Republic of South Africa

A SURVEY ON THE RADIOLOGICAL AND CHEMICAL QUALITY OF THE WATER RESOURCES IN SELECTED SITES OF THE NORTHERN CAPE PROVINCE

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DOCUMENT INDEX

This document covers the radiological and chemical water quality of selected sites in the Northern Cape Province

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EXECUTIVE SUMMARY

Major towns in the Northern Cape are either supplied with good quality treated surface water from the Orange and Vaal Rivers or from good quality ground water. As such, for the major portion, the population in the province are supplied with good quality potable water and there is for the majority no water quality problem attributable to the source of the water. On the other hand, while surface water supplies are sound, there are some borehole supplies that are of very poor quality. Problems such as very high salinities, high nitrates, and high fluorides are present in some of the ground water in the region, which lead to very poor water quality. In addition, there is a tendency for high levels of naturally occurring radioactivity material (NORM) to be present in the water due to the dissolution of naturally occurring radionuclides from the surrounding rocks and soils (Wullschleger et al, 1999).

Following a report published by Water Research Commission (Toens et al., 1998), concerns grew about the radiological quality of drinking water supplied to the residents of the Northern Cape region. The study pointed out that there are possible problems with the quality of the water in the Northern Cape and that people may be at risk of drinking water contaminated with radioactivity. Prominence was also given to the issue in the news media (Cape Times, 1998).

As a result of the above concerns the Chief Directorate: Water Services of the Department of Water Affairs and Forestry (DWAF) initiated a survey in 1999 to verify the findings of Toens et al. (1998). The aim of the survey was to establish the possible health risks associated with the radiological quality of drinking water resources in selected areas of the Northern Cape region. Resource Quality Services (RQS) formally known as the Institute for Water Quality Studies (IWQS) in co-operation with the DWAF Northern Cape Regional Office assisted the Chief Directorate: Water Services in the design and implementation of the survey in the area. Various boreholes were identified for sampling. Two different laboratories (Technology Services International Laboratory (TSIL) and DWAF: RQS) were appointed to perform trace metal-, inorganic salt-, and physical parameter analyses. The radio analytical laboratory from the South African Nuclear Energy Cooperation (NECSA) performed the radiological analyses.

Some of the boreholes were sampled only once whereas others, when elevated water quality levels were detected, were sampled more than once. Some variation was observed in the chemical data obtained from TSIL and RQS. This could be attributed to the fact that analyses done by these two laboratories were performed on samples that were not collected at the same monitoring frequency. In addition, factors such as recharge, blending and rainfall might have contributed to discrepancies in the results. Additional chemical data (for boreholes that are included in the National Groundwater Monitoring Programme) were obtained from DWAF's Water Management System (WMS) to try and verify the variation in the chemical data. It was noted that some of the data generated by the RQS laboratory corresponded with the data obtained from the WMS. Where possible, the chemical data for the boreholes were also compared with the results obtained from Toens and Partners (1998). Both data sets show poor water quality in ground water in the study area. The macro chemical data for most sites indicate that the water resources in the study area are generally not in a healthy state and that they are unsuitable for domestic use. From the results, it can be concluded that most of the boreholes that were sampled are in high-risk areas in terms of the macro-chemical quality of the water.

The radiological results are showing possible contamination in some of the boreholes and more monitoring would be required to make a solid judgement on the status of the radiological quality of the water resources in the Northern Cape area. According to the survey only one borehole namely the one at Kotzerus will pose a radiological health hazard to the most sensitive age groups in the 0-1 year and also 1-2 year category. For the rest of the age groups the water in this borehole is of marginal radiological quality. It was, however, confirmed by the DWAF Northern Cape Regional Office that the people in the Kotzerus area are not using the water from this borehole for domestic purposes as they are making use of rainwater. The boreholes at Fonteintjie, Riemvasmaak and Kenhardt have shown marginal radiological water quality whereby a routine three monthly monitoring would be required. Other boreholes have shown no indication of a health risk to any of the age groups. In general, no solid conclusions regarding the radiological quality of the water resources in the area could be made due to the fact that water quality or fitness for use cannot be determined from a single measurement, but should be based on long term trends. It is thus recommended that all water resources used for domestic water supplies in the area should be monitored on a regular basis to ensure that the water is safe to drink. Further the National Radioactivity Monitoring Programme should ensure some coverage of the area.

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1.0 INTRODUCTION

Following a report published by Water research Commission (Toens et al., 1998), concerns grew about the radiological quality of drinking water supplied by local councils to the residents of the Northern Cape region. The study, which focused on the Poffadder area in the Northern Cape, found that the uranium concentrations at some boreholes were three times higher than the recommended values for drinking water by the Department of Water Affairs and Forestry (Department of Water Affairs and Forestry, 1993). The hydrochemical analysis for that study also indicated that the ground water from certain aquifers in the Pofadder area contain high concentrations of arsenic and fluoride as well as elevated levels of radioactitivity. These concerns were also published in the media stating that, “the people in the Northern Cape are drinking radioactive water”. (Cape Times, 1999).

Another study carried by Wullschleger et al (1998) showed that more than 50% of the communities visited in the Northern Cape utilise class three water, according to Wullschleger et al (1998), class three water is defined as containing constituents at concentrations where serious health effects may be anticipated. Higher levels of gross alpha and beta activity and total uranium were found in the drinking water of Fonteintjie, Kenhardt, Riemvasmaak, Kotzerus, Nourivier, Eyams, and Groot Mier.

A limited uranium survey carried out by the Atomic Energy Cooperation (AEC) also showed that out of approximately 8 500 water samples analysed, 10 areas were identified with anomalous uranium concentration containing between 25μg and 100μg uranium per litre, which relates to a mean activity of between 0.3 and 1.25 Bq/l of 235-U. (Faanhof et al., 1995). Some of the identified areas are within the Northern Cape region and it is suspected that these uranium concentrations might influence the quality of the water resources in the area. The identified areas are: Springbok flats coal area, Namaqualand in the vicinity of Springbok and the North-Western Cape in the vicinity of Upington and Kernhardt.

The National Water Act (Act No.36 of 1998) ensures protection of the quality of our nation's water resources. It mandates the minister to establish monitoring systems that records, assess, monitor, and disseminate information on water resources. To make sound decisions on the quality of our water resource, it is important to establish the health risk associated with domestic water supplies that might be contaminated or containing radionuclides occurring in nature.

This study was carried out so as to evaluate the risk of radiation exposure due to water consumption and also to verify the findings from Toens et al.,(1998).

1.1 Purpose of the study

- To identify possible high-risk areas in the Northern Cape, which might result in exposure to radioactivity as a result of consumption from drinking water
- To give more information on the macro-chemical quality of selected water resources in the study area.
- To establish the total radiation dose a person would receive on annual basis when drinking water in the selected areas.
- To report on the levels, nature, and extent of radiological and chemical quality of the drinking water sources in the selected areas of the Northern Cape region.

1.2 Purpose of the Report

The main purpose of this report is to provide an assessment of the radiological and chemical quality of the water resources that is utilised for domestic purposes by communities (large and small) in the selected areas of the Northern Cape region.

2.0 BACKGROUND INFORMATION

2.1 General Geology of the Northern Cape Province

Northern Cape is the largest and driest province in South Africa with average annual precipitation ranging from less than 100mm over the vast majority of the province to approximately 500mm in the Kamiesberge. The only two perennial rivers in the Northern Cape are the Vaal and Orange Rivers with most of the larger towns in the area obtaining drinking water from the Orange River while majority of farming communities rely on ground water. Major towns in the Northern Cape are either supplied with good quality treated surface water from the Orange and Vaal Rivers or from good quality ground water. As such for the major portion of the population in the province are supplied with good quality potable water and there is in reality for the majority no water quality problem attributable to the source of water. On the other hand, while surface water supplies are sound, there are some boreholes supplies that are of very poor quality. Problems such as very high salinities, high nitrates, and high fluorides are present in some of the ground water in the region, which lead to very poor water quality. In addition, there is a tendency of high levels of naturally occurring radioactivity material (NORM) in the water due to the dissolution of naturally occurring radionuclides from the surrounding rocks and soils. Some of the ground water in the Northern Cape has shown an elevated level of uranium concentration (Wullschleger et al., 1998).

The general geology of the study area (Figure 1) consists of Precambrian Molokian Aged basement rocks forming the Namaqua Metamorphic Province. The rocks are composed of highly deformed faulted and often mineralised granitic gneisses, quartzites, schists and granites (Wullschleger et al., 1998). The Namamqua Metamorphic Province is overlain by younger, flat lying sandstones and shales of the Karoo groups. The end of the Karoo era was characterised by great volcanic activity, numerous dolerite dykes and sills intruded at about 190 Ma. The youngest rocks in the Northern Cape Province belongs to the Kalahari group and consists of gravel, clayey marls, limestones, calcretes and unconsolidated sediments. (Wullschleger et al., 1998)

2.2 Demography

According to the Central Statistical Service, the Northern Cape had an area of 361 800 square km (29.7% of total area), population of 737 310 (1.8% of total population) and the population density of 2.0 per square km as in 27 April 1994. (exinet.co.za)

2.3 Water users

Communities in the study area are mostly supplied with water from boreholes with an estimated volume of 400,000 cubic litres per annum. At some of the communities i.e. Riemvasmaak, Kharkams, Gladkop, Eyams and Skuitberg livestock also use the same boreholes for drinking purposes. The identified boreholes are not used for any irrigation purposes.

2.4 Radioactivity and its occurrence

Radioactivity is ubiquitous, it occurs both naturally in the environment and artificially as a result of man made activities. Apart from natural radioactivity, environmental radioactive pollution may result from past nuclear activities such as nuclear waste disposal, transportation, storage and operation of nuclear power plants.

Different radionuclides differ markedly in the potential health risk associated with their radiation. There is evidence from both human and animal studies that radiation exposures at low to moderate doses may increase the long-term incidence of cancer (WHO, 2003). It is also known that the rate of genetic malformations may be increased by radiation exposure.

Acute health effects of radiation, appearing with symptoms of nausea, vomiting, diarrhoea, weakness, headache, anorexia leading to reduced blood cell counts and in very severe cases to death, occur at high doses of exposure of the whole body or large part of the body. The acute effects of radiation are usually not a concern in continuously monitored radioactivity content of central drinking water supplies, however extreme measures may be required in situations such as terrorist use of radioactive materials to contaminate drinking water supplies (WHO, 2003).

Different radioactive isotopes follow the same trends and behaviour as any other chemical elements. Certain tissues in the human body are element specific and therefore an intake of such isotopes by human body tissue results in internal exposure that is due to ionising radiation from ingestion or consumption. E.g. radium-226 and radium-228, these radionuclides are the two most common isotopes in water. Both of them are decay products of uranium and thorium respectively.

Radium can enter ground water by dissolution of aquifer materials, desorption from rocks or sediments surfaces, and ejection from rock by radioactive decay. It is metabolised in the human body in much the same way as calcium (they both share the same group in the periodic table). Due to this similarity in metabolism, ingestion of trace quantities of radium over time will result in an accumulation of radium in the skeleton. Radium that has been accumulated in the tissue, decays in a series of short-lived daughter products, resulting in the emission of a number of alpha and beta particles over a short time span. The decay of radium and its daughters can result in striping of electrons from atoms. The stripped electrons have a capacity to break chemical bonds as they travel through the living tissue, causing the release of additional electrons. The atoms in the living tissues becomes ionised with very high energy capable of producing chemical reactions that would not have been otherwise possible. The damage from continuous exposure can potentially cause bone and sinus cancer (USGS, 1999).

3.0 DATA COLLECTION AND INFORMATION GENERATION

3.1. Sampling and sampling frequency

The DWAF Northern Cape regional office undertook sampling of the water resource (boreholes) in the study area. Due to insufficient funding, sampling frequency was not consistent and this lead to some boreholes being sampled only once whereas other boreholes were sampled more than once. Boreholes sampled more than once were those that gave marginal and unacceptable quality during the initial screening. The dates on which samples were collected at the various boreholes are indicated in Table 3.1 and Table 3.2.

3.2. Variables measured

3.2.1 Chemical variables of concern and sample analysis

Information on the variables that were measured can be found in Appendix 1.Two different laboratories namely DWAF:Resource Quality Services (RQS) and Technology Services International Laboratory (TSIL) performed both the trace metal and inorganic chemical analysis. Additional chemical data that were collected as part of the National Groundwater Monitoring Programme were obtained on the Water Management System (WMS) of DWAF and was also used in order to supplement the chemical data for some of the boreholes.

3.1.3 Radiological variables of concern and Sample analysis

In nature, radioactivity is mainly from natural elements such as uranium, thorium and potassium. These elements occur with unstable isotopes, which follows a certain decay series. Under natural circumstances, it is believed that the radioactivity of all isotopes in a specific decay series are in equilibrium, which means that they all produce as appropriate, alpha and beta particles and associated gamma rays at the same rate.

The radiological variables measured in this project were all from the natural decay series of uranium-238, uranium-235 and thorium-232. Individual radiological variables measured were gross alpha/ beta activity and the individual activities of uranium-238 (^{238}U), radium-226 (^{226}Ra) and thorium-232 (^{232}Th), radium –223 (^{223}Ra), radium-224 (^{224}Ra) and uranium-235 (^{235}U). Also included were polonium-210 (^{210}Po), lead 210 (^{210}Pb), thorium-230 (^{230}Th), thorium-227 (^{227}Th), uranium-234 (^{234}U), and radium-228 (^{228}Ra). This was done to clarify uncertainties in the dose calculated, relating to the none-equilibrium of nuclides in the parent nuclides in the water phase. Palladium-231 (^{131}Pa) and actinium-227 (^{227}Ac) were determined on selected water samples. The radio-analytical laboratory at the South African Nuclear Energy Cooperation (NECSA) performed the radio-analytical analysis for all water samples collected in this study.

3.3 Data handling and storage

The set of chemical data obtained from DWAF: RQS and Technology Services International Laboratories (TSIL) are available electronically on the DWAF's database (i.e. Water Management Systems (WMS)), and the radioactivity data is available on WaterRad software. The WaterRad software is a computer based system that contains a dose calculation function and assessment guidelines used by DWAF to process the radiological data. The software converts the radioactivity data from Activity (Bq/l) to radiation dose (Sv/A) and classifies the water quality according to the dose evaluation and calculation guidelines

Table 3.1: Sampling frequency for chemical variables measured in this study together with the coordinates of each borehole

		Sampling frequency for Macro Chemical Variables analysed by RQS			
Sampling Date	**Sampling Point**	**Latitude (DD Cape datum**	**Longitude (DD Cape Datum)**	**Latitude DMS Cape datum**	**Longitude DMS Cape Datum**
29-Apr-99	Klein Mier	-26.7319	20.276806	-26^{0} 43’ 51”	20^{0} 16’ 36”
	Fonteintjie	-29.670078	17.919222	-29^{0} 40’ 14”	17^{0} 55’ 09”
	Reimvasmaak	-28.405639	20.313083	-28^{0} 24’ 20”	20^{0} 17’ 47”
	Bulletrap 1	-29.483083	17.772333	-29^{0} 28’ 59”	17^{0} 46’ 20”
	Bulletrap 2	-29.465778	17.809174	-29^{0} 27’ 56”	17^{0} 46’ 51”
	Kotzesrus	-30.949167	17.841667	-30^{0} 56’ 57”	17^{0} 50’ 30”
	Karkhams	-30.386667	17.888417	-30^{0} 23’ 01”	17^{0} 53’ 18”
13-Sep-99	Fonteintjie	-29.670078	17.919222	-29^{0} 40’ 14”	17^{0} 55’ 09”
	Riemvasmaak	-28.405639	20.313083	-28^{0} 24’ 20”	20^{0} 17’ 47”
	Klein Mier	-26.7319	20.276806	-26^{0} 43’ 51”	20^{0} 16’ 36”
	Bulletrap 1	-29.483083	17.772333	-29^{0} 28’ 59”	17^{0} 46’ 20”
	Bulletrap 2	-29.465778	17.809174	-29^{0} 27’ 56”	17^{0} 46’ 51”
	Karkhams Suidgat	-30.386667	17.889722	-30^{0} 23’ 01”	17^{0} 53’ 18”
	Karkhams Reservoir	-30.386667	17.888417	-30^{0} 23’ 12”	17^{0} 53’ 22”
		Sampling frequency for Chemical Variables analysed by TSIL			
Sampling Date	**Sampling Point**	**Latitude (DD Cape Datum)**	**Longitude (DD Cape Datum)**	**Latitude (DMS Cape Datum)**	**Longitude (DMS Cape Datum)**
04-Nov-99	Kotzesrus	-30.949167	17.841667	-30^{0} 56’ 57”	17^{0} 50’ 30”
30-May-00	Kharkams	-30.386667	17.888417	-30^{0} 23’ 01”	17^{0} 53’ 18”

RQS: Resource Quality Services
TSIL: Technological Services International Laboratory

Table 3.2: Sampling frequency for radiological variables measured in this study together with the coordinates of each borehole

Sampling Date	Sampling Point	Sampling frequency of radiological Variables analysed by NECSA			
		Latitude (DD Cape Datum)	Longitude (DD Cape Datum)	Latitude (DMS Cape Datum)	Longitude (DMS Cape Datum)
29-Apr-99	Fonteintjie	-29.670078	17.919222	-29^0 40' 14"	17^0 55' 09"
	Karkhams Suidgat	-30.386667	17.889722	-30^0 23' 01"	17^0 53' 18"
	Karkhams Reservoir	-30.386667	17.888417	-30^0 23' 12"	17^0 53' 22"
	Klein Mier	-26.7319	20.276806	-26^0 43' 51"	20^0 16' 36"
	Bulletrap 1	-29.483083	17.772333	-29^0 28' 59"	17^0 46' 20"
	Bulletrap 2	-29.465778	17.809174	-29^0 27' 56"	17^0 46' 51"
	Riemvasmaak	-28.405639	20.313083	-28^0 24' 20"	20^0 17' 47"
	Kotzesrus	-30.949167	17.841667	-30^0 56' 57"	17^0 50' 30"
	Kenhardt	-29.358806	21.129667	-29^0 21' 31"	21^0 07' 46"
07-Oct-99	Fonteintjie	-29.670078	17.919222	-29^0 40' 14"	17^0 55' 09"
	Karkhams Suidgat	-30.386667	17.889722	-30^0 23' 01"	17^0 53' 18"
	Karkhams Reservoir	-30.386667	17.888417	-30^0 23' 12"	17^0 53' 22"
	Klein Mier	-26.7319	20.276806	-26^0 43' 51"	20^0 16' 36"
	Bulletrap 1	-29.483083	17.772333	-29^0 28' 59"	17^0 46' 20"
	Bulletrap 2	-29.465778	17.809174	-29^0 27' 56"	17^0 46' 51"
	Riemvasmaak	-28.405639	20.313083	-28^0 24' 20"	20^0 17' 47"
	Kotzesrus	-30.949167	17.841667	-30^0 56' 57"	17^0 50' 30"
	Kenhardt	-29.358806	21.129667	-29^0 21' 31"	21^0 07' 46"
14-Jan-00	Kenhardt	-29.358806	21.129667	-29^0 21' 31"	21^0 07' 46"
25-Jul-00	Riemvasmaak	-28.405639	20.313083	-28^0 24' 20"	20^0 17' 47"
	Spoegrivier	-30.266667	17.75651	-30^0 16' 00"	17^0 45' 23"
	Klipfontein	-30.5	17.83073	-30^0 30' 00"	17^0 49' 50"
	Eyams	-29.351902	17.623955	-29^0 21' 06"	17^0 37' 26"
	Skuiterberg	-29.3256	17.563127	-29^0 19' 30"	17^0 33' 47"
	Gladkop	-29.325241	17.670344	-29^0 22' 19"	17^0 40' 13"
14-Aug-00	Fonteintjie	-29.670078	17.919222		

NECSA: South African Nuclear Energy Cooporation

3.4 Water quality assessment criteria

The chemical and radioactivity water quality status of water resources in the study area were evaluated in terms of fitness-for-use for domestic purposes.

3.4.1 Classification system for chemical water quality

A classification system based on the Quality of Domestic Water Supplies: Assessment Guide (DWAF, 1998), and the South African Water Quality Guidelines – Domestic Use (DWAF, 1996) was used to assess the suitability for use of the groundwater in the study (Table 3.4.1). The guideline allows the quality of water supplied for domestic use to be assessed by using a simple, colour coded classification system that shows the nature of the effects of water quality on domestic user in terms of concentration values. The classification system describes the effects of increasing concentration of each of the substances considered important for domestic use. The system uses a simple colour and number code ranging from ideal to totally unacceptable water quality (DWAF, 1998).

When classifying the water, the overall class of a particular borehole was based on the highest rating of any of the variables that were measured on a particular date. For example, if any of the variables within a borehole fell within Class 3 (Marginal water quality), and the others fell below Class 3 (i.e. either Class 2 or 1), then the chemical quality of that particular borehole would be in Class three. The problem variable would be outlined next to that borehole.

Table 3.4.1: Classification system describing the suitability of the different classes of water on domestic uses of water

Class / Colour	Description	Effects
Class 0 (Blue)	Ideal water quality	Ideal drinking water quality suitable for long-term use
Class 1 (Green)	Good water quality	Water quality is still fit for long-term use, with rare instances negative effects
Class 2 (Yellow)	Marginal water quality	Water quality fit for short term or emergency use only. Negative effects may occur in some sensitive groups
Class 3 (Red)	Poor water quality	Not suitable for use as drinking water without adequate treatment. Chronic effects may occur
Class 4 (Purple)	Unacceptable water quality	Totally unsuitable for use. Acute effects may occur

3.4.2 Classification system for radiological water quality

For any chronic exposures to radiation, the most important parameter that needs to be known is the radiation dose. The dose is given in milli Sievert per annum (mSv/a). The radiological quality of the water resource is described in terms of fitness if the water from the source is consumed on a lifetime basis. The radiological quality is described by a simplified colour classification system each class indicating a dose range and the radiation dose range for that colour. Table 3.4.2 describes the colour classifications used to describe the radiological quality of the water resource.

The overall radiological quality of a particular borehole is based on the highest radiation dose that may be received by a particular age group if water from that borehole is consumed. For example if the radiation dose for a particular age group falls within Class 3 (i.e. poor water quality) and the dose for other age groups falls within Class 2 or 1 then the overall quality of the water resource within that borehole is regarded as Class 3. A detailed analysis of the radiological quality is presented in Appendix 2.

Table 3.4.2: Classification system describing the suitability of the different classes of radioactive water on domestic uses of water (DWAF, 2002)

Class / Colour	***Radioactive Dose range mSv/a***	***Health Effects and Typical Exposure Scenarios***	***Intervention Decision Time Frames***
Class 0 **(Blue – Ideal water quality)**	0.01 – 0.10	• There are no observable health effects. • This is the range of exposure from ideal quality water sources. • Most treated water falls in this water quality range. • Additional doses that result from human activities that fall within this range are difficult or impossible to determine and/or to distinguish from variations in background doses with sufficient confidence.	Intervention not applicable for this class of water.
Class 1 **(Green - Good water quality)**	> 0.10 – 1	• There are no observable health effects. • It is the range of exposure from some natural and untreated water sources (e.g. ground water / wells) as well as water sources that could be influenced by mining and mineral processing activities. • A dose between 0.2 to 0.8 mSv/a is the typical worldwide range of ingestion radiation dose resulting from water as well as food. • A dose equal to 1 mSv/a corresponds to the regulatory public dose limit for human activities involving radioactive material.	No intervention is required although ALARA principles apply.
Class 2 **(Yellow – Marginal water quality)**	> 1 – 10	• A small increase in fatal cancer risk associated with this dose range. • Probably only a small number of natural water sources of this quality exist, resulting from exceptional geological conditions. • Abnormal operating conditions at some nuclear certified mineral and mining processes may result in a dose in this range when a person drinks the untreated water. Intervention will most likely be required to improve the quality of water that is released into the public domain. • The total natural background radiation from all exposure pathways, not only water, falls in this range.	Intervention considerations within 2 years.
Class 3 **(Red – Poor water quality)**	> 10 – 100	• Health effects are statistically detectable in very large population groups. • This range represents excessive exposure. • It is highly unlikely to find water of this poor quality in the natural environment.	Intervention is required in less than 1 year.
Class 4 **(Purple – Unacceptable water quality)**	> 100	• Health effects may be clinically detectable and a significant increase in the fatal cancer risk (greater than one in a thousand). • A dose greater than 100 mSv can usually only occur during a major accident at a nuclear facility. These facilities have to demonstrate that such an accident cannot happen with a frequency of more than once in a million years.	Immediate intervention is required.

