges at a number of localities from these units in the form of springs. The village of Mokokwane some 5 kilometres west of Seolwane, has historically utilized such a water source. Recharge to the groundwater body clearly occurs over the Tswapong Hills and will influence the longterm resources of the shallow alluvial aquifers. It is less likely, however, to have any effect on the fractured Basement aquifers which will largely depend upon local replenishment via the uppermost weathered zone during periods of high precipitation.

Abstraction potential as assessed from existing borehole data indicates yields up to 12m<sup>3</sup>/hr in the Seolwane area, which is considerably greater than the regional potential of 3.5 m<sup>3</sup>/hr indicated on Hydrogeological Reconnaissance Map, Sheet 8. This is most likely as a result of significant contributions from the alluvial aquifers in the area.

### 3. Hydrochemistry

Only a limited number of historical analyses are available for groundwater in the Seolwane area and none pertain to boreholes in Seolwane itself. Additional groundwater samples were collected during the field activities phase of the present programme, both from existing boreholes and from boreholes drilled and tested during the programme. Unfortunately, very little of this new analytical data has become available by the completion of the project. Discussion of the groundwater chemistry of the Seolwane area is therefore limited to general comments related to the suitability of the water for human and animal consumption.

Groundwater in the area around Seolwane may be classified as Na-Mg-HCO<sub>3</sub>-Cl water, having low electrical conductivity, low dissolved solids and medium/low total hardness. It has previously been stated (Aquatech 1985) that water from some boreholes in the Seolwane area is unpotable due to high iron and high sulphate contents but this statement is not substantiated from available analytical data. Sulphate content appears to be very low (less than 3 mg/l) and iron content is well within the generally accepted limit (0.3 mg/l) at which precipitation and staining occurs. In terms of potability both fluoride and chloride are within acceptable limits and historical data for nitrate leads to similar conclusions. Information concerning nitrate content from recently drilled boreholes (Boreholes BH 5940 and BH 5942) does, however, indicate elevated nitrate levels (up to 34 mg/l). These particular samples were, however, taken during drilling and higher nitrate levels are most probably a function of water or other materials introduced during the drilling process.

Hydrochemical data thus indicate that groundwater in the Seolwane area is suitable for human consumption. Individual sources should, however, be checked for bacteriological contamination prior to and during usage.

Data pertaining to the groundwater chemistry of the Seolwane area is included as ~~Table 1, Appendix 3, Volume III~~ of this report.

in Section 3, Volume II p. 3.26

#### 4. Existing Groundwater Exploitation

Data compiled for the Inception Report (June 1988) revealed the presence of at least 10 boreholes in and around Seolwane village. Four boreholes were reported dry when drilled and the remainder were reported to yield between 2 and 12m<sup>3</sup>/hr. During the course of the project all such boreholes have been visited and it has been established that only one borehole (BH 3493) is currently supplying the village of Seolwane. Indications are that this borehole is badly silted and has a much reduced yield and that a second supply borehole (BH 3784) at Makgabo is also unusable due to siltation problems. Records of all boreholes in the Seolwane area are contained in ~~Volume III~~ of this report.

*Section 3, Volume II p. 3,30*

Clearly, the village of Seolwane is suffering from a shortage of water largely as a result of existing borehole failure rather than a total lack of groundwater resources. Future water demand estimates (Section II,3) indicate a requirement of 170 m<sup>3</sup>/day in 1998. From existing knowledge this demand should be able to be satisfied by the location and adequate installation of 2 - 3 new boreholes each yielding some 5 m<sup>3</sup>/hr (on a 12 hour pumping day). Such requirements thus constituted the exploration programme target yield.

A point of note is that despite the apparently reasonable yields of boreholes in the Seolwane area considerable difficulty has been experienced with continuity of supply. It is believed that this is largely as a result of inadequate borehole construction which has failed to cope with the fine, often unconsolidated, alluvial aquifers, resulting in borehole siltation and collapse. Such difficulties are discussed in detail in paragraph 6.

## 5. Project Survey Programme

### 5.1 Target Identification

Target areas are selected on the basis of existing knowledge of hydrogeological conditions and structural interpretations from aerial photographs. Photographs used were obtained from Dept. of Surveys and Lands, Motloutse and North East block: 1:50000 scale, 1981/82 Series, Strip Mot B 35, Nos 128 - 133 and Strip Mot B 36, Nos 29 - 32. These photographs are panchromatic black and white and give stereo coverage of the search area around Seolwane. Structural trends and drainage patterns, both active and abandoned, were identified and tonal and textural variations on the photographs enabled the extent of the alluvial deposits at the foot of the Tswapong Hills to be discerned. Of particular interest were fracture intersections as these may constitute sites of enhanced weathering.

(Vol II, p. 1.1)

All geological (and aerial photograph data was compiled on Map III.1 and six target areas were initially selected for field geophysical investigation. (Inception Report June 1988) Three target areas are located on the northern edge of the Tswapong Hills and three areas are located on the Basement to the north of the Lechana Fault Zone. (Map III.2, Vol II, p. 1.2)

### 5.2 Geophysical Surveys

The following section contains a brief area by area description of geophysical work undertaken. Interpreted survey data and profiles are contained in Volume II Section 2 and raw data in Volume III. Site location plans are included in Volume II Section 1.

Target Area 1: (Site Plan III.3, Vol II, p. 1.3)

This target area has previously been investigated by Aqua Tech Groundwater Consultants (Aqua Tech 1985.) The area forms an intersection point of several fault zones. Borehole BH 3784, sited by Aqua Tech, was estimated to yield 12 m<sup>3</sup>/hr during drilling. The magnetic traverse lines 1/1 and 1/2, were run to magnetic anomaly and traverse line 1 was further investigated with resistivity depth soundings SE01 to SE015. (Vol II, p. 2.1, 2.2)

SE 0 11

The soundings indicated the absence of the gravel aquifer penetrated by borehole BH 3784. Clayey gravels or shales were indicated to be very shallow, not more than 10 metres below surface.

*could you provide a visual reference?*

*Soundings and*

*geological reference*

**Target Area 2:** (Site Plan III.4) (Vol II, p. 14)

This area is located west of Seolwane and is near Gomosweu village. A fault intersection was mapped in this area. The two magnetic traverse lines 21 and 22 revealed magnetic anomalies. The two anomalies were interpreted to indicate two faults trending east-west and north-south. A resistivity profiling survey (Profile No. 21) across the north-south fault indicated a significant apparent resistivity change from 45 to over 100 ohm metres and ~~two~~ resistivity probes were conducted to determine the depth of the weathering profile within the fault zone (SEO211 and SEO212). Depth probe SEO211 indicated clayey gravel to a depth of 52 metres. However, the third layer of resistivity of 95 ohm metres and thickness of 13 metres was interpreted to indicate reduced silt content. The basal resistivity of 5109 ohm metres was interpreted to be the Basement Complex. Probe SEO212 indicated 20 metres of high resistivity first, second, third and fourth layers. The fifth and the sixth layers were interpreted to be the aquifer within a fractured ~~substrum~~ Basement Complex.

*(Vol II, p. 2.9)*

*(Vol II, p. 2.2, 2.3)*

*see next page and BH profile*

**Target Area 3:** (Site Plan III.5) (Vol II, p. 45)

The area is located around Seolwane village, at the foot of the Tswapong Hills. An intersection of the Lechana Fault Zone and an east-west trending fault was mapped in the village. Two magnetic lines were run across the faults and close to the existing borehole BH 3493 and an old abandoned borehole near the primary school. (Traverse lines 32 and 31). These two lines were aimed at locating the faults and to determine the magnetic signature of the aquifers penetrated by the old boreholes. A reference resistivity sounding (SEO521) was carried out close to borehole BH 3493. It indicated shallow, low resistivity, (3 ohm metres), alluvial deposits underlain by a layer of resistivity of 26 ohm metres which was interpreted to indicate clayey gravels. Resistivity profiling across the faults indicated a low resistivity layer along the fault zone. (Profile No 32). The zone was further investigated by additional resistivity depth probes. Probes SEO321 to SEO325 indicated a clayey gravel aquifer close to Tswapong Hills. Very low resistivity lenses, interpreted as clays, made it difficult to interpret absolute thicknesses.

*(Vol II, p. 2.8)*

*(Vol II, p. 2.12)*

*(Vol II, p. 2.4, 2.5)*

Target Area 2? 3?

The same aquifer unit was also investigated west of the village. Magnetic traverse line 32 was run parallel to a DWA water pipeline from Makgabo borehole (BH 3487) to the village. A broad diffuse magnetic anomaly was delineated over a large area (line 30). To establish a better understanding resistivity profiling was conducted across the broad anomaly. (Vol II, p 2.10)

The results were a rapidly changing resistivity from station to station (Profile No 30). Two depth probes were carried out at low resistivity points which were interpreted to be highly weathered fractures within a fracture zone. Probe SEO302 indicated a high resistivity superficial cover of 30 metres thickness underlain by a 62 ohm metre resistivity layer of 60 metres thickness. (Vol II, p 2.11)

The fifth layer was interpreted to indicate an aquiferous unit of scree and the weathered material overlying the basement complex of resistivity of 922 ohm metres. The second probe was difficult to interpret because the points were scattered probably as a result of lateral lithological inhomogeneity. (Vol II, p. 2.3)

#### Target Area 4: (Site Plan III.6) (Vol II p. 1.6)

The area is located north-east of the village close to the Maunatlala - Lerala main road. Three photo-lineaments were identified with an intersection close to the Seolwane River, which itself appears to be structurally controlled. Magnetic and resistivity profiling traverses were run across the faults. (Traverse No. 41 and Profile No 41). These were aimed at locating weathered and fractured zones below the superficial calcrete cover. A magnetic anomaly, interpreted to be caused by a faulted lithological boundary, was delineated close to the Seolwane River. The resistivity profiling traverse revealed a minor low resistivity area south of the magnetic anomaly. Four resistivity depth probes SEO411 to SEO414 were carried out across the resistivity anomaly. Generally all the probes indicated a maximum of 15 metres of weathering. No additional fracturing below the weathered zone was apparent from the resistivity profile. (Vol II, p 2.10, 2.12)

### 5.3 Drilling Site Selection

The sites selected for exploratory drilling are discussed below in order of their prioritized potential. (Vol II, p 2.5, 2.6)

Drilling Site Priority 1 (BH 5940)

(Target Area 2,) (Site Plan III.4) Vol II, p 1.4)

The site is located about 3 km from Seolwane along the road to Goomosweu village. Probe SEO212 was pegged for drilling. The site is situated close to the Tswapong Hills on an alluvial area overlying faulted gneisses. (Vol II, p 2.3)

From the geophysical survey the site geology was interpreted as follows:

<u>Depth (m)</u>	<u>Geology</u>
0 - 1	dry sand
1 - 5	clayey sand
5 - 20	scree (gravel / boulders)
20 - 34	clayey gravel / boulders
34 - 87	weathered gneiss / clayey sand
87 -	Basement Complex gneiss

Probe SEO302 (Vol II, p 2.3) indicated a similar sequence and as a result this site was also pegged as priority 1 site. 2

A relatively shallow water strike was anticipated in the gravel / boulder units and certain drilling difficulties were expected as a result. The main aquifer is formed by the weathered gneiss. The borehole was recommended to be drilled to a depth of 100 metres.

Drilling Site Priority 2

(Target Area 3) (Site Plan III.5) Vol II p 1.5)

The site is located 1 kilometre south of the village and it is about 800 m east of borehole BH 3493. The site was pegged on resistivity probe SEO325 which was sited on an alluvial fan overlying the faulted boundary between the Tswapong Formation and Basement Complex gneisses. The Lechana Fault Zone and an east-west trending fault intersect in this area. The expected geology of the borehole is as follows: (Vol II p 2.5)

<u>Depth (m)</u>	<u>Geology</u>
0 - 1	dry sand
1 - 4	clayey sand
4 - 5	clay
5 - 22	scree (gravel / boulders)
22 - 99	shales / siltstones
99 -	fractured gneisses

A shallow water strike was expected in the gravel / boulder unit and as a result drilling difficulties were anticipated. The main aquifer is formed by the siltstone / fractured gneiss. The borehole was recommended to be drilled to a depth of 100 m.

### Drilling Site Priority 3

(Target Area 1) Site Plan III.3) *Vol II, p. 1.3*)

The site is located 8 km east of the village near Makgabo borehole, BH 3487. Probe SEO11<sup>v</sup> was pegged and it indicated a 64 ohm metre resistivity 4th layer overlain by 9 metres of sand and gravel. Water strike was anticipated in the 4th layer. The substratum of 528 ohm metres was interpreted to indicated fractured gneisses. The borehole was expected to penetrate through the geology tabulated below: *(Vol II p. 2.1)*

<u>Depth (m)</u>	<u>Geology</u>
0 - 1	wet sand (surface water)
1 - 3	gravel
3 - 9	sand
9 - 46	silty sand (shales?)
46 -	fractured gneiss or fractured quartzites

Relatively shallow water strike was anticipated in the silty sand layer, with the main aquifer being formed by the fractured gneiss. No drilling problems were expected on this site. The borehole was recommended to be drilled to a depth of 80 m.

#### Drilling Site Priority 4

(Target Area 3) (Site Plan III.5X Vol II p.1.5)

The site is located 2.5 kilometres west of the village and close to the DWA water pipeline from Makgabo borehole (BH 3487) to the village. Probe SE031<sup>17</sup> was conducted on a magnetic high and was intended to investigate the nature of the same aquifer penetrated by borehole BH 3493 which is close to the village. The exploratory borehole was expected to penetrate the following geology: (Vol II p. 2.3)

<u>Depth (m)</u>	<u>Geology</u>
0 - 3	dry sand
3 - 53	sand
53 - 87	sandy gravel
87 -	gneisses

Water strike was anticipated in the sand layer. This particular site was chosen as a lower priority alternative site and was recommended to be drilled to a depth of 100 metres.

## 6. Groundwater Exploration

### 6.1 Drilling

Exploratory drilling works in the Seolwane area were undertaken by TGB Drill Contractors using conventional rotary percussion techniques. A total of 5 boreholes (numbers BH 5940 - BH 5944) were attempted although drilling difficulties in the alluvial materials caused four of these to be either abandoned or inadequately completed. The summary results of the exploratory drilling programme are indicated in Table III.2 and III.3 and complete borehole data (lithological logs and construction plans) and ~~DWA completion certificates~~ <sup>and</sup> is included in Volume II, Section 3. A brief site by site description indicating any pertinent hydrogeological observations or drilling problems follows.

#### Drilling Site Priority 1, Target Area 2 (BH 5940)

The borehole was drilled at 216 mm diameter to 55 m and at 166 mm from 55 m to the terminal depth at 150 m. A comparison of the expected geology and formation thicknesses, interpreted from the depth sounding SEO212, to the actual geology deduced from drilling samples is given in Table III.3. <sup>and in Vol. II, p. 3.1.</sup>

It was expected from the depth sounding (SEO212) <sup>(Vol II, p 2.3)</sup> that water would be encountered within a 50 metre thick layer of weathered and fractured gneiss (Section 5.3 above). However, the aquiferous zone was identified from the drilling results as a 16 metre thick weathered dolerite. This was, however, overlain by 40 metres of shale which completely masked the weathered dolerite in the interpretation of the depth sounding and thus resulted in an anomalous estimate of individual thicknesses.

#### Drilling Site Priority 4, Target Area 3 (BH 5941 and BH 5943)

BH 5941 was drilled at 216 mm diameter down to 36 m from surface, followed by 165 mm diameter from 36 m to 39 m. The presence of viscous flowing mud and clays at 6m - 7m and at 35m - 36m resulted in so much caving in of the borehole that in the end any further conventional drilling had to be abandoned.

The Odex continuous casing drilling technique was then attempted at a fresh site, BH 5943, which was pegged 10 m away from and to the west of the abandoned BH 5941.

BH 5943 was Odex drilled at 216 mm diameter through the first 52 metres and 166 mm diameter from 52m to 120m, the terminal depth. In spite of it having been drilled to the terminal depth, BH 5943 was, however, certified incomplete in construction and development. This was the result of the fact that during the drilling the welding between the bottom-most length of the casing broke away from the rest of the string at 39m. The unconsolidated formation between 39m and 52m was therefore uncased. Hence the caving of the borehole between 40m and 52m could not be checked.

The 9 metre and 15 metre thick layers of sandy gravels at 10m and 52m respectively, were not identified on the depth sounding SEO325 (Table III.3). The same sounding failed to discriminate the 15m sandy gravels from the 20m thick sandstones just above the gneisses. The combined 35m thick layer of sandy gravel / sandstones is the aquifer. The presence of the ground water in the formation masks any specific apparent resistivity signature of the two component aquifer formations. *A graphical comparison of geophysics and drilling results is given in Vol II, p. 2.5*

#### Drilling Site Priority 3, Target Area 1 (BH 5944)

Instead of this borehole being drilled at the exact site of probe SEO11, it was drilled 4m to the south of the Makgabo borehole (BH 3784). The Makgabo borehole registered an air-lift yield of 12m<sup>3</sup>/hr at 18m below surface when it was drilled four years ago. On the basis of an already known potential yield and the existence of an intact pump engine house and piping to Seolwane village adjacent to the site, it was decided that BH 5944 should be drilled near BH 3784, instead of probe site SEO11. *(Vol II p 2.1)*

BH 3784 and site SEO11 are both in the same valley, are about 100m to the north of the Tswapong Hills and are close to the Makgabo stream. BH 3784 is about 100m to the west of site SEO11. Hence the geology of the two sites could be expected to be very similar to each other.

BH 5944 was Odex drilled at 216mm diameter to 31m, which is the terminal depth of the borehole. The entire string of Odex drill tools, which comprised the pilot bit, a reamer, vice guide, and Odex shoe, were lost in the borehole at 31m. When attempts to fish out the tools were unsuccessful, drilling was abandoned. By then 10m<sup>3</sup>/hr of water had been struck at 22m and plain and slotted casing were thus installed.

In the interpretation of the geology, Table III.3<sup>and Vol II, p 3.5,</sup> the 3m thick aquifer which is made up of sands, clays and pebbles was too thin to have been discriminated from the depth soundings. 2

#### Drilling Site Priority 2, Target Area 3 (BH 5942)

In anticipation of possible drilling difficulties BH 5942 was Odex drilled at 216 mm diameter to 30 metres. The 4.5 m<sup>3</sup>/hr of water which was struck at 12 m as well as a sequence of viscous and flowing clays and mud which had been intersected from 19m onwards, were sealed off by the plain 203mm diameter Odex casing. In order to restore the flow of the water into the borehole the Odex casing was pulled up by 4m to 26m. In turn a string of 12m plain 127mm plus 18m slotted casing was installed from surface to the bottom within the outer 203mm diameter casing. However this construction could not handle the ingress of flowing muds into the borehole. In order to prevent the loss of drilling tools the hole was thus eventually abandoned at 30m depth.

Due to the nature of the formation, no representative sludge samples were collected and thus no formation logs for BH 5942 are indicated in Table III.3. However a sample was collected for sieve analysis and the plot is included in Volume II, Section 3.

#### Discussion of Drilling Results

At an early stage of the programme and following the examination of pre-existing borehole data, the question of the most appropriate drilling method in Seolwane area was discussed with the Client. A suitable borehole construction and a technique utilizing stiff foam during drilling was proposed by the Consultant and in principle, agreed by the Client. Unfortunately it proved impossible at short notice to vary the drilling contract specifications to accommodate this.

The Contractor (TGB) did, however, suggest and have available ODEX equipment and this drilling method was thus approved by the Client. However, in the geological environment encountered, this technique also proved inadequate and a number of holes were thus classed as incomplete for production purposes. Nevertheless, the estimated (airlift) yield from the two boreholes which may possibly be utilized for village supply (BH No's 5940 and 5944) totals 13.5 m<sup>3</sup>/hr, which is considerably in excess of the projected demand of 7 m<sup>3</sup>/hr (170m<sup>3</sup>/day) indicated on Table III.1. Suitable reconstruction of these holes with the knowledge of geological conditions and in order to provide for their longevity is, however, desirable.

## 6.2 Aquifer Testing

The nature of the aquiferous units at Seolwane created considerable drilling difficulty and only one borehole was successfully completed to recommended depth (see 6.1 above). From exploration borehole airlift yield data it is apparent that sufficient groundwater does exist in the vicinity of Seolwane to satisfy projected demand. However, since the exploratory boreholes were inadequately constructed both in terms of satisfactory completion and basic design (see Section 8 - Development Recommendations) it was concluded that a controlled aquifer testing exercise at this stage would be unwarranted. Testing should rather be undertaken when properly designed and completed production boreholes have been installed in order to define aquifer parameters and determine optimum abstraction potential.

SEOLMANE SUMMARY OF EXPLORATORY DRILLING RESULTS

TABLE III.2

TARGET AREA	DRILLING SITE PRIORITY (sounding number)	DRILLING CONTRACTOR	BOREHOLE NO	TERMINAL DEPTH (metre)	1ST WATER STRIKE (metre)	MAX AIRLIFT YIELD (cu. metre / hour)	STATIC WATER LEVEL (metre)
2	1 (seo 212)	tgb	5940	150	56	3,5	36,9
3	2 (seo 325)	tgb	5942	30	12	4,5+	-
1	3 (seo 31)	tgb	5944	31	18	10,0	13,1
3	4 (seo 3784)	tgb	5941	39		-	-
	* (seo 31)	tgb	5943	120	52	4,5	-

\* Borehole 5943 was drilled next to 5941

*Subs. log discrepancy*

TABLE III.3 SEOLWANE - COMPARISON OF EXPECTED GEOLOGY TO DRILLING FORMATION LOGS

DRILLING PRIORITY	LOCATION	BH NO	INTERPRETATION OF DEPTH PROBE	DRILLING FORMATION LOGS
PRIORITY 1 (target area 2)	seo 212	5940	<ul style="list-style-type: none"> <li>0 - 1m dry sand</li> <li>1 - 5m clayey sand</li> <li>5 - 20m scree (gravel/boulders)</li> <li>20 - 34m clayey gravel/boulders</li> <li>34 - 87m weathered gneiss.clayey sand</li> <li>87m basement complex gneiss (substratum)</li> </ul>	<ul style="list-style-type: none"> <li>0 - 6m sand</li> <li>6 - 14m weathered quartzites</li> <li>14 - 56m shales</li> <li>56 - 72m weathered dolerite</li> <li>72 -150m pink/grey gneisses (basement complex substratum)</li> </ul>
PRIORITY 4 (target area 3)	seo 31	5941 5943	<ul style="list-style-type: none"> <li>0 - 1m dry sand</li> <li>1 - 4m clayey sand</li> <li>4 - 5m clays</li> <li>5 - 22m scree (gravel+boulders)</li> <li>22 - 99m shales/siltstones</li> <li>99m fractured gneisses</li> </ul>	<ul style="list-style-type: none"> <li>0 - 1m sand and gravel</li> <li>7m gravel</li> <li>10 - 19m weathered gneisses</li> <li>19 - 52m clays and mudstones</li> <li>52 - 67m weathered gneisses</li> <li>67 - 88m sandstones</li> <li>88 -120m purple/brown gneiss (basement complex substratum)</li> </ul>

Cont...

TABLE 111.3 cont

DRILLING PRIORITY	LOCATION BH NO	INTERPRETATION OF DEPTH PROBE	DRILLING FORMATION LOGS
PRIORITY 3 (target area 1)	seo 3784 5944	0 - 1M wet sand (surface water of the stream) 1 - 3M gravel 3 - 9M sand 9 - 49M shales 49M fractured gneisses (bed rocks)	0 - 1M sandy soil 1 - 22M gravels 22 - 25M clays + sandstones pebbles 25 - 31M clays + gravels
PRIORITY 2 (target area 3)	seo 325 5942	0 - 3M dry sand 3 - 53M sand 53 - 87M sandy gravel 87M gneisses	no sludge samples (sieve analysis aquifer sample collected)

## 7. Hydrogeological Assessment

The following section comprises a summary of the hydrogeological conditions and groundwater potentials in the Seolwane area as deduced from the present study.

- Seolwane is situated on Basement gneisses immediately adjacent to the Lechana Fault and Palapye Group metasediments to the south. Alluvial material is present in considerable thickness.
- only secondary aquifers created by fracturing enhanced by weathering exist in the Basement gneisses. Primary aquifers exist in the overlying alluvial deposits and scree.
- groundwater levels are shallow (less than 30 m.b.g.l) and regional piezometric gradient is low, northeasterly. A surface and groundwater divide occurs in the Palapye Group formations to the south.
- groundwater levels are confined/semiconfined both in the Basement gneisses and the alluvial aquifers. The former possess low storage and generally low transmissivity while the latter have both higher storage and higher transmissivity.
- recharge is primarily by runoff from the Palapye Group hills into the adjacent alluvial aquifers. These in turn replenish the secondary Basement aquifers by downward leakage where they are contiguous. Elsewhere the secondary aquifers are most probably recharged by direct infiltration of runoff into the weathered zone.
- groundwater in the Seolwane area from both secondary and alluvial aquifers appears to be within acceptable potable limits and no adverse chemical constituents have been determined.
- the nature of the alluvial aquiferous unit in the Seolwane area prevented adequate borehole construction and hence thorough aquifer testing. Airlift yields during drilling do, however, indicate sufficient groundwater resources are present in the area to meet the projected demand.

## 8. Development Recommendations

The following summary presents the suggested groundwater development for the supply of Seolwane village.

- due to the exploratory nature of the boreholes drilled during this programme and the ground conditions in the alluvial aquifers encountered, no boreholes suitable for longterm production purposes were completed in these units. Only BH 5940, completed in Basement formations, is adequately constructed for production use. Estimated yield from this hole is 3.5 m<sup>3</sup>/hr. ✓
- drilling results indicate that suitably constructed production boreholes at BH 5944 (10 m<sup>3</sup>/hr) and BH 5942 (4.5 m<sup>3</sup>/hr) (both in the alluvial aquifers) will satisfy village demand. BH 5943 (4.5 m<sup>3</sup>/hr) may also warrant redevelopment. Final selection of sites for production purposes will, to a degree, depend on pipeline design and costing. ✓
- production boreholes should be drilled in the alluvial deposits by fluid flush techniques at 305 mm (12 inch) diameter to a total depth of ± 40 metres. A graded gravel pack and 152 mm (6 inch) diameter casing and suitable screens should then be installed. The borehole should then be adequately grouted to provide a sanitary seal and prevent surface pollution ingress.
- development of the borehole should be of sufficient duration and at sufficiently high rates to minimise ingress of fines and maximise borehole yield.
- analysis of samples obtained from the exploratory programme indicate that a screen mesh of 350 microns and a gravel pack in the range 1.5 to 3 mm should allow the borehole to be fully developed and the resource exploited to its maximum. ✓
- BH 5940 and the newly installed production boreholes indicated above should be thoroughly tested prior to any decisions on pump and reticulation design.

- in order to provide a safeguard in case of failure of a piped water scheme, hand pumps could be installed on BH 521 (now supplying the clinic), on an old unnumbered borehole near the primary school (after cleaning) and on an old borehole in the school grounds (after cleaning). Supplies from such sources would, however, have to be tested for quality and have proper sanitary protection.
  
- if future demands require additional supplies in excess of the sources identified during this study, it would be possible to locate supplementary boreholes in the alluvial area around BH 5944. This possibility should be borne in mind during the pipeline design stage.

SECTION IV

TOBANE

## 1. Geology and Structure

The area around Tobane has been geologically mapped by Bennett (1969) (sheet 2128C Mojojaphate) and Key (1976) (sheet 2127D Pikwe) and the immediate vicinity of Selibe Phikwe has been studied in detail as part of the BCL mining operation. The area is underlain by a complex sequence of granitoid basement rock types ranging from porphyritic and porphyroblastic granite gneiss to tonalitic flaggy gneiss to migmatitic grey gneiss containing amphibolite and calc-silicate horizons. Numerous intrusions of mafic to ultramafic rocks such as dolerites, amphibolites and anorthosites are common. Several outliers of Karoo rocks tentatively correlated with the Middle Ecca (sandstones, shales, mudstones and conglomerates) occur to the east of Tobane village and as faulted outliers along the downthrow side of the Letlhakane Fault. This latter, large regional fault structure transects the area in an approximate ENE - WSW direction north of the Motloutse River on which Tobane is situated. The Letlhakane Fault abruptly terminates the cataclastic formations of the Tuli - Sabi Straightening Zone to the north against the gneissose basement lithologies to the south and forms the major structural feature of the area.

The structural fabric of the area is dominated by the shearing and fracturing of the Tuli - Sabi Straightening Zone in the north and the complex folding of the gneissic terrain in the south. Four tectonic events have been recognised (Key 1976) and have produced complex isoclinal interference fold patterns which are most easily visible in the amphibolite and anorthosite assemblages to the west of Tobane. Axial trends are mainly eastnortheasterly plunging to the north. Other major fault structures in the area, apart from the Letlhakane Fault, are generally aligned east-west with a downthrow to the south. Movement on all faults clearly occurred in post-Karoo times but the structures themselves are probably of an earlier age. A number of structurally controlled dykes of dolerite and metadolerite aligned in a WNW-ESE direction are also apparent and are related to the post-Karoo phase of dyke intrusion seen elsewhere in Botswana.

Quaternary deposits in the area are solely related to the Motloutse River and its major tributaries. They comprise clayey materials interbedded with sands and gravels, with minor calcrete developments along some of the smaller drainage channels south of Tobane. Recent deposits of medium / coarse sand, gravel and clay occur in the Motloutse River channel itself, giving rise to an important but very localised sand river aquifer.

*What about the Karoo sandstones?*

## 2. Hydrogeology

There are no reported results of any previous groundwater exploration in the area around Tobane. The only studies that have been undertaken relate to the Motloutse sand river aquifer (Wikner 1980, Nord 1985) and these are discussed below.

In general, groundwater potential in the Tobane area appears limited since regionally only secondary aquifers created by fracturing and fissuring exist. The permeability of such aquifers may be enhanced by weathering processes but the probability of open fractures at depth is reduced due to earlier structural activity and resultant fissure infilling by metasomatic processes. Such fracture aquifers may possess relatively high transmissivity but low storage due to their poor interconnection. This latter fact will also adversely affect their recharge potential with the result that any abstraction points may suffer from lack of continuity of supply.

The exception to the general hydrogeological situation in the Basement formations is in areas of major shearing and enhanced weathering. The main regional feature in this respect is the Letlhakane Fault Zone which transects the northwest margin of the Tobane study area. Indications are that the Fault has a significant shatter zone on its southern, downthrow side which forms a broad (0.5 - 1 km) linear three layer semi confined aquiferous unit up to 120 metres deep and capable of providing individual borehole yields up to 40 m<sup>3</sup>/hr. (Australian Groundwater Consultants, 1974). More recent evaluation (Macdonald and Partners, 1988) has suggested that the Letlhakane Fault Zone constitutes a groundwater resource of regional significance, having good storage and transmitting properties, good recharge potential and capable of an annual yield of 1.5m<sup>3</sup> 10<sup>6</sup>. However, its distance from and the low projected demands of the village of Tobane, do not justify its inclusion in the present study. The only primary aquifers that exist are the Quaternary alluvium and possibly the isolated Karoo outliers. The recent Motloutse sands are a rather special case in that they possess reasonable storage, good transmissivity and excellent recharge prospects but are very limited in areal extent. They have been developed for village water supply upstream at Mmadinare via a series of high capacity wellpoints and are capable of producing yields of up to 16000 m<sup>3</sup> per kilometre length of river channel. Such a source may be possible for Tobane but careful consideration must be given to sand river usage in view of possible major surface water development on the Motloutse and the recently identified pollution of the sand river by discharges from the Selibe Phikwe BCL mine. Such factors are further discussed in Section 8 below.

### 3. Hydrochemistry

Only three groundwater analyses appear to be available for Tobane itself, one from an existing borehole (BH 3403) and two from exploration boreholes drilled during the course of the present study.

The older borehole exhibits the expected 'granitic terrain' chemistry of Na-Mg-HCO<sub>3</sub> with low total dissolved solids, low electrical conductivity and low/medium hardness. All parameters are within accepted potable limits.

Of the new boreholes, borehole BH 6126 drilled in alluvium and granitic rocks adjacent to the Motloutse River suprisingly indicates a similar groundwater composition, albeit with lower sodium and bicarbonate but higher sulphate. Again total dissolved solids are low and all parameters are within potable limits.

Borehole BH 6125, also drilled during the current programme does, however, exhibit somewhat different hydrochemistry despite being located in granitic rocks. In this case both total dissolved solids and electrical conductivity are high (1570 mg/l and 2550 µS/cm respectively), as are nitrate (29.6 mg/l), chloride (358 mg/l) and bicarbonate (958 mg/l). Fluoride is also very high (6.13 mg/l) and outside the limit for potable supplies. The chemical composition of this water is a little unusual for 'granitic water' and would actually have seemed more likely from the borehole drilled in the river alluvial deposits. There is therefore a distinct possibility that the water samples from the two new boreholes may have been confused during the analysis. Confirmatory re-sampling is recommended prior to either borehole being utilised for supply purposes.

Samples of groundwater from the Motloutse River sand aquifer were also taken for analysis during the field programme in Tobane. Considerable pollution of the Letlhakane River sand aquifer has been identified downstream of effluent discharge from the Selibe Phikwe mine and its transport and distribution in both the Letlhakane and Motloutse is currently being studied.

Samples taken during the present programme indicate a potable groundwater consistent with recent (rainfall) recharge, having low conductivity, low total dissolved solids and minimal mineral constituents, upstream of the Letlhakane/Motloutse confluence. Below this point the sand river water is much more acid (pH 5 to pH 3), with high sulphate, chloride and iron content. This would tend to confirm industrial pollution via the Letlhakane channel for a distance downstream at least as far as Tobane (Dam Site 31 on the Motloutse River).

Pollution of this nature may, in the future, have considerable influence on the use of boreholes in the river alluvium (eg BH 6126) for potable supply to Tobane as recharge to such sources to a large degree originates from the adjacent sandriver aquifer.

Data pertaining to the groundwater chemistry of the Tobane area is included in ~~Table 2, Appendix 3, Volume III~~ of this report. *Section 3, Volume II p. 3.28*

4. Existing Groundwater Exploitation

Borehole archives only record the existence of one borehole at Tobane (BH 1456), having an estimated yield of  $1.3 \text{ m}^3/\text{hr}$  from a gneiss aquifer (Inception Report, June 1988). Investigations during the field survey failed, however, to locate this borehole but identified other holes. Data pertaining to these boreholes is contained in ~~Volume III, Section 3~~. It would appear that borehole BH 1051 was closed due to salinity problems and that the current supply to the Tobane reticulation system is solely from borehole BH 3403. However, local sources indicate that this hole is susceptible to failure during drought periods and the village population then relies on shallow well supplies from the Motloutse sand river aquifer.

Section 3, Volume II  
p. 3.31

Population projections indicate that for the ten year planning horizons to 1998 the water demand in Tobane will rise to some  $68 \text{ m}^3/\text{per day}$  (Section II, 3). Assuming a 12 hour pumping day for the purposes of abstraction, this demand could be satisfied by a single borehole yielding  $5 - 6 \text{ m}^3/\text{hr}$ . However, due to the historically poor bedrock aquifer performance in the area and in order to provide an adequate safety margin, it is proposed that at least two, and preferably three, boreholes each yielding  $2 - 3 \text{ m}^3/\text{hr}$  would be a desirable outcome of the present study.

## 5. Project Survey Programme

### 5.1 Target Identification

Areas to be subjected to detailed ground survey were selected on the basis of geological and structural interpretations from aerial photographs and existing knowledge of hydrogeological conditions. Aerial photographs used were Dept. of Surveys and Lands, Motloutse and Northeast 1:50 000 scale, 1981/82 series, Strip Mot B26 Nos 022 - 029 and Strip Mot B25 Nos 163 - 170. These photographs are vertical panchromatic black and white and give stereo coverage of the potential search areas around Tobane.

The structural grain of both the Basement gneisses and in the Tuli - Sabi Straightening Zone is clearly discernible on the photographs. On the basis of textural and tonal variation on the photographs lithological boundaries could also be mapped. Photo-lineations (faults and dykes) and abandoned river features related to the Motloutse were also easily identifiable. (Map N.1, Vol II, pl.7)

A total of five target areas were initially identified in the Tobane area from photo interpretation of structural intersections, lithological contacts and abandoned river features. (Inception report, June 1988). These areas are indicated on Map IV.2. Two areas were to investigate recent channel deposits (Areas 1 and 5), one area was to investigate a possible Karoo outlier (Area 4) and the remaining two a number of structural features (Areas 2 and 3). (Vol II p. 18)

### 5.2 Geophysical Surveys

The following section contains a brief area by area description of geophysical work undertaken. Interpreted survey data and profiles are contained in Volume II Section 2 and raw data in Volume III. Site location plans are included in Volume II Section 1.

Target Area 1: (Site Plan IV.19, Vol II, p. 1.9)

The area is located around Tobane village and includes the sand aquifer along the Motloutse river. The semi-circular feature around Tobane has been interpreted as an old abandoned river meander. The geophysical survey was primarily aimed at delineating the alluvium thickness and the dimensions of the old channel and to assess the nature and thickness of the colluvial deposits along the margins of the present Motloutse River channel. During the field survey local sources reported that borehole BH 1051, located in the old abandoned channel, had pumped saline water. The fieldwork also revealed presence of a village graveyard within the feature. As a result of traditional resistance to any invasion of this type of locality very little geophysical work was thus undertaken along the semi-circular feature of Target Area 1.

Within Target Area 1 two borehole reference soundings were conducted at borehole BH 1051 and at BH 3403. Reference probe TO3403 at borehole 3403 indicated a fracture zone at 14 metre depth. However, this borehole is reported to dry up during periods of drought (see Section 4 above) which indicates a very limited and discontinuous fracture system. Borehole BH 1051, located in the semi-circular Motloutse River meander, appears to have drawn saline water from an 18 metre thick weathered zone in the bedrock below the channel feature.

(Vol II, p 2.21)

A magnetic traverse (Traverse No 12) was run adjacent to the Motloutse River and across the old meander channel. This traverse indicated an anomaly which it was concluded probably coincides with a tightly folded amphibolite band identified from the aerial photograph interpretation (Map IV.1).

(Vol II, p 2.13)

Resistivity depth probes TO101 and TO1A1 were conducted north of Tobane village in the alluvial area close to the Motloutse River in order to investigate the thickness of these shallow deposits. Results indicated alluvial thicknesses of 9 and 13 metres respectively.

Target Area 2: (Site Plan IV.2) (Vol II p 1.9, 1.10)

This target area was located along the Tobane River, a tributary of the Motloutse to the west and southwest of the village. The river course may be structurally controlled since there is evidence of a NE-SW trending photolineament along its alignment.

The area was divided into several sub-areas for ease of identification. Sub-area 2A lies at the intersection of the NE-SW photolineament and the Motloutse River and sub-areas 2B and 2C are situated upstream on the Tobane River where the river course and the photolineament are intersected by NW-SE trending features interpreted as dolerite dykes. (Map IV.1) (Vol II, p 1.9)

In Target Area 2A both magnetic (Vol II p 2.23) and resistivity profiling traverses were run across the photolineament and the Tobane River. (Traverse No 2A1 Profile 2A1) (Vol II p 2.28) The magnetic signature was quiet except for an anomaly at the beginning of the traverse, which coincided with an amphibolite outcrop. Resistivity profiling revealed relatively deep weathering east of the Tobane River. Follow-up with depth soundings (TO2A11 to TO2A14) (Vol II p 2.14, 2.15) indicated a maximum of 13 metres of weathering profile. A fifth probe was conducted close to Motloutse River and indicated approximately 16 metres of unconsolidated sequence.

In Target Area 2B magnetic line 2B1 (Vol II p 2.24) revealed a magnetic anomaly west of the Tobane River. The anomaly was interpreted to indicate a dolerite dyke. A resistivity profiling traverse (Profile Ref 2B1) (Vol II p 2.28) was carried out across the dyke in order to investigate possible fracture zones along the dyke. The profile was characterised by erratic resistivity values which revealed little of the weathering depth. Two depth probes were also conducted to investigate this magnetic anomaly. Results indicated very shallow weathering profiles of approximately 7 metres depth.

Another dolerite dyke was encountered in Target Area 2C as indicated by magnetic anomalies on traverse lines 2C2, 2C3 and 2C4. (Vol II p 2.25) Resistivity soundings were then conducted along lines 2C2 and 2C4. Probes TO2C21 and TO2C22 on line 2C2 indicated a weathering profile of between 5 and 8 metres, while probes on line 2C4 (TO2C41 and TO2C42) indicated 11 metres of weathering. (Vol II, p 2.16, 2.17) Intermediate layers apparent at the last two probe sites were interpreted to indicate fractured gneisses.

Target Area 3: (Site Plan IV.3) (Vol II, p 1.11)

The area is located on an intersection of several photolineaments in an area underlain by tightly folded amphibolites to the south west of Tobane village. Geophysical surveys were aimed at delineating fractures and assessing the depth of weathering, especially in the amphibolites which are inherently more susceptible to weathering processes than the adjacent granitic rocks.

Initially a magnetic traverse (Traverse No. 31) <sup>(Vol II p 2.26)</sup> was run north-south across the photolineaments and two broad anomalies were apparent. A constant separation resistivity profile was also undertaken along the same line (Profile 31) <sup>(Vol II p 2.28)</sup> and indicated a relatively deep weathered zone coinciding with one of the magnetic anomalies. Two depth probes (TO311 and TO312) <sup>(Vol II p 2.17, 2.18)</sup> were then conducted in order to assess the depth of weathering. The resultant weathering thickness of between 16 - 21 metres was less than expected from the profiling, but probe TO312 indicated a fairly low resistivity substratum (307 ohm metres) which was interpreted as enhanced weathering in a fractured zone.

Target Area 4: (Site Plan IV.4 Vol II p 1.12)

This area is located on the margins of a possible Karoo outlier to the east of Tobane village. Two photlineaments (NE - SW and WNW - ESE) also appear to intersect in this area (Map IV.1).

Two magnetic traverse lines (Traverse Nos 41 and 42) <sup>(Vol II p. 2.26)</sup> were run across the possible outlier to locate faulted and /or lithological contacts with the gneisses. Both traverses indicated a magnetic 'high' on the southern edge of the sandstone. Line 42 was further investigated by a constant separation resistivity traverse. (Profile 42) <sup>(Vol II p 2.29)</sup> This profile indicated a relatively thick sandstone and/or weathered gneiss unit to about 30 metres depth. This same zone of possible sandstone was further examined by a series of depth probes (TO421 - TO427) <sup>(Vol II p 2.18 - 2.20)</sup> which appeared to reveal a relatively thick sedimentary wedge within the gneiss basement, probably overlying a deeper weathering profile.

Target Area 5: Site Plan IV.5) <sup>(Vol II p 1.13)</sup>

This area is located at the confluence of the Molabe and the Motloutse Rivers to the north of Tobane. The field geophysics was carried out on the Molabe/Motloutse floodplain to investigate the thickness and extent of the river alluvials and potential of any possible unconsolidated sand aquifer.

Two magnetic traverse lines (Traverse Nos 51 and 52) <sup>(Vol II, p 2.27)</sup> were run perpendicular to each other, with line 51 being arrayed north-south across the Motloutse River channel. The magnetic signature of both traverses was rather 'silent' with a few erratic peaks.

A short constant separation resistivity line was also performed across the Motloutse River, along magnetic traverse 51. (Profile 51). The resistivity profile indicated a relatively high resistivity layer at about 30m depth which was interpreted to be channel sands interlayered with silts and clays. A total of three depth probes were also conducted at specific points along the profile (T0511, T0512 and T0513). Depth probes T0511 and T0512 indicated the presence of a possible sand aquifer interbedded with silts and clays. Soundings T0513 indicated a shallow alluvial sequence underlain by the Basement gneiss. (Vol II p 2.29) (Vol II p 2.20, 2.21)

### 5.3 Drilling Target Selection

#### Drilling Site Priority 1

(Target Area 4) (Site Plan IV.4)

The site is located about 3.5 km east of Tobane village at the edge of a stream valley on a faulted contact between Karoo sandstone and Basement Complex gneisses. Both magnetic traverses and resistivity profiling indicated faulting. Resistivity depth probe T0426 conducted at the site indicated 5 metres of superficial sand and calcrete cover underlain by Karoo sandstone. The borehole was expected to penetrate through the following sequence. (Vol II p. 2.20)

<u>Depth</u>	<u>Geology</u>
0 - 5	sand / calcrete
5 - 31	sandstone
31 - 46	fractured gneisses
46 -	gneisses

Water strike was anticipated in the Karoo sandstone and the potential aquifer was expected to include part of fractured gneisses. The borehole was recommended to be drilled to a depth of 80+ metres.

## Drilling Site Priority 2

(Target Area 4) (Site Plan IV.4)

(Vol II p 2.19) The site is located 370 metres south-west of Drilling Site Priority 1 in the same valley. The site was located in the middle of Karoo sandstone outlier. Probe T0424<sup>v</sup> indicated the same geology as Site 1 except that the resistivity substratum was not apparently fractured and indicated a resistivity of 12356 ohm metres. The borehole was expected to penetrate through the following geological sequence:

<u>Depth (m)</u>	<u>Geology</u>
0 - 7	sand / calcrete
7 - 36	siltstone / sandstone
36 - 56	sandstone
56 -	gneisses

Water strike was anticipated in the Karoo sandstone and the borehole was recommended to be drilled to a depth of 80+ metres.

## Drilling Site Priority 3

(Target Area 5) (Site Plan IV.5)

The site is close to the Motloutse River and it is about 4 km downstream from the village. The geophysical results from Target Area 5 indicate the presence of a potential alluvial aquifer along the southern bank of the river. Probe T0512<sup>v</sup> was chosen as the drilling site (Vol II p 2.21) and indicated a sequence of channel sands interbedded with clays. This sequence was interpreted as follows:

<u>Depth</u>	<u>Geology</u>
0 - 0.6	dry sand
0.6 - 8	sand / clay
8 - 12	silty sand
12 - 23	sand
23 -	gneisses

Drilling problems were expected due to the unconsolidated nature of the deposits and the drilling methods available. Recommended drilling depth was 50 metres.

#### Drilling Site Priority 4

(Target Area 3) (Site Plan IV.3)

The site is located 2.5 km along the old Tobane / Selibi Phikwe road. An intersection of two photolineaments was identified in this area. A resistivity profiling traverse (Profile 31) run across these faults revealed deep weathering across the NE-SW trending photolineament. Following depth probing at this locality probe T0312<sup>✓</sup> was chosen for drilling on the basis of an enhanced weathering profile. The borehole was expected to penetrate through the following geological sequence:

(Vol II p 2.18)

<u>Depth (m)</u>	<u>Geology</u>
0 - 5	dry sand / calcrete
5 - 22	weathered gneisses
22 -	fractured gneisses

Shallow water strike was anticipated in the weathered gneiss zone and the potential aquifer was expected to include part of the fractured bedrock. A drilling depth of 50 metres was recommended.

## 6. Groundwater Exploration

### 6.1 Drilling

De Wet Drilling Contractors undertook the exploratory drilling in Tobane. In all, four boreholes (BH 6123 to BH 6126) were completed using conventional rotary percussion drilling techniques. All except BH 6126 were properly constructed. The results of the drilling programme are summarised in Table IV.1. The complete borehole data which includes graphic borehole logs and construction plans and DWA Completion Certificates is appended in Volume II Section 3. Pertinent hydrogeological observations as well as the drilling and construction problems which were encountered on each borehole are briefly described below.

#### Drilling Site Priority 1, Target Area 4 (BH 6123)

BH 6123 was drilled at 216 mm diameter down to 19 metres from surface and at 165 mm diameter from 19 m to 100 m terminal depth. The geology which was interpreted from the depth sounding T0426 is compared to the actual geology from the drilling formation logs in Table IV.2. With the exception of the estimation of the depth to the Basement Complex substratum, the inferred thicknesses of the sand/sandstone cover and the weathered/fractured gneiss immediately below the sandstone do not tie up with the thickness of the formation which were intersected during the drilling. The Karoo sandstone and fractured gneiss contrary to expectations turned out to be dry. (Vol II, p 2.20) and in Vol II, p 3.6

#### Drilling Site Priority 2, Target Area 4 (BH 6124)

The drilling and construction design of BH 6124 were comparable to that of BH 6123. A 216 mm diameter hole was drilled to 66 metres. From 66m to 100m, the terminal depth, the borehole was drilled at 165 mm diameter. (Vol II p 3.7)

A 36 metre thick layer of moist mudstones and sandstone was intersected from 18 m to 54 m. The apparent resistivity low which was identified as the anomaly on the depth probe T0424 was in fact a result of this moist layer. (Vol II p 2.19)

No water was struck in the borehole.

Drilling Site Priority 3 Target Area 5 (BH6126)

The first 6 metres of the borehole were drilled at a diameter of 216 mm through unconsolidated collapsing sands. For this reason the diameter was changed to 254 mm and the same hole was eventually drilled to 18m at this diameter. Successive depths of 18m to 24m, and 24m to the terminal depth of 50m, were drilled at 216mm and 165mm diameter respectively. (Vol II p 3.9)

So why  
was not  
drilled

Both the layer of fractured gneisses between 18m and 27m as well as the 1 metre thick layer of coarse sand and boulders which make up the bed of the fossil Motloutse River channel from 17m to 18m could not be identified from the depth probe T0512. ~~The old Motloutse River bed which is the potential aquifer in this target area is too thin to be resolved by the apparent resistivity survey.~~

(Vol II p 2.21)

The borehole registered an estimated air-lift yield of 4.5 m<sup>3</sup>/hr when water was struck at 18m. However, the 203mm diameter plain casing which was installed down to 18m in order to check the caving of the borehole between 3m and 18m sealed off the aquifer and the final air-lift yield dropped to 1.5 m<sup>3</sup>/hr.

Drilling Site Priority 4 Target Area 3 (BH 6125)

The borehole was drilled at 216 mm and 165 mm diameter respectively from surface to 18 m and from 18 m to the terminal depth of 80 m. (Vol II p 3.8)

The sand / calcrete near surface layer was interpreted with reasonable accuracy. However, neither the thickness of the fractured / weathered gneisses nor the depth from surface to the substratum could be estimated from the depth sounding T0312. ~~The overall 100 m spread of the current electrodes from the centre of the sounding was not large enough to enable the direct current to penetrate beyond the fractured gneisses down to the Basement Complex below. The anticipated shallow water table was intersected at 18m within a low yielding aquifer (only 1.5 m<sup>3</sup>/hr) of weathered gneisses.~~

(Vol II p 2.18)

So the resistivity of the depth sounding was not

## Discussion of Drilling Results

The exploratory drilling programme at Tobane resulted in one low yielding borehole (No BH 6125 - 1.5 m<sup>3</sup>/hr) in fractured basement gneisses and a much higher yielding hole (No BH 6126 - 4.5 m<sup>3</sup>/hr) in old Motloutse River alluvials. The total estimated air-lift yield (6 m<sup>3</sup>/hr) of these two holes may more than satisfy the projected water demand of 67 m<sup>3</sup>/day for Tobane (Table II.1) but caution must be exercised with respect to borehole BH 6126. Borehole BH 6126 is inadequately constructed to allow meaningful aquifer testing and would certainly require redesign and redrilling for production purposes. It is also extremely susceptible to pollution since its recharge undoubtedly occurs from the recent Motloutse alluvials / sand river, the groundwater of which is known to be polluted upstream of Tobane by effluent discharges from the BCL copper - nickel mine at Selibe Phikwe.

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TABLE IV.1

TOBANE SUMMARY OF EXPLORATORY DRILLING RESULTS

DRILLING PRIORITY	SITE LOCATION	DRILLING CONTRACTOR	BH NO	BH TERMINAL DEPTH (metre)	1ST WATER STRIKE (metre)	ESTIMATED MAX AIR LIFT YIELD (cu. metre /hour)	STATIC WATER LEVEL (metre)
1	to 426	de wet	6123	100	-	-	-
2	to 424	de wet	6124	100	-	-	-
3	to 512	de wet	6126	50	18	4.5	21,10
4	to 312	de wet	6125	80	23	1,5	15,18

TABLE IV.2 TOBANE - COMPARISON OF EXPECTED GEOLOGY TO DRILLING FORMATION LOGS

DRILLING PRIORITY	LOCATION	INTERPRETATION OF DEPTH PROBES	DRILLING FORMATION LOGS
1 (target area 4)	to 452	0 - 5 sand/calcrete 5 - 31 sandstone 31 - 46 fractured gneisses 46 gneisses - basement complex	0 - 15 sandstone 15 - 39 weathered gneiss 39 - 100 grey/amphibolitic gneiss succession (basement complex)
2	to 424	0 - 7 sand/calcrete 7 - 36 siltstone/sandstone 36 - 56 sandstone 56 gneisses	0 - 18 sandstone 18 - 33 mudstones 33 - 51 mudstones 51 - 54 mudstones 54 - 63 basalts bedrock 63 - 100 gneisses (basement complex)

CONT ...

TABLE IV.2 CONT ...

DRILLING PRIORITY	LOCATION	BH NO	INTERPRETATION OF DEPTH PROBES	DRILLING FORMATION LOGS
3 (target area 5)	to 512	6126	0 - 0.6 sand 0.6 - 8 sand clay 8 - 12 silty sand 12 - 23 sand 23 gneisses	0 - 3 sand 3 - 15 sand and clays 15 - 17 fractured gneiss 17 - 18 quartz, sands, boulders and fractured gneiss (old motloutse river channel/bed) 18 - 27 fractured gneiss 27 - 50 pink/grey gneiss (basement complex)
4 (target area 3)	to 312	6125	0 - 5 sand/calcrete 5 - 22 weathered gneiss 22 fractured gneiss	0 - 1 sand 1 - 6 calcrete 6 - 42 pink/grey weathered gneiss 42 - 52 grey gneiss (basement complex)

## 7. Hydrogeological Assessment

The following section comprises a summary of the hydrogeological conditions and groundwater potential in the Tobane area as deduced from the present study.

- Tobane is situated on intensively folded Basement gneisses having a strong NE/SW structural fabric, adjacent to the Motloutse River and immediately south of the Letlhakane Fault. Outliers of Karoo sediments exist in the area and riverine alluvial deposits occur along the course of the Motloutse River.
- only secondary aquifers created by fracturing enhanced by weathering exist in the Basement gneisses. However, a significant shatter zone aquifer is present along the Letlhakane Fault elsewhere in the region. Primary aquifers exist in the Motloutse alluvial deposits and possibly in the Karoo outliers. The Motloutse river sands provide a high potential primary aquifer of limited areal extent.
- groundwater conditions are confined/semiconfined in both the Basement gneisses and the Karoo/alluvial aquifers. Transmissivity and storage are both likely to be low in the Basement units, except in the Letlhakane Fault zone. Alluvial aquifers possess higher transmissivity and considerably greater storage.
- recharge to the Basement secondary aquifers is from direct infiltration via the thin weathered zone. Recharge to the Letlhakane Fault zone is most probably directly from periodic flows in the Letlhakane River and the Motloutse alluvial aquifers almost certainly receive replenishment from the Motloutse sand river storage on a regular basis.
- groundwater from the Basement units in the Tobane area is generally of potable quality. Water from the shallow alluvial aquifers may be poorer in quality and susceptible to both chemical and bacteriological degradation.
- Basement aquifers in the area possess little groundwater potential. Sufficient potential to meet the projected demand does, however, exist in the alluvial units provided a suitable borehole construction is adopted and cognizance is taken of the possible quality of the groundwater.

## 8. Development Recommendations

The following summary presents the suggested groundwater development for the supply of Tobane village.

- the exploratory borehole (BH 6126) drilled in the Motloutse alluvials was not adequately constructed for production purposes. However, its estimated yield was 4.5 m<sup>3</sup>/hr and it is considered that a suitably constructed production borehole in the same location would satisfy the village demand.
- a new production borehole should be drilled in alluvial deposits adjacent to BH 6126 by fluid flush techniques at 254 mm (10 inch) diameter to a total depth of ± 30 metres. 152 mm (6 inch) diameter casing and suitable screens should then be installed. The borehole should then be adequately grouted to provide a sanitary seal and prevent surface pollution ingress.
- development of the borehole should be of sufficient duration and at sufficiently high rates to produce a natural gravel pack, to minimise ingress of fines and maximise borehole yield.
- although no sieve analyses are available for the Motloutse alluvial aquifer, observations during drilling indicate a coarse well screen in the channel sands/highly weathered gneiss will be adequate.
- any newly installed production borehole should be thoroughly testpumped prior to decisions on pump and reticulation design. Additional hydrochemical analyses should also be undertaken during testing and during production pumping to monitor potential pollution. (See Section 3).

- if future demands require additional supplies in excess of the sources identified during this study, it would be possible to locate supplementary boreholes in the alluvial area around BH 6126. This possibility should be borne in mind during the pipeline design stage.
  
- the existing production borehole (BH 3403) appears to be very 'seasonal' in its yield and frequently fails. Consideration should be given as to whether it is worthwhile incorporating in a revised reticulation system, or possibly equipping with a handpump.
  
- Exploratory borehole BH 6125 has an estimated yield of 1.5 m<sup>3</sup>/hr and is suitably constructed for handpump installation. However, the distance of the site from the main village may preclude this.

**SECTION V**

**NOGAPI**

## 1. Geology and Structure

The geology of the Mogapi area has been mapped by Thomas (1968) (Sheet 2227B) and comprises Banded Gneisses of the central zone of the Limpopo Mobile Belt of Pre-Cambrian age. The Banded Gneisses in the area around Mogapi consist of leucocratic quartz-feldspar gneiss with biotite and hornblende exhibiting a strong NNE-SSW foliation. The Banded Gneiss unit is considered to be of sedimentary origin and comprises a varying lithology of paragneisses and ortho-amphibolites.

A prominent NNE/SSW ridge to the north of Mogapi village provides the only major outcrop in the area. Elsewhere the gneissic terrain is overlain by a thin cover of superficial soil and alluvial material. To the south of Mogapi are a number of east-west trending post-Karoo dolerite dykes, presumably intruded along lines of weakness.

The strong NNE/SSW structural fabric of the area appears to parallel the latest phase of folding which has given rise to the present distribution of the Banded Gneisses in series of antiforms and synforms. At least three earlier fold phases have also been recognised with isoclinal folds having been successively refolded. No major shears are apparent in the area although minor shearing and mylonization trending ENE/WSW is visible immediately adjacent to Mogapi village. This trend appears to parallel the large Kgophathata Fault, some 15 km south of Mogapi, as well as the direction of many of the post-Karoo dolerite dykes.

## 2. Hydrogeology

The area around Mogapi village has been subjected to groundwater investigation on no less than five occasions prior to the present study (DWA 1983; Aquatech 1981, 1982; Wellfield Consulting Services 1984, 1987). A considerable volume of geophysical surveying has been undertaken, particularly in close proximity to the village and at least 13 boreholes have been drilled. Most boreholes were, however, dry or very low yielding. Previous borehole data is appended in ~~Volume III~~ of this report.

*Section 3 Volume II p 3.31*

No primary aquifers exist in the Mogapi area and the hydrogeological regime is one of secondary aquifers created by fracturing and fissuring, enhanced by weathering processes. Groundwater levels in the gneissic terrain are relatively shallow (less than 30 m.b.g.l.) and indicate a gradient of approximately 1% in a south-south-easterly direction across the area towards the Lotsane River. A regional groundwater divide trending E/W occurs just to the north of Mogapi village.

Groundwater potential in the area has been categorised as 'uniformly poor' (Hydrogeological Reconnaissance Map Sheet 8) and borehole yields are generally very low. Aquifer parameters determined from isolated test pumping exercises carried out by DWA illustrate the characteristic low storage and poor transmitting properties of the Basement gneisses. Analysis of data from borehole number BH 4915 at Mogapi indicated a transmissivity of 0.1 m<sup>2</sup>/d and minimal storage (Inception Report, June 1988).

Minor shallow groundwater occurs in the thin alluvials along stream courses and probably forms the main source of recharge to any underlying fracture aquifers.

### 3. Hydrochemistry

The limited number of hydrochemical analyses available for boreholes drilled in the Mogapi area, indicate groundwater which is slightly brakish (total dissolved solids 1000 - 1500 mg/l and conductivity 1600 - 2500  $\mu$ S/cm) and Na-Mg-HCO<sub>3</sub>-Cl in character. The groundwater is also moderately hard, with a total hardness in the range 200 - 360 mg/l CaCO<sub>3</sub>.

Of particular interest is the high concentration of fluoride (up to 5 mg/l). The origin of this constituent can only be ascribed to the original sedimentary nature of the Banded Gneisses of the area and the existence of a high proportion of fluoride-rich amphibole minerals produced as a result of several periods of remobilisation and metamorphism. The high levels of fluoride make the groundwater of Mogapi area unsuitable for human consumption despite the main mineral constituents being within tolerable limits.

Nitrate levels recorded from Mogapi boreholes are also considerably in excess of accepted limits (ranging from 50 to 100 mg/l). A natural source of nitrate in the formations of the area is unlikely and the high levels of nitrate in borehole water is most probably due to ingress of pollutants of organic origin immediately at the point of abstraction. This may possibly be corrected by better borehole construction but further investigation would be required to definately identify the source of the nitrate.

Data pertaining to the groundwater chemistry of the Mogapi area is included ~~in Table 3, Appendix 3, Volume III~~ of this report.

Section 3 Volume II, p 3.28

#### 4. Existing Groundwater Exploitation

Records indicate the presence of at least 13 boreholes in the vicinity of Mogapi. (Inception Report June 1988) Since most of the holes that have previously been drilled were dry, this list may not be complete due to non-recording of additional dry holes from earlier programmes.

Mogapi presently has two operational boreholes. Borehole BH 1468 was drilled in 1962 and currently supplies the village with approximately 7 m<sup>3</sup>/hr. A second low yielding borehole (BH 4915) has recently been equipped to supply water to the newly constructed Secondary School. Records of these boreholes and all other boreholes in the Mogapi area, are contained in ~~Volume III~~ of this report.

*Section 3, Volume II p 331*

The village of Mogapi is currently served by two boreholes which may satisfy current demand with continuous pumping. However, one borehole (BH 1468) provides by far the largest proportion of the supply and there are no additional sources in the event of failure, mechanical or otherwise. Projected water demand estimates for 1998 indicate a daily water requirement of some 112 m<sup>3</sup>/day for Mogapi village and this clearly cannot be met from existing sources, or any source in the immediate vicinity of the village. New sources must therefore be sought some distance away.

An optimum situation would be a grouping of 3 boreholes supplying some 3-4 m<sup>3</sup>/hr on a continuous basis. This requirement has been taken as the exploration programme target, but with difficulties expected in locating such supplies in the area around Mogapi.

## 5. Project Survey Programme

### 5.1 Target Identification

An initial data review during the desk study phase of the programme revealed that the most obvious hydrogeological target areas close to the village have all been previously examined (Section 2). A new area of interest, which had earlier been recommended for possible study (WCS 1986), is located in the amphibolite area around Kgophathata, some 16 kilometres southwest of Mogapi. However, this area was taken as part of, and is discussed under the Kgagodi / Mogapinyana / Diloro village group (Section VI of this report).

Several additional target areas were nevertheless identified on the basis of existing knowledge of the hydrogeological regime and structural interpretation from aerial photographs. Photographs used were Dept. of Surveys and Lands, Motloutse and North East Block. 1:50,000 scale 1981/82 series, Strip 31 Nos 104-114, Strip 32 Nos 166-174 and Strip 33 Nos 241-246. These photographs are panchromatic black and white and give stereo coverage of the search area around Mogapi. Structural trends and drainage patterns were identified from the photographs, as well as minor amphibolitic units within the Basement Gneisses and the ubiquitous post-Karoo dolerite dykes.

Ground truth checks of aerial photo interpretation revealed two possible areas for detailed geophysical surveying to the southeast and to the west of the village. These areas, together with aerial photograph interpretation, are indicated on Maps V.1 and V.2 (Volume II, p. 1.14, 1.15)

### 5.2 Geophysical Surveys

The following section contains a brief area by area description of geophysical work undertaken. Interpreted survey data and profiles are contained in Volume II Section 2 and raw data in Volume III. Site location plans are included in Volume II Section 1.

Target Area 1 (Site Plan V.1) Vol II, p 1.16, 1.17)

The area is located 4.5 km SSE of the village. Two photo lineaments appear to intersect in the area. The north-west trending lineament forms a broad surface drainage zone that further to the east becomes the Senka River. Superficial cover comprises black cotton soils dotted with few fractured calcrete outcrops. The geophysical survey work was aimed at determining the nature of the structural features and also to assess the weathering pattern. A long magnetic traverse (Traverse 11) and an EM profile (profile 11) were run north-south across both photo lineaments. Magnetic traversing revealed dolerite dyke-like anomalies although the EM signature was rather 'silent'. The NW trending lineament was expressed as a minor anomaly. Resistivity depth probes MOG11, MOG12 and MOG13 revealed fairly shallow weathering of about 10 metres although MOG12 appeared to indicate a fractured gneissic 4th layer. The interpretation of depth probe MOG12 was as follows.

<u>Resistivity</u> (ohm-m)	<u>Depth</u> (m)	<u>Interpreted Lithology</u>
531-388	2	calcrete
61	14	weathered gneiss/dyke
149	30	fractured gneiss or dolerite dyke
3400	30 +	gneiss <i>Resistant</i>

An additional EM profile (Profile 3) was conducted across the dolerite dyke on which borehole BH 4684 was sited. However, no significant results ensued.

Target Area 2 (Site Plan V.2) Vol II, p 1.18)

The area is located at the base of the hills west of the village. Several dry boreholes have been drilled in this area and hence the geophysical work was intended to establish the geological environment in which the boreholes were sited.

Two magnetic traverses (Traverse 21 and 23) were run parallel to the hills and Traverse 22 and 24 were run in an east-west direction. ~~Magnetic traverses were aimed at establishing the magnetic signature on which the previous siting was most probably based.~~ (Vol II p 2.22, 2.23) An EM profile (Profile No 23) (Vol II p 2.34) was also conducted along magnetic traverse 23. The EM profile revealed a fairly uniform signature. However, two resistivity probes, (Probe No MOG31 and MOG32) were conducted along traverse 23 and indicated a weathered depth of 20 metres. (Vol II p 2.31)

The geophysical work in Target Area 2 revealed that the previous boreholes had been sited on a non-structurally significant trend interpreted from the magnetic field and EM signature. The weathering in this area is extremely variable in thickness (ranging from 7 to 26 metres) and no conclusions could be drawn as to its relation with bedrock structures.

### 5.3 Drilling Site Selection

From the geophysical survey work undertaken in the two target areas selected around Mogapi, no positive hydrogeological interpretations could be made. As a result no sites were selected for exploratory drilling in the Mogapi area.

## 7. Hydrogeological Assessment

The following section comprises a summary of the hydrogeological conditions and groundwater potential in the Mogapi area as deduced from the present study

- Mogapi is situated on Banded Gneisses of the central zone of the Limpopo Mobile Belt which exhibit a strong NNE/SSW foliation. Very thin alluvial material exists in the area.
- only secondary aquifers created by fracturing enhanced by weathering exist in the Banded Gneisses. No primary aquifers are present in the area.
- groundwater levels in the area are shallow (less than 30 m.b.g.l.) and the piezometric gradient is low and in a southeasterly direction. A regional groundwater divide trending E/W occurs just to the north of Mogapi.
- groundwater conditions are confined/semiconfined and transmissivity is very low ( $1 \text{ m}^2/\text{d}$ ). Storage properties are similarly very low.
- recharge to any secondary aquifers in the area can only take place by direct infiltration via the weathered zone.
- groundwater in the Mogapi area is slightly brackish and frequently has an unacceptably high fluoride content. Water is thus generally unsuitable for potable supplies.
- groundwater potential in the area is poor, with low borehole yields and inferior water quality. Insufficient resources exist in the vicinity of Mogapi to satisfy the projected water demand for the village.

SECTION VI

KGAGODI/MOGAPINYANA/DILORO

11/14

## 1. Geology and Structure

The geology of the area has been mapped by Thomas (1968) and comprises almost exclusively Granitic and Banded Gneisses of the central zone of the Limpopo Mobile Belt of Precambrian age. The Banded Gneiss formation is considered to be of sedimentary origin and consists of a varying lithology of paragneisses and ortho-amphibolites. The Granitic Gneiss unit occurs as isolated selvages enclosed within the much more widespread Banded Gneiss strata and comprises mainly leucocratic quartz-feldspar gneiss and migmatites.

In the Mogapinyana area there are also outcrops of coarse-grained prophyroblastic gneiss characterised by large pink porphyroblasts of microcline microperthite (Thomas 1968). This unit forms the typical rounded granite kopjies with very irregular jointing which are particularly noticeable to the north and north-east of Mogapinyana. Also in the present study area there is an intrusive occurrence of ultrabasic rock (pyroxene peridotite and serpentinite) at Semalore Hill to the northwest of Mogapinyana. Dolerite dykes of Karoo age on a NW-SE trend form distinct photolineaments. Recent deposits comprise thin soils, calcretes, alluvial sands and silts.

The structural fabric of the area is dominated by a north-northeast foliation parallel to the latest phase of folding which has given rise to the distribution of the Banded and Granitic Gneisses in a series of broad antiforms, synforms, domes and basins. At least two earlier fold phases have also been recognised with isoclinal folds having been successively refolded. The structural trends in the intensively folded amphibolites around Kgophathata illustrate the complexity of the deformation and multiphase folding, varying from west northwest to the regional north northeast. A fairly large NW-SE shear zone with echelon shears indicated by mylonized gneiss occurs along the Tshokana River south-east of Mogapinyana but this appears to die out in the vicinity of the study villages themselves. Other sub parallel shear zones or faults are also visible on aerial photographs, some of which are infilled with Karoo dolerite. Most of the faulting and shearing appears to have occurred late in the history of the Limpopo Mobile Belt with renewed movement along some of these lines in post Waterberg and post Karoo times.

The Basement gneisses form a significant fault contact (Lechana Fault) with the Upper Palapye Group metasedimentary formations some 15 kilometres to the southeast of the study villages. This regional shear constitutes the major structural feature of the area.

## 2. Hydrogeology

The groundwater potential of the Kgagodi / Mogapinya / Diloru area has previously been extensively investigated by Dept. of Water Affairs, Aqua Tech (1981) and Wellfield Consulting Services (1984, 1987). A considerable volume of geophysical surveying has been undertaken, particularly in close proximity to the villages, and has resulted in the drilling of a large number of boreholes. Unfortunately, most of the boreholes drilled under these programmes were either dry or very low yielding. Previous borehole data is appended in Volume III of this report.

No primary aquifers exist in the study area and the hydrogeological regime is one of secondary aquifers created by fracturing and fissuring, enhanced by weathering processes. Groundwater levels in the gneissic terrain are relatively shallow (less than 30 m.b.g.l.) and indicate a gradient of approximately 1% in a south-south-easterly direction across the study area towards the Lotsane River. A regional groundwater divide trending E/W appears to occur some 15 - 20 km to the north of the study villages.

Groundwater potential in the area has been categorised as 'uniformly poor' (Hydrogeological Reconnaissance Map Sheet 8) and borehole yields are generally less than 2 m<sup>3</sup>/hr. Aquifer parameters determined from isolated test pumping exercises carried out by DWA illustrate the characteristic low storage and poor transmitting properties of the gneissic units. Analysis of data from borehole BH 4667 at Mogapinyana indicated a transmissivity of 0.4 m<sup>2</sup>/d and a very low storage (Inception Report June 1988).

Shallow groundwater occurs in the alluvial deposits along the Tshokana and Moakatuma Rivers but it is undoubtedly susceptible to depletion during the dry season and failure during drought periods.

### 3. Hydrochemistry

For the Kgagodi / Mogapinyana / Dilorro study area hydrochemical data is available for some twelve boreholes. However, six of these boreholes are located in the vicinity of Tamasane, some 15 kilometres to the southwest and adjacent to the Lechana Fault Zone and the Palapye Group Formations to the south of this structure.

Groundwater from the Tamasane area appears to be slightly more brakish (average total dissolved solids 1290 mg/l) than water from the Kgagodi group of boreholes (average total dissolved solids 860 mg/l), although groundwater from both areas may be classified as Na-Mg-Cl-HCO<sub>3</sub> type. Both groups of water are moderately hard. Important constituents such as fluoride and nitrate are similar from both the Tamasane and Kgagodi areas, with fluoride values generally being within acceptable limits and nitrate levels being excessively high. This latter constituent is most likely the result of wellhead or near wellhead pollution of organic origin which has taken place over time in the older boreholes, since the newly drilled and currently unequipped boreholes (BH 6115 and BH 6121) exhibit only low nitrate levels. It would appear therefore, that this degradation of quality of the groundwater may be avoided if boreholes are adequately constructed and protected prior to their inclusion in the supply system.

Apart from the elevated nitrate levels in the older boreholes, the groundwater of the area is acceptable for potable supply, despite being slightly brakish. In this connection it is interesting to note that groundwater quality improved during the course of the testpumping of borehole number BH 6115, with a reduction in total dissolved solids from 2664 mg/l to 1370 mg/l and chloride from 1390 mg/l to 490 mg/l.

Data pertaining to the groundwater chemistry of the Kgagodi / Mogapinyana / Dilorro area is included as ~~Table 4, Appendix 3, Volume III~~ of this report.

in Section 3, Volume I p 3.29

#### 4. Existing Groundwater Exploitation

Archive data indicates the presence of at least 24 boreholes in the vicinity of the study villages of Kgagodi / Mogapinyana and Diloru (Inception Report June 1988). This list may not be exhaustive since over 90% of these holes were dry and additional dry holes from earlier drilling exercises may not have been adequately recorded. The villages of Kgagodi / Mogapinyana at present rely almost entirely on one borehole (BH 4667) which was drilled in 1984 during an earlier Wellfield Consulting Services programme. This borehole was test pumped following drilling for 48 hours at 10.5 m<sup>3</sup>/hr. Diloru is presently being supplied by water sent to Diloru from Kgagodi by bowser and by a single low yielding borehole (BH 5200). All available records of boreholes in the area are contained in ~~Volume III~~ of this report.

*Section 3, Volume II p 3.32*

A large number of hand dug wells occur along the valley of the Moakatuma, Setote, Kgophathata and Seoka Rivers. These wells are used primarily for livestock watering although they may supplement domestic water supplies when difficulties arise with the borehole supply system.

The village group of Kgagodi / Mogapinyana and Diloru is suffering from a serious shortage of water, especially during drought periods when shallow wells dry up. Projected water demand estimates for 1998 indicate a daily water requirement of some 316 m<sup>3</sup>/day for the village group. This clearly cannot be met from existing sources or from any location in the near vicinity of the villages (Section 2 above) and new sources can only be sought some distance away. An optimum situation would be a fairly closely located group of 5 - 6 boreholes each capable of yielding some 5 m<sup>3</sup>/hr on a continuous basis. This requirement has thus been taken as the exploration programme target.

## 5. Project Survey Programme

### 5.1 Target Identification

Target areas were identified on the basis of existing knowledge of the hydrogeological regime and structural interpretation from aerial photographs. Photographs used were Dept. of Surveys and Lands, Motloutse and North East Block, 1:50 000 scale, 1981/82 series, Strip 30 Nos 033-045, Strip 31 Nos 100-115 and Strip 32 Nos 165-180. These photographs are panchromatic black and white and give stereo coverage of the search area around Kgagodi/Mogapinyana and Diloru. Structural trends and drainage patterns were identified from the photographs, as well as amphibolitic units within the Basement gneisses and the ubiquitous post-Karoo dolerite dykes. Of particular interest were the Tshokana Shear Zone, the Kgophathata Fault and the major Lechana Fault, and the intersections of these and other fracture patterns. Most usually fracture intersections constitute sites of enhanced weathering.

All aerial photograph interpretation is compiled on Maps VI.1 - VI.3 (Volume II, p. 1.19, 1.21, 1.23). Three target areas were initially selected for field geophysical investigation (Inception Report June 1988) and are indicated on Maps VI.4 - VI.6 as Target Areas 1, 2 and 3. During the early stages of the field programme and in consultation with DWA a further four target areas were also proposed and these are delineated on Maps VI.1 - VI.3 as Target Areas 4, 5 and 5. Target Area 7 (Raphiri) is indicated on Map III.2 - Seolwane. All target areas were determined on the basis of possible structurally controlled aquiferous zones.

Vol II  
p. 1.20, 1.22,  
1.24

Vol II p. 1.2

### 5.2 Geophysical Surveys

The following section contains a brief area by area description of geophysical work undertaken. Interpreted survey data and profiles are contained in Volume II, Section 1.

Target Area 1A, 1B, 1C (Kgophothata)  
and 1D (Tshokana)

(Site Plans VI.1A; VI.1B; VI.1C; VI.1D) (Vol II p 1.25 - 1.28)

An area of amphibolites about 13 km south-east of Mogapinyana was previously recommended as a potential target for future exploration work (WCS, 1987) and was investigated as Target Areas 1A, 1B, 1C (Map VI.1). Relatively deep weathering can be expected in such amphibolite. NW trending faults and shear zones, together with the ENE trending Kgophathata Fault, have been mapped in the area. Magnetic traverse line 1<sup>v</sup> was run across Tshokana River with the intention of locating a shear zone that apparently controls the course of the river. This traverse revealed a dyke-like anomaly east of the river. An electromagnetic (EM) horizontal loop traverse was also run along the same line across the river and indicated a clay conductive zone along the river valley. (Vol II p 2.64)

(Vol II p 2.50)

Both magnetic and electromagnetic traverses were also run across a NW trending meta-dolerite dyke (traverse lines 2, 3, 4, 5, 6 and 7).<sup>v</sup> Traverse line 2 indicates a faulted dyke feature although the EM profile only revealed a minor conductive zone associated with it. Traverse 3 along the dyke revealed fairly uniform magnetic and EM signature with no significant weathering zones.

(Vol II p 2.50  
- 2.53  
and p 2.65-2.66)

The same dyke feature was further investigated near the Kgophathata River. Traverse lines 4 and 6 were run across the river and the dyke, and lines 5 and 7 were run along the river in order to traverse a number of amphibolite bands which were characterised by magnetic anomalies.

Erratic EM profiles proved difficult to interpret and resistivity depth probes were conducted at points chosen solely on the basis of magnetic anomalies. Most of these probes indicated very shallow weathering profiles. However probe KGO31<sup>v</sup>, conducted on traverse line 3, indicated 21 metres of fractured meta-dolerite and probe KGO43<sup>v</sup> an extensively weathered zone of 20 metres thickness. General conclusions concerning this area were that only shallow weathering profiles exist on both the gneisses and the amphibolites. The erratic electromagnetic and magnetic response of the amphibolites also made it difficult to locate significant fracture zones which normally would enhance this weathering.

(Vol II p 2.35)  
(Vol II p 2.36)

As a result of the poor results in Target Areas 1A, 1B and 1C efforts were directed towards a prominent air photolineament intersection west of Kgophathata (Target Area 1D - Tshokana) since it was considered that structures in a more uniform geological environment may be more easily determined from magnetic and EM surveys. Magnetic traverse lines 10, 10A, 10B, 10C and 10D were run north-south across the two apparent fault zones and several fracture type anomalies were delineated. The east-west structural trend was also traversed by a number of short traverse lines (10G, 10E and 10F). These lines enabled delineation of a magnetic (low) anomaly some 400 metres in width. Traverse 10A produced a fairly 'silent' signature indicating a relatively uniform geology with no amphibolite or dolerite present. Traverse 10B located on dolerite dyke at station 400 and a broad anomaly between stations 400 and 750. An EM profile (Profile No 10B) was thus run from station 300 to 900 on line 10B. This profile indicated two conductive zones. Magnetic traverse 10C indicated an anomaly some 400 metres in width which appears to coincide with a broad NW-SE photolineament. EM profiles (Profile No's 10 and 10C) on both lines 10 and 10C indicated alternating high and low conductive zones. The highly conductive zones were interpreted as fractured bedrock features within a larger fault zone corresponding to the photolineaments and the magnetic anomaly. Magnetic traverse 10D, located between 10A and 10B, revealed the same anomaly as traverse 10B. This anomaly has been further investigated by resistivity depth probes TS10B1, TS10B2, TS10B3 and TS10B4. Probe TS10B2 indicated 4.5 metres of high resistivity strata underlain by a 15 metres low resistivity (18 ohm metres) layer above a substratum with a resistivity of over 400 ohm metres. The other probes also revealed similar apparent resistivity profiles.

The east-west photolineament was also investigated near the Tshokana River which itself appeared to be structurally controlled. Magnetic lines 11A and 11C were run north-south while lines 12 and 11D were run east-west across the rivers. The east-west lineament was traced into the river, where it intersects a broad magnetic 'high' (Magnetic traverse 12). Traverse line 12 also revealed a magnetic anomaly that coincided with a shallow stream about 450 metres west of the Tshokana River. An EM profile (Profile No 11A) along line 11A indicated a fairly uniformly conductive area, which was interpreted as alluvial clays derived from the gneisses. The EM profile (Profile No 12) along line 12 revealed three conductive areas, two of which coincided with the edges of a magnetic anomaly. Resistivity depth probes were then conducted along traverse line 12 but only probe TS122 indicated a fairly thick fractured zone ( $\pm$  33m) at a depth of 22 metres. The remainder of the probes revealed shallow weathered profiles that varied between 5 and 10 metres in thickness.

Target Area 2 (Tamasane) (Site Plan VI.28 Vol II p 1.29)

The major NW-SE trending Lechana Fault Zone was mapped south of Tamasane village which lies 18km west of Kgagodi. This fault is the structural boundary between the Basement Complex gneisses and the Palapye Group rocks. The Lechana Fault appears to have terminated several NE-SW trending photolineaments within the Basement and Target Area 2 was located at the intersection of one of these and the Lechana Fault Zone itself.

This target area had previously been investigated by DWA in early 1988 when a total of 4 sites were pegged and drilled. The table below summarizes borehole data resulting from this DWA study.

<u>Borehole No</u>	<u>Depth (m)</u>	<u>Water Strike (m)</u>	<u>Est. Yield (m<sup>3</sup>/hr)</u>	<u>Lithology</u>
5925	253	-	dry	calcrete (69m) shales (bottom)
5926	248	-	dry	
5927	210	-	dry	shales/siltstone
5928	121	23	15	calcrete (4m) gneisses (bottom)

Re-examination of the DWA geophysical data indicated the following:

- all the above boreholes were drilled at the coincidence of magnetic and EM anomalies
- both EM and magnetic traverses failed to accurately locate the main Lechana Fault
- resistivity depth probing did not reliably identify shales units within the Palapye Group strata due to shale / siltstone inter bedding, except at probe DP2, line PR8.

(Vol II p 2.58; 2.68)

For the purposes of the present survey a long magnetic and EM traverse line (Traverse 1; Profile No 1) was run south of Tamasane village. This was followed by two short east-west lines 2 and 3. Magnetic Traverse 1 revealed a broad 250 m wide, magnetic 'high' to the south between stations 200 and 450, and a minor anomaly at station 860.

(Vol II p 2.58,  
2.59, 2.69)

EM profile 1 revealed a progressive decrease in conductivity to station number 690 and thereafter conductivity remained fairly constant. Magnetic traverses and EM profiles on lines 2 and 3 were fairly uniform except for two minor anomalies on EM profile 2. Two resistivity depth probes on these EM anomalies (TAM21 and TAM22) indicated weathering depth of 6 and 15 metres respectively.

(Vol II p 2.24, 2.35)

DWA traverse PR6 was also repeated with an extension northwards (Traverse ~~PR6~~, Profile No PR6). ~~The magnetic signature was relatively silent except for two minor anomalies.~~ The EM profile along this line revealed a conductive environment south of an aerial photolineament at station 200m. Borehole BH 5927, which penetrated shales and siltstone, was drilled south of this lineament. A total of 5 resistivity depth probes were conducted along this traverse. These were aimed at determining the nature of the underlying bedrock. The first three (TAM600, TAM60 and TAM61) ~~were sited on an~~ EM anomaly close to borehole BH 5927 and they indicated a decrease in thickness of the Lotsane Formation from 60 m to 30 m in a northerly direction. At probe TAM62, the sedimentary unit had completely disappeared, indicating the presence of a lithological boundary. Probe TAM63 also indicated a similar profile to a depth of 15 metres. The results of the survey in Target Area 2 indicate that it is not possible to accurately identify the Lechana Fault with surface magnetic and EM survey techniques and that resistivity methods have limited resolution because of the shaley members of the Palapye Group Lotsane Formation. In consequence, no drilling sites were chosen in this target area.

(Vol II p 2.59, 2.69)

(Vol II p 2.35, 2.36)

Target Area 3 (Matholwane West) (Site Plan VI.3) (Vol II p 1.30)

This area is located at an intersection of two structural features in the Basement Complex gneisses 12 km south-west of Kgagodi. Further to the southwest these structures are terminated by the Lechana Fault. A broad drainage valley conforms to the NW-SE trend. Superficial cover comprises calcrete and black-cotton soils. Initially it was understood that DWA during their earlier survey had also identified this same target area. However, the field investigations revealed that DWA had sited a successful borehole (BH 5928) north west of this target area.

(Vol II p 2.57)

A magnetic traverse (Traverse 1) across both structural features indicated a broad indistinct magnetic 'high' 150 metres wide which coincided with the drainage valley. A follow-up with EM Profile 1 identified a conductive zone east of the magnetic anomaly. (Vol II p 2.70)

(Vol II p 2.32) Resistivity probe MAT011 at this locality indicated the depth profile below:

<u>Resistivity</u> (Ohm/m)	<u>Thickness(m)</u>	<u>Interpreted</u> <u>Lithology</u>
489	0.5	calcrete
32	3	clays
77	14	weathered gneiss
2475	-	fresh gneiss

These results are indicative of very shallow weathering. The nature and size of the magnetic anomaly also made it difficult to locate any fractured zones.

#### Target Areas 4A, 4B, 4C (Kgagodi - Maunatlala)

(Site Plans VI.4A ; VI.4B ; VI.4C, Vol II p 1.31 - 1.33)

The area is located about 6 km south of Kgagodi along the Kgagodi/Maunatlala gravel road. This target area was identified during the fieldwork in consultation with DWA. An indistinct photolineament trending NW-SE appears to intercept a circular photo feature which appears on the geology map as a fold dome within the Banded Gneisses. During the field work it was also noted that a fence running between Kgagodi and Maunatlala arable lands had been erected along the broad valley and that all the pole diggings revealed calcrete. The geophysical work was thus primarily aimed at determining the depth of weathering across the valley.

(Vol II p 2.60) Magnetic traverse 1 revealed a broad magnetic high that coincided with the middle of the valley and an anomaly 200 metres further south was interpreted to indicate amphibolite gneisses. A resistivity profile (Profile 1) (Vol II p 2.73) along the same line revealed a resistivity low at the magnetic high anomaly. Two resistivity soundings at this point (KG-M11 and KG-M12) indicated deep weathering of the order of 90 metres. The resistivity of the substrata (150 ohm metres), also tended to indicate fractured gneisses.

On the basis of this work a borehole site was selected and drilled (see 5.3). Following the completion of this successful borehole, an expanded geophysical programme in the area was discussed with and agreed by DWA. This additional work involved the running of magnetic traverses across the valley both to the east and to the west of the road. Traverses 2, 3 and 4 were located to the east of the road, with traverse 2 intersecting a NW trending photolineament and the valley itself. Resistivity profiling along this line (Profile 2) revealed only very shallow weathering of about 7 metres thickness. Magnetic traverses 3 and 4 were also run across the valley and revealed very little information. However, resistivity profiling along line 3 revealed a decrease in resistivity from 200 ohm metres in the north to 90 ohm metres in the south. The four soundings on this line (MAKG31 to MAKG34) indicated fairly deep weathering and the resistivity substrata were interpreted to reflect fractured gneisses.

(Vol II p 2.61)

Traverse line 5 was on the western side of the road. The magnetic signature revealed a magnetic 'high' at the beginning of the traverse and it was apparent that the traverse was too short to reveal the nature of the feature. However, resistivity profiling (Profile 5) along this line revealed an anomaly which was further investigated by soundings MAKG51 to MAKG53. All the probes indicated a weathering depth in excess of 100 metres. Target area 4A was comprised of Lines 1, 3 and 5 and target area 4B was comprised of lines 2 and 4.

(Vol II p 2.61)

Traverse 6 was south in target area 4C and was run along the road. The magnetic survey revealed very little information. Resistivity profiling along the same line (Profile 6) revealed low resistivity of 10 ohm metres at AB/2 of 50 metres. A resistivity sounding conducted in the middle of the profile indicated very low resistivities. The substrata of resistivity 33 ohm metres was interpreted to reflect a weathered gneissic aquifer containing saline water and as a result work was terminated south of this area.

#### Target Area 5A, 5B (Kgagadi South)

(Site Plans VI.5A ; VI.5B Vol II p 1.34, 1.35)

This area was identified during the field survey phase as the continuation of a prominent NW/SE photolineament which had previously been investigated to the south of Kgagodi (WCS, 1984).

Two north-south magnetic traverses (Traverses 1 and 3) were run across the lineament and a third (Traverse 2) parallel to the lineament. However, no significant anomalies were identified. EM profiling (Profiles 1 and 3) along lines 1 and 3 indicated shallow weathering (less than 20 metres) which was confirmed by resistivity soundings (KGS11<sup>and</sup> KGS12) ~~and KGS13~~ conducted at the more highly conductive points on profile 1. A small number of short reconnaissance magnetic traverses were also undertaken across minor photolineaments in the area but no significant results ensued.

(Vol II p 2.70)

(Vol II p 2.62)

(Vol II p 2.43, 2.44)

Target Area 6 (Kgagodi West) (Site Plan VI.6, Vol II p 1.36)

The area is located 1.5 km west of Kgagodi village close to the Kgagodi-Palapye road. The area forms an intersection of a prominent NW trending lineament and an ENE trending minor lineament.

The geophysical work was aimed at locating this intersection and also to determine the depth of weathering. A N-S magnetic traverse (Traverse 1) revealed an anomaly in the middle of the line. An EM profile along the same line and across the anomaly revealed two conductive zones. One conductive zone coincided with a broad surface drainage south of the road and the second was located on the magnetic anomaly. Resistivity depth probes KGW11 and KGW12 were conducted at these points. Probe KGW11, in the drainage, indicated a clay layer 4 m thick underlain by weathered bedrock. Interpretation of probe KGW12 is tabulated below.

(Vol II p 2.63)

(Vol II p 2.71)

(Vol II p 2.43)

<u>Depth (m)</u>	<u>Interpretation Lithology</u>
1.5	clayey sand
6	clays
15	weathered gneisses
15 +	fresh gneisses

From the magnetics it appeared as though the major structure was intruded by the dolerite dyke and both EM and resistivity sounding indicated minimal weathering depth. As a result no drilling site was pegged in this target area.

Target Area 7 (Raphiri) (Site Plan VI.78 Vol II p 1.37)

The area is situated 5 km west of Maunatlala, 27 km south of Kgagodi village, and lies between the Lotsane River and the Tswapong Hills. The area was suggested by DWA since they had previously carried out borehole siting work there early in 1986. During this earlier programme three boreholes were sited and drilled by DWA but only borehole BH 5415 struck water. The data for boreholes BH 5415 and BH 5416 is summarised below.

<u>Borehole No</u>	<u>Depth (m)</u>	<u>Water Strike (m)</u>	<u>Est Yield (m<sup>3</sup>/hr)</u>	<u>Lithology</u>
5415	180	37.56	10	alluvium (36m) shales (bottom)
5416	108	35	little	alluvium (9m) shales (bottom)

The number of the second dry borehole could not be established although the hole itself was located in the field. During the Lesenepole village borehole siting survey (WCS 1985) a saline borehole was sited and drilled in the same area but somewhat closer to the Lotsane River. DWA also recorded saline water in the Maunatlala area.

The geophysical survey was aimed at mapping out structure and also to determine the nature and thickness of scree derived from the Tswapong Hills. Lotsane River colluvial deposits were not investigated.

Aerial photo interpretation revealed NW and NE trending faults easily discernable on the hills. The scree at the foot of the hills obscured any structure and as a result four long magnetic and EM traverses were run. Traverses 1 and 3 were east-west while 2 and 4 were run north-south. All the magnetic signatures (Traverses 1, 2, 3 and 4) were noisy and tended to fluctuate with subdued 'amplitude' variations. The EM profiles (Profiles 2 and 4) indicated a highly conductive environment close to the river and less conductive environment close to the hills. This change in conductivity was interpreted to reflect a gradation from scree into the clayey alluvium close to the Lotsane River.

Resistivity constant separation profiling was also conducted across the boundary of the two types of superficial cover on line 2. ~~The resistivity changed from an average of 45 to 25 ohm metres, indicating the edge of the scree from the hills.~~ (Vol II p 2.75)

Resistivity depth probes were conducted both in the conductive and the non-conductive areas and were meant to determine the nature of the alluvium. It was difficult to collect field data in the conductive area since at AB/2 of 20 meters it appeared clay lenses in the alluvial deposits caused interference, with the result that the Schlumberger curves were difficult to interpret. A resistivity depth probe (RAP11) carried out close to the hills indicated a potential aquifer 96 metres thick with a substratum resistivity of 966 ohm metres. The other four probes (RAP12, RAP13, RAP14 and RAP24) conducted on the same traverse line all revealed similar resistivity depth profiles. (Vol II p 2.84) (Vol III p 2.45, 2.47)

### 5.3 Drilling Site Selection

A total of 9 drilling sites were selected in all, 3 in Target Area 1D, Tshokana, 3 in Target Area 7 (Raphiri), 5 in Target Area 4 (kgagodi - Maunatlala). These sites were prioritised area by area.

#### Target Area 1D. Drilling Site Priority 1 (Tshokana)

This site is located 14 km south east of Kgagodi village and it is accessed by an old Kgagodi/Maunatlala track. Probe TS/10B1, conducted at the edge of a 'noisy' magnetic anomaly of traverse 10B, was selected for drilling. The probe indicated a weathering depth of 21 metres. The borehole was expected to penetrate through the lithology tabulated below. (Vol II p 2.30)

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
3	dry sandy soil
24	weathered gneisses
59	fractured, weathered gneisses
59 +	fresh gneisses

Shallow water strike was anticipated in the weathered gneisses and substantial yield increase in the fractured gneisses. The borehole was recommended to be drilled to 100 metre depth.

Target Area 1D. Drilling Site Priority 2 (Tshokana)

The site is located 150 m west of Drilling Site Priority 1 and the sounding was conducted in the middle of the above mentioned 'noisy' magnetic anomaly. The probe chosen (TSØ10B2)✓ for drilling indicated the same depth sequence as shown above. The same drilling depth of 100 metres was recommended. (Vol II p 2.32)

Target Area 1D. Drilling Site Priority 3 (Tshokana)

The site is located about 2 km east of Drilling Site Priority 1 and close to Tshokana River. This site was chosen on the basis of a large magnetic high (Traverse 12) on the Tshokana River and two EM conductive areas which coincided with the edges of the magnetic anomaly. The sounding selected for drilling was conducted on the eastern side of the magnetic high. The sounding, TSØ122 ✓ was interpreted as tabulated below. (Vol II p 2.33)

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
3	clayey wet sand
8	alluvium (clays)
22	fractured gneisses
55	fractured, weathered gneisses
55 +	fresh gneisses

Water strike was anticipated in the fractured gneisses below the alluvium. The yield was expected to increase with depth. Recommended drilling depth was 100 metres.

Target Area 4, Drilling Site Priority 1 (Kgagodi-Maunatlala)

The site is located 6 km south of Kgagodi along the Kgagodi-Maunatlala road and it is on the western side close to the road. The borehole was sited on the basis of deep weathering indicated by two soundings, (MAKG11 and MAKG12) conducted at low resistivity points along resistivity profile 1. The borehole was expected to penetrate the following lithologies.

KG M 11

KG M 12

Vol II p 2.37

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
0.5	wet sand
2	calcrete
25	weathered gneisses
89	fractured weathered gneisses
89 +	fractured gneisses

Shallow water strike was anticipated in the extensively weathered gneisses and the yield was expected to increase with depth. The borehole was recommended to be drilled to 100+ metres depth.

Target Area 4, Drilling Site Priority 2 and 3

(Kgagodi - Maunatlala)

The sites are located 1.6 km west of Drilling Site Priority 1. Site 2 is close to a fence that crosses the road at site 1 and site 3 is 400 metres south of site 2. Three soundings, MAKG51 to MAKG53, were conducted along resistivity profile 5. Probe MAKG51 was located at the edge of a resistivity low and probe MAKG53 was conducted in the resistivity low area. Both probes indicated deep weathering. The interpreted sequences are tabulated below.

(Vol II p 2.41, 2.42)

(Vol II p 2.74)

Drilling Site Priority 2 (Probe MAKG51)

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
0.5	sandy clays
5	calcrete
22	weathered gneisses
43	fractured weathered gneisses
87	weathered gneisses
133	fractured weathered gneisses
133 +	fractured gneisses

Drilling Site Priority 3 (Probe MAKG53)

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
1.0	sandy clays
5	calcrete
25	clayey weathered gneisses
47	weathered gneisses
115	clayey weathered gneisses
115 +	fractured weathered gneisses

A thick potential aquifer was expected on these two sites. Drilling depth of 120 + metres was recommended for both boreholes.

Target Area 4. Drilling Site Priority 4 (Kgagodi-Maunatlala)

The site is located 1 km east of Drilling Site Priority 1 and it is 200 metres north of the fence. The site was chosen on the basis of deep weathering indicated by sounding MAKG32. Both magnetics and EM revealed minor anomalies along the valley. The borehole was expected to penetrate through the following sequence. (Vol II, p 2.39)

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
0.5	clays
7	calcrete
51	weathered gneisses
123	fractured gneisses
123 +	fresh gneisses

Water strike was expected in the extensively weathered gneisses. The fractured gneiss sequence of 72 m was also expected to form part of the potential aquifer. The borehole was recommended to be drilled to a depth of 120+ metres

Target Area 4. Drilling Site Priority 5 (Kgagodi-Maunatlala)

The site is located 340 metres south of Drilling Site Priority 4 and it is 150 metres south of the fence. Resistivity profile 3 revealed a resistivity low that coincided with a minor NE-SW photo lineament. Sounding MAKG35 conducted at the resistivity low indicated deep weathering. The table below summarises the expected lithologies. (Vol II p 2.40)

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
0.4	sandy clays
11	calcrete
73	fractured weathered gneisses
83	weathered gneisses
83 +	fresh gneisses

Water was anticipated in the fractured weathered gneisses and yield increase was expected in the underlying weathered gneisses. The borehole was recommended to be drilled to a depth of 100 + metres.

Target Area 7. Drilling Site Priority 1 (Raphiri)

Raphiri is 33 km south of Kgagodi village and it is situated between the Lotsane River and Tswapong range of hills (see 5.2 above). The site is located 2.25 km south of the Lotsane River. The selected sounding for drilling was conducted on an EM low conductivity area adjacent to the hills. Resistivity profiling (line 2) also indicated the same trend. The high resistivity was interpreted to reflect quartzitic scree from the hills. The selected probe (RAP24), indicated a lithological sequence as follows. (Vol II p 2.76)

Drilling Site Priority 1 (Probe RAP24)

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
1	dry sands
7	clayey sands
39	quartzitic boulders
66	sand / boulders
66 +	quartzite

Water strike was anticipated in the clayey sands, although the main potential aquifer was expected in the sand / boulders. A drilling depth of 100 metres was recommended.

Target Area 7. Drilling Site Priority 2 (Raphiri)

The site is located 3 km west of Drilling Site Priority 1 and 1.8 km south of the Lotsane River. Magnetic traverse 4 was fairly uniform. The EM signature indicated an anomaly similar to the anomaly of profile 2 on which the old Lesenepole borehole, (BH 1662), was sited. Probe RAP42, conducted at this point, was difficult to interpret. It appeared as though very shallow highly conductive layer(s) interfered and as a result no usable data could be collected. However, this site was chosen for drilling and the borehole was recommended to be drilled to 150 metres depth. (Vol II p 2.64)

Target Area 7. Drilling Site Priority 3 (Raphiri)

This site is located 1.8 km south of the Lotsane River and 600m north-east of Drilling Site Priority 1. Magnetic traverse 3 revealed a fairly uniform magnetic environment. The EM profile also revealed the same trend. Resistivity sounding RAPSP1 was conducted by DWA in 1986. This probe aimed at the intersection of a NE-SW lineament and a stream that drains the hill slope scree. The borehole was expected to penetrate through the 21 metres of alluvium and the underlying shaly layers. Shallow water strike was anticipated in the alluvium. The borehole was recommended to be drilled to a depth of 150 + metres. Interpreted lithology is as follows:

<u>Depth (m)</u>	<u>Interpreted Lithology</u>
2.2	dry sand
5.3	wet sand
22	alluvium
70	shales / boulders
70 +	shales

lwr case \*

## 6. GROUNDWATER EXPLORATION

### 6.1 Drilling

Out of the seven Target Areas, no sites were pegged for drilling in Target Areas 2, 3, 5 and 6. Results from geophysical surveys in these areas did not warrant exploratory drilling. In all a total of 11 boreholes were drilled in Target Areas 1, 4 and 7 by both De Wet Drilling Contractors and TGB Drill Contractors who used conventional rotary percussion drilling techniques.

Target Areas 1, 4 and 7 are in Tshokana, Kgagodi / Maunatlala and Raphiri respectively, within the Kgagodi / Mogapinyana / Dilorro survey area. In Target Area 1, three boreholes were sited in structurally controlled deeply weathered zones. Another 3 boreholes were drilled in Target Area 7, mainly in alluvium and the Tswapong Formations of the Raphiri area. The last 5 boreholes were drilled in the area south of Kgagodi near the road to Maunatlala in extensively weathered zones related to structures in the Basement gneisses.

Table VI.1 summarises the results of the exploration drilling in the Kgagodi / Mogapinyana / Dilorro area. The relevant borehole data from the drilling exercise is appended in Section 3, Volume II, in the form of graphic logs <sup>and</sup> construction plans. and ~~Dept. of Water Affairs Completion Certificates.~~ Pertinent hydrogeological observations as well as drilling and construction problems which were encountered in each borehole are discussed briefly in the following sections.

#### Target Area 1

Three boreholes, (BH5938, BH5939 and BH6117) were drilled in this Target Area. TGB Drill Contractors drilled the first two and de Wet Drilling Contractors the third hole.

#### Target Area 1D. Drilling Site Priority 1 (BH 5938)

The borehole was drilled at 216 mm diameter down to 38 m from surface and at 165 mm diameter from 38 m to 120 m, the terminal depth. Plain steel casing, 165 mm diameter, was grouted in at 38 metres depth. Comparison of interpreted lithological sequence from resistivity depth sounding TS#10B1 to the actual formation log is indicated in Table VI.2. and in Vol II p 3.10.

Shallow water strike was anticipated within the first 24 metres of the weathered layer and substantial yield increase in the fractured gneisses. However, during drilling moist amphibolite gneisses were encountered between 13 and 16 metres depth and fractured pink gneisses between 31 and 40 metres. This fractured layer was completely masked in the sounding interpretation which resulted in anomalous layer thicknesses in the initial interpretation.

#### Target Area 1D, Drilling Site Priority 2 (BH 5939)

The borehole was drilled at 216 mm diameter down to 28 m depth and at 165 mm diameter to terminal depth of 100 m. Plain steel casing 165 mm diameter was cement grouted at 28 metres depth. The borehole was drilled through 17 m of weathered grey gneisses underlain by micaceous grey gneisses. These lower micaceous gneisses were initially wrongly interpreted as partly weathered fractured gneisses and also considered to be an extension of the main potential aquifer, the weathered zone. The top 5 m of calcrete coated gravel was interpreted as dry sand. (Table VI.2% and Vol II p 3.11)

Water strike was expected in the top 21 metres in the weathered zone, but the borehole was in fact dry.

#### Target Area 1D, Drilling Site Priority 3 (BH 6117)

The borehole was drilled at 216 mm diameter down to 15 m depth and at 165 mm diameter to a terminal depth of 100 metres. Plain steel casing was inserted to 15.4 metres.

The borehole penetrated gravels and weathered zone in the uppermost 16 metres and the underlying formation was unweathered pink-grey gneisses. A fourth layer interpreted from the sounding was not encountered in the borehole. This layer was thought to represent a potential aquifer (a large weathered fracture zone). The absence of this layer can only be explained by the masking effects of the upper alluvium in the original interpretation. (Table VI.2% and Vol II p 3.16)

#### Target Area 4

Five boreholes (BH6115, BH6127, BH6121, BH6122, BH6120) drilled in this area were completed by de Wet Drilling Contractors.

Target Area 4. Drilling Site Priority 1 (BH 6115) *cam 1/1*

The borehole was drilled at 203 mm diameter to 18 m depth and the 165 mm diameter plain casing was cement grouted in. The borehole was then drilled to the terminal depth of 120 metres. The borehole penetrated through a sequence of weathered amphibolites, fractured quartz veins and an extensively weathered zone at 110 metres depth.

Water strike was at 33 metres and substantial yield increases were encountered at 42, 54, 60, 73 and 90 metres (~~see Borehole Logs~~, Section 3, Volume II *p. 3.14*). After drilling the borehole was developed by jetting\* compressed air through the drilling stem. ←

The geophysical interpretation compared fairly well with the drilling results (Table VI.2 *and Vol II p 3.14*.) The probe indicated a weathering profile to a depth of 89 metres and drilling encountered unweathered gneisses below 97 metre depth. In the initial interpretation water was expected in the top 25 metres of weathered, highly conductive, gneisses.

Target Area 4. Drilling Site Priority 2 (BH 6127) *cam 5/1*

The borehole was drilled at 203 mm diameter to 36 metres depth and at 165 mm diameter to a terminal depth of 150 metres. Plain steel 165 mm diameter casing was inserted to 36 m depth. The borehole penetrated through 32 m of extensively weathered gneiss. The underlying quartz rich gneisses were extensively fractured and quartz veins were intercepted throughout the sequence.

Water strike was at 37 metres and substantial yield increase was at 94 metre depth in a fractured quartz vein. Air lift yield was estimated at  $12^3$ /hr using a 90 degrees V-notch weir. After drilling the borehole was developed by jetting compressed air at the bottom of the hole through the drilling stem.

The geophysical lithology interpretation (Table VI.2 *and Vol II p 3.20*) compared fairly well with drilling results to a depth of 84 metres and weathered and fractured gneisses were penetrated. The interpreted fractured/weathered 6th layer between 87 and 133 metres depth seemed to have lowered the resistivity of the substratum.

Target Area 4, Drilling Site Priority 3 (BH 6121) *cam 5/3*

The borehole was drilled at 203 mm diameter to a depth of 76 metres and at 165 mm to a terminal depth of 107 metres.

The first water strike was at 40 metres depth in running sand and as a result it was decided to continue drilling the borehole at 203 mm diameter. At 60 to 65 metres depth an extensively weathered zone was intercepted and loose blocks continued collapsing in the hole during drilling. The driller attempted to insert a temporary 165 mm diameter plain steel casing to 76 metres depth, but unfortunately a 42 metre length of casing was dropped into the borehole. This was eventually fished out and the borehole was then terminated at 107 metres depth. The borehole was completed with 152.4 mm diameter steel plain and slotted casing (*see Construction Logs, Section 3, Volume II p. 3.18*)

The geophysical lithology interpretation indicated 115 metres of weathered zone as compared to 65 metres penetrated by the borehole (Table VI.2). A weathered fracture zone was expected between 65 and 115 metres depth but the drilling was terminated at 107 metres due to problems mentioned above. It appeared from drilling that the magnetic anomaly could have been the result of fractures or the mafic mineral-rich grey gneisses. It is apparent that the resistivity low on line 5, (see 5.3 above) was a result of the deep weathering encountered in both boreholes BH6127 and BH6121. *and Vol II p 3.18*

Target Area 4, Drilling Site Priority 4 (BH 6122)

The borehole was drilled at 216 mm diameter to a depth of 24 metres and at 165 mm diameter to a terminal depth of 120 metres. Plain steel 165 mm diameter casing was inserted to a depth of 24 metres. The borehole penetrated 34 m of weathered zone underlain by unweathered greyish gneisses. The depth sounding indicated an anomalous thickness of weathered zone (Table VI.2 *and Vol II p 3.19*)

Mica-quartz rich amphibolitic gneisses were interpreted as fractured gneisses to a depth of 123 metres.

Water strike was at 53 metres in a fracture zone and this had been interpreted as the base of the weathered zone. (*See Borehole Logs Section 3, Volume II p 3.19*)

The borehole was developed by jetting compressed air through the drilling stem.

#### Target Area 4, Drilling Site Priority 5 (BH 6120)

The borehole was drilled at 216 mm diameter to a depth of 15 metres and at 165 mm to the terminal depth of 120 metres. Plain steel casing 178 mm diameter was inserted to a depth of 15 metres.

The borehole penetrated through a weathered zone of 60 metres and fractured zone to 80 metres depth. This sequence compared fairly well with the depth sounding interpretation which indicated a weathered and fractured zone of 83 metres (Table VI.2v.) A resistivity low was created by the deep weathering encountered in both boreholes, BH6122 and BH 6120 (see 5.3 above).

and Vol II  
p 3.17

Water strike was at 45 metres depth and significant yield increases were at 69 and 90 metres depth. The final yield was estimated at 4 m<sup>3</sup>/hr. The borehole was developed by jetting compressed air through the drilling stem.

#### Target Area 7

Three boreholes (BH 6116, BH 6114 and BH 6002) were drilled in this area.

#### Target Area 7, Drilling Site Priority 1 (BH 6116)

The borehole was drilled at 216 mm to a depth of 9 metres and a 200 mm plain steel casing was inserted because loose gravel and sand kept collapsing into the hole and locking the drilling stem. At a depth of 18.4 metres when the formation became more solid a 168 mm plain steel casing was inserted. After casing insertion the borehole was completed at a depth of 100 metres at a diameter of 165 mm.

The borehole was drilled in boulders and gravel to a depth of 33 metres and in quartzite, siltstones and sandstones to total depth. The lithology corresponds to the depth sounding interpretation with high resistivity layers with minor variations introduced by silt content. Table VI.2 lists both the borehole formation log and the sounding interpretation. Both are graphically presented in Vol II p. 3.15

Water was encountered as shallow as 3 metres depth but was cased off since it represented near surface flow which is common in gravels close to the Tswapong Hills. Main water strike was at 33 metres depth and the airlift yield estimate was 15 m<sup>3</sup>/hr.

The borehole was developed by jetting compressed air through the drilling stem. During development a considerable amount of sandy gravel was flushed out which suggested cavity formation below the 168 mm casing.

Target Area 7. Drilling Site Priority 2 (BH 6114)

The borehole was drilled at 203 mm diameter to a depth of 60 metres and at 165 mm diameter to the terminal depth of 150 metres. The 165 mm diameter plain casing was inserted to 60 metres.

The borehole penetrated through 14 metres of gravel, 28 metres of shales and then siltstone and quartzite to total depth. The resistivity depth sounding indicated anomalous layer thicknesses which would appear to have been the result of the shales. This unit was wrongly interpreted as clayey gravels since it is difficult to distinguish shales from clayey gravels from a resistivity probe. (Table VI.28 and Vol II p 3.13)

Very little water was struck at the base of the gravels and this was cased off. After drilling the casing was pulled out and the borehole was back filled.

Target Area 7. Drilling Site Priority 3 (BH 6002)

The borehole was drilled at 203 mm diameter to a depth of 6 metres and 203 mm diameter plain casing had to be inserted because there were no returns and no circulation. At a depth of 42 metres a 165 mm diameter casing was inserted. The borehole was then drilled at 165 mm diameter until it was terminated at a depth of 202 metres.

The borehole penetrated 10 metres of clayey sand, 29 metres of shale and then siltstone to total depth. The resistivity again indicated anomalous thicknesses due to the presence of the shale unit. (Table VI.28 and Vol II p 3.12)

No water was struck in this borehole and an attempt to pull out the casing failed.

TABLE VI.1 KGAGODI DILORO SUMMARY OF EXPLORATION DRILLING RESULTS

TARGET AREA	DRILLING SITE PRIORITY (sounding number)	DRILLING CONTRACTOR	BOREHOLE NO	TERMINAL DEPTH (metre)	WATER STRIKE	MAX AIRLIFT YIELD (cu. metre / hour)	STATIC WATER LEVEL (metre)
1 (TSOKANA)	1 (tso 10b/1)	tyb	5938	150	-	*very low	40.2
	2 (tso 10b/2)	tyb	5939	100	-	dry	-
	3 (tso 10b/3)	de wet	6117	100	-	dry	-
4 (KGAGODI - MAUNATLALA)	1 (makg 1/1)	de wet	6115	120	33,54,60	5	23.7
	2 (makg 5/1)	de wet	6127	150	73 37,94	12	26.1
	3 (makg 5/3)	de wet	6121	107	40,62,90	15	34.4
	4 (makg 3/2)	de wet	6122	120	53	3	20.2
	5 (makg 3/5)	de wet	6120	120	45,69,90	4	24.8
7 (RAPHIRI)	1 (rap 2/4)	de wet	6116	100	33	15	3.0
	2 (rap 4/2)	de wet	6114	100	-	*very low	-
	3 (rap sp/1)	de wet	6002	202	-	dry	-

\* "Very Low" indicates air-lift yields which are less than 1,5 cu. metre/hour

KGAGODI/DILORO - COMPARISON OF EXPECTED GEOLOGY TO DRILLING FORMATION LOGS

TABLE VI.2

TARGET AREA	DRILL SITE LOCATION	BH NO	INTERPRETATION OF DEPTH PROBE	DRILLING FORMATION LOGS
1  (TSHOKANE)	TSO 10B 1	5938	0 - 3m dry sand 3 - 24m weathered gneisses  24 - 59m fractured, weathered gneisses 59m unweathered gneisses	0 - 4m sand, gravel 4 - 25m greyish/pink weathered gneisses 25 - 31m pink/grey fresh gneiss 31 - 40m pink/grey weathered gneiss 40 - 81m pink/grey gneiss
	TSO 10B 2	5939	similar to drill site TSO 10B 1 above	0 - 1m gravel, calcrete 1 - 9m grey amphibolites 9 - 17m fractured and weathered amphibolitic gneisses 17 - 30m micaceous amphibolites, quartz 30 - 60m amphibolitic gneisses, quartz 60 - 100m pink/grey gneisses

KGAGODI/DILORO - COMPARISON OF EXPECTED GEOLOGY TO DRILLING FORMATION LOGS

TABLE VI. 2

TARGET AREA	DRILL SITE LOCATION	BH NO	INTERPRETATION OF DEPTH PROBE	DRILLING FORMATION LOGS
(TSHOKANE)	TSO 122	6117	0 - 3M clay, wet sand 3 - 8M alluviums, clays	0 - 7M sand, gravel, clays 7 - 16M weathered and fractured gneisses
			8 - 22M fractured gneisses 22 - 55M fractured weathered gneisses 55M unweathered gneisses	16 - 100M pink/grey gneisses
4	MAKG 11	6115	0 - 2M sand, calcrete 25 - 89M fractured + weathered gneisses 89M fractured gneisses	0 - 6M black cotton soil, calcrete 12 - 71M fractured + weathered gneisses 71 - 97M fractured grey amphibolitic gneisses 97 - 120M pink gneisses

KGAGODI/DILORO - COMPARISON OF EXPECTED GEOLOGY TO DRILLING FORMATION LOGS

TABLE U1.2

TARGET AREA	DRILL SITE LOCATION	BH NO	INTERPRETATION OF DEPTH PROBE	DRILLING FORMATION LOGS
4  (KGAGODI/ MAUNATLALA)	MAKG 51	6127	0 - 5m sand, clays, calcrete	0 - 6m black sandy soil, calcrete
			5 - 22m weathered gneisses	6 - 23m weathered fractured gneisses
			22 - 43m fractured weathered gneisses	23 - 64m weathered pink amphibolitic gneisses
			43 - 87m weathered gneisses	64 - 84m fractured pink gneisses
			87 - 133m fractured weathered gneisses	84 - 150m pink/grey gneisses
			133m fractured gneisses	
	MAKG 32	6121	0 - 5m sand, clays, calcrete	0 - 5m sand soil, calcrete
			5 - 25m clayey weathered gneisses	5 - 40m pink/grey weathered gneisses
			25 - 47m weathered gneisses	40 - 65m fractured pink gneisses
			47 - 115m clayey weathered gneisses	65 - 107m pink/grey gneisses
			115m fractured weathered gneisses	

KGAGODI/DILORO - COMPARISON OF EXPECTED GEOLOGY TO DRILLING FORMATION LOGS

TABLE VI.2

TARGET AREA	DRILL SITE LOCATION	BH NO	INTERPRETATION OF DEPTH PROBE	DRILLING FORMATION LOGS
4  (KGAGODI/ MAUNATLALA)	MARG 53	6122	0 - 7m sand clay, calcrete	0 - 5m sandy clay soil, calcrete
			7 - 51m weathered gneisses	5 - 34m weathered pink gneisses
			51 - 123m fractured gneisses	34 - 96m fresh greyish gneisses
			123m unweathered gneisses	96 - 120m mica/quartz rich amphibolitic gneisses
	MARG 35	6120	0 - 11m sand, clays, calcrete	0 - 15m sand, calcrete weathered gneisses
11 - 73m fractured, weathered gneisses			15 - 60m fractured, weathered gneisses	
73 - 83m weathered gneisses			60 - 80m fractured gneisses	
83m unweathered gneisses			80 - 120m pink/grey gneisses with quartz	

KGAGODI/DILORO - COMPARISON OF EXPECTED GEOLOGY TO DRILLING FORMATION LOGS

TABLE VI.2

TARGET AREA	DRILL SITE LOCATION	BH NO	INTERPRETATION OF DEPTH PROBE	DRILLING FORMATION LOGS
7 (RAPHIRI)	RAP 24	6116	0 - 7M sand, clays 7 - 39M quartzitic boulders 39 - 66M sandy boulders 66M quartzite	0 - 5M sand 5 - 33M gravel, quartzite 33 - 78M siltstones, quartzite 78 - 85M sandstone 85 - 100M siltstones
	RAP 42	6114	0 - 6M sand 6 - 39M clays, gravel 39 - 75M fractured quartzite 75M quartzite	0 - 1M sand 1 - 14M sandy clays, gravel 14 - 42M shales 42 - 141M shales, siltstone 141 - 150M siltstones, quartzite
	RAP SP1	6002	0 - 4M sand 4 - 22M sand (alluvium) 22 - 55M shales/boulders 50M siltstones/shales	0 - 5M sand 5 - 33M gravel, clays, gravel boulders 33 - 78M siltstones, quartzites 78 - 85M sandstone 85 - 202M siltstones

## 6.2 Aquifer Testing

The theory and practise of aquifer testing is well described in groundwater literature and the general limiting criteria influencing data analysis are similarly well documented. Such criteria, when applied to a particular aquifer, relate to the apparently infinite areal extent and uniform thickness of an homogenous isotropic unit fully penetrated by an abstraction borehole. These ideal conditions are not often fully satisfied under natural conditions, more especially in the type of hydrogeological environment that exists in granitic rock terrains. It is therefore necessary to take into consideration the divergence of the aquifers under test from these controlling criteria when applying traditional data analysis techniques and when reviewing the derived aquifer parameters. The following observations on the hydrogeological conditions in the Basement terrain of the Kgagodi / Mogapinyana / Diloru area indicate to what extent these controlling criteria are satisfied.

- all aquiferous units possess secondary permeability created by fissures, possibly enhanced by weathering. These fissures are usually narrow and may be discontinuous, although over a large area may provide a certain degree of homogeneity.
  
- in productive boreholes water was often struck at several discrete depths with a resulting incremental increase in borehole yield. The relative importance of each fissure zone to the overall yield and its longevity is very difficult to assess.
  
- although occurring in fissures which may have tenuous connection to the ground surface and allow a certain amount of recharge, the groundwater body behaves in a confined / semiconfined manner under test. In the absence of a definite confining layer this behaviour must be the result of the presence of weathering products both near surface and within the fissures and by the nature of the fissures themselves. In this latter context fissure discontinuity and capillary forces in the finer fissures will play a considerable part in influencing groundwater flow and hence apparent test conditions.

- flow through a network of fissures providing water to an abstraction point is more likely to be non-horizontal and turbulent in nature than horizontal and lamina.
  
- no observation boreholes were available to establish the nature of the piezometric surface prior to testing or to gauge the degree of anisotropy of the 'aquifer'. In the absence of observation boreholes no reliable storage parameters could be derived.

Test pumping works on the exploration boreholes drilled in the Kgagodi / Mogapinyana / Diloru area were undertaken by a Department of Water Affairs Wellfield Section Testing Unit using a range of electrical submersible pumps capable of discharges ranging from 2 to 24 m<sup>3</sup>/hr. Standard electric contact gauges were used for water level measurement and discharge was monitored by a standard container (210/117 litre drum) and adjusted by a wellhead valve. General test procedures and data collection were to normal D.W.A. standards.

It was the intention that a 48 hour Constant Discharge test be performed on each successful and adequately completed borehole at a discharge rate to be estimated from the (drilling) airlift yield. However, some initial confusion occurred between the testing crews, who were then under the direct control of D.W.A. (the Client) and the Consultant who was to design and supervise the testing. This resulted in one borehole (BH6115) being retested later in the programme at a higher discharge rate.

Analysis of test data collected during the programme has been undertaken using standard graphical methods. Data plots are included in Section 3, Volume II of this report and basic data is appended in Volume III. A summary of aquifer testing results is included in Table VI.3.

There follows a site by site description of testing procedures and analysis results for each of the five boreholes tested.

### Borehole BH 6115

This borehole was tested twice since the initial test was run at a very low discharge rate (2.6 m<sup>3</sup>/hr) and drawdown after 48 hours was only 4.46 metres. A second test was thus undertaken at a considerably higher discharge rate (6.1 m<sup>3</sup>/hr) in order to more effectively examine the potential of the borehole.

For the first test an SP4-46 submersible pump was installed to 64 metres and a discharge rate of 2.6 m<sup>3</sup>/hr established. The test was conducted for 48 hours and water level recovery monitored for 24 hours. A maximum drawdown of 4.46 metres indicated that the borehole was likely to be considerably more productive than anticipated and a second test was thus undertaken at a higher discharge rate. Due to a misunderstanding with the testing crew this test was undertaken in three successive steps of 2.15, 4.13 and 6.11 m<sup>3</sup>/hr. The first two steps were of 90 and 100 minutes duration and the final step 46 hours duration. Recovery was monitored for 30 hours.

Analysis of test data (see Volume II, Section 3, p. 321) indicates a transmissivity of between 8 and 15 m<sup>2</sup>/day. Specific capacity of the borehole is calculated as 0.36 m<sup>3</sup>/hr/m. Although there was a minor water strike at 33 m.b.g.l. main inflows appear to be at 54 and 60 m.b.g.l. If production pumping water levels are to be maintained above this level such that there is no danger of dewatering the main inflow zones, the abstraction rate should be less than 10 m<sup>3</sup>/hr. In order to allow an adequate factor of safety it is thus proposed that the production abstraction rate of BH 6115 be set at 8 m<sup>3</sup>/hr.

### Borehole BH 6120

An electric submersible pump (SP 4-46) was installed at a depth of 95 m.b.g.l and the borehole was pumped for an initial 12 hours at a discharge rate of 3.5 m<sup>3</sup>/hr. Drawdown after 12 hours was only 12.7 metres and the discharge rate was thus increased to 5.8 m<sup>3</sup>/hr for the remaining 36 hours of the test.

This discharge increase was in order to create a greater drawdown and so examine the relative contribution of the three recognised inflow zones (45, 69 and 90 m.b.g.l) and the possible variation in specific capacity with depth. Groundwater level recovery was monitored for 24 hours after completion of the test.

Examination of drawdown data indicates that there was no significant acceleration in the rate of drawdown as the pumping water level fell below the uppermost inflow horizon (45 m.b.g.l) which would tend to confirm the airlift yield measurements during drilling that the relative contribution of this fracture to the overall yield is very small. At the higher pumping rate of 5.8 m<sup>3</sup>/hr, water level stabilized at a depth of 72.95 m.b.g.l, some 3-4 metres below the second inflow zone recorded during drilling (69 m.b.g.l). It is likely, therefore, that this zone is continuing to contribute to the borehole yield.

p. 3.22)

Data analysis (Section 3, Volume II) indicates low transmissivity of between 3 and 8 m<sup>2</sup>/d. The calculated specific capacity, using the final stabilized drawdown of 48.95 metres, is 0.12 m<sup>3</sup>/hr/m. If a maximum drawdown of 40 metres is envisaged during production pumping in order to maintain water levels above the significant lower inflow zones this would require borehole BH 6120 to be equipped to produce 4.5 m<sup>3</sup>/hr.

#### Borehole BH 6121

An electric submersible (SP8-25) pump was installed at 65 m.b.g.l. and an initial test commenced at 10.4 m<sup>3</sup>/hr. After a first step of 100 minutes and a minimal drawdown of 4.7 metres this discharge rate was increased to the maximum capacity of the pump (11.7 m<sup>3</sup>/hr) and the test continued. This second step proceeded for 16 hours but was then abandoned when the test pump generator failed.

The borehole was subsequently re-tested at a discharge rate of 11.7 m<sup>3</sup>/hr (the maximum output of the pump) for 48 hours and the water level recovery monitored for 24 hours. A maximum stabilized drawdown of 7.99 metres was recorded during this test.

Examination of the test data indicates that there was no noticeable increase in the rate of drawdown when water levels reached the uppermost (fracture) inflow horizon at 40 m.b.g.l. Pumping water levels did, in fact, stabilize at 42.3 m.b.g.l for the final 6 hours of the test. This would tend to indicate a relatively significant contribution by the upper inflow zone to the overall borehole yield.

Data analysis (Section 3, Volume II) <sup>p. 3.23</sup> indicates a much higher transmissivity in this locality than in other boreholes in the same area (see above). A value of between 30 and 34 m<sup>2</sup>/d has been calculated. The borehole similarly exhibits a fairly high specific capacity of 1.48 m<sup>3</sup>/hr/m. If this value of specific capacity is used to estimate a production pumping rate, assuming an allowable drawdown of 25 metres in order to maintain the water level above the lower fracture zones and above the pump, a production rate of 37 m<sup>3</sup>/hr would result. However, in order to accommodate a possible reduction in specific capacity due to significantly higher discharge and the possible dewatering effects on the upper fracture zone it is recommended that borehole BH 6121 be equipped for an abstraction of 25 m<sup>3</sup>/hr.

#### Borehole BH 6122

A submersible pump unit (SP4-46) was installed to a depth of 53 m.b.g.l and a Constant Discharge test at 2.43 m<sup>3</sup>/hr was run for 48 hours. Maximum drawdown attained was 18.32 metres. Water level recovery was then monitored for a period of 24 hours.

Examination of drilling records indicates only a single contributory fracture at 53 metres. It is thus advisable to maintain a production pumping water level above this horizon to prevent any future problems with dewatering of this inflow zone. Data analysis (Section 3, Volume II) <sup>p. 3.24</sup> indicates a very low transmissivity (2.7 to 3.9 m<sup>2</sup>/day) which would be expected with only a single yielding fracture supplying water to the hole. A check on this transmissivity value using Logans Approximation (T = 1.22 Q/s) confirms its low value (3.8 m<sup>2</sup>/d). The specific capacity of the borehole has been calculated as 0.13 m<sup>3</sup>/hr/m and at low abstraction rates is expected to remain constant if drawdown does not fall below the main inflow zone. Thus in order to maintain adequate production pumping water levels it is recommended that borehole BH 6122 be equipped for an abstraction of 3.5 m<sup>3</sup>/hr.

Borehole BH 6127

Following the installation of SP8-25 submersible pump to a depth of 112 m.b.g.l. a Constant Discharge test at 6.6 m<sup>3</sup>/hr was undertaken for 48 hours. Recovery was monitored for 24 hours from a maximum drawdown of 20.48 metres. During drilling two inflow (fracture) zones were identified at 37 and 94 m.b.g.l. providing similar contributions of 5 and 7 m<sup>3</sup>/hr to the borehole yield. Following approximately 2 hours of testing, pumping water levels fell below the level of the uppermost inflow horizon and finally stabilized some 5 metres below it, but no increase in the rate of drawdown is apparent. This would tend to confirm the drilling observations that the upper inflow horizon provides a significant proportion of the yield.

Data analysis (Section 3, Volume II) <sup>p. 3.25</sup> indicates a transmissivity similar to that of BH 6115 ( $\pm 10$  m<sup>2</sup>/d). If pumping water levels are to be maintained at approximately 40 m.b.g.l. then borehole BH 6127 should be equipped for an abstraction rate of 5 m<sup>3</sup>/hr.

The nature of the fractured aquifer and the distribution of the productive boreholes in Target Area 4 of the Kgagodi / Mogapinyana / Diloro village group has necessitated some consideration as to possible interference between the boreholes if they should all be brought into production. The most likely problems to arise will be in relation to BH 6121 and BH 6127 which are situated some 400 metres distant from each other. Since no monitoring of nearby boreholes was undertaken during test pumping only a re-examination of geophysical survey works and aerial photographs can be used to attempt to assess whether adjacent boreholes are located on the same fracture system and hence to gauge whether they may interfere with one another under production conditions. This re-evaluation has indicated that BH 6121 and BH 6127 appear to be located on fractures of a different orientation, have different static water levels and hence may be hydraulically unconnected. However, both boreholes have similar water inflow levels and both exhibit the same deep weathering profile, which may enhance hydraulic connection between them. It is therefore difficult to predict whether interference will occur during production pumping. In view of the fact that the recommended abstraction rate for BH 6121 (25 m<sup>3</sup>/hr) is considerably in excess of the rate at which it was tested (11.7 m<sup>3</sup>/hr) it may be prudent to retest this borehole at the higher rate and simultaneously monitor water levels in the adjacent borehole BH 6127.

TABLE U1.3 SUMMARY OF TEST PUMPING RESULTS - KGAGODI/MOGAPINYANA/DILORO

Bh No	Total Depth mbgl	Water Strikes mbgl	U Notch Yield cu.m/hr	SWL mbgl	Test Yield cu.m/hr	Maximum Drawdown metre	Calculated Transmissivity sq.m/d	Specific Capacity cu.m/hr/m	Recommended Abstraction Rate cu.m/hr
6115	120.0	33.0 42.0 54.0 60.0 73.0 90.0	1.8 2.0 2.5 3.0 3.5 5.0	24.6	6.1	16.69	8 - 15	0.36	8.0
6120	120.0	45.0 69.0 90.0	0.5 2.5 4.0	24.0	5.8	48.95	3 - 8	0.12	4.5
6121	120.0	40.0 62.0 90.0	3.0 5.0 15.0	34.4	11.7	7.99	30 - 34	1.48	25.0
6122	120.0	53.0	3.0	19.6	2.4	18.32	3 - 4	0.13	3.5
6127	150.0	37.0 94.0	5.0 12.0	23.3	6.6	20.48	9 - 10	0.32	5.0

## 7. Hydrogeological Assessment

The following section comprises a summary of the hydrogeological conditions and groundwater potential in the Kgagodi / Mogapinyana / Dilorro area as deduced from the present study.

- Kgagodi / Mogapinyana and Dilorro are situated on Granitic and Banded Gneisses of the Basement Complex. The area is complexly folded and a number of shear zones exist. The major Lechana Fault forms a junction with Palapye Group metasediments some 15 kilometres to the southeast of the study villages.
- only secondary aquifers created by fracturing enhanced by weathering exist in the Basement gneisses. No primary aquifers are present in the area.
- groundwater levels in the Basement units are shallow (less than 30 m.b.g.l) and the piezometric gradient is low, south southeasterly. A regional groundwater divide trending E/W occurs approximately 15 kilometres north of Kgagodi.
- groundwater conditions are confined/semiconfined and in general the secondary aquifers exhibit low transmissivity and low storage. An exception to this general statement is in an area to the south of Kgagodi / Mogapinyana / Dilorro (Target Area 4) where fracture controlled weathering is much deeper (up to 30 m.b.g.l) and aquifer parameters are somewhat higher. (see 6.2 above)
- recharge to the gneissic aquifers is by direct infiltration of runoff to the weathered zone and then to the fracture system proper. In areas of thicker weathering (eg Target Area 4) the weathered zone will provide recharge to the fractured aquifer by leakage over a longer duration.
- groundwater quality in the gneissic aquifers around the Kgagodi group of villages is generally acceptable and within potable limits. Nearer the Lechana Fault (Tamasane) the water is more brakish.

- groundwater potential in the immediate vicinity of Kgagodi / Mogapinyana / Dilorro and over much of the surrounding area is generally poor. However, a limited area (Target Area 4) to the south of the villages appears to possess sufficient potential to satisfy the projected group water demand and may also be capable of supplying the village of Mogapi.

## 8. Development Recommendations

The following summary presents the suggested groundwater development for the supply of the Kgagodi / Mogapinyana / Dilorro group of villages.

- the group of boreholes located, drilled and tested approximately 6 km south of Kgagodi should be developed as a small wellfield. (Kgagodi South Wellfield). Boreholes are in Basement gneisses and are unlikely to require any reconstruction for production use. Recommended abstraction rates for individual boreholes are indicated in Section 6.2 above and should satisfy the projected water demand of the Kgagodi / Mogapinyana / Dilorro village group.
- in the absence of adequate groundwater sources in the Mogapi area (Section V) it is suggested that Mogapi village may be supplied from the proposed Kgagodi South Wellfield. It is possible that additional sites could be developed to the east and southeast of BH's 6122 and 6120 to specifically supply Mogapi by a direct pipeline. Alternatively these additional sites, together with other possible developments to the west of BH 6121, could be incorporated into one wellfield source to supply Mogapi via a Kgagodi / Mogapinyana / Dilorro pipeline. Clearly, the development strategy for the Kgagodi South Wellfield will have considerable impact on pipeline routes, design and cost.
- if any supplementary works are envisaged in the development of the proposed Kgagodi South Wellfield, it is suggested that some additional test pumping at recommended production rates be undertaken prior to pipeline design.
- the development of Kgagodi South Wellfield will require the consideration of and installation of suitable monitoring systems for water levels and water quality.

- as an adjunct to the present study it is suggested that BH 6116 (Target Area 7, Raphiri) may warrant testpumping with a view to its use in supplementing Maunatlala village supply. BH 6116 is approximately 5 kilometres from Maunatlala but may possibly be connected to the present supply system from BH 5415 since it is in the same direction.

- an old borehole (unnumbered), located near the chief's house in Kgagodi is reputed to be productive. Cleaning, testpumping and equipping with a hand pump may be warranted in order to provide an extra factor of safety to the proposed system.

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