GROUNDWATER OCCURRENCE IN THE TABLE MOUNTAIN AREA OF CAPE TOWN, SOUTH AFRICA

CHANGHONG WU

GROUNDWATER OCCURRENCE IN THE TABLE MOUNTAIN AREA OF CAPE TOWN, SOUTH AFRICA

Changhong Wu

A mini-thesis submitted in fulfilment of the requirements for the degree of MPHIL, Integrated Water Resources Management in the Department of Earth Sciences, Faculty of Natural Sciences, University of the Western Cape, South Africa.

Supervisor: Prof. Yongxin Xu

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DECLARATION

I declare that "**Groundwater Occurrence of Table Mountain area in Cape Town, South Africa**" is my own work, that it has been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledge by complete references.

Full name: Changhong Wu   Date: 15 November 2008

Signed:

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ABSTRACT

GROUNDWATER OCCURRENCE OF TABLE MOUNTAIN AREA IN CAPE TOWN, SOUTH AFRICA

Keywords: Geology, Hydrology, Precipitation, Groundwater Occurrence, Spring, Runoff, Geochemical analysis, IWRM, Table Mountain, South Africa.

Groundwater is an important water resource to be used to supplement the water demand for the City of Cape Town for present and future generations. Understanding the groundwater occurrence of the Table Mountain area is very important for future groundwater exploitation and management.

Apart from the sea in the west, Table Mountain is mostly surrounded by the unconsolidated sediments including the Kirstenbosch, Newlands, and Oranjezicht areas. These areas are rich in groundwater resources, like springs; some of them were utilized, others not. However, there are few studies that focused on spring resource in this area. No up to date information is available for spring resources research and relative data is lacking from local research institutions. In fact, some of the spring resources in the Table Mountain area had been extracted and been utilized for local community for many years. Data and information newly obtained from this study about such groundwater resources will help future groundwater development and management.

There are at least 13 springs in the selected study area. Those springs were investigated for groundwater occurrence, because spring is an important manifestation of the underlying aquifer through which groundwater dynamics can be detected. The main objective of the study was to sketch a clear picture of groundwater occurrence and to obtain an improved understanding of how geomorphology affects groundwater flow, its manifestation and quality. Water resources management is also important because this kind of water resource can be used to help meet the water demand of this local area in the future.

There is relationship between the topographical features of the Table Mountain and spring occurrence. The research area delineated is used to interpret the relationship. Hydro-geochemical analysis is carried out to indicate the chemical components of the groundwater and to understand the groundwater type and water quality of this particular area. Based on the completed analysis and interpretation of factors influencing discharge and recharge, some good results were obtained and useful information is made available for first time.

ABBREVIATIONS

IWRM	Integrated Water Resources Management
USGS	U.S. Geological Survey
WRC	Water Research Commission
DWAF	Department of Water Affairs and Forestry
WR2005	Water Research Commission Flow Data in 2005
GIS	Geographic Information System
TMG	Table Mountain Group
TDS	Total Dissolved Solids
EC	Electrical Conductivity
T	Temperature
Ca	Calcium
Na	Sodium
K	Potassium
Cl	Chloride
Mg	Magnesium
HCO_3	Bicarbonate
$CaCO_3$	Calcium Carbonate
SO_4	Sulphate
NO_3	Nitrate
PO_4	Phosphates
NH_4	Ammonium
Fe	Iron
Mn	Manganese
Si	Silica
B	Boron
F	Fluoride
Sr	Strontium
Ba	Barium
Al	Aluminium
Cr	Chromium
Ni	Nickel
Cu	Copper
Zn	Zinc
Cd	Cadmium
Pb	Plumbum

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CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

In most areas of the world over 90% of water stored in a catchment at any one time, is found underground in aquifers. Groundwater could therefore represent a huge strategic water resource and plays a vital role in the water cycle. Its use in irrigation, industries, municipalities, and rural homes continues to increase (Todd & Mays, 2005).

South Africa is a semi-arid country with an average annual precipitation of 550mm which is below the average rate of the world. However, the hydrogeological environment is complicated, and this conduces toward rich groundwater resources in South Africa. Since Precambrian, over about 800 million years ago, hard rocks experienced metamorphism and heterotaxy, therefore the structure of the aquifers are highly variable and provide an abundance of groundwater resources. Because of geological setting of South Africa, the 90% of the country groundwater occurs in the hard rock, with only secondary openings. Groundwater is contained mainly in fractures, and to some extent also in pores in weathered rock (Braune, 2000). According to Hobbs, (1997), groundwater‘s role and importance has risen significantly in the past few years. There has already been a common trend towards greater utilization of local groundwater resources in South Africa.

For many years, groundwater was regarded as a cheap source of water, requiring little or no planning or management (Braune, 2000). A few failed groundwater abstraction schemes have unfortunately led to the misconception that groundwater is an unreliable source of supply which should be replaced as soon as possible by more reliable surface water resources (Braune, 2000). A lack of understanding of the occurrence, movement and recharge of groundwater has however, in many instances led to unsustainable utilization of this resource (Braune, 2000), because utilization of groundwater greatly preceded understanding of its origin, occurrence, and movement

(Todd & Mays, 2005). The successful exploitation and management of groundwater resources in the future is essentially dependent on the understanding of groundwater occurrence and movement dynamics (Won and Lee, 2006).

The surveys of South Africa government indicated that over 12 million people, distributed over some 15000 villages, did not have a basic water supply of 25l/person/day. With rapidly economic development, more and more surface water bodies get polluted and local river levels decrease during the dry seasons. This provides groundwater with a completely new role as the most feasible option to meet the massive backlog in domestic water needs everywhere in the country (Braune, 2000).

Currently, most of water supply of Cape Town is obtained from surface water, stored inland in big dams and reservoirs, including those at Theewaterskloof, Voelvlei and Steenbras (Davies, 2006) and other dams with a total yield 447.85 million m^3 per year (2001 data). According to the document "Water Balance, Resource planning and Management of City of Cape Town" (2001) the groundwater resources data showed that there are four groundwater resources which account yield about 33.4 million m^3 per year. These resources could be supplemented to future water supply for the City of Cape Town.

The study area was selected from the northern to the eastern part of the Table Mountain. Eight springs' sites distributed within the study area, and sixteen water samples were collected from those sites. Four surface water samples were also collected from Kirstenbosch gardens and Table Mountain streams in order to comparing with groundwater samples. Spring flow rate is important for the study so that the yield of springs is compared in period. For instance, date back a long way, in 1888 Main Spring had $1.08*10^6$ litres per day, in 1995, is $2.25*10^6$ litres per day(Visagie, 1995), in 1999, more than $1.44*10^6$ litres per day (Harris, 1999) and in 2008, it flows $2.2*10^6$ litres per day. The springs flow changes year by year, and reason might be caused by temperature, precipitation, evaportranspiration or hydrogeology conditions. Those elements of groundwater occurrence are discussed in this study. After the investigation, we found that some of the springs are no longer fulfilling the role of water provision for the local community. Some of springs have fallen into disuse and discharge into the storm water system as observed during the fieldwork. The reason might be considered as pollution, probably fertilizers and sewage (Bishop& Killick, 2002). The main task for doing spring research is to understand the occurrence of the groundwater and to analyse the groundwater quality so that the reason why spring water is continued or ceased to be utilized could be determined.

1.2 AIMS AND OBJECTIVES

The main objective of the study is to sketch a clear picture of groundwater occurrence in the Table Mountain area. A second objective is to achieve an improved understanding of how topography affects groundwater flow, groundwater's manifestation and the quality of groundwater. Water resources management is also an issue that need to be mentioned.

The specific objectives of this study are

- To investigate the groundwater occurrence in the study area to groundwater learners.
- To examine the groundwater quality to groundwater users.
- To suggest the strategies of integrated management of groundwater resources to water resources managers.
- To show the environmental and social-economic value of groundwater resources to local community.

1.3 STUDY AREA SELECTION

The selected area for study is in the latitude 33°56.172'S to 33°58.007'S and longitude 18°24.528'E to 18°28.073'E (See Figure 1.1), including the Oranjezicht area, the Newlands area, and Kirstenbosch. The study area is located along the northern to eastern parts of Table Mountain, which includes the flat topography, part of Table Mountain Group.

Spring is an important manifestation of underlying aquifer. Through spring investigations, the hydrogeologists can determine certain groundwater dynamics. In the study area, eight springs were investigated for formation analysis and sixteen water samples were taken and a hydrogeochemical analysis was executed for each of them.

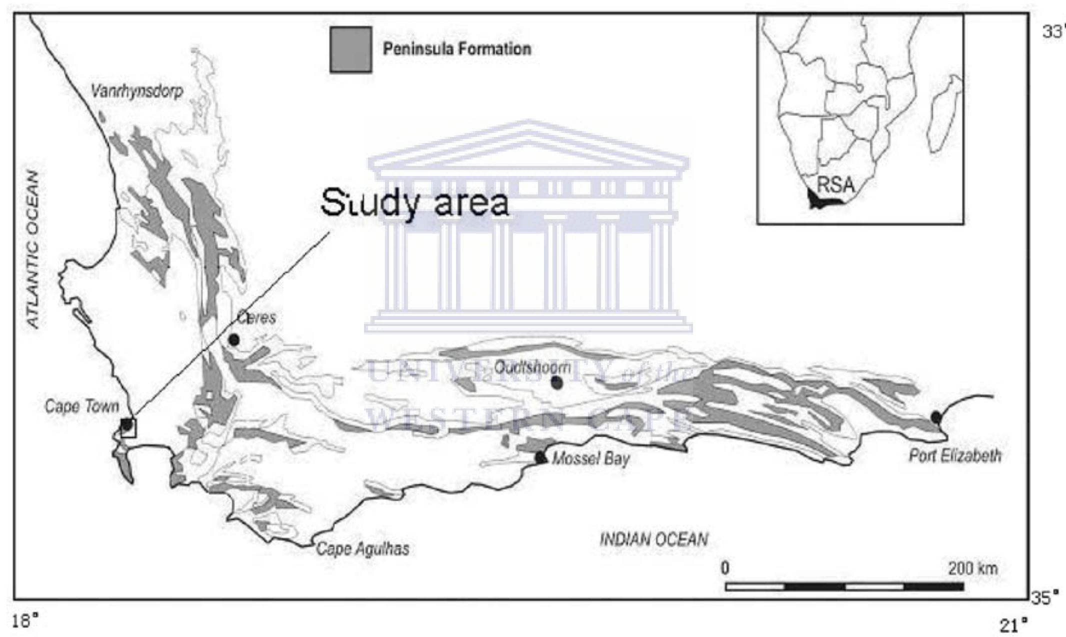

Figure 1. 1 Locality of the study area

1.4 THESIS STRUCTURE

This thesis is explained the groundwater occurrence from climatic, geology and hydrogeology aspect, and estimation of groundwater recharge and groundwater quality is investigated simultaneously. The Table Mountain area has been shown the evidence that the groundwater resource is abundant, therefore the integrated water resources management and groundwater social-economic values are important to be concerned.

- Chapter one is the introduction. The background and motivation of the study is introduced.
- Chapter two is the literature review. In this chapter, groundwater studies carried out to date in Table Mountain Group are summarised. The basic concepts of groundwater occurrence, such as geology and hydrogeology setting, types of aquifers are introduced. The methods of groundwater recharge, groundwater discharge and groundwater quality examination are interpreted. Groundwater utilization in South Africa is briefly indicated in this chapter as well.
- Chapter three outlines the methodology of the study. Field work is delineated in detail. The methods of estimating groundwater recharge and discharge are pointed out. The geochemical analysis techniques are also presented in this chapter.
- Chapter four is the groundwater occurrence part. In the chapter, the locality of the study area and water sample site is interpreted, including the climatic situation, geological setting and hydrological setting. Springs which were investigated are explained in detail with photographs.
- Chapter five is about water quality analyses. Twenty water samples were tested and the results are interpreted and analyzed. The chemical components of the groundwater samples are compared by analyzing the results. The spring water quality is also indicated by comparing with Domestic Water Use Guidelines of South Africa.
- The conclusion is drawn in Chapter six. This chapter emphasizes the implication of the study from Integrated Water Resources Management aspect. The environmental and social-economic value of the groundwater is signified according to the main findings from the study.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

It is necessary to do a review of previous studies and research in order to understanding current research into groundwater occurrence in the particular area. There are only a few recent research studies applied in the study area. However, many literatures have discussed related methods, such as groundwater occurrence, geology and the hydrogeology cycle, and groundwater recharge estimation and so on.

Reports and papers were reviewed according to the topics of groundwater process, geology setting, and hydrogeology setting. Groundwater occurrence focused on the physiography, geology, and hydrology of location. Climatic situation is other important aspect needs to be attention. Some concepts, such as the types of aquifer and their characteristics, groundwater recharge and discharge, and groundwater quality, those works done on the local geology and hydrogeology by local authors. The hydrogeology of aquifer systems in general, with a focus on the TMG was reviewed (Nakhwa, 2005). The water balance method is used as a tool to estimate groundwater recharge; this is also reviewed in this section.

2.2 GROUNDWATER STUDIES CARRIED OUT TO DATE IN TMG

Bredenkamp; Botha; Tonder van; Van Rensburg. 1995. Produced a manual on recharge and storativity estimation, which includes many case studies and data. Namely a manual on quantitative estimation of groundwater recharge and aquifer storability.

Cape Town's springs investigation report. Twenty-four springs had been investigated by reporter. In the report, springs' location and history, water samples chemical analysis, and yield were detailed delineated (Visagie, 1995).

Geochemistry and Isotopes for Resources Evaluation in the Fractured Rock Aquifers of the Table Mountain Group (Weaver, et al. 1999).

Preliminary investigation of the oxygen and hydrogen isotope hydrology of the greater Cape Town area and an assessment of the potential for using stable isotopes as tracers. The research was use the isotope tracer to investigate the groundwater quality and quantity. Some of springs which were located around Table Mountain were pointed with volume and quality (Harris, et al. 1999).

Groundwater development in South Africa and an introduction to the hydrogeology of groundwater regions. The reference disabuses the bigger picture for South Africa groundwater explanations. The history and development of groundwater of South Africa were briefly demonstrated (Vegter, 2001).

A very good basic knowledge of the stratigraphy, lithology and structure of the Table Mountain Group was given by Beer (2001) report.

Hydrogeological characteristics of the Table Mountain Group Aquifer were given by Rosewarne (2001) report.

A review recharge definition and methods in Table Mountain Group Aquifer System was produced by Parsons, 2001.

Groundwater dependent ecosystems in the Fynbos Biome, and their vulnerability to groundwater abstraction. Groundwater discharge is particularly explained (Maitre, et al. 2001).

Groundwater Quality and Fitness for Use. The relationship between chemical constituents and groundwater quality was well explained in the report (Smart and Tredoux, 2001).

Towards a management tool for groundwater exploitation in the Table Mountain sandstone fractured aquifer. The spring flow was reviewed in the report (Kotze, 2002)

Evaluation of groundwater flow patterns in fractured rock aquifers using CFSs and Isotopes (Talma and Weaver, 2003).

Groundwater recharges estimation of Table Mountain Group Aquifer Systems with Case Studies. The report provides an overview of recharge methods and studies carried out in the Table Mountain aquifer (Xu, et al. 2007)

In 2002, Bishop and Killick had a report "Role of groundwater in meeting Cape Town's water demand". In the conference report, they mentioned a lot of information about the Table Mountain Aquifer, Newlands Aquifer and Cape Flats Aquifer. They did review existing groundwater resources and proposed the spring water resource for Cape Town. Groundwater resources not only supply domestic bulk water, but also water for irrigation purposes. Some of the springs had been illustrated in the report, such as Kotze Spring, Newlands Spring, Kommetjie Spring, Palmboom Spring and Waterhof Spring.

Isinuka Spring in Transkei region of the Eastern Cape, South Africa, was assessed for water quality. The research did a physical examination of springs and Rivers. The water quality assessment method is helpful to spring water quality test. The groundwater quality had also been analyzed (Faniran, et al. 2001).

2.3 GROUNDWATER UTILIZATION

Groundwater occurs with varying prevalence, extent, and natural quality over the globe, and therefore its importance for humans and nature varies from region to region (Villholth, 2006). However, looking at the globe as a whole, across various climatic zones, and various countries and regions with various levels of economic development, groundwater plays a very significant role in the supply of water for human activities (Shah, 2004).

Groundwater has a number of unique features rendering it particularly suitable as a water supply, including the following (Coughanowr, 1994):

-Groundwater has excellent natural quality. It is generally free of pathogens, color, and turbidity and can be consumed directly without treatment;

-Groundwater is widely distributed and can frequently be developed in close proximity to needs;

-Groundwater sources are dependable and are relatively unaffected by short droughts; and

-Groundwater can be developed incrementally, at points near the water demand, thus avoiding the need for large-scale storage, treatment and distribution systems.

Coughanowr (1994) estimated the groundwater use as 25% of the total water supply in each of Ghana and Comoros Islands, and as 40% in Mauritius Island. The groundwater use in Egypt amounts to about of 10% of the total use of water. In fact, the irrigation of vast areas of arable land with groundwater from wells and deep boreholes has become widespread in many countries like Libya, Chad, and Sudan and South Africa. Groundwater is considered a potential future water source by the City's bulk water supply in South Africa. The latest data from WRC indicated that there is a total of 235000 million m^3/annum groundwater that is stored; also between 10000 million $m^3$and 16000 million m^3 are available for use in an average rainfall year and 7000 million m^3 in a drought year. Groundwater utilization in South Africa is increased from approximately 684 million m^3 in 1950 to 1770 million m^3 in 2004. Nationally, irrigation comprises over 64% of groundwater use, while mining and domestic consumption in urban areas, and rural areas, each use around 8%.

Visagie, (1995) reported the utilization of thirteen springs which had been researched. Some of springs belong to City Council and used for local community. The Newlands Spring is used by The South Africa Breweries Limited Company for beer production since 1889. The Kommetjie Spring is shared by Breweries Company and local school in nowadays. The Main Spring and the Waterhof Spring are used also for local community for domestic purpose. The Kirstenbosch Spring is used for collecting groundwater and irrigating gardens.

2.4 GROUNDWATER OCCURRENCE

2.4.1 Geology and Hydrology

Sophocleous (2004) mentioned that groundwater moves in systems of predictable pattern in topography-controlled flow regimes. The TMG area has unique topographic characteristics. The Cape Super-group, although deformed, shows great lateral continuity in its lithological character along the almost 1000km length of the Cape Fold Belt (Nakhwa, 2005). It consists of a succession of sandstones, shales and minor conglomerates unconformably overlying Precambrian-Cambrian basement (Broquet, 1992). Descriptions of the TMG lithostratigraphy, isopachs, rock genesis, and palaeo-environments have been made in detailed work by Rust (1967), but no mountain-front process explanations were included.

The large extent of the TMG required investigation as a potential major water source. In order to this to be done all its attributes and the dynamics of its systems need to be understood. The flow concept needs to recognize possible differences in dynamics and paths in specific geographic areas and domains. A holistic approach was adopted in compiling work done on the TMG in the areas of exploration, resource evaluation and management (Pieterson & Parsons, 2002).

Two Hydrogeological domains are identified in the TMG, the inter-montane and the coastal. The former has deep groundwater flow, hot springs, high potential, high recharge, visible targets, artesian flow and good quality water. The latter has shallow flow, cold springs, sand cover making targets difficult, and wave cut platforms and potential saline intrusion and lower quality of water (Rosewarne, 2002). The Table Mountain study area falls into the latter domain, with unconsolidated sediments. The study area specific information relating to mountain-front process and geology needs to be included as they do not appear in domain descriptors. The quality of groundwater can be tested by chemical analysis through the samples which were collected from the springs.

No comprehensive recharge investigation has been done of the TMG and because recharge is driven by single/ multiple events and not averages, no single method for recharge can be adequate (Nakhwa, 2005). The use of direct groundwater measurement of springs and river flow is proposed, but evaportranspiration (ET) estimation still remains a difficulty (Parsons, 2002). Topography, outcrops, and geological trends need to be considered when estimating recharge since the effects of fault boundaries and flow paths on the distribution of the recharge to groundwater is also important (Nakhwa, 2005).

Several Hydrogeological domains exist across the TMG area each with unique conceptual models and Hydrogeological inter-relationships (Umvoto/SRK, 2000). Aquifer boundaries need to be delineated and the groundwater flow system, flow dynamics, and parameters qualified and quantified (Kotze & Xu, 2003). The above mentioned points illustrate the multiplicity of components that require integration into conceptual models and the difficulty in applying the models (Nakhwa, 2005). There needs to be a strong geological basis for any model, requiring a very good understanding of the lithology, structure and their field expression (Nakhwa, 2005).

2.4.2 Types of Aquifers

Groundwater occurs in permeable geological formations known as aquifers. An aquifer is a body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs. Aquifers have structures that permit appreciable amounts of water to move through them under ordinary field conditions. An aquiclude is an impermeable formation, which may contain water but is incapable of transmitting significant water quantities. An aquifuge is an impermeable formation neither containing nor transmitting water. For instance, clay is an aquiclude while solid granite is an example of the aquifuge (Todd, 1959).

According to Wilson (1983) most aquifers are of large areal extent and, in a way, can be regarded as groundwater storage reservoirs. When the reservoir consists of a number of aquifers separated by impermeable or semi-permeable layers it is referred to as aquifer system (See Figure 2.1). Whether the reservoir consists of a single aquifer or multi aquifers, aquifers can be classified into three different types:

-An unconfined aquifer is one where a water table serves as the upper surface of saturation, or the surface of zero pressure. A rise or fall in the water table level corresponds to the change in the volume of water in storage within the aquifer.

-A confined aquifer is found where groundwater is confined under pressure greater than the atmospheric pressure by overlying and underlying aquiclude, which are completely impermeable layers or strata.

-The third type of aquifer is known as semi-confined. This type of aquifer occurs when the aquifer material, instead of being bounded by an impermeable layer or aquiclude, is bounded by a weakly permeable layer known as aquitard. Figure 2.1 shows the different types of aquifers as sketched by Wilson (1983).

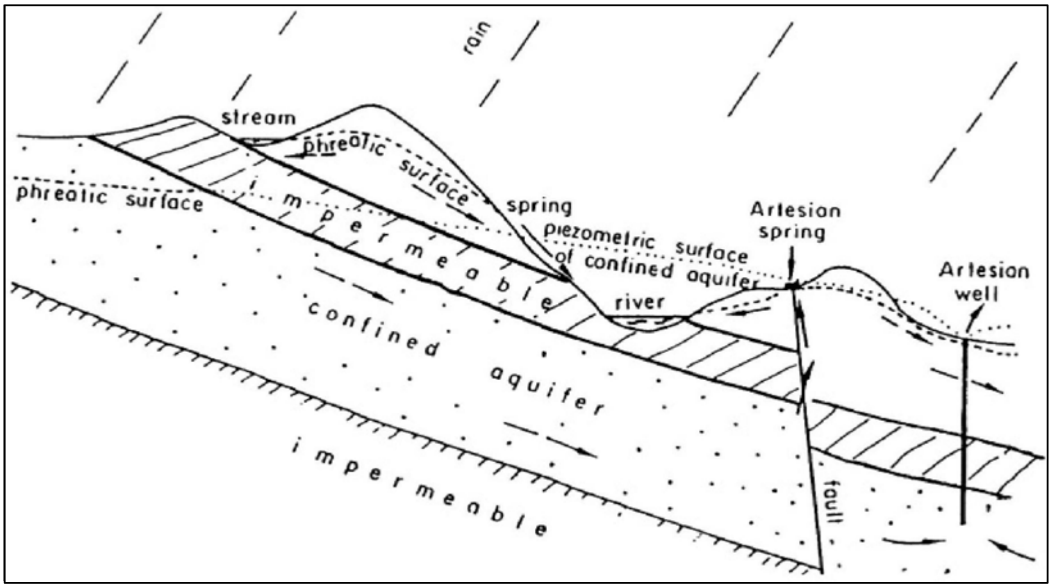

Figure 2.1 Modes of occurrence of groundwater (Wilson, 1983)

2.4.3 Groundwater Recharge

Recharge is the balance between the amount of water that infiltrates into the ground and evaportranspiration losses (Mazor, 2004). Adequate recharge to an aquifer system is necessary to sustain a groundwater resource. Recharge occurs as a result of precipitation through the ground surface at a rate that is able to make up and exceed the soil moisture deficit. The excess water joins the ground water body, and the process is termed direct recharge. Groundwater recharge occurs either naturally as the net gain from precipitation, or artificially as the result of human influence.

Parsons, (2001) determined that the recharge process includes most elements of the hydrological system: rainfall (depth, duration, intensity); topography and altitude; lithology; soil types and depth; vegetation types; fracture; depth of groundwater, regional groundwater flow pattern, and existing groundwater abstraction.

There are as many methods available for quantifying groundwater recharge, as there are different sources and processes of recharge. They are (a) direct versus indirect, (b) water balance (c) Darcy’s physical methods, (d) chemical, isotopic and gaseous tracer methods (Lerner et al., 1990; Kinzelbach et al., 2002). At present, a Geographic Information System approach is also used to estimate groundwater recharge. Each of the methods has its own limitations in terms of applicability and reliability (Sun, 2005). The advantages of water balance methods are that they use readily available data (rainfall, runoff, water levels), are easy to apply, and account for all water entering a system (Sophocleous, 2004). The major disadvantage is that recharge is the residual or remainder of all other hydrologic components in the water balance equation, and constitutes only a small difference between large-number components, such as precipitation and ET. Errors can be high (Sophocleous, 2004). Spring flow fluctuation is a direct indicator of groundwater recharge. The springs are maintained in part by overflow from the Peninsula aquifer and a local shallow aquifer (Xu, et al. 2007). Spring flow records could be used to estimate recharge by hydrogeological models.

Recharge is very difficult to estimate reliably, and more than one method should be used. The choice of the recharge estimation methods will depend on the conceptualization of the recharge processes and the accuracy required in a given situation (Sun, 2005).

2.4.4 Groundwater Discharge

2.4.4.1 Discharge

The term discharge relates to the emergence of groundwater at the surface as springs, water feeding swamps and lakes, and water pumped from wells (Mazor, 2004). Discharge is the yield of groundwater. The rate of discharge is measured in units of volume per time, for example, cubic meters per second (m^3/s) or liters per day (l/day).

Discharge of a spring is a most informative parameter because it provides insight into the quantitative aspects of groundwater hydrology (Mazor, 2004). Maitre, et al. (2002) indicated that there are three main kinds of groundwater discharge pathways:

1. Springs in localized groundwater systems: where shallow, water-bearing fractures in the sandstones intersect the surface; storage is likely to be limited and flow rates fast; many of them may be in the form of seasonal, perched water tables.

2. The contact between the sandstones and the relatively impermeable shales; these are likely to be higher yielding, with greater storage volume in the fractures and faults

and deep flow systems;

3. The faulted contact between the sandstones and the basement rocks (Malmesbury, Cape Granite), where the systems are likely to be similar to the previous class in terms of storage and flow; discharge areas can also be found along major fault lines in these contact zones.

The latter two kinds of Table Mountain Group groundwater systems have the greatest potential for exploitation (Weaver, et al. 1999).

2.4.4.2 Springs

A spring is a natural opening in the Earth's surface from which groundwater flows. In order to distinguish springs from a range of other groundwater discharge features (such as wetlands), it is worth expanding this simple definition by adding that the emerging groundwater flow briskly away from the spring in an open channel (Younger, 2007). Springs occur when an impermeable rock intersects a permeable rock that contains groundwater (an aquifer). The occurrence of springs is closely related to the geology of an area.

Springs provide the principle means of natural discharge from confined aquifers and are also important outflow features in many unconfined aquifers (Younger, 2007). In practice, the springs which have been investigated in the Table Mountain area can be identified as depression springs, which are formed simply by the intersection of the water table by the land surface.

2.4.4.3 Control of Groundwater Discharge

In all of its manifestations, groundwater discharge is controlled by the interplay between subsurface geological structure and landscape (Younger, 2007). At the scale of an entire catchment, the details of the interaction between geological structure and landscape critically determine patterns of groundwater discharge via springs, wetlands, and stream beds (Younger, 2007). Clearly the occurrence of different types of spring depends upon the manner in which hills-lopes intersect sedimentary contacts, intrusive contacts, faults, and other geological features (Younger, 2007). The climate conditions and other physical characteristics, such as elevation of mountain, topography, vegetation and soil type of the mountain area, geology of the area, human alterations and the environment, all these determine not only the ultimate water supply through precipitation, but also the extent to which that the flow velocity and yield of groundwater is controlled.

In the Visagie report (1995), five springs, including Fountain, Bellevug, Gill, Cloete and Cannon had been calculated for volume of flow. In the Harris, et al. (1999) report, they adapted O-and H-isotope to analyze the spring water sample. The yield of springs was estimated from the research.

2.5 GROUNDWATER QUALITY

Much of the literature on routine groundwater quality has been published in the past years. The bulk of works have emphasized contamination. Groundwater flow through the rocks accounts for much of the dissolved contents so that the groundwater quality is influenced. Water of high quality (low salt content, good taste) should be saved for drinking, irrigation, and a number of specific industries; while poorer water (more salts, poor taste) may be used, in order of quality, for domestic purposes (other than drinking and cooking), certain types of agricultural applications, stock raising, and industrial consumption (Mazor, 2004).

Groundwater quality can reflect the influence of lithology and topography. The Table Mountain Aquifer generally yields groundwater of high quality, since it has a low salinity; in some of areas, the groundwater is devoid of calcium and magnesium. Smart and Tredous (2002) explained that it is largely due to the inert quartzitic nature of the host rock, as well as the fact that these resistant rock formations mostly form topographic highs with elevated rainfall and flushing of salts via recharge.

Chemical parameters are very important to the effective planning of sampling; Chemical measurements can give a general overview of groundwater quality (Barcelona, at el, 1985). Physicochemical characteristics, including temperature, Electronic Conductivity, and pH, are often easily measured for basic groundwater quality analyses. Generally, the dominant type of groundwater can be determined according to the concentration of cations and anions. The natural water compositions are graphically displaying. The result of charge balance, maybe positive or negative, is depending on whether cations or anions are more abundant. The geochemical analysis is important in the study of groundwater occurrence and water quality.

Younger, (2007) explains the hydro-chemical faces: having mastered the presentation and comparison of hydro-chemical data, it is possible to systematically distinguish one type of water from another. The water samples were assigned to a diagram (Piper Diagram, for example) which can be defined as zones within a groundwater system which display distinctive combinations of cation and anion concentrations. Those zones are temporally where the quality of groundwater at a particular pint changes over time. The predominant cations and anions are in given water on the basis of percent of total meq/l.

In the Visagie report (1995), the chemical compositions of springs' water samples did laboratory test, the parameters included pH, Electrical Conductivity, Turbidity, and Ultraviolet absorbance. Alkalinity, Chloride, Sodium, Potassium, Calcium, Magnesium, Aluminum, Iron and Manganese composition also were tested for water samples.

2.6 CONCLUSION

The literature that was included in this review was spread over the main topics of groundwater processes, geology, and hydrogeology and water quality. However groundwater occurrences are depending on the different climate patterns, geomorphology, geological situation, and hydrological characteristics. Groundwater recharge estimation is also not easy to apply for the case study.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

An understanding of how groundwater occurs is needed so that it can be effectively located, quantified, utilized, protected and managed. Investigation and analysis of the existing and relevant information helps to obtain a comprehensive understanding of the groundwater occurrence. The study deals with two aspects of groundwater occurrence: geological and hydrological conditions, and geochemical analyses of groundwater. The methodology includes the following main steps:

- A desktop study
- Fieldwork
- The interpretation of geological and hydrological data
- Analysis of geochemical data
- Explanation of the Spring flow rates and comparison with previous studies

3.2 DESKTOP STUDY

3.2.1 Historical Data Review

The desktop work includes (1) a literature review of previous research and studies; (2) review of existing data, including geological and hydrological reports and maps, remote sensing of images, groundwater research and studies; (3) interviewing people and new data collection from relevant departments and institutions.

3.2.2 Data Collection

Some reports were obtained from the Water Research Commission of South Africa and the Cape Town Springs Resource Report was provided by the Water and Sanitation Department of City of Cape Town.

The list of maps and sources:

- GIS map for City of Cape Town Bulk Water Supply; Water & Sanitation Department, City of Cape Town.
- Geological Series 3418BA and 3318CD (both 1:50000) sources the Department

of Mineral and Energy Affairs.

- Cape Town map 3318CD (1: 50000); Earth Science Department of University of the Western Cape.
- Hydrogeological map series of SA (1:500000); Department of Water Affairs and Forestry.
- Groundwater Harvest Potential of SA map, (1:500000); Department of Water Affairs and Forestry.
- Electronic copy of a contour map of Table Mountain, Newlands and Cape Town, (1:5000); Department of Land Affairs, Surveys and Mapping.
- The satellite image of Table Mountain and Cape Town; Department of Land Affairs, Surveys and Mapping.

Rainfall data (1998-2007) and temperature data (1998-2007) were provided by the South African Weather Service for different rainfall stations, i.e. rainfall stations in Oranjezicht area, Newlands, Table Mountain and Kirstenbosch.

Evaporation data were captured from the Computer Procedure. The electronic evaporation data is available from Water Research Commission.

3.3 FIELD WORK

The fieldwork includes:

- Geological and geomorphologic investigations for the study area; major task is to investigate the geological structure and geomorphologic characteristics of the Table Mountain area;
- Hydrogeological investigation for water sample sites; major task is to arrange the field trip to confirm the water sample sites location and coordinates.
- Spring water sampling in Table Mountain, Newlands, Oranjezicht, and Kirstenbosch;

3.3.1 Data Collection

Environmental data collected at each sample site included geological notes, longitude and latitude, rock types, soil depth and texture, and mountain slope. In addition, the vegetation of the site was also observed. Water samples were taken at the site, and, pH, EC, TDS and temperature (for both air and water sample) were measured.

The study area is indicated from latitude 33°56.172'S to 33°58.007'S and longitude 18°24.528'E to 18°28.073'E, and include Oranjezicht, Newland, and Kirstenbosch areas. According to existing information, the location of springs was determined properly. Eight springs were investigated and water samples collected at location. The springs' names are Albion Spring, Kirstenbosch Spring, Kommetjie Spring, Main Spring, Newlands Spring, Palmboon Spring, Table Mountain Spring, and Waterhof Spring. The surface water samples which are from the stream of Kirstenbosch Garden and Table Mountain were also collected (see Table 4.6)

3.3.2 Data Collation

The water samples firstly were collected in February 2008, and secondly were collected in July of 2008 because some of springs flow seasonably. The groundwater flow was compared between summer and winter. The collection was according to Groundwater Sample Guide and carefully labelled samples were analyzed at an accredited laboratory: **BemLab**$^{(Edms)\ Bpk}$. Registered No is 2002/017933/07.

3.4 GROUNDWATER OCCURRENCE

3.4.1 Groundwater Occurrence

The identification of study area and water sample site is important to start the investigation of geology and hydrology. The climatic conditions, including rainfall, temperature, and evaporation, are major factors which affect groundwater recharge and discharge. Geology, physiography, rock formation and lithology, all aided to achieve a better understanding of the hydrological setting. Some cold springs exist around the Table Mountain area. The research of springs is a good way to explore the groundwater resource of a certain area.

3.4.2 Understanding the Concepts

The climatic situation and environmental information (such as mountain slope, soil texture) will be discussed in detail. Temperature, precipitation, and evaporation data at study sites are clearly listed to assist to understand groundwater occurrence. Geological group, formation and lithology are basic concepts for studying groundwater occurrence. Types of aquifer and types of spring also need to be indicated.

Mountain Block and Mountain Front, two geological terms, are introduced to understand groundwater occurrence, flow and infiltration. A local system, which has its recharge area at a topographic high and its discharge area at the immediately adjacent topographic low, could be chosen to explain the study area groundwater flow process.

Groundwater recharge and groundwater discharge is explained in the below paragraph to understand groundwater occurrence. The recharge and discharge characteristics are crucial for efficient development and management of groundwater resources, as well as for minimizing pollution risks to the aquifer and connected surface water (Arnold, et al. 2000).

3.4.3 Groundwater Recharge

The geographer Thornthwaite (1899-1963) pioneered the water balance as an account of the inputs and outputs of water. The water balance of a place, whether it is an agricultural field, watershed, or continent, can be determined by calculating the input, output, and storage changes of water at the Earth's surface. The basic principle of water balance is $P - (Q + ET) = 0$; where P is precipitation, Q is runoff and ET is evaportranspiration.

The hypothesis for groundwater recharge estimation in the study area is divided Table Mountain into two parts: west and south side and north and east side, which is the study area included.

$$V=P*1/2\ A \qquad (1)$$

Where V is water body of the area, P is precipitation, A is area of Table Mountain area.

$$\text{Recharge estimation } \% = L/\ V \qquad (2)$$

Where L is total amount of groundwater yield

3.4.4 Groundwater Discharge

The average flow velocity of spring can be calculated in terms of head rod method. The head rod method is quick and possibly more accurate for shallow stream. Average velocity (m/s) = $\sqrt{2gh}$, where g is the gravitational constant of 9.81. The gravitational constant is not significantly affected by height above sea level.

There is only the Kirstenbosch Spring discharge is calculated by the flow volume and the flow time in the study. The equation is represent as Q (l/s) =V (l)/ average T (s); where Q is recharge, V is area of groundwater flow through, and T is flow time.

3.4.5 Spring Occurrence

Springs, which were selected for studying, were delineated by location, longitude and latitude. The water sample sites had been photographed for water flow comparison. The springs resource under the City of Cape Town had been investigated, the spring flow volume has been determined already. The calculated values were compared with values from the 1995 report and 1999 research. From the comparison the change of precipitation, temperature, evaportranspiration and other influencing factors were observed.

1995 report by Visagie recorded the flow rate of Albion Spring, Palmboom Spring, Main Spring, Kommetjie Spring and Waterhof Spring. Harris (1999) recorded the flow rate of Kirstenbosch Spring, Albion Spring, Newlands Spring, Palmboom Spring, Main Spring, Table Mountain Spring, Kommetjie Spring and Waterhof Spring. The Breweries Limited South Africa provided the flow rate of Kirstenbosch Spring, Albion Spring, Newlands Spring, Palmboom Spring, Main Spring and Kommetjie Spring.

3.4.6 Error Analysis

Some of data which were captured from monitoring stations were analysed, so that the calculating errors were brought under control.

3.5 GEOCHEMICAL ANALYSIS

By measuring the physical and chemical characteristics of the local water-bodies can determine the health of our water and therefore its ability to sustain life. Results may merely indicate the condition of the water body, or they may give very accurate data that can be used to identify matters significant for the water-body's ecology and health. The following chemical constituents were analyzed for all water samples by **Bemlab**:

--Major Ions: Na^+, K^+, Ca^+, Mg^+, HCO_3^-, CO_3^-, SO_4^-, Cl^-, NH_4-N, NO_3-N and PO_4^-;

--Minor Ions: B, Si, As, F;

--Trace elements: P, Li, Pb, Sr, Ba, Mo, Mn, Al, V, Cr, Fe, Ni, Cu, Zn, Cd, Hg.

The general physical parameters such as Temperature, pH, Electrical Conductivity, Turbidity and Total Dissolved Solids, were also provided by **Bemlab** at the same time.

The laboratory results were evaluated by **Aquachem** software to (1) determine the type of groundwater; (2) identify groundwater characteristics; (3) compare groundwater quality with Domestic Water Use of SA.

The results of the chemical analyse are represented by Piper diagrams and expanded Durov diagrams, which can be defined as zones within a groundwater system which display distinctive combination of cation and anion concentrations. The quality of groundwater at a particular point is always changing overtime; these changes can be expressed in the diagrams as well.

The anion and cation balance is explained by calculation. The result of groundwater quality will be compared with the South Africa Domestic Water Use Guideline, so that the groundwater quality could be clearly seen from the check list.

CHAPTER 4 GROUNDWATER OCCURRENCE

4.1 INTRODUCTION

The Hydrogeological situation in South Africa is complicated because of the complex nature of the geology and hence the aquifers. To discuss the groundwater occurrence around Table Mountain in detail, we need to investigate groundwater manifestations of geologic formations. The topographic characteristics, the various regional climate situations, and hydrogeology varieties are key information that would help improve our understanding of the groundwater occurrence and recharge process. The chronostratigraphy, lithology and hydrology of the Table Mountain area, which all may influence groundwater occurrence, are discussed in this chapter.

4.2 STUDY LOCATION AND PHYSIOGRAPHY

The study area is located on Table Mountain and its surrounding area, in Cape Town, South Africa (See Figure 4.2). It ranges from 33°56′ to 33°59′ latitude to 18°24′ to 18°28.5′ longitude. The topography of Table Mountain and the range of adjacent mountains are influenced by the climate, geology and hydrological environment in the vicinity.

The geology of the study area includes the Table Mountain Group (specifically the Peninsula Formation and Graafwater Formation); Malmesbury Group, and also the Cape Granite Suite (See Figure 4.1). The study focuses on the northern (See Figure 4.4 and Figure 4.5) and eastern side (See Figure 4.3) of the Table Mountain area. The springs occurring in the area are not covered by a recent WRC report (Xu et al., 2007).

Liesbbeek River is one of the drainage systems in the study area, with a few smaller streams, such as streams from Nursary Ravine and Window Gorge. To the north of Table Mountain, the Platteklip stream and the Silver stream becomes conflux.

The dominant vegetation of the Cape Mountains is determined by the nature of soil, and the change in the character of the vegetation on passing from Table Mountain sandstone to another formation is usually very striking (Luckhoff, 1951). The present oak forests above Kirstenbosch, Newlands, and Groote Schuur are probably derived from the original planting (Campbell and Moll, 1977). The Table Mountain area falls within the Fynbos Biome (Kruger, et al. 1981). The vegetation consists mainly of the sclerophylous shrubland (Kruger, et al. 1981) which Acocks, 1953 describes as Fynbos. To the north of Table Mountain, Cape Fynbos Shrublands, Renosterveld Shrublands, and Cliff Community types are occurring with high cover value. The dry proteoid communities also occur on the slopes of the mountain (Moll & Campbell, 1976). Distinctive vegetation, where still preserved, is found in the study area: Proteaceae, Ericaceae, Restionaceae and Compositae predominate. Some others, for instance, Acacia Cyclops, Acacia Cyanopbylla, and Hakea Tenuifolia have already forced their way into widespread areas.

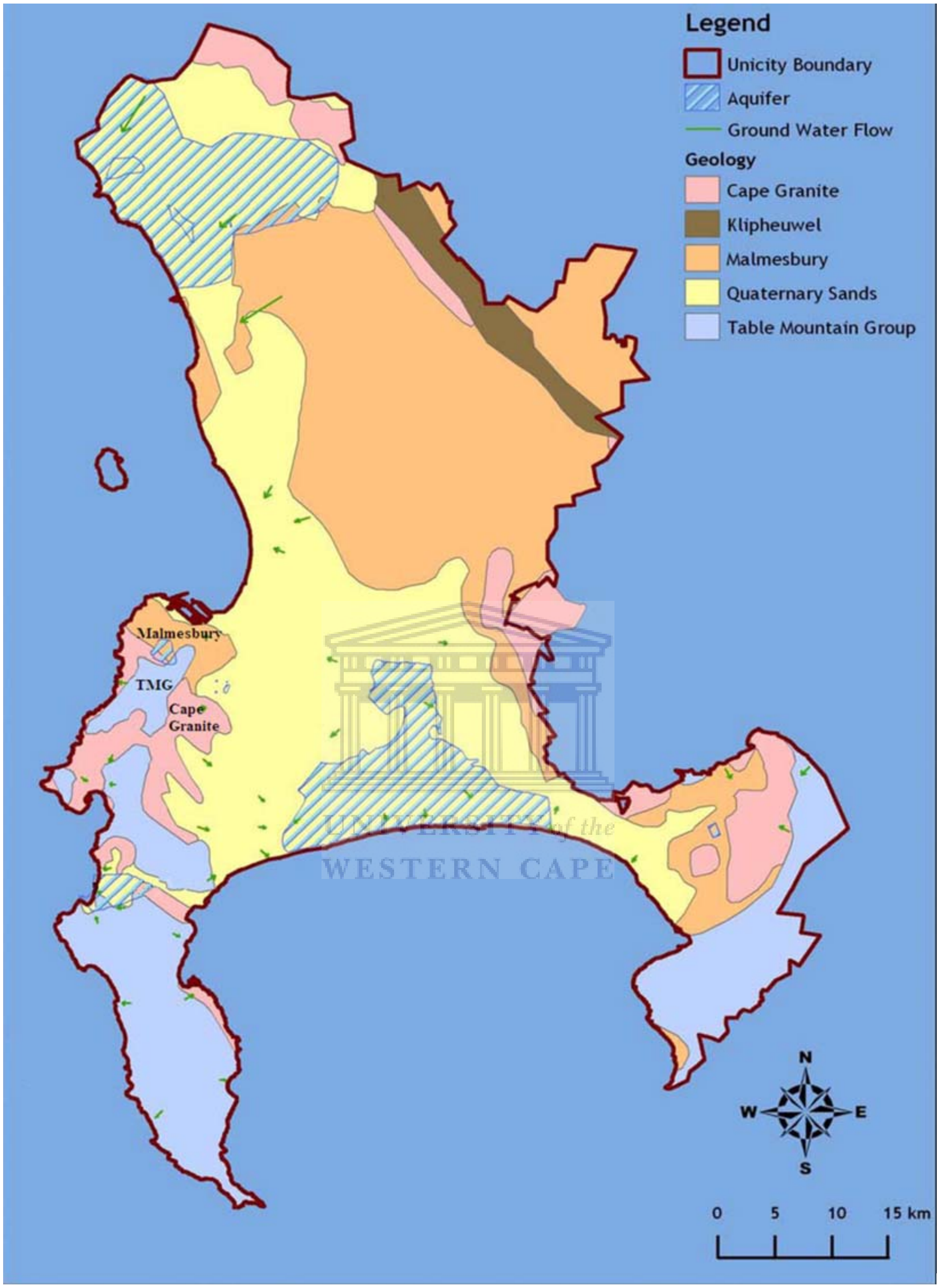

Figure 4.1 Geology and Hydro-geology (Adapted from City of Cape Town Integrated Waste Management Plan. 2004)

The major topographic types include mountains, hills, gorges, plains as shown in the following figures.