4.0 WATER QUALITY ASSESSMENT RESULTS

4.1 Selected boreholes in the Northern Cape region

A summary of the selected boreholes is represented in Table 4.1. The coordinates provided in this table are taken from the Geographic Cape datum and they are given in Decimal Degrees (DD) and Degrees Minutes and Seconds (DMS). These data can be retrieved from the Geographical projection: Cape Datum. An effort was also made to convert this coordinates to Degree Minute and Seconds.

4.2 Chemical water quality

Appendix 1 provides detailed information on the chemical water quality for the variables measured in each of the boreholes in the study area. In some cases the results indicate large variation in the water quality sampled at different dates from the same borehole. Unfortunately not enough samples were taken to conduct a proper statistical analysis on the data and it was thus, for most of the boreholes, difficult to conclude on the chemical quality with a high level of confidence.

However, although the low monitoring frequency might have influenced the results in this study, the obtained data shows that the overall chemical quality of the water resources sampled in the study area is unacceptable and unsuitable for domestic use (Table 4.2). These results show some correlation with the results obtained by Wullschleger et al., (1998). Out of all of the boreholes sampled in the study area, only one borehole at Vyemond (Figure 6) showed ideal quality for inorganic chemicals and physical variables. The results suggest that the chemical quality of almost all of the boreholes sampled is either poor or unacceptable for use and chronic or acute effects may occur. A summary of the overall water quality of each borehole is presented in Table 4.2 in which each water source (borehole) is classified according to the colour classification system described in section 4.5.1.The problem variable/s of concern within a given borehole is/are indicated. The geographical location and chemical quality of the boreholes and the overall class of each of the boreholes is indicated on the maps from page 17 to 23.

Table 4.1: Selected boreholes in the Northern Cape region

Sampling Area	Borehole Name	Geographic Coordinates			
		Lat_DD_Cape	Long_DD_Cape	Lat_DMS_Cape	Long_DMS_Cape
Fonteintjie	Fonteintjie	-29.670078	17.919222	-29^{0} 40’ 14’’	17^{0} 55’ 09’’
Karkhams	Suidgat	-30.386667	17.889722	-30^{0} 23’ 01’’	17^{0} 53’ 18’’
Karkhams	Reservoir	-30.386667	17.888417	-30^{0} 23’ 12’’	17^{0} 53’ 22’’
Vyemond	Vyemond	-30.343890	17.979450	-30^{0} 20’ 38’’	17^{0} 58’ 46’’
Spoegrivier	R45 Spoegrivier	-30.266667	17.756510	-30^{0} 16’ 00’’	17^{0} 45’ 23’’
Klipfontein	R46 Klipfontein	-30.500000	17.830730	-30^{0} 30’ 00’’	17^{0} 49’ 50’’
Klein Mier	Klein Mier	-26.731900	20.276806	-26^{0} 43’ 51’’	20^{0} 16’ 36’’
Bulletrap	Bulletrap1	-29.483083	17.772333	-29^{0} 28’ 59’’	17^{0} 46’ 20’’
	Bulletrap2	-29.465778	17.780917	-29^{0} 27’ 56’’	17^{0} 46’ 51’’
Eyams	R47 Eyams	-29.351902	17.623955	-29^{0} 21’ 06’’	17^{0} 37’ 26’’
Skuiterberg	R48 Skuiterberg	-29.325241	17.563127	-29^{0} 19’ 30’’	17^{0} 33’ 47’’
Gladkop	R49 Gladkop	-29.372183	17.670344	-29^{0} 22’ 19’’	17^{0} 40’ 13’’
Riemvasmaak	Riemvasmaak	-28.405639	20.313083	-28^{0} 24’ 20’’	20^{0} 18’ 47’’
Kotzesrus	Kotzerus	-30.949167	17.841667	-30^{0} 56’ 57’’	17^{0} 50’ 30’’
Kenhardt	Municipal borehole	-29.358806	21.129667	-29^{0} 21’ 31’’	21^{0} 07’ 46’’
Loubos	R37Loubus Borehole	-26.717222	20.115000	-26^{0} 43’ 01’’	20^{0} 06’ 54’’
Warmbron	Warmbron Gat3	-28.494990	20.314720	-28^{0} 29’ 41”	20^{0} 18’ 52”

Lat_DD_Cape: Latitude in Decimal degree from Cape datum
Long_DD_Cape: longitude in Decimal degrees from Cape datum
Lat_DMS_Cape: Latitude in Degrees Minutes and Seconds from Cape datum
Long_DMS_Cape: Longitude in Degree Minutes and Seconds from Cape datum

Table 4.2: A summary of the characterization of the **chemical quality** of selected boreholes in the Northern Cape region

		Geographic Coordinates						
Sites Name	**Borehole Name**	**Lat_DD_Cape**	**Long_DD_Cape**	**Lat_DMS_Cape**	**Long_DMS_Cape**	**Water Quality Classification**	**Status of water resource**	**Problem Variable/s**
Warmbron	Gat-R3	-28.49499	20.31472	-28^0 29' 41''	20^0 18' 52''	Red	Poor	F, NO_3
Fonteintjie	Fonteintjie	-29.670078	17.919222	-29^0 40' 14''	17^0 55' 09''	Yellow	Marginal	F, K,Al
	R 50	-29.670078	17.919222	-29^0 40' 14''	17^0 55' 09''	Red	Poor	NO_3
Riemvasmaak	Riemvasmaak	-28.405639	20.313083	-28^0 24' 20''	20^0 18' 47''	Purple	Unacceptable	F
Klein Mier	Klein Mier	-26.7319	20.276806	-26^0 43' 51''	20^0 16' 36''	Purple	Unacceptable	Mg
Bulletrap	Bulletrap1	-29.483083	17.772333	-29^0 28' 59''	17^0 46' 20''	Purple	Unacceptable	F
	Bulletrap2	-29.465778	17.780917	-29^0 27' 56''	17^0 46' 51''	Red	Poor	F, Mg, Ca, K
Karkharms	Reservoir	-30.386667	17.888417	-30^0 23' 01''	17^0 53' 18''	Red	Poor	Mg, K, Ca,F,
	Suidgat	-30.386667	17.889722	-30^0 23' 12''	17^0 53' 22''	Red	Poor	F, Cl,Mg
	Vyemond	-30.34389	17.97945	-30^0 20' 38''	17^0 58' 46''	Green	Good	
Kotzerus	Kotzerus Borhole	-30.949167	17.841667	-30^0 56' 57''	17^0 50' 30''	Purple	Unacceptable	Mg, K, Ca, TDS, Na, Cl, EC
Kenhardt	Kenhardt Reservoir	-29.358806	21.129667	-29^0 21' 31''	21^0 07' 46''	Red	Poor	F, K

A more detailed description of the water quality problem variables at each of the sites is given below:

Warmbron: The results obtained for Warmbron (Figure 2) suggest that the water quality within the borehole is poor due to high levels of fluorides and nitrates which falls within the red class. These results need to be verified due to the fact that the borehole was only sampled once. The high Fluoride concentration in the water could, with chronic intake, cause marked tooth staining and could damage the skeleton causing hardening of the bones and making them brittle. The nitrate, at the levels found in the water, could pose a possible chronic risk to some babies resulting in tiredness and failure to thrive.

