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DEPARTMENT: WATER AFFAIRS AND FORESTRY

Directorate: Water Resources Planning

OLIFANTS/DORING WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

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OLIFANTS/DORING WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

MAIN REPORT

OVERVIEW

The water resources of South Africa are vital to the health and prosperity of its people, the sustenance of its natural heritage and to its economic development. Water is a national resource that belongs to all the people who should therefore have equal access to it, and although the resource is renewable, it is finite and distributed unevenly both spatially and temporally. The water also occurs in many forms that are all part of a unitary and inter-dependent cycle.

The National Government has overall responsibility for and authority over the nation's water resources and their use, including the equitable allocation of water for beneficial and sustainable use, the redistribution of water and international water matters. The protection of the quality of water resources is also necessary to ensure sustainability of the nation's water resources in the interests of all water users. This requires integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level where all persons can have representative participation.

This report is based on a desktop or reconnaissance level assessment of the available water resources and quality and also patterns of water requirements that existed during 1995 in the Olifants/Doring Water Management Area, which occupies portions of the Western Cape and Northern Cape Provinces. The report does not address the water requirements beyond 1995 but does provide estimates of the utilisable potential of the water resources after so-called full development of these resources, as this can be envisaged at present. A separate national study has been conducted to consider future scenarios of land use and water requirements and the effects of water conservation and demand management measures on these requirements and to identify alternative water resource developments and water transfers that will reconcile these requirements with the supplies.

The main purpose of this report is to highlight the principal water related issues, to identify existing water shortages, to provide information that is necessary to formulate future strategies such as the national water resources strategy and catchment management strategies and to stimulate initial actions to ensure the best overall sustainable utilisation of the water, with minimal waste and harm to the aquatic ecosystems.

The National Water Act (No. 36 of 1998), requires that a national water resources strategy (NWRS) be established that sets out the policies, strategies, objectives, plans, guidelines and procedures and the institutional arrangements for the protection, use, development, conservation, management and control of water resources for the country as a whole, and establish and define the boundaries of water management areas taking into account catchment boundaries, socio-economic development patterns, efficiency considerations and communal interests. This strategy is binding on all authorities and institutions exercising powers or performing duties under the National Water Act.

The national water resources strategy will, *inter alia*, provide for at least the requirements of the Reserve, international rights and obligations, actions required to meet projected future water needs and water use of strategic importance. Furthermore, it will contain estimates of present and future water requirements, set out principles relating to water conservation and demand management, give the total quantity of water available within each water management area, state the surpluses or deficits, provide for inter-catchment water transfers required to balance the supply with the requirements and state the objectives in respect of water quality to be achieved through the classification system to be provided for the water resources.

A catchment management agency established in terms of the National Water Act (No. 36 of 1998), must progressively develop a catchment management strategy, objectives, plans, guidelines and procedures for the protection, use, development, conservation, management and control of water resources within its water management area. Such a strategy must not be in conflict with the national water resources strategy, must take into account the class of water resource and resource quality objectives, the requirements of the Reserve and any applicable international obligations, the geology, land use, climate, vegetation and waterworks within its water management area. The strategy shall contain water allocation plans, take account of any relevant national or regional plans prepared in terms of any other law; enable public participation and take into account the needs and expectations of existing and potential water users. This report provides the initial baseline data that can be used by the catchment management agency to develop its catchment management strategy, objectives, plans, guidelines and procedures for the protection, use, development, conservation, management and control of the water resources in its area of responsibility.

The national water resources strategy will be reviewed and published at five-yearly intervals, with Addenda being issued in the interim, when required. The strategy will give guidance to the Department of Water Affairs and Forestry in respect of the protection, use, development, conservation, management and control of water resources and will also serve as a very important means of communication with all the stakeholders. The overall responsibility for the compilation of the national water resources strategy rests with the Directorate: Strategic Planning of the Department of Water Affairs and Forestry, while the Directorate: Water Resources Planning is responsible for:

- Identification of water resources to meet particular requirements
- Identification of international rights and obligations
- Identification of water use of strategic importance
- Calculating water balances
- Developing plans to reconcile water requirements and resources.

A number of inter-related studies have therefore been included by the Directorate: Water Resources Planning of the Department of Water Affairs and Forestry in the national future scenario study that will supply the information required for formulating the strategies, as given above.

The main objective of this water resources situation assessment has been to determine the water requirements of all the user sectors (including those of the riverine and estuarine ecosystems) and the ability of the available water resources to supply these requirements. However, other aspects such as water quality, legal and institutional aspects, macro-economics, and existing infrastructure have also been addressed. This report outlines the 1995 water resources situation, using information obtained from previous study reports to identify the main water related issues of concern. The large body of information available in the Department of Water Affairs and Forestry and from other sources has also been collated and presented in this assessment. This has been collected on a catchment basis at the quaternary catchment level of resolution. The levels of confidence that can be attached to the data on land use, water requirements and surface water and groundwater resources have however, been found to vary considerably because of the desktop nature of the study. This has therefore also provided a basis for identifying where improvements need to be made to the data in future and to prioritise such studies. It is also important to note that where information on land and water use and sensitive ecosystems is not given, this could be due to the fact that it does not exist or because it has not been documented in a format or source that is readily accessible.

The larger inter-related studies that have supported this water resources situation assessment have been the following:

- Development of a computerised database

  Data collected in this water resources situation assessment has been used to populate the database of the Chief Directorate: Planning of the Department of Water Affairs and Forestry. The database design has mainly been based on the requirements of a water balance model that has been developed to compare the water requirements with the available water resources.

- Demographic study

  An important part in the development of the national water resources strategy is the future scenarios. Since water use is mainly driven by the requirements of the various socio-economic groupings of the population, a national demographic study was initiated. An important part of the study was an estimate of the base year (1995) population. The study has also associated the population with defined water user categories to facilitate estimating existing and future water requirements. These categories have *inter alia* been defined on the basis of reports on urban water supplies and questionnaires completed by local authorities.

- Macro-economic study

  Economic activity and its effects on the spatial distribution of the population and vice versa is an important determinant of water use. With the ever-increasing need for water for domestic use and protection of the water resources, water availability is already becoming a limiting factor in various regions of the country. The economic viability of continuing to supply water for existing sectors, such as irrigation and also of expanding such activities to satisfy socio-economic aspirations will need careful consideration. A national macro-economic study has therefore been undertaken to provide basic economic data for use in the demographic study and to provide macro-economic overviews for each water management area.

- Formulation and development of a water situation assessment model

  The primary function of the water situation assessment model is to reconcile water supply and water requirements by quantifying the surplus or deficit per catchment area. Water balances are compiled from the quaternary catchment level of resolution of the data, which can then be aggregated to suite any desired predetermined catchment boundaries. The water situation assessment model is nevertheless only a coarse planning tool and does not replace the detailed hydrological studies that are required for basin studies or project investigations.

- Water requirements for the ecological component of the Reserve

  The National Water Act (No. 36 of 1998) requires that water be provided for the Reserve, which is the quantity and quality of water required to satisfy basic human needs and to protect the aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant resource. The ecological sensitivity and importance of the rivers in South Africa and the present ecological status class was therefore established at the quaternary catchment level of resolution, using available data and local knowledge. At the same time the results of previous field assessments of the water requirements of the aquatic ecosystems at selected sites in South Africa were used in a separate study to develop a model for estimating the water required for the ecological component of the Reserve for various ecological management classes that correspond to those determined previously for the rivers throughout the country.

SYNOPSIS

1. INTRODUCTION

1.1 PURPOSE OF THE STUDY

The National Water Act No. 36 of 1998 requires the Minister of Water Affairs and Forestry to establish a national water resource strategy for the protection, use, development, conservation, management and control of water resources. To enable the strategy to be established, information on the present and probable future situations regarding water requirements and water availability is required, that is, a national water resources situation assessment providing information on all the individual drainage basins in the country.

The Department of Water Affairs and Forestry (DWAF) appointed consulting engineers to undertake Water Resources Situation Assessments for the purpose of gathering information and using it to reconcile the present water requirements of all the user sectors with the presently available water resources. The information produced by all the studies will be consolidated by DWAF into a national database which will be used to establish the National Water Resource Strategy. Scenarios of future water requirements and availability are being dealt with in a separate study. These scenarios will be taken up in the National Water Resource Strategy and will be reported on separately for each water management area.

As a component of the National Water Resource Strategy, the Minister of Water Affairs and Forestry has established water management areas and determined their boundaries.

The information gathered in the Water Resources Situation Assessments has been presented in the form of a separate report on each water management area (WMA). This report is in respect of the Olifants/Doring Water Management Area.

1.2 APPROACH TO THE STUDY

The study was carried out at quaternary catchment resolution as a desktop investigation using data from reports and electronic databases, or supplied by associated studies, local authorities and DWAF. The study considered conditions as they were in the year 1995 and did not make projections of future conditions. Data at reconnaissance level of detail was collected on land-use, water requirements, water use, water related infrastructure, water resources and previous investigations of water supply development possibilities. Relevant data was used to calculate the yield of the water resources at development levels as they were in 1995, and the likely maximum yield that could be obtained from future development of these resources. The water balance (the relationship between water requirements and water availability) at selected points in each water management area was also calculated.

Information on urban water use and water related infrastructure was obtained from reports on urban water supplies and from questionnaires filled in by local authorities. The collected data on urban water use was supplied to consultants appointed to carry out a separate national demographic study, in relation to water requirements.

In that study, data from the 1996 census, and other sources, was used to derive demographic information for the whole country for the year 1995. In addition, the information on urban water use that was supplied by the water resources situation assessment studies, was analysed in the demographic study to derive typical unit water requirements. These were used, in conjunction with the demographic data, to estimate water requirements in 1995 for urban areas for which no recorded data was available.

Both the demographic data and the estimated water requirements in 1995, as supplied for the Olifants/Doring WMA by the national demographic study (DWAF, 2000b), are presented in this report. In addition to the separate studies on the water balance model and demography referred to above, separate studies were carried out to provide information on a national basis on :

- Macro-economic aspects
- Legal aspects of water resource management
- Institutional arrangements for water supply
- Effects of alien vegetation on runoff
- Groundwater resources
- Bacteriological contamination of water resources
- Water requirements for irrigation
- Ecological classification of rivers
- Water requirements for the ecological component of Reserve
- Effects of afforestation on runoff
- Storage-yield characteristics of rivers

Information from all the above studies, that is relevant to the Olifants/Doring Water Management Area, is included in the appropriate sections of this report, and is summarised in this synopsis.

2. PHYSICAL FEATURES

The entire Olifants/Doring River drainage basin lies within the boundaries of the water management area, as well as the catchments of the smaller rivers that lie between that basin and the Atlantic Ocean.

The Olifants/Doring Water Management Area is bounded in the north and the east by the Lower Orange Water Management Area and in the south by the Berg, Breede and Gouritz Water Management Areas. It falls partly within the boundaries of the Western Cape Province and partly within the Northern Cape Province, as shown on Figure 2.1.1, which is bound into the back of the report.

The topography is of three distinct types, namely rolling hills and sand dunes in the west along the coastal strip, rugged mountains with peaks rising to about 2 000 m above sea level in the south-western area, and plains and rocky hills in the north-eastern area that are typical of the Western Karoo.

The main rivers are the Olifants and its major tributary, the Doring. The Olifants River rises in the mountains in the south-west which are the source of 46% of the surface water runoff of the WMA. The Doring River has a very large catchment area and, even though much of its catchment is arid, it provides 48% of the total runoff of the WMA. The WMA contains a total of 88 quaternary catchments.

Several rivers flow into the sea to the north and the south of the Olifants River estuary, but they do not make a significant contribution to the water resources of the WMA because their catchment areas are small and the rainfall is low.

The rolling hills and plains of the 30 to 40 km wide strip along the coast from the sourthern boundary of the WMA to the estuary of the Olifants River are known as the Sandveld. The deep sandy deposits that overlie the bedrock in this area provide a significant groundwater resource.

The geology of the area is dominated by sedimentary rocks of the Cape Supergroup, which form the main mountain ranges, and rocks of the Karoo Supergroup, which form most of the eastern and northern areas of the catchment of the Doring River. Sedimentary strata of the Vanrhynsdorp Group occur in the north, with exposures of pre-Cape metamorphic rock in the north-western and north-eastern corners of the area. The coastal plain comprises sandstones of the Malmesbury Formation, overlain by sand and calcrete deposits.

Climatic conditions vary considerably as a result of the variation in topography with minimum temperatures in July ranging from -3ºC to 3ºC and maximum temperatures in January ranging from 39ºC to 44ºC. The area lies within the winter rainfall region, with the majority of rain occurring between May and September each year. The mean annual precipitation is more than 900 mm in the mountains in the south-west, but decreases sharply to about 200 mm to the north, east and west of the mountains, and to less than 100 mm in the far north of the WMA. Average gross mean annual evaporation (as measured by Symons pan), ranges from 1 500 mm in the south-west to more than 2 200 mm in the dry northern parts.

Karoo and Karroid type vegetation, consisting of scrub, bushes and a few grasses, all typically less than 1 m in height, and dwarf trees, occupies some 75% of the WMA. In the north, False Karoo vegetation, which is similar, but contains more grasses, predominates. Sclerophyllous Bush, also referred to as Fynbos, occurs just inland from the coast in the south-western part of the area. Towards the southern boundary of the WMA there are small patches of Temperate and Transitional Forest and Scrub.

The present condition of the river at the outlet of each quaternary catchment was determined in terms of habitat integrity and referred to as the present ecological status class (PESC). The PESC was used to estimate the quantities of water required to maintain the rivers in their present condition. One quaternary catchment in the upper reaches of the Olifants River was determined to be Class A : Unmodified natural, and 14 quaternary catchments of the Doring River were classified as Class B : Largely natural. These catchments all have high ecological flow requirements. The remaining catchments were classified Class C : Moderately modified or Class D : Largely modified, with lower ecological flow requirements.

Both the Olifants River and its tributary, the Doring River are important from a conservation perspective because they contain a number of species of indigenous fish that occur in no other river systems and that are endangered. In addition, reaches of some of the tributaries are virtually unspoiled by human manipulation and are of high to very high ecological importance. The Olifants River estuary is still in a relatively pristine condition and is of high ecological importance.

There are several protected natural areas and Natural Heritage Sites in the Olifants/Doring WMA. It will be important to check at an early stage in the planning of any new development of water resources that none of these sites will be affected, as the viability of the development could be influenced by their presence.

3. DEVELOPMENT STATUS

3.1 HISTORICAL DEVELOPMENT OF WATER RELATED INFRASTRUCTURE

The towns in the Olifants/Doring WMA are all small with the result that, in the early years of their development their water supplies were provided from local sources via infrastructure owned by the municipalities. With a few exceptions, this situation has continued.

The first major infrastructure development was driven by the water requirements of agriculture, when, in 1917, parliament approved the construction of the Bulshoek Barrage and a canal system to irrigate land extending along the Olifants River to close to its mouth. These works were completed in 1923, and in 1935 construction of the Clanwilliam Dam was completed, to make more water available for the scheme. Since then, improvements and extensions to the scheme have been made at intervals. The most recent of these was in 1993, when the capacities of portions of the main canal were increased to enable water to be provided for the Namakwa Sands heavy minerals mine.

With the availability of water from the irrigation canal, the towns along its route also obtained their supplies from the canal when augmentation of their original schemes was needed as a result of growing water requirements.

The towns further away from the canal have continued to rely on their own supplies from local sources, generally groundwater. The exceptions to this are the small towns of Bitterfontein and Nuwerus, which since 1990 have been supplied by the small Southern Namaqualand Government Regional Water Scheme which supplies desalinated groundwater and was implemented because of the severe shortage of suitable sources of water in the area.

3.2 DEMOGRAPHY

A national study to develop water use projections to the year 2025 was undertaken for DWAF by a team of specialists, in order to support the development of the National Water Resource Strategy. This included the development of baseline 1995 population estimates. The work commenced well before the results of the 1996 census became available, and a number of sources were used to develop the baseline data set. The database developed was subsequently reconciled with the results of the census in areas where the census had provided superior information.

Accurate historical population data for the WMA as a whole is not readily available. The reason for this is that the main sources of data are the national population census for which published data are available in terms of magisterial districts. As the boundaries of the latter do not coincide with the boundaries of the WMA, the population of the WMA can only be roughly estimated. Nevertheless, this information can be used to obtain an indication of trends in population growth.

It appears from data extracted from population censuses and published by the Development Bank of Southern Africa in 1991, that the average growth rate of the population in the area between 1980 and 1990 was about 0,5% per year. In most parts of the WMA the urban populations increased at about 0,5% per year and the rural population decreased at between 1% and 2% per year. The exception was the magisterial district of Vredendal where the population of the town of Vredendal grew at 7% per year, to increase from 5 000 to 10 000 people between 1980 and 1990. The rural population in this magisterial district also grew at about 2% per year during the same period.

In 1995, approximately 104 000 people lived in the WMA. About 50 000 of these lived in urban or peri-urban areas, and the rest in rural areas. The population is concentrated in the Olifants River Valley and the Sandveld. Only 30% of the population live in the arid areas of the Doring River Catchment, the catchments of the northern tributaries of the Olifants River, and the Namaqualand coastal catchments, even though these account for 80% of the area of the WMA.

3.3 MACRO-ECONOMICS

Of the total labour force of 58 600 people in 1994, 8,1% were unemployed, which was lower than the national average of 29,3%. Approximately 75% of the labour force was active in the formal economy, and 50% of the formally employed labour force worked in the agricultural sector.

In 1997, the agricultural sector contributed 43,3% of the gross geographic product of the water management area of R1,9 billion. No other economic sector contributed more than 15% (see Diagram 3.3.1). The significance of the agricultural sector can be attributed to the variety of products cultivated in the area, mostly under irrigation. Two of the other more important economic sectors, namely trade and manufacturing, are strongly linked to the agricultural sector because a large proportion of their activities concern the sale or processing of agricultural products.

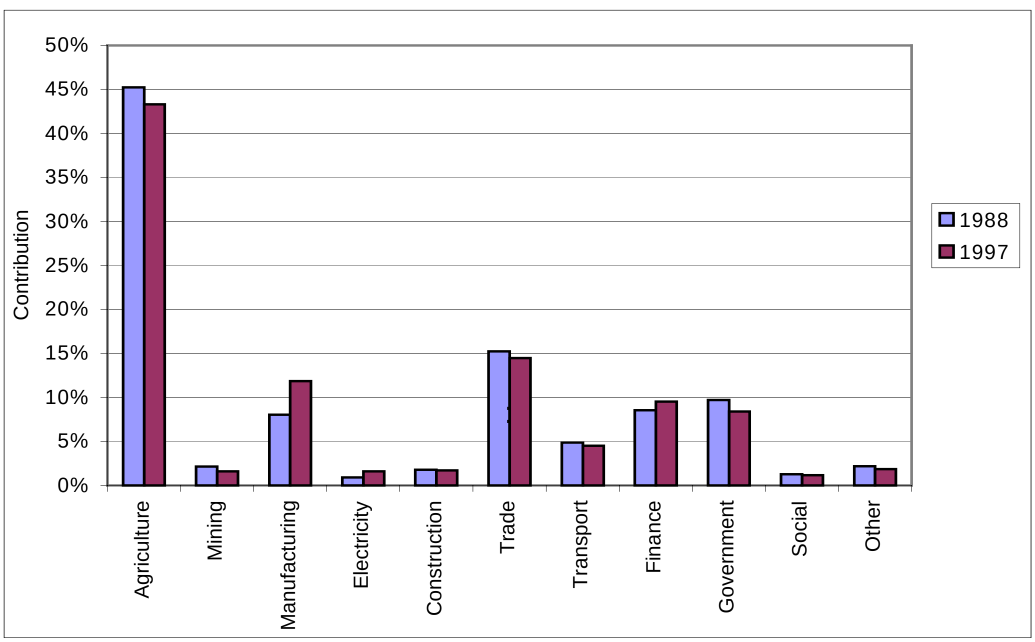

Figure 3.3.1: Contribution by sector to economy of Olifants/Doring Water Management Area, 1988 and 1997 (%)

The agricultural sector showed a growth of 3,7% per annum between 1988 and 1997, indicating that this sector has an important role in the future.

3.4 LEGAL AND INSTITUTIONAL ARRANGEMENTS FOR WATER SUPPLY

The National Water Act (Act No. 36 of 1998) (NWA) was assented to by the President on 20 August 1998. As from 1 October 1999 the whole of the NWA came into full effect and is now the only Act dealing with water law.

The NWA does away with some far-reaching previously existing concepts and introduces new ones. Some of the more important of these relating to the quantity, quality and availability of water resources in the WMA are listed below :

- The riparian principle is done away with and the nation's water resources become common property, belonging to the nation as a whole. Therefore, the previous concept of private ownership of water is done away with.
- Water must be available for the Reserve to satisfy basic human needs and to protect the aquatic ecosystems.
- All right to use water derives from the NWA,
- The emphasis is shifted from the traditional "supply management" approach towards "demand management", that is conservation of the nation's water resources by lessening the demand and providing for an innovative pricing system.
- The NWA regards water use as including, amongst other uses, taking water from a water resource, storage of water, diverting water, discharging waste into a water course, disposing of waste in a manner that may detrimentally impact on a water resource, and recreational use.
- The Minister of Water Affairs and Forestry can declare any activity to be a streamflow reduction activity, if that activity reduces the availability of water. Afforesttion has already been declared a streamflow reduction activity.

There are a number of other acts relating to aspects such as land use, protection of the environment, protection of agricultural resources and restitution of land rights, to which a water user and the State must comply. In addition, there is a close connection between the Water Services Act (Act No. 108 of 1997) and the NWA.

The NWA creates various institutions, including :

- Catchment Management Agencies, which will be responsible for various aspects of the management of the water resources of WMAs,
- Water User Associations, which are co-operative associations of individual water users who wish to undertake water related activities for mutual benefit, and which will operate at a restricted local level, and
- Advisory Committees which may be established for a particular purpose and have powers delegated to them by the Minister of Water Affairs and Forestry.

Irrigation Boards established under the Water Act of 1956 had until 29 February 2000 to transform into Water User Associations.

The Water Services Act provides for the creation of various bodies for the provision of water supply services and sanitation services in a manner consistent with the broader goals of water resource management. Some of these bodies are Water Services Authorities, Water Boards and Advisory Committees.

There are no Water Boards or Advisory Committees in the Olifants/Doring WMA and the municipalities are the Water Services Authorities responsible for water services. The municipalities were restructured in the year 2000. As this report deals with the period prior to that, only the institutional arrangements prior to the re-restructuring are reported on here. Thus, the Water Services Authorities prior to the restructuring were:

- The West Coast District Council
- The Hantam District Council
- The Breede River District Council
- The Central Karoo District Council
- The Namaqualand District Council

Within the District Council areas, Transitional Local Councils were responsible for water services to towns and Transitional Regional Councils were responsible for water services in sub-divisions of the rural areas.

There were four Irrigation Boards in the WMA in 1995.

3.5 LAND-USE

The Olifants/Doring WMA covers an area of approximately 56 500 km^2. The mean annual precipitation over much of the area is less than 200 mm, with the result that, except in the wetter south-west, the climate is not suitable for dryland farming on a large scale. Consequently, more than 90% of the land is used as rough grazing for livestock. There were about 560 000 head of livestock in the WMA in 1995, of which 95% were sheep or goats.

Land use is summarised in Table 3.5.1, where it can be seen that an estimated 2 190 km^2, or approximately 4% of the land area is used for dryland farming. This area is only indicative of the area cultivated, which can be expected to vary considerably from year to year, depending on climatic conditions.

Table 3.5.1 has a column for dryland sugarcane because the cultivation of this crop causes a reduction in the low flows in rivers in areas where it occurs on a large scale. However, sugarcane is not grown on a commercial scale in the Olifants/Doring WMA because the climate is not suitable.

Citrus, deciduous fruits, grapes and potatoes are grown on a large scale in the south-western part of the WMA. It is estimated that a total area of about 467 km^2 of land is under irrigation, but some of this is used only in years when water is plentiful. Consequently, it is estimated that an average area of about 400 km^2 of crops grown under irrigation is harvested.

Commercial timber plantations, totalling 10 km^2 in area, are cultivated in the mountainous high rainfall areas in the south-west of the WMA. Alien vegetation other than afforestation covers a condensed area of 122 km^2.

TABLE 3.5.1: LAND USE BY DRAINAGE AREAS IN km^2

DRAINAGE AREA	IRRIGATION (km^2)	DRYLAND SUGAR CANE (km^2)	OTHER DRYLAND CROPS (km^2)	AFFORESTATION (km^2)	NATURE RESERVES (km^2)	URBAN (km^2)	OTHER (km^2)	TOTAL AREA (km^2)
Kouebokkeveld (E21)	86	0	180	2	121	0	2 683	3 072
Upper Doring (E22)	6	0	20	0	0	0	4 128	4 154
Tankwa (E23)	4	0	30	0	217	0	6 195	6 446
Lower Doring (E24)	16	0	430	0	222	0	6 980	7 648
Oorlogskloof (E4)	4	0	200	0	0	6	2 562	2 722
Sub-total : Doring at confluence with Olifants (E2 + E4)	**116**	**0**	**860**	**2**	**560**	**6**	**22 548**	**24 042**
Upper Olifants (E10)	107	0	450	8	455	3	1 865	2 888
Kromme (E31)	0	0	0	0	0	2	9 717	9 719
Hantams (E32)	3	0	100	0	54	0	4 044	4 201
Lower Olifants (E33)	111	0	170	0	0	12	7 923	8 216
Sub-total : Olifants River at mouth (E1, E2, E3, E4)	**337**	**0**	**1 580**	**10**	**1 069**	**23**	**46 097**	**49 066**
Namaqualand coastal catchments (F6)	0	0	0	0	0	3	2 787	2 790
Sandveld (G3)	130	0	610	0	0	5	3 845	4 590
TOTAL OLIFANTS/DORING WMA	**467**	**0**	**2 190**	**10**	**1 069**	**31**	**52 679**	**56 446**

(1) See the first paragraph of Section 7 for definitions of the drainage areas.

Urban areas are small, covering a total area that is estimated to be 31 km^2. There are a few small rural settlements, but they occupy an insignificant area of land.

Several nature reserves have been proclaimed.

Apart from the Namakwa Sands heavy minerals mine on the coast in the north-western corner of the WMA, mining operations are small and are concerned mainly with quarrying, or with dredging for marine diamonds.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

Industries in the WMA are small and the majority of them are concerned with the processing of agricultural products.

The only powerstation is a small hydro-electric installation at Clanwilliam Dam which supplies electricity to the town of Clanwilliam.

3.7 MINES

The only major mine in the area is the Namakwa Sands heavy minerals mine which is situated on the coast in the north-west of the WMA and has a water supply from the Olifants River canal. There are also several quarrying operations in the vicinities of Vredendal and Vanrhynsdorp.

4. WATER RELATED INFRASTRUCTURE

The main development in the Olifants/Doring WMA is along its western portion in the vicinity of the Olifants River valley, with the result that this is where the main water related infrastructure occurs. This is in the form of the Olifants River (Vanrhynsdorp) Government Water Scheme which supplies water for irrigation, urban, industrial and mining use to an area that extends northwards from Clanwilliam Dam, the source of the water, for some 130 km to the Namakwa Sands Mine on the coast at Brand-se-Baai.

A second state owned water supply scheme, the Southern Namakwaland Government Water Scheme, supplies water from boreholes to the small towns of Bitterfontein and Nuwerus. The towns that are not supplied from the state owned schemes have their own municipal supplies from local surface or groundwater sources.

Roughly half of the population lives in urban areas and the other half lives on farms or in small rural settlements. It appears that about 10% of the rural population obtains potable water from the town schemes. The remainder appears to rely mainly on boreholes which are either privately owned or communal ones that were owned by the District Councils in 1995.

There are also a large number of privately owned small irrigation schemes :

- In the Koue Bokkeveld and the upper reaches of the Olifants River numerous small farm dams have been constructed for the irrigation of fruit and vegetables.
- Also in the upper Doring River catchment, approximately 2,5 million m^3/a of water is imported by canal from diversion weirs in the Breede WMA.

- At the confluence of the Tankwa and Doring Rivers water is abstracted from the Doring River for the irrigation of 350 ha of land from the water works of the Elandskaroo Irrigation Board.
- The Oudebaaskraal Dam on the Tankwa River supplies water to approximately 320 ha of land.
- Along the Olifants River there are numerous small private schemes with various abstraction systems, including pumping stations and small diversion weirs and canals. There were three irrigation districts in the area in 1995, namely Citrusdal, Clanwilliam and Vredendal.

Information on the capacities of state and municipal potable water supply schemes is summarised in Table 4.1.

TABLE 4.1: COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES IN 1995 BY DRAINAGE AREA

DRAINAGE AREA (1)	AREA (km^2)	POPULATION	TOWN AND REGIONAL WATER SUPPLY SCHEMES			
			Number of People Supplied	% of Drainage Area Population	CAPACITY	
					(million m^3/a)	(ℓ/c/d)
Upper Olifants	2 888	17 600	8 150	46	2,45	823
Doring	21 350	15 900	0	0	0	0
Lower Olifants	22 169	38 600	30 850	80	6,67	592
Oorlogskloof	2 722	9 200	8 150	89	0,36	121
Namaqualand Coastal Catchments	2 790	3 600	2 650	73	0,07	72
Sandveld	4 527	18 800	11 460	61	1,33	331
TOTALS FOR WMA	56 446	103 700	61 260	59	10,88	486

(1) See the first paragraph of Section 7 for definitions of drainage areas.

Reliable data on population, capacities of water supply schemes, and the number of people supplied was not available. Therefore, the information shown in Table 4.1 should be regarded as indicative only of the true situation.

Table 4.1 shows the average availability of water to those supplied by town and regional schemes to be 486 ℓ/c/d. However, in 1995 the adequacy of supplies to individual towns varied widely from a low availability of 43 ℓ/c/d in Graafwater to a high of 712 ℓ/c/d in Vredendal and Vanrhynsdorp. As far as bulk supplies are concerned, the availability of water in all towns exceeds the Reconstruction and Development Programme minimum standard of 25 ℓ/c/d.

Information similar to that presented in Table 4.1, but disaggregated on a provincial basis, is shown in Table 4.2. As in the case of Table 4.1, the reliability of the data is not high.

Information on the main dams in the water management area is given in Table 4.3. Clanwilliam Dam and Bulshoek Barrage are state owned dams that are the storage components of the Olifants River (Vanrhynsdorp) Government Water Scheme. Oudebaaskraal Dam is privately owned and used for irrigation. Its yield is not known.

TABLE 4.2: COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES BY PROVINCE AND DISTRICT COUNCIL AREAS

PROVINCE	DISTRICT COUNCIL AREA	AREA (km^2)	POPULATION	OWN AND REGIONAL WATER SUPPLY SCHEMES			
				Number of People Supplied	% of Population	CAPACITY	
						(million m^3/a)	(ℓ/c/d)
Western Cape	West Coast	348	75 100	51 200	68	10,45	560
	Breede River	56	12 800	0	0	0,00	0
	Central Karoo	581	200	0	0	0,00	0
TOTAL FOR WESTERN CAPE		685	88 100	46 800	53	10,45	612
Northern Cape	Namaqualand	3 508	400	0	0	0,00	0
	Hantam	22 253	15 200	10 050	66	0,43	117
TOTAL FOR NORTHERN CAPE		25 761	15 600	10 050	64	0,43	117
TOTAL FOR WMA		56 446	103 700	61 260	59	10,88	486

TABLE 4.3: MAIN DAMS IN THE OLIFANTS/DORING WMA

NAME	LIVE STORAGE CAPACITY (million m^3/a)	APPROXIMATE ALLOCTION OF 1:50 YEAR YIELD IN 1995			TOTAL (million m^3/a)	OWNER
		DOMESTIC SUPPLIES (million m^3/a)	IRRIGATION (million m^3/a)	MINING/ INDUSTRY (million m^3/a)		
Clanwilliam Dam	122	6	145	4	155	DWAF
Bulshoek Barrage	5,7					DWAF
Oudebaaskraal Dam	34,0	0	Not known	0	Not known	Private

The Olifants River Government Water Scheme supplies raw water from the Clanwilliam Dam to farmers, municipalities, mines and industries in the Olifants River valley between the dam and the river estuary. Water is released from Clanwilliam Dam into the river to flow to Bulshoek Barrage, some 30 km downstream.

Farmers with land between the dam and the barrage are not scheduled under the scheme but abstract 18 million m^3/a of compensation water from the releases by pumping directly from the river. Downstream of the barrage water is distributed by a canal system consisting of main and distribution canals totaling 186 km in length.

The canal system supplies water to 11 500 ha of irrigated land, which is used mainly for growing grapes. It also supplies raw water for domestic and industrial use to the towns of Vredendal, Lutzville, Vanrhynsdorp, Klawer, Ebenhaezer, Strandfontein and Doringbaai, and to the Namakwa Sands Mine and, in small quantities, to several wine cellars and a number of small mining activities.

The 1:50 year yield of Clanwilliam and Bulshoek Dams combined is 155 million m^3/a. A quantity of 28 million m^3/a is used for irrigation (27 million m^3/a) and urban requirements (1 million m^3/a), in the area between Clanwilliam and Bulshoek Dams, leaving 127 million m^3/a at 1:50 year assurance for use further downstream.

Water allocations from the canal system downstream of Bulshoek in 1995 were about 225 million m^3/a, including 28% canal conveyance losses. Domestic mining and industrial allocations downstream of Bulshoek totalled about 9 million m^3/a, including canal losses, and the rest was for irrigation.

It is apparent that the allocations are considerably greater than the yield of the dams. Consequently, irrigation supplies are frequently curtailed to less than the full allocations. Clanwilliam Dam is operated at a draft that exceeds its 1:50 year yield and is drawn down to between 5% and 20% of its full supply capacity in most years. As its capacity is only 33% of the present day mean annual runoff, it fills during the wet winter months in most years. The approximate distribution of yield between user sectors in 1995 is shown in Table 4.1.3. The quantities include conveyance losses.

5. WATER REQUIREMENTS

Water requirements in the WMA totalled an estimated 589 million m^3/a in 1995, distributed amongst user groups and the ecological Reserve as shown in Table 5.1.1. The major user group was agriculture, which, at 442 million m^3/a, accounted for 96% of total consumptive water requirements (i.e. excluding the requirements of the ecological Reserve and hydropower). The next biggest requirement was the ecological Reserve which provides the 127 million m^3/a of water estimated to be needed to sustain the riverine ecosystem. Hydropower generation at Clanwilliam Dam used a substantial 75 million/a, but this is a secondary use from water that is released from the dam through the turbine on its way to being used for other purposes downstream and is not, therefore, included in the total requirements. Urban and domestic water use was small at 11 million m^3/a, and the remaining groups of mining (shown as bulk water use in Table 5.1.1), alien vegetation and afforestation used only small quantities of water.

The values shown in Table 5.1.1 include conveyance and distribution losses, where applicable, and have not had return flows that are re-used further downstream deducted from them. Therefore, they represent estimates of gross water requirements.

It should be noted that, because of the limited availability of reliable data, the level of confidence in the estimates is not high. Values are given to one decimal place only for ease of correlation with other more detailed tables.

The agricultural water requirements shown in Table 5.1.1 represent both irrigation and livestock watering requirements, but livestock accounted for only 1,8 million m^3/a.

The requirements at 1:50 year assurance are equivalent requirements. They are presented in this way to bring quantities of water that are required at different assurances of supply by consumers to a common base for purposes of comparing water requirements with the available yield at the same assurance of supply.

TABLE 5.1.1: WATER REQUIREMENTS PER USER GROUP IN 1995

USER GROUP	ESTIMATED WATER REQUIREMENT (million m^3/a)	EQUIVALENT REQUIREMENTS AT 1:50 YEAR ASSURANCE (million m^3/a)
Ecological Reserve [(5)]	126,9	14,3
Domestic [(1)]	10,7	10,7
Bulk water use [(4)]	4,2	4,2
Neighbouring States	0	0
Agriculture [(2)]	442,5	354,4
Afforestation	1,5	0,8
Alien vegetation	3,4	0,9
Water transfers [(3)]	0	0
Hydropower	(75,0)	(75,0)
TOTALS	589,2	385,3

(1) Includes urban and rural domestic requirements and commercial, institutional and municipal requirements.
(2) Includes requirements for irrigation, dry land sugar cane, livestock and game.
(3) Only transfers out of the WMA are included.
(4) Includes industries and mines supplied individually by DWAF.
(5) At outlet of WMA in 1995. The requirement at 1:50 year assurance would increase if more dams were constructed.

Domestic water requirements and the drinking water requirements of livestock have been assumed to be supplied at 1:50 year assurance under normal conditions. The assurances at which water for irrigation is required have been assumed to vary with the commercial value of the crops irrigated. This accounts for the smaller requirement at 1:50 year assurance for agriculture in Table 5.1.1.

The estimated water requirement for the ecological Reserve shown in Table 5.1.1 is the average volume of water that needs to be allowed to flow into the sea from the WMA to maintain the Present Ecological Status Class, that is Class D : Largely modified, for the Olifants River and Class C : Moderately modified for the other rivers. The requirement at 1:50 year assurance is the impact of the Reserve requirement on the 1:50 year yield of the water resources as developed in 1995. It is much lower than the average volume of water required because the rivers in most of the water management area that are not regulated by dams, have no 1:50 year yield. Consequently, the ecological Reserve would have no impact on the yields of these river reaches. Thus, the 1:50 year requirements of the ecological Reserve shown in Table 5.1.1 are the estimated impact of those requirements on the utilisable yield in 1995 of only the upper Olifants River and the Tankwa River. The estimate is at a low level of confidence and requires further investigation of ecological flow requirements and their impact on yield, to verify it.

Similarly, the estimated requirements for afforestation and alien vegetation are the reductions that they cause in mean annual runoff, while the requirements at 1:50 year assurance are their impacts on the utilisable yield in 1995.

6. WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

It has been estimated from the data provided in the Water Research Commission publication, "The Surface Water Resources of South Africa, 1990" (Midgley *et al*, 1994) that, under virgin conditions, the total mean annual runoff (MAR) of the Olifants/Doring WMA was 1 108 million m^3. Approximately 95% of this, or 1 047 million m^3, flowed out to sea through the mouth of the Olifants River.

The remainder of the natural runoff, totalling 61 million m^3/a on average, came from the catchments comprising the coastal strips to the north and south of the Olifants estuary. The contribution of the northern coastal strip to this was only about 1 million m^3/a, because the area is very arid.

The natural runoff has been reduced by evaporation losses from the surfaces of dams, the use of water and, to a small extent, by the effects of timber plantations and alien vegetation. As a result, the present day MAR at the Olifants estuary is estimated (DWAF 1998c) to be about 690 million m^3. The reduction in runoff from the coastal catchments has been less severe, and their present day MAR is probably about 55 million m^3. Thus, the total present day MAR is estimated to be 745 million m^3, which is 67% of the natural MAR. Most of the runoff occurs during the winter months and, with the exception of the upper Olifants River catchment, little or no water can be obtained from run-of-river flow during the summer months, when there is a high demand for water for irrigation. Consequently, two major dams (Clanwilliam and Bulshoek) and about 210 farm dams have been constructed in the WMA. It is estimated that, as a result of this development, a yield of 289 million m^3/a can be obtained from the surface water resources under 1:50 year drought conditions. The distribution of this yield amongst the catchments making up the WMA is shown in Table 6.1 as the "1:50 year developed yield in 1995".

Several sites at which dams could be constructed have been identified in previous studies. If more large dams were constructed at these sites, the yield available from surface water at 1:50 year assurance could be increased to an estimated maximum of approximately 531 million m^3/a.

The yields shown in Table 6.1 are those available before the ecological Reserve has been provided for. As the National Water Act (No. 36 of 1998) provides for the Reserve to take preference over water users in the allocation of water resources, the yield available for the user sectors is less than the totals shown in Table 6.1. However, it has been estimated, as described in Section 5 above, that the effect of making releases for the ecological Reserve, once the details of the releases have been determined, will be to reduce the 1:50 year yield available for water users at 1995 levels of water resource development by only about 14 million m^3/a.

The base flow in rivers originates from seepage from groundwater. Therefore, where boreholes extract water from the same groundwater source, the surface water base flow is reduced by the quantity of water abstracted from the boreholes. However, in areas where the nature of the topography or the climate make it impractical to develop surface water resources on a large scale, groundwater may be the more important component of the water resources.

TABLE 6.1: WATER RESOURCES

CATCHMENT [1]						SURFACE WATER RESOURCES (million m³/a)			SUSTAINABLE GROUNDWATER EXPLOITATION POTENTIAL (million m³/a)		TOTAL WATER RESOURCE (million m³/a)	
PRIMARY		SECONDARY		TERTIARY		CUMU-LATIVE NATURAL MAR	1:50 YEAR DEVELOPED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD	DEVELOPED IN 1995	TOTAL POTENTIAL [2]	1:50 YEAR DEVELOPED IN 1995	1:50 YEAR TOTAL POTENTIAL [2]
No.	Description	No.	Description	No.	Description							
E		E1	Upper Olifants	None	---	511	214	325	3,8	88,1	217,8	328,8
		TOTAL IN UPPER OLIFANTS				**511**	**214**	**325**	**3,8**	**88,1**	**217,8**	**328,8**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	278	60	60	5	52,3	65,0	65
				E22	Upper Doring (W Cape)	40	4	80	0,0	16,6	4,0	80,0
					Upper Doring (N Cape)	319	0	0	0,0	1,2	0	0
				E23	Tankwa (W Cape)	35	5	5	0,2	18,3	5,2	18,3
					Tankwa (N Cape)	36						
				E24	Lower Doring (W Cape)	507	0	55	1,4	58,8	1,4	58,8
					Lower Doring (N Cape)	447						
			Sub-total (Western Cape)			**507**	**69**	**200**	**6,6**	**147,2**	**75,6**	**222,1**
			Sub-total (Northern Cape)			**447**						
		E4	Oorlogskloof (W Cape)	None		27	0	0	0	3,5	0	3,5
			Oorlogskloof (N Cape)	None		20	1	1	1,8	16,3	2,8	16,3
			Sub-total (Western Cape)			**27**	**0**	**0**	**0**	**3,5**	**0**	**3,5**
			Sub-total (Northern Cape)			**20**	**1**	**1**	**1,8**	**16,3**	**2,8**	**16,3**
			TOTAL IN DORING CATCHMENT IN WESTERN CAPE			534	-	-	-	-	-	-
			TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE			467	-	-	-	-	-	-
			TOTAL IN DORING CATCHMENT			**534**	**70**	**201**	**8,4**	**167,0**	**78,4**	**241,9**
		E3	Lower Olifants	E31	Kromme (All N Cape)	6	0	0	0,3	8,7	0,3	8,7
				E32	Hantams (All N Cape)	12	0	0	1,0	18,7	1,0	18,7
				E33	Lower Olifants (W Cape)	1 047	0	0	1,9	17,0	1,9	17,0
					Lower Olifants (N Cape)	1	0	0	0	0,3	0	0,3
			Sub-total (Western Cape)			**1 047**	**0**	**0**	**1,9**	**17,0**	**1,9**	**17,0**
			Sub-total (Northern Cape)			**19**	**0**	**0**	**1,3**	**27,7**	**1,3**	**27,7**
			TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE			1 047	-	-	-	-	-	-
			TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE			486	-	-	-	-	-	-
			TOTAL IN OLIFANTS CATCHMENT			**1 047**	**284**	**526**	**15,4**	**299,8**	**299,4**	**615,4**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		1	0	0	0,4	3,8	0,4	3,8
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**1**	**0**	**0**	**0,4**	**3,8**	**0,4**	**3,8**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		60	5	5	30,1	78,0	35,1	78,0
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**60**	**5**	**5**	**30,1**	**78,0**	**35,1**	**78,0**
TOTAL IN WMA IN WESTERN CAPE						1 108	-	-	-	-	-	-
TOTAL IN WMA IN NORTHERN CAPE						486	-	-	-	-	-	-
TOTAL IN WMA						**1 108**	**289**	**531**	**45,9**	**381,6**	**334,9**	**697,2**

(1) See the first paragraph of Section 7 for definitions of catchment areas.
(2) The effects of high salinities in groundwater have not been allowed for. It may not be economically viable to develop the full groundwater potential where desalination is required to bring the water to a potable standard.

In an assessment of the extent to which the groundwater resources are additional to the surface water resources of the Olifants/Doring WMA it was concluded that, as a rough approximation, groundwater resources and surface water resources should be assumed to be linked. It has, however, also been assumed that the surface water yields determined for development in 1995 made allowance for the effects on surface water runoff of groundwater use as it was in 1995. Therefore, in Table 6.1, the total water resource developed in 1995 is the sum of the developed surface water and groundwater yields. The total potential water resource includes, in addition to the surface and groundwater development in 1995, all potential additional surface water resource developments that comprehensive separate detailed studies have shown to be economically viable. The development of groundwater potential that was not developed in 1995 has been added only in those areas where the groundwater potential is greater than the surface water potential.

The total developed water resource in 1995 was estimated to have a yield at 1:50 year assurance of 335 million m^3/a (289 million m^3/a from surface water and 46 million m^3/a from groundwater). The total potential yield at 1:50 year assurance is estimated to be 697 million m^3/a. The approximate contributions to the yields of areas of land within the Western Cape Province and the Northern Cape Province are shown in Table 6.1, where this is possible.

6.2 WATER QUALITY

The mineralogical quality of both surface water and groundwater was classified in terms of total dissolved salts (TDS). Water quality within the WMA is quite variable. Concentrations of salts are generally low in both surface water and groundwater in the upper Olifants River catchment and in the south-western portion of the Doring River catchment where the geology consists of strata of the Table Mountain Group. In most of the rest of the Doring River catchment the geology consists of strata of the Karoo Supergroup which cause higher salinities in both surface water and groundwater, and higher levels of total suspended solids, consisting mostly of clay particles, in surface water.

There was insufficient data for surface water quality to be assessed in the northern portion of the Olifants River catchment, and in the Namaqualand coastal catchments. The groundwater in these areas is generally high in dissolved salts, and it is estimated that about 50%, on average, of the groundwater that could be abstracted would not be of potable standard. There is a trend of deteriorating groundwater quality from south to north and there are large areas in the northern part of the WMA where it is unlikely that any of the groundwater is of potable standard because of the high salinity of the geological strata. In the Sandveld area, groundwater is highly saline close to the coast, but improves further inland where more than 85% of the exploitable groundwater is expected to be of potable standard. There is too little data on surface water for an accurate assessment to be made, but the indications are that it follows the same pattern as the groundwater in terms of salinity.

An assessment of the risk of microbial contamination of the surface and groundwater resources of the WMA resulting from human and animal wastes indicated that there is a high risk for the coastal aquifers in the south-west of the WMA and a medium risk for groundwater in the upper reaches of the Tankwa and Olifants Rivers, and in parts of the Oorlogskloof River catchment. Elsewhere the risk to groundwater is low. The risk of contamination of surface water appears to be low throughout the WMA, but data is incomplete.

6.3 SEDIMENTATION

Regional data on the potential for sediment accumulation in dams indicates that it is low in the Olifants River catchment upstream of its confluence with the Doring River (an accumulation of less than 1% of MAR in a 25 year period), and high in the central part of the Doring River catchment and in the northern part of the WMA (more than 50% of MAR in a 25 year period). The potential elsewhere is low to moderate (2% to 25% of MAR in a 25 year period).

7. WATER BALANCE

For purposes of considering the water balance situation in the WMA, a number of key points were selected. These are either the outlets of drainage areas that are the catchments of the main tributaries of the Olifants River or groupings of several minor catchments. The catchment areas upstream of the key points are shown in Table 7.1. The catchment numbers shown in the table refer to the numbering system used to divide the WMA into hydrological sub-catchments. The numbered sub-catchments are shown on Figure 2.1.3 which is bound into the back of this report.

The water balance has been calculated on the basis of the 1:50 year yield of the water resources. The results are shown in Table 7.1 where the 1:50 year developed yield in 1995 is compared with the equivalent water requirements at 1:50 year assurance. It can be seen that, for the WMA as a whole, the requirements exceed the yield plus imports and re-usable return flows by approximately 40 million m^3/a.

The main shortages of water occur in the upper Olifants River catchment where there is a shortfall of 29 million m^3/a and in the lower Olifants where the shortfall is 11 million m^3/a. There is also a shortfall of about 5 million m^3/a in the lower Doring catchment, which is 70% of the requirements in that catchment, and there are small shortfalls indicated in the Oorlogskloof catchment and the Sandveld.

The other areas are either balanced, or show slight surpluses. The surpluses in the upper Doring and Tankwa River areas, although fairly small in quantity, are large relative to the estimated water requirements in those areas. This may indicate that surface water yields have been over-estimated, or that the irrigation water use has been under-estimated.

8. COSTS OF WATER RESOURCE DEVELOPMENT

Costs of developing the surface water resources of the Olifants/Doring River Catchment to provide an additional 242 million m^3/a of yield were estimated in the Olifants/Doring River Basin Study (DWAF, 1998e) and were converted to equivalent costs in the year 2000.

The costs include costs of conveyance structures for delivering the water to the areas where it would probably be used.

The schemes have been selected to give an indication of the cost of developing the surface water resources, but, in practice, different combinations of dam sizes, or other dam sites, such as the Rosendal site in the upper Olifants River catchment might be used.

TABLE 7.1: WATER REQUIREMENTS AND AVAILABILITY IN 1995

CATCHMENT						AVAILABLE 1:50 YEAR YIELD IN 1995			WATER TRANSFERS AT 1:50 YEAR ASSURANCE		RETURN FLOWS AT 1:50 YEAR ASSURANCE		WATER REQUIREMENTS AT 1:50 YEAR ASSURANCE (1) (million m^3/a)	YIELD BALANCE (2) AT 1:50 YEAR ASSURANCE (million m^3/a)
PRIMARY		SECONDARY		TERTIARY		SURFACE WATER (million m^3/a)	GROUNDWATER NOT LINKED TO SURFACE WATER (million m^3/a)	TOTAL (million m^3/a)	IMPORTS (million m^3/a)	EXPORTS (million m^3/a)	RE-USABLE (million m^3/a)	TO SEA (million m^3/a)		
No.	Description	No.	Description	No.	Description									
E	Olifants	E1	Upper Olifants	None	---	214	3,8	217,8	0	127,0	6,0	0	126,0	-29,2
		TOTAL IN UPPER OLIFANTS				**214**	**3,8**	**217,8**	**0**	**127,0**	**6,0**	**0**	**126,0**	**-29,2**
		E2	Doring	E21	Kouebokkeveld	60	5,0	65,0	0	0	3,0	0	66,0	+ 2
				E22	Upper Doring	4	0,0	4,0	1,5	0	0	0	1,8	+3,7
				E23	Tankwa	5	0,2	5,2	0	0	0	0	3,6	+1,6
				E24	Lower Doring	0	1,4	1,4	0,6		0		6,7	-4,7
			Sub-total			**69**	**6,6**	**75,6**	**2,1**	**0**	**3,0**	**0**	**78,1**	**+2,5**
		E4	Oorlogskloof	None		1	1,8	2,8	0	0	0,2	0	3,6	-0,6
		TOTAL IN DORING CATCHMENT				**70**	**8,4**	**78,4**	**2,1**	**0**	**3,2**	**0**	**81,7**	**+2,0**
		E3	Lower Olifants	E31	Kromme	0	0,3	0,3	0	0	0	0	0,2	+0,1
				E32	Hantams	0	1,0	1,0	0	0	0	0	1,0	0
				E33	Lower Olifants	0	1,9	1,9	127,0	2,5	0	13	137,8	-11,4
			Sub-total			**0**	**3,2**	**3,2**	**127,0**	**2,5**	**0**	**13**	**139,0**	**-11,3**
		TOTAL IN OLIFANTS CATCHMENT				**284**	**15,4**	**299,4**	**1,5**	**1,9**	**9,2**	**13**	**346,7**	**-38,5**
F (Part)	Namaqualand Catchments	F6	Goerap	None		0	0,4	0,4	1,5	0	0	0	1,9	0
G (Part)	Berg (Part)	G3	Sandveld	None		5	30,1	35,1	0,4	0	0	0,2	36,7	-1,2
		TOTAL IN WMA				**289**	**45,9**	**334,9**	**1,5**	**0**	**9,2**	**13,2**	**385,3**	**-39,7**

(1) To avoid double accounting, water exports within the WMA are not included in the "Water Requirements" column. Water losses and water exports from the WMA are included.
(2) Surplusses indicated by a+ and deficits by a-.

The cost estimates are based on development of the infrastructure components listed below :

- A new 330 million m^3 capacity dam at Grootfontein with a yield of 90 million m^3/a.
- Additional capacity of 25 million m^3 at Clanwilliam Dam to increase the yield by 11 million m^3/a.
- Additional farm dams with a yield of 10 million m^3/a, and an estimated capacity of 14 million m^3 in the upper Olifants catchment.
- A new 395 million m^3 capacity dam at Aspoort with a yield of 76 million m^3/a.
- A new 388 million m^3 capacity dam at Melkboom with a yield of 50 million m^3/a.
- Additional farm dams with a yield of 5 million m^3/a and an estimated capacity of 8 million m^3 in the lower Doring catchment.

These developments would increase the developed yield of the surface water resources from 289 million m^3/a in 1995 to the estimated total potential of 531 million m^3/a, at a cost of approximately R1 800 million m^3/a, inclusive of VAT.

The remaining potential yield of 166 million m^3/a of the estimated total potential of 697 million m^3/a is from groundwater. A groundwater yield of 46 million m^3/a was developed in 1995, leaving 120 million m^3/a to be developed to reach the full potential. The cost of developing this potential was estimated to be R578 million inclusive of VAT.

Thus, the additional cost of developing the water resources to their full potential of 695 million m^3/a is estimated to be R2 386 million, inclusive of VAT, at year 2000 price levels.

There may also be opportunity for developing deep Table Mountain Group groundwater aquifers in the upper Olifants River valley and for storing surface water in groundwater aquifers to the south of the lower Olifants River. As the feasibility of these developments is still being investigated they have not been included in the above estimates.

9. CONCLUSIONS AND RECOMMENDATIONS

In this section the main conclusions that can be drawn from the information gathered in this situation assessment are listed, followed by a discussion of requirements for additional data and, finally, recommendations on the actions needed to obtain the additional data.

The main conclusions are :

(i) The Olifants/Doring WMA covers an area of 56 446 km^2 in which the mean annual precipitation ranges from 100 mm in the far north to above 900 mm in the mountains in the south.

(ii) The geology of the WMA consists of Karoo sediments in the east, sedimentary rocks of the Cape Supergroup in the west, and sedimentary strata of the Vanrhynsdorp Group in the north, with exposures of pre-Cape metamorphic rock in the north-western and north-eastern corners of the WMA. The mountains in the southern central part of the area are composed of rocks of the Table Mountain Group, which in general give surface water and groundwater of good quality. In the areas where Karoo and Vanrhynsdorp sediments occur, base flows in the rivers are generally saline. There is a trend of deteriorating groundwater quality from south to north in the WMA, and there are large areas in the northern parts where it is unlikely that any of the groundwater is of potable standard because of the high salinity of the geological strata.

(iii) The present ecological status of the uppermost reaches of the Olifants River is Class A : unmodified natural, and of very high ecological importance. Consequently, the ecological flow requirements are high. The tributaries of the Doring River on the eastern slopes of the Cederberg, the lower portion of the Oorlogskloof River and the upper reaches of the Kromme and the Hantams Rivers, along the north-eastern edges of the WMA are classified as Class B : largely natural, and are of high ecological importance and sensitivity, with correspondingly high ecological flow requirements. The other rivers are classified as moderately or largely modified, with lower ecological flow requirements.

(iv) The population of the WMA in 1995 was approximately 104 000 people, of whom 50 000 lived in the towns.

(v) Much of the economic activity is concentrated in the south-western portion of the WMA, with the Vredendal, Ceres and Clanwilliam areas contributing 75% of the GGP in 1997. The GGP of the whole WMA was R1,6 billion in 1997, with the most important economic sectors, in terms of their contributions to GGP, being Agriculture (43,3%), Trade (14,5%) and Manufacturing (11,8%).

(vi) Land-use is predominantly for rough grazing for livestock. Some 467 km^2, or 0,8% of the surface area of the WMA is used for irrigated crops, but only about 85% of the area is irrigated in average years, with larger areas irrigated occasionally when rainfall is favourable in the semi-arid areas. Dryland crops, mainly in the south-eastern part of the WMA, are grown on an estimated 2 190 km^2, and nature reserves occupy 1 069 km^2. The area of land under afforestation is small at 10 km^2, and alien vegetation, other than afforestation, covers an equivalent condensed area of 122 km^2.

(vii) There were about 560 000 head of livestock in the WMA in 1995. Sheep and goats made up 94% of the livestock numbers, with cattle, horses and pigs comprising most of the remainder.

(viii) Water related infrastructure is well developed, particularly in the south-western part of the WMA, where most of the water requirements occur.

(ix) Town bulk water supply schemes were generally adequate in 1995, but the requirements of some of the isolated towns that rely on local sources were approaching the scheme capacities and supplies are likely to require augmentation soon.

(x) Allocations of water for irrigation, urban, industrial and mining use from the Olifants River (Vanrhynsdorp) Government Water Scheme exceed the 1:5 year yield of the scheme by a considerable amount, with the result that only a portion of irrigation quotas is supplied in drier years.

(xi) Water requirements in 1995 in the WMA as a whole were estimated to total 462 million m^3, excluding the requirements of the ecological Reserve, but including water use by afforestation and alien vegetation. The major water user sector was agriculture, which required 442 million m^3/a, or 96% of the total consumptive requirement (i.e. excluding the ecological Reserve). The next biggest water user was the urban and rural domestic sector, at 2% of the total consumptive requirement, followed by bulk water use of industry and mining (1%), alien vegetation (0,7%) and afforestation (0,3%). With the requirements of the ecological Reserve added, the total water requirement becomes 589 million m^3/a.

(xii) The equivalent water requirement at 1:50 year assurance, with the requirements of the ecological Reserve and water use by alien vegetation and afforestation all included as impacts on yield, was 385 million m^3/a. The estimates of the impacts on yield are at a low level of confidence.

(xiii) The natural MAR of the Olifants/Doring WMA was 1 108 million m^3 and the yield developed from surface water resources in 1995 was 289 million m^3/a at 1:50 year assurance. Some 53% of the developed yield was from major dams (Clanwilliam Dam and Bulshoek Barrage) and 47% was from farm dams and run-of-river yield. In addition, boreholes with an estimated yield of 46 million 3m/a had been developed, bringing the total developed yield to 335 million m^3/a at 1:50 year assurance.

(xiv) Comparison of the equivalent 1:50 year assurance water requirements of 385 million m^3/a with the developed yield of 335 million m^3/a shows a deficit of 50 million m^3/a, but re-usable return flows of 9 million m^3/a and water imports of 1,5 million m^3/a reduce the deficit to approximately 40 million m^3/a. The main shortages of water occur in the Upper Olifants River catchment, where there is a deficit of 29 million m^3/a, and in the Lower Olifants Catchment, where the deficit is 11 million m^3/a. There is also a deficit of about 5 million m^3/a in the Lower Doring River catchment and there are small deficits in the Oorlogskloof catchment and the Sandveld. The other areas are either balanced or show slight surpluses.

(xv) Conveyance losses in the Olifants River Canal system are 28% of the quantity conveyed in the canals. The conveyance losses are more than three times the deficit in water availability at 1:50 year assurance that occurs in the area supplied by the canals. It is clear that there is scope for improving the situation through the application of appropriate water conservation measures.

(xvi) The maximum potential yield of the water resources of the WMA is estimated to be 697 million m^3/a at 1:50 year assurance, which is 362 million m^3/a more than the developed yield in 1995. It is estimated that 67% of the undeveloped potential yield could be obtained from surface water and the rest from diffuse groundwater developments mainly in the arid northern part of the WMA and in the Sandveld.

(xvii) There may be an opportunity for developing deep Table Mountain Group groundwater aquifers in the upper Olifants River valley and for storing surface water in groundwater aquifers to the south of the lower Olifants River, but the feasibility of these developments is still being investigated. Therefore they have not been included in the above estimates.

(xviii) The groundwater studies showed that, because of the high salinity of the groundwater in many parts of the WMA, only 27%, on average, of the groundwater exploitation potential is likely to be of potable standard. The estimates of maximum potential yield given in (xvi) above do not take this into account and it is apparent that the economic viability of developing the maximum potential groundwater yield may be adversely affected by poor water quality and the resulting need to desalinate the water to make it fit for use.

(xix) The capital cost of developing the full potential yield of the water resources was roughly estimated to be R2 386 million, inclusive of VAT, at year 2000 price levels. This included R578 million for groundwater development, but this amount did not allow for the cost of desalinating groundwater where required to bring it to a potable standard.

In the course of gathering information for this study, the available data on the following aspects have been found to be inadequate :

- Ecological Reserve requirements of both rivers and estuaries and their impact on the available yield of the water resources.
- The extent of alien vegetation and its impact on the yield of the water resources.
- The extent and distribution of irrigated agriculture in the Upper Doring River catchment and the associated water requirements (the yield balance showed excess yield of nearly 4 million m^3/a to be available, part of which is provided by water imported from the Breede WMA).
- The extent and distribution of irrigated crops in the Sandveld area, as well as the quantity of water required and the extent of the groundwater resource that is being used for irrigation.

In the present situation, the main importance of the ecological Reserve requirements are the effect that they will have on the yield of Clanwilliam Dam. In this study the impact on the 1:50 year yield of the dam has been estimated to be 12,3 million m^3/a. As the ecological Reserve, when implemented, will affect those receiving water from the dam, it is important that it be determined at least at the "intermediate" level, as prescribed in the standard DWAF procedures, to improve the reliability of the determination, which is at a low level of confidence at present.

It is understood that the ecological Reserves at the "intermediate" level for both the Olifants River and its estuary are being determined in a current study on the feasibility of a dam at Melkboom on the Doring River. The study has been commissioned by the Western Cape Province Department of Agriculture and is also investigating the feasibility of further groundwater exploitation and the storage of surface water runoff in groundwater aquifers with excess storage capacity.

The possibility of exploiting artesian groundwater in aquifers of the Table Mountain Group is being investigated in the upper Olifants catchment (DWAF, 2000D) and the results of this investigation might influence the need for further development of the surface water resources of the catchment.

Thus, some of the information identified in this report as being inadequate is being obtained in the investigation for further development of the water resources of the Olifants/Doring River catchment that are taking place at present. However, the uncertainty regarding the true extent and distribution of irrigated agriculture in the upper Doring River catchment where the yield balance showed an excess of nearly 4 million m^3/a will not be addressed in the current studies. The situation here should be clarified when the opportunity arises, but, because the quantity of water involved is relatively small, it is not critical in the context of the development of the resources of the Doring River by constructing a major dam at Melkboom at the bottom of the catchment. However, clarification will be important if it is decided to further investigate a dam at Aspoort. In the context of present level of development, the advantage of clarifying the situation would be in ascertaining that the water that is transferred to the area from the Breede River catchment is being fully utilised.

It is understood that recent aerial photography is available for the area. This should be used to determine the area of land cultivated and field investigations should be undertaken to determine the types of crops grown and the quantities of water used. At the same time, information should be obtained on the quantities of water used from local sources, and the manner of abstraction, and on the manner in which the water imported from the Breede WMA is distributed and used.

There is also uncertainty regarding the true extent and distribution of irrigated crops in the Sandveld area, as well as the extent of the groundwater resource that is being used for irrigation. This area is not included in the current Melkboom Dam study. Nevertheless, it appears that the area of land under irrigation may be increasing and the urban areas along the coast may also grow. Therefore, it will be important for the future Catchment Management Agency to have reliable information on the potential yield of the water resources of the area so that planning of future water supplies can be done timeously.

Consequently, it is recommended that more detailed investigations be carried out in this area. The investigations should include :

- The use of aerial photography combined with field investigations to determine the areas of land cultivated and the areas and types of crops grown under irrigation each year;
- determination of the extent to which surface water is used for irrigation, livestock watering, rural domestic water supplies and urban water supplies;
- determination of the impact of alien vegetation on surface water yield;
- the collection and correlation of data on groundwater use and the size of the groundwater resource;
- the collection and correlation of existing data on the quality of both groundwater and surface water, and field work to collect additional water quality data if found to be necessary;
- the collection of data on existing urban water supply schemes and the determination of present and probable future urban and rural domestic and livestock water requirements;
- the determination of probable future water requirements for irrigation;
- the preparation of a water resources management plan for the area.

There are no streamflow gauging stations in the Sandveld area, with the result that the available streamflow data has been estimated from rainfall records and is of uncertain reliability. If the investigations recommended above show that the surface water resources are heavily exploited, the establishment of a gauging station on the Verlorevlei River, which is the biggest river in the area, should be considered with a view to improving knowledge of the surface water hydrology of the area. It might also be necessary to determine the ecological flow requirements of the Verlorevlei at the intermediate level in order to establish the maximum quantity of water that can be abstracted from the river system.

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DIAGRAMS

ABBREVIATIONS AND ACRONYMS

AEMC	Suggested Ecological Management Class
CMA	Catchment Management Agency
DBSA	Development Bank of Southern Africa
DEMC	Default Ecological Management Class
DESC	Default Ecological Sensitivity Class
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EISC	Ecological Importance and Sensitivity Class
GIS	Geographical Information System
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act (Act No. 36 of 1998)
PESC	Present Ecological Status Class
TDS	Total Dissolved Salts
TLC	Transitional Local Council
TRC	Transitional Rural Council
WMA	Water Management Area
WRSA	Water Resources Situation Assessment
WSAM	Water Situation Assessment Model
ha	hectare
km^2	square kilometres
m^3	cubic metre
10^6m^3	million cubic metres
$10^6m^3/a$	million cubic metres per year
%	percent

GLOSSARY OF TERMS

ASSURANCE OF SUPPLY	The reliability at which a specified quantity of water can be provided, usually expressed either as a percentage or as a risk. For example "98% reliability" means that, over a long period of time, the specified quantity of water can be supplied for 98% of the time, and less for the remaining 2%. Alternatively, this situation may be described as a "1 in 50 year risk of failure" meaning that, on average, the specified quantity of water will fail to be provided in 1 year in 50 years, or 2% of time.
BASIN	The area of land that is drained by a large river, or river system.
BIOTA	A collective term for all the organisms (plants, animals, fungi, bacteria) in an ecosystem.
CONDENSED AREA	The equivalent area of alien vegetation with a maximum concentration/density that represents the more sparsely distributed alien vegetation that occurs over a large area.
CATCHMENT	The area of land drained by a river. The term can be applied to a stream, a tributary of a larger river or a whole river system.
COMMERCIAL FARMING	Large scale farming, the products of which are normally sold for profit.
COMMERCIAL FORESTS	Forests that are cultivated for the commercial production of wood or paper products.
DAM	The wall across a valley that retains water, but also used in the colloquial sense to denote the lake behind the wall.
DEFICIT	Describes the situation where the availability of water at a particular assurance of supply is less than the unrestricted water requirement.
DEMC	Default Ecological Management Class (A-D). A class indicating the ecological importance and sensitivity of an area, as it is likely to have been under natural (undeveloped) conditions, and the risks of disturbance that should be tolerated. Values range from ClassA (highly sensitive, no risks allowed) to ClassD (resilient systems, large risk allowed).
DRAINAGE REGION	The drainage regions referred to in this document are either single large river basins, or groups of contiguous catchments or smaller catchments with similar hydrological characteristics. They follow the division of the country into drainage regions as used by the Department of Water Affairs and Forestry.

ECOSYSTEM	A unit made up of all the living and non-living components of a particular area that interact and exchange materials with each other.
ECOSYSTEM HEALTH	An ecosystem is considered healthy if it is active and maintains its organisation and autonomy over time, and is resilient to stress. Ecosystem health is closely related to the idea of sustainability.
ECOLOGICAL IMPORTANCE	A measure of the extent to which a particular species, population or process contributes towards the healthy functioning of an ecosystem. Important aspects include habitat diversity, biodiversity, the presence of unique, rare or endangered biota or landscapes, connectivity, sensitivity and resilience. The functioning of the ecosystem refers to natural processes.
ENDANGERED SPECIES	Species in danger of extinction and whose survival is unlikely if the causal factors bringing about its endangered status continue operating. Included are species whose numbers have been reduced to a critically low level or whose habitat has been so drastically dimished and/or degraded that they are deemed to be in immediate danger of extinction.
ENDEMIC	Occurring within a specified locality; not introduced.
ENDOREIC	Portion of a hydrological catchment that does not contribute towards river flow in its own catchment (local) or to river flow in downstream catchments (global). In such catchments the water generally drains to pans where much of the water is lost through evaporation.
ENVIRONMENTALLY SENSITIVE AREA	A fragile ecosystem which will be maintained only by conscious attempts to protect it.
EPHEMERAL RIVERS	Rivers where no flow occurs for long periods of time.
FORMAL IRRIGATION SCHEME	The term applies to a scheme where water for irrigation purposes is stored in a dam controlled by DWAF or an Irrigation Board and supplied in pre-determined quotas to irrigators registered under the scheme.
HISTORICAL FLOW SEQUENCE	A record of river flow over a defined period and under a defined condition of catchment development in the past, calculated from a record of observed flow corrected for inaccuracies, or from records of observed rainfall, or a combination of the two.
HYDROLOGICAL YEAR	The twelve-month period from the beginning of October in one year to the end of September in the following year.
INVERTEBRATE	An animal without a backbone - includes insects, snails, sponges, worms, crabs and shrimps.

IRRIGATION QUOTA	The quantity of water, usually expressed as m^3/ha per year, or mm per year, allocated to land scheduled under the scheme. This is the quantity to which the owner of the land is entitled at the point at which he or she takes delivery of the water and does not include conveyance losses to that point.
LOTIC	Pertaining to fast running aquatic habitats such as fast flowing streams or rivers.
MEAN ANNUAL RUNOFF	Frequently abbreviated to MAR, this is the long-term mean annual flow calculated for a specified period of time, at a particular point along a river and for a particular catchment and catchment development condition. In this report, the MARs are based on the 70-year period October 1920 to September 1990 inclusive.
OPPORTUNISTIC IRRIGATION	Irrigation from run-of-river flow, farm dams, or compensation flows released from major dams. As storage is not provided to compensate for reduced water availability in dry years, areas irrigated generally have to be reduced in dry years.
PRESENT ECOLOGICAL STATUS CLASS	A class indicating the degree to which present conditions of an area have been modified from natural (undeveloped) conditions. Factors that are considered in the classification include the extent of flow modification, inundation, water quality, stream bed condition, riparian condition and proportion of exotic biota. Values range from ClassA (largely natural) to ClassF (critically modified).
QUATERNARY CATCHMENT	The basic unit of area resolution used in the WR90 series of reports published by the Water Research Commission and also in this report. The primary drainage regions are divided into secondary, tertiary and quaternary catchments. The quaternary catchments have been created to have similar mean annual runoffs : the greater the runoff volume the smaller the catchment area and vice versa. The quaternary catchments are numbered alpha-numerically in downstream order. A quaternary catchment number, for example R30D, may be interpreted as follows : the letter R denotes Primary Drainage Region R, the number 3 denotes secondary catchment 3 of Primary Drainage Region R, the number 0 shows that the secondary catchment has not, in this case, been sub-divided into tertiary catchments, and the letter D shows that the quaternary catchment is the fourth in sequence downstream from the head of secondary catchment R30.
RARE	Species with small or restricted populations, which are not at present endangered or vulnerable, but which are at risk. These species are usually localised within restricted geographical areas or habitats, or are thinly scattered over a more extensive range. These may be species which are seldom recorded but may be more common than supposed, although there is evidence that their numbers are low.

CHAPTER 1: INTRODUCTION

1.1 PURPOSE OF THE STUDY

The National Water Act No. 36 of 1998 requires the Minister of Water Affairs and Forestry to establish a national water resource strategy for the protection, use, development, conservation, management and control of water resources. To enable the strategy to be established, information on the present and probable future situations regarding water requirements and water availability is required, that is, a national water resources situation assessment providing information on all the individual drainage basins in the country.

The Department of Water Affairs and Forestry (DWAF) has appointed consulting engineers to undertake Water Resources Situation Assessments for the purpose of gathering information and using it to reconcile the present water requirements of all the user sectors with the presently available water resources. The information produced by all the studies will be consolidated by DWAF into a national database which will be used to establish the National Water Resource Strategy. Scenarios of future water requirements and availability are being dealt with in a separate study. These scenarios will be taken up in the National Water Resource Strategy and will be reported on separately for each water management area.

As a component of the National Water Resource Strategy, the Minister of Water Affairs and Forestry has established water management areas and determined their boundaries. The National Water Act provides for the delegation of water resource management from central government to the regional or catchment level by establishing catchment management agencies. It is intended that the documents produced in this study as well as in the subsequent scenario studies referred to above should, in addition to contributing to the establishment of the National Water Resource Strategy, provide information for collaborative planning of water resources development and utilisation by the central government and the future catchment management agencies.

In order to facilitate use by future catchment management agencies, the information has been presented in the form of a separate report on each water management area (WMA). This report is in respect of the Olifants/Doring Water Management Area, which occupies portions of the Western Cape Province and the Northern Cape Province. A provincial water resources situation assessment can be derived by assembling the provincial data from each of those reports that describe the water management areas that occupy the province.

1.2 APPROACH TO THE STUDY

The study was carried out as a desktop investigation using data from reports and electronic databases, or supplied by associated studies, local authorities and DWAF. The study considered conditions as they were in the year 1995 and did not make projections of future conditions. Data at reconnaissance level of detail was collected on land-use, water requirements, water use, water related infrastructure, water resources and previous investigations of water supply development possibilities. Relevant data was used in a computerised water balance model, developed in a separate study (DWAF, 2000a) to calculate the yield of the water resources at development levels as they were in 1995, and the maximum yield that could be obtained from future development of these resources. The water balance (the relationship between water requirements and water availability at a 1:50 year assurance of supply) at selected points in each water management area was also calculated.

Information on urban water use and water related infrastructure was obtained from reports on urban water supplies and from questionnaires filled in by local authorities. The collected data on urban water use was supplied to consultants appointed to carry out a separate national demographic study, in relation to water requirements.

In that study, data from the 1996 census, and other sources, was used to derive demographic information for the whole country for the year 1995. In addition, the information on urban water use, that was supplied by the water resources situation assessment studies, was analysed in the demographic study to derive typical unit water requirements. These were used, in conjunction with the demographic data, to estimate water requirements in 1995 for urban areas for which no recorded data was available.

Both the demographic data and the estimated water requirements in 1995, as supplied for the Olifants/Doring Water Management Area by the national demographic study (DWAF, 2000b), are presented in this report. In addition to the separate studies on the water situation assessment model and demography referred to above, separate studies were carried out to provide information on a national basis on :

- Macro-economic aspects
- Legal aspects of water resource management
- Institutional arrangements for water supply
- Effects of alien vegetation on runoff
- Groundwater resources
- Bacteriological contamination of water resources
- Water requirements for irrigation
- Ecological classification of rivers
- Water requirements for ecological component of Reserve
- Effects of afforestation on runoff
- Storage-yield characteristics of rivers

Information from all the above studies, that is relevant to the Olifants/Doring Water Management Area, is included in the appropriate sections of this report.

1.3 REPORT LAYOUT AND CONTENT

The findings of the study in respect of the Olifants/Doring Water Management Area are presented in the nine chapters that make up the main body of this report, and a number of appendices containing mainly statistics for the quaternary hydrological sub-catchments that make up the water management area. (The system used to divide the area into hydrological sub-catchments is explained in Section 2.1 of the report).

The chapter headings are :

Chapter 1 : Introduction
Chapter 2 : Physical Features
Chapter 3 : Development Status
Chapter 4 : Water Related Infrastructure
Chapter 5 : Water Requirements
Chapter 6 : Water Resources
Chapter 7 : Water Balance
Chapter 8 : Costs of Water Resources Development
Chapter 9 : Conclusions and Recommendations

Chapters 2, 3 and 4 describe climatic and physical features, and land-uses that affect water resources or water supply. Chapter 5 describes the various water user sectors and their requirements. It includes information on water allocations, water conservation and demand management, and water losses and return flows. Chapter 6 describes the groundwater and surface water resources of the water management area, and Chapter 7 compares water requirements with the available resource. In Chapter 8, rough estimates are given of the cost of developing the portion of the total water resource that was not developed by 1995, and the conclusions and recommendations arising from the study are presented in Chapter 9.

CHAPTER 2: PHYSICAL FEATURES

2.1 THE STUDY AREA

The study area comprises the whole of the Olifants/Doring Water Management Area, which is shown on Figure 2.1.1. The entire Olifants/Doring River drainage basin lies within the boundaries of the water management area, as well as the catchments of the smaller rivers that lie between that basin and the Atlantic Ocean.

The Olifants/Doring Water Management Area is bounded in the north and the east by the Lower Orange Water Management Area, and in the south by the Berg, Breede and Gouritz Water Management Areas. It falls partly within the boundaries of the Western Cape Province and partly within the Northern Cape Province, as shown on Figure 2.1.1.

The topography is of three distinct types, namely rolling hills and sand dunes in the west along the coastal strip, rugged mountains with peaks rising to about 2 000 m above sea level in the south-western area, and plains and rocky hills in the north-eastern area that are typical of the Western Karoo.

The main rivers are the Olifants and its major tributary, the Doring.

The Olifants River rises in the mountains in the south-east of the water management area (see Figure 2.1.2) and flows in a north-westerly direction, initially through a deep narrow valley which widens and flattens downstream of Clanwilliam until the river flows through a wide floodplain downstream of Klawer.

The Doring River catchment is fan shaped and has a large number of contributing tributaries. The main river starts in the south and follows a generally northward trend. It is first joined by the Groot River from the west and then by the Tra-Tra and the Tankwa Rivers before flowing in an almost westerly course to the confluence with the Olifants River just upstream of Klawer. In the south-west where the Tra-Tra and Groot Rivers rise, the topography is very mountainous with peaks rising to 2 000 m above sea level. The main tributaries of the Groot River are the Riet and Leeu Rivers.

The east and north of the catchment has much less relief and much of the basin lies between 500 and 900 m above mean sea level. In the east are a number of significant ranges viz. the Hantam near Calvinia and the Roggeveld to the south, which rise to about 1 500 m above sea level. Just to the west of Nieuwoudtville there is an escarpment where the plateau elevation of about 700 m drops to about 300 m. This is known as the Bokkeveldberge. The major tributaries in this region, although not contributing much to the run-off, are the Oorlogskloof, Troe-Troe and Vars Rivers.

Several rivers flow into the sea to the north and the south of the Olifants River estuary, but they do not make a significant contribution to the water resources of the water management area because their catchment areas are small and the rainfall is low.

The rolling hills and plains of the 30 to 40 km wide strip along the coast from the southern boundary of the water management area to the estuary of the Olifants River are known as the Sandveld. The deep sandy deposits that overlie the bedrock in this area provide a significant groundwater resource.

For purposes of assessing water requirements and the available water resources, the water management area has been divided into quaternary catchments (see Figure 2.1.3). These are the basic units of area used in the report on the Surface Water Resources of South Africa, 1990 (Midgley *et al*, 1994), which is the main source of the hydrological data used in this study.

In this system, drainage regions throughout the country are divided into secondary, tertiary and quaternary catchments. The quaternary catchments have been selected to have similar runoffs : the greater the runoff volume, the smaller the catchment area and vice versa. The quaternary catchments are numbered alpha-numerically in downstream order. A quaternary catchment number, for example E23C, may be interpreted as follows. The letter E denotes Drainage Region E (sometimes referred to as a primary catchment). The number 2 denotes secondary catchment 2 of Drainage Region E. The number 3 shows that the secondary catchment has, in this case, been sub-divided into tertiary catchments and that the tertiary catchment is the third in sequence downstream from the head of secondary catchment E2. The letter C shows that the quaternary catchment is the third in sequence downstream from the head of tertiary catchment E23.

The Olifants/Doring Water Management Area consists of the whole of drainage region E and portions of drainage regions F and G. It includes a total of 95 quaternary catchments from these drainage regions.

For purposes of describing the characteristics of the WMA, it was divided into a number of key areas. These are either the catchments of the main rivers within the WMA, or groupings of several minor catchments. The key areas are listed and described in Table 2.1.1 and their boundaries are shown on Figure 2.1.2 and most of the other figures in the report. The key areas are also used in many of the tables.

TABLE 2.1.1: KEY AREAS WITHIN THE OLIFANTS/DORING WMA

KEY AREA	QUATERNARY CATCHMENTS	DESCRIPTION
Upper Olifants	E10A to E10K	Olifants River upstream of its confluence with the Doring River
Kouebokkeveld	E21A to E21L	Groot River upstream of its confluence with the Doring River
Upper Doring	E22A to E22G	Doring River upstream of its confluence with the Tankwa River
Tankwa	E23A to E23K	Tankwa River upstream of its confluence with the Doring River
Oorlogskloof	E40A to E40D	Oorlogskloof River upstream of its confluence with the Doring River
Lower Doring	E24A to E24M	Doring River downstream of its confluence with the Tankwa River, but excluding the Oorlogskloof catchment
Kromme	E31A to E31H	Arid northern part of Olifants River catchment
Hantams	E32A to E32E	Arid north-eastern part of Olifants River catchment
Lower Olifants	E33A to E33H	Arid north-western part of Olifants River catchment and main channel of Olifants River between its confluence with the Doring River and the sea.
Goerap	E60A to F60E	Namaqualand coastal catchments to the north of the Olifants River estuary
Sandveld	G30A (part) to G30H	Coastal catchments to the south of the Olifants River estuary

2.2 CLIMATE

Climatic conditions can vary considerably within the Olifants/Doring Water Management Area as a result of the variation in the topography. The mean annual temperature, calculated from records for the towns of Calvinia, Ceres, Clanwilliam and Vredendal is 18º C (Ceres lies just outside the boundary of the water management area, but it is included as being representative of the southern edge of the water management area). Maximum temperatures are experienced in January and minimum temperatures usually occur in July. Typical temperature data is shown in Table 2.2.1.

Frost occurs throughout the area except along the coastal strip, typically in the period mid-May to September.

TABLE 2.2.1: TEMPERATURE DATA

MONTH	TEMPERATURE	AVERAGE (ºC)	RANGE (ºC)
January	Mean temperature	24	22 – 26
	Maximum temperature	41	39 – 44
	Minimum temperature	11	10 – 13
	Diurnal range	16	15 – 18
July	Mean temperature	13	10 – 14
	Maximum temperature	28	24 – 30
	Minimum temperature	1	-3 – 3
	Diurnal range	13	11 – 14

The area lies within the winter rainfall region, with the majority of rainfall occurring between the months of May and September. The rainfall results from the convergence of cold fronts moving from the Atlantic Ocean over the Western Cape. Snow occurs occasionally on the mountain ranges during most winters. The mean lightning flash density is 0 – 1 per km^2 per annum. As a result of the influence of the mountains, a large spatial variability in the mean annual precipitation is experienced (see Figure 2.2.1). Along the Groot Winterhoekberge (Catchment E10B) the mean annual precipitation is above 900 mm, whereas it decreases sharply to the north and east to around 200 mm and to less than 100 mm in the far north. The average coefficient of variation ranges from 35 to 40%.

For the driest year in five (80% exceedance probability) the annual precipitation for the northern half of the water management area is about 200 mm, but it can be as low as 90 mm in places. For the southern half, the annual precipitation is generally about 600 mm but can be as low as 100 mm in places. For the wettest year in five (20% exceedance probability) the annual precipitation in the north is typically about 400 mm, but can be as low as 200 mm in places, while in the southern half, it is generally about 600 mm but can be as low as 300 mm in places. In accordance with the rainfall pattern the relative humidity is higher in winter than in summer. Humidity is generally highest in June (the daily mean ranges from 69% in the south-west to 62% north-east) and lowest in January (the daily mean ranges from 65% in the south-west to 56% in the north-east).

Average potential mean annual evaporation (as measured by Symons-pan) ranges from 1 500 mm in the south-west to as high as 2 200 mm in the dry northern parts (see Figure 2.2.2). The highest Symons-pan evaporation is in January (range 320 mm to 360 mm) and the lowest in June (60 to 90 mm).

The gross irrigation requirement ranges from 1 800 mm/annum in the southern parts to 2 000 mm/annum in the dry northern areas (Schulze *et al*, 1997). The minimum monthly requirement is in June (ranging from 30 mm to 80 mm) and the maximum monthly requirement is in January (ranging from 175 to 200 mm).

2.3 GEOLOGY

The geology of the area is shown in simplified form on Figure 2.3.1. It is dominated by sedimentary rocks of the Cape Supergroup and the lower part of the Karoo Supergroup, with sedimentary strata of the Vanrhynsdorp Group in the north. Exposures of pre-Cape metamorphic rock occur in the north-western and north-eastern corners of the area, and the coastal plain comprises sandstones of the Malmesbury Formation overlain by sand and calcrete deposits.

The mountains in the southern central part of the area are composed of intercalcated arenaceous and argillaceous strata of the oldest member of the Cape Supergroup rocks in the Western Cape, the well known Table Mountain Group, which comprises predominantly quartzitic sandstones with minor interlaced shale horizons. In the western Cederberg a basal conglomerate known as the Piekenierskloof Formation is locally well developed. Also halfway through the major succession of the quartzitic sandstones is the conspicuous shale marker known as the Cederberg Formation. The sandstones below this belong to the Peninsula Formation while those above it form the Nardouw Formation.

North of the Cederberg in the lower Doring River and the Matsikamma Mountains, the Nardouw Formation is the main representative of the Cape Supergroup, resting unconformably on pre-Cape rocks. Further north the basal Karoo Dwyka Tillite directly overlies the pre-Cape rocks. Most of the eastern and northern areas of the Doring River catchment are in the Karoo rocks, mainly Ecca and Beaufort Shale. These give rise to the much higher silt loads carried in the Doring River compared to the Olifants River.

In the Olifants basin the Nardouw Formation is overlain by shaly rocks of the Bokkeveld Group. These strata contain numerous well preserved marine fossils. They are in turn overlain by Witteberg Group quartzites and shales. The Witteberg Group is not represented in the main Olifants valley but does occur in the upper reaches of the Doring River.

Two important troughs of the Bokkeveld Group shale occur in the Olifants River, one in the Agter Witzenberg area and one around Citrusdal. In the vicinity of Klawer the river crosses underlying Malmesbury Formation metasediments.

The area is not rich in minerals and mining and quarrying activities are generally small, the Namakwa Sands heavy minerals mining operation being the only major one in the water management area. There are a number of small quarries producing gypsum, lime, marble or granite, and alluvial diamond diggings occur along the coast to the north of the Olifants River estuary.

2.4 SOILS

Figure 2.4.1 shows a generalized soils map of the WMA based on some sixteen broad soil groupings. The figure was obtained from the report on the Water Resources of South Africa, 1990 (Midgley *et al*, 1994). The 16 groupings were derived by the department of Agricultural Engineering of the University of Natal using a national base map which was divided into 82 soil types. These soil types were then analysed according to features most likely to influence hydrological response, viz. depth, texture and slope.

The following soil types occur in the Olifants/Doring Water Management Area :

- Moderately deep to deep sandy soils that occur along a 15 to 30 km wide flat coastal strip along the western boundary of the WMA from the south to the southern edge of the Olifants River estuary, and in undulating terrain northwards along the coast from the northern edge of the floodplain of the river. In this area, these sandy soils extend inland from the coast for between 50 and 100 km.

- Moderately deep to deep clayey loam in the south-west of the WMA on the slopes between the sandy coastal strip and the interior mountain range.

- Moderately deep to deep sandy loam along the flat floor of the Olifants River valley and along the north-eastern boundary of the WMA.

- Moderately deep to deep sandy loam on the steep slopes of the high mountains in the south of the WMA, the escarpment along its eastern edge, and the hilly area in the north-east.

- Moderately deep to deep clayey soils on the steep slopes of the hilly area adjoining the coastal strip in the north.

2.5 NATURAL VEGETATION

2.5.1 Introduction

Some 20 000 different plant species occur throughout South Africa. These are however not randomly distributed within the region but are organised into distinct communities, largely dependent on the prevailing climatic (especially rainfall) and edaphic (soil) conditions. For the purposes of identifying and managing the heterogenous range of vegetation within South Africa, it is necessary to be able to recognise relatively homogenous vegetation groups or types. Furthermore, for the recognised groups to be meaningful, it is essential that they are readily apparent and spatio-temporally robust. Acocks (1988) introduced the concept of "Veld type", which he defined as : "a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities". Acocks identified a total of 70 veld types in South Africa (see Table 2.5.1.1), including 75 variations. These 70 veld types fall into 11 broad categories, ranging from various forest types to sclerophyllous (Fynbos) types (Table 2.5.1.1). These "simplified" Acocks veld type categories are used for the purposes of this report, and accordingly the description of the natural vegetation types occurring within the Water Management Area is rather broad.

TABLE 2.5.1.1: A LIST OF THE DETAILED AND SIMPLIFIED ACOCKS VELD TYPES (Acocks, 1988)

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Coastal Forest and Thornveld	1	**Coastal Tropical Forest**
Alexandria Forest	2	
Pondoland Coastal Plateau Sourveld	3	
Knysna Forest	4	
‘Ngongoni Veld	5	
Zululand Thornveld	6	
Eastern Province Thornveld	7	
North-eastern Mountain Sourveld	8	**Inland Tropical Forest**
Lowveld Sour Bushveld	9	

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Lowveld	10	**Tropical Bush and Savanna**
Arid Lowveld	11	
Springbok Flats Turf Thornveld	12	
Other Turf Thornveld	13	
Arid Sweet Bushveld	14	
Mopani Veld	15	
Kalahari Thornveld	16	
Kalahari Thornveld invaded by Karoo	17	
Mixed Bushveld	18	
Sourish Mixed Bushveld	19	
Sour Bushveld	20	
False Thornveld of Eastern Cape	21	**False Bushveld**
Invasion of Grassveld by Acacia karoo	22	
Valley Bushveld	23	**Karoo and Karroid**
Noorsveld	24	
Succulent Mountain Scrub	25	
Karroid Broken Veld	26	
Central Upper Karoo	27	
Western Mountain Karoo	28	
Arid Karoo	29	**Karoo and Karroid**
Central Lower Karoo	30	
Succulent Karoo	31	
Orange River Broken Veld	32	
Namaqualand Broken Veld	33	
Strandveld	34	
False Arid karoo	35	**False Karoo**
False Upper Karoo	36	
False Karroid Broken Veld	37	
False Central Lower Karoo	38	
False Succulent Karoo	39	
False Orange River Broken Karoo	40	
Pan Turf Veld invaded by Karoo	41	
Karroid Merxmuellera Mountain Veld replaced by Karoo	42	
Mountain Renosterveld	43	
Highveld Sourveld and Dohne Sourveld	44	**Temperate and Transitional Forest and scrub**
Natal Mist Belt 'Ngongoni Veld	45	
Coastal Renosterveld	46	
Coastal Fynbos	47	
Cymbopogon – Themeda Veld	48	**Pure Grassveld**
Transitional Cymbopogon – Themeda Veld	49	
Dry Cymbopogon – Themeda Veld	50	
Pan Turf Veld	51	
Themeda Veld or Turf Highveld	52	
Patchy Highveld to Cymbopogon – Themeda Veld	53	
Turf Highveld to Highland Sourveld Transition	54	
Bakenveld to Turf Highveld Transition	55	
Highland Sourveld to Cymbopogon – Themeda Veld	56	
North-eastern Sandy Highveld	57	
Themeda – Festuca Alpine Veld	58	
Stormberg Plateau Sweetveld	59	
Karroid Merxmuellera Mountain veld	60	
Bankenveld	61	**False Grassveld**
Bankenveld to Sour Sandveld Transition	62	
Piet Retief Sourveld	63	
Northern Tall Grassveld	64	
Southern Tall Grassveld	65	
Natal Sour Sandveld	66	
Pietersburg Plateau False Grassveld	67	
Eastern Province Grassveld	68	
Fynbos	69	**Sclerophyllous Bush**
False Fynbos	70	**False Sclerophyllous Bush**

2.5.2 Natural Vegetation Types within the Olifants/Doring WMA

The Olifants/Doring WMA encompasses portions of the Northern and Western Cape. The vegetation within these provinces is dominated by Karoo and Karroid Types, False Karoo Types, Temperate and Transitional Forest and Scrub Types, and Sclerophyllous Bush Types. The veld types that occur within the WMA are described in more detail below and illustrated in Figure 2.5.2.1.

Karoo and Karroid

This veld type dominates, occupying some 75% of its area. The flora is characteristically low, typically less than 1 m in height, and includes scrub, bushes, dwarf trees and a few grasses. Rainfall within this vegetation type typically ranges between 150 mm and 500 mm, but does reach a maximum of up to 900 mm in some of the river valleys. Karoo and Karroid bushveld occurs at any altitude from sea level to 1 700 m above mean sea level (MSL).

False Karoo

Occurs predominantly in the north of the WMA, with small patches also occurring along the eastern and south-eastern boundaries. Similar to Karoo and Karroid Bushveld, the False Karoo vegetation type is typified by low vegetation, but in contrast contains more grassy elements. The areas occupied by this veld type are typically very arid and in parts may receive less than 100 mm of rainfall per annum. This veld type generally occurs below 1 200 m in elevation.

Temperate and Transitional Forest and Scrub

Small patches occur towards the southern boundary of the WMA. As the name implies this veld type is typical of relatively temperate habitats. This general veld type includes areas of forest, grassland and fynbos. Temperate and Transitional Forest and Scrub occurs from sea level up to 1 350 m. Rainfall is typically high, ranging from 650 to 1 150 mm per annum, although it may be somewhat lower within the coastal renosterveld and fynbos elements of this veld type, where it typically ranges between 300 to 500 mm per annum.

Sclerophyllous Bush

Occurs in a broad band along the south-western portions of this WMA, just inland from the coast. This vegetation type, also referred to as Fynbos, contains a bewildering array of species which are characteristically small leafed (hence the term Sclerophyllous Bush). No single species dominates and there is a tremendous spatial turnover in species composition. The areas occupied by the Sclerophyllous Bush veld type are typically fairly mesic, receiving in excess of 500 mm, and up to 1 500mm, of rainfall per annum.

2.6 ECOLOGICALLY SENSITIVE SITES

2.6.1 Sensitive Ecosystems

The conservation of living resources is essential for sustaining development by maintaining the essential ecological processes and life support systems, preserving genetic diversity and ensuring that utilisation of species and ecosystems is sustainable. However, for conservation to succeed it should be underpinned by two basic principles, namely the need to plan resource management (including exploitation) on the basis of an accurate inventory and the need to implement proactive protective measures to ensure that resources do not become exhausted. Accordingly, a vital component of ensuring sustainable conservation practices is the identification of conservation worthy habitats or sensitive ecosystems.

In terms of Section 2 (1) of the Environment Conservation Act (No. 73 of 1989), South Africa's schedule of protected areas was published in the Government Gazette 15726 in May 1994 (Notice 449 of 1994). This classification identifies the following sensitive or protected areas:

Scientific and Wilderness Areas, National Parks and Equivalent Reserves, Natural Monuments and Areas of Cultural Significance, Habitat and Wildlife Management Areas and Protected Land/Seascapes, based on their location and the functions they fulfil.

South Africa has also recognised the importance of its wetlands as sensitive ecosystems which require conservation, and accordingly has become a signatory to the international Convention on Wetlands of International Importance especially as Waterfowl Habitat or RAMSAR Convention. In terms of this convention, signatories undertake to include wetland conservation considerations in their national land-use planning, and as far as possible to ensure the wise use of wetlands within their territory.

Before moving on to discuss ecosystems of concern to the study area it would be prudent to give some consideration to the definition of aquatic ecosystems, especially with respect to the National Water Act (No. 36 of 1998). In general terms an ecosystem may be defined as a community of organisms and their physical environment interacting as an ecological unit. Hence, aquatic ecosystems encompass the aquatic community and water resources necessary to sustain its ecological integrity. Within the National Water Act the water resource requirements of aquatic ecosystems are recognised and protected by the introduction of the concept of an ecological Reserve, viz. the water required to protect the aquatic ecosystem of the water resources. The Reserve refers to both the quantity and quality of the resource. Accordingly, development must take cognisance not only of the sensitivity of the receiving ecosystem but also of the resource requirements or ecological reserve of the aquatic communities it supports.

The procedure for establishing the Reserve requires each water resource to be classified and the resource quality objectives to be set as initial steps towards determining the Reserve.

As estimates of the quantity of water required for the ecological component of the Reserve are an essential requirement if a meaningful assessment of water resources is to be carried out, and the process of classifying all the water resources has not yet been completed, rapid preliminary classifications were made and used to make rough estimates of the Reserve for purposes of the situation assessments.

The procedure followed to classify the rivers is described in Section 2.6.2, below, and the use of the classifications to make rough estimates of the quantity of water required for the ecological component of the Reserve for each of the quaternary catchments in the WMA is described in Section 5.2.

2.6.2 River Classification

The water resources of South Africa are to be protected in terms of the National Water Act (No. 36 of 1998). This will be accomplished by classifying each water resource, setting the resource quality objectives and determining the Reserve. This process had not yet been completed and therefore it was necessary to determine the present condition or present ecological status class (PESC) of the water resources so as to estimate the quantities of water required to maintain them in this condition for the purpose of the 1995 water resources situation assessment.

The water resources situation assessment has been performed at the quaternary catchment scale of resolution as described in Section 2.1. However, the delineation of these quaternary catchments was not based on ecological principles. In order to provide some ecological basis for the estimates of water requirements to maintain a particular class of river it was decided to base estimates of water requirements on an index of the ecological importance and sensitivity class (EISC) of the rivers in the quaternary catchment of concern. The ecological importance and sensitivity class of the rivers was used to derive the default ecological management class (DEMC), which relates to a default ecological status class (DESC). The default ecological status class and the present ecological status class (PESC) have been used to arrive at a suggested future ecological management class (AEMC) to be considered for the water resources. The default ecological status class would normally be assigned to a water resource on the basis of ecological sensitivity and importance. This methodology is based on the assumption that the ecological importance and sensitivity of a river would generally be closely associated with its default ecological management class and that its current ecological status and potential to recover from past ecological damage will determine the possibility of restoring it to a particular ecological management class.

This section describes the procedures and methods adopted to estimate the various status and management classes of the rivers that will be used to estimate the corresponding quantities of water required for that component of the Reserve that is necessary to protect the aquatic ecosystems according to the designated class.

The procedure that has been followed to determine the various classifications is illustrated in Diagram 2.6.2.1. The descriptions of the various ecological importance and sensitivity classes (EISC), default ecological management classes (DEMC), default ecological status classes (DESC), present ecological status classes (PESC) and the suggested future ecological management class (AEMC) are given in Diagram 2.6.2.2.

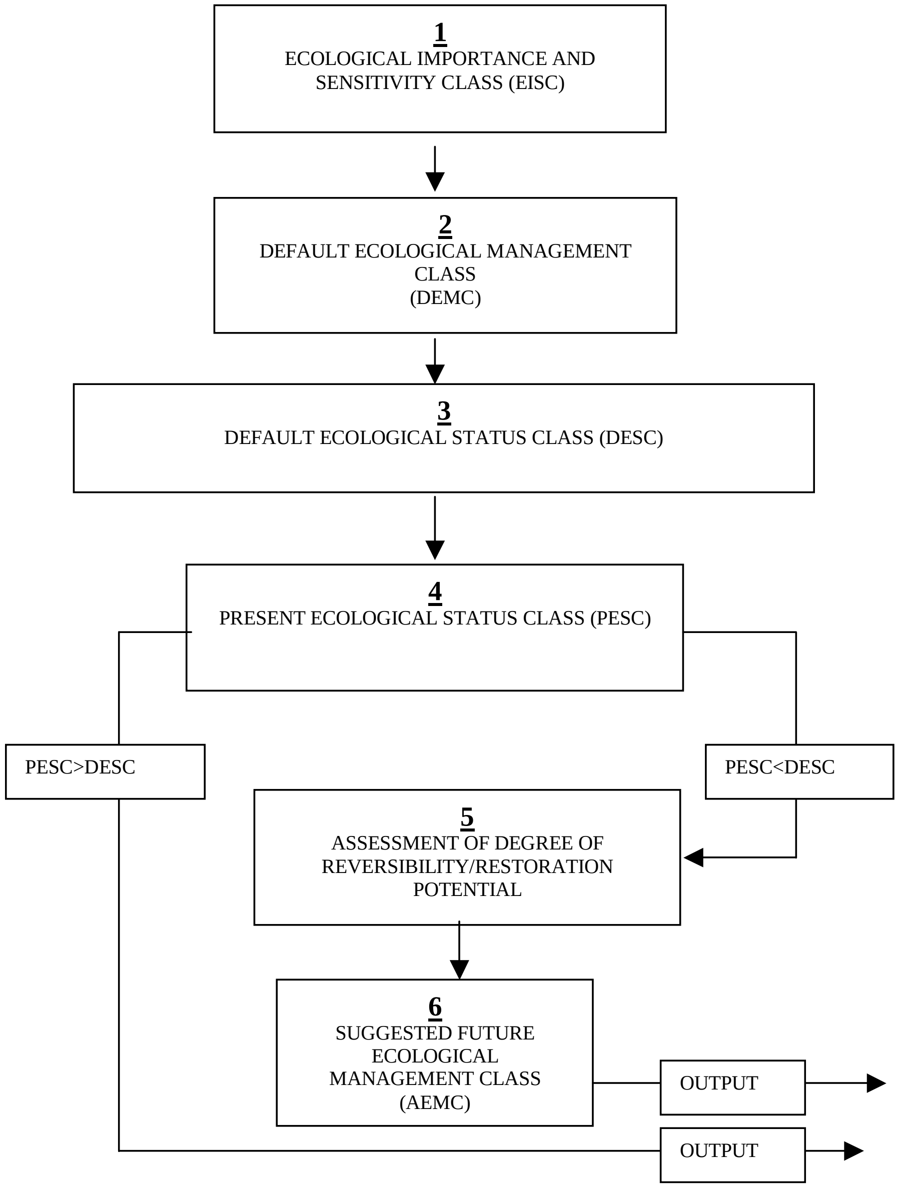

Diagram 2.6.2.1: Procedure followed to determine the river classifications

EISC		DEMC and DESC
Very high	→ No human induced hazards	→Class A: Unmodified natural
High	→ Small risk allowed	→Class B: Largely natural
Moderate	→ Moderate risk allowed	→Class C: Moderately modified
Low/marginal	→ Large risk allowed	→Class D: Largely modified

PESC	PESC: SUGGESTED ATTAINABLE IMPROVEMENT Acceptable range of AEMC:
Class A: Unmodified natural	Class A: Unmodified natural
Class B: Largely natural	Class B: Largely natural
Class C: Moderately modified	Class C: Moderately modified
Class D: Largely modified	Class D: Largely modified
Class E: Seriously modified	Class E: Seriously modified
Class F: Critically modified	Class F: Critically modified

→: indicates relationship.
——►: indicates possible direction of desirable change.

Diagram 2.6.2.2: Descriptions of EISC, DEMC, DESC, PESC and AEMC.

Individual assessors familiar with the ecology of a particular area or a comparable area were engaged in discussions and workshops during which a number of biotic and habitat determinants, considered important for the determination of ecological importance and sensitivity, were quantified or scored. The procedure that was followed was considered to be suitable for the situation where the delineation of the quaternary catchment units was not based on ecological considerations. The approach may however, have a low ecological sensitivity because of the absence of an ecological typing framework. The median of the scores assigned by the assessors was calculated to derive the ecological importance and sensitivity class. The assessors were then required to compare this with their overall estimation of the ecological importance and sensitivity class of the mainstem river of the quaternary catchment of concern near its outlet.

The assessors were required to record and be able to substantiate their assessments to a reasonable degree for possible review in future.

The ecological importance and sensitivity classes were either assessed during meetings or at a workshop held during 1998. This was followed by a second workshop during 1999 that was primarily concerned with the assessment of the present ecological status class, the potential to improve the ecological status class and the suggested future management class. The second workshop however, also involved an overall review of the ecological importance and sensitivity assessments determined during the original workshop.

The procedure that was adopted to classify the rivers was qualified in the following respects:

- Only lotic systems (i.e. streams and rivers and associated habitats such as lotic wetlands) can be classified and the procedure is not meant to be applied to lakes, pans, impoundments or estuaries. Although several of the components considered in this assessment may be generally applicable, the application of the procedure to systems other than rivers and streams was not attempted.

- Where a quaternary catchment contained an estuary, this procedure was only applied to the riverine part of the catchment.

- Only the mainstem river in a quaternary catchment was considered in the assessment and therefore the management class must not be applied to any tributary streams in the quaternary catchment. These tributaries and their associated water requirements do however, become relevant when a water resources situation assessment is conducted at a sub-quaternary level.

- In cases where a dam wall was present at or relatively close to the outlet of a quaternary catchment, the assessments for that quaternary catchment were based on the river upstream of the dam (i.e. upstream of the backwater effect of the dam).

- In cases where degradation has occurred along certain sections of the mainstem of a quaternary catchment, but where there are still substantial less disturbed sections, the classification was based on those less disturbed areas. The intention of this was to ensure that the ecological component of the Reserve would provide for these less disturbed sections as if they were situated at the outlet of the quaternary catchment, where the ecological component of the Reserve will be estimated for the water resources situation assessments.

- The classifications were fundamentally considered from an instream and riparian zone perspective. Although the catchment in itself plays a major role in the condition and functioning of the rivers and streams in the catchment, the purpose of this procedure was not to provide an overall assessment of the condition of each catchment.

- The riparian zone has broadly been regarded as that part of the river bordering on the river channel. Usually characteristic plant species and/or vegetation structure provided an indication of the extent of the riparian zone.

The specific aspects that were considered when classifying the rivers are described below.

Ecological Importance and Sensitivity Class (EISC)

The following ecological aspects were considered for the estimation of the ecological importance and sensitivity class:

- The presence of rare and endangered species, unique species (i.e. endemic or isolated populations) and communities, species intolerant to changes in flow regime or water quality and also species diversity were taken into account for both the instream and riparian components of the river.

- Habitat diversity was also considered. This included specific habitats and river reaches with a high diversity of habitat types such as pools, riffles, runs, rapids, waterfalls and riparian forests.

- The importance of the particular river or stretch of river in providing connectivity between different sections of the river, i.e. whether it provides a migration route or corridor for species.

- The presence of conservation or relatively natural areas along the river section serving as an indication of ecological importance and sensitivity.

- The ecological sensitivity (or fragility) of the system to environmental changes. Both the biotic and abiotic components were included.

The ecological importance of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and broader scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its resilience or capability to recover from a disturbance that has occurred.

The present ecological status was not considered when determining the ecological importance and sensitivity *per se*. The ecological importance and sensitivity that has been established for the water resources situation assessments is a general and unrefined estimate. It is strongly biased towards the potential importance and sensitivity of the mainstem river of the quaternary catchment under close to unimpaired conditions.

Present Ecological Status Class (PESC)
Habitat integrity i.e. ecological integrity, condition and change from the natural condition, was regarded as a broad preliminary indicator of present ecological status for the purpose of the water resources situation assessments.

The above attributes that were used to estimate the present ecological status were each scored, from which the mean was calculated. This mean was used to assign a present ecological status class to the mainstem river in the vicinity of the outlet of the quaternary catchment.

Suggested Future Ecological Management Class (AEMC)
The potential to improve the ecological conditions was assessed only in terms of the present flow regime. Degradation of the system purely because of non-flow related changes was ignored.

The practicality of improving an existing modified ecological system to arrive at the suggested future ecological management class was assessed on the basis of the changes that have occurred, by comparing the difference between the present ecological status class and the default ecological status. For the purpose of these water resources situation assessments restoration was accepted to be the "…re-establishment of the structure and function of an ecosystem, including its natural diversity". Generally, structure is the native or natural species diversity of the ecosystem, while function is its productivity in terms of growth of plant biomass as the basis for food webs and the functions of hydrology, trophic structure and transport. Restoration is to reverse the decline of the health of a degraded ecosystem towards its historic structure. In contrast, reclamation and rehabilitation are usually more local and site-specific, while habitat creation refers to the establishment of new habitat, without regard to historical conditions.

The water resources situation assessment is, *inter alia*, concerned with the quantity of water, and therefore particular emphasis was placed on flow modification. Where the impact on the biota and the habitats of the estimated present flow modification was less than can be inferred from the present ecological status, this was taken into account and specifically highlighted (emphasised or flagged). It is obvious that such a state of affairs needs more specific attention. This situation arose only in a limited number of cases and has been indicated in the assessment of both the present ecological status class and the suggested future ecological management class, but needs more specific attention in future.

2.6.3 Aquatic Ecosystems of Concern to the Study

It is important to recognise that within the context of the current report sensitive ecosystems refer specifically to ecosystems which are sensitive with respect to possible changes in water quantity and quality. Other sensitive ecosystems, specifically protected areas, are discussed in Section 2.6.4 below.

The Olifants/Doring WMA derives its name from the Olifants River and its main tributary, the Doring River. Both are rivers of regional significance, and are the subject of increasing water resource demands. The Olifants River and its tributaries are important from a conservation perspective, for the following reasons :

- they contain eight species of endemic fish (i.e. occur only in the Olifants River system), the highest number of endemic fish in any system south of the Zambezi River. Of these, two species are considered vulnerable, three endangered and three critically endangered.

- they have possible historical links with the Orange River and geological links with Gondwanaland which makes the river important from a scientific perspective.

The Doring River and its tributaries are particularly important from a conservation perspective for the following reasons :

- they are inhabited by nine indigenous fish species, of which seven are endemic to the river system.

- the reaches upstream of the confluence of the Tankwa River are vital breeding areas for the sawfin (*Barbus serra*), the Clanwilliam yellowfish (**Barbus capensis**) and the Clanwilliam sandfish (*Labeo seeberi*). Of these, the sawfin is endangered, the Clanwilliam yellowfish is vulnerable and the Clanwilliam sandfish is critically endangered.

- the Doring River is the only major river in the region that is not impounded.

- they have a high ecological status down their entire lengths.

The ecological significance/conservation importance of the river systems falling within the Olifants/Doring WMA, as exemplified by their Ecological Importance and Sensitivity Classes (EISC), are summarised in terms of associated ecological management or status classes in Figures 2.6.3.1 to 2.6.3.3. These show, respectively for each quaternary catchment, the default ecological management class, the present ecological status class, and the suggested future ecological management class. As outlined in Section 2.6.2, the EISC of a river is an expression of its importance to the maintenance of ecological diversity and functioning on a local and wider scale, as well as the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred. The EISC leads to the DEMC shown on Figure 2.6.3.1. As evident from Figure 2.6.3.1, a minority of the river reaches within the Olifants/Doring WMA exhibit a "high" EISC and an associated DEMC of Class B : largely natural (E10A, E10B, E24H, E24J, E24L, E24M, E40C, E40D, G30A, G30E and G30F) or "very high" (E10C and E22G) EISC and a DEMC of Class A : unmodified natural, and human manipulation of these systems would require very strong motivation. The majority of the river reaches, however, exhibit a "moderate" to "low" EISC, corresponding to DEMCs of Class C : moderately modified, and Class D : largely modified, and reflecting the anthropogenic modification of these systems, mainly as a result of farming activities. Nevertheless, despite their modified nature, many of these river reaches, especially those in the Olifants River, contain the endemic fish species referred to in the preceding paragraphs. Accordingly, developers should take cognisance of the significant risk of negative environmental impacts associated with the utilisation of these areas for further water resource developments.

This overview of the ecological significance and conservation importance of the river systems within the Olifants/Doring WMA is of necessity superficial. However, the assessment of the EISC and DEMC for the various quaternary catchments (outlined in Section 2.6.2) involved the consideration of a range of ecological determinants, including : rare and endangered biota, unique biota, intolerant biota, species richness, diversity of habitats types or features, refuge value of habitat types, sensitivity to flow changes, sensitivity to water quality changes, migration route/corridor for instream and riparian biota and presence of conservation or natural areas. This information is summarised within DWAF's EcoInfo database, and accordingly this database should be consulted as a matter of course at the onset of any water utilisation and development projects, to provide insight into the ecological sensitivity of the environment which is likely to be impacted by the proposed project, particularly with respect to sensitive habitats and rare and endangered species.

The ecological sensitivity of aquatic systems other than rivers, including lakes, wetlands and groundwater systems, has to date not been assessed within the Olifants/Doring WMA.

Similarly, the estuarine systems are generally not well studied, but could be ecologically important and sensitive to reduced flows and changes in water quality, especially salinity. In this regard, the Olifants River estuary is still in relatively pristine condition and is one of the only two permanently open estuaries on the west coast of South Africa. It is considered to be of national importance from a vegetation and piscifaunal perspective, and of international importance from an avifaunal perspective. Given its considerable ecological value, and the fact that at present the mean annual inflow to the estuary has been reduced by about 34%, it is imperative that if any future development of the water resources in the Olifants or Doring River catchments is considered, a comprehensive study of the freshwater requirements of the estuary should be undertaken to ascertain the environmental acceptability of the development.

2.6.4 National Heritage Sites, Proclaimed Game and Nature Reserves, Wilderness Areas

As previously alluded to, the sensitive ecosystems outlined above only include those relevant to aquatic ecosystems. However, in addition to these ecosystems the Olifants/Doring WMA contains other protected areas which may be impacted directly or indirectly upon by development activities associated with water resources. These protected areas include Natural Heritage Sites as well as those areas listed in Section 2.6.1, viz. Scientific and Wilderness Areas, National Parks and Equivalent

Reserves, Natural Monuments and Areas of Cultural Significance, Habitat and Wildlife Management Areas, Protected Land/Seascapes.

Table 2.6.4.1 contains a list of the protected areas within the Olifants/Doring WMA. All water resource development should take cognisance of these sites and it is the developer's responsibility to identify the exact proximity of activities to any of these sites, and to ensure that activities do not threaten the integrity of these sites. This consideration is particularly pertinent where water resource development activities impact on the supply of water resources to these areas and hence their long-term ecological sustainability.

TABLE 2.6.4.1: PROTECTED NATURAL AREAS AND NATURAL HERITAGE SITES WITHIN THE OLIFANTS/DORING WMA

AREA NAME	CATEGORY	GRID REFERENCE
Bo-Boschkloof	Natural Heritage Site	32º 58'S 19º 12'E
Bushmans Kloof	Natural Heritage Site	32º 07'S 19º 08'E
Cederberg Wilderness Area	Wilderness Area	32º 15'S 19º 15'E
Cederberg State Forest	Habitat and Wildlife Management Area	32º 35'S 19º 15'E
Elandsbaai Nature Reserve	Habitat and Wildlife Management Area	32º 20'S 18º 35'E
Elephant Rock	Habitat and Wildlife Management Area	31º 38'S 18º 07'E
Gannabos	Natural Heritage Site	31º 08'S 19º 12'E
Groot Groenfontein Private Nature Reserve	Natural Heritage Site	32º 50'S 19º 34'E
Grootfontein	Natural Heritage Site	32º 55'S 19º 06'E
Gys se Kraal	Natural Heritage Site	32º 42'S 18º 32'E
Matroosberg State Forest	Habitat and Wildlife Management Area	33º 25'S 19º 50'E
Oorlogskloof Nature Reserve	Habitat and Wildlife Management Area	31º 27'S 19º 00'E
Penguin Island (Lamberts Bay)	Habitat and Wildlife Management Area	32º 05'S 18º 18'E
Perdefontein	Natural Heritage Site	33º 20'S 19º 20'E
Rocherpan Nature Reserve	Habitat and Wildlife Management Area	32º 35'S 18º 17'E
St Helena Bay Rock Lobster Sanct.	Habitat and Wildlife Management Area	32º 45'S 18º 03'E
Tankwa Karoo National Park	National Parks and Equivalent Reserves	32º 14'S 19º 50'E
Verlorenvlei	RAMSAR Site	32º 22'S 18º 27'E
Visgat	Natural Heritage Site	32º 57'S 19º 12'E

The aforementioned list of protected areas should be regarded as dynamic, since other protected areas are likely to be identified within this WMA in the future. Accordingly, it is the developer's responsibility to ensure that he or she is familiar with the most recent status of protected areas within the Olifants/Doring WMA.

2.7 CULTURAL AND HISTORICAL SITES

Development of water supplies and services can have a negative impact on the archaeological and cultural heritage by way of development of dams, pipelines, canals, water services infrastructure and enterprises following on the provisions of water.

The National Monuments Act (No. 28 of 1969) provides for the protection and conservation of cultural resources including all archaeological sites. In addition, the

Environment Conservation Act (No. 73 of 1989) provides for the integration of cultural resources into environmental management processes.

Any given development may have an impact on archaeological or cultural heritage sites. It is essential therefore that potential impacts of any water supply and services related development should be assessed at the earliest possible phase of project planning.

Permission for the development to proceed is granted by the National Monuments Council once it is satisfied that steps have been taken to safeguard archaeological or cultural heritage sites, or that they have been adequately recorded and/or sampled.

Previous studies have revealed that within the Olifants/Doring WMA, the main rivers and their tributaries are rich in sites of archaeological/cultural interest. The nature of these sites is diverse, but consists mainly of Late Stone Age artefacts, including rock paintings, cave deposits and open scatters of debris related to occupation. Earlier material, in the form of Middle and Early Stone Age artefact scatters, is also present but less numerous, and colonial material in the form of building remains and graves also occurs. The presence of these sites implies that there is a considerable risk of damage to artefacts of archaeological/cultural/historical significance associated with water resource development within this WMA, and that extensive mitigation programmes may be required to alleviate any negative impacts.

No general listing of the sites of palaeontological, archaeological and historical significance within the WMA is available. The National Monuments Council does possess a database of National Monuments within each province, but this is only of limited use since it only lists National Monuments (as declared within the Government Gazette), and the vast majority of these occur within urban areas which are unlikely to be impacted upon by water projects. Accordingly, it is the responsibility of the developer to liaise with the National Monuments Council and South African Museum to establish whether they are aware of any sites of cultural/historical/archaeological interest within any area earmarked for development. Moreover, it is the developer’s responsibility to ensure that the development area is surveyed for archaeological sites or artefacts, and that necessary steps are taken to conserve them if they are present. To this end, the developer should be familiar with the relevant sections of the National Monuments Act and any other relevant legislation (e.g. National Parks Act (No. 57 of 1975)), and should consult with the National Monument Council on discovering sites or artefacts of palaeontological, archaeological or historical significance. Also, developers should take cognisance of the fact that the National Heritage Act superseded the National Monuments Act in April 2000, and should undertake to familiarise themselves with the contents of the new Act.

CHAPTER 3: DEVELOPMENT STATUS

3.1 HISTORICAL DEVELOPMENT OF WATER RELATED INFRASTRUCTURE

The towns in the Olifants/Doring WMA are all small with the result that, in the early years of their development their water supplies were provided from local sources via infrastructure owned by the municipalities. With a few exceptions, this situation has continued.

The first major infrastructure development was driven by the water requirements of agriculture, when, in 1917, parliament approved the construction of the Bulshoek Barrage and a canal system to irrigate land extending along the Olifants River to close to its mouth. These works were completed in 1923, and in 1935, construction of the Clanwilliam Dam was completed, to make more water available for the scheme. Since then, improvements and extensions to the scheme have been made at intervals. The most recent of these was in 1993, when the capacities of portions of the main canal were increased to enable water to be provided for the Namakwa Sands heavy minerals mine.

With the availability of water from the irrigation canal, the towns along its route also obtained their supplies from the canal when augmentation of their original schemes was required as a result of growing water requirements.

The towns further away from the canal have continued to rely on their own supplies from local sources, generally groundwater. The exceptions to this are the small towns of Bitterfontein and Nuwerus, which since 1990 have been supplied by the small Southern Namaqualand Government Regional Water Scheme which supplies desalinated groundwater and was implemented because of the severe shortage of suitable sources of water in the area.

3.2 DEMOGRAPHY

3.2.1 Introduction

A national study (Schlemmer *et al*, 2001) to develop water use projections to the year 2025 was undertaken for the Department of Water Affairs and Forestry by a team of specialists, in order to support the development of the National Water Resource Strategy. This included the development of baseline 1995 population estimates. The work commenced well before the results of the 1996 census became available, and a number of sources were used to develop the baseline data set. The database developed was subsequently reconciled with the results of the census in areas where the census had provided superior information.

The study focused on so-called functional urban centres having or likely to have reticulated water supply systems in the future. In a number of instances areas on the fringe of urban centres and classified as rural in the 1996 census were incorporated with the functional urban centres defined in the study, and urban populations identified in this study therefore differed from the urban populations enumerated in the census. The regional weighting of census counts to compensate for undercounts was also identified as a factor distorting some urban populations in smaller centres reported in the census.

3.2.2 Methodology

Functional urban areas were identified within magisterial districts. Estimates were made of the 1995 population in these centres, while the populations outside of these urban areas were grouped together as a so-called rural remainder. The urban populations were further categorised in order to provide a basis for developing estimates of urban water use for the entire country (see Section 5.3).

A number of sources and approaches were used to obtain baseline population data for the year 1995. These included projections and estimates made by the following institutions:

- The Development Bank of Southern Africa.
- The Demographic Information Bureau.
- The Bureau for Market Research.
- Local authority estimates, where available.

The data from the above sources were compared with extrapolations and estimates based on the following:

- Household counts from the sampling database held by one of the participating consultants.
- Previous census results from 1970 onwards, including former homeland censuses.
- Estimates obtained from very large surveys such as that of the SAARF.
- The database of villages of the Directorate: Water Services of the Department of Water Affairs and Forestry.

Discrepancies were reconciled on the basis of local knowledge and special enquiries directed at local authorities. The results of the 1996 census became available after this had been completed, and was used as an additional check on the database. Where discrepancies were significant these were investigated, and the database was revised where the 1996 census provided improved information.

As an overall check the population distribution database for 1995 that was developed as part of this study was projected for one year on the basis of a ruling population growth rate of 1,9%. An effective population of 42 379 000 persons in 1996 was arrived at in this way, which is only 1% above the 1996 census population of 41 945 000 persons.

A reasonable estimate of the distribution of the rural population was made, using the census results for the rural population as a guideline, to develop a spatially distributed database.

3.2.3 Historical Population Growth Rate

Accurate historical population data for the WMA as a whole is not readily available. The reason for this is that the main sources of data are the national population censuses for which published data are available in terms of magisterial districts. As the boundaries of the latter do not coincide with the boundaries of the WMA, the population of the WMA can only be roughly estimated. Nevertheless, this information can be used to obtain an indication of trends in population growth.

It appears from data extracted from population censuses and published by the Development Bank of Southern Africa (DBSA, 1991), that the average growth rate of the population in the area between 1980 and 1990 was about 0,5% per year. In most parts of the WMA the urban populations increased at about 0,5% per year and the rural population decreased at between 1% and 2% per year. The exception was the magisterial district of Vredendal where the population of the town of Vredendal grew at 7% per year, to increase from 5 000 to 10 000 people between 1980 and 1990. The rural population in this magisterial district also grew at about 2% per year during the same period.

3.2.4 Population Size and Distribution in 1995

In 1995, approximately 104 000 people lived in the WMA. About 50 000 of these lived in urban or peri-urban areas, and the rest in rural areas. The distribution of the population is shown in Table 3.2.4.1 and in Figure 3.2.4.1, where it can be seen that the population is concentrated in the Olifants River Valley (E10 and E33F, G, H) and the Sandveld (G3). Only 30% of the population live in the arid areas of the Doring River Catchment (E2 and E4), the catchments of the northern tributaries of the Olifants River (E31, E32 and E33A to E), and the Namaqualand coastal catchments (F6), even though these account for 80% of the area of the WMA.

TABLE 3.2.4.1: POPULATION IN 1995

CATCHMENT						POPULATION IN 1995		
PRIMARY		SECONDARY		TERTIARY		URBAN	RURAL	TOTAL
No.	Description	No.	Description	No.	Description			
E	Olifants	E1	Upper Olifants	None	---	8 150	11 196	**17 556**
		TOTAL IN UPPER OLIFANTS				**8 150**	**11 196**	**17 556**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	0	9 292	**9 292**
				E22	Upper Doring (W Cape)	0	925	**925**
					Upper Doring (N Cape)	0	135	**135**
				E23	Tankwa (W Cape)	0	816	**816**
					Tankwa (N Cape)	0	240	**240**
				E24	Lower Doring (W Cape)	0	2 900	**2 900**
					Lower Doring (N Cape)	0	1 635	**1 635**
			Sub-total (Western Cape)			**0**	**13 933**	**13 933**
			Sub-total (Northern Cape)			**0**	**2 010**	**2 010**
		E4	Oorlogskloof (W Cape)	None		0	120	**120**
			Oorlogskloof (N Cape)	None		8 150	916	**9 066**
			Sub-total (Western Cape)			**0**	**120**	**120**
			Sub-total (Northern Cape)			**8 150**	**916**	**9 066**
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				0	14 054	**14 054**
		TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE				8 150	2 926	**11 076**
		TOTAL IN DORING CATCHMENT				**8 150**	**16 979**	**25 129**
		E3	Lower Olifants	E31	Kromme (All N Cape)	1 900	587	**2 487**
				E32	Hantams (All N Cape)	0	971	**971**
				E33	Lower Olifants (W Cape)	21 300	11 888	**35 088**
					Lower Olifants (N Cape)	0	100	**100**
			Sub-total (Western Cape)			21 300	11 888	**35 088**
			Sub-total (Northern Cape)			1 900	1 658	**3 558**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				**29 450**	**37 138**	**66 588**
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				**10 050**	**4 584**	**14 634**
		TOTAL IN OLIFANTS CATCHMENT				**39 500**	**41 722**	**81 222**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None	-	2 650	962	**3 612**
	TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)					**2 650**	**962**	**3 612**
G (Part)	Berg (Part)	G3	Sandveld (All Western Cape)	None	-	7 400	11 460	**18 860**
	TOTAL IN PART OF BERG CATCHMENT (All Western Cape)					**7 400**	**11 460**	**18 860**
	TOTAL IN WMA IN WESTERN CAPE					39 500	49 560	**89 060**
	TOTAL IN WMA IN NORTHERN CAPE					10 050	4 584	**14 634**
	TOTAL IN WMA					**49 550**	**54 144**	**103 694**

3.3 MACRO-ECONOMICS

3.3.1 Introduction

The purpose of this section is to provide an economic overview of the salient features of the Olifants/Doring Water Management Area (WMA) in terms of the following aspects:

- The present economic development of the Olifants/Doring WMA on a sectoral basis, taking into account the context of economic development in South Africa.
- The comparative advantages of the Olifants/Doring WMA.

Selected graphs are included to illustrate the text and additional supporting information is given in **Appendix B.1**.

3.3.2 Data Sources

The information presented has been derived from a database of macroeconomic indicators that was prepared by Urban-Econ: Development Economists from a number of sources, including the Development Bank of Southern Africa. **Appendix B.2** contextualises each WMA economy in terms of its significance to the national economy, as derived from the national economic database. Only gross geographic product (GGP) and labour data are analysed. A brief description of the database of macro-economic indicators and associated economic information system is given in **Appendix B4.**

Gross geographic product is the total value of all final goods and services produced within the economy in a geographic area for a given period. GGP is the most commonly used measure of total domestic activity in an area and is also the basis for the national account. Changes in the local economy can therefore be expressed as an increase in GGP. Base GGP data for 1972, 1975, 1978, 1981, 1984, 1988, 1991, 1993 and 1994 were obtained from Statistics South Africa. Data for unknown years between 1972 and 1994 were interpolated applying a compound growth formula. The interpolated data was balanced with national account figures. Data for 1995 to 1997 is based on weighted least squares estimates of the long-term trend, taking into account the change in electricity consumed. The projected data was balanced with national account figures. The major limitation of GGP figures is that activities in the informal sector are largely unmeasured.

The **labour** distribution provides information on the sectoral distribution of formal economic activities, as do the GGP figures, but in addition, information is provided on the extent of informal activities, as well as dependency. Dependency may be assessed from unemployment figures, as well as by determining the proportion of the total population that is economically active. *Total economically active* population consists of those employed in the formal and informal sectors, and the unemployed. *Formally employed* includes employers, employees and self-employed who are registered taxpayers. *Unemployment figures* include people who are actively looking for work, but are not in any type of paid employment, either formal or informal. *Active in informal sector* includes people who are employers, employees or self-employed in unregistered economic activities, i.e. businesses not registered as such. The labour data was obtained directly from the Development Bank of Southern Africa (DBSA). The DBSA has utilised the 1980 and 1991 population censuses as the basis but has also updated the figures utilising the 1995 October Household Surveys of Statistics South Africa (CSS statistical release P0317 for South Africa as a whole and P3017.1 to P0317.9 for the nine provinces).

The GGP and labour statistics are disaggregated into the following major economic sectors:

- Agriculture
- Mining
- Manufacturing
- Electricity
- Construction
- Trade
- Transportation
- Finance
- Government and Social Services (Community Services).

Separate GDP figures for government and social services are available. However, in the labour market these figures are combined into the community services sector. The nature and composition of each sector are described in Appendix B.3.

3.3.3 Methodology

Each sector of the economy was dealt with in an appropriate way to reflect a reasonable approximation of the spatial distribution of production and labour:

- **Agriculture**
  The digitised geographic layer of WMAs was merged with the Magisterial District (MD) boundaries, and the surface area for each of the newly generated polygons was determined. The proportion of the surface area of each of the MD, which falls within each WMA, was calculated, and that proportion was used to allocate the part of a GGP figure that falls on each side of a WMA-boundary.

- **Trade and Community Services**
  To take account of the subdivision of local authority areas by MD or WMA boundaries, the number of enumerator areas (EAs) falling within each subdivision of a local authority area, as a proportion of the total number of EAs in a local authority area, was determined. This proportion was applied to the latest population figure (1996 census) of each local authority area. As EAs are of approximately equal population size, these proportions were used to calculate the approximate population for that part of a local authority area which falls within each MD, as they are subdivided by WMA boundaries. The population of each MD segment, as a proportion of the total MD population, was used to calculate the proportion of a GGP figure which should be allocated to each segment of a MD, so that theses figures could be totalled up within the WMA boundaries.

- **Other Sectors**
  Historical factors, such as the relocation of certain segments of the population to non-productive areas, had to be taken into account when allocating the GGP figure to the WMAs. Subsequently, for all the sectors apart from those discussed above, only the Caucasian population was used to perform the calculations as described above. Economic activities in these sectors are less dependent on population per se, but are dependent on the same factors which affect the kind of population distribution that is not distorted by government intervention or other external factors. The Caucasian population has typically not been influenced by the latter

factors, and its distribution is therefore a better guide for determining the distribution of economic activities in these sectors.

3.3.4 Status of Economic Development

The GGP of the Olifants/Doring WMA was R1,6 bn in 1997. The most important magisterial districts in terms of contribution to GGP in this WMA are shown below:

- Vredendal 33,2%
- Ceres 22,0%
- Clanwilliam 19,4%
- Calvinia 8,9%
- Piketburg 5,0%
- Other 11,5%

Economic Profile

The composition of the Olifants/Doring WMA economy is shown in Diagram 3.3.1. The most important sectors in terms of contribution to GGP are shown below:

- Agriculture 43,3%
- Trade 14,5%
- Manufacturing 11,8%
- Financial Services 9,5%
- Government 8,4%
- Other 24,3%

The significance of the agricultural sector (43.3%) can be attributed to the variety of products cultivated in this area. This sector focuses on the cultivation of wine and table grapes, oranges, potatoes and tomatoes, and the production of wine, rooibos tea, fresh fruit, dried fruit, wheat, and fisheries.

The manufacturing sector is based on steel, minerals and food processing activities. Especially Vredendal is a focus area for manufacturing. Manufacturing is also strongly linked to the region's agricultural activities with a large percentage of activities in the food and beverage sub-sectors.

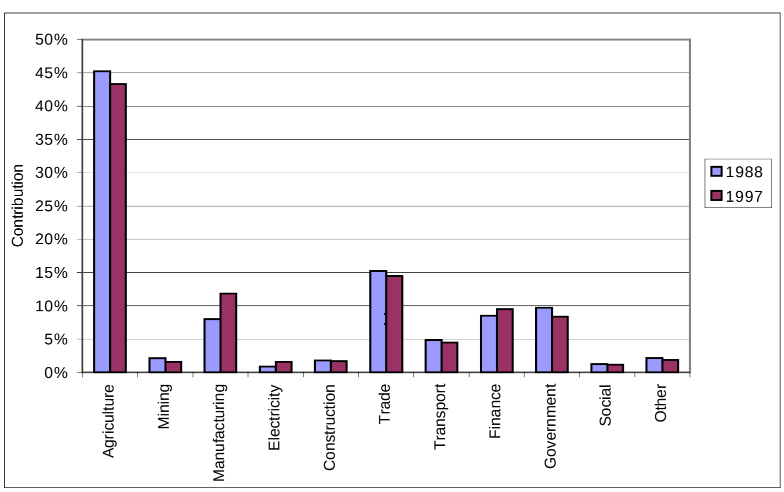

Diagram 3.3.1: Contribution by sector to economy of Olifants/Doring Water Management Area, 1988 and 1997 (%)

Trade activities mainly comprise wholesale in wine, fruit, wheat and other agricultural products, as well as trade services to the local community.

Economic Growth

The average annual economic growth by sector is shown in Diagram 3.3.2. Between 1987 and 1997, the highest average growth rates were recorded in the following sectors:

- Electricity : 10.4%
- Manufacturing : 8.2%

Agriculture, which forms the base of the economy, recorded a growth rate of 3.2%, indicating that this sector has an important role in the future. The growth potential will further be stimulated by strong export opportunities for local fruit, wine and wheat.

The high growth in the electricity sector occurred from a relatively small base and this increase can be traced to growth in manufacturing demand as well as electrification projects in previously disenfranchised areas.

In the manufacturing sector, opportunities for steel and other exports are expected to emerge once the upgrading of harbour facilities have taken place.

Growth in the manufacturing sector will further stimulate growth in the electricity sector, since manufacturing industries are important consumers of electricity.

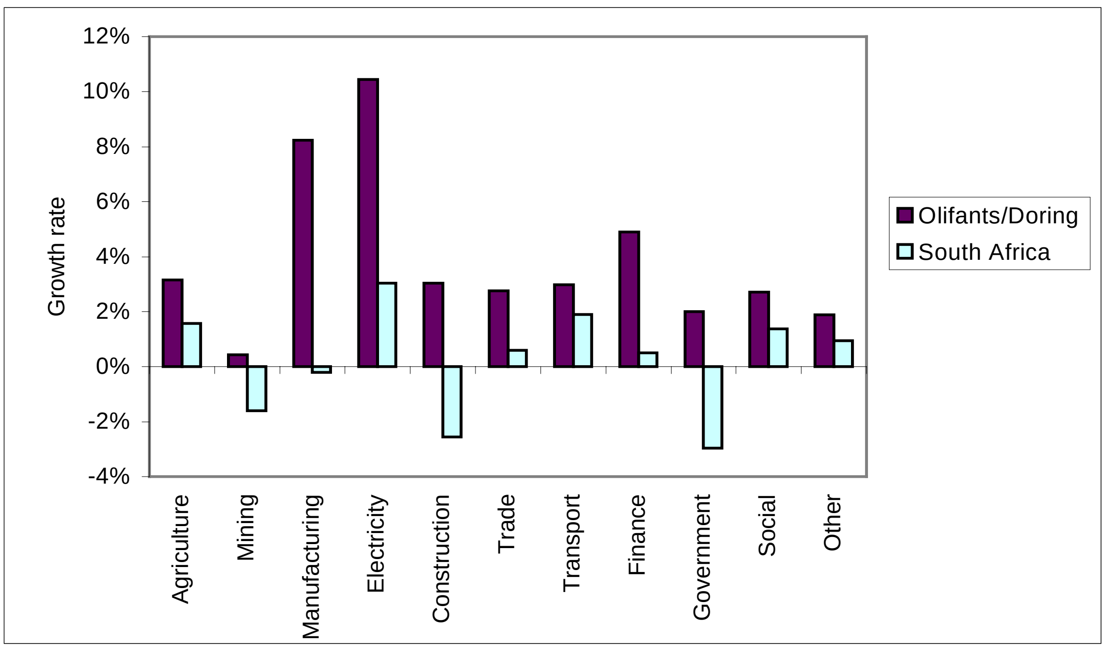

Diagram 3.3.2: Average annual economic growth by sector of Olifants/Doring Water Management Area and South Africa, 1988-1997

Labour

Of the total labour force of 58 600 in 1994, 8.1% were unemployed, which is lower than the national average of 29.3%. Seventy five percent (75.5%) were active in the formal economy. Forty nine percent (49.5%) of the formally employed labour force work in the agricultural sector, while 20%, work in the government sector and 8.7% in trade.

Employment growth was recorded in the mining sector (4.8% per annum); financial services (2.7% per annum); the agricultural sector (2.8% per annum); and construction (2.4% per annum).

High growth rates were recorded in GGP, but not in the labour market. It can thus be concluded that manufacturing growth was mostly capital intensive.

3.3.5 Comparative Advantages

A comparative advantage of a particular region indicates that the economy poses a relatively more competitive production function for a specific product or service than other regions in the aggregate economy (e.g. South Africa). A comparative advantage may be measured by means of a location quotient, which compares the economic sector's share in gross geographic product (GGP) with its percentage share in some basic aggregate, such as gross national product (GNP). A value of more than one implies that the region has a comparative advantage in a specific production function *vis-à-vis* the rest of South Africa.

Diagram 3.3.3 shows the location quotients for Olifants/Doring WMA. The Figure shows that, based on the location quotients for 1997, the Olifants/Doring WMA economy is relatively more competitive than the remainder of South Africa in the following economic activities:

- Electricity : 4.0
- Mining : 2.8
- Agriculture : 1.4.

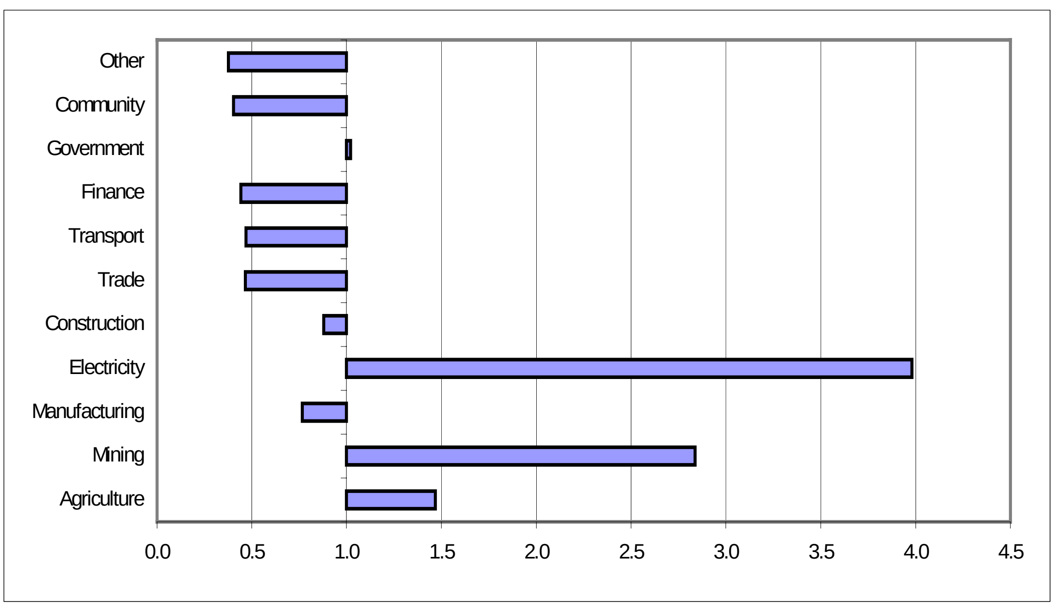

Diagram 3.3.3: Olifants/Doring Gross Geographic Product location quotient by sector, 1997

Agriculture plays an important role in the economy of the study area as a result of the great diversity of agricultural products. Especially grapes, citrus, and related products play an important role in this WMA.

Namakwa Sands mining operation near Vredendal where titanium slag and other minerals are mined contributes to the comparative advantage in the mining sector.

3.4 LEGAL ASPECTS AND INSTITUTIONAL ARRANGEMENTS FOR WATER SUPPLY

3.4.1 Past History

The history of settlement in southern Africa is linked to the availability and supply of fresh water. From early times South African water law was based on the needs of white settlers who in colonising the land promulgated a water law in which domestic and agriculture needs and later industrial needs played the major role (*res publica)* and the government had the function to regulate the use of water (*dominus fluminis*).

Initially Roman and Roman Dutch law had a strong influence in the shaping of South African water law and water running in rivers was regarded as common property. This changed in the latter half of the 19^{th} century, after the occupation of the Cape by the British. The judges trained by the British introduced the principle that owners of property riparian to a river became entitled to water from that river.

The first codification of water law in South Africa was in the Irrigation and Conservation of Waters Act of 1912. The emphasis was still on irrigation and carried down the riparian principle. This Act was repealed by the Water Act of 1956, which also placed a major emphasis on the use of water for irrigation, although other water uses, such as domestic, urban and industrial, also received recognition.

This remained the situation until the National Water Act (Act No. 36 of 1998) (NWA) was assented to by the President on 20 August 1998. As from 1 October 1999 the whole of the NWA came into full effect and is now the only Act dealing with water law.

3.4.2 National Water Act

The NWA does away with and introduces some far-reaching concepts. These concepts have both economic and social features. The former to address water management by conservation and pricing strategy and the latter by ensuring that past discriminatory principles are not continued in the NWA. The most important of these can be summarised as follows:

- The riparian principle is done away with. The nation's water resources become common property, belonging to the nation as a whole. Therefore the previous concept of private ownership in water is done away with;
- The national government, through the Minister of Water Affairs and Forestry, becomes responsible as the public trustee of all water resources to ensure that water resources are protected and water allocated equitably and used beneficially in the public interest. Therefore the NWA reflects the constitutional right of access to sufficient water (Section 27 of the Constitution);
- All right to use water derives from the NWA;
- Water must be available for the Reserve. The Reserve is a new concept and consists of two legs, namely the quantity and quality of water required to satisfy basic human

needs as prescribed by the Water Services Act (Act No 108 of 1997) for people who now or will in future require water and to protect the aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource. Thus environmental considerations are anchored in the NWA;

- Setting out in the purposes of the Act that institutions which have appropriate community, racial and gender representation must be developed to give effect to the NWA;
- Shifts the emphasis from the traditional "supply management" approach towards "demand management", that is conservation of the nation's water resources by lessening the demand and providing for an innovative pricing system.
- Providing for extensive public participation. Virtually no decision can be made without public participation;
- The abolishment of the Water Courts and introducing a Water Tribunal where administrative final decisions can be appealed to; and
- Recognition of international obligations.

3.4.3 Strategies

The NWA makes provision for establishment of two water management strategies. These are the National Water Resource Strategy and the Catchment Management Strategy. The National Water Resource Strategy is binding on the Minister of the Department of Water Affairs and Forestry, other organs of State and all water management institutions for anything contained therein, while the catchment management strategy is binding on the relevant catchment management agency and is more on a local level.

Water resource management will in future be based on the management strategies and the classification system for the protection of water resources provided for in the NWA. The contents of the National Water Resource Strategy are wide and included therein are the principles relating to water conservation and water demand management; the objectives in respect of water quality to be achieved through the classification system, as well as having to establish the future water needs. The National Water Resource Strategy will also provide for international rights and obligations.

3.4.4 Environmental Protection

Chapter 3 of the NWA deals with protection of the water resources.

The Minister must classify the nation's water resources and then determine the class and resource quality objectives for each class. This will establish clear goals for resource protection and at the same time provide for a balance between the need to protect and sustain one's water resources and the need to develop and use them on the other hand.

An important function is for the Minister to determine the Reserve, which as stated above, is closely linked to the Water Services Act (Act No. 108 of 1997).

Section 19 of the NWA provides *inter alia* that any person who is in control of land over which pollution is taking place or who causes pollution or potential pollution to take place, must take the necessary steps to prevent this from continuing. Should this not be done, the Minister shall have the right to take the necessary steps to recover the cost from the responsible person.

3.4.5 Recognition of Entitlements

The NWA abolishes the historical distinction between public and private water. There is no ownership in water and all water is subject to a licensing system, except for the following :

- Water use that is set out under Schedule 1 of the NWA;
- General authorisations issued under Section 39 of the NWA; and
- Existing lawful use recognised under the NWA until such time as the person is required to apply for a licence.

The statutory difference between water resources within an area proclaimed as a government water control area in terms of the Water Act of 1956 and areas outside a government water control area has now been done away with. In actual fact the whole of the country is a government water control area.

3.4.6 Licensing

Whereas the Water Act of 1956 divided water into different categories, in the NWA all water has the same status. Section 21 of the NWA sets out what is regarded as water use. These include, amongst other uses, taking water from a water resource, storage of water, diverting water, discharging waste into a watercourse, disposing of waste in a manner that may detrimentally impact on a water resource and recreational use.

Two new concepts of water use are created. The first is that the Minister can declare any activity to be a stream flow reduction activity, if that activity reduces the availability of water. Afforestation has already been declared a stream flow reduction activity. The second new concept is that the Minister can declare any activity to be a controlled activity if that activity impacts on a water resource. Activities such as irrigation on any land with waste, recharging of an aquifer are examples of activities that are already controlled activities.

All water use requires a licence unless it falls into a Schedule 1 use (this deals with the *de minimus* use, such as water for reasonable domestic use, small gardening and animal watering (excluding feedlots); or was permissible as an existing lawful use (water use permitted under previous laws and which were exercised during the period of two years before the date that Section 32 came into effect; namely 1 October 1998); and under a general authorisation.

An important innovation is that a licence can only be for a maximum period of 40 years and is subject to a review period, which may not be at intervals of more than five years. A licence can be increased at each review period but not for more than the review period. This is known as the "revolving licence".

If a person who has an existing lawful use applies for a licence under Section 43 of the NWA (compulsory licensing), and the application has been refused or has been granted for a lesser amount which results in severe economic prejudice, the applicant may claim compensation. Compensation cannot be claimed if the reduction is to provide for the Reserve, rectify a previous over-allocation or a previous unfair allocation.

Compensation must be claimed from the Water Tribunal.

The Minister has the right to attach conditions to any licence as well as to make regulations on various topics set out in Section 26 of the NWA.

It is important to note that although the Water Services Act (Act No. 108 of 1997) deals with water services, the actual water use is controlled under the NWA.

3.4.7 Other Legislation

The NWA is aligned with other laws in order to prevent, for example, duplication of applications, unnecessary expenses and where possible, a "one stop" can be issued. Specific examples are as follows:

- Environment assessments in terms of the Environmental Conservation Act of 1989 can be taken into account by the responsible authority when issuing a licence;
- If a licence is issued under other acts that meet the purpose of the NWA, the responsible authority can dispense with the issuing of a licence for water under the NWA; and
- Provisions in the Constitution of the Republic of South Africa must be complied with.

Further, there is a close connection between the Water Services Act (Act No. 108 of 1997) and the NWA.

The Abolition of Racially Based Land Measures Act repealed laws that previously restricted black persons from owning or occupying land. These acts had the effect of preventing black persons from having any water rights or under certain circumstances, limited water entitlements.

Notwithstanding the NWA there are other acts to which a water user and indeed the State must comply.

These Acts are the following:

Physical Planning Act (Act No. 125 of 1991)
Under this act no land use, development or subdivision may be permitted unless in accordance with an approved plan.

Development Facilitation Act (Act No. 67 of 1995)
This act prescribes the set of principles with which all development projects and all land use and land use planning should comply, and which will serve as guidelines for the administration of land use and development schemes.

Restitution of Land Rights (Act No. 22 of 1994)
This act is aimed at the restitution of land to those who have been deprived thereof in terms of discriminatory laws. Claims are lodged with the Land Claims Commission. It is because of this act that when a transfer of water entitlements is approved in terms of the NWA an indemnity is required from the transferor that a claim was not lodged against the land in terms of the Restitution of Land Rights Act.

Environmental Conservation Act (Act No. 73 of 1989)
This act provides for the effective protection and control of the environment. It makes provision for the declaration of an environmental conservation policy.

In terms of this act the state has a responsibility to act as trustee of the natural environment and to consider all activities which may have an influence on the environment.

Activities, which may have a detrimental effect on the environment, have been published in terms of Section 21 of this act. To undertake any of these activities, authorisation is required, which can only be obtained from the Minister of Environmental Affairs and Tourism after the prescribed procedure has been complied with. The construction of various forms of water works (dams, water diversions, water transfer schemes, etc.) are subject to the new process.

Through a consultative process a White Paper for Sustainable Coastal Development in South Africa was prepared. In terms thereof it is the joint responsibility of the Departments of Water Affairs and Forestry and of Environmental Affairs and Tourism to protect the in-shore marine environment.

In terms of this act the Department of Environmental Affairs and Tourism is responsible for issuing waste permits under this act and has published a Government Notice 1986 of 24 August 1990 relating to the identification of waste. This government notice needs drastic amendment to bring it in line with the NWA.

In May 2000 the Department of Environmental Affairs and Tourism published a White Paper on Integrated Pollution and Waste Management for South Africa. Aspects included water pollution; diffuse water pollution, marine pollution; and land pollution.

National Environmental Management Act (Act No. 107 of 1998)

This act lays a new foundation for environmental management. The act includes 20 principles that serve as a general framework within which environmental management and implementation plans must be formulated and guide any other law concerned with the protection or management of the environment. Environment is defined as the natural environment and the physical chemical, aesthetic and cultural properties of it that influence human well-being.

To give effect to these principles this act creates the National Environmental Forum and the Committee for Environmental Co-ordination and defines the procedure for the establishment of a Coastal Management Subcommittee of the Committee for Environmental Co-ordination in order to achieve better inter-governmental co-ordination of coastal management.

This act provides for the drawing up of environmental implementation plans by certain scheduled national Government Departments and the Provinces. In addition, environmental management plans are to drawn up by certain national Departments. The two sets of plans do not have to be drawn up by the private sector and may be consolidated. The purpose of the plans is set out in detail and must co-ordinate and harmonise environmental policies, plans, decisions of the three spheres to prevent duplication; give effect to co-operative governance and enable monitoring the achievement.

Chapter 7 of this act relates to environmental damage, duty of care, emergencies and remediation.

Conservation of Agriculture Resources Act (Act No. 43 of 1983)

This act is to provide for control over the utilisation of the natural agricultural resources in order to promote the conservation of the soil; the water resources and vegetation and the combating of weeds and invader plants. Except for weeds and invader plants, this act does not apply to land in an urban area.

3.4.8 Institutions Created Under the National Water Act

The NWA creates various institutions, some of which are listed below.

The first are Catchment Management Agencies (CMA) and one CMA will be established in each of the Water Management Areas that have been promulgated by Government Notice 1160 of 1 October 1999 (19 in total). These will have various functions either delegated or assigned to them, thus bringing the management of water resources to the regional or catchment level. A CMA will operate via a board along the lines set out in Schedule 4 to the NWA. The composition of the board is recommended by an Advisory Committee that is established by the Minister and has the important task to recommend to the Minister proposed members who are racially, gender and community representative.

A second institution, is that of Water User Associations (WUA) that will operate on a restricted local level and are in effect cooperative associations of individual water users who wish to undertake related water activities for a mutual benefit. Irrigation Boards established under the Water Act of 1956 had until 29 February 2000 to transform into a WUA. All WUAs must have a constitution based on the lines set out in Schedule 5 to the NWA, which must be approved by the Minister. The policy of the Department of Water Affairs and Forestry is that these must also as far as possible be racially, gender and community representative.

A third institution is bodies to implement international agreements. This can only be established by the Minister in consultation with the Cabinet.

A fourth body that the Minister can establish is Advisory Committees. These committees may be established for a particular purpose but can also have powers delegated to it by the Minister.

Lastly, the NWA establishes a Water Tribunal where appeals against administrative decisions by the Department of Water Affairs and Forestry and CMAs can be heard. The question of compensation for loss of entitlements to use water is also to be heard in this Tribunal. Appeals on questions of law from the Tribunal are heard in the High Court.

3.4.9 Institutions Responsible for Community Water Supplies

The Water Services Act, No. 108 of 1997, deals with the provision of water supply services and sanitation services in a manner consistent with the broader goals of water resource management. The institutional structure provided for in the Act includes, in addition to the National Government, represented by the Department of Water Affairs and Forestry, the following bodies:

(i) Water Services Authorities, which are municipalities, including district or rural councils, that are responsible for ensuring access to water services.

(ii) Water Boards, which may be established by the Minister of Water Affairs and Forestry, after due consultation with stakeholders, for the primary purpose of providing water services to other water services institutions.

(iii) Water Services Committees, which may be established by the Minister of Water Affairs and Forestry to provide water services to communities within their own service areas where the Water Services Authorities having jurisdiction in the areas in question are unable to provide water services effectively.

(iv) The Provincial Government, which may take over the functions of a Water Services Committee or a Water Board, if requested to do so by the Minister of Water Affairs and Forestry

(v) Advisory Committees, which may be appointed by the Minister of Water Affairs and Forestry to provide advice on matters falling within the scope of the Act.

3.4.10 Water Related Institutions in the Olifants/Doring WMA

There are no water boards or advisory committees in the Olifants/Doring WMA and the municipalities are the Water Services Authorities responsible for water services in the WMA. The municipalities were restructured in the year 2000. As this report deals with the period prior to that, only the institutional arrangements prior to the re-restructuring are reported on here. Thus, the Water Services Authorities prior to the restructuring were:

- The West Coast District Council
- The Hantam District Council
- The Breede River District Council
- The Central Karoo District Council
- The Namaqualand District Council

The boundaries of the areas of jurisdiction of the District Councils are shown on Figure 3.4.8.1. For general administrative purposes, but not for water supply, each District Council area is subdivided into magisterial districts, the boundaries of which are also shown on Figure 3.4.8.1.

The relevant magisterial districts are:

- Within the West Coast District Council Area
  - Clanwilliam
  - Piketberg
  - Vredendal
  - Vanrhynsdorp
- Within the Hantam District Council Area
  - Calvinia
- Within the Breede River District Council Area
  - Ceres
  - Tulbagh (a very small area)
- Within the Central Karoo District Council Area
  - Laingsburg
- Within the Namaqualand District Council Area
  - Namaqualand

Within the District Council areas, Transitional Local Councils were responsible for water services to towns and Transitional Regional Councils were responsible for water services in sub-divisions of the rural areas. The boundaries of these areas are shown on Figure 3.4.8.2.

In 1995 there were four irrigation boards in the WMA, namely :

- The Citrusdal Irrigation Board
- The Clanwilliam Irrigation Board
- The Vredendal Irrigation Board
- The Elandskaroo Irrigation Board

As mentioned earlier, these are required to transform into Water User Associations.

3.5 LAND-USE

3.5.1 Introduction

The Olifants/Doring WMA covers an area of approximately 56 500 km^2. The mean annual precipitation over much of the area is less than 200 mm, with the result that, except in the wetter south-west, the climate is not suitable for dryland farming on a large scale. Consequently, more than 90% of the land is used as rough grazing for livestock.

Land use is summarised in Table 3.5.1.1, where it can be seen that an estimated 2 190 km^2, or approximately 4% of the land area is used for dryland farming. This area was calculated from land cover maps derived from satellite images (CSIR, 1996) and is only indicative of the area cultivated, which can be expected to vary considerably from year to year, depending on climatic conditions.

Table 3.5.1.1 has a column for dryland sugar cane because the cultivation of this crop causes a reduction in the low flows in rivers in areas where it occurs on a large scale, and is regarded as a streamflow reduction activity. Therefore, it is of interest in any analysis of water resources. However, sugar cane is not grown on a commercial scale in the Olifants/Doring WMA because the climate is not suitable.

Citrus, deciduous fruits, grapes and potatoes are grown on a large scale in the south-western part of the WMA. It is estimated that a total area of about 463 km^2 of land is under irrigation, but much of this is used only in years when water is plentiful. Consequently, it is estimated that an average area of about 400 km^2 of crops grown under irrigation is harvested.

Commercial timber plantations, totalling 10 km^2 in area, are cultivated in the mountainous high rainfall areas in the south-west of the WMA.

Urban areas are small, covering a total area that is estimated to be 31 km^2. There are a few small rural settlements, but they occupy an insignificant area of land.

Several nature reserves have been proclaimed and their boundaries are shown on Figure 3.5.1.1.

Apart from the Namakwa Sands heavy minerals mine on the coast in the north-western corner of the WMA, mining operations are small and are concerned mainly with quarrying, or with dredging for marine diamonds.

Land use by province and district council area are shown in Table 3.5.1.2, and the main land uses are described in more detail in the following sections.

TABLE 3.5.1.1: LAND USE

DRAINAGE AREA	IRRIGATION (km^2)	DRYLAND SUGAR CANE (km^2)	OTHER DRYLAND CROPS (km^2)	AFFORESTATION (km^2)	NATURE RESERVES (km^2)	URBAN (km^2)	OTHER (km^2)	TOTAL AREA (km^2)
Kouebokkeveld (E21)	86	0	180	2	121	0	2 683	3 072
Upper Doring (E22)	6	0	20	0	0	0	4 128	4 154
Tankwa (E23)	4	0	30	0	217	0	6 195	6 446
Lower Doring (E24)	16	0	430	0	222	0	6 980	7 648
Oorlogskloof (E4)	4	0	200	0	0	6	2 562	2 722
Sub-total : Doring at confluence with Olifants (E2 + E4)	**116**	**0**	**860**	**2**	**560**	**6**	**22 548**	**24 042**
Upper Olifants (E10)	107	0	450	8	455	3	1 865	2 888
Kromme (E31)	0	0	0	0	0	2	9 717	9 719
Hantams (E32)	3	0	100	0	54	0	4 044	4 201
Lower Olifants (E33)	111	0	170	0	0	12	7 923	8 216
Sub-total : Olifants River at mouth (E1, E2, E3, E4)	**337**	**0**	**1 580**	**10**	**1 069**	**23**	**46 097**	**49 066**
Namaqualand coastal catchments (F6)	0	0	0	0	0	3	2 787	2 790
Sandveld (G3)	130	0	610	0	0	5	3 845	4 590
TOTAL OLIFANTS/DORING WMA	**467**	**0**	**2 190**	**10**	**1 069**	**31**	**52 679**	**56 446**

TABLE 3.5.1.2: LAND USE BY PROVINCE AND DISTRICT COUNCIL AREA

TYPE OF LAND USE	AREAS IN WESTERN CAPE PROVINCE				AREAS IN NORTHERN CAPE PROVINCE			TOTAL AREA (km^2)
	WEST COAST DISTRICT COUNCIL (km^2)	BREEDE RIVER DISTRICT COUNCIL (km^2)	CENTRAL KAROO DISTRICT COUNCIL (km^2)	TOTAL (km^2)	HANTAM DISTRICT COUNCIL (km^2)	NAMAQUALAND DISTRICT COUNCIL (km^2)	TOTAL (km^2)	
IRRIGATION	355	96	0	450	21	0	21	467
DRYLAND SUGAR CANE	0	0	0	0	0	0	0	0
OTHER DRYLAND CROPS	1 420	370	0	1 790	400	0	400	2 190
AFFORESTATION	5	5	0	10	0	0	0	10
NATURE RESERVES (1)	706	38	0	744	325	0		1 069
URBAN AREAS	25	0	0	25	6	0	6	31
OTHER	18 873	8 247	581	27 338	21 832	3 508	25 340	52 689
TOTALS	**21 348**	**8 756**	**581**	**30 685**	**22 253**	**3 508**	**25 761**	**56 446**

(1) Includes National Parks, wilderness areas, etc.

3.5.2 Irrigation

Table 3.5.2.1 shows the distribution of irrigated land within the WMA and an estimate of the average areas of the different types of crops harvested. This information was obtained from earlier studies carried out in the area (DWAF, 1990a and DWAF, 1998a), from information provided by the Western Cape Province Department of Agriculture, and from DWAF officials who work in the area.

The various sources provided very different figures for the areas of the different types of crops and, in general, the crop mix suggested in discussions with the DWAF officials has been used. Nevertheless, confidence in the accuracy of the areas of individual crops shown in Table 3.5.1.2 is low and the information should be used with caution. The values for the total irrigated areas are thought to be reasonably reliable. They represent the area of land that is irrigated in years when water is plentiful, except in the Sandveld, where land used for growing potatoes is allowed to lie fallow every second year.

It is generally recognised that future growth in irrigation will be severely limited by the availability of water and profitability. In the context of the national economy, irrigation contributes less than 4% to the GDP, but accounts for about 60% of the total water use. Thus, it is evident that the economic efficiency of water use in irrigation compares poorly to other sectors and needs to be improved. In more water-scarce areas it may even become necessary to curtail some irrigation to meet the growing requirements of domestic and urban water use. In order to do this, it will be necessary to base such decisions on sound economic principles that include the economic return per unit of water. Although acknowledged to be fairly generalised, it is suggested that only three assurance categories of irrigated crops be used for this purpose. Table 3.5.2.2 shows the typical crops within each category.

TABLE 3.5.2.1: IRRIGATION LAND USE

CATCHMENT						TOTAL IRRIGATED AREA (1)	AREA HARVESTED IN AVERAGE RAINFALL YEARS (km^2) (2)							
PRIMARY		SECONDARY		TERTIARY			Deciduous Fruit	Grapes (Wine, Table, Raisins)	Citrus	Lucerne and Pastures	Potatoes	Other Vegetables	Other Crops	TOTAL
No.	Description	No.	Description	No.	Description									
E	Olifants	E1	Upper Olifants	None	---	106,7	10,7		74,0			19,0	3,0	106,7
		TOTAL IN UPPER OLIFANTS (ALL WESTERN CAPE)				**106,7**	**10,7**	**0**	**74,0**	**0**	**0**	**19,0**	**3,0**	**106,7**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	86,0	70,0					16,0		86,0
				E22	Upper Doring (W Cape)	3,9				0,6		1,0		1,8
					Upper Doring (N Cape)	1,6						0,7		0,5
				E23	Tankwa (W Cape)	0,8						--		0,4
					Tankwa (N Cape)	3,2						2,2		1,8
				E24	Lower Doring (W Cape)	11,9		1,7		0,4		3,1	3,2	7,8
					Lower Doring (N Cape)	4,1		--				1,6		2,2
			Sub-total (Western Cape)			**102,6**	**70,0**	**1,7**	**0**	**1,0**	**0**	**20,1**	**3,2**	**96,0**
			Sub-total (Northern Cape)			**8,9**	**0**	**0**	**0**	**0**	**0**	**4,5**	**0**	**4,5**
		E4	Oorlogskloof (W Cape)	None		0								0
			Oorlogskloof (N Cape)	None		4,6				4,3			0,3	4,6
			Sub-total (Western Cape)			0	0	0	0	0	0	0	0	0
			Sub-total (Northern Cape)			4,6	0	0	0	4,3	0	0	0,3	4,6
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				102,6	70,0	1,7	0	1,0	0	20,1	3,2	96,0
		TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE				13,5	0	0	0	4,3	0	4,5	0,3	9,1
		TOTAL IN DORING CATCHMENT				**116,1**	**70,0**	**1,7**	**0**	**5,3**	**0**	**24,6**	**3,5**	**105,1**
		E3	Lower Olifants	E31	Kromme (All N Cape)	0								0
				E32	Hantams (All N Cape)	2,7				1,4				1,4
				E33	Sout (W Cape)	111,7	2,0	102,0		3,0		8,4		115,4
					Sout (N Cape)	0								0
			Sub-total (Western Cape)			**111,7**	**2,0**	**102,0**		**3,0**	**0**	**8,4**	**0**	**115,4**
			Sub-total (Northern Cape)			**2,7**	**0**	**0**	**0**	**1,4**	**0**	**0**	**0**	**1,4**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				321,0	82,7	103,7	74,0	4,0	0	47,5	6,2	318,1
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				16,2	0	0	0	5,7	0	4,5	0,3	10,5
		TOTAL IN OLIFANTS CATCHMENT				337,2	82,7	103,7	74,0	9,7	0	52,0	6,5	328,6
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		0								0
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		130,0		0,8			60,0		9,2	70,0
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**130,0**	**0**	**0,8**	**0**	**0**	**60,0**	**0**	**9,2**	**70,0**
TOTAL IN WMA IN WESTERN CAPE						451,0	82,7	104,5	74,0	4,0	60,0	47,5	15,4	388,1
TOTAL IN WMA IN NORTHERN CAPE						16,2	0	0	0	5,7	0	4,5	0,3	10,5
TOTAL IN WMA						**467,2**	**82,7**	**104,5**	**74,0**	**9,7**	**60,0**	**52,0**	**15,7**	**398,6**

(1) Areas obtained from the Olifants/Doring River Basin Study reports (DWAF, 1998a), the Olifants River System Analysis (DWAF, 1990a), and discussions with officials of the DWAF Western Cape Regional Office.
(2) Areas of crop types obtained from the Western Cape Province Dept of Agriculture and officials of the DWAF Western Cape Regional Office. Confidence in the accuracy is low.

TABLE 3.5.2.2: ASSURANCE OF IRRIGATION WATER FOR CROP TYPES

CATEGORY	CROP EXAMPLES
Low	Lucerne and pasture for small stock
Medium	Vegetables, potatoes, lucerne and pasture for dairying and ostrich
High	Citrus, deciduous fruit and nuts, grapes, dates and speciality vegetables

The nature of irrigation practices varies widely throughout the WMA, as the following discussion shows.

The Upper Olifants River Catchment (upstream of the Doring River confluence)
The Olifants River rises in mountains formed of rocks of the Table Mountain Group along the southern boundary of the WMA (E10A to E10C) and flows north between high mountain ranges for about a hundred kilometres (E10D to E10K) to the Bulshoek Barrage (E10K). Between the Bulshoek Barrage and the Doring River confluence 20 km downstream (the lower portion of E10K), the valley widens out. The upper Olifants Valley is intensively cultivated with an estimated 10 670 ha under irrigation. A large proportion of the irrigated land is under citrus trees, with a smaller area of deciduous fruit orchards.

Drip irrigation is widely used in the orchards. Upstream of Clanwilliam Dam (E10J), water for irrigation is either stored in farm dams from natural runoff in winter, or pumped from the Olifants River. Downstream of Clanwilliam Dam, water is supplied by canal from the dam.

Most of the land developed for irrigation is irrigated each year because of the large area of orchards and the reasonably reliable water supply.

The Doring River Catchment
The Doring River is the main tributary of the Olifants River and contributes half of the mean annual runoff at the estuary. As the catchment of the Doring River is large (24 420 km^2), it is convenient to divide it into the Kouebokkeveld, the upper Doring, the Tankwa, the lower Doring and the Oorlogskloof for purposes of describing irrigation.

The Kouebokkeveld (E21A to E21D) has been extensively developed for the cultivation of deciduous fruit and vegetables. Water is stored in numerous farm dams during the wet winters and 8 600 ha of land, much of it under deciduous fruit trees, are irrigated. The orchards are generally watered by drip irrigation and the vegetables by sprinklers.

About 450 ha of mainly lucerne and pasture can be irrigated in the upper Doring (E22A to E22G), but the climate is dry, with mean annual precipitation of less than 300 mm, and in average years only about 230 ha are irrigated. Much of this occurs in catchment E22C, where water is imported from the Breede River Basin by means of the Inverdoorn Canal.

The Tankwa River drains an area of 466 km^2 (E23A to E23K) in the dry Ceres Karoo. The geology of its catchment consists of Karoo rocks, resulting in the water being more silt laden than that of the Olifants River. In addition to winter rainfall, occasional summer thunderstorms occur in the catchment. There are several farm dams in the tributaries of the upper reaches of the catchment (E23A to E23D) and the relatively big privately owned Oudebaaskraal Dam is situated on the main river channel further downstream (E23F). In years of good rainfall, when the dams fill, about 400 ha of land is irrigated, 320 ha from the Oudebaaskraal Dam and 80 ha from the dams upstream. In most years the dams do not fill and the average area irrigated is about 220 ha. Crops grown are mainly lucerne and pastures.

For purposes of this discussion, the lower Doring River is assumed to be the river reach from the confluence of the Tankwa River with the Doring (E24H) to the confluence of the Doring with the Olifants (E24M). Its catchment covers an area of 7 648 km^2 (E24A to E24M) and extends from the eastern slopes of the Cederberg Mountains (E24A, E24J, E24L) across the Springbok Flats, to the Roggeveld Mountains (E24C, E24D) which form the edge of the interior plateau. The eastern portion is an arid area where irrigation is negligible.

Most water comes from the mountains along the western edge of the catchment where the winter rainfall is high, but the summers are dry. Consequently, even though the Doring River is very strong flowing in winter, it is normally completely dry during the summer months. Therefore, water for irrigation has to be stored during the winter months for use in summer, and most of the irrigation occurs along the western edge of the catchment, where a number of farm dams have been constructed.

The area in the Doring River catchment that is developed for irrigation is about 1 600 ha, but only about 1 000 ha is irrigated on average. Of this, about 350 ha is situated in the vicinity of the confluence of the Tankwa and Doring Rivers (E22G, E24H), where mainly lucerne is grown using water abstracted from the river by the Elandskaroo Irrigation Board. Lucerne and pasture are grown on up to 100 ha of irrigated land at Aspoort (E22G) between the confluences with the Doring River of the Groot River and the Tankwa River. The remainder of the irrigated land is in small private schemes along the Doring and its tributaries (E24A, E24B, E24J, E24L) downstream of the Tankwa confluence where about 780 ha is irrigated on average. This includes about 300 ha of vegetables in the Brandewyn River valley (E24L), the rest being mainly lucerne and pasture.

The Oorlogskloof River rises in the Roggeveld Mountains north of Calvinia and along the eastern edge of the WMA (E40A) and flows west across the plains of the Onder Bokkeveld (E40B, E40C) to the Bokkeveld Mountains (E40D), where it enters a deep valley and flows south to join the Doring River. There are several farm dams in the small tributaries of the headwaters of the (E40A, E40B) which are used for irrigation. Diffuse irrigation, spread along the length of the river, occurs on about 460 ha of land where mainly lucerne and pasture are grown. The area irrigated does not vary much from year to year.

The Lower Olifants Catchment (downstream of the Doring River confluence)
Downstream of the Doring River confluence the valley floor grows progressively wider for some 10 km to the town of Klawer (E33G), and thereafter opens out into the wide plain across which the river meanders for about 70 km to the sea. Along this reach of the river some 11 200 ha of land is irrigated from canals leading from the Bulshoek Barrage, using mostly water released from Clanwilliam Dam. Crops grown include grapes (wine, table and raisins), deciduous fruits, and vegetables, with grapes predominating. As a result of some double cropping of vegetables, the harvested area is normally about 11 500 ha.

The Hol River, which drains the north-western portion of the WMA, flows into the Olifants River between Vredendal and Lutzville (E33E). Its main tributaries are the

Kromme, the Hantams, the Sout and the Vars. This river system drains an area of more than 17 000 km^2, but the mean annual precipitation is less than 200 mm and there is little scope for irrigation. However, some irrigation by the "saaidam" method does occur at irregular intervals, and very extensively, when there is strong flow in the rivers. The "saaidam" method entails constructing a series of parallel bunds, almost at right angles to the flow in a river, to divert flood water onto lands. It is thought that a maximum of about 270 ha of land is irrigated in this way, with the average area being half of that. The crop grown by this method is normally lucerne.

Even the "saaidam" method can only be used in the upper reaches of the Sout and Vars Rivers as, in the lower reaches salt crusts develop on the river beds during summer and the water is too saline to be used for irrigation.

The Namaqualand Coastal Catchments
The mean annual precipitation in the coastal strip to the north of the Olifants River mouth is less than 100 mm and there is no irrigation because there is insufficient water.

The Sandveld
The 30 to 40 km wide strip along the coast from the southern boundary of the WMA to the estuary of the Olifants River (G30A to G30H) is known as the Sandveld. Potatoes are grown on a large scale under irrigation from groundwater in the area between Elandsbaai, Graafwater and Lambertsbaai (G30E, G30F, G30G). A total area of about 11 600 ha of land is used for potatoes, but only about 5 800 ha is used in any one year because the land is allowed to lie fallow every second year.

There is also a recent development of about 50 ha of vineyards on the coast near Strandfontein (G30H), which is doing quite well on land and in a climate which was previously considered unsuitable.

3.5.3 Dryland Farming

No information on the types of dryland crops grown, other than wheat and rooibos tea, was obtained in this study. Information obtained from land-use maps derived from satellite images (CSIR, 1996), showed a total area of 219 000 ha under dryland cultivation. Because of the small scale of the images used, this area probably includes roads and other uncultivated areas between fields, and the area actually under crops is likely to be about half of the area shown. The distribution of the dryland farming areas within the WMA is shown in Table 3.5.1.1. As explained earlier, the dryland crop that is known to cause a significant reduction in streamflow if grown over large areas is sugar cane, but none is grown in the Olifants/Doring WMA.

3.5.4 Livestock and Game Farming

The distribution of the main types of livestock found in the WMA is shown in Table 3.5.4.1, which also shows the Equivalent Large Stock Units (ELSU).

TABLE 3.5.4.1: LIVESTOCK AND GAME

CATCHMENT							NUMBERS OF LIVESTOCK AND GAME			NO. OF ELSU
PRIMARY		SECONDARY		TERTIARY			Cattle and Horses	Sheep and Goats	Pigs	
No.	Description	No.	Description	No.	Description	Area (km^2)				
E	Olifants	E1	Upper Olifants	None	---	2 888	2 700	39 700	2 600	9 995
		TOTAL IN UPPER OLIFANTS (ALL WESTERN CAPE)				**2 888**	**2 700**	**39 700**	**2 600**	**9 995**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	3 072	2 200	46 900	2 300	10 336
				E22	Upper Doring (W Cape)	3 884	2 400	51 500	2 500	11 351
					Upper Doring (N Cape)	270	300	6 300	300	1 384
				E23	Tankwa (W Cape)	2 302	1 900	40 600	1 900	8 940
					Tankwa (N Cape)	4 144	100	7 400	10	1 236
				E24	Lower Doring (W Cape)	3 348	500	48 500	100	8 136
					Lower Doring (N Cape)	4 300	0	500	10	71
			Sub-total (Western Cape)			**12 606**	**7 000**	**187 500**	**6 800**	**38 763**
			Sub-total (Northern Cape)			**8 714**	**400**	**4 200**	**320**	**2 691**
		E4	Oorlogskloof (W Cape)	None		250	50	3 000	10	506
			Oorlogskloof (N Cape)	None		2 472	0	200	0	36
			Sub-total (Western Cape)			**250**	**50**	**3 000**	**10**	**506**
			Sub-total (Northern Cape)			**2 472**	**0**	**200**	**0**	**36**
		TOTAL IN DORING CATCHMENT IN THE WESTERN CAPE				**12 856**	**7 050**	**190 500**	**6 810**	**39 269**
		TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE				**11 186**	**400**	**14 400**	**320**	**2 727**
		TOTAL IN DORING CATCHMENT				**24 042**	**7 450**	**204 900**	**7 130**	**41 996**
		E3	Lower Olifants	E31	Kromme (All N Cape)	9 719	3	2 400	0	393
				E32	Hantams (All N Cape)	4 201	0	0	0	0
				E33	Lower Olifants (W Cape)	8 016	1 600	89 000	1 200	15 886
					Lower Olifants (N Cape)	200	0	0	0	0
			Sub-total (Western Cape)			**8 016**	**1 600**	**89 000**	**1 200**	**15 886**
			Sub-total (Northern Cape)			**14 120**	**30**	**2 400**	**0**	**393**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				**23 760**	**11 350**	**319 200**	**10 610**	**65 150**
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				**25 306**	**430**	**16 800**	**320**	**3 120**
		TOTAL IN OLIFANTS CATCHMENT				**49 066**	**11 780**	**336 000**	**10 930**	**68 270**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		2 790	220	32 200	500	5 374
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**2 790**	**220**	**32 200**	**500**	**5 374**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		4 590	5 900	156 000	7 800	39 000
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**4 590**	**5 900**	**156 000**	**7 800**	**39 000**
TOTAL IN WMA IN WESTERN CAPE						**31 140**	**17 470**	**507 400**	**18 910**	**109 524**
TOTAL IN WMA IN NORTHERN CAPE						**25 306**	**430**	**16 800**	**320**	**3 120**
TOTAL IN WMA						**56 406**	**17 900**	**524 200**	**19 230**	**112 644**

(1) Numbers were obtained per magisterial district from the 1994 national livestock census (Department of Agriculture, 1994) and converted to numbers in catchment areas in proportion to land area. No information on numbers of game could be found.

ELSU are used to measure the water requirements of livestock. Each ELSU is assumed to represent a water requirement of 45 ℓ/day. For example, one ELSU is equivalent to 0,85 head of cattle, or 1 horse, or 6,5 sheep, or 4 pigs. A detailed table for use in converting mature livestock and game populations to ELSU is included in Appendix D. The numbers of livestock shown in Table 3.5.4.1 are approximate only because the information was obtained from the 1994 livestock census (Department of Agriculture, 1994), which gives information in terms of magisterial districts and not hydrological catchments. The data was converted to hydrological catchments by assuming the distribution of livestock to be proportional to land area.

The climate in most of the WMA is arid, with the result that the vegetation is better suited to small stock than to cattle. This is reflected in Table 3.5.4.1, where it can be seen that sheep and goats account for 93% of the estimated total number of livestock of approximately 560 000. The number of goats is relatively small, making up less than 10% of the combined population of sheep and goats.

The distribution of livestock, expressed in terms of ELSUs, is shown diagrammatically on Figure 3.5.4.1.

3.5.5 Afforestation and Indigenous Forest

Areas of indigenous forest in the WMA are insignificant because of the arid climate prevailing over most of the WMA. Afforestation occurs (CSIR, 1995) as shown on Figure 3.5.1.1 on a small scale in :

- the headwaters of the Olifants River (E10A, B and C) where 380 ha of the slopes of the Witzenberg and Groot Winterhoek Mountains are under pine plantations
- the Cederberg (E10G) where 385 ha of land is afforested,
- the slopes of the mountains fringing the Kouebokkeveld (E21A, B, C and G) where 232 ha of pine plantations are cultivated.

Thus, the total area of afforestation, consisting mainly of pine plantations, is 997 ha, which is less than 0,02% of the land area of the WMA.

3.5.6 Alien Vegetation

The impacts of the widespread infestations by alien plants in South Africa are increasingly recognised. The total incremental water use of invading alien plants was estimated at 3 300 million m³/a by Le Maitre *et al* (1998) but this estimate is not widely recognised by the water resources planning community. This estimate is almost twice as high as the estimate for stream flow reduction resulting from commercial afforestation. Le Maitre *et al* (1998) estimate that the impact of alien vegetation will increase significantly in the next 5 to 10 years, resulting in the loss of much, or possibly even all, of the available water in certain catchment areas. Again, this is a debatable point requiring more research to verify these statements.

Much of the infested areas is in the riparian zones where the degree of infestation is largely independent of the rainfall in the surrounding areas. The acacias, pines, eucalyptus, and prosopis species and melia azedarachs are among the top ten invading aliens, which account for about 80% of the water use by aliens.

Commercial afforestation has been one of the major sources of alien vegetation in South Africa, largely as a result of poor past forestry management practices. The results of a recent national scale study (Nel *et al*, 1999) showed that about 44% of the area invaded by plantation trees (pine, eucalyptus and black wattle) overlaps with areas affected by commercial afforestation practices. The new commercial afforestation plantations generally tend to be well-managed, maximising benefits of forestry and minimising environmental impacts.

Alien vegetation infestations across South Africa were mapped under supervision of a CSIR (Environmentek) team using a "best expert knowledge" approach, supplemented by existing detailed localised maps and Geographic Information System (GIS) data sets obtained from certain specific authorities. The expert knowledge was gathered through workshops in different regions and the expert information was mapped directly onto overlays on 1:250 000 scale topographic maps. Data capture procedures were designed to standardise the approach and terminology and to ensure consistency and comparability in the inputs made by the wide range of people involved.

Areas invaded by alien vegetation were mapped as independent polygons with each polygon accompanied by attribute data regarding species and density. All polygons and attribute data were captured in a GIS (Arc/Info).

The following shortcomings and limitations of the CSIR database on alien vegetation infestation have been highlighted by Görgens (1998):

- The quality of data gathered is known to be variable as it depended on the level of expert knowledge available, the nature of the terrain and the extent and complexity of the actual invasion.

- Mapping of alien vegetation ending very abruptly (and artificially) along some or other administrative boundary.

- Mapping of riparian infestations along rivers at the coarse scale of the available GIS coverages (generally, 1:500 000 with 1:250 000 for some areas) could have led to significant under-estimates of river lengths and, therefore, of infested riparian areas. For example, a pilot comparison by the CSIR of 1:50 000 scale (a suitable scale) and 1:500 000 scale maps yielded a river length ratio of 3,0 and greater.

- Riparian infestation identification in a particular catchment with the simple statement: "all rivers are invaded". In these cases, all the river lengths appearing in the particular coverages were assigned a uniform infested "buffer" strip of specific width, say 20 m.

- Small rivers not reflected on the smaller scale mapping were not accounted for and therefore infestation along these particular rivers was not mapped or quantified.

DWAF officials who have detailed knowledge of the area are of the opinion that the areas estimated by the CSIR are too high and that the actual areas are about 10% of the CSIR values.

Estimated actual areas of alien vegetation per secondary catchment (i.e. 10% of CSIR values) are shown in Table 3.5.6.1. The values are for condensed areas, which are the equivalent areas that the alien vegetation would occupy if it were condensed to provide completely closed canopy cover. On Figure 3.5.6.1, the estimated actual areas of alien vegetation in key areas are shown diagramatically.

It is apparent that the most severe infestation by alien vegetation occurs along the western edge of the WMA.

Alien vegetation in the WMA is being eradicated through the DWAF Working for Water programme. During the year 2000, some 30 eradication projects with a budget of R11,8 million were underway in the WMA.

TABLE 3.5.6.1: INFESTATION BY ALIEN VEGETATION

CATCHMENT						CONDENSED AREA OF ALIEN VEGETATION [(1)] (km^2)
PRIMARY		SECONDARY		TERTIARY		
No.	**Description**	**No.**	**Description**	**No.**	**Description**	
E	Olifants	E1	Upper Olifants	None	---	4,8
		TOTAL IN UPPER OLIFANTS (ALL WESTERN CAPE)				4,8
		E2	Doring	E21	Kouebokkeveld (All W Cape)	2,3
				E22	Upper Doring (W Cape)	0
					Upper Doring (N Cape)	0,1
				E23	Tankwa (W Cape)	0
					Tankwa (N Cape)	0,1
				E24	Lower Doring (W Cape)	0,5
					Lower Doring (N Cape)	1,1
			Sub-total (Western Cape)			**2,8**
			Sub-total (Northern Cape)			**1,3**
		E4	Oorlogskloof (W Cape)	None		0
			Oorlogskloof (N Cape)	None		2,7
			Sub-total (Western Cape)			**0**
			Sub-total (Northern Cape)			**2,7**
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				2,8
		TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE				4,0
		TOTAL IN DORING CATCHMENT				**6,8**
		E3	Lower Olifants	E31	Kromme (All N Cape)	1,1
				E32	Hantams (All N Cape)	0
				E33	Lower Olifants (W Cape)	22,4
					Lower Olifants (N Cape)	0
			Sub-total (Western Cape)			**22,4**
			Sub-total (Northern Cape)			**1,1**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				30,0
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				5,1
		TOTAL IN OLIFANTS CATCHMENT				**35,1**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		31,4
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**31,4**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		61,1
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**61,1**
TOTAL IN WMA IN WESTERN CAPE						117,4
TOTAL IN WMA IN NORTHERN CAPE						5,1
TOTAL IN WMA						**122,5**

(1) Areas are 10% of the areas estimated by the CSIR (Le Maitre *et al*, 1998). The level of confidence in the accuracy of these values is low.

3.5.7 Urban Areas

Urban areas, obtained from the CSIR land-use maps (CSIR, 1996) total 31 km^2, which is less than 0,06% of the area of the WMA. Even though the urban areas are small, the biggest town, Vredendal, having a population in 1995 of 13 000 people, about 47% of the population of the WMA live in the towns.

The towns are shown on Figure 3.5.1.1.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

Industries in the WMA are small and the majority of them are concerned with the processing of agricultural products.

The only power station is a small hydro-electric installation at Clanwilliam Dam which supplies electricity to the town of Clanwilliam.

3.7 MINES

The major mine in the area is the Namakwa Sands heavy mineral mine which is situated on the coast in the north-west of the WMA (F60D) and has a water supply from the Olifants River canal. There are also several quarrying operations in the vicinities of Vredendal and Vanrhynsdorp (see Figure 3.7.1).

3.8 WATER RELATED INFRASTRUCTURE

The urban and rural domestic water supplies in the Olifants/Doring WMA were generally adequate in 1995, but some needed improvement in the near future to meet expected increases in water requirements.

Infrastructure for irrigation, both private and State owned, is well developed.

The water related infrastructure is described in detail in Chapter 4.

CHAPTER 4. WATER RELATED INFRASTRUCTURE

4.1 OVERVIEW

The main development in the Olifants/Doring WMA is along its western portion in the vicinity of the Olifants River valley, with the result that this is where the main water related infrastructure occurs. This is in the form of the Olifants River (Vanrhynsdorp) Government Water Scheme which supplies water for irrigation, urban, industrial and mining use to an area that extends northwards from Clanwilliam Dam, the source of the water, for some 130 km to the Namakwa Sands Mine on the coast at Brand-se-Baai (see Figure 4.1.1). As the mine is situated in Drainage Region F, outside the catchment of the Olifants River (which is in Drainage Region E), the water supply is by means of an inter-basin transfer.

A second state owned water supply scheme, the Southern Namakwaland Government Water Scheme also involves a very small inter-basin transfer. It supplies water from boreholes situated in Drainage Region F to the small towns of Bitterfontein, also in Drainage Region F, and Nuwerus in Drainage Region E. The towns that are not supplied from the state owned schemes have their own municipal supplies from local surface or groundwater sources.

Roughly half of the population lives in urban areas and the other half lives on farms or in small rural settlements. It appears that about 10% of the rural population obtains potable water from the town schemes. The remainder appears to rely mainly on boreholes which are either privately owned or communal ones owned by the District Councils.

There are also a large number of privately owned small irrigation schemes :

- In the Koue Bokkeveld (Catchment E21) and the upper reaches of the Olifants River (Catchment E10) numerous small farm dams have been constructed for the irrigation of fruit and vegetables.
- Also in the upper Doring River catchment, approximately 2,5 million m^3 of water per year is imported to Catchment E22C by canal from diversion weirs in Catchment H20C in the Breede WMA.
- At the confluence of the Tankwa and Doring Rivers (Catchment E23J) water is abstracted from the Doring River for the irrigation of 350 ha of land from the water works of the Elandskaroo Irrigation Board.
- The Oudebaaskraal Dam in the Tankwa River supplies water to approximately 320 ha of land (Catchment E23F).
- Along the Olifants River there is a large number of small private schemes with various abstraction systems, including pumping stations and small diversion weirs and canals. There were three irrigation boards in the area in 1995, namely Citrusdal, Clanwilliam and Vredendal.

The main features of the existing water related infrastructure are shown on Figure 4.1.1 and information on the capacities of state and municipal potable water supply schemes is summarised in Table 4.1.1.

TABLE 4.1.1: COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES BY KEY AREA

CATCHMENT						LAND AREA (km^2)	POPULATION	NUMBER OF PEOPLE SUPPLIED [(1)]	% POPULATION	CAPACITY		TOWNS
PRIMARY		SECONDARY		TERTIARY						(million m^3/a)	(ℓ/c/d)	
No.	Description	No.	Description	No.	Description							
E	Olifants	E1	Upper Olifants	None	---	2 888	17 556	8 150	46	2,45	823	Clanwilliam, Citrusdal
		TOTAL IN UPPER OLIFANTS (ALL WESTERN CAPE)				**2 888**	**17 556**	**8 150**	**46**	**2,45**	**823**	
		E2	Doring	E21	Kouebokkeveld (All W Cape)	3 072	9 292	0	0	0	0	None
				E22	Upper Doring (W Cape)	3 884	925	0	0	0	0	None
					Upper Doring (N Cape)	270	135	0	0	0	0	None
				E23	Tankwa (W Cape)	2 302	816	0	0	0	0	None
					Tankwa (N Cape)	4 144	240	0	0	0	0	None
				E24	Lower Doring (W Cape)	3 348	2 900	0	0	0	0	None
					Lower Doring (N Cape)	4 300	1 635	0	0	0	0	None
			Sub-total (Western Cape)			**12 606**	**13 933**	**0**	**0**	**0**	**0**	
			Sub-total (Northern Cape)			**8 714**	**2 010**	**0**	**0**	**0**	**0**	
		E4	Oorlogskloof (W Cape)	None		250	120	0	0	0	0	None
			Oorlogskloof (N Cape)	None		2 472	9 066	8 150	89	0,36	121	Calvinia, Nieuwoudtville
			Sub-total (Western Cape)			**250**	**120**	**0**	**0**	**0**	**0**	
			Sub-total (Northern Cape)			**2 472**	**9 066**	**8 150**	**89**	**0,36**	**121**	
		TOTAL IN DORING CATCHMENT IN THE WESTERN CAPE				**12 856**	**14 054**	**0**	**0**	**0**	**0**	
		TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE				**11 186**	**11 076**	**8 150**	**89**	**0,36**	**121**	
		TOTAL IN DORING CATCHMENT				**24 042**	**25 129**	**8 150**	**89**	**0,36**	**121**	
		E3	Lower Olifants	E31	Kromme (All N Cape)	9 719	2 487	1 900	76	0,07	100	Loeriesfontein
				E32	Hantams (All N Cape)	4 201	971	0	0	0	0	None
				E33	Lower Olifants (W Cape)	8 016	35 088	29 650	85	6,67	616	Vredendal, Vanrhybsdorp, Lutzville, Ebenhaeser, Nuwerus, Strandfontein, Doringbaai [(3)]
					Lower Olifants (N Cape)	200	100	0	0	0	0	None
			Sub-total (Western Cape)			**8 016**	**35 088**	**29 650**	**85**	**6,67**	**616**	
			Sub-total (Northern Cape)			**14 120**	**3 558**	**1 900**	**53**	**0,07**	**100**	
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				**23 760**	**66 588**	**37 800**	**57**	**9,12**	**661**	
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				**25 306**	**14 634**	**10 050**	**67**	**0,43**	**117**	
		TOTAL IN OLIFANTS CATCHMENT				**49 066**	**81 222**	**47 850**	**60**	**9,55**	**547**	
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		2 790	3 612	2 650	73	0,07	72	Bitterfontein, Rietpoort, Nuwerus [(2)]
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**2 790**	**3 612**	**2 650**	**73**	**0,07**	**72**	
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		4 590	18 860	6 550	35	1,07	447	Graafwater, Elandsbaai, Lambertsbaai
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**4 590**	**18 860**	**6 550**	**35**	**1,07**	**447**	
TOTAL IN WMA IN WESTERN CAPE						**31 140**	**89 060**	**47 000**	**53**	**10,52**	**613**	
TOTAL IN WMA IN NORTHERN CAPE						**25 306**	**14 634**	**10 050**	**69**	**0,43**	**117**	
TOTAL IN WMA						**56 406**	**103 694**	**57 050**	**55**	**10,95**	**526**	

(1) Urban population from WSAM, except for catchment E33 which includes the urban population and 9 550 rural people.
(2) Nuwerus is in catchment E33E but is supplied from F60B
(3) Strandfontein and Doringbaai are in catchment G30H but are supplied from E33H.

Reliable data on population, capacities of water supply schemes, and the number of people supplied was not available. Therefore, the information shown in Table 4.1.1 should be regarded as indicative only of the true situation. In spite of the uncertainty regarding population figures, they have not been rounded off because it is easier to correlate them with the values in the Water Situation Assessment Model in their unrounded format.

Table 4.1.1 shows the average availability of water to those supplied by town and regional schemes to be 526 ℓ/c/d. However, in 1995 the adequateness of supplies to individual towns varied widely, as shown later in this chapter where individual schemes are described in more detail.

Information similar to that presented in Table 4.1.1, but disaggregated on a provincial basis, is shown in Table 4.1.2. As in the case of Table 4.1.1, the reliability of the data is not high.

Information on the main dams in the WMA is given in Table 4.1.3 and brief descriptions of the individual schemes are given in the following sections.

TABLE 4.1.2: COMBINED CAPACITIES OF INDIVIDUAL TOWN AND REGIONAL POTABLE WATER SUPPLY SCHEMES BY PROVINCE ANDD DISTRICT COUNCIL AREAS

PROVINCE	DISTRICT COUNCIL AREA	AREA (km^2)	POPULATION	TOWN AND REGIONAL WATER SUPPLY SCHEMES			
				Number of People Supplied	% of Population	DRAINAGE	
						(million m^3/a)	(ℓ/c/d)
Western Cape	West Coast	21 348	76 063	47 000	62	10,52	613
	Breede River	8 756	12 841	0	0	0	0
	Central Karoo	581	156	0	0	0	0
TOTAL FOR WESTERN CAPE		30 685	89 060	47 000	53	10,52	613
Northern Cape	Namaqualand	3 508	417	0	0	0	0
	Hantam	22 253	14 217	10 050	70	0,43	117
TOTAL FOR NORTHERN CAPE		25 761	14 634	10 050	69	0,43	117
TOTAL FOR WMA		56 446	103 694	57 050	55	10,95	475

TABLE 4.1.3: MAIN DAMS IN THE OLIFANTS/DORING WMA

NAME	LIVE STORAGE CAPACITY (million m^3/a)	YIELD				OWNER
		DOMESTIC SUPPLIES (million m^3/a)	IRRIGATION (million m^3/a)	MINING/INDUSTRY (million m^3/a)	TOTAL (million m^3/a)	
Clanwilliam Dam (E10G)	122	6	145	4	155	DWAF
Bulshoek Barrage (E10K)	5,7					DWAF
Oudebaaskraal Dam (E23F)	34,0	0	Not known	0		Private

NOTES :

(1) The 1:50 year yield of Bulshoek and Clanwilliam combined, after subtracting compensation releases from Clanwilliam, was calculated (DWAF, 1992) to be 137 million m^3/a. Adding the compensation releases of 18 million m^3/a to this brings the total 1:50 year yield to 155 million m^3/a.

(2) The storage capacity of Bulshoek was not taken into account in the analysis because it is operated at near full supply capacity in order to divert water into the irrigation canal. The natural runoff to Bulshoek from catchments below Clanwilliam Dam is 74,6 million m^3/a.

4.2 THE OLIFANTS RIVER (VANRHYNSDORP) GOVERNMENT WATER SCHEME

The Olifants River Government Water Scheme supplies raw water from the Clanwilliam Dam to farmers, municipalities, mines and industries in the Olifants River valley between the dam and the river estuary. Water is released from Clanwilliam Dam into the river to the Bulshoek Barrage, some 30 km downstream.

Farmers with land between the dam and the barrage are not scheduled under the scheme but abstract compensation water from the releases by pumping directly from the river. Downstream of the barrage water is distributed by a canal system consisting of main and distribution canals totaling 186 km in length.

The main canal, which has a capacity of 7 m^3/s, runs along the left bank of the Olifants River for approximately 25 km downstream of the barrage. Thereafter, it splits into two canals, one along the left bank of the river and the other along the right. These canals continue to the vicinity of Lutzville (see Figure 4.1.1) becoming progressively smaller downstream. Water is abstracted at numerous points along the lengths of the canals and is distributed from near Lutzville towards the coast by means of secondary canals.

The scheme supplies water to 11 500 ha of irrigated land, which is used mainly for growing grapes. It also supplies raw water for domestic and industrial use to the towns of Vredendal, Lutzville, Vanrhynsdorp, Klawer, Ebenhaezer, Strandfontein and Doringbaai, and to the Namakwa Sands Mine and, in small quantities, to several wine cellars and a number of small mining activities in the form of gypsum, lime, marble and granite quarries.

The 1:50 year yield of Clanwilliam Dam and Bulshoek Barrage combined was estimated (DWAF, 1992) to be 155 million m^3/a with upstream water use as it was in 1990. Of this, only 127 million m^3/a was available for the Olifants River Government Water Scheme downwstream of Bulshoek Barrage. The remainder is used for irrigation between Clanwilliam Dam and Bulshoek (18 million m^3/a), for the water supply to Clanwilliam (0,8 million m^3/a) and for irrigation direct from the dam by the Citrusdal Irrigation Board (9.2 million m^3/a).

Of the total yield of 155 million m^3/a, the Bulshoek Barrage contributes 12 million m^3/a from runoff from the catchment downstream of Clanwilliam Dam which is diverted into the irrigation canal at Bulshoek. (The mean annual runoff from this catchment, which includes the Jan Dissels River tributary of the Olifants River is 74,6 million m^3/a). The Bulshoek Barrage is operated at close to full supply capacity in order to divert water into the irrigation canal. Consequently, its active storage volume is small.

The yields at less than 1:50 year assurance of Clanwilliam Dam and Bulshoek Barrage combined are 168 million m^3/a at 1:10 year assurance and 174 million m^3/a at 1:5 years (DWAF, 1992).

Water requirements from the canal system downstream of Bulshoek in 1995 were about 225 million m^3/a, including 28% canal conveyance losses. Domestic, industrial and mining requirements totaled about 7 million m^3/a, excluding canal losses, and the rest was for irrigation. (The yield allocations shown in Table 4.1.3 include conveyance losses).

It is apparent that requirements are considerably greater than even the 1:5 year yield of the dams. Consequently, irrigation supplies in most years are curtailed to less than the full theoretical requirement. Clanwilliam Dam is operated at a draft that exceeds its historical firm yield and is drawn down to between 5% and 20% of its full supply capacity in most years. As its capacity is only 33% of the present day mean annual runoff, it fills during the wet winter months in most years.

The main features of the scheme are summarised in Table 4.2.1.

TABLE 4.2.1: THE OLIFANTS RIVER (VANRHYNSDORP) GOVERNMENT WATER SCHEME

SOURCE OF WATER				CONSUMERS IN 1995 [1]	
NAME	**1:50 YEAR YIELD AVAILABLE BELOW BULSHOEK (million m^3/a)**	**ADDITIONAL 1:50 YEAR YIELD ALLOCATED TO OTHER USERS (million m^3/a)**	**TOTAL YIELD O DAMS (million m^3/a)**	**CATEGORY**	**WATER REQUIREMENT (million m^3/a)**
Clanwilliam Dam	115	28	143	Irrigators (11 500 ha) Towns	155 4
Bulshoek Barrage	12	0	12	Quarries, industries Namakwa Sands Mine Conveyance losses	2 1 63
TOTALS	127	28	155		225

NOTES :
1. Consumers shown in the table are all downstream of Bulshoek and are supplied from the canals.
2. Irrigation requirements upstream of Clanwilliam Dam are 82 million m^3/a but it is estimated (DWAF, 1998) that the average quantity of water supplied from farm dams and the Olifants River is 58 million m^3/a.
3. The yield allocated to other users is 10 million m^3/a for irrigation direct from the dam and Clanwilliam town water supply and 18 million m^3/a for compensation releases to irrigators between Clanwilliam Dam and Bulshoek.
4. The irrigation requirement between Clanwilliam Dam and Bulshoek is 25,4 million m^3/a, but part of this (7,4 million m^3/a) is obtained from spills from Clanwilliam Dam).

4.3 TOWN WATER SUPPLIES

Of the eighteen towns in the WMA, seven obtain water supplies from the canals of the Olifants River Government Water Scheme. The principal features of the urban water supplies are summarised in Table 4.3.1. Brief descriptions follow.

(i) Klawer has a permit to abstract 946 540 m^3 of water per year from the canal on the right bank of the Olifants River. In 1995, approximately 0,31 million m^3/a was treated and distributed to consumers for domestic, commercial and industrial use, and 0,59 million m^3/a was used for urban irrigation. Klawer also has a borehole with an estimated yield of 0,2 million m^3/a, but it is used only when the canal is shut down for maintenance.

(ii) Vredendal and Vanrhynsdorp : Vredendal abstracts raw water from the canal system and treats it in a purification plant with a peak capacity of 12 Mℓ/day, or 4,38 million m^3/a. As well as supplying consumers within the town, it supplies Vanrhynsdorp and domestic consumers in areas adjacent to Vredendal. In 1995 some 13 000 people in Vredendal and its surrounds were supplied, in addition to about 3 850 people in Vanrhynsdorp. Water requirements in 1995 were approximately 2,4 million m^3/a, including 0.7 million m^3/a supplied to Vanrhynsdorp.

TABLE 4.3.1: POTABLE WATER SUPPLY SCHEMES IN THE OLIFANTS/ DORING WMA IN 1995

SCHEME NAME	RAW WATER SOURCE	POPULATION SUPPLIED	WATER REQUIREMENTS IN 1995 (million m^3/a)	SCHEME CAPACITY		
				million m^3/a	ℓ/c/d	LIMITING FACTOR
Klawer	Olifants River Govt Water Scheme Borehole	4 200	0,31	0,31	204	Raw water storage volume for use during canal maintenance
Vredendal and Vanrhynsdorp	Olifants River Govt Water Scheme	167 850	2,40	4,38	712	Treatment Works
Lutzville	Olifants River Govt Water Scheme	3 600	0,40	1,09	830	Canal capacity
Ebenhaezer, Strandfontein, Doringbaai	Olifants River Govt Water Scheme	5 000	0,40	1,05	575	Pumpstation, Treatment Works
Citrusdal	Olifants River	3 750	0,70	0,95	694	Treatment Works
Clanwilliam	Clanwilliam Dam, Jan Dissels River	4 400	0,83	1,5	934	Treatment Works
Graafwater	Boreholes	1 350	0,13	0,21	43	Number of bore-holes (more could be drilled)
Elandsbaai	2 boreholes	1 100	0,05	0,07	174	Borehole yield
Lambertsbaai	Groundwater (well)	4 100	0,80	at least 0,8	534	Pumps and pipelines
Bitterfontein and Nuwerus	7 boreholes	1 300	0,04	0,06	126	Number of bore-holes (more could be developed)
Rietpoort	2 boreholes	1 350	0,02	0,03	71	Availability of groundwater. Water quality
Loeriesfontein	6 boreholes	1 900	0,06	0,07	100	Groundwater quality
Nieuwoudtville	1 borehole	1 000	0,03	0,05	137	Borehole yield
Calvinia	Small dam and 3 boreholes	7 150	0,40	0,31	106	Pumps and pipelines
		57 050	6,57	10,88	522	

(iii) Lutzville abstracts water from the canal system and treats it in a purification plant with a capacity of 3 M ℓ/day, or 1,1 million m^3/a. Water use in 1995 was approximately 0,4 million m^3/a and approximately 3 600 consumers were supplied.

(iv) Ebenhaezer, Strandfontein and Doringbaai are supplied with potable water by a scheme operated by the West Coast District Council. Water is abstracted from the canal system near Ebenhaezer, treated in a purification plant with a capacity of 2,9 Mℓ/day, or 1,05 million m^3/a, and distributed by means of a pumpstation and pipeline to the towns and consumers in the surrounding area. Approximately 5 000 people were supplied in 1995, when water requirements were about 0,4 million m^3/a.

The other eleven towns rely on supplies from local sources as described below :

(i) Citrusdal abstracts water from the Olifants River upstream of Clanwilliam Dam and treats it in a plant with a capacity of 2,6 Mℓ/day, or 0,95 million m^3/a. In 1995 the scheme supplied approximately 0,7 million m^3/a to 3 750 consumers.

(ii) Clanwilliam abstracts water from Clanwilliam Dam and from the Jan Dissels River which flows through the town and joins the Olifants River downstream of Clanwilliam Dam. The pumps and pipelines associated with each of these sources of raw water can provide approximately 2 Mℓ/day, giving a total raw water supply of approximately 1,5 million m^3/a, but it appears that the treatment works need upgrading to be able to provide water of good quality during peak demand periods. Water requirements in 1995 were 0,83 million m^3/a, and some 4 400 people were supplied.

(iii) Graafwater obtains its water from a borehole near the town with an estimated yield of 0,2 million m^3/a (DWAF, 1990b). The estimated water requirement in 1995 was 0,13 million m^3/a, and the population supplied is estimated to have been 1 350 people.

(iv) Elandsbaai obtains water from two boreholes some 3 km north-east of the town with a combined yield of 0,07 million m^3/a. Water requirements in 1995 were estimated (DWAF, 1990b) to be 0,05 million m^3/a, but, because the town is a holiday resort, the boreholes may not be able to fully satisfy the summer peak demand. It is estimated that 1 100 permanent residents were supplied in 1995.

(v) Lambertsbaai abstracts groundwater from a pit some 15 km south of the town and water is pumped to the town through two pipelines. The capacity of the scheme is not known, but the groundwater resources have been assessed (DWAF, 1990b) as being adequate for the foreseeable future. Water requirements in 1995 were 0,8 million m^3/a (Gaffney Group, 1998), indicating that the scheme has at least that capacity, and some 4 100 people were supplied with water.

(vi) Bitterfontein and Nuwerus are supplied by the Southern Namaqualand Government Regional Water Scheme. Saline water from a wellfield near Bitterfontein is treated to potable standards in a reverse osmosis plant and distributed to consumers in Bitterfontein and Nuwerus. The scheme was designed to be developed in stages to an ultimate capacity of 0,16 million m^3/a (White Paper H-87). The first phase was commissioned in 1990 with a capacity of 0,06 million m^3/a. It was estimated in the White Paper that water requirements in 1995 would be 0,04 million m^3/a. Approximately 1 300 people were supplied in 1995.

(vii) Rietpoort, which is situated some 25 km north-west of Bitterfontein relies on two local boreholes for its supply (White Paper H-87). The salinity of the water is between 1 800 and 2 100 mg/ℓ TDS and the water is not desalinated. The yield of the scheme is 0,03 million m^3/a. It was estimated in the White Paper that water requirements in 1995 would be 0,02 million m^3/a for the 1 350 people supplied.

(viii) Loeriesfontein is supplied by six boreholes with a combined yield of 0,07 million m^3/a. The water requirements in 1995 were 0,06 million m^3/a and approximately 1 900 people were supplied. The water is reported by the Town Clerk to be highly saline.

(ix) Nieuwoudtville relies on a single borehole with a yield of 0,05 million m^3/a. The water requirement in 1995 is not known, but the population supplied totaled approximately 1 000 people, and if per capita requirements are similar to those of Loeriesfontein, the total water requirement would have been about 0,03 million m^3.

(x) Calvinia obtains water from the Karee Dam with a capacity of 0,85 million m^3 and an estimated yield of 0,18 million m^3/a, and three boreholes with a combined yield of 0,13 million m^3/a, giving a total yield of 0,31 million m^3/a. Water requirements in 1995 were 0,4 million m^3/a for a population of 7 150 people. The supply from the dam failed in 1995 and the town had to rely solely on the boreholes. Several new boreholes have been drilled by DWAF, but they are located up to 17 km away from the town and funds to develop them were not available (in 1997).

4.4 THE NAMAKWA SANDS MINE WATER SUPPLY

The Namakwa Sands Mine, a heavy metals mining operation, has a permit to abstract 2,38 million m^3/a from the right bank canal of the Olifants River Government Water Scheme at a point some 10 km north of Lutzille. The water is diverted from the canal into a 140 Mℓ storage dam whence some of it is pumped through a 250 mm diameter steel pipeline to a mineral separation plant approximately 6 km from the canal abstraction point, and the rest is pumped to the mine on the coast some 40 km north-west of the abstraction point. The total length of the pipeline is 47 km.

The maximum freshwater requirement of the mine under full production will be 2,8 million m^3/a. Of this, approximately 0,4 million m^3/a is required at the mineral separation plant, 1,1 million m^3/a is required for domestic and operational purposes at the mine itself, and the remaining quantity of 1,3 million m^3/a is required for irrigation of vegetation planted to rehabilitate mining areas. The requirements of the individual sectors will vary slightly from year to year, but the total requirement is expected to be close to 2,8 million m^3/a from 1997 to at least 2020. The requirement in 1995 was 1,1 million m^3, as the mine was still being developed.

The difference between the 2,38 million m^3/a allowed by the permit and the 2,8 million m^3/a that is required is made up by using an irrigation allocation under the Olifants River Government Water Scheme for a farm owned by the mining company.

4.5 HYDRO-POWER AND PUMPED STORAGE

The only hydro-power station in the WMA is a small one at Clanwilliam Dam. It uses water released for irrigation to generate some of the electricity requirements of the town of Clanwilliam.

CHAPTER 5: WATER REQUIREMENTS

5.1 SUMMARY OF WATER REQUIREMENTS

Water requirements in the WMA totalled an estimated 589 million m^3/a in 1995, distributed amongst user groups and the ecological Reserve as shown in Table 5.1.1. The major user was agriculture, which, at 442 million m^3/a, accounted for 96% of total consumptive water requirements (i.e. excluding the requirements of the ecological Reserve and hydropower). The next biggest requirement was the ecological Reserve which provides the 127 million m^3/a of water estimated to be needed to sustain the riverine ecosystem. Hydropower generation at Clanwilliam Dam uses a substantial 75 million m^3/a, but this is a secondary use from water that is released from the dam through the turbine on its way to being used for other purposes downstream and is not, therefore, included in the total requirements. Urban and domestic water use was small at 11 million m^3/a, and the remaining groups of industry and mining (shown as bulk water use in Table 5.1.1), alien vegetation and afforestation used only small quantities of water.

The values shown in Table 5.1.1 include conveyance and distribution losses, where applicable, and have not had return flows that are re-used further downstream deducted from them. Therefore, they represent estimates of gross water use.

It should be noted that, because of the limited availability of reliable data, the level of confidence in the estimates is not high. Values are given to one decimal place in Table 5.1.1 for ease of correlation with other more detailed tables appearing later in this chapter, but that does not mean that the values are accurate to one decimal place.

The agricultural water use shown in Table 5.1.1 represents both irrigation and livestock watering requirements, but livestock accounts for only 1,8 million m^3/a.

The requirements at 1:50 year assurance for the domestic, bulk water use and agricultural user groups, are equivalent requirements. They are represented in this way to bring quantities of water that are required at different assurances of supply by consumers to a common base for purposes of comparing water requirements with the available yield. For example, a portion of the yield of a dam might be allocated to industrial use at 1:200 year assurance, a portion to irrigation of orchards at 1:20 year assurance, and a portion to annual crops at 1:5 year assurance. The yield/assurance curve for a dam defines the quantity of water that can be supplied at any particular assurance : the lower the assurance, the greater the quantity of water that can be provided. Thus, for the hypothetical dam of the above example, the quantity of water supplied at 1:200 year assurance could be converted to a theoretical equivalent greater quantity of water at 1:50 year assurance by using the yield/assurance curve. Similarly, the quantities of water supplied at 1:20 year assurance and 1:5 year assurance. Adding together the three equivalent quantities at 1:50 year assurance would give the total equivalent requirement at 1:50 year assurance. This value could be compared with the yield of the dam at 1:50 year assurance to determine the balance between yield and allocations of water.

TABLE 5.1.1: WATER REQUIREMENTS PER USER GROUP IN 1995

USER GROUP	ESTIMATED WATER REQUIREMENT (million m^3/a)	REQUIREMENTS AT 1:50 YEAR ASSURANCE (million m^3/a)
Ecological Reserve (5)	126,9	14,3
Domestic (1)	10,7	10,7
Bulk water use (4)	4,2	4,2
Neighbouring States	0	0
Agriculture (2)	442,5	354,4
Afforestation	1,5	0,8
Alien vegetation	3,4	0,9
Water transfers (3)	0	0
Hydropower	(75,0)	(75,0)
TOTALS	589,2	385,3

(1) Includes urban and rural domestic requirements and commercial, institutional and municipal requirements.
(2) Includes requirements for irrigation, dry land sugar cane, livestock and game.
(3) Only transfers out of the WMA are included.
(4) Includes industries and mines not supplied by municipalities.
(5) At outlet of WMA.

Domestic water requirements and the drinking water requirements of livestock have been assumed to be supplied at 1:50 year assurance under normal conditions. The assurances at which water for irrigation is required have been assumed to vary with the commercial value of the crops irrigated. This accounts for the smaller requirement at 1:50 year assurance for agriculture in Table 5.1.1.

The estimated water requirement for the ecological Reserve shown in Table 5.1.1 is the average volume of water that needs to be allowed to flow into the sea from the WMA. The requirement at 1:50 year assurance is the impact of the Reserve requirement on the 1:50 year yield of the water resources as developed in 1995.

Similarly, the estimated requirements for afforestation and alien vegetation are the reductions that they cause in mean annual runoff, while the requirements at 1:50 year assurance are their impacts on the developed yield in 1995.

5.2 ECOLOGICAL COMPONENT OF THE RESERVE

5.2.1 Introduction

The classification of the main stem rivers in the vicinity of the outlets of the quaternary catchments is described in Section 2.6.2. On the basis of this classification, a so-called desktop method has been developed (Hughes and Münster, 1999) to provide a low-confidence estimate of the quantity of water required for the ecological component of the Reserve, which is suitable for use in this water resources situation assessment.

The method involves the extrapolation of high confidence results of previous in stream flow requirement (IFR) workshops, the use of a reference time series of monthly runoff at the outlet of the quaternary catchment and a number of hydrological indices or parameters that have been defined for 21 desktop Reserve parameter regions in South Africa. These desktop Reserve parameter regions are described and shown in Figure 5.2.1.1. The instream flow requirements that were determined previously were mostly based on the use of the Building Block Method (King and Louw, 1998). The monthly time series of natural flow that has been used is described in Section 6.3. The following are the two main hydrological parameters:

- a measure of the longer term variability, which is a combination of the coefficients of variation of winter and summer volumes (CV); and
- an estimate of the proportion of the total flow that occurs as base flow (BFI), which can be considered to be a measure of short-term variability.

The ratio of the above two indices (CV/BFI) has been used as an overall hydrological index of flow variability or reliability. Rivers with low variability and a high base flow response have very low hydrological indices of flow variability and vice versa.

A relationship has been found between the hydrological index of flow variability, the ecological status and the annual requirements for low and high flows for the so-called maintenance and drought periods of the modified flow regime for the river. The essence of the relationship is that for a particular ecological status or class, the water required for the ecological component of the Reserve will increase as the hydrological index of flow variability decreases, and vice versa. Furthermore, the water requirement will decrease as the ecological status is decreased.

The method that has been used is based on a series of assumptions, many of which have not yet been verified due to either a lack of information or of time since the method was developed. The following is a summary of the main limitations in order to provide an indication of the level of accuracy that can be expected:

- The extrapolations from past IFR workshops are based on a very limited data set, which does not cover the whole of the country. While some development work has been completed to try and extend the extrapolations and has improved the high flow estimations for dry and variable rivers, this has been limited.

- The extrapolations are based on a hydrological index and no allowance (in the desktop method adopted for this water resources situation assessment) has been made for regional, or site specific ecological factors. It is unlikely that an index based purely on hydrological characteristics can be considered satisfactory but it represents a pragmatic solution in the absence of sufficient ecological data.

- The method assumes that the monthly time series of natural flows are representative of real natural flow regimes and many of the algorithms rely upon the flow characteristics being accurately represented. Should the data indicate more extended base flows than actually occur, the hydrological index of flow variability would be under-estimated and the water requirements for the ecological component of the Reserve would be over-estimated.

5.2.2 Quantifying the Water Requirements

A simulation model has been developed to simulate the relationships that were found to exist between the hydrological index of flow variability, the ecological status and the annual requirements for low and high flows and for so-called maintenance and drought flow periods (Hughes and Münster, 1999).

The simulation model provides annual maintenance and drought low flows and maintenance high flows (expressed as a proportion of the mean annual runoff). The model also provides for the seasonal distribution and assurances associated with the monthly flows on the basis of a set of default parameters that has been developed for each of the 21 desktop Reserve parameter regions of South Africa referred to in Section 5.2.1. The quaternary catchments in the Olifants/Doring Water Management Area fall predominantly within the so-called Western Karoo region, with portions in Western Cape (wet) and the Western Cape (dry) regions (see Figure 5.2.1.1.).

The monthly time series of natural flows at the outlets of the quaternary catchments have been used to generate an equivalent time series of water requirements for the ecological component of the Reserve. This has been accomplished by relating the assurances of the natural flows in a particular month to the assurances of the flow required for the ecological component of the Reserve during the same month.

In the water balance model it is necessary to express the water requirements for the ecological component of the Reserve in terms of annual requirements that are directly comparable to those of any other sector. It therefore becomes necessary to reduce these water requirements to a common assurance and more specifically the effect that these requirements will have on the capacity of the river system to supply water at a specific assurance, i.e. the effect on the yield of the river system.

The effects on the yield of the river system of the water required for the ecological component of the Reserve have been based on an analysis of the monthly time series of these water requirements for the same 70-year period as for the natural time series of flows, that is described in Section 6.3. This has been estimated by establishing the average annual quantity of water required for the ecological component of the Reserve during the most severe or so-called critical drought that has determined the yield of the river system at a recurrence interval of 50 years. The duration of the critical drought can be approximated by the (inverse of) marginal rate of increase of the yield of the river system per unit increase in storage capacity, i.e. the slope of the storage-yield curve at the storage capacity under consideration. The periods of high and low flows in the monthly time series of water requirements for the ecological component of the Reserve also mimic the periods of high and low flows in the monthly time series of natural flows used to establish the yield of the river system. Therefore, the portion of the yield of the system that is required for the ecological component of the Reserve can be estimated by finding the lowest average flow for all periods in the monthly time series of water requirements for the ecological component of the Reserve that are as long as the critical drought period.

The monthly time series of water requirements for the ecological component of the Reserve has been determined at the outlet of each quaternary catchment for each of the ecological status Classes A to D. These time series have been analysed for various lengths of the critical drought to establish the system yield required for the ecological component of the Reserve. This has been done for a range of system capacities, from which the appropriate value corresponding to the storage capacity being considered has then been selected for use in the water balance.

The method that has been used to quantify the water requirements is based on a series of assumptions, many of which have not yet been verified due to either a lack of information or of time since the method was developed. The following is a summary of the main limitations in order to provide an indication of the level of accuracy that can be expected:

- The seasonal distributions of the annual estimates of water requirements are based on analyses of the base flow characteristics of some 70 rivers using daily data, the results of which were then regionalised. Some individual quaternary catchments that have been allocated to a specific region may however, have somewhat different characteristics.

- Similarly, the regional parameters for the assurance rule curves have been based on the duration curve characteristics of the natural flow regimes represented by the monthly time series of flow described in Section 6.3 and some experience of setting assurance rules used at past IFR workshops. Regionalising was done by investigating a representative sample of quaternary catchments and it is therefore possible that some have been assigned to the wrong regions.

- The estimates of water required for the ecological component of the Reserve are the best estimates that can be given at this stage, but must be regarded as low confidence estimates. As more detailed estimates are made for a wider range of rivers, the estimates will be improved through modifications made to the delineation of the regions and the regional parameters that have been assigned. It is also anticipated that a better way of accounting for regional or site specific ecological considerations will be added in due course.

5.2.3 Comments on the Results

The members of the specialist team that carried out the assessment expressed their opinions on the strengths and weaknesses of the processes. These opinions are summarised below :

- Accuracy of assessments was facilitated by the diverse number of specialists involved in the process. However, some considered the fact that, in most cases, only one specialist in each field was present made it difficult to verify the results obtained.

- The upgrading of rivers to a higher class is decided by possible improvements through flow modification. This leaves uncertainty as to how other factors should be addressed. It was felt, for instance, that in some instances catchment management options such as removing invasive alien vegetation and reducing bulldozing of river beds would improve conditions, yet these options were not addressed. Very few rivers have the potential to be upgraded over a short period and the majority require upgrading over ten years or more.

- Groupings of various catchments are rather big, leading to very broad based assessments which could result in inaccuracies. A number of quaternaries were linked together, but only the main stem river was taken into account. The tributaries could be ecologically more important than the main stem, in which case the class determined for the main stem might not be accurate for the quaternary overall.

- Confidence levels need to be attached to all the classes determined.

- Ideally, rivers should be grouped according to ecotones rather than quaternary catchments, as the latter are ecologically inappropriate, but it is acknowledged that this would not meet the resolution requirements of the water balance component of the study.

5.2.4 Presentation of Results

The results of the assessment are shown in Table 5.2.4.1 where the requirements of the ecological component of the Reserve are shown in terms of percentage of MAR, long term average annual flow volume and impact on 1:50 year yield, for key points. The key points are all located at the outlets of catchments and are points of particular interest from the water resources point of view. They are described in more detail in Section 1.1.

The long term average total ecological flow requirement for the whole WMA is 127 million m^3/a, or 11,5% of the total MAR. However, it can be seen from Table 5.2.4.1 that the percentage of the MAR required for ecological flows varies considerably from key point to key point in the WMA. The highest requirement in terms of percentage of MAR is in the Lower Doring River where 22,2% is required at its confluence with the Olifants River to maintain a PESC of Class C.

Variation in the PESC also occurs within the catchment areas of key points, and may also occur for river reaches within individual quaternary catchments. For instance, in the catchment area of Clanwilliam Dam, the PESC of the river at the outlet of catchment E10C is Class A, while that of the river at Clanwilliam Dam is Class D.

Information on individual quaternary catchments is given in Appendix F, and ecological flow requirements are shown diagramatically on Figure 5.2.4.1.

It should be noted that the ecological Reserve for the Olifants Estuary has not been determined. The estuary currently receives about 34% of the virgin MAR (DWAF, 1998b). As it is considered to be of national importance from a vegetation and fish perspective, and of international importance in terms of bird life, its ecological Reserve requirements may be higher than the 10,1% of MAR determined for the Olifants River at its outlet.

TABLE 5.2.4.1: WATER REQUIREMENTS FOR THE ECOLOGICAL COMPONENT OF THE RESERVE

KEY POINT	PRESENT ECOLOGICAL STATUS CLASS (PESC)	RIVERINE ECOLOGICAL WATER REQUIREMENTS FOR PESC		
		% VIRGIN MAR	LONG-TERM AVERAGE REQUIREMENT (million m^3/a)	IMPACT ON 1:50 YEAR YIELD (million m^3/a)
Olifants River at Clanwilliam Dam (E10G)	D	15,9	68,6	12,3
Olifants River at confluence with Doring (E10K)	B	15,9	81,2	0
The Leeu River at outlet to Kouebokkeveld (E21L)	B	10,5	29,2	0
Doring River at proposed Aspoort Dam (E22G)	C	10,5	33,5	0
Doring River at confluence with Olifants (E24M)	C	22,2	112,6	2,0
Olifants River mouth (E33H)	D	10,1	118,8	0
Sandveld river mouths (G30A, E, F, G H)	C	13	8	0
Namaqualand coastal river mouths (F60A, D, E)	C	9,7	0,1	0
TOTAL FOR WMA (E33H, F60A, D, E, G30A, C, F, G, H)	---	---	126,9	14,3

5.2.5 Discussion and Conclusions

The estimated water requirement for the ecological Reserve shown in Table 5.2.4.1 is the average volume of water that needs to be allowed to flow into the sea from the WMA to maintain the present ecological status of the rivers. The requirement at 1:50 year assurance is the impact of the Reserve requirement on the 1:50 year yield of the water resources as developed in 1995. It is much lower than the average volume of water required because the rivers in most of the water management area would dry up during a 1:50 year drought and, as they are not regulated by dams, have no 1:50 year yield. Consequently, the ecological Reserve would have no impact on the 1:50 year yields of these river reaches. The exceptions are the upper Olifants River, which would continue to flow during a 1:50 year drought, and is also regulated by Clanwilliam and Bulshoek Dams, and the Tankwa River which is regulated by Oudebaaskraal Dam. The lower Olifants River would also continue to flow, but it has been assumed that it has no utilisable 1:50 year yield because of the high salinity of low flows. Consequently, it has also been assumed that the ecological Reserve has no impact on the yield of the lower Olifants River. Thus, the 1:50 year requirements of the ecological Reserve shown in Table 5.2.4.1 are the estimated impact of those requirements on the developed yield of the upper Olifants River and the Tankwa River. The estimate is at a low level of confidence and requires further investigation of ecological flow requirements and their impact on yield, to verify it. It should also be noted that, if more dams were constructed, there would be an increase in the impact of the ecological Reserve on the 1:50 year yield of the system.

It is emphasised that the estimates of the long-term average flow requirements for the ecological Reserve originating from the procedure used in this study should be used only for broad, very general planning purposes. The confidence levels in the classes determined for individual quaternary catchments are highly variable, as they depend on the levels of knowledge of the individuals of the specialist team. This, as well as the comments regarding each quaternary catchment that are presented in Appendix F, should be borne in mind when using the data. In all cases where information requirements go beyond the general planning level, the procedures developed for the determination of the ecological Reserve at the Rapid, Intermediate, or Comprehensive levels should be applied.

5.3 URBAN AND RURAL

5.3.1 Introduction

The distribution of urban water requirements and rural domestic water requirements is shown on Figure 5.3.1.1 and in Table 5.3.1.1

The total combined requirement in 1995 was estimated to be 10 million m³/a, of which approximately 7 million m³/a was required by the towns and 3 million m³/a by consumers in the rural areas. Most of the water requirements in these categories occur in the western part of the WMA, with the result that 86% of the total requirement is in the Western Cape Province and only 14% in the Northern Cape.

Table 5.3.1.1 also shows estimated requirements at 1:50 year assurance. As both urban and rural domestic supplies have been assumed to be required under normal conditions at 1:50 year assurance, there is no difference between the total requirements and the 1:50 year requirements.

TABLE 5.3.1.1: URBAN AND RURAL DOMESTIC WATER REQUIREMENTS IN 1995

CATCHMENT						URBAN REQUIREMENTS (million m³/a)	RURAL DOMESTIC WATER REQUIREMENTS (1) (million m³/a)	COMBINED URBAN AND RURAL DOMESTIC REQUIREMENTS (million m³/a)	REQUIREMENTS AT 1:50 YEAR ASSURANCE (million m³/a)	HUMAN RESERVE (million m³/a)
PRIMARY		SECONDARY		TERTIARY						
No.	Description	No.	Description	No.	Description					
E	Olifants	E1	Upper Olifants	None	---	1,76	0,54	2,30	2,30	0,174
		TOTAL IN UPPER OLIFANTS				**1,76**	**0,54**	**2,30**	**2,30**	**0,174**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	0	0,50	0,50	0,50	0,084
				E22	Upper Doring (W Cape)	0	0,06	0,06	0,06	0,009
					Upper Doring (N Cape)	0	0	0	0	0,001
				E23	Tankwa (W Cape)	0	0,01	0,01	0,01	0,002
					Tankwa (N Cape)	0	0,17	0,17	0,17	0,007
				E24	Lower Doring (W Cape)	0	0,20	0,20	0,20	0,028
					Lower Doring (N Cape)	0	0,10	0,10	0,10	0,013
			Sub-total (Western Cape)			**0**	**0,77**	**0,77**	**0,77**	**0,123**
			Sub-total (Northern Cape)			**0**	**0,18**	**0,18**	**0,18**	**0,021**
		E4	Oorlogskloof (W Cape)	None		0	0,01	0,01	0,01	0,002
			Oorlogskloof (N Cape)	None		0,66	0,05	0,71	0,71	0,080
			Sub-total (Western Cape)			**0**	**0,01**	**0,01**	**0,01**	**0,002**
			Sub-total (Northern Cape)			**0,66**	**0,05**	**0,71**	**0,71**	**0,080**
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				0	0,78	0,78	0,78	0,125
		TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE				0,66	0,23	0,89	0,89	0,101
		TOTAL IN DORING CATCHMENT				**0,66**	**0,81**	**1,47**	**1,47**	**0,226**
		E3	Lower Olifants	E31	Kromme (All N Cape)	0,16	0,04	0,20	0,20	0,022
				E32	Hantams (All N Cape)	0	0,09	0,09	0,09	0,009
				E33	Lower Olifants (W Cape)	2,96	1,77	4,73	4,73	0,312
					Lower Olifants (N Cape)	0	0	0	0	0
			Sub-total (Western Cape)			**2,96**	**1,77**	**4,73**	**4,73**	**0,312**
			Sub-total (Northern Cape)			**0,16**	**0,13**	**0,29**	**0,29**	**0,031**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				4,72	3,09	7,81	7,81	0,595
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				0,82	0,36	1,18	1,18	0,132
		TOTAL IN OLIFANTS CATCHMENT				**5,54**	**3,45**	**8,99**	**8,99**	**0,727**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		0,18	0,06	0,24	0,24	0,033
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**0,18**	**0,06**	**0,24**	**0,24**	**0,033**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		1,00	0,50	1,50	1,50	0,170
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**1,00**	**0,50**	**1,50**	**1,50**	**0,170**
TOTAL IN WMA IN WESTERN CAPE						5,90	3,65	9,55	9,55	0,814
TOTAL IN WMA IN NORTHERN CAPE						0,82	0,36	1,38	1,38	0,132
TOTAL IN WMA						**6,72**	**4,01**	**10,73**	**10,73**	**0,946**

(1) Domestic requirements plus small scale irrigation from Table 5.3.3.2 plus losses of 20% of total requirements including losses.

The table also shows the Human Reserve requirement, calculated on the basis of 25*l* /person/day for the total population, and totalling 0,95 million m³/a for the WMA. This requirement is included in the requirements shown in the other columns of Table 5.3.1.1.

5.3.2 Urban

Introduction

A study by Schlemmer *et al* (2001) in support of the development of the National Water Resource Strategy developed a methodology to provide a framework for estimation of both direct and indirect water requirements for the entire South Africa, as well as for the development of long-term projections. A framework methodology was developed on the basis of available information. Information collected in the field as part of the Water Resources Situation Assessments was used to refine the analysis, identify default values and where available update the default database figures.

Methodology

Urban water requirements were classified into direct use by the population plus indirect use by commerce, industries, institutions and municipalities related to the direct use in 1995. These are dealt with below.

Direct Water Use

The following criteria were considered significant in identifying categories of direct water use:

- Economic strata.
- Types of housing.
- Levels of service provided.
- Extent of local authority records.

It was recognised that a critical factor to be considered was the dependence on data that was required from Local and Water Service Authorities. Generally many authorities have records of water supplied to different users; individual households, and at times to flats and multi-household complexes. Further detail is not common.

Categories of direct water use were then identified in order to develop profiles of use per urban centre (see table below). The populations of the urban centres that had been determined were allocated to these categories by Schlemmer *et al* (2001), on the basis of socio-economic category characteristics of each centre.

The study then proceeded to derive per capita water use for each of these categories using information from the South African Local Government Handbook, and the data collected as part of the Water Resources Situation Assessments from local authorities at the time. Where detailed data was not available, an estimation procedure was followed. The categories defined were associated with default unit water uses to generate overall water use estimates where hard data was not available. These categories and default unit water uses are listed in Table 5.3.2.1.

TABLE 5.3.2.1: DIRECT WATER USE: CATEGORIES AND ESTIMATED UNIT WATER USE

CATEGORY	WATER USE ℓ/c/d
1. Full service : Houses on large erven > 500m^2	320
2. Full service: Flats, Town Houses, Cluster Houses	320
3. Full service : Houses on small erven <500m^2	160
4. Small houses, RDP houses and shanties with water connection but minimal or no sewerage service	90
5. Informal houses and shanties with service by communal tap only	10
6. No service from any water distribution system	6
7. Other/Miscellaneous	90

Indirect water use

Indirect water use was considered in terms of four categories, viz. commercial, industrial, institutional and municipal. Again, available information was complemented by data collected as part of the Water Resources Situation Assessments from local authorities at the time. Limited hard data was obtained at the level of detail sought.

In order to develop a comprehensive set of estimates, a standard table relating the components of indirect water use to the total direct water use of an urban centre was developed. The urban centres were first classified according to shared characteristics related to water use. The classification used is shown in Table 5.3.2.2.

TABLE 5.3.2.2: CLASSIFICATION OF URBAN CENTRES RELATED TO INDIRECT WATER USE

CLASSIFICATION	TYPE OF CENTRE	PERCEPTION
1.	Long established Metropolitan centres (M)	Large conurbation of a number of largely independent local authorities generally functioning as an entity.
2.	City (C)	Substantial authority functioning as a single entity isolated or part of a regional conurbation.
3.	Town: Industrial (Ti)	A town serving as a centre for predominantly industrial activity.
4.	Town: Isolated (Tis)	A town functioning generally as a regional centre of essentially minor regional activities.
5.	Town: Special (Ts)	A town having significant regular variations of population consequent on special functions. (Universities, holiday resorts, etc.).
6.	Town: Country (Tc)	A small town serving essentially as a local centre supporting only limited local activities.
New Centres		
7.	Contiguous (Nc)	A separate statutory authority, or number of authorities adjacent to, or close to, a metropolis or city and functioning as a component part of the whole conurbation.
8.	Isolated (Nis)	A substantial authority or group of contiguous authorities not adjacent to an established metropolis or city.
9.	Minor (Nm)	Smaller centres with identifiable new or older established centres not constituting centres of significant commercial or industrial activity.
10.	Rural (Nr)	All other areas not having significant centres.

Default profiles of indirect water use in relation to total water use were developed on the basis of available information for these classes, and are given in Table 5.3.2.3.

TABLE 5.3.2.3: INDIRECT WATER USE AS A COMPONENT OF TOTAL DIRECT WATER USE

URBAN CENTER CLASSIFICATION	COMMERCIAL	INDUSTRIAL	INSTITUTIONAL	MUNICIPAL
Metropolitan	0.2	0.3	0.15	0.08
Cities				
Towns Industrial				
Towns Isolated				
Towns Special	0.30	0.15	0.08	0.03
Towns Country	0.10	0.15	0.03	0.10
New Centres	0.15	0.08	0.08	0.08

Where detailed data was not available, Table 5.3.2.3 was used as a basis for estimating the indirect water use.

The distribution of urban water requirements determined on this basis is shown in Table 5.3.2.4, where bulk conveyance losses and distribution losses have been added to the estimated direct and indirect water requirements to derive total water requirements.

Information on water use by different categories of housing and on the ratios of indirect to direct water use was not available for the towns in the Olifants/Doring WMA. Therefore, the appropriate ratios of those shown in the above tables were used to estimate the split between direct and indirect water use. Bitterfontein, Nuwerus and Graafwater were classified as "rural" centres, Lamberts Bay as a "Special Town" because of the holidaymakers that it attracts, and all the other towns were classified as "Country Towns" (see Table 5.3.2.2).

It can be seen from Table 5.3.2.4 that most (88%) of the urban water requirements of 6,7 million m³/a in 1995 occurred in the Western Cape Province, chiefly in the Olifants River Valley, where the main towns of Vredendal, Vanrhynsdorp, Clanwilliam and Citrusdal are situated.

For purposes of analysing the adequacy of water resources, it is of interest to consider the extent to which water use could reasonably be curtailed under 1:50 year drought conditions. Based on experience in other parts of the country during severe droughts, it was estimated that by applying restrictions on the use of water for domestic purposes, it should be possible to reduce consumption in urban areas by about 11%. This reduction is shown in the column headed "Total at 1:50 year assurance" in Table 5.3.2.4.

It can be deduced from the figures shown in the table that conveyance and distribution losses account for approximately 23% of the estimated total urban requirements in the WMA. The reasons for this are discussed in the following section.

TABLE 5.3.2.4: URBAN WATER REQUIREMENTS IN 1995

CATCHMENT						URBAN WATER REQUIRMENTS (million m^3/a)								RETURN FLOWS			
PRIMARY		SECONDARY		TERTIARY		DIRECT (million m^3/a)	INDIRECT (million m^3/a)	BULK CONVEYANCE LOSSES		DISTRIBUTION LOSSES		TOTAL	TOTAL AT 1:50 YEAR ASSURANCE	EFFLUENT	IMPERVIOUS URBAN AREA	TOTAL RETURN FLOW	RETURN FLOW AT 1:50 YEAR ASSURANCE
No.	Description	No.	Description	No.	Description			(million m^3/a)	%	(million m^3/a)	%	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)	(million m^3/a)
E	Olifants	E1	Upper Olifants (W Cape)	None	---	1,1	0,5	0,08	5	0,08	5	1,76	1,76	0,8	0	0,8	0,8
		E2	Doring	E21-E24		0	0	0	0	0	0	0	0	0	0	0	0
		E4	Oorlogskloof (W Cape)	None		0	0	0	0	0	0	0	0	0	0	0	0
			Oorlogskloof (N Cape)	None		0,36	0,13	0,05	10	0,12	20	0,66	0,66	0,20	0	0,20	0,20
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				0	0	0	0	0	0	0	0	0	0	0	0
		TOTAL IN DORING CATCHMENT IN NORTHERN CAPE				0,36	0,3	0,05	10	0,12	20	0,66	0,66	0,20	0	0,20	0,20
		TOTAL IN DORING CATCHMENT				**0,36**	**0,13**	**0,05**	**5**	**0,12**	**20**	**0,66**	**0,66**	**0,20**	**0**	**0,20**	**0,20**
		E3	Lower Olifants	E31	Kromme (All N Cape)	0,10	0,03	0,01	10	0,02	20	0,16	0,16	0,01	0	0,01	0,01
				E32	Hantams (All N Cape)	0	0	0	0	0	0	0	0	0	0	0	0
				E33	Lower Olifants (W Cape)	1,5	0,55	0,8	28	0,11	5	2,96	2,96	1,30	0	1,30	1,30
					Lower Olifants (N Cape)	0	0	0	0	0	0	0	0	0	0	0	0
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				2,6	1,05	0,88	18	0,19	5	4,72	4,72	2,10	0	2,10	2,10
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				0,46	0,16	0,06	7	0,14	17	0,82	0,82	0,21	0	0,21	0,21
		TOTAL IN OLIFANTS CATCHMENT				**3,06**	**1,21**	**0,94**	**17**	**0,33**	**6**	**5,54**	**5,54**	**2,31**	**0**	**2,31**	**2,31**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		0,10	0,04	0,03	20	0,01	5	0,18	0,18	0,07	0	0,07	0,07
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		0,49	0,25	0,23	20	0,03	5	1,00	1,00	0,23	0	0,23	0,23
		TOTAL IN WMA IN WESTERN CAPE				3,19	1,34	1,14	19	0,23	5	5,90	5,90	2,40	0	2,40	2,40
		TOTAL IN WMA IN NORTHERN CAPE				0,46	0,16	0,06	7	0,14	17	0,82	0,82	0,21	0	0,21	0,21
		TOTAL IN WMA				**3,65**	**1,50**	**1,20**	**18**	**0,37**	**6**	**6,72**	**6,72**	**2,61**	**0**	**2,61**	**2,61**

Water Losses

Water losses occur in the conveyance of water from the raw water source to the water treatment works and from the treatment works to bulk treated water storage reservoirs. These are referred to in this report as bulk conveyance losses. They occur as a result of spillage, leakage and evaporation from canals, leakage from pipelines and storage reservoirs, and backwashing of filters at water treatment works.

Further losses occur between the bulk treated water storage reservoirs and consumers, mainly as a result of leaking or broken pipes and fittings. These are known as distribution losses.

Little information on losses in the various town supplies could be obtained. Therefore it was necessary to make assumptions based on the type of raw water supply, the distance over which water is conveyed, and the nature of the distribution system. The assumed values are shown in Table 5.3.2.4.

As described in Section 4.3, many of the towns obtain water from Clanwilliam and Bulshoek Dams via the Olifants River canal system. Consequently, the water is conveyed over long distances and losses are substantial. According to DWAF officials, conveyance losses amount to about 28% of the total volume of water released into the canal from the dams. Losses between the canals and the bulk treated water storage reservoirs of the towns were assumed to be included in this allowance as well. Added to these are distribution losses which, for the towns supplied from the canal system, were assumed to be 5% of the total water use of the towns, including losses.

In the context of the overall water resources of the WMA, some of the water used by urban consumers is returned to the rivers as treated effluent, and can contribute to ecological flow requirements or be abstracted and re-used further downstream.

Return Flows

Reliable information on return flows was not available for most of the towns. Therefore, it was assumed that for the bigger towns return flows are approximately 50% of the combined direct and indirect water use, excluding losses, and less for the smaller towns that do not have extensive water borne sewerage systems. The assumed return flows are shown in Table 5.3.2.4.

Where there are large urban areas, increased runoff from paved areas can significantly increase the runoff to rivers. This runoff can be considered to be a component of urban return flows. However, the urban areas in the Olifants / Doring WMA are too small to have a significant effect on runoff. Therefore, it has been assumed that there is no increased runoff from paved areas.

5.3.3 Rural

Rural water users include the inhabitants of farms, small rural settlements not classified as towns, and coastal resorts that are not classified as towns. No detailed information on rural water use was found, but it is known that water use patterns vary wildly, depending on the economic circumstances of the consumers.

In order to obtain an estimate of the total water requirements, consumers were considered to fall into three economic categories, with associated unit water requirements. These categories are "Rural", being people living far from towns and not part of the communities of large commercial farms, "Developing Urban" being people of the lower income group living close to towns and typically on smallholdings, and "Commercial farming" being the owners of large commercial farms and their workers.

The assumed unit water requirements are shown in Table 5.3.3.1. For want of better information, losses were assumed to be 20% of total water requirements, including losses.

TABLE 5.3.3.1: PER CAPITA WATER REQUIREMENTS IN RURAL AREAS IN 1995

USER CATEGORY	UNIT WATER REQUIREMENTS			
	Direct Use (ℓ/c/d)	Distribution losses		Total (ℓ/c/d)
		(ℓ/c/d)	(%)	
Rural	75	19	20	94
Developing urban	150	38	20	188
Commercial farming	175	44	20	219

Rural water requirements were calculated from the estimated number of people in each user category in each quaternary catchment. Detailed estimates are given in Appendix F and the results and summarised in Table 5.3.3.2. .

It appears that some untreated water is supplied from the Olifants Canal to rural domestic consumers for irrigation of gardens or smallholdings and this is shown in Table 5.3.3.2 as small scale irrigation. This is shown in the table to total 0,74 million m³/a, but this estimate is of very uncertain reliability.

Drinking water for livestock is also considered to be part of rural water requirements and was calculated as 45ℓ/ELSU/day using the Equivalent Large Stock Units shown in Table 3.5.4.1.

The distribution of water requirements for livestock is shown in Table 5.3.3.2 where it can also be seen that all rural water requirements were estimated to total 6,31 million m³/a in 1995, including distribution losses.

It was assumed that the total rural water requirement is supplied at 1:50 year assurance.

Return flows from rural users are assumed to be negligible.

TABLE 5.3.3.2: RURAL DOMESTIC WATER REQUIREMENTS IN 1995

CATCHMENT						RURAL WATER REQUIRMENTS (million m³/a)							RETURN FLOWS	
PRIMARY		SECONDARY		TERTIARY		DOMESTIC (million m³/a) (1)	SMALL SCALE IRRIGATION (million m³/a) (2)	LIVESTOCK AND GAME (million m³/a)	LOSSES		TOTAL	TOTAL AT 1:50 YR ASSURANCE	NORMAL	TOTAL AT 1:50 YR ASSURANCE
No.	Description	No.	Description	No.	Description				(million m³/a)	%	(million m³/a)	(million m³/a)	(million m³/a)	(million m³/a)
E	Olifants	E1	Upper Olifants (W Cape)	None	---	0,43		0,16	0,15	20	0,74	0,74		
		TOTAL IN UPPER OLIFANTS				**0,43**	**0**	**0,16**	**0,15**	**20**	**0,74**	**0,74**	**0**	**0**
		E2	Doring	E21	Kouebokkeveld (All W Cape	0,40		0,17	0,14	20	0,71	0,71		
				E22	Upper Doring (W Cape)	0,05		0,21	0,06	20	0,32	0,32		
					Upper Doring (N Cape)	0		0	0	0	0	0		
				E23	Tanqua (W Cape)	0,01		0,13	0,04	20	0,18	0,18		
					Tanqua (N Cape)	0,04		0,03	0,02	20	0,09	0,09		
				E24	Lower Doring (W Cape	0,16		0,10	0,06	20	0,32	0,32		
					Lower Doring (N Cape)	0,08		0	0,02	20	0,10	0,10		
			Sub-total (Western Cape)			**0,62**	**0**	**0,61**	**0,31**	**20**	**1,53**	**1,53**	**0**	**0**
			Sub-total (Northern Cape)			**0,12**	**0**	**0,03**	**0,04**	**20**	**0,19**	**0,19**	**0**	**0**
		E4	Oorlogskloof (W Cape)	None		0,01		0	0	20	0,01	0,01		
			Oorlogskloof (N Cape)	None		0,04		0,01	0,01	20	0,06	0,06		
			Sub-total (Western Cape)			**0,01**	**0**	**0**	**0**	**20**	**0,01**	**0,01**	**0**	**0**
			Sub-total (Northern Cape)			**0,04**	**0**	**0,01**	**0,01**	**20**	**0,06**	**0,06**	**0**	**0**
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				**0,63**	**0**	**0,61**	**0,31**	**20**	**1,54**	**1,54**	**0**	**0**
		TOTAL IN DORING CATCHMENT IN NORTHERN CAPE				**0,16**	**0**	**0,04**	**0,05**	**20**	**0,25**	**0,25**	**0**	**0**
		TOTAL IN DORING CATCHMENT				**0,79**	**0**	**0,65**	**0,36**	**20**	**1,79**	**1,79**	**0**	**0**
		E3	Lower Olifants	E31	Kromme (All N Cape)	0,03		0,01	0,01	20	0,05	0,05		
				E32	Hantams (All N Cape)	0,07		0	0,02	20	0,09	0,09		
				E33	Lower Olifants (W Cape)	0,70	0,74	0,26	0,42	20	2,12	2,12		
					Lower Olifants (N Cape)	0		0	0	0	0	0		
		Sub-total (Western Cape)				**0,70**	**0,74**	**0,26**	**0,42**	**20**	**2,12**	**2,12**	**0**	**0**
		Sub-total (Northern Cape)				**0,10**	**0**	**0,01**	**0,03**	**20**	**0,14**	**0,14**	**0**	**0**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				1,76	0,74	1,03	0,88	20	4,41	4,41	0	0
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				0,26	0	0,05	0,08	20	0,39	0,39	0	0
		TOTAL IN OLIFANTS CATCHMENT				**2,02**	**0,74**	**1,08**	**0,96**	**20**	**4,79**	**4,79**	**0**	**0**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		0,05		0,09	0,03	20	0,17	0,17		
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**0,05**	**0**	**0,09**	**0,03**	**20**	**0,17**	**0,17**	**0**	**0**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		0,40		0,68	0,27	20	1,35	1,35	0	0
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**0,40**	**0**	**0,68**	**0,27**	**20**	**1,35**	**1,35**	**0**	**0**
		TOTAL IN WMA IN WESTERN CAPE				2,21	0,74	1,80	1,18	20	5,92	5,92	0	0
		TOTAL IN WMA IN NORTHERN CAPE				0,26	0	0,05	0,05	20	0,39	0,39	0	0
		TOTAL IN WMA				**2,47**	**0,74**	**1,85**	**1,23**	**20**	**6,31**	**6,31**	**0**	**0**

(1) Excluding losses
(2) Irrigation of gardens and smallholdings

5.4 BULK WATER USE

This section deals with industries, mines and thermal powerstations having individual bulk water supplies or direct supplies from DWAF. The main water user in this category is the Namakwa Sands mine which receives water by pipeline from the Olifants River Canal near Lutzville (see Section 4.4). In 1995 the mine on the coast near Brand-se-Baai (F60D) used about 1,1 million m^3, but it was still being developed at that stage. Once the mine is fully operational, it will require about 2,4 million m^3/a and the mineral separation plant, which is located near Lutzville (E33H) will use 0,4 million m^3/a. There are several quarrying operations in the area between Vredendal and Vanrhynsdorp which use small quantities of water. It is estimated that these, together with the Namakwa Sands mine, used a total quantity of about 2,6 million m^3 in 1995.

Return flows from the mining operations are assumed to be negligible.

Conveyance losses incurred in supplying water to the mines occur mainly in the Olifants Canal, and amount to 39% of the quantity of water used by mines, or 1,0 million m^3/a. This equates to 28% of the quantity of water released into the canal from Bulshoek Dam for supplies to the mines.

There are no thermal powerstations in the WMA. There are a few light industries, wine cellars etc. that receive individual water supplies from the Olifants Canal. The water allocations for these total 0,4 million m^3/a, and conveyance losses amount to 0,15 million m^3/a.

Thus bulk water requirements in 1995 totalled 4,15 million m^3. They occurred in only two key areas, namely the Lower Olifants (E33) where they totalled 2,62 million m^3, and the Namaqualand Catchments (F6) where they totalled 1,53 million m^3.

5.5 NEIGHBOURING STATES

No water is supplied to neighbouring states, nor are any water resources shared with them.

5.6 IRRIGATION

5.6.1 General

Comprehensive detailed observed data on water use for irrigation in the WMA is not available. Therefore, irrigation water requirements were estimated from available information on irrigated areas, typical quotas and assurances of supply.

Much of the information on irrigated areas was that shown in Table 3.5.2.1, which was obtained from the sources described in Section 3.5.2. Water requirements were calculated by applying typical values of water use per hectare, provided by officials of the DWAF Western Cape Regional Office, to the average irrigated areas shown in Table 3.5.2.1.

5.6.2 Water Use Patterns

Estimated average water requirements for irrigation in 1995 and equivalent requirements at 1:50 year assurance are shown per tertiary sub-catchment in Table 5.6.2.1. The table also shows estimated canal or river losses, estimated on farm conveyance losses, and estimated return flows.

TABLE 5.6.2.1: IRRIGATION WATER REQUIREMENTS

CATCHMENT						FIELD EDGE WATER REQUIREMENT (million m^3/a)	ASSUMED CANAL OR RIVER LOSSES		ON FARM CONVEYANCE LOSSES		TOTAL WATER REQUIRE-MENT (million m^3/a)	TOTAL WATER REQUIREMENT AT 1:50 YR ASSURANCE (1) (million m^3/a)	RETURN FLOWS				
PRIMARY		SECONDARY		TERTIARY									LEACHING BEYOND THE ROOT ZONE (million m^3/a)	ADDITIONAL RETURN FLOW FROM LANDS (million m^3/a)	FROM CONVEYANCE LOSSES (million m^3/a)	TOTAL RETURN FLOW (million m^3/a)	
No.	Description	No.	Description	No.	Description		(million m^3/a)	%	(million m^3/a)	%						NORMAL	AT 1:50 YR ASSURANCE
E	Olifants	E1	Upper Olifants (W Cape)	None	---	120,0	0	0	6,3	5	126,3	110	0	6,0	0	6,0	5,4
		TOTAL IN UPPER OLIFANTS				120,0	**0**	**0**	**6,3**	**5**	**126,3**	**110**	**0**	**6,0**	**0**	**6,0**	**5,4**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	73,0	0	0	3,8	5	76,8	65,2	0	3,6	0	3,6	3,0
				E22	Upper Doring (W Cape)	1,3	0	0	0,1	10	1,4	1,2	0	0	0	0	0
					Upper Doring (N Cape)	0,4	0	0	0	10	0,4	0,3	0	0	0	0	0
				E23	Tankwa (W Cape)	0,3	0	0	0	10	0,3	0,2	0	0	0	0	0
					Tankwa (N Cape)	1,2	0	0	0,1	10	1,3	1,1	0	0	0	0	0
				E24	Lower Doring (W Cape	5,5	0	0	0,6	10	6,1	5,0	0	0	0	0	0
					Lower Doring (N Cape)	1,5	0	0	0,1	10	1,6	1,3	0	0	0	0	0
			Sub-total (Western Cape)			80,1	**0**	**0**	**4,5**	**5,3**	**84,6**	**71,6**	**0**	**3,6**	**0**	**3,6**	**3,0**
			Sub-total (Northern Cape)			3,1	**0**	**0**	**0,2**	**10**	**3,3**	**2,7**	**0**	**0**	**0**	**0**	**0**
		E4	Oorlogskloof (W Cape)	None		0	0	0	0	0	0	0	0	0	0	0	0
			Oorlogskloof (N Cape)	None		3,2	0	0	0,4	10	3,6	2,9			0		
			Sub-total (Western Cape)			0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
			Sub-total (Northern Cape)			3,2	**0**	**0**	**0,4**	**10**	**3,6**	**2,9**	**0**	**0**	**0**	**0**	**0**
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				80,1	0	0	4,5	5,3	84,6	71,6	0	3,6	0	3,6	3,0
		TOTAL IN DORING CATCHMENT IN NORTHERN CAPE				6,3	0	0	0,6	8,7	6,9	5,6	0	0	0	0	0
		TOTAL IN DORING CATCHMENT				86,4	**0**	**0**	**5,1**	**5,7**	**91,5**	**77,2**	**0**	**3,6**	**0**	**3,6**	**3,0**
		E3	Lower Olifants	E31	Kromme (All N Cape)	0	0	0	0	0	0	0	0	0	0	0	0
				E32	Hantams (All N Cape)	1,0	0	0	0	0	1	0,9	0	0	0	0	0
				E33	Lower Olifants (W Cape)	126,9	49,5	28	- (2)	-	176,4	130	0	8,0	5,0	13,0	11,7
					Lower Olifants (N Cape)	0	0	0	0	0	0	0	0	0	0	0	0
		Sub-total (Western Cape)				126,9	**49,5**	**28**	-	-	**176,4**	**130**	**0**	**8,0**	**5,0**	**13,0**	**11,7**
		Sub-total (Northern Cape)				1,0	**0**	**0**	**0**	**0**	**1,0**	**0,9**	**0**	**0**	**0**	**0**	**0**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				327,0	49,5	10,5	10,6	-	387,3	311,6	0	17,6	5,0	22,6	20,1
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				7,3	0	0	0,6	7,6	7,9	6,5	0	0	0	0	0
		TOTAL IN OLIFANTS CATCHMENT				334,3	**49,5**	**10,3**	**11,4**	**-**	**395,2**	**318,1**	**0**	**17,6**	**5,0**	**22,6**	**20,1**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		0	0	0	0	0	0	0	0	0	0	0	0
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				0	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		45,0	0	0	0	0	45,0	34,0	0	0	0	0	0
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				45,0	**0**	**0**	**0**	**0**	**45,0**	**34,0**	**0**	**0**	**0**	**0**	**0**
		TOTAL IN WMA IN WESTERN CAPE				372,0	49,5		10,8		432,3	345,6	0	17,6	5,0	22,6	20,1
		TOTAL IN WMA IN NORTHERN CAPE				7,3	0		0,6		7,9	6,5	0	0	0	0	0
		TOTAL IN WMA				379,3	**49,5**		**11,4**		**440,2**	**352,1**	**0**	**17,6**	**5,0**	**22,6**	**22,6**

(1) Calculated by WSAM on the basis of the assurance categories of the types of crops grown and the yield characteristics of Clanwilliam and Bulshoek Dams.
(2) On-farm conveyance losses are assumed to have been included in the canal losses.

In the Lower Olifants area (E33), on-farm losses are assumed to be included in the canal conveyance losses as no information on the split between the two categories of losses is available.

The typical annual irrigation requirements per hectare on which the calculation of the field edge water requirements shown in Table 5.6.2.1 was based on are shown in Table 5.6.2.2.

The equivalent requirements at 1:50 year assurance were calculated by WSAM on the basis of the assurance categories defined for the types of crops grown and the yield characteristics of Calnwilliam and Bulshoek Dams.

TABLE 5.6.2.2: TYPICAL ANNUAL FIELD EDGE IRRIGATION REQUIREMENTS

AREA	CATCHMENTS	PREDOMINANT CROP	TYPICAL FIELD EDGE WATER REQUIREMENT (m^3/ha/a)
Olifants Catchment :			
Witzenberg	E10A, B	Citrus	8 500
Citrusdal	E10C to G	Citrus	12 000
Clanwilliam	E10H to K	Citrus, vegetables	12 000
Vredendal	E33G, H	Grapes	11 000
Kouebokkeveld	E21A to D	Orchards (deciduous)	9 000
	E21G, H	Vegetables	6 000
Doring	E22	Lucerne	7 000
	E24		
Tankwa	E23	Lucerne	7 000
Oorlogskloof	E40	Lucerne	7 000
Hantams	E32	Lucerme	7 000
Sandveld	G3	Potatoes, oats, etc.	6 000
			9 000

(1) Values provided by officials of the DWAF Western Cape Regional Office.

Most of the irrigation occurs in the south-western quarter of the WMA, which falls within the winter rainfall region. Runoff is stored during the wet winter months and used for irrigation during the dry summer months. The exception is the Sandveld (G30A to G30H), where irrigation is predominantly from groundwater. In the Olifants River valley, upstream of Clanwilliam Dam, irrigation is from water stored in farm dams and from run-of-river flow. In addition, about 8 million m³/a of water from boreholes in the Table Mountain Group aquifers is used for irrigation (DWAF 1998). Large scale, sustainable development of the Table Mountain Group aquifers may be possible by siting boreholes on large fault systems, which cross the Olifants Valley and may be preferred flow paths for, and/or barriers to groundwater movement. High yields are postulated, but investigations to verify that these can be obtained are still in progress.

From Clanwilliam Dam to the Olifants Estuary (E10G to K and E33G and E33H), water for irrigation is supplied mainly from the dam, with a small additional quantity coming from the Bulshoek Barrage.

In the Kouebokkeveld water for irrigation is obtained mainly from farm dams which store runoff from winter rainfall.

In the Doring River catchment, farm dams store water from winter rainfall and from occasional summer thunderstorms in the eastern part of the WMA. In addition, about 2,5 million m³/a of water is imported by canal from the Lakenvallei Dam in the Breede WMA for irrigation in catchment E22C.

In the catchments of the Hantams (E32) and Sout (E33A to E33F) Rivers, the "Saaidam" method of irrigation, described in Section 3.5.2, is used on the rare occasions when there is strong flow in the rivers.

Total irrigation water requirements in 1995 are estimated to have been 440 million m³/a, including conveyance losses. About 98% of these were used in the Western Cape Province, mainly in the Olifants River valley, the Kouebokkeveld, and the Sandveld. These areas, comprising only 22% of the surface area of the WMA, account for 96% of the irrigation water requirements. As there is no shortage of land that is suitable for irrigation farming in the other parts of the WMA (DWAF, 1998), the absence of irrigation on a significant scale can be attributed to lack of water. The distribution of irrigation water requirements is shown diagramatically on Figure 5.6.2.1.

5.6.3 Water Losses

Irrigation water losses are considered in two categories, namely :

- Canal or rivers losses incurred in conveying water from the dam in which it is stored to the farms where it is used for irrigation, and

- On farm conveyance losses, which occur in conveying the water from the point at which it is abstracted from a canal, river or farm dam to field edge.

The main canal conveyance losses occur in the canal system that distributes water from the Bulshoek Barrage to the lower Olifants River valley (E33G, E33H). Officials of the DWAF Western Cape Regional Office estimate that about 28% of the total quantity of water released into the canals from Bulshoek is lost through evaporation and spillage and leakage from the canals between Bulshoek and field edge.

As reliable information on farm conveyance losses is not available, estimates of combined canal and river losses and on farm conveyance losses were provided by officials of the DWAF Western Cape Region office as shown in Table 5.6.3.1. In the area supplied by the Olifants Canal the on-farm conveyance losses are included under canal losses in Table 5.6.3.1. In other areas there are no major canals and the losses are shown as on-farm losses.

TABLE 5.6.3.1: ESTIMATED IRRIGATION CONVEYANCE LOSSES

AREA	CATCHMENTS	CONVEYANCE LOSSES (% OF TOTAL REQUIREMENT INCLUDING LOSSES) [1]
Olifants Catchment :		
Witzenberg	E10A, B	5%
Citrusdal	E10C to G	5%
Clanwilliam	E10H to K	10%
Vredendal	E33G, H	28%
Kouebokkeveld	E21A to D, E21G, H	5%
Doring	E22, E24	10%
Tankwa	E23	10%
Oorlogskloof	E40	10%
Hantams	E32	0
Sandveld	G3	0

(1) Estimated by officials of the DWAF Western Cape Regional Office.

5.6.4 Return Flows

Irrigation return flows are generated from water lost during conveyance to irrigated lands by surface runoff and seepage of irrigation water applied to lands, and by excess water applied to leach unwanted salts from the soils of irrigated lands.

Leaching of soils is not widely practised in the Olifants/Doring WMA, and most of the irrigation return flows arise from conveyance losses and normal irrigation of lands.

Whilst irrigation return flows add to the volume of flow in the watercourses, they are frequently highly saline and have an adverse effect on water quality. This is particularly apparent in the lower Olifants River where salinities are very high during summer, largely because of the effects of irrigation return flows.

No reliable observed data on the quantity of irrigation return flows were found. Therefore estimates, provided by officials of the DWAF Western Cape Regional Office, of the percentages of field edge applications that become return flows were used to obtain an indication of the volume of return flows generated. The assumed percentages are shown in Table 5.6.4.1.

Return flows in the arid areas of the WMA are negligible because the low soil moisture contents and high evaporation losses prevent excess irrigation water from reaching the watercourses.

Similarly, in the Sandveld, the deep sandy soils prevent any excess water from reaching the watercourses, even though it may replenish groundwater aquifers.

TABLE 5.6.4.1: ESTIMATED IRRIGATION RETURN FLOWS AS PERCENTAGES OF FIELD EDGE IRRIGATION REQUIREMENTS

AREA	CATCHMENTS	RETURN FLOWS (1) (% OF FIELD EDGE IRRIGATION REQUIREMENTS)
Olifants Catchment :		
Witzenberg	E10A, B	5%
Citrusdal	E10C to G	5%
Clanwilliam	E10H to K	10%
Vredendal	E33G, H	10%
Kouebokkeveld	E21A to D, E21G, H	5%
Doring	E22, E24	0
Tankwa	E23	0
Oorlogskloof	E40	0
Hantams	E32	0
Sandveld	G3	0

(1) Estimates made by officials of the DWAF Western Cape Regional Office.

5.7 DRYLAND SUGARCANE

No sugarcane is grown commercially in the Olifants/Doring WMA.

5.8 WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

No information is available on water losses from rivers and wetlands.

Evaporation from the approximately 210 farm dams in the WMA has been estimated to amount to 55 million m^3/a, on average. The large, shallow Oudebaaskraal Dam (E23F), which has a capacity of 34 million m^3 and a surface area of 8 km^2 is estimated to account for about 11 million m^3 of these evaporation losses.

Evaporation losses from Clanwilliam Dam and the Bulshoek Barrage are estimated to total an additional 9 million m^3/a on average, bringing total evaporation losses from dams to 64 million m^3/a.

These are rough estimates only, and are probably indicative of the upper limits of evaporation losses, which vary widely from year to year, depending on climatic conditions and the storage volumes in the dams.

The distribution of evaporation losses from dams is shown in Table 5.8.1.

TABLE 5.8.1: EVAPORATION LOSSES FROM DAMS

CATCHMENT						EVAPORATION LOSSES FROM DAMS (million m^3/a)
PRIMARY		SECONDARY		TERTIARY		
No.	**Description**	**No.**	**Description**	**No.**	**Description**	
E	Olifants	E1	Upper Olifants (W Cape)	None	---	16,8
		TOTAL IN UPPER OLIFANTS				**16,8**
		E2	Doring	E21 E22 E23 E24	Kouebokkeveld (All W Cape) Upper Doring (W Cape) Upper Doring (N Cape) Tankwa (W Cape) Tankwa (N Cape) Lower Doring (W Cape Lower Doring (N Cape)	28,2 1,5 0 11,6 1,3 0,5 1,0
			Sub-total (Western Cape)			**41,8**
			Sub-total (Northern Cape)			**2,3**
		E4	Oorlogskloof (W Cape) Oorlogskloof (N Cape)	None None		0 2,3
			Sub-total (Western Cape)			0
			Sub-total (Northern Cape)			2,3
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				**41,8**
		TOTAL IN DORING CATCHMENT IN NORTHERN CAPE				**4,6**
		TOTAL IN DORING CATCHMENT				**46,4**
		E3	Lower Olifants	E31 E32 E33	Kromme (All N Cape) Hantams (All N Cape) Lower Olifants (W Cape) Lower Olifants (N Cape)	0,1 0,2 0,1 0
		Sub-total (Western Cape)				**0,1**
		Sub-total (Northern Cape)				**0,3**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				58,7
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				4,9
		TOTAL IN OLIFANTS CATCHMENT				**63,6**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		0,1
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**0,1**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		0,8
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**0,8**
		TOTAL IN WMA IN WESTERN CAPE				59,6
		TOTAL IN WMA IN NORTHERN CAPE				4,9
		TOTAL IN WMA				**64,5**

5.9 AFFORESTATION

The water use by commercial afforestation is based on the so-called CSIR curves (CSIR, 1995), which have replaced the so-called Van der Zel curves that were used for the preparation of WR90 (Midgley, *et al*, 1994). The Van der Zel curves were considered to be too simplistic compared to the CSIR curves, which now take the species, age and site conditions into account in estimating the stream flow reductions. A study was undertaken (Ninham Shand, 1999) to provide adjusted naturalised flow sequences for the Water Situation Assessment Model (WSAM) (DWAF, 2000) based on the WR90 naturalised flow data. This now enables the CSIR curve-based stream flow reduction estimates to be used in the WSAM and these reduction estimates have been used in the WRSA reports. Details of the method of estimating the reduction in runoff by or water use of commercial afforestation are described in CSIR (1995).

The impact of the reduction in runoff due to afforestation on the yield of a catchment depends on the storage in that catchment. It was accepted that the storage/yield characteristics of a catchment with afforestation were similar to those of the natural catchment and that the latter characteristics could be used to estimate the yield of a catchment with afforestation. The estimates of the impact on the yield of a catchment were made separately for each of the incremental catchments between key points. The total storage within the incremental catchment was transposed to its outlet and formed the basis for determining the incremental yield of the catchment under both natural conditions and the effects of only the afforestation. The yields were estimated from the storage yield characteristics used in the WSAM for any particular recurrence interval of concern. The difference between the incremental yields under natural conditions and with only the effects of afforestation was the impact of the reduction in runoff due to affrorestation in the incremental catchment on the yield of the catchment.

Only small areas of the Olifants/Doring WMA are climatically suited to commercial timber plantations, with the result that significant reduction in runoff occurs only in the upper Olifants River catchment (E10A, E10B, E10C and E10G), and in the mountains of the Kouebokkeveld (E21A, E21B, E21C). In the upper Olifants catchment the reduction in runoff is estimated to be 1,3 million m^3/a, and in the Kouebokkeveld it is only 0,2 million m^3/a. The corresponding reductions in 1:50 year yield are 0,7 million m^3/a and 0,1 million m^3/a. This information is shown diagramatically on Figure 5.9.1.

5.10 HYDROPOWER AND PUMPED STORAGE

The small hydropower installation at Clanwilliam Dam (see Section 4.5) uses a flow of 3 m^3/s for about 80% of each year. Thus, its water requirement is 75 million m^3/a. However, only overflows from the dam or water released for irrigation are used. Therefore the hydropower generation does not affect the availability of water for other users.

5.11 ALIEN VEGETATION

Tertiary and quaternary catchment information on condensed areas of infestation by alien vegetation and stream flow reductions was obtained from the CSIR (Environmentek) (Versfeld *et al*, 1997).

It has been assumed that water consumption of alien vegetation outside of the riparian zone cannot exceed the natural runoff and water use inside and outside of the riparian zone has been estimated separately wherever possible. In the absence of any better information, it was assumed that 10% of the condensed area under alien vegetation is riparian. The reduction in runoff due to alien vegetation was taken from WSAM using the above assumptions. The impact of this reduction in runoff on catchment yield was determined in the same manner as for afforestation.

The distribution of alien vegetation in the Olifants/Doring WMA is described in Section 3.5.6. Corresponding estimates of average reduction in runoff and reduction in the system 1:50 year yield are shown in Table 5.11.1 and on Figure 5.11.1.

It can be seen from the table that most of the reduction in runoff caused by alien vegetation occurs in the upper Olifants River catchment and in the Sandveld area. These areas between them account for 80% of the total reduction in runoff of 3,4 million m^3/a for the whole WMA. The total reduction in the system 1:50 year yield is 0,9 million m^3/a.

It should be noted that the reliability of these estimates is uncertain, as neither the true extent of infestation by alien vegetation, nor its effect on runoff is accurately known.

TABLE 5.11.1: WATER USE BY ALIEN VEGETATION IN 1995

CATCHMENT						**AVERAGE REDUCTION IN RUNOFF**		**REDUCTION IN SYSTEM 1:50 YEAR YIELD**	
PRIMARY		**SECONDARY**		**TERTIARY**		**(million m^3/a)**	**(mm/a) (1)**	**(million m^3/a)**	**(mm/a) (1)**
No.	**Description**	**No.**	**Description**	**No.**	**Description**				
E	Olifants	E1	Upper Olifants	None	---	0,8	0,4	0,5	0,2
		TOTAL IN UPPER OLIFANTS (ALL WESTERN CAPE)				0,8	0,4	0,5	0,2
		E2	Doring	E21	Kouebokkeveld (All W Cape)	0,3	0,1	0,1	0,03
				E22	Upper Doring (W Cape)	0	0	0	0
					Upper Doring (N Cape)	0	0	0	0
				E23	Tankwa (W Cape)	0	0	0	0
					Tankwa (N Cape)	0	0	0	0
				E24	Lower Doring (W Cape)	0	0	0	0
					Lower Doring (N Cape)	0	0	0	
			Sub-total (Western Cape)			**0,3**	0,02	**0,1**	**0,01**
			Sub-total (Northern Cape)			**0**	0	**0**	**0**
		E4	Oorlogskloof (W Cape)	None		0	0	0	0
			Oorlogskloof (N Cape)	None		0	0	0	0
			Sub-total (Western Cape)			**0**	0	**0**	**0**
			Sub-total (Northern Cape)			**0**	0	**0**	**0**
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				0,3	0,02	0	0,01
		TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE				0	0	0	0
		TOTAL IN DORING CATCHMENT				0,3	0,01	0,1	**0**
		E3	Lower Olifants	E31	Kromme (All N Cape)	0	0	0	0
				E32	Hantams (All N Cape)	0	0	0	0
				E33	Lower Olifants (W Cape)	0,2	0,1	0	0
					Lower Olifants (N Cape)	0	0	0	0
			Sub-total (Western Cape)			**0,2**	0,02	**0**	**0**
			Sub-total (Northern Cape)			**0**	0	**0**	**0**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				1,3	0,05	0,6	0,2
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				0	0	0	0
		TOTAL IN OLIFANTS CATCHMENT				**1,3**	0,02	**0,6**	**0,01**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		0,2	0,07	0	0
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**0,2**	0,07	**0**	**0**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		1,9	0,4	0,3	0,06
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**1,9**	0,4	**0,3**	**0,06**
TOTAL IN WMA IN WESTERN CAPE						3,4	0,1	0,9	0,03
TOTAL IN WMA IN NORTHERN CAPE						0	0	0	0
TOTAL IN WMA						**3,4**	**0,06**	**0,9**	**0,01**

(1)Calculation based on the catchment area, not the afforested area.

5.12 WATER CONSERVATION AND DEMAND MANAGEMENT

5.12.1 Introduction

The Department of Water Affairs and Forestry is entrenching and insisting on efficient water management and use. This concept has been strongly emphasised, both in legislation and through key demonstration water conservation and water demand management projects. The Department of Water Affairs and Forestry is therefore developing a National Water Conservation and Demand Management Strategy, which is aimed at the water supply industry and South African society at large and aims to cover all water use sectors including agriculture, forestry, industry, recreational, ecological, and water services.

Evidence of inefficient water usage can be found in all water use sectors throughout the country and the value of water seems largely unrecognised by many water users. South Africa is a developing country that is water stressed and requires improved management of its limited water resources.

The implementation of water conservation and demand management principles is essential in meeting the national goals of basic water supply for all South Africans and the sustainable use of water resources.

Water conservation and water demand management are not synonymous. The following meanings are therefore assigned to these terms in this report :

- Water conservation is the minimisation of loss or waste, the preservation, care and protection of water resources and the efficient and effective use of water. Water conservation should be both an objective in water resource and water services management as well as a strategy.

- Water demand management is the adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water requirements and use of water in order to meet any of the objectives of economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability. Water supply institutions should set water demand goals and targets by managing the distribution systems and consumer requirements in order to achieve the above objectives.

Water demand management is deemed to include the entire water supply chain - from the point of abstraction at the source to the point of use. This includes all levels of water distribution management and consumer demand management. The conservation measures related to the water resources and return flow are part of water resource management and return flow management respectively.

Various obstacles and constraints have to be overcome before the full potential of water conservation and demand management can be achieved.

This section describes the National Water Conservation and Demand Management objectives that will lead to the development of action plans to be implemented by the various water institutions. The needs and opportunities for the implementation of water conservation are described, as are some of the important principles on water conservation and demand management. This section also describes the platform on which the National Water Conservation and Demand Management strategy will be based. This National

Strategy Framework will also be used to develop the functions of the Directorate : Water Conservation within the Department of Water Affairs and Forestry and the functions of other departments and other water institutions. It is also intended that those principles will assist the water industry to comprehensively implement water conservation and demand management.

5.12.2 Background

Water resources and supply

The sustainability of the limited water resources is threatened in terms of quantity and quality. Unless the current water use pattern is changed, future water requirements will greatly exceed existing available fresh water resources. Frequently the water supply and quality are unreliable or improperly managed, leading to the wasteful use of water by consumers in anticipation of possible supply failures.

Environmental degradation and the prevention thereof is a key focus in the current policy and legislation. Measures such as providing for water of suitable quality in sufficient quantity in the Reserve to protect the integrity, health and productivity of the rich and diverse ecosystems have become necessary.

Neighbouring states

South Africa and the neighbouring states of Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe have certain common water resources and must collaborate to achieve the optimal use of these resources. Except for Lesotho all of these countries are water scarce and it is imperative that none of them should allow the wastage of water resources to the detriment of the other countries.

Basic water supply needs

By the application of water demand management measures to existing water services, water resources and bulk infrastructure can be reallocated for the provision of new services where adequate services do not yet exist. Water demand management is also essential in ensuring the sustainability of the new water service delivery projects and can help to ensure that water remains affordable.

Existing water services

It is estimated that up to 50% of the total quantity of water that is supplied is not accounted for in many of the urban areas. This unaccounted for water consists of a combination of reticulation system leaks, unauthorised water connections, faulty water meters and domestic plumbing leaks. These factors, combined with the low levels of payment and institutional problems of local authorities, affect the sustainability of water services. Current indications are that levels of unaccounted for water are growing despite the formulation of several water conservation strategies in the past.

Irrigation

Irrigation accounts for an estimated 95% of total water use in the Olifants/Doring Water Management Area. Irrigation losses are often quite significant and it is estimated that often no more than 60% of water abstracted from water resources is correctly applied to the root systems of plants. Some irrigation system losses return to the river systems but this return water can be of reduced quality. Irrigation methods, irrigation scheduling, soil preparation, crop selection, crop yield targets and evaporation all affect the efficient use of water.

Forestry
Forestry accounts for an estimated 0,3% of total water use in the Olifants/Doring Water Management Area. Issues such as site selection and preparation, species selection, rotation periods and plantation management all affect the efficient use of water.

Industry, mining and power generation
Industry is expected to be the biggest contributor to future economic growth in South Africa. The industrial sector is projected to have the greatest growth in water requirements. Much of this growth will occur in major urban centres that only have limited water resources nearby. It is imperative to have assured water supplies at a reasonable cost to support the industrial development and for the industrial sector to improve its efficiency of water use and to minimise waste.

5.12.3 Legal and Regulatory Framework

General
The Water Services Act (No. 108 of 1997) and the National Water Act (No. 36 of 1998) variously require and provide for the implementation of water conservation and demand management measures. One of the functions of the National Water Conservation and Demand Strategy is to fulfil the requirements made through the legislation and to utilise the opportunities created through the legislation to develop comprehensive policies and to identify and develop regulations.

Complimentary to the regulations promulgated in terms of the above two Acts are codes of practice that present guidelines for the maintenance of uniform standards within the water supply industry.

Water Services Act
The Water Services Act (No. 108 of 1997) sets out a framework to ensure the provision of basic water supply and sanitation and a regulatory framework for water services institutions. All water services institutions are required to develop conditions for the provision of water services that must include for measures to promote water conservation and demand management.

National Water Act
The purpose of the National Water Act (No. 36 of 1998) is to, inter alia, ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways that, amongst others, promote efficient, sustainable and beneficial use of water in the public interest.

Codes of Practice
The SABS Code of Practice 0306 : 1998 titled The Management of Potable Water in Distribution Systems has been drafted to establish the management, administrative and operational functions required by a water services institution to account for potable water within distribution systems and apply corrective actions to reduce and control unaccounted for water.

5.12.4 The Role of Water Conservation and Demand Management

Security of supply
The role of water conservation and demand management in ensuring security of supply can be divided into short-term rationing measures during droughts, which amount to a

reduction in assurance of supply in respect of some of the water, and sustainable long-term functions.

With the current growth of water requirements it is estimated that unless water conservation and sustainable development policies are implemented, South African will utilise all its natural fresh water resources within 30 years. Possible alternative water resources such as importation of water from neighbouring states, desalination and harvesting icebergs are considered to be too expensive.

Protection of the aquatic environment
Aquatic ecosystems are under threat from current land use practices and over-utilisation of water resources. Reducing water requirements reduces water abstractions that affect the aquatic environment and results in increased stream flows and/or decreased demand on groundwater sources and also reduces or defers the need for dams, that have their own impacts on the environment.

Protection of existing water resources
The protection of water resources through water conservation measures can be achieved as follows :

- The removal of alien invading plants, which reduce surface runoff and the yield of existing resources.
- Rehabilitation of wetlands.
- Protection of groundwater resources by limiting abstraction to the sustainable yield.
- Minimising pollution of water resources.

Economic efficiency
One of the main objectives of water demand management is economic efficiency through the entire water cycle.

In the potable water services sector, economic efficiency may often be a more important objective than water resource considerations. A certain measure that may be economically efficient from the perspective of society may not be economically efficient from the perspective of a specific water institution or user, which can be a major constraint on water demand management. However, the perspective of society needs to have priority over the economic efficiency perspective of the various water institutions or users.

Reducing the growth in water requirements can postpone large infrastructure development costs.

Social development, equity and accountability
Water demand management can enhance the objectives of social development and equity in a number of ways, some of which are given below :

- To promote maintenance, management and prevention of abuse of water infrastructure.
- To reduce domestic water consumption and waste and the cost of potable water services.
- To provide new services to people by using existing resources and bulk infrastructure.
- To offer more employment opportunities to the community.
- To make water institutions accountable to the public and understand the consumers and their needs.

5.12.5 Planning Considerations

Water conservation and demand management initiatives are not only strategies associated with environmental or communications initiatives but must be integrated into the water resource planning process as potential alternatives to increasingly expensive supply side management options.

All water demand management activities that decrease the water requirement tend to affect supply management because existing system capacity is released for other users.

The opportunities for water demand management exist where there are high levels of loss and inefficient use, particularly where water is used for the service that is derived from it and not for the water itself.

5.12.6 Water Conservation and Demand Management Measures

There are a number of categories of water conservation and demand management measures and initiatives that can be implemented. The following categories are general for all water sectors and are according to the different components of the water supply chain :

- Water conservation measures in resource management.
- Water demand management in distribution of supply management.
- Water demand management measures of customer or end user.
- Water conservation measures for return flow management.

5.12.7 Objectives of the National Water Conservation and Demand Management Strategy

The objectives of the National Water Conservation and Demand Management Strategy are as follows :

- Create a culture of water conservation and demand management within all water management and water service institutions in South Africa.
- Support water management and water services institutions to implement water demand management and water conservation.
- Create a culture of water conservation and demand management for all consumers and users in South Africa.
- Promote international co-operation and participate with other Southern African countries, particularly co-watercourse states, to develop joint water conservation and demand management strategies.
- Enable water management and water resources institutions to adopt integrated resource planning.
- Promote social development and equity in South Africa.
- Contribute to the protection of the environment, ecology and water resources.
- Contribute to the parameters of water economics to development planning processes.

5.12.8 Water Conservation in South Africa

History
Since 1982 the droughts have accentuated the awareness of the need to conserve water. In 1985 the Water Research Commission initiated a process to establish the National

Water Supply Regulation (NWSR), which was proposed to be promulgated under the then Water Act. Participating local authorities were however, encouraged to promulgate the NWSR as their own Water Regulations (by-laws). Port Elizabeth Municipality was the first to adopt the NWSR in 1987. However, in 1992 the Department of Water Affairs and Forestry indicated it would not be involved with the administration of the (then) proposed NWSR and although the United Municipal Executive resolved in 1993 that the NWSR should be adopted by local authorities, little progress was made.

The proceedings of the National Water Supply and Sanitation Policy Conference of 1994 included an estimate of the extent of the problem of water losses due to leakage at 330 million m^3/a and proposed a policy of water demand management. The subsequent Water Supply and Sanitation Policy White Paper published in 1994 referred to water conservation and demand management and encouraged a culture of water conservation and the introduction of stringent water demand management strategies to reduce water usage and the stress on resources.

The Working for Water programme

The Working for Water programme is part of the National Water Conservation Campaign and is based on the key assumption that invading alien plants pose a considerable threat to South Africa's extremely rich biological diversity, and to the ecological functioning of its natural systems. Also provided by the campaign is a catalogue of devices that can contribute to the efficient consumption of water.

Water restrictions

Restricting water use during extreme droughts through the imposition of conservation measures on consumers is an intermittent form of water demand management. The effects of past water restrictions give an indication of the extent and direction that future water conservation strategies could have.

Overall savings in water use (median estimates) achieved through water restrictions were found to vary according to region and severity of restriction. In the Rand Water area of supply mild restrictions saved about 15% whereas stringent restrictions saved about 27%. For the rest of Gauteng, Free State and Northern Cape these savings were about 19% (mild) and 34% (stringent). In the Umgeni Water area of supply mild restrictions saved only 1% to 5%, whereas stringent measures saved as much as 50%. For the rest of KwaZulu/Natal these savings were 29% (mild) and 46% (stringent).

It was difficult to determine the financial effects of water restrictions. In the Vaal River Supply Area the reduction in water requirements due to water restrictions for the Rand Water, Goldfields and Vaal River supply areas for the period 1982 to 1984 was almost 240 million m^3 of water or 22,5% of the requirement for the year 1982. The greatest total direct tangible financial impact was on public institutions such as the Department of Water Affairs and Forestry, Water Boards, Local Authorities and Eskom. Private households also bore a large financial impact of water restrictions. Mining had the least financial burden to bear because of water restrictions, yet achieved a net saving in water use of almost 32% in the same period. The greatest reduction in water use was for the agricultural sector, which had the second lowest direct financial impact.

Experience from past water restrictions that have proved to be the most effective during times of drought, which are relevant to future water conservation efforts are :

- The overall reduction in water use depends on a number of factors. However, when water use is reduced beyond 30% it can be detrimental to the user from a financial and motivational perspective.

- Voluntary reduction in water use fails to achieve the savings possible with mandatory steps.

- The most effective methods of reducing water use are higher tariffs, restriction of garden watering times, the banning of domestic hose pipe usage and allotting quotas to industry, bulk consumers and irrigators.

- The most effective motivations are pamphlets/newsletters, higher tariffs and punitive measures.

- The major interventions required to reduce both physical and non-physical losses from pipe networks are leak detection/monitoring, replacing old plumbing and the repair/monitoring of meters.

- The most effective methods of saving water used by commerce and industry are technical adjustments, recycle/re-use and promotion campaigns.

The measures implemented during the drought in the mid- 1980s reduced water use and the growth rate in water usage after the drought had ended. However, there is little or no incentive for existing or new consumers to continue to retain or to adopt the water saving measures when there is no drought.

5.12.9 Water Conservation in the Olifants/Doring Water Management Area

Based on experience elsewhere in South Africa an overall sustainable reduction in water use of up to 25% can be expected without having a detrimental effect on users. Return flows could be reduced by up to 10% of total water use.

The greatest scope for water conservation appears to be in reducing the conveyance losses that occur in the Olifants River canal system.

5.13 WATER ALLOCATIONS

5.13.1 Introduction

As explained in Section 3.4, numerous allocations of water have been made in the past under the provisions of the Water Act of 1956 and earlier legislation. Under the National Water Act (Act No. 36 of 1998) these allocations will be replaced by general authorisations or by licensing of specific water uses. The previous allocations were, however, still valid in 1995, and are summarised in this section of the report for comparison with estimated water availability in 1995.

Allocations of water were made and permits for use of water issued under the following articles of the Water Act of 1956 :

(a) Article 63 : Irrigation scheduling and quotas from Government Water Schemes.
(b) Article 56(3) : Allocations to other users from Government Water Schemes.
(c) Article 62 : Scheduling and quotas from Government Water Control Areas.

(d) Articles 32A and 32B : Scheduling and quotas from Government Subterranean Water Control Areas.
(e) Industrial, mining and effluent permits (including Articles 12, 12B and 21).
(f) Other allocations (including Section 9B permits, Water Court orders and older legislation).

Under (c) and (d) above, reference is made to Government Water Control Areas and Government Subterranean Water Control Areas. The first mentioned were a feature of the Water Act of 1956 which was applied to areas in which it was necessary in the public interest for the allocation of rights to the use of public water to be based on considerations other than the extent of irrigable riparian land. The Water Act of 1956 provided for such cases to be dealt with by empowering the State President to declare the relevant area a Government Water Control Area in which the Minister of Water Affairs was entitled to allocate water rights. In all other areas rights could be allocated only by a Water Court, primarily in proportion to the extent of irrigable riparian land.

Government Subterranean Water Control Areas provided for a similar situation in areas where over exploitation of groundwater aquifers occurred.

With the implementation of the National Water Act of 1998, Government Water Control Areas no longer exist.

In the Olifants/Doring WMA, the whole of the Olifants River Valley, a portion of the Kouebokkeveld, the upper and middle reaches of the Doring River, and the Tankwa River were Government Water Control Areas. In addition, Government Subterranean Water Control Areas were declared in the vicinity of Strandfontein (G30H), Wadrif (G30F) and Graafwater (G30G).

5.13.2 Permits and Other Allocations in the Olifants/Doring WMA

In the Olifants/Doring WMA, the main allocations of water have been made from the Olifants River (Vanrhynsdorp) Government Water Scheme. Article 63 allocations for irrigation were made to a total annual volume of water of 128,7 million m^3, as summarised in Table 5.13.2.1. Additional allocations of water from the scheme to other users were made under Article 56(3) to a total quantity of 13,83 million m^3/a. The categories under which these allocations were made are shown in Table 5.13.2.2. The allocations for mining were not fully utilised in 1995 as the Namakwa Sands Mine was still being developed.

TABLE 5.13.2.1: ARTICLE 63 - SCHEDULING AND QUOTAS FROM GOVERNMENT WATER SCHEMES

SCHEME	QUATERNARY CATCHMENTS	SCHEDULING (ha)	QUOTA	ALLOCATION
			(m^3/ha/a)	(million m^3/a)
Olifants River (Vanrhynsdorp) Government Water Scheme	E10K E24M E33G, H	10 550	12 200	128,7

TABLE 5.13.2.2: ARTICLE 56(3) - ALLOCATIONS FROM GOVERNMENT WATER SCHEMES

SCHEME	QUATERNARY CATCHMENTS	ALLOCATION (million m^3/a)					
		HOUSEHOLD & STOCK WATERING	MUNICIPALITIES	BULK STRATEGIC	BULK MINING	IRRIGATION	TOTAL
Olifants River (Vanrhynsdorp) Government Water Scheme	E10K E24M E33G, H	0,40	9,22	0	3,39	0,82	13,83

Allocations of water in Government Water Control Areas falling outside the supply zone of the Olifants River (Vanrhynsdorp) Government Water Scheme were almost entirely for irrigation. Scheduled areas and quotas in these areas are shown in Table 5.13.2.3.

TABLE 5.13.2.3: ARTICLE 62 - SCHEDULING AND QUOTAS IN GOVERNMENT WATER CONTROL AREAS

SCHEME	QUATERNARY CATCHMENTS	SCHEDULING (ha)	QUOTA (m^3/ha/a)	ALLOCATION (million m^3/a)
Olifants River : Citrusdal Irrigation District	E10D, E, F	4 984,3	12 000	59,8
Clanwilliam Irrigation District	E10C, G	610,93	12 000	7,3
Doring River : Elandskaroo Irrigation District	E22C, E 24H	690	7 000	4,8

5.13.3 Allocations in Relation to Water Requirements and Availability

Allocations from the Olifants River (Vanrhynsdorp) Government Water Scheme totalled 142,53 million m^3/a in 1995. If canal conveyance losses are added to the allocations, the total requirement becomes about 197 million m^3/a, which exceeds even the 1:5 year yield of Clanwilliam and Bulshoek Dams combined of 156 million m^3/a by a considerable margin. In addition, as described in Section 4.2, the actual requirements from the dams total about 225 million m^3/a. In the upper Olifants River valley, the area in which the Citrusdal and Clanwilliam Irrigation Boards operate, the total water requirement for irrigation is estimated to be 126 million m^3/a. This is considerably more than the allocation of 67,1 million m^3/a.

Reliable information on water availability in the Elandskaroo Irrigation District was not obtained in this study.

5.14 EXISTING WATER TRANSFERS

The following water transfers occur in the Olifants/Doring WMA :

- The import of approximately 2,5 million m^3/a of water for irrigation from the catchment area of the Lakenvallei Dam in the Breede WMA and via the Inverdoorn Canal to the upper Doring catchment (E22C).

- The transfer of 2,4 million m^3/a from the Olifants River Canal near Lutzville (E33H) to the Namakwa Sands Mine (F60D), which is an inter-drainage basin transfer.

- The transfer of 0,61 million m^3/a from the Olifants River Canal to Catchment E24M for irrigation in the vicinity of the confluence of the Olifants and Doring Rivers.

- The transfer of 1,16 million m^3/a of water from the Olifants River Canal near Vredendal (E33G) to Vanrhynsdorp (E33F) for urban use.

- The transfer of 0,4 million m^3/a of water from the Olifants River Canal near Ebenhaezer (E33H) to Strandfontein and Doring Baai (G30H) and rural domestic consumers in the vicinity.

Information on these transfers is summarised in Table 5.14.1, and they are shown diagramatically on Figure 5.14.1.

TABLE 5.14.1: AVERAGE TRANSFERS WITHIN AND INTO THE OLIFANTS/DORING WMA AT 1995 DEVELOPMENT LEVELS

DESCRIPTION OF TRANSFER	SOURCE QUATERNARY	DESTINATION QUATERNARY	QUANTITY (million m^3/a)
Inverdoorn Canal for irrigation	H20C (Breede WMA)	E22C	2,5
Namakwa Sands Mine	E33H	F60D	2,4 (1)
Irrigation water transfer	E10K	E24M	0,61
Vanrhynsdorp water supply	E33G	E33F	1,16
Strandfontein/Doringbaai water supply	E33H	G30H	0,4

(1) The quantity in 1995 was about 1 million m^3 because the mine was still being developed.

5.15 SUMMARY OF WATER LOSSES AND RETURN FLOWS

A summary of water requirements, losses and return flows is presented in Table 5.15.1. As about 35% of the water requirements in the WMA are supplied via the Olifants River Canal, in which losses amount to about 28% of the water released into it, the average losses in the WMA are fairly high. The proportions of the categories of losses are shown on Diagram 5.15.1.

About 50% of the return flows are to the lower Olifants River from irrigation. These are not re-usable because of their high salinity, but they do contribute to the requirements of the ecological Reserve for the river and estuary.

TABLE 5.15.1: SUMMARY OF WATER REQUIREMENTS, LOSSES AND RETURN FLOWS

CATEGORY		ON-SITE WATER REQUIREMENTS (million m^3/a)	LOSSES		RETURN FLOW (million m^3/a)
			(million m^3/a)	(%)	
Irrigation		379	61	14	23
Urban		5	1,6	24	3
Rural		5	1,2	20	0
Bulk	a) Strategic	0	0	0	0
	b) Mining	3	1,2	28	0
	c) Other	0	0	0	0
Hydro-power (1)		(75)	0	0	(75)
Rivers, wetlands, dams		0	65	--	0
TOTAL		392	130	--	26

(1) Hydropower use is secondary and not consumptive and therefore is not included in the totals.

The proportions of the categories of the return flows are shown on Diagram 5.15.2.

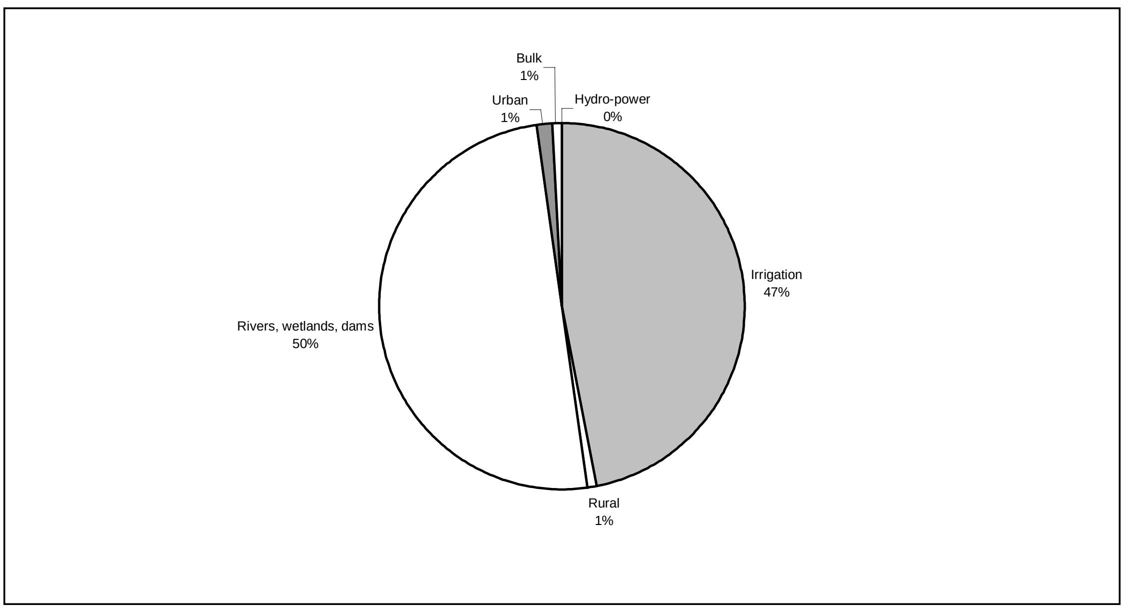

Diagram 5.15.1: Category loss as a portion of the total water losses in the Olifants/Doring WMA

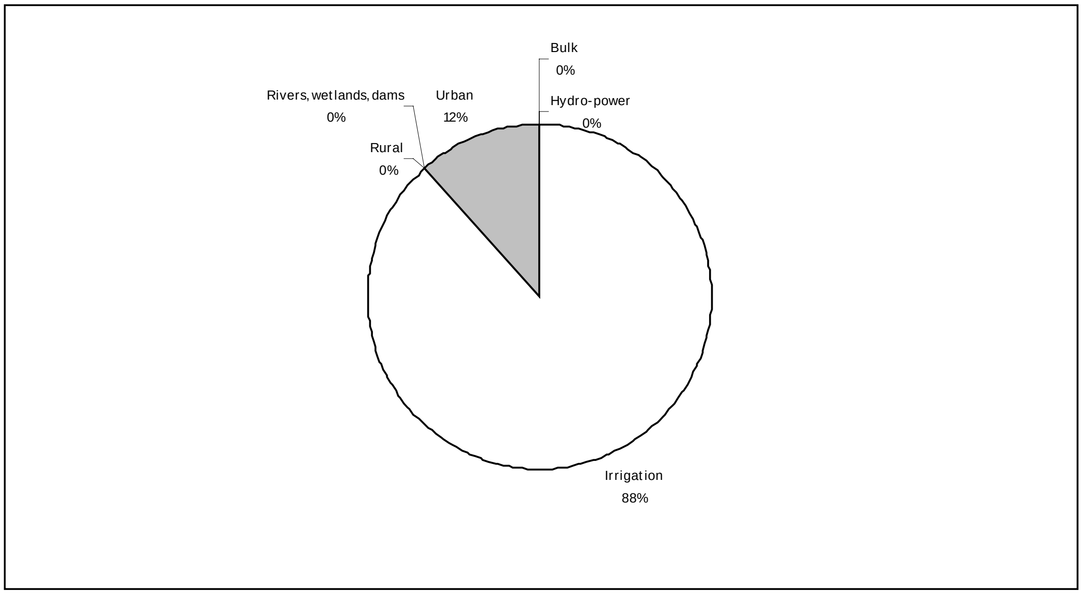

Diagram 5.15.2: Category return flows as a portion of the total return flows in the Olifants/Doring WMA

CHAPTER 6: WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

It has been estimated from the data provided in the Water Research Commission publication, "The Surface Water Resources of South Africa, 1990" (Midgley *et al*, 1994) that, under natural conditions, the total MAR of the Olifants/Doring WMA was 1 108 million m^3. Approximately 95% of this, or 1 047 million m^3, flowed out to sea through the mouth of the Olifants River (E33H).

The remainder of the natural runoff, totalling 61 million m^3/a on average, came from the catchments comprising the coastal strips to the north (F60) and south (G30) of the Olifants estuary. The contribution of the northern coastal strip to this was only about 1 million m^3/a, because the area is very arid.

The natural runoff has been reduced by evaporation losses from the surfaces of dams, the use of water and, to a small extent, by the effects of timber plantations and alien vegetation. As a result, the present day MAR at the Olifants estuary is estimated (DWAF 1998c) to be about 690 million m^3. The reduction in runoff from the coastal catchments has been less severe, and their present day MAR is probably about 55 million m^3. Thus, the total present day MAR is estimated to be 745 million m^3, which is 67% of the natural MAR. Most of the runoff occurs during the winter months and, with the exception of the upper Olifants River catchment, little or no water can be obtained from run-of-river flow during the summer months, when there is a high demand for water for irrigation. Consequently, two major dams (Clanwilliam and Bulshoek) and about 210 farm dams have been constructed in the WMA. It is estimated that, as a result of this development, a yield of 290 million m^3/a can be obtained from the surface water resources under 1:50 year drought conditions. The distribution of this yield amongst the catchments making up the WMA is shown in Table 6.1.1 as the "1:50 year developed yield in 1995".

Several sites at which dams could be constructed have been identified in previous studies. If more large dams were constructed at these sites, the yield available from surface water at 1:50 year assurance could be increased to an estimated maximum of approximately 530 million m^3/a. These sites, and the results of the previous studies, which are the source of the estimate of the maximum potential yield, are discussed in Section 6.3.

The yields shown in Table 6.1.1 are those available before the ecological Reserve has been provided for. As the National Water Act (No. 36 of 1998) provides for the Reserve to take preference over other water users in the allocation of water resources, the yield available for other user sectors is less than the totals shown in Table 6.1.1. However, it has been estimated, as described in Chapter 7, that the effect of making releases for the ecological Reserve, once the details of the releases have been determined, will be to reduce the 1:50 year yield available for other users at present by only about 14 million m^3/a. If more major dams are constructed the impact of the ecological Reserve on the available yield will increase.

The base flow in rivers originates from seepage from groundwater. Therefore, where boreholes extract water from the same groundwater source, the surface water base flow is reduced by the quantity of water abstracted from the boreholes. However, in areas where the nature of the topography or the climate make it impractical to develop surface water resources on a large scale, groundwater may be the more important component of the water resources.

TABLE 6.1.1: WATER RESOURCES

CATCHMENT						SURFACE WATER RESOURCES (million m³/a)			SUSTAINABLE GROUNDWATER EXPLOITATION POTENTIAL (million m³/a)		TOTAL WATER RESOURCE (million m³/a)	
PRIMARY		SECONDARY		TERTIARY								
No.	Description	No.	Description	No.	Description	CUMU-LATIVE NATURAL MAR	1:50 YEAR DEVELOPED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD	DEVELOPED IN 1995	TOTAL POTENTIAL	1:50 YEAR DEVELOPED IN 1995	1:50 YEAR TOTAL POTENTIAL
		E1	Upper Olifants	None	---	511	214	325	3,8	88,1	217,8	328,8
		TOTAL IN UPPER OLIFANTS				**511**	**214**	**325**	**3,8**	**88,1**	**217,8**	**328,8**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	278	60	60	5	52,3	65,0	65
				E22	Upper Doring (W Cape)	40	4	80	0,0	16,6	4,0	80,0
					Upper Doring (N Cape)	319	0	0	0,0	1,2	0	0
				E23	Tankwa (W Cape)	35	5	5	0,2	18,3	5,2	18,3
					Tankwa (N Cape)	36						
				E24	Lower Doring (W Cape)	507	0	55	1,4	58,8	1,4	58,8
					Lower Doring (N Cape)	447						
			Sub-total (Western Cape)			**507**	**69**	**200**	**6,6**	**147,2**	**75,6**	**222,1**
			Sub-total (Northern Cape)			**447**						
		E4	Oorlogskloof (W Cape)	None		27	0	0	0	3,5	0	3,5
			Oorlogskloof (N Cape)	None		20	1	1	1,8	16,3	2,8	16,3
			Sub-total (Western Cape)			**27**	**0**	**0**	**0**	**3,5**	**0**	**3,5**
			Sub-total (Northern Cape)			**20**	**1**	**1**	**1,8**	**16,3**	**2,8**	**16,3**
			TOTAL IN DORING CATCHMENT IN WESTERN CAPE			534	-	-	-	-	-	-
			TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE			467	-	-	-	-	-	-
			TOTAL IN DORING CATCHMENT			**534**	**70**	**201**	**8,4**	**167,0**	**78,4**	**241,9**
		E3	Lower Olifants	E31	Kromme (All N Cape)	6	0	0	0,3	8,7	0,3	8,7
				E32	Hantams (All N Cape)	12	0	0	1,0	18,7	1,0	18,7
				E33	Lower Olifants (W Cape)	1 047	0	0	1,9	17,0	1,9	17,0
					Lower Olifants (N Cape)	1	0	0	0	0,3	0	0,3
			Sub-total (Western Cape)			**1 047**	**0**	**0**	**1,9**	**17,0**	**1,9**	**17,0**
			Sub-total (Northern Cape)			**19**	**0**	**0**	**1,3**	**27,7**	**1,3**	**27,7**
			TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE			1 047	-	-	-	-	-	-
			TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE			486	-	-	-	-	-	-
			TOTAL IN OLIFANTS CATCHMENT			**1 047**	**284**	**526**	**15,4**	**299,8**	**299,4**	**615,4**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		1	0	0	0,4	3,8	0,4	3,8
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**1**	**0**	**0**	**0,4**	**3,8**	**0,4**	**3,8**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		60	5	5	30,1	78,0	35,1	78,0
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**60**	**5**	**5**	**30,1**	**78,0**	**35,1**	**78,0**
		TOTAL IN WMA IN WESTERN CAPE				1 108	-	-	-	-	-	-
		TOTAL IN WMA IN NORTHERN CAPE				486	-	-	-	-	-	-
		TOTAL IN WMA				**1 108**	**289**	**531**	**45,9**	**381,6**	**334,9**	**697,2**

In an assessment of the extent to which the groundwater resources are additional to the surface water resources of the Olifants/Doring WMA it was concluded that, as a rough approximation, groundwater resources and surface water resources should be assumed to be linked. It has, however, also been assumed that the surface water yields determined for development in 1995 made allowance for the effects on surface water runoff of groundwater use as it was in 1995. Therefore, in Table 6.1.1, the total water resource developed in 1995 is the sum of the developed surface water and groundwater yields. The total potential water resource includes, in addition to the surface and groundwater development in 1995, all potential additional surface water resource developments that comprehensive separate detailed studies have shown to be economically viable. The development of groundwater potential that was not developed in 1995 has been added only in those areas where the groundwater potential is greater than the surface water potential. It has been assumed that in these areas both groundwater and surface water would be developed to give a combined yield equal to the total potential groundwater yield. This is based on the simplistic assumption that any further development of groundwater yield would result in an equal reduction in potential surface water yield.

The total developed water resource in 1995 was estimated to have a yield at 1:50 year assurance of 335 million m^3/a (289 million m^3/a from surface water and 46 million m^3/a from groundwater). The total potential yield at 1:50 year assurance is estimated to be 697 million m^3/a. The approximate contributions to the yields of areas of land within the Western Cape Province and the Northern Cape Province are shown in Table 6.1.1, where this is possible. In the Doring Catchment the yields cannot be easily separated because the rivers cross the provincial boundary several times. The distribution of the yield amongst the key areas is shown diagrammatically on Figure 6.1.1 and Figure 6.1.2 shows the total potential yield.

6.2 GROUNDWATER

Groundwater is an important part of the total water resources of South Africa and is included in the hydrological cycle. The information provided here gives an overview of the groundwater resources, its interaction with the base flow component of the surface water, the present groundwater use (1995), and its potential for further development.

It must be noted that this information is intended for regional strategic planning and is not suitable for local site evaluations. More detailed information on the approach and methodology can be obtained in Appendix G. All information was collated on a quaternary catchment basis.

The Groundwater Harvest Potential (Seward and Seymour, 1996) was used as the basis for the evaluation. The Harvest Potential is defined as the maximum volume of groundwater that is available for abstraction without depleting the aquifer systems, and takes into account recharge, storage and drought periods (see Figure 6.2.1).

The Harvest Potential was reduced by an exploitation factor, determined from borehole yield data, to obtain an exploitation potential, i.e. the portion of the Harvest Potential which can practically be exploited (see Table 6.2.1 and Figure 6.2.2).

The interaction of the groundwater and the surface water was assessed by evaluating the base flow component of the surface water, or more specifically the contribution of the Harvest Potential to the base flow. This contribution can be seen as water which can either be abstracted as groundwater or surface water. From this, the extent to which groundwater abstraction will reduce the base flow component of the surface water has been quantatively evaluated (see Appendix G.4). Where the contribution of groundwater to the base flow component of the surface flow is zero the impact will be negligible, where the contribution is less than 30% of the base flow the impact will be low, where the contribution is between 30% and 80% of the base flow the impact will be moderate, and where the contribution to base flow is more than 80% the impact will be high. This assessment of the interaction of groundwater and the base flow component of the surface water can however, not be used directly to determine the additional contribution of groundwater abstraction to the total utilisable water resource without also taking account of the effect of surface water storage capacity and the reduction in surface water runoff that is caused by the increase of groundwater recharge (induced recharge) that results from groundwater abstraction. The estimates of utilisable surface water given in Section 6.3 have been derived on the basis of no increased groundwater abstraction. For the purpose of this water resources assessment the proportion of the utilisable groundwater not contributing to the base flow of the surface water that can be added to the utilisable surface water to estimate the total utilisable resources has therefore been ignored, except in those areas where there was little utilisation of surface water in 1995 and there is little potential for future surface water development.

The existing groundwater use was determined by Baron and Seward (2000). Estimates of groundwater use were also made at a workshop held in the Berg WMA by the water resources situation assessment team. This provided local input to the estimates of groundwater use provided by Baron and Seward which were then adjusted accordingly to obtain the estimated groundwater use shown in Table 6.2.1 and Figure 6.2.3.

The groundwater balance compares existing groundwater use to the Harvest and Exploitation Potential to determine the extent to which the groundwater resources are utilised (see Figure 6.2.4). If the total use was greater than the Harvest Potential the groundwater in the catchment was considered to be over-utilised, if the total use was greater than the Exploitation Potential but less than the Harvest Potential the groundwater in the catchment was considered to be heavily utilised, if the total use was more than 66% of the Exploitation Potential the groundwater in the catchment was considered to be moderately utilised, and if the total use was less than 66% of the Exploitation Potential, the groundwater in the catchment was considered to be under-utilised.

In the Olifants/Doring WMA, groundwater in catchments E32B and E40A is moderately utilised, and it is under-utilised in all the other catchments. It is surprising that the analysis has shown the resource to be under-utilised in catchments G30F, G30G and G30H, where government subterranean water control areas were created because the groundwater resources appeared to be stressed. This anomaly requires clarification.

Total groundwater use in 1995 was estimated to be 46 million m^3/a, of which about 2 million m^3/a was for municipal use, 2 million m^3/a for livestock, rural domestic use, and 42 million m^3/a for irrigation. About 30 million m^3/a of the agricultural use is in the Sandveld (G30A to G30H).

In estimating the total resource, it has been assumed that mainly surface water resources will be developed in catchment E24, but that an additional 2,4 million m^3/a of groundwater yield (the amount by which the maximum groundwater potential exceeds the maximum surface water potential) could be developed to bring the combined total of surface water and groundwater yield to the value of the full groundwater potential. It has been assumed that the total groundwater exploitation potential in excess of the developed surface water yield in 1995 in catchments E23, E3, E4, F6 and G3, amounting to some 154 million m^3/a will contribute as there is little potential for the further development of surface water in these areas. It has also been assumed that the groundwater potential developed in 1995 in the other catchments will continue to contribute to the total resources. This totals 10,2 million m^3/a. Thus, the total contribution of groundwater to the total potential water resource shown in Table 6.1.1 is 166 million m^3/a.

DWAF is currently investigating the possibility of extracting water from deep boreholes in aquifers of the Table Mountain Group of geological strata in the Upper Olifants catchment. It is not known what the effects of these wellfields, if developed, would be on surface water yield. Therefore, the potential of these deep aquifers has not been included in the estimated total potential resource shown in Table 6.1.1. Similarly, because the economic feasibility of exploiting these aquifers is still being investigated, their yield is not included in the other figures and tables in this chapter, or in Appendix G.

TABLE 6.2.1: GROUNDWATER RESOURCES AT 1:50 YEAR ASSURANCE OF SUPPLY

CATCHMENT						GROUNDWATER EXPLOITATION POTENTIAL (million m^3/a)	GROUNDWATER USE IN 1995 (million m^3/a)	UNUSED GROUNDWATER EXPLOITATION POTENTIAL IN 1995 (million m^3/a)	GROUNDWATER CONTRIBUTION TO SURFACE BASE FLOW (million m^3/a)	PORTION OF GROUNDWATER EXPLOITATION POTENTIAL NOT CONTRIBUTING TO SURFACE BASE FLOW (million m^3/a)
PRIMARY		SECONDARY		TERTIARY						
No.	Description	No.	Description	No.	Description					
E	Olifants	E1	Upper Olifants	None	---	88,1	3,8	84,3	8,3	79,8
		TOTAL IN UPPER OLIFANTS (All Western Cape)				**88,1**	**3,8**	**84,3**	**8,3**	**79,8**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	52,3	5,0	47,3	7,3	45,0
				E22	Upper Doring (W Cape)	16,6	0,0	16,6	0,0	16,6
					Upper Doring (N Cape)	1,2	0,0	1,2	0,0	1,2
				E23	Tankwa (W Cape)	5,9	0,0	5,9	0,0	5,9
					Tankwa (N Cape)	12,4	0,2	12,2	0,0	12,4
				E24	Lower Doring (W Cape)	39,8	0,0	39,8	0,5	39,3
					Lower Doring (N Cape)	19,0	1,4	17,6	0,0	19,0
			Sub-total (Western Cape)			**114,6**	**5,0**	**109,6**	**7,8**	**106,8**
			Sub-total (Northern Cape)			**32,6**	**1,6**	**31,0**	**0,0**	**32,6**
		E4	Oorlogskloof (W Cape)	None		3,5	0,0	3,5	0,0	3,5
			Oorlogskloof (N Cape)	None		16,3	1,8	14,5	0,0	16,3
			Sub-total (Western Cape)			**3,5**	**0,0**	**3,5**	**0,0**	**3,5**
			Sub-total (Northern Cape)			**16,3**	**1,8**	**14,5**	**0,0**	**16,3**
			TOTAL IN DORING CATCHMENT IN WESTERN CAPE			118,1	5,0	113,1	7,8	110,3
			TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE			48,9	3,4	45,5	0,0	48,9
			TOTAL IN DORING CATCHMENT			**167,0**	**8,4**	**158,6**	**7,8**	**159,2**
		E3	Lower Olifants	E31	Kromme (All N Cape)	8,7	0,3	8,4	0,0	8,7
				E32	Hantams (All N Cape)	18,7	1,0	17,7	0,0	18,7
				E33	Lower Olifants (W Cape)	17,0	1,9	15,1	0,0	17,0
					Lower Olifants (N Cape)	0,3	0,0	0,3	0,0	0,3
			Sub-total (Western Cape)			**17,0**	**1,9**	**15,1**	**0,0**	**17,0**
			Sub-total (Northern Cape)			**27,7**	**1,3**	**26,4**	**0,0**	**27,7**
			TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE			223,2	10,7	212,5	16,1	207,1
			TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE			76,6	4,7	71,9	0,0	76,6
			TOTAL IN OLIFANTS CATCHMENT			**299,8**	**15,4**	**284,4**	**16,1**	**283,7**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		3,8	0,4	3,4	0,0	3,8
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**3,8**	**0,4**	**3,4**	**0,0**	**3,8**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		78,0	30,1	47,9	0,8	77,2
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**78,0**	**30,1**	**47,9**	**0,8**	**77,2**
TOTAL IN WMA IN WESTERN CAPE						305,0	41,2	263,8	16,9	288,1
TOTAL IN WMA IN NORTHERN CAPE						76,6	4,7	71,9	0,0	76,6
TOTAL IN WMA						381,6	**45,9**	**335,7**	**16,9**	**364,7**

6.3 SURFACE WATER RESOURCES

The basis for the analysis of surface water resources was the synthesised streamflow data at quaternary catchment level developed for the Water Research Commission funded study of the water resources of South Africa (Midgley *et al*, 1994) which is commonly referred to as WR90. Certain adjustments, as described below were made to these flow sequences. On the basis of a detailed analysis of the hydrology of the catchment of the Olifants River upstream of Bulshoek Barrage (DWAF, 1990a), the MAR values for the quaternary catchments (E10A to E10K) were amended. The result was to increase the total MAR for the catchment of the Olifants River upstream of the confluence with the Doring River to 510,8 million m^3 from the 472,2 million m^3 given in WR90.

In addition, the WR90 naturalised flows have taken account of afforestation-related streamflow reductions according to the "Van der Zel curves". Recently these curves have been seen as too simplistic, and have been superseded by the "CSIR curves". These curves allow the species, age and site conditions of the afforested area to be taken into account in estimating the streamflow reduction, and are currently the preferred estimation method.

For the purposes of the water resources situation assessment studies it was decided to adjust the WR90 quaternary naturalised flows to reflect the CSIR afforestation related streamflow reduction effects. In those parts of the country where there are large areas of afforestation, this adjustment caused significant changes in the naturalised flows for some quaternary catchments, but the effects were negligible (less than 0,1%) in the Olifants/Doring WMA because the areas of afforestation are small. In view of this, no detailed account of the method used to make the adjustments is given in this report.

Several detailed studies of the hydrology of portions of the WMA have been carried out in the past. Brief descriptions of them follow.

- The Olifants River System Analysis Phase 1 (DWAF, 1990A), carried out by BKS in 1990, produced a detailed yield analysis of the area upstream of the Bulshoek Barrage.

- The Olifants River System Analysis, Phase 2 (DWAF, 1992) carried out by Ninham Shand in association with BKS derived operating rules for Clanwilliam Dam using stochastic hydrology.

- Hydrological analysis of the Doring River (DWAF, 1994), carried out by Ninham Shand, investigated the hydrology of the Doring River.

- Olifants/Doring River Basin Study (DWAF, 1998b), carried out by BKS in association with Ninham Shand, reviewed the hydrology of the Doring River, investigated soils and irrigation potential in the Olifants/Doring catchment, and investigated surface water resources development options at a pre-feasibility study level.

The results of the basin study were used to derive most of the 1995 and total potential yields shown in Table 6.3.1. In those areas not covered by the basin study (the Sandveld (G3)), the Namaqualand coastal catchments (F6), and the Kromme (E31) and Hantams (E32) catchments), and those areas where the basin study data were not sufficiently detailed (the Kouebokkeveld (E21), the Tankwa (E23) and the Oorlogskloof (E4) catchments), the appropriate deficient flow-duration-frequency curves from WR90 were used to estimate run-of-river yield, and the storage-draft-frequency curves were used to estimate the yields of farm dams.

Run-of-river yield under 1:50 year drought conditions is likely to be available only in the upper Olifants River catchment and in the Kouebokkeveld. In all the other areas, apart from the main stem of the Olifants River, there will probably be little or no flow during the summer months. While there is likely to be water in the lower reaches of the Olifants River, it is probable that it will be too saline for normal use.

The potential maximum yield of the Olifants/Doring River system could be developed in a number of different ways. These include :

- Construction of a new dam (Grootfontein) in the upper Olifants catchment (E10C), raising of Clanwilliam Dam, and construction of a new dam on the Doring River just upstream of its confluence with the Olifants (Melkboom Dam in E24M).

- Raising of Clanwilliam Dam, construction of a new dam on the upper Doring River at Aspoort (E22G) and construction of a new dam at Melkboom (E24M) on the lower Doring River.

Both the above scenarios include the construction of additional farm dams in the upper Olifants River catchment and in the lower Doring catchment to develop any potential yield not developed by the construction of the major dams.

The total potential yield shown in Table 6.3.1 is based on the following assumptions :

- In the upper Olifants catchment :
  - the 1995 yield of 155 million m^3/a from Clanwilliam Dam and Bulshoek Barrage,
  - the 1995 yield of 59 million m^3/a from farm dams and run-of-river flow,
  - 90 million m^3/a from a new 2,5 MAR capacity dam at Grootfontein (E10C),
  - 10 million m^3/a from additional farm dams,
  - 11 million m^3/a from raising Clanwilliam Dam, giving a total yield of 325 million m^3/a.

- In the Doring catchment :
  - the 1995 yield of 60 million m^3/a from farm dams and run-of-river in the Kouebokkeveld, (E21),
  - the 1995 yield of 9 million m^3/a from farm dams in the upper Doring (E22) and the Tankwa (E23) catchments,
  - the 1995 yield of 1 million m^3/a from farm dams in the Oorlogskloof catchment (E4)
  - 76 million m^3/a from a new 2 MAR capacity dam at Aspoort (E22G),
  - 50 million m^3/a from a new 1 MAR capacity dam at Melkboom,
  - 5 million m^3/a from new farm dams in the lower Doring catchment (E24),

  giving a total yield of 201 million m^3/a.

TABLE 6.3.1: SURFACE WATER RESOURCES

CATCHMENT						CATCHMENT AREA (km²)	MEAN ANNUAL PRECIPITATION (mm/a)	MEAN ANNUAL EVAPORATION (mm/a)	NATURAL MAR		INCREMENTAL YIELD (1:50 YEAR)	
PRIMARY		SECONDARY		TERTIARY					INCREMENTAL (million m³/a)	CUMULATIVE (million m³/a)	DEVELOPED IN 1995 (million m3/a)	TOTAL POTENTIAL
No.	Description	No.	Description	No.	Description							
E	Olifants	E1	Upper Olifants	None	---	2 888	460	1 670	511	511	214	325
		TOTAL IN UPPER OLIFANTS				**2 888**	**460**	**1 670**	**511**	**511**	**214**	**325**
		E2	Doring	E21	Kouebokkeveld (All W Cape)	3 072	413	1 680	278	278	60	60
				E22	Upper Doring (W Cape)	3 884	231	1 820	40	40	4	80
					Upper Doring (N Cape)	270	173	1 730	1	319	0	0
				E23	Tankwa (W Cape)	2 302	167	1 810	9	35	5	5
					Tankwa (N Cape)	4 144	222	1 870	27	36		
				E24	Lower Doring (W Cape)	3 348	263	1 750	85	507	0	55
					Lower Doring (N Cape)	4 300	203	1 870	40	447		
			Sub-total (Western Cape)			**12 606**	**270**	**--**	**412**	**507**	**69**	**200**
			Sub-total (Northern Cape)			**8 714**	**210**	**--**	**68**	**447**		
		E4	Oorlogskloof (W Cape)	None		250	284	1 850	7	27	0	0
			Oorlogskloof (N Cape)	None		2 472	250	1 940	20	20	1	1
			Sub-total (Western Cape)			**250**	**284**	**--**	**7**	**27**	**0**	**0**
			Sub-total (Northern Cape)			**2 472**	**250**	**--**	**20**	**20**	**1**	**1**
		TOTAL IN DORING CATCHMENT IN WESTERN CAPE				12 856	271	--	412(1)	507(2)	--	--
		TOTAL IN DORING CATCHMENT IN THE NORTHERN CAPE				11 186	218	--	88(1)	467(2)	--	--
		TOTAL IN DORING CATCHMENT				**24 042**	**248**	**--**	**507**	**507**	**70**	**201**
		E3	Lower Olifants	E31	Kromme (All N Cape)	9 718	118	2 100	6	6	0	0
				E32	Hantams (All N Cape)	4 201	198	1 980	12	12	0	0
				E33	Lower Olifants (W Cape)	8 016	144	1 900	10	1 047	0	0
					Lower Olifants (N Cape)	200	130	2 000	1	1	0	0
			Sub-total (Western Cape)			**8 016**	**144**	**--**	**10**	**1 047**	**0**	**0**
			Sub-total (Northern Cape)			**14 120**	**142**	**--**	**19**	**19**	**0**	**0**
		TOTAL IN OLIFANTS CATCHMENT IN WESTERN CAPE				23 760	251	--	940(1))	1 047(2)	--	--
		TOTAL IN OLIFANTS CATCHMENT IN NORTHERN CAPE				25 306	175	--	107(1)	486(2)	--	--
		TOTAL IN OLIFANTS CATCHMENT				**49 066**	**213**	**--**	**1 047**	**1 047**	**284**	**526**
F (Part)	Namaqualand Catchments	F6	Goerap (All W Cape)	None		2 790	115	1 800	1	1	0	0
		TOTAL IN NAMAQUALAND CATCHMENTS (All Western Cape)				**2 790**	**115**	**1 800**	**1**	**1**	**0**	**0**
G (Part)	Berg (Part)	G3	Sandveld (All W Cape)	None		4 827	295	1 600	60	60	5	5
		TOTAL IN PART OF BERG CATCHMENT (All Western Cape)				**4 827**	**295**	**1 600**	**60**	**60**	**5**	**5**
TOTAL IN WMA IN WESTERN CAPE						31 377	252	--	1 001(1)	1 108	--	--
TOTAL IN WMA IN NORTHERN CAPE						25 306	175	--	107(1)	486	--	--
TOTAL IN WMA						**56** 683	**215**	**--**	**1 108**	**1 108**	**289**	**531**

(1) Runoff from catchments in the Western or Northern Cape as applicable
(2) Cumulative runoff from both the Western and Northern Cape catchments at the applicable point.

- In the Sandveld, the 1995 yield of 5 million m^3/a from farm dams, with no further significant surface water development expected.

- In the other catchments, which are all located in the arid northern part of the WMA, no existing 1:50 year yield from surface water, and none expected to be developed.

The natural MAR generated by each quaternary catchment is shown on Figure 6.3.1 and the remaining total potential surface water yield is shown diagrammatically on Figure 6.3.2 for each key area.

As an aid to estimating the total potential yield available from the catchments within a WMA where detailed studies have not been carried out, future storage dams of a particular maximum net storage capacity have been postulated. Net incremental storage capacities have been proposed for each group of quaternary catchments that falls within the same hydrological zone, as defined in WR90 (Midgley *et al*, 1994). These range from 150% of the MAR in the higher rainfall quaternary catchments (E10A to E10G) to 400% of the MAR in the drier quaternary catchments (F60A to F60E) within the WMA.

Dams that will capture and regulate all the runoff from a catchment are not economical to build. In the drier areas where the runoff is more variable the sizes of such dams also become prohibitive. A simple technique, based on past experience, has therefore been developed whereby plausible estimates of maximum feasible dam sizes have been derived for the entire South Africa and which will provide consistent results throughout the country. The water situation assessment model will, however, be enhanced in future to contain additional functionality to allow users to optimise the likely maximum storage capacity.

The technique that was adopted introduces a limit line to the net storage-gross yield relationship for a 50 year recurrence interval, as shown in Diagram 6.3.1. The net total incremental quaternary catchment storage capacity used to estimate the potential contribution to the yield by a quaternary catchment has been determined from the intersection of the net storage-gross yield relationship for a 50 year recurrence interval for a particular hydrologic zone, and the limit line shown in Diagram 6.3.1. This is illustrated by means of the typical net storage-gross yield relationships shown in Diagram 6.3.1 for rivers of low, moderate and high flow variability, which generally correspond to rivers draining high, moderate and low rainfall catchment areas respectively. The net total incremental storage capacities derived by means of this method have been rounded off to 100%, 125%, 150%, 200%, or 300% of the MAR, as appropriate.

It is of interest to compare the maximum storage capacities determined in the Olifants/Doring River Basin Study (DWAF, 1998b) for the development of the total potential economically viable surface water yield of the WMA with the theoretical maximum economical storage capacities described above.

In the Upper Olifants River catchment (E10A to E10K), the theoretical maximum storage capacity is 150% of the MAR of 511 million m^3, giving a storage volume of 766 million m^3. The estimated total potential yield of 325 million m^3/a shown in Table 6.3.1 is based on a storage capacity of 528 million m^3, or 103% of MAR. The reasons for the lower maximum economical storage capacity determined in the detailed studies are not known, but may be the physical characteristics of the available dam sites and the high value of the agricultural land that would be inundated by bigger dams.

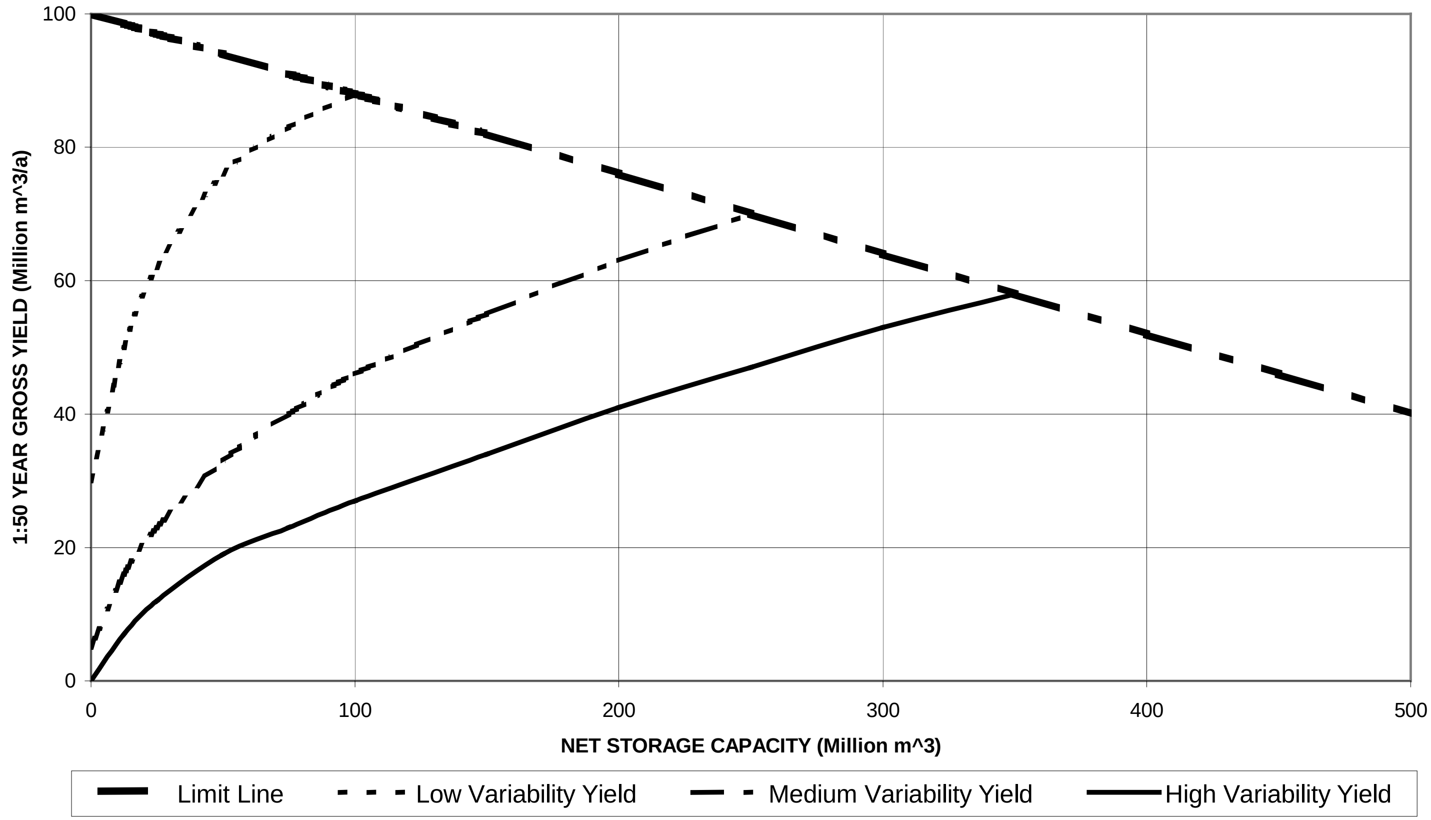

DIAGRAM 6.3.1: DAM STORAGE LIMITS

In the Doring River catchment, the theoretical maximum storage capacity is 1 244 million m^3 (245% of MAR) made up of 200% of MAR for catchments E21A to D21K, and 300% of MAR for the other catchments. The estimated potential yield of 201 million m^3/a shown in Table 6.2.1 is derived from total storage of 890 million m^3, or 175% of MAR. As in the case of the Upper Olifants catchment, the reason for the lower maximum economical storage derived in the detailed studies is not known, but it may be because of the physical characteristics of the dam sites. Another factor may be the cost of providing storage in relation to the value of the irrigated crops which the water would be used to produce.

6.4 WATER QUALITY

6.4.1 Mineralogical Surface Water Quality

The purpose of this assessment is to provide an indication of where water quality problems can be expected rather than provide a comprehensive overview of water quality in the Water Management Area.

The mineralogical water quality of the surface water bodies is described in terms of total dissolved salts (TDS). Data for the assessment were obtained from the water quality database of the Department of Water Affairs and Forestry.

The surface water quality monitoring stations that were used to provide the data are shown on Figure 6.4.1.1. Water quality is poorly monitored in the Olifants/Doring WMA, although the Olifants River sub-catchment (E1) has a fair distribution of monitoring points. There are 7 monitoring points on the Olifants River, the most upstream one situated at Citrusdal (E1H013Q01). The Clanwilliam Dam (E1R002) and Bulshoek Dam (E1R001) each have an in-lake monitoring point and one downstream of the dam. The best-monitored sampling point is the Jan Dissels River at Clanwilliam where 304 samples have been collected since 1978. In the Doring River Basin (E2 and E4) there are 8 routine water quality monitoring stations of the which the most downstream monitoring point, E2H003Q01 – Doring River at Melkboom, has the best data record. The E3 catchment is very poorly sampled. There are only two monitoring points where 3 and 7 samples have been collected since the late 1980s. The E4 catchment has only one monitoring point situated at Karee Dam (E4R001Q01) where a moderate data record exists. As this station is situated in the upper reaches of the catchment, it is not necessarily representative of the catchment as a whole, and the data are insufficient to assess the water quality of even the upper reaches. There are no routine DWAF river/stream monitoring points in the F6 catchment. The G3 catchment has six routine monitoring points. A fair data record exists at the Kruis River at Tweekuilen/Eendekuil (G3H001Q01), situated in the upper reaches of the catchment. The other points were sampled on an ad hoc basis and the data record at Papkuilsvlei (G3H005Q01) stopped in 1990.

Only data sets that had data for the last five years (1994-1998) were used. The data sets were filtered to monthly data, and where possible various techniques were used to fill in missing values. The assessment method calls for the consultants to use only those data sets that spanned at least two years and contained at least 24 data points for analysis. These should be used to derive the mean and maximum TDS concentrations. Due to the poor status of water quality monitoring in the WMA, the whole 5 year data set of monthly TDS values was used in some cases to characterise the water quality because there were no monitoring points which fully met the criteria.

Details of the TDS and electrical conductivity (EC) for the various catchments are given in Appendix G.

The water quality is described in terms of a classification system developed for this water resources situation assessment. The uses that were taken into account were domestic use and irrigation. It was assumed that if the water quality met the requirements for domestic and irrigation use it would in most cases satisfy the requirements for other uses. The South African Water Quality Guidelines of the Department of Water Affairs and Forestry (1998f) for these two uses were combined into a single classification system as shown in Table 6.4.1.1.

TABLE 6.4.1.1: CLASSIFICATION SYSTEM FOR MINERALOGICAL WATER QUALITY

CLASS	COLOUR CODE	DESCRIPTION	TDS RANGE (mg/ℓ)
0	Blue	Ideal water quality	<260
1	Green	Good water quality	260 - 600
2	Yellow	Marginal water quality	601 - 1800
3	Red	Poor water quality	1801 - 3400
4	Purple	Completely unacceptable water quality	>3400

Where water quality data were available, water quality was assessed at a quaternary catchment level of resolution. The final classification of the mineralogical surface water quality of a quaternary catchment was based on both average conditions and extreme conditions. Where sufficient data was available the data set was inspected for the worst two-year period. The average concentration and the maximum were used to determine the class of the water as shown in Table 6.4.1.2.

TABLE 6.4.1.2: OVERALL CLASSIFICATION

AVERAGE CONCENTRATION CLASS	MAXIMUM CONCENTRATION CLASS	OVERALL CLASSIFICATION
Blue	Blue Green Yellow Red Purple	Blue Green Green Yellow Red
Green	Green Yellow Red Purple	Green Yellow Yellow Red
Yellow	Yellow Red Purple	Yellow Red Purple
Red	Red Purple	Red Purple
Purple	Purple	Purple

The water quality of the Olifants/Doring Water Management Area is summarised in Table 6.4.1.3 and is shown in Figure 6.4.1.1.

TABLE 6.4.1.3: SUMMARY OF MINERALOGICAL SURFACE WATER QUALITY OF THE OLIFANTS/DORING WATER MANAGEMENT AREA

SECONDARY CATCHMENT	NO. OF QUATERNARY CATCHMENTS	NO. OF QUATERNARY CATCHMENTS IN CLASS					
		BLUE	GREEN	YELLOW	RED	PURPLE	NO DATA
E10	10	10	0	0	0	0	0
E20	40	11	1	0	0	0	28
E30	21	0	0	0	0	0	21
E40	4	0	0	0	0	0	4
F60	5	0	0	0	0	0	5
G30	8	0	0	0	0	2	6

The mineralogical surface water quality of the Olifants/Doring Water Management Area is quite variable. Water quality in the Clanwilliam Dam area of interest (Olifants River (E10)) is ideal and suitable for all uses. There is a slight increase in concentration in a downstream direction. Previous studies (DWAF, 1998d) found that there was a difference between unimpacted catchments and the main stem Olifants River that was impacted by agricultural activities. Unimpacted catchments, like the Jan Dissels River, showed no trend over time although a seasonal trend was evident in the data. The seasonal trend indicated elevated TDS concentrations at the end of summer (March/April) and decreased concentrations at the end of winter (July – October). It was found that TDS concentrations in the main stem Olifants River were higher but still ideal for agricultural and domestic purposes (DWAF, 1998d). No trend over time was evident but there were strong seasonal variations with higher concentrations early in winter (April – July), probably originated from the wash-off of salts from the catchment, and reduced concentrations at the end of winter (August – November). In the Olifants River downstream of Clanwilliam Dam and upstream of the Doring River confluence the water quality remained ideally suitable for agriculture and domestic water supplies.

Water quality in the Kouebokkeveld area of interest (E21), was ideally suited for all uses. A trend of increasing TDS over time was observed in the Leeu River (DWAF, 1998d) even though the quality was still ideally suited. Marked seasonal differences were also found with higher concentrations in summer than in winter (DWAF, 1998d).

The quality of water in the upper Doring area of interest (E22) is ideally suited for agriculture and domestic water supplies. However, TDS concentrations in the Kruis River at Ebenezer are very high and variable and the water quality has been classified as marginal to poor (yellow to red) (DWAF, 1998d).

Water quality in the Lower Doring area of interest (E24) is marginal and TDS concentrations increase in a downstream direction. In the lower reaches the water quality varies between good (green) at the end of winter and marginal (yellow) at the end of summer, probably as a result of irrigation agriculture in the catchment. The water quality is still suitable for all uses but does indicate a deterioration. The status changes from ideal in the upper reaches to good in the lower reaches.

There was insufficient data to assess the water quality status in the Oudekraal (E23), Oorlogskloof (E40), Kromme (E31), Hantams (E32), Lower Olifants (E33) and Namaqualand (F60) key areas.

In the Sandveld (G30) area water quality is poor to completely unacceptable in the Kruis River catchment (upper reaches of the Verlorenvlei River). It improves slightly in a downstream direction but the lack of data precludes any concrete conclusions about water quality in the Verlorenvlei River and in Verlorenvlei. The cause of the poor water quality is the result of agricultural activities on the Malmesbury shales which are high in salts and cover a large part of the Kruis River catchment (Sinclair *et al.*, 1986).

6.4.2 Mineralogical Groundwater Quality

The groundwater quality is one of the main factors affecting the development of available groundwater resources. Although there are numerous problems associated with water quality, some of which are easily corrected, total dissolved solids (TDS), nitrates (NO_3 as N) and fluorides (F) are thought to represent the majority of serious water quality problems that occur.

The water quality has been evaluated in terms of TDS and potability. The information was obtained from WRC Project K5/841 (Simonic, 2000). The mean TDS together with the highest value, lowest value and range is given for each catchment where analyses were available. Where no analyses were available an estimate of the mean was made using Vegter's maps (Vegter, 1995). The potability evaluation done by Simonic (2000) was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume I (DWAF, 1998f).

The portion of the groundwater resources considered to be potable has been calculated as that portion classified as ideal, good and marginal (Class 0, 1 and 2) according to the classification system given in Section 6.4.1. Water classified as poor and unacceptable (Class 3 and 4) has been considered to be **not** potable.

In catchments where no information was available, estimates of the portion of potable groundwater were made using Vegter's maps (Vegter, 1995).

Figure 6.4.2.1 gives an evaluation of the mean TDS per quaternary catchment and Figure 6.4.2.2 gives an estimate of the percentage of potable groundwater per quaternary catchment.

6.4.3 Microbiological Water Quality

Background

A method was developed and applied to assess the risk of microbial contamination of surface water and groundwater resources in South Africa. (Refer to Appendix G2 for details of the study). Maps depicting the potential vulnerability of surface water and groundwater to microbial contamination were produced at a quaternary catchment resolution. The maps provide a comparative rating of the risk of faecal contamination of the surface water and groundwater resources. The microbial information that has been provided is, however, intended for planning purposes only and is not suitable for detailed water quality assessments.

Mapping microbial contamination of surface water resources

As part of the National Microbiological Monitoring Programme a screening method was developed to identify the risk of faecal contamination in various catchments. This screening method uses a simple rule based weighting system to indicate the relative faecal contamination from different land use areas. It has been confirmed that the highest faecal contamination rate is derived from high population densities with poor sanitation services. The Programme produced a map, at quaternary catchment resolution, showing the potential faecal contamination in the selected catchments. Unfortunately, the map did not cover the entire country.

As part of this study, the same screening method was applied to produce a potential surface faecal contamination map for the whole of South Africa using national databases for population density and degree of sanitation. The portion applicable to the Olifants/Doring WMA is given in Figure 6.4.3.1. The map shows that there were few areas where there were sufficient data to assess the potential for faecal contamination of surface water (Figure 6.4.3.1). A low risk of contamination was estimated for the lower reaches of the Oorlogskloof River and the Olifants River as well as the upper reaches of the Doring River and the Olifants River.

Mapping aquifer vulnerability of groundwater resources

Certain aquifers are more vulnerable to contamination than others. The DRASTIC method used in this study is an acknowledged method for assessing aquifer vulnerability to contamination. The method is a weighting and rating technique that considers up to seven geologically and geohydrologically based factors to estimate groundwater vulnerability. The magnitudes or severities of pollution sources are, however, not considered. Three of the above factors were used in this study to estimate the vulnerability of groundwater to microbial contamination.

Because of attenuation mechanisms that control microbial contamination entering the subsurface, it was considered conceptually correct to only consider groundwater depth, soil media and impact of the vadose zone media. Comparison of the different maps showed remarkable similarity and confirmed that the vulnerability is largely controlled by the selected three parameters. This similarity promotes confidence in the resultant microbial contamination vulnerability map.

A GIS model, which considered the three factors, was developed and a vulnerability rating of low, medium and high was calculated for each grid element in the GIS coverage. A numerical control was included to account for deep groundwater below 35 metres. At this depth it was assumed that the surface contamination rate would be low, irrespective of the other two factors.

Mapping microbial contamination of groundwater sources

The potential surface faecal contamination and aquifer vulnerability maps were then intersected to derive a potential groundwater faecal contamination map for South Africa at a quaternary scale. The portion applicable to the Olifants/Doring WMA is given in Figure 6.4.3.2. This map shows the degree of potential surface faecal contamination using a rating scale which ranges from low to medium to high. It shows that there is a low risk of surface faecal contamination throughout the WMA.

With regard to groundwater, it was found that high risk areas occur along the coastal aquifers of G30A,E and F and that there is a medium risk of contamination in the upper reaches of the Tankwa River, Groot River and Olifants River. A medium risk of groundwater contamination was also estimated for areas of the Namaqualand coastal catchments.

Conclusions and recommendations

A limitation of the study was the inability to validate results due to the limited information on groundwater contamination resulting from human wastes.

Once sufficient microbial data becomes available, the numerical methods and associated assumptions should be validated and the maps replotted. Monitoring data from selected areas should also be collected to assess the validity of the vulnerability assessment presented in this report.

6.4.4 Water Quality Issues

Other water quality variables was also examined in DWAF (1998c) and it was concluded for the Olifants River that :

- The source water of the Olifants River had elevated TDS and nitrogen concentrations, probably as a result of agricultural activities in the upper catchment which have an impact on the river, especially during the summer months.
- Physical and chemical characteristics of the Olifants River gorge and the mountain river reaches largely resemble natural conditions in unimpacted streams of the Western Cape. Water quality is ideal until the valley widens at Citrusdal.
- The middle reaches of the river are impacted by agricultural activities which lead to elevated levels of dissolved and suspended solids, and nutrients, in particular nitrate. The effect of poorer water quality is exacerbated during the summer months.
- In the area of Clanwilliam Dam and Bulshoek weir, variable degrees of impacts were observed and strong seasonal patterns were observed.
- Downstream of the confluence of the Doring and Hols Rivers, the concentrations of TDS, TSS, anions, cations and alkalinity increased dramatically. This was ascribed to the introduction of more saline Doring River water coupled with additional saline irrigation return flows. A marginal decrease in nutrient concentrations was observed suggesting that nutrient enrichment in this reach was marginal.

For the Doring River it was concluded that (DWAF, 1998c) :

- The Doring River is influenced by two distinct water chemistry systems, the one originating in the Karoo, and the other in the Cederberg Mountains. The differences in these two systems are largely the result of geological characteristics of their catchments although landuse affects it to some degree.
- Rivers flowing into the Doring River from the Karoo region tend to have higher salinities, higher pH and elevated levels of nutrients and total suspended solids (mostly clay particles).
- Rivers flowing off the southern Cederberg have low nutrient levels and lower TDS concentrations. These rivers are similar to "fynbos" rivers of the western Cape.
- The combined affect of the two systems result in elevated salinities during periods of high flow from the Karoo rivers. When the Karoo rivers stop flowing, continued discharge from the Cederberg tributaries continue to dilute Doring River water, resulting in lower salinity levels. Towards the end of summer, salinities tend to increase again as the Doring River starts to dry out.

6.5 SEDIMENTATION

The relationship between the flow in a river and the quantity of sediment that it carries is not constant but varies with the availability of sediment in the catchment of the river. This, in turn, varies with factors such as the condition of natural vegetation, the area of land cultivated and type of crops grown, and the extent of human settlements. Nevertheless, the analysis of measurements taken by DWAF, over many years, of silt accumulation in existing reservoirs countrywide, has made it possible to calculate average sediment yields for the catchments of these reservoirs. The results of analysis of data for reservoirs in the Olifants/Doring WMA is shown in Table 6.5.1. Data is available for only two reservoirs in the WMA, but it can be seen that the yields vary considerably. The much lower sediment yield recorded for Bulshoek relative to that recorded for Clanwilliam Dam can probably be attributed to the rocky mountainous terrain that comprises most of the catchment area between the two dams. The catchment upstream of Clanwilliam Dam, even though mountainous, has a much wider valley floor which is intensively cultivated and, as a result, can be expected to produce a higher sediment yield. Differences in the accuracies of the basin surveys carried out to determine the extent of sediment deposits may also have distorted the results.

TABLE 6.5.1: RECORDED RESERVOIR SEDIMENATION RATES FOR RESERVOIRS IN THE OLIFANTS/DORING WMA

QUATERNARY CATCHMENT NO.	RIVER	DAM NAME	ECA (km^2)	PERIOD	V_T (million m^3)	V_{50} (million m^3)	SEDIMENT YIELD ($t/km^2.a$)
E10G	Olifants	Clanwilliam	2 033	1935-1980	9,715	10,117	134
E10K	Olifants	Bulshoek	736	1922-1980	0,486	0,46	17

ECA = Total catchment area - catchment area of next major dam upstream
V_T = Sediment volume at end of period
V_{50} = Estimated sediment volume after fifty years at the same average yield.

Using the available data of this type on sediment accumulation in reservoirs and additional data on sediment loads in rivers, Rooseboom, *et al* in 1992 prepared a mean sediment yield map of South Africa. From this map and associated soil erodibility maps, an estimate of the average sediment yield from any desired area can be made. The Water Research Commission publication, *Surface Water Resources of South Africa, 1990 (WR90)*, presents estimates of the mean sediment yield for quaternary sub-catchments calculated from the sediment yield and soil erodibility maps. Mean values of sediment yield in the Olifants/Doring WMA, calculated from the WR90 estimates range from a low of 6 $t/km^2.a$ in the south-western corner of the WMA to 35 $t/km^2.a$ in the north-eastern interior. Rooseboom also carried out statistical analyses of the recorded sediment yield data to obtain an indication of the confidence with which the sediment yield could be estimated for the various regions of South Africa. From these analyses he derived sets of curves which give multiples by which the estimated mean sediment yields should be multiplied to change the confidence level from the 50% confidence level of the mean yields. However, the data presented in this report is at the 50% confidence level.

Values of sediment yield in tonnes per year, and the 25 year sediment volume, expressed in million m^3 and adjusted to allow for consolidation of the sediment, are presented for each quaternary catchment in Appendix G. On Figure 6.5.1, the 25 year sediment volume is shown as a percentage of the naturalised incremental MAR for each quaternary catchment.

The information has been produced in this form for use in predicting the probable effects of sediment on the yields of dams in the WMA.

Research has shown that reservoirs with storage capacities in excess of 10% of the mean annual runoff will retain at least 70% of incoming sediments. It is only where reservoirs have storage capacities of very much less than 10% of mean annual runoff that it becomes possible to pass most of the incoming sediments through by designing the reservoirs so that high flow velocities are maintained through them during floods. Even so, a great deal of doubt exists regarding the accuracy with which the effective losses in the storage capacities of small reservoirs can be predicted. Only where adequate discharge facilities are provided and proper operational procedures are followed is it possible to ensure that a small reservoir will not lose virtually all its storage capacity, permanently or intermittently. Therefore, unless conditions for scouring are particularly favourable, it is not advisable to construct small storage dams on big rivers that carry high sediment loads. Where large dams are constructed, it is necessary to provide sufficient additional storage to accommodate the volume of sediment expected to accumulate during the economic life of the dam. Depending upon the characteristics of the dam site, it may be necessary either to construct the dam initially to provide the full volume of additional storage required to accommodate sediment, or to design the dam to be raised at a later stage if the accumulation of sediment begins to reduce the yield of the dam significantly.

CHAPTER 7: WATER BALANCE

7.1 METHODOLOGY

7.1.1 Water Situation Assessment Model

The Water Situation Assessment Model (WSAM) was developed with the purpose of providing a reconnaissance level decision support tool. The model is intended to provide a broad overview of the water situation in South Africa taking into account all significant water uses and resources. The model can produce output at a variable resolution, down to quaternary catchment scale.

The data input to the model was gathered by various organisations and individuals, but the Water Resources Situation Assessments (WRSA) were the main vehicle for providing data for the model. Appendix H lists the organisations responsible for the various components of the data. This list also gives the reader a good indication of the type of data in the database.

The intention was to use the WSAM to determine the water balance for the WRSA reports and also to use the WSAM reporting tools to produce as many of the tables in the WRSA reports as was practical. However, due to various unresolved developmental problems with the WSAM, another approach was adopted, as described in this section. For this reason, the WSAM is not described in any detail in this report. The reader is referred to the WSAM user manual for more information on this model.

7.1.2 Estimating the Water Balance

The water balance is simply the difference between the yield obtainable from the water resources and the sum of all the water requirements and losses. While the water requirements and losses are easily abstracted from the database, to estimate the water resource in complex systems directly from the known yields of dams would be difficult and impractical. The main reason for this is that the run-of-river component of the resource is difficult to determine without some form of modelling, especially where there are multiple dams and abstractions and the different modes of operation of the dams influence the yields.

The water balance produced by the WSAM is not yet correct in all cases due to the following unresolved problems :

- The ecological Reserve has spurious impacts on the water balance, which do not appear to be correct;
- The impacts of afforestation and alien vegetation, as reported on the balance do not appear to be correct;
- It is not possible to model actual known river losses; and
- Return flows from irrigation are not modelled correctly.

The approach taken to determine the water balance was therefore to remove the above questionable components out of the WSAM modelling procedure. This is done relatively easily. The above impacts (ecological Reserve, etc.) were then determined externally to the model and added or subtracted from the WSAM water balance as appropriate. This procedure achieved a resultant water balance that seemed to be in reasonable agreement with other estimates in most cases. However, in the case of the Olifants/Doring WMA, WSAM did not appear to determine the run-of-river yield or the yield from farm dams reliably. Therefore, these were determined external to the model, but making use of the database in the model.

7.1.3 Estimating the Water Requirements

The water requirements determined by the WSAM are mostly accepted to be correct. In order to facilitate the production of the WRSA reports, this data was abstracted from the WSAM into a spreadsheet and various worksheets set up, which reference this abstracted data. These worksheets were structured so as to present most of the information contained in the tables of this report. This is not only limited to water requirements but also lists land uses such as irrigated areas, afforested areas, etc.

The data was abstracted in two different formats: at key area resolution (incremental between key points) and at quaternary catchment resolution. The key area data has been aggregated by the WSAM except for a few parameters relating mainly to irrigation, which the WSAM did not aggregate correctly. In these cases, default values were used. A list of these parameters and the default values is attached as Appendix H. The data at quaternary catchment resolution was abstracted for information purposes only. It is attached in the Appendixes to this report.

Water requirements or gains that the WSAM could not calculate were determined as follows :

Ecological Reserve

The impact of the ecological Reserve on the yield of a catchment depends on the storage in that catchment. It was accepted that the water required for the ecological Reserve follows the same general pattern of (i.e. mimics) the natural flow and that the storage/yield characteristics of the natural catchment could therefore also be used to estimate the yield of the catchment after allowing for the water requirements of the ecological Reserve. The estimates of the impact on the yield of a catchment were made separately for each of the incremental catchments between key points. The total storage within the incremental catchment was transposed to its outlet and formed the basis for determining the incremental yield of the catchment under natural conditions, both with and without provision for the ecological Reserve. The yields were estimated from the storage yield characteristics used in the WSAM for any particular recurrence interval of concern. The incremental impact of the ecological Reserve on the water resources of a particular key area was taken to be the difference between the impact at the downstream key point less the impact at the upstream key point.

The impact of the ecological Reserve on the run-of-river yield was accepted to be the annual equivalent of the lowest 4-month water requirement for the ecological Reserve. This value was used to establish the incremental impact of the ecological Reserve on the yield at a key point at which there was no significant storage in the incremental catchment.

Using the above method, negative impacts are sometimes possible. The reason for this is that the water required for the ecological Reserve at an upstream point may become available for use further downstream, if the ecological Reserve is less at the downstream point.

In the case of the Olifants/Doring WMA, the majority of the rivers are naturally dry during the summer months during droughts. Therefore, with the exceptions of the upper and lower Olifants River, and the upper Doring River, the ecological Reserve has no impact on run-of-river yields.

Water losses

The WSAM models losses as a function of the flow in the river. The water loss under natural flow conditions is used in the WSAM to calculate the water loss under the altered flow conditions. While this is conceptually correct, it is found to be very difficult to model the known loss under current conditions. For this reason, the WSAM was run with zero losses and the known losses taken into account external to the model when determining the water balance.

Irrigation return flows

The average return flow from irrigation in South Africa according to the WSAM is in the order of 3%. This is clearly erroneous and not in accordance with the 10% to 15% default agreed upon at various workshops. Irrigation return flows were therefore calculated external to the model and were usually assumed to be 10%. Where the consultant and/or other persons had more detailed information of the return flows that could be expected these were adopted instead.

7.1.4 Estimating the Water Resources

The WSAM does not report directly on the available water resource, as required for this WRSA report. This was therefore calculated external to the model as described in Section 6.2 for groundwater and Section 6.3 for surface water.

7.2 OVERVIEW

For purposes of considering the water balance situation within the WMA, the outlets of the key areas defined in Table 2.1.1 in Section 2.1, and used in most of the tables in this report, were used, and referred to as key points. For key areas comprising two or more separate rivers flowing into the sea, the water balances at the river mouths were combined to obtain a composite value for a hypothetical key point for the key area. The key points are shown on Table 7.2.1.

In Table 7.2.2 the average water requirements at the key points are shown.

It can be seen from Table 7.2.2 that the total water requirement in the WMA in 1995 is estimated to have been 589 million m^3/a. This value includes the provision of 127 million m^3/a for the ecological Reserve. A requirement of 528 million m^3/a, or 90% of the total requirements occur in the catchment of the Olifants River.

Within the Olifants catchment, 36% of the requirements are in the upper Olifants valley (upstream of the confluence with the Doring), 30% are in the catchment of the Doring River tributary, and the remaining 44% are in the lower Olifants catchment. As the requirements in the catchments of the tributaries that join the lower Olifants from the north are very small, it is apparent that the requirements in the lower Olifants are concentrated along the main stem of the river.

TABLE 7.2.1: KEY POINTS FOR YIELD DETERMINATION

LOCATION OF KEY POINT			DESCRIPTION
PRIMARY CATCHMENT		QUATERNARY CATCHMENT	
NO.	NAME		
E	Upper Olifants River	E10K	Upper Olifants River at its confluence with the Doring River
	Groot River	E21L	Outlet of the Kouebokkeveld area on the Groot River at its confluence with the Doring River.
	Upper Doring River	E22G	The Doring River at its confluence with the Tankwa River (site of proposed Aspoort Dam)
	Tankwa River	E23K	Tankwa River at its confluence with the Doring River
	Oorlogskloof River	E40D	Oorlogskloof River at its confluence with the Doring River
	Doring River	E24M	Doring River at its confluence with the Olifants River
	Kromme River	E31H	Kromme River at its confluence with the Hantams River
	Hantams River	E32E	Hantams River at its confluence with the Kromme River
	Olifants River	E33H	Mouth of the Olifants River
F	Namaqualand Coastal Catchments	F60A, D, E	The combined outlets of the coastal catchments north of the Olifants Estuary
G	The Sandveld	G30A, E, F, G, H	The combined outlets of the catchments of the Sandveld

As the water balance has been calculated on the basis of the 1:50 year yield of the water resources, it is necessary to consider the equivalent water requirements at 1:50 year assurance. These are shown in Table 7.2.3, where it can be seen that the total equivalent water requirements have reduced by 35% from 589 million m^3/a to 385 million m^3/a.

The main reduction is in the requirements of the ecological Reserve, where the impact of the Reserve requirements on the 1:50 year yield is shown rather than the total quantity of water that should be allowed to flow to the sea under average conditions. Because most of the rivers are likely to be dry during the summer under severe drought conditions, there is no 1:50 year run-of-river yield in most areas, and hence the ecological Reserve has no impact on run-of-river yield in the areas. Flow in those areas where there is likely to be run-of-river yield is regulated by dams. Consequently, the impact of the reserve is on the yields of these dams, namely Clanwilliam Dam (a reduction of 12,3 million m^3/a) and Oudebaaskraal Dam (a reduction of 2,0 million m^3/a).

The water requirements of afforestation and alien vegetation are also shown in Table 7.2.3 as impacts on yield, which are also less than the water use shown in Table 7.2.2.

The other significant reduction in water requirements is in irrigation where the equivalent water requirements at 1:50 year assurance are about 20% less than the average requirements.

TABLE 7.2.2: AVERAGE WATER REQUIREMENTS IN 1995

CATCHMENT						STREAMFLOW REDUCTION ACTIVITIES		WATER USE		WATER REQUIREMENT						ECO-LOGICAL RESERVE (million m³/a)	TOTAL (million m³/a)
PRIMARY		SECONDARY		TERTIARY		AFFORE-STATION (million m³/a)	DRYLAND SUGAR CANE (million m³/a)	ALIEN VEGE-TATION (million m³/a)	RIVER LOSSES (million m³/a)	BULK (1) (million m³/a)	IRRI-GATION (2) (million m³/a)	RURAL (3) (million m³/a)	URBAN (4) (million m³/a)	HYDRO-POWER (5) (million m³/a)	WATER TRANS-FERS OUT OF WMA (million m³/a)		
No.	Description	No.	Description	No.	Description												
E	Olifants	E1	Upper Olifants	None	---	1,3	0	0,85	0	0	126,3	0,74	1,76	(75)	0	81,2	212,15
		TOTAL IN UPPER OLIFANTS				1,3	0	0,85	0	0	126,3	0,74	1,76	(75)	0	81,2	212,15
		E2	Doring	E21	Kouebokkeveld	0,2	0	0,25	0	0	76,8	0,71	0	0	0	29,2	107,16
				E22	Upper Doring	0	0	0	0	0	1,8	0,32	0	0	0	33,5	35,62
				E23	Tankwa	0	0	0	0	0	1,6	0,27	0	0	0	3,7	5,57
				E24	Lower Doring	0	0	0,04	0	0	7,7	0,42	0	0	0	86,2	94,36
			Sub-total			0,2	0	0,29	0	0	87,9	1,72	0	0	0	86,2	176,31
		E4	Oorlogskloof	None		0	0	0,04	0	0	3,6	0,07	0,66	0	0	2,8	7,17
		TOTAL IN DORING CATCHMENT				0,2	0	0,33	0	0	91,5	1,79	0,66	0	0	86,2	180,68
		E3	Lower Olifants	E31	Kromme	0	0	0,01	0	0	0	0,05	0,16	0	0	0,6	0,82
				E32	Hantams	0	0	0	0	0	1	0,09	0	0	0	1,2	2,29
				E33	Lower Olifants	0	0	0,17	0	2,7	176,4	2,12	2,96	0	0	118,8	303,15
			Sub-total			0	0	0,18	0	2,7	177,4	2,26	3,12	0	0	118,8	304,46
		TOTAL IN OLIFANTS CATCHMENT				1,5	0	1,36	0	2,7	395,2	4,79	5,54	(75)	0	118,8	529,89
F (Part)	Namaqualand Catchments	F6	Goerap	None		0	0	0,17	0	1,5	0	0,17	0,18	0	0	0,1	2,12
G (Part)	Berg (Part)	G3	Sandveld	None		0	0	1,90	0	0	45,0	1,35	1,00	0	0	8,0	57,25
TOTAL IN WMA						1,5	0	3,43	0	4,2	440,2	6,31	6,72	(75)	0	126,9	589,26

(1) Requirements of wet industries, mines, and any other bulk users supplied individually by a water board or DWAF.
(2) Includes conveyance and distribution losses.
(3) Requirements for rural household use, livestock and game watering, and subsistence irrigation, including losses.
(4) Requirements for urban residential, commercial, municipal and institutional use, and requirements of industries supplied by local authorities, all including water losses.
(5) Hydropower is a secondary use and therefore is not included in totals.

TABLE 7.2.3: WATER REQUIREMENTS IN 1995 AT 1:50 YEAR ASSURANCE

CATCHMENT						STREAMFLOW REDUCTION ACTIVITIES (million m^3/a)		WATER USE (million m^3/a)		WATER REQUIREMENT						ECOLOGICAL RESERVE (million m^3/a)	TOTAL (million m^3/a)
PRIMARY		SECONDARY		TERTIARY		AFFORE-STATION (million m^3/a)	DRYLAND SUGAR CANE (million m^3/a)	ALIEN VEGE-TATION (million m^3/a)	RIVER LOSSES (million m^3/a)	BULK[(1)] (million m^3/a)	IRRI-GATION[(2)] (million m^3/a)	RURAL[(3)] (million m^3/a)	URBAN[(4)] (million m^3/a)	HYDRO-POWER (million m^3/a)	WATER TRANSFERS OUT OF WMA (million m^3/a)		
No.	Description	No.	Description	No.	Description												
E	Olifants	E1	Upper Olifants	None	---	0,7	0	0,5	0	0	110	0,74	1,76	(75)	0	12,3	126,00
		TOTAL IN UPPER OLIFANTS				**0,7**	**0**	**0,5**	**0**	**0**	**110**	**0,74**	**1,76**	**(75)**	**0**	**12,3**	**126,00**
		E2	Doring	E21	Kouebokkeveld	0,1	0	0,1	0	0	65,2	0,71	0	0	0	0	66,11
				E22	Upper Doring	0	0	0	0	0	1,5	0,32	0	0	0	0	1,82
				E23	Tankwa	0	0	0	0	0	1,3	0,27	0	0	0	2,0	3,57
				E24	Lower Doring	0	0	0	0	0	6,3	0,42	0	0	0	0	6,72
			Sub-total			**0,1**	**0**	**0,1**	**0**	**0**	**74,3**	**1,72**	**0**	**0**	**0**	**2,0**	**78,22**
		E4	Oorlogskloof	None		0	0	0	0	0	2,9	0,07	0,66	0	0	0	3,63
		TOTAL IN DORING CATCHMENT				**0,1**	**0**	**0,1**	**0**	**0**	**77,2**	**1,79**	**0,66**	**0**	**0**	**2,0**	**81,85**
		E3	Lower Olifants	E31	Kromme	0	0	0	0	0	0	0,05	0,16	0	0	0	0,21
				E32	Hantams	0	0	0	0	0	0,9	0,09	0	0	0	0	0,99
				E33	Sout	0	0	0	0	2,7	130	2,12	2,96	0	0	0	137,78
			Sub-total			0	0	0	0	2,7	130,9	2,26	3,12	0	0	0	138,98
		TOTAL IN OLIFANTS CATCHMENT				**0,8**	**0**	**0,6**	**0**	**2,7**	**318,1**	**4,79**	**5,54**	**(75)**	**0**	**14,3**	**346,83**
F (Part)	Namaqualand Catchments	F6	Goerap	None		0	0	0	0	1,5	0	0,17	0,18	0	0	0	1,85
G (Part)	Berg (Part)	G3	Sandveld	None		0	0	0,3	0	0	34,0	1,35	1,00	0	0	0	36,65
		TOTAL IN WMA				**0,8**	**0**	**0,9**	**0**	**3,0**	**352,1**	**6,31**	**6,72**	**(75)**	**0**	**14,3**	**385,33**

(1) Requirements of wet industries, mines, thermal powerstations and any other bulk users supplied individually by a water board or DWAF.
(2) Includes conveyance and distribution losses.
(3) Requirements for rural household use, livestock and game watering, and subsistence irrigation, including losses.
(4) Requirements for urban residential, commercial, municipal and institutional use, and requirements of industries supplied by local authorities, all including water losses.
(5) Hydropower is a secondary use and therefore is not included in totals.

The equivalent 1:50 year water requirements in 1995 are compared in Table 7.2.4 with the 1:50 year developed yield in 1995. It can be seen that, for the WMA as a whole, the requirements exceed the yield plus imports and re-usable return flows by approximately 40 million m^3/a.

The main shortages of water occurs in the upper Olifants River catchment where the table indicates a shortfall of 29 million m^3/a, and in the lower Olifants where the shortfall is 11 million m^3/a. There is also a shortfall of nearly 5 million m^3/a in the lower Doring catchment, which is 70% of the requirements in that catchment, and there are small shortfalls indicated in the Oorlogskloof catchment and the Sandveld.

The other areas are either balanced, or show slight surpluses. The surpluses in the upper Doring and Tankwa River areas, although fairly small in quantity, are large relative to the estimated water requirements in those areas. This may indicate that surface water yields have been over-estimated, or that the irrigation water use has been underestimated.

In the Tankwa River catchment, the available 1:50 year yield of 5,2 million m^3/a is only slightly less than the average water requirements of 5,57 million m^3/a shown in Table 7.2.2.

In the upper Doring River catchment a quantity of 2,5 million m^3/a of water is imported from the Breede WMA via the Inverdorn Canal. The water is used for irrigation, and it has been assumed that the equivalent quantity at 1:50 year assurance is 1,5 million m^3/a. Even with this assumption, Table 7.2.4 shows a surplus yield of more than twice the estimated average water requirements. Even though the excess is small in the context of the water requirements of the whole WMA, it does suggest that actual water use in the upper Doring area may be considerably higher than estimated.

It should be noted that the deficit between the equivalent water requirements and the available yield in the lower Olifants River catchment is not bigger only because of the large quantity (127 million m^3/a) imported from the upper Olifants catchment.

The water balance is shown diagrammatically in Figure 7.2.1.

TABLE 7.2.4: WATER REQUIREMENTS AND AVAILABILITY IN 1995

CATCHMENT						AVAILABLE 1:50 YEAR YIELD IN 1995			WATER TRANSFERS AT 1:50 YEAR ASSURANCE		RETURN FLOWS AT 1:50 YEAR ASSURANCE		WATER REQUIREMENTS AT 1:50 YEAR ASSURANCE (1) (million m^3/a)	YIELD BALANCE (2) AT 1:50 YEAR ASSURANCE (million m^3/a)
PRIMARY		SECONDARY		TERTIARY		SURFACE WATER (million m^3/a)	GROUNDWATER NOT LINKED TO SURFACE WATER (million m^3/a)	TOTAL (million m^3/a)	IMPORTS (million m^3/a)	EXPORTS (million m^3/a)	RE-USABLE (million m^3/a)	TO SEA (million m^3/a)		
No.	Description	No.	Description	No.	Description									
E	Olifants	E1	Upper Olifants	None	---	214	3,8	217,8	0	127,0	6,0	0	126,0	-29,2
		TOTAL IN UPPER OLIFANTS				**214**	**3,8**	**217,8**	**0**	**127,0**	**6,0**	**0**	**126,0**	**-29,2**
		E2	Doring	E21	Kouebokkeveld	60	5,0	65,0	0	0	3,0	0	66,0	+ 2
				E22	Upper Doring	4	0,0	4,0	1,5	0	0	0	1,8	+3,7
				E23	Tankwa	5	0,2	5,2	0	0	0	0	3,6	+1,6
				E24	Lower Doring	0	1,4	1,4	0,6		0		6,7	-4,7
			Sub-total			**69**	**6,6**	**75,6**	**2,1**	**0**	**3,0**	**0**	**78,1**	**+2,5**
		E4	Oorlogskloof	None		1	1,8	2,8	0	0	0,2	0	3,6	-0,6
		TOTAL IN DORING CATCHMENT				**70**	**8,4**	**78,4**	**2,1**	**0**	**3,2**	**0**	**81,7**	**+2,0**
		E3	Lower Olifants	E31	Kromme	0	0,3	0,3	0	0	0	0	0,2	+0,1
				E32	Hantams	0	1,0	1,0	0	0	0	0	1,0	0
				E33	Lower Olifants	0	1,9	1,9	127,0	2,5	0	13	137,8	-11,4
			Sub-total			**0**	**3,2**	**3,2**	**127,0**	**2,5**	**0**	**13**	**139,0**	**-11,3**
		TOTAL IN OLIFANTS CATCHMENT				**284**	**15,4**	**299,4**	**1,5**	**1,9**	**9,2**	**13**	**346,7**	**-38,5**
F (Part)	Namaqualand Catchments	F6	Goerap	None		0	0,4	0,4	1,5	0	0	0	1,9	0
G (Part)	Berg (Part)	G3	Sandveld	None		5	30,1	35,1	0,4	0	0	0,2	36,7	-1,2
		TOTAL IN WMA				**289**	**45,9**	**334,9**	**1,5**	**0**	**9,2**	**13,2**	**385,3**	**-39,7**

(1) To avoid double accounting, water exports within the WMA are not included in the "Water Requirements" column. Water losses and water exports from the WMA are included.
(2) Surplusses indicated by a+ and deficits by a-.

CHAPTER 8: COSTS OF WATER RESOURCE DEVELOPMENT

Costs of developing the surface water resources of the Olifants/Doring River Catchment to provide an additional 242 million m^3/a of yield were estimated in the Olifants/Doring River Basin Study (DWAF 1998e) at 1997 levels. These estimates were converted to equivalent costs in the year 2000 by applying a factor of 1,22 (an average rate of escalation of 7% per anum).

The schemes have been selected to give an indication of the cost of developing the surface water resources, but, in practice, different combinations of dam sizes, or other dam sites, such as the Rosendal site in the upper Olifants River catchment might be used.

The costs include costs of conveyance structures for delivering the water to the areas where it would probably be used.

The cost of farm dams was assumed to be R8 per m^3/a of yield, but this is a rough estimate only as costs are likely to vary considerably from place to place.

The cost estimates are based on development of the infrastructure components listed below:

- A new 330 million m^3 capacity dam at Grootfontein with a yield of 90 million m^3/a.
- Additional capacity of 25 million m^3 at Clanwilliam Dam to increase the yield by 11 million m^3/a.
- Additional farm dams with a yield of 10 million m^3/a, and an estimated capacity of 14 million m^3 in the upper Olifants catchment.
- A new 395 million m^3 capacity dam at Aspoort with a yield of 76 million m^3/a.
- A new 388 million m^3 capacity dam at Melkboom with a yield of 50 million m^3/a.
- Additional farm dams with a yield of 5 million m^3/a and an estimated capacity of 8 million m^3 in the lower Doring catchment.

These developments would increase the developed yield of the surface water resources from 289 million m^3/a in 1995 to the estimated total potential of 531 million m^3/a, at a cost of approximately R1 800 million, inclusive of VAT.

The remaining potential yield of 166 million m^3/a of the estimated total potential of 697 million m^3/a is from groundwater. A groundwater yield of 46 million m^3/a was developed in 1995, leaving 120 million m^3/a to be developed to reach the full potential. The cost of developing this potential was estimated to be R578 million inclusive of VAT, derived as follows from the data shown on Diagram 8.1 :

- A yield of 3 million/a from diffuse boreholes in the Namaqualand Catchments with an assumed average yield of 0,6 ℓ/s at a capital cost of R10/m^3 of yield per year, giving a total cost of R30 million.

- A yield of 41 million m^3/a from diffuse boreholes in the catchments of the Kromme, Hantams and Sout Rivers with an assumed average individual borehole yield of 1,3 ℓ/s at a capital cost of R6/m^3 of yield per year, giving a total cost of R246 million.

- A yield of 20 million m^3/a from diffuse boreholes in the Oorlogskloof area and the lower Doring catchment with an assumed average individual borehole yield of 1,7 ℓ/s at a capital cost of R5/m^3 of yield per year, giving a total cost of R100 million.

- A yield of 13 million m^3/a from diffuse boreholes in the catchment of the Tankwa River with an assumed yield of 2,0 ℓ/s at capital cost of R4/m^3 of yield per year, giving a total cost of R52 million.

- A yield of 43 million m^3/a from diffuse boreholes in the Sandveld area with an assumed average individual borehole yield of 2,3 ℓ/s at a capital cost of R3,50/m^3 of yield per year, giving a total cost of R150 million.

TABLE 8.1: COSTS OF FUTURE WATER RESOURCE DEVELOPMENT AT YEAR 2000 PRICES INCLUDING VAT

CATCHMENT NO	SCHEME	STORAGE VOLUME (million m^3)	INCREMENTAL SURFACE WATER YIELD (million m^3/a)	WELLFIELD YIELD (million m^3/a)	COSTS			
					DAMS (R x 10^6)	WELLFIELDS (R x 10^6)	CANALS AND PIPELINES (R x 10^6)	TOTALS (R x 10^6)
E10C	Grootfontein Dam	330	90	-	400	-	-	400
E10G	Clanwilliam Dam Raising	25	11	-	146	-	-	146
E10A-G	Farm dams	14	10	-	80	90		80
E22	Aspoort Dam	395	76	-	200		258	458
E24M	Melkboom Dam	388	50	-	456		228	684
E24A-M	Farm dams	8	5	-	40			40
SUB-TOTAL : SURFACE WATER		**1170**	**242**	**-**	**1322**		**486**	**1808**
F60	Diffuse boreholes	**-**	**-**	**3**	**-**	**30**	**-**	**30**
E31, E32, E33	Diffuse boreholes	-	-	**41**	-	**246**	-	**246**
E40	Diffuse boreholes	-	-	**20**	-	**100**	-	**100**
E23	Diffuse boreholes	-	-	**13**	-	**52**	-	**52**
G30	Diffuse boreholes	-	-	**43**	-	**150**	-	**150**
SUB-TOTAL : GROUNDWATER		**-**	**-**	**120**	**-**	**578**	**-**	**578**
TOTAL RESOURCE		**1170**	**242**	**120**	**1322**	**578**	**486**	**2386**

The total cost of developing an additional 362 million m^3/a of yield is, therefore estimated to be R2 386 million, at year 2000 prices including VAT as shown in Table 8.1.

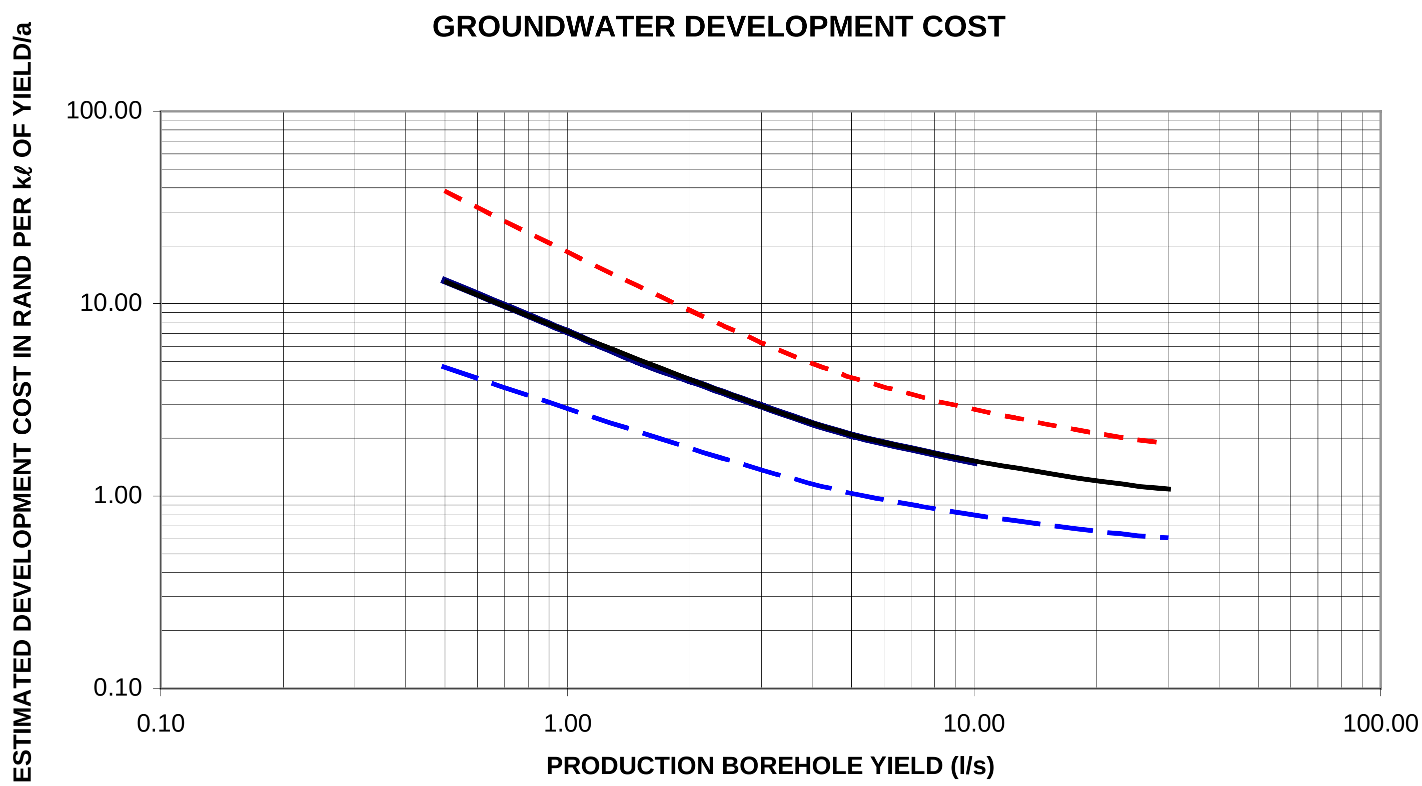
GROUNDWATER DEVELOPMENT COST
ESTIMATED DEVELOPMENT COST IN RAND PER kℓ OF YIELD/a
100.00
10.00
1.00
0.10
0.10
1.00
10.00
100.00
PRODUCTION BOREHOLE YIELD (l/s)

Diagram 8.1

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

In this chapter the main conclusions that can be drawn from the information gathered in this situation assessment are listed, followed by a discussion of requirements for additional data and, finally, recommendations on the actions needed to obtain the additional data.

The main conclusions are :

(i) The Olifants/Doring WMA covers an area of 56 446 km^2 in which the mean annual precipitation ranges from 100 mm in the far north to above 900 mm in the mountains in the south.

(ii) The geology of the WMA consists of Karoo sediments in the east, sedimentary rocks of the Cape Supergroup in the west, and sedimentary strata of the Vanrhynsdorp Group in the north, with exposures of pre-Cape metamorphic rock in the north-western and north-eastern corners of the WMA. The mountains in the southern central part of the area are composed of rocks of the Table Mountain Group, which in general give surface water and groundwater of good quality. In the areas where Karoo and Vanrhynsdorp sediments occur, base flows in the rivers are generally saline. There is a trend of deteriorating groundwater quality from south to north in the WMA, and there are large areas in the northern parts where it is unlikely that any of the groundwater is of potable standard because of the high salinity of the geological strata.

(iii) The present ecological status of the uppermost reaches of the Olifants River is Class A : unmodified natural, and of very high ecological importance. Consequently, the ecological flow requirements are high. The tributaries of the Doring River on the eastern slopes of the Cederberg, the lower portion of the Oorlogskloof River and the upper reaches of the Kromme and the Hantams Rivers, along the north-eastern edges of the WMA are classified as Class B : largely natural and are of high ecological importance and sensitivity, with correspondingly high ecological flow requirements. The other rivers are classified as moderately or largely modified, with lower ecological flow requirements.

(iv) The population of the WMA in 1995 was approximately 104 000 people, of whom 50 000 lived in the towns.

(v) Much of the economic activity is concentrated in the south-western portion of the WMA, with the Vredendal, Ceres and Clanwilliam areas contributing 75% of the GGP in 1997. The GGP of the whole WMA was R1,6 billion in 1997, with the most important economic sectors, in terms of their contributions to GGP, being Agriculture (43,3%), Trade (14,5%) and Manufacturing (11,8%).

(vi) Land-use is predominantly for rough grazing for livestock. Some 467 km^2, or 0,8% of the surface area of the WMA is used for irrigated crops, but only about 85% of the area is irrigated in average years, with larger areas irrigated occasionally when rainfall is favourable in the semi-arid areas. Dryland crops, mainly in the south-eastern part of the WMA, are grown on an estimated 2 190 km^2, and nature reserves occupy 1 069 km^2. The area of land under afforestation is small at 10 km^2, and alien vegetation, other than afforestation, covers an equivalent condensed area of 122 km^2.

(vii) There were about 560 000 head of livestock in the WMA in 1995. Sheep and goats made up 94% of the livestock numbers, with cattle, horses and pigs comprising most of the remainder.

(viii) Water related infrastructure is well developed, particularly in the south-western part of the WMA, where most of the water requirements occur.

(ix) Town bulk water supply schemes were generally adequate in 1995, but the requirements of some of the isolated towns that rely on local sources were approaching the scheme capacities and supplies are likely to require augmentation soon.

(x) Allocations of water for irrigation, urban, industrial and mining use from the Olifants River (Vanrhynsdorp) Government Water Scheme exceed the 1:5 year yield of the scheme by a considerable amount, with the result that only a portion of irrigation quotas is supplied in drier years.

(xi) Water requirements in 1995 in the WMA as a whole were estimated to total 462 million m^3, excluding the requirements of the ecological Reserve, but including water use by afforestation and alien vegetation. The major water user sector was agriculture, which required 442 million m^3/a, or 96% of the total consumptive requirement (i.e. excluding the ecological Reserve). The next biggest water user was the urban and rural domestic sector, at 2% of the total consumptive requirement, followed by bulk water use of industry and mining (1%), alien vegetation (0,7%) and afforestation (0,3%). With the requirements of the ecological Reserve added, the total water requirement becomes 589 million m^3/a.

(xii) The equivalent water requirement at 1:50 year assurance, with the requirements of the ecological Reserve and water use by alien vegetation and afforestation all included as impacts on yield, was 385 million m^3/a. The estimates of the impacts on yield are at a low level of confidence.

(xiii) The natural MAR of the Olifants/Doring WMA was 1 108 million m^3 and the yield developed from surface water resources in 1995 was 289 million m^3/a at 1:50 year assurance. Some 53% of the developed yield was from major dams (Clanwilliam Dam and Bulshoek Barrage) and 47% was from farm dams and run-of-river yield. In addition, boreholes with an estimated yield of 46 million m^3/a had been developed, bringing the total developed yield to 335 million m^3/a at 1:50 year assurance.

(xiv) Comparison of the equivalent 1:50 year assurance water requirements of 385 million m^3/a with the developed yield of 335 million m^3/a shows a deficit of 50 million m^3/a, but re-usable return flows of 9 million m^3/a and water imports of 1,5 million m^3/a reduce the deficit to approximately 40 million m^3/a. The main shortages of water occur in the Upper Olifants River catchment, where there is a deficit of 29 million m^3/a, and in the Lower Olifants Catchment, where the deficit is 11 million m^3/a. There is also a deficit of about 5 million m^3/a in the Lower Doring River catchment and there are small deficits in the Oorlogskloof catchment and the Sandveld. The other areas are either balanced or show slight surpluses.

(xv) Conveyance losses in the Olifants River Canal system are 28% of the quantity conveyed in the canals. The conveyance losses are more than three times the deficit in water availability at 1:50 year assurance that occurs in the area supplied by the canals. It is clear that there is scope for improving the situation through the application of appropriate water conservation measures.

(xvi) The maximum potential yield of the water resources of the WMA is estimated to be 697 million m^3/a at 1:50 year assurance, which is 362 million m^3/a more than the

(xvii) developed yield in 1995. It is estimated that 67% of the undeveloped potential yield could be obtained from surface water and the rest from diffuse groundwater developments mainly in the arid northern part of the WMA and in the Sandveld.

(xviii) There may be an opportunity for developing deep Table Mountain Group groundwater aquifers in the upper Olifants River valley and for storing surface water in groundwater aquifers to the south of the lower Olifants River, but the feasibility of these developments is still being investigated. Therefore they have not been included in the above estimates.

(xix) The groundwater studies showed that, because of the high salinity of the groundwater in many parts of the WMA, only 27%, on average, of the groundwater exploitation potential is likely to be of potable standard. The estimates of maximum potential yield given in (xvi) above do not take this into account and it is apparent that the economic viability of developing the maximum potential groundwater yield may be adversely affected by poor water quality and the resulting need to desalinate the water to make it fit for use.

(xx) The capital cost of developing the full potential yield of the water resources was roughly estimated to be R2 386 million, inclusive of VAT, at year 2000 price levels. This included R578 million for groundwater development, but this amount did not allow for the cost of desalinating groundwater where required to bring it to a potable standard.

In the course of gathering information for this study, the available data on the following aspects have been found to be inadequate :

- Ecological Reserve requirements of both rivers and estuaries and their impact on the available yield of the water resources.
- The extent of alien vegetation and its impact on the yield of the water resources.
- The extent and distribution of irrigated agriculture in the Upper Doring River catchment and the associated water requirements (the yield balance showed excess yield of nearly 4 million m^3/a to be available, part of which is provided by water imported from the Breede WMA).
- The extent and distribution of irrigated crops in the Sandveld area, as well as the quantity of water required and the extent of the groundwater resource that is being used for irrigation.

In the present situation, the main importance of the ecological Reserve requirements are the effect that they will have on the yield of Clanwilliam Dam. In this study the impact on the 1:50 year yield of the dam has been estimated to be 12,3 million m^3/a. As the ecological Reserve, when implemented, will affect those receiving water from the dam, it is important that it be determined at least at the "intermediate" level, as prescribed in the standard DWAF procedures, to improve the reliability of the determination, which is at a low level of confidence at present.

It is understood that the ecological Reserves at the "intermediate" level for both the Olifants River and its estuary are being determined in a current study on the feasibility of a dam at Melkboom on the Doring River. The study has been commissioned by the Western Cape Province Department of Agriculture and is also investigating the feasibility of further groundwater exploitation and the storage of surface water runoff in groundwater aquifers with excess storage capacity.

The possibility of exploiting artesian groundwater in aquifers of the Table Mountain Group is being investigated in the upper Olifants catchment (DWAF, 2000D) and the results of this investigation might influence the need for further development of the surface water resources of the catchment.

Thus, some of the information identified in this report as being inadequate is being obtained in the investigation for further development of the water resources of the Olifants/Doring River catchment that are taking place at present. However, the uncertainty regarding the true extent and distribution of irrigated agriculture in the upper Doring River catchment where the yield balance showed an excess of nearly 4 million m^3/a will not be addressed in the current studies. The situation here should be clarified when the opportunity arises, but, because the quantity of water involved is relatively small, it is not critical in the context of the development of the resources of the Doring River by constructing a major dam at Melkboom at the bottom of the catchment. However, clarification will be important if it is decided to further investigate a dam at Aspoort. In the context of present level of development, the advantage of clarifying the situation would be in ascertaining that the water that is transferred to the area from the Breede River catchment is being fully utilised.

It is understood that recent aerial photography is available for the area. This should be used to determine the area of land cultivated and field investigations should be undertaken to determine the types of crops grown and the quantities of water used. At the same time, information should be obtained on the quantities of water used from local sources, and the manner of abstraction, and on the manner in which the water imported from the Breede WMA is distributed and used.

There is also uncertainty regarding the true extent and distribution of irrigated crops in the Sandveld area, as well as the extent of the groundwater resource that is being used for irrigation. This area is not included in the current Melkboom Dam Study. Nevertheless, it appears that the area of land under irrigation may be increasing and the urban areas along the coast may also grow. Therefore, it will be important for the future Catchment Management Agency to have reliable information on the potential yield of the water resources of the area so that planning of future water supplies can be done timeously.

Consequently, it is recommended that more detailed investigations be carried out in this area. The investigations should include :

- The use of aerial photography combined with field investigations to determine the areas of land cultivated and the areas and types of crops grown under irrigation each year;
- determination of the extent to which surface water is used for irrigation, livestock watering, rural domestic water supplies and urban water supplies;
- determination of the impact of alien vegetation on surface water yield;
- the collection and correlation of data on groundwater use and the size of the groundwater resource;
- the collection and correlation of existing data on the quality of both groundwater and surface water, and field work to collect additional water quality data if found to be necessary;
- the collection of data on existing urban water supply schemes and the determination of present and probable future urban and rural domestic and livestock water requirements;
- the determination of probable future water requirements for irrigation;
- the preparation of a water resources management plan for the area.

There are no streamflow gauging stations in the Sandveld area, with the result that the available streamflow data has been estimated from rainfall records and is of uncertain reliability. If the investigations recommended above show that the surface water resources are heavily exploited, the establishment of a gauging station on the Verlorevlei River, which is the biggest river in the area, should be considered with a view to improving knowledge of the surface water hydrology of the area. It might also be necessary to determine the ecological flow requirements of the Verlorevlei at the intermediate level in order to establish the maximum quantity of water that can be abstracted from the river system.

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APPENDICES

LIST OF CONTENTS

NOTE: BLANKS INDICATE THAT DATA WAS NOT READILY AVAILABLE

ABBREVIATIONS AND ACRONYMS

AEMC	Suggested Ecological Management Class
CMA	Catchment Management Agency
DBSA	Development Bank of Southern Africa
DEMC	Default Ecological Management Class
DESC	Default Ecological Sensitivity Class
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
EISC	Ecological Importance and Sensitivity Class
GIS	Geographical Information System
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NWA	National Water Act (Act No. 36 of 1998)
PESC	Present Ecological Status Class
TDS	Total Dissolved Salts
TLC	Transitional Local Council
TRC	Transitional Rural Council
WMA	Water Management Area
WRSA	Water Resources Situation Assessment
WSAM	Water Situation Assessment Model
ha	hectare
km^2	square kilometres
m^3	cubic metre
$10^6 m^3$	million cubic metres
$10^6 m^3/a$	million cubic metres per year
%	percent

APPENDIX A

DEMOGRAPHIC DATA

Listing of urban, rural and total populations per quaternary catchment as contained in the database of the Water Situation Assessment Model.

OLIFANTS-DORING WATER MANAGEMENT AREA

APPENDIX A

DEMOGRAPHIC DATA PER QUATERNARY CATCHMENT

Quaternary catchment	oPOPi Urban Population	oPORi Rural Population	Total Population	Quaternary catchment	oPOPi Urban Population	oPORi Rural Population	Total Population
	Number	Number	Number		Number	Number	Number
E10A	0	1041	1041	**E24G**	0	150	150
E10B	0	1942	1942	**E24H**	0	167	167
E10C	0	962	962	**E24J**	0	654	654
E10D	0	1333	1333	**E24K**	0	278	278
E10E	3750	1428	5178	**E24L**	0	661	661
E10F	0	1614	1614	**E24M**	0	616	616
E10G	0	1086	1086	**E31A**	0	57	57
E10H	0	312	312	**E31B**	1900	132	2032
E10J	4400	1004	5404	**E31C**	0	87	87
E10K	0	473	473	**E31D**	0	40	40
E21A	0	1533	1533	**E31E**	0	34	34
E21B	0	386	386	**E31F**	0	78	78
E21C	0	962	962	**E31G**	0	35	35
E21D	0	1758	1758	**E31H**	0	124	124
E21E	0	372	372	**E32A**	0	246	246
E21F	0	456	456	**E32B**	0	171	171
E21G	0	2313	2313	**E32C**	0	205	205
E21H	0	946	946	**E32D**	0	116	116
E21J	0	307	307	**E32E**	0	233	233
E21K	0	167	167	**E33A**	0	201	201
E21L	0	93	93	**E33B**	0	62	62
E22A	0	156	156	**E33C**	0	162	162
E22B	0	39	39	**E33D**	0	109	109
E22C	0	385	385	**E33E**	0	1086	1086
E22D	0	21	21	**E33F**	3850	309	4159
E22E	0	269	269	**E33G**	14900	6071	20971
E22F	0	119	119	**E33H**	2550	3989	6539
E22G	0	75	75	**E40A**	0	325	325
E23A	0	154	154	**E40B**	7150	289	7439
E23B	0	106	106	**E40C**	1000	177	1177
E23C	0	40	40	**E40D**	0	245	245
E23D	0	105	105	**F60A**	200	325	525
E23E	0	257	257	**F60B**	1300	26	1326
E23F	0	66	66	**F60C**	1150	562	1712
E23G	0	57	57	**F60D**	0	49	49
E23H	0	60	60	**F60E**	0	0	0
E23J	0	131	131	**G30A**	1650	689	2339
E23K	0	77	77	**G30B**	0	2409	2409
E24A	0	316	316	**G30C**	0	893	893
E24B	0	647	647	**G30D**	0	1254	1254
E24C	0	269	269	**G30E**	0	468	468
E24D	0	255	255	**G30F**	300	1204	1504
E24E	0	303	303	**G30G**	5450	1074	6524
E24F	0	218	218	**G30H**	0	3472	3472
Totals	8150	24612	32762		41400	29535	70935

APPENDIX B

SUPPLEMENTARY ECONOMIC DATA

APPENDIX B.1

GRAPHS: GROSS GEOGRAPHIC PRODUCT, LABOUR AND SHIFT-SHARE

APPENDIX B.1
DESCRIPTION OF GRAPHS

Diagram No	Graphic Illustration	Description
	• **Gross Geographic Product**:	
B.1	Contribution by Magisterial District to Olifants/Doring Economy, 1997 (%)	Each WMA comprises a number of Magisterial Districts. This graph illustrates the percentage contribution of each MD to the WMA economy as a whole. It shows which are the most important sub-economies in the region.
B.2	Contribution by sector to National Economy, 1988 and 1997 (%)	This graph illustrates the percentage contribution of each sector in the WMA economy, e.g. agriculture, to the corresponding sector in the national economy.
	• **Labour Force Characteristics**:	
B.3	Composition of Berg Labour Force 1994 (%)	The total labour force may be divided into three main categories, namely formal employment, informal employment and unemployment, as outlined in this graph.
B.4	Contribution by Sector to Olifants/Doring Employment, 1980 and 1994 (%)	Shows the sectoral composition of the formal WMA labour force.
B.5	Contribution by Sectors of Olifants/Doring Employment to National Sectoral Employment, 1980 and 1994 (%)	Similar to the production function (i.e. GGP), this graph illustrates the percentage contribution of each sector in the WMA economy, e.g. mining, to the corresponding sector in the national economy.
B.6	Compound Annual Employment Growth by Sector of Berg versus South Africa, 1988 to 1994 (%)	Annual compound growth by sector is shown for the period 1980 to 1994.
	• **Shift-Share**:	
B.7	Shift-Share Analysis, 1997	Compares the contribution of each sector in the WMA economy to its recent growth performance. This serves as an instrument to identify sectors of future importance (towards top right hand side of the graph) and sectors in distress (towards the bottom left hand side of the graph).

Figure B.1: Contribution by Magisterial District to Olifants/Doring economy, 1997 (%)

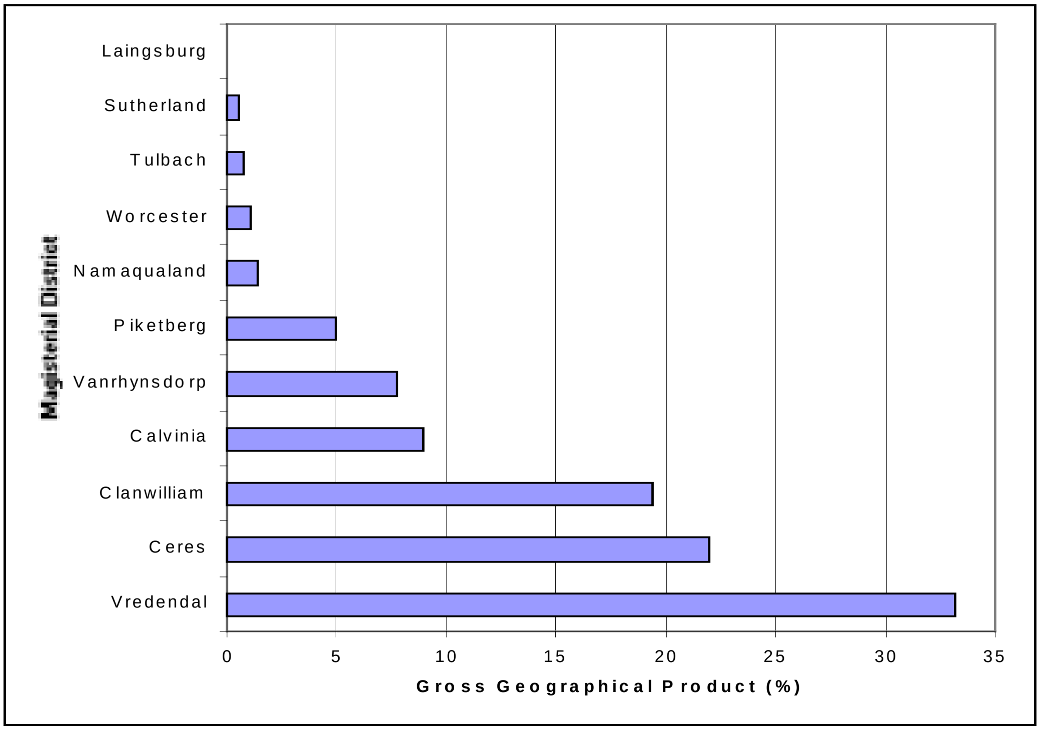


Figure B.2: Contribution by Sector to National Economy, 1988 and 1997 (%)

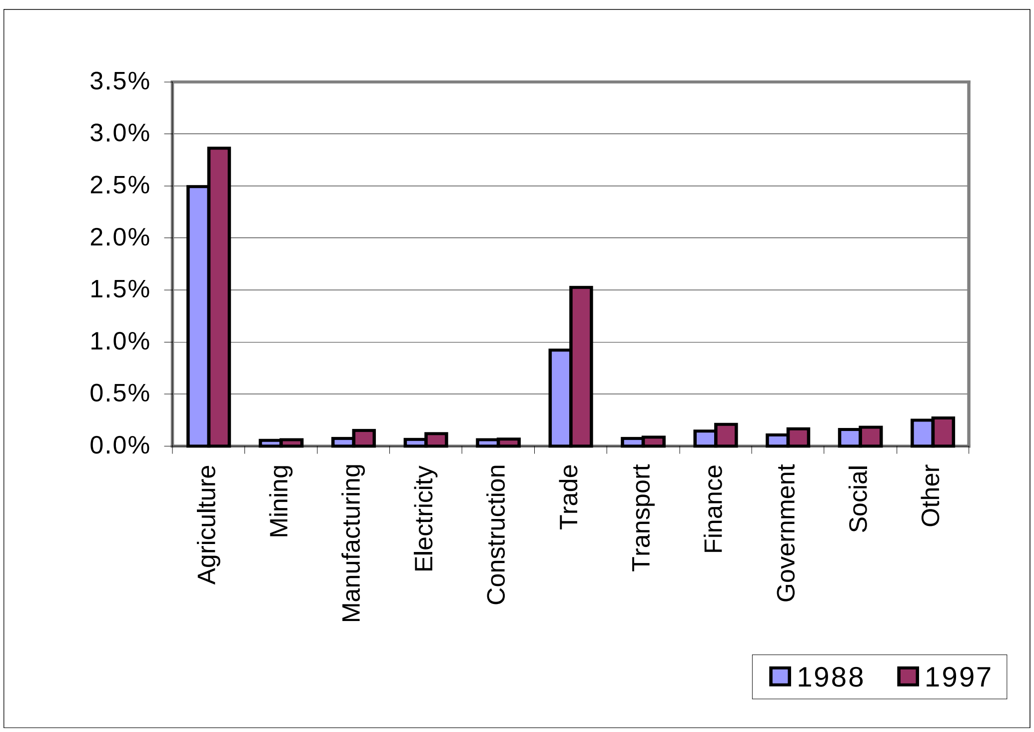


Figure B.3: Composition of Olifants/Doring Labour Force, 1994 (%)

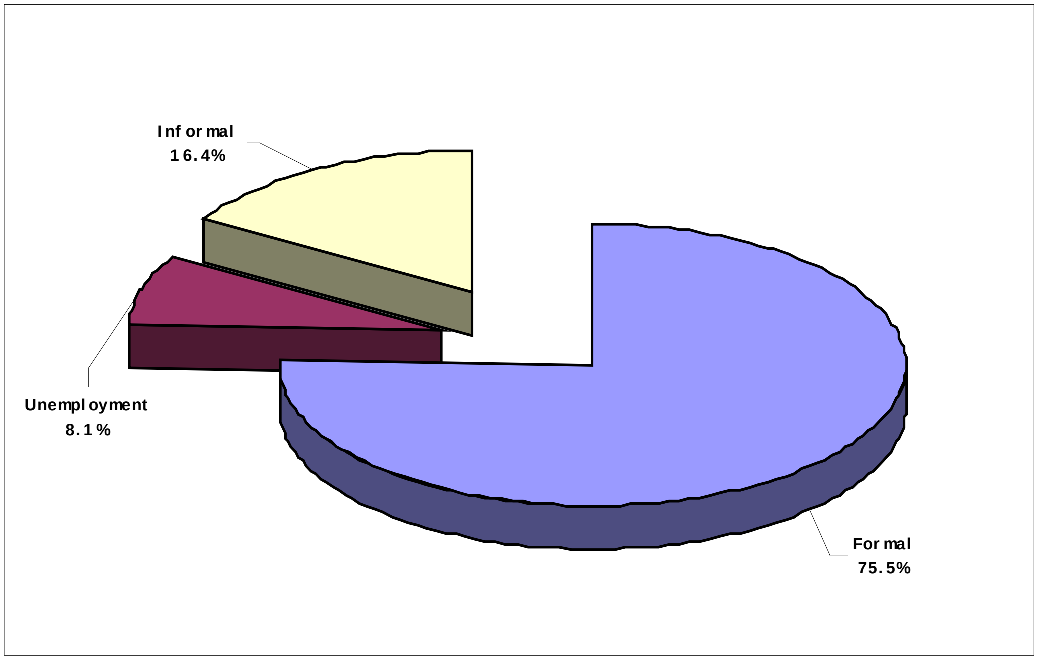


Figure B.4: Contribution by Sector to Olifants/Doring Employment, 1980 and 1994 (%)

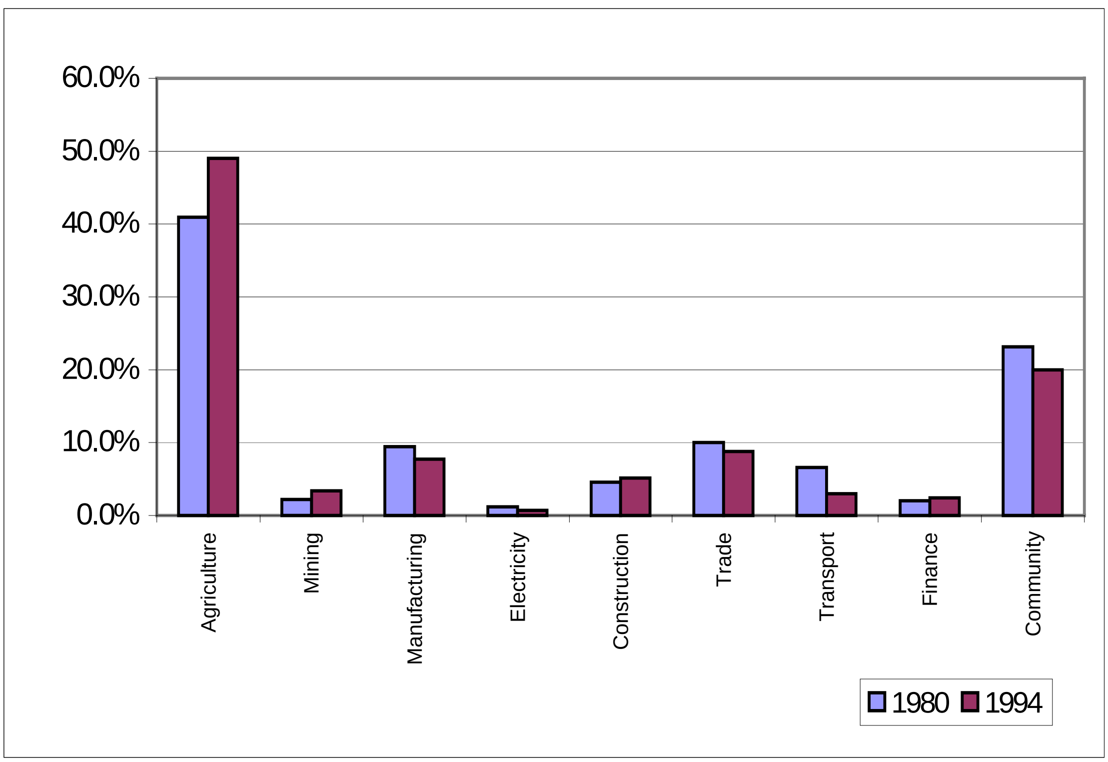


Figure B.5 **Contribution by Sectors of Olifants/Doring Employment to National Sectoral Employment, 1980 and 1994 (%)**

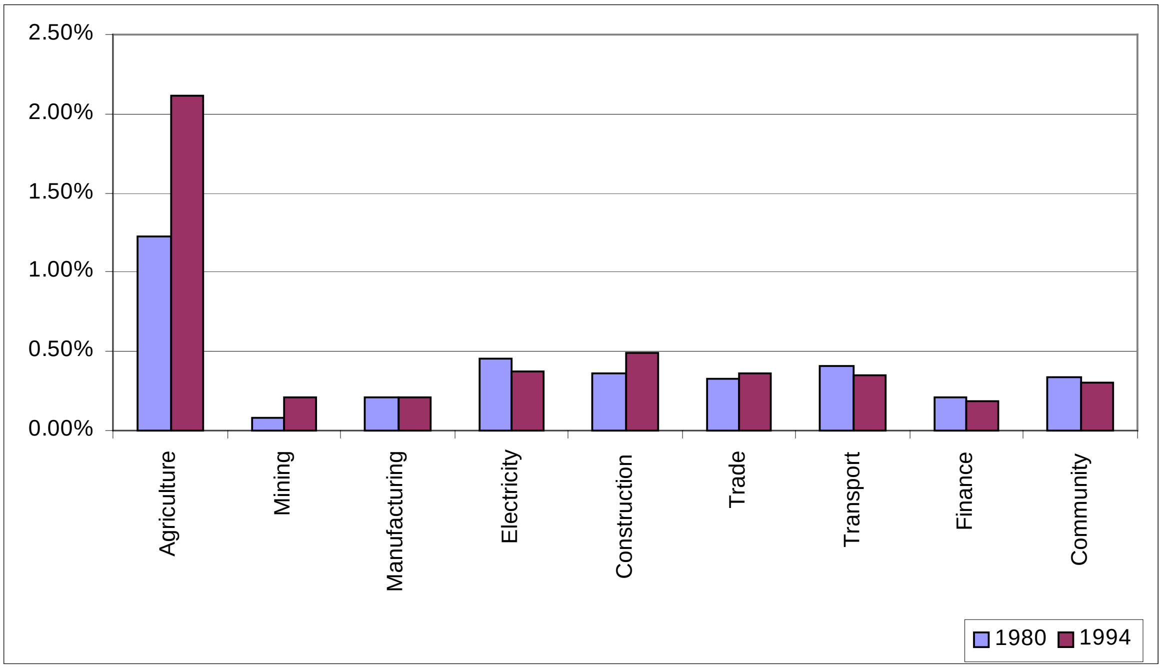


Figure B.6: **Average Annual Employment Growth by Sector of Olifants/Doring versus South Africa, 1980 to 1994 (%)**

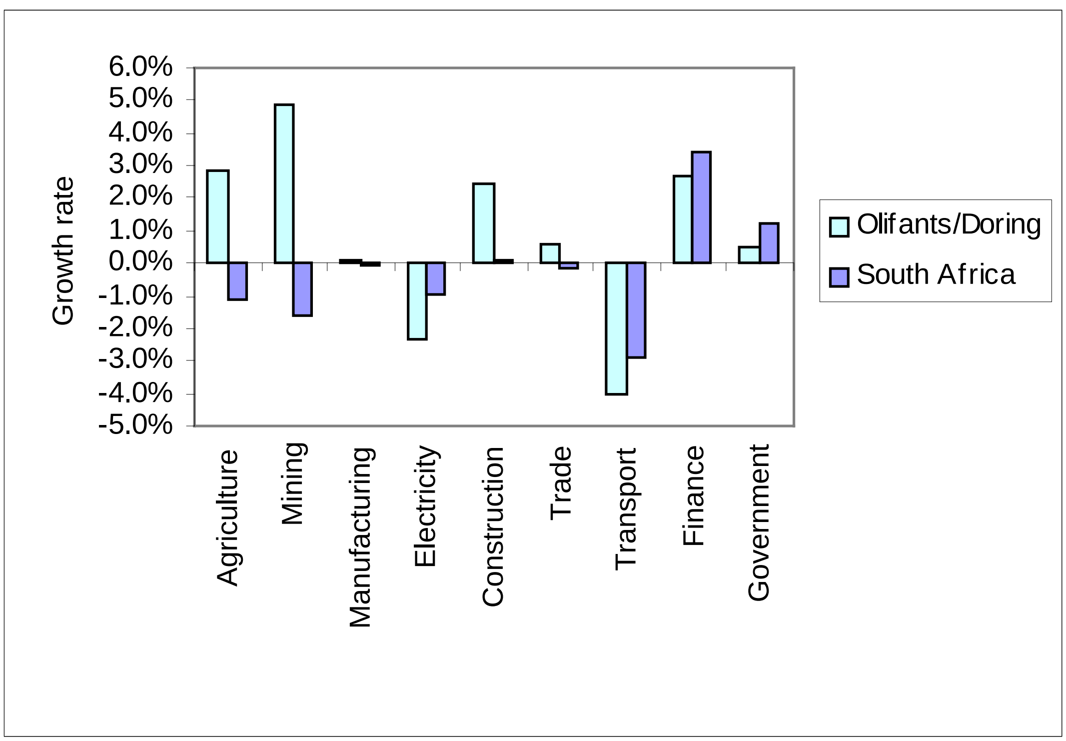
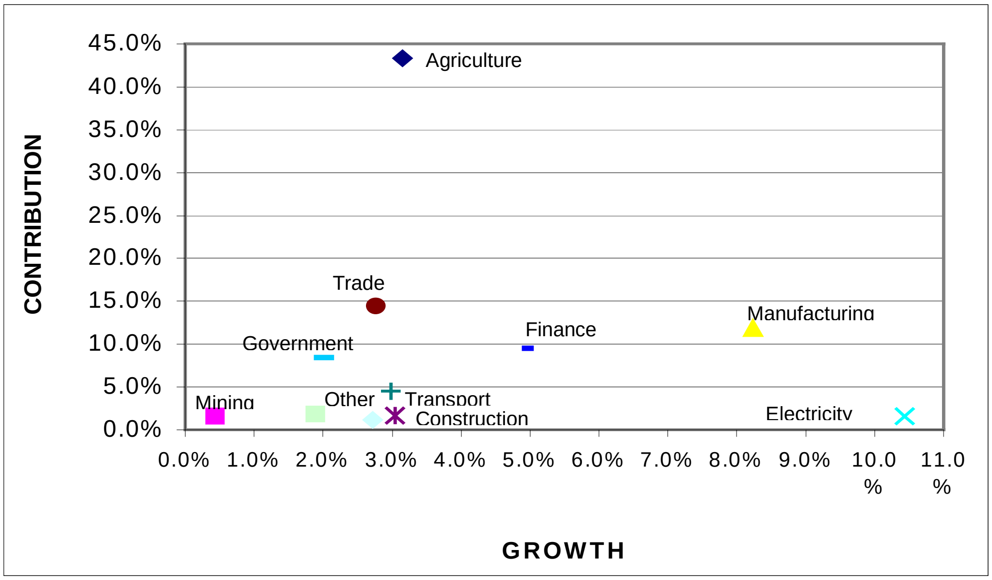


Figure B.7: Shift-Share Analysis, 1997



APPENDIX B.2

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

WATER MANAGEMENT AREAS IN NATIONAL CONTEXT

B.1 INTRODUCTION

The purpose of this section is to illustrate the relative importance of the nineteen different water management areas (WMAs) in South Africa. The following aspects are outlined:

- Contribution by WMA to national economy
- Contribution by WMA to formal employment
- Economic growth by WMA.

B.2 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL ECONOMY

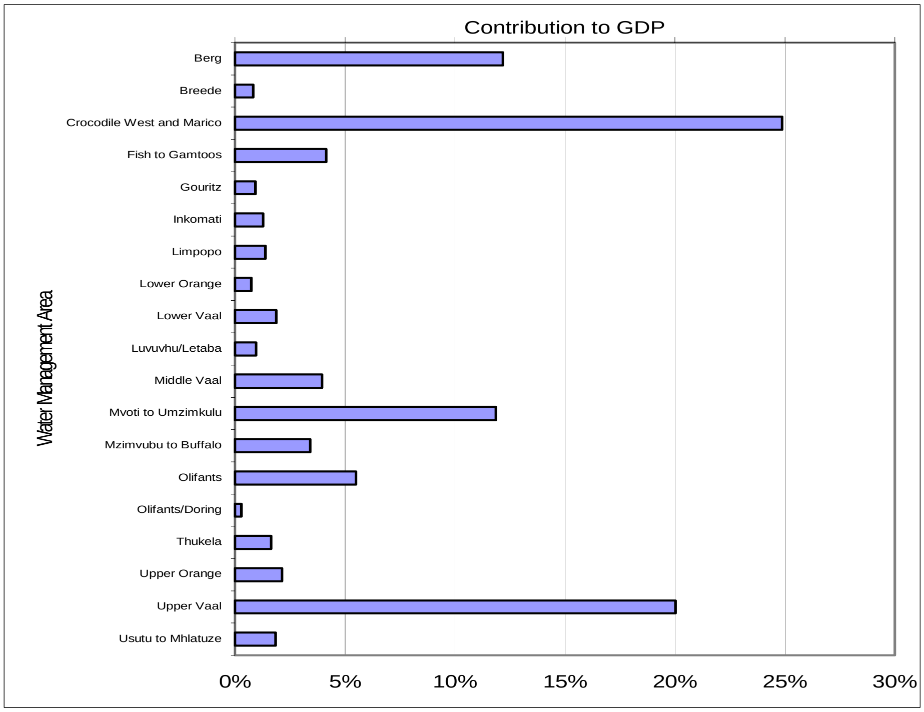
- The largest contribution to the national economy is made by the Crocodile West and Marico WMA which contributes (19.1%) to GDP. This WMA comprises, inter alia, magistrates districts of Pretoria, Johannesburg, Germiston, Kempton Park, Benoni, Thabazimbi and Lichtenburg.

- The second largest WMA to the national economy, is the Upper Vaal, which contributes 16.6% to GDP. This WMA comprises mainly portions of Johannesburg, Vereeniging and Vanderbijlpark.

- The Berg WMA contributes 11.25% to the GDP of the national economy and comprises mainly the Cape Metropolitan Area (CMA).

- Mvoti to Umzimkulu WMA makes the fourth largest contribution of 10.72% to the GDP of the national economy. This WMA includes the Durban-Pinetown Metropolitan Area.

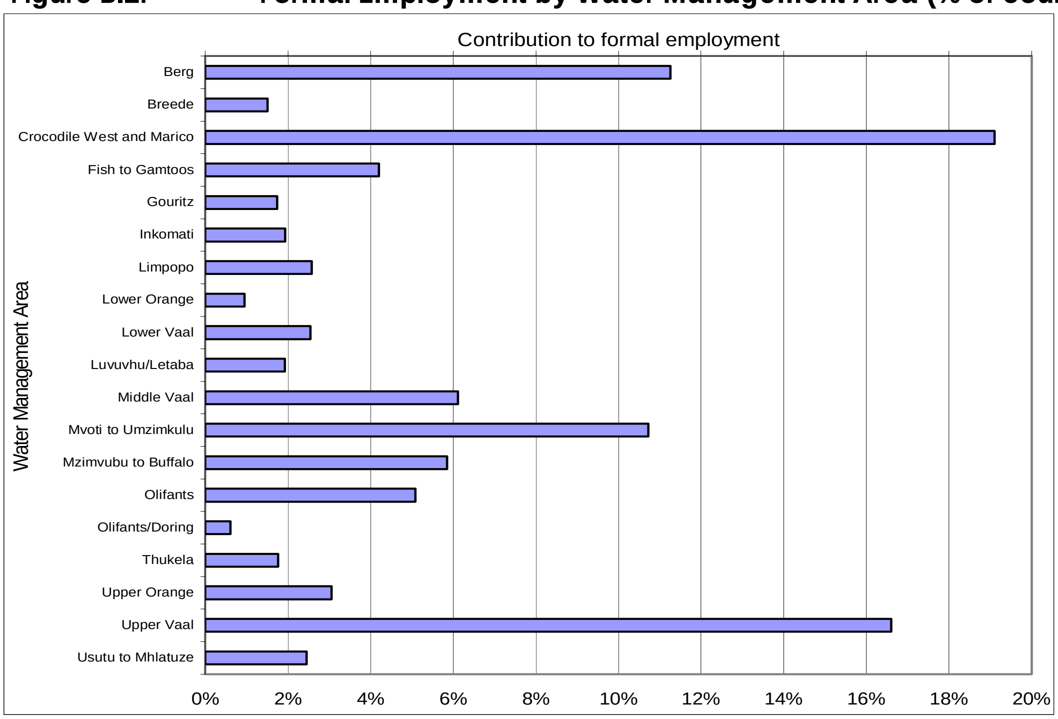
Figure B.1: Total GDP by Water Management Area (% of Country)



B.3 CONTRIBUTION BY WATER MANAGEMENT AREA TO NATIONAL EMPLOYMENT

- Contribution to formal employment corresponds to economic production and is mainly concentrated in the four dominant WMAs.

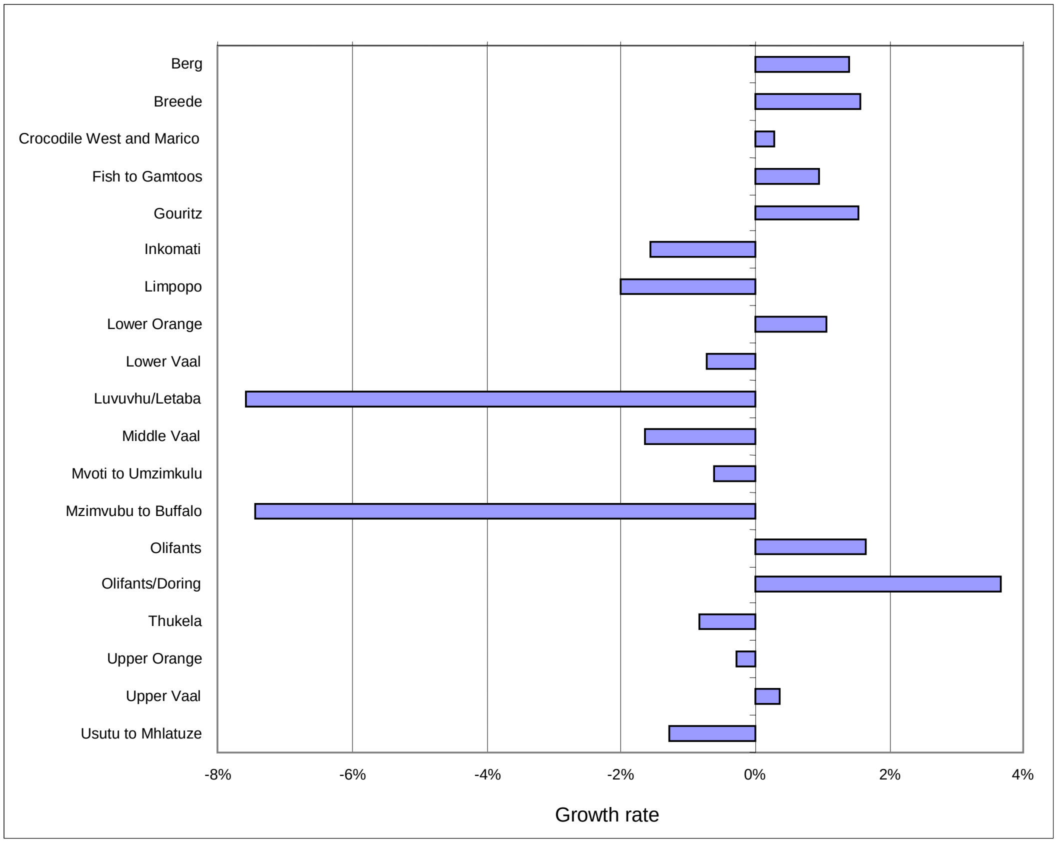
Figure B.2: Formal Employment by Water Management Area (% of country)



B.4 ECONOMIC GROWTH BY WATER MANAGEMENT AREA

- In terms of economic growth, three of the dominant four WMAs recorded positive economic growth between 1988 and 1997: the Berg grew at 1.4% per annum, Crocodile West and Marico at 0.28% per annum and Upper Vaal at 0.36% per annum. Marginal negative growth was recorded over the nine year period in the Mvoti to Umzimkulu WMA: -0.62% per annum.

Figure B.3: Average Annual Economic Growth by Water Management Area, 1988-1997 (%)



APPENDIX B.3
ECONOMIC SECTOR DESCRIPTION

ECONOMIC SECTOR DESCRIPTION

- **Agriculture:** This sector includes agriculture, hunting and related services. It comprises activities such as growing of crops, market gardening, horticulture, mixed farming, production of organic fertiliser, forestry, logging and related services and fishing, operation of fish hatcheries and fish farms.

- **Mining:** This section entails the mining and quarrying of metallic minerals (coal, lignite, gold, cranium ore, iron ore, etc); extraction of crude petroleum and natural gas, service activities incidental to oil and gas extraction; stone quarrying; clay and sand pits; and the mining of diamonds and other minerals.

- **Manufacturing:** Manufacturing includes, inter alia, the manufacturing of food products, beverages and tobacco products; production, processing and preserving of meat, fish, fruit, vegetables, oils and fats, dairy products and grain mill products; textile and clothing; spinning and weaving; tanning and dressing of leather; footwear; wood and wood products; paper and paper products; printing and publishing; petroleum products; nuclear fuel; and other chemical substances.

- **Electricity, Water and Gas:** Utilities comprise mainly three elements, namely electricity, water and gas. The services rendered to the economy include the supply of electricity, gas and hot water, the production, collection and distribution of electricity, the manufacture of gas and distribution of gaseous fuels through mains, supply of steam and hot water, and the collection, purification and distribution of water.

- **Construction:** This sector includes construction; site preparation building of complete constructions or parts thereof; civil engineering; building installation; building completion; and the renting of construction or demolition equipment with operators all form part of the construction sector.

- **Trade:** Trade entails wholesale and commission trade; retail trade; repair of personal household goods; sale, maintenance and repair of motor vehicles and motor cycles; hotels, restaurants, bars canteens, camping sites and other provision of short-stay accommodation.

- **Transport:** The transportation sector comprises land transport; railway transport; water transport; transport via pipelines; air transport; activities of travel agencies; post and telecommunications; courier activities; and storage.

- **Business and Financial Services:** The economic activities under this category include, inter alia, financial intermediation; insurance and pension funding; real estate activities; renting of transport equipment; computer and related activities; research and development; legal; accounting, book-keeping and auditing activities; architectural, engineering and other technical activities; and business activities not classified elsewhere.

- **Government and Social services (Community Services)**: This sector includes public administration and defence, social and related community services (education, medical, welfare and religious organisations), recreational and cultural services and personal and household services.

- **Other:** Private households, extraterritorial organisations, representatives of foreign governments and other activities not adequately defined.

APPENDIX B.4
ECONOMIC INFORMATION SYSTEM

ECONOMIC INFORMATION SYSTEM
for Department of Water Affairs and Forestry

1. Background

The Economic Information System was developed for the Department of Water Affairs and Forestry due to a need for a comprehensive source of readily available economic data that can be utilised as a management tool for decision making.

Relevant information required for planning the allocation and utilisation of scarce resources such as water has always been a difficult process due to:

- **Inaccessibility of information**
- **Incompatibility of information**
- **No framework of reference for analysis**

The purpose of the Economic Information System was thus to combine all readily available economic information into a single computer package that would be readily accessible, easy to use and could be distributed without restrictions.

2. The System

The characteristics of the Economic Information System can be summarised as follows:

- Provides immediate access to a comprehensive economic database.
- Stand alone software programme that can be loaded onto a personal computer.
- System provides not only the existing data but also allows first degree transformation of data both geographically and functionally.
- Allows multidimensional access and presentation of information, that is, on a sectoral, geographical and functional basis.
- Provides time series information to enable users to determine trends and make projections.

Urban-Econ collected existing data from a range of secondary sources. The following data were combined in a single database which can be queried spatially, thematically and temporally *via* a user-friendly computer interface.

Diagram 1 depicts the economic information system in a flow chart format. It is possible to display the data in:

- Tables
- Graphs
- Thematic maps (this provides a better perspective of the spatial context and significance of other spatial features relevant to the data.

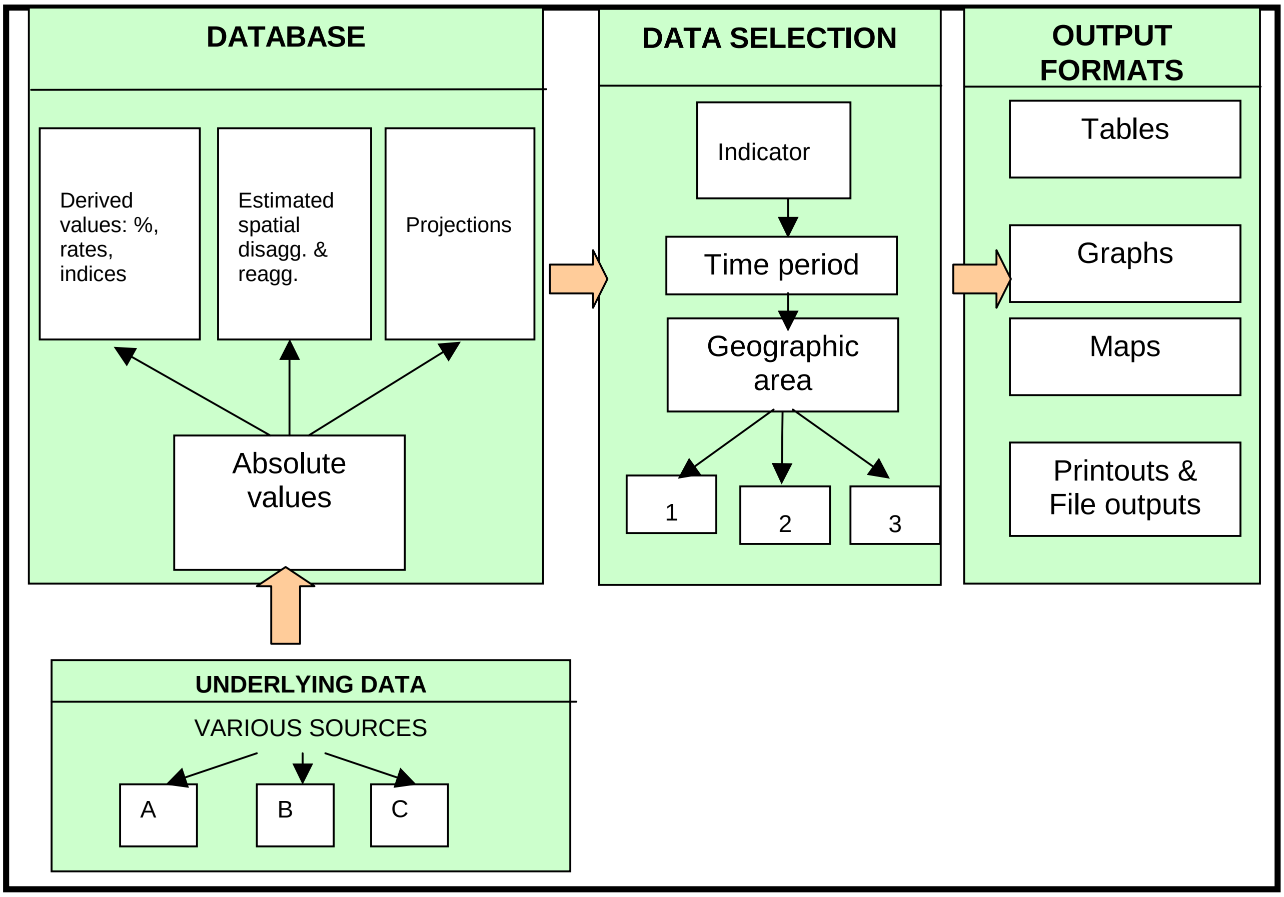
Indicator	Categories	Timespan	Geographic detail
Gross geographic product	Major sectors	1972-1997	Magisterial districts
Labour distribution	Employment/un-employment Major sectors	1980, 1991, 1994	Magisterial districts
Electricity consumption	Economic sectors, domestic	1988-1997	Local authority area, service council area
Electricity connections	Economic sectors, domestic	1988-1997	Local authority area, service council area
Remuneration*	Economic sectors	1993-1998	Magisterial districts
Turnover*	Economic sectors	1993-1998	Magisterial districts
Number of firms*	Economic sectors	1992-1998	Magisterial districts
Tax revenue	Company, Personal, VAT	1992-1997	Tax office area
Buildings completed	Residential, office, shops, industrial	1991-1996	Local authority area, service council area
Telephone connections	Business, residence	1998 1976-1997	Magisterial district Province
Vehicle sales	Commercial, passenger	1980-1997	Towns

* Figures complete for totals, but incomplete for economic sectors

On-line documentation is provided which gives information on:

- The definition of an indicator
- How the figures were obtained
- How reliable the figures are
- How complete the figures are
- To what detail the figures are available
- What the relevance or limitations of the figures are for analytical purposes.

Diagram 1: Overview of Economic Information System



3. Examples of utilisation

- A user can select a main area for analysing the spatial variations of an indicator. Within that area, any level of geographic detail, i.e. magisterial district level or town level in the case of data relating to a local authority area can be assessed.
- It is possible to compare changes over time between different areas. This may indicate whether patterns of economic activity are changing, for example that it is growing in one area and declining in another area, which will have an impact on, for example, human settlement and the demand for water.
- A user can select more than one indicator to ascertain how the trends of the different indicators are correlated in different areas or over time. If indicators are correlated, there may be a causal relationship between the two, or it may reveal that changes in both indicators are a consequence of some other factor. If these causal relationships can be determined, it may also become known whether the causal factors are changing permanently or temporarily, which will inform the user whether there should be a long-term planning response or not.

APPENDIX C

LEGAL ASPECTS

Not used

APPENDIX D

LAND USE DATA

APPENDIX D.1	**Listing per quaternary catchment of land use data contained in the database of the Water Situation Assessment Model.**
APPENDIX D.2	**Conversion of mature livestock and game populations to Equivalent Large Stock Units.**
APPENDIX D.3	**Tree species in commercial forests.**

OLIFANTS-DORING WATER MANAGEMENT AREA

APPENDIX D.1

LAND USE DATA CONTAINED IN THE DATABASE OF THE WATER SITUATION ASSESSMENT MODEL

Quaternary catchment	aAAAi	aFCAi	aFINi	aLSAi	aNAEi	oRSUi
	Area under alien vegetation	Area under afforestation	Indigenous forest area	Field area irrigated	Urban areas	Number of large stock units
	km^2	km2	km2	km^2	km^2	Number
E10A	0.721	2.187	0	12.56	0	775
E10B	0.192	0.7557	0	10.75	0	756
E10C	0.841	0.8727	0	4.078	0	1049
E10D	0.477	0	0	8.14	0	754
E10E	0.206	0	0	19.98	1.13	1259
E10F	0.092	0	0	19.56	0	1190
E10G	0.868	3.851	0	6.32	0	1567
E10H	0.135	0	0	1.47	0	500
E10J	0.234	0	0	15.03	2.26	1444
E10K	1.066	0	0	8.8	0	701
E21A	0.227	0.3628	0	11.33	0	674
E21B	0.104	0.1071	0	2.86	0	792
E21C	0.405	1.758	0	2.26	0	827
E21D	0.066	0	0	28.16	0	858
E21E	0.076	0	0	10.36	0	1038
E21F	0.134	0	0	1.03	0	1343
E21G	0.004	0.1079	0	25.04	0	942
E21H	0.853	0	0	3.71	0	1426
E21J	0.261	0	0	0	0	1050
E21K	0.104	0	0	1.24	0	1018
E21L	0.031	0	0	0	0	368
E22A	0	0	0	0.1	0	1965
E22B	0	0	0	0	0	2299
E22C	0	0	0	1.3	0	1736
E22D	0	0	0	0	0	1758
E22E	0	0	0	2.5	0	3593
E22F	0	0	0	0	0	1104
E22G	0.1	0	0	1.6	0	280
E23A	0	0	0	0.255	0	11
E23B	0	0	0	0	0	2
E23C	0	0	0	0	0	30
E23D	0	0	0	0.487	0	822
E23E	0	0	0	1.252	0	403
E23F	0.064	0	0	1.51	0	657
E23G	0	0	0	0	0	2647
E23H	0	0	0	0	0	2310
E23J	0	0	0	0	0	3131
E23K	0.076	0	0	0.5	0	163
E24A	0.002	0	0	0.57	0	785
E24B	0.016	0	0	0.76	0	1274
E24C	0.548	0	0	0.9	0	0
E24D	0.544	0	0	0.72	0	0
E24E	0	0	0	0.18	0	0
E24F	0	0	0	0.86	0	0

Quaternary catchment	aAAAi	aFCAi	aFINi	aLSAi	aNAEi	oRSUi
	Area under alien vegetation	Area under afforestation	Indigenous forest area	Field area irrigated	Urban areas	Number of large stock units
	km^2	km2	km2	km^2	km^2	Number
E24G	0.007	0	0	0.15	0	0
E24H	0.084	0	0	1.08	0	671
E24J	0.113	0	0	4.1	0	2540
E24K	0.008	0	0	0	0	71
E24L	0.019	0	0	5.98	0	1585
E24M	0.21	0	0	0.74	0	1281
E31A	0	0	0	0	0	0
E31B	0	0	0	0	0	0
E31C	0.079	0	0	0	0	0
E31D	0.288	0	0	0	0	0
E31E	0.263	0	0	0	0	0
E31F	0.209	0	0	0	1.714	0
E31G	0	0	0	0	0	208
E31H	0.237	0	0	0	0	185
E32A	0	0	0	0.73	0	0
E32B	0	0	0	1.02	0	0
E32C	0.016	0	0	0	0	0
E32D	0.006	0	0	0	0	0
E32E	0.023	0	0	1	0	2
E33A	0.041	0	0	0	0	2274
E33B	0	0	0	0	0	1302
E33C	0.236	0	0	1.6	0	1732
E33D	0	0	0	0.02	0	2966
E33E	0.205	0	0	0.4	0.533	2599
E33F	3.574	0	0	5.23	1.169	1379
E33G	9.542	0	0	71.01	3.53	1923
E33H	8.813	0	0	33.47	0.448	1711
E40A	0.096	0	0	4.17	0	0
E40B	0.556	0	0	0.39	2.463	0
E40C	2.039	0	0	0	2.466	36
E40D	0	0	0	0	0	506
F60A	14.49	0	0	0	0	600
F60B	0.895	0	0	0	1.731	639
F60C	2.723	0	0	0	0	1183
F60D	3.503	0	0	0	0	1067
F60E	9.831	0	0	0	0	1885
G30A	17.61	0	0	16.75	0.2061	10800
G30B	6.825	0	0	6.56	0	9137
G30C	0.103	0	0	20.47	0	1654
G30D	12.3	0	0	32.35	0	7623
G30E	6.301	0	0	13.24	0	4906
G30F	10.08	0	0	31.53	0	2944
G30G	7.86	0	0	9.04	1.944	1973
G30H	0	0	0	0	0	2686
Totals	127.632	10.0022	0	467.202	19.5941	115369

Note: aLSAi corresponds to the total irrigated area referred to in Table 3.5.2.1 in the main report.

APPENDIX D.2

CONVERSION OF MATURE LIVESTOCK AND GAME POPULATIONS TO EQUIVALENT LARGE STOCK UNITS (ELSU)

SPECIES	GROUP *	NUMBER PER ELSU
Livestock :		
Cattle	L	0,85
Sheep	S	6,5
Goats	S	5,8
Horses	L	1
Donkeys / mules	S	1,1
Pigs	S	4
Game :		
Black Wildebeest	LA	3,3
Blesbuck	SA	5,1
Blou Wildebeest	LA	2,4
Buffalo	BG	1
Eland	BG	1
Elephant	BG	0,3
Gemsbok	LA	2,2
Giraffe	BG	0,7
Hippopotamus	BG	0,4
Impala	SA	7
Kudu	LA	2,2
Nyala	SA	3,3
Ostrich	--	2,7
Red Hartebeest	LA	2,8
Roan Antelope	LA	2
Sable Antelope	LA	2
Southern Reedbuck	SA	7,7
Springbok	SA	10,3
Tsessebe	LA	2,8
Warthog	O	5
Waerbuck	SA	2,4
Rhinoceros	BG	0,4
Zebra	O	1,6

* Groups (in terms of water consumption :
L = cattle and horses; S = small livestock; LA = large antelope; SA = small antelope; BG = big game;
O = other game.

OLIFANTS-DORING WATER MANAGEMENT AREA

APPENDIX D.3

TREE SPECIES IN COMMERCIAL FORESTS PER QUATERNARY CATCHMENT

Quaternary catchment	aFCAi Area under afforestation km²	Species	Quaternary catchment	aFCAi Area under afforestation km²	Species
E10A	2.187	Pine	**E24G**	0	
E10B	0.756	Pine	**E24H**	0	
E10C	0.873	Pine	**E24J**	0	
E10D	0		**E24K**	0	
E10E	0		**E24L**	0	
E10F	0		**E24M**	0	
E10G	3.851	Pine	**E31A**	0	
E10H	0		**E31B**	0	
E10J	0		**E31C**	0	
E10K	0		**E31D**	0	
E21A	0.363	Pine	**E31E**	0	
E21B	0.107	Pine	**E31F**	0	
E21C	1.758	Pine	**E31G**	0	
E21D	0		**E31H**	0	
E21E	0		**E32A**	0	
E21F	0		**E32B**	0	
E21G	0.108	Pine	**E32C**	0	
E21H	0		**E32D**	0	
E21J	0		**E32E**	0	
E21K	0		**E33A**	0	
E21L	0		**E33B**	0	
E22A	0		**E33C**	0	
E22B	0		**E33D**	0	
E22C	0		**E33E**	0	
E22D	0		**E33F**	0	
E22E	0		**E33G**	0	
E22F	0		**E33H**	0	
E22G	0		**E40A**	0	
E23A	0		**E40B**	0	
E23B	0		**E40C**	0	
E23C	0		**E40D**	0	
E23D	0		**F60A**	0	
E23E	0		**F60B**	0	
E23F	0		**F60C**	0	
E23G	0		**F60D**	0	
E23H	0		**F60E**	0	
E23J	0		**G30A**	0	
E23K	0		**G30B**	0	
E24A	0		**G30C**	0	
E24B	0		**G30D**	0	
E24C	0		**G30E**	0	
E24D	0		**G30F**	0	
E24E	0		**G30G**	0	
E24F	0		**G30H**	0	
TOTAL				**10.002**	

APPENDIX E

WATER RELATED INFRASTRUCTURE

APPENDIX E.1	**Existing water supply schemes.**
APPENDIX E.2	**Main dams.**
APPENDIX E.3	**Farm dam data per quaternary catchment.**

OLIFANTS/DORING WATER MANAGEMENT AREA
APPENDIX E.1 : EXISTING WATER SUPPLY SCHEMES

Scheme Name	Consumers supplied			Raw water source /yield	Water Treatment Works			Source of Data	Reliability of Data
	Urban/Domestic/Mining /Industrial	Irrigation	Catchment		Name	Capacity (Mℓ/d)	Owner		
Olifants River (Vanrhynsdorp) Government Water Scheme	Klawer Vredendal Vanrhynsdorp Lutzville Ebenhaezer Strandfontein Doring Baai Namakwa Sands Mine Quarries Light Industries	(a) 11 500 ha of irrigated lands with a quota of 12 200m^3/ha supplied from a 186km long canal system. (b) Small scale irrigators receive 0,82 million m^3/ha from the canal. (c) Commercial irrigation is supplied with 10 million m^3/a by pumping from Clanwilliam Dam. (d) An additional 18 million m^3/a is supplied from Clanwilliam Dam as compensation water for irrigation between Clanwilliam and Bulshoek Dams.	E10G, J, K E24M E33G, H G30H	Clanwilliam Dam 143 million m^3/a (1:50 year including compensation releases but excluding the ecological Reserve) Bulshoek Barrage 12 million m^3 /a (1:50 year)	None as part of the Govt Water Scheme			Olifants/Doring River Basin Study (1998) reports.	Moderate
Klawer	4 200 people supplied in 1995. 0,5 million m^3/a in 1996/97.	0,59 million m^3/a untreated "leiwater"	E33G	Olifants River Canal Borehole 0,2 million m^3/a	Chlorination Only	- -	Klawer Municipality Klawer Municipality	Municipality Municipality	Good
Vredendal and Vanrhynsdorp	17 000 people supplied in 1995 with 2,4 million m^3/a	None	E33G E33F	Olifants River Canal	Vredendal	12	Vredendal Municipality	Municipality	Good
Lutzville	3 600 people supplied in 1995 with 0,4 million m^3/a	None	E33H	Olifants River Canal	Lutzville	3	Lutzville Municipality	Municipality	Moderate
Ebenhaezer, Strandfontein and Doringbaai	5 000 people supplied in 1995. 0,4 million m^3/a.	None	E33H G30H	Olifants River Canal	Ebenhaezer Treatment Worksand Pumpstation	2,9	West Coast District Council	West Coast District Council	Good
Namakwa Sands Mine	Mining operations and domestic 1,5 million m^3/a. Less than this used in 1995	Rehabilitation of dunes 1,3 million m^3/a. Less than this used in 1995	E33G F60D	From Olifants River Canal via a 47km long 250mm diameter pipeline	Mine Mineral Separation Plant	1,1 0,4	Namakwa Sands Mining Co	Ninham Shand Files	Moderate

OLIFANTS/DORING WATER MANAGEMENT AREA
APPENDIX E.1 : EXISTING WATER SUPPLY SCHEMES (Cont)

Scheme Name	Consumers supplied			Raw water source /yield	Water Treatment Works			Source of Data	Reliability of Data
	Urban/Domestic/Mining /Industrial	Irrigation	Catchment		Name	Capacity (Mℓ/d)	Owner		
Clanwilliam	4 400 people supplied 0,83 million m^3/year in 1995	None	E10J	Clanwilliam Dam 0,7 million m^3/year Jan Dissels River 0,8 million m^3/year	Clanwilliam	Not known	Clanwilliam Municipality	Clanwilliam Municipality	Good
Citrusdal	3 750 people supplied with 0,17 million m^3/year in1995	None	E10E	Olifants River upstream of Clanwilliam Dam.	Citrusdal	2,6	Citrusdal Municipality	Citrusdal Municipality	Good
Graafwater	1 350 people supplied 0,13 million m^3 /year in 1995 (Estimate)	None	G30G E33F	Borehole 0,2 million m^3/year	None	--	--	DWAF 1990 report	Poor
Elandsbaai	1 100 people supplied with 0,05 million m^3 /year in 1995 (Estimate)	None	G30E	2 Boreholes 0,7 million m^3/year	None	--	--	DWAF 1990 report	Poor
Lambertsbaai	4 100 people supplied with 0,8 million m^3/year in 1995	None	G30G	Well	None	--	--	DWAF 1990 report. Municipal year book	Poor
Southern Namaqualand Government Water Scheme	Bitterfontein and Nuwerus with a combined population of 1 300 people in 1995	None	F60B E33E	7 Boreholes / 0,06 million m^3/year	Bitterfontein	0,06	DWAF	Govt. White Paper H-87	Moderate
Rietpoort	1 150 people	None	F60C	2 Boreholes / 0,03 million m^3/year	None	--	--	Govt. White Paper H-87	Moderate
Loeriesfontein	1 900 people (municipality says 4 000 people	None	E31F	6 Boreholes / 0,07 million m^3/year	None	--	--	Municipality	Good
Niewoudtville	1 400 people	None	E40C	1 Boreholes / 0,5 million m^3/year	None	--	--	Ninham Shand files	Moderate
Calvinia	8 000 people requiring 0,4 million m^3/year in 1995	None	E40B	3 Boreholes / 0,13 million m^3/year Karee Dam / 0,18 million ^{m3} /year	Calvinia	Not known	Calvinian Municipality	Ninham Shand files	Moderate

OLIFANTS/DORING WATER MANAGEMENT AREA
APPENDIX E.2 : MAIN DAMS

NAME	STORAGE CAPACITY			YIELD					FULL SUPPLY SURFACE AREA ($km)^2$	CATCHMENT	CO-ORDINATES		RELIABILITY OF DATA
	DEAD (10^6m^3)	LIVE (10^6m^3)	TOTAL (10^6m^3)	DOMESTIC SUPPLIES (10^6m^3)	IRRIGATION (10^6m^3)	OTHER (10^6m^3)	SURPLUS (10^6m^3)	TOTAL (10^6m^3)			LAT.	LONG.	
Clanwilliam Dam	2,5	121,8	124,3	7,6	130,8	3,6	0	142,0	11,04	E10J	32°11'05"	18°52'30"	High
Bulshoek Barrage	0,6	5,7	6,3	0	12,0	0	0	12,0	1,8	E10K	31°59'45"	18°47'15"	High
Oudekraal Dam	0	34,0	34,0	0	Not known	0	Not known	Not known	8,0	E23F	32°23'	19°54'	Poor

1. Yields of Clanwilliam and Bulshoek are historical firm yields from DWAF (1990a).
2. The storage capacity of Bulshoek was not taken into account in the analysis because it is operated near full supply capacity in order to divert water into the irrigation canal. The natural runoff to Bulshoek from catchments below Clanwilliam Dam is 74,6 x 10^6m^3 /a.
3. The historical firm yield of Bulshoek and Clanwilliam combined, after subtracting compensation releases for irrigators between Clanwilliam and Bulshoek was calculated (DWAF, 1992) to be 136 x 10^6m^3 /a.
4. The 1:50 year yield of Bulshoek and Clanwilliam combined, after subtracting compensation releases from Clanwilliam, was calculated (DWAF, 1992) to be 137 x 10^6m^3 /a.
5. The allocation shown under "other" for Clanwilliam is for mining and industry.
6. Data on Oudekraal Dam are from WR90.
7. Capacity and surface area data for Clanwilliam and Bulshoek are from the DWAF list of hydrological gauging stations, July 1990.

Data Sources :

- DWAF (1990a) Olifants River System Analysis: Yield Analysis of Area Upstream of Bulshoek Dam. BKS Consulting Engineers.
- DWAF (1992) Olifants River System Analysis: Operating Tule determination by use of stochastic hydrology. Ninham Shand in association with BKS.
- WR90: The Surface Water Resources of South Africa, 1990. Report to the Water Research Commission by Midgley et al. 1994.

OLIFANTS-DORING WATER MANAGEMENT AREA
APPENDIX E.3
FARM DAM DATA
PER QUATERNARY CATCHMENT

Quaternary catchment	oDlSi	aDMli	oDlEo	Quaternary catchment	oDlSi	aDMli	oDlEo
	Full supply capacity	Full supply area	Evaporation Losses		Full supply capacity	Full supply area	Evaporation Losses
	million m^3	km^2	million m^3/a		million m^3	km^2	million m^3/a
E10A	4.68	1.5	1.124	**E24G**	0	0	0
E10B	17.95	3.45	3.042	**E24H**	0	0	0
E10C	0.53	0.15	0.1429	**E24J**	0.13	0.06	0.08038
E10D	0	0	0	**E24K**	0	0	0
E10E	3.1	0.52	0.5687	**E24L**	0.58	0.18	0.224
E10F	7.54	1.69	1.834	**E24M**	0.35	0.13	0.1695
E10G	3.21	0.65	0.7129	**E31A**	0	0	0
E10H	0	0	0	**E31B**	0	0	0
E10J	0	0	0	**E31C**	0	0	0
E10K	0	0	0	**E31D**	0	0	0
E21A	21.43	4.72	4.55	**E31E**	0	0	0
E21B	0.56	0.2	0.214	**E31F**	0	0	0
E21C	3.88	2.99	3.218	**E31G**	0	0	0
E21D	26.3	7.3	6.957	**E31H**	0.11	0.05	0.08025
E21E	6.13	3.34	3.848	**E32A**	0.32	0.08	0.1237
E21F	0.22	0.1	0.1208	**E32B**	0	0	0
E21G	17.09	7.46	7.914	**E32C**	0	0	0
E21H	5.88	1.22	1.342	**E32D**	0	0	0
E21J	0	0	0	**E32E**	0.21	0.09	0.1356
E21K	0	0	0	**E33A**	0	0	0
E21L	0	0	0	**E33B**	0	0	0
E22A	5.61	1.07	0.763	**E33C**	0	0	0
E22B	0.25	0.03	0.04249	**E33D**	0	0	0
E22C	0.93	0.17	0.2035	**E33E**	0	0	0
E22D	0	0	0	**E33F**	0	0	0
E22E	0	0	0	**E33G**	0.24	0.07	0.09284
E22F	0	0	0	**E33H**	0	0	0
E22G	0	0	0	**E40A**	2.03	0.92	1.338
E23A	0.23	0.12	0.1709	**E40B**	1.8	0.65	0.9417
E23B	0	0	0	**E40C**	0	0	0
E23C	2.28	0.66	0.9355	**E40D**	0	0	0
E23D	0.2	0.06	0.08559	**F60A**	0.15	0.03	0.04306
E23E	0.37	0.07	0.0952	**F60B**	0	0	0
E23F	34	8	11.6	**F60C**	0	0	0
E23G	0	0	0	**F60D**	0	0	0
E23H	0	0	0	**F60E**	0	0	0
E23J	0	0	0	**G30A**	0	0	0
E23K	0	0	0	**G30B**	2.32	0.47	0.5096
E24A	0	0	0	**G30C**	0.17	0.06	0.06404
E24B	0	0	0	**G30D**	0.65	0.16	0.1679
E24C	0.2	0.13	0.1837	**G30E**	0	0	0
E24D	0	0	0	**G30F**	0.16	0.03	0.03375
E24E	1.15	0.64	0.9274	**G30G**	0	0	0
E24F	0.1	0.01	0	**G30H**	0	0	0
				Totals	173.04	49.23	54.5999

APPENDIX F

WATER REQUIREMENTS

APPENDIX F.1	**Urban water requirements per quaternary catchment.**
APPENDIX F.2	**Rural water requirements per quaternary catchment.**
APPENDIX F.3	**Bulk water requirements per quaternary catchment.**
APPENDIX F.4	**Irrigation water requirements per quaternary catchment.**
APPENDIX F.5	**Streamflow reduction activity water requirements per quaternary catchment.**
APPENDIX F.6	**Notes on proceedings of the workshops on ecological flow requirements.**
APPENDIX F.7	**Assumed rural domestic per capita water requirements.**

OLIFANTS-DORING WATER MANAGEMENT AREA

APPENDIX F.1

URBAN WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	fNUIi	fUBLi	gUIRo	gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo	oUTFo	oUTLo
	Distribution loss factor	Bulk loss factor	Indirect urban use	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Indirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	Number	mill m^3/a	mill m^3/a	mill m^3/a	mill m^3/a	mill m^3/a
E10A		0.05	0	0	0	0	0	0	0	0	0
E10B		0.05	0	0	0	0	0	0	0	0	0
E10C		0.05	0	0	0	0	0	0	0	0	0
E10D		0.05	0	0	0	0	0	0	0	0	0
E10E	0.05	0.05	0.227	1.070	0	3750	0.583	0.227	0.490	0.490	0.260
E10F		0.05	0	0	0	0	0	0	0	0	0
E10G		0.05	0	0	0	0	0	0	0	0	0
E10H		0.05	0	0	0	0	0	0	0	0	0
E10J	0.05	0.05	0.244	1.160	0	4400	0.656	0.244	0.530	0.530	0.260
E10K		0.05	0	0	0	0	0	0	0	0	0
E21A		0.05	0	0	0	0	0	0	0	0	0
E21B		0.05	0	0	0	0	0	0	0	0	0
E21C		0.05	0	0	0	0	0	0	0	0	0
E21D		0.05	0	0	0	0	0	0	0	0	0
E21E		0.05	0	0	0	0	0	0	0	0	0
E21F		0.05	0	0	0	0	0	0	0	0	0
E21G		0.05	0	0	0	0	0	0	0	0	0
E21H		0.05	0	0	0	0	0	0	0	0	0
E21J		0.05	0	0	0	0	0	0	0	0	0
E21K		0.05	0	0	0	0	0	0	0	0	0
E21L		0.05	0	0	0	0	0	0	0	0	0
E22A		0.05	0	0	0	0	0	0	0	0	0
E22B		0.05	0	0	0	0	0	0	0	0	0
E22C		0.05	0	0	0	0	0	0	0	0	0
E22D		0.05	0	0	0	0	0	0	0	0	0
E22E		0.05	0	0	0	0	0	0	0	0	0
E22F		0.05	0	0	0	0	0	0	0	0	0
E22G		0.05	0	0	0	0	0	0	0	0	0

Areas	fNUIi	fUBLi	gUIRo	gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo	oUTFo	oUTLo
	Distribution loss factor	Bulk loss factor	Indirect urban use	Total urban water use	Increased runoff due to urban areas	Urban population	Direct urban use	Indirect urban use	Total return flows	Return flows generated in the catchment	Total losses
	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	Number	mill m^3/a	mill m^3/a	mill m^3/a	mill m^3/a	mill m^3/a
E23A		0.05	0	0	0	0	0	0	0	0	0
E23B		0.05	0	0	0	0	0	0	0	0	0
E23C		0.05	0	0	0	0	0	0	0	0	0
E23D		0.05	0	0	0	0	0	0	0	0	0
E23E		0.05	0	0	0	0	0	0	0	0	0
E23F		0.05	0	0	0	0	0	0	0	0	0
E23G		0.05	0	0	0	0	0	0	0	0	0
E23H		0.05	0	0	0	0	0	0	0	0	0
E23J		0.05	0	0	0	0	0	0	0	0	0
E23K		0.05	0	0	0	0	0	0	0	0	0
E24A		0.05	0	0	0	0	0	0	0	0	0
E24B		0.05	0	0	0	0	0	0	0	0	0
E24C		0.05	0	0	0	0	0	0	0	0	0
E24D		0.05	0	0	0	0	0	0	0	0	0
E24E		0.05	0	0	0	0	0	0	0	0	0
E24F		0.05	0	0	0	0	0	0	0	0	0
E24G		0.05	0	0	0	0	0	0	0	0	0
E24H		0.05	0	0	0	0	0	0	0	0	0
E24J		0.05	0	0	0	0	0	0	0	0	0
E24K		0.05	0	0	0	0	0	0	0	0	0
E24L		0.05	0	0	0	0	0	0	0	0	0
E24M		0.05	0	0	0	0	0	0	0	0	0
E31A		0.05	0	0	0	0	0	0	0	0	0
E31B	0.20	0.10	0.035	0.168	0	1900	0.091	0.035	0.061	0.061	0.042
E31C		0.05	0	0	0	0	0	0	0	0	0
E31D		0.05	0	0	0	0	0	0	0	0	0
E31E		0.05	0	0	0	0	0	0	0	0	0
E31F		0.05	0	0	0	0	0	0	0	0	0
E31G		0.05	0	0	0	0	0	0	0	0	0
E31H		0.05	0	0	0	0	0	0	0	0	0
E32A		0.05	0	0	0	0	0	0	0	0	0

Areas	fNUIi	fUBLi	gUIRo	gUTRo	oNUQo	oPOPi	oUDRo	oUIRi	oURFo	oUTFo	oUTLo
	Distribution loss factor	**Bulk loss factor**	**Indirect urban use**	**Total urban water use**	**Increased runoff due to urban areas**	**Urban population**	**Direct urban use**	**Indirect urban use**	**Total return flows**	**Return flows generated in the catchment**	**Total losses**
	Factor	**Factor**	**million m^3/a**	**million m^3/a**	**million m^3/a**	**Number**	**mill m^3/a**	**mill m^3/a**	**mill m^3/a**	**mill m^3/a**	**mill m^3/a**
E32B		0.05	0	0	0	0	0	0	0	0	0
E32C		0.05	0	0	0	0	0	0	0	0	0
E32D		0.05	0	0	0	0	0	0	0	0	0
E32E		0.05	0	0	0	0	0	0	0	0	0
E33A		0.05	0	0	0	0	0	0	0	0	0
E33B		0.05	0	0	0	0	0	0	0	0	0
E33C		0.05	0	0	0	0	0	0	0	0	0
E33D		0.05	0	0	0	0	0	0	0	0	0
E33E		0.05	0	0	0	0	0	0	0	0	0
E33F	0.05	0.20	0.244	1.160	0	3850	0.606	0.244	0.530	0.530	0.310
E33G	0.05	0.20	0.740	3.500	0	14900	1.820	0.740	1.610	1.610	0.940
E33H	0.05	0.20	0.289	1.360	0	2550	0.711	0.289	0.620	0.620	0.360
E40A		0.05	0	0	0	0	0	0	0	0	0
E40B	0.20	0.10	0.116	0.560	0	7150	0.304	0.116	0.213	0.213	0.140
E40C	0.20	0.10	0.018	0.087	0	1000	0.047	0.018	0.030	0.030	0.022
E40D		0.05	0	0	0	0	0	0	0	0	0
F60A	0.05	0.20	0.003	0.017	0	200	0.009	0.003	0.006	0.006	0.004
F60B	0.05	0.20	0.020	0.095	0	1300	0.051	0.020	0.032	0.032	0.024
F60C	0.05	0.20	0.012	0.061	0	1150	0.033	0.012	0.023	0.023	0.015
F60D		0.05	0	0	0	0	0	0	0		0
F60E		0.05	0	0	0	0	0	0	0		0
G30A	0.05	0.20	0.038	0.180	0	1650	0.097	0.038	0.077	0.077	0.045
G30B		0.05	0	0	0	0	0	0	0	0	0
G30C		0.05	0	0	0	0	0	0	0	0	0
G30D		0.05	0	0	0	0	0	0	0	0	0
G30E		0.05	0	0	0	0	0	0	0	0	0
G30F	0.05	0.20	0.007	0.032	0	300	0.017	0.007	0.015	0.015	0.008
G30G	0.05	0.20	0.168	0.635	0	5450	0.309	0.168	0.289	0.289	0.159
G30H		0.05	0	0	0	0	0.000	0.000	0	0	0
Totals	1.15	5.90	2.16	10.08	0.0	49550.0	5.34	2.16	4.53	4.53	2.59

OLIFANTS-DORING WATER MANAGEMENT AREA
APPENDIX F.2
RURAL WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	gRCRo	gRIRo	gRSRo	gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consumption rate	1:50 Year Small scale irrigation	Large stock units consumption rate	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	ℓ/c/d	million m^3/a	ℓ/u/d	mill m^3/a	Number	mill m^3/a	mill m^3/a	Number	Factor
E10A	106.5	0	45	0.067	1041	0	0	775	0.2
E10B	106.5	0	45	0.111	1942	0	0	756	0.2
E10C	106.5	0	45	0.069	962	0	0	1049	0.2
E10D	106.5	0	45	0.081	1333	0	0	754	0.2
E10E	106.5	0	45	0.097	1428	0	0	1259	0.2
E10F	106.5	0	45	0.104	1614	0	0	1190	0.2
E10G	106.5	0	45	0.087	1086	0	0	1567	0.2
E10H	106.5	0	45	0.026	312	0	0	500	0.2
E10J	106.6	0	45	0.080	1004	0	0	1444	0.2
E10K	106.6	0	45	0.350	473	0	0	701	0.2
E21A	108.9	0	45	0.091	1533	0	0	674	0.2
E21B	89.9	0	45	0.033	386	0	0	792	0.2
E21C	108.9	0	45	0.066	962	0	0	827	0.2
E21D	70.8	0	45	0.076	1758	0	0	858	0.2
E21E	108.9	0	45	0.041	372	0	0	1038	0.2
E21F	108.9	0	45	0.052	456	0	0	1343	0.2
E21G	108.9	0	45	0.136	2313	0	0	942	0.2
E21H	108.9	0	45	0.078	946	0	0	1426	0.2
E21J	108.9	0	45	0.038	307	0	0	1050	0.2
E21K	108.9	0	45	0.031	167	0	0	1018	0.2
E21L	108.9	0	45	0.013	93	0	0	368	0.2
E22A	109.9	0	45	0.051	156	0	0	1965	0.2
E22B	109.9	0	45	0.053	39	0	0	2299	0.2
E22C	109.9	0	45	0.058	385	0	0	1736	0.2
E22D	109.9	0	45	0.040	21	0	0	1758	0.2
E22E	109.9	0	45	0.093	269	0	0	3593	0.2
E22F	109.9	0	45	0.030	119	0	0	1104	0.2
E22G	109.0	0	45	0.010	75	0	0	280	0.2
E23A	109.9	0	45	0.008	154	0	0	11	0.2
E23B	109.9	0	45	0.005	106	0	0	2	0.2
E23C	109.9	0	45	0.003	40	0	0	30	0.2
E23D	109.9	0	45	0.023	105	0	0	822	0.2
E23E	109.9	0	45	0.022	257	0	0	403	0.2
E23F	109.9	0	45	0.018	66	0	0	657	0.2
E23G	109.9	0	45	0.062	57	0	0	2647	0.2
E23H	109.9	0	45	0.054	60	0	0	2310	0.2
E23J	109.9	0	45	0.076	131	0	0	3131	0.2
E23K	109.9	0	45	0.007	77	0	0	163	0.2
E24A	48.4	0	45	0.024	316	0	0	785	0.2
E24B	109.9	0	45	0.061	647	0	0	1274	0.2
E24C	109.9	0	45	0.014	269	0	0	0	0.2
E24D	109.9	0	45	0.013	255	0	0	0	0.2
E24E	109.9	0	45	0.015	303	0	0	0	0.2
E24F	109.9	0	45	0.011	218	0	0	0	0.2
E24G	109.9	0	45	0.008	150	0	0	0	0.2

Areas	gRCRo	gRIRo	gRSRo	gRURo	oPORi	oRIRo	oRRFo	oRSUi	oRTLi
	Rural water consumption rate	1:50 Year Small scale irrigation	Large stock units consumption rate	Total rural water use	Rural population	Small scale irrigation	Rural return flow	Number of large stock units	Rural loss factor
	ℓ/c/d	million m^3/a	ℓ/u/d	mill m^3/a	Number	mill m^3/a	mill m^3/a	Number	Factor
E24H	109.2	0	45	0.023	167	0	0	671	0.2
E24J	101.6	0	45	0.086	654	0	0	2540	0.2
E24K	109.2	0	45	0.015	278	0	0	71	0.2
E24L	109.3	0	45	0.068	661	0	0	1585	0.2
E24M	109.3	0	45	0.059	616	0	0	1281	0.2
E31A	109.9	0	45	0.003	57	0	0	0	0.2
E31B	109.9	0	45	0.007	132	0	0	0	0.2
E31C	109.9	0	45	0.004	87	0	0	0	0.2
E31D	109.9	0	45	0.002	40	0	0	0	0.2
E31E	109.9	0	45	0.002	34	0	0	0	0.2
E31F	109.9	0	45	0.004	78	0	0	0	0.2
E31G	109.9	0	45	0.006	35	0	0	208	0.2
E31H	109.9	0	45	0.010	124	0	0	185	0.2
E32A	109.9	0	45	0.012	246	0	0	0	0.2
E32B	109.9	0	45	0.009	171	0	0	0	0.2
E32C	109.9	0	45	0.010	205	0	0	0	0.2
E32D	109.9	0	45	0.006	116	0	0	0	0.2
E32E	102.2	0	45	0.011	233	0	0	2	0.2
E33A	56.0	0	45	0.056	201	0	0	2274	0.2
E33B	109.9	0	45	0.032	62	0	0	1302	0.2
E33C	71.4	0	45	0.044	162	0	0	1732	0.2
E33D	109.9	0	45	0.071	109	0	0	2966	0.2
E33E	109.9	0	45	0.112	1086	0	0	2599	0.2
E33F	109.9	0	45	0.046	309	0	0	1379	0.2
E33G	107.8	0.33	45	4.370	6071	0.37	0	1923	0.2
E33H	70.1	0.33	45	2.824	3989	0.37	0	1711	0.2
E40A	109.9	0	45	0.016	325	0	0	0	0.2
E40B	109.9	0	45	0.015	289	0	0	0	0.2
E40C	109.9	0	45	0.010	177	0	0	36	0.2
E40D	109.9	0	45	0.024	245	0	0	506	0.2
F60A	51.0	0	45	0.022	325	0	0	600	0.2
F60B	113.4	0	45	0.016	26	0	0	639	0.2
F60C	113.4	0	45	0.056	562	0	0	1183	0.2
F60D	113.4	0	45	0.027	49	0	0	1067	0.2
F60E	113.4	0	45	0.043	0	0	0	1885	0.2
G30A	112.4	0	45	0.279	689	0	0	10790	0.2
G30B	108.1	0	45	0.319	2409	0	0	9137	0.2
G30C	85.4	0	45	0.071	893	0	0	1654	0.2
G30D	108.9	0	45	0.230	1254	0	0	7623	0.2
G30E	109.1	0	45	0.131	468	0	0	4906	0.2
G30F	112.4	0	45	0.128	1204	0	0	2944	0.2
G30G	112.4	0	45	0.100	1074	0	0	1973	0.2
G30H	57.3	0	45	0.152	3472	0	0	2686	0.2
Totals	9235.9	0.7	3960.0	12.0	54147.2	0.7	0.0	115359.0	17.6

OLIFANTS-DORING WATER MANAGEMENT AREA
APPENDIX F.3
BULK WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Areas	fBMFi	fBMLi	fBOFi	fBOLi	fBSFi	fBSLi	gBMRo	gBORo	gBSRo	oBMFo	oBMGi	oBMRi	oBOFo	oBOOi	oBSFo	oBSRi
	Return flow factor (mining)	Loss factor (mining)	Return flow factor (other)	Loss factor (other)	Return flow factor (strategic)	Loss factor (strategic)	Mining water use	Other water use	Strategic water use	Return flow (mining)	Ground-water decant/ mine de-watering	On-site water use (mining)	Return flow (other)	On-site water use (other)	Return flow (strategic)	On-site water use (strategic)
	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a
E10A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E10K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E21L	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E22A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E22B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E22C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E22D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E22E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E22F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E22G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0

Areas	fBMFi	fBMLi	fBOFi	fBOLi	fBSFi	fBSLi	gBMRo	gBORo	gBSRo	oBMFo	oBMGi	oBMRi	oBOFo	oBOOi	oBSFo	oBSRi
	Return flow factor (mining)	Loss factor (mining)	Return flow factor (other)	Loss factor (other)	Return flow factor (strategic)	Loss factor (strategic)	Mining water use	Other water use	Strategic water use	Return flow (mining)	Ground-water decant/ mine de-watering	On-site water use (mining)	Return flow (other)	On-site water use (other)	Return flow (strategic)	On-site water use (strategic)
	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a
E23D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E23K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24J	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24K	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24L	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E24M	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E31A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E31B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E31C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E31D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E31E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E31F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E31G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E31H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E32A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E32B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E32C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E32D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E32E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E33A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E33B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0

Areas	fBMFi	fBMLi	fBOFi	fBOLi	fBSFi	fBSLi	gBMRo	gBORo	gBSRo	oBMFo	oBMGi	oBMRi	oBOFo	oBOOi	oBSFo	oBSRi
	Return flow factor (mining)	Loss factor (mining)	Return flow factor (other)	Loss factor (other)	Return flow factor (strategic)	Loss factor (strategic)	Mining water use	Other water use	Strategic water use	Return flow (mining)	Ground-water decant/ mine de-watering	On-site water use (mining)	Return flow (other)	On-site water use (other)	Return flow (strategic)	On-site water use (strategic)
	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a	million m^3/a
E33C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E33D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E33E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E33F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E33G	0	0.1	0	0.1	0	0.05	1.51	0.28	0	0	0	1.1	0	0.2	0	0
E33H	0	0.1	0	0.1	0	0.05	0.55	0.28	0	0	0	0.4	0	0.2	0	0
E40A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E40B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E40C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
E40D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
F60A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
F60B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
F60C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
F60D	0	0.1	0	0.1	0	0.05	1.53	0	0	0	0	1.1	0	0	0	0
F60E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G30A	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G30B	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G30C	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G30D	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G30E	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G30F	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G30G	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
G30H	0	0.1	0	0.1	0	0.05	0	0	0	0	0	0	0	0	0	0
Totals							3.59	0.56	0	0	0	2.6	0	0.4	0	0

OLIFANTS-DORING WATER MANAGEMENT AREA

APPENDIX F.4

IRRIGATION WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Quaternary catchment	aIHAi	aILAi	aIMAi	aISAi	fIHCi	fILCi	fIMCi	fIPHi	fIPLi	fIPMi	gIARo
	Area under high category crops	Area under low category crops	Area under medium category crops	Field area irrigated	Conveyance losses for high category crops	Conveyance losses for low category crops	Conveyance losses for medium category crops	Application efficiency for high category crops	Application efficiency for low category crops	Application efficiency for medium category crops	Total water use by irrigators
	km^2	km2	km2	km2	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a
E10A	12.560	0	0	12.560	0.05	0.05	0.05	0.850	0	0	10.755
E10B	3.011	0	7.735	10.750	0.05	0.05	0.05	0.850	0	0.75	8.974
E10C	4.031	0	0.048	4.078	0.05	0.05	0.05	0.834	0	0.75	4.932
E10D	8.140	0	0	8.140	0.05	0.05	0.05	0.750	0	0	9.842
E10E	19.980	0	0	19.980	0.05	0.05	0.05	0.850	0	0	24.230
E10F	19.560	0	0	19.560	0.05	0.05	0.05	0.750	0	0	23.720
E10G	0	0	6.320	6.320	0.05	0.05	0.05	0	0	0.75	7.391
E10H	1.470	0	0	1.470	0.10	0.10	0.10	0.759	0	0.75	1.857
E10J	4.730	0	10.300	15.030	0.10	0.10	0.10	0.751	0	0.75	18.842
E10K	8.800	0	0	8.800	0.28	0.28	0.28	0.769	0	0.75	12.272
E21A	11.330	0	0	11.330	0.05	0.05	0.05	0.850	0	0	9.347
E21B	2.860	0	0	2.860	0.05	0.05	0.05	0.850	0	0	2.359
E21C	2.260	0	0	2.260	0.05	0.05	0.05	0.850	0	0	1.865
E21D	27.900	0	0.400	28.160	0.05	0.05	0.05	0.850	0	0.75	23.800
E21E	0	0	10.360	10.360	0.05	0.05	0.05	0	0	0.75	5.421
E21F	0	0	1.030	1.030	0.05	0.05	0.05	0	0	0.75	0.539
E21G	25.040	0	0	25.040	0.05	0.05	0.05	0	0	0.75	19.657
E21H	0	0	3.710	3.710	0.05	0.05	0.05	0	0	0.75	1.942
E21J	0	0	0	0	0.05	0.05	0.05	0	0	0	0
E21K	0.740	0	0.500	1.240	0.05	0.05	0.05	0.818	0	0.75	0.871
E21L	0	0	0	0	0.05	0.05	0.05	0	0	0	0
E22A	0	0.500	0	0.100	0.10	0.10	0.10	0	0.75	0.75	0.293
E22B	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E22C	0	0.480	0	1.300	0.10	0.10	0.10	0	0.75	0	0.279
E22D	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E22E	0	0	0.800	2.500	0.10	0.10	0.10	0	0	0.75	0.495
E22F	0	0	0	0.000	0.10	0.10	0.10	0	0	0	0.000
E22G	0	0	0.490	1.600	0.10	0.10	0.10	0	0	0.75	0.312

Quaternary catchment	aIHAi	aILAi	aIMAi	aISAi	fIHCi	fILCi	fIMCi	fIPHi	fIPLi	fIPMi	gIARo
	Area under high category crops	Area under low category crops	Area under medium category crops	Field area irrigated	Conveyance losses for high category crops	Conveyance losses for low category crops	Conveyance losses for medium category crops	Application efficiency for high category crops	Application efficiency for low category crops	Application efficiency for medium category crops	Total water use by irrigators
	km^2	km2	km2	km2	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a
E23A	0	0	0.100	0.255	0.10	0.10	0.10	0	0	0.75	0.062
E23B	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E23C	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E23D	0	0	0.330	0.487	0.10	0.10	0.10	0	0	0.75	0.204
E23E	0	0	0.800	1.252	0.10	0.10	0.10	0	0	0.75	0.495
E23F	0	0	1.000	1.510	0.10	0.10	0.10	0	0	0.75	0.619
E23G	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E23H	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E23J	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E23K	0	0	0.350	0.500	0.10	0.10	0.10	0	0	0.75	0.217
E24A	0	0	0.380	0.570	0.10	0.10	0.10	0	0	0.75	0.235
E24B	0	0	0.510	0.760	0.10	0.10	0.10	0	0	0.75	0.316
E24C	0	0	0.600	0.900	0.10	0.10	0.10	0	0	0.75	0.371
E24D	0	0	0.480	0.720	0.10	0.10	0.10	0	0	0.75	0.297
E24E	0	0	0.120	0.180	0.10	0.10	0.10	0	0	0.75	0.074
E24F	0	0	0.580	0.860	0.10	0.10	0.10	0	0	0.75	0.359
E24G	0	0	0.100	0.150	0.10	0.10	0.10	0	0	0.75	0.062
E24H	0	0	0.720	1.080	0.10	0.10	0.10	0	0	0.75	0.456
E24J	0	0	2.600	4.100	0.10	0.10	0.10	0	0	0.75	1.646
E24K	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E24L	0	0	4.000	5.980	0.10	0.10	0.10	0	0.75	0.75	2.507
E24M	0	0	0.500	0.740	0.28	0.28	0.28	0.750	0	0	0.609
E31A	0	0	0	0	0	0	0	0	0	0	0
E31B	0	0	0	0	0	0	0	0	0	0	0
E31C	0	0	0	0	0	0	0	0	0	0	0
E31D	0	0	0	0	0	0	0	0	0	0	0
E31E	0	0	0	0	0	0	0	0	0	0	0
E31F	0	0	0	0	0	0	0	0	0	0	0
E31G	0	0	0	0	0	0	0	0	0	0	0
E31H	0	0	0	0	0	0	0	0	0	0	0
E32A	0	0.100	0.270	0.730	0	0	0	0	0.75	0.75	0.205

Quaternary catchment	aIHAi	aILAi	aIMAi	aISAi	fIHCi	fILCi	fIMCi	fIPHi	fIPLi	fIPMi	gIARo
	Area under high category crops	Area under low category crops	Area under medium category crops	Field area irrigated	Conveyance losses for high category crops	Conveyance losses for low category crops	Conveyance losses for medium category crops	Application efficiency for high category crops	Application efficiency for low category crops	Application efficiency for medium category crops	Total water use by irrigators
	km^2	km2	km2	km2	Factor	Factor	Factor	Factor	Factor	Factor	million m^3/a
E32B	0	0.130	0.370	1.020	0	0	0	0	0.75	0.75	0.277
E32C	0	0	0	0	0	0	0	0	0	0	0
E32D	0	0	0	0	0	0	0	0	0	0	0
E32E	0	0.140	0.360	1.000	0	0	0	0	0.75	0.75	0.277
E33A	0	0	0	0	0	0	0	0	0	0	0
E33B	0	0	0	0	0	0	0	0	0	0	0
E33C	0	0	0.800	1.600	0	0	0	0	0	0.75	0.450
E33D	0	0.010	0	0	0	0	0	0.750	0.75	0.75	0.005
E33E	0.200	0	0	0.400	0	0	0	0.750	0	0	0.119
E33F	0	2.720	0.100	5.230	0	0	0	0.750	0.75	0.75	1.370
E33G	71.010	0	0	71.010	0.28	0.28	0.28	0.750	0	0	93.652
E33H	33.470	0	0	33.470	0.28	0.28	0.28	0.750	0	0	44.115
E40A	4.170	0	0	4.170	0.10	0.10	0.10	0.750	0	0	2.737
E40B	0.390	0	0	0.390	0.10	0.10	0.10	0.750	0	0	0.256
E40C	0	0	0	0	0.10	0.10	0.10	0	0	0	0
E40D	0	0	0	0	0.10	0.10	0.10	0	0	0	0
F60A	0	0	0	0	0	0	0	0	0	0	0
F60B	0	0	0	0	0	0	0	0	0	0	0
F60C	0	0	0	0	0	0	0	0	0	0	0
F60D	0	0	0	0	0	0	0	0	0	0	0
F60E	0	0	0	0	0	0	0	0	0	0	0
G30A	0	0	8.400	16.750	0	0	0	0	0.75	0.75	5.040
G30B	0	0	3.280	6.560	0	0	0	0.754	0.75	0	1.968
G30C	3.270	0	8.600	20.470	0	0	0	0.850	0.75	0.75	8.103
G30D	1.350	0	15.500	32.350	0	0	0	0.850	0.75	0.75	10.515
G30E	0	0	6.600	13.240	0	0	0	0	0.75	0.75	3.960
G30F	0	0	15.700	31.530	0	0	0	0	0	0.75	9.420
G30G	4.300	0	2.850	9.040	0	0	0	0.750	0	0.75	5.580
G30H	0	0	0	0	0	0	0	0.750	0	0.75	0
Totals	386.573	4.080	117.693	467.182							386.573

OLIFANTS-DORING WATER MANAGEMENT AREA

APPENDIX F.5

STREAMFLOW REDUCTION ACTIVITY (SFRA) WATER REQUIREMENTS PER QUATERNARY CATCHMENT

Quaternary catchment	aAAAi	aCAUi	aFCAi	aFINi	oARDo	oCRDo	oFRDo	vRTLi
	Area under alien vegetation	Area under dryland sugar cane	Area under afforestation	Area of indigenous forests	Reduction in runoff due to alien vegetation	Reduction in runoff due to dryland sugar cane	Reduction in runoff due to afforestation	River losses
	km^2	km^2	km^2	km^2	million m^3/a	million m^3/a	million m^3/a	million m^3/a
E10A	0.721	0	2.187	0	0.249	0	0.479	0
E10B	0.192	0	0.756	0	0.040	0	0.054	0
E10C	0.841	0	0.873	0	0.167	0	0.098	0
E10D	0.477	0	0	0	0.119	0	0	0
E10E	0.206	0	0	0	0.035	0	0	0
E10F	0.092	0	0	0	0.016	0	0	0
E10G	0.868	0	3.851	0	0.148	0	0.622	0
E10H	0.135	0	0	0	0.034	0	0	0
E10J	0.234	0	0	0	0.024	0	0	0
E10K	1.066	0	0	0	0.023	0	0	0
E21A	0.227	0	0.363	0	0.043	0	0.062	0
E21B	0.104	0	0.107	0	0.014	0	0.013	0
E21C	0.405	0	1.758	0	0.049	0	0.160	0
E21D	0.066	0	0	0	0.013	0	0	0
E21E	0.076	0	0	0	0.006	0	0	0
E21F	0.134	0	0	0	0.009	0	0	0
E21G	0.004	0	0.108	0	0.001	0	0.008	0
E21H	0.853	0	0	0	0.094	0	0	0
E21J	0.261	0	0	0	0.019	0	0	0
E21K	0.104	0	0	0	0.009	0	0	0
E21L	0.031	0	0	0	0.001	0	0	0
E22A	0.000	0	0	0	0.000	0	0	0
E22B	0.000	0	0	0	0.000	0	0	0
E22C	0.000	0	0	0	0.000	0	0	0
E22D	0.000	0	0	0	0.000	0	0	0
E22E	0.000	0	0	0	0.000	0	0	0
E22F	0.000	0	0	0	0.000	0	0	0
E22G	0.100	0	0	0	0.001	0	0	0
E23A	0.000	0	0	0	0.000	0	0	0
E23B	0.000	0	0	0	0.000	0	0	0
E23C	0.000	0	0	0	0.000	0	0	0
E23D	0.000	0	0	0	0.000	0	0	0
E23E	0.000	0	0	0	0.000	0	0	0
E23F	0.064	0	0	0	0.000	0	0	0
E23G	0.000	0	0	0	0.000	0	0	0
E23H	0.000	0	0	0	0.000	0	0	0
E23J	0.000	0	0	0	0.000	0	0	0
E23K	0.076	0	0	0	0.001	0	0	0
E24A	0.002	0	0	0	0.000	0	0	0
E24B	0.016	0	0	0	0.001	0	0	0
E24C	0.548	0	0	0	0.017	0	0	0
E24D	0.544	0	0	0	0.013	0	0	0
E24E	0.000	0	0	0	0.000	0	0	0
E24F	0.000	0	0	0	0.000	0	0	0
E24G	0.007	0	0	0	0.000	0	0	0

Quaternary catchment	aAAAi Area under alien vegetation km²	aCAUi Area under dryland sugar cane km²	aFCAi Area under afforestation km²	aFINi Area of indigenous forests km²	oARDo Reduction in runoff due to alien vegetation million m³/a	oCRDo Reduction in runoff due to dryland sugar cane million m³/a	oFRDo Reduction in runoff due to afforestation million m³/a	vRTLi River losses million m³/a
E24H	0.084	0	0	0	0.002	0	0	0
E24J	0.113	0	0	0	0.004	0	0	0
E24K	0.008	0	0	0	0.000	0	0	0
E24L	0.019	0	0	0	0.001	0	0	0
E24M	0.210	0	0	0	0.006	0	0	0
E31A	0.000	0	0	0	0.000	0	0	0
E31B	0.000	0	0	0	0.000	0	0	0
E31C	0.079	0	0	0	0.001	0	0	0
E31D	0.288	0	0	0	0.002	0	0	0
E31E	0.263	0	0	0	0.003	0	0	0
E31F	0.209	0	0	0	0.003	0	0	0
E31G	0.000	0	0	0	0.000	0	0	0
E31H	0.237	0	0	0	0.003	0	0	0
E32A	0.000	0	0	0	0.000	0	0	0
E32B	0.000	0	0	0	0.000	0	0	0
E32C	0.016	0	0	0	0.000	0	0	0
E32D	0.006	0	0	0	0.000	0	0	0
E32E	0.023	0	0	0	0.000	0	0	0
E33A	0.041	0	0	0	0.000	0	0	0
E33B	0.000	0	0	0	0.000	0	0	0
E33C	0.236	0	0	0	0.002	0	0	0
E33D	0.000	0	0	0	0.000	0	0	0
E33E	0.205	0	0	0	0.001	0	0	0
E33F	3.574	0	0	0	0.020	0	0	0
E33G	9.542	0	0	0	0.096	0	0	0
E33H	8.813	0	0	0	0.052	0	0	0
E40A	0.096	0	0	0	0.002	0	0	0
E40B	0.556	0	0	0	0.013	0	0	0
E40C	2.039	0	0	0	0.030	0	0	0
E40D	0.000	0	0	0	0.000	0	0	0
F60A	14.490	0	0	0	0.073	0	0	0
F60B	0.895	0	0	0	0.004	0	0	0
F60C	2.723	0	0	0	0.012	0	0	0
F60D	3.503	0	0	0	0.015	0	0	0
F60E	9.831	0	0	0	0.064	0	0	0
G30A	17.610	0	0	0	0.478	0	0	0
G30B	6.825	0	0	0	0.374	0	0	0
G30C	0.103	0	0	0	0.005	0	0	0
G30D	12.300	0	0	0	0.445	0	0	0
G30E	6.301	0	0	0	0.084	0	0	0
G30F	10.080	0	0	0	0.246	0	0	0
G30G	7.860	0	0	0	0.108	0	0	0
G30H	0	0	0	0	0.084	0	0	0
Totals	127.632	0.000	10.002	0.000	3.376	0.000	1.495	0.000

APPENDIX F.6

WESTERN CAPE WATER RESOURCES SITUATION ASSESSMENT

WORKSHOP ON ECOLOGICAL FLOW REQUIREMENTS PHASE 2:

NOTES ON PROCEEDINGS

Prepared for

THE DEPARTMENT OF WATER AFFAIRS AND FORESTRY
Directorate: Water Resources Planning

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Report No. 2949b/ 7970

April 2000

WESTERN CAPE WATER RESOURCES SITUATION ASSESSMENT

WORKSHOP ON ECOLOGICAL FLOW REQUIREMENTS PHASE 2: NOTES ON PROCEEDINGS

CONTENTS

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Western Cape Water Resources Situation Assessment has been commissioned by the Directorate: Water Resources Planning, of the Department of Water Affairs and Forestry (DWAF) as one of several studies required to provide data for the development of a national water resource strategy in compliance with the provisions of the National Water Act No. 36 of 1998. A requirement of the study was that rough, desktop (i.e. based on available information) estimates of the ecological flow requirements of rivers should be made for each quaternary catchment in the study area (Ninham Shand, 1999) by a procedure prescribed by the Department (Kleynhans *et al.*, 1998). During these workshops, the Ecological Importance and Sensitivity Class (EI&SC) was determined in order to derive the Default Ecological Management Class (DEMC).

Subsequently, a second phase of workshops was commissioned to build on work done in Phase 1. In the Phase 2 workshops, the EI&SC and DEMC were reviewed and then the Present Ecological Status Class (PESC) and Attainable Ecological Status Class (AESC) of rivers within quaternary catchments were determined. This second round of workshops was therefore primarily concerned with assessing the present ecological status of rivers, as well as their potential for rehabilitation with respect to flow, and obtaining an Attainable Ecological Status Class for the rivers. Phase 2 also comprises a rough, desktop estimate, and is based on the methodology prescribed by the Department (Kleynhans, 1999 - see Annexure A). These notes are in respect of the second phase of workshops held for this purpose.

1.2 PARTICIPANTS

A two day workshop was held and a number of experts representing various disciplines relating to rivers and people knowledgeable of the Western Cape rivers were invited to attend. The workshop was held on 15 and 16 July 1999 at Ninham Shand in Cape Town and was facilitated by Mike Luger of Ninham Shand's Environmental Section. The delegates who took part in the workshop were as follows:

- Cate Brown of Southern Waters
- Rebecca Tharme of the Freshwater Research Unit at the University of Cape Town
- Charlie Boucher of Stellenbosch University's Botany Department
- Dean Impson of Cape Nature Conservation
- Wietsche Roets of Cape Nature Conservation
- Neels Kleynhans of DWAF (IWQS)
- Gareth McConkey of DWAF Water Quality Management (Western Cape Region)
- Gerrit van Zyl of DWAF (Western Cape Region)
- Jan van Staden of DWAF (Western Cape Region)
- Mike Luger of Ninham Shand
- Susie Tyson of Ninham Shand
- Liesl Nettmann of Ninham Shand

1.3 PURPOSE AND STRUCTURE OF THIS REPORT

The purpose of this report is to summarise the findings of the workshop. It contains information on the EI&SC, DEMC, PESC, and AESC of the main stem river in each quaternary catchment. In addition, during the workshop, issues and concerns were raised and these are summarised in order to convey these concerns to DWAF. Lastly, it was suggested at the workshop that participants should be given the opportunity to review the findings. Therefore, this draft report affords the participants the opportunity to review the findings by assessing the EI&SC, DEMC, PESC and AESC information contained in the figures and spreadsheet.

CHAPTER 2: METHODOLOGY

2.1 INTRODUCTION

The methodology utilised in the workshop is described in Kleynhans (1999 - see Annexure A). This methodology is summarised in Figure 2.1, which indicates the steps required in the determination of the AEMC.

The first step in the process is to determine the EI&SC. The EI&SC refers to the ecological importance and sensitivity of rivers, i.e. an expression of its importance to the maintenance of ecological diversity and functioning on a local and wider scale, as well as the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred. Once the EI&SC has been determined, this index is used as an indicator of the DEMC. For the purposes of the National Water Act, a high EI&SC should justify the assignment of a very high DEMC, as the DEMC is defined in terms of the sensitivity of a system to disturbance and the risk of damaging the system and its capacity for self-recovery. These first two steps in assessing the AEMC were undertaken during the first phase workshop and were merely reviewed during this second phase workshop.

After the EI&SC and DEMC have been determined, the PESC needs to be assessed. This PESC is based on the present habitat integrity (i.e. ecological integrity, condition and naturalness) of the system. Using the EI&SC, DEMC and PESC, the AEMC is then determined. The AEMC is then used as an input into the hydrological model of Hughes and Munster, and is indicative of the most attainable ecological management class that can be achieved for each quaternary as a result of restoring the system from the PESC. In the context of the workshop, restoration is defined as the reestablishment of the structure and function of an ecosystem, including its natural diversity within a 5 year period as a result of changing flows only (Kleynhans, 1999).

Utilisation of this methodology was essential in order to ensure a consistent approach for each of the provinces. An updated version of the previous EcoInfo programme was used to process all the data obtained about the quaternary catchments during the workshop. The programme allowed the classes to be derived immediately as the data was entered.

2.2 GROUPING OF QUATERNARY CATCHMENTS

Due to the vast number of quaternary catchments in the Western Cape, it was decided that "like" quaternary catchments would be grouped together. Those catchments which displayed similar characteristics were therefore dealt with as one catchment, and thus only one quaternary catchment for each group was entered into the EcoInfo database. Where knowledge about riverine systems was low, the systems were compared to more well known rivers and low confidence scorings were given.

The quaternary catchment groupings are listed below. Those catchments in bold and underlined contain information in the database that is relevant for all quaternary catchments within that grouping. It was decided during the second round of workshops to subdivide certain groups so as to facilitate assessment thereof. These groups are indicated in the following list.

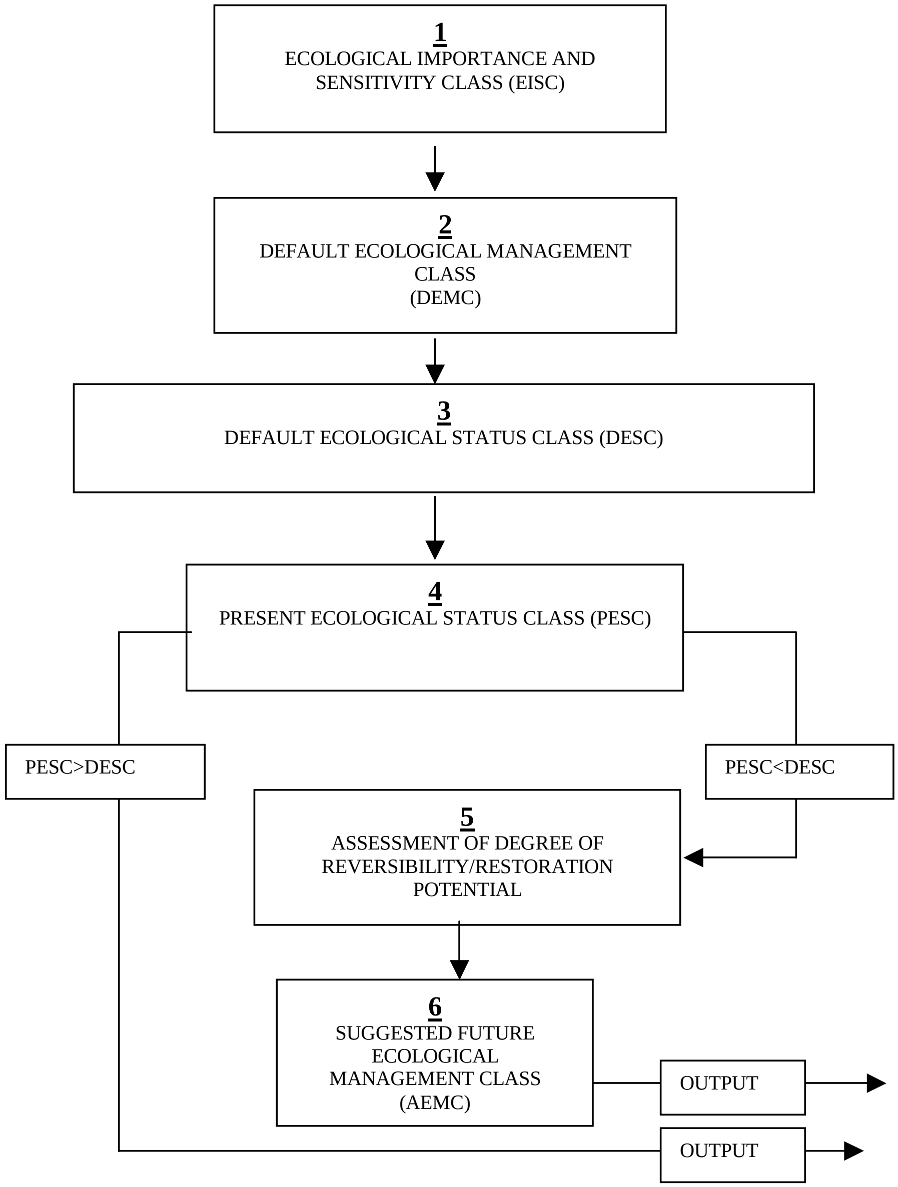


Figure 2.1: Flow Diagram indicating the sequence of steps proposed for the determination of the attainable Ecological Management Class.

- E10A, E10B
- E10C
- E10D, E10E, E10F, E10G, E10J
- E10K (gorge section and below)
- E21A, E21B, E21C, E21D
- E21E, E21F, E21G, E21H, E21J, E21K, E21L, E24A, E24B
- E22A, E22B, E22C, E22D, E22E, E22F, E23A, E23B, E23C, E23D, E23E, E23F, E23G, E23H, E23J, E23K, E24C, E24E, E24F, E24G, E24K
- E22G
- E24L, E24M, E24J, E24H
- E32A, E31B, E31C
- E33A, E33B, E33C, E33D, E31D, E31E, E31F, E31G, E31H, E32B, E32C, E32D, E32E
- E33F, E33G, E33H
- E40A, E40B
- E40C, E40D
- F60A, F60B, F60C, F60D, F60E, F40A, F40B, F40C, F40D, F40E, F40F, F40G, F40H, F50A, F50B, F50C, F50D, F50E, F50F, F50G
- G10A, G10B
- G10C
- G10D, G10F
- G10J (alone due to the presence of a downstream dam)
- G10E
- G10G

- G10L
- G10H
- G10K
- G10M (no rivers)
- G21A
- G21B
- G21D, G21C, G21E
- G21F
- G22A, G22B
- G22C, G22D
- G22E, G22G, G22H, G22J, G22K
- G22F
- G30B, G30C, G30D, G10H
- G30E, G30F, G30A
- G30G
- G30H (no rivers)
- G40A, G40B, G40D
- G40C
- G40E, G40F, G40G
- G40H, G40J, G40K, G40L
- G40M, G50A, G50B, G50C, G50D, G50E, G50F
- G50G, G50H, G50K

- G50J (no rivers)
- H10A, H10B, H10C
- H10D
- H10F, H10G
- H10E
- H10J, H10K
- H10L, H10H, H40C, H40D, H40E (mainstem of Breede River, before and after Hex River)
- H20A, H20B, H20C, H20D, H20E, H20F, H20G, H20H
- H30A, H30B
- H30E
- H40A, H40B, H30C, H30D
- H40F, H40G, H40H, H40J, H40K, H40L
- H50A, H50B, H70A
- H60A, H60B, H60C
- H60D, H60E, H60F, H60G, H60H
- H60J, H60K, H60L
- H70B, H70C, H70D, H70E, H70F
- H70G, H70H, H70J, H70K
- H80A, H80B, H80C, H90A, H90B, H90C
- H80D, H80E, H80F

- J11A, J11B, J11C, J11D, J11E, J11F, J11G, J11H, J11K, J12A, J12B, J12C, J12D, J12E, J12F, J12G, J12H, J12J, J12K, J12L, J12M, J13A, J13B, J13C (no data available for EI&SC)

- J11J

- J22A, J22B, J22C, J22D, J22E, J22F, J22G, J22H, J22J, J22K, J21A, J21B, J21C, J21D, J21E, J24A, J24B, J24C, J24D, J24E, J24F, J23A, J23B, J23C, J23D, J23E, J23F, J23G, J23H, J32A, J32B, J32C, J32D, J32E, J31A, J31B, J31C, J31D

- J23J, J25A, J25B, J25C, J25D (possibly B/ A due to pristine nature of tributaries and rugged terrain)

- J25E, J35A, J35B, J35C, J35D, J35E, J35F, J33A, J33B, J33C, J33D, J33E, J33F

- J34A, J34B, J34C, J34D, J34E, J34F

- J40A, J40B, J40C, J40D, J40E

- K10A, K10B, K10C, K10D, K10E, K10F, K20A, K30A, K30B, K30C

- K30D, K40A, K40B, K40C, K40D, K40E, K50A, K50B, K60A, K60B, K60C, K60D, K60E, K60F, K60G, K70A, K70B

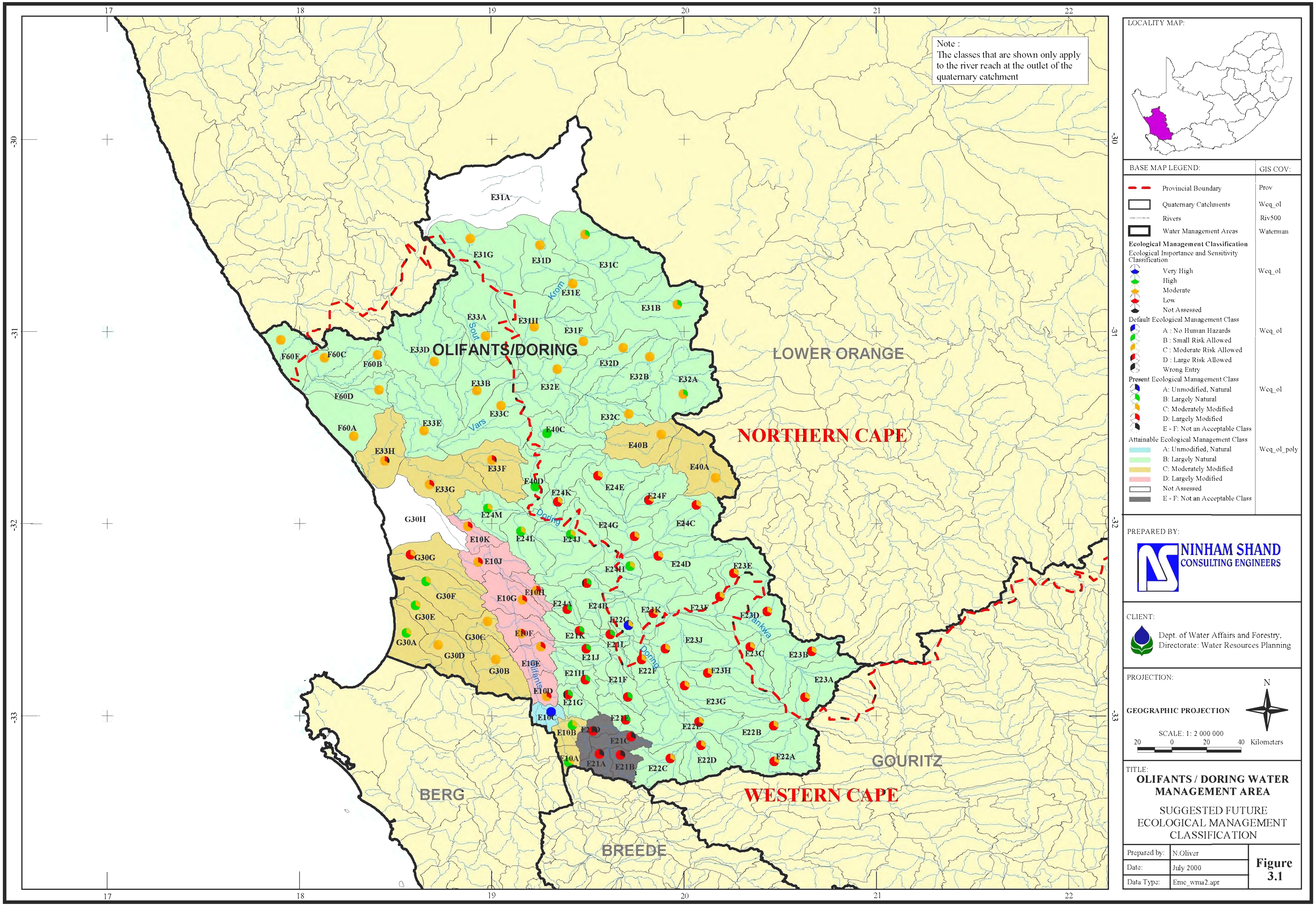
CHAPTER 3: RESULTS OF THE WORKSHOP

3.1 INTRODUCTION

During the previous workshop, a number of participants requested that the results of the workshop be reviewed once they have been captured and made available by DWAF in a GIS format. The primary reason for this request can be attributed to the conservative EI&SC which the Ecoinfo programme derived from information put into the different categories. Participants felt that the DEMC were sometimes not reflective of the river, and also wanted to get an overall picture of the quaternary catchments for the Western Cape.

3.2 MANAGEMENT CLASSES

Since the abovementioned information was not available in GIS format prior to the Phase 2 workshops, this report contains a summary of the EI&SC and DEMC, as well as the PESC and AESC in both GIS format (see Figures 3.1 to 3.4) and the data entered in the Ecoinfo programme on CD Rom (see Annexure B).



Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
OLIFANTS/DORING
LOWER ORANGE
NORTHERN CAPE
WESTERN CAPE
GOURITZ
BERG
BREEDE
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary
Prov
Quaternary Catchments
Weq_ol
Rivers
Riv500
Water Management Areas
Waterman
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Management Class
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
Weq_ol_poly
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Dept. of Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
SCALE: 1: 2 000 000
20 0 20 40 Kilometers
TITLE:
OLIFANTS / DORING WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Emc_wma2.apr
Figure 3.1


18
19
-33
-34
Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
WESTERN CAPE
OLIFANTS / DOORN
BERG
GOURITZ
BREEDE
G30A
G10K
G10M
G10H
G10G
G10J
G10L
G10E
G10F
G21A
G21C
G21D
G10D
G21B
G21E
G21F
G10C
G10B
G22G
G22C
G10A
G22B
G22E
G22H
G22F
G22D
G22J
G22K
G40A
G22A
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary — Spr_rsa_geo
Quaternary Catchments — Weq_rsa_geo
Rivers — Wri500_rsa_geo
Water Management Areas — Wma_rsa_geo
Ecological Management Classification
Ecological Importance and Sensitivity Classification — Wecqpnt1_berg_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class — Wecqpnt1_berg_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Status Class — Wecqpnt1_berg_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class — Weqberg_sass_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 1 000 000
10 0 10 20 Kilometers
TITLE:
BERG WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Environmental.apr
Figure 3.2


LOWER ORANGE
WESTERN CAPE
BERG
GOURITZ
BREEDE
Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
H10A H10B H10C H10D H10E H10F H10G H10H H10J H10K H10L
H20A H20B H20C H20D H20E H20F H20G H20H
H30A H30B H30C H30D H30E
H40A H40B H40C H40D H40E H40F H40G H40H H40J H40K H40L
H50A H50B
H60A H60B H60C H60D H60E H60F H60G H60H H60J H60K H60L
H70A H70B H70C H70D H70E H70F H70G H70H H70J H70K
G40B G40C G40D G40E G40F G40G G40H G40J G40K G40L G40M
G50B G50C G50D G50E G50F G50G G50H G50J G50K
19
20
21
-33
-34
-35
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary
Spr_rsa_geo
Quaternary Catchments
Weq_rsa_geo
Rivers
Wri500_rsa_geo
Water Management Areas
Wma_rsa_geo
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Weqpnt_brde_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class
Weqpnt -brde_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Management Class
Weqpnt_brde_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
Weqpoly_brde_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
PREPARED BY:
NINHAM SHAND
CONSULTING ENGINEERS
CLIENT:
Dept. of Water Affairs and Forestry,
Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 1 000 000
10 0 10 20 Kilometers
TITLE:
BREEDE WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Eme_wma2.apr
Figure 3.3


LOWER ORANGE
NORTHERN CAPE
OLIFANTS / DORING
FISH TO TSITSIKAMMA
EASTERN CAPE
GOURITZ
BERG
WESTERN CAPE
BREEDE
Note :
The classes that are shown only apply to the river reach at the outlet of the quaternary catchment
LOCALITY MAP:
BASE MAP LEGEND:
GIS COV:
Provincial Boundary
Spr_rsa_geo
Quaternary Catchments
Wcq_rsa_geo
Rivers
Wri500_rsa_geo
Water Management Areas
Wma_rsa_geo
Ecological Management Classification
Ecological Importance and Sensitivity Classification
Weqpnt_gour_geo
Very High
High
Moderate
Low
Not Assessed
Default Ecological Management Class
Weqpnt_gour_geo
A : No Human Hazards
B : Small Risk Allowed
C : Moderate Risk Allowed
D : Large Risk Allowed
Wrong Entry
Present Ecological Management Class
Weqpnt_gour_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
E - F: Not an Acceptable Class
Attainable Ecological Management Class
Weqpoly_gour_geo
A: Unmodified, Natural
B: Largely Natural
C: Moderately Modified
D: Largely Modified
Not Assessed
E - F: Not an Acceptable Class
PREPARED BY:
NINHAM SHAND CONSULTING ENGINEERS
CLIENT:
Dept. of Water Affairs and Forestry, Directorate: Water Resources Planning
PROJECTION:
GEOGRAPHIC PROJECTION
N
SCALE: 1: 2 000 000
20 0 20 40 Kilometers
TITLE:
GOURITZ WATER MANAGEMENT AREA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASSIFICATION
Prepared by: N.Oliver
Date: July 2000
Data Type: Eme_wma2.apr
Figure 3.4

CHAPTER 4: DISCUSSION

4.1 COMMENTS AND OBSERVATIONS BY PARTICIPANTS

The participants made the following comments with regard to the methodology and the updated EcoInfo computer programme in particular. At the end of the workshop the participants were encouraged to provide feedback on the strengths and weaknesses of the process. These are:

- The computer programme tended to crash and over-writing of previous data caused problems. As a result, there was a lack of confidence in the computer programme.

- There were problems with the data from the previous workshop, as data had not been converted to the requested GIS format. Furthermore, data seemed to be missing from the DWAF report on the Western Cape rivers.

- Accuracy of assessments was facilitated by the diverse number of experts involved in the decision-making process. However, it was viewed by some that in most cases only one expert per field was present which makes it difficult to verify the results obtained.

- A lack of knowledge of inland and middle-eastern (e.g. the Klein Karoo) areas as well as the Gouritz area has made it difficult to assess these areas accurately. The concern is that this will affect the overall accuracy of the results obtained. An in-depth study of the unfamiliar areas is necessary to improve the data. Areas rated with a confidence level of “1" or “2" are those quaternaries where there is a lack of information.

- A request by participants is that the information contained in the water quality database, as well as other information regarding the issues concerned, be expanded and made available for detailed research.

- The scoring system is regarded as being easy to use and general consensus regarding areas discussed was reached within a short time frame. However, greater clarification regarding the confidence scoring system is necessary in order to facilitate evaluation.

- The upgrading of rivers to a higher class is decided by the possible improvement of flow modification. This leaves doubt as to how the other criteria should be addressed. It was felt that by removing invasive vegetation and reducing bulldozing of river beds flow would improve, yet these options were not addressed. Very few rivers have the potential to be upgraded over the specified five year period as the majority require upgrading over ten years or more.

- Groupings of various catchments are too big, thus a very broad assessment was made resulting in inaccuracies. A number of quaternaries are linked together but only the main stem river was taken into account. This could result in the inaccurate scoring of the tributaries.

- The format of the methodology paper should be made clearer and user-friendly tables should be included, especially for EI&SC and DEMC. Furthermore, if the GIS layout of the results from the previous workshop had been available it would have aided the process greatly.

- The confidence levels need to be attached to all classes and a confidence level common denominator given.

- Ideally, rivers should be grouped according to ecotones rather than quaternary hydrological catchments as they are ecologically inappropriate, but it is acknowledged that this would not meet the requirements of the water balance model.

- The results should be reviewed by participants on a GIS database before the data is used for the national water balance.

- The overall workshop is still a lengthy process.

CHAPTER 5: CONCLUSIONS

5.1 CONCLUSIONS

This report has described the methodology used during the workshop and also presented the observations made by participants regarding the process and the methodology. Comments on the process, as well as recommendations, can be viewed in Chapter 4. This draft report will be finalised once the results of the study have been reviewed by the workshop participants.

It should be reiterated (from Kleynhans, 1999) that the estimates originating from the application of this procedure only be used for broad, very general planning purposes. In addition, the confidence levels assigned to the various classes are highly variable, depending on the level of knowledge of participants, and this, as well as the comments given regarding each quaternary, should be borne in mind when utilising the data. In all cases where information requirements go beyond the general planning level, the procedures being developed for the determination of the preliminary, intermediate, or full reserve should be applied.

REFERENCES

Kleynhans, C.J. 1999. *A procedure for the determination of the ecological reserve for the purpose of the National Water Balance Model for South African rivers.* Department of Water Affairs and Forestry.

Ninham Shand, 1999. *Western Cape water resources situation assessment: Workshop on ecological flow requirements: notes on proceedings.* Prepared for the Department of Water Affairs and Forestry. Report No. 2949/ 7970

OLIFANTS - DORING WATER MANAGEMENT AREA

APPENDIX F.7

ASSUMED RURAL DOMESTIC PER CAPITA WATER REQUIREMENTS PER QUATERNARY

Quaternary	PER CAPITA PER DAY RURAL USAGE					Average Consumption ℓ/c/d
	30	30	30	100	l/c/d	
	Rural %	Advanced Rural %	Developing Urban %	Farming %	Comments	
E10A	0	0	0	100		100
E10B	0	0	0	100		100
E10C	0	0	0	100		100
E10D	0	0	0	100		100
E10E	0	0	0	100		100
E10F	0	0	0	100		100
E10G	0	0	0	100		100
E10H	0	0	0	100		100
E10J	0	0	0	100		100
E10K	0	0	0	100		100
E21A	0	0	0	100		100
E21B	0	25	0	75	Olkersia	82.5
E21C	0	0	0	100		100
E21D	0	0	50	50	Op die Berg	65
E21E	0	0	0	100		100
E21F	0	0	0	100		100
E21G	0	0	0	100		100
E21H	0	0	0	100		100
E21J	0	0	0	100		100
E21K	0	0	0	100		100
E21L	0	0	0	0	No farming	0
E22A	0	0	0	100		100
E22B	0	0	0	100		100
E22C	0	0	0	100		100
E22D	0	0	0	100		100
E22E	0	0	0	100		100
E22F	0	0	0	100		100
E22G	0	0	0	100		100
E23A	0	0	0	100		100
E23B	0	0	0	100		100
E23C	0	0	0	100		100
E23D	0	0	0	100		100
E23E	0	0	0	100		100
E23F	0	0	0	100		100
E23G	0	0	0	100		100
E23H	0	0	0	100		100
E23J	0	0	0	100		100
E23K	0	0	0	100		100
E24A	0	0	80	20	Wuppertal	44
E24B	0	0	0	100		100
E24C	0	0	0	100		100
E24D	0	0	0	100		100
E24E	0	0	0	100		100
E24F	0	0	0	100		100

Quaternary	PER CAPITA PER DAY RURAL USAGE					Average Consumption ℓ/c/d
	30	30	30	100	l/c/d	
	Rural %	Advanced Rural %	Developing Urban %	Farming %	Comments	
E24G	0	0	0	100		100
E24H	0	0	0	100		100
E24J	0	10	0	90	Heuningvlei nedersetting	93
E24K	0	0	0	100		100
E24L	0	0	0	100		100
E24M	0	0	0	100		100
E31A	0	0	0	100		100
E31B	0	0	0	100		100
E31C	0	0	0	100		100
E31D	0	0	0	100		100
E31E	0	0	0	100		100
E31F	0	0	0	100		100
E31G	0	0	0	100		100
E31H	0	0	0	100		100
E32A	0	0	0	100		100
E32B	0	0	0	100		100
E32C	0	0	0	100		100
E32D	0	0	0	100		100
E32E	0	10	0	90	Brandkop village	93
E33A	0	70	0	30	Kliprand village	51
E33B	0	0	0	100		100
E33C	0	50	0	50	Marble mines,etc	65
E33D	0	0	0	100		100
E33E	0	0	0	100		100
E33F	0	0	0	100		100
E33G	0	0	0	100		100
E33H	0	0	50	50	Papendorp	65
E40A	0	0	0	100		100
E40B	0	0	0	100		100
E40C	0	0	0	100		100
E40D	0	0	0	100		100
F60A	0	50	0	50	Kotzesrus, Lepelfontein	65
F60B	0	0	0	100		100
F60C	0	0	0	100		100
F60D	0	0	0	100		100
F60E	0	0	0	100		100
G30A	0	0	0	100		100
G30B	0	0	0	100		100
G30C	0	30	0	70	Paleisheuwel, Het Kruis	79
G30D	0	0	0	100		100
G30E	0	0	0	100		100
G30F	0	0	0	100		100
G30G	0	0	0	100		100
G30H	0	0	70	30	Strandfontein, Doringbaai	51

APPENDIX G

WATER RESOURCES

APPENDIX G.1	**Hydrological data per quaternary catchment.**
APPENDIX G.2	**Potential vulnerability of surface water and groundwater to microbial contamination.**
APPENDIX G.3	**Sedimentation data.**
APPENDIX G.4	**Groundwater.**
APPENDIX G.5	**Water quality information.**

OLIFANTS-DORING WATER MANAGEMENT AREA

APPENDIX G.1

HYDROLOGICAL DATA PER QUATERNARY CATCHMENT

Areas	aMTCi	eMRTo	oMAEi	oMAPi	oMARi
	Catchment area	Natural mean annual runoff (accumulative)	Mean annual evaporation	Mean annual precipitation	Natural mean annual runoff (incremental)
	km^2	million m^3/a	mm/a	mm/a	million m^3/a
E10A	134	95.40	1650	899	95.40
E10B	202	132.00	1650	736	36.60
E10C	192	166.70	1640	587	34.70
E10D	235	224.80	1640	518	58.10
E10E	366	287.00	1640	419	62.20
E10F	386	349.40	1645	407	62.40
E10G	508	431.40	1650	407	82.00
E10H	162	39.20	1680	495	39.20
E10J	468	505.80	1675	344	35.20
E10K	235	510.80	1690	284	5.00
E21A	190	34.88	1660	620	34.88
E21B	223	26.94	1670	497	26.94
E21C	233	86.75	1675	467	24.93
E21D	242	45.37	1665	627	45.37
E21E	293	151.70	1680	360	19.59
E21F	379	168.30	1690	289	16.55
E21G	266	30.56	1655	475	30.56
E21H	404	68.66	1670	429	38.10
E21J	317	87.44	1680	338	18.78
E21K	330	21.47	1680	352	21.47
E21L	195	278.50	1700	216	1.34
E22A	750	8.12	1920	251	8.12
E22B	638	14.87	1850	248	6.75
E22C	490	13.41	1690	324	13.41
E22D	496	17.33	1760	226	3.92
E22E	1013	38.69	1725	212	6.49
E22F	400	39.65	1715	163	0.96
E22G	367	319.30	1730	173	1.11
E23A	762	7.69	1895	254	7.69
E23B	705	13.61	1870	240	5.92
E23C	318	1.80	1850	213	1.80
E23D	750	20.08	1850	219	4.67
E23E	564	6.60	1870	265	6.60
E23F	473	27.20	1835	134	0.52
E23G	747	3.16	1810	190	3.16
E23H	660	3.63	1820	205	3.63
E23J	895	35.17	1805	139	1.18
E23K	572	45.68	1800	126	0.53
E24A	255	17.31	1695	393	17.31
E24B	468	27.58	1725	272	10.27
E24C	784	10.24	1880	235	10.24
E24D	997	15.92	1845	178	5.68
E24E	671	5.81	1890	204	5.81
E24F	582	9.98	1895	192	4.17
E24G	633	3.81	1845	174	3.81

Areas	aMTCi	eMRTo	oMAEi	oMAPi	oMARi
	Catchment area	Natural mean annual runoff (accumulative)	Mean annual evaporation	Mean annual precipitation	Natural mean annual runoff (incremental)
	km^2	million m^3/a	mm/a	mm/a	million m^3/a
E24H	483	416.30	1795	190	4.01
E24J	1078	436.60	1800	247	20.34
E24K	652	446.80	1860	238	10.18
E24L	516	497.20	1745	291	23.36
E24M	529	507.00	1760	265	9.82
E31A	2865	0.29	2230	84	0.29
E31B	1476	1.62	2100	151	1.62
E31C	1572	2.17	2150	113	0.55
E31D	839	2.48	2105	114	0.31
E31E	478	3.09	2080	157	0.61
E31F	525	1.00	2025	175	1.00
E31G	1238	0.68	2090	110	0.39
E31H	726	5.55	2015	150	0.78
E32A	1118	3.77	2020	207	3.77
E32B	828	5.59	2000	184	1.82
E32C	638	8.57	1950	227	2.98
E32D	616	9.72	2005	176	1.15
E32E	1001	12.34	1950	193	2.62
E33A	1355	18.89	2000	136	1.00
E33B	702	19.21	1910	114	0.32
E33C	980	0.99	1880	140	0.99
E33D	1559	1.23	1905	131	1.23
E33E	1282	22.25	1835	124	0.82
E33F	725	3.30	1835	212	3.30
E33G	894	1024.00	1760	186	2.54
E33H	719	1047.00	1730	134	0.62
E40A	941	7.38	1940	236	7.38
E40B	707	13.36	1945	241	5.98
E40C	530	20.12	1905	285	6.76
E40D	544	27.07	1850	284	6.95
F60A	572	0.13	1800	103	0.13
F60B	320	0.17	1800	129	0.17
F60C	622	0.38	1800	114	0.21
F60D	481	0.58	1800	120	0.20
F60E	795	0.29	1800	116	0.29
G30A	761	4.76	1495	260	4.76
G30B	658	18.87	1615	394	18.87
G30C	351	11.28	1615	410	11.28
G30D	534	42.04	1570	384	11.89
G30E	352	43.90	1510	249	1.86
G30F	780	6.82	1600	285	6.82
G30G	314	1.74	1600	253	1.74
G30H	1077	3.26	1625	214	3.26
Totals	56683				1108.03

APPENDIX G.2

WATER RESOURCES SITUATION ASSESSMENTS

DEPARTMENT: WATER AFFAIRS & FORESTRY
DIRECTORATE: WATER RESOURCE PLANNING

POTENTIAL VULNERABILITY OF SURFACE WATER & GROUNDWATER TO MICROBIAL CONTAMINATION

AUGUST 2001

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SUMMARY

This report forms part of the Water Resources Situation Assessments undertaken for the Department of Water Affairs and Forestry. Information is provided on the potential microbial contamination of surface water and groundwater resources in South Africa.

For surface water, initial mapping information was taken from the National Microbiological Monitoring Program where priority contaminated areas were identified and mapped. As part of this project, it was necessary to produce a surface contamination map for the whole country. A national surface faecal contamination map was produced using population density and sanitation type available from DWAF databases. A three category rating system was used (low, medium and high) to describe the surface faecal contamination. This information was delineated on a quaternary catchment basis for the whole country.

For groundwater, the first step involved the development of a groundwater vulnerability map using the depth to groundwater, soil media and impact of the vadose zone media. A three category rating system was used (least, moderate, most) to describe the ease with which groundwater could be contaminated from a source on the surface. The second step involved using the surface contamination and aquifer vulnerability maps to derive a groundwater contamination map. The derived map shows the degree of faecal contamination that could be expected of the groundwater for all areas in South Africa.

Conclusions and recommendations

- Maps were produced that provide an overall assessment of potential microbial contamination of the surface water and groundwater resources of South Africa.

- Spatial resolution of the maps is based on a quaternary catchment scale. It is recommended that these maps are not used to derive more detailed spatial information.

- Once sufficient microbial data are available, it is recommended that the numerical methods, and their associated assumptions, be checked, and the maps replotted where necessary.

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ACKNOWLEDGEMENT

The support of Mr Julian Conrad of Environmentek, CSIR for providing the GIS DRASTIC coverages. His help is fully acknowledged and appreciated.

GLOSSARY

Aquifer	Strata, or a group of interconnected strata, comprising of saturated earth material capable of conducting groundwater and of yielding usable quantities of groundwater to boreholes
Contamination	Introduction into the environment of an anthropogenic substance
DRASTIC	Numerical method that describes groundwater characteristics, using: water depth, recharge, aquifer media, soil media, topography, impact on vadose zone, and conductivity
Faecal	Material that contains bodily waste matter derived from ingested food and secretions from the intestines, of all warm-blooded animals including humans
Fitness for use	Assessment of the quality of water based on the chemical, physical and biological requirements of users
Groundwater	Subsurface water occupying voids within a geological stratum
Microbial	Microscopic organism that is disease causing
Ratio	Mathematical relationship defined by dividing one number by another number
Rating	Classification according to order, or grade
Vadose zone	Part of the geological stratum above the saturated zone where voids contain both air and water
Vulnerability	In the context of this report, it is the capability of surface water or groundwater resources to become contaminated

1. INTRODUCTION

The purpose of the Water Resources Situation Assessments is to prepare an overview of the water resources in South Africa. This will take account of the availability and requirements for water, as well as deal with issues such as water quality. The country has been divided into nineteen water management areas. Eight separate studies are being carried out within catchment boundaries that roughly approximate provincial borders. Once these studies have been completed, all information will also be synthesized into a single report for the whole country.

This report describes the method used to prepare a series of maps that show the microbial rating of surface water and groundwater resources in South Africa. Maps are produced at a quaternary catchment scale. It is intended that the appropriate portions of the maps be incorporated into each of the Water Management Area reports.

The microbial information provided in this report is intended for planning purposes, and is not suitable for detailed water quality assessment. The maps provide a comparative rating of the faecal contamination status of the surface water and groundwater resources in South Africa.

This report contains five sections:

- Section One: Introduction
- Section Two: Mapping of surface contamination
- Section Three: Mapping of Groundwater Resources
- Section Four: Conclusions and Recommendations
- Section Five: References

2. MAPPING SURFACE WATER RESOURCES

2.1 Background

The water resources of South Africa have come under increasing influence from faecal contamination as a result of increased urban development and lack of appropriate sanitation. Due to increased use of contaminated water for domestic consumption, people are at serious risk of contracting water-borne disease (e.g. gastroenteritis, salmonellosis, dysentery, cholera, typhoid fever and hepatitis). The Department of Water Affairs and Forestry (DWAF) is the custodian of the national water resources and should ensure *fitness for use* of the water resources. Thus, the Department has developed a monitoring system to provide the necessary management information to assess and control the health hazard in selected areas. This project is called the National Microbiological Monitoring Programme (NMMP).

As part of the NMMP, a screening exercise was carried out to determine the number of catchments that experience faecal contamination. A short-list of tertiary catchment areas was compiled. Data from the database of the Directorate: Water Services Planning of DWAF was used to prioritize catchments to assess the overall health hazard (see Figure 1).

Ratings for land use activity were assigned using the method developed by Goodmin & Wright (1991), IWQS (1996), and Murray (1999). Ratings for land and water use were combined to establish an overall rating. Water use was considered to have a higher effect than the land use so that a 60:40 weighting was used (see Equation 1).

$$OR = 0.4\ TLU + 0.6\ TWU \qquad \text{........ (1)}$$

Where OR = Area Rating (no units)
TLU = Total land use rating for area (no units)
TWU = Total water use rating for area (no units)

Each area was assigned a rating to indicate low (1), medium (2) or high (3) potential risk to users in the catchment area. The following values were used to designate each class:

Low	OR = 0 to 1000
Medium	OR = 1001 to100 000
High	OR > 100 000 ....(2)

Figure 1 shows the surface faecal contamination map for priority rated catchments in South Africa.

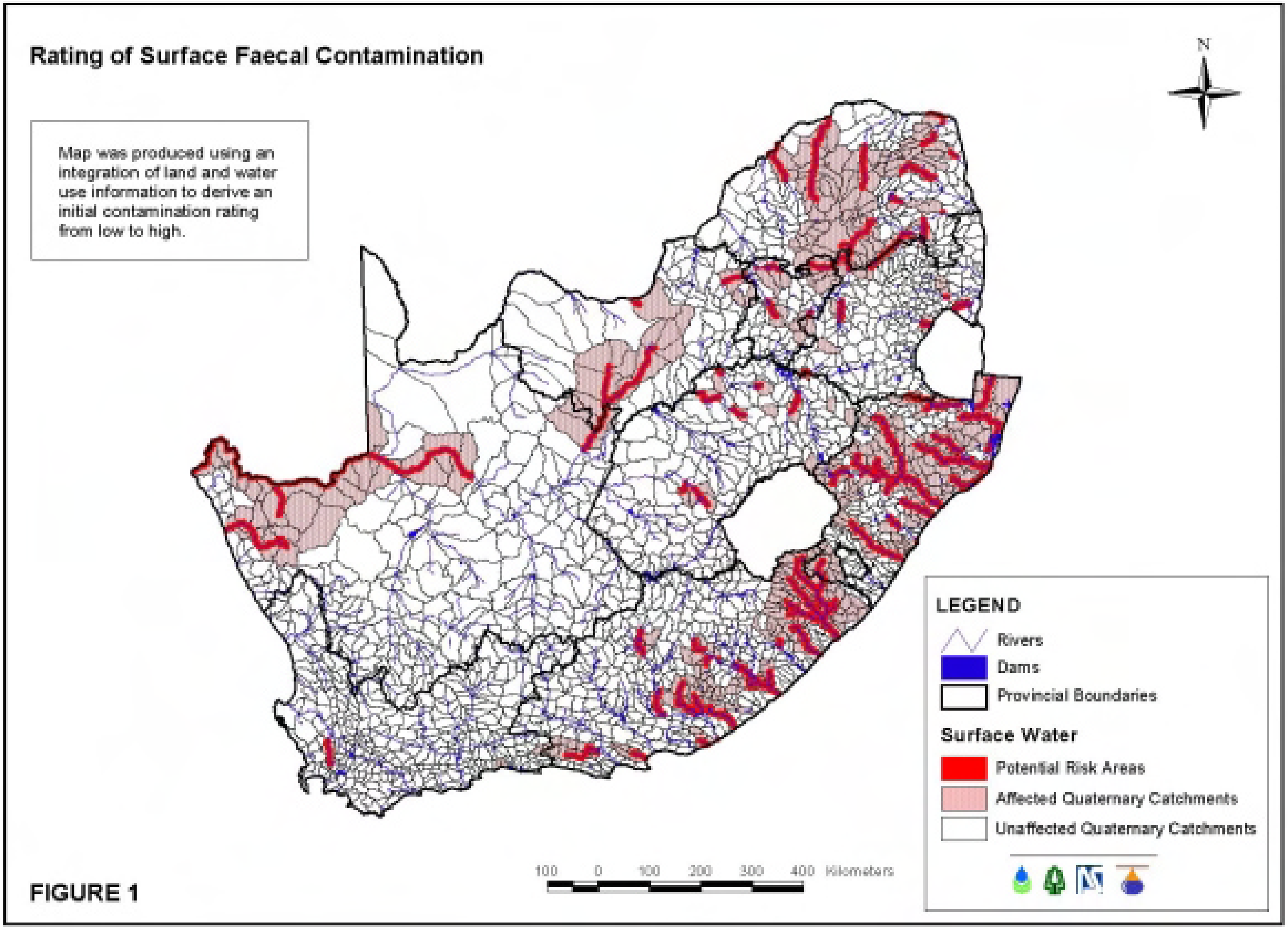

Rating of Surface Faecal Contamination
Map was produced using an integration of land and water use information to derive an initial contamination rating from low to high.
N
LEGEND
Rivers
Dams
Provincial Boundaries
Surface Water
Potential Risk Areas
Affected Quaternary Catchments
Unaffected Quaternary Catchments
100 0 100 200 300 400 Kilometers

FIGURE 1

2.2 Surface faecal contamination

Figure 2 shows the potential surface faecal contamination map, developed using average population density (for a quaternary) and degree of sanitation (Venter, 1998). The land use rating is given by:

$$LU = SA + PD \qquad \text{........ (3)}$$

Where LU = Land use rating per settlement (no units)
SA = No/poor sanitation rating (no units)
PD = Population Density rating (no units)

Land use rankings for quaternary catchments were determined by calculating the total ratings of all settlements within a particular quaternary catchment, given by:

$$TLU = (LU_n) \qquad \text{........ (4)}$$

Where TLU = Total land use rating per quaternary catchment
LU_n = Land use rating for n settlements, per quaternary

Each quaternary catchment was allocated a low (1), medium (2) and high (3) priority rating used to map the information using GIS. Classes were designated by the following values:

Low = $TLU < 1000$
Medium = $1000 < TLU < 3000$
High = $TLU > 3000$ .... (5)

2.3 Results: GIS Surface Water Mapping

Figure 1 was plotted on GIS by firstly assembling the national coverages for the quaternary catchments, rivers and dams. The data described above were processed using the following method:

The quaternary catchments were shaded according to whether they were considered potential risk areas or not (refer to Equations 1 & 2).

Within the quaternaries at risk, the rivers were buffered and shaded red to indicate the risk to potential surface water users.

Figure 2, the potential surface faecal contamination map, was produced as follows:

The ratings (TLU) were distributed into intervals (refer to Equations 5 and 6).

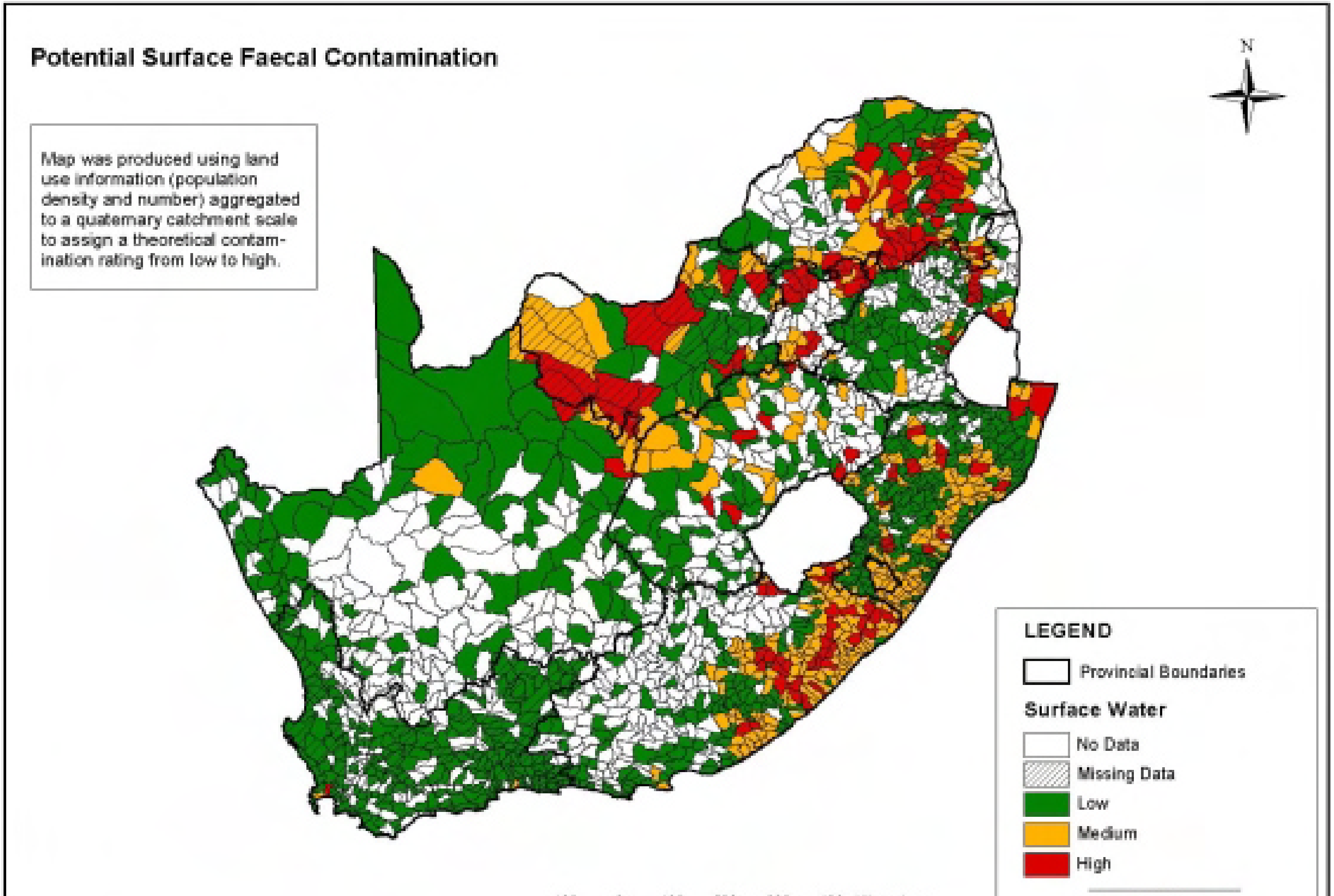

Potential Surface Faecal Contamination
N
Map was produced using land use information (population density and number) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
LEGEND
Provincial Boundaries
Surface Water
No Data
Missing Data
Low
Medium
High
100 0 100 200 300 400 Kilometers

FIGURE 2

The quaternary catchments were then shaded according to these rating intervals indicating areas of Low, Medium or High Risk, see below.

Low	Green	TLU < 1000	
Medium	Yellow	1000 < TLU < 3000	
High	Red	TLU > 3000	.... (6)

Quaternary catchments with no data were unshaded.

Quaternary catchments containing missing data were hatched.

3. MAPPING GROUNDWATER RESOURCES

3.1 Background

Groundwater is an important national water resource that plays an important role in meeting water requirements in remote areas. This is particularly true in areas where rainfall is low and surface water resources are scarce.

Microbial contamination of groundwater increases in high population density areas and areas with inadequate sanitation. Approximately three quarters of the population of South Africa do not have access to adequate sanitation.

Considerable work has already been carried out to map the groundwater resources in South Africa. Examples include: the national Groundwater Resources of the Republic of South Africa map produced by Vegter (1995) for the Water Research Commission (WRC), regional 1: 500 000 scale hydrogeological maps produced by DWAF, the national groundwater vulnerability map prepared by Reynders & Lynch (1993) and the aquifer classification map of Parsons & Conrad (1998). Figure 3 shows the vulnerability map used by Parsons & Conrad (1998). The existing work, particularly the vulnerability map (Figure 3), has therefore been used as a basis for assessing the potential of microbial contamination of groundwater systems.

3.2 Method

It is recognised that certain aquifers are more vulnerable to contamination than others. The DRASTIC method (Aller *et al.*, 1985) is a well-known and studied method of assessing aquifer vulnerability to contamination. Reynders & Lynch (1993) and Lynch *et al*. (1994, 1997) prepared a national scale aquifer vulnerability map using DRASTIC that was revised by Parsons & Conrad (1998) using additional data (see Figure 3).

DRASTIC is a weighting, and rating, technique that considers seven factors when estimating the groundwater vulnerability. Factors are geologically and geohydrologically based. Controls relating to the magnitude or severity of the pollution source are not considered. DRASTIC factors are shown in Table 1.

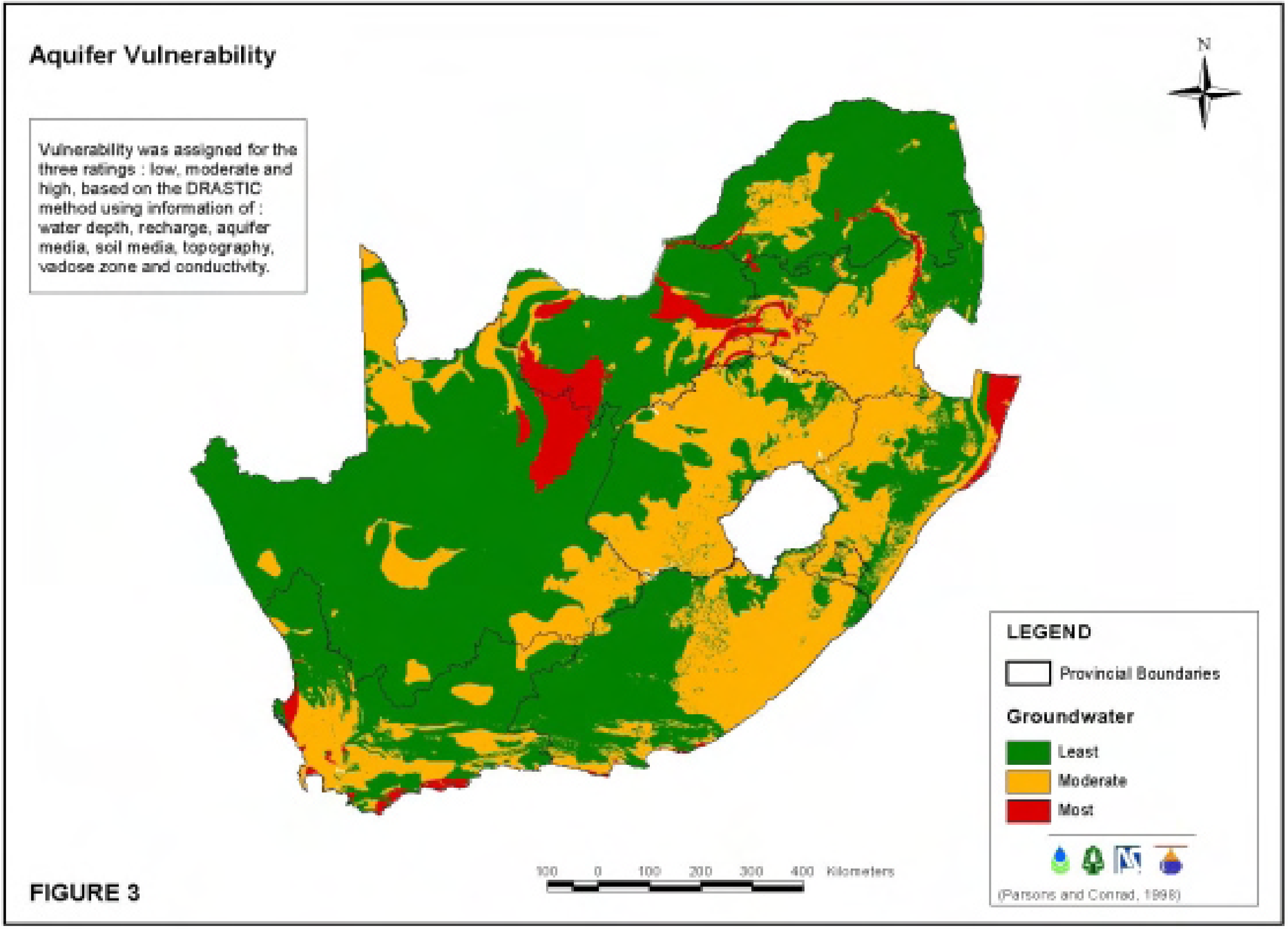

Aquifer Vulnerability
Vulnerability was assigned for the three ratings : low, moderate and high, based on the DRASTIC method using information of : water depth, recharge, aquifer media, soil media, topography, vadose zone and conductivity.
N
LEGEND
Provincial Boundaries
Groundwater
Least
Moderate
Most
(Parsons and Conrad, 1998)
100 0 100 200 300 400 Kilometers

FIGURE 3

TABLE 1: FACTORS USED BY DRASTIC

D	Depth to water
R	(net) Recharge
A	Aquifer media
S	Soil media
T	Topography (slope)
I	Impact of the vadose zone media
C	Conductivity (hydraulic) of the aquifer

Each factor was weighted according to its relative importance (Aller *et al.*, 1985). Using a set of tables, a rating is assigned based on prevailing conditions. A relative DRASTIC index (I) is derived using the following formula, with higher index values showing greater groundwater vulnerability:

$$I = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \qquad .....(7)$$

where: I = index rating
$_R$ is the rating for each factor, and
$_W$ is the weighting for each factor.

DRASTIC was also developed to assess the vulnerability to pesticide contamination (Aller *et al.*, 1985). In this case, those factors that play an important role in defining vulnerability to pesticide contamination are assigned higher weights.

In the case of microbial contamination, other factors are more important in terms of aquifer vulnerability to microbial contamination. Travel time in the vadose zone is recognised as an important control in this regard (Xu & Braune, 1995; Wright, 1995; DWAF, 1997). It was hence decided to assess aquifer vulnerability to microbial contamination in terms of D, S and I (i.e. all factors that relate to the vadose zone). [1]

The weighting and rating technique used by DRASTIC was followed in the current study, adopting the weights used by the pesticide DRASTIC. Using the following formula, the highest possible index value is 140 and the lowest value is 14,

$$\text{Index} = 5\ D_R + 5\ S_R + 4\ I_R \qquad ......(8)$$

It must be noted that (1) the value of the index is relative, (2) the factors used in the index were considered by the team to have the greatest influence in assessing the potential for microbial contamination at the surface entering underlying aquifers.

[1] A similar approach was used by Xu & Braune (1995) where they used the factors D, A and S, and used the weightings assigned by DRASTIC and not Pesticide DRASTIC.

3.3 Aquifer vulnerability map

Three DRASTIC groundwater coverages were used to produce an indication of vulnerability of groundwater contamination, namely, depth to groundwater, soil media and vadose.

Each grid element on the DRASTIC coverages was allocated a rating, that was multiplied by a weighting factor (Depth = 5, Soil = 5, Vadose = 4) to produce a score. These three coverages were intersected and their scores added to produce a relative index for each point on the resulting coverage. An additional assumption was applied that assigned a low vulnerability to all areas with a Depth score of less than or equal to 2. This was used to account for deep infiltration of groundwater (over 35 metres) where long residence time and filtration will reduce the degree of contamination.

The relative index (RI) obtained for each grid allowed for grouping into high, medium and low categories. However, setting the intervals for the three categories proved difficult because of sensitivity to the interval chosen. A large percentage of indices fell in the interval of 60 to 80. It was thus decided to use the interval of 70 to 85 to allow for equal distribution between high, medium and low vulnerability areas (see Figure 4), namely:

Low	Green	$RI < 70$	
Medium	Yellow	$70 < RI < 85$	
High	Red	$RI > 85$	.... (9)

To illustrate the sensitivity to the interval chosen the map was replotted using two further intervals of 60-90 and 65-90 (see Figure 5).

Because of attenuation mechanisms that control microbial contamination entering the subsurface, it was considered conceptually correct to only consider D, S and I. Comparison of Figures 3 and 4 shows remarkable similarity and confirms that the vulnerability *per se* is largely controlled by the three factors (D, S and I), which promotes confidence in the resultant microbial contamination vulnerability map.

A limitation of the study is the inability to validate results obtained. Little information is available regarding groundwater microbial contamination. Monitoring data, from selected areas, should be collected to assess the validity of the vulnerability assessment presented in this report.

3.4 Groundwater faecal contamination

Figure 2 (*Potential Surface Faecal Contamination)* and Figure 4 (*Aquifer vulnerability to Faecal Contamination)* maps were intersected to produce a combined *Risk of Faecal Contamination of Aquifers* map on a quaternary basis, see Figure 6.

A total rating score was calculated for each quaternary (e.g. two medium risk areas and one high risk area gives 2 + 2 + 3). This total was then divided by the total number of different risk areas present in each quaternary to produce an average risk value. Each quaternary catchment was shaded according to this average risk value.

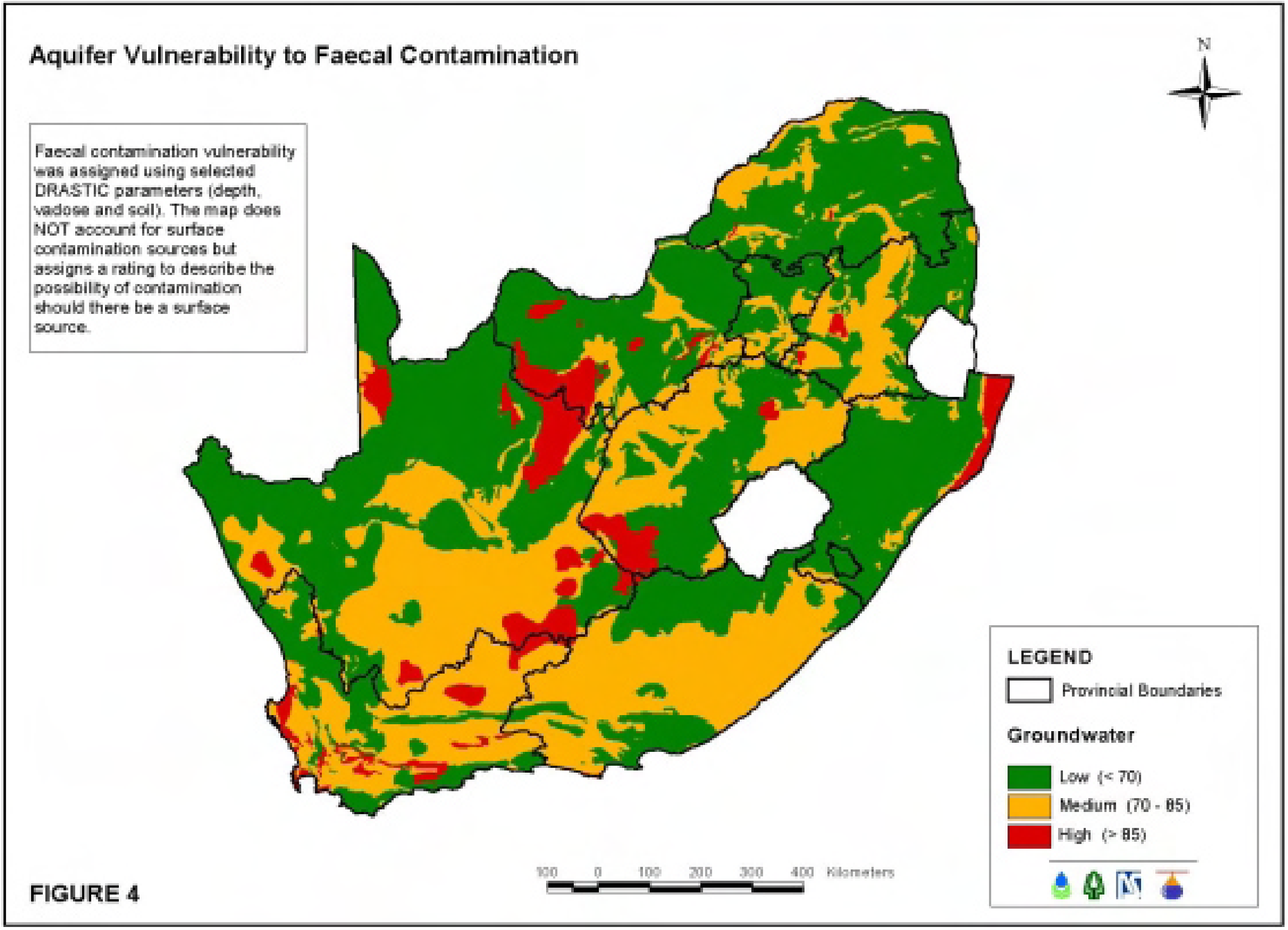
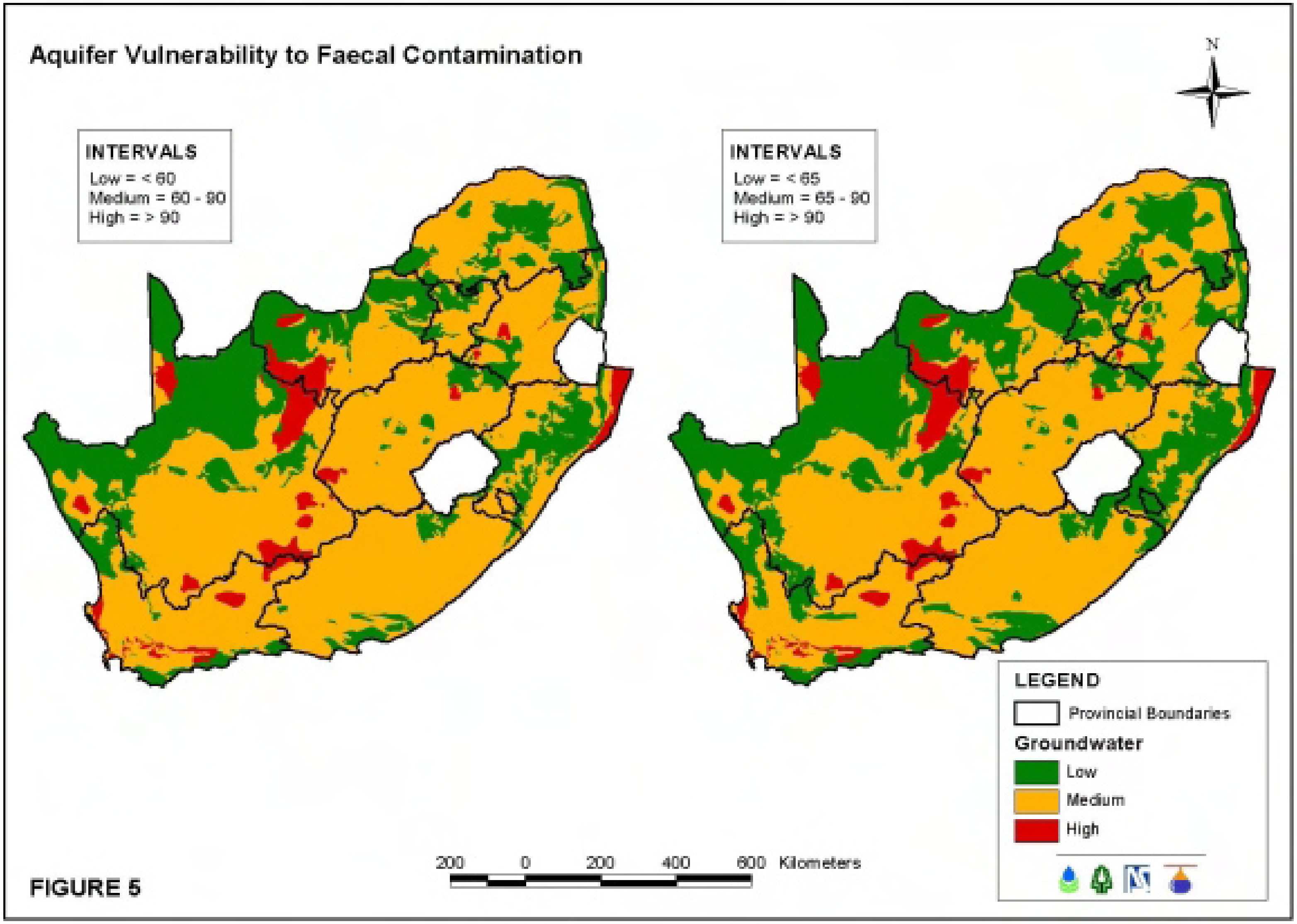

Aquifer Vulnerability to Faecal Contamination
Faecal contamination vulnerability was assigned using selected DRASTIC parameters (depth, vadose and soil). The map does NOT account for surface contamination sources but assigns a rating to describe the possibility of contamination should there be a surface source.
N
LEGEND
Provincial Boundaries
Groundwater
Low (< 70)
Medium (70 - 85)
High (> 85)
100 0 100 200 300 400 Kilometers

FIGURE 4


Aquifer Vulnerability to Faecal Contamination
N
INTERVALS
Low = < 60
Medium = 60 - 90
High = > 90
INTERVALS
Low = < 65
Medium = 65 - 90
High = > 90
LEGEND
Provincial Boundaries
Groundwater
Low
Medium
High
200 0 200 400 600 Kilometers
FIGURE 5

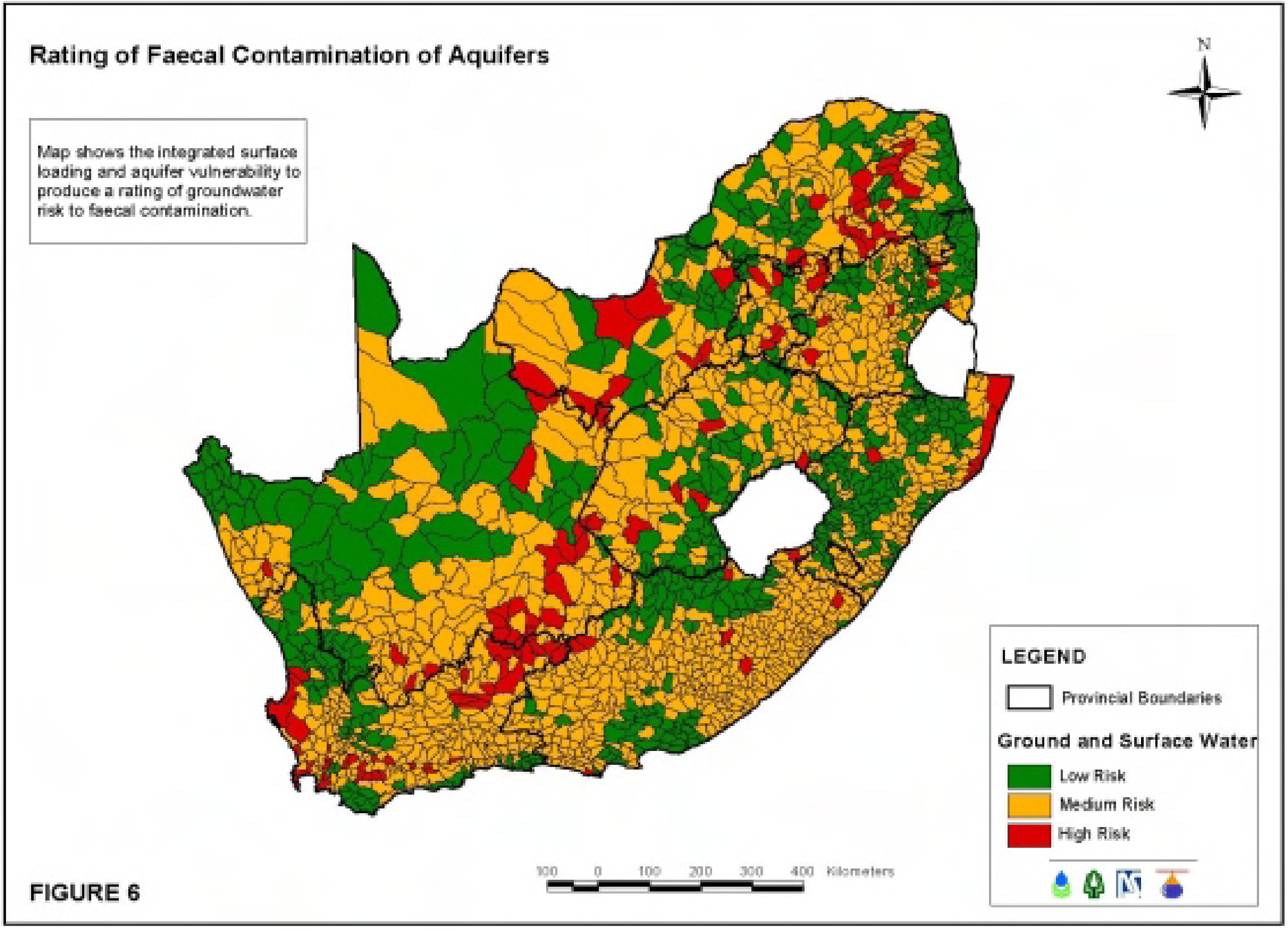

Rating of Faecal Contamination of Aquifers
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
N
100 0 100 200 300 400 Kilometers
LEGEND
Provincial Boundaries
Ground and Surface Water
Low Risk
Medium Risk
High Risk

FIGURE 6

4. CONCLUSIONS & RECOMMENDATIONS

- A series of maps (and their associated GIS coverages) have been produced to show the potential microbial contamination of surface water and groundwater resources in South Africa.

- Maps are produced on a quaternary catchment scale. Where more detailed spatial information is required, alternative methods should be used.

- Once sufficient microbial data are available, it is recommended that the numerical methods are calibrated, and the maps replotted.

- The surface water and groundwater maps should be used in the assessments of water quality for each water management area.

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OLIFANTS-DORING WATER MANAGEMENT AREA

APPENDIX G.3

SEDIMENTATION DATA PER QUATERNARY CATCHMENT

Quaternary Catchment	Area	Yield	25 year sediment Volume	Quaternary Catchment	Area	Yield	25 year sediment Volume
	km^2	tonnes/a	tonnes		km^2	tonnes/a	tonnes
E10A	134	1,000	27,400	**E24G**	633	22,000	602,800
E10B	202	2,000	54,800	**E24H**	483	17,000	465,800
E10C	192	2,000	54,800	**E24J**	1078	35,000	959,000
E10D	235	3,000	82,200	**E24K**	652	23,000	630,200
E10E	366	5,000	137,000	**E24L**	516	11,000	301,400
E10F	386	5,000	137,000	**E24M**	529	14,000	383,600
E10G	508	7,000	191,800	**E31A**	2865	90,000	2,466,000
E10H	162	1,000	27,400	**E31B**	1476	52,000	1,424,800
E10J	468	8,000	219,200	**E31C**	1572	55,000	1,507,000
E10K	235	5,000	137,000	**E31D**	839	29,000	794,600
E21A	190	6,000	164,400	**E31E**	478	17,000	465,800
E21B	223	8,000	219,200	**E31F**	525	18,000	493,200
E21C	233	8,000	219,200	**E31G**	1238	43,000	1,178,200
E21D	242	6,000	164,400	**E31H**	726	25,000	685,000
E21E	293	8,000	219,200	**E32A**	1118	30,000	822,000
E21F	379	12,000	328,800	**E32B**	828	29,000	794,600
E21G	266	5,000	137,000	**E32C**	638	22,000	602,800
E21H	404	3,000	82,200	**E32D**	616	22,000	602,800
E21J	317	5,000	137,000	**E32E**	1001	35,000	959,000
E21K	330	5,000	137,000	**E33A**	1355	47,000	1,287,800
E21L	195	7,000	191,800	**E33B**	702	25,000	685,000
E22A	750	26,000	712,400	**E33C**	980	30,000	822,000
E22B	638	22,000	602,800	**E33D**	1559	55,000	1,507,000
E22C	490	17,000	465,800	**E33E**	1282	43,000	1,178,200
E22D	496	17,000	465,800	**E33F**	725	25,000	685,000
E22E	1013	35,000	959,000	**E33G**	894	24,000	657,600
E22F	400	14,000	383,600	**E33H**	719	17,000	465,800
E22G	367	13,000	356,200	**E40A**	530	33,000	904,200
E23A	762	27,000	739,800	**E40B**	544	25,000	685,000
E23B	705	25,000	685,000	**E40C**	530	19,000	520,600
E23C	318	11,000	301,400	**E40D**	544	19,000	520,600
E23D	750	26,000	712,400	**F60A**	544	0	0
E23E	564	20,000	548,000	**F60B**	320	0	0
E23F	473	17,000	465,800	**F60C**	622	0	0
E23G	747	26,000	712,400	**F60D**	481	0	0
E23H	660	23,000	630,200	**F60E**	795	0	0
E23J	895	31,000	849,400	**G30A**	761	8,000	219,200
E23K	572	20,000	548,000	**G30B**	658	23,000	630,200
E24A	255	3,000	82,200	**G30C**	351	8,000	219,200
E24B	468	16,000	438,400	**G30D**	534	12,000	328,800
E24C	784	27,000	739,800	**G30E**	352	3,000	82,200
E24D	997	35,000	959,000	**G30F**	780	15,000	411,000
E24E	671	23,000	630,200	**G30G**	314	11,000	301,400
E24F	582	20,000	548,000	**G30H**	1077	17,000	465,800

APPENDIX G.4

GROUNDWATER RESOURCES OF SOUTH AFRICA

1. BACKGROUND

The Department of Water Affairs and Forestry (DWAF) has decided to conduct a Water Situation Assessment Study for South Africa to give a broad overview of national water requirements and water resources. These studies will enable the DWAF to utilize the Water Situation Assessment Model (WSAM), to assist in the decision making process when doing long term water resources planning.

WSM (Pty) Ltd was appointed to undertake the Situation Assessment Study of the Ground Water Resources of South Africa. This study took the form of a desk study evaluating all relevant existing data and reports at a reconnaissance level. The study area consists of all the quaternary sub-catchments of South Africa and the adjoining sub-catchments of the neighbouring states.

This report gives the findings of the study.

2. STUDY OBJECTIVES

The objective of the study is mainly to provide quantitative information on the Ground Water Resources on a quaternary catchment basis for the whole of South Africa for input into the WSAM. The information provided will consist of the following, viz :-

- ground water resource potential or harvest potential
- ground water resources available to be exploited or exploitation potential
- interaction between ground water and surface water ie the portion of ground water that contributes to stream flow (base flow)
- present ground water use
- a ground water balance identifying quaternary catchments where over exploitation occurs as well as catchments having a potential for increased ground water development
- ground water quality evaluation, determining the portion of ground water which is potable

3. METHODOLOGY

This study is a reconnaissance study making use of existing available information.

The quantification of the ground water resources is probably one of the most difficult aspects of ground water to access. Information on recharge to the ground water systems, storage capacity of the ground water systems, the hydraulic conductivity and thickness of these ground water systems, the interaction with surface water and water quality is required. Once the ground water resources are quantified a ground water balance is set up, comparing the resource with the existing use, to determine areas of over exploitation and identify areas which have a potential for further ground water exploitation. These parameters have been evaluated and the methodology is given below.

3.1 Harvest Potential

The evaluation of the mean annual recharge and storage on a national scale has been done by Vegter, 1995. This information together with a rainfall reliability factor (20^{th} percentile precipitation divided by the median precipitation), which gives an indication of the possible drought length, has been utilized by Seward and Seymour, 1996, to produce the Harvest Potential of South Africa.

The Harvest Potential is defined as the maximum volume of ground water that may be abstracted per area without depleting the aquifers. The Harvest Potential as determined by Seward and Seymour, 1996 has been used as the starting point for the determination of the Ground Water Resources of South Africa.

3.2 Exploitation Potential

It is however not possible to abstract all the ground water available. This is mainly due to economic and/or environmental considerations. The main contributing factor is the hydraulic conductivity or transmissivity of the aquifer systems. As no regional information is available, a qualitative evaluation has been done using available borehole yield information, as there is a good relationship between borehole yield and transmissivity.

The average borehole yield was determined for each quaternary catchment using information available from the National Ground Water Database and the borehole database of the Chief Directorate Water Services. Where no information was available, the average of the tertiary catchment was used. The average yields were then divided into 5 groups and an exploitation factor allocated to each group as follows, viz:-

AVERAGE BOREHOLE YIELD	EXPLOITATION FACTOR
>3.0 ℓ/s	0.7
1.5 - 3.0 ℓ/s	0.6
0.7 - 1.5 ℓ/s	0.5
0.3 - 0.7 ℓ/s	0.4
<0.3 ℓ/s	0.3

This factor was then multiplied by the Harvest Potential of each quaternary catchment to obtain the exploitation potential. The exploitation potential is considered to be a conservative estimate of the groundwater resources available for exploitation.

3.3 Ground Water, Surface Water Interaction

In order to avoid double counting the water resources, the interaction between Surface and Ground Water needs to be quantified. At a workshop held at the DWAF where ground and surface water specialists were represented, it was agreed that the baseflow, be regarded as the portion of water common to both ground and surface water for the purposes of this study.

- ***Baseflow***

  The baseflow has been considered as that portion of ground water which contributes to the low flow of streams. Baseflow can therefore be regarded as that portion of the total water resource that can either be abstracted as ground water or surface water. The baseflow in this study is defined as the annual equivalent of the average low flow that is equaled or exceeded 75% of the time during the 4 driest months of the year. The baseflow has been calculated by Schultz and Barnes, 2001.

- ***Baseflow factor***

  The baseflow factor gives an indication of the portion of ground water which contributes to base flow and has been calculated by dividing the baseflow by the Harvest Potential.

  If baseflow = 0, then ground water does not contribute to baseflow and the baseflow factor is therefore also = 0.

If baseflow ≥ harvest potential then all ground water can be abstracted as surface water and the baseflow factor is therefore ≥ 1. As the contribution of the Harvest Potential to baseflow cannot be greater than the Harvest Potential, the baseflow factor has therefore been corrected to equal 1 where it was > 1.

- ***Impact of Ground Water Abstraction on Surface Water Resources***

The impact that ground water abstraction will have on surface water resources has been evaluated qualitatively by using the corrected baseflow factor ie,

- negligible where corrected baseflow factor is = 0
- low where the corrected baseflow factors is ≤ 0.3
- moderate where the corrected baseflow factor is ≤ 0.8
- high where the corrected baseflow factor is > 0.8

- ***Contribution of Ground Water to the Total Utilization Water Resource***

This assessment of the interaction of groundwater and the base flow component of the surface water can however, not be used directly to determine the additional contribution of groundwater abstraction to the total utilizable water resource without also taking account of the effect of surface water storage capacity and the reduction in surface water runoff that is caused by the increase of groundwater recharge (induced recharge) that results from groundwater abstraction. For the purpose of this water resources assessment the proportion of the utilizable groundwater not contributing to the base flow of the surface water that can be added to the utilizable surface water to estimate the total utilizable resources has therefore been ignored.

3.4 <u>Existing Ground Water Use</u>

Data on existing ground water use was not readily accessible especially the main use sectors, viz agriculture and mining. Available borehole information was thus utilized to give a first estimate.

This was done by adding all the estimated yields or blow yields of all the boreholes for an 8 hr/day pumping period, 365 days per year.

Ground Water use was also evaluated from work done by Jane Baron (Baron and Seward, 2000). The use was evaluated for the following sectors, ie

- Municipal Use

This data was obtained from a study done by DWAF in 1990 with additional information obtained from DWAF hydrogeologists and town clerk /engineers.

- Rural Use

Rural use was estimated from the DWAF, Water Services Database linking water source to population and allowing for 25 ℓ/capita/day.

- Livestock use

The number of equivalent large livestock units per quaternary catchment was taken from the WSAM and multiplied by 45 ℓ/day and then multiplied by the % reliance on ground water obtained from the Glen College Food Survey (1990).

- Irrigation Use

  The total irrigation use per quaternary catchment was taken from the WSAM. This use was then multiplied by the % reliance on ground water obtained from the Glen College Food Survey (1990).

The total use was determined by summation of the municipal, rural, livestock and irrigation use. It must be noted that information on mining and industrial use was not available and has not been included in the total use.

Workshops held in each of the Water Management Area's by the Water Resources Situation Assessment teams, provided local input to the water use numbers. These numbers were then adjusted by applying a factor to the Baron & Seward (2000) number to give the final ground water use figures.

3.5 Ground Water Balance

The Ground Water Balance was calculated for each quaternary catchment to determine the extent to which the ground water resources have been developed. This was done by means of comparing the values of Harvest Potential and Exploitation Potential with adjusted ground water use (as determined by Baron and Seward, 2000).

The following scenarios were mapped, viz :-

- If the total use was greater than the Harvest Potential then the catchment was considered to be over utilized.
- If the total use was greater than the Exploitation Potential but less than the Harvest Potential then the catchment was considered to be heavily utilized.
- If the total use was less than the Exploitation Potential but greater than 66% of the Exploitation Potential then the catchment was considered to be moderately utilized.
- If the total use was less than 66% of the Exploitation Potential the catchment was considered under utilized.

3.6 Water Quality

The ground water quality is one of the main factors affecting the development of available ground water resources. Although there are numerous problems associated with water quality, some of which are easily remediated, total dissolved solids (TDS), nitrates (NO_3 as N) and fluorides (F) are thought to represent the majority of serious water quality problems that occur.

The water quality has been evaluated in terms of TDS and potability. The information was obtained from WRC Project K5/841 (M Simonic 2000). The mean TDS together with the highest value, lowest value and range is given for each catchment where analyses were available. Where no analyses were available an estimate of the mean was made using Vegters Maps (Vegter, 1995). The potability evaluation done by Simonic (M Simonic, 2000) was based on the evaluation of chloride, fluoride, magnesium, nitrate, potassium, sodium, sulfate and calcium using the Quality of Domestic Water Supplies, Volume I (DWAF, 1998).

The TDS is described in terms of a classification system developed for this water resources situation assessment. The uses that were taken into account were domestic use and irrigation. It was assumed that if the water quality met the requirements for domestic and irrigation use it would in most cases satisfy the requirements of other uses. The South

African Water Quality Guidelines for the Department of Water Affairs and Forestry (1996) for these two uses were combined into a single classification system as shown in Table 3.6.1

TABLE 3.6.1: CLASSIFICATION SYSTEM FOR MINERALOGICAL WATER QUALITY

Class	Colour Code	Description	TDS Range (mg/l)
0	Blue	Ideal water quality	<260
1	Green	Good water quality	260 – 600
2	Yellow	Marginal water quality	601 – 1800
3	Red	Poor water quality	1801 – 3400
4	Purple	Completely unacceptable water quality	>3400

The portion of the ground water resources considered potable has been calculated as that portion classified as ideal, good and marginal (Class 0, 1 and 2) according to the Quality of Domestic Water Supplies, Volume I (DWAF, 1998). Water classified as poor and unacceptable has been considered **not** potable.

In catchments where no information was available estimates of the portion potable were made using Vegters maps (Vegter 1995).

4. DATA LIMITATIONS

It must be noted that this evaluation was done using existing available information. The evaluation is based on the harvest potential map which was derived from interpretations of limited existing information on recharge and a very broad qualitative assessment of storage capacity. The comparison of base flow with the harvest potential indicates that the harvest potential could be significantly underestimated in the wetter parts of the country. It is thought that this is due to an under estimation of the storage capacity.

Although yield data on some 91000 boreholes was used the accuracy of this data in some instances is questionable, as it was not known whether the yield was a blow yield estimated during drilling, or a yield recommended by a hydrogeologist from detailed pumping test results. In general, however, the yields do highlight areas of higher and lower yield potential such as the dolomite areas but in some areas such as catchment W70 appear to grossly underestimate the yield. Underestimation of the yield would negatively impact on the calculation of exploitation potential.

Information on ground water use was obtained mainly from indirect qualitative evaluations. Further, mining and industrial use was not available and was therefore not included in the total usage. This could have a significant effect on the ground water balance in specifically the gold mining areas.

Water quality data should also only be used to give regional trends. In many catchments data at only a few sample points were available. As a catchment could be underlain by numerous different lithologies, a large range in water quality can occur. The samples used in the analysis could thus be non representative of the catchment as a whole.

In general this study should be seen as a first quantitative estimate of the ground water resources of South Africa.

5. OVERVIEW OF THE GROUNDWATER RESOURCES OF SOUTH AFRICA

In over 90% of the surface area of South Africa, ground water occurs in secondary openings such as pores in weathered rock and faults, fractures, fissures and dissolution channels in so-called hard rock. These rocks consist of igneous, metamorphic and sedimentary rocks and range in age from Jurassic (± 140 x 10^6 yrs) to Swazian (3750 x 10^6 yrs).

In the remaining 10% of the surface area of South Africa ground water occurs in primary openings i.e., intergranular pores in mainly unconsolidated classic rocks. These rocks are generally recent in age (< 65 x 10^6 yrs) and consist of the Kalahari beds, the alluvial strip along some rivers and cenozoic deposits fringing the coast line, mainly in Northern Kwa Zulu Natal and the Southern and Western Cape.

The total Harvest Potential for South Africa has been calculated as 19100 x $10^6 m^3$/annum and varies from less than 0.5 mm/annum in quaternary catchment D82J to more than 352 mm/annum in quaternary catchment W12J.

Borehole yields vary considerably. The highest boreholes yields (up to 100 ℓ/s) have been found in the Malmani Dolomites. Other high borehole yielding (> 10 ℓ/s) lithostratigraphic units include the Table Mountain Quartsites of the Southern Cape, Basement Granites in the Pietersburg Dendron and Coetzerdam area, coastal deposits along Northern Natal, the eastern southern and western Cape, and alluvial deposits along certain sections of some of the major rivers such as the Limpopo River.

Moderate to good yields (> 5 ℓ/s) are found in the Letaba Basalt formation and where the Ecca has been intruded by dolerite dykes and sheets.

The total exploitation potential for South Africa has been calculated as 10100 x $10^6 m^3$/annum and varies from less than 0.2 mm/annum in quaternary catchment D82G to more than 211 mm/annum in quaternary catchment W12J.

The ground water use, excluding mines and industries, has been estimated to be some 1040 x $10^6 m^3$/annum and is concentrated in a few isolated areas.

The ground water balance shows that in general ground water is underutilized except for a few areas where over or heavy utilization occurs.

The extreme north western parts of South Africa show the poorest quality with TDS > 20000 mg/ℓ. The higher rainfall eastern parts have the best water quality, TDS < 100 mg/ℓ. The potability ranges between 0% in the extreme north-western parts of South Africa and 100% in the central and eastern areas. The main problems being brackish water and high nitrates and fluorides.

GROUNDWATER USE PER QUATERNARY CATCHMENT

QUATERNARY	AREA (km^2)	HARVEST POTENTIAL (mm)	oGHPi HARVEST POTENTIAL ($M.m^3/a$)	AVERAGE YIELD BOREHOLES (ℓ/s, 8hrs/day)	fGECi EXPLOITATION FACTOR	EXPLOITATION POTENTIAL (mm)	oGEPo EXPLOITATION POTENTIAL ($M.m^3/a$)	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (ℓ/s)	SUM OF BOREHOLE YIELDS ($M.m^3/a$)	MUNICIPAL USE ($M.m^3/a$)	RURAL USE ($M.m^3/a$)	LIVESTOCK USE ($M.m^3/a$)	IRRIGATION USE ($M.m^3/a$)	TOTAL USE FACTOR	oGWSo TOTAL USE ($M.m^3/a$)	TOTAL USE (mm/a)
E10A	134	85.4	11.44	9.95	0.7	59.8	8.01	32	318.50	3.35	0.0000	0.0000	0.0015	3.1679	0.9500	3.0109	22.5
E10B	202	87.5	17.68	4.29	0.7	61.3	12.37	1	4.29	0.05	0.0000	0.0000	0.0002	0.5584	1.0000	0.5586	2.8
E10C	192	62.9	12.09	8.13	0.7	44.1	8.46	2	16.25	0.17	0.0000	0.0000	0.0030	0.2053	1.0000	0.2083	1.1
E10D	235	87.5	20.56	2.47	0.6	52.5	12.34	8	19.74	0.21	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E10E	366	28.3	10.35	4.02	0.7	19.8	7.25	27	108.49	1.14	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E10F	386	35.5	13.69	4.76	0.7	24.8	9.59	21	99.88	1.05	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E10G	508	36.1	18.33	2.46	0.6	21.7	11.00	27	66.46	0.70	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E10H	162	34.2	5.54	3.10	0.7	23.9	3.88	0	0.00	0.00	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E10J	468	35.3	16.54	3.51	0.7	24.7	11.58	25	87.74	0.92	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E10K	235	30.6	7.20	0.88	0.5	15.3	3.60	20	17.59	0.18	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E21A	190	18.5	3.51	8.73	0.7	12.9	2.46	11	95.98	1.01	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	2.6
E21B	223	12.7	2.83	6.19	0.7	8.9	1.98	13	80.42	0.85	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	2.2
E21C	233	12.7	2.96	9.38	0.7	8.9	2.07	2	18.75	0.20	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	2.1
E21D	242	51.4	12.45	7.89	0.7	36.0	8.71	7	55.22	0.58	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	2.1
E21E	293	12.6	3.70	3.96	0.7	8.9	2.59	3	11.87	0.12	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	1.7
E21F	379	24.1	9.14	0.36	0.4	9.6	3.66	3	1.09	0.01	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	1.3
E21G	266	37.5	9.98	7.99	0.7	26.3	6.98	3	23.97	0.25	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	1.9
E21H	404	44.9	18.13	3.24	0.7	31.4	12.69	10	32.39	0.34	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	1.2
E21J	317	27.7	8.77	1.12	0.5	13.8	4.39	6	6.74	0.07	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	1.6
E21K	330	30.4	10.02	2.15	0.6	18.2	6.01	10	21.47	0.23	0.0000	0.0000	0.0000	0.5000	1.0000	0.5000	1.5
E21L	195	12.2	2.39	0.21	0.3	3.7	0.72	3	0.63	0.01	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E22A	750	7.2	5.42	1.01	0.5	3.6	2.71	37	37.30	0.39	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E22B	638	6.3	4.04	2.38	0.6	3.8	2.42	37	88.16	0.93	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E22C	490	11.9	5.83	7.12	0.7	8.3	4.08	13	92.52	0.97	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E22D	496	5.6	2.79	0.33	0.4	2.2	1.11	5	1.63	0.02	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E22E	1013	7.9	7.99	2.39	0.6	4.7	4.79	6	14.33	0.15	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E22F	400	9.5	3.78	0.61	0.4	3.8	1.51	7	4.29	0.05	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E22G	367	7.5	2.76	0.68	0.4	3.0	1.10	4	2.70	0.03	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E23A	762	8.1	6.16	2.68	0.6	4.8	3.69	13	34.90	0.37	0.0000	0.0000	0.0000	0.0046	1.0000	0.0046	0.0
E23B	705	6.8	4.79	2.95	0.6	4.1	2.88	11	32.50	0.34	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E23C	318	4.2	1.33	1.00	0.5	2.1	0.66	0	0.00	0.00	0.0000	0.0000	0.0001	0.0000	1.0000	0.0001	0.0

QUATERNARY	AREA (km^2)	HARVEST POTENTIAL (mm)	oGHPi HARVEST POTENTIAL ($M.m^3/a$)	AVERAGE YIELD BOREHOLES (ℓ/s, 8hrs/day)	fGECi EXPLOITATION FACTOR	EXPLOITATION POