THE RELIABILITY OF SMALL SPRING WATER SUPPLY SYSTEMS FOR COMMUNITY WATER SUPPLY PROJECTS

I Pearson · J Weaver · P Ravenscroft

WRC Report No. 859/1/03

Water Research Commission

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Report to the

Water Research Commission

Volume 1: **Assessment of the characteristics of Spring flows in small springs**
by Ian Pearson

Volume 2: **The hydrogeology of South African Springs**
by John Weaver

Volume 3: **Spring assessment and construction methods**
by Phillip Ravenscroft

With inputs from

Isaac Manala and Melanie Wilkinson
Environmentek, CSIR

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A BRIEF NOTE ON THE STRUCTURE OF THIS REPORT AND THE THREE MAIN AUTHORS

This report comprises three volumes:

Volume 1	***The assessment of the characteristics of Spring flows in small springs*** by Ian Pearson *et al*,
Volume 2	***The hydrogeology of South African springs*** by John Weaver,
Volume 3	***Construction methods for spring capture*** by Phillip Ravenscroft.

The first volume comprises the bulk of the WRC funded research project. This project addressed the need to assess the factors affecting spring flow, and develop ways of predicting the seasonability and reliability of flows from these springs. The research project involved extensive field measurements of spring flows.

The main author, Ian Pearson, is an engineer with extensive experience of implementation of rural water supply and sanitation projects. He is currently practising as a freelance rural water supply and sanitation engineer and is based in Gauteng.

The second volume describes the hydrogeological controls giving rise to springs. This report is particularly aimed at describing South African geological conditions and towards the cold springs found throughout South Africa.

The author of this section, John Weaver, has wide experience of groundwater investigations throughout most of southern Africa. John has over 20 years of hydrogeological experience. He is a senior hydrogeologist with Environmentek, CSIR.

The third volume is a synthesis of Phillip Ravenscroft's experience of spring construction. His experience of spring protection construction as well as his observations of numerous spring protections that have failed has resulted in him understanding both good and poor spring construction practice. The report conveys the do's and don'ts of spring construction.

Phillip Ravenscroft is a Civil Engineer with 15 years experience in implementing rural water supply projects. He has worked intensively in the Eastern Cape and has also been involved in numerous other projects throughout Southern Africa. He is a director of Maluti Water, a civil engineering consultancy specialising in rural water supply.

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Volume 1: Assessment of the characteristics of Spring flows in small springs

by

Ian Pearson

With inputs from

Isaac Manala and Melanie Wilkinson

Environmentek, CSIR

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EXECUTIVE SUMMARY

1. BACKGROUND AND MOTIVATION

In many rural areas of South Africa, particularly in the eastern parts, many small water supply schemes have been based on the water supplied from springs. These springs have usually been used by the communities for many decades, and the water supply improvement has been to protect these springs and to transport the water to storage tanks and taps closer to the residents. However, in a number of cases these developments have not resulted in any significant improvement in the water supply to the communities, and in certain cases the original natural spring has been irreparably damaged when attempts were made to protect the spring.

Some of the main issues related to the protection and use of spring water in rural communities and the associated problems are as follows:

- Flows from small springs have not been measured over time and seasons, and hence there is little information regarding their reliability and yields during different periods of the year. Usually the community is asked whether the springs ever dry up, for which the answer is usually no, but this could mean a number of things, e.g.

    - there is always water there, even though in the dry season it is only a trickle;
    - the water flow appears to be constant, but we have never measured it and hence the flow in dry season could be only 10% of the summer flow, even though it "looks" similar;
    - it actually only flows for four or five months in the year, and the rest of the time it is just wet there;
    - it used to flow continuously, but since we have chopped the vegetation and planted crops above the spring, the flow virtually dries up in winter.

- The effect of different land use practices on the flow and quality of springs are not well understood, and these effects also vary under different climatic, geographical and geological conditions;

- The differences between springs are dependent to a large extent on the geophysical nature of the aquifer supplying the spring and the recharge characteristics of the aquifer. These are poorly understood for small springs.

- The practice of protecting springs is often poorly implemented, resulting in a reduction of spring flow and a loss of the resource as a potential water supply.

These and other factors have indicated the need for a proper study on the nature of spring flow from small springs. This is of particular relevance at the present time when so much attention is being given to the implementation of sustainable rural water supply schemes.

There is then a need to assess the factors affecting spring flows, and develop ways of predicting the seasonality and reliability of flows from these springs. This will considerably improve the planning and design of rural water supply schemes in the rural areas where springs are a significant resource. In this way funds spent on springs which cannot sustain the required yield will be limited. Conversely when springs are able to provide sufficient water for a community, this resource could be developed with increased assurance and usually considerable cost savings over alternative supplies.

Up to the present time, most work and assessment of springs has been focused on the large dolomitic resources, and certain other high flow springs such as the Uitenhage Springs. Studies on small springs which are used as water supplies in rural communities have been mainly limited to technical manuals on methods of spring protection.

The study will also demonstrate the value of monitoring springs over a longer period and will hopefully result in improved records being obtained on an ongoing basis of spring flows at a number of sites in the country. Spring flow monitoring can provide valuable information on the consequences of drought events and how to predict the need for emergency measures for water supply to rural communities during drought periods.

2. MAIN OBJECTIVES

The primary aims and objectives of the project were stated as follows:

- To determine the factors affecting the flow from springs with potential for use as water supplies to rural communities.
- To provide guidelines to consultants and planners where springs are being considered as full or complementary sources for community water supplies.
- To evaluate spring flow enhancement techniques for their effectiveness and practicality.

3. EXTENT TO WHICH THE CONTRACT OBJECTIVES WERE MET

The main objectives listed in 1.2 have been largely met.

In terms of the first objective, the factors affecting flow from small springs have been assessed and categorized, at least on the springs that were monitored. It is acknowledged that certain other factors will also play a role in the flow from springs, and some of these have been discussed in relation to the reports published in the literature.

In terms of the second objective, some guidelines are provided in this report. However it is acknowledged that these are not complete in themselves, as a certain level of knowledge and experience in the assessment of the lithology, climatology and vegetation cover is assumed. Other guidelines for these aspects already exist, and should be referred to if required.

The third objective could not be achieved within the revised scope of the project. The project budget was reduced and this component of the research was limited to minor labour intensive approaches on one or two of the springs being monitored.

4. MAJOR RESULTS AND CONCLUSIONS

The project extended over a four-year period, of which some two and a half years of spring monitoring was carried out. During this period a number of important and relevant findings were made. These include the following:

- There are a number of different types of springs, not only in terms of their appearance at the surface, but in terms of this project particularly related to the underground aquifers or lithological systems from which they emanate.
- The flow characteristics of a particular type of spring do adhere to the general characteristics of other springs of the same type.
- Certain types of springs can be used as a reliable source of water for community water supply schemes, whereas other types of springs will, under average circumstances, result in failure of the water supply if it is the sole source for a particular scheme.
- A number of springs that will usually fail during the dry season have been protected and channelled into community water supply systems by various organisations. Their failure during the annual dry season has lead to vandalism of the works and severe disappointment and distrust in development programmes in some situations.
- In some situations steps can be taken to improve the flow of water captured from a spring. However without extensive development (not undertaken within this project), such activities do not alter the overall flow characteristics of the spring, and the seasonal variations will be as before.
- A spring classification system is proposed which from the limited monitoring data available does enable the flow variations of a particular spring to be estimated.

5. RECOMMENDATIONS

The advantages of being able to more accurately assess the flow and flow variations from small springs at remote small community water supply systems cannot be overstated within the context of rural development in South Africa and other developing countries. Following this relevant work, certain follow-up activities are recommended in order to ground the work in the practice of rural development, and to refine the initial findings by continuing certain aspects of the programme. In this light the following recommendations are put forward:

5.1 Finalising and publishing the guidelines for general use.

The guidelines emanating from this research project should be finalised into an acceptable format, and linked to existing guidelines on the development and protection of springs. These should be made available to all relevant role players, including local governments responsible for rural areas.

5.2 Development and implementation of a strategy for the promotion and transfer of the findings of the study.

A strategy for the effective dissemination of relevant aspects of the report and guidelines to role players and other stakeholders should be developed and implemented. This will require support financing.

5.3 Development of a training programme

A training and support programme should be developed on the assessment of small springs. The training programme should also include protection and distribution of water from springs, and recommended monitoring procedures.

5.4 Establishment of additional longer term monitoring programmes

It is considered imperative that additional monitoring of small springs takes place over a period of several years. This may include some of the springs that have already been monitored on this programme, as well as new springs from other lithological groups and other development regions. The data from these programmes should be centrally collated (by DWAF?) and be made available for researchers and practitioners.

5.5 Development of a flow model for small springs

It would be useful to have a simple flow model for small springs based on the different classifications proposed in this report. The development of a model would involve the evaluation of existing models based on data obtained in this and other surveys, and the detailed measurement of flow responses of specific rainfall events. The parameters for the model should be easy to measure and not require long flow records of the springs – i.e. a deterministic model would be appropriate, even if the models are calibrated from a stochastic analysis of existing flow data.

5.5 Further development and testing of sub-surface spring capture techniques

Sub-surface spring capture techniques have a number of benefits over surface systems. These include better protection, improved water quality, and in some cases improved flow and reliability. It is recommended that additional resources be put into developing and evaluating these techniques.

ACKNOWLEDGEMENTS

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" The reliability of small spring water supply systems for community water supply projects, and the enhancement of flows from springs"

The Steering Committee responsible for this project consisted of the following persons:

Dr A.G. Reynders	Water Research Commission
Mr K. Pieterson	Water Research Commission
Dr G.C. Green	Water Research Commission
Mr B. Taylor	Environmentek, CSIR
Ms G.M. King	Department of Water Affairs and Forestry (Dbn)
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Mr R. Murray	Environmentek, CSIR
Mr J. Weaver	Environmentek, CSIR
Mr D.J. Marais	Water Research Commission
Ms U. Wium	Water Research Commission

The financing of the project by the Water Research Commission and the contribution of the members of the Steering Committee is acknowledged gratefully.

This project was only possible with the co-operation and support of many individuals and institutions. The authors therefore wish to record their sincere thanks to the following:

- Mssrs Graham Crawford and Barry Soden for the installation of monitoring equipment and follow-up of springs in the South Coast region.
- Mr J.W. Mensah and staff of ECATU for identification of springs in the former Transkei.
- Mr. Goodenough Molefe, formerly of CSIR, for the identification of springs in the Bergville area.
- Mr Isaac Manala of CSIR for the installation of monitoring equipment and follow-up of springs in the Bergville area.
- Ms Melanie Wilkinson of CSIR for follow-up and monitoring of springs on the South Coast.

TABLE OF CONTENTS

1. INTRODUCTION

In many rural areas of South Africa, particularly in the eastern parts, many small water supply schemes have been based on the water supplied from springs. The communities have usually used these springs for many decades. In some cases the spring has been upgraded through a support agent or local authority. This has usually entailed the protection of the springs and transport of the water to storage tanks and taps closer to the residents.

However, in a number of cases these developments have not resulted in any significant improvement in the water supply to the communities, and have instead raised unmet expectations that there would be sufficient water from the spring throughout the year. In certain cases there has even been a loss of water from the spring when the eye was "protected" because critical components of the aquifer were damaged by the excavations. In such cases the original natural spring has been irreparably damaged and residents have had to go elsewhere for their water supplies.

Some of the main issues related to the protection and use of spring water in rural communities and the associated problems are as follows:

- Flows from small springs have not been measured over time and seasons, and hence there is little information regarding their reliability and yields during different periods of the year. Usually the community is asked whether the springs ever dry up, for which the answer is usually no, but this could mean a number of things, e.g.
  - there is always water there, even though in winter it is only a trickle;
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- The effect of different land use practices on the flow and quality of springs are not well understood, and these effects also vary under different climatic, geographical and geological conditions;

- The differences between springs is dependent to a large extent on the geophysical nature of the aquifer supplying the spring and the recharge characteristics of the aquifer. These are poorly understood for small springs.

- The practice of protecting springs is often poorly implemented, resulting in a reduction of spring flow and a loss of the resource as a potential water supply. This is because the project agents have not had the knowledge to be able to assess the aquifer and its confining boundaries.

- Springs are viewed by some engineers as being highly variable and hence unreliable to develop as water sources for community supplies. They consequently opt for much more costly water sources, which are also usually very much more costly to operate and maintain.

- Springs when properly utilised can provide an extremely low cost, reliable, safe supply of water to rural communities. However, incorrect use of springs or the development of springs which are inadequate for the purpose result in negative attitudes about springs and their applicability as a water source.

These and other factors have indicated the need for a proper study on the nature of spring flow from small springs. This is of particular relevance at the present time when so much attention is being given to the implementation of sustainable rural water supply schemes, and local governments are faced with advising or assessing proposals for the development of community water supply schemes.

This project also acknowledges the considerable work that has gone before in the study of springs, both in South Africa and in countries elsewhere. The findings of these studies has been assessed where reports are available, and some of the applicable lessons from these have been taken into account in this project. However it is also noted that compared to studies on other water sources, the available literature on springs is very small and hence much has still to be done in this field.

There is then a need to assess the factors affecting spring flows, and develop ways of predicting the seasonality and reliability of flows from these springs. This will considerably improve the planning and design of rural water supply schemes in the rural areas where springs are a significant resource. In this way funds spent on springs, which cannot sustain the required yield, will be limited. Conversely when springs are able to provide sufficient water for a community, this resource could be developed with increased assurance and usually considerable cost savings over alternative supplies.

Up to the present time, most work and assessment of springs has been focused on the large dolomitic springs and certain other high flow springs such as the Uitenhage Springs in the Eastern Cape. Studies on small springs that are used as water supplies in rural communities have been mainly limited to technical manuals on methods of spring protection.

The study has also demonstrated the value of monitoring springs over a longer period and will hopefully result in improved records being obtained on an ongoing basis of spring flows at a number of sites in the country. Spring flow monitoring can provide valuable information on the consequences of drought events and how to predict the need for emergency measures for water supply to rural communities during drought periods.

This project had as its main objectives, the aim to examine the factors affecting the potential of springs that can be used for community water supply systems. The objectives as set out in the contract were as follows:

- To determine the factors affecting the flow from small springs with potential for use as water supplies to rural communities;

- To provide guidelines to consultants and planners where springs are being considered as full or complementary water sources for community water supplies;
- To evaluate spring flow enhancement techniques for their effectiveness and practicality.

Although the funding for the third part of the project, addressing the third aim, was cut, the aims have to a large extent been achieved.

2. LITERATURE SURVEY

This survey has been subdivided into the following sections:

- Flow from springs
- Recharge rates
- Modelling of spring flows
- Quality of spring water
- Diurnal variations in flow from springs
- Technical considerations

2.1 Flow from springs

General comments

Flows from springs are usually reported in terms of site specific variables. However a number of authors have attempted to classify spring flows according to their lithological structures or topographical characteristics. In particular the paper by Perez (1996) classified flows from springs according to nine groups of lithological classes. Other factors are also reported as being significant in influencing flow from springs, including geological structures (faults and fractures), topography, recharge rate, vegetation cover and rainfall events.

Specific references

Pérez (1996) reported on the hydraulic characteristics of springs in Spain. The flow from springs were classified according to their lithologies, with nine groups of lithological classes representing similar hydrogeological characteristics. These groups are: 1) alluvial sediments, sands and gravels; 2) conglomerates; 3) sandstones; 4) calcarenites, fractured limestones, karstic limestones, dolomitic limestones, dolomites, marbles, tuff; 5) marls, silts and clays; 6) quartzites; 7) slates, schists; 8) plutonic rocks, gneisses, dykes; 9) other rocks, gypsum, volcanic rocks. The first 5 groups supply some 97% of flow from all recorded springs in Spain. Pérez also assessed the recharge rate for the groups, and reported the following net recharge (% precipitation that infiltrates as groundwater) for the groups: 1) 5.3%, 2) 3.2%, 3) 3.3%, 4) 20.3%, 5) 2.4%, 6) 1.7%, 7) 0.6%, 8)0.75%, 9) 0.35%.

In a report by Brereton, McEwen and Lee (1987) the flow from springs was studied in a granite basement region overlaid with peat and moraine in Scotland. Three techniques were used in the study, namely the use of thermal infrared line scan techniques to detect groundwater discharges, the analysis of fractures and relating these to fracture lineaments observed on aerial photographs, and the use of geophysics to define lithological variations, faults and fracture zones beneath the peat cover.

Infrared results identified three general categories of springs. These were: distinct point discharges into the headwaters of streams and riverbanks, more diffuse discharges into the beds of streams and rivers, and thirdly springs which discharge into "dubh lochs" (small deep lakes).

The mapping of fractures and lineaments as well as the geophysical investigations gave very poor correlation between the dominant lineament direction and the measured fractures. Approximately 29% of spring alignments corresponded to lineaments, while 71% of spring alignments did not correlate with lineaments at all and no springs were associated with some 85% of lineaments had no springs associated with them. Of the magnetic anomalies, 27% correlated reasonably well with lineaments and 13% with spring alignments. Of the identified faults, 67% correlated well with lineaments, 17% with ground magnetics and 21% with spring alignments.

The conclusions of the report were that the majority of groundwater circulation takes place within the near surface and is strongly influenced by topographical features. However some of the spring alignments are associated with faults and fractures, and the groundwater is being discharged from deeper structures.

Lopez and Smith (1996) studied the flow of fluids within fault zones. They noted that fault zones can be characterised in terms of three structural elements: a zone of distributed cracking in the country rock surrounding the fault, a cataclasite zone of broken and crushed rock forming the core of the fault zone, and thin lenses of clay gouge within the cataclasite zone. These extent and nature of these elements, together with the effects of mineralisation, lead to fault zones with widely varying hydraulic behaviour, ranging from the fault acting as a permeable conduit, to acting as a barrier to flow in clay rich highly mineralised cataclasite zones. Permeability variations within the fault zones have been measured and found to range from 10^{-20} to 10^{-13} m^2. Generally spatial variations in permeability will be encountered within fault zones, and flow is likely to be concentrated in thin, highly permeable zones, and not across the whole width of the fracture.

Bren and Turner (1985) studied the hydrological behaviour of a small stream emanating from a spring at the head of a forested catchment. Of interest from this study (which was also compared and found to be similar to the response in two South African catchments) were:

- The soil moisture never became a limiting factor for transmitting water to the lower levels in the catchment material during a storm event;
- There was a positive correlation between groundwater slope and streamflow during non-stormflow periods. Groundwater slopes increased after storm events, with a lag time of several hours.
- The hydraulic gradient differed from the ground surface slope by between 5° and 12° (where the average surface slope was 25°). An application of the Bousinesq equation to the catchment with assumed parameters of the phreatic aquifer enabled the researchers to reproduce many of the characteristics of the stream hydrographs.

In their study of the springs in the Jordan Valley, Husary et al (1998) investigated the effect of rainfall on spring discharges, but in general found no deterministic relationship. However most of the springs do display a reliance on rainfall occurring in their recharge areas, with an approximate 2-month lag between rainfall peaks and discharge peaks. Springs from deeper geological structures tended to display an almost constant discharge over the whole year, while those from shallower system have seasonal fluctuations in discharge that are correlated to rainfall.

Sartz, Curtis and Tolsted (1977) drilled a number of wells above a spring located in sandstones to gain a better understanding of the relation between spring flow and the groundwater table. They found that some wells were dry, even at 3m below the spring level, and in others the water table was often below the spring level. This indicated that the aquifer is discontinuous at the spring level and contains unpredictable perched water bodies and dry pockets. Movement of water to the spring is complex.

2.2 Recharge rates

General comments

Recharge rates were reported to vary from between 1% (in the semi-arid karoo) and 30% (in dolomitic areas) of rainfall. Generally rainfall based recharge is estimated by first stipulating a threshold amount below which no recharge occurs. Variances in recharge were attributed to transmission losses, differences in field capacity, and the spatial distribution of soil moisture. In large geological systems (e.g. the dolomitic areas of the North West Province of South Africa), there are long lag periods between rainfall and water table fluctuations (up to 3 years), with resulting changes in spring flows. However with small springs these fluctuations occur within a matter of days. A number of different recharge models are proposed and demonstrated in the literature.

Specific references

Sami and Hughes (1996) reported on recharge estimation in the semi arid Karoo aquifers. They found recharge rates to be approximate 1% of annual rainfall in these areas. These estimates were made by applying a variable time interval (VTI) model as well as measuring the chloride mass balance over the hydrological systems. Within sub-areas, recharge rates varied from 0.6 to 1.7 % of annual rainfall. Variances in recharge were attributed to transmission losses, differences in field capacity, and the spatial distribution of soil moisture.

Xu, Ma and Partridge (1994) assessed the time lag between rainfall, water table level changes and spring flow in the dolomitic aquifers in the semi-arid North West province. They found that there was a 2 to 3 year lag between rainfall and water table fluctuations (where the water table was approximately 10m below the surface). There was also an approximate 1 year lag between water table changes and changes in spring flows.

Bredenkamp and Zwarts (1987) found that in the dolomites 30% of the rainfall in excess of a threshold amount constitutes recharge.

Perez (1997) estimated recharge rates for spring aquifers based on three different approaches. Each of these required a complete measurement of the spring outflow following a series of rainfall events. Perez also considered the effect of temperature on recharge and flow rates. The three methods discussed are:

- Recession curve displacement whereby the increase in the recession curve after a critical time following the rainfall event is used to estimate the recharge;
- Discharge curve and increase of aquifer potential whereby an aquifer is considered as a series of layers with different discharge rates and different modes of releasing stored water. The coefficients of the equations can be determined from the hydrograph, and usually only three layers are necessary.
- Aquifers whose potential is only a function of flow as may be evident in certain small aquifers.

2.3 Modelling of spring flows

General comments
A number of spring flow models are proposed in the literature. These are generally logarithmic in nature and use a range of parameters as inputs to the models. Typical model parameters are precipitation, initial flow, evapo-transpiration, temperature, soil moisture content, aquifer storage, and boundary conditions. Some models use a direct logarithm relationship – including the Boussinesq equation, while others use a non-linear time series approach where the autocorrelation coefficients are determined to the level that they are no longer significant.

Specific references
Felton and Currens (1994) assessed the peak flow and low flow characteristics of a karst spring in Kentucky, USA. They calculated the correlation coefficients between various variables and the peak and low flows following a rainfall event. They found significant correlation between peak and low flows and the following variables:

- Q_i - the initial flow
- Precipitation

Other factors (Antecedent moisture content, evapotranspiration, temperature) were not significant to the same degree. The flow recession curves, which were logarithmic in nature, displayed an interesting characteristic. During the summer the flow curves asymptotically approached a base flow value of 14 ℓ/s, while in the winter the curves approached a base flow value of 71 ℓ/s. The explanation given is that soil moisture is a pertinent factor in base flows.

Ibrahim and Cordery (1995) developed a simple rainfall-runoff model that can be applied to small ungauged catchments. The parameters are determined from easily measurable catchment characteristics. These parameters are soil storage, mean monthly evapotranspiration, and groundwater storage. The baseflow is then given as:

$$BF = COGR \times GWS$$

Where BF = base flow rate, COGR = coefficient of groundwater flow, and GWS = ground water storage. The COGR is the complement of the base flow recession constant. The article gives methods for estimating the groundwater storage capacity, the soil water storage capacity, and a fitting parameter C.

Bredenkamp and Zwarts (1987) used a simple equation to estimate recharge in dolomitic areas based on a linear relationship with average rainfall. The equation includes a threshold level below which no recharge is effected.

Recharge = 0.30(Rain – 313) for average annual flow and rainfall (mm).

From the recharge estimates, average spring flow was estimated as a proportion of recharge over the past 4 time periods plus a base flow component related to the actual flow in the previous time period. For the dolomites, the time period was in years.

$$Q_i = x.\{a.Re_i + b.Re_{i-1} + c.Re_{i-2} + d.Re_{i-3} + e.Re_{i-4}\} + y.Q_{i-1}$$

Jian et al (1998) modelled spring flows using a non-linear time series model. The model uses a threshold parameter that relates different precipitation processes, and a lag parameter that relates the time lag between precipitation and increased spring flow.

Manga (1997) developed a single parameter model (an approximation of a two dimensional problem) based on Darcy flow using the Boussinesq equation to model spring flows from basalts in the Oregon Sate of the USA. The single parameter once the model was calibrated is a normalised length of the aquifer. To determine the value of the normalised length requires a significant length of spring flow data (at least a year of daily flows).

2.4 Quality of spring water

General comments

The quality of groundwater discharged through springs is reported in a number of studies. In general it is reported that the majority of large springs are from karst systems, and therefore display an alkaline carbonate rich quality. Springs from deeper structures will tend to have a higher total dissolved solids content, while springs in highly populated rural areas may display nitrate and faecal contamination.

Specific references

In a study of the long term patterns of spring water quality carried out in Virginia, USA, Helfrich and Weigmann (1990) used data from 60 years of records. They found that discharge rates had decreased for most of the springs, with an increase in nitrate and TDS levels, and a decrease in bicarbonate alkalinities.

Petrie et al (1994) found that the quality of spring water from 4 springs monitored in West Yorkshire, UK was of a high standard both chemically and biologically during the periods of dry weather. But contamination increased rapidly after a rainfall event (with animal-originated faecal pollution, manganese and iron all showing marked increases).

Conversely Burg and Heaton (1997) in a study of two springs in Israel found that nitrate concentrations decreased during the wet season. The origin of the nitrate was principally septic tank systems, and the rainfall resulted in some level of dilution through fissure flows.

2.5 Diurnal variations in spring flow

General Comments
The literature report two main phenomena that give rise to diurnal variations in spring flows. These are earth-tide phenomena and changes in barometric pressures. Barometric changes result in a single maximum pressure coinciding with the coldest hours of the day, and a single minimum pressure coinciding with the warmest hours of the day. Earth-tide phenomena are characterised by two maxima and two minima per day. Earth tide fluctuations in groundwater level are small relative to barometric changes. An additional influence on diurnal changes is the effect of evapo-transpiration on shallow systems in well-vegetated catchments. These effects are strongest in forested areas.

Specific references

Hobbs and Fourie (2000) reported that earth-tide phenomena and barometric pressures cause diurnal variations in groundwater levels. Barometric changes result in a single maximum pressure coinciding with the coldest hours of the day, and a single minimum pressure coinciding with the warmest hours of the day. Earth-tide phenomena are characterised by two maxima and two minima per day. Earth tide fluctuations in groundwater level are small (<30mm/day), whereas fluctuations due to barometric changes were measured up to 90mm.

The relative influence of these two effects (barometric efficiency and earth-tide efficiency) is strongly influenced by the compressibility of the aquifer matrix. For inelastic media, the barometric effect is high, while for elastic media the tidal effect is more pronounced.

An additional influence on diurnal changes is the effect of evapo-transpiration on shallow systems in well-vegetated catchments. These effects are strongest in forested areas.

Weekly effects were also noted, corresponding to the phases of the moon.

During this study springs with pronounced diurnal variations in flow were reported in the Eastern Cape. The visible effects were the strong flow early in the morning which then dried up by about 10:00 am. The spring began to flow again during the night. This could be explained by the barometric pressure effect whereby the higher pressure in the early morning caused an increase in the water table and hence the flow of the spring, which reduced as the warm hours of the day occurred.

2.6 Technical considerations

General comments
Technical considerations with respect to the protection and capture of spring water are described in a number of articles and reports. These include methods to collect spring water as it comes out the ground, and methods to tap into the spring source before it reaches the surface.

Specific references

Robertson & Edberg (1993) described a number of technical aspects related to the abstraction or collection method of springwater. These relate specifically to bottled water sold for human consumption. They usefully describe the main objectives of springwater interception as being:

- To protect and ensure the quality of the springwater source by reducing their vulnerability to alteration or contamination;
- To facilitate the control and conveyance of the water flow for its intended use; and
- To minimize waste of the water resource.

Hence spring protection consists of:

- minimizing the accessibility of the spring source to humans, other biota, silt, chemicals and other substances from the atmosphere, adjacent land surface and adjacent water bodies; and
- development of an engineered collection, storage and conveyance system.

They describe examples of both surface and sub-surface springwater collection systems. Surface systems collect water after it has exited from its discharge point, while sub-surface methods intercept the water before it would normally exited its discharge points. Specific systems for surface collection are well known. Sub-surface systems described include interception wells near spring discharge, horizontal interception channels or pipes, and under-drain or gallery collection methods.

2.7 Relevant lessons from the literature

The experience and findings of other researchers on the nature of spring flows is relevant to the aims of this project. The following aspects are of particular relevance:

- Spring flows have a complex relationship with the lithology, topography and climatic conditions. However certain basic issues that affect the flow of springs have been defined and can be assessed for most springs.
- The flow from springs also has a strong dependence on the storage characteristics of the aquifer, and the recharge of the aquifer. These aspects are of particular relevance to long-term variations in flow and drought events.
- The flow from springs can be modelled mathematically using models that are based on catchment characteristics as well as historical flow data. However it is usually necessary to have a detailed analysis of the effects of particular rainfall events.
- The quality of spring water is usually relatively pure, with low levels of salts and suspended particles. This applies to most small springs, with the exception of dolomitic springs, which may be high in calcium carbonates. However unless proper precautions are taken, small springs may have significant levels of coliform bacteria and/or nitrates as a result of human activities in the catchments. Simple precautions can usually overcome such problems.

- In terms of the capture of spring water, very little has been done in South Africa to develop sub-surface techniques for the capture of spring water. However, it is important to fully understand the spring system that is being exploited before subsurface techniques are employed.

3. MATERIALS AND METHODS

A number of springs were selected for monitoring during the period of the project. These were selected on the basis of their lithological characteristics as well as their current use as water sources in rural areas.

3.1 Selection of springs to monitor

Reconnaissance visits were made to a total of forty springs - 34 in KwaZulu/Natal and six in the Eastern Cape. The initial visits were facilitated by DWAF in KwaZulu/Natal and by ECATU in the Eastern Cape. Follow-up visits were undertaken by the project team to assess the characteristics of the springs, and to select specific springs for more detailed monitoring.

The purpose of the reconnaissance visits was to assess:

- the natural conditions and spring characteristics before any construction had taken place,
- the appropriateness of the spring for protection works,
- where the spring had been protected or was imminently due for protection, the methods of construction and the results achieved, and
- the potential sites for placement of required monitoring instrumentation.

Some of the spring protection projects visited had been unsuccessful for various reasons, mostly due to the unsuitability of the spring for long term reliable supply, but also due to inappropriate choice of protection methodology.

The following areas were visited:

- Bergville area of KwaZulu/Natal

  This region is characterised by the geological Drakensberg Formations and the Karoo Supergroup. The formations are generally weathered and fractured, and often related to dolerite intrusions and associated fracture zones. Boreholes and springs are generally moderate to good yielding, with the potential to provide an adequate supply of water for domestic use. Springs are gravity flow type mainly occurring as spring eyes in steep valleys. Gravity seepage fields also occur.

  Seven sites were selected for further spring flow monitoring.

- KwaHlogwa (South Coast inland of Hibberdene)

  This region is characterised by deeply weathered gniess and granites. Boreholes and springs are generally low yielding. Spring types tend to be gravity fed eyes or seepage fields in valley bottoms. All the springs surveyed were of the protected eye type, although many were located within a seepage field. This resulted in poor flows with much of the potential yield bypassing the spring water collection system.

  Three sites were selected for further spring flow monitoring, with a plan to install a drainage field type spring water collection system at one of the springs after a suitable baseline monitoring period.

- Highflats/Jollivet area

  This area is characterised by Table Mountain Sandstones and shales. The formations are generally weathered and fractured, and topography characterised by steep exposed cliffs and deep valleys. Boreholes and springs are generally moderate to good yielding, with the potential to provide an adequate supply of water for domestic use. Springs are gravity flow type mainly occurring as spring eyes in steep valleys.

  One spring was selected for monitoring.

- Transkei

  This region is characterised by the geological Beaufort Formations of the Karoo Supergroup. The formations are generally weathered and fractured, and often related to semi-horizontal contact zones and dolerite sheets. Boreholes and springs are generally moderate to poor yielding. However many springs do have the potential to provide an adequate supply of water for domestic use. Springs are gravity flow type mainly occurring as spring eyes in steep valleys. Gravity seepage fields also occur.

  Two sites were selected for further spring flow monitoring.

3.2 Water Quality Monitoring

The objectives of this part of the springs survey project were:

- to evaluate the chemical and microbiological quality of water from the springs
- to ascertain whether it could be concluded that protecting springs reduces the incidence of water-related diarrhoea in those families who use this source of water.

Water samples were taken from the springs for analysis. This included the springs to be monitored as well as some other springs for comparison. The results of the analysis are given in appendix B.

Chemical and bacteriological quality of water

The water quality parameters measured for the Mzumbe (South Coast) and Cathedral Peak areas are recorded in appendix B. Turbidity in all the Mzumbe samples exceeded the maximum allowable limits with the exception of one site which was at the maximum. Similarly the recommended colour limits for all samples were far in excess of the recommended limit. Nitrate at one site exceeded the recommended limit but was slightly below the maximum. Iron at one site was also above the recommended but below the maximum. The heavy metal cadmium was slightly higher than the maximum allowable limit in all samples. This was probably related to particulate matter or turbidity of the samples taken. Faecal coliforms ranged from 6-133 per 100 ml, but generally less than 10 per 100 ml. These are all above the maximum limit for faecal coliforms which is set at zero. In general, the water quality parameters at Mzumbe did not meet the criteria set for drinking water standards. The values recorded for cadmium and faecal coliforms are of some concern, but are not excessive.

The water quality for samples from the Cathedral Peak area was generally better than that measured for the Mzumbe area. The turbidity at one site slightly exceeded the maximum allowable limit and the colour was above the recommended limit. Cadmium was not measured for these samples. The faecal coliforms for all samples, with the exception of one site, were also of some concern and ranged from 2-398 per 100 ml, with most samples having values less than 20 per 100 ml.

Follow-up sampling was undertaken on the Mzumbe springs in November 1999 at the start of the rainy season. From these results the iron content was high at one of the springs, and all samples again displayed low levels of bacterial contamination. At this time water samples from the Transkei springs and Cathedral Peak springs were analysed. These were all chemically acceptable, but also showed some low levels of bacteriological contamination.

From a discussion with the residents regarding the quality of the water from the springs, most respondents found the water fully acceptable, and had little experience of diarrhoeal diseases from the water.

From these results low levels of bacteriological contamination of spring water can be expected in all areas where human or livestock activity is taking place in the catchment areas. However, this low level may be considered acceptable where other conditions (e.g. poor sanitation) give rise to significantly higher levels of faecal contamination. Low levels of coliforms do maintain a level of immunity within regular consumers.

The current practice of spring protection does not fully prevent this level of contamination. Chemical contamination of spring waters is usually minor in extent, and dependent of the natural rock and vegetation in the catchment. Some additional contamination may be prevalent in industrial and peri-urban areas.

3.3 Assessment of catchment characteristics

An assessment of the land use and lithological characteristics was carried out in the catchment areas of the springs. From these reports there are predominantly three types of land use in the rural areas. These are:

- livestock and small scale crop farming (Bergville and Transkei)
- sugar cane farming (South Coast)
- small forestry (Bergville, South Coast, Transkei)

Land-use types may have a significant impact on the yield or flow of a spring. Examples of land use include afforestation, growing of crops, grazing areas for livestock, clustered rural dwellings, infrastructure including schools, roads and sports fields, protected environments (rivers, reserves, etc.).

Of these sugar cane crops and small forestry, which can have a significant impact on the soil moisture content, were found in the areas studied. The actual impact could not be measured in this study, but other studies have indicated that forestry can consume up to 30% of the base-flow of small streams.

Cattle and other livestock, while not having a significant impact on the soil moisture, are found in all areas. Their main impact is in terms of using the springs as a drinking water source, and grazing in the wetlands which may result in some impact on the seepage characteristics. Cattle may also cause some damage to spring water collection structures.

The land-use in each of the three areas studied is described briefly below.

3.3.1 Land-use types/activities in Mzumbe

Afforestation through *Eucalyptus Grandis*, sugar cane, and grazing pastures are the most common land-use types in the Mzumbe area. The small grower afforestation normally covers a plot of about ¼ ha on an individual household. The small timber grower's programme began about a decade ago and was introduced by LIMA with Tongaat-Hullets. In areas where afforestation was introduced, the individual community household has to herd their cattle. This is similar with the sugar-cane farmers. Afforested areas and sugar-cane fields have an impact on the yield and reliability of springs. The community identified shortages of water and long queues during drier seasons in springs below these forest plantations and sugar-cane fields. The yield of the protected spring next to KwaHlongwa magisterial office at Umgubu has gradually decreased even during the summer season due to the "eight-year" forest plantation grown above it. This was a unanimous observation of local community members.

About a quarter of the upper Umgubu ward along The Umzumbe River has forest plantations and sugar-cane fields, all owned by individual households in the area. Afforested areas are normally on top of undulating hill slopes, and sugar-cane farms are along the valleys and on the banks of the Umzumbe River. Grazing areas are scattered all over between sugar and forested lands, and around households who are not sugar cane & timber farmers. Livestock has been consistently reduced in the KwaHlongwa area over the past years as more people convert to sugar-cane farming This is a result of lack of resources to herd livestock and the time required to look after them. The impact of livestock on the watershed vegetation is acceptable if not beneficial, and does not result in over-grazing.

In all cases, the community does not exercise any level of watershed management. Their main focus remains on income generation from the land.

3.3.2 Land-use types/activities in Bergville

In the Bergville area, livestock and crop farming are the most dominant land-use types/activities. In the mountainous areas there are limited opportunities for planting crops, and livestock farming is the only feasible alternative for these communities. For livestock farming not to have a negative impact on the watershed soil water condition, sound livestock management strategies have to be practiced. This is a problem in the Bergville are because traditional authorities lack management vision, strategies, and will to proactively engage communities in finding solutions. This is generally a problem in all rural areas in South Africa. In most cases, the watersheds in the Bergville area have been seriously damaged due to overgrazing. There has also been uncoordinated burning of the veld throughout the area.

3.3.3 Land-use types/activities in the Transkei

As in the Bergville area, livestock and crop farming are the most dominant land-use types/activities. In the Transkei there are also a number of state owned forestry areas, particularly in the watersheds that provide springs and streams to the rural communities. There are also a large number of areas where overgrazing has resulted in severe soil erosion, with significant impacts on the springs within those catchments. There is a need for sound livestock management strategies to be developed and practiced. There are however, a number of areas where livestock numbers are not excessive and overgrazing is not a problem.

The lithological characteristics of the catchments also have a major impact on the type of springs and their flow characteristics. The main lithological types are described below.

3.3.4 Lithological Types

The sites were predominantly in sandstone areas (Bergville and Transkei) and weathered granites (Mzumbe), and hence emphasis has been placed on the lithological description of the sites. Three types of lithologies were identified:

Weathered regolith

The first type of springs are associated with weathered regolith and tabus. The areas around these springs consist of shallow to moderately deep sandy clays, often with good grass and shrub cover. The material is significantly porous. Recharge is typically high in good rainfall seasons. Most springs in these areas were reported to have "strong flows" in the summer but reduced significantly in the dry months.

Examples of these springs were found in the Mzumbe area in the Karoo Sandstones and the Granitic Gneisses. The springs may often occur as several eyes or large seepage areas.

Sandstone contact zones

The *second* type of spring occurs in areas where sandstones overlie clay horizons. The springs typically occur at the contact of the sandstones and clays. The springs occur as strong flowing individual eyes. A number of springs may occur at almost the same altitude at distances of 2 or more kilometers apart, clearly indicating preferential flow paths through the media. Flow from these springs is usually more reliable with lower seasonal fluctuations.

Examples of these were found in the Karoo Sandstones and Shales of the Ndwedwe area of KwaZulu/Natal, and in areas of the Transkei of the Eastern Cape.

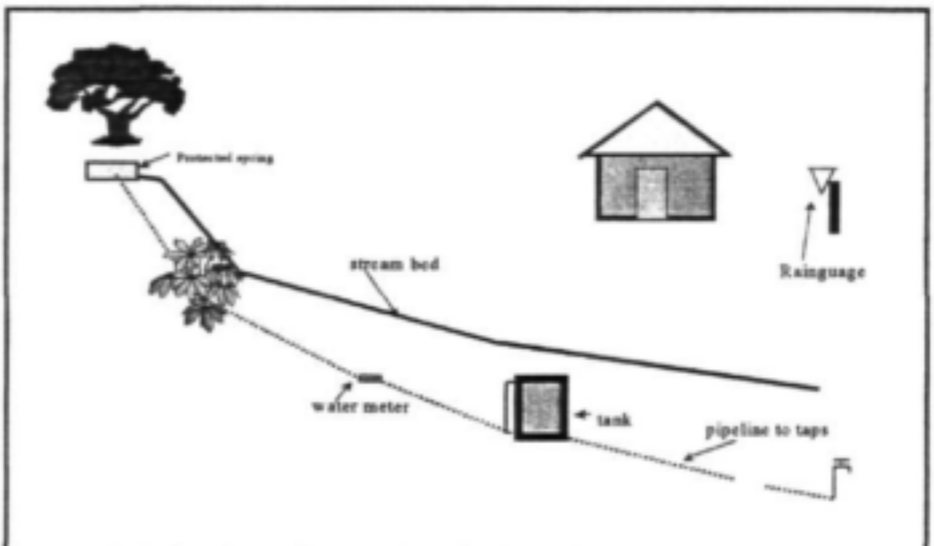
Fractured sandstone zones

The third type of spring found issued from fractured sandstones in mountainous and hilly areas. Examples were found in the Bergville area and in the Lubisi area of the Eastern Cape. Springs were strong flowing and reportedly never dried up. The areas are underlain by consolidated sandstones, mostly exposed at the surface or under a thin cover. Water moves along vertical fractures and exits as a spring at the base of the fracture. In some cases at Lubisi a series of springs occurs along the same fracture line, one below the other. Similar springs were found at dolerite dyke contacts in KwaZulu/Natal.

3.4 Purchase and installation of monitoring equipment

Each spring was equipped to be able to monitor flows as follows:

- The eye of the spring was protected, and a pipeline laid to transfer the spring water to a storage tank. In most cases this had already been done and only required checking and minor maintenance by the project team.
- The transfer pipeline was cut at a point close to the tank, and a water meter installed in the pipeline.
- The water meter was protected by enclosing it within a steel, lockable water meter box.
- A rain gauge was installed at the selected monitor's home close to the spring site.



Typical spring catchment and monitoring equipment

The monitors were trained to read the water meter and rain gauge, and to record the readings on prepared forms. Readings of spring flows were taken twice per week, and rain-gauge readings after every rain fall event.

4. ASSESSMENT OF SPRING CLASSIFICATION

Springs can be classified in many different ways. A simple classification is proposed to divide springs into two main types based on the dominant macro groundwater flow regime - gravity springs and artesian springs. Within these main categories are two sub-categories related to whether the spring is constrained with boundaries or whether the outflow is a result of an intersection of the phreatic surface and the ground topography.

Table 4.1: Proposed spring classification system for the springs monitored

CLASSIFICATION	DESCRIPTION	FLOW REGIME
A: Springs that are primarily controlled by gravity		
A1 – seasonal phreatic	A shallow aquifer system with spring outlets solely related to the interception of the phreatic surface with the ground topography. These springs will usually dry up during the winter (dry) period	Flows in the wet season may be quite high (>$10m^3/d$), but highly variable and strongly correlated with rainfall events. The flow in the dry season will usually dwindle to zero.
A2 – seasonal with boundaries	As for A1, but there exist impervious boundaries that affect the outflow from the system. These boundaries could reduce the summer season outflows by reducing the catchment size, but will also usually extend the dry season outflows by channelling deeper groundwater out at the level of an impervious layer	As for A1, but with greatly extended dry period flows. Variability of flows is still high and correlated with rainfall events. In many cases these springs will continue to provide water throughout the dry period, even though the flow rate decreases substantially.

CLASSIFICATION	DESCRIPTION	FLOW REGIME
B: Springs that are controlled by gravity and artesian (pressure) forces		
B1 – non-seasonal phreatic	These springs obtain their water from deep aquifers or from very extensive shallow aquifers. As with A1 the outflow is derived from the point of interception of the phreatic surface with the topography. However the water stored in the aquifer is large enough such that the phreatic surface does not fluctuate significantly between seasons or with rainfall events.	The outflow from these springs fluctuates to a small extent between seasons, but not more hat 20%. Rainfall event peaks may occur, but the baseflow makes up at least 80% of the flow. The springs provide a reliable supply of water throughout the year.
B2 – non-seasonal with boundaries	As for B1, with the addition that the aquifer is bounded by impervious layers either horizontally or vertically. These boundaries will usually mean that the variability of flow is reduced further, with almost no difference in flow between summer and winter periods.	As for B2, but with even smaller variations in flow.

This classification system applies to all types of aquifer systems and lithologies, with other variables only providing variations of porosity, permeability, storage, hydraulic head, and water quality within these classifications.

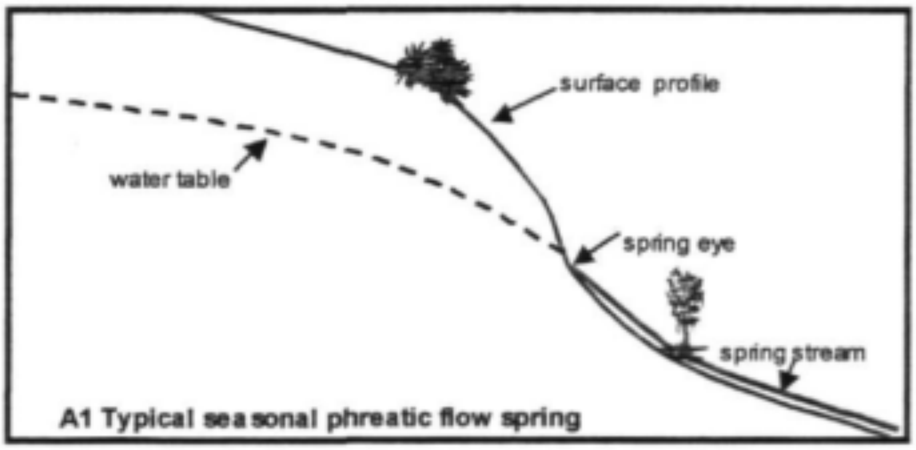
4.1 Type A: Seasonal springs

Seasonal springs are greatly affected by the rainfall and dry periods that occur seasonally. This generally implies that the portion of the aquifer that feeds the spring has a water table level that fluctuates significantly between wet and dry seasons, and often directly following a rainfall event.

A1 Seasonal phreatic springs{tc \l2 "Gravity springs}

Seasonal phreatic springs occur where groundwater emerges at the surface because the steepness of the surface terrain intercepts the phreatic surface of the ground water table. This type usually occurs on sloping ground, although it can also be found in areas that seem to be flat to the eye. Typically, its flow changes with variations in the height of the water table.

In many cases these springs are used as water sources by communities, but may fail to provide water during the dry season.



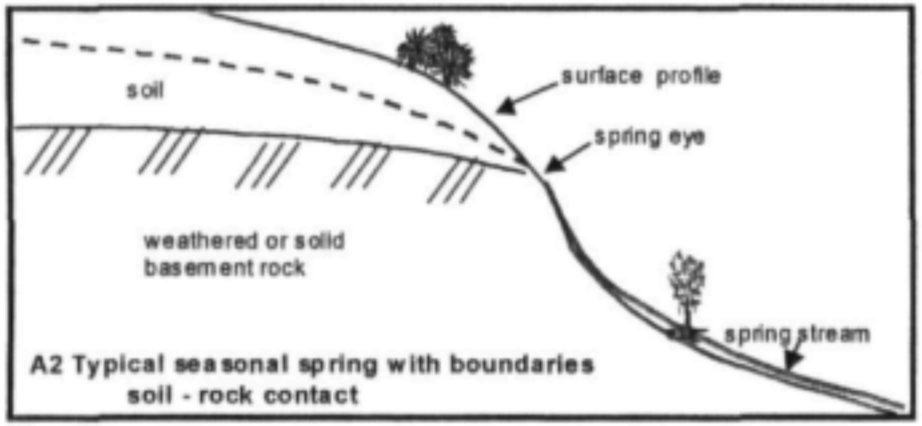
A1 Typical seasonal phreatic flow spring

A2 Seasonal springs with boundaries

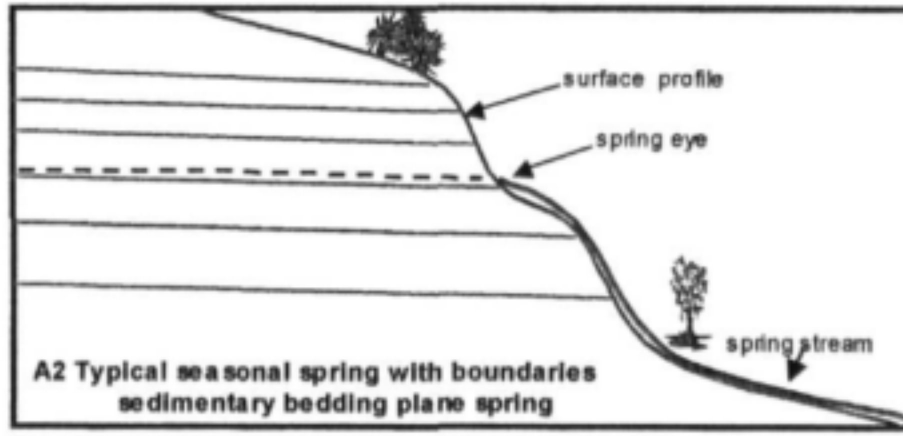
Seasonal springs with boundaries, the second sub-type, occur where an outcrop of impervious material, such as a clay horizon, prevents further downward flow of ground water and causes it to flow out to the ground surface. The contact where soils meet fresh unweathered bedrock at sloping ground surfaces, thereby forcing the water table to intersect the ground surface, is an example of these springs. Similar spring types occur at the contact between water bearing porous rock and impervious rock, or where very weathered rock grades into unweathered rock. Conditions where flow along horizontal or near-horizontal sedimentary bedding planes exits at the surface provide another example.

Other seasonal springs with boundaries occur at dyke contacts, sill contacts and at fractured lithological contacts. Seasonal springs with boundaries offer much larger and less variable yield than seasonal phreatic springs. However, fluctuation may occur in periods of drought, with the possibility of springs drying up. Generally, the flow from most seasonal phreatic springs and springs with boundaries can be increased by appropriate excavation and flow interception structures.

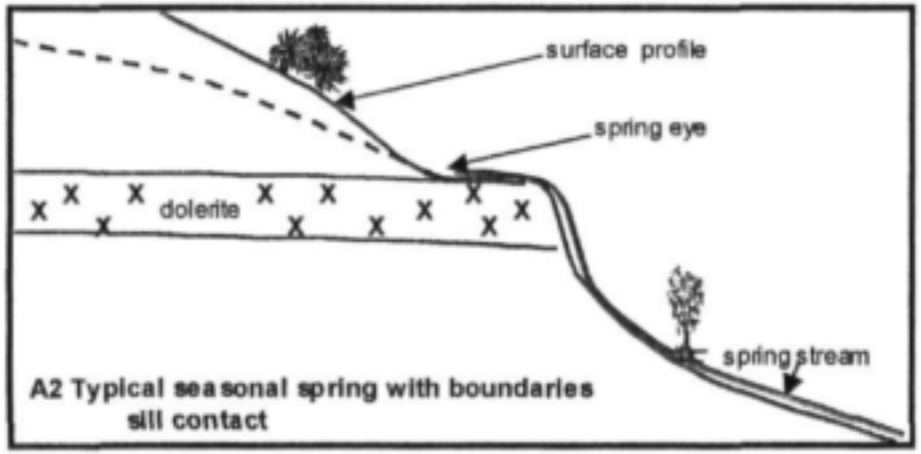
Seasonal springs with boundaries may also occur as depression springs where the ground surface dips below the water table. Any such depression will be filled with water. An example of this type is the small to medium wetland seepages that are usually seen in flat to nearly flat areas where shallow permeable soil overlies clay or impermeable bedrock. The seeps occur at the sides of the depression in horseshoe or semi-circular fashion. Depression springs often have a low yield, which is further reduced during the dry season particularly if nearby groundwater withdrawals result in lowering of the local water table.



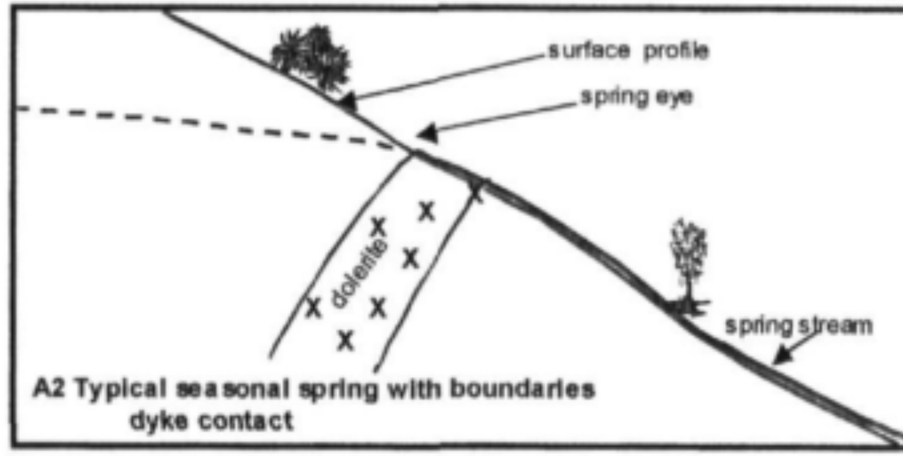
A2 Typical seasonal spring with boundaries
soil - rock contact



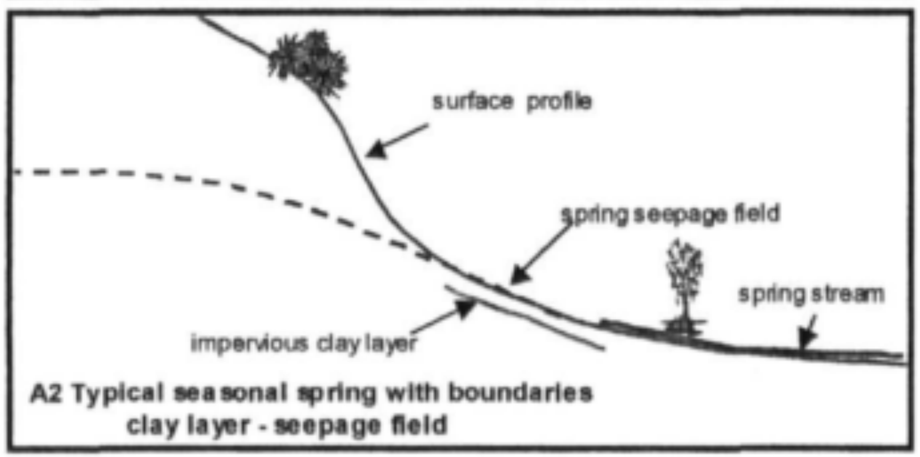
A2 Typical seasonal spring with boundaries
sedimentary bedding plane spring



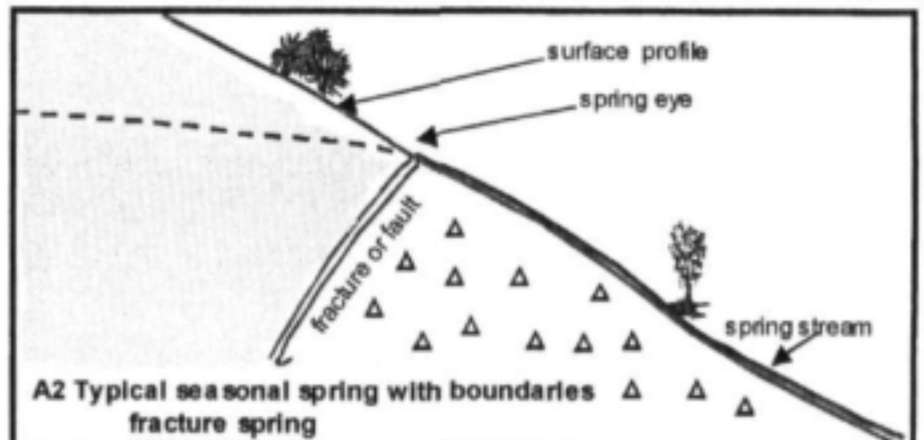
A2 Typical seasonal spring with boundaries
sill contact



A2 Typical seasonal spring with boundaries
dyke contact



A2 Typical seasonal spring with boundaries
clay layer - seepage field



A2 Typical seasonal spring with boundaries
fracture spring

4.2 Type B: Non-seasonal springs

Non-seasonal springs comprise the second major grouping of springs. These occur where groundwater emerges at the surface from a very large water storing aquifer (with an effective storage volume of at least 3 but usually considerably more years of spring flow). These springs are termed "non-seasonal" because they are not affected by seasonal variations in rainfall (or this effect is less than 10% of the average flow).

B1. Non-seasonal phreatic spring

These springs obtain their water from deep aquifers or from very extensive shallow aquifers. As with A1 springs the outflow is derived from the point of interception of the phreatic surface with the topography. However the water stored in the aquifer is large enough such that the phreatic surface does not fluctuate significantly between seasons or with rainfall events.

In many cases these springs are used as water sources by communities. They are generally reliable with the outflow fluctuating little between the wet and dry seasons.

Springs in dolomite and other carbonate rock areas are dominantly non-seasonal phreatic springs although springs with boundaries may occasionally be found where the dolomites are overlain by shales. As a generalisation, springs in these areas have very high yields in the order of tens of litres per second as compared to other geological environments where average flows normally range from less than one to under ten litres per minute. It should be noted however that yields of karst springs may display strong seasonal variation with flows dropping from, say, hundreds of litres per second in wet seasons/years to tens of litres per second in dry seasons or during drought. This variation is often a result of local impacts of rainfall on the water table close to the spring eye or outlet, but the base flow maintains the characteristics of B1 springs.

B2. Non-seasonal springs with boundaries

Non-seasonal springs with boundaries are of a similar occurrence to seasonal springs with boundaries, except that there is sufficient storage in the aquifer to ensure a minimum of flow fluctuations over the seasons. The aquifer storage will be at least 3 times (but usually considerably more) of the annual flow from the spring.

A particular type of non-seasonal spring with boundaries is the artesian spring, which discharges at the surface after confinement between two impervious layers of rock. A fault or fissure in the overlying impervious layer or some other natural breach in the impervious layer such as a change in rock composition and pore-space distribution which renders it permeable provides an outlet to the surface as an artesian spring. A spring of this type is likely to be very uniform in yield, and flow is very nearly constant in spite of seasonal variation in rainfall and evapotranspiration over the catchment.

The discharge from artesian springs is higher than from gravity springs and shows less seasonal fluctuation. A drop in the water table during dry periods may only have a slight impact on the flow of the spring. Artesian springs are most ideal for community water supply purposes, with the advantage of contaminant free water due to the impervious cover protecting the aquifer.

5. RESULTS OF FIELD MONITORING OF SPRINGS

A total of 12 springs were monitored over a period of 2 to 2½ years. Each individual spring was assessed and classified, and the flows were measured twice weekly over this period.

The flow characteristics of each spring are shown in the following graphs. In addition comments on the spring and any flow anomalies are discussed. More details on the description of each spring are given in appendix-D

5.1 Umzumbe/Hibberdene Springs

These springs are located in the steep hilly regions inland of the coast close to the Umzumbe River. The area consists mainly of granites with the water bearing strata being the weathered granites and fractures. These springs have relatively small storage volumes supplying them with water, and are consequently highly variable in terms of flow. Two springs were monitored, both of which were subject to spring flow enhancement attempts to try to improve the quantity of water available and to reduce the variability of flows. This involved an excavated channel with collection pipe in the wetland portion of the spring outlet. In the case of the first spring, (Nkalokazi) both the original eye and the excavated interception system dried up during the dry season. Unfortunately the residents then destroyed the protection and collection structures by allowing their cattle in to the area. The collector pipes became clogged and the trenches silted up. In the second case (Sidlodwana Mnt) the flow improved through the development of the interceptor channel, but the outflow from this has been slowly decreasing with time.

SPRING NAME: Nkalokazi (figure 5.1)

DESCRIPTION

Nkalokazi Spring consisted of a protected eye in a minor wetland. The spring is fed from a small granite hill with weathering estimated at about 5m. During the wet season the eye flowed strongly, and a large quantity of additional seepage water also flowed out of other sections of the wetland. During the dry season all water sources gradually dried up. An attempt was made to capture additional water from the spring by installing a slotted pipe within the wettest sections of the wetland, and to fence it off to prevent cattle coming into this section of the wetland. This additional source provided significantly more water than the eye. However both sources dried up at the end of the dry season (September to November 1998). Hence although more water was collected by the flow enhancement measures, the length of the season when water could be collected could not be extended.

Both springs again dried up at the end of January 1999. This was mainly due to cattle being allowed through the fence and damaging the wetland area. During the 1999/2000 wet season both collectors began to flow again, but unfortunately the responsible monitor did not record the meters.

This spring would fit into classification A1 within the spring classification system. Figure 5.1 indicates the rapid response of the spring to rainfall events, and again the steep recession curve at the end of the rainy season.

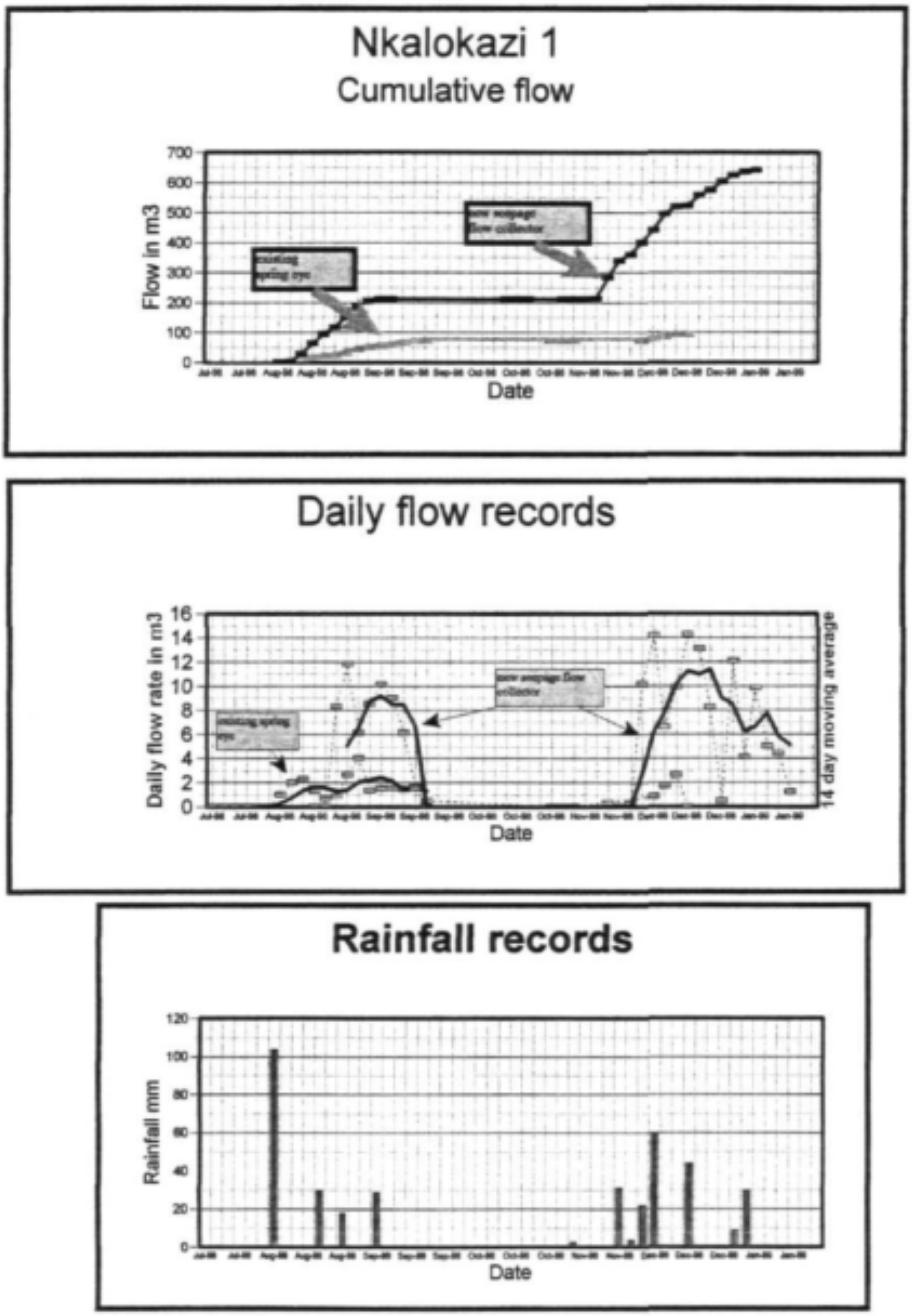


Figure 5.1 Nkalokazi Spring Flow Characteristics

SPRING NAME: Sidlodwana Mountain (figure 5.2)
DESCRIPTION

Sidlodwana Mountain spring is located in a similar setting to Nkalokazi, but with a greater storage volume. In this case a single eye had also been protected and this was where the monitoring equipment was installed. Although no alterations were made to the catchment area, this spring also dried up during January 1999. However, water was still flowing strongly from other sections in the wetland, and it was just the particular eye that dried up. In April and May the spring was reconstructed by installing a slotted pipe in a more productive section of the wetland and fencing off this area. The initial results were promising with the dry period flows being consistently higher than were previously obtained from the single protected eye. However during the 1999/2000 wet season the flow from the spring did decrease compared to the previous season. This decrease is due to clogging of the pipe collector system by the fine silt. The majority of the clogging has occurred during the rainy season when the wetland would have become totally waterlogged. The second part of the graph shows flows from this capture system.

This spring would fit into classification system A1 within the spring classification system. Figure 5.2 indicates a rapid response to rainfall events, and a relatively steep recession curve at the end of the wet season. However the figure also indicates problems with the spring capture system at times, with a complete drying up of the spring at the point of capture in January 1999 (even though water was still flowing from other outlets of the spring system). Following the rehabilitation of the spring capture system, a good initial flow was obtained, with rapid response to rainfall events. However this again began showing irregular responses to rainfall and a gradual but consistent decline in flow with time. These results indicated the difficulty of the design and construction of spring capture systems in wetland seepage areas.

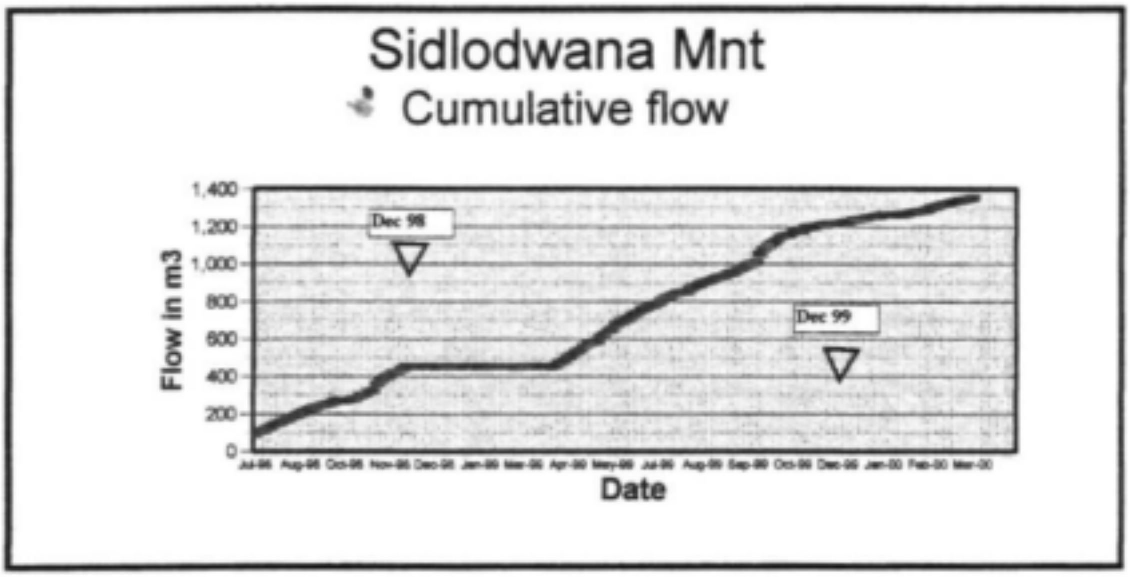
5.2 Highflats/Jollivet spring

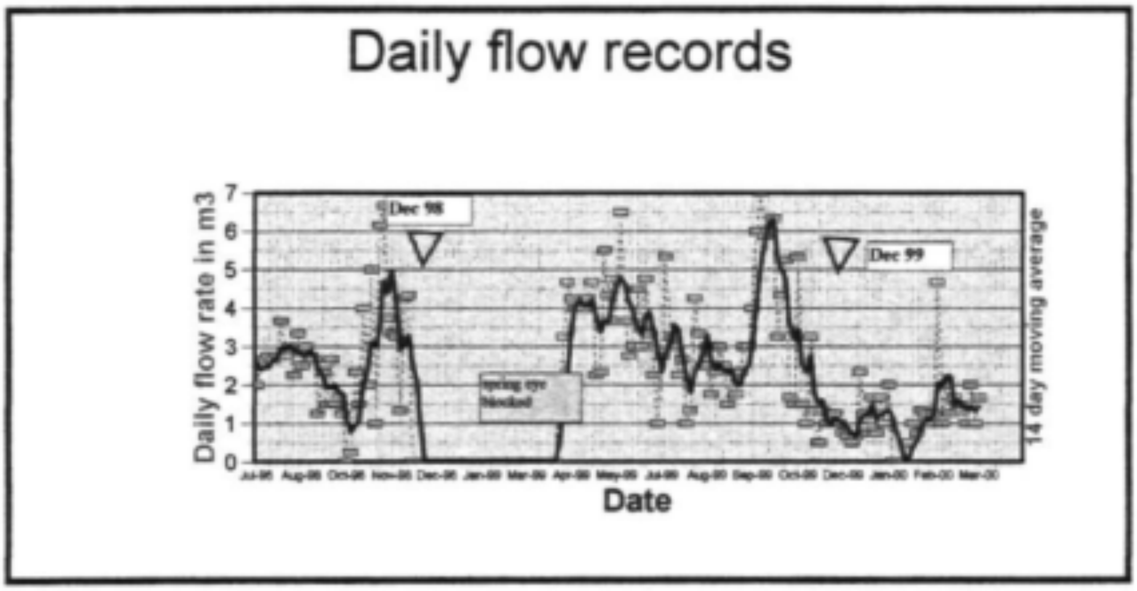
This area is characterised by Table Mountain Sandstones and shales. The formations are generally weathered and fractured, and topography characterised by steep exposed cliffs and deep valleys. The spring selected for monitoring close to Jollivet is located at the top of a steep valley, emanating at the contact zone between the Table Mountain sandstone and thin baked mudstone layers.

SPRING NAME: Jollivet (figure 5.3)

DESCRIPTION
Jollivet spring consisted of a number of eyes at the top of a steep valley. One of the eyes had been partially protected and piped to a small tank, from where the water was further piped to two reservoirs in the valley supplying water to a number of standpipes. The sandstone from which the springs were supplied with water is a large hill of approximately 2 km^2 and an elevation difference from the spring to the top of the hill of 100m.

Unfortunately there were constant disputes regarding the use of the water, and the capture system was regularly vandalised. The research team attempted to address this by capturing additional eyes and ensuring that there would always be water available for the





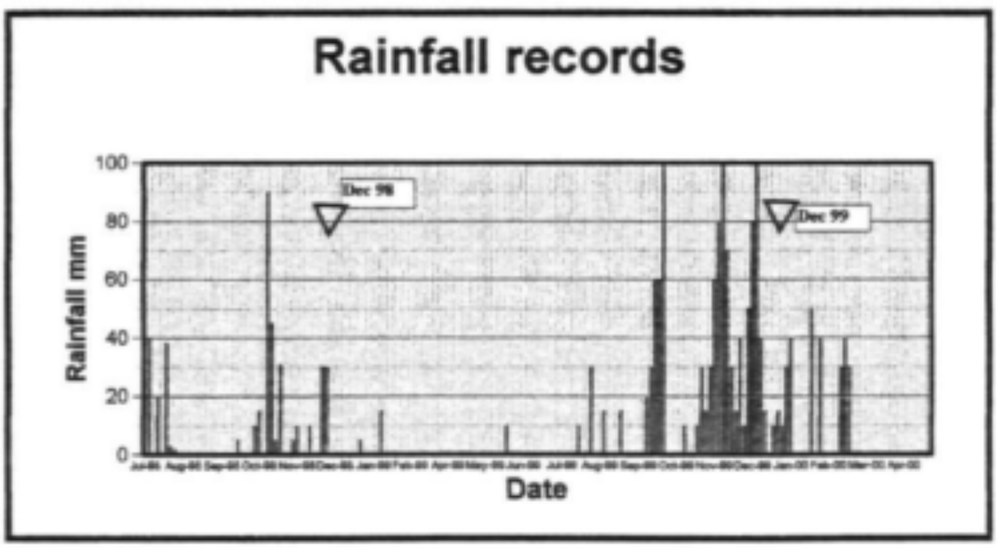
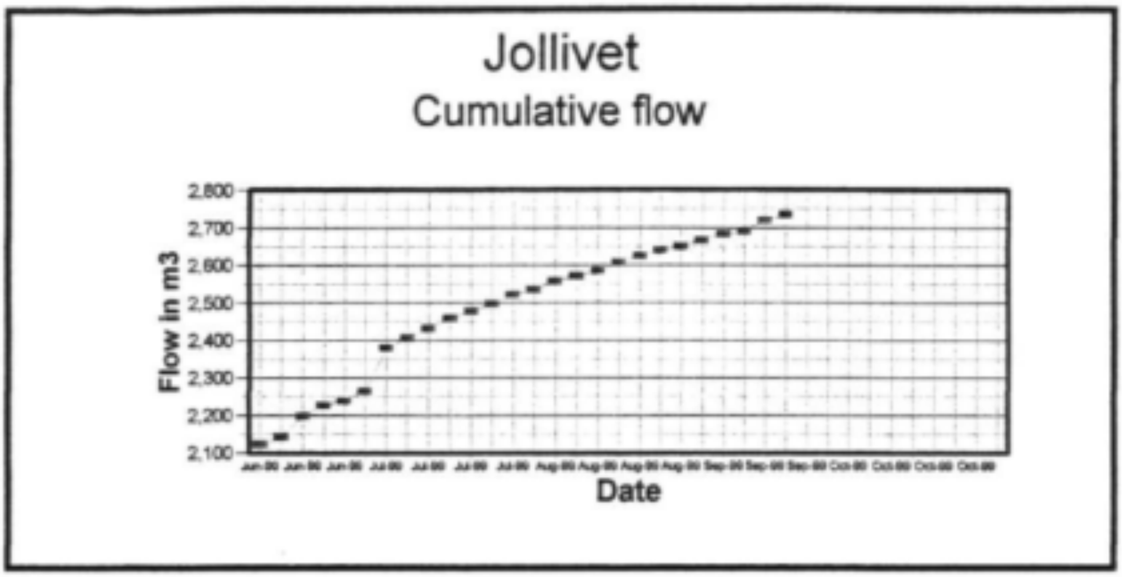
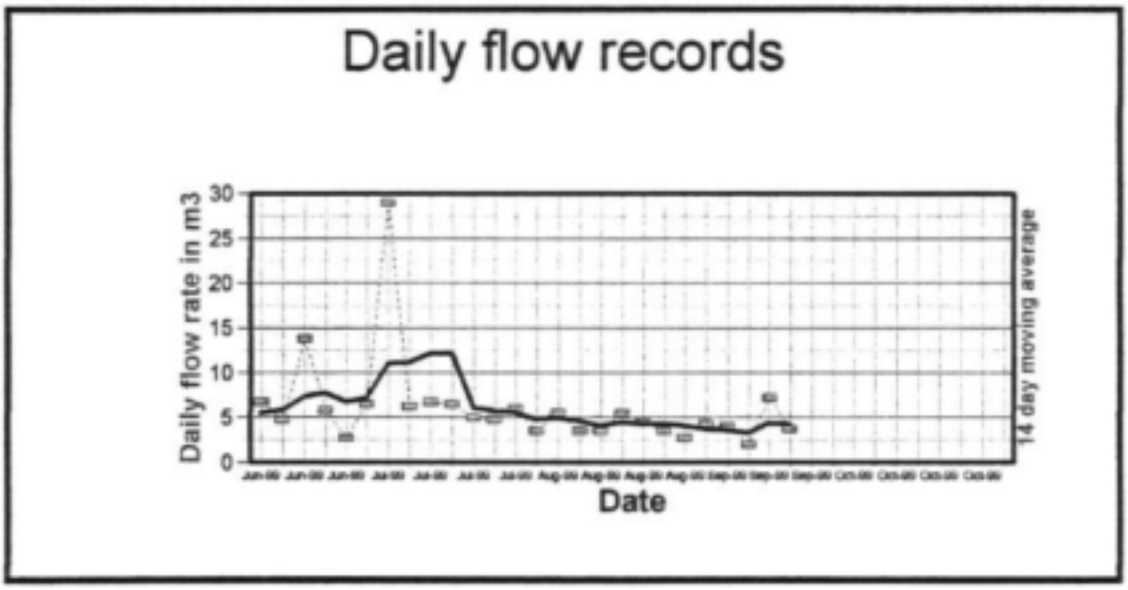


Figure 5.2 Sidlodwana Mnt Spring Flow Characteristics





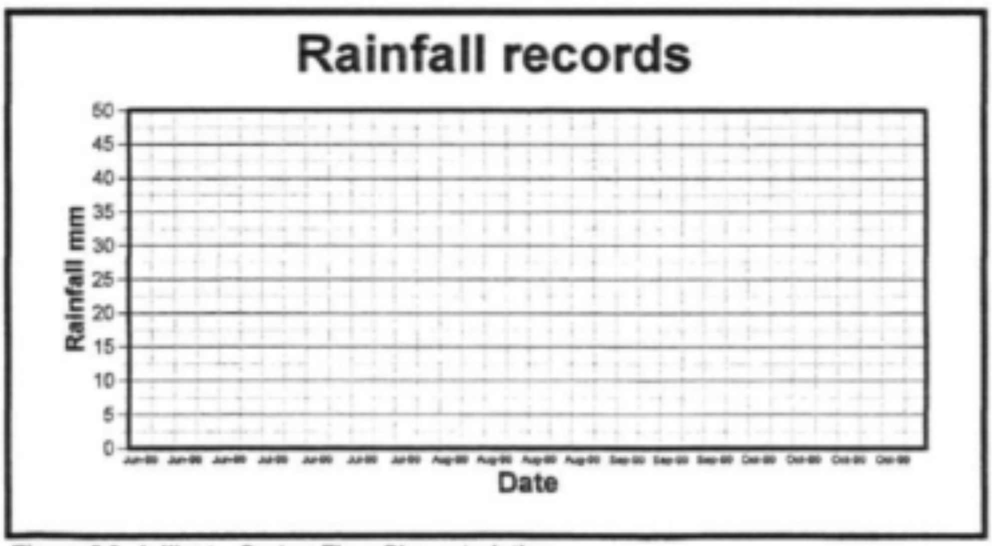


Figure 5.3 Jollivet Spring Flow Characteristics

residents living near and above the spring eye. However even this was vandalised and all the fencing destroyed to allow cattle into the area. Only about 4 months of reasonably reliable results were obtained during the dry season of 1999 (figure 5.3). During this period the spring was fairly steady with a gradual decline over this period. Response to rainfall was not well enough documented to be able to make accurate predictions. However the nature of the catchment indicated that the spring is probably a type A2, but with a strong baseflow and significant feeder storage system, tending towards a spring type B2.

5.3 Bergville Springs in the Lower Drakensberg

The water bearing structures in the Bergville area consist mainly of sandstones, siltstones, mudstones and compartments or fractures caused by dolerite dykes.

SPRING NAME: Makwabe

DESCRIPTION:

Location: The spring is located near the head of a small valley at the side of the main hill east of the village at an estimated altitude of 1460m. Protection works are constructed at the spring. A small amount of seepage occurs around the protection works, especially at the bottom.

The area is underlain by indurated intercalated siltstone, fine-grained sandstone, and mudstone. While the siltstone and mudstone beds are generally thin (less than 20cm), the sandstone layers thicken appreciably with depth. At the spring, the sandstone is about 2m thick and overlies slightly weathered to unweathered dolerite. The horizontally bedded sandstone dips slightly to north-east at about 5^{O}. It is characterised by jointing along bedding planes. The sandstone is cross-jointed, with a major north-striking joint being observed at the spring.

The catchment area above the spring is approximately 50 hectares. About 62% of this land lies between 1460 – 1480m altitude with average slope of about 1:25. The slopes increase to a very steep 1:4 in places, especially above 1480m. The altitude peaks at Trig. Beacon # 262 at 1524,1m with a secondary peak at 1511m only 200m north east of the spring.

The main land use in the catchment is grazing. The vegetation consists of grasses and shrubs with the occasional exotic tree.

Unfortunately despite numerous attempts at training and re-training the monitor, the data from the flow monitoring equipment was unreliable. However indications are that there is a short time lag in flow response to rain. The flow peak is subdued, suggesting that there is generally good infiltration over the catchment and response is to the overall catchment and not just due to interflow from the immediate vicinity of the spring. From the results the spring was shown to be strongly influenced by rainfall events, yet there remains a reliable, consistent base flow throughout the year. Some improvements were carried out to seal minor leaks in the pipes and to clean out the spring box.

This spring would fit into classification system A2 within the spring classification system. Average flows vary between 2 and 10 m^3/d.

SPRING NAME: Kholakazana 1 (figure 5.4)

DESCRIPTION:
Location: The spring lies at the foot of a large wild fig tree. There are no rock exposures in the immediate area around the spring; neither is there a valley or donga. The spring is about 150m south of the settlement at an estimated altitude of 1430m. The spring is well protected with no leakage visible. From the size of the protection works, the spring probably issues from a single well-defined eye.

There are no rock exposures in the vicinity of the spring. A small exposure (approx 50 x 20cm) of flat un-weathered dolerite was observed about 5m downstream of the spring. This is probably a boulder in location on part of the dyke observed further south in the locality of Kholakazana 2.

The catchment area above the spring is approximately 135 hectares. It includes the catchment of the Makwabe Spring which occurs at an altitude difference of about 30m with this spring. About 85% of the catchment lies between 1430 – 1480m altitude with average slope of about 1:25.

In addition to the land-use described for Makwabe, about 20ha of the land was planted with trees, mainly wattle. However a large proportion of these trees have since been cut.

The results of the monitoring (figure 5.4) indicate that the time lag between rainfall and flow response is longer than at Makwabe. This is consistent with the larger size of catchment. Furthermore, the spring is more reliable with smaller fluctuations between summer and winter flows, and the response to rainfall is more subdued.

Average flows vary between 10 and 30 m^3/d. The winter flows have improved over the period of monitoring, particularly during the year 2000. This is in part due to the removal of the wattle trees from the catchment.

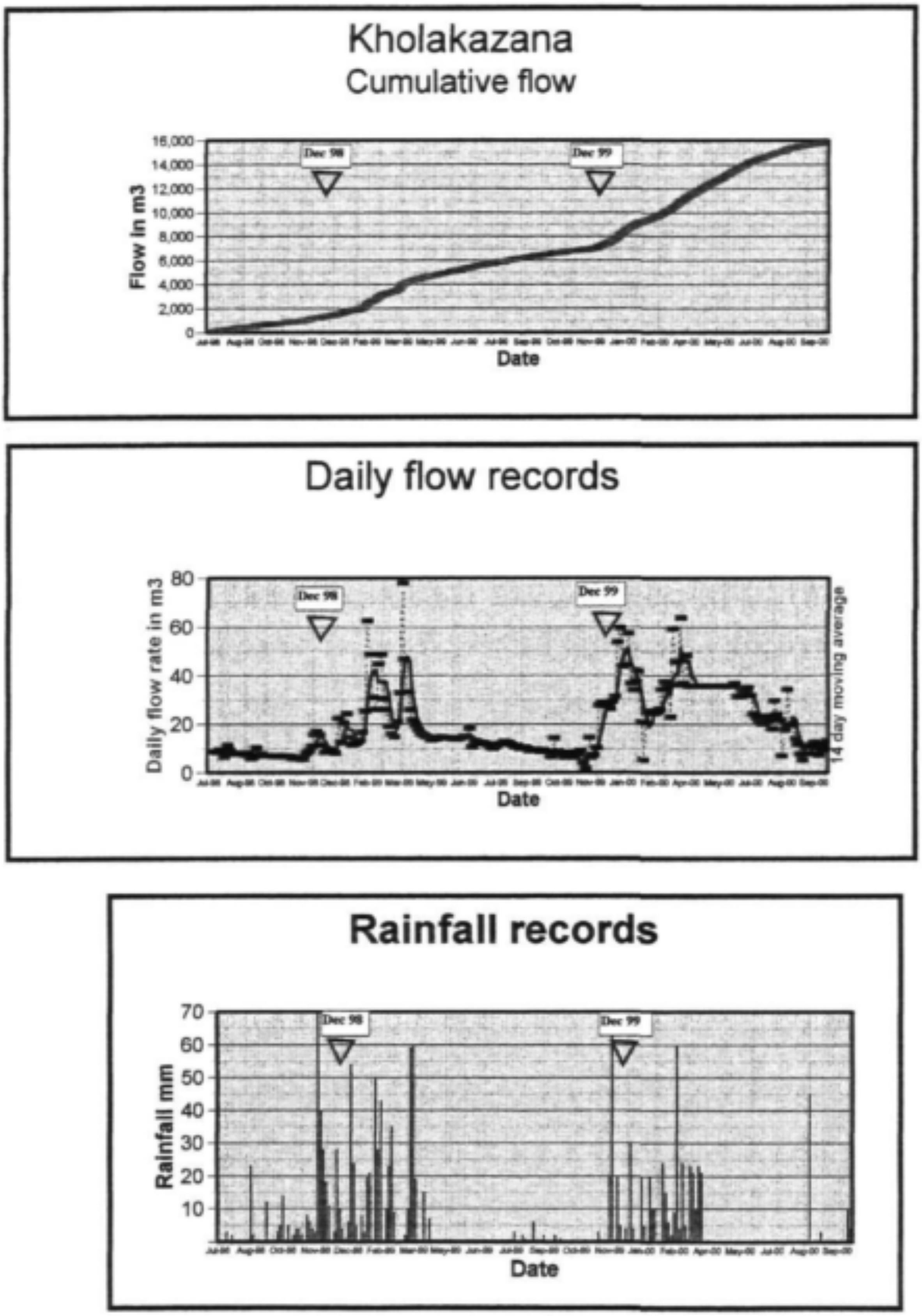
The spring is classified as A2 in the spring classification table.

SPRING NAME: Kholakazana 2 (figure 5.5)

DESCRIPTION:
Location: The spring is located at the head of a small deeply gouged-out donga about 300m east of Kholakazana 1 spring at an estimated altitude of 1420m. The original protection works are partly damaged and some seepage can be seen, though it is not clear whether this is entirely due to the damage. This also appears to be a single eye spring.

The area is underlain by slightly weathered and fragmented interbedded siltstone, fine-grained sandstone, and mudstone. The beds are generally thin (less than 20cm) as exposed in the contiguous vicinity of the spring. The spring occurs at a lateral contact

Figure 5.4: Kholokazana 1 Spring Flow Characteristics



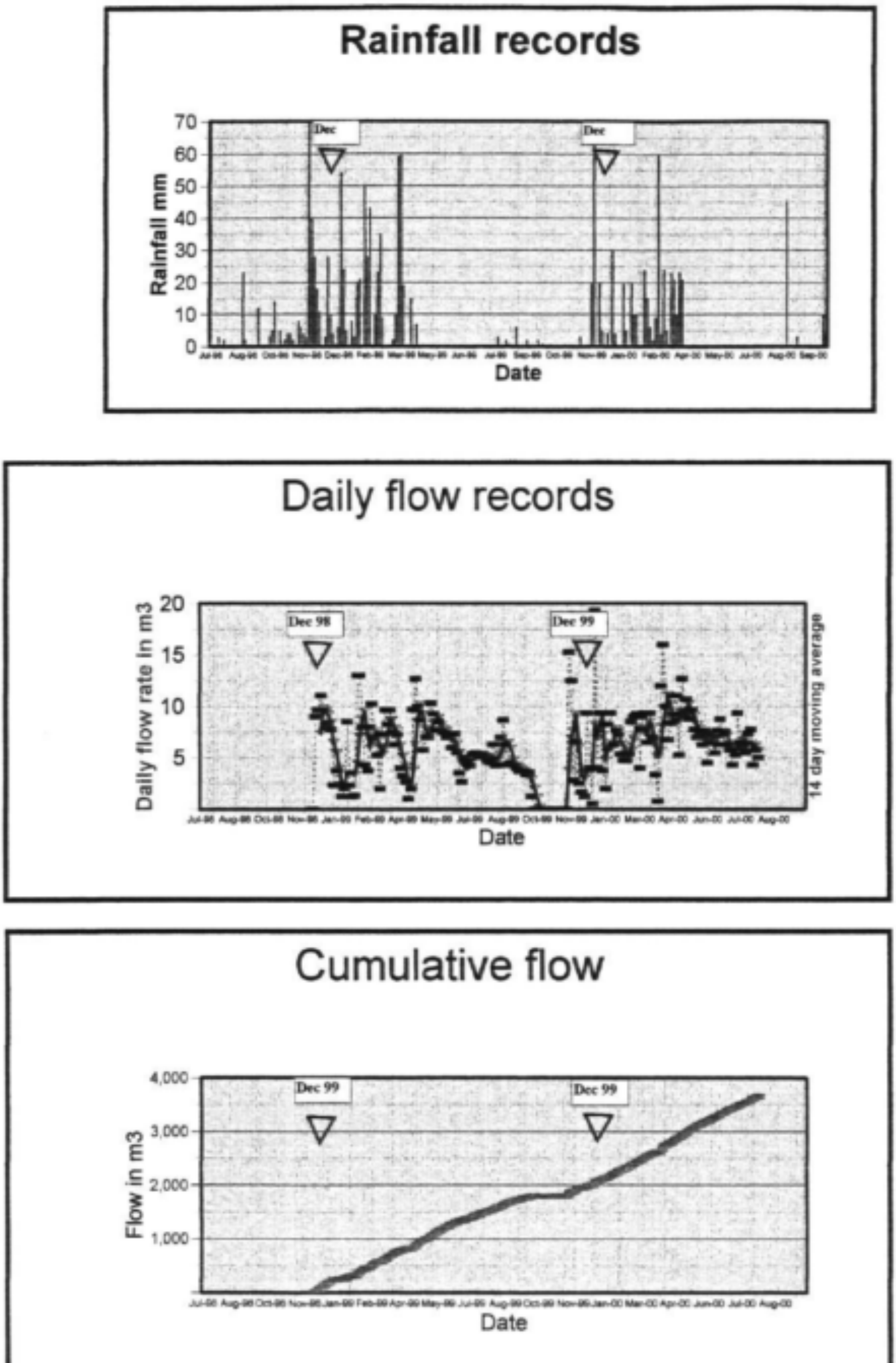


Figure 5.5: Kholokazana 2 Spring Flow Characteristics

between the dolerite and sedimentary beds, with the dolerite downstream of the spring. The dolerite occurs as a bouldery ridge with reddish residual clays in the joints.

The catchment largely coincides with that of Kholakazana 1 spring 300m to the west.

The results of the monitoring (figure 5.4) indicate that this spring appears to be sensitive to rain fall events, but this sensitivity has reduced following some work on improving the spring catchment structure. There was a probability that some surface runoff was flowing into the spring collector previously. Tentative indications are that the flow at this spring is more strongly dominated by fracture or boundary structures than either Makwabe or Kholakazana 1, which occur in the same catchment and also draw from fractures. Although this spring occurs at lower altitude than the other two, it is likely to be less reliable than both due to more rapid drainage of the fractures feeding it.

The spring is classified as A2 in the spring classification table. Discharge volumes average between 2 and 8 m^3/d.

SPRING NAME: Magangangozi 1 (figure 5.6)

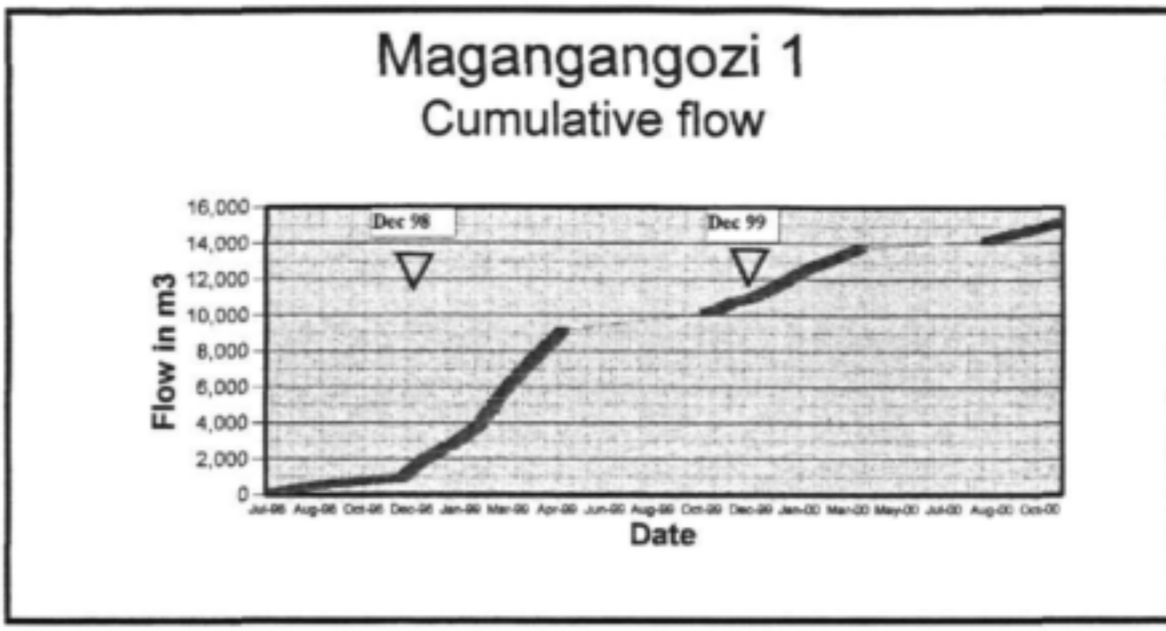
DESCRIPTION:
Location: There are two springs about 10m apart at this site. One spring is located at the head of a deeply gouged-out donga. The second spring occurs about 10m downstream of a donga filled with collapsed rock and soil rubble at the same altitude as the first. This second spring feeds into the same donga as the first after passing through a small (approx 2 x 2 m) grassy patch. The estimated altitude of the springs is 1300m.

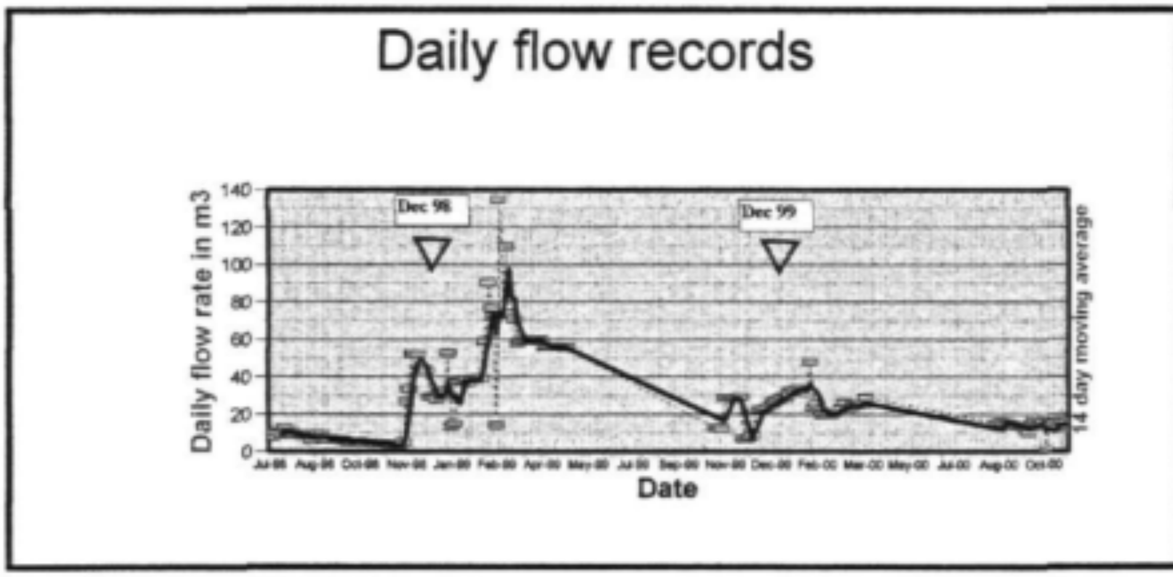
The immediate area around the springs is underlain by slightly weathered and fragmented interbedded siltstone, fine-grained sandstone, and mudstone. The beds are generally thin (less than 20cm) as exposed in the contiguous vicinity of the spring. The spring occurs at an apparent contact between the sandstone and the more indurated mudstone along a bedding plane. The mudstone has a baked, slatey texture which suggests a possible occurrence of a dolerite sill not far below.

The catchment above the spring is shared with the Makwabe and Kholakazana springs, but with this spring being situated much lower down in the catchment. Within 5km of the spring, the surface area of the catchment is about 11km^2. Much of the landscape is rugged and bare of vegetation, with occasional gently sloping grassy stretches where people have settled and carry out diverse traditional subsistence agriculture

The results of the monitoring (figure 5.6) indicate that the flows are strong with a subdued response to rain, similar to Kholakazana 1. With the larger catchment area and potential storage volume, this spring could be expected to be consistent and reliable. However the flow did drop to a very low level at the end of the dry season in 1998, indicating that the flow from the fractures dwindled and was not replenished at a sufficient rate to maintain a high flow.

The spring is classified as displaying characteristics of both A2 and B2 classes in the spring classification table. Average flows vary between 4 and up to 60 m^3/d. However the collection system did become clogged during the rainy season of 1999/2000, resulting in





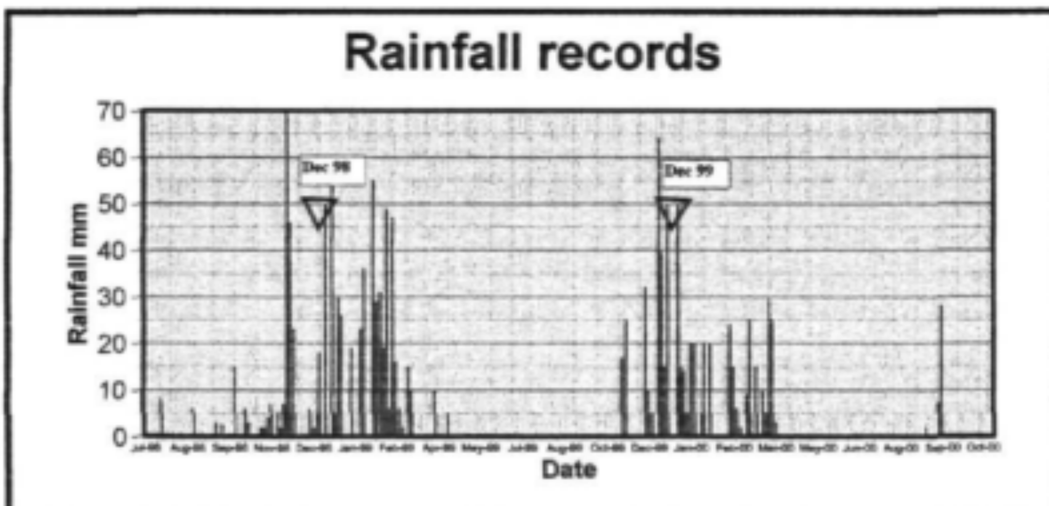


Figure 5.6 Magangangozi 1 Spring Flow Characteristics

much of the water bypassing the collectors (and hence also the monitoring system). Attempts to clear it out have helped, but have not restored it to its original status. An option will be to install rodding eyes in the future at the spring eye that can be cleared at regular intervals.

SPRING NAME: Magangangozi 2 (figure 5.7)

DESCRIPTION:
Location: The protected spring issues from a joint in dolerite outcrops just below the Emmaus Mission – Cathedral Peak road. There is no sign of any other seep or spring within 30m of this site. The estimated altitude of the spring is 1320m.

The spring occurs in the lower slopes of The Little Berg mountains at a dolerite/baked sandstone contact. The catchment coincides with that of Magangangozi 1. The land immediately above the spring appears to consist of deeply weathered scree with sandstone boulders. Below the spring the land slopes more gently towards the Mlambonja river.

The results of the monitoring (figure 5.7) indicate that, consistent with the large catchment, the spring has a strong flow. The emerging trend is of declining flow with little immediate response to rainfall. This is not surprising as the bulk of the catchment consists of steep slopes. It is expected that this spring is fed from the mountains, which lie within 5km linear distance.

A problem arose during the monitoring period in that the pipes leading from the spring to the tanks blocked or constricted the maximum flow possible. This resulted in a back-up and overflow at the spring itself. This meant that a portion of the flow was no longer being monitored. The project team have subsequently installed an additional meter on the overflow, while at the same time encouraging the community to excavate and unblock the constrictions. The overflow presently averages at about 4 m^3/d, while the main spring averages 5 to 15 m^3/d.

The spring is classified as A2 in the spring classification table

SPRING NAME: Ntsukangihlale 1 (figure 5.8)

DESCRIPTION:
Location: The spring consists of spread-out seeps in a natural wetland surrounded by homes. Two of these, located near the head of the vlei and about three metres apart are protected and supply the storage tank. Some of the unprotected eyes seem to be seasonal. The springs occur at an estimated altitude of 1300m.

The area is gently undulating with a moderate slope towards the well-grassed natural wetland. Weathering appears to be deep, with the black clayey vlei soil supporting local brick-making. The spring is a result of a dolerite dyke that cuts through the water bearing sandstone layers. This results in a considerable outflow from the spring since the sandstone matrix is very thick behind the dolerite dyke.

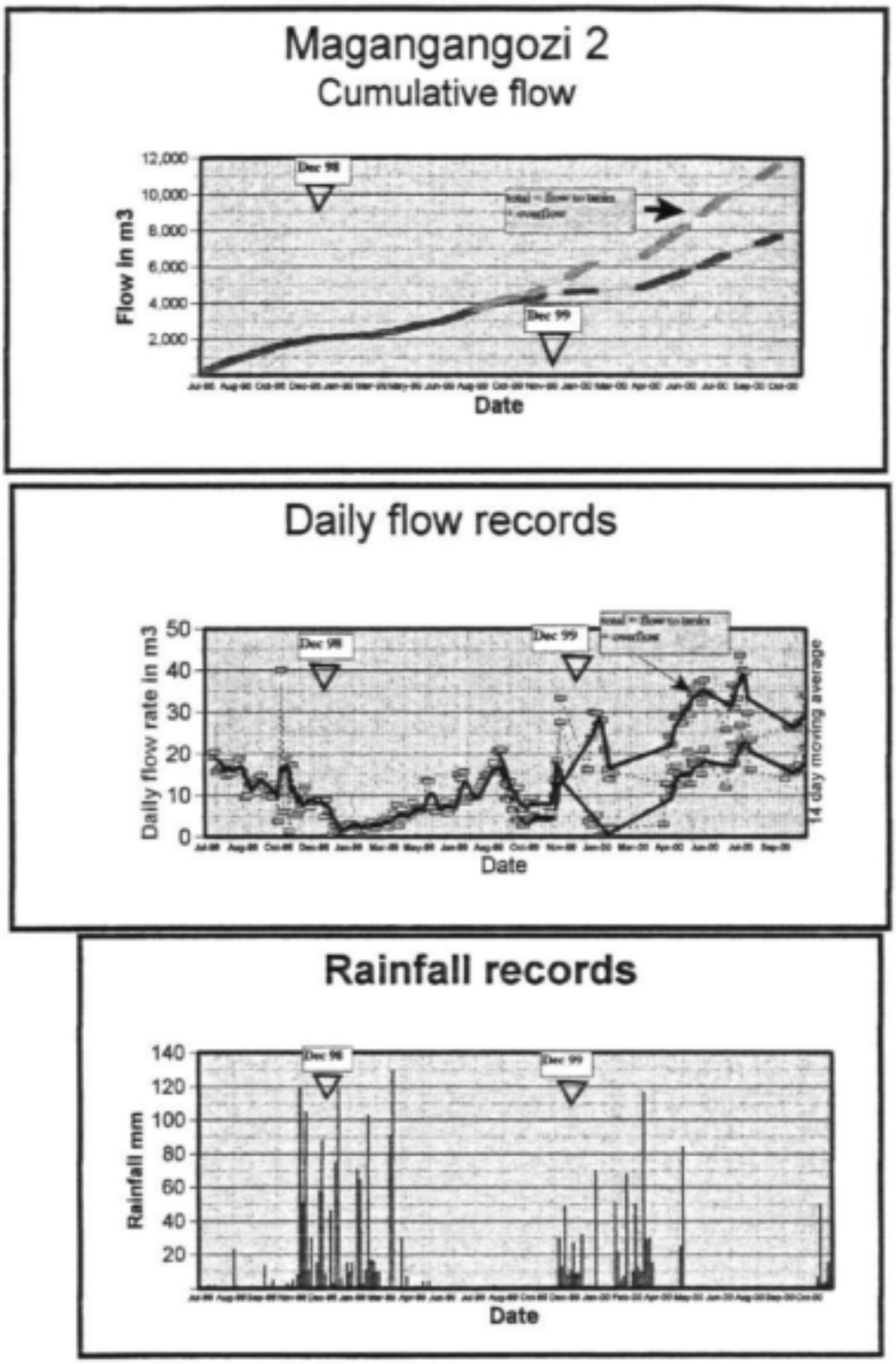


Figure 5.7 Magangangozi 2 Spring Flow Characteristics

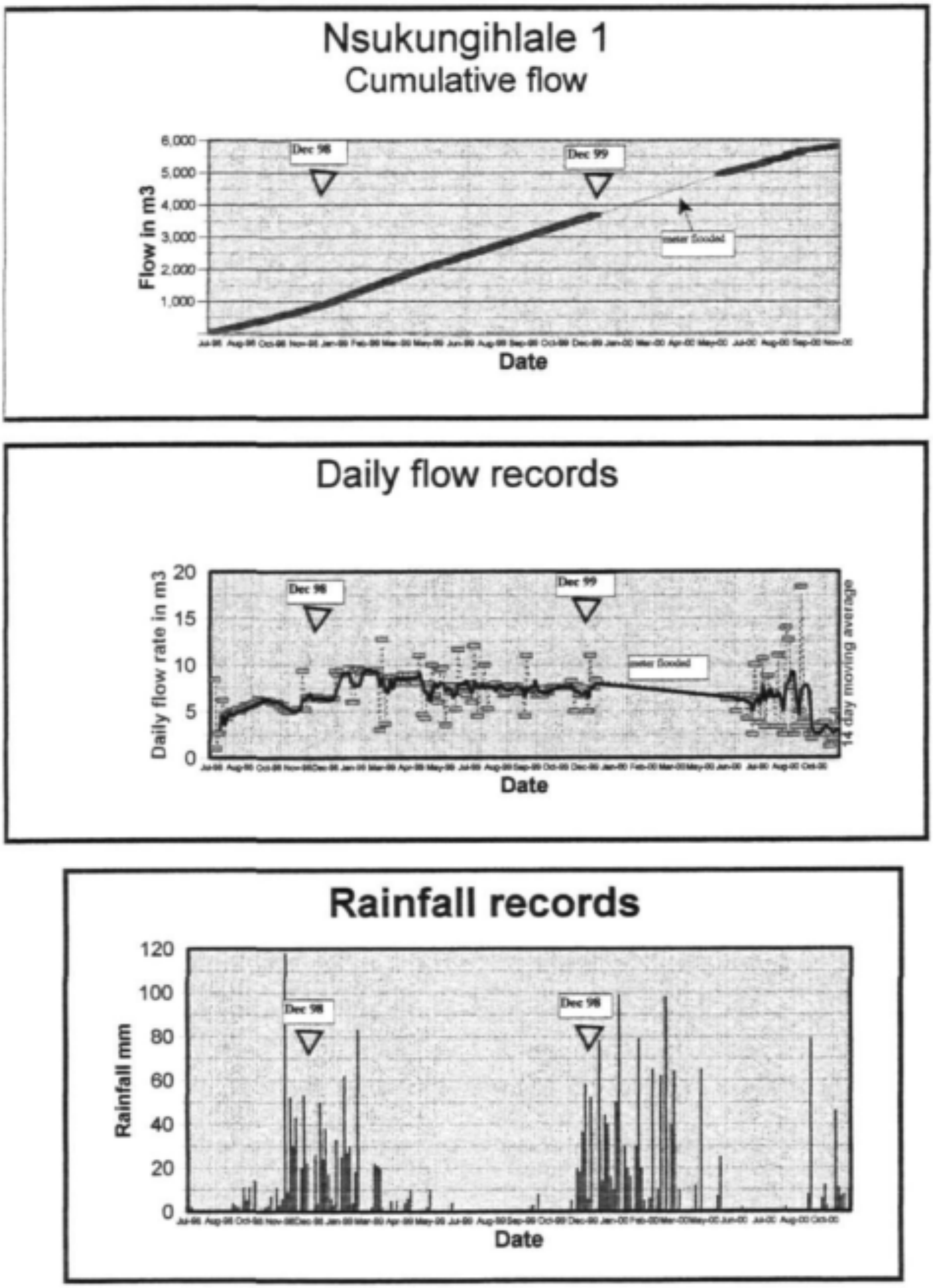


Figure 5.8 Ntsukangihlale 1 Spring Flow Characteristics

The catchment is comprised of a rolling grass plain used primarily as grazing, with minor cultivation especially around the homesteads within the catchment. The plain rises with increasingly steeper slopes towards the mountains in the distance. The probability of hydraulic connection with the scree-slopes is high.

The results of the monitoring (figure 5.8) indicate that the measured flow is fairly constant, suggesting that most of the flow is derived from beyond the immediate catchment. The spring responds rapidly to rainfall over the contiguous catchment, but the response is clearly superimposed over the longer trend.

Average flows vary between 4 and 8 m^3/d, although considerably more water is available in this seepage area than what is captured by the monitoring equipment. The results consequently just indicate the consistency or otherwise of the flows, as opposed to the total flow available.

The spring is classified as B2 in the spring classification table

SPRING NAME: Ntsukangihlale 2 (figure 5.9)

DESCRIPTION:
Location: The spring is located at the head of a rugged boulder-strewn valley at the foot of an escarpment at an estimated altitude of 1380m. The spring issues from two well-defined eyes that are protected. No leakage or seepage is evident.

The area is underlain by jointed sandstone overlain by a thin, less than one metre thick weathered sequence of interbedded siltstone, fine-grained sandstone, and mudstone. The spring occurs at an intersection of joints running at right angles to each other.

The results of the monitoring (figure 5.9) indicate that discharge is strongly dominated by fracture flow. Response to rain is both rapid and large, implying that some of the contributing fractures may be open at, or very near to the surface. The flow reduces rapidly in the dry season, providing very little water for the residents. This indicates that although the catchment appears large, the actual storage is very limited and rapidly draining.

The spring is classified as A1 in the spring classification table

5.4 Transkei Springs

The springs monitored in the Transkei are from similar geological structures as the Bergville springs. This is the Beaufort series of sandstones, siltstones and mudstones, with dolerite intrusions having a significant impact on groundwater characteristics.

After considerable negotiations with various communities, a number of concerns were raised regarding the monitoring of the springs. As a result only two springs were monitored.

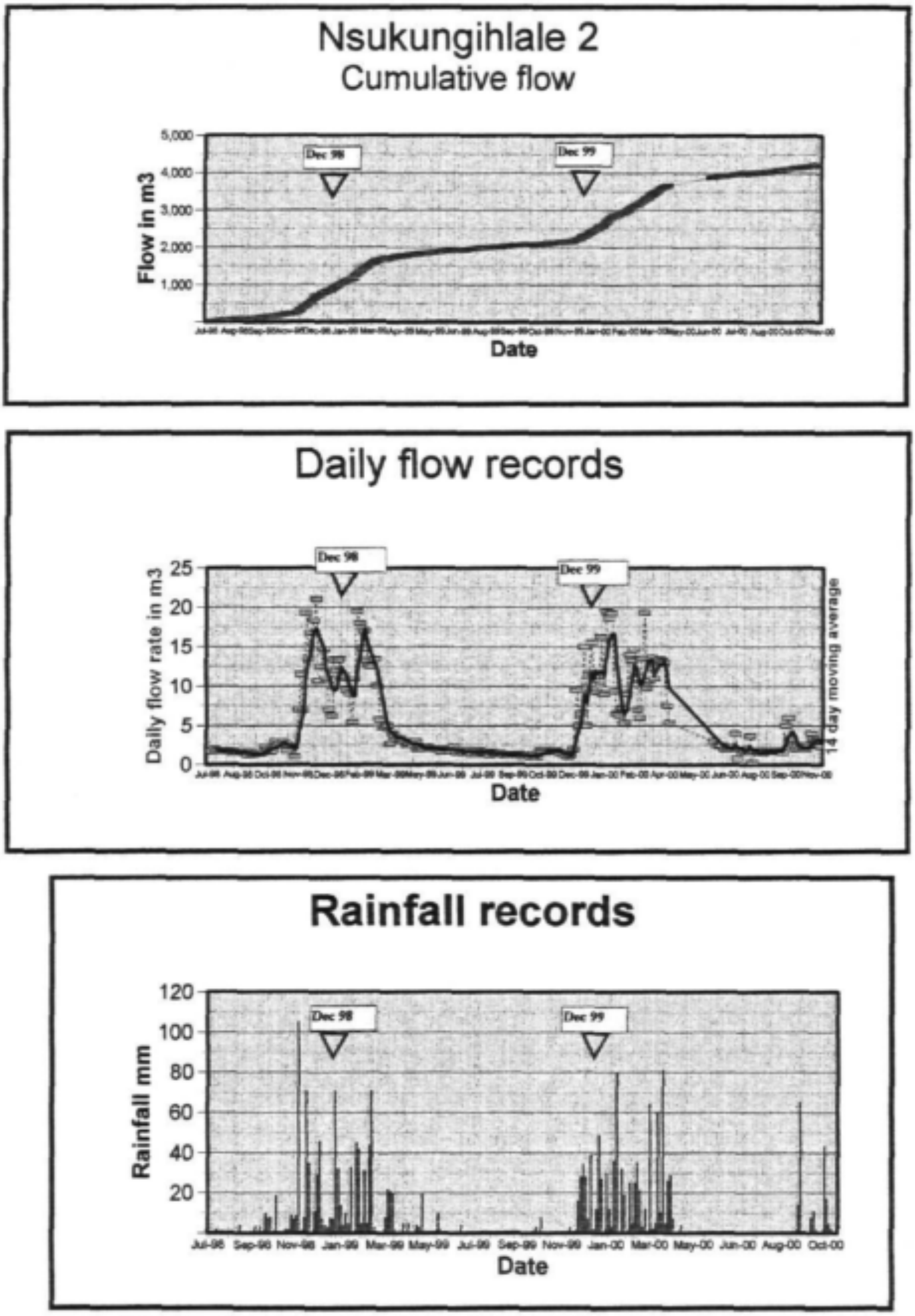


Figure 5.9 Ntsukangihlale 2 Spring Flow Characteristics

Spring Name: Sixuzulu (figure 5.10)

Description

Sixuzulu spring is located near the foot of a mountain and consequently has a considerable storage volume. There is increasing soil erosion in the vicinity, however, and this is likely to impact on spring flows in the longer term. The results of the monitoring (figure 5.10) indicate that flows average between 10 and 20 m^3/d. There is a subdued response to rainfall events as was expected, which results in a reliable, consistent water supply.

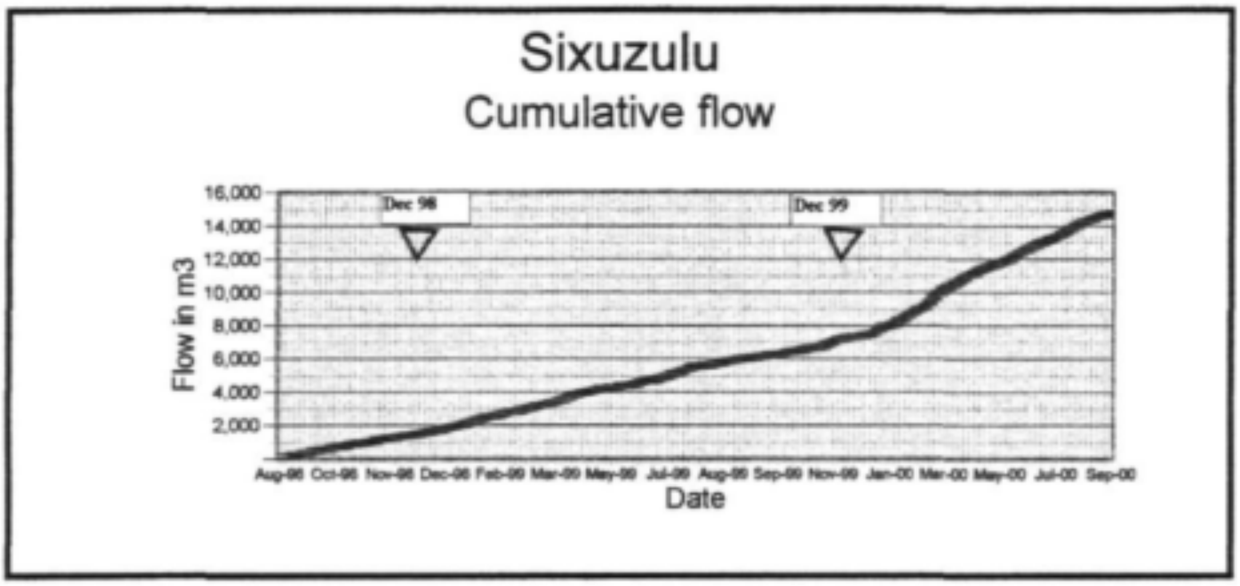
The spring is classified as B2 in the spring classification table

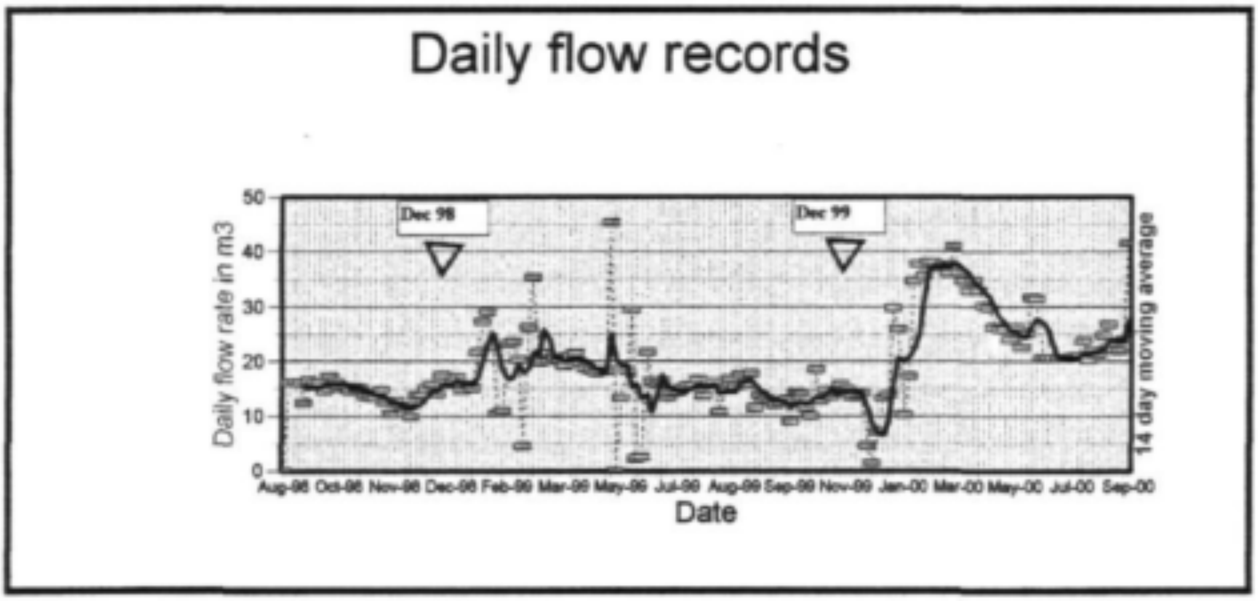
Spring Name: Macosa (figure 5.11)

Description

Macosa Spring is located at the contact of sandstones and less pervious siltstones and mudstones. Although not confirmed, there appears to be a minor fracture or fault resulting in this spring being stronger than all those in the surrounding area. This would imply that the spring draws water from a much greater catchment area than its immediate vicinity, and the fracture acts as a porous conduit to carry the water to the spring. The results of the monitoring (figure 5.11) indicate that although the storage volume appears to be relatively small, the spring is consistent and reliable.

The spring is classified as A2 in the spring classification table.





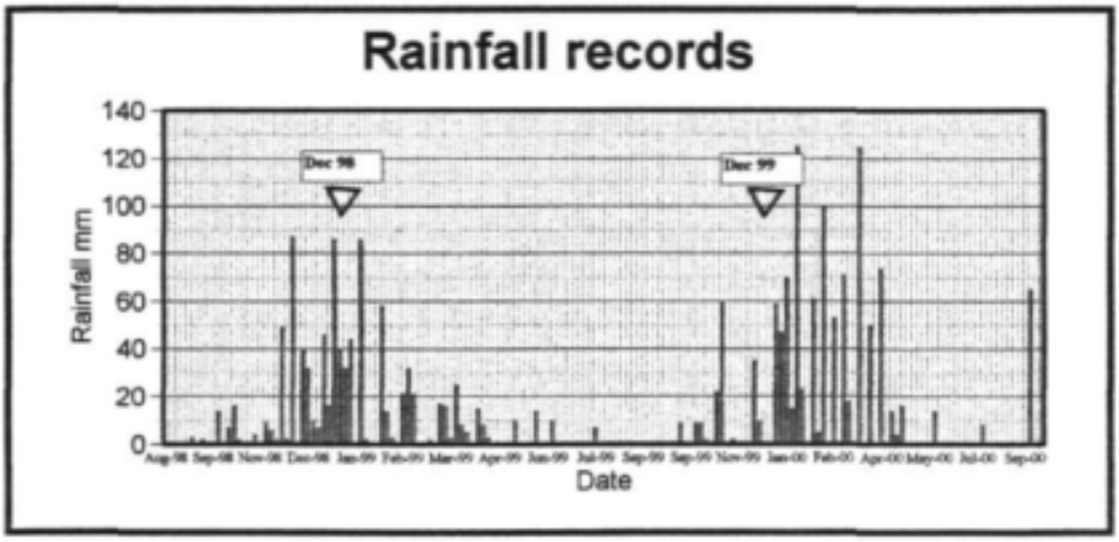


Figure 5.10 Sixuzulu Spring Flow Characteristics

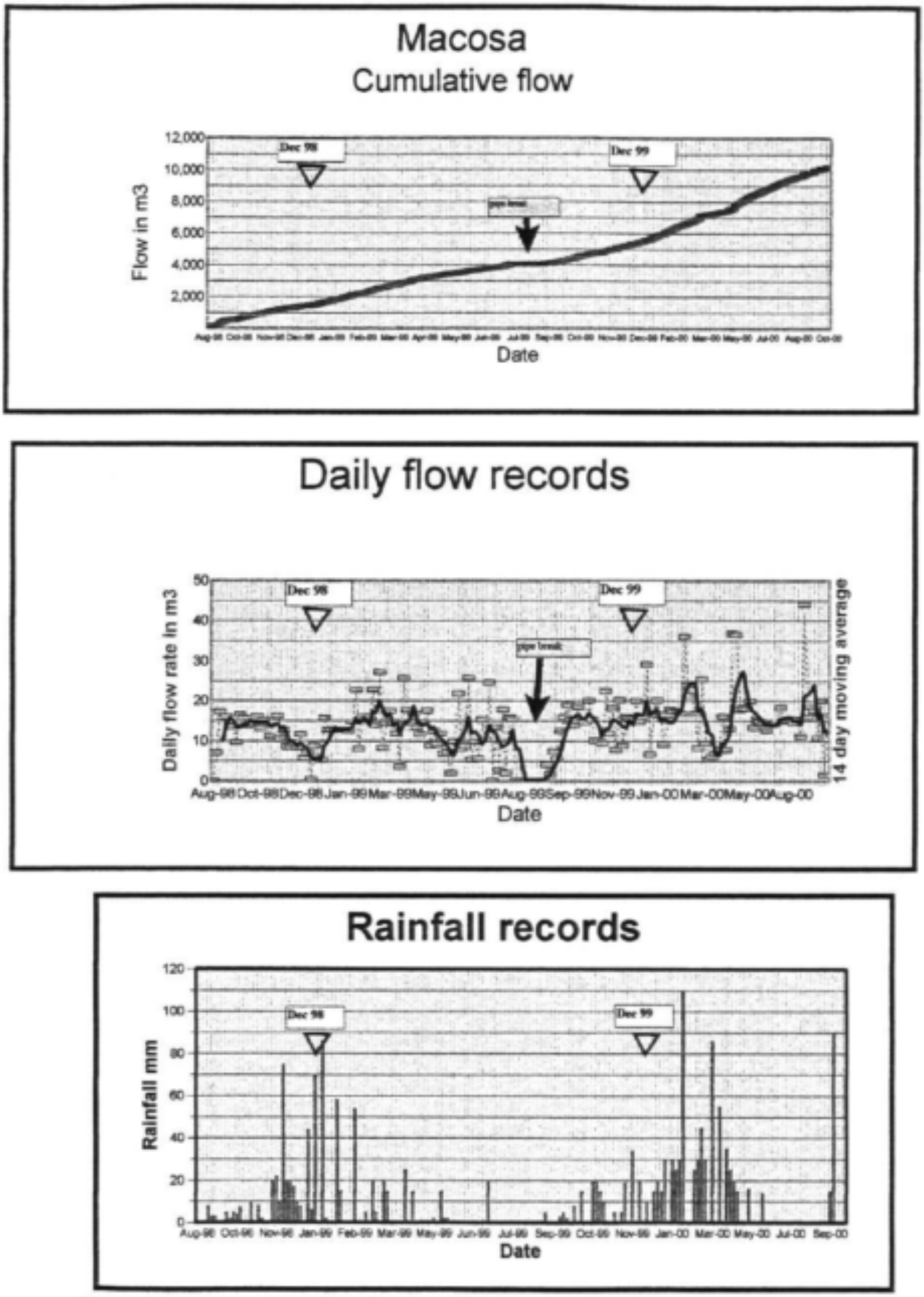


Figure 5.11 Macosa Spring Flow Characteristics

5.5 Other Related Aspects

A number of other aspects related to the water supplies from the springs were noted during the study period and certain specific assessments were carried out. These are as follows:

- **Maintenance of spring protection systems**

  In the Transkei community leaders generally take responsibility for the maintenance of the springs, and do carry out minor repairs whenever a problem occurs. However no funds are collected from community members to be able to purchase spares or pay for labour. Hence most repairs are of the "blou draad and inner-tube" type, which usually continue to leak after the repair.

  In KwaZulu no repairs whatsoever were carried out on a voluntary basis. The project technician was usually contacted to come and carry out repairs, including paying for local people to help. This approach (or general lack of ownership) was evident in a number of old spring systems no longer functioning at many places.

- **Problems with leaking or damaged taps**

  At many of the springs taps were leaking constantly. The project team regularly replaced taps or replaced washers. A decision was made to test an alternative type of tap that does not require the stop to be screwed closed. A gravity closing tap was purchased and installed at a number of spring water collection points, particularly in the Bergville area. However many of these taps did not close properly, even when first installed. In the end they were all removed and conventional taps were again installed.

- **Effect of activities in the catchments**

  Catchment activities did have an impact on the flow from the springs. The following particular activities were noted to reduce flows:
    - The growing of exotic trees (wattle);
    - Allowing cattle to graze in a wetland area (the impact is more the damage or clogging of the collectors than the actual spring flows);
    - Soil erosion due to overgrazing

5.6 Estimating flow characteristics from ungauged springs

The results of this study point to the following guidelines for estimating the flow characteristics from ungauged springs:

Step 1 – Measure the present flow rate from the spring (e.g. stop-watch and bucket);

Step 2 – Study the catchment and the spring site itself. Observe any faults, dykes, bedding planes, fractures, sills, or other lithological anomalies. Observe the geological structures. Note any other springs coming from the same lithological system. Estimate the approximate area of the catchment and the contours describing the shape of the overlying formations. Note the vegetation and the human activities in the catchment above the spring.

Step 3 - Ask the local residents about the history of the spring, particularly its flow characteristics during the dry periods and droughts.

Step 4 - Estimate the aquifer storage volume using average porosity values (e.g 30% for soil and fracture zones, and 10% for porous rock).

Step 5 - Make a seasonal correction for the measured flow. This will depend on the estimation of the catchment characteristics. If the spring appears to be classified as a B type, make a small correction for summer and winter flows (say 10% downwards for summer and 10% upwards for winter). If the spring appears to be a type A, make a larger correction. Say 30% downwards for summer flows and 30% upwards for late winter flows.

Step 6 - Estimate an average annual flow from the corrected flow obtained in step 5. Compare this with the estimated aquifer storage obtained in step 4. From this use the table below to make an estimation of the reliability of the spring flow for use as a community water supply. Note however that it is recommended that a portion of the spring flow should be allowed to bypass the collectors to maintain the ecology of the spring stream below the collection point.

Average annual spring flow as a % of aquifer storage	**Spring type**	**Options for use as a community water supply source**
1 – 20%	Type B (B1 or B2)	Very good – high level of flow reliability
20 – 33%	Type B (B1 or B2)	Very good – reasonable level of flow reliability
33 – 50%	Type A (A1 or A2)	Acceptable – flows will fluctuate between wet and dry seasons, but the low flows should not drop below approximately 25% of the average flow
50 – 100%	Type A (A1 or A2)	These springs should only be considered as a possible back-up to other water sources.
> 100%	Type A (A1 or A2)	These springs should not be considered as a source for community water supplies.

6. CONCLUSIONS

The advantages of being able to more accurately assess the flow and flow variations from small springs at remote small community water supply systems cannot be overstated within the context of rural development in South Africa and other developing countries. Following this relevant work, certain follow-up activities are recommended in order to ground the work in the practice of rural development, and to refine the initial findings by continuing certain aspects of the programme.

6.1 Achievement of objectives

This study started out with three primary objectives. These were to determine the factors affecting the flow from small springs, to provide guidelines to consultants and planners where springs are being considered as full or complementary water sources for community water supplies, and to evaluate spring flow enhancement techniques for their effectiveness and practicality.

In terms of the first objective, the factors affecting flow from small springs have been assessed and categorized, with particular emphasis on the springs that were monitored. It is acknowledged that certain other factors that have not been fully assessed in this study will also play a role in the flow from springs, and some of these have been discussed in relation to the reports published in the literature.

In terms of the second objective, some guidelines are provided in this report. However it is acknowledged that these are not complete in themselves, as a certain level of knowledge and experience in the assessment of the lithology, climatology and vegetation cover is assumed. Other guidelines for these aspects already exist, and should be referred to if required. However it may be a future requirement to specifically develop more comprehensive guidelines incorporating all existing knowledge and guidelines.

The third objective could not be achieved within the revised scope of the project. The project budget was reduced and this component of the research was limited to minor labour intensive approaches on two or three of the springs being monitored. However valuable lessons have been learnt regarding the installation of sub-surface collection systems in seepage fields, and in assessing the options for flow enhancement from other type A springs.

6.2 Sustainability of springs

The key aspect of this study has been to assess the sustainability of the flow from springs. It has been found that a number of aspects impact on the sustainability and seasonal variation of spring flows. Many of these aspects cannot be improved by any technical or management interventions. However there are certain aspects which, if addressed, can result in the improvement of the sustainability of some springs. At the same time the improved understanding of the factors that impact on the flow of springs can be used to improve the effectiveness of the development of sustainable water supplies for small communities. Table 6.1 indicates the key factors and their impact on spring flows.

6.3 Enhancement of flows from springs

In theory, the flow from springs can be increased by simply excavating deeper into the water table that is supply the spring without damaging the impervious boundary layers that ensure outflow at the particular eye or wetland. Historically this technique was used to supply water to many cities and towns. However its implementation on small springs may be risky or not cost effective. Many small springs access water from a limited water table with fragile impervious boundary conditions. Attempts at further enhancement of the flow can result in more rapid draining of the limited source, and hence a shorter season when the spring flows at the rate required for use, or alternatively the fragile boundary conditions may be damaged resulting in the water draining to deeper underground regions and no longer flowing out at the spring.

However, in certain circumstances spring flows can be beneficially enhanced without curtailing the period of spring flow or damaging the spring boundaries. This could either take the form of careful excavation of the spring eye to increase the hydraulic flow characteristics from the water table supplying the spring (e.g. horizontal drilling or manual excavation), or the installation of underground filters into existing wetlands. It may even be possible to intercept a water table that does not currently supply any springs, and thereby develop a "spring" source. Any such development of springs requires careful assessment by a knowledgeable expert prior to excavations being carried out.

FACTOR	SUB-COMPONENTS	PRIMARY IMPACT ON SPRING FLOW	OPTIONAL STEPS FOR MAINTAINING OR MITIGATING THE IMPACT
rainfall		re-charges groundwater resources that supply the spring, and hence boosts spring flow	Maintain the catchment area so as to optimise infiltration of rainfall into the groundwater
agricultural activities within the catchment	crop planting	reduces infiltration rate of rainfall by permitting rapid runoff	contour ploughing and maintaining natural vegetation (grasslands) between ploughed fields
	grazing lands	reduces infiltration rate of rainfall when overgrazing causes rapid runoff	prevent overgrazing by good management of animals and fencing grazing camps
	trees and forestry	consumes infiltrated soil water at a rate greatly exceeding that of the natural vegetation	minimise planting of exotic tree types, and remove all non-indigenous trees that have grown naturally
building and construction activities within the catchment	roads	reduces infiltration rate of rainfall by permitting rapid runoff	construct regular drainage drains that channel runoff away from the road, preferably to open lands
	housing and schools	reduces infiltration rate of rainfall by permitting rapid runoff	ensure good drainage to open lands, and maintain grass or vegetated areas around the buildings
	other construction	reduces infiltration rate of rainfall by permitting rapid runoff	ensure good drainage to open lands, and maintain grass or vegetated areas around the buildings
burning of the veld		annual and uncontrolled burning results in loss of certain vegetation types and consequent more rapid runoff from the catchment and reduced infiltration	manage burning of veld by ensuring that burning does not happen every year, and when burning is required the soil moisture is still high enough to protect and propagate seeds
damaging of springs and wetlands	spring eyes	excavating close to the spring eye can result in damage to the impervious layer which channels the water to flow at this point, in which case the ground water may penetrate deeper levels and no longer flow out at the spring eye	carry out thorough investigations of spring eyes before any excavations of or close to the eye, ensuring that any impervious layers are not breached
	wetlands	excavating, ploughing or permitting cattle to graze within wetlands can result in damage to the impervious layer which channels the water to flow at this point, in which case the ground water may penetrate deeper levels and no longer seep out in the wetland	carry out thorough investigations of wetlands before any excavations or other developments are permitted within the wetland, ensuring that any impervious layers are not breached. Preferably wetlands should be fully protected with no development allowed.
sinking of boreholes within the catchment		Sinking of boreholes may drain perched water tables that feed springs. Pumping from boreholes may abstract water that would otherwise flow out at the spring.	Ensure boreholes are not located close to springs, and that borehole pumping rates do not result in abstracting water that may otherwise feed springs

Table 6.1: Factors affecting flow from small springs.

6.4 Recommendations

In this light the following recommendations are put forward:

6.4.1 Finalising and publishing the guidelines for general use.

The guidelines emanating from this research project should be finalised into an acceptable format, and linked to existing guidelines on the development and protection of springs. These should be made available to all relevant role players, including local governments responsible for rural areas.

6.4.2 Development of a training programme

A training and support programme should be developed on the assessment of small springs. The training programme should also include protection and distribution of water from springs, and recommended monitoring procedures.

6.4.3 Establishment of additional longer term monitoring programmes

It is considered imperative that additional monitoring of small springs takes place over a period of several years. This may include some of the springs that have already been monitored on this programme, as well as new springs from other lithological groups and other development regions. The data from these programmes should be centrally collated (by DWAF?) and be made available for researchers and practitioners. The data should in particular be used to extend the proposed classification system to other areas and at the same time to refine the system to be able to further sub-divide the categories and improve the predictability of flows from ungauged springs.

6.4.4 Development of a flow model for small springs

It would be useful to have a simple flow model for small springs based on the different classifications proposed in this report. The development of a model would involve the evaluation of existing models based on data obtained in this and other surveys, and the detailed measurement of flow responses of specific rainfall events. The parameters for the model should be easy to measure and not require long flow records of the springs – i.e. a deterministic model would be appropriate, even if the models are calibrated from a stochastic analysis of existing flow data.

6.4.5 Further development and testing of sub-surface spring capture techniques

Sub-surface spring capture techniques have a number of benefits over surface systems. These include better protection, improved water quality, and in some cases improved flow and reliability. It is recommended that additional resources be put into developing and evaluating these techniques.

6.4.6 *Strategy for improved management of watersheds in rural areas*

Rural residents are very aware of the degradation of their agricultural areas, and would be willing to develop programmes for improved management and hence the prevention of the degradation of susceptible zones and even the recovery of badly degraded areas. Although the main focus should be on watershed protection to maintain spring flows, this should also be integrated with ecological and agricultural support agents to protect existing vegetation and introduce new vegetation species into badly degraded areas. Particular aspects that can be dealt with include:

- controlled burning (when the soil moisture is not below a critical deficit);
- maintenance of livestock stocking rates and grazing strategies within acceptable limits;
- prevention of the encroachment of alien vegetation in the watersheds;
- careful management of the planting and harvesting of agricultural crops.

APPENDIX A

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APPENDIX B

WATER QUALITY ANALYSES

TABLE B1 : WATER QUALITY ANALYSES MZUMBE

SITE	UNITS	borehole	spring unprotected	spring Sidlodwana	spring Nkalokazi	spring Nkalokazi
Ph		7.5	8.1	6.9	6.9	7.4
E. CONDUCTIVITY	mS/m	71	42	30	34	20
TURBIDITY	Ntu	61	5.5	11	5.0	28
COLOUR	Pt/Co	>70	40	70	30	>70
ALKALINITY	mg/l $CaCO_3$	189	180	80	44	70
NITRATE	mg/l N	0.01	0.03	0.60	9.5	0.02
NITRITE	mg/l N	<0.02	<0.02	<0.02	0.03	<0.02
SULPHATE	mg/l SO_4	30	4.7	40	21	13
CHLORIDE	mg/l Cl	126	46	31	51	3.5
FLUORIDE	mg/l F	0.58	0.28	0.39	0.20	0.21
CALCIUM	mg/l Ca	44	27	12	13	7.5
MAGNESIUM	mg/l Mg	22	18	11	13	6.5
SODIUM	mg/l Na	83	45	39	39	30
ZINC	mg/l Zn	0.06	0.04	0.07	0.05	0.05
COPPER	mg/l Cu	0.01	0.02	0.02	0.02	0.03
IRON	mg/l Fe	<0.01	0.01	0.46	0.10	1.2
LEAD	mg/l Pb	0.04	<0.04	<0.04	<0.04	<0.04
MANGANESE	mg/l Mn	0.16	0.21	0.01	0.01	0.04
CADMIUM	mg/l Cd	0.03	0.03	0.03	0.04	0.04
CATION/ANION BALANCE	%	97.7	97.8	97.7	99.7	95.8
FAECAL COLIFORMS	per 100 ml	27	8	133	6	8

TABLE B2: WATER QUALITY ANALYSES CATHEDRAL PEAK

DETERMINAND	UNITS	Magangangozi 1		Magangangozi 2	Kholakazana 2	Kholakazana 1	Makwabe
pH		7.6	7.2	6.6	8.6	6.3	6.6
E. CONDUCTIVITY	mS/m	10	14	3.4	3.7	3.5	5.8
TURBIDITY	Ntu	5.5	1.5	4.5	1.5	1.5	3.5
COLOUR	Pt/Co	30	10	15	5	<5	10
ALKALINITY	mg/l $CaCO_3$	63	98	24	22	14	32
NITRATE	mg/l N	0.85	1.2	0.23	4.0	1.9	0.02
NITRITE	mg/l N	0.02	0.03	<0.02	0.02	<0.02	<0.02
SULPHATE	mg/l SO_4	2.6	2.1	3.5	2.8	2.8	6.8
CHLORIDE	mg/l Cl	0.6	2.9	<0.3	2.5	<0.3	<0.3
FLUORIDE	mg/l F	0.07	0.07	0.06	0.91	0.56	0.04
CALCIUM	mg/l Ca	14	22	3.8	6.7	2.6	8.8
MAGNESIUM	mg/l Mg	4.7	8.7	2.0	2.3	1.2	1.8
SODIUM	mg/l Na	7.1	8.3	3.2	6.1	4.5	3.5
ZINC	mg/l Zn	0.01	0.02	0.02	0.02	0.01	0.02
COPPER	mg/l Cu	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
IRON	mg/l Fe	0.05	<0.02	0.04	<0.02	<0.02	<0.02
LEAD	mg/l Pb	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
MANGANESE	mg/l Mn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CATION/ANION BALANCE	%	99.9	100	92.6	93.3	91.2	94.5
FAECAL COLIFORMS	per 100 ml	16	5	2	53	2	13

E-MAIL: ESimpson@csir.co.za

Certificate of Analysis
Microbiological Analysis

CLIENT: Goodenough Molefe
East Coast Programme
Environmentek
Durban.

TEL : 031-2618161 FAX : 031-812509

DATE RECEIVED: 98.08.13 DATE COMPLETED: 98.08.31

LABORATORY REFERENCE NUMBER : 98263
SAMPLE IDENTITY : 3x Water samples (Linda Godfrey)

SAMPLE	HETEROTROPHIC PLATE COUNT cfu/ml	TOTAL COLIFORMS /100ml	FAECAL COLIFORMS /100ml
1) KwaHlongwa Shop - Nkalonkazi	955	100	90
2) Mbhele - Spring	9.05×10^4	650	150
3) Hluthamkangu Mpunga - Mzinto	32	2	0

SIGNED :______________________________ DATE :__________

Mrs Elizabeth Simpson : Microbiologist

Certificate of Analysis
Chemical

CLIENT: MS LINDA GODFREY				REPORT NO. 98263
ENVIRONMENTEK				Page 1 of 1
TEL : 031- 2618161				FAX : 031-812509
DATE RECEIVED: 25/08/98				DATE COMPLETED: 27/08/98
SAMPLE DESCRIPTION			WATER SAMPLES	
CSIR REFERENCE			98263	
DATE SAMPLED			13/08/98	
SAMPLE DETAILS			SEE BELOW TABLE	
DETERMINAND	**UNITS**	**1**	**2**	**3**
pH - 25 °C		7.0	6.6	6.9
E. CONDUCTIVITY - 25 °C	mS/m	34	31	5.5
TURBIDITY	Ntu	15	47	0.2
COLOUR	Pt/Co	60	>70	5
ALKALINITY	mg/l $CaCO_3$	70	62	7
CALCIUM	mg/l Ca	11	9.7	1.2
CADMIUM	mg/l Cd	<0.01	<0.01	<0.01
SIGNED:____________________ JIMMY CHETTY, ANALYTICAL CHEMIST				DATE:__________

Sample Details

1. Mbhele - Sidludlwana
2. WRC Spring survey - Mzumbe "shop spring" 11h00
3. Mpunga - Mzinto

APPENDIX C

RESULTS OF SPRING FLOW MONITORING

			Nkalokazi 1 - MZUMBE				
			(KwaHlongwa Store)				
meter no.	Date	Time	Cum. Vol (m^3)	Flow m^3/d	14 day av m^3/d	Rainfall (mm)	Comments
	13-Jul-98		0	0		0	No water passing
	16-Jul-98		0	0		0	No water passing
1	23-Jul-98		0	0		0	No water passing
1	27-Jul-98		0	0		0	No water passing
1	30-Jul-98		0	0	0.00	0	No water passing
1	03-Aug-98		0	0	0.00	0	No water passing
1	06-Aug-98		1	1	0.25	104	All dials in motion
1	10-Aug-98		9	2	0.75	0	All dials in motion
1	13-Aug-98	05:45 PM	16	2.3	1.33		
1	17-Aug-98	04:00 PM	21	1.3	1.65		
1	20-Aug-98	05:05 PM	24	0.7	1.58	30	
1	24-Aug-98	07:00 AM	27	0.84	1.28		
1	27-Aug-98	03:42 PM	36	2.68	1.38	18	
1	30-Aug-98	02:45 PM	48	4.05	2.07		
1	04-Sep-98	04:00 PM	55	1.39	2.24		
1	07-Sep-98	08:29 AM	59	1.49	2.40	29	
1	10-Sep-98	02:09 PM	64	1.55	2.12		
1	14-Sep-98	04:55 PM	70	1.46	1.47		
1	17-Sep-98	03:30 PM	75	1.70	1.55		
1	21-Sep-98	02:50 PM	77	0.50	1.30		
1	24-Sep-98						
1	28-Sep-98						
1	01-Oct-98						
1	05-Oct-98						
1	08-Oct-98						
1	12-Oct-98						
1	15-Oct-98						
1	19-Oct-98						
1	22-Oct-98						
1	26-Oct-98						
1	29-Oct-98	03:30 PM	77				
1	02-Nov-98	04:02 PM	77	0.00			
1	05-Nov-98	04:05 PM	77	0.00		3	
1	09-Nov-98						
1	12-Nov-98						
1	16-Nov-98						
1	19-Nov-98					31	
1	23-Nov-98					4	
1	26-Nov-98	06:28 PM	77			22	
1	03-Dec-98	03:00 PM	83	0.88		60	
1	07-Dec-98	03:25 PM	90	1.74			
1	10-Dec-98	04:01 PM	98	2.64			
1	14-Dec-98	07:08 PM	98	0.00		44	
1	17-Dec-98						
1	21-Dec-98						
1	24-Dec-98						
1	28-Dec-98					9	
1	31-Dec-98					30	
1	04-Jan-99						
1	07-Jan-99						
1	11-Jan-99						

meter no.	Date	Time	Cum. Vol (m^3)	Flow m^3/d	14 day av m^3/d	Rainfall (mm)	Comments
1	14-Jan-99						
1	18-Jan-99						
1	21-Jan-99						
2	13-Jul-98						
2	16-Jul-98						
2	23-Jul-98						
2	27-Jul-98						
2	30-Jul-98						
2	03-Aug-98						
2	06-Aug-98						
2	10-Aug-98						
2	13-Aug-98						
2	20-Aug-98	05:06 PM	0	0			
2	24-Aug-98	07:00 AM	0	0.00			
2	27-Aug-98	03:43 PM	28	8.33			
2	30-Aug-98	02:47 PM	63	11.82	5.04		
2	04-Sep-98	04:03 PM	94	6.14	6.57		
2	07-Sep-98	08:32 AM	117	8.56	8.71		
2	10-Sep-98	02:14 PM	150	10.19	9.18		
2	14-Sep-98	05:00 PM	187	8.99	8.47		
2	17-Sep-98	03:31 PM	205	6.13	8.47		
2	21-Sep-98	02:51 PM	211	1.51	6.71		
2	24-Sep-98	03:01 PM	211	0.00	0.00		
2	28-Sep-98						
2	01-Oct-98						
2	05-Oct-98						
2	08-Oct-98						
2	12-Oct-98						
2	15-Oct-98						
2	19-Oct-98						
2	22-Oct-98						
2	26-Oct-98						
2	29-Oct-98	03:31 PM	211				
2	02-Nov-98	04:03 PM	211	0.00			
2	05-Nov-98	04:07 PM	211	0.00		3	
2	09-Nov-98						
2	12-Nov-98						
2	16-Nov-98	04:32 PM	211				
2	19-Nov-98	01:18 PM	212	0.35		31	
2	23-Nov-98	06:02 PM	212	0.00		4	
2	26-Nov-98	06:29 PM	213	0.33	0	22	
2	03-Dec-98	03:01 PM	283	10.21	2.72	60	
2	07-Dec-98	03:26 PM	340	14.19	6.18		
2	10-Dec-98	04:02 PM	360	6.61	7.84		
2	14-Dec-98	07:10 PM	401	9.93	10.23	44	
2	17-Dec-98	04:01 PM	442	14.29	11.25		
2	21-Dec-98	05:10 PM	495	13.09	10.98		
2	24-Dec-98	06:01 PM	520	8.24	11.39		

Nkalokazi

meter no.	Date	Time	Cum. Vol (m^3)	Flow m^3/d	14 day av m^3/d	Rainfall (mm)	Comments
2	28-Dec-98	04:40 PM	522	0.51	9.03	9	
2	31-Dec-98	04:03 PM	558	12.10	8.49	30	
2	04-Jan-99	06:19 PM	575	4.15	6.25		
2	07-Jan-99	05:01 PM	604	9.84	6.65		
2	11-Jan-99	04:35 PM	624	5.02	7.78		
2	14-Jan-99	03:01 PM	637	4.43	5.86		
2	18-Jan-99	03:10 PM	642	1.25	5.14		
2	21-Jan-99					19	
2							

Date	Time	Sidlodwana Mnt - MZUMBE Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
13-Jul-98		1	1		0	Flow very small
16-Jul-98		8	2.3		0	Flow very small
23-Jul-98		15	1		1	Flow very small
27-Jul-98		27	3		0	Better flow
30-Jul-98		36	3	2.33	1	Better flow
03-Aug-98		47	2.8	2.45	0	Better flow
06-Aug-98		55	2.7	2.88	85	Better flow
09-Aug-98		65	3.3	2.95	0	Better flow
13-Aug-98	07:30	74	2.3	2.78	0	Better flow
17-Aug-98	07:30	85	2.75	2.76		
20-Aug-98	07:30	91	2.00	2.59		
24-Aug-98	07:30	101	2.50	2.39	40	
27-Aug-98	07:30	109	2.67	2.48		
31-Aug-98	07:30	120	2.75	2.48	20	
03-Sep-98	07:30	128	2.67	2.65		
07-Sep-98	07:30	139	2.75	2.71	38	
10-Sep-98	07:30	150	3.67	2.96	3	
14-Sep-98	07:30	161	2.75	2.96	2	
17-Sep-98	07:30	170	3.00	3.04		
21-Sep-98	07:30	179	2.25	2.92		
24-Sep-98	07:30	189	3.33	2.83		
28-Sep-98	07:30	199	2.50	2.77		
01-Oct-98	07:30	208	3.00	2.77		
05-Oct-98	07:30	219	2.75	2.90		
08-Oct-98	07:30	227	2.67	2.73		
12-Oct-98	07:30	232	1.25	2.42		
15-Oct-98	07:30	239	2.33	2.25		
19-Oct-98	07:30	245	1.50	1.94		
22-Oct-98	07:30	253	2.67	1.94		
26-Oct-98	07:30	259	1.50	2.00		
29-Oct-98	07:30	264	1.67	1.83		
02-Nov-98	07:30	269	1.25	1.77		
05-Nov-98	07:30	269	0.00	1.10	5	
09-Nov-98	07:30	270	0.25	0.79		
12-Nov-98	07:30	277	2.33	0.96		
16-Nov-98	07:30	283	1.50	1.02		
19-Nov-98	07:30	295	4.00	2.02	10	
23-Nov-98	07:30	303	2.00	2.46	15	
26-Nov-98	07:30	318	5.00	3.13		
01-Dec-98	07:30	323	1.00	3.00	90	
07-Dec-98	07:30	360	6.17	3.54	45	
10-Dec-98	07:30	380	6.67	4.71	5	
14-Dec-98	07:30	395	3.75	4.40	31	
17-Dec-98	07:30	405	3.33	4.98		
21-Dec-98	07:30	418	3.25	4.25		
24-Dec-98	07:30	422	1.33	2.92	5	
28-Dec-98	07:30	439	4.25	3.04	10	
31-Dec-98	07:30	452	4.33	3.29		
04-Jan-99	07:30	452	0.00	2.48		meter faulty
07-Jan-99	07:30	452	0.00	2.15	10	meter faulty
11-Jan-99	07:30	452	0.00	1.08		meter faulty

Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
14-Jan-99	07:30	452	0.00	0.00		meter faulty
18-Jan-99	07:30	452	0.00	0.00	30	meter faulty
22-Jan-99	07:30	452	0.00	0.00	30	meter faulty
25-Jan-99	07:30	452	0.00	0.00		meter faulty
28-Jan-99	07:30	452	0.00	0.00		meter faulty
01-Feb-99	07:30	452	0.00	0.00		meter faulty
04-Feb-99	07:30	452	0.00	0.00		meter faulty
08-Feb-99	07:30	452	0.00	0.00		meter faulty
11-Feb-99	07:30	452	0.00	0.00		meter faulty
15-Feb-99	07:30	452	0.00	0.00		meter faulty
18-Feb-99	07:30	452	0.00	0.00	5	meter faulty
22-Feb-99	07:30	452	0.00	0.00		meter faulty
25-Feb-99	07:30	452	0.00	0.00		meter faulty
01-Mar-99	07:30	452	0.00	0.00		meter faulty
08-Mar-99	07:30	452	0.00	0.00		meter faulty
11-Mar-99	07:30	452	0.00	0.00	15	meter faulty
15-Mar-99	07:30	452	0.00	0.00		meter faulty
18-Mar-99	07:30	452	0.00	0.00		meter faulty
22-Mar-99	07:30	452	0.00	0.00		meter faulty
25-Mar-99	07:30	452	0.00	0.00		meter faulty
29-Mar-99	07:30	452	0.00	0.00		meter faulty
01-Apr-99	07:30	452	0.00	0.00		meter faulty
05-Apr-99	07:30	452	0.00	0.00		meter faulty
08-Apr-99	07:30	452	0.00	0.00		meter faulty
12-Apr-99	07:30	452	0.00	0.00		meter faulty
15-Apr-99	07:30	452	0.00	0.00		meter faulty
19-Apr-99	07:30	452	0.00	0.00		meter faulty
22-Apr-99	07:30	452	0.00	0.00		meter faulty
26-Apr-99	07:30	452	0.00	0.00		meter faulty
29-Apr-99	07:30	452	0.00	0.00		meter faulty
03-May-99	07:30	452	0.00	0.00		meter faulty
06-May-99	07:30	452	0.00	0.00		meter faulty
10-May-99	07:30	452	0.00	0.00		meter faulty
13-May-99	07:30	457	1.67	0.42		
17-May-99	07:30	470	3.25	1.23		
20-May-99	07:30	484	4.67	2.40		
24-May-99	07:30	501	4.25	3.46		
27-May-99	07:30	513	4.00	4.04		
31-May-99	07:30	529	4.00	4.23		
03-Jun-99	07:30	541	4.00	4.06		
07-Jun-99	07:30	558	4.25	4.06		
10-Jun-99	07:30	572	4.67	4.23		
14-Jun-99	07:30	581	2.25	3.79		
17-Jun-99	07:30	588	2.33	3.38		
21-Jun-99	07:30	610	5.50	3.69		
24-Jun-99	07:30	623	4.33	3.60	10	
28-Jun-99	07:30	642	4.75	4.23		
01-Jul-99	07:30	653	3.67	4.56		
05-Jul-99	07:30	679	6.50	4.81		
08-Jul-99	07:30	690	3.67	4.65		
12-Jul-99	07:30	701	2.75	4.15		
15-Jul-99	07:30	710	3.00	3.98		
19-Jul-99	07:30	728	4.50	3.48		

Sidlodwana

	Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
			(cubic m)	m3/d	m3/d	(mm)	
	22-Jul-99	07:30	737	3.00	3.31		
	26-Jul-99	07:30	756	4.75	3.81		
	29-Jul-99	07:30	766	3.33	3.90		
	02-Aug-99	07:30	775	2.25	3.33		
	05-Aug-99	07:30	778	1.00	2.83		
	09-Aug-99	07:30	789	2.75	2.33		
	12-Aug-99	07:30	805	5.33	2.83		
	16-Aug-99	07:30	818	3.25	3.08		
	19-Aug-99	07:30	827	3.00	3.58		
	23-Aug-99	07:30	836	2.25	3.46	10	
	26-Aug-99	07:30	844	2.67	2.79		
	30-Aug-99	07:30	848	1.00	2.23		
	02-Sep-99	07:30	852	1.33	1.81	30	
	06-Sep-99	07:30	869	4.25	2.31		
	09-Sep-99	07:30	879	3.33	2.48		
	13-Sep-99	07:30	889	2.50	2.85	15	
	16-Sep-99	07:30	898	3.00	3.27		
	20-Sep-99	07:30	905	1.75	2.65		
	23-Sep-99	07:30	912	2.33	2.40		
	26-Sep-99	07:30	921	3.00	2.52	15	
	30-Sep-99	07:30	931	2.50	2.40		
	04-Oct-99	07:30	937	1.50	2.33		
	07-Oct-99	07:30	944	2.33	2.33		
	11-Oct-99	07:30	951	1.75	2.02		
	14-Oct-99	07:30	958	2.33	1.98		
	18-Oct-99	07:30	970	3.00	2.35	20	
	22-Oct-99	07:30	982	3.00	2.52	30	
	25-Oct-99	07:30	994	4.00	3.08	60	
	26-Oct-99	07:30	1000	6.00	4.00	60	
	27-Oct-99	07:30	1007	7.00	5.00	100	
	04-Nov-99	07:30	1054	5.88	5.72		
	08-Nov-99	07:30	1078	6.00	6.22		
	11-Nov-99	07:30	1097	6.33	6.30		
	15-Nov-99	07:30	1110	3.25	5.36		
	18-Nov-99	07:30	1123	4.33	4.98	10	
	22-Nov-99	07:30	1144	5.25	4.79		
	25-Nov-99	07:30	1149	1.67	3.62		
	29-Nov-99	07:30	1155	1.50	3.19	10	
	02-Dec-99	07:30	1171	5.33	3.44	30	
	06-Dec-99	07:30	1177	1.50	2.50	15	
	09-Dec-99	07:30	1180	1.00	2.33	30	
	13-Dec-99	07:30	1193	3.25	2.77	60	
	16-Dec-99	07:30	1197	1.33	1.77	80	
	20-Dec-99	07:30	1199	0.50	1.52	100	
	23-Dec-99	07:30	1203	1.33	1.60	70	
	27-Dec-99	07:30	1207	1.00	1.04	30	
	30-Dec-99	07:30	1210	1.00	0.96	15	
	03-Jan-00	07:30	1215	1.25	1.15	40	
	06-Jan-00	07:30	1218	1.00	1.06	10	
	10-Jan-00	07:30	1221	0.75	1.00	50	
	13-Jan-00	07:30	1223	0.67	0.92	80	
	17-Jan-00	07:30	1225	0.50	0.73	100	
	20-Jan-00	07:30	1227	0.67	0.65	40	

	Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
			(cubic m)	m3/d	m3/d	(mm)	
	23-Jan-00	07:30	1234	2.33	1.04	15	
	27-Jan-00	07:30	1239	1.25	1.19		
	31-Jan-00	07:30	1242	0.75	1.25	10	
	03-Feb-00	07:30	1247	1.67	1.50	15	
	07-Feb-00	07:30	1250	0.75	1.10	10	
	10-Feb-00	07:30	1255	1.67	1.21	30	
	14-Feb-00	07:30	1259	1.00	1.27	40	
	17-Feb-00	07:30	1265	2.00	1.35		
	21-Feb-00	07:30	1265	0.00	1.17		pipe silted up
	24-Feb-00	07:30	1265	0.00	0.75		pipe silted up
	28-Feb-00	07:30	1265	0.00	0.50		pipe silted up
	02-Mar-00	07:30	1265	0.00	0.00	50	pipe silted up
	06-Mar-00	07:30	1267	0.50	0.13		
	09-Mar-00	07:30	1270	1.00	0.38	40	
	13-Mar-00	07:30	1273	0.75	0.56		
	16-Mar-00	07:30	1277	1.33	0.90		
	20-Mar-00	07:30	1282	1.25	1.08		
	23-Mar-00	07:30	1285	1.00	1.08		
	27-Mar-00	07:30	1290	1.25	1.21	30	
	30-Mar-00	07:30	1304	4.67	2.04	40	
	03-Apr-00	07:30	1308	1.00	1.98	30	
	06-Apr-00	07:30	1314	2.00	2.23		
	10-Apr-00	07:30	1319	1.25	2.23		
	13-Apr-00	07:30	1324	1.67	1.48		
	17-Apr-00	07:30	1330	1.50	1.60		
	20-Apr-00	07:30	1334	1.33	1.44		
	24-Apr-00	07:30	1338	1.00	1.38		
	27-Apr-00	07:30	1344	2.00	1.46		
	01-May-00	07:30	1348	1.00	1.33		
	04-May-00	07:30	1353	1.67	1.42		

Jollivet - MZINTO/HIGHFLATS

Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation	
		(cubic m)	m3/d	m3/d	(mm)		
11-Jun-99	07:30	1888					
15-Jun-99	07:30	1910	5.50				
19-Jun-99	07:30	1937	6.75				
23-Jun-99	07:30	1964	6.75		5		
27-Jun-99	07:30	1998	8.50	6.88	8		
30-Jun-99	07:30	2011	4.33	6.58			
04-Jul-99	07:30	2036	6.25	6.46			
08-Jul-99	07:30	2049	3.25	5.58			
12-Jul-99	07:30	2080	7.75	5.40			
16-Jul-99	07:30	2097	4.25	5.38			
20-Jul-99	07:30	2124	6.75	5.50			
24-Jul-99	07:30	2143	4.75	5.88			
28-Jul-99	07:30	2198	13.75	7.38			
02-Aug-99	07:30	2227	5.80	7.76			
06-Aug-99	07:30	2238	2.75	6.76			
10-Aug-99	07:30	2264	6.50	7.20			
14-Aug-99	07:30	2380	29.00	11.01			
18-Aug-99	07:30	2405	6.25	11.13			
22-Aug-99	07:30	2432	6.75	12.13			
26-Aug-99	07:30	2458	6.50	12.13			
30-Aug-99	07:30	2478	5.00	6.13			
03-Sep-99	07:30	2497	4.75	5.75			
07-Sep-99	07:30	2521	6.00	5.56			
11-Sep-99	07:30	2535	3.50	4.81			
15-Sep-99	07:30	2557	5.50	4.94			
19-Sep-99	07:30	2571	3.50	4.63			
23-Sep-99	07:30	2585	3.50	4.00			
27-Sep-99	07:30	2607	5.50	4.50			
01-Oct-99	07:30	2625	4.50	4.25			
05-Oct-99	07:30	2639	3.50	4.25			
09-Oct-99	07:30	2650	2.75	4.06			
13-Oct-99	07:30	2667	4.25	3.75			
17-Oct-99	07:30	2683	4.00	3.63			
21-Oct-99	07:30	2691	2.00	3.25			
25-Oct-99	07:30	2720	7.25	4.38			
29-Oct-99	07:30	2735	3.75	4.25			
02-Nov-99	07:30						

Kholakazana 1 - BERGVILLE

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
14-Jul-98	12:00	54			0	
16-Jul-98	08:00	70	8.73		0	
20-Jul-98	08:00	105	8.75		0	
23-Jul-98	07:00	130	8.45		3	
27-Jul-98	07:00	168	9.50	8.86	0	
30-Jul-98	07:00	194	8.67	8.84	2	
03-Aug-98	07:00	220	6.50	8.28	0	
06-Aug-98	07:00	254	11.33	9.00	0	
10-Aug-98	07:00	291	9.25	8.94	0	
13-Aug-98	07:00	314	7.67	8.69		
17-Aug-98	07:00	345	7.75	9.00		
20-Aug-98	07:00	368	7.67	8.08	0	
24-Aug-98	07:00	400	8.00	7.77	23	
27-Aug-98	07:00	423	7.67	7.77	2	
31-Aug-98	07:00	453	7.50	7.71		
03-Sep-98	07:00	477	8.00	7.79		
07-Sep-98	07:00	501	6.00	7.29		
10-Sep-98	07:00	520	6.33	6.96		
14-Sep-98	07:00	561	10.25	7.65	12	
17-Sep-98	07:00	582	7.00	7.40		
21-Sep-98	07:00	613	7.75	7.83		
24-Sep-98	07:00	634	7.00	8.00		
28-Sep-98	07:00	662	7.00	7.19	3	
01-Oct-98	07:00	683	7.00	7.19	5	
05-Oct-98	07:00	711	7.00	7.00	14	
08-Oct-98	07:00	731	6.67	6.92		
12-Oct-98	07:00	759	7.00	6.92	5	
15-Oct-98	07:00	780	7.00	6.92		
19-Oct-98	07:00	807	6.75	6.85	2	
22-Oct-98	07:00	827	6.67	6.85	4	
26-Oct-98	07:00	854	6.75	6.79	4	
29-Oct-98	07:00	874	6.67	6.71	2	
02-Nov-98	07:00	898	6.00	6.52		
05-Nov-98	07:00	916	6.00	6.35	8	
09-Nov-98	07:00	941	6.25	6.23	6	
12-Nov-98	07:00	958	5.67	5.98	4	
16-Nov-98	07:00	980	5.50	5.85	3	
19-Nov-98	08:00	1005	8.22	6.41	70	
23-Nov-98	08:00	1041	9.00	7.10	40	
26-Nov-98	08:00	1074	11.00	8.43	28	
30-Nov-98	08:00	1137	15.75	10.99	18	
03-Dec-98	08:00	1188	17.00	13.19	11	
07-Dec-98	08:00	1251	15.75	14.88		
10-Dec-98	08:00	1285	11.33	14.96	3	
14-Dec-98	08:00	1319	8.50	13.15	28	
17-Dec-98	08:00	1348	9.67	11.31	10	
21-Dec-98	08:00	1385	9.25	9.69	4	
24-Dec-98	08:00	1411	8.67	9.02	1	
28-Dec-98	08:00	1443	8.00	8.90	6	
31-Dec-98	08:00	1510	22.33	12.06	54	
04-Jan-99	08:00	1560	12.50	12.88	24	

Magangangozi 2

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
07-Jan-99	08:00	1621	20.33	15.79	5	
11-Jan-99	08:00	1718	24.25	19.85		
14-Jan-99	08:00	1762	14.67	17.94	8	
18-Jan-99	08:00	1808	11.50	17.69	3	
21-Jan-99	08:00	1843	11.67	15.52	20	
25-Jan-99	07:00	1892	12.38	12.55	21	
28-Jan-99	07:00	1932	13.33	12.22		
01-Feb-99	07:00	1999	16.75	13.53	50	
04-Feb-99	07:00	2075	25.33	16.95	28	
08-Feb-99	07:00	2325	62.50	29.48	43	
11-Feb-99	07:00	2471	48.67	38.31		
15-Feb-99	07:00	2595	31.00	41.88	10	
18-Feb-99	07:00	2673	26.00	42.04	23	
22-Feb-99	07:00	2852	44.75	37.60	35	
25-Feb-99	07:00	2998	48.67	37.60	9	
01-Mar-99	07:00	3120	30.50	37.48		
04-Mar-99	07:00	3198	26.00	37.48		
08-Mar-99	07:00	3274	19.00	31.04		
11-Mar-99	07:00	3322	16.00	22.88	2	
15-Mar-99	06:30	3381	14.83	18.96	10	
18-Mar-99	06:30	3444	21.00	17.71	59	
22-Mar-99	06:30	3576	33.00	21.21	60	
25-Mar-99	06:30	3810	78.00	36.71	19	
29-Mar-99	06:30	3997	46.75	44.69		
01-Apr-99	06:30	4097	33.33	47.77		
05-Apr-99	06:30	4201	26.00	46.02	15	
08-Apr-99	06:30	4266	21.67	31.94		
12-Apr-99	06:30	4345	19.75	25.19	7	
15-Apr-99	06:30	4398	17.67	21.27		
19-Apr-99	06:30	4463	16.25	18.83		
22-Apr-99	06:30	4510	15.67	17.33		
26-Apr-99	07:00	4570	14.92	16.13		
29-Apr-99	07:00	4614	14.67	15.38		
03-May-99	07:00	4668	13.50	14.69		
06-May-99	07:00	4709	13.67	14.19		
10-May-99	07:00	4764	13.75	13.90		
13-May-99	07:00	4808	14.67	13.90		
17-May-99	07:00	4867	14.75	14.21		
20-May-99	07:00	4910	14.33	14.38		
24-May-99	07:00	4968	14.50	14.56		
27-May-99	07:00	5010	14.00	14.40		
31-May-99	07:00	5067	14.25	14.27		
03-Jun-99	07:00	5108	13.67	14.10		
07-Jun-99	07:00	5164	14.00	13.98		
10-Jun-99	07:00	5207	14.33	14.06		
14-Jun-99	07:00	5267	15.00	14.25		
17-Jun-99	07:00	5312	15.00	14.58		
20-Jun-99	07:00	5367	18.33	15.67		
24-Jun-99	07:00	5410	10.75	14.77		
28-Jun-99	07:00	5463	13.25	14.33		
01-Jul-99	07:00	5501	12.67	13.75		
05-Jul-99	07:00	5549	12.00	12.17		
08-Jul-99	07:00	5586	12.33	12.56		

Kholakazana

Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
12-Jul-99	07:00	5634	12.00	12.25		
15-Jul-99	07:00	5668	11.33	11.92		
19-Jul-99	07:00	5709	10.25	11.48		
22-Jul-99	07:00	5739	10.00	10.90		
26-Jul-99	07:00	5783	11.00	10.65		
29-Jul-99	07:00	5818	11.67	10.73	3	
02-Aug-99	07:00	5866	12.00	11.17		
05-Aug-99	07:00	5904	12.67	11.83		
09-Aug-99	07:00	5954	12.50	12.21	2	
12-Aug-99	07:00	5991	12.33	12.38	1	
16-Aug-99	07:00	6037	11.50	12.25		
19-Aug-99	07:00	6069	10.67	11.75		
23-Aug-99	07:00	6114	11.25	11.44	6	
26-Aug-99	07:00	6144	10.00	10.85		
30-Aug-99	07:00	6185	10.25	10.54		
02-Sep-99	07:00	6216	10.33	10.46		
06-Sep-99	07:00	6256	10.00	10.15	2	
09-Sep-99	07:00	6283	9.00	9.90		
13-Sep-99	07:00	6320	9.25	9.65		
16-Sep-99	07:00	6347	9.00	9.31		
20-Sep-99	07:00	6385	9.50	9.19	2	
23-Sep-99	07:00	6411	8.67	9.10		
26-Sep-99	07:00	6439	9.33	9.13	1	
30-Sep-99	07:00	6474	8.75	9.06		
04-Oct-99	07:00	6509	8.75	8.88		
08-Oct-99	07:00	6535	6.50	8.33		
12-Oct-99	07:00	6592	14.25	9.56		
15-Oct-99	07:00	6615	7.67	9.29		
18-Oct-99	07:00	6640	8.33	9.19		
21-Oct-99	07:00	6665	8.33	9.65		
25-Oct-99	07:00	6690	6.25	7.65		
29-Oct-99	07:00	6715	6.25	7.29		
01-Nov-99	07:00	6740	8.33	7.29		
05-Nov-99	07:00	6765	6.25	6.77		
09-Nov-99	07:00	6790	6.25	6.77		
12-Nov-99	07:00	6815	8.33	7.29		
15-Nov-99	07:00	6842	9.00	7.46	3	
18-Nov-99	07:00	6854	4.00	6.90		
22-Nov-99	07:00	6861	1.75	5.77		
24-Nov-99	07:00	6890	14.50	7.31		
29-Nov-99	07:00	6921	6.20	6.61	20	
06-Dec-99	07:00	6972	7.29	7.43	64	
10-Dec-99	07:00	7013	10.25	9.56		
13-Dec-99	07:00	7096	27.67	12.85	20	
17-Dec-99	07:00	7211	28.75	18.49	5	
20-Dec-99	07:00	7293	27.33	23.50		
23-Dec-99	07:00	7379	28.67	28.10	4	
27-Dec-99	07:00	7484	26.25	27.75		
30-Dec-99	07:00	7572	29.33	27.90	30	
03-Jan-00	07:00	7697	31.25	28.88	4	
06-Jan-00	07:00	7858	53.67	35.13		
10-Jan-00	07:00	8096	59.50	43.44		
13-Jan-00	07:00	8227	43.67	47.02	20	

Kholakazana

	Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
	17-Jan-00	07:00	8404	44.25	50.27	5	
	20-Jan-00	07:00	8576	57.33	51.19		
	24-Jan-00	07:00	8723	36.75	45.50	20	
	27-Jan-00	07:00	8825	34.00	43.08	10	
	31-Jan-00	07:00	8976	37.75	41.46	10	
	03-Feb-00	07:00	9102	42.00	37.63		
	07-Feb-00	07:00	9185	20.75	33.63		
	14-Feb-00	07:00	9222	5.29	26.45	24	
	17-Feb-00	07:00	9297	25.00	23.26	15	
	21-Feb-00	07:00	9397	25.00	19.01	6	
	24-Feb-00	07:00	9473	25.33	20.15	2	
	28-Feb-00	07:00	9571	24.50	24.96	9	
	02-Mar-00	07:00	9646	25.00	24.96	60	
	06-Mar-00	07:00	9751	26.25	25.27	4	
	09-Mar-00	07:00	9854	34.33	27.52	24	
	13-Mar-00	07:00	10004	37.50	30.77	5	
	16-Mar-00	07:00	10109	35.00	33.27	1	
	20-Mar-00	07:00	10201	23.00	32.46	23	
	23-Mar-00	07:00	10379	59.33	38.71	21	
	27-Mar-00	07:00	10562	45.75	40.77	10	
	31-Mar-00	07:00	10707	36.25	41.08	23	
	04-Apr-00	07:00	10962	63.75	51.27	21	
	06-Apr-00	07:00	11036	37.00	45.69		
	10-Apr-00	07:00	11229	48.25	46.31		
	13-Apr-00	07:00	11336	35.67	46.17		
	17-Apr-00	07:00	11479	35.75	39.17		
	20-Apr-00	07:00	11586	35.67	38.83		
	24-Apr-00	07:00	11729	35.75	35.71		
	27-Apr-00	07:00	11836	35.67	35.71		
	01-May-00	07:00	11979	35.75	35.71		
	04-May-00	07:00	12086	35.67	35.71		
	08-May-00	07:00	12229	35.75	35.71		
	11-May-00	07:00	12336	35.67	35.71		
	15-May-00	07:00	12479	35.75	35.71		
	18-May-00	07:00	12586	35.67	35.71		
	21-May-00	07:00	12693	35.67	35.69		
	25-May-00	07:00	12836	35.75	35.71		
	28-May-00	07:00	12943	35.67	35.69		
	01-Jun-00	07:00	13086	35.75	35.71		
	04-Jun-00	07:00	13193	35.67	35.71		
	08-Jun-00	07:00	13336	35.75	35.71		
	12-Jun-00	07:00	13483	36.75	35.98		
	15-Jun-00	07:00	13577	31.33	34.88		
	19-Jun-00	07:00	13703	31.50	33.83		
	22-Jun-00	07:00	13801	32.67	33.06		
	26-Jun-00	07:00	13940	34.75	32.56		
	29-Jun-00	07:00	14045	35.00	33.48		
	03-Jul-00	07:00	14172	31.75	33.54		
	06-Jul-00	07:00	14245	24.33	31.46		
	10-Jul-00	07:00	14337	23.00	28.52		
	13-Jul-00	07:00	14401	21.33	25.10		
	17-Jul-00	07:00	14482	20.25	22.23		
	20-Jul-00	07:00	14542	20.00	21.15		

	Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
			(cubic m)	m3/d	m3/d	(mm)	
	24-Jul-00	07:00	14635	23.25	21.21		
	27-Jul-00	07:00	14702	22.33	21.46		
	31-Jul-00	07:00	14774	18.00	20.90		
	03-Aug-00	07:00	14863	29.67	23.31		
	07-Aug-00	07:00	14959	24.00	23.50		
	10-Aug-00	07:00	15024	21.67	23.33		
	14-Aug-00	07:00	15052	7.00	20.58		
	17-Aug-00	07:00	15105	17.67	17.58		
	21-Aug-00	07:00	15242	34.25	20.15	45	
	24-Aug-00	07:00	15301	19.67	19.65		
	28-Aug-00	07:00	15381	20.00	22.90		
	31-Aug-00	07:00	15423	14.00	21.98		
	04-Sep-00	07:00	15470	11.75	16.35	3	
	07-Sep-00	07:00	15493	7.67	13.35		
	11-Sep-00	07:00	15514	5.25	9.67		
	14-Sep-00	07:00	15546	10.67	8.83		
	18-Sep-00	07:00	15577	7.75	7.83		
	21-Sep-00	07:00	15611	11.33	8.75		
	25-Sep-00	07:00	15661	12.50	10.56		
	28-Sep-00	07:00	15696	11.67	10.81		
	02-Oct-00	07:00	15725	7.25	10.69		
	05-Oct-00	07:00	15753	9.33	10.19		
	09-Oct-00	07:00	15798	11.25	9.88	10	
	12-Oct-00	07:00	15837	13.00	10.21	4	

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
Kholakhazana 2B						
Date	time	Cum. Vol	daily flow	14 day av		
11-Dec-98	08:00	6	0.00		3	
14-Dec-98	08:00	33	9.00		28	
17-Dec-98	08:00	62	9.67		10	
21-Dec-98	08:00	106	11.00	7.42	4	
24-Dec-98	08:00	135	9.67	9.83	1	
28-Dec-98	08:00	167	8.00	9.58	6	
31-Dec-98	08:00	192	8.33	9.25	54	
04-Jan-99	08:00	223	7.75	8.44	24	
07-Jan-99	08:00	230	2.33	6.60	5	
11-Jan-99	08:00	245	3.75	5.54		
14-Jan-99	08:00	252	2.33	4.04	8	
18-Jan-99	08:00	257	1.25	2.42	3	
21-Jan-99	07:00	263	2.03	2.34	20	
25-Jan-99	07:00	297	8.50	3.53	21	
28-Jan-99	07:00	304	2.33	3.53		
01-Feb-99	07:00	309	1.25	3.53	50	
04-Feb-99	07:00	313	1.33	3.35	28	
08-Feb-99	07:00	365	13.00	4.48	43	
11-Feb-99	07:00	404	13.00	7.15		
15-Feb-99	07:00	436	8.00	8.83	10	
18-Feb-99	07:00	449	4.33	9.58	23	
22-Feb-99	07:00	464	3.75	7.27	35	
25-Feb-99	07:00	488	8.00	6.02	9	
01-Mar-99	07:00	529	10.25	6.58		
04-Mar-99	07:00	550	7.00	7.25		
08-Mar-99	07:00	571	5.25	7.63		
11-Mar-99	07:00	577	2.00	6.13	2	
15-Mar-99	06:30	606	7.29	5.38	10	
18-Mar-99	06:30	635	9.67	6.05	59	
22-Mar-99	06:30	668	8.25	6.80	60	
25-Mar-99	06:30	697	9.67	8.72	19	
29-Mar-99	06:30	727	7.50	8.77		
01-Apr-99	06:30	746	6.33	7.94		
05-Apr-99	06:30	775	7.25	7.69	15	
08-Apr-99	06:30	787	4.00	6.27		
12-Apr-99	06:30	800	3.25	5.21	7	
15-Apr-99	06:30	808	2.67	4.29		
19-Apr-99	06:30	812	1.00	2.73		
22-Apr-99	06:30	818	2.00	2.23		
26-Apr-99	07:00	857	9.70	3.84		
29-Apr-99	07:00	895	12.67	6.34		
03-May-99	07:00	935	10.00	8.59		
06-May-99	07:00	961	8.67	10.26		
10-May-99	07:00	984	5.75	9.27		
13-May-99	07:00	1005	7.00	7.85		
17-May-99	07:00	1033	7.00	7.10		
20-May-99	07:00	1064	10.33	7.52		
24-May-99	07:00	1101	9.25	8.40		
27-May-99	07:00	1124	7.67	8.56		
31-May-99	07:00	1158	8.50	8.94		
03-Jun-99	07:00	1181	7.67	8.27		

Magangangozi 2

	Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
			(cubic m)	m3/d	m3/d	(mm)	
	07-Jun-99	07:00	1211	7.50	7.83		
	10-Jun-99	07:00	1232	7.00	7.67		
	14-Jun-99	07:00	1260	7.00	7.29		
	17-Jun-99	07:00	1278	6.00	6.88		
	20-Jun-99	07:00	1300	7.33	6.83		
	24-Jun-99	07:00	1322	5.50	6.46		
	28-Jun-99	07:00	1336	3.50	5.58		
	01-Jul-99	07:00	1344	2.67	4.75		
	05-Jul-99	07:00	1364	5.00	4.17		
	08-Jul-99	07:00	1378	4.67	3.96		
	12-Jul-99	07:00	1395	4.25	4.15		
	15-Jul-99	07:00	1411	5.33	4.81		
	19-Jul-99	07:00	1433	5.50	4.94		
	22-Jul-99	07:00	1449	5.33	5.10		
	26-Jul-99	07:00	1470	5.25	5.35		
	29-Jul-99	07:00	1486	5.33	5.35	3	
	02-Aug-99	07:00	1506	5.00	5.23		
	05-Aug-99	07:00	1520	4.67	5.06		
	09-Aug-99	07:00	1538	4.50	4.88	2	
	12-Aug-99	07:00	1557	6.33	5.13	1	
	16-Aug-99	07:00	1574	4.25	4.94		
	19-Aug-99	07:00	1587	4.33	4.85		
	23-Aug-99	07:00	1615	7.00	5.48	6	
	26-Aug-99	07:00	1641	8.67	6.06		
	30-Aug-99	07:00	1666	6.25	6.56		
	02-Sep-99	07:00	1679	4.33	6.56		
	06-Sep-99	07:00	1697	4.50	5.94	2	
	09-Sep-99	07:00	1710	4.33	4.85		
	13-Sep-99	07:00	1726	4.00	4.29		
	16-Sep-99	07:00	1737	3.67	4.13		
	20-Sep-99	07:00	1752	3.75	3.94	2	
	23-Sep-99	07:00	1763	3.67	3.77		
	26-Sep-99	07:00	1773	3.33	3.60	1	
	30-Sep-99	07:00	1787	3.50	3.56		
	04-Oct-99	07:00	1792	1.25	2.94		
	08-Oct-99	07:00	1792	0.00	2.02		
	12-Oct-99	07:00	1792	0.00	1.19		
	15-Oct-99	07:00	1792	0.00	0.31		
	18-Oct-99	07:00	1792	0.00	0.00		
	21-Oct-99	07:00	1792	0.00	0.00		
	25-Oct-99	07:00	1792	0.00	0.00		
	29-Oct-99	07:00	1792	0.00	0.00		
	01-Nov-99	07:00	1792	0.00	0.00		
	05-Nov-99	07:00	1792	0.00	0.00		
	09-Nov-99	07:00	1792	0.00	0.00		
	12-Nov-99	07:00	1792	0.00	0.00		
	15-Nov-99	07:00	1792	0.00	0.00	3	
	18-Nov-99	07:00	1792	0.00	0.00		
	22-Nov-99	07:00	1853	15.25	3.81		
	24-Nov-99	07:00	1878	12.50	6.94		
	29-Nov-99	07:00	1892	2.80	7.64	20	
	06-Dec-99	07:00	1938	6.57	9.28	64	
	10-Dec-99	07:00	1948	2.50	6.09		

Kholakazana

Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
13-Dec-99	07:00	1953	1.67	3.38	20	
17-Dec-99	07:00	1958	1.25	3.00	5	
20-Dec-99	07:00	1986	9.33	3.69		
23-Dec-99	07:00	1998	4.00	4.06	4	
27-Dec-99	07:00	2000	0.50	3.77		
30-Dec-99	07:00	2058	19.33	8.29	30	
03-Jan-00	07:00	2074	4.00	6.96	4	
06-Jan-00	07:00	2102	9.33	8.29		
10-Jan-00	07:00	2117	3.75	9.10		
13-Jan-00	07:00	2123	2.00	4.77	20	
17-Jan-00	07:00	2156	8.25	5.83	5	
20-Jan-00	07:00	2184	9.33	5.83		
24-Jan-00	07:00	2209	6.25	6.46	20	
27-Jan-00	07:00	2232	7.67	7.88	10	
31-Jan-00	07:00	2261	7.25	7.63	10	
03-Feb-00	07:00	2277	5.33	6.63		
07-Feb-00	07:00	2296	4.75	6.25		
14-Feb-00	07:00	2329	4.71	5.51	24	
17-Feb-00	07:00	2345	5.33	5.03	15	
21-Feb-00	07:00	2379	8.50	5.82	6	
24-Feb-00	07:00	2406	9.00	6.89	2	
28-Feb-00	07:00	2443	9.25	8.02	9	
02-Mar-00	07:00	2455	4.00	7.69	60	
06-Mar-00	07:00	2491	9.00	7.81	4	
09-Mar-00	07:00	2519	9.33	7.90	24	
13-Mar-00	07:00	2545	6.50	7.21	5	
16-Mar-00	07:00	2573	9.33	8.54	1	
20-Mar-00	07:00	2601	7.00	8.04	23	
23-Mar-00	07:00	2611	3.33	6.54	21	
27-Mar-00	07:00	2614	0.75	5.10	10	
31-Mar-00	07:00	2662	12.00	5.77	23	
04-Apr-00	07:00	2726	16.00	8.02	21	
06-Apr-00	07:00	2746	10.00	9.69		
10-Apr-00	07:00	2773	6.75	11.19		
13-Apr-00	07:00	2798	8.33	10.27		
17-Apr-00	07:00	2835	9.25	8.58		
20-Apr-00	07:00	2868	11.00	8.83		
24-Apr-00	07:00	2889	5.25	8.46		
27-Apr-00	07:00	2927	12.67	9.54		
01-May-00	07:00	2963	9.00	9.48		
04-May-00	07:00	2995	10.67	9.40		
08-May-00	07:00	3030	8.75	10.27		
11-May-00	07:00	3059	9.67	9.52		
15-May-00	07:00	3090	7.75	9.21		
18-May-00	07:00	3111	7.00	8.29		
21-May-00	07:00	3133	7.33	7.94		
25-May-00	07:00	3158	6.25	7.08		
28-May-00	07:00	3181	7.67	7.06		
01-Jun-00	07:00	3199	4.50	6.44		
04-Jun-00	07:00	3221	7.33	6.44		
08-Jun-00	07:00	3249	7.00	6.63		
12-Jun-00	07:00	3271	5.50	6.08		
15-Jun-00	07:00	3294	7.67	6.88		

Kholakazana

	Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
			(cubic m)	m3/d	m3/d	(mm)	
	19-Jun-00	07:00	3329	8.75	7.23		
	22-Jun-00	07:00	3348	6.33	7.06		
	26-Jun-00	07:00	3378	7.50	7.56		
	29-Jun-00	07:00	3397	6.33	7.23		
	03-Jul-00	07:00	3420	5.75	6.48		
	06-Jul-00	07:00	3433	4.33	5.98		
	10-Jul-00	07:00	3454	5.25	5.42		
	13-Jul-00	07:00	3482	9.33	6.17		
	17-Jul-00	07:00	3508	6.50	6.35		
	20-Jul-00	07:00	3526	6.00	6.77		
	24-Jul-00	07:00	3548	5.50	6.83		
	27-Jul-00	07:00	3570	7.33	6.33		
	31-Jul-00	07:00	3601	7.75	6.65		
	03-Aug-00	07:00	3614	4.33	6.23		
	07-Aug-00	07:00	3637	5.75	6.29		
	10-Aug-00	07:00	3652	5.00	5.71		

Magangangozi 1 - BERGVILLE

Date	Time	Cum. Vol (cubic m)	Flow rate m3/d	14 day av m3/d	Rainfall (mm)	Explanation
10-Jul-98	08:00 AM	31				
13-Jul-98	08:15 AM	54	7.64			
16-Jul-98	08:15 AM	85	10.33			
19-Jul-98	08:15 AM	114	9.67			
22-Jul-98	08:15 AM	142	9.33	9.24		
25-Jul-98	08:15 AM	180	12.67	10.50	8	
28-Jul-98	08:15 AM	210	10.00	10.42		
31-Jul-98	08:15 AM	241	10.33	10.58		
03-Aug-98	08:15 AM	268	9.00	10.50		
06-Aug-98	08:15 AM	295	9.00	9.58		
09-Aug-98	08:15 AM	322	9.00	9.33		
12-Aug-98	08:15 AM	348	8.67	8.92		
15-Aug-98	08:15 AM	373	8.33	8.75		
18-Aug-98	08:15 AM	401	9.33	8.83		
21-Aug-98	08:15 AM	418	5.67	8.00		
24-Aug-98	08:15 AM	442	8.00	7.83	6	
27-Aug-98	08:15 AM	470	9.33	8.08		
30-Aug-98	08:15 AM	496	8.67	7.92		
02-Sep-98	08:27 AM	515	6.32	8.08		
05-Sep-98	08:15 AM	535	6.69	7.75		
08-Sep-98	08:00 AM	555	6.69	7.09		
11-Sep-98	08:00 AM	574	6.33	6.51		
14-Sep-98	08:00 AM	592	6.00	6.43	3	
17-Sep-98	08:00 AM	610	6.00	6.26		
20-Sep-98	08:00 AM	628	6.00	6.08	2.5	
23-Sep-98	08:00 AM	645	5.67	5.92		
26-Sep-98	08:00 AM	661	5.33	5.75		
29-Sep-98	08:00 AM	676	5.00	5.50		
02-Oct-98	08:00 AM	692	5.33	5.33	15	
05-Oct-98	08:00 AM	708	5.33	5.25		
08-Oct-98	08:00 AM	724	5.33	5.25		
11-Oct-98	08:00 AM	738	4.67	5.17	6	
14-Oct-98	08:00 AM	752	4.67	5.00	3	
17-Oct-98	08:00 AM	766	4.67	4.83		
20-Oct-98	08:00 AM	779	4.33	4.58		
23-Oct-98	08:00 AM	791	4.00	4.42		
26-Oct-98	08:00 AM	803	4.00	4.25	2	
29-Oct-98	08:00 AM	815	4.00	4.08	2	
01-Nov-98	08:00 AM	828	4.33	4.08	4	
04-Nov-98	08:00 AM	839	3.67	4.00	7	
07-Nov-98	08:00 AM	849	3.33	3.83		
10-Nov-98	08:00 AM	859	3.33	3.67	5	
13-Nov-98	08:00 AM	869	3.33	3.42	2	
16-Nov-98	08:00 AM	879	3.33	3.33	7	
19-Nov-98	08:00	894	5.00	3.75	70	
22-Nov-98	08:00	974	26.67	9.58	46	
25-Nov-98	08:00	1074	33.33	17.08	23	
28-Nov-98	08:00	1230	52.00	29.25		
01-Dec-98	08:00	1386	52.00	41.00		
04-Dec-98	08:00 AM	1542	52.00	47.33		
07-Dec-98	08:00	1672	43.33	49.83		
10-Dec-98	08:00	1804	44.00	47.83	6	

Date	Time	Cum. Vol (cubic m)	Flow rate m3/d	14 day av m3/d	Rainfall (mm)	Explanation
13-Dec-98	08:00	1934	43.33	45.67	2	
16-Dec-98	08:00	2022	29.33	40.00	5	
19-Dec-98	08:00	2109	29.00	36.42	18	
22-Dec-98	08:00	2193	28.00	32.42		
25-Dec-98	08:00 AM	2288	31.67	29.50	50	
28-Dec-98	08:00	2377	29.67	29.58		
31-Dec-98	08:00	2474	32.33	30.42	55	
03-Jan-99	08:00	2632	52.67	36.58	5	
06-Jan-99	08:00	2672	13.33	32.00	30	
09-Jan-99	08:00	2717	15.00	28.33	26	
12-Jan-99	08:00	2829	37.33	29.58		
15-Jan-99	08:00	2941	37.33	25.75		
18-Jan-99	08:00	3053	37.33	31.75	19	
21-Jan-99	08:00	3168	38.33	37.58		
24-Jan-99	08:00	3278	36.67	37.42		
27-Jan-99	08:00	3394	38.67	37.75	23	
30-Jan-99	08:00	3510	38.67	38.08	36	
02-Feb-99	08:00	3627	39.00	38.25		
05-Feb-99	08:00	3744	39.00	38.83		
08-Feb-99	08:00	3921	59.00	43.92	55	
11-Feb-99	08:00	4191	90.00	56.75	29	
14-Feb-99	08:00	4421	76.67	66.17	31	
17-Feb-99	08:00	4638	72.33	74.50	19	
20-Feb-99	08:00	4680	14.00	63.25	49	
23-Feb-99	08:00	5084	134.67	74.42	6	
26-Feb-99	08:00	5303	73.00	73.50	47	
28-Feb-99	08:00	5522	109.50	82.79	16	
03-Mar-99	08:00	5742	73.33	97.62	6	
06-Mar-99	08:00	5963	73.67	82.38	2	
09-Mar-99	08:00	6175	70.67	81.79		
12-Mar-99	08:00	6348	57.67	68.83	15	
15-Mar-99	08:00	6526	59.33	65.33	10	
18-Mar-99	08:00	6704	59.33	61.75		
21-Mar-99	08:00	6881	59.00	58.83		
24-Mar-99	08:00	7059	59.33	59.25		
27-Mar-99	08:00	7238	59.67	59.33		
30-Mar-99	08:00	7416	59.33	59.33		
02-Apr-99	08:00	7595	59.67	59.50		
05-Apr-99	08:00	7772	59.00	59.33	10	
08-Apr-99	08:00	7939	55.67	58.42		
11-Apr-99	08:00	8106	55.67	57.42		
14-Apr-99	08:00	8273	55.67	56.50		
17-Apr-99	08:00	8440	55.67	55.67	5	
20-Apr-99	08:00	8607	55.67	55.67		
23-Apr-99	08:00	8774	55.67	55.67		
26-Apr-99	08:00	8940	55.33	55.58		
29-Apr-99	08:00	9107	55.67	55.58		
03-May-99	08:00					missing records
06-May-99	08:00					missing records
10-May-99	08:00					missing records
13-May-99	08:00					missing records
17-May-99	08:00					missing records
20-May-99	08:00					missing records
24-May-99	08:00					missing records

Date	Time	Cum. Vol (cubic m)	Flow rate m3/d	14 day av m3/d	Rainfall (mm)	Explanation
27-May-99	08:00					missing records
31-May-99	08:00					missing records
03-Jun-99	08:00					missing records
07-Jun-99	08:00					missing records
10-Jun-99	08:00					pipe blocked
14-Jun-99	08:00					pipe blocked
17-Jun-99	08:00					pipe blocked
20-Jun-99	08:00					pipe blocked
24-Jun-99	08:00					pipe blocked
28-Jun-99	08:00					pipe blocked
01-Jul-99	08:00					pipe blocked
05-Jul-99	08:00					pipe blocked
08-Jul-99	08:00					pipe blocked
12-Jul-99	08:00					pipe blocked
15-Jul-99	08:00					pipe blocked
19-Jul-99	08:00					pipe blocked
22-Jul-99	08:00					pipe blocked
26-Jul-99	08:00					pipe blocked
29-Jul-99	08:00					pipe blocked
02-Aug-99	08:00					no flow
05-Aug-99	08:00					no flow
09-Aug-99	08:00					no flow
12-Aug-99	08:00					no flow
16-Aug-99	08:00					no flow
19-Aug-99	08:00					no flow
23-Aug-99	08:00					no flow
26-Aug-99	08:00					no flow
30-Aug-99	08:00					no flow
02-Sep-99	08:00					no flow
06-Sep-99	08:00					no flow
09-Sep-99	08:00					no flow
13-Sep-99	08:00					no flow
16-Sep-99	08:00					no flow
20-Sep-99	08:00					no flow
23-Sep-99	08:00					no flow
26-Sep-99	08:00					no flow
30-Sep-99	08:00					no flow
04-Oct-99	08:00					no flow
08-Oct-99	08:00					no flow
12-Oct-99	08:00					no flow
02-Nov-99	08:00	10162				
05-Nov-99	08:00	10200	12.67			
08-Nov-99	08:00	10238	12.67		17	
11-Nov-99	08:00	10275	12.33		25	
14-Nov-99	08:00	10361	28.67	16.58		
17-Nov-99	08:00	10447	28.67	20.58		
20-Nov-99	08:00	10532	28.33	24.50		
23-Nov-99	08:00	10618	28.67	28.58		
26-Nov-99	08:00	10704	28.67	28.58		
29-Nov-99	08:00	10792	29.33	28.75	32	
02-Dec-99	08:00	10812	6.67	23.33	10	
05-Dec-99	08:00	10832	6.67	17.83	5	
08-Dec-99	08:00	10855	7.67	12.58		
11-Dec-99	08:00	10881	8.67	7.42	64	

Magangangozi 1

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
14-Dec-99	08:00	10946	21.67	11.17	40	
17-Dec-99	08:00	11012	22.00	15.00	15	
20-Dec-99	08:00	11079	22.33	18.67	50	
23-Dec-99	08:00	11147	22.67	22.17		
26-Dec-99	08:00	11217	23.33	22.58		
29-Dec-99	08:00	11292	25.00	23.33	50	
01-Jan-00	08:00	11371	26.33	24.33	15	
04-Jan-00	08:00	11453	27.33	25.50	14	
07-Jan-00	08:00	11537	28.00	26.67	5	
10-Jan-00	08:00	11625	29.33	27.75	20	
13-Jan-00	08:00	11711	28.67	28.33	20	
16-Jan-00	08:00	11805	31.33	29.33		
19-Jan-00	08:00	11903	32.67	30.50	5	
22-Jan-00	08:00	12001	32.67	31.33	20	
25-Jan-00	08:00	12102	33.67	32.58		
28-Jan-00	08:00	12199	32.33	32.83	20	
31-Jan-00	08:00	12296	32.33	32.75		
03-Feb-00	08:00	12390	31.33	32.42		
05-Feb-00	08:00	12486	48.00	36.00		
09-Feb-00	08:00	12581	23.75	33.85		
12-Feb-00	08:00	12658	25.67	32.19		
15-Feb-00	08:00	12725	22.33	29.94	24	
18-Feb-00	08:00	12785	20.00	22.94	15	
21-Feb-00	08:00	12845	20.00	22.00	6	
24-Feb-00	08:00	12905	20.00	20.58	2	
27-Feb-00	08:00	12965	20.00	20.00		
01-Mar-00	08:00	13028	21.00	20.25	9	
04-Mar-00	08:00	13093	21.67	20.67	25	
07-Mar-00	08:00	13163	23.33	21.50		
10-Mar-00	08:00	13242	26.33	23.08	15	
13-Mar-00	08:00	13311	23.00	23.58		
16-Mar-00	08:00	13381	23.33	24.00	10	
19-Mar-00	08:00	13455	24.67	24.33	5	
22-Mar-00	08:00	13529	24.67	23.92	30	
25-Mar-00	08:00	13605	25.33	24.50	25	
28-Mar-00	08:00	13681	25.33	25.00	3	
31-Mar-00	08:00	13768	29.00	26.08		
04-Apr-00	08:00					missing records
06-Apr-00	08:00					missing records
10-Apr-00	08:00					missing records
13-Apr-00	08:00					missing records
17-Apr-00	08:00					missing records
20-Apr-00	08:00					missing records
24-Apr-00	08:00					missing records
27-Apr-00	08:00					missing records
01-May-00	08:00					missing records
04-May-00	08:00					missing records
08-May-00	08:00					missing records
11-May-00	08:00					no flow
15-May-00	08:00					no flow
18-May-00	08:00					no flow
21-May-00	08:00					no flow
25-May-00	08:00					no flow
28-May-00	08:00					no flow

Magangangozi 1

Date	Time	Cum. Vol (cubic m)	Flow rate m3/d	14 day av m3/d	Rainfall (mm)	Explanation
01-Jun-00	08:00					no flow
04-Jun-00	08:00					no flow
08-Jun-00	08:00					no flow
12-Jun-00	08:00					no flow
15-Jun-00	08:00					no flow
19-Jun-00	08:00					no flow
22-Jun-00	08:00					no flow
26-Jun-00	08:00					no flow
29-Jun-00	08:00					no flow
03-Jul-00	08:00					no flow
06-Jul-00	08:00					no flow
10-Jul-00	08:00					no flow
13-Jul-00	08:00					no flow
17-Jul-00	08:00					no flow
20-Jul-00	08:00					no flow
24-Jul-00	08:00					no flow
27-Jul-00	08:00					no flow
31-Jul-00	08:00					no flow
03-Aug-00	08:00					no flow
07-Aug-00						no flow
10-Aug-00						no flow
14-Aug-00						no flow
17-Aug-00						no flow
21-Aug-00						no flow
24-Aug-00						no flow
27-Aug-00	07:40	14156				
30-Aug-00	08:00	14202	15.26			
02-Sep-00	07:00	14250	16.23			
05-Sep-00	06:20	14296	15.48	11.74	2	
08-Sep-00	06:00	14342	15.40	15.59		
11-Sep-00	06:05	14387	14.98	15.52		
14-Sep-00	06:20	14429	13.95	14.95		
17-Sep-00	06:00	14470	13.73	14.52	7	
20-Sep-00	06:00	14511	13.67	14.08	28	
23-Sep-00	06:07	14551	13.31	13.67		
26-Sep-00	06:00	14585	11.35	13.02		
29-Sep-00	06:10	14615	9.98	12.08		
02-Oct-00	07:50	14661	14.99	12.41		
05-Oct-00	06:30	14708	15.96	13.07		
08-Oct-00	06:30	14750	14.00	13.73		
11-Oct-00	06:30	14795	15.00	14.99		
14-Oct-00	06:30	14843	16.00	15.24		
17-Oct-00	06:30	14845	0.67	11.42		
20-Oct-00	06:30	14891	15.33	11.75		
23-Oct-00	06:30	14935	14.67	11.67		
26-Oct-00	06:30	14972	12.33	10.75		
29-Oct-00	06:30	15012	13.33	13.92		
01-Nov-00	06:30	15061	16.33	14.17		
04-Nov-00	06:30	15109	16.00	14.50		
08-Nov-00	06:30	15157	12.00	14.42		

Magangangosi 2 - BERGVILLE

Date	Time	Cum. Vol (cubic m)	Flow rate m3/d	14 day av m3/d	Rainfall (mm)	over flow cumul.	over flow m3/d	14 day av m3/d	total flow m3/d	14 day av m3/d	cum vol m3
14-Jul-98	03:00 PM	117									
17-Jul-98	08:00 AM	168	18.83								
21-Jul-98	08:00 AM	248	20.00								
24-Jul-98	08:00 AM	309	20.33		2						
28-Jul-98	08:00 AM	371	15.50	18.67							
31-Jul-98	08:00 AM	420	16.33	18.04	2						
04-Aug-98	08:00 AM	487	16.75	17.23							
07-Aug-98	08:00 AM	531	14.67	15.81							
11-Aug-98	08:00 AM	602	17.75	16.38							
15-Aug-98	08:00 AM	662	15.00	16.04							
18-Aug-98	08:00 AM	711	16.33	15.94							
21-Aug-98	08:00 AM	760	16.33	16.35							
26-Aug-98	08:00 AM	854	18.80	16.62	23						
29-Aug-98	08:00 AM	901	15.67	16.78	2						
01-Sep-98	08:00 AM	929	9.33	15.03							
04-Sep-98	08:00 AM	959	10.00	13.45							
08-Sep-98	08:00 AM	1009	12.50	11.88							
11-Sep-98	08:00 AM	1048	13.00	11.21	1						
15-Sep-98	08:00 AM	1103	13.75	12.31							
18-Sep-98	08:00 AM	1142	13.00	13.06	1						
22-Sep-98	08:00 AM	1201	14.75	13.63							
24-Sep-98	08:00 AM	1225	12.00	13.38							
29-Sep-98	08:00 AM	1274	9.80	12.39	1						
02-Oct-98	08:00 AM	1309	11.67	12.05	14						
06-Oct-98	08:00 AM	1347	9.50	10.74							
09-Oct-98	08:00 AM	1385	12.67	10.91							
13-Oct-98	08:00 AM	1400	3.75	9.40	5						
16-Oct-98	08:00 AM	1520	40.00	16.48							
20-Oct-98	08:00 AM	1544	6.00	15.60							
23-Oct-98	08:00 AM	1602	19.33	17.27							
30-Oct-98	08:00 AM	1611	1.29	16.65							
03-Nov-98	08:00 AM	1680	17.25	10.97	3						
06-Nov-98	08:00 AM	1710	10.00	11.97	2						
10-Nov-98	08:00 AM	1731	5.25	8.45	5						
13-Nov-98	08:00 AM	1750	6.33	9.71							
17-Nov-98	08:00 AM	1781	7.75	7.33	8						
20-Nov-98	08:00	1817	12.00	7.83	120						
24-Nov-98	08:00	1852	8.75	8.71	51						
27-Nov-98	08:00	1873	7.00	8.88	105						
01-Dec-98	08:00	1907	8.50	9.06	11						
04-Dec-98	08:00	1932	8.33	8.15	30						
08-Dec-98	08:00	1968	9.00	8.21	1						
11-Dec-98	08:00	1994	8.67	8.63	15						
16-Dec-98	08:00	2018	4.80	7.70	58						
18-Dec-98	08:00	2036	9.00	7.87	88						
22-Dec-98	08:00	2061	6.25	7.18	9						
25-Dec-98	08:00	2062	0.33	5.10	1						
29-Dec-98	08:00	2072	2.50	4.52	46						
01-Jan-99	08:00	2075	1.00	2.52	3						
05-Jan-99	08:00	2080	1.25	1.27	75						
08-Jan-99	08:00	2086	2.00	1.69	120						

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	over flow	over flow	14 day av	total flow	14 day av	cum vol
		(cubic m)	m3/d	m3/d	(mm)	cumul.	m3/d	m3/d	m3/d	m3/d	m3
12-Jan-99	08:00	2098	3.00	1.81	6						
15-Jan-99	08:00	2106	2.67	2.23							
19-Jan-99	08:00	2119	3.25	2.73	15						
22-Jan-99	08:00	2126	2.33	2.81	10						
26-Jan-99	08:00	2136	2.50	2.69	15						
29-Jan-99	08:00	2145	3.00	2.77							
02-Feb-99	08:00	2151	1.50	2.33	71						
05-Feb-99	08:00	2158	2.33	2.33	65						
09-Feb-99	08:00	2165	1.75	2.15	3						
12-Feb-99	08:00	2174	3.00	2.15	11						
16-Feb-99	08:00	2189	3.75	2.71	103						
19-Feb-99	08:00	2195	2.00	2.63	17						
23-Feb-99	08:00	2207	3.00	2.94	16						
26-Feb-99	08:00	2216	3.00	2.94	10						
02-Mar-99	08:00	2231	3.75	2.94	10						
05-Mar-99	08:00	2245	4.67	3.60	1						
09-Mar-99	08:00	2254	2.25	3.42							
12-Mar-99	08:00	2268	4.67	3.83							
23-Mar-99	08:00	2330	5.64	4.30	91						
26-Mar-99	08:00	2353	7.67	5.05	130						
30-Mar-99	08:00	2364	2.75	5.18							
02-Apr-99	08:00	2384	6.67	5.68							
06-Apr-99	08:00	2401	4.25	5.33	30						
09-Apr-99	08:00	2417	5.33	4.75	1						
13-Apr-99	08:00	2438	5.25	5.38	7						
20-Apr-99	08:00	2497	8.43	5.82							
23-Apr-99	08:00	2517	6.67	6.42							
04-May-99	08:00	2586	6.27	6.65							
07-May-99	08:00	2605	6.33	6.93							
11-May-99	08:00	2634	7.25	6.63							
14-May-99	08:00	2675	13.67	8.38	4						
18-May-99	08:00	2728	13.25	10.13							
21-May-99	08:00	2749	7.00	10.29	4						
25-May-99	08:00	2774	6.25	10.04							
28-May-99	08:00	2792	6.00	8.13							
01-Jun-99	08:00	2822	7.50	6.69							
03-Jun-99	08:00	2838	8.00	6.94							
07-Jun-99	08:00	2872	8.50	7.50							
10-Jun-99	08:00	2889	5.67	7.42							
14-Jun-99	08:00	2916	6.75	7.23							
17-Jun-99	08:00	2938	7.33	7.06							
22-Jun-99	08:00	2979	8.20	6.99							
25-Jun-99	08:00	3024	15.00	9.32							
29-Jun-99	08:00	3080	14.00	11.13							
02-Jul-99	08:00	3127	15.67	13.22							
06-Jul-99	08:00	3161	8.50	13.29							
09-Jul-99	08:00	3190	9.67	11.96							
13-Jul-99	08:00	3228	9.50	10.83							
16-Jul-99	08:00	3257	9.67	9.33							
27-Jul-99	08:00	3365	9.82	9.66							
30-Jul-99	08:00	3401	12.00	10.25							
03-Aug-99	08:00	3454	13.25	11.18							
06-Aug-99	08:00	3498	14.67	12.43							

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	over flow	over flow	14 day av	total flow	14 day av	cum vol
		(cubic m)	m3/d	m3/d	(mm)	cumul.	m3/d	m3/d	m3/d	m3/d	m3
10-Aug-99	08:00	3559	15.25	13.79							
13-Aug-99	08:00	3607	16.00	14.79							
16-Aug-99	08:00	3660	17.67	15.90	1	4			17.67		3664
20-Aug-99	08:00	3726	16.50	16.35	2	20	4.00		20.50		3746
23-Aug-99	08:00	3772	15.33	16.38	1	36	5.33		20.67		3808
26-Aug-99	08:00	3818	15.33	16.21		53	5.67		21.00	19.96	3871
31-Aug-99	08:00	3864	9.20	14.09		71	3.60	4.65	12.80	18.74	3935
05-Sep-99	08:00	3910	9.20	12.27		88	3.40	4.50	12.60	16.77	3998
09-Sep-99	08:00	3946	9.00	10.68		105	4.25	4.23	13.25	14.91	4051
13-Sep-99	08:00	3972	6.50	8.48		121	4.00	3.81	10.50	12.29	4093
17-Sep-99	08:00	3988	4.00	7.18		136	3.75	3.85	7.75	11.03	4124
21-Sep-99	08:00	4004	4.00	5.88		167	7.75	4.94	11.75	10.81	4171
27-Sep-99	08:00	4020	2.67	4.29		183	2.67	4.54	5.33	8.83	4203
03-Oct-99	08:00	4036	2.67	3.33		199	2.67	4.21	5.33	7.54	4235
07-Oct-99	08:00	4052	4.00	3.33		215	4.00	4.27	8.00	7.60	4267
11-Oct-99	08:00	4068	4.00	3.33		231	4.00	3.33	8.00	6.67	4299
14-Oct-99	08:00	4084	5.33	4.00		243	4.00	3.67	9.33	7.67	4327
19-Oct-99	08:00	4108	4.80	4.53							
24-Oct-99	08:00	4130	4.40	4.63							
29-Oct-99	08:00	4152	4.40	4.73							
03-Nov-99	08:00	4175	4.60	4.55							
07-Nov-99	08:00	4192	4.25	4.41							
10-Nov-99	08:00	4206	4.67	4.48		309	2.44	3.61	7.11	8.11	4515
20-Nov-99	08:00	4254	4.80	4.58		319	1.00	2.86	5.80	7.56	4573
23-Nov-99	08:00	4284	10.00	5.93		330	3.67	2.78	13.67	8.98	4614
26-Nov-99	08:00	4323	13.00	8.12		346	5.33	3.11	18.33	11.23	4669
30-Nov-99	08:00	4433	27.50	13.83	30	369	5.75	3.94	33.25	17.76	4802
06-Dec-99	08:00				13					16.31	
10-Dec-99	08:00				49					12.90	
13-Dec-99	08:00				8						
17-Dec-99	08:00				11						
20-Dec-99	08:00				27						
23-Dec-99	08:00				9						
27-Dec-99	08:00				9						
30-Dec-99	08:00				32						
03-Jan-00	08:00										
06-Jan-00	08:00	4572	3.76			826	12.35		16.11		5398
10-Jan-00	08:00	4583	2.75			910	21.00		23.75		5493
13-Jan-00	08:00	4596	4.33			987	25.67		30.00		5583
17-Jan-00	08:00	4617	5.25	4.02	70	1085	24.50	20.88	29.75	24.90	5702
20-Jan-00	08:00	4617	0.00	3.08		1165	26.67	24.46	26.67	27.54	5782
23-Jan-00	08:00	4617	0.00	2.40		1249	28.00	26.21	28.00	28.60	5866
27-Jan-00	08:00	4619	0.50	1.44		1331	20.50	24.92	21.00	26.35	5950
30-Jan-00	08:00	4621	0.67	0.29		1377	15.33	22.63	16.00	22.92	5998
03-Feb-00	08:00	4630	2.25	0.85		1423	11.50	18.83	13.75	19.69	6053
06-Feb-00	08:00	4636	2.00	1.35		1463	13.33	15.17	15.33	16.52	6099
14-Feb-00	08:00				51						
17-Feb-00	08:00				21						
21-Feb-00	08:00				5						
24-Feb-00	08:00				7						
28-Feb-00	08:00				68						
02-Mar-00	08:00				1						
06-Mar-00	08:00				10						

Magangangozi 2

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	over flow	over flow	14 day av	total flow	14 day av	cum vol
		(cubic m)	m3/d	m3/d	(mm)	cumul.	m3/d	m3/d	m3/d	m3/d	m3
09-Mar-00	08:00				50						
13-Mar-00	08:00				13						
16-Mar-00	08:00				10						
20-Mar-00	08:00				117						
23-Mar-00	08:00				29						
27-Mar-00	08:00				30						
31-Mar-00	08:00				15						
04-Apr-00	08:00										
06-Apr-00	08:00										
10-Apr-00	08:00										
14-Apr-00	08:00	4841	3.01								
18-Apr-00	08:00	4878	9.25			1719	3.56		12.81		6597
21-Apr-00	08:00	4916	12.67			1754	11.67		24.33		6670
25-Apr-00	08:00	4961	11.25	9.05		1797	10.75		22.00		6758
28-Apr-00	08:00	5008	15.67	12.21		1836	13.00	9.74	28.67	21.95	6844
02-May-00	08:00	5076	17.00	14.15		1885	12.25	11.92	29.25	26.06	6961
05-May-00	08:00	5121	15.00	14.73	25	1926	13.67	12.42	28.67	27.15	7047
09-May-00	08:00	5171	12.50	15.04	84	1985	14.75	13.42	27.25	28.46	7156
12-May-00	08:00	5212	13.67	14.54	1	2037	17.33	14.50	31.00	29.04	7249
16-May-00	08:00	5294	20.50	15.42		2098	15.25	15.25	35.75	30.67	7392
19-May-00	08:00	5332	12.67	14.83		2148	16.67	16.00	29.33	30.83	7480
22-May-00	08:00	5385	17.67	16.13		2199	17.00	16.56	34.67	32.69	7584
25-May-00	08:00	5437	17.33	17.04		2249	16.67	16.40	34.00	33.44	7686
28-May-00	08:00	5496	19.67	16.83		2301	17.33	16.92	37.00	33.75	7797
31-May-00	08:00	5541	15.00	17.42		2352	17.00	17.00	32.00	34.42	7893
03-Jun-00	08:00	5604	21.00	18.25		2402	16.67	16.92	37.67	35.17	8006
06-Jun-00	08:00	5657	17.67	18.33		2453	17.00	17.00	34.67	35.33	8110
09-Jun-00	08:00	5709	17.33	17.75		2503	16.67	16.83	34.00	34.58	8212
15-Jun-00	08:00										
19-Jun-00	08:00										
22-Jun-00	08:00										
26-Jun-00	08:00										
29-Jun-00	08:00										
04-Jul-00	08:00	6006	11.88			2847	13.76		25.64		8853
07-Jul-00	08:00	6055	16.33			2894	15.67		32.00		8949
11-Jul-00	08:00	6143	22.00			2952	14.50		36.50		9095
14-Jul-00	08:00	6196	17.67	16.97		2992	13.33	14.32	31.00	31.29	9188
18-Jul-00	08:00	6277	20.25	19.06		3044	13.00	14.13	33.25	33.19	9321
21-Jul-00	08:00	6357	26.67	21.65		3095	17.00	14.46	43.67	36.10	9452
25-Jul-00	08:00	6450	23.25	21.96		3162	16.75	15.02	40.00	36.98	9612
28-Jul-00	08:00	6516	22.00	23.04		3215	17.67	16.10	39.67	39.15	9731
01-Aug-00	08:00	6598	20.50	23.10		3252	9.25	15.17	29.75	38.27	9850
04-Aug-00	08:00	6646	16.00	20.44		3274	7.33	12.75	23.33	33.19	9920
07-Aug-00	08:00										
10-Aug-00	08:00										
14-Aug-00	08:00										
17-Aug-00	08:00										
21-Aug-00	08:00										
24-Aug-00	08:00										
28-Aug-00	08:00										
31-Aug-00	08:00										
04-Sep-00	08:00										
07-Sep-00	08:00										

Magangangozi 2

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	over flow	over flow	14 day av	total flow	14 day av	cum vol
		(cubic m)	m3/d	m3/d	(mm)	cumul.	m3/d	m3/d	m3/d	m3/d	m3
10-Sep-00	08:00										
14-Sep-00	08:00										
19-Sep-00	08:00	7291	14.02			3651	8.20				10942
22-Sep-00	08:00	7341	16.67			3681	10.00		26.67		11022
26-Sep-00	08:00	7403	15.50			3723	10.50		26.00		11126
29-Sep-00	08:00	7449	15.33	15.38		3757	11.33		26.67		11206
03-Oct-00	08:00	7513	16.00	15.88		3797	10.00	10.46	26.00	26.33	11310
07-Oct-00	08:00	7582	17.25	16.02		3838	10.25	10.52	27.50	26.54	11420
10-Oct-00	08:00	7630	16.00	16.15		3872	11.33	10.73	27.33	26.88	11502
13-Oct-00	08:00	7694	21.33	17.65		3910	12.67	11.06	34.00	28.71	11604
16-Oct-00	08:00					3939	9.67	10.98	9.67	24.63	
19-Oct-00	08:00					3965	8.67	10.58	8.67	19.92	
22-Oct-00	08:00				1	3987	7.33	9.58	7.33	14.92	
25-Oct-00	08:00				7	4002	5.00	7.67	5.00	7.67	
28-Oct-00	08:00				50	4012	3.33	6.08	3.33	6.08	
31-Oct-00	08:00				3	4021	3.00	4.67	3.00	4.67	
03-Nov-00	08:00				4	4030	3.00	3.58	3.00	3.58	
06-Nov-00	08:00				15	4040	3.33	3.17	3.33	3.17	
09-Nov-00	08:00				6	4049	3.00	3.08	3.00	3.08	

Nsukangihlale 1 - BERGVILLE

Date	Time	Cum. Vol (cubic m)	Flow rate m3/d	14 day av m3/d	Rainfall (mm)	Explanation
16-Jul-98	08:00 AM	0				
23-Jul-98	07:30 AM	59	8.45		2	
27-Jul-98	07:00 AM	63	1.01			
30-Jul-98	07:30 AM	71	2.65	3.03		
03-Aug-98	08:00 AM	96	6.22	4.58		
06-Aug-98	07:30 AM	109	4.36	3.56		
10-Aug-98	08:00 AM	126	4.23	4.36		
13-Aug-98	07:30 AM	140	4.70	4.88		
17-Aug-98	07:00 AM	160	5.03	4.58		
20-Aug-98	08:00 AM	175	4.93	4.72		
24-Aug-98	07:30 AM	196	5.28	4.98		
27-Aug-98	08:00 AM	211	4.97	5.05		
31-Aug-98	07:30 AM	232	5.28	5.11		
03-Sep-98	07:30 AM	249	5.67	5.30		
07-Sep-98	07:30 AM	271	5.50	5.35		
10-Sep-98	07:30 AM	288	5.67	5.53		
14-Sep-98	07:00 AM	311	5.78	5.65	4	
17-Sep-98	08:00 AM	329	5.82	5.72	3	
21-Sep-98	07:00 AM	354	6.32	5.92	2	
24-Sep-98	07:30 AM	373	6.29	6.08		
28-Sep-98	08:00 AM	398	6.22	6.19	11	
01-Oct-98	07:00 AM	416	6.08	6.23	5	
05-Oct-98	07:00 AM	441	6.25	6.21	11	
08-Oct-98	08:00 AM	459	5.92	6.12		
12-Oct-98	08:00	483	6.00	6.06	14	av used - flooded
15-Oct-98	08:00	501	6.00	6.04		
19-Oct-98	08:00	523	5.50	5.85		
22-Oct-98	07:00	540	5.75	5.81		
26-Oct-98	08:00	561	5.20	5.61	2	
29-Oct-98	08:00	576	5.00	5.36	3	
02-Nov-98	08:00	596	5.00	5.24	7	
05-Nov-98	07:30	611	5.03	5.06		
09-Nov-98	08:00	632	5.22	5.06	11	
12-Nov-98	08:00	648	5.33	5.15	3	
16-Nov-98	08:00	669	5.25	5.21	6	
19-Nov-98	07:30	697	9.40	6.30	118	av used - flooded
23-Nov-98	07:30	718	5.25	6.31	9	
26-Nov-98	08:00	738	6.62	6.63	52	av used - flooded
30-Nov-98	08:00	764	6.50	6.94	30	
03-Dec-98	08:00	783	6.33	6.18	43	av used - flooded
07-Dec-98	07:30	809	6.53	6.50		
10-Dec-98	08:00	829	6.62	6.50	20	
14-Dec-98	07:00	854	6.32	6.45	53	av used - flooded
17-Dec-98	08:00	873	6.25	6.43	22	av used - flooded
21-Dec-98	08:00	898	6.25	6.36		
24-Dec-98	08:00	917	6.33	6.29		
28-Dec-98	08:00	943	6.50	6.33	26	av used - flooded
31-Dec-98	07:30	962	6.38	6.37	4	
04-Jan-99	07:00	999	9.30	7.13	50	av used - flooded
07-Jan-99	07:00	1026	9.00	7.79	24	av used - flooded
11-Jan-99	08:00	1064	9.40	8.52	38	

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
14-Jan-99	08:00	1091	9.00	9.18	17	av used - flooded
18-Jan-99	08:00	1127	9.00	9.10	6	av used - flooded
21-Jan-99	08:00	1156	9.67	9.27	3	av used - flooded
25-Jan-99	08:00	1180	6.00	8.42	33	av used - flooded
28-Jan-99	08:00	1198	6.00	7.67		
02-Feb-99	08:00	1245	9.40	7.77	25	
04-Feb-99	07:30	1264	9.60	7.75	62	av used - flooded
08-Feb-99	08:00	1301	9.20	8.55	27	av used - flooded
11-Feb-99	07:30	1329	9.40	9.40	30	av used - flooded
15-Feb-99	08:00	1367	9.45	9.41	4	av used - flooded
18-Feb-99	07:30	1395	9.40	9.36	18	av used - flooded
22-Feb-99	08:00	1432	9.20	9.36	83	av used - flooded
25-Feb-99	08:00	1460	9.33	9.35		
01-Mar-99	08:00	1498	9.50	9.36		av used - flooded
04-Mar-99	07:30	1507	3.02	7.76		
08-Mar-99	07:30	1558	12.75	8.65		
11-Mar-99	07:30	1569	3.67	7.23	2	
15-Mar-99	08:00	1604	8.70	7.04	22	
18-Mar-99	08:00	1630	8.67	8.45	21	
22-Mar-99	08:00	1665	8.75	7.45	20	
25-Mar-99	08:00	1690	8.33	8.61	2	
29-Mar-99	08:00	1725	8.75	8.63		
01-Apr-99	08:00	1749	8.00	8.46		
05-Apr-99	08:00	1785	9.00	8.52	5	
08-Apr-99	08:00	1809	8.00	8.44		
12-Apr-99	08:00	1845	9.00	8.50	5	
15-Apr-99	08:00	1870	8.33	8.58		
19-Apr-99	08:00	1906	9.00	8.58		
22-Apr-99	08:00	1930	8.00	8.58	4	
26-Apr-99	08:00	1974	11.00	9.08	6	
29-Apr-99	08:00	1988	4.67	8.17	10	
03-May-99	08:00	2005	4.25	6.98		
06-May-99	08:00	2029	8.00	6.98		
10-May-99	08:00	2059	7.50	6.10		
13-May-99	08:00	2089	10.00	7.44		
17-May-99	08:00	2116	6.75	8.06		
20-May-99	08:00	2134	6.00	7.56	2	
24-May-99	08:00	2172	9.50	8.06	10	
27-May-99	08:00	2201	9.67	7.98		
31-May-99	08:00	2215	3.50	7.17		
03-Jun-99	08:00	2238	7.67	7.58		
07-Jun-99	08:00	2269	7.75	7.15		
10-Jun-99	08:00	2290	7.00	6.48		
14-Jun-99	08:00	2311	5.25	6.92		
17-Jun-99	08:00	2346	11.67	7.92		
20-Jun-99	08:00	2369	7.67	7.90	4	
24-Jun-99	08:00	2397	7.00	7.90		
28-Jun-99	08:00	2424	6.75	8.27		
01-Jul-99	08:00	2448	8.00	7.35		
05-Jul-99	08:00	2472	6.00	6.94		
08-Jul-99	08:00	2508	12.00	8.19		
12-Jul-99	08:00	2526	4.50	7.63		
15-Jul-99	08:00	2549	7.67	7.54		
19-Jul-99	08:00	2580	7.75	7.98		

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
22-Jul-99	08:00	2610	10.00	7.48		
26-Jul-99	08:00	2631	5.25	7.67		
29-Jul-99	08:00	2654	7.67	7.67		
02-Aug-99	08:00	2685	7.75	7.67		
05-Aug-99	08:00	2709	8.00	7.17		
09-Aug-99	08:00	2739	7.50	7.73		
12-Aug-99	08:00	2762	7.67	7.73		
16-Aug-99	08:00	2789	6.75	7.48		
19-Aug-99	08:00	2810	7.00	7.23		
23-Aug-99	08:00	2841	7.75	7.29		
26-Aug-99	08:00	2864	7.67	7.29		
30-Aug-99	08:00	2895	7.75	7.54		
02-Sep-99	08:00	2918	7.67	7.71		
06-Sep-99	08:00	2946	7.00	7.52		
09-Sep-99	08:00	2968	7.33	7.44		
13-Sep-99	08:00	2986	4.50	6.63		
16-Sep-99	08:00	3019	11.00	7.46		
20-Sep-99	08:00	3048	7.25	7.52		
23-Sep-99	08:00	3070	7.33	7.52		
27-Sep-99	08:00	3100	7.50	8.27	1	
30-Sep-99	08:00	3120	6.67	7.19	3	
04-Oct-99	08:00	3148	7.00	7.13		
07-Oct-99	08:00	3168	6.67	6.96	8	
11-Oct-99	08:00	3198	7.50	6.96		
14-Oct-99	08:00	3219	7.00	7.04		
18-Oct-99	08:00	3249	7.50	7.17		
21-Oct-99	08:00	3272	7.67	7.42		
25-Oct-99	08:00	3302	7.50	7.42		
28-Oct-99	08:00	3325	7.67	7.58		
01-Nov-99	08:00	3355	7.50	7.58		
04-Nov-99	08:00	3378	7.67	7.58		
08-Nov-99	08:00	3408	7.50	7.58		
11-Nov-99	08:00	3431	7.67	7.58		
15-Nov-99	08:00	3464	8.25	7.77		
18-Nov-99	08:00	3479	5.00	7.10	5	
22-Nov-99	08:00	3510	7.75	7.17		
25-Nov-99	08:00	3530	6.67	6.92	20	
29-Nov-99	08:00	3560	7.50	6.73	18	
02-Dec-99	08:00	3580	6.67	7.15	36	
06-Dec-99	08:00	3600	5.00	6.46	58	
09-Dec-99	08:00	3633	11.00	7.54	6	
13-Dec-99	08:00	3663	7.50	7.54	52	
16-Dec-99	08:00	3688	8.33	7.96		
20-Dec-99	08:00					
23-Dec-99	08:00				78	
27-Dec-99	08:00				14	
30-Dec-99	08:00				44	
03-Jan-00	08:00				40	
07-Jan-00	08:00				16	
10-Jan-00	08:00				10	
13-Jan-00	08:00				50	
17-Jan-00	08:00				99	
20-Jan-00	08:00					
24-Jan-00	08:00				30	

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
27-Jan-00	08:00				20	
31-Jan-00	08:00				16	
03-Feb-00	08:00					
07-Feb-00	08:00				30	
14-Feb-00	08:00				79	
17-Feb-00	08:00				20	
21-Feb-00	08:00				5	
24-Feb-00	08:00					
28-Feb-00	08:00				6	
02-Mar-00	08:00				65	
06-Mar-00	08:00					
09-Mar-00	08:00				10	
13-Mar-00	08:00				62	
16-Mar-00	08:00					
20-Mar-00	08:00				98	
23-Mar-00	08:00					
27-Mar-00	08:00				40	
31-Mar-00	08:00				64	
04-Apr-00	08:00					
06-Apr-00	08:00				10	
10-Apr-00	08:00					
13-Apr-00	08:00					
17-Apr-00	08:00					
20-Apr-00	08:00					
24-Apr-00	08:00					
27-Apr-00	08:00				12	
01-May-00	08:00					
04-May-00	08:00				65	
08-May-00	08:00					
11-May-00	08:00					
15-May-00	08:00					
18-May-00	08:00					
21-May-00	08:00					
25-May-00	08:00				7	
28-May-00	08:00				25	
01-Jun-00	08:00					
05-Jun-00	08:00	4944				
08-Jun-00	08:00	4964	6.67			
12-Jun-00	08:00	4989	6.25			
15-Jun-00	08:00	5009	6.67			
19-Jun-00	08:00	5034	6.25	6.46		
22-Jun-00	08:00	5054	6.67	6.46		
26-Jun-00	08:00	5074	5.00	6.15	2	
29-Jun-00	08:00	5094	6.67	6.15		
03-Jul-00	08:00	5119	6.25	6.15		
06-Jul-00	08:00	5139	6.67	6.15		
10-Jul-00	08:00	5156	4.25	5.96		
13-Jul-00	08:00	5176	6.67	5.96		
17-Jul-00	08:00	5186	2.50	5.02		
20-Jul-00	08:00	5216	10.00	5.85		
24-Jul-00	08:00	5242	6.50	6.42		
28-Jul-00	08:00	5257	3.75	5.69		
31-Jul-00	08:00	5289	10.67	7.73		
03-Aug-00	08:00	5299	3.33	6.06		

Ntsukangihlale 1

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
07-Aug-00	08:00	5334	8.75	6.63		
10-Aug-00	08:00	5354	6.67	7.35		
14-Aug-00	08:00	5382	7.00	6.44		
17-Aug-00	08:00	5392	3.33	6.44		
21-Aug-00	08:00	5436	11.00	7.00	2	
24-Aug-00	08:00	5446	3.33	6.17		
28-Aug-00	08:00	5456	2.50	5.04		
30-Aug-00	08:00	5484	14.00	7.71		
05-Sep-00	08:00	5560	12.67	8.13		
07-Sep-00	08:00	5575	7.50	9.17		
11-Sep-00	08:00	5585	2.50	9.17		
14-Sep-00	08:00	5595	3.33	6.50		
18-Sep-00	08:00	5615	5.00	4.58	8	
21-Sep-00	08:00	5670	18.33	7.29	79	
25-Sep-00	08:00	5687	4.25	7.73		
28-Sep-00	08:00	5697	3.33	7.73		
02-Oct-00	08:00	5707	2.50	7.10		
05-Oct-00	08:00	5713	2.00	3.02	6	
09-Oct-00	08:00	5723	2.50	2.58	12	
12-Oct-00	08:00	5733	3.33	2.58	3	
16-Oct-00	08:00	5743	2.50	2.58		
19-Oct-00	08:00	5754	3.67	3.00		
23-Oct-00	08:00	5769	3.75	3.31	46	
26-Oct-00	08:00	5779	3.33	3.31	11	
30-Oct-00	08:00	5784	1.25	3.00	7	
02-Nov-00	08:00	5790	2.00	2.58	8	
06-Nov-00	08:00	5810	5.00	2.90		
09-Nov-00	08:00	5820	3.33	2.90	10	

Nsukangihlale 2 - BERGVILLE

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
13-Jul-98	07:45 AM	0				
16-Jul-98	07:45 AM	5	1.67			
20-Jul-98	07:45 AM	12	1.75			
23-Jul-98	07:45 AM	18	2.00		2	
27-Jul-98	07:45 AM	25	1.75	1.79		
30-Jul-98	07:45 AM	30	1.67	1.79	1	
03-Aug-98	07:45 AM	37	1.75	1.79		
06-Aug-98	07:45 AM	42	1.67	1.71		
10-Aug-98	07:45 AM	49	1.75	1.71		
13-Aug-98	07:45 AM	54	1.67	1.71		
17-Aug-98	07:45 AM	60	1.50	1.65		
20-Aug-98	07:45 AM	65	1.67	1.65		
24-Aug-98	07:45 AM	71	1.50	1.58	4	
27-Aug-98	07:45 AM	76	1.67	1.58		
31-Aug-98	07:45 AM	82	1.50	1.58		
03-Sep-98	07:45 AM	87	1.67	1.58		
07-Sep-98	07:45 AM	92	1.25	1.52		
10-Sep-98	07:45 AM	97	1.67	1.52		
14-Sep-98	07:45 AM	102	1.25	1.46	3.5	
17-Sep-98	07:45 AM	106	1.33	1.38		
21-Sep-98	07:45 AM	112	1.50	1.44	3.5	
24-Sep-98	07:45 AM	116	1.33	1.35		
28-Sep-98	07:45 AM	122	1.50	1.42	10	
01-Oct-98	08:00 AM	129	2.33	1.66	7.5	
05-Oct-98	07:45 AM	137	2.01	1.79	8	
08-Oct-98	07:45 AM	142	1.67	1.87		
12-Oct-98	07:45 AM	149	1.75	1.94	19	
15-Oct-98	07:45 AM	158	3.00	2.11		
19-Oct-98	07:45 AM	168	2.50	2.23		
22-Oct-98	07:45 AM	176	2.67	2.48		
26-Oct-98	07:45 AM	188	3.00	2.79	2	
29-Oct-98	07:45 AM	196	2.67	2.71	2	
02-Nov-98	07:45 AM	203	1.75	2.52	9	
05-Nov-98	07:45 AM	210	2.33	2.44	7	
12-Nov-98	07:45 AM	226	2.29	2.26	9	
17-Nov-98	07:45 AM	231	1.00	1.84	105	
20-Nov-98	07:45 AM	252	7.00	3.15	1	
24-Nov-98	07:45 AM	298	11.50	5.45	8	
27-Nov-98	07:45 AM	319	7.00	6.63	71	
01-Dec-98	07:45 AM	396	19.25	11.19	35	
03-Dec-98	07:45 AM	423	13.50	12.81		
07-Dec-98	07:45 AM	490	16.75	14.13	11	
10-Dec-98	07:45 AM	545	18.33	16.96	29	
14-Dec-98	07:45 AM	629	21.00	17.40	46	
17-Dec-98	07:45 AM	661	10.67	16.69	7	
21-Dec-98	07:45 AM	711	12.50	15.62	4	
24-Dec-98	07:45 AM	755	14.67	14.71	3	
28-Dec-98	07:45 AM	799	11.00	12.21	8	
31-Dec-98	07:45 AM	820	7.00	11.29	7	
04-Jan-99	07:45 AM	845	6.25	9.73	71	
07-Jan-99	07:45 AM	885	13.33	9.40	32	
11-Jan-99	07:45 AM	933	12.00	9.65	14	

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
14-Jan-99	07:45 AM	973	13.33	11.23	4	
18-Jan-99	07:45 AM	1017	11.00	12.42	10	
21-Jan-99	07:45 AM	1051	11.33	11.92	5	
25-Jan-99	07:45 AM	1089	9.50	11.29	33	
28-Jan-99	07:45 AM	1116	9.00	10.21		
02-Feb-99	07:45 AM	1143	5.40	8.81	45	
04-Feb-99	07:45 AM	1165	11.00	8.73	42	
08-Feb-99	07:45 AM	1243	19.50	11.23	5	
11-Feb-99	07:45 AM	1297	18.00	13.48	31	
15-Feb-99	07:45 AM	1356	14.75	15.81	5	
18-Feb-99	07:45 AM	1407	17.00	17.31	44	
22-Feb-99	07:45 AM	1460	13.25	15.75	71	
25-Feb-99	07:45 AM	1498	12.67	14.42	3	
01-Mar-99	07:45 AM	1548	12.50	13.85		
04-Mar-99	07:45 AM	1588	13.33	12.94	1	
08-Mar-99	07:45 AM	1628	10.00	12.13		
11-Mar-99	07:45 AM	1645	5.67	10.38	8	
15-Mar-99	07:45 AM	1664	4.75	8.44	22	
18-Mar-99	07:45 AM	1678	4.67	6.27	21	
22-Mar-99	07:45 AM	1698	5.00	5.02	20	
25-Mar-99	07:45 AM	1706	2.67	4.27	2	
29-Mar-99	07:45 AM	1722	4.00	4.08		
01-Apr-99	07:45 AM	1733	3.67	3.83		
05-Apr-99	07:45 AM	1746	3.25	3.40	5	
08-Apr-99	07:45 AM	1756	3.33	3.56		
12-Apr-99	07:45 AM	1768	3.00	3.31	5	
15-Apr-99	07:45 AM	1777	3.00	3.15		
19-Apr-99	07:45 AM	1787	2.50	2.96		
22-Apr-99	07:45 AM	1795	2.67	2.79	4	
26-Apr-99	07:45 AM	1805	2.50	2.67	3	
29-Apr-99	07:45 AM	1814	3.00	2.67	20	
03-May-99	07:45 AM	1822	2.00	2.54		
06-May-99	07:45 AM	1829	2.33	2.46		
10-May-99	07:45 AM	1837	2.00	2.33		
13-May-99	07:45 AM	1844	2.33	2.17		
17-May-99	07:45 AM	1853	2.25	2.23		
20-May-99	07:45 AM	1859	2.00	2.15	10	
24-May-99	07:45 AM	1867	2.00	2.15	2	
27-May-99	07:45 AM	1873	2.00	2.06		
31-May-99	07:45 AM	1881	2.00	2.00		
03-Jun-99	07:45 AM	1886	1.67	1.92		
07-Jun-99	07:45 AM	1894	2.00	1.92		
10-Jun-99	07:45 AM	1900	2.00	1.92		
14-Jun-99	07:45 AM	1908	2.00	1.92		
17-Jun-99	07:45 AM	1913	1.67	1.92		
20-Jun-99	07:45 AM	1920	2.33	2.00	4	
24-Jun-99	07:45 AM	1926	1.50	1.88		
28-Jun-99	07:45 AM	1933	1.75	1.81		
01-Jul-99	07:45 AM	1938	1.67	1.81		
05-Jul-99	07:45 AM	1944	1.50	1.60		
08-Jul-99	07:45 AM	1949	1.67	1.65		
12-Jul-99	07:45 AM	1956	1.75	1.65		
15-Jul-99	07:45 AM	1960	1.33	1.56		
19-Jul-99	07:45 AM	1967	1.75	1.63		

Ntsukangihlale 2

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
22-Jul-99	07:45 AM	1971	1.33	1.54		
26-Jul-99	07:45 AM	1978	1.75	1.54		
29-Jul-99	07:45 AM	1983	1.67	1.63		
02-Aug-99	07:45 AM	1989	1.50	1.56		
05-Aug-99	07:45 AM	1994	1.67	1.65		
09-Aug-99	07:45 AM	1999	1.25	1.52		
12-Aug-99	07:45 AM	2004	1.67	1.52		
16-Aug-99	07:45 AM	2010	1.50	1.52		
19-Aug-99	07:45 AM	2014	1.33	1.44		
23-Aug-99	07:45 AM	2020	1.50	1.50		
26-Aug-99	07:45 AM	2024	1.33	1.42		
30-Aug-99	07:45 AM	2029	1.25	1.35		
02-Sep-99	07:45 AM	2033	1.33	1.35		
06-Sep-99	07:45 AM	2038	1.25	1.29		
09-Sep-99	07:45 AM	2042	1.33	1.29		
13-Sep-99	07:45 AM	2047	1.25	1.29		
16-Sep-99	07:45 AM	2051	1.33	1.29		
20-Sep-99	07:45 AM	2056	1.25	1.29		
23-Sep-99	07:45 AM	2059	1.00	1.21		
27-Sep-99	07:45 AM	2064	1.25	1.21	1	
30-Sep-99	07:45 AM	2068	1.33	1.21	3	
04-Oct-99	07:45 AM	2072	1.00	1.15		
07-Oct-99	07:45 AM	2076	1.33	1.23	8	
11-Oct-99	07:45 AM	2080	1.00	1.17		
14-Oct-99	07:45 AM	2083	1.00	1.08		
18-Oct-99	07:45 AM	2090	1.75	1.27		
21-Oct-99	07:45 AM	2095	1.67	1.35		
25-Oct-99	07:45 AM	2102	1.75	1.54		
28-Oct-99	07:45 AM	2107	1.67	1.71		
01-Nov-99	07:45 AM	2114	1.75	1.71		
04-Nov-99	07:45 AM	2119	1.67	1.71		
08-Nov-99	07:45 AM	2126	1.75	1.71		
11-Nov-99	07:45 AM	2131	1.67	1.71		
15-Nov-99	07:45 AM	2137	1.50	1.65	3	
18-Nov-99	07:45 AM	2141	1.33	1.56		
22-Nov-99	07:45 AM	2146	1.25	1.44		
25-Nov-99	07:45 AM	2149	1.00	1.27	16	
29-Nov-99	07:45 AM	2154	1.25	1.21	28	
02-Dec-99	07:45 AM	2160	2.00	1.38	34	
06-Dec-99	07:45 AM	2198	9.50	3.44	28	
09-Dec-99	07:45 AM	2213	5.00	4.44	7	
13-Dec-99	07:45 AM	2239	6.50	5.75	39	
16-Dec-99	07:45 AM	2284	15.00	9.00	2	
20-Dec-99	07:45 AM	2304	5.00	7.88	12	
23-Dec-99	07:45 AM	2338	11.33	9.46	49	
27-Dec-99	07:45 AM	2400	15.50	11.71	27	
30-Dec-99	07:45 AM	2435	11.67	10.88		
03-Jan-00	07:45 AM	2472	9.25	11.94	30	
06-Jan-00	07:45 AM	2504	10.67	11.77	12	
10-Jan-00	07:45 AM	2569	16.25	11.96	3	
13-Jan-00	07:45 AM	2596	9.00	11.29	36	
17-Jan-00	07:45 AM	2674	19.50	13.85	80	
20-Jan-00	07:45 AM	2730	18.67	15.85		
24-Jan-00	07:45 AM	2807	19.25	16.60	32	

Ntsukangihlale 2

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
27-Jan-00	07:45 AM	2835	9.33	16.69	19	
31-Jan-00	07:45 AM	2861	6.50	13.44		
03-Feb-00	07:45 AM	2880	6.33	10.35	25	
07-Feb-00	07:45 AM	2909	7.25	7.35	5	
10-Feb-00	07:45 AM	2925	5.33	6.35	25	
14-Feb-00	07:45 AM	2961	9.00	6.98	35	
17-Feb-00	07:45 AM	3003	14.00	8.90	21	
21-Feb-00	07:45 AM	3056	13.25	10.40	3	
24-Feb-00	07:45 AM	3100	14.67	12.73	12	
28-Feb-00	07:45 AM	3128	7.00	12.23		
02-Mar-00	07:45 AM	3146	6.00	10.23	64	
06-Mar-00	07:45 AM	3200	13.50	10.29	2	
09-Mar-00	07:45 AM	3258	19.33	11.46	5	
13-Mar-00	07:45 AM	3297	9.75	12.15	60	
16-Mar-00	07:45 AM	3329	10.67	13.31	10	
21-Mar-00	07:45 AM	3397	13.60	13.34	81	
23-Mar-00	07:45 AM	3419	11.00	11.25	5	
27-Mar-00	07:45 AM	3471	13.00	12.07	26	
30-Mar-00	07:45 AM	3511	13.33	12.73	29	
04-Apr-00	07:45 AM	3577	13.20	12.63	7	
06-Apr-00	07:45 AM	3603	13.00	13.13		
10-Apr-00	07:45 AM	3633	7.50	11.76		
13-Apr-00	07:45 AM	3649	5.33	9.76	4	
17-Apr-00	07:45 AM					
20-Apr-00	07:45 AM					
24-Apr-00	07:45 AM					
27-Apr-00	07:45 AM					
01-May-00	07:45 AM					
04-May-00	07:45 AM					
08-May-00	07:45 AM					
11-May-00	07:45 AM					
15-May-00	07:45 AM					
18-May-00	07:45 AM					
21-May-00	07:45 AM					
25-May-00	07:45 AM					
28-May-00	07:45 AM					
01-Jun-00	07:45 AM					
04-Jun-00	07:45 AM					
08-Jun-00	07:45 AM					
12-Jun-00	07:45 AM	3880				
15-Jun-00	07:45 AM	3889	3.00			
19-Jun-00	07:45 AM	3899	2.50			
22-Jun-00	07:45 AM	3906	2.33			
26-Jun-00	07:45 AM	3916	2.50	2.58		
29-Jun-00	07:45 AM	3922	2.00	2.33		
03-Jul-00	07:45 AM	3931	2.25	2.27		
06-Jul-00	07:45 AM	3937	2.00	2.19		
10-Jul-00	07:45 AM	3945	2.00	2.06		
13-Jul-00	07:45 AM	3957	4.00	2.56		
17-Jul-00	07:45 AM	3960	0.75	2.19		
20-Jul-00	07:45 AM	3966	2.00	2.19		
24-Jul-00	07:45 AM	3974	2.00	2.19		
27-Jul-00	07:45 AM	3979	1.67	1.60		
31-Jul-00	07:45 AM	3987	2.00	1.92		

Date	Time	Cum. Vol	Flow rate	14 day av	Rainfall
		(cubic m)	m3/d	m3/d	(mm)
03-Aug-00	07:45 AM	3998	3.67	2.33	
07-Aug-00	07:45 AM	3999	0.25	1.90	
10-Aug-00	07:45 AM	4004	1.67	1.90	
14-Aug-00	07:45 AM	4011	1.75	1.83	
17-Aug-00	07:45 AM	4016	1.67	1.33	
21-Aug-00	07:45 AM	4022	1.50	1.65	
24-Aug-00	07:45 AM	4027	1.67	1.65	
28-Aug-00	07:45 AM	4034	1.75	1.65	
31-Aug-00	07:45 AM	4039	1.67	1.65	
04-Sep-00	07:45 AM	4046	1.75	1.71	
07-Sep-00	07:45 AM	4051	1.67	1.71	
11-Sep-00	07:45 AM	4058	1.75	1.71	
14-Sep-00	07:45 AM	4063	1.67	1.71	
18-Sep-00	07:45 AM	4069	1.50	1.65	14
21-Sep-00	07:45 AM	4084	5.00	2.48	65
25-Sep-00	07:45 AM	4108	6.00	3.54	
28-Sep-00	07:45 AM	4118	3.33	3.96	
02-Oct-00	07:45 AM	4128	2.50	4.21	
05-Oct-00	07:45 AM	4134	2.00	3.46	8
09-Oct-00	07:45 AM	4144	2.50	2.58	11
12-Oct-00	07:45 AM	4150	2.00	2.25	2
16-Oct-00	07:45 AM	4158	2.00	2.13	
19-Oct-00	07:45 AM	4164	2.00	2.13	
23-Oct-00	07:45 AM	4174	2.50	2.13	43
26-Oct-00	07:45 AM	4186	4.00	2.63	17
30-Oct-00	07:45 AM	4199	3.25	2.94	5
02-Nov-00	07:45 AM	4208	3.00	3.19	2
06-Nov-00	07:45 AM	4218	2.50	3.19	
09-Nov-00	07:45 AM	4225	2.33	2.77	8

Sixuzulu - Transkei

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
27-Aug-98	11:00 AM	0	0.00			
03-Sep-98	09:20 AM	112	16.16			
05-Sep-98	08:48 AM	144	16.18			
12-Sep-98	06:30 AM	255	16.08			
13-Sep-98	05:20 PM	273	12.40	15.20		
18-Sep-98	11:30 AM	352	16.61	15.32	3	
19-Sep-98	04:12 PM	371	15.89	15.24		
25-Sep-98	02:15 PM	466	16.05	15.24	2	
27-Sep-98	03:20 PM	496	14.67	15.80		
29-Sep-98	02:30 PM	530	17.30	15.98	1	
02-Oct-98	02:48 PM	579	16.27	16.07	14	
08-Oct-98	12:30 PM	669	15.24	15.87	1	
12-Oct-98	05:30 PM	734	15.45	16.06	7	
15-Oct-98	02:10 PM	776	14.68	15.41	16	
19-Oct-98	06:45 PM	840	15.27	15.16	2	
22-Oct-98	06:10 PM	885	15.12	15.13	1	
25-Oct-98	04:20 PM	925	13.68	14.69		
28-Oct-98	05:35 PM	966	13.43	14.38	4	
01-Nov-98	08:35 AM	1014	13.24	13.87		
04-Nov-98	05:30 PM	1064	14.83	13.80	9	
12-Nov-98	08:10 AM	1159	12.48	13.50	6	
15-Nov-98	07:50 AM	1190	10.38	12.73	2	
19-Nov-98	11:25 AM	1243	12.77	12.62	49	
22-Nov-98	10:20 AM	1278	11.84	11.87	2	
26-Nov-98	09:10 AM	1324	11.64	11.66	87	
29-Nov-98	10:15 AM	1354	9.85	11.53		
02-Dec-98	08:10 AM	1394	13.73	11.77	39	
05-Dec-98	02:20 PM	1439	13.82	12.26	32	
08-Dec-98	11:20 AM	1482	14.96	13.09	10	
12-Dec-98	09:20 AM	1544	15.83	14.58	7	
15-Dec-98	03:42 PM	1590	14.09	14.67	46	
19-Dec-98	07:20 AM	1654	17.53	15.60	16	
23-Dec-98	09:35 AM	1719	15.88	15.83	86	
27-Dec-98	11:10 AM	1784	15.99	15.87	40	
01-Jan-99	07:05 AM	1867	17.18	16.64	32	
05-Jan-99	10:20 AM	1928	14.75	15.95	44	
09-Jan-99	01:20 PM	1993	15.76	15.92		
13-Jan-99	11:15 AM	2052	15.08	15.69	86	
17-Jan-99	10:20 AM	2138	21.71	16.82	2	
21-Jan-99	09:35 AM	2246	27.21	19.94		
25-Jan-99	08:24 AM	2361	29.11	23.28		
29-Jan-99	10:05 AM	2453	22.60	25.16	58	
03-Feb-99	07:10 AM	2504	10.45	22.34	14	
08-Feb-99	08:05 AM	2559	10.92	18.27	3	
11-Feb-99	07:20 AM	2628	23.24	16.80		
15-Feb-99	10:05 AM	2725	23.57	17.05	21	
19-Feb-99	11:45 AM	2808	20.40	19.53	32	
24-Feb-99	09:05 AM	2830	4.50	17.93	21	broken pipe
26-Feb-99	07:45 AM	2881	26.23	18.67		
28-Feb-99	06:10 PM	2967	35.33	21.61	1	
04-Mar-99	07:40 AM	3038	19.93	21.50	2	
08-Mar-99	06:35 AM	3123	21.49	25.75		

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
10-Mar-99	04:10 PM	3171	20.01	24.19	17	
14-Mar-99	07:05 AM	3246	20.71	20.53	16	
18-Mar-99	07:50 AM	3328	20.34	20.64	3	
21-Mar-99	08:10 AM	3386	19.24	20.08	25	
25-Mar-99	05:15 PM	3478	21.01	20.33	8	
31-Mar-99	09:20 AM	3600	21.52	20.53	5	
05-Apr-99	08:40 AM	3698	19.71	20.37		
12-Apr-99	09:45 AM	3830	18.74	20.24	15	
17-Apr-99	07:25 AM	3920	18.36	19.58	8	
21-Apr-99	09:10 AM	3993	17.92	18.68	3	
24-Apr-99	10:05 AM	4048	18.10	18.28		
26-Apr-99	09:15 AM	4084	18.32	18.18		
29-Apr-99	11:20 AM	4224	45.35	24.92		
07-May-99	12:45 PM	4224	0.00	20.44		broken pipe
12-May-99	09:05 AM	4289	13.41	19.27	10	
13-May-99	08:40 AM	4307	18.32	19.27		
15-May-99	10:20 AM	4368	29.48	15.30		
22-May-99	08:00 AM	4384	2.32	15.88		
29-May-99	11:10 AM	4402	2.52	13.16	14	broken pipe
01-Jun-99	03:20 PM	4471	21.74	14.02		
08-Jun-99	03:00 PM	4585	16.32	10.73		
14-Jun-99	05:05 PM	4681	15.77	14.09	10	
16-Jun-99	04:10 PM	4713	16.31	17.54		
18-Jun-99	02:45 PM	4739	13.40	15.45		broken pipe
26-Jun-99	09:00 AM	4850	14.30	14.95		
04-Jul-99	09:00 AM	4965	14.38	14.60		
12-Jul-99	09:20 AM	5087	15.22	14.32		
17-Jul-99	09:00 AM	5165	15.64	14.89		
22-Jul-99	09:00 AM	5243	15.60	15.21		
31-Jul-99	04:10 PM	5399	16.78	15.81	7	
07-Aug-99	09:05 AM	5491	13.72	15.44		
10-Aug-99	09:40 AM	5539	15.87	15.40		
13-Aug-99	09:50 AM	5588	16.30	15.67		
16-Aug-99	09:30 AM	5620	10.72	14.15		
19-Aug-99	09:10 AM	5664	14.73	14.40		
23-Aug-99	09:50 AM	5732	16.88	14.66		
26-Aug-99	09:30 AM	5778	15.40	14.43		
30-Aug-99	09:20 AM	5848	17.53	16.14		
02-Sep-99	10:10 AM	5896	15.82	16.41		
06-Sep-99	09:40 AM	5967	17.84	16.65		
09-Sep-99	09:10 AM	6001	11.41	15.65		
12-Sep-99	09:50 AM	6043	13.87	14.74		
15-Sep-99	10:15 AM	6083	13.26	14.10		
18-Sep-99	09:20 AM	6121	12.83	12.84		
21-Sep-99	09:05 AM	6157	12.04	13.00		
24-Sep-99	10:10 AM	6195	12.48	12.65	9	
27-Sep-99	09:45 AM	6234	13.08	12.61		
29-Sep-99	12:10 PM	6253	9.04	11.86		
04-Oct-99	04:40 PM	6327	14.27	12.22	9	
08-Oct-99	08:35 AM	6379	14.20	12.65	9	
11-Oct-99	09:20 AM	6414	11.55	12.26	2	
15-Oct-99	09:05 AM	6454	10.03	12.51		
18-Oct-99	05:10 PM	6516	18.58	13.59	22	
27-Oct-99	09:10 AM	6628	12.92	13.27	60	

Sixuzulu

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
29-Oct-99	08:10 AM	6657	14.81	14.08		
31-Oct-99	07:45 AM	6684	13.62	14.98	2	
05-Nov-99	08:20 AM	6756	14.33	13.92	1	
13-Nov-99	08:00 AM	6882	15.78	14.63		
21-Nov-99	09:00 AM	7002	14.92	14.66		
30-Nov-99	06:10 PM	7128	13.43	14.62	35	
06-Dec-99	06:20 PM	7211	13.82	14.49	10	
13-Dec-99	09:20 AM	7306	14.34	14.13		
18-Dec-99	09:00 AM	7329	4.61	11.55		
24-Dec-99	06:00 PM	7338	1.41	8.55	59	broken pipe
31-Dec-99	06:00 PM	7388	7.14	6.88	47	
06-Jan-00	09:10 AM	7463	13.32	6.62	70	
10-Jan-00	04:25 PM	7523	13.95	8.95	15	
18-Jan-00	06:00 PM	7763	29.75	16.04	125	
25-Jan-00	08:45 AM	7934	25.85	20.72	23	
30-Jan-00	06:00 AM	7984	10.23	19.95		
03-Feb-00	06:00 PM	8062	17.33	20.79	61	broken pipe
10-Feb-00	06:00 PM	8305	34.71	22.03	5	
14-Feb-00	06:00 PM	8456	37.75	25.01	100	
19-Feb-00	06:00 PM	8634	35.60	31.35		
23-Feb-00	06:00 PM	8786	38.00	36.52	53	
28-Feb-00	06:00 PM	8976	38.00	37.34		
03-Mar-00	08:10 AM	9109	37.04	37.16	71	
10-Mar-00	03:05 PM	9383	37.60	37.66	18	
18-Mar-00	02:00 PM	9670	36.08	37.18		
25-Mar-00	06:00 PM	9964	41.02	37.94	125	
30-Mar-00	06:00 PM	10145	36.20	37.72		
04-Apr-00	06:00 PM	10318	34.60	36.98	50	
09-Apr-00	06:00 PM	10482	32.80	36.16		
14-Apr-00	10:20 AM	10645	34.82	34.61	74	
20-Apr-00	06:00 PM	10853	32.91	33.78		
27-Apr-00	02:20 PM	11059	30.09	32.66	14	
30-Apr-00	11:45 AM	11145	29.73	31.89	4	
07-May-00	02:10 PM	11331	26.19	29.73	16	
12-May-00	09:00 AM	11455	25.92	27.98		
16-May-00	11:00 AM	11560	25.71	26.89		
21-May-00	09:00 AM	11678	24.00	25.46		
25-May-00	11:00 AM	11785	26.20	25.46		
30-May-00	09:00 AM	11896	22.58	24.62		
03-Jun-00	01:20 PM	12001	25.12	24.47	14	
09-Jun-00	11:00 AM	12188	31.68	26.39		
16-Jun-00	09:20 AM	12406	31.45	27.71		
23-Jun-00	09:00 AM	12550	20.61	27.22		
30-Jun-00	09:00 AM	12694	20.57	26.08		
06-Jul-00	09:00 AM	12818	20.67	23.33		
13-Jul-00	09:00 AM	12962	20.57	20.61		
20-Jul-00	09:00 AM	13106	20.57	20.60		
26-Jul-00	09:00 AM	13230	20.67	20.62		
31-Jul-00	09:00 AM	13334	20.80	20.65	8	
08-Aug-00	09:00 AM	13502	21.00	20.76		
15-Aug-00	09:00 AM	13668	23.71	21.55		
23-Aug-00	09:00 AM	13830	20.25	21.44		
31-Aug-00	03:00 PM	14011	21.94	21.73		
07-Sep-00	03:10 PM	14160	21.26	21.79		

Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
12-Sep-00	11:00 AM	14280	24.86	22.08		
16-Sep-00	09:00 AM	14385	26.81	23.72		
21-Sep-00	11:00 AM	14498	22.23	23.79		
26-Sep-00	02:20 PM	14611	21.99	23.97	65	
28-Sep-00	05:30 PM	14662	23.92	23.74		
30-Sep-00	04:45 PM	14744	41.65	27.45		

MACOSA - TRANSKEI

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
27-Aug-98	07:00 AM	0	0.00			
30-Aug-98	07:00 AM	21	7.00			
06-Sep-98	07:00 AM	142	17.29		1	
13-Sep-98	07:00 AM	252	15.71	10.00	8	
20-Sep-98	07:00 AM	364	16.00	14.00	3	
27-Sep-98	07:00 AM	465	14.43	15.86	3	
29-Sep-98	07:00 AM	492	13.50	14.91		
01-Oct-98	06:20 AM	511	9.63	13.39	1	
04-Oct-98	07:10 AM	561	16.48	13.51	5	
07-Oct-98	08:50 AM	609	15.64	13.81	2	
11-Oct-98	07:20 AM	663	13.71	13.87	5	
15-Oct-98	06:30 AM	721	14.63	15.11	4	
18-Oct-98	06:50 AM	764	14.27	14.56	7	
22-Oct-98	07:10 AM	829	16.19	14.70		
25-Oct-98	08:50 AM	869	13.03	14.53		
28-Oct-98	06:30 AM	913	15.16	14.66	10	
30-Oct-98	07:00 AM	943	14.85	14.81		
04-Nov-98	07:45 AM	999	11.13	13.54	8	
08-Nov-98	07:45 AM	1058	14.75	13.97	2	
12-Nov-98	07:30 AM	1123	16.29	14.25		
15-Nov-98	06:50 AM	1154	10.43	13.15		
18-Nov-98	06:45 AM	1192	12.68	13.54	20	
22-Nov-98	07:10 AM	1226	8.46	11.97	22	
25-Nov-98	06:30 AM	1251	8.41	10.00	10	
29-Nov-98	06:10 AM	1289	9.53	9.77	75	
02-Dec-98	06:30 AM	1314	8.29	8.68	20	
06-Dec-98	06:10 AM	1360	11.54	9.44	20	
09-Dec-98	06:20 AM	1377	5.65	8.76	17	
12-Dec-98	06:40 AM	1398	6.97	8.11	10	
17-Dec-98	06:21 AM	1400	0.40	6.14	8	
22-Dec-98	06:30 AM	1444	8.79	5.45		
27-Dec-98	06:20 AM	1473	5.81	5.49	44	
31-Dec-98	11:45 AM	1495	5.21	5.05	6	
05-Jan-99	06:30 AM	1570	15.69	8.87	70	
09-Jan-99	06:30 AM	1621	12.75	9.86		
13-Jan-99	06:30 AM	1672	12.75	11.60	86	
17-Jan-99	06:30 AM	1723	12.75	13.48	2	
21-Jan-99	06:30 AM	1774	12.75	12.75		
25-Jan-99	06:30 AM	1825	12.75	12.75		
29-Jan-99	06:30 AM	1876	12.75	12.75	58	
04-Feb-99	10:30 AM	1953	12.49	12.68	15	
07-Feb-99	06:10 AM	1995	14.90	13.22		
11-Feb-99	09:40 AM	2089	22.67	15.70		
14-Feb-99	06:40 AM	2112	8.00	14.51		
17-Feb-99	11:10 AM	2163	16.00	15.39	54	
21-Feb-99	09:15 AM	2223	15.31	15.49		
24-Feb-99	06:30 AM	2269	15.94	13.81		
27-Feb-99	07:10 AM	2338	22.79	17.51	5	
03-Mar-99	07:40 AM	2394	13.93	16.99		
06-Mar-99	07:10 AM	2475	27.19	19.96	20	
11-Mar-99	06:40 AM	2516	8.23	18.03	5	
14-Mar-99	07:50 AM	2560	14.43	15.95		

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
17-Mar-99	07:15 AM	2612	17.47	16.83	20	
21-Mar-99	06:10 AM	2670	14.67	13.70	15	
25-Mar-99	07:15 AM	2718	11.87	14.61		
28-Mar-99	09:15 AM	2729	3.57	11.89		
31-Mar-99	08:20 AM	2805	25.66	13.94		
04-Apr-99	07:10 AM	2875	17.72	14.70		
06-Apr-99	08:40 AM	2905	14.55	15.37	25	
11-Apr-99	08:10 AM	2989	16.87	18.70		
15-Apr-99	12:00 PM	3045	13.46	15.65	15	
18-Apr-99	08:50 AM	3078	11.51	14.10		
22-Apr-99	07:15 AM	3135	14.49	14.08		
25-Apr-99	07:50 AM	3188	17.52	14.25		
28-Apr-99	08:40 AM	3215	8.90	13.10		
02-May-99	08:10 AM	3265	12.57	13.37		
05-May-99	07:00 AM	3292	9.15	12.03	2	
09-May-99	09:40 AM	3341	11.92	10.63		
13-May-99	09:05 AM	3368	6.79	10.11	15	
17-May-99	09:40 AM	3397	7.21	8.77	2	
19-May-99	10:05 AM	3401	1.98	6.97	2	
23-May-99	11:10 AM	3441	9.89	6.47		
24-May-99	11:20 AM	3463	21.85	10.23		
31-May-99	12:30 PM	3520	8.09	10.45		
03-Jun-99	09:30 AM	3545	8.70	12.13		
05-Jun-99	08:10 AM	3595	25.71	16.09		
08-Jun-99	07:40 AM	3611	5.37	11.97		
13-Jun-99	10:10 AM	3661	9.80	12.39		
15-Jun-99	09:05 AM	3672	5.63	11.63		
17-Jun-99	09:30 AM	3703	15.37	9.04		
20-Jun-99	11:10 AM	3735	10.43	10.30		
21-Jun-99	09:40 AM	3758	24.53	13.99	20	blocked pipe
23-Jun-99	11:10 AM	3758	0.00	12.58		
29-Jun-99	09:30 AM	3838	13.49	12.11		
01-Jul-99	08:20 AM	3843	2.56	10.15		
04-Jul-99	07:30 AM	3896	17.87	8.48		
07-Jul-99	09:40 AM	3902	1.94	8.97		meter out of orde
12-Jul-99	09:00 AM	3981	15.89	9.57		
18-Jul-99	07:20 AM	4073	15.51	12.80		
23-Jul-99	09:00 AM	4073	0.00	8.34		
28-Jul-99	09:00 AM	4073	0.00	7.85		
03-Aug-99	09:00 AM	4073	0.00	3.88		
08-Aug-99	09:00 AM	4073	0.00	0.00		
13-Aug-99	09:00 AM	4073	0.00	0.00		
18-Aug-99	06:30 AM	4073	0.00	0.00		
27-Aug-99	07:10 AM	4073	0.00	0.00		
29-Aug-99	09:20 AM	4073	0.00	0.00		
01-Sep-99	08:10 AM	4073	0.00	0.00	5	
05-Sep-99	07:40 AM	4089	4.02	1.01		
12-Sep-99	07:10 AM	4100	1.58	1.40		
14-Sep-99	08:15 AM	4115	7.33	3.23		
19-Sep-99	10:30 AM	4143	5.50	4.61	3	
23-Sep-99	11:45 AM	4194	12.59	6.75	5	
27-Sep-99	07:20 AM	4255	15.99	10.35	2	
29-Sep-99	08:40 AM	4294	18.97	13.26		
04-Oct-99	08:40 AM	4370	15.20	15.69	8	

Date	Time	Cum. Vol (cubic m)	Flow m3/d	14 day av m3/d	Rainfall (mm)	Explanation
06-Oct-99	07:15 AM	4397	13.91	16.02		
10-Oct-99	08:20 AM	4472	18.54	16.66	15	
14-Oct-99	08:15 AM	4532	15.01	15.67		
18-Oct-99	07:20 AM	4590	14.64	15.53		
20-Oct-99	08:15 AM	4631	20.12	17.08	20	
24-Oct-99	07:25 AM	4692	15.38	16.29	20	
26-Oct-99	07:10 AM	4712	10.05	15.05	15	
31-Oct-99	10:45 AM	4763	9.90	13.86	10	
01-Nov-99	07:20 AM	4771	9.33	11.17		
05-Nov-99	08:25 AM	4862	22.50	12.95		
10-Nov-99	07:30 AM	4921	11.89	13.40	5	
14-Nov-99	06:21 AM	4993	18.22	15.48		
16-Nov-99	07:45 AM	5009	7.77	15.09	5	
21-Nov-99	06:10 AM	5109	20.27	14.54	19	
23-Nov-99	07:15 AM	5127	8.80	13.77		
29-Nov-99	06:40 AM	5224	16.01	13.21	34	
02-Dec-99	07:40 AM	5271	15.89	15.24		
06-Dec-99	08:45 AM	5334	15.57	14.07	20	
08-Dec-99	09:50 AM	5375	20.05	16.88		
13-Dec-99	07:40 AM	5448	14.87	16.59	10	
16-Dec-99	07:35 AM	5496	16.02	16.63		
19-Dec-99	07:15 AM	5583	29.13	20.02	15	
23-Dec-99	08:06 AM	5610	6.69	16.68	20	
31-Dec-99	07:15 AM	5742	16.57	17.10	15	
04-Jan-00	07:40 AM	5823	20.16	18.14	30	
11-Jan-00	06:20 AM	5938	16.56	15.00		
15-Jan-00	07:10 AM	5975	9.17	15.62	30	
22-Jan-00	07:50 AM	6082	15.23	15.28	25	
29-Jan-00	07:35 AM	6207	17.88	14.71	30	
05-Feb-00	07:45 AM	6329	17.41	14.92	110	
10-Feb-00	07:10 AM	6415	17.28	16.95		
15-Feb-00	07:40 AM	6500	16.93	17.38		
17-Feb-00	07:35 AM	6572	36.06	21.92	25	
21-Feb-00	06:45 AM	6667	23.96	23.56	30	
24-Feb-00	08:10 AM	6732	21.25	24.55	45	
02-Mar-00	07:15 AM	6849	16.81	24.52	30	
10-Mar-00	07:10 AM	6914	8.13	17.54		
18-Mar-00	07:40 AM	7118	25.43	17.90	86	
23-Mar-00	07:45 AM	7165	9.39	14.94		
30-Mar-00	07:50 AM	7203	5.43	12.10	55	
04-Apr-00	07:20 AM	7233	6.03	11.57		
09-Apr-00	07:15 AM	7267	6.80	6.91	35	
13-Apr-00	07:20 AM	7299	7.99	6.56	25	
18-Apr-00	06:45 AM	7379	16.08	9.23	20	
20-Apr-00	08:10 AM	7395	7.77	9.66	15	
27-Apr-00	07:45 AM	7486	13.03	11.22		
30-Apr-00	07:30 AM	7596	36.79	18.42		
07-May-00	07:30 AM	7852	36.57	23.54	16	
14-May-00	07:30 AM	7977	17.86	26.06		
21-May-00	07:30 AM	8105	18.29	27.38		
28-May-00	07:30 AM	8232	18.14	22.71		
03-Jun-00	07:30 AM	8352	20.00	18.57	14	
10-Jun-00	07:30 AM	8445	13.29	17.43		
16-Jun-00	07:30 AM	8536	15.17	16.65		

Date	Time	Cum. Vol	Flow	14 day av	Rainfall	Explanation
		(cubic m)	m3/d	m3/d	(mm)	
22-Jun-00	07:30 AM	8625	14.83	15.82		
29-Jun-00	07:30 AM	8726	14.43	14.43		
06-Jul-00	07:30 AM	8814	12.57	14.25		
13-Jul-00	07:30 AM	8916	14.57	14.10		
19-Jul-00	07:30 AM	9002	14.33	13.98		
26-Jul-00	07:30 AM	9106	14.86	14.08		
31-Jul-00	07:30 AM	9198	18.40	15.54		
05-Aug-00	07:30 AM	9273	15.00	15.65		
10-Aug-00	07:30 AM	9349	15.20	15.86		
15-Aug-00	07:30 AM	9426	15.40	16.00		
20-Aug-00	07:30 AM	9499	14.60	15.05		
25-Aug-00	07:30 AM	9576	15.40	15.15		
31-Aug-00	09:30 AM	9643	11.01	14.10		
02-Sep-00	07:10 AM	9727	44.15	21.29		
07-Sep-00	07:21 AM	9807	15.98	21.63		
09-Sep-00	08:20 AM	9845	18.62	22.44		
17-Sep-00	07:30 AM	9985	17.58	24.08	15	
20-Sep-00	07:15 AM	10017	10.70	15.72	90	
24-Sep-00	07:50 AM	10098	20.13	16.76		
26-Sep-00	07:45 AM	10101	1.50	12.48		
02-Oct-00	08:15 AM	10198	16.11	12.11		

APPENDIX D

DESCRIPTION OF SPRINGS MONITORED

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION - Nkalokazi Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Umzumbe - Hibberdene
	Local Council	Uqoloqolo
	Community name	Nkalokazi
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	3030CB Port Shepstone
	Longitude	30° 28' 18.5"
	Latitude	30° 33' 59"
	Altitude	138 m
3. Community References		
	Contact person	Mr Shezi
	Chief/Induna	Mr Khumalo
	Local Councillor	
	Population	± 1000
	No. of households	± 170
4. Spring Details	topographical setting	Catchment head/valley side
	Spring regime	non-perennial
	Vegetation above spring	Grasslands/cultivation/bush/
	Agriculture above spring	Ploughed fields/small plantation/grazing/
	Forestation above spring	Indigenous/eucalyptus
	Geological formations	Granites and weathered granites
	Land degradation	Mild

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	0.46 x 10^6 m^3
no. of families using spring	± 15
other springs from aquifer?	Yes – estimated as tapping 50% of storage
% of flow captured (estimate)	80
6. Type of spring and spring development	
Type of spring	Type A / B (see sketches)
Spring protection	Spring box + underground collectors
Pipeline	HDPE
Reservoir	10,000 ℓ plastic
Taps	Single
7. Technical problems	
Spring protection	Spring box not covered + fence removed
Pipelines	
Reservoir	Cement covering flaking off
Taps	Does not close – water leaks permanently
Pollution	Cattle grazing in spring catchment wetland
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	None
Other water sources	Other springs + KwaMalukaka River
Involvement of chief/TLC	Informed
Attitude towards spring	No responsibility or desire to maintain
9. Support institutions	
Contractor which developed spring:	Lima
Ongoing support from:	
10. Recommended additional work	Tap should be repaired and fence around spring improved and repaired
11. Other comments	The storage capacity in the catchment is limited, and the spring can be expected to dry up during the dry season on an annual basis.

Name of Responsible Officer: ______________________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION - Sidlodwana Mountain Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Umzumbe - Hibberdene
	Local Council	Uqoloqolo
	Community name	Nkalokazi
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	3030CB Port Shepstone
	Longitude	30° 28' 55"
	Latitude	30° 34' 32"
	Altitude	110 m
3. Community References		
	Contact person	Mr Shezi
	Chief/Induna	Mr Khumalo
	Local Councillor	
	Population	± 1000
	No. of households	± 170
4. Spring Details	topographical setting	Catchment head/valley side
	Spring regime	Non-perennial
	Vegetation above spring	Grasslands/cultivation/bush/
	Agriculture above spring	Grazing
	Forestation above spring	Indigenous
	Geological formations	Granites and weathered granites
	Land degradation	Mild

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	0.30×10^6 m^3
no. of families using spring	± 10
other springs from aquifer?	Yes – estimated as tapping 60% of storage
% of flow captured (estimate)	60
6. Type of spring and spring development	
Type of spring	Type A / B (see sketches)
Spring protection	Spring box - replaced with underground collectors
Pipeline	HDPE
Reservoir	10,000 ℓ plastic
Taps	Single
7. Technical problems	
Spring protection	Spring box not properly developed – resulting in blocks. Consequently replaced with seepage collectors.
Pipelines	
Reservoir	
Taps	
Pollution	Minimal
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	None
Other water sources	Other springs + KwaMalukaka River
Involvement of chief/TLC	Informed
Attitude towards spring	Users responsible and prepared to maintain
9. Support institutions	
Contractor which developed spring:	Lima
Ongoing support from:	
10. Recommended additional work	Tank should be covered (plastered), seepage field should be improved.
11. Other comments	The storage capacity in the catchment is limited, and the spring can be expected to dry up during the dry season on an annual basis.

Name of Responsible Officer: ______________________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION - Jollivet Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Jollivet – Highflats
	Local Council	Highflats
	Community name	Jollivet
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	3030AD Jollivet
	Longitude	30° 19' 10"
	Latitude	30° 17' 43"
	Altitude	940 m
3. Community References		
	Contact person	
	Chief/Induna	
	Local Councillor	
	Population	± 1500
	No. of households	± 220
4. Spring Details	topographical setting	Catchment head
	Spring regime	perennial
	Vegetation above spring	Grasslands/cultivation/bush/houses
	Agriculture above spring	Ploughed fields/grazing
	Forestation above spring	Indigenous
	Geological formations	Table Mountain Sandstones/Impervious intrusions
	Land degradation	Mild

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	$5.1 \times 10^6 m^3$
no. of families using spring	± 60
other springs from aquifer?	Yes – estimated as tapping 50% of storage
% of flow captured (estimate)	60
6. Type of spring and spring development	
Type of spring	Type A / B (see sketches)
Spring protection	Spring box + underground collectors
Pipeline	HDPE + galvanised
Reservoir	50,000 ℓ concrete + 10,000 ℓ concrete
Taps	Multiple
7. Technical problems	
Spring protection	Spring box damaged + fence removed
Pipelines	Pipelines damaged and cut at places
Reservoir	
Taps	
Pollution	Cattle grazing in spring catchment wetland
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	None
Other water sources	Other springs
Involvement of chief/TLC	
Attitude towards spring	No responsibility or desire to maintain
9. Support institutions	
Contractor which developed spring:	
Ongoing support from:	
10. Recommended additional work	Fence around spring improved and repaired, collector systems repaired, pipelines repaired and supported
11. Other comments	

Name of Responsible Officer: ______________________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION - Makwabe Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Upper Tugela – Bergville
	Local Council	
	Community name	Manduluza
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	2829CD Zunckels
	Longitude	29° 19' 39"
	Latitude	28° 53' 09"
	Altitude	1470 m
3. Community References		
	Contact person	
	Chief/Induna	
	Local Councillor	
	Population	± 800
	No. of households	± 120
4. Spring Details	topographical setting	Catchment head/valley side
	Spring regime	Perennial
	Vegetation above spring	Grasslands/bush/invasive wattle
	Agriculture above spring	Grazing
	Forestation above spring	Non-indigenous
	Geological formations	Sandstones and mudstones with dolerite intrusions
	Land degradation	Mild

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	0.75×10^6 m^3
no. of families using spring	± 15
other springs from aquifer?	Yes – estimated as tapping 80% of storage
% of flow captured (estimate)	80
6. Type of spring and spring development	
Type of spring	Type A / B (see sketches)
Spring protection	Spring box
Pipeline	HDPE
Reservoir	5,000 ℓ ferro-cement
Taps	2 sets of double taps
7. Technical problems	
Spring protection	Constructed in stream bed, with surface intrusion during rain
Pipelines	Not well buried, resulting in leaks caused by cattle
Reservoir	
Taps	
Pollution	Some during rain
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	None
Other water sources	Other springs
Involvement of chief/TLC	
Attitude towards spring	Users responsible but do not repair when problems
9. Support institutions	
Contractor which developed spring:	DWAF
Ongoing support from:	
10. Recommended additional work	Pipeline should be buried properly, + rain trench dug around spring.
11. Other comments	

Name of Responsible Officer: ______________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION - Kholakazana Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Upper Tugela – Bergville
	Local Council	
	Community name	Manduluza
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	2829CD Zunckels
	Longitude	29° 19' 40"
	Latitude	28° 53' 22"
	Altitude	1440 m
3. Community References		
	Contact person	
	Chief/Induna	
	Local Councillor	
	Population	± 800
	No. of households	± 120
4. Spring Details	topographical setting	Catchment head
	Spring regime	Perennial
	Vegetation above spring	Grasslands/bush/invasive wattle
	Agriculture above spring	Grazing
	Forestation above spring	Non-indigenous + some indigenous
	Geological formations	Sandstones and mudstones with dolerite intrusions
	Land degradation	Mild

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	1.5×10^6 m^3
no. of families using spring	± 15
other springs from aquifer?	Yes – estimated as tapping 80% of storage
% of flow captured (estimate)	90
6. Type of spring and spring development	
Type of spring	Type A (see sketches)
Spring protection	Spring box
Pipeline	HDPE
Reservoir	5,000 ℓ ferro-cement
Taps	1 set of double taps
7. Technical problems	
Spring protection	
Pipelines	
Reservoir	
Taps	
Pollution	
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	None
Other water sources	Other springs
Involvement of chief/TLC	
Attitude towards spring	Users responsible but do not repair when problems
9. Support institutions	
Contractor which developed spring:	DWAF
Ongoing support from:	
10. Recommended additional work	
11. Other comments	

Name of Responsible Officer: ______________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION – Kholakazana 2 Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Upper Tugela – Bergville
	Local Council	
	Community name	Manduluza
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	2829CD Zunckels
	Longitude	29° 19' 50"
	Latitude	28° 53' 30"
	Altitude	1420 m
3. Community References		
	Contact person	
	Chief/Induna	
	Local Councillor	
	Population	± 800
	No. of households	± 120
4. Spring Details	topographical setting	Catchment head
	Spring regime	Perennial
	Vegetation above spring	Grasslands/bush/invasive wattle
	Agriculture above spring	Grazing
	Forestation above spring	Non-indigenous + some indigenous
	Geological formations	Sandstones and mudstones with dolerite intrusions
	Land degradation	Mild

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	3.5×10^6 m^3
no. of families using spring	± 40
other springs from aquifer?	Yes – estimated as tapping 80% of storage
% of flow captured (estimate)	60
6. Type of spring and spring development	
Type of spring	Type A (see sketches)
Spring protection	Spring box
Pipeline	HDPE
Reservoir	5,000 ℓ ferro-cement
Taps	2 sets of double taps
7. Technical problems	
Spring protection	The spring is in the stream bed and the protection has been partly damaged by high rainfall events
Pipelines	
Reservoir	
Taps	Taps have been damaged and not repaired
Pollution	Some pollution during rainfall events
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	None
Other water sources	Other springs
Involvement of chief/TLC	
Attitude towards spring	Users responsible but do not repair when problems
9. Support institutions	
Contractor which developed spring:	DWAF
Ongoing support from:	
10. Recommended additional work	Repair spring protection, divert rainfall runoff, and repair taps
11. Other comments	

Name of Responsible Officer: ______________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION – Magangangozi 1 Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Upper Tugela – Bergville
	Local Council	
	Community name	Magangangozi
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	2829CD Zunckels
	Longitude	29° 18' 48"
	Latitude	28° 53' 24"
	Altitude	1280 m
3. Community References		
	Contact person	
	Chief/Induna	
	Local Councillor	
	Population	± 2000
	No. of households	± 350
4. Spring Details	topographical setting	Catchment head
	Spring regime	Perennial
	Vegetation above spring	Grasslands/bush
	Agriculture above spring	Grazing/cultivation
	Forestation above spring	Non-indigenous + some indigenous
	Geological formations	Sandstones and mudstones with dolerite intrusions
	Land degradation	Severe erosion

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	8.0×10^6 m^3
no. of families using spring	± 20
other springs from aquifer?	Yes – estimated as tapping 75% of storage
% of flow captured (estimate)	80
6. Type of spring and spring development	
Type of spring	Type A (see sketches)
Spring protection	Spring box
Pipeline	HDPE
Reservoir	3 x 5,000 ℓ ferro-cement
Taps	1 set of tripple taps
7. Technical problems	
Spring protection	The severe erosion above the spring is likely to cause flow depletion with time
Pipelines	
Reservoir	
Taps	
Pollution	
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	None
Other water sources	Other springs
Involvement of chief/TLC	
Attitude towards spring	Users responsible but do not repair when problems
9. Support institutions	
Contractor which developed spring:	DWAF
Ongoing support from:	
10. Recommended additional work	
11. Other comments	An attempt was made to develop an additional small eye during the dry period, but this gives negligible benefit.

Name of Responsible Officer: ______________________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION – Magangangozi 2 Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Upper Tugela – Bergville
	Local Council	
	Community name	Magangangozi
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	2829CD Zunckels
	Longitude	29° 18' 11"
	Latitude	28° 53' 56"
	Altitude	1300 m
3. Community References		
	Contact person	
	Chief/Induna	
	Local Councillor	
	Population	± 2000
	No. of households	± 350
4. Spring Details	topographical setting	Catchment head
	Spring regime	Perennial
	Vegetation above spring	Grasslands/bush/cultivated land/houses
	Agriculture above spring	Grazing/cultivation
	Forestation above spring	Non-indigenous + some indigenous
	Geological formations	Sandstones and mudstones with dolerite intrusions
	Land degradation	Mild

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	$3.6 \times 10^6 m^3$
no. of families using spring	± 25
other springs from aquifer?	Yes – estimated as tapping 50% of storage
% of flow captured (estimate)	80
6. Type of spring and spring development	
Type of spring	Type A (see sketches)
Spring protection	Spring box
Pipeline	HDPE
Reservoir	2 x 5,000 ℓ ferro-cement
Taps	1 set of double taps + 3 other taps not currently working
7. Technical problems	
Spring protection	
Pipelines	The pipeline to the other taps is blocked
Reservoir	
Taps	The additional single taps are damaged
Pollution	
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	None
Other water sources	Other springs
Involvement of chief/TLC	
Attitude towards spring	Users responsible but do not repair when problems
9. Support institutions	
Contractor which developed spring:	DWAF
Ongoing support from:	
10. Recommended additional work	
11. Other comments	An attempt was made to repair the blocked pipe and distribute water to the other taps, but the community is unwilling to take any initiative.

Name of Responsible Officer: ______________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION – Nsukangihlale 1 Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Upper Tugela – Woodstock Dam
	Local Council	
	Community name	Nsukangihlale
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	2829CA Oliviershoek
	Longitude	29° 40' 32"
	Latitude	29° 04' 02"
	Altitude	1320 m
3. Community References		
	Contact person	
	Chief/Induna	
	Local Councillor	
	Population	± 4000
	No. of households	± 600
4. Spring Details	topographical setting	Catchment head
	Spring regime	Perennial
	Vegetation above spring	Grasslands/houses
	Agriculture above spring	Grazing
	Forestation above spring	Minimal
	Geological formations	Sandstones and mudstones with dolerite intrusions
	Land degradation	Mild – partly built up

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	3.7×10^6 m^3
no. of families using spring	± 45
other springs from aquifer?	Yes – estimated as tapping 70% of storage
% of flow captured (estimate)	80
6. Type of spring and spring development	
Type of spring	Type A (see sketches)
Spring protection	Spring box
Pipeline	HDPE
Reservoir	5,000 ℓ plastic
Taps	1 set of double taps
7. Technical problems	
Spring protection	Could be extended to capture more of the water available
Pipelines	
Reservoir	
Taps	The taps are damaged from time to time
Pollution	Cattle can contaminate the area and water
8. Social situation	
Water committee	Not active but recently re-established
Cost recovery for maintenance	None
Other water sources	Other springs
Involvement of chief/TLC	
Attitude towards spring	Users responsible but do not repair when problems
9. Support institutions	
Contractor which developed spring:	
Ongoing support from:	
10. Recommended additional work	Excess water could be captured and pumped to the higher sections of the village
11. Other comments	The spring covers a large seepage area and appears to be partly artesian.

Name of Responsible Officer: ______________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION – Nsukangihlale 2 Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	KwaZulu/Natal
	District	Upper Tugela – Woodstock Dam
	Local Council	
	Community name	Nsukungihlale
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	2829CA Oliviershoek
	Longitude	29° 41' 25"
	Latitude	29° 03' 46"
	Altitude	1360 m
3. Community References		
	Contact person	
	Chief/Induna	
	Local Councillor	
	Population	± 4000
	No. of households	± 600
4. Spring Details	topographical setting	Catchment head
	Spring regime	Non-perennial
	Vegetation above spring	Grasslands
	Agriculture above spring	Grazing
	Forestation above spring	Minimal
	Geological formations	Sandstones and mudstones with dolerite intrusions
	Land degradation	Mild

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	2.8×10^6 m^3
no. of families using spring	± 25
other springs from aquifer?	Yes – estimated as tapping 60% of storage
% of flow captured (estimate)	90
6. Type of spring and spring development	
Type of spring	Type A (see sketches)
Spring protection	Spring box
Pipeline	HDPE
Reservoir	2 x 5,000 ℓ ferro-cement
Taps	1 set of double taps
7. Technical problems	
Spring protection	Springs dry up in the dry season, and spring boxes silt up
Pipelines	
Reservoir	Leaking
Taps	
Pollution	
8. Social situation	
Water committee	Not active but recently re-established
Cost recovery for maintenance	None
Other water sources	Other springs
Involvement of chief/TLC	
Attitude towards spring	Users responsible but do not repair when problems
9. Support institutions	
Contractor which developed spring:	
Ongoing support from:	
10. Recommended additional work	Excess water could be captured at the lower sections of the village and pumped to the higher sections.
11. Other comments	The spring is not sustainable and dries up early in the season

Name of Responsible Officer: ______________________________

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION - Macosa Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	Eastern Cape
	District	Mqanduli
	Local Council	Macosa
	Community name	Macosa
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	3128DC Elliotdale
	Longitude	31° 47' 45"
	Latitude	28° 41' 30"
	Altitude	860 m
3. Community References		
	Contact person	Mr Nicodemus Madaza
	Chief/Induna	Mr Kori
	Local Councillor	
	Population	± 875
	No. of households	± 125
4. Spring Details	topographical setting	Catchment head
	Spring regime	perennial
	Vegetation above spring	Grasslands/cultivation/houses
	Agriculture above spring	Ploughed fields/grazing
	Forestation above spring	None
	Geological formations	Beaufort sandstones, siltstones and mudstones
	Land degradation	Mild – some dongas

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	$0.46 \times 10^6\ m^3$
no. of families using spring	All (± 125)
other springs from aquifer?	Yes – estimated as tapping 20% of storage
% of flow captured (estimate)	70
6. Type of spring and spring development	
Type of spring	Type A / B (see sketches)
Spring protection	Spring box + underground collectors
Pipeline	HDPE
Reservoir	5,000 *ℓ* ferro-cement
Taps	Single
7. Technical problems	
Spring protection	Spring box not properly covered + leaks, and other seepage in close proximity
Pipelines	
Reservoir	Overflow leaking
Taps	Does not close – water leaks permanently
Pollution	Cattle and sheep grazing in spring catchment area
8. Social situation	
Water committee	Not active
Cost recovery for maintenance	Money is collected when repairs are needed
Other water sources	Other springs (minor)
Involvement of chief/TLC	Informed
Attitude towards spring	Some responsibility and desire to maintain by elders of village
9. Support institutions	
Contractor which developed spring:	ECATU
Ongoing support from:	
10. Recommended additional work	Tap should be repaired and fence erected around spring + improved and repair of spring box
11. Other comments	The spring provides an ongoing reliable supply of water, but is far and steep for many residents. They would appreciate a small pump and reservoir at the top of the ridge.

WATER RESEARCH COMMISSION/ENVIRONMENTEK CSIR

EVALUATION OF SPRINGS FOR SMALL WATER SUPPLIES

Project K5/859

SPRING DESCRIPTION - Sixuzulu Spring

ITEM		DESCRIPTION/QUALIFICATION
1. Location -	Province	Eastern Cape
	District	Umtata
	Local Council	Bangaliswe
	Community name	Sixuzulu
2. Topographical References		
	Quartenary catchment	
	1:50 000 map reference	3128CB Baziya
	Longitude	31° 36' 28"
	Latitude	28° 20' 10"
	Altitude	840 m
3. Community References		
	Contact person	Mr Z Belemsi
	Chief/Induna	
	Local Councillor	
	Population	± 700
	No. of households	± 100
4. Spring Details	topographical setting	Catchment head - side of stream bank
	Spring regime	Perennial
	Vegetation above spring	Grasslands/natural forest/plantations
	Agriculture above spring	Pine plantations
	Forestation above spring	Natural forest + planted pine trees
	Geological formations	Beaufort sandstones, siltstones and mudstones
	Land degradation	Mild – some dongas and erosion

5. Flow conditions flow estimate (l/s)	See spring flow table
water storage volume (m3)	
no. of families using spring	All (± 100)
other springs from aquifer?	Yes – estimated as tapping 20% of storage
% of flow captured (estimate)	100
6. Type of spring and spring development	
Type of spring	Type A / B (see sketches)
Spring protection	Spring box
Pipeline	HDPE
Reservoir	6,000 ℓ ferro-cement
Taps	Multiple at points within village
7. Technical problems	
Spring protection	none
Pipelines	Pipeline collapses from time to time where it crosses badly eroded sections
Reservoir	
Taps	Some taps leak
Pollution	Cattle and sheep grazing in spring catchment area
8. Social situation	
Water committee	Active
Cost recovery for maintenance	Money is collected when repairs are needed
Other water sources	None
Involvement of chief/TLC	
Attitude towards spring	Some responsibility and desire to maintain by elders of village
9. Support institutions	
Contractor which developed spring:	ECATU
Ongoing support from:	
10. Recommended additional work	Re-route pipeline or improve pillar supports over dongas.
11. Other comments	The spring provides an ongoing reliable supply of water, close to their homes.

THE RELIABILITY OF SMALL SPRING WATER SUPPLY SYSTEMS FOR COMMUNITY WATER SUPPLY PROJECTS

Report to the

Water Research Commission

Volume 2: The hydrogeology of South African springs

by

John Weaver

Groundwater Group
Environmentek, CSIR
Stellenbosch

VOLUME 2

THE HYDROGEOLOGY OF SOUTH AFRICAN SPRINGS

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1.1 REVIEW OF EXISTING INFORMATION

There is a surprising lack of written information, both published and unpublished regarding the hydrogeology of South African springs. Information regarding the dolomite springs (Enslin 1967, Enslin & Kriel 1967, Vegter 1984, Vegter & Foster 1992) and of hot springs (Frommurze 1933, Hoffman 1979, Heaton *et al* 1986, Kent 1949, Kent 1969, Mazor & Verhagen 1983) is plentiful, but for the low temperature local springs information is virtually non-existent. The localities and associated geologies are recorded in a few documents (Bond 1946, Frommurze 1933, van Eeden 1972) but the underlying geological structure leading to the spring issuing at that point is seldom described. This apparent lack of published information is surprising in view of the great importance that springs have played in the lives of early inhabitants and settlers in South Africa. Many of these springs have continuing importance both today and into the future. An exception to the above comments, is the recently published paper by Meyer (2002) describing springs in the Table Mountain Group.

An indication of the importance of springs in opening up dry South Africa is the number of towns and farms named after the local spring. It seems as if every second farm has the suffix "fontein". The most common farm name in South Africa is Rietfontein, (Reed Fountain). Towns such as De Aar (The Springs), Bloemfontein (Flower Fountain) and Graafwater (Dig for water) come to mind.

Some of the better known springs that influenced early development of South Africa are noted :-

- The Albion Spring in Newlands, Cape Town, upon which SA Breweries founded their industry, later used by Schweppes for cool-drink manufacture and now by the City for water supply.
- Mackie Pits are the springs at Graaf-Reinet, which for many years was the sole source of water for the town and upon which the town was founded. Graaf-Reinet was the fourth settlement to be declared a city in South Africa.
- The existence of a high-yielding spring was the deciding factor for the Transvaal Republic to establish their new capital at the spring "Die Fonteine", or Pretoria Fountains.

- Gasegonyane Spring (little water calabash), commonly known as "Die Oog" was first recorded in 1801 and in 1820 Robert Moffat established a mission station around which the town of Kuruman developed. This oasis in the Kalahari desert has featured extensively in the colonial history of Southern Africa. Even during severe doughts this spring has remained a reliable source of water, yielding about 20 000 m^3/day for the 10 000 inhabitants of Kuruman.
- In the Eastern Cape, the coastal villages Port Alfred, Bushmans River Mouth and Kenton-on-Sea all relied on springs for their water-supply. Only recently have they developed additional sources of water.
- Similiarly in the Southern Cape, the coastal villages of Stilbaai, Jongensfontein and Die Kelders rely on springs for their water-supply.

The following three case-studies demonstrate the influence that springs have had on local demographics.

1.1.1 Heuningvlei, N. Cape

Heuningvlei (23°10'E, 26° 18'S) lies 130 km north of Kuruman and 175 kms northwest of Vryburg. This saltpan of about 5 km^2 is surrounded by Kalahari sand-plain semi-desert. At the northern end of the salt-pan is a fresh-water spring which yields about 330 m^3/day (Martinelli 1983). The spring is at the southern end of a north-south running range of hills composed of banded ironstones of the Asbestos Hills Formation. This range of hills is about 10 m wide and runs about 35 km north of Heuningvlei and about 25 km south. This ridge of hard rock is about 100 metres above the surrounding featureless sands, and at Heuningvlei ends in an abrupt vertical cliff-face about 50 metres high. This cliff is probably fault controlled and at the base of this cliff is the spring. On this cliff-face are number of hives of wild honeybees. Some very rickety dangerous-looking ladders and natural-fibre ropes are evidence that honey is or was being collected. All the elements of an idyllic hunter-gatherer camp-site are present, perennial fresh water, a salt-pan with abundant game, honey and shady trees at the base of the cliff.

During the course of a water-supply project, I visited Heuningvlei. This project was planned to distribute water for cattle-watering each side of the ridge for up to a hundred kilometres distant. These grassy plains either side have a good cattlecarrying capacity, but no standing water, and groundwater beneath these grassy plains has both limited areal development and is poor quality. The idea was to use the elevation of the ridge to gravity-feed water to the watering points, and the project turned out to be quite successful. I camped in a grove of trees some distance from the spring. This campsite was on a mound of gravelly sand about 30 metres across and a few metres above the general topography. The gravel was almost entirely composed of chippings from the making of stone-tools. The very large volume of the mound is a clear indication that this site had been well-used and probably for centuries.

1.1.2 Botrivier

Botrivier is a small village about 100 kms east of Cape Town alongside the N2 highway (Weaver 2002). It is situated on the eastern edge of the Hottentots Holland mountains and overlooks the wheat fields of the Overberg. Botrivier owes its existence to being the last staging post for the ox-wagons leaving the Overberg before crossing the mountains to Cape Town. Here the oxen could get good fodder and fresh water, before the rough mountain crossing. After rail transport was introduced the town retained its importance, as it was a main watering point for the steam engines.

Botrivier is underlain by quartzites and shales. The village is bisected by a NE-SW trending scissor-fault which at Botrivier has a 600 m downthrow to the east. This fault brings quartzites of the Skurweberg Formation (Nardouw Subgroup) into contact with shales of the Gydo Formation (Ceres Subgroup, lower zone of the Bokkeveld Group). This fault also passes west of Arabella Country Estate (Parsons 2002) and controls the headland at Kleinmond where throw is greatest. Towards the north the displacement reduces to a few metres and the fault veers to the East and links up with the east-west trending Greyton fault. The quartzites form the high ground and mountains of the Hottentots Holland, while the shales form lower ground and the fertile wheatfields.

The fault and consequent geometry of the geological formations has had a strong influence on historical social development at Botrivier. At the contact of the higher lying quartzites with the shale, there are a number of springs (barrier types). All the older houses of the village are situated on the shale, ie they lie downgradient of these springs. What happened is that the early settlers chose parcels of land with good agricultural potential (soils derived from the shales), which could be watered by gravity from the springs.

1.1.3 **Uitenhage** (After Maclear 2002)

Stone-age artifices and a pre-historic mammal tooth found at the present-day Uitenhage Springs indicate that the eyes have been a constant supply of water to early inhabitants for at least 200 000 years. With the arrival of settlers in the region, an abundant supply of fresh water was one of the main considerations for the siting of a new Drostdy on the farm Rietvallei in 1804, on instructions for Commissioner-General Uitenhage de Mist. This Drostdy, or the Garden Town as it was known in the early 1800's was later renamed Uitenhage and obtained all its water from a stream fed by the Springs. In 1773 the total yield from 20 different eyes was estimated at 105 L/s, whereas in 1829 this flow was estimated to be 80 L/s. The first official and reliable gauging was in 1867 when a flow of 89 L/s was recorded. At the turn of the 20th century, spring-water was already being used for irrigation of market-gardens in Uitenhage. Irrigation intensity increased with time, with farming activities extending eastward from Uitenhage along the Coega Ridge as the artesian groundwater resource became more extensively utilised.

1.2 SPRINGS AND THE HYDROLOGICAL CYCLE

Spring water is groundwater that appears at the surface of the earth while it is flowing downgradient to its ultimate destination, the sea. The reason that this groundwater appears at ground surface is either a change of geological continuity or is a geomorphological effect. Once in the sea this water rejoins the hydrological cycle of evaporation and precipitation.

Rain (and snow) falls on the earth and infiltrates into the ground. Once underground it flows downgradient under the force of gravity. Essentially there are three reasons causing this groundwater to daylight at surface as a spring, and these can be used to classify the types of springs. **Seepage** springs occur where the topographic surface cuts below the watertable, and groundwater thus seeps out at surface. **Barrier** springs occur where a lower permeability geological horizon (the barrier) is in contact with a higher permeability horizon, which is upgradient. Groundwater flowing from the higher area is thus "dammed" and the pressure of the groundwater from the upgradient area causes groundwater to overtop and flow at surface as a spring. **Artesian** springs occur where a discontinuity allows groundwater at depth and which is confined by a low permeability horizon to be "forced" to surface as an artesian spring. Artesian springs are well described and illustrated in most textbooks on groundwater and springs. South African examples are Albion Springs, Cape Town and Uitenhage Springs (Maclear 2002).

The following springs are described in this chapter:

- Gravity springs– geologically controlled
- Gravity springs – topography controlled
- Fault controlled – down-slope springs
- Fault controlled – cross-slope springs
- Geological discontinuity controlled springs

1.2.1 Gravity Springs

1.2.1.1 Gravity Springs Geology controlled

These springs are quite common in South Africa, especially where sedimentary formations of the Karoo Group are found. They are found in the Lesotho Drakensberg, the foothills north, south, east and west of the Lesotho Drakensberg, most of the Eastern Cape and up through to the coalfields of Mpumalanga. The most spectacular examples are at the base of the sandstone of the Clarens Formation typified by the orange cliffs of Golden Gate.

The hydrogeological controlling factor is the combination of a more permeable geological layer either overlying a layer which is much less permeable, or upgradient of the less permeable layer. In the Karoo this is usually sandstone overlying shale. Very often the more permeable layer will be the weathered and fractured zone of a dolerite sill, which has intruded into the horizontally bedded strata. The unweathered dolerite will form the impermeable base. In the unsaturated zone the percolating water moves essentially vertically downwards until it reaches the water-table. Below the water-table groundwater will move sub-horizontally down-gradient (under gravity) until it discharges at a spring or seep and becomes surface flow, or river water.

Another geological setting, which has been noted in recent literature (Meyer 2002), is the Table Mountain Group. The Cederberg Formation is a shale band separating the underlying quartzites of the Peninsula Formation from the overlying Nardouw Formation. Where the topographic setting is suitable springs are developed at the contact. Most common are relatively low yielding springs at the base of the Nardouw against the Cederberg. Occasionally, when the beds are overturned or steep-dipping and the Peninsula Formation is at a higher elevation then springs develope at the Cederberg Formation - Peninsula Formation contact. These springs invariably are associated with a fault feature (see the next chapter on fault controlled springs). However in the specific case of the TMG these faults sometimes do not maintain high permeability through the shale band, and this shale thus acts as the impermeable horizon. Some of the larger and better known springs are Hoeksberg Spring south of McGregor, Vermaaks and Marnewicks Springs in the Kamanassie Mountains east of Oudtshoorn, Meiringspoort Spring north-east of Oudtshoorn, Swartberg Spring at Prince Albert, and the Humansdorp Spring. (Meyer 2002)

Another geological setting which commonly produces such springs is where calcrete horizons are developed at or close to surface. This calcrete is often highly permeable and springs are developed at the basal contact of the calcrete deposit. The coastal town of Stilbaai is entirely dependant on 5 springs developed at the base of the calcretised fossil dunes of the Bredasdorp Formation where these are in contact with the underlying quartzites of the TMG and shales of the Bokkeveld. These springs have yields ranging from 6.6 to 16.0 L/sec.

Figure 1.1a shows the geological cross-section illustrating this setting and Figure 1.1b shows a perspective sketch.

The flow and reliability of gravity springs is controlled by two factors. The areal extent within the catchment of the permeable formation governs the volume of water stored in the aquifer. This in turn is related to the reliability of the spring, in that if there is a large storage volume and a relatively low rate of outflow then the spring will be reliable and vice versa. Secondly the annual recharge to the aquifer, which is closely related to the rainfall, will influence the annual available water.

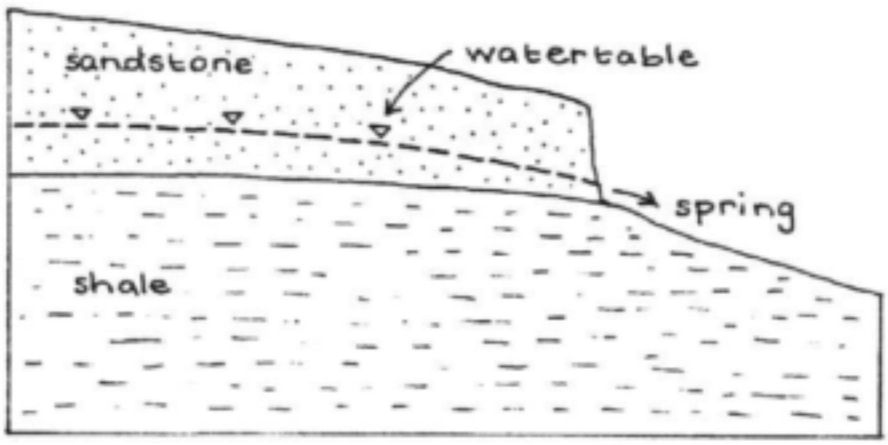

Figure 1.1a Geological cross-section of a Gravity Spring - Geology controlled

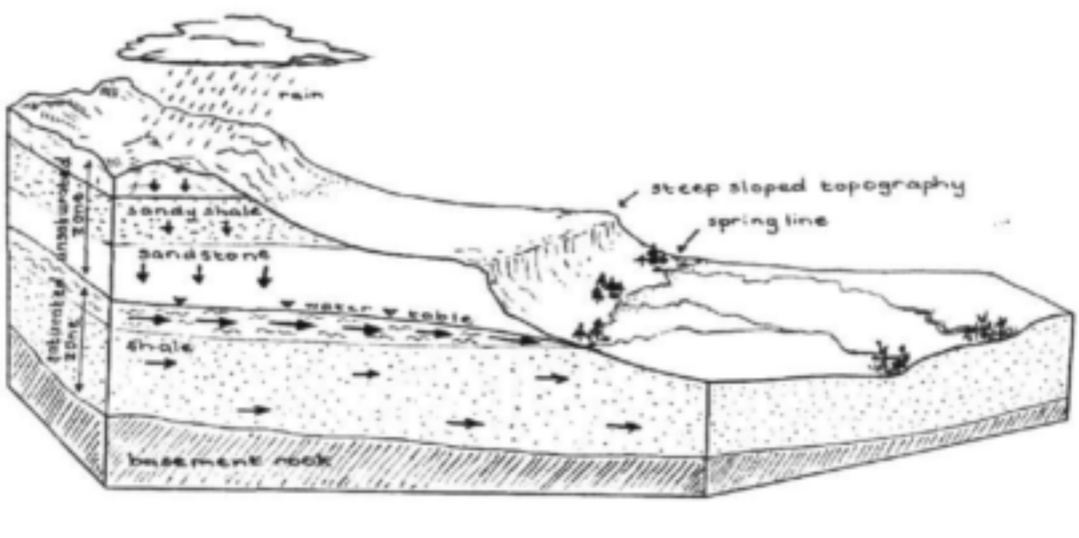

Figure 1.1b Perspective sketch of Gravity Springs - Geology Controlled

1.2.1.1 Gravity springs – topography controlled

Groundwater flows downgradient from the recharge point towards the low point of the topography where it discharges. Generally in South Africa groundwater discharge will be as seepage in a river-bed, or along the side-walls of the river. If one drills a traverse line of boreholes, it will be found that the water-table from the recharge point to the discharge point will mimic the land surface topography. It is not an exact image, but rather is a smoothed version. In the recharge areas (high lying areas) the depth to water-table will be the greatest and as one approaches the discharge point the depth to water-table will become less and less until at the discharge point it is zero. The slope of the water table is controlled mainly by the permeability (ability to convey water) of the aquifer and by the recharge rate (amount of water entering the aquifer). Occasionally the slope of the topography has excessive steepness and the land surface dips below the average water-table. When this happens groundwater daylights as a spring. Quite commonly the out-flow of groundwater in this setting is low and this "spring" will be called a seep and can normally be recognised only by a difference of vegetation.

Figure 1.2 shows a geological cross-section illustrating this setting.

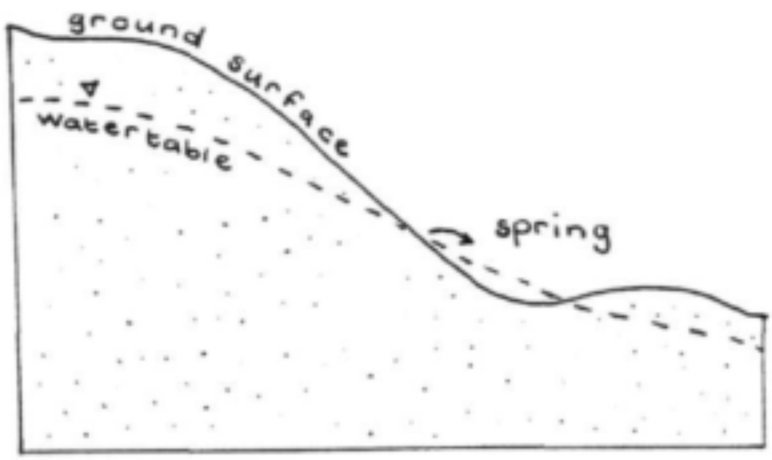

Figure 1.2 Geological cross-section of a Gravity Spring - Topography controlled

1.2.2 Fault controlled springs

1.2.2.1 Fault Controlled - down slope springs

The geological structure which controls these springs are faults which run from higher up the slope to lower down the slope. Generally the slope of the topography will be steeper rather than flatter. The fault has caused a weakness in the rock and the flowing spring water plus occasional heavy rainstorm has eroded the fractured rock associated with the fault resulting in a valley. One or more springs will be encountered along the valley floor and usually there will be a spring at the head of the valley.

The fault can also have a dyke associated with it. When this dyke material is softer (erosionally speaking) than the surrounding rock then a valley, or negative erosion feature, will form. Similarly, springs will be encountered along the valley.

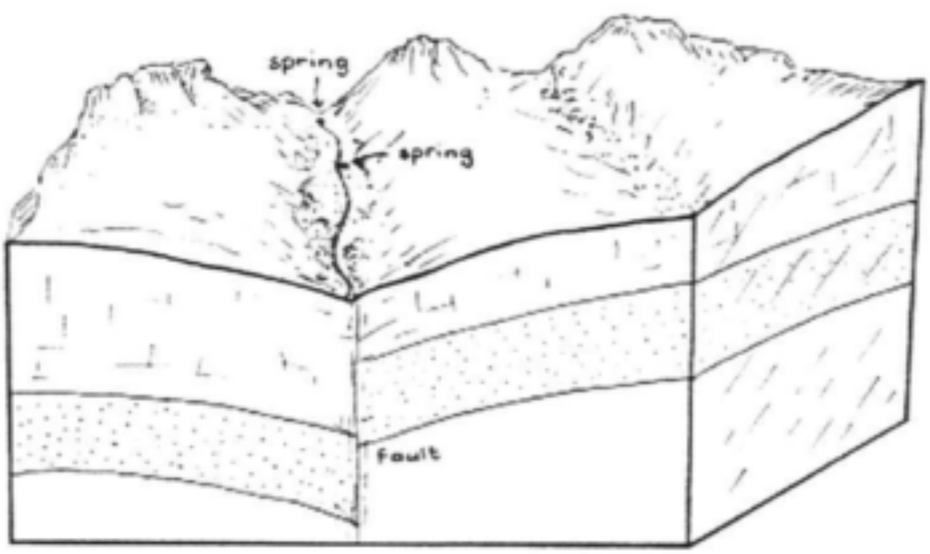

Figure 1.3 Perspective sketch of a Fault Controlled down-slope Spring

1.2.2.2 Fault Controlled – cross slope springs

In some situations when a fault is filled with dyke material, the dyke can be harder (erosionally speaking) than the surrounding rock. In this case the fault/dyke can become a barrier to subsurface gravitational flow of groundwater. In such a case and especially when the fault/dyke runs across the trend of topography, at a low point of the fault/dyke there will be overtopping of groundwater and a consequent spring. The two geological formations in South Africa where this feature is commonly encountered are the Dolomites and the Karoo. Figure 1.4a is a geological cross-section illustrating this spring setting.

Springs in the Dolomite are mostly developed at cross-slope dykes. These dykes divide the Dolomite in separate aquifer units called compartments. Springs in the Dolomites have been extensively and comprehensively described (Enslin 1967, Enslin & Kriel 1967, Vegter 1984, Vegter & Foster 1992). Some of the more famous dolomite springs are:

- The Pretoria Fountains, which for many years was the sole source of water for Pretoria, and which to this day supplies a substantial percentage of the water-supply. Pretoria was established at its location because of the abundant water supply from the Pretoria Fountains.
- "Die Oog van Kuruman" Spring, upon which was based the Mission Station of Reverend Moffat, and is now the source of water for the town of Kuruman.
- Die Oog van Schoonspruit Springs, which supply Ventersdorp.

In the Karoo intrusive dolerite dykes are common. In the arid areas of the Central Karoo these dykes are harder than the sandstones and shales. Consequently at the low point of topographic basins these dykes continue occur as a positive feature, or range of hills. At the exit poort of such a basin where the drainage crosses such a dyke are found springs. Many, if not all, of the original Karoo Settler homesteads are situated below these springs. Figure 1.4c is a sketch perspective showing the geological setting of such a typical Karoo homestead.

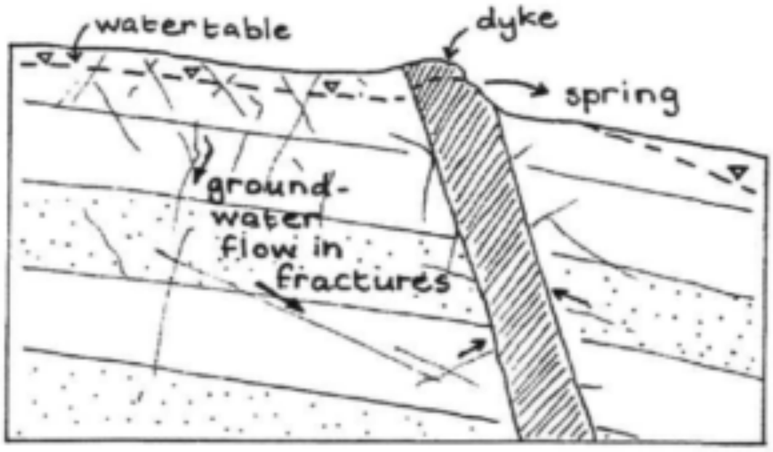

Figure 1.4a Geological cross-section of a fault controlled cross-slope spring. Fig 1.4a shows an impermeable dyke causing the barrier.

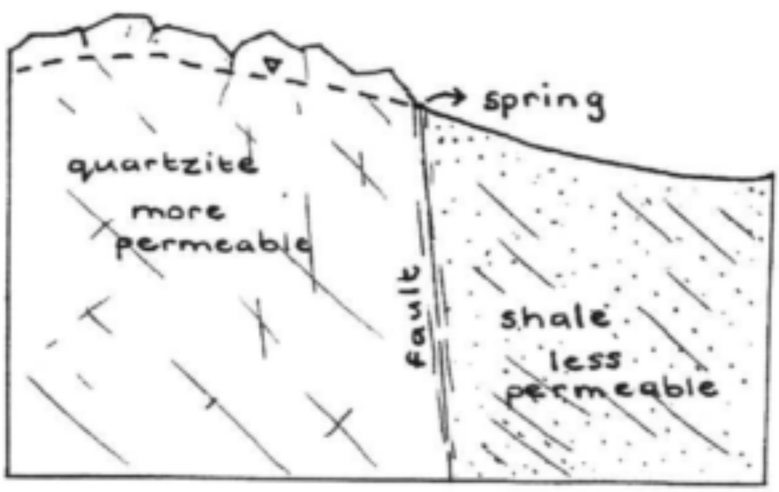

Figure 1.4b Geological cross-section of a fault controlled cross-slope spring. Fig 1.4b shows a less permeable shale faulted in contact with a permeable quartzite. Botrivier is such an example.

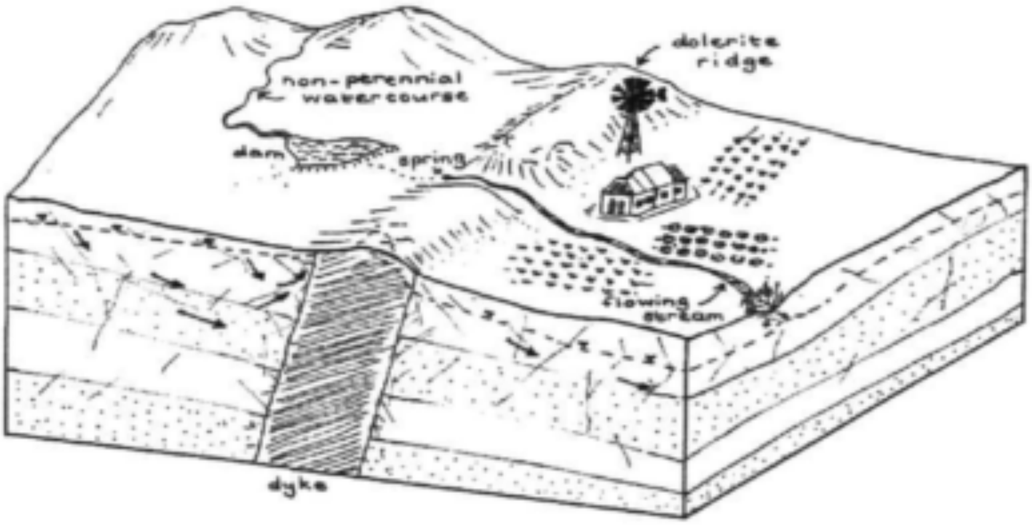

Figure 1.4c Perspective sketch of a fault controlled cross slope spring. The sketch shows a typical Karoo homestead setting.

Graaf-Reinet, the fourth city to be established in South Africa, owes its situation to the springs at Mackies Pits. These springs are developed at a dolerite sill and dyke complex. Similarly the town of Aberdeen is dependent on springs at a dolerite sill and dyke complex.

In humid areas where Karoo rocks are found this feature is less common, as the dolerite tends to weather more rapidly than the surrounding rocks, forming a negative topographic feature.

2.2.2 Mountain rubble and alluvial fan springs

A common feature of mountain areas are alluvial fans of rubble that has been transported by flood events from the mountains and dumped when the stream gradient and velocity has reduced. These are often associated with ephemeral rivers which flow only after rain. Sometimes they have permanent streams associated with them. Water from these intermittent or semi-permanent streams will rapidly infiltrate these coarse sediments and the visible stream disappears. This water then re-appears at the base of the fan as a spring. The seasonal permanence of these springs depends on the size of the fan (storage within the aquifer of the fan) and also whether the river feeding the fan is ephemeral or permanent. Large landslides can also have springs developed at the base of the landslide. Figure 1.5 shows a geological cross-section of this setting. Before extensive exploitation of groundwater by boreholes, alluvial fan springs were widespread in the Hex River Valley. Nowadays only a few of these springs still flow year round, most flow for only a few months towards the end of the rainy season. The spring supplying the village of Pniel a few kilometres north of Stellenbosch is an example of a mountain rubble spring.

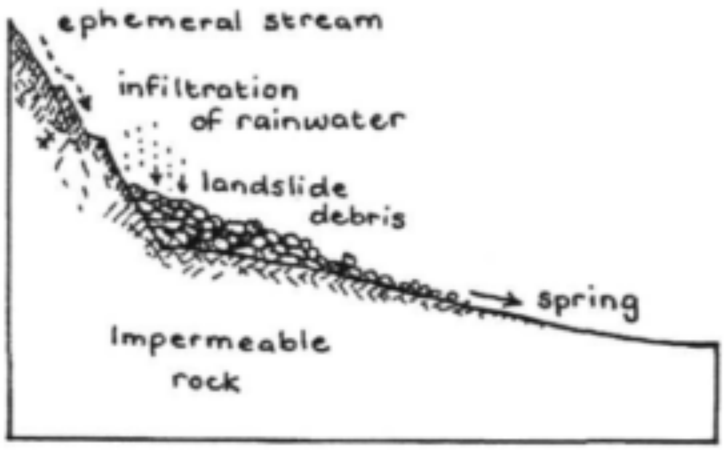

Figure 1.5 Geological cross section of mountain rubble or alluvial fan spring

1.3 ENHANCING SPRING FLOW

Theoretically one can enhance the flow from a spring. Spring flow is controlled by hydraulic gradient and the permeability of the seepage face. Nothing can be done on a permanent basis about the hydraulic gradient. Thus the permeability of the seepage face is the only factor that can be attended to. This involves opening of fractures, which may have been closed by chemical precipitates or by mechanical deposits. Alternatively permeability can increased by widening the seepage face.

However discussing spring flow enhancement with Messrs P Ravenscroft and R Murray, both commented that in their practical exerience, spring enhancement is not achieved by excavation, and is not recommended. Their recommendation is that excavation should be limited to the excavation of the loose material that is required for proper spring construction.

The spring flow enhancement that is recommended is the removal of vegetation, trees especially, from above the spring. This applies especially to the removal of alien vegetation such as black wattle, Australian acaias and Australian gum-trees.

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THE RELIABILITY OF SMALL SPRING WATER SUPPLY SYSTEMS FOR COMMUNITY WATER SUPPLY PROJECTS

Report to the

Water Research Commission

Volume 3: Spring assessment and construction methods

by

Phillip Ravenscroft

Maluti Water & Community Engineering Services
Stellenbosch

VOLUME 3

SPRING ASSESMENT AND CONSTRUCTION METHODS

TABLE OF CONTENT

Acknowledgement:

Ricky Murray and John Weaver for editing

1 Introduction

This document is the third volume of a three volume series on spring protection. The first volume documents research on the reliability of small springs for community water supplies and the second documents the hydrogeology of South African springs. This third volume aims to provide practical guidance for developing springs as sources for water supplies.

Within the geological classification of springs contained in the second volume, two hydraulic categories of springs are defined, gravity springs and artesian springs. Gravity springs are the result of gravitational flow from a body of groundwater and generally emerge from the side of slopes.

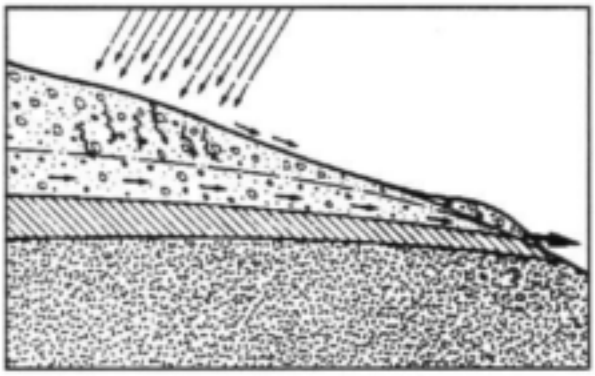

Figure 1.1 Gravity spring (from Meuli and Wehrle, 2001)

Artesian springs are the release of groundwater under pressure and generally flow vertically out of the ground.

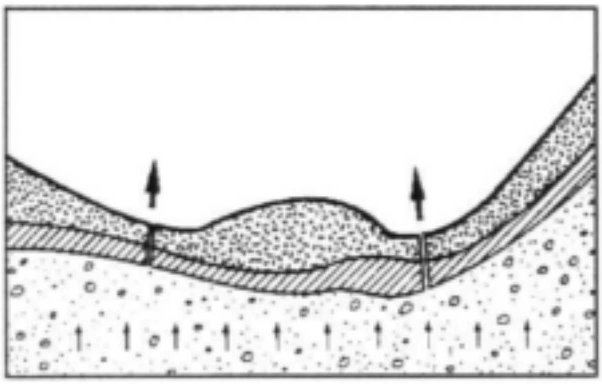

Figure 1.2 Artesian spring (from Meuli and Wehrle, 2001)

2 The Case for Developing Springs

Investigation of springs as a potential water source must form part of the water resource assessment for any new water supply or upgrading of a supply for the following reasons:

- Springs can often provide good quality water (both chemical and microbiological) that does not require treatment to render it potable.
- When situated above a settlement, springs can be utilised with gravity flow and without incurring energy costs.
- Protected springs have low maintenance costs relative to other technologies.
- Even in situations where springs may not be able to supply the full demand for a settlement, it is worth developing them as they can supply a base flow of "cheap" and reliable water that can be supplemented with more expensive water that requires pumping and/or treatment.
- Historically, almost all rural settlements in South Africa were based upon being near springs. As a result, there are often springs located close to existing settlements. Currently there are a huge number of unprotected springs that are used for water supply in South Africa in a range of situations. These include springs in rural areas where water is collected by hand, springs feeding piped and pumped water supplies on farms and municipal water supplies.

3 Spring Assessment

3.1 Locating springs

- The local community is often the best source of information on the location and reliability of water sources, especially springs. The collectors of domestic water will often have the best information about the location and reliability of springs located near the settlement while people who have herded animals are often the best source of information about springs more distant.

- It is important to ask which springs continued to provide water in the most recent drought episodes. When doing on site investigations, try to get your local information sources to distinguish between running and standing water. A common misconception is to visualise and describe a spring as "powerful" or having a lot of water when there is a pool of water at the source, even if the spring flow is very weak.
- Always visit all possible springs and not just the ones that are rated as good by the community. It may be that a spring that is a good choice for supplying the settlement is not seen as such by the community.
- Ask about water quality (and take samples to verify).
- The first springs to investigate are those that are presently being used for water supply and then move on to the springs that people know of but do not regularly use.
- If springs are being developed as stand-alone sources and not as part of a piped water supply, it is preferable to develop the springs closest to the community. If a more distant spring is developed, the community may chose to continue using the closer unprotected spring.
- There may also be cultural or personal reasons why springs (or a particular spring) are not considered suitable for community water supply. It is important to be sensitive to these attitudes and incorporate them in the design and construction.
- Green areas of vegetation in an otherwise dry area can often indicate the presence of a spring or seep.
- One may need to follow small

Cala village and the snake in the box

In 1989 in a rural village in the Cala district of the former Transkei, a recently protected spring had been badly damaged. The top of the spring box had been smashed and the eye of the spring lay exposed. This was discussed with the local water committee who said they thought the vandalism was probably carried out by naughty youngsters and they would investigate. The spring box was repaired but again the lid to the spring box smashed. This time it was not repaired and after further investigations, the water committee was able to identify the guilty party.

To everyone's surprise, it was not the youth but an old man. He was unrepentant and said it was his duty to smash the lid so that the snake could get in and out of the spring. If he did not do it, the snake would take the water away and the spring would dry up. He believed that there was a snake living in the spring and that the snake wielded power over the spring and the water provided by it. The design of the spring box was altered by including an oversized overflow that allowed the snake to get in and out of the spring box. The old man was satisfied and the spring could supply the village.

streams uphill to find the spring source of the stream. Observe the stream flow carefully as there may be a spring emerging directly into the bed of the stream. Always check that the spring is not the result of a small stream higher up the slope going under the surface and re-emerging as a false spring.

3.2 Water Quality

During on site investigations, the water quality should be observed and sampled. Simple observation of taste, odour, colour and turbidity will give an immediate indication of the suitability of the spring source but this must be verified by taking samples and testing for both microbiological and chemical determinands. Try and get a turbidity sample from the maximum flow period when the turbidity will be at its highest as this is useful for the design of the sedimentation chamber. Observe the spring and surrounding area carefully when taking the sample to ensure that only the spring water is being sampled and not a combination of spring and surface runoff water.

When taking a microbiological sample it is very important to collect the sample as close as possible to where it is emerging from the ground. Even a short distance away from the "eye" most spring water will show contamination from biological matter. For information on how to sample and what determinands to sample for refer to Volume 1 and 2 of the Quality of Domestic Water Supplies published by the Water Research Commission. The corrosivity of the water should be investigated and the results must inform the choice of materials used for the construction. The soft ground waters of the quartzites of the Table Mountain Group and of large parts of the eastern and southern parts of the country are often corrosive and need to be investigated (Smart & Tredoux, 2002). Refer to Stasoft4 software available from the WRC for information on the corrosivity of water. (Loewenthal, Wiechers & Marais, 1986)

3.3 Water Quantity

Most springs show seasonal fluctuations and fluctuations between years of high and low rainfall. Springs discharging from small aquifers, and in particular, gravity springs, are most likely to show significant seasonal and/or yearly fluctuations. It is recommended that a spring flow be measured monthly for at least a year to determine the minimum flow for that year. Rainfall records for the year of investigation should be compared to the rainfall of previous years to identify the relative wetness of the monitoring period to give an indication of the reliability of the maximum and minimum flows measured.

The most reliable way to establish spring flows is obtained by combining direct measurement with historical information. This information is seldom captured in reports (although many of the larger springs have been described in some way or another in the past, and it may require searching through archives at museums, newspapers, etc. to get an indication of previous flow estimates). The most useful historical information comes from people who have used and observed the spring for a number of years. Methods for measuring spring flows directly, are described below.

It is possible to estimate the reliability of springs using hydrogeological principles that take recharge, storage and permeability into account. Murray (1997) describes a method using these parameters for assessing single borehole yields. The same methods could be applied by substituting a spring for a borehole. These methods are summarised in Sami & Murray (1998). This document also describes a theoretical method specifically developed for assessing the safe yield of springs.

It is important to have a measurement of the maximum and the minimum flow for the design. The minimum flow gives an indication of the sustainable yield while the maximum flow is needed for the sizing of the outlet and overflow pipes. Under maximum flow conditions, there may be additional seasonal "eyes" near the spring that must be included in the design and construction. The fluctuation in the flow can give an indication of the reliability of the spring. If there is a large fluctuation, it indicates that the spring is very responsive to rainfall.

A spring that shows a dramatic increase in flow immediately after a storm event is more likely to have contamination by surface water than a spring where there is a lag of a few weeks between high rainfall periods and an increase in flow.

3.4 Measuring Spring Flow

3.4.1 Bucket and Stopwatch Method

This is the most common and easiest way of measuring flow.
Build a temporary dam (of clay or soil) to collect all the water flowing from the spring and place a pipe in the wall of the dam so that the whole flow is channeled through the pipe. Allow the water to run for some time until the flow has steadied. The larger the area of water behind the dam, the longer this will take. Ensure that the pipe is completely stable and that it does not move while the flow is measured.

Use a bucket and a stopwatch to measure the time taken to fill the bucket. Ensure that you know exactly how much water the bucket holds. If the bucket fills in less than 5 seconds, a larger bucket should be used or the flow should be split into a number of smaller flows that can be measured separately.

Place the bucket under the pipe and record how many seconds it takes to fill the bucket. The flow (in litres per second) is obtained by dividing the volume of the bucket by the number of seconds it took to fill the bucket. Always take 4 or 5 readings to ensure that the flow has reached a steady state. If the flow is not constant, continue to take measurements until the readings vary by less than 10%.

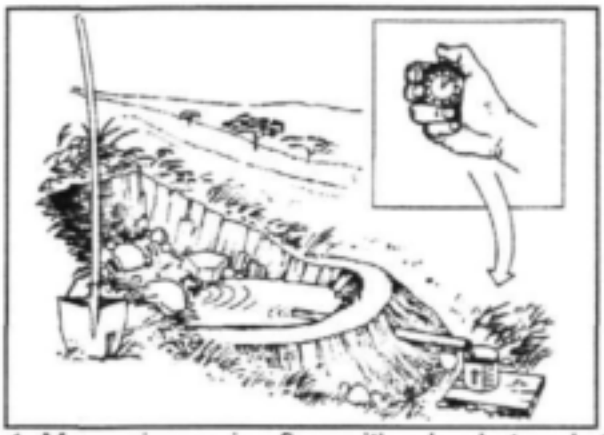

Figure 3. 1 Measuring spring flow with a bucket and stopwatch (from Meuli and Wehrle, 2001)

Q=V/t

Q is flow in litres per second

V is the volume of the bucket in litres

t is the time taken to fill the bucket in seconds

3.4.2 V-Notch Weir

For springs with a large flow, it may not be possible to measure with a bucket and then a V-notch weir should be used. Using a V-notch weir with a 90 degree notch, the following table gives the flows corresponding to head above the weir.

Head mm	50	60	70	80	90	100	110	120	130	140	150	160	170	180	200
Flow l/s	0.73	1.21	1.79	2.49	3.34	4.36	5.54	6.91	8.41	10.2	12.0	14.1	16.4	18.9	24.7

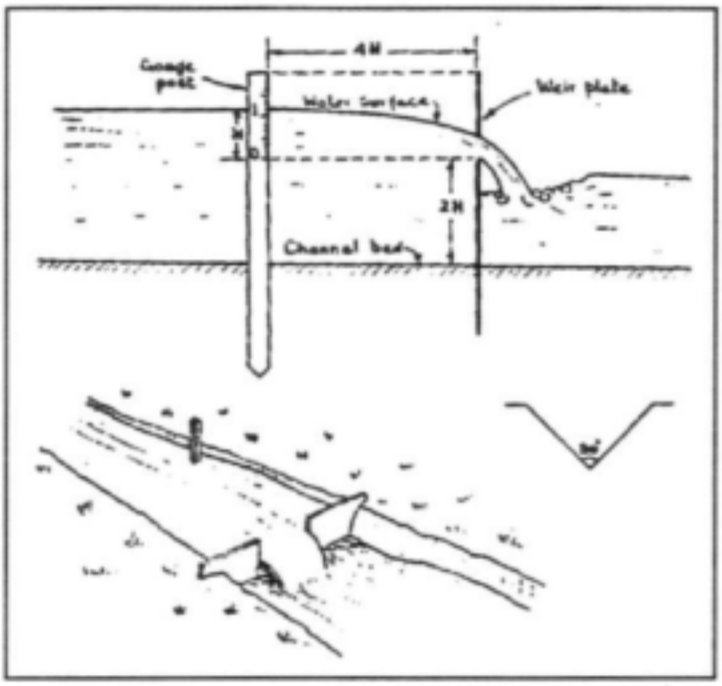

Figure 3.2 V-Notch Weir (adapted from Stern 1979)

3.5 Establish the Environmental Impact

The environmental impact of protecting the spring should be assessed. This assessment should include an estimation of the impact of the construction on the immediate environment of the spring as well as the impact of removing the spring flow as a water source for the downstream environment.

4 Spring Development and Construction Methods

4.1 Introduction

Two types of spring protection have commonly been used in Southern Africa, the spring box method and the spring catchment and chamber method. Variations of the spring box method are the most common form of spring protection in South Africa while the spring catchment and chamber has been used extensively in Lesotho rural water supplies. For the purpose of this document they will be referred to as the spring box and the spring catchment methods.

4.2 Basic Principles of Spring Development

There are two basic principles that need to be followed when developing springs.

- **The first principle is to keep the spring flowing freely.** At all times water from the spring must be allowed to flow freely away from the "eye" or source of the spring without any obstruction. The water should never dam up, as this will cause backpressure on the spring, which can lead to the groundwater finding an easier alternative route and the spring will stop flowing. The water must flow freely even under maximum flow conditions, during construction and when the construction is completed.

- **The second principle is protect the groundwater from surface water contamination.** The design and construction must ensure that surface water cannot infiltrate the spring water. This involves the protection of the immediate area of the spring with fencing, erosion control, adequate drainage of surface water and control of vegetation.

4.3 *The spring box method*

4.3.1 Components of the spring box

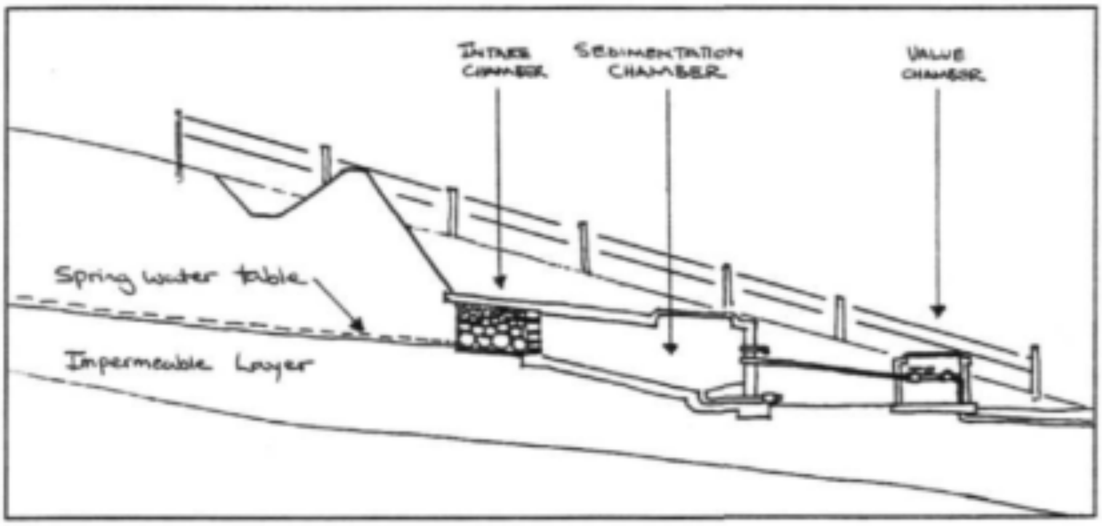

Figure 4.1 Components of Spring Protection

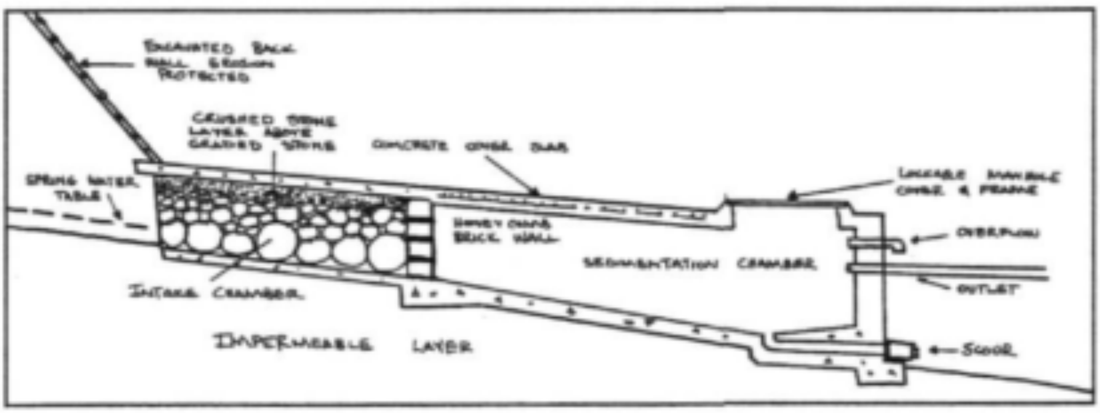

Figure 4.2 Components of Spring Box

The spring box consists of two chambers, the intake chamber and the sedimentation chamber. The intake chamber is constructed against the water-bearing layer and is separated from the sedimentation chamber by a honeycomb wall that allows for the free flow of water.

The intake chamber is constructed against the water-bearing layer and is filled with a filter pack of graded washed stone that supports the water bearing layer from being eroded and washed out by the spring flow.

The sedimentation chamber is where of sand particles carried in the spring water can settle out of the water and be removed through a scour pipe in the floor of the chamber during operation and maintenance.

The outlet pipe and the overflow pipes are oversized such that they can accommodate the maximum possible flow. This is done to ensure that at no time can backpressure be exerted on the eye of the spring.

4.3.2 Construction

Construction is easiest when the flow of water is at its minimum and should be planned to coincide with the dry season. The following sections are described in detail: Clearing, excavation, building the temporary dam, sedimentation chamber, casting the foundation and floor, pipe details, barrage and side wall construction, honeycomb partition wall, filter pack, roof and inspection manhole, outlet pipe and scour fittings, the protection zone.

4.3.2.1 Clearing

Clear all the vegetation from the immediate area of the spring. If there are large trees within 10m of the spring, they should be removed, including the roots. The need to clear the area needs to be balanced against the environmental impact of removing vegetation. Where the trees are invasive alien species, these must be completely removed but, if the trees are indigenous species, the effect of the roots must be carefully assessed before deciding on the removal of any trees.

Entsikeni Yellowwood Forest

In 1996 a powerful spring supplying 2.5l/s was developed to supply Entsikeni Village in Umzimkulu in the Eastern Cape. The spring is located within the Ensikeni forest reserve and is surrounded by majestic 30m high Yellowwood Trees. No trees were removed for the spring development and the spring excavation showed the flow emerging from a horizontal fracture in rocks that was largely free of tree roots. On the same project a flexible pipeline was used and snaked between the trees so that no trees were removed for the pipeline construction.

4.3.2.2 Excavation

Start excavation at the point that the water is coming out of the ground and follow the flow of the spring back into the slope. Do not dig down into the impervious layer as this could allow the water to seep down into the ground and only excavate to the width that is required to work at the spring to minimise the size of the construction required. Always ensure that the water can flow freely away from the spring and that the water does not dam up against the spring. Only use hand tools for excavation and take care not to disturb the water-bearing layer of the spring while excavating. Excavate until bedrock is reached or until the surrounding soil is stable. The quantity of the excavation varies considerably depending on the particular spring and the ground conditions. The excavated spring should be inspected by a person with experience at this point and before construction work begins as it is often only after the spring has been excavated that the construction plans can be finalised.

Figure 4.3 Spring excavation (from Meuli and Wehrle, 2001)

When the spring source is a "seep" or the flow is emerging from a swampy area, it is often difficult to assess the source without doing some excavation. By excavating, one drains the water away from the area and is able to evaluate if the spring is an artesian or a gravity spring.

Often springs do not emerge from a single "eye" but from a broad layer. When excavating this type of spring, first excavate the main flow and when complete, return and excavate the along the smaller side flows.

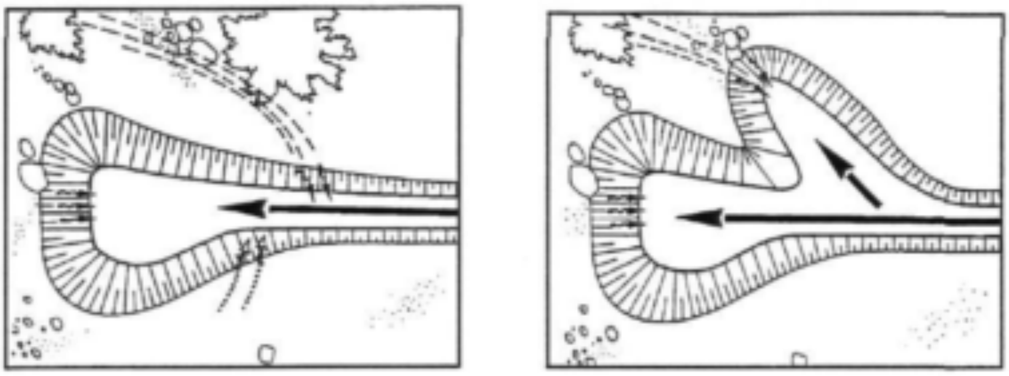

Figure 4.4 Excavating a spring emerging from more than one point (from Meuli and Wehrle, 2001)

4.3.2.3 Building a temporary dam

When the excavation is complete and has been inspected, a temporary dam of clay is built including a temporary diversion pipe to remove the water from the site of construction. The pipe should be large enough to take the maximum flow expected during the construction period and should be long enough to take the water well clear of the construction.

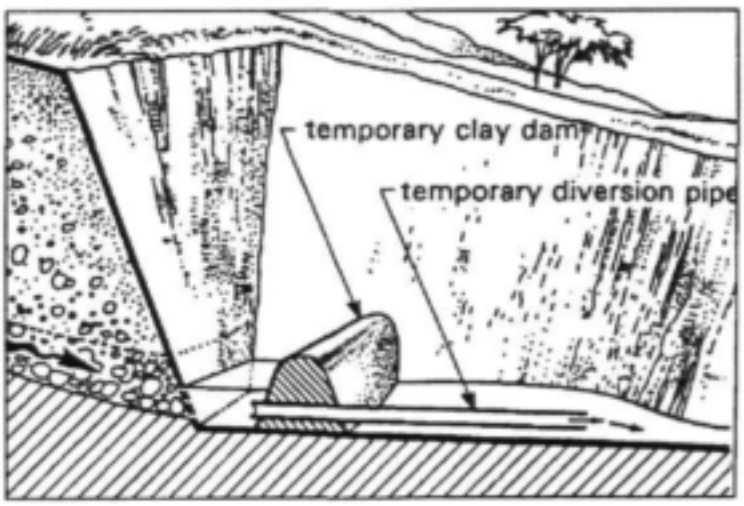

Figure 4.5 Temporary dam construction (from Meuli and Wehrle, 2001)

4.3.2.4 Sedimentation chamber

A retention time of between 5 and 30 minutes should be used for sizing the sedimentation chamber. If the water only contains fine sand (±0.1mm diameter) and coarser materials, less than a minute retention time is required to settle the particles. If one needs to remove silt particles (±0.01mm diameter) from the water, a retention time of 30 should be used.

In addition to the sedimentation chamber, scours must be provided at low points in the supply pipeline and at storage reservoirs for removing any particles that do not settle in the sedimentation chamber.

4.3.2.5 Casting the foundation and floor

1. Cast a foundation for the barrage a minimum of 300mm into the impermeable layer and extending 300mm into the side walls of the excavated area. The foundation must be cast against the in-situ material. The exact dimensions and position of the barrage will depend on the particular conditions of that spring and should be assessed on site after excavation has been completed.
2. The floor of the intake chamber of the spring box must have a slope of between 1% and 2 %. If the impermeable layer is sandy and not consolidated a floor must be cast for the intake chamber as well as the sedimentation chamber. This should be confirmed on site prior to constructing the barrage. The sedimentation chamber floor must fall with a slope of a minimum of 3% to the scour outlet.
3. The scour pipe and fittings must be cast into the floor of the sedimentation chamber and must have a cover of 75mm of concrete, above, below and on the sides of the pipe. (see the next section for scour pipe details). The floor of the sedimentation chamber must slope by a minimum of 5% to the scour outlet.

4.3.2.6 Scour, outlet and overflow pipe details

1. Sizing of the scour, outlet and overflow pipes should be based upon the maximum flow of the spring. The outlet and overflow will not be flowing under pressure and the pipes should be sized based on the open pipe capacity with a free water level. As an example, assuming a gradient of 3% and galvanised pipes 2/3 full, the minimum pipe sizes listed in the following table should be used.

Nominal Internal Diameter	Flow
mm	l/s
50	0.85
65	1.7
80	3
100	5.4

The outlet pipe size can be reduced to the size of the water delivery pipeline (from the source to the reservoir) after the outlet valve and air valve.

2. Use pipe of galvanised steel or uPVC. High density polyethylene (HDPe) pipe should not be used because HDPe has a smooth surface that does not bond with concrete. If the water is corrosive, uPVC pipes should be used. In the contact zone between the pipe and the concrete, ensure a watertight bond between the pipe and the concrete. This can be done using a flange or, for uPVC, by roughening the pipe through applying PVC glue to that section of the pipe and sprinkling sand onto the glue. For structural strength, a minimum of class 9 uPVC pipe must be used.
3. The outlet pipe must be positioned at a height such that it is clear of the floor of the sedimentation chamber (100 to 150mm clear of the floor) to allow sufficient space for the sediment to settle. At the same time the outlet and overflow must be below the natural level of the water in the water bearing layer to ensure no back pressure is exerted on the spring. The outlet pipe should have an even slope of between 3% and 10% up to the valve chamber. Again, if the water is corrosive, uPVC pipes should be used.
4. An overflow pipe must be installed with its base 75mm above the top of the supply pipes. If the outlet pipe becomes blocked, the overflow must be able to freely discharge the full flow of the spring without the water damming up in the spring box. As a result, the height of the overflow pipe in the barrage wall must be below the natural water level in the water bearing layer to ensure that back pressure cannot be applied to the spring. Also check the overflow regularly for blockages during operation and

maintenance. To protect the sedimentation chamber from potential vandalism and contamination, the end of the overflow pipe must be fitted with a downward facing 90 degree bend and with a coarse mesh to stop animals getting into the pipes. If there is a potential for vandalism, it is best to use a gavanised steel overflow pipe and not plastic. The water from the overflow must be able to drain away from the spring protection and not create a pool of water around the spring.

4.3.2.7 Barrage and side wall construction

1. Cast the barrage wall a minimum of 400mm high onto the foundation (after roughening and cleaning) and against the in-situ material of the excavated side wall. The barrage must be constructed of watertight concrete or be plastered with a watertight plaster layer on the inside wall. For ease of construction, place the temporary drainage pipe within the supply pipe so all the water can drain away below the construction area.

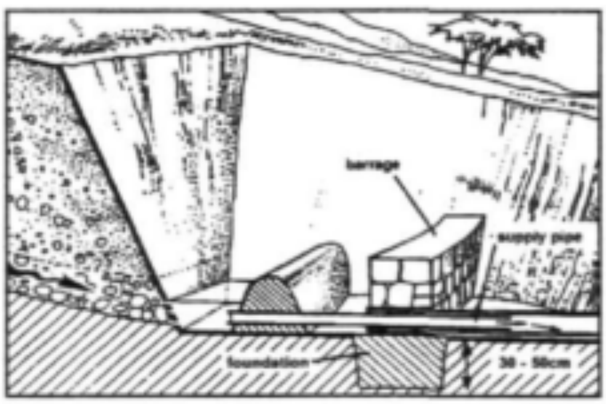

Figure 4.6 Barrage construction (from Meuli and Wehrle, 2001)

2. The side walls of spring box must be built up to provide support for the roof of the sedimentation chamber and to stop the side walls from caving into the spring box.

4.3.2.8 Honeycomb partition wall

The honeycomb partition wall separates the intake chamber with its gravel pack from the sedimentation chamber. Build the partition from bricks or blocks with gaps of 50% of the brick length between the bricks. Even the bottom layer of brick must have gaps between the bricks.

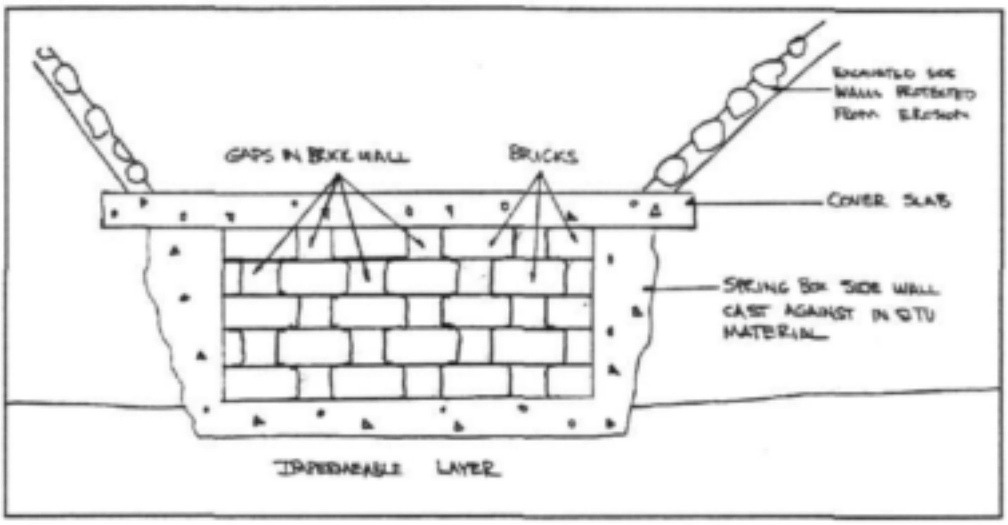

Figure 4.7 Honeycomb partition wall

4.3.2.9 Filter pack

Use washed and brushed clean stone of 150mm to 300mm diameter. Place the stones between the honeycomb partition wall and the water-bearing layer at the back wall ensuring that there is adequate space for the passage of the maximum flow between the stones. Use progressively smaller stones packed above the bottom layer until the top layer of crushed stone or gravel pack is a smooth surface that can support the casting of a concrete cover. The top of the filter pack must have a slope of grade 5% from the back wall to the honeycomb partition wall wall. The stone packing must not be walked on and conditions must be kept as clean as possible during the construction.

4.3.2.10 Roof and inspection manhole

1. A concrete cover of a minimum thickness of 50mm must be cast on top of the filter pack over the top of the honeycomb partition wall and keyed 200mm into the side and back walls. The slab must fall at a grade of 5% to the front and

must be cast against the in-situ material of the side and back walls. The slab must be watertight to prevent contamination.

2. Over the sedimentation chamber, construct a supported wooden formwork to support the slab construction over the chamber. Reinforce the slab with weldmesh and cast the manhole frame and locking bar lugs into the slab. The thickness of the slab and the quantity of reinforcing will depend on the wall to wall span of the chamber. Ensure that the locking bar lugs and weldmesh have a concrete cover of 25mm. The manhole frame must be raised above the slab surface by at least 25mm and the slab must have a slope of 3% towards the barrage wall to ensure drainage of water away from the opening.
3. A standard 645mm by 495mm manhole provides sufficient space for inspecting and cleaning the sediment chamber and can easily be removed by one person. A cheap and effective locking bar (for use in low security rural applications) can be made using a length of galvanised steel 20mm pipe with a socket on each end. The lugs are made of a 25mm galvanised equal tee with a short piece of 25mm galvanised pipe splayed and cast into the slab. To unlock, the operator needs two pipe wrenches to undo one of the sockets and to remove the pipe lock.

4.3.2.11 Outlet Pipe and Scour Fittings

1. Within 5m to 10m from the spring box, an isolating valve and an air valve must be positioned on the outlet pipeline. The isolating valve is used for isolating the delivery pipeline during maintenance and the function of the air valve (positioned after the isolating valve) is to allow air into and out of the pipeline during draining and filling of the pipeline. These valves should be contained in a drained valve chamber that is large enough to able to work on the valves during operation and maintenance. At this point the outlet pipeline can be reduced to the size of the delivery pipeline.
2. It is good practice to position a water meter at this point for measuring the quantity of water being abstracted from the spring. Measuring abstraction allows one to monitor the performance of the spring and is also required for water use licensing under the new national water act of South Africa. Refer to

the manufacture's specifications for the correct size of water meter for the range of the flows expected as well as the pipe detail specifications.

3. The scour pipe should by fitted with a stopper or a gate valve that can be opened when one is cleaning the sedimentation tank. Position the scour pipe such that when it is open the water drains freely away from the spring area.

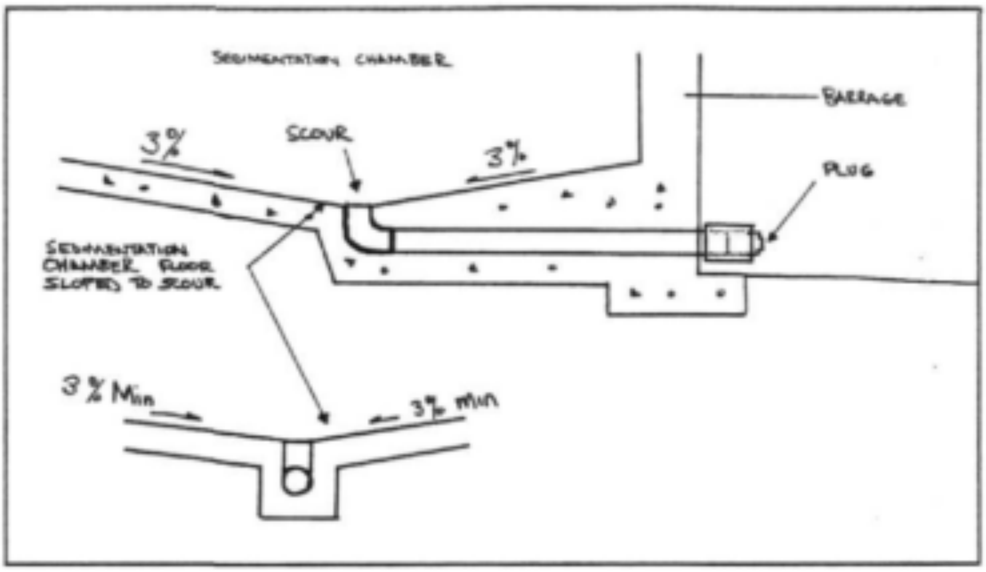

Figure 4.8 Scour pipe details

4.3.2.12 The Protection Zone

1. The back and side walls of the excavation must be protected from eroding and collapsing onto the spring box by stabilising the excavated face. Each spring site is different and the method of protection used should be based upon on site inspection of the height, slope and quality of the excavation face, the location of the spring relative to watercourses and the conditions of surrounding environment. Generally a combination of the following methods are used:
   - Gabion baskets and reno mattresses (gabion "mattresses")
   - Retaining walls or retaining block walls (like Terraforce)
   - Reducing the excavation slope to a minimum stable slope
   - Planting grass
   - Stone pitching (stone set in concrete)
2. Within a radius of 10m to 20m of the spring is the inner protection zone. This area must be planted with grass and fenced. It must also be kept clear of

trees and bushes as their roots could infiltrate the spring box and damage the construction by cracking the concrete and mortar and blocking pipes.

3. Surface water must be kept away from the spring box. This is done by constructing a drainage ditch above the spring box directing storm water away from the spring box. The drainage ditch must be large enough to divert the water during a peak rainfall event and must be located within the fenced inner protection zone for it to be effective and to protect it from being damaged by animals.
4. A strong and effective fence must be erected around the inner protection zone with a lockable gate for access. The fence is only effective if it keeps all animals and unauthorised people out of the area and choosing appropriate fencing materials should be based upon the conditions at the particular spring. Consulting the local community representatives on what fencing will be secure is important both in understanding the local conditions and in initiating the discussion of the role of the community in ensuring long term security of the source.
5. Management of the environment in the catchment area will ensure the long term sustainability of the water source. Alien vegetation, especially water thirsty and invasive trees (black wattle, gum, poplar, rooikraans etc) should be removed from within 100m to 150m of the spring and water efficient vegetation indigenous to the area encouraged. The use of the area should be monitored to ensure the following:
    - Livestock grazing is managed to ensure that overgrazing in avoided.
    - People do not settle in the area
    - If there are settlements above the spring, ensure that pit latrines are not constructed close to the spring
    - No light industry, livestock kraals, rubbish dumping or other potential groundwater polluting activities are allowed

4.4 The spring catchment (or Lesotho) method

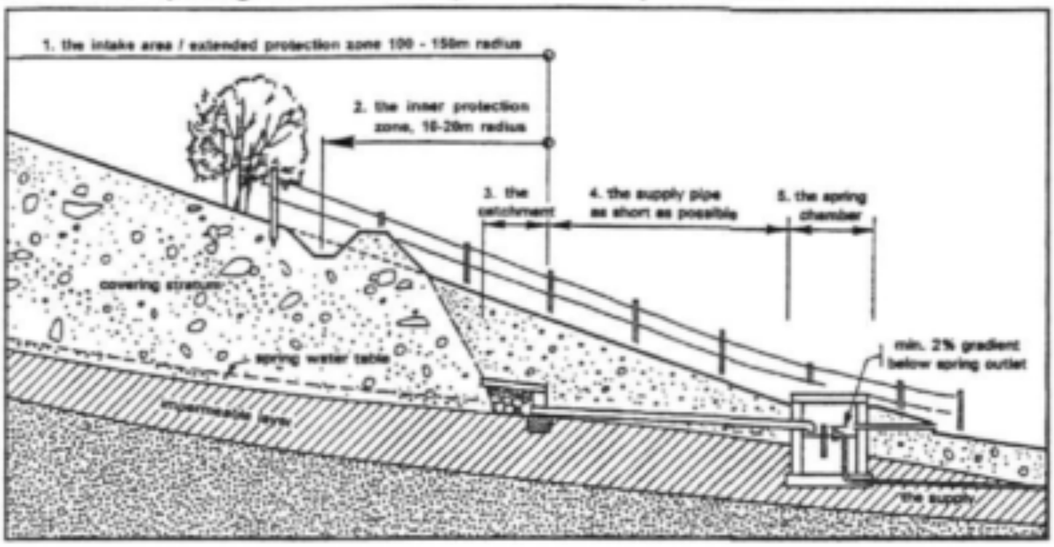

Figure 4.9 Components of the spring catchment (from Meuli and Wehrle, 2001)

There are two main differences between this method and the spring box method.

1. With the spring catchment method, the spring is excavated further into the hillside and then after construction is complete, the ground above the spring chamber is backfilled.
2. The spring catchment method involves the building of two separate structures, the spring catchment at the source and the spring chamber for sedimentation.

A comprehensive manual has been produced on the spring catchment method by SKAT as part of their series of manuals on water supply (Meuli C and K Wehrle, 2001).

4.5 Artesian spring construction

With artesian springs, the groundwater flows vertically out of the ground. The construction is mostly the same as for a gravity spring with some additional considerations listed below.

4.5.1 Excavation

A trench must be dug before the construction can start to drain the area of the spring and to keep the water away from the source during the subsequent excavation and construction. Once the area of the spring source is drained, one can assess the source and plan the excavation and construction. As the spring is excavated, the drainage trench may need to be deepened to ensure that the water continues to flow away from the source.

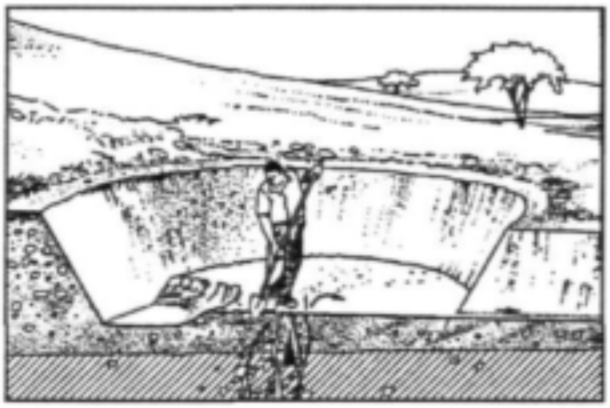

Figure 4.10 Artesian spring excavation (from Meuli and Wehrle, 2001)

4.5.2 Construction

Artesian spring construction requires a watertight construction surrounding the source on all four sides. This applies to the temporary dam construction and for the permanent barrage construction.

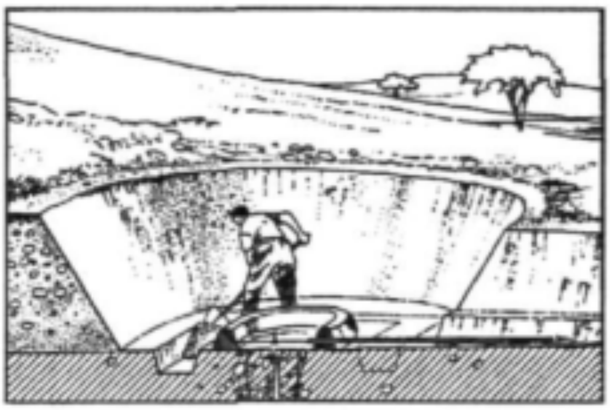

Figure 4.11 Artesian spring barrage (from Meuli and Wehrle, 2001)

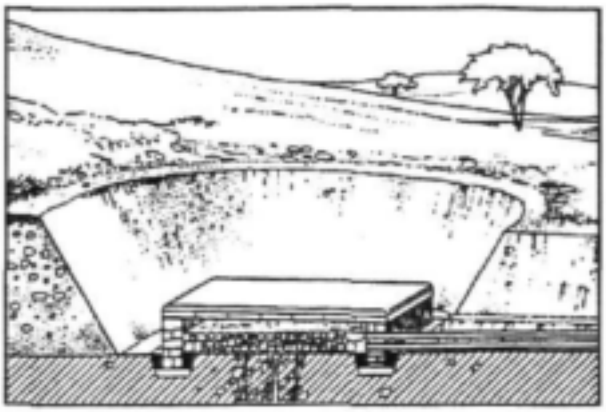

Figure 4.12 Artesian spring catchment (from Meuli and Wehrle, 2001)

4.5.3 Artesian spring construction in loose ground

Artesian springs in loose ground should be constructed using the methods of construction normally used for the construction of hand-dug shallow wells. These methods are described in Collins S 2000.

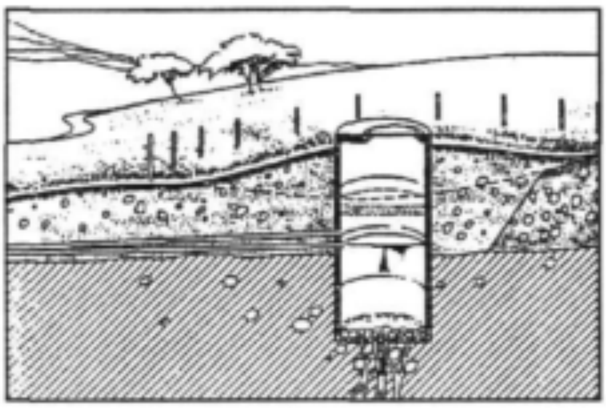

Figure 4.12 Artesian spring construction (from Meuli and Wehrle, 2001)

5 Operation and maintenance

Protected springs need very little operation and maintenance in comparison to other types of water supply sources. Periodic inspections of the spring protection should be carried out once a month and the following specific tasks should be incorporated into the operator's maintenance schedule. Note that it is recommended that the operator have a logbook for recording all activities including the spring flow records and spring maintenance activities.

- Check the state of the fence and look for evidence of animals having been in the inner protection zone - repair where needed
- Check the state of the gabions/stone pitching/retaining structures – repair and report for maintenance where needed
- Check the state of the diversion drain above the spring – dig out and repair where needed
- Check for wet spots indicating leaks – report for maintenance
- Remove any tree or bush seedlings from the inner protection zone
- Cut or harvest the grass within the inner protection zone to avoid the grass becoming a temptation for grazing of animals.
- Clean any vegetation and ground from the top of the covering slab
- See if there is water coming out of the overflow. This would indicate a blockage in the outlet pipe – unblock or report for maintenance
- Open the scour pipe and clean any sediment from the chamber – report on sediment load
- Check that the water from the scour and overflow can drain away from the spring area
- Check all pipes and valves for leakage – repair and report for maintenance where needed
- Record the water meter reading and check that the meter is operating correctly. Every 3 months a manual reading of the flow should be taken and compared with the meter reading to check the meter operation.
- Check that the overflow pipe including the mesh is clear of any obstruction – clean.

- Check the water quality by observing the taste, odour, colour and turbidity and record the observations. In addition, water samples must be taken and sent for analysis on a regular basis. The frequency of sampling and the determinands to be tested for will depend on the water quality of that spring and the sampling plan for the scheme it serves. As a minimum, microbiological samples at the source should be taken twice a year, in the dry and wet seasons.

During maintenance activities always ensure that the water can flow freely out of the outlet, scour or overflow and never block the pipes so that the water can dam up in the spring box.

6 Common errors to be avoided

1. No or not enough monitoring of the spring flow prior to development with the result the spring is unable to provide the "planned" water demand. Lack of knowledge of the high flow conditions can result in too small pipes being used and causing back pressure and spring failure.
2. Trees not cleared (and kept clear) from the inner protection zone resulting in roots damaging the spring box.
3. Insufficient excavation so that the spring is constructed in unstable material.
4. Mechanical excavation or unsupervised excavation damaging the impermeable layer or resulting in back pressure on the water bearing layer.
5. The excavation extends too far to the sides with the result that a long barrage wall is needed requiring unnecessary work and expenditure.
6. No scour facility installed.
7. No manhole cover provided or an inappropriate manhole cover provided that does not seal, does not provide security of the source or cannot be removed by one person.
8. Manhole level with slab and the slab not sloped away from the manhole resulting in contamination of the water source with surface water.
9. Geofabrics used in the source which eventually block with sediment causing back pressure and failure.
10. Galvanised steel pipe used in corrosive water.
11. No flanges or pipe roughening at the interface of pipes with concrete resulting in leaks developing around the pipe.
12. Barrage wall not built with waterproof materials.
13. Outlet and overflow pipes built above the level of the source.
14. No isolating valve on the outlet
15. No air valve on the outlet (vacuum breaker for pipeline)
16. No water meter for measuring water abstracted
17. No or not big enough drainage channel above the spring resulting in surface storm water contamination and erosion.
18. No or inadequate fence and no locked gate in the fence for access.
19. No protection of the slopes behind and to the sides of the spring protection resulting in erosion and collapse of the walls onto the spring protection.

20. Pools of water allowed to form around the spring protection by not providing drainage for scour and overflow water away from the area of the spring.

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www.wateraid.org.uk/site/in_depth/technology_notes/300.asp

www.bae.ncsu.edu/programs/extension/publicat/wqwm/ag473-15.html

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A synthesis of the hydrogeology of the Table Mountain Group formation of a research strategy

Kevin Pietersen and Roger Parsons

A project was initiated during 2000 to synthesize the current knowledge about the Table Mountain Group (TMG) aquifer systems. This resulted in a document on the "Synthesis of the Hydrogeology of TMG – Formation of a Research Strategy". The document is subdivided onto technical papers and appropriate case studies. This exercise resulted in the understanding that to realize the potential of this groundwater supply, many uncertainties and barriers need to be overcome, including: deficient understanding of the occurrence, attributes and dynamics of TMG aquifer systems; lack of understanding of environmental impacts of exploitation; and uncertainties about how best to manage the resource within a multi-objective environment. Research of a multi-disciplinary nature is thus needed to find answers to questions concerning the water resource potential and optimal management of TMG aquifers, in the interest of furthering integrated water resource management in the region.

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Hydrogeology of the main Karoo Basin: Current knowledge and future research needs

AC Woodford • L Chevallier (editors)

A large part of South Africa (approximately 50% of the country as a whole) is underlain by the Karoo Supergroup of geological formations. A major characteristic of the Karoo Supergroup, which consists mainly of sandstone, mudstone, shale and siltstone. The majority of boreholes drilled in Karoo formations have very low yields . However, large volumes of groundwater are pumped from wellfields supplying towns, mines and the basements of buildings on a daily basis in areas underlain by the Karoo formations, which is not what one would expect from aquifers with a limited yield.

Karoo aquifers have a very complex and unpredictable behaviour. The general view is thus that Karoo aquifers are not reliable sources of water. However, there is no doubt that these aquifers played a significant part in the development of South Africa. This is evident in numerous place and area names, such as De Aar, Bitterfontein, Koffiefontein, Springfontein, Lelieput, Syfergat and Putsonderwater.

The Water Research Commission (WRC) has co-ordinated and funded numerous research projects aimed at understanding the hydrogeology, flow characteristics and exploitability of Karoo fractured-aquifers over the past 20 years. The research was conducted by various research institutions, governmental organisations and private consultants, involving both intensive localised and more extensive regional studies.

This document review and collate the vast amount of existing knowledge on Karoo fractured-aquifers and identify future research priorities.

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