Fonteintjie: The results obtained at the Fonteintjie (Figure 3) shows that the chemical water quality of the water resource in the area have an elevated concentration of nitrate that falls within Class 3. This suggests that the water quality in the area might be poor but this need to be confirmed as this result only account for a single sample collected on the 22 April 2000. Samples which were collected on the 29 April 1999 show that the water quality in the area is marginal (Yellow) due to elevated levels of fluoride, potassium and aluminium whereas the results obtained on 13 September 1999 shows that the water was in the Green Class and thus of good quality. The sample collected on the 22 April 00 at Fonteintjie contained high concentration of nitrate, which could pose a possible chronic risk to some babies, and it recommended that water from this borehole should not be used for bottle fed babies as it could cause blue baby syndrome.

Riemvasmaak: The borehole at Riemvamaak (Figure 2) has a large data set as it is also monitored as part of the National Groundwater Monitoring Programme. The data show that there is a high concentration of fluoride in the water with unacceptable limits at times falling into the Purple Class of the water quality guidelines. The water quality in the area is unsuitable for domestic use as it may cause severe tooth staining and damage to the skeleton.

Klein Mier: The water quality in Klein Mier (Figure 4) shows a high variation in the concentration of magnesium sampled at different dates. It is thus recommended that the borehole be re-sampled to verify the results. Magnesium concentrations above 70 mg/l imparts a bitter taste to water and could cause diarrhoea in sensitive groups above 200mg/l. The borehole also contained high concentrations of sodium and fluoride. Sodium concentrations above 400 mg/l could pose a possible health risk to babies as it can place a strain on kidneys and the heart and lead to disturbances in the salt balance in the body with water retention. Fluoride concentrations above 1,5 mg/l could cause tooth staining.

Bulletrap: There is a large variation in the results obtained at different sampling dates both for Bulletrap 1 and Bulletrap 2 and it is recommended that the boreholes be re-sampled to verify the results. The overall chemical quality of the water resource in the area (Figure 5) shows that the water is unacceptable for domestic use. The high concentration of fluoride in Bulletrap 1 and Bulletrap 2 may cause severe tooth staining and damage to the skeleton. Bulletrap 1 shows high concentrations of potassium and calcium at one sampling date as well as elevated TDS levels that would impart a distinctly salty taste to the water.

Karkhams: The overall water quality Karkhams (Figure 6) is unacceptable and unsuitable for use due to high concentration of fluoride in the area. Only one borehole in the area namely; Vyemond showed good chemical quality with all the inorganic salts variables falling within an ideal or good water quality range. The water quality for Karkhams reservoir, and Suidgat, shows that the water quality in the area is poor due to high levels of magnesium, potassium, and calcium as well as elevated TDS. Some of the boreholes were sampled only once and the results from different sampling dates for the same borehole did not correlate very well. It is thus recommended that additional samples be taken to verify the results.

Kotzesrus: The overall quality of the water resource in Kotzerus (Figure 7) is unsuitable for domestic purposes. The results show that there are high concentration (poor quality) of chloride, calcium, magnesium, sodium, potassium and TDS as well as marginal concentration of manganese in the water. The result from different sampling dates at Kotzerus does not correlate well it thus proposed that the boreholes at Kotzerus be sampled again to verify the results.

Kenhardt: The overall results obtained for Kenhardt (Figure 8) shows that the water quality in the area is unacceptable for use as the chemical quality in the area is poor with high concentrations of fluoride and potassium

4.3 Radiological water Quality

The Radioactivity Dose Calculation and Water Quality Evaluation Guidelines for Domestic Water, were used to asses the radiological data. The new revised criteria, based on the International Commission for Radiological Protection (ICRP) recommendations, were used to classify the radiological quality of the water resources together with the revised Guidelines for Domestic Use.

The data shows that the radiological quality of most of the sampled boreholes was good. Only one borehole from Kotzerus indicated that the water quality in the area is poor and it might have health effects to the most sensitive age groups (0-1 and 1-2 years) if it used for domestic purposes. The radiological quality of the water resource for the other age groups is marginal and a small increase in fatal cancer risk associated with this dose range can occur. The people in Kotzerus do not use this borehole but instead they depend on rainwater for domestic use. A brief summary of the overall radiological quality of the water resources in the study area is presented in Table 4.3.

Fonteintjie: The results in appendix 2 shows that the radiological quality of the water resource in Fonteintjie ranges from ideal to good for all age groups expect for the most sensitive age group (i.e. 0-1 year) which falls under marginal water (Figure 9). The data for the two sampling dates do not correlate well and it is recommended that the borehole should be re-sampled to verify the results.

Karkhams: The results shows that the radiological quality of the water resource sampled from Kharkams reservoir, Karkhams Suidgat; Vyemond; Spoegrivier, and Klipfontein is good (Figure 10; 11 and 12) and no intervention is required in those boreholes although the radiation doses must be kept as low as reasonably achievable.

Klein Mier: The overall radiological quality of the water resource in Klein Mier falls within an Ideal Water Quality Class for all age groups except for only one sample taken on the 7 October 2000 that indicates that the water quality in the area is in the green Class (good) (Figure13).

Bulletrap: The results for Bulletrap 1 and 2 (Figure 14) show that the overall radiological quality of the water resource falls within a Green (good) Class for the most sensitive age group (i.e. 0-1 year) and also 12-17, the radiological quality for the other age groups show that the water is ideal for domestic purposes.

Eyams: The radiological quality of the water resource in Eyams (Figure 15) is ideal for all age groups and no intervention would be required in the area.

Skuitberg: The results shows that the overall radiological quality of the borehole (Figure 15) falls within a Green Class (good quality) and no intervention would be required in the area.

Gladkop: The results in Gladkop (Figure 15) shows that the overall radiological quality of the water resource falls within a Green Class (good) and no intervention would be required in the area.

Riemvasmaak: The overall radiological quality of the water in Riemvasmaak (Figure 16) shows that the water in the area falls within ideal to good water quality for all age groups except for the most sensitive age group for which the water quality is marginal. The radiological data sampled at different dates do not correlate well and it is recommended that the borehole be sampled again to verify the results.

Kotzesrus: The borehole sampled at Kotzerus showed very different results, The results for 29 April 1999 shows that the water quality is either ideal or good whereas the sample taken on the 07 October 1999 shows that the water quality in the area is poor (Figure 17) for 0-1 and 1-2 years age groups and marginal for other age groups. The borehole should be re-sampled to verify the results.

Kenhardt: The results show that the radiological quality of the borehole sampled in Kenhardt municipality gives marginal water quality for 0-1 year age group (Figure 18), good water quality was observed for the other age groups.

Loubos: Loubos Borehole (Figure 19) shows that the radiological quality for all age groups is ideal for domestic purposes.

Table 4.3: A summary of the characterization of the **radiological quality** of the water resource in the selected boreholes in the Northern Cape region:

Sampling Area	Borehole Name	Geographic Coordinates				Class	Status Of Water Resource	Affected Age group
		Lat_DD_Cape	Long_DD_Cape	Lat_DMS_Cape	Long_DMS_Cape			
Fonteintjie	Fonteintjie	-29.670078	17.919222	-29^0 40' 14''	17^0 55' 09''	Yellow	Marginal	0-1 Year
Kharkams	Suidgat	-30.386667	17.889722	-30^0 23' 01''	17^0 53' 18''	Green	Good	0-1; 1-2; 12-17 Years; LAD
Kharkams	Reservoir	-30.386667	17.888417	-30^0 23' 12''	17^0 53' 22''	Green	Good	All
Vyemond	Vyemond	-30.343890	17.979450	-30^0 20' 38''	17^0 58' 46''	Green	Good	0-1; 17-70 Years
Spoegrivier	R45 Spoegrivier	-30.266667	17.756510	-30^0 16' 00''	17^0 45' 23''	Green	Good	0-1;12-17 Years
Klipfontein	R46 Klipfontein	-30.500000	17.830730	-30^0 30' 00''	17^0 49' 50''	Green	Good	All
Klein Mier	Klein Mier	-26.731900	20.276806	-26^0 43' 51''	20^0 16' 36''	Green	Good	0-1 Year
Bulletrap	Bulletrap1	-29.483083	17.772333	-29^0 28' 59''	17^0 46' 20''	Green	Good	0-1 Year,
	Bulletrap2	-29.465778	17.780917	-29^0 27' 56''	17^0 46' 51''	Green	Good	0-1;12-17 Years
Eyams	R47 Eyams	-29.351902	17.623955	-29^0 21' 06''	17^0 37' 26''	Blue	Ideal	All
Skuitberg	R48 Skuiterberg	-29.325241	17.563127	-29^0 19' 30''	17^0 33' 47''	Green	Good	0-1; 12-17; Years
Gladkop	R49 Gladkop	-29.372183	17.670344	-29^0 22' 19''	17^0 40' 13''	Green	Good	0-1 Year
Riemvasmaak	Riemvasmaak	-28.405639	20.313083	-28^0 24' 20''	20^0 18' 47''	Yellow	Marginal	0-1 Year
Kotzesrus	Kotzerus	-30.949167	17.841667	-30^0 56' 57''	17^0 50' 30''	Red	Poor	0-1;1-2 Years
Kenhardt	Municipal borehole	-29.358806	21.129667	-29^0 21' 31''	21^0 07' 46''	Yellow	Marginal	0-1 Year
Loubos	R37Loubus Borehole	-26.717222	20.115000	-26^0 43' 01''	20^0 06' 54''	Blue	Ideal	All

5.0 CONCLUSIONS

The main aim of this study was to identify high-risk areas in selected regions in the Northern Cape Province where the chemical and radiological quality of drinking water resources could possibly pose a health risk to consumers.

From a chemical point of view the results obtained, from the study show that most of the boreholes sampled could indeed pose a health risk to people using the water for drinking purposes. Only one borehole namely at Vyemond has shown good quality.

Out of sixteen boreholes sampled, only one borehole at Kotzesrus has shown a possible health risk due to radiation. The results show that the overall radiological quality of this borehole falls within Class 3 for the age groups 0-1 and 1- 2 years. The radiological quality for the other age groups is marginal. This borehole should thus not be used for domestic purposes.

Except for the boreholes at, Fonteintjie, Kenhardt and Riemvasmaak that have shown marginal water quality for the most sensitive age group (0 – 1 year) all the other boreholes had either ideal or good water quality for all the age groups. According to the Department of Water Affairs and Forestry (2002) it is recommended that routine three monthly monitoring be done in water resources where the radiological dose from water exceeds 1mSv per annum.

Due to the inconsistency in the monitoring frequency (i.e. some of the boreholes were sampled once and the others were sampled twice or three times) as well as the large variation in the results at different sampling dates it is important to do a follow up study in order to verify the results. Unfortunately only a few boreholes in the study area (at Riemvasmaak and Kenhardt) are included in the National Groundwater Monitoring Programme for which additional chemical data could be obtained to verify the chemical results. No additional radiological data were available and thus it is important to perform follow up studies for individual boreholes showing suspected levels of radioactivity in the Northern Cape area.

No solid conclusions regarding the quality of the water resources could thus be made due to the fact that water quality or fitness for use can not be determined from single measurements, but should be based on a long term records. More results would be required to verify the results reported in the study, to determine the changes in the water quality over time and space and also to identify the causes of the reported contamination. Further the NRNP should ensure coverage of the monitoring points sampled in the area.

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APPENDIX 01

CHEMICAL WATER QUALITY DATA

WARMBRON

Inorganic Salts and Physical parameters

Borehole Name	Sampling date	Laboratory	As	pH	NO3	F	Na	Mg	SO4	Cl	K	Ca	EC	TDS	Guidelines Class
Wambron Gat 3	29-Apr-99	RQS													
	13-Sep-99	RQS													
	04-Nov-99	TSIL													
	30-May-00	TSIL													
	22-Apr-00	TSIL	0.05	7.4	24	3.3	84	22	71	70	2	73			NO3, F

Trace Metals

Borehole Name	Sampling date	Laboratory	Al	Cd	Cr	Cu	Fe	Mn	Pb	V	Zn	Hg	Se		Guidelines Class
Warmbron Gat 3	29-Apr-99	RQS													
	13-Sep-99	RQS													
	04-Nov-99	TSIL													
	30-May-00	TSIL													
	22-Apr-00	TSIL					0.05	0.05		0.05	0.05		0.05		
													Problem Variables		NO3**, F**

Red

					FONTEINTJIE											
					Inorganic Salts and Physical parameters											**Guidelines Class**
Borehole Name	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	
	29-Apr-99	RQS		7.8	0.2	0.07	1.16	100	86	0.021	0.02	84	140	1.2	63	**F, K**
Fonteintjie	13-Sep-99	RQS		7.1	6.02		0.7	71	14	81	88	1.4	30	65.9	385	F
	04-Nov-99	TSIL														
	30-May-04	TSIL														
	Toens and Partners			7.3	0.04		1.1	92	20	0.02	153	1.8	49	89.5	544	
				Trace Metals												
Borehole Name	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			
	29-Apr-99	RQS	0.025	0.01	0.005	0.005	0.005	0.001	0.05		0.005	0.01				**Al**
Fonteintjie	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-04	TSIL														
R 50	22-Apr-00	TSIL					1.5	0.05		0.34	0.05					Fe
															Problem Variables	NO3**, F*,Al*,K*

*Yellow **Red

				RIEMVASMAAK												
				Inorganic Salts and Physical parameters												
Riemvasmaak	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**N**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	**Guidelines Class**
	29-Apr-99	RQS		8.4	0.74	0.02	6.65	351	113	0.015	62	6.6	56	6.8	61	F
	13-Sep-99	RQS		7.6	6.1		3.6	116	31	0.015	58	161	101	115	961	F, K
	13-May-97	WMS		8.49			3.44	123.7	32.3	62.6	55	7.37	99.8	107.8		
	10-Sep-97	WMS		7.61			3.54	118.1	30.5	61.5	57	7.61	103	112		
	18-Sep-98	WMS		8.07			3.65	126.2	29.5	70.4	61.5	7.42	103.2	120		
	27-Apr-98	WMS		8.06			3.57	111.5	32	65.8	56.3	7.4	108.9	112.4		
	11-Apr-01	WMS		8.16			3.601	123.956	31.737	67.022	71.814	7.802	100.608	120		
	19-Sep-01	WMS		8.217			3.615	120.198	33.875	83.489	76.9	7.582	110.328	122.6		
	19-Sep-03	WMS		7.883			3.784	111.101	33.266	71.252	74.879	7.807	122.402	119.4		F
	Toens and Partners		0.03	8.1			3.6	122	31	60	59	6.9	99	114.9	952	
	Toens and Partners		0.03	8.1			6.4	466	26	336	360	5.1	71	246	1764	
				Trace Metals												
Riemvasmaak	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			**Guidelines Class**
	29-Apr-99	RQS	0.025	0.01	0.005	0.005	0.005	0.001	0.05		0.005	0.01				Al
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	Toens and Partners		0.02	0.005		0.005	0.005	0.001	0.03		0.005					
														Problem variables		Al*;F**,K**,F***

*Yellow, **Red, ***Purple

KLEIN MIER																
Inorganic salts and Physical parameters																
Klein Mier	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	**Guidelines Class**
	29-Apr-99	RQS		8.6	0.12	0.02	2.67	585	540	0.091	0.09	161	313	4.9	19	Mg
	13-Sep-99	RQS		8.4	13		3.2	538	11	161	331	5.2	24	266	1855	F,Na
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	22-Apr-00	TSIL														
	Toens and Partners			8.5	0.04		1.7	292	6	49	76	4.7	12	133	1103	
Trace Metals																
Klein Mier	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			**Guidelines Class**
	29-Apr-99	RQS	0.025	0.01	0.005	0.005	0.005	0.001	0.05		0.005	0.01				Al, Cd
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL														Mg
	22-Apr-00	TSIL														
	Toens and Parteners		0.02	0.005		0.005	0.005	0.001			0.005					
														Problem Variables		Mg***,F**,Na**, TDS*,EC*, N+NO3

*Yellow, **Red, ***Purple

BULLETRAP 1																
Inorganic Salts and Physical parameters																
Bulletrap 1	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	**Guidelines Class**
	29-Apr-99	RQS		7.6	0.26	0.02	3.71	63	136	0.01	0.009	275	323	3.4	165	F
	13-Sep-99	RQS		7.5	3.54		2.5	141	34	289	340	3.4	176	188	1095	F
	04-Nov-99	TSIL														
	Toens and Partners			8.4	0.04		1.8	261	87	173	666	4.1	132	260		
	Toens and Partners			8	0.04	4.82	3.5	566	121	410	1257	5.4	290	487	2891	
	Trace Metals															
Bulletrap 1	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			**Guidelines Class**
	29-Apr-99	RQS	0.025	0.01	0.005	0.005	0.005	0.001	0.05		0.005	0.01				Al
	Toens and Partners		0.02	0.005		0.005	0.005	0.001	0.03							
	Toens and Partners		0.02	0.005		0.005	0.005	0.001	0.03		0.347					
														Problem Variables		F***, K**, Ca**

* Yellow, ** Red, ***Purple

BULLETRAP 2																
Inorganic Salts and Physical parameters																
Bulletrap 2	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDC**	**Guidelines Class**
	29-Apr-99	RQS		7.7	0.28	0.02	2.97	120	228	0.011	0.01	199	412	3.1	109	F,Mg.K. Ca
	13-Sep-99	RQS		7.6	3.72		3.3	236	50	205	441	3.2	109	212	1222	F
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	22-Apr-00	TSIL														
Trace Metals																
Bulletrap 2	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			**Guidelines Class**
	29-Apr-99	RQS	0.025	0.01	0.005	0.005	0.005	0.001	0.05		2.502	0.01				Al, Cd
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	22-Apr-00	TSIL														
															Problem Variables	Mg**, K**,Ca**,F**

**Red

KARKHAMS																
Inorganic Salts and Physical Parameters																
Karkhams Reservoir	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	**Guidelines Class**
	29-Apr-99	RQS		8	0.25	0.02	0.05	146	322	0.0025	0.0025	131	776	6.8	129	Mg,K,Ca
	13-Sep-99	RQS		8.1	0.09		4	275	66	134	574	6.3	104	247	1370	F
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	22-Apr-00	TSIL														
	Toens and Partners			8			3.6	222	56	132	468	5.8	95	194	1167	
Trace Metals																
Karkhams Reservoir	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			**Guidelines Class**
	29-Apr-99	RQS	0.025	0.01	0.005	0.005	0.005	0.14	0.05		0.52	0.01				Al, Cd
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	Toens and Partners		0.02	0.005		0.005	0.005	0.001	0.03		0.821					
														Problem Variables		Mg**,K**,Ca**,F**

**Red

KARKHAMS																
Inorganic Salts and Physical parameters																
Karkhams Suidgat	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	**Guidelines Class**
	29-Apr-99	RQS		8	0.18	0.05	0.06	155	385	0.013	0.012	123	983	7.7	160	Mg
	13-Sep-99	RQS		7.6	0.04		2.6	388	97	46	977	7.7	96	342	1709	F, Cl
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	22-Apr-00	TSIL														
	Toens and Partners															
			Trace Metals													
Karkhams Suidgat	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			**Guidelines Class**
	29-Apr-99	RQS	0.025	0.01	0.005	0.005	0.005	0.742	0.05		0.005	0.01				Al, Cd
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	22-Apr-00	TSIL														
														Problem Variables		Mg**, F**, Cl**

** Red

VYEMOND																
Inorganic Salts and Physical parameters																
Karkhams Vyemond	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	**Guidelines Class**
	29-Apr-99	RQS														
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL	0.05	6.1		5.1	0.2	50	7.3	2	70	2	7.5	32		As
	22-Apr-00	TSIL														
Trace Metals																
Karkhams Vyemond	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			**Guidelines Class**
	29-Apr-99	RQS														
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	1.7	0.05	0.05			Cd,Cr,Pb,Hg,Se
	22-Apr-00	TSIL														
														Problem Variables		

KOTZESRUS																
Inorganic Salts and physical parameters																
Kotzesrus Borehole	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	**Guidelines Class**
	29-Apr-99	RQS		7.7	0.29	0.04	0.34	92	2460	0.015	0.014	695	5360	27.5		Mg,K,Ca,TDS
	13-Sep-99	RQS		7.9	0.37		1.8	2529	263	976	5370	19.8	737	1580	10068	Na,Cl,EC,TDS
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	Toens and Partners			8	0.05	0.94	1.8	2792	262	734	5541	25.1	74.5	1590	10297	
Trace Metals																
	Sampling date	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**	**Se**			**Guidelines Class**
	29-Apr-99	RQS	0.025	0.002	0.005	0.005	0.005	1.571	0.05		0.322	0.01				Mn
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL														
TSIL														**Problem Variables**		Mg***, K***, a***, TDS***, Na***, Cl***

**Red, ***Purple

				KENHARDT												
				Inorganic Salt and Physical parameters												
Kenhardt Reservoir	**Sampling date**	**Laboratory**	**As**	**pH**	**N +NO3**	**NO3**	**F**	**Na**	**Mg**	**SO4**	**Cl**	**K**	**Ca**	**EC**	**TDS**	**Guidelines Class**
	29-Apr-99	RQS		7.9	0.42	0.02	1.8	239	158	0.017	0.016	148	257	3.3	117	F,K
	13-Sep-99	RQS		7.7	2.32		1.98	180	41	169	289	3.2	115	178	1124	F
	05-Nov-97	WMS		7.5			3.01	221.2	28	165.4	229.7	2.12	73.2	153.6		
	07-May-97	WMS		8.03			1.92	57.3	19.4	47.4	95.2	2.42	85.9	82.7		
	14-Sep-98	WMS		7.7			2.9	224.5	37.1	192.4	289.8	2.85	99.7	178		
	24-Apr-98	WMS		8.08			1.79	77.3	29.5	111.6	198	3.3	130.2	106.1		
	23-Apr-99	WMS		7.1			3.01	290	39.5	224	359.4	2.5	91.1	211		
	05-Oct-01	WMS		8.312			2.364	168.54	31.846	125.214	207.295	2.419	78.917	139		
	Toens and Partners		0.03	8.2	1.26		2.4	131	25	118	180	2.5	89	111.7	843	
				Trace Metals												
Kenhardt Reservoir	**Sampling date**	**Laboratory**	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**V**	**Zn**	**Hg**				**Guidelines Class**
	29-Apr-99	RQS	0.025	0.01	0.005	0.005	0.005	0.001	0.05		0.028	0.01				Al, Cd
	13-Sep-99	RQS														
	04-Nov-99	TSIL														
	30-May-00	TSIL														
	Toens and Partners		0.002	0.005			0.005	0.001	0.03		0.005					
														Problem Variables		F**,K**, Na*, Mg*, Cl*,Ca*, EC*, Al*, Cd*

*Yellow, ** Red

APPENDIX 02

RADIOLOGICAL WATER QUALITY DATA

	FONTEINTJIE									
Sampling Site	Sampling Date	Dose (Msv/a)								
		0-1 year	1-2 years	2-7 Years	7-12 Years	12-17Years	17 -70 Years	LAD	Overall Quality	Based on annual Radiation dose
Fonteintjie	29-Apr-99	0.088	0.0148	0.0105	0.011	0.0209	0.008	0.0106	Blue	0-1 year
Fonteintjie	07-Oct-99	1.32	0.5	0.34	0.34	0.71	0.28	0.338	Yellow	LAD
							Highest quality		Yellow	0-1 Year

	KARKHAMS									
Sampling Site	Sampling Date	Dose (mSv/a)								
		0-1 year	1-2 years	2-7 Years	7-12 Years	12-17Years	17 -70 Years	LAD	Overall Quality	Based on annual Radiation dose
Kharkams Suidgat	29-Apr-99	0.062	0.0082	0.0006	0.005	0.005	0.005	0.006	Blue	0-1 year
Kharkams Suidgat	07-Oct-99	0.37	0.12	0.08	0.09	0.21	0.07	0.87	Green	0-1, 12-17 Years, LAD
							Highest quality		Green	0-1; 1-2; 12-17 Years

	KARKHAMS									
Sampling Site	Sampling Date	Dose (mSv/a)								
		0-1 year	1-2 years	2-7 Years	7-12 Years	12-17Years	17 -70 Years	LAD	Overall Quality	Based on annual Radiation dose
Kharkams Reservoir	29-Apr-99	0.103	0.013	0.009	0.008	0.009	0.008	0.0096	Green	0-1 year
Kharkams Reservoir	07-Oct-99	0.902	0.22	0.164	0.214	0.605	0.166	0.212	Green	All
							Highest quality		Green	All

VYEMOND										
Sampling Site	Sampling Date	Dose (mSv/a)								
		0-1 year	1-2 years	2-7 Years	7-12 Years	12-17Years	17 -70 Years	LAD	Overall Quality	Based on annual Radiation dose
Vyemond	20-Jul-00	0.302	0.119	0.0711	0.055	0.08	0.519	0.0601	Green	0-1and 17-70Years
							Highest quality		Green	0-1and 17-70Years

SPOEGRIVIER										
Sampling Site	Sampling Date	Dose (mSv/a)								
		0-1 year	1-2 years	2-7 Years	7-12 Years	12-17Years	17 -70 Years	LAD	Overall Quality	Based on annual Radiation dose
R45 Spoegrivier	20-Jul-00	0.443	0.074	0.06	0.06	0.119	0.075	0.0815	Green	0-1 , 12-17Years
							Highest quality		Green	

KLIPFONTEIN										
Sampling Site	Sampling Date	Dose (mSv/a)								
		0-1 year	1-2 years	2-7 Years	7-12 Years	12-17Years	17 -70 Years	LAD	Overall Quality	Based on annual Radiation dose
R46 Klipfontein	20-Jul-00	0.916	0.146	0.155	0.105	0.165	0.143	0.149	Green	All
							Highest quality		Green	All

KLEIN MIER										
		Dose (mSv/a)								
Sampling site	Sampling Date	0-1 year	1-2 years	2-7 Years	7-12 Years	12-17Years	17 -70 Years	LAD	Overall Quality	Based on annual Radiation dose
Klein Mier	29-Apr-99	0.01	0.0014	0.0012	0.0011	0.0017	0.002	0.002	Blue	All
Klein Mier	07-Oct-99	0.214	0.069	0.051	0.05	0.084	0.054	0.058	Blue	0-1Year
							Highest Quality		Green	0-1 Year

BULLETRAP 1										
		Dose (mSv/a)								
Sampling Site	Sampling Date	0-1 year	1-2 years	2-7 Years	7-12 Years	12-17Years	17 -70 Years	LAD	Overall Quality	Based on annual Radiation dose
Bulletrap1	29-Apr-99	0.02	0.002	0.002	0.0015	0.002	0.002	0.002	Blue	All
Bulletrap1	07-Oct-99	0.133	0.051	0.035	0.037	0.073	0.031	0.036	Blue	0-1 Year
							Highest Quality		Green	0-1 Year

BULLETRAP 2										
	Dose (mSv/a)									
Sampling Site	**Sampling Date**	**0-1 year**	**1-2 years**	**2-7 Years**	**7-12 Years**	**12-17Years**	**17 -70 Years**	**LAD**	**Overall Quality**	**Based on annual Radiation dose**
Bulletrap2	29-Apr-99	0.0626	0.009	0.0067	0.006	0.0099	0.0068	0.0078	Blue	0-1 year
Bulletrap2	07-Oct-99	0.32	0.08	0.059	0.059	0.12	0.066	0.072	Green	0-1 and 12-17 Years
							Highest Quality		Green	0-1 and 12-17 Years

EYAMS										
	Dose (mSv/a)									
Sampling Site	**Sampling Date**	**0-1 year**	**1-2 years**	**2-7 Years**	**7-12 Years**	**12-17Years**	**17 -70 Years**	**LAD**	**Overall Quality**	**Based on annual Radiation dose**
R47 Eyams	20-Jul-00	0.05	0.02	0.013	0.011	0.018	0.009	0.01	Blue	All
							Highest Quality		Blue	All

SKUITERBERG										
	Dose (mSv/a)									
Sampling Site	**Sampling Date**	**0-1 year**	**1-2 years**	**2-7 Years**	**7-12 Years**	**12-17Years**	**17 -70 Years**	**LAD**	**Overall Quality**	**Based on annual Radiation dose**
R48 Skuitberg	20-Jul-00	0.215	0.068	0.046	0.053	0.138	0.042	0.53	Green	0-1 and 12-17 Years
							Highest Quality		Green	

GLADKOP										
	Dose (mSv/a)									
Sampling Site	**Sampling Date**	**0-1 year**	**1-2 years**	**2-7 Years**	**7-12 Years**	**12-17Years**	**17 -70 Years**	**LAD**	**Overall Quality**	**Based on annual Radiation dose**
R49 Gladkop	20-Jul-00	0.333	0.055	0.045	0.042	0.067	0.058	0.06	Green	0-1 Year
							Highest Quality		Green	0-1 Year

RIEMVASMAAK										
		Dose (mSv/a)								
Sampling site	**Sampling Date**	**0-1 year**	**1-2 years**	**2-7 Years**	**7-12 Years**	**12-17Years**	**17 -70 Years**	**LAD**	**Overall Quality**	**Based on annual Radiation dose**
Riemvasmaak	29-Apr-99	0.02	0.0027	0.0023	0.002	0.0032	0.0037	0.0036	Blue	All
Riemvasmaak	07-Oct-99	0.718	0.17	0.134	0.124	0.2	0.174	0.177	Green	All
R38 Riemvasmaak Warmbron-gat	20-Jul-00	3.98	0.665	0.544	0.483	0.733	0.708	0.728	Yellow	0-1 Year
							Highest Quality		Yellow	0-1 Year

KOTZESRUS										
		Dose (mSv/a)								
Sampling site	**Sampling Date**	**0-1 year**	**1-2 years**	**2-7 Years**	**7-12 Years**	**12-17Years**	**17 -70 Years**	**LAD**	**Overall Quality**	**Based on annual Radiation dose**
Kotzesrus	29-Apr-99	0.144	0.021	0.015	0.014	0.022	0.0121	0.015	Green	0-1 year
Kotzesrus	07-Oct-99	23.09	10.29	6.15	4.62	5.78	4.25	4.878	Red	0-1 Year
							Highest Quality		Red	0-1;1-2 years

KENHARDT										
Dose (mSv/a)										
Sampling site	**Sampling Date**	**0-1 year**	**1-2 years**	**2-7 Years**	**7-12 Years**	**12-17Years**	**17 -70 Years**	**LAD**	**Overall Quality**	**Based on annual Radiation dose**
Kenhardt Municipal Borehole	29-Apr-99	0.0254	0.0041	0.003	0.003	0.006	0.003	0.004	Blue	0-1 year
Kenhardt Municipal Borehole	07-Oct-99	1.96	0.47	0.37	0.34	0.56	0.46	0.47	Yellow	0-1 Year
Kenhardt Municipal Borehole	20-Oct-99	1.578	0.316	0.252	0.234	0.376	0.316	0.323	Yellow	0-1 Year
Kenhardt Municipal Borehole	06-Jan-00	3.132	0.7	0.56	0.52	0.84	0.72	0.74	Yelllow	0-1 Year
							Highest Quality		Yelllow	0-1 Year

LOUBOS										
Dose (mSv/a)										
Sampling site	**Sampling Date**	**0-1 year**	**1-2 years**	**2-7 Years**	**7-12 Years**	**12-17Years**	**17 -70 Years**	**LAD**	**Overall Quality**	**Based on annual Radiation dose**
R 37Loubos Borehole	14-Jan-00	0.111	0.022	0.015	0.017	0.036	0.096	0.04	Blue	All
							Highest Quality		Blue	All