Figure 4.2 Table Mountain.

Figure 4.3 Area east of Table Mountain

Figure 4.4 Area north of Table Mountain

Figure 4.5 Slope to the north of Table Mountain.

Figure 4.6 Close-up photo of the sandstone on Table Mountain

4.3 CLIMATIC SITUATION

4.3.1 Temperature

The study area experiences a Mediterranean climate with dry summers starting December each year, with averaging temperatures around 21.4℃. The winter rains begin in June, with averaging temperatures around 14.0 ℃ (See Figure 4.7). The prevailing wind in summer is known as the “South Easter”; and is from the northwest in winter so it can precede the cold fronts that bring rain to local area (City of Cape Town Integrated Waste Management Plan. 2004). The temperature data was taken from Cape Town International Airport.

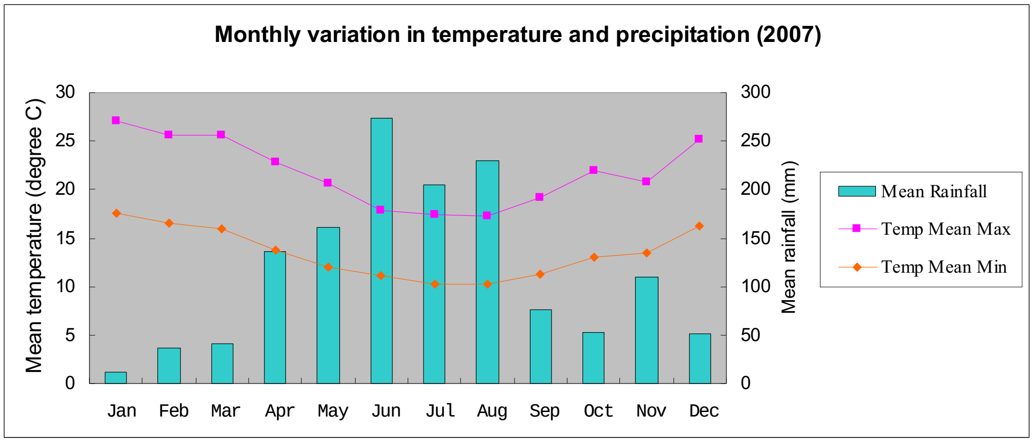

Figure 4.7 Monthly variation in precipitation and temperature (2007, Cape Town International Airport)

4.3.2 Precipitation

The maximum precipitation, during May to September, is largely controlled by the topography. The average climatic figures for the study area (Table Mountain, Newlands, Molteno, and Kirstenbosch) are given in Table 4.1. The data was offered by Cape Town International Airport.

Table 4.1 The average climatic figures for study area

Mean Annual Precipitation	1279.8 (Mm/year)
Rainfall Max in 24hrs	110.0 0 (mm)
Temp Mean	17.6 (°C)
Temp Mean Max	21.8 (°C)
Temp Mean Min	13.4 (°C)

The rainfall stations were chosen around the Table Mountain area, two were located at north of mountain, nearly to the Molteno Reservoir; one was near to the Newlands area, one was at Kirstenbosch garden, the other four were on Table Mountain. From the figure 4.8 below, the rainfall value of north of mountain is less than that in mountain of east of the mountain.

Figure 4. 8 Precipitation distributed at study area (2002)

4.3.3 Evaporation

Evaporation data were obtained from Water Research Commission and Department of Water Affairs and Forestry. The average annual potential evaporation is 1400mm (WR 2005). North of Table Mountain area, where Main Spring and Waterhof Spring are located, the mean monthly evaporation for 2007 was 139.60 mm; annual total evaporation was 1675.30mm. The lower evaporation value occurred in May, June and July. East of the Table Mountain area, in the Newlands area, where the Albion Spring, Palmboom Spring, Newlands Spring and Kommetjie Spring are located, and the mean monthly evaporation for 2007 was 108.00 mm; annual total evaporation was 1296.40 mm. The lower evaporation value occurs in June, July and August. By comparison, high rainfall always occurred during the months with low evaporation.

From the data it can be seen that, during the high rainfall season, the evaporation value is low. It is expected that the most groundwater recharge will take place in the winter (rainy season). A comparison of the precipitation and evaporation in the study area for 2007 (monthly) is showed in Figure 4.9 below.

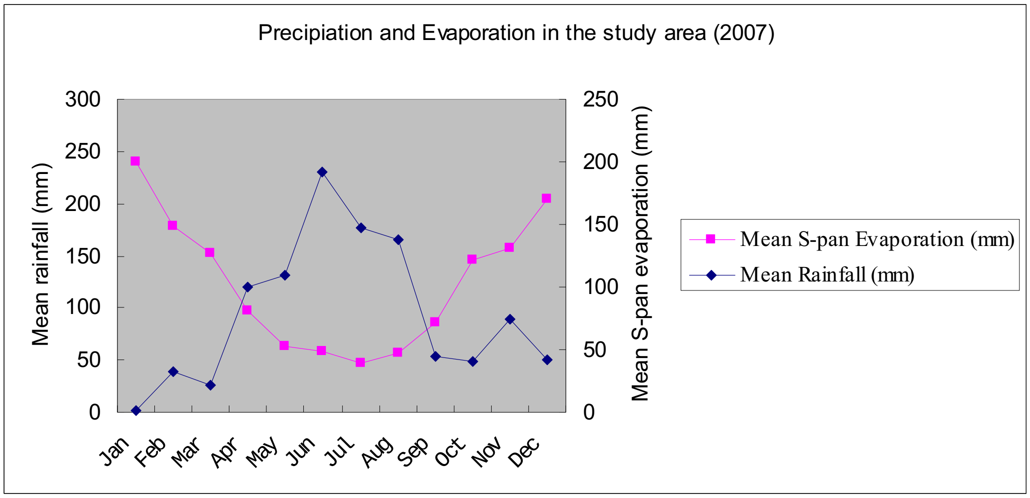

Figure 4.9 Comparison of precipitation and evaporation in the study area (2007)

4.4 GEOLOGY SETTING

Table Mountain consists of two plateaus surrounded by cliffs which give way to gentle slopes (Moll & Campbell, 1976). The flat top at an average altitude of about 1030m, falls away steeply (Moll & Campbell, 1976) and then gradually to form the lower plain to its north, east, and south side; to the west side, steep slopes extend to the sea form the boundary.

Soil types are dependent on the parent material. Soils derived from Table Mountain sandstone are usually coarse sand and sandy clay (Moll & Campbell, 1976). Soils produced by weathering are acidic, sandy and poor, chiefly due to the lack of feldspar (Luckhoff, 1951). Quartz pebbles are released from the sandstone and occurs in the soil (Luckhoff, 1951). The soil is generally shallow, and less than 0.5m thick. The soil derived from granite and especially shale, contains more clay (Moll & Campbell, 1976). The lower slopes are often covered with sandstone debris which gives rise to a soil of mixed origin (Moll & Campbell, 1976).

Table 4.2 below shows the environmental information for slope, rock size, and soil depth and soil texture of selected areas in the study area.

Table 4.2 Environmental data of study area (McKenzie, Moll & Campbell, 1977)

	Northern slope	Newlands area	Kirstenbosch
Slope	Moderate (8.5-16.5°)	1. Moderate (8.5-16.5°) 2. Very steep (26.5-45°)	1. Gentle (3-8.5°) 2. Moderate(8.5-16.5°) 3. Steep(16.5-26.5°) 4. Very steep (26.5-45°)
Rock size	Average 60cm	Average 60cm	1. Average 15cm 2. Average 60cm
Soil depth	0.2m	0.05m	1. 0.1m 2. 0.3m 3. 0.5m
Soil texture	Coarse sandy loam	Coarse sandy loam	1. Coarse sandy loam 2. Sandy clay loam

Geologically the study area consists of the Table Mountain Group, the Malmesbury Group, and Cape Granite Suite (See Table 4.3). The mass of Table Mountain consists of hard, white and flat-lying sandstone (See Figure 4.6) supported by a base of granite and slates (Luckhoff, 1951), the latter known as the Malmesbury division.

Table 4.3 Geological sequence in the study area

Super-group	Group	Formation	Lithology
Cape	Table Mountain	1.Peninsula 2.Graafwater	1. Coarse-grained, white quartz arenites with scattered small pebbles; largely thick –bedded; maximum thickness is 1800m. 2. Thickness of 25-65m and comprises of thin-bedded sandstone, siltstone, shale and mudstone.
	Malmesbury	Berg River formation	Shales, greywacke, phyllite and quartzitic sandstone with volcanic intercalations;
	Cape Granite Suite	Cape Peninsula Pluton	Agglomerate and basalt; Coarse porphyritic granite, Locally medium grained, With inclusions;

The sediments of the Cape Super-group were deposited in a shallow marine environment under tidal, wave and storm influences, as well as in a non-marine, braided-fluvial environment from early Ordovician to early Carboniferous (Xu et al., 2007).

The medium to coarse grain sizes and relative purity of some of the quartz arenites, together with their well indurate nature and fracturing due to folding and faulting in the fold belt, enhance both the quality of the groundwater and its exploitation potential (Xu et al., 2007). A major characteristic of the coarse grained quartzitic sandstone of the Table Mountain Group is its high permeability.

The late-Precambrian age Malmesbury Group is the oldest rock formation in the area, consisting of alternating layers of dark grey fine-grained greywacke sandstone and slate. These sediments were originally deposited on an ancient continental slope by submarine slumping and turbidity currents (Anonymous_1, 2008). Malmesbury Group was deposited on the Kibaran basement and intruded by the Cape Granite Suite; therefore, deposition, deformation and metamorphism of Malmesbury Group occurred between 1.2 Ga and 510 Ma (Belcher and Kisters, 2003) by heat and pressure and folded tightly in a north-western direction so that the rock layers are now almost vertical. The Malmesbury Group is a clearly detrical sequence, composed of three formations (Piketberg, Tygerberg and Porterville). Structurally, the Malmesbury group is characterized by upright open to tight folding and axial planar cleavage (Villaros, 2006). In the City of Cape Town, many building are founded on these kinds of rocks, which were scoured by wave action during past periods of higher sea level. The groundwater which occurs in this formation is almost NaCl water.

The massive, relatively coarse-grained igneous rock of the Cape Granite underlies the major part of the Peninsula mountain chain (Moore, 1994). On the base of petrolgical and geochemical characteristics (Villaros, 2006), a few types of granites are identified with several subtypes. Each type is also found only in specific parts of the Saldanhan belt (Villaros, 2006). The Cape Peninsula Pluton is one formation of the Cape Granite Suite with coarse-porphyritic granite.

Almost springs in the study area fall under the Malmesbury Group, Klipheuwel formation; except the Table Mountain Spring come under by Table Mountain Group, Peninsula formation; and Kirstenbosch Spring influences by Cape Granite Suite, Cape Peninsula Pluton formation (See Figure 4.10).

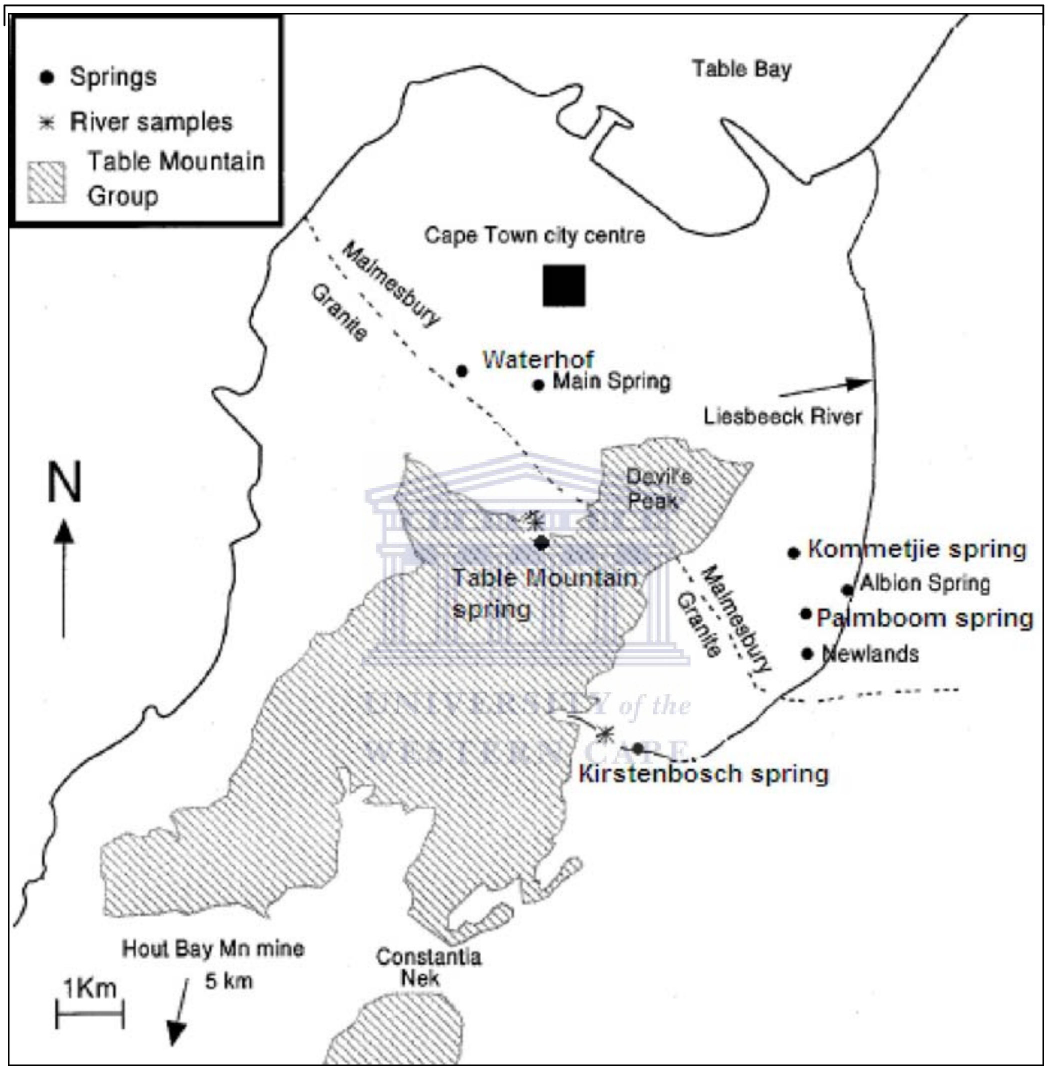

Figure 4.10 Location map for Water sample sites (Harris, et al. 1999)

4.5 HYDROGEOLOGY SETTING

Groundwater occurs in two types of aquifer systems in the study area, namely fractured aquifers, fractured and intergranular aquifers. All these aquifer systems occur in different geological units, namely the Table Mountain Group, the Malmesbury Group, and the Cape Granite Suite.

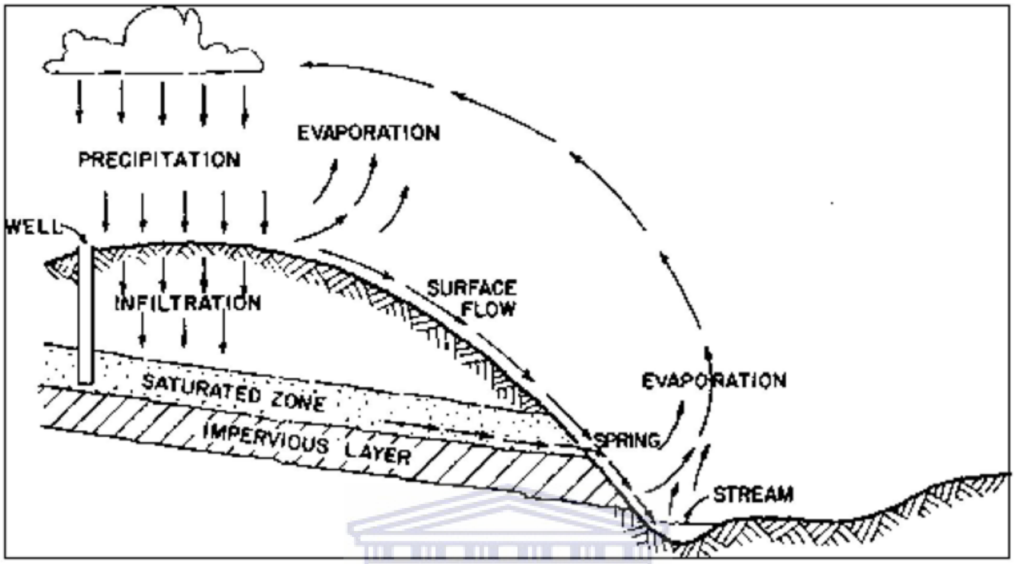

Figure 4.11 Water Cycle

4.5.1 Fractured Aquifer

Fractured aquifers are composed of the varying metamorphic rock of the Malmesbury Group, the quartzitic sandstone of the Table Mountain Group. With fractured aquifers, the rock mass was metamorphosed a number of times over hundreds of millions of years. The deformation processes and succeeding orogenesis, continental uplift, weathering and erosion all aided in the development of the present groundwater environment (Meyer, 2001). All those rock units were subjected to deformation, and a variety of fold and fault structures abound, resulting in widespread fracturing and jointing, especially in the more competent lithology. The yield of groundwater is in excess of 5 l/s quite common in the TMG area.

In fractured rock aquifers, groundwater is stored in the fractures, joints, bedding planes and cavities of the rock mass. Water availability is largely dependent on the nature of the fractures and their interconnection. The flow in a fully fractured medium is largely controlled by the fracture dimension, orientation and connectivity (Botha, et al. 1998). In the Table Mountain, the beds are occasionally crossed by vertical lines of fracture or faulting, along which the rocks have broken bodily, while one side has moved upward or downwards relative to the other (Luckhoff, 1951). The sandstone is always highly shattered along such lines.

The existence or absence of rock fracturing and joining and prevailing conditions of groundwater recharge plays a decisive role in the occurrence and characteristics of groundwater in the different consolidated rock units of the Cape Fold Belt (Meyer, 2001).

Groundwater quality in these high-yielding areas is good, and EC value seldom exceeds 100 ms/m (See Chapter 5). Groundwater in the fractured aquifers tends to be of a sodium-chloride nature (Na-Cl type)

4.5.1.1 Table Mountain Group

The Table Mountain Group generally constitutes the mountainous areas which, in turn influence precipitation to a significant extent (Meyer, 2001). Due to the fractured nature of the sandstones in generally high rainfall regions, groundwater recharge is favourable and a high infiltration rate of precipitation in certain areas is not unrealistic (Meyer, 2001). It would appear that the Table Mountain Group thus offers by far the most favourable opportunities for groundwater development from fractured aquifers in the South-Western Cape region (Meyer, 2001).

An abundance of springs is a further characteristic of the Table Mountain Group (Meyer, 2001). The springs occurring in the study area are lithologically controlled, with relatively shallow circulation. Yields from those springs are less constant and seasonal yield fluctuations are distinctive. The Table Mountain Spring occurred in the Table Mountain Group.

4.5.1. 2 Malmesbury Group

The structural and stratigraphical features of the Malmesbury Group are complex, due to factors such as lateral faces variations and structural intricacies (Meyer, 2001). Groundwater exploitation in the Malmesbury Group is usually problematic due to the poor exposure, the largely argillaceous and thus incompetent nature of many of the lithological units and the overall structural complexities (Meyer, 2001). Main Spring and six other springs, including Waterhof Spring occurred in the Malmesbury Group.

4.5.2 Fractured and Intergranular Aquifer

In fractured and intergranular aquifers, the groundwater occurs in both weathered and in jointed bedrock so that it can be termed fractured and Intergranular (Meyer, 2001), such as in various granites in the study area. Groundwater quality is still fine in Fractured and intergranular aquifer, EC value vary between 30 and 350 ms/m and the groundwater has a sodium-chloride-sulphate nature ($Na\text{-}Cl\text{-}SO_4$ type)

4.5.2.1 Cape Granite Suite

The Cape Granite Suite covers mainly the Western Cape Town area and it represents the intergranular and fractured regime. A distinct characteristic of granite bodies is that they are composed of coarse-gained porphyritic granite, interspersed with fine- to medium-grained biotite granite (Meyer, 2001). Since fine-, medium- and coarse-grained granite with varied compositions occur, diverse weathering forms can be expected, with diverse groundwater implications. Weathered medium-grained granite with a more balanced composition is likely to be a better aquifer (Meyer, 2001).

The identification that groundwater moves in systems of predictable pattern in topography-controlled flow regimes, and that various identifiable natural phenomena are regularly associated with different segments of the flow systems (Sophocleous, 2004). The System-nature of groundwater flow has provided a unifying theoretical background for the study and understanding of a wide range of natural processes and phenomena (See Figure 4.11), and has thus shown flowing groundwater to be a general geological agent (Sophocleous, 2004). Geological and hydrological units combine to produce the groundwater. Spring waters provide valuable information about subsurface hydrogeological and chemical process, particularly in complex groundwater flow systems (Toth and Katz, 2006).

4.6 SPRING

4.6.1 Spring Occurrence

The groundwater properties imply that a spring is an area on the surface of the Earth where the water table intersects the surface and water flows out of the ground. Springs occur when an impermeable rock (called an aquiclude) intersects a permeable rock that contains groundwater (an aquifer). The occurrence of springs is closely related to the geology of an area. If an impervious layer, such as a clay deposit, underlies a layer of saturated soil or rock, then a line of springs will tend to appear on a slope where the clay layer outcrops. Cold spring abound and occur particularly numerously in the Table Mountain Group.

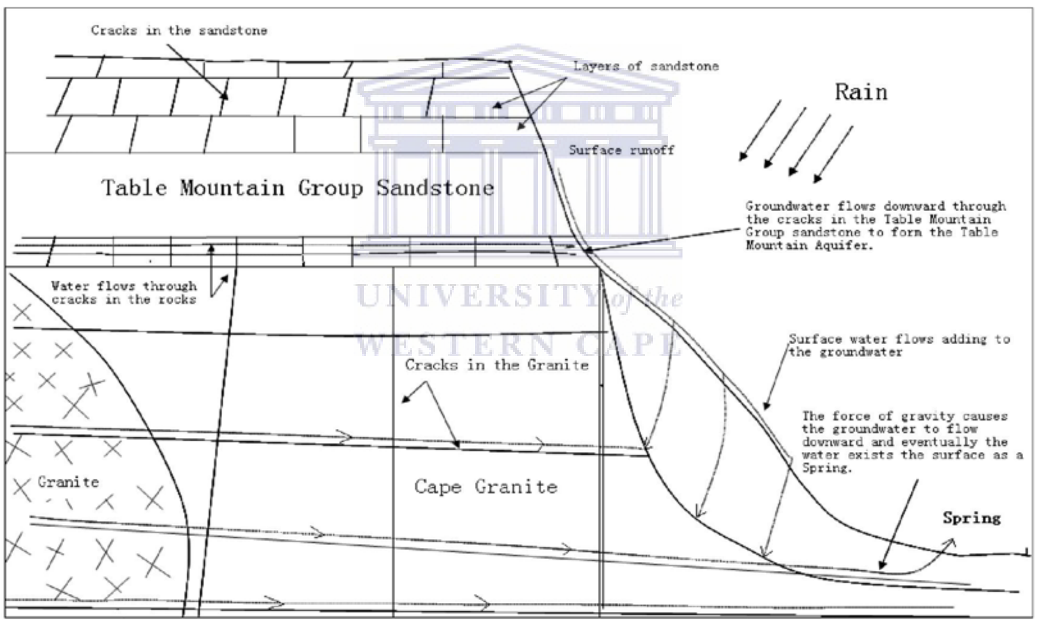

Figure 4. 12 Spring Occurrence

4.6.1.1 Mountain Block and Mountain Front

Wilson and Guan, (2004), briefly summarized the definition of a mountain block: it includes all the mass composing the mountain, including vegetation, soil, bedrock, and water. The most important characteristic of a mountain block is its significant topographic relief which is formed through a number of geological processes; all hydrologic processes in the mountain block, including the temporal and spatial distribution of precipitation, vegetation interception, evaportranspiration, runoff, water flow and surface water and subsurface water interactions, has been examined by Mountain-block hydrology. The mountain front is positioned somewhere between the mountain block and the basin floor.

In the hydrological cycle the groundwater occurrence is influenced by various factors, such as climate, physiography and geological factors. Some rainfall water will flow on the ground surface, others infiltrates into the sub-ground when the precipitation arrives. However, water which infiltrates into the ground not only recharges the groundwater, they are evaporated from the soil, transpirated by vegetation, and also adheres to soil grain. The rest of the water is recharged to the groundwater.

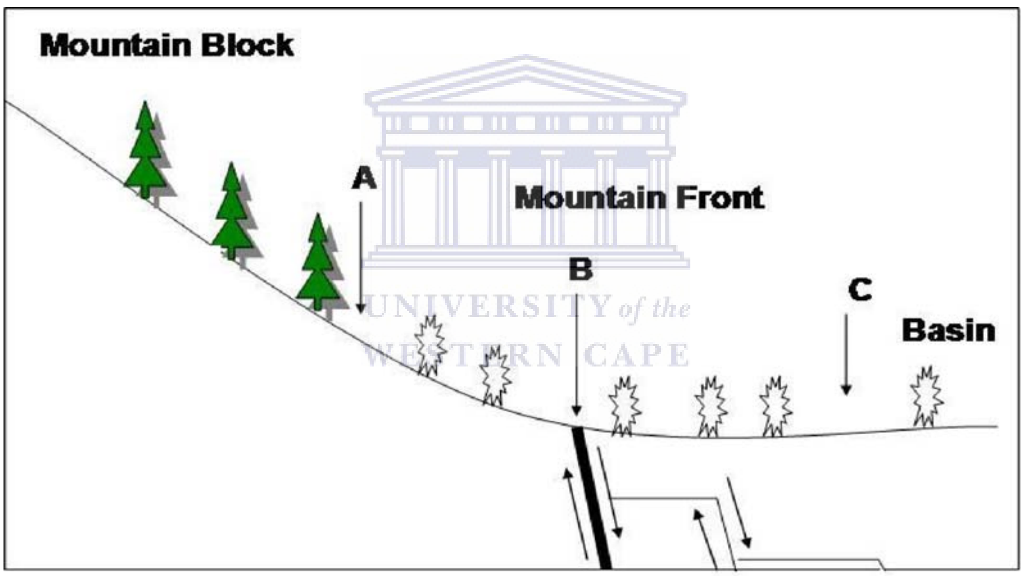

Figure 4. 13 Mountain front definition. A=point of vegetation change, B=point of piedmont angle, and C=point of plinth angle. (Russel and Snelson, 1990)

A spring is a concentrated discharge of groundwater appearing at the ground surface as a current of flowing water (Todd & Mays, 2005). Springs occur in many forms and have been classified as to cause, rock structure, discharge, temperature, and variability (Todd & Mays, 2005). Rain water runs off the mountain into streams and rivers. It also soak down through soils into cracks of the under-lying rocks until it hits rocks that it can’t flow as easily through, like granite. Here it collects to form groundwater.

The springs that were investigated in the Table Mountain area is gravity springs. The depression Spring is a type of springs which is formed where the groundwater surface intersects the water table (See Figure 4.13). Springs appear where water from an aquifer flows out through a crack in the ground.

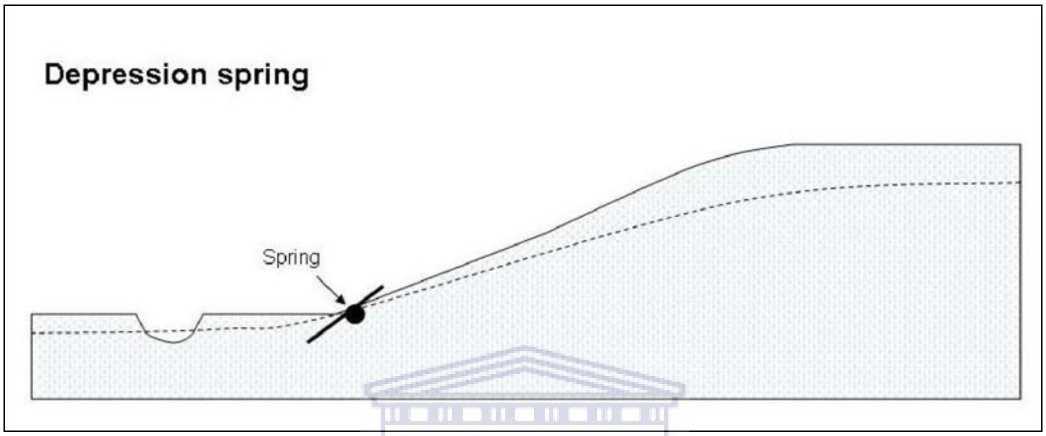

Figure 4.14 Depression Spring

There are ten springs that have been investigated within the study area. All of them occurred on the slopes of Table Mountain, of which a selection were sampled (Harris et al.,, 1999). Kirstenbosch Spring and Table Mountain Spring are hosted in Table Mountain Sandstone; the others are either in the Malmesbury Group or Cape Granite (or Quaternary cover) on the lower slopes of the Mountain area (Harris et al., 1999). The Molteno Spring and Kildare Spring are underneath of buildings so that the water samples could not be taken. In the Main Spring yard, there are five springs that flow into one chamber; so only one water sample was collected. Finally, eight springs' water samples were obtained from spring sites and analyse. They are named: Albion Spring, Palmboon Spring, Newlands Spring, Kommetjie Spring, Main Spring, Waterhof Spring, Kirstenbosch Natural Spring and Table Mountain Spring. Two addition water samples were taken from surface water, one was from Kirstenbosch stream flow and other was from Table Mountain stream flow. Two types of springs occur in the Table Mountain Group Aquifer: shallow springs emanating at perched water tables and lithologically controlled springs.

4.6.1.2 Precipitation

Precipitation is a very important factor in the groundwater occurrence process and is influenced mainly by climatic change, both globally and regionally. These affect precipitation characteristics such as pattern, amount, spatial distribution, periodicity, tendency, intensity and duration (Sun, 2005). The climate in the Table Mountain area is largely influenced by mountain and maritime air from the Atlantic Ocean and Indian Ocean.

Rainfall records taken from stations were higher on the mountain side than in the basin. The rainfall stations had been chosen from the north of the mountain side to the east. Rainfall on Table Mountain obviously is higher than on the extended plain area. Molteno Reservoir and Molteno rainfall stations are located north of the Table Mountain area, where the average rainfall is less than 1000 mm per year. Kirstenbosch area rainfall is lower than Table Mountain, but is affected by a Mountain climate. Groote Schuur area is near to Newlands, and is also affected by a Mountain climate. It has an annual rainfall of more than 1000mm (Table 4.4).

Table 4.4 Precipitation in the study area

Station	Year	Annual (mm)	Max (mm)	Min (mm)
TM Woodheal tunnel	1998-2002	1200.98	1538.50	474.50
Woodhead dam	1998-2007	1696.96	2309.40	1177.50
Waaivlei	1998-2002	1413.60	2050.00	852.00
TM house	1998-2007	1522.29	2009.40	816.90
Molteno reservoir	2001-2007	709.23	870.40	548.60
Molteno	1998-2007	816.70	1094.10	637.30
Kirstenbosch	1999-2007	1245.60	1661.40	899.70
Groote Schuur	1998-2007	1143.20	1508.80	865.60
Total		9748.56	13042.00	6272.1

From the Table4.4 above, it can be seen that the rainfall decreases from the top of mountain downwards. East of the Mountain, rainfall is higher than to the north. The rainfall of top of the mountain is almost two times than of the lower mountain side. This causes that water from the top mountain infiltrate into the rocks to form recharge water. By comparison the area of the mountain: the area to the east has steeper slopes than north of the mountain so that the climate of the area to the east is influenced more by the mountain than to the north. The result is that the eastern areas, Newlands and Kirstenbosch receive more rainfall. All the precipitation data for the mountain area is attached and shown in appendix 1-6.

4.6.1.3 Seasonal Distribution of Precipitation

The seasonal distribution of the precipitation is related to the climatic zones. The rainy season shifts from winter in the west towards all year in the east (Sun, 2005). A Mediterranean climatic zone dominates in the extreme west (Sun, 2005) of the study area around Table Mountain where rainfall arrives exclusively in the winter months. The records of four rainfall stations show average precipitation patterns in these regions (See Figure 4.14) where the precipitation occurs mainly in May, June, July and August. In the mountain and close to the mountain area, the rainfall starts from April. The amount of rainfall for the four months accounts for more than 64% of the annual rainfall and the four months are the best groundwater recharge months and winter is the best season. December, January and February are the driest months and the average monthly rainfall is less than 33.0 mm; at the Molteno station, located north of Table Mountain, the rainfall during the three months are less than 25.4 mm. The north area and east area of mountain, January has the lowest volume of rainfall, always counts 2mm, or 3mm.

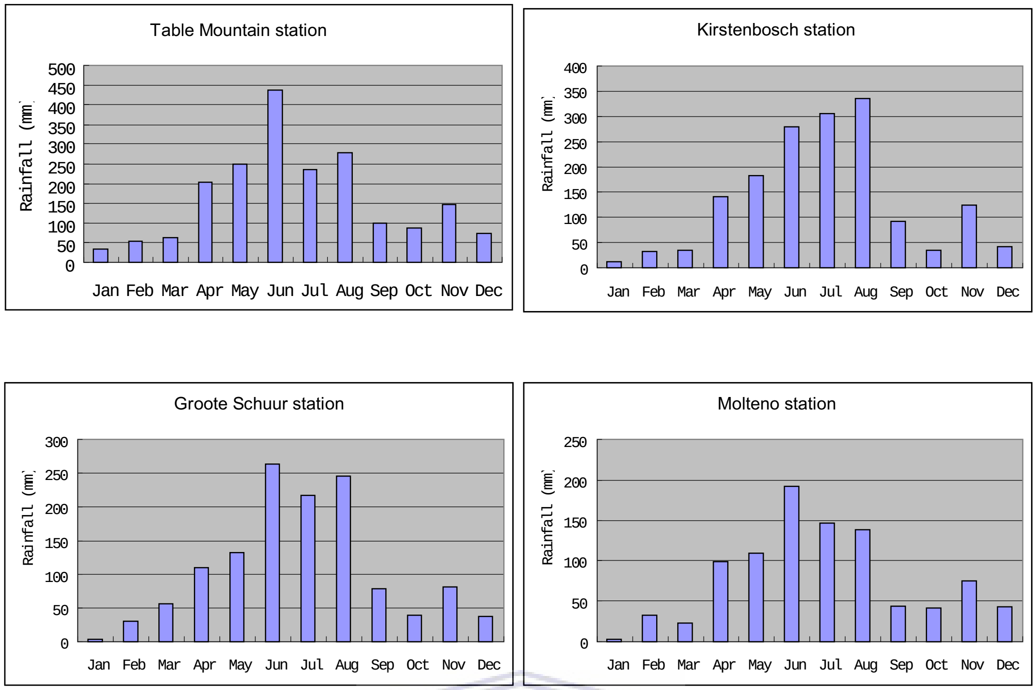

Figure 4.15 Rainfall patterns

4.6.1.4 Evaporation

In this study, the value of transpiration is not readily to be used. Only the evaporation rate received from the Water Research Commission and Department of Water Affairs and Forestry for recently years is used.

4.6.1.5 Relationship between Precipitation and Evaporation

The potential evaporation of two stations, Newlands and Molteno, has been chosen for comparison with precipitation.

The table indicating the relationship between evaporation and precipitation shows that the potential evaporation decreases when the precipitation increases in study area. But rainfall is not only the factor influencing evaporation. A number of other factors, such as rainfall seasonality, rainfall distribution and intensity, as well as temperature have important effects on the evaporation (Sun, 2005).

Table 4.5 Comparison of rainfall and evaporation in the study area

Stations	Winter (May-Aug)	Summer (Dec-March)	Amount (mm/yr)
Newlands rainfall	857.40	126.90	1294.30
Newlands evaporation	218.50	655.30	1296.40
Molteno rainfall	587.5	98.40	946.20
Molteno evaporation	229.50	897.60	1675.30

During the winter rainfall season, evaporation is about 20-30% of precipitation. In summer, evaporation is much higher than precipitation. The annual precipitation and evaporation is approximately equal with evaporation often more than precipitation because the transpiration has not been estimated (See Table 4.5).

4.6.1.6 Relationship between Temperature and Evaporation

Temperature is also a key factor to the evaporation. The evaporation is continually to increasing (Sun, 2005) at increased temperature rates as long as there is water to evaporate (See Figure 4.15).

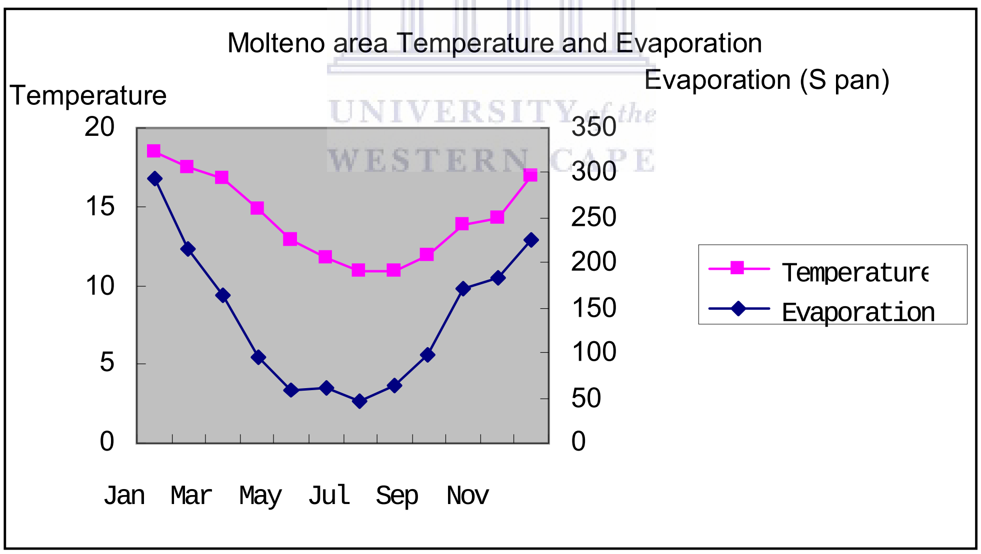

Figure 4.16 Molteno area (north of Table Mountain) temperature and evaporation comparison

Some other factors also exist, which can influence evaporation, like vegetation, wind, solar radiation, relative humidity, land form, soil and even human activities. But the detail of those factors will not be discussed in this study. In the summer season, Kommetjie Spring and Table Mountain Spring cease to flow because the high temperature, evaporation and lower precipitation.

4.6.2 Delineation of Springs Samples

The location and description of the eight spring's sources are given in Table 4.6 and Figure 4.16.

Table 4.6 Location and description of water sampling

Location and description of water sampling	
Sampling code & name	Description of sample location and field observations
GW-Kirsten01/02 Kirstenbosch Spring	33°59.219′S, 18°25.446′E; Clean water and odourless; The velocity of flow is measured at sampling time; Currently is used for gardens
GW-Albion01/02 Albion Spring	33°58.007′S, 18°28.073′E; Water flow differs between summer and winter season
GW-Newlands01/02 Newlands Spring	33°58.484′S, 18°27.440′E. Currently is used by local community and business; Very clean water
GW-Palm01/02 Palmboon Spring	33°58.429′S, 18°27.552′E; Flow seasonally; The flow yield is measured
GW-Main01/02 Main Spring	33°94.186′S, 18°41.552′E; Consisting with 5 Springs
GW-TM01/02 Table Mountain Spring	33°95.822′S, 18°41.658′E; Emerges under a rock
GW-Komm01/02 Kommetjie Spring	33°97.020′S, 18°45.341′E; Protected by a concrete tank away from contamination; Supply water to local school and business; Water flow seasonally
GW-Water01/02 Waterhof Spring	33°93.658′S, 18°40.845′E; Water use for gardens
SW-Kirsten01/02 Kirstenbosch stream flow	33°59.263′S, 18°25.902′E; Developed for garden plants and vegetation
SW-TM01/02 Table Mountain streams flow	33°57.480′S, 18°24.954′E; Rainwater

Figure 4.17 Sample site marked from Google Earth

The pictures of springs were taken during a field trip, and are displayed below (See Figure 4.17 to 4.25):

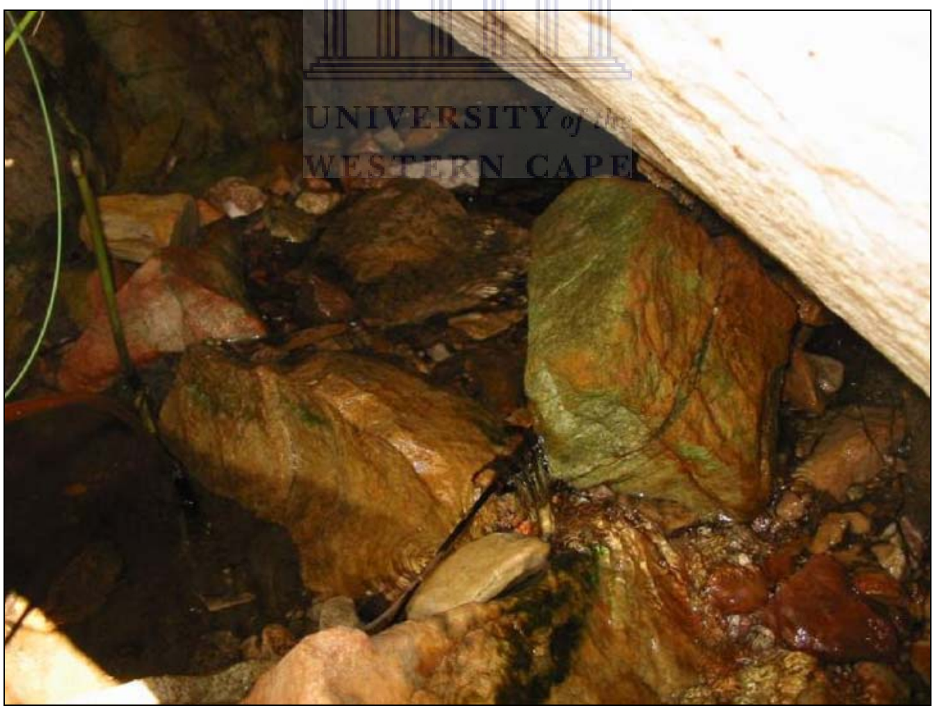

Figure 4.18 Table Mountain Spring

Figure 4.19 Overflow of Kommetjie Spring

Figure 4.20 Palmboom Spring

Figure 4.21 Overflow of Newlands Spring

Figure 4.22 Albion Spring

Figure 4.23 Natural Spring of Kirstenbosch

Figure 4.24 Springs around Main Spring

Figure 4.25 Spring flows together into Main Spring

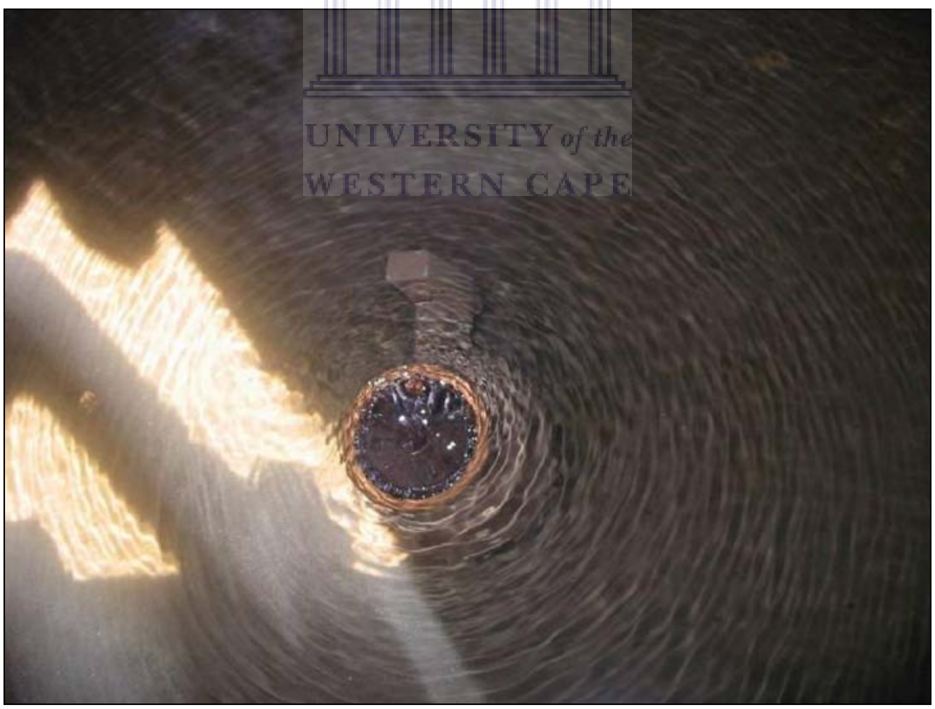

Figure 4.26 Waterhof Spring

Springs usually flow seasonally and with different flow rates. A comparison of the flow of two springs, Kommetjie Spring and Albion Spring, in summer and winter are showed below (See Figure 4.26-4.29):

Comparison of the summer and winter seasonal flow (Kommetjie Spring):

Figure 4. 27 Kommetjie Spring in summer (22nd Feb. 2008)

Figure 4. 28 Kommetjie Spring in winter 31st July, 2008

Comparison of the summer and winter seasonal flow (Albion Spring):

Figure 4. 29 Albion Spring in summer 22nd Feb. 2008

Figure 4. 30 Albion Spring in winter 31st July. 2008

4.6.3 Spring Flow

From Todd & Mays, (2005), the discharge of a spring depends on the area contributing recharge to the aquifer and the rate of recharge. Adequate spring water to supply the needs of a single family can be obtained from a few hectares, whereas large areas with high rainfall are necessary to produce a first magnitude spring. Most springs fluctuate in their rate of discharge. Fluctuations are in response to variations in rate of recharge with periods ranging from minutes to years, depending on geologic and hydrologic conditions. In the water balance principle, discharge decreases usually dominate over recharge increases and the yield of a groundwater system is at the expense of the groundwater discharge component (Wright and Xu, 2000).

The yields of the springs are very important parameters for further groundwater recharge estimation. Some spring yield data came from elderly people without direct measurement, such as Albion Spring, and Main Spring. Palmboom Spring and Kirstenbosch Spring were measured in the field; the yield could be calculated from statistics collected. Newlands Spring and Kommetjie Spring yield data came from the local company which is utilizing the spring water for products currently manufactured. The yield data of the Newlands Spring and the Table Mountain Spring were not available. Waterhof Spring data came from old information somehow. The yield data that were taken from 1995, 1999 and 2008 is compared in Table 4.7 below.

Table 4.7 Springs flow rates compared 1995, 1999 and 2008

	1995 (l/day)	1999 (l/day)	2008 (l/day)
Kirstenbosch Spring	No record	0.077×10^6	0.9×10^6
Albion Spring	4.63×10^6	1.44×10^6	3.0×10^6
Newlands Spring	No record	1.44×10^6	1.55×10^6
Palmboom Spring	0.95×10^6	0.077×10^6	0.23×10^6
Main Spring	2.25×10^6	1.44×10^6	2.2×10^6
Table Mountain Spring	No record	0.008×10^6	No records
Kommetjie Spring	0.35×10^6	0.077×10^6	0.35×10^6
Waterhof Spring	0.17×10^6	1.44×10^6	$1.20X10^6$
Total flow rate	8.35×10^6	5.99×10^6	9.43×10^6

The spring yield which was recorded in 1995 report was measured in 1981. The 1999 records were collected by Harris (1999) only with a certain range. The spring yield of 2008 (See Table 4.7) was obtained from City of Cape Town, Newlands Reservoir and South Africa Brewers Limited Company. Kirstenbosch Spring water flow rate was calculated according to the measurements:

Length=4m; Width: 0.12cm; Deep (h) =0.57m

$V=0.27m^3=270l$

Average flow Time= 40.54s

$Q=V/T=270l/40.54s=6.7l/s=0.58*10^6 l/day$

From the Table 4.7, the spring flow is near stable situation. Since 1995, the discharge rate change is little. Albion Spring, Newland Spring, Main Spring and Kommetjie Spring have reasonable constant discharge rates (See Figure 4.30). This kind of groundwater resource is reliable to exploit in the future.

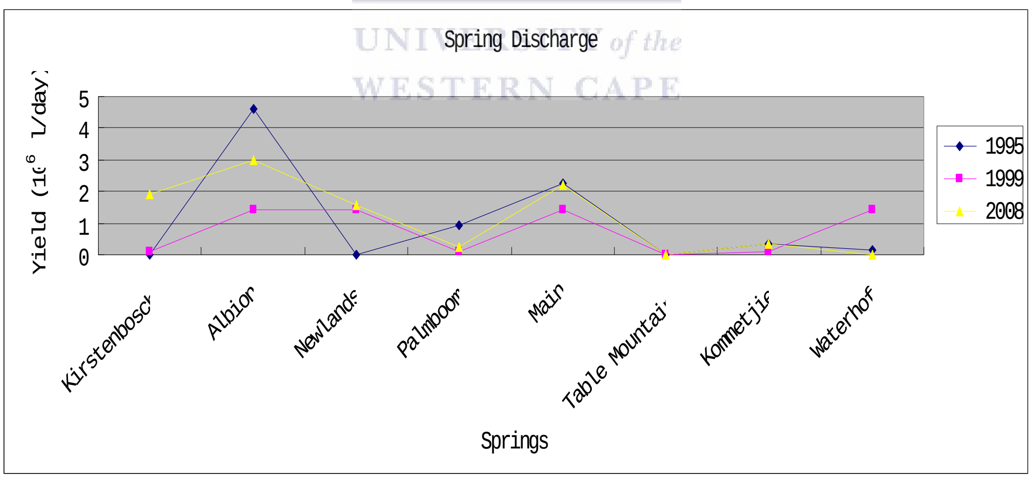

Figure 4.31 Spring runoff distribution

The precipitation from 1998 to 2007 within study area is listed in Figure 4.31. From the figure, we can see that the rainfall for Newlands area (Groote Schuur) keeps stable, without an increase or decrease. The Table Mountain area (Woodhead dam and Table mountain house) rainfall value is far higher than the other places. The Kirstenbosch area rainfall is also higher; the result is that Kirstenbosch Spring discharge has increased from 1999 to the present. The rainfall of north area of Table Mountain (Molteno and Molteno reservoir) is less than other area of the mountain so that the discharge of the Main Spring and the waterhof Spring (located at north of Table Mountian) is not so much comparing other springs. The flow of the main spring is 2.2×10^{6} litre per day (even bigger in winter season). Such amount of flowing because there have other five springs in the same yard. Those springs flow together into a chamber, which is called main spring. The Table Mountain area has the highest rainfall in Cape Town. The north of the mountain rainfall rate is higher than average rainfall of South Africa.

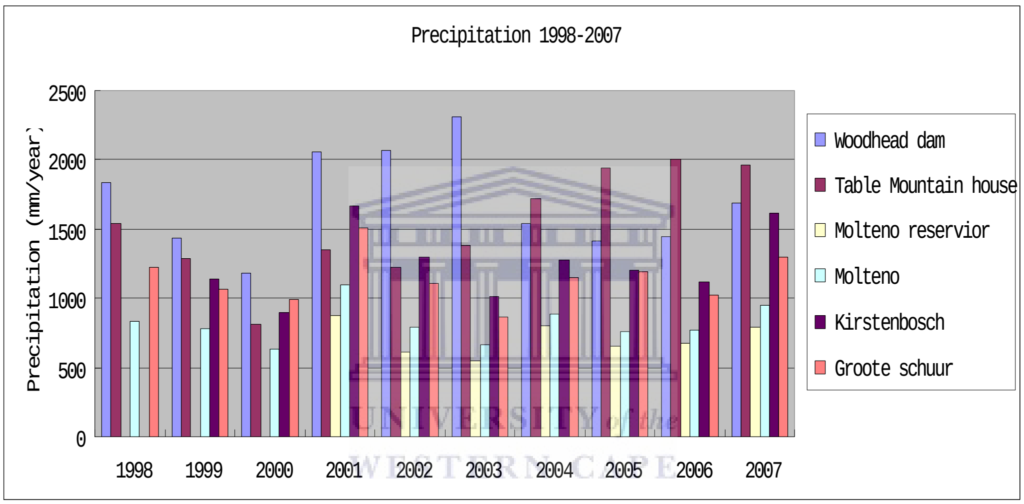

Figure 4.32 Precipitation of the study area (1998 to 2007)

4.6.4 Recharge of Springs

There are various methods for aquifer recharge estimation as reviewed by Lerner et al., 1990; Simmers, 1989; Kinzelbach, at el, 2002; Sanford, 2002; Scanlon et al., 2002. The method chosen depends on the objectives and expected precision of results, dimensions of the system and local hydrogeological conditions. The estimation process is interactive and involves continuous alteration of evaluated recharge when additional data are collected (Wendland, et al., 2007). The recharge estimation is a complicated process as many factors must be involved in the estimation procedure. The amount of groundwater recharge to an aquifer depends on the amount of precipitation and its seasonal distribution, the air temperature, the land use, and other factors; direct measurement of the recharge components are not always possible (Korkmaz, 1990).

The hypothesis of groundwater recharge estimation in the study area is simply divided Table Mountain into two parts: the north and east side is calculated for recharge rate, which is the study area included.

$V=P*1/2\ A$

Where V is water body, is equal to precipitation (P) multiply area of Table Mountain (A). The annual average precipitation data of the Table Mountain area were taken from Woodhead Dam, Waaivlel, Table Mountain House, Molteno Reservoir station, Molteno station, Kirstenbosch station and Groote Schuur station.

$V= 9748.56mm*\ 1/2*24.3km^2$

$V=118.46*10^6\ m^3=118460*10^6 l$

Recharge estimation rate % =Yield of spring/V

Recharge estimation rate %=$9.43*10^6*365$ days/$118460*10^6 l=2.9\%$

The detailed discussion of groundwater recharge estimation is beyond the scope of this study. But understanding the methods for groundwater recharge would bring better understanding of groundwater occurrence. For the Table Mountain area groundwater resources exploration and development, estimating the spring recharge rate could be very significant for future study.

4.6.5 Spring Water Utilization

4.6.5.1 History of Springs

According to the 1995 report of City of Cape Town report, springs were issued to be valuable asset and those resources with excellent quality were utilized since early of 18 century. Some of them originally belong to the private estate, and they then transferred the right to City Council or City of Cape Town. Local community started to use spring water around middle of 19 century.

The springs of the City of Cape Town are not only a water supply resource; they are also the heritage of the city. Albion Spring was granted in 1715, 1889, a steam pump station was built and in 1891 the first water was pumped into the mains that fed the reticulation of Claremont, Woodstock, Mowbary and Mainland municipalities. Newlands Spring and Kommetjie Spring was found to use in 1885. It had been used for Ohlsson's Brewery for more than 100 years. Nowadays, company still uses it with very high level quality.

4.6.5.2 Current Utilization of Springs

Groundwater is widely but variably used across the whole of the country. Estimation of the available groundwater resource potential of South Africa ranges from a maximum of 47.727×10^9 m^3/annum to as low as 7.536×10^9 m^3/annum (Rosewarne et al. 2005); this means groundwater has a significant socio-economic value for the nation. The discharge rate of the springs which are located around the Table Mountain area, could be estimated at least 3441.95×10^6 l/annum.

There are two dialogs that took place in the study period. One was between the student and Mr. Rodney Bishop, Principal Engineer of Water & Sanitation Department, City of Cape Town. The other one was between the student and Mr. Josiah Mpofu, Engineering manager, the South African Breweries Limited. The same opinions from two dialogs were raised, namely that the groundwater resources must be very carefully protected and developed. Local people must be educated to respect those resources for future generations. Groundwater economic value must be realized. The integrated water resources management for groundwater will be discussed in the conclusion section.

Classification of users:

Casual walkers: These include mountaineers, picnickers and campers. They use the mountain routs, like Platteklip Gorge (Table Mountain spring location), Skeleton Gorge (Kirstenbosch spring location) etc. to climb or walk within the mountain area. People may stay overnight on the mountain area.

Company: Newlands Spring and Kommetjie Spring are used by South Africa Brewers Limited Company for beer products. Newlands Spring had been utilized since 1989 for beers productions. Kommetjie Spring water now is used not for beers products; it is only for cleaning purpose for the company. Part of Kommetjie Spring also is used by Newlands School, not drinking purpose.

Reservoir: Two Springs flow into nearby reservoir. Part of Waterhof Spring flows into old Molteno Reservoir. Main Spring and Molteno Spring flow into Molteno Reservoir.

Local community:

Waterhof Spring flow into old Molteno Reservoir, and local residents are using this water for gardening purposes. SACS school which is located in Newlands is sharing Kommetjie Spring with South Africa Brewers Limited Company for cleaning and gardening purpose. Newlands Spring is not only used for beer products, but also for nearly private property gardening. Nelson Mandela hotel currently utilizes two springs water for gardens, Main Spring and Waterhof Spring. The Gardens Company is also use main spring water for vegetation and plants. Residents in Newlands are taking water from Albion Spring which overflows into Liesbeek River for domestic utilization.

CHAPTER 5 DATA INTERPRETATION AND ANALYSIS

5.1 INTRODUCTION

Naturally, groundwater quality is dependent on geological conditions under which water occurs. Groundwater is the natural solution which contains various constituents. It is also a good solvent which can dissolve the chemical constituents when the water is transmitted through porous media. During the hydrologic cycle, the exchange occurs simultaneously among the chemical components at the same time the groundwater interacts with the atmosphere, hydrosphere and biosphere.

Knowledge of the natural groundwater quality can provide important insights into the nature of the resource (Todd & Mays, 2005). Evaluation of the physical and chemical attributes of groundwater can provide inferences of the origin, recharge, movement, mixing, and discharge of groundwater .In this chapter the laboratory results of water samples are interpreted and analyzed; and the quality of groundwater is therefore explained by analyzed results. Study of groundwater chemistry is a good tool for understanding groundwater flow processes, interaction with the environments.

5.2 SURFACE WATER AND GROUNDWATER

5.2.1 Surface Water and Groundwater

Surface water is natural water which flow above the water table on the surface of the earth, including all streams, rivers, lakes, or other fresh water sources used for drinking water supplies.

Available stores of natural water are made up of groundwater, impounded of flowing surface water and seawater. In a simplified definition, groundwater is subsurface water below the water table (Younger, 2006), which exists in the pore spaces and fractures in rock and sediment beneath the earth surface. Groundwater originates as rainfall or snowmelt, and then moves through the soil into the groundwater system, where it eventually makes its way back to surface streams, lakes, or oceans.

5.2.2 The Characteristics of Surface Water and Groundwater

The Table 5.1 below compares the characteristics of surface water and groundwater based on the major analysis parameters.

Table 5.1 Comparison of surface water and groundwater

Parameters	**Surface water**	**Groundwater**
Temperature	Varies with season	Relatively constants, and usually lower than air temperature
Turbidity	Level variable, sometimes high	Low or nil
Colour	Due mainly to substance, like clays, algae	Due all to dissolved solids
Mineral content	Varies with soil, rainfall effluents, etc.	Largely constant, generally appreciably higher than in surface water from the same area
Fe & Mn in solution	Usually none	Usually present
NH_4	Found only in polluted water	Often found
Silica (Si)	Usually moderate proportions	Level very high
Chlorinated solvents	Rarely present	Often present
Nitrates (NO_3)	Level generally low	Level often high

5.3 PHYSICAL ANALYSIS

5.3.1 General Concepts

Properties of groundwater evaluated in a physical analysis include temperature, colour, odour, turbidity and taste; the analysis also includes measurement of pH, specific electrical conductance, and Total Dissolved Solids. Hardness is also an important concept for physical analysis which is expressed as $CaCO_3$.

According to the definition of the U.S Geological Survey (USGS), the pH of water is a measure of its reactive characteristics. Low values of pH (<4.0) indicate an acidic water that will tend to dissolve metals and other substances; high values of pH (>8.5) indicates an alkaline water. The geology and geochemistry of the rocks and soils of a particular catchment area affect the pH and alkalinity of the water (SA domestic water use guideline, 1996). The pH significantly affects the treatment and use of water. The pH range is from 5.5-6 or <8.0, water quality is generally good.

Salty water conducts electricity more readily than purer water. Therefore, Electrical Conductivity is routinely used to measure salinity. According to Todd & Mays (2005), Electrical conductivity (EC) is a valuable indicator of the amount of material dissolved in water. The larger the EC, the more mineralized the water. In South Africa, the EC value less than 70 ms/m is generally regarded as good.

The South Africa Domestic Water Use Guidelines define Total Dissolved Solids (TDS) as a measure of the amount of various inorganic salts dissolved in water and is, therefore, a very useful parameter in the evaluation of water quality. The TDS of natural waters is often dependent on the characteristics of geological formations the water is contact with. The TDS range, which is from 0 to 450 mg/l, and EC range from 0-70 ms/m, suggests that there is no negative health effects associated with water.

The principal cause for hardness is Calcium and Magnesium dissolved in the water expressed as mg/l of Calcium Carbonate. South Africa criteria require that total hardness for domestic use should be limited to between 50-100 mg/l as $CaCO_3$, where possible.

5.3.2 Water Samples Physical Characteristics Explanation

Twenty water samples were selected from 10 sites located around Table Mountain. Four water samples came from stream which means that they are surface water samples. The others were taken from springs which mean groundwater. The Table 5.2 below shows all physical parameters of twenty water samples.

Table 5.2 Water sample physical characteristics

20	Sample name	Water T(°C)	Ambient T(°C)	pH	EC(mS/m)	TDS(mg/l)	Hardness (mg/l)
1	GW-Kirsten01	17.5	23.5	6.2	13.49	56.6	10.1
2	GW-Kirsten02	17.5	23.5	5.8	12.60	50.8	9.5
3	GW-Albion01	21.6	26.0	5.6	23.70	105.4	31.4
4	GW-Albion02	21.6	26.0	5.8	21.90	106.7	32.3
5	GW-Newlands01	19.4	26.0	5.9	13.60	58.7	14.0
6	GW-Newlands02	19.4	26.0	5.7	13.67	56.9	14.0
7	GW-Palm01	16.7	24.2	5.7	15.54	72.2	18.8
8	GW-Palm02	16.7	24.2	5.7	15.46	70.3	19.1
9	GW-Main01	19.2	29.1	6.2	19.26	88.3	16.7
10	GW-Main02	19.2	29.1	6.2	19.05	82.0	15.4
11	GW-TM01	15.4	29.1	5.1	7.29	32.6	7.2
12	GW-TM02	15.4	29.1	4.7	7.24	36.0	6.7
13	GW-Komm01	19.5	29.1	5.3	13.85	61.6	19.3
14	GW-Komm02	19.5	29.1	5.3	13.81	66.7	19.5
15	GW-Water01	22.1	29.1	6.2	36.00	161.8	39.7
16	GW-Water02	22.1	29.1	5.4	33.20	176.8	54.2
17	SW-Kirsten01	18.0	18.0	6.2	12.17	65.7	12.40
18	SW-Kirsten02	18.0	18.0	6.1	12.41	51.5	13.60
19	SW-TM01	16.5	18.0	5.5	10.98	43.2	12.40
20	SW-TM02	16.5	18.0	5.1	11.05	44.6	18.60

The knowledge of groundwater temperatures is essential for the correct interpretation of solution chemistry especially for assessing the tendency for minerals to be dissolved in, or precipitates from, a given groundwater (Younger, 2007). The temperatures of groundwater are always lower than ambient. There is a general tendency for groundwater between 5m and 150m below ground surface to closely approximate the local mean annual air temperature. The mean annual temperature of Cape Town in 2007 is 17.6 °C.

All water samples expressed a weak acidity value ranging from 4.7 - 6.2, mostly the water pH values range from 5.1 - 5.9.

Total hardness technically is the sum of all polyvalent cations; and in practice, can be indicated by the amount of calcium and magnesium ions (See Table 5.3). Total hardness should be limited to between 50 - 100 mg/l as $CaCO_3$, where possible. This is South Africa Domestic Water Use criteria. Hardness of water is classified as follows by Kunin (1972):

Table 5.3 Hardness standard of groundwater

Hardness Range (mg $CaCO^3$/l)	**Description**
0-50	Soft
50-100	Moderately soft
100-150	Slightly hard
150-200	Moderately hard
200-300	Hard
>300	Very hard

The Total Hardness value for most water samples of the Table Mountain groundwater can meet South Africa Domestic Water Use guideline, which is lower than 50, except one sample taken from Waterhof Spring, which is higher than 50. One water sample of Waterhof Spring was obtained from outside of spring chamber, which means water had been stayed in the pond for long period. Hardness can be calculated:

$H_T = 2.5\ Ca + 4.1\ Mg$

Electrical Conductivity of all water samples showed low values ranging from 7.24—36.00 ms/m (See Table 5.2); most spring water EC is around 13-19 ms/m. This indicted a low concentration of dissolved salts. The groundwater quality is generally good according to South Africa Domestic Guideline according to EC value.

5.4 CHEMICAL DETERMINANTS

The analysis of the chemical components is essential for water quality evaluation. The major chemical determinants for estimating include mineralization or TDS, HCO_3^-, SO_4^{2-}, Cl^-, Ca^{2+}, Mg^{2+}, K^+, Na^+. Some minor ions and trace elements are also tested for water type and quality analysis as listed in Table 5.6 below.

5.4.1 Principal Chemical Constituents in Groundwater

Mineralization (g/l) or TDS are present at Table 5.4 below:

Table 5.4 Mineralization standard of groundwater

Mineralization (g/l)	Ions	Description
<1	HCO_3, Ca	very low salt content, fresh water
1-3	SO_4, Ca, Mg	low saltish, very weak mineralization
3-10	SO_4, Ca, Mg	Moderate mineralization
10-50	Cl, Na, K	high mineralization, high content of salt
>50	Cl, Na, K	Haloid

Seven ions are present:

Cl^- (Chloride) is widely distributed in the groundwater, and it can be indicative of the amount of salt content in the water; and it is also the indicator to distinguish if the water is contaminated. Chloride inputs to surface waters can arise from irrigation return flows, sewage effluent discharges and various industrial processes (DWAF, 1996). According to SA Water Use Guideline, 1996, 0-100 mg/l won't cause health effects, and it is below the corrosion acceleration threshold.

SO_4^{2-} (Sulphate) is the oxy-anion of Sulphur and forms salts with various cations such as Potassium, Sodium, Calcium, and Magnesium (DWAF, 1996); in the water, SO_4

has transmissibility a little lower than Cl. SO_4 arises from the dissolution of mineral Sulphate in soil and rock (DWAF, 1996). For South Africa, 0-200 mg/l Sulphate doesn't have human health effects.

HCO_3^- (Bicarbonate) is an indicator for fresh water. The saltness is usually low when the groundwater type is HCO_3^-. The HCO_3^- anion is always explained with associated cations.

Na^+ (Sodium) is an alkali metal which reacts with water to form highly soluble, positively-charged sodium ions (DWAF, 1996). The cation is highly transmissible and it is widely distributed in the groundwater. Sodium is omnipresent in the environment and usually occurs as Sodium Chloride, sometimes as Sodium Sulphate or Sodium, Bicarbonate (DWAF, 1996). The South Africa Water Use Guideline, 1996, indicated that a content of 0-100 mg/l of Sodium has no health effects on human.

K^+ (Potassium) content is less than Na^+ in the groundwater. K^+ is an alkali metal that reacts with water to form positively-charged potassium ions (DWAF, 1996). It always occurs in water with associated with anions, such as Cl^-, SO_4^{2+} or HCO_3^-. Potassium is everywhere in the environment. According to DWAF, 1996, typically the concentration of Potassium in fresh water is within the range of 2-5 mg/l; there are no effects to human health when K has concentration of 0-50 mg/l in the water.

Ca^{2+} (Calcium) is a major cation that indicates lower salt content in the groundwater. The concentrations of Ca^{2+} should be interpreted in conjunction with major associated anions, normally HCO_3^-, Cl^-, or SO_4^{2-}, as well as Mg^{2+}, K^+ and Na^+ (DWAF, 1996). Mineral deposits of Ca are common, usually as Calcium Bicarbonate, Calcium Phosphate or Calcium Sulphate (DWAF, 1996). In the South Africa Water Use Guideline, 1996, the average concentration of Calcium in freshwater is 15 mg/l.

Mg^{2+} (Magnesium) is an alkaline earth metal which reacts with oxygen and water to form magnesium oxide and hydroxide (DWAF, 1996). It has similar chemical characteristics to Ca^{2+}, it is widely distributed, and it occurs at lower content than Ca^{2+}

in the groundwater. Mg^{2+}, together with Calcium, is responsible for the hardness of water (DWAF, 1996). According to the South Africa Water Use Guideline, 1996, typically, the concentration of Mg^{2+} in fresh water is between 4-10 mg/l; 0-30 mg/l in the water won't cause bitter taste, scaling problems and health effects.

The chemical data of groundwater reflects the hydrological interactions (Douglas, 2001). Groundwater chemistry is also determined firstly by rainfall and secondly by geochemical interactions that occur firstly in the unsaturated zone as the water filtrates down to groundwater level, and secondly, in the saturated aquifer matrix, and thirdly, when pollutants enter the aquifer (Bredenkamp, 2000). Geochemical analysis is an important tool for understanding groundwater flow processes, interaction with environment.

5.4.2 Major Ions Analysis

All groundwater contains salts in solution that resulted from the location and past movement of the water (Todd & Mays 2005).

Table 5. 5 Chemical characteristics of water samples

20	Spring No	Na	K	Ca	Mg	HCO_3	CO_3	SO_4	Cl	NO_3	PO_4	NH4-N	Water type
1	GW-Kirsten01	17.44	2.31	1.25	1.70	16.64	0.00	1.99	26.38	0.39	0.00	0.10	Na-Cl-HCO_3
2	GW-Kirsten02	14.96	2.08	1.02	1.69	18.15	0.00	0.45	24.62	0.32	0.00	0.04	Na-Cl-HCO_3
3	GW-Albion01	22.70	5.76	4.58	4.85	30.26	0.00	7.00	43.97	1.84	0.00	0.03	Na-Mg-Cl-HCO_3
4	GW-Albion02	23.19	1.45	4.70	5.00	27.23	0.00	7.04	36.06	1.90	0.00	0.03	Na-Mg-Cl-HCO_3
5	GW-Newlands01	15.59	1.04	1.77	2.33	16.64	0.00	1.20	28.14	0.46	0.30	0.06	Na-Cl-HCO_3
6	GW-Newlands02	15.63	0.98	1.75	2.33	15.13	0.00	1.58	26.38	0.49	0.00	0.05	Na-Cl-HCO_3
7	GW-Palm01	16.36	1.15	2.27	3.19	18.15	0.00	3.01	27.26	0.50	0.07	0.03	Na-Mg-Cl-HCO_3
8	GW-Palm02	16.30	1.04	2.41	3.17	15.13	0.00	2.77	29.02	0.00	0.00	0.12	Na-Mg-Cl-HCO_3
9	GW-Main01	30.00	1.34	1.78	2.97	18.34	0.00	11.90	36.94	0.53	0.18	0.08	Na-Cl
10	GW-Main02	28.11	1.00	1.43	2.88	15.29	0.00	8.97	35.18	0.55	0.03	0.05	Na-Cl
11	GW-TM01	10.30	0.00	0.83	1.25	0.10	0.00	2.21	17.62	0.11	0.00	0.1	Na-Cl
12	GW-TM02	9.87	0.00	0.82	1.13	0.11	0.00	1.87	22.03	0.00	0.00	0.1	Na-Cl
13	GW-Komm01	19.30	0.63	2.44	3.21	0.10	0.00	4.78	29.96	0.97	0.00	0.14	Na-Mg-Cl
14	GW-Komm02	19.43	0.59	2.47	3.24	0.12	0.00	4.37	35.24	0.99	0.00	0.16	Na-Mg-Cl
15	GW-Water01	54.97	1.92	3.85	7.32	0.12	0.00	9.50	81.06	2.84	0.00	0.07	Na-Mg-Cl
16	SW-Water02	55.93	1.94	7.56	8.60	0.31	0.00	20.05	80.18	1.69	0.00	0.12	Na-Mg-Cl
17	SW-Kirsten01	14.57	1.84	1.54	1.42	15.13	0.00	2.07	25.50	0.00	0.03	0.05	
18	SW-Kirsten02	14.90	1.40	2.37	1.30	16.64	0.00	2.06	22.86	0.10	0.09	0.15	
19	SW-TM01	12.75	0.56	1.04	1.48	15.13	0.00	2.06	21.11	0.00	0.00	0.05	
20	SW-TM02	12.68	0.55	1.17	1.50	22.69	0.00	2.48	21.99	0.00	0.00	0.03	

Twenty water samples were tested by Bemlab and the results are displayed at Table 5.5 and Table 5.6.

Ca-values range from 0.82- 7.56 mg/l which falls within the South Africa Domestic Water Use Guideline, (1996).

Na-values range from 9.87-30.00 mg/l which is measured up to South Africa Domestic Water Use Guideline, (1996); except Waterhof Spring Na determinant is 54.97 mg/l and 55.93 mg/l higher than other examples but it still does not has affects to human health.

K-values range from 0 – 2.31 mg/l which is measured up to South Africa Domestic Water Use Guideline, (1996); except one sample from Albion Spring is 5.76 mg/l which exceeds South Africa guideline. This would be caused by two reasons: water sample had impurity when it collected, or the lab result was wrong.

The SO_4^{2-} result ranged from 0.45- 20.05 mg/l and they are under the South Africa Domestic Water Use Guideline limit, (1996).

Cl^- has values from 17.6- 81.06 mg/l and they are within South Africa Domestic Water Use Guideline, (1996). The samples with the higher value of Cl^- also has higher value of TDS or mineralization, compared to all water sample taken from Springs, Albion Spring and Waterhof Spring had higher Cl^-, their TDS was also higher than other groundwater samples. The Cl^- of groundwater has more Chloride dissolution ability in sediments.

HCO_3^- always reacts with associated metal ions. The value for the water samples is arranged from 0.10-30.26 mg/l.

5.4.3 Minor Ions

The minor ions (Table 5.6) are at low concentrates in the groundwater and with limited distribution. Their presence can't determine the chemical type of groundwater, but they do have particular characteristics or functions of groundwater. For the twenty water samples, only element Si has values in contrast to the others. In the Table Mountain area, Water is able to descend along the vertical lines of fracture with greater ease than through the solid rock, and as it sometime carries compounds of iron and manganese in solution, a vertical vein of iron or manganese ore may finally be produced (Luckhoff, 1951).

Table 5. 6 Minor ions of water samples

20	Spring No	B	F^-	Sr	Ba	Al	Cr	Mo	Mn	Fe	Ni	Cu	Si	Zn	Cd	Pb
1	GW-Kirsten01	0.04	0.00	0.02	0.02	0.06	0.01	0.01	0.00	0.06	0.00	0.006	4.026	0.004	0.001	0
2	GW-Kirsten02	0.03	0.03	0.01	0.02	0.03	0.00	0.01	0.00	0.00	0.01	0	4.158	0.004	0.005	0.018
3	GW-Albion01	0.03	0.03	0.04	0.02	0.05	0.01	0.00	0.00	0.03	0.01	0.005	3.449	0.004	0.003	0
4	GW-Albion02	0.03	0.00	0.04	0.02	0.03	0.00	0.00	0.00	0.00	0.02	0	3.610	0.004	0.002	0
5	GW-Newlands01	0.02	0.06	0.02	0.02	0.08	0.01	0.00	0.02	0.07	0.02	0	3.006	0.003	0.002	0
6	GW-Newlands02	0.02	0.15	0.02	0.02	0.09	0.01	0.00	0.00	0.04	0.01	0	3.049	0.002	0.003	0
7	GW-Palm01	0.02	0.09	0.03	0.02	0.04	0.01	0.00	0.00	0.04	0.00	0.001	3.594	0.005	0.004	0
8	GW-Palm02	0.02	0.16	0.03	0.02	0.07	0.01	0.00	0.00	0.03	0.00	0	3.576	0.005	0.002	0.014
9	GW-Main01	0.03	0.00	0.02	0.02	0.04	0.00	0.00	0.01	0.02	0.00	0	3.225	0	0.002	0
10	GW-Main02	0.02	0.00	0.02	0.02	0.04	0.00	0.01	0.00	0.02	0.01	0	3.187	0.001	0.001	0
11	GW-TM01	0.00	0.00	0.01	0.00	0.05	0.01	0.00	0.01	0.01	0.00	0	0	0.001	0	0
12	GW-TM02	0.00	0.01	0.01	0.00	0.06	0.00	0.00	0.01	0.01	0.00	0	0	0	0	0
13	GW-Komm01	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0	0	0	0.001	0
14	GW-Komm02	0.00	0.00	0.02	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0	0	0	0	0
15	GW-Water01	0.00	0.00	0.04	0.02	0.01	0.00	0.00	0.02	0.04	0.00	0	0	0	0.002	0
16	SW-Water02	0.01	0.03	0.07	0.02	0.02	0	0.00	0.02	0.23	0.00	0	0	0.002	0	0
17	SW-Kirsten01	0.03	0.14	0.21	0.06	13.48	0.01	0.00	0.00	0.27	0.01	0	3.541	0.004	0	0
18	SW-Kirsten02	0.03	0.09	0.02	0.02	0.24	0.00	0.01	0.00	0.44	0.01	0	3.209	0.003	0.002	0
19	SW-TM01	0.03	0.02	0.01	0.00	0.10	0.00	0.01	0.00	0.04	0.01	0	0.897	0.003	0.002	0
20	SW-TM02	0.03	0.10	0.01	0.00	0.08	0.01	0.00	0.00	0.02	0.02	0.009	0.867	0.006	0.004	0

5.5 GRAPHIC REPRESENTATIONS

Graphic representations are useful for display purposes, for comparing analyse, and for emphasizing similarities and differences because simple tables may be difficult to interpret the results of chemical quality of groundwater, especially when more than a few analyses are involved (Todd and Mays, 2005). Spring-water chemistry represents the integrated changes of water chemical components in the large parts of an aquifer. Interpreting the subtle differences in the chemical composition of spring waters will enable someone to better understand the groundwater flow and mixing patterns in the aquifers (Toth and Katz, 2006).

5.5.1 Types of Groundwater

There are four types of groundwater found based on the results of the twenty water samples. They are listed as follows:

Na-Cl-HCO_3 groundwater: Kirstenbosch Spring and Newland Spring. This kind of groundwater is Carbonate with alkali water. It belongs to deep phreatic groundwater with good quality.

Na-Mg-Cl-HCO_3: Albion Spring and Palmboom Spring. This determined that Albion Spring and Palmboom Spring is the shallow groundwater.

Na-Cl: Main Spring and Table Mountain Spring is classified as Na-Cl dominant. This type of groundwater is called Carbonate with soft alkali. This type of groundwater might be ancient saline groundwater (Younger, 2007) and therefore it is with corrosive. The groundwater is always influenced by the sea water.

Na-Mg-Cl: Kommetjie Spring and Waterhof Spring. It is due to the mixing of fresh and saline waters. The Na^+ may interact by soil or by Mg^+ which is contained in aquifer. The chemical composition therefore changed because such ions exchange. This type of groundwater belongs to mixed groundwater and occurs in the sedimentary rock. The TDS or mineralization is high.

5.5.2 Graphic Illustration

In the Piper Diagram, the cations, expressed as percentages of total cations in milliequivalents per liter (meq/l), plot as a single point on the left triangle; anions, similarly appear as a point in the right triangle. These two points are then projected into the central diamond-shaped area parallel to the upper edges of the central area. This single point is thus uniquely related to the total dissolved solids. The trilinear diagram conveniently reveals similarities and difference among groundwater samples---those with similar qualities will plot together as groups.

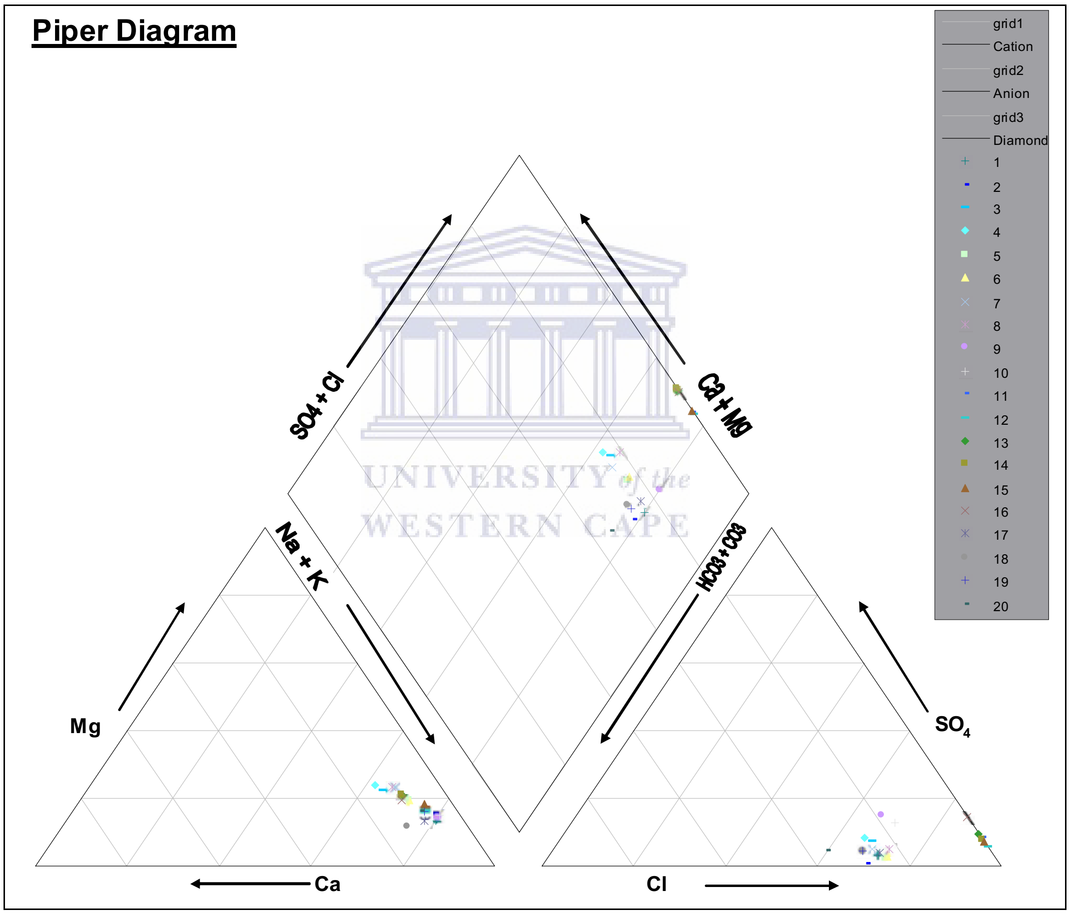

Figure 5.1 Piper Diagram of water samples

In the Piper Diagram the left corner represents newly recharged water which is relatively high in Ca, Mg and alkalinity, and low in SO_4 and Cl. The right hand corner is regarded as stagnant water from the discharge zone of an aquifer. Also the right hand corner represents sea water.

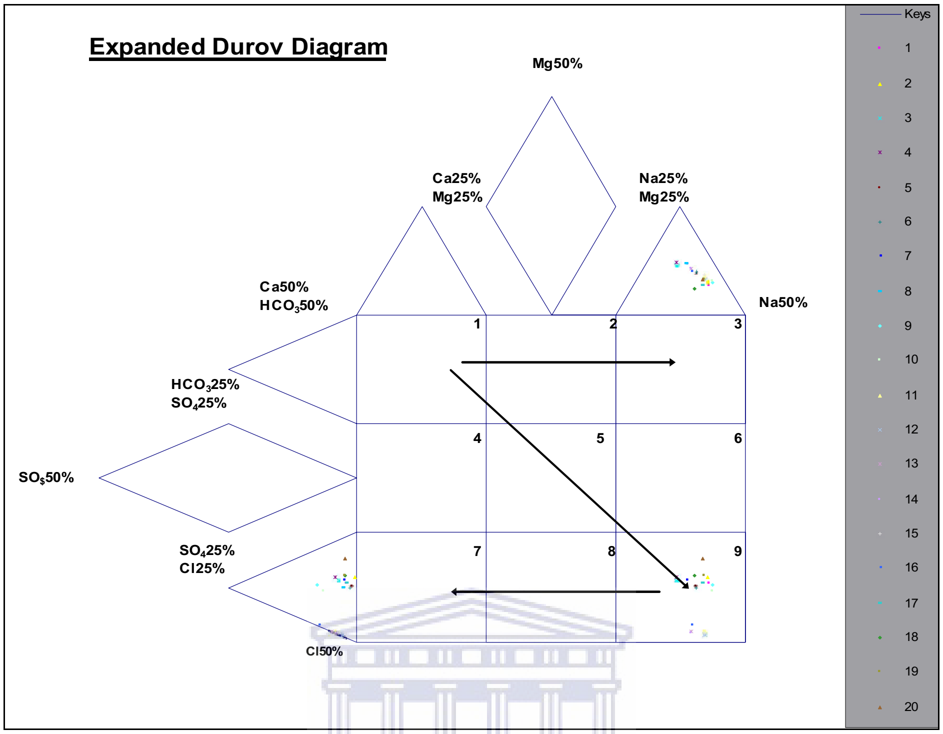

Figure 5.2 Expanded Durov Diagram of water samples

Expanded Durov Diagram allow for the plotting of six chemical variables for a single water sample. Each surface or groundwater chemistried may be plotted. From Figure 5.2, the spring water samples are Cl^-, Ca-HCO3 and Na-Mg enrichment. The diagram is also determined the type of groundwater.

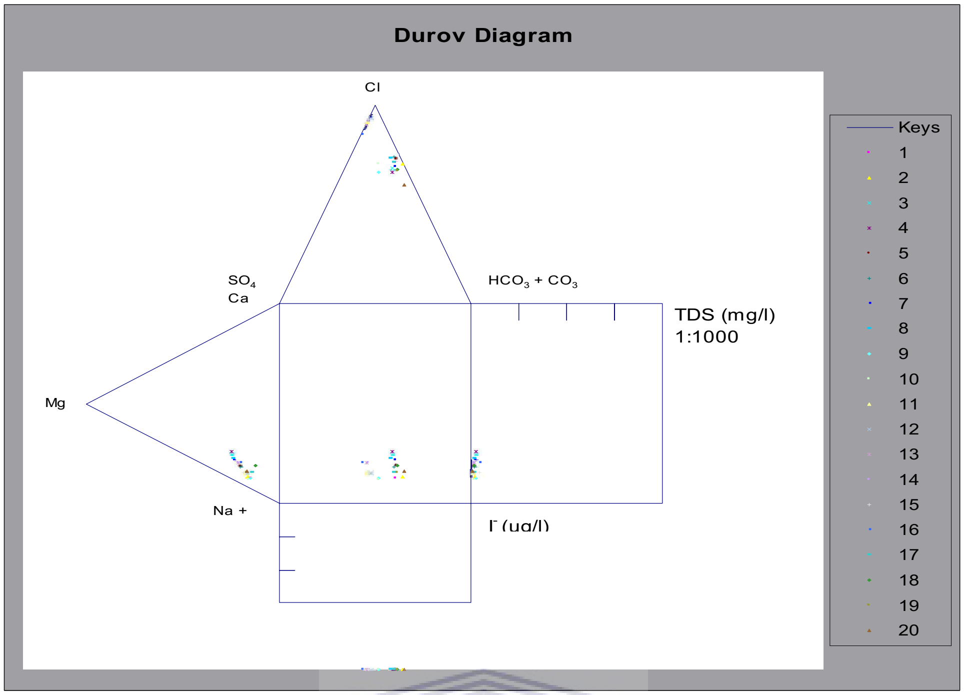

Figure 5.3 Durov diagram of water samples

The Durov Diagram plots the major ions as percentages in two base triangles. The total cations and the total anions are set equal to 100% and the data points in the two triangles are projected onto a square grid that lies perpendicular to the third axis in each triangle. This plot display useful properties and relationships for all spring water samples. Figure 5.3 above, shows clustering of the data points to indicate samples that have similar compositions.

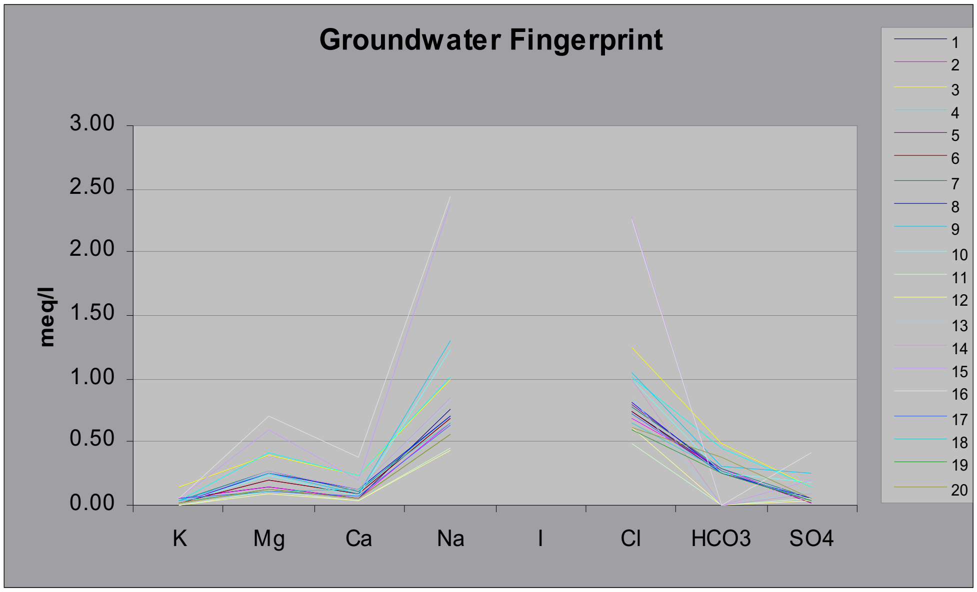

Figure 5.4 Groundwater fingerprints of water samples

Fingerprint Diagram displays the Chemical data (See Table 5.5). In this figure, each spring is represented by one line that provides a visual description of the relative abundance pattern of the dissolved ions and the relative salinity. Each line is the compositional imprint of a water sample, and various samples can be compared to each other in the way people can be sorted and identified by their fingerprint. Cations are by convention plotted on the left and anions on the right.

5.5.3 The Cation-Anion Balance (Charge-Balance)

Aqueous solution must be electrically neutral. In other words, the sum of all negative charges must equal the sum of all positive charges. One check on the quality of a water analysis is the charge-balance error. Calculated as follows:

% difference = ($\sum$cations - $\sum$anions) / ($\sum$cations + $\sum$anions).

The Cation- Anion Balance check is done based on a percentage differences between the total positive charge and negative charge (Murray and Wade, 1995), Where contributions to charge are in units of meq/l, if a balance value is less than $\pm$5%, then the analysis can be regarded as sufficiently accurate for all uses. If a balance lies in the range $\pm$5-15%, then the analyses should be used with caution, while those values is greater than $\pm$15% cannot really be regarded as being sufficiently reliable to justify using them for serious scientific purpose (Younger, 2007). The Table 5.7 shows the sixteen results of Cation-Anions Balance. There are seven balance lies in the range ±5-15%.

Table 5.7 Cation-anion balance of water samples (only spring water samples)

	CATION	ANIONS	Balance
1	1.03	1.07	-1.90%
2	0.90	1.01	-5.76%
3	1.69	1.67	0.60%
4	1.77	1.94	-4.58%
5	0.99	1.05	-2.94%
6	0.99	1.11	-5.71%
7	1.12	1.13	-0.31%
8	1.12	1.15	-1.32%
9	1.56	1.45	3.65%
10	1.68	1.61	2.13%
11	0.57	0.66	-7.32%
12	0.60	0.55	4.35 %
13	1.26	1.12	5.88%
14	1.23	0.98	11.31%
15	3.58	2.74	13.29%
16	3.24	2.58	11.34%

5.6 WATER QUALITY COMPARISON WITH SOUTH AFRICA DOMESTIC WATER SUPPLIES ASSESSMENT GUIDE

The South Africa Water Use Guidelines (DWAF, 1996) is technical document aimed at users with a basic level of expertise concerning water quality management. According to the guideline (DWAF,1996), this document is intended to provide the information required to make judgments as to the fitness of water to be used for domestic purposes, primarily for human consumption, but also for bathing and other household uses.

The results of chemical test of the water samples were compared with South Africa Domestic Water Use Guideline (DWAF, 1996) to see whether they were satisfy with the requirements of water quality for local community utilization. This is important for future groundwater resources development and management in this area. The parameters which were used for water quality comparison with the South Africa Domestic Water Use Guideline include: pH, Electric Conductivity, Chloride as Cl^-, Sulphate as SO_4^{2-}, Fluoride as F^+, Sodium as Na^+, Magnesium as Mg^{2+} and Iron as Fe^{2+}.

Table 5.8 Suitability of samples for domestic use

Sample ID:	Kistenbosch	Checking	*ideal*, *good*, *marginal*, *poor*, *unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	6.20	*6.20*	*6.20*	*6.20*	*6.20*	*6.20*
E Conductivity mS/m	13.49	*13.49*	*13.49*	*13.49*	*13.49*	*13.49*
Nitrate as N mg/l	0.39	*0.39*	*0.39*	*0.39*	*0.39*	*0.39*
Chloride as Cl mg/l	26.38	*26.38*	*26.38*	*26.38*	*26.38*	*26.38*
Sulphate as SO_4 mg/l	1.99	*1.99*	*1.99*	*1.99*	*1.99*	*1.99*
Fluoride as F mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sodium as Na mg/l	17.44	*17.44*	*17.44*	*17.44*	*17.44*	*17.44*
Magnesium as Mg mg/l	1.70	*1.70*	*1.70*	*1.70*	*1.70*	*1.70*
Iron as Fe mg/l	0.06	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*

The checking list above (See Table 5.8) shows that springs which were investigated around the Table Mountain area have a good water quality, with no negative health affects to humans. This kind of groundwater resource can be choosing to supplement the domestic water use in the future for City of Cape Town. Other water sample checking lists are in Appendix 9-18.

CHAPTER 6 CONCLUSIONS AND FUTURE WORK

6.1 RESULT FROM STUDY

6.1.1 Groundwater Resources in Study Area

When rain falls on the ground, it forms run off contributing to streams and rivers. It also soaks down through soils into cracks of the underlying rocks until it hits impermeable rocks, like shales. Here it collects to form ground water. Table Mountain sandstone is a group of rock formations that can store a large amount of water in its fracture networks to form an underground reservoir, called an aquifer. Springs appear where water from an aquifer flows out through a crack in the ground. Occurrences of TMG springs may be controlled by large faults and by the climatic situation as well. The springs investigated in the Table Mountain area confirm this hypothesis.

6.1.2 Groundwater Quality

The chemical characteristics of the groundwater have been affected by topography, lithology, and the climatically situation. The study area is located in and around Table Mountain; the major source of recharge is rain. The water chemistry of the study area is subjected to the infiltration and evaporation processes; the water quality is good with minimal mineralization, e.g., low TDS. The major cation, Na^+ and Mg^+, is influenced by lithology; major anions, HCO_3^- and Cl^- forming 90% of types of groundwater; which is related to topographic characteristics.

The water quality of most water samples is good as they meet South Africa Domestic Water Use Guidelines. These water resources could be considered for use joined to the bulk water supply system for Cape Town in the future.

6.1.3 Groundwater Recharge Rate

The recharge rate of springs was estimated around 2.9% in the Table Mountain area; some of spring's water is good enough to be exploited as a source of municipal domestic and drinking water.

6.2 INTEGRATED WATER RESOURCES MANAGEMENT

The water resource is a complex ecological system on which humans also have impacts. Surface water, land use, and ecosystems are all linked in a dynamic hydrologic cycle. Rain falls on the surface, forming runoff from the land and infiltrating through the top soil into the groundwater, while evaportranspiration would take some water from the ground back to the atmosphere. Each step is a part of a complex process. After we have understood this complex system, we need a proper strategy to manage our water resources.

The surface water resources, however, have now almost been exploited to their limits. South Africa, therefore, will have to make greater use of its groundwater resources in the future, to meet the demand of the growing population, and also in a more efficient manner (Botha, Verway, at el. 1998). In 2004, Department of Water Affairs and Forestry published National Water Resource Strategy, with title "our blue print for survival". It indicated that there is increasing understanding internationally that water resources can be successfully managed only if the natural, social, economic and political environments in which water occurs and is used are taken fully into consideration. Integrated Water Resources Management (IWRM) is defined as a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner. IWRM therefore aims to strike a balance between the use of resources for livelihoods and conservation of the resource to sustain its functions for future generations, and promotes social equity, environmental sustainability and economic efficiency. Because the resource cannot be separated from the people who use and manage it, a balance mix of technological and social approaches must be used to achieve integrated management.

As groundwater resources are crucial for the country, efficient management strategies must be established and implemented. Integrated Water Resources Management should not operate in isolation; it is driven with proper policy, positive strategies, the involvement of the communities and information systems (Gupta and Onta, 1997), highlighted three important management strategies, which included enhancement of understanding of resources availability, the reorganization of groundwater as a vital component of water resources by the resource manager and decision-makers, and the improving of knowledge and understanding of groundwater systems. To achieve the management of groundwater resources, information is the cornerstone on which implementation of the strategies is based and on which the new institutions can function effectively. The need for Integrated Water Resource Management will create the need for much greater integration of the relevant information systems (Braune, 2000), e.g. geology, hydrogeology, geochemical analysis, land type, vegetation, and groundwater recharge and discharge.

Groundwater quality protection is another aspect for Integrated Water Resources Management. The groundwater of Table Mountain must therefore be protected against contaminating activities that may potentially take place in the vicinity.

6.3 FUTURE WORK

1. Groundwater contamination

Near Main Spring, water runs down a narrow channel next to the property, the resident complained that the water could be contaminated by the sewage. In the analysis report, the Alkalinity as $CaCO_3$ was 99.0 mg/l, Ammonia was 0.2 mg/l, Chloride was 132.4 mg/l and Conductivity was 62.0 mg/l. The analysis indicates that this is probably sewer water and it should be urgently investigated where this contamination is coming from, as it cannot be from the Main Spring. This alert is to warn the potential contamination would be taken place near to springs and might be affected the future utilization for the local community.

2. The groundwater yield needs to be determined; especially for Albion Spring and Main Spring because the yield seems much larger in the winter season.

3. Newlands Spring and Kommetjie Spring need to be re-tested because the groundwater is utilized by a local company for drinking purpose at present. The water samples were taken from the overflow of the spring, and the chemical result did not meet the requirement for potable water.

4. Groundwater recharge needs to be estimated on the basis of more data in detailed. Groundwater recharge is very important for future exploring and development of local spring water.

5. How to use groundwater resources in the future for City of Cape Town

The groundwater resource data need to be linked to a proper information system that can provide management information on the quantitative and qualitative aspects of groundwater and surface water, as well as precipitation data (National Water Resources Strategy, 2004). From Seward et al (2006), the knowledge of groundwater use, the knowledge of groundwater parameters, the monitoring data all need to be adapted and improved for sustainable groundwater development.

There is a good potential storage of groundwater in the Table Mountain area, but a more detailed research still needs to be carried out.

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APPENDIXES

Appendix 1 Table Mountain House Rainfall station 1998 to 2007

Unit: mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	54.50	7.50	90.00	112.50	372.00	170.00	209.50	103.70	137.40	81.40	101.50	98.00
1999	22.00	16.00	4.20	182.00	111.70	191.00	209.50	252.50	202.50	13.50	65.00	12.50
2000	51.00	0.00	19.00	49.50	160.50	105.50	89.00	112.00	142.50	24.20	19.70	44.00
2001	28.00	40.00	0.10	93.50	160.00	153.50	337.40	229.50	135.00	125.50	17.40	25.50
2002	227.00	43.00	42.00	57.00	185.00	213.00	219.00	108.50	29.50	0.00	76.00	20.70
2003	27.50	35.50	113.80	53.50	131.00	100.50	214.00	326.30	152.50	109.20	16.40	100.70
2004	44.70	9.50	41.50	198.40	42.20	185.60	305.00	361.80	154.00	308.50	11.50	59.50
2005	103.00	16.70	19.00	243.50	329.50	411.00	136.50	387.00	157.60	77.50	48.80	12.50
2006	8.00	44.00	36.00	97.50	535.00	239.00	404.00	289.50	79.00	78.20	117.70	81.50
2007	33.80	53.00	62.50	203.50	249.50	437.20	236.90	278.00	99.50	89.00	146.50	75.00

Appendix 2 Woodhead Dam Rainfall station 1998 to 2007

Unit: mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	72.50	9.00	99.00	137.50	400.00	217.50	256.00	129.50	162.60	92.90	122.00	141.50
1999	26.50	20.00	5.50	173.50	134.40	198.00	211.70	300.50	264.00	14.50	72.50	14.50
2000	60.70	0.00	22.50	48.60	172.70	175.30	138.10	174.80	269.40	36.80	27.30	51.30
2001	51.00	58.50	0.10	133.50	298.80	244.70	508.70	454.70	263.50	100.80	12.20	26.50
2002	168.90	40.70	44.90	176.10	291.30	324.80	508.90	188.80	79.00	110.50	101.00	32.30
2003	29.00	79.00	160.00	103.00	168.50	144.70	373.10	641.20	329.70	142.00	20.20	119.00
2004	44.20	11.50	46.60	199.50	51.60	194.80	236.00	342.70	125.50	230.50	14.00	44.00
2005	54.50	14.10	18.50	196.50	259.00	261.20	114.00	294.50	95.50	55.00	35.20	15.50
2006	10.00	64.50	27.00	99.80	353.80	133.00	282.30	185.50	68.50	63.20	87.50	65.00
2007	18.30	44.00	52.50	180.50	202.00	301.50	198.00	269.00	101.20	78.50	169.70	77.20

Appendix 3 Molteno Reservoir Rainfall station 2001 to 2007

Unit: mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	0.00	0.00	0.00	36.60	138.20	75.40	231.20	224.40	76.80	54.80	24.40	8.60
2002	88.60	8.60	12.60	48.40	80.20	96.20	120.60	58.20	29.20	37.60	21.00	10.80
2003	5.40	12.40	78.80	17.40	48.80	40.60	72.60	127.40	67.20	29.00	3.40	45.60
2004	16.20	1.00	10.80	116.20	17.60	119.40	128.40	173.60	48.00	143.00	9.60	19.20
2005	22.60	0.60	15.80	102.20	140.20	118.80	57.40	138.20	28.20	26.20	6.20	2.80
2006	1.20	25.80	9.60	46.60	167.40	60.00	133.60	85.60	39.80	29.80	52.40	27.40
2007	4.40	26.60	18.40	81.00	90.00	167.80	125.20	111.00	37.80	32.40	63.60	34.00

Appendix 4 Molteno Rainfall station 1998 to 2007

Unit: mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	20.80	3.50	34.00	68.80	218.90	106.00	113.20	59.10	44.10	47.10	65.80	57.10
1999	2.20	8.60	0.10	110.70	64.70	133.00	78.60	204.90	133.30	4.00	39.80	5.10
2000	20.00	0.00	3.90	16.60	136.40	130.10	72.00	78.70	114.50	24.60	13.40	27.10
2001	11.00	19.10	0.30	49.80	175.70	98.10	277.30	251.20	99.00	68.20	31.00	13.40
2002	117.40	10.60	16.60	63.50	95.30	117.00	168.00	67.00	39.30	46.30	34.00	12.90
2003	6.70	19.70	99.90	25.30	45.60	48.60	88.60	158.10	79.80	35.20	3.80	52.70
2004	19.50	3.10	16.50	114.20	20.50	137.30	143.30	184.90	67.10	148.40	10.70	18.00
2005	25.90	1.50	13.50	108.40	162.30	139.10	65.10	157.40	34.50	28.40	15.40	5.00
2006	1.50	31.00	10.60	54.30	187.60	70.20	136.80	101.00	54.10	34.20	60.40	32.40
2007	1.90	32.10	22.10	99.70	109.60	192.30	147.40	138.20	44.40	41.20	75.00	42.30

Appendix 5 Kirstenbosch Rainfall station 1999 to 2007

Unit: mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1999	17.70	4.00	1.60	102.00	109.90	251.70	159.30	222.50	201.90	3.40	50.30	11.00
2000	39.30	2.50	10.70	32.90	152.10	137.20	135.70	105.50	220.80	26.70	15.40	20.90
2001	28.20	15.20	1.20	76.50	281.50	151`.2	422.90	369.80	167.00	104.00	25.70	18.20
2002	128.90	37.20	27.00	83.80	183.60	201.80	290.30	135.20	52.40	79.70	62.10	17.80
2003	17.40	21.60	102.00	37.90	46.10	46.30	118.10	299.20	146.30	74.30	8.40	92.30
2004	20.10	5.70	24.40	118.20	39.00	168.50	258.20	339.60	110.40	159.10	11.40	18.00
2005	31.60	7.10	7.30	138.00	209.20	228.00	140.30	286.50	77.70	33.60	37.00	2.10
2006	3.20	21.10	18.20	62.00	248.40	191.70	204.70	179.60	46.10	40.10	53.30	51.50
2007	11.80	31.40	33.90	139.70	183.20	280.20	305.20	334.80	91.70	33.40	125.20	42.90

Appendix 6 Groote Schuur Rainfall station 1998 to 2007

Unit: mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	17.5	2.7	46.8	110.8	316.2	186.3	184.2	72.3	86.5	77.3	75.6	49.6
1999	15.00	7.50	2.10	79.10	110.40	213.20	107.50	240.40	233.70	2.70	52.20	2.50
2000	41.30	0.00	7.20	24.70	214.60	184.10	135.00	145.00	178.70	18.00	20.30	22.70
2001	28.20	26.00	0.00	53.40	257.40	115.80	356.00	350.50	189.60	75.30	21.50	35.10
2002	104.40	31.70	24.80	68.80	174.90	179.80	250.60	56.60	60.30	73.70	63.70	17.90
2003	14.30	23.40	74.40	25.90	81.60	44.60	132.40	206.40	117.40	73.30	4.60	67.30
2004	11.60	1.10	29.80	161.60	53.00	187.30	197.50	266.00	56.20	151.50	12.40	25.00
2005	38.70	2.90	8.20	114.80	292.60	208.80	161.30	249.80	59.20	35.30	22.40	1.00
2006	2.00	34.90	11.70	62.90	240.30	99.40	180.70	143.40	54.90	57.20	87.30	49.70
2007	3.10	30.70	55.90	110.50	132.50	263.10	216.40	245.40	77.90	39.60	82.00	37.20

Appendix 7 Study area evaporation from 1998 to 2007

HYMONTH V93 Output

Site:

G2E003 Molteno

30/09/2008

Variable: Total Evaporation from S Class Pan in

711.50 Millimetres, Daily

YEAR	Oct	Nov	Dce	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean Monthly	Annual Total
1998	144.4E	179.4E	210.1	236.7E	226.0E	163.1E	102.6E	46.4E	34.0E	35.1E	46.6E	61.6E	123.8E	1486E
1999	163.0E	200.4E	242.6E	248.5E	229.0E	181.9E	122.3E	54.4E	49.6E	33.3E	54.3E	70.4E	137.5E	1649E
2000	172.8E	200.9E	245.5E	249.0E	210.1E	164.3E	94.5E	61.0E	49.7E	68.2E	68.0E	61.5E	137.1E	1645E
2001	133.2E	222.0E	247.9	226.4E	203.7E	145.1E	87.0E	41.4E	42.6E	37.8E	65.9E	101.3	129.5E	1554E
2002	143.6	202.8E	missing	243.8E	202.7E	139.9E	83.2E	52.5E	39.0E	47.3E	57.6E	64.8E	116.1	1277
2003	135.2E	195.6E	198.4E	262.5E	206.7E	164.3E	65.4E	43.8E	34.0E	50.4E	54.5E	104.8E	126.3E	1515E
2004	134.1E	211.7E	245.3E	265.9E	202.3E	159.0E	93.2	66.9E	41.8E	41.6E	57.2E	76.5	132.9E	1595E
2005	124.2E	193.5E	257.7E	264.6E	213.0E	171.1E	92.6E	65.8E	51.7E	49.0E	44.9E	98.1E	135.5E	1625E
2006	155.2E	199.4E	246.8E	241.9	153.9E	166.4E	81.7E	70.4E	55.8E	46.9E	72.2E	93.8E	132.0E	1548E
2007	171.0E	184.7E	226.0E	292.8E	215.6E	163.2	94.9E	58.3E	60.6E	47.2E	63.4 E	97.6E	139.6E	1675.3E
Mean	147.7E	199.0E	235.6E	253.2E	206.3E	161.8E	91.7E	56.1E	45.9E	45.5E	57.9E	81.4E	133.4	1540
Med.	144.0E	199.9E	245.3E	248.7E	208.4E	163.7E	92.9E	56.4E	46.1E	46.9E	57.2E	76.5E		
Max	172.8E	222.0E	257.7E	292.8E	229.0E	181.9E	122.3E	70.4E	60.6E	68.2E	72.2E	104.8E	163	1649
Min	124.2E	179.4E	198.4E	226.4E	153.9E	139.9E	65.4E	41.4E	34.0E	33.3E	44.9E	61.5E	116.1	1277

Appendix 8 Study area evaporation from 1998 to 2007

HYMONTH V93 Output 30/09/2008

Site:

G2E005 Newlands

Variable: 711.50 Total Evaporation from S Class Pan in Millimetres, Daily Site G2E005

YEAR	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean Monthly	Annual Total
1998	120.2E	141.6E	173.8E	185.3E	169.5E	135.5	90.8E	39.1	62.8E	64.7E	81.4	70.7E	111.3	1335
1999	131.5E	132.1E	214.3E	208.0E	164	143.6	101.0E	59.2E	72.2E	44.6E	48.5E	66.2E	115.4E	1385E
2000	136.5	168.8E	176.5E	182.3E	151.5E	143.2	70.4E	73.4E	65.1E	46.9E	65.3E	77.8E	113.1E	1357E
2001	98.6E	168.7E	188.1E	165.4E	157.0E	134.2	80.7E	48.7E	51.5E	53.0E	74.6E	89.3E	109.1E	1309E
2002	128.8E	141.5E	176.2E	191.8E	160.3E	103.8E	95.5E	43.8E	36.4E	59.8E	62.5E	64.3E	105.4E	1264E
2003	111.4E	149.5E	156.2E	176.5E	149.9E	134	82.9E	68	59.8E	46.8E	61.8E	78.4E	106.3E	1275E
2004	134.7E	169.7E	202.5E	196.4	150.0E	138.7E	87.5E	45.1E	41.0E	44.8E	34.0E	66.9E	109.3E	1311E
2005	123.5E	149.5E	218.2E	211.2E	169.8E	139.3E	95.5E	46.5E	56.5E	52.1E	53.7E	89.3E	117.1E	1405E
2006	120.8E	157.7E	178.0E	184.2E	164	148.5	88.2E	59.8E	64.0E	44.1E	50.3E	80.4E	111.7E	1340E
2007	120.8E	129.3E	181.3E	188.6E	142.4E	143	98.9E	67.9E	55.6E	45.3E	49.7E	73.6E	108.0E	1296.4E
Mean	122.7E	150.8E	186.5E	189.0E	157.8E	136.4E	89.1E	55.1	56.5E	50.7E	59.1E	75.9E	112.4	1311
Med.	122.1E	149.5E	179.7E	186.9E	158.6E	139.0E	89.5E	53.9	58.2E	46.9E	61.8E	77.8E		
Max	136.5E	169.7E	218.2E	211.2E	169.8E	148.5E	101.0E	73.4	72.2E	64.7E	81.4E	89.3E	125.3E	1405
Min	98.6E	129.3E	156.2E	165.4E	142.4E	103.8E	70.4E	39.1	36.4E	44.1E	34.0E	64.3E	105.4	1127

Appendix 9 Assessment guide for quality of domestic water use (South Africa)--Kirstenbosch Spring water samples

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	**1**	Check		*ideal, good, marginal, poor, unacceptable*		
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	6.20	6.20	6.20	6.20	6.20	6.20
E Conductivity mS/m	13.49	13.49	13.49	13.49	13.49	13.49
Nitrate as N mg/l	0.39	0.39	0.39	0.39	0.39	0.39
Chloride as Cl mg/l	26.38	26.38	26.38	26.38	26.38	26.38
Sulphate as SO_4 mg/l	1.99	1.99	1.99	1.99	1.99	1.99
Fluoride as F mg/l	0.00	0.00	0.00	0.00	0.00	0.00
Sodium as Na mg/l	17.44	17.44	17.44	17.44	17.44	17.44
Magnesium as Mg mg/l	1.70	1.70	1.70	1.70	1.70	1.70
Iron as Fe mg/l	0.06	0.06	0.06	0.06	0.06	0.06
Faecal coliforms no/100ml	x	x	x	x	x	X
Arsenic as As mg/l	x	x	x	x	x	X
Turbidity (NTU)	x	x	x	x	x	X

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	**2**	Check		*ideal, good, marginal, poor, unacceptable*		
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	5.80	5.80	5.80	5.80	5.80	5.80
E Conductivity mS/m	12.60	12.60	12.60	12.60	12.60	12.60
Nitrate as N mg/l	0.32	0.32	0.32	0.32	0.32	0.32
Chloride as Cl mg/l	24.62	24.62	24.62	24.62	24.62	24.62
Sulphate as SO_4 mg/l	0.45	0.45	0.45	0.45	0.45	0.45
Fluoride as F mg/l	0.03	0.03	0.03	0.03	0.03	0.03
Sodium as Na mg/l	14.96	14.96	14.96	14.96	14.96	14.96
Magnesium as Mg mg/l	1.69	1.69	1.69	1.69	1.69	1.69
Iron as Fe mg/l	0.00	0.00	0.00	0.00	0.00	0.00
Faecal coliforms no/100ml	x	x	x	x	x	x
Arsenic as As mg/l	x	x	x	x	x	x
Turbidity (NTU)	x	x	x	x	x	x

Appendix 10 Assessment guide for quality of domestic water use (South Africa)--Albion Spring water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	3	Check	*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.60	*5.60*	*5.60*	*5.60*	*5.60*	*5.60*
E Conductivity mS/m	23.70	*23.70*	*23.70*	*23.70*	*23.70*	*23.70*
Nitrate as N mg/l	1.84	*1.84*	*1.84*	*1.84*	*1.84*	*1.84*
Chloride as Cl mg/l	43.97	*43.97*	*43.97*	*43.97*	*43.97*	*43.97*
Sulphate as SO_4 mg/l	7.00	*7.00*	*7.00*	*7.00*	*7.00*	*7.00*
Fluoride as F mg/l	0.03	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Sodium as Na mg/l	22.70	*22.70*	*22.70*	*22.70*	*22.70*	*22.70*
Magnesium as Mg mg/l	4.85	*4.85*	*4.85*	*4.85*	*4.85*	*4.85*
Iron as Fe mg/l	0.03	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	4	Check	*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.80	*5.80*	*5.80*	*5.80*	*5.80*	*5.80*
E Conductivity mS/m	21.90	*21.90*	*21.90*	*21.90*	*21.90*	*21.90*
Nitrate as N mg/l	1.90	*1.90*	*1.90*	*1.90*	*1.90*	*1.90*
Chloride as Cl mg/l	36.06	*36.06*	*36.06*	*36.06*	*36.06*	*36.06*
Sulphate as SO_4 mg/l	7.04	*7.04*	*7.04*	*7.04*	*7.04*	*7.04*
Fluoride as F mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sodium as Na mg/l	23.19	*23.19*	*23.19*	*23.19*	*23.19*	*23.19*
Magnesium as Mg mg/l	5.00	*5.00*	*5.00*	*5.00*	*5.00*	*5.00*
Iron as Fe mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Appendix 11 Assessment guide for quality of domestic water use (South Africa)—Newlands Spring water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	5		*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.90	*5.90*	*5.90*	*5.90*	*5.90*	*5.90*
E Conductivity mS/m	13.60	*13.60*	*13.60*	*13.60*	*13.60*	*13.60*
Nitrate as N mg/l	0.46	*0.46*	*0.46*	*0.46*	*0.46*	*0.46*
Chloride as Cl mg/l	28.14	*28.14*	*28.14*	*28.14*	*28.14*	*28.14*
Sulphate as SO_4 mg/l	1.20	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
Fluoride as F mg/l	0.06	*0.06*	*0.06*	*0.06*	*0.06*	*0.06*
Sodium as Na mg/l	15.59	*15.59*	*15.59*	*15.59*	*15.59*	*15.59*
Magnesium as Mg mg/l	2.33	*2.33*	*2.33*	*2.33*	*2.33*	*2.33*
Iron as Fe mg/l	0.07	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	6		*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.70	*5.70*	*5.70*	*5.70*	*5.70*	*5.70*
E Conductivity mS/m	13.67	*13.67*	*13.67*	*13.67*	*13.67*	*13.67*
Nitrate as N mg/l	0.49	*0.49*	*0.49*	*0.49*	*0.49*	*0.49*
Chloride as Cl mg/l	26.38	*26.38*	*26.38*	*26.38*	*26.38*	*26.38*
Sulphate as SO_4 mg/l	1.58	*1.58*	*1.58*	*1.58*	*1.58*	*1.58*
Fluoride as F mg/l	0.15	*0.15*	*0.15*	*0.15*	*0.15*	*0.15*
Sodium as Na mg/l	15.63	*15.63*	*15.63*	*15.63*	*15.63*	*15.63*
Magnesium as Mg mg/l	2.33	*2.33*	*2.33*	*2.33*	*2.33*	*2.33*
Iron as Fe mg/l	0.04	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*X*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*X*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*X*

Appendix 12 Assessment guide for quality of domestic water use (South Africa)—Palmboom Spring water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Check

Sample ID:	7		*ideal, good, marginal, poor, unacceptable*			
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	5.70	5.70	5.70	5.70	5.70	5.70
E Conductivity mS/m	15.54	15.54	15.54	15.54	15.54	15.54
Nitrate as N mg/l	0.50	0.50	0.50	0.50	0.50	0.50
Chloride as Cl mg/l	27.26	27.26	27.26	27.26	27.26	27.26
Sulphate as SO_4 mg/l	3.01	3.01	3.01	3.01	3.01	3.01
Fluoride as F mg/l	0.09	0.09	0.09	0.09	0.09	0.09
Sodium as Na mg/l	16.36	16.36	16.36	16.36	16.36	16.36
Magnesium as Mg mg/l	3.19	3.19	3.19	3.19	3.19	3.19
Iron as Fe mg/l	0.04	0.04	0.04	0.04	0.04	0.04
Faecal coliforms no/100ml	x	x	x	x	x	x
Arsenic as As mg/l	x	x	x	x	x	x
Turbidity (NTU)	x	x	x	x	x	x

Assessment guide for quality of domestic water supplies (South Africa)

Check

Sample ID:	8		*ideal, good, marginal, poor, unacceptable*			
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	5.70	5.70	5.70	5.70	5.70	5.70
E Conductivity mS/m	15.46	15.46	15.46	15.46	15.46	15.46
Nitrate as N mg/l	0.00	0.00	0.00	0.00	0.00	0.00
Chloride as Cl mg/l	29.02	29.02	29.02	29.02	29.02	29.02
Sulphate as SO_4 mg/l	2.77	2.77	2.77	2.77	2.77	2.77
Fluoride as F mg/l	0.16	0.16	0.16	0.16	0.16	0.16
Sodium as Na mg/l	16.30	16.30	16.30	16.30	16.30	16.30
Magnesium as Mg mg/l	3.17	3.17	3.17	3.17	3.17	3.17
Iron as Fe mg/l	0.03	0.03	0.03	0.03	0.03	0.03
Faecal coliforms no/100ml	x	x	x	x	x	x
Arsenic as As mg/l	x	x	x	x	x	x
Turbidity (NTU)	x	x	x	x	x	x

Appendix 13 Assessment guide for quality of domestic water use (South Africa)—Main Spring water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Check

Sample ID:	9		ideal, good, marginal, poor, unacceptable			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	6.20	*6.20*	*6.20*	*6.20*	*6.20*	*6.20*
E Conductivity mS/m	19.26	*19.26*	*19.26*	*19.26*	*19.26*	*19.26*
Nitrate as N mg/l	0.53	*0.53*	*0.53*	*0.53*	*0.53*	*0.53*
Chloride as Cl mg/l	36.94	*36.94*	*36.94*	*36.94*	*36.94*	*36.94*
Sulphate as SO_4 mg/l	11.90	*11.90*	*11.90*	*11.90*	*11.90*	*11.90*
Fluoride as F mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sodium as Na mg/l	30.00	*30.00*	*30.00*	*30.00*	*30.00*	*30.00*
Magnesium as Mg mg/l	2.97	*2.97*	*2.97*	*2.97*	*2.97*	*2.97*
Iron as Fe mg/l	0.02	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Assessment guide for quality of domestic water supplies (South Africa)

Check

Sample ID:	10		ideal, good, marginal, poor, unacceptable			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	6.20	*6.20*	*6.20*	*6.20*	*6.20*	*6.20*
E Conductivity mS/m	19.05	*19.05*	*19.05*	*19.05*	*19.05*	*19.05*
Nitrate as N mg/l	0.55	*0.55*	*0.55*	*0.55*	*0.55*	*0.55*
Chloride as Cl mg/l	35.18	*35.18*	*35.18*	*35.18*	*35.18*	*35.18*
Sulphate as SO_4 mg/l	8.97	*8.97*	*8.97*	*8.97*	*8.97*	*8.97*
Fluoride as F mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sodium as Na mg/l	28.11	*28.11*	*28.11*	*28.11*	*28.11*	*28.11*
Magnesium as Mg mg/l	2.88	*2.88*	*2.88*	*2.88*	*2.88*	*2.88*
Iron as Fe mg/l	0.02	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Appendix 14 Assessment guide for quality of domestic water use (South Africa)—Table Mountain Spring water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	11		ideal, good, marginal, poor, unacceptable			
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	5.10	*5.10*	*5.10*	*5.10*	*5.10*	*5.10*
E Conductivity mS/m	7.29	*7.29*	*7.29*	*7.29*	*7.29*	*7.29*
Nitrate as N mg/l	0.11	*0.11*	*0.11*	*0.11*	*0.11*	*0.11*
Chloride as Cl mg/l	17.62	*17.62*	*17.62*	*17.62*	*17.62*	*17.62*
Sulphate as SO_4 mg/l	2.21	*2.21*	*2.21*	*2.21*	*2.21*	*2.21*
Fluoride as F mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sodium as Na mg/l	10.30	*10.30*	*10.30*	*10.30*	*10.30*	*10.30*
Magnesium as Mg mg/l	1.25	*1.25*	*1.25*	*1.25*	*1.25*	*1.25*
Iron as Fe mg/l	0.01	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	12		ideal, good, marginal, poor, unacceptable			
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	4.70	*4.70*	*4.70*	*4.70*	*4.70*	*4.70*
E Conductivity mS/m	7.24	*7.24*	*7.24*	*7.24*	*7.24*	*7.24*
Nitrate as N mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Chloride as Cl mg/l	22.03	*22.03*	*22.03*	*22.03*	*22.03*	*22.03*
Sulphate as SO_4 mg/l	1.87	*1.87*	*1.87*	*1.87*	*1.87*	*1.87*
Fluoride as F mg/l	0.01	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Sodium as Na mg/l	9.87	*9.87*	*9.87*	*9.87*	*9.87*	*9.87*
Magnesium as Mg mg/l	1.13	*1.13*	*1.13*	*1.13*	*1.13*	*1.13*
Iron as Fe mg/l	0.01	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Appendix 15 Assessment guide for quality of domestic water use (South Africa)—Kommetjie Spring water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	13	Check	*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.30	*5.30*	*5.30*	*5.30*	*5.30*	*5.30*
E Conductivity mS/m	13.85	*13.85*	*13.85*	*13.85*	*13.85*	*13.85*
Nitrate as N mg/l	0.97	*0.97*	*0.97*	*0.97*	*0.97*	*0.97*
Chloride as Cl mg/l	29.96	*29.96*	*29.96*	*29.96*	*29.96*	*29.96*
Sulphate as SO_4 mg/l	4.78	*4.78*	*4.78*	*4.78*	*4.78*	*4.78*
Fluoride as F mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sodium as Na mg/l	19.30	*19.30*	*19.30*	*19.30*	*19.30*	*19.30*
Magnesium as Mg mg/l	3.21	*3.21*	*3.21*	*3.21*	*3.21*	*3.21*
Iron as Fe mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	14	Check	*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.30	*5.30*	*5.30*	*5.30*	*5.30*	*5.30*
E Conductivity mS/m	13.81	*13.81*	*13.81*	*13.81*	*13.81*	*13.81*
Nitrate as N mg/l	0.99	*0.99*	*0.99*	*0.99*	*0.99*	*0.99*
Chloride as Cl mg/l	35.24	*35.24*	*35.24*	*35.24*	*35.24*	*35.24*
Sulphate as SO_4 mg/l	4.37	*4.37*	*4.37*	*4.37*	*4.37*	*4.37*
Fluoride as F mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sodium as Na mg/l	19.43	*19.43*	*19.43*	*19.43*	*19.43*	*19.43*
Magnesium as Mg mg/l	3.24	*3.24*	*3.24*	*3.24*	*3.24*	*3.24*
Iron as Fe mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Faecal coliforms no/100ml	x	*x*	*x*	*X*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*X*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*X*	*x*	*x*

Appendix 16 Assessment guide for quality of domestic water use (South Africa)—Waterhof Spring water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	15		*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	6.20	*6.20*	*6.20*	*6.20*	*6.20*	*6.20*
E Conductivity mS/m	36.00	*36.00*	*36.00*	*36.00*	*36.00*	*36.00*
Nitrate as N mg/l	2.84	*2.84*	*2.84*	*2.84*	*2.84*	*2.84*
Chloride as Cl mg/l	81.06	*81.06*	*81.06*	*81.06*	*81.06*	*81.06*
Sulphate as SO_4 mg/l	9.50	*9.50*	*9.50*	*9.50*	*9.50*	*9.50*
Fluoride as F mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sodium as Na mg/l	54.97	*54.97*	*54.97*	*54.97*	*54.97*	*54.97*
Magnesium as Mg mg/l	7.32	*7.32*	*7.32*	*7.32*	*7.32*	*7.32*
Iron as Fe mg/l	0.04	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	16		*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.40	*5.40*	*5.40*	*5.40*	*5.40*	*5.40*
E Conductivity mS/m	33.20	*33.20*	*33.20*	*33.20*	*33.20*	*33.20*
Nitrate as N mg/l	1.69	*1.69*	*1.69*	*1.69*	*1.69*	*1.69*
Chloride as Cl mg/l	80.18	*80.18*	*80.18*	*80.18*	*80.18*	*80.18*
Sulphate as SO_4 mg/l	20.05	*20.05*	*20.05*	*20.05*	*20.05*	*20.05*
Fluoride as F mg/l	0.03	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Sodium as Na mg/l	55.93	*55.93*	*55.93*	*55.93*	*55.93*	*55.93*
Magnesium as Mg mg/l	8.60	*8.60*	*8.60*	*8.60*	*8.60*	*8.60*
Iron as Fe mg/l	0.23	*0.23*	*0.23*	*0.23*	*0.23*	*0.23*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Appendix 17 Assessment guide for quality of domestic water use (South Africa)—Kirstenbosch surface water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Check

Sample ID:	17	ideal, good, marginal, poor, unacceptable				
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	6.20	6.20	6.20	6.20	6.20	6.20
E Conductivity mS/m	12.17	12.17	12.17	12.17	12.17	12.17
Nitrate as N mg/l	0.00	0.00	0.00	0.00	0.00	0.00
Chloride as Cl mg/l	25.50	25.50	25.50	25.50	25.50	25.50
Sulphate as SO_4 mg/l	2.07	2.07	2.07	2.07	2.07	2.07
Fluoride as F mg/l	0.14	0.14	0.14	0.14	0.14	0.14
Sodium as Na mg/l	14.57	14.57	14.57	14.57	14.57	14.57
Magnesium as Mg mg/l	1.42	1.42	1.42	1.42	1.42	1.42
Iron as Fe mg/l	0.27	0.27	0.27	0.27	0.27	0.27
Faecal coliforms no/100ml	x	x	x	x	x	X
Arsenic as As mg/l	x	x	x	x	x	X
Turbidity (NTU)	x	x	x	x	x	X

Assessment guide for quality of domestic water supplies (South Africa)

Check

Sample ID:	18	ideal, good, marginal, poor, unacceptable				
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	6.10	6.10	6.10	6.10	6.10	6.10
E Conductivity mS/m	12.41	12.41	12.41	12.41	12.41	12.41
Nitrate as N mg/l	0.10	0.10	0.10	0.10	0.10	0.10
Chloride as Cl mg/l	22.86	22.86	22.86	22.86	22.86	22.86
Sulphate as SO_4 mg/l	2.06	2.06	2.06	2.06	2.06	2.06
Fluoride as F mg/l	0.09	0.09	0.09	0.09	0.09	0.09
Sodium as Na mg/l	14.90	14.90	14.90	14.90	14.90	14.90
Magnesium as Mg mg/l	1.30	1.30	1.30	1.30	1.30	1.30
Iron as Fe mg/l	0.44	0.44	0.44	0.44	0.44	0.44
Faecal coliforms no/100ml	x	x	x	x	x	X
Arsenic as As mg/l	x	x	x	x	x	X
Turbidity (NTU)	x	x	x	x	x	X

Appendix 18 Assessment guide for quality of domestic water use (South Africa)—Table Mountain surface water samples.

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	19	Check	*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.50	*5.50*	*5.50*	*5.50*	*5.50*	*5.50*
E Conductivity mS/m	10.98	*10.98*	*10.98*	*10.98*	*10.98*	*10.98*
Nitrate as N mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Chloride as Cl mg/l	21.11	*21.11*	*21.11*	*21.11*	*21.11*	*21.11*
Sulphate as SO_4 mg/l	2.06	*2.06*	*2.06*	*2.06*	*2.06*	*2.06*
Fluoride as F mg/l	0.02	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Sodium as Na mg/l	12.75	*12.75*	*12.75*	*12.75*	*12.75*	*12.75*
Magnesium as Mg mg/l	1.48	*1.48*	*1.48*	*1.48*	*1.48*	*1.48*
Iron as Fe mg/l	0.04	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Assessment guide for quality of domestic water supplies (South Africa)

Sample ID:	20	Check	*ideal, good, marginal, poor, unacceptable*			
Substance		***D-Health***	***D-Aesth***	***Food Prep.***	***Bathing***	***Laundry***
pH(units)	5.10	*5.10*	*5.10*	*5.10*	*5.10*	*5.10*
E Conductivity mS/m	11.05	*11.05*	*11.05*	*11.05*	*11.05*	*11.05*
Nitrate as N mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Chloride as Cl mg/l	21.99	*21.99*	*21.99*	*21.99*	*21.99*	*21.99*
Sulphate as SO_4 mg/l	2.48	*2.48*	*2.48*	*2.48*	*2.48*	*2.48*
Fluoride as F mg/l	0.10	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*
Sodium as Na mg/l	12.68	*12.68*	*12.68*	*12.68*	*12.68*	*12.68*
Magnesium as Mg mg/l	1.50	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*
Iron as Fe mg/l	0.02	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Appendix 19 Certificate of Analysis by Department of Water and Sanitation.

Assessment guide for quality of domestic water supplies (South Africa)

Check

Sample ID:	19		ideal, good, marginal, poor, unacceptable			
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	5.50	*5.50*	*5.50*	*5.50*	*5.50*	*5.50*
E Conductivity mS/m	10.98	*10.98*	*10.98*	*10.98*	*10.98*	*10.98*
Nitrate as N mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Chloride as Cl mg/l	21.11	*21.11*	*21.11*	*21.11*	*21.11*	*21.11*
Sulphate as SO_4 mg/l	2.06	*2.06*	*2.06*	*2.06*	*2.06*	*2.06*
Fluoride as F mg/l	0.02	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Sodium as Na mg/l	12.75	*12.75*	*12.75*	*12.75*	*12.75*	*12.75*
Magnesium as Mg mg/l	1.48	*1.48*	*1.48*	*1.48*	*1.48*	*1.48*
Iron as Fe mg/l	0.04	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*

Assessment guide for quality of domestic water supplies (South Africa)

Check

Sample ID:	20		ideal, good, marginal, poor, unacceptable			
Substance		*D-Health*	*D-Aesth*	*Food Prep.*	*Bathing*	*Laundry*
pH(units)	5.10	*5.10*	*5.10*	*5.10*	*5.10*	*5.10*
E Conductivity mS/m	11.05	*11.05*	*11.05*	*11.05*	*11.05*	*11.05*
Nitrate as N mg/l	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Chloride as Cl mg/l	21.99	*21.99*	*21.99*	*21.99*	*21.99*	*21.99*
Sulphate as SO_4 mg/l	2.48	*2.48*	*2.48*	*2.48*	*2.48*	*2.48*
Fluoride as F mg/l	0.10	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*
Sodium as Na mg/l	12.68	*12.68*	*12.68*	*12.68*	*12.68*	*12.68*
Magnesium as Mg mg/l	1.50	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*
Iron as Fe mg/l	0.02	*0.02*	*0.02*	*0.02*	*0.02*	*0.02*
Faecal coliforms no/100ml	x	*x*	*x*	*x*	*x*	*x*
Arsenic as As mg/l	x	*x*	*x*	*x*	*x*	*x*
Turbidity (NTU)	x	*x*	*x*	*x*	*x*	*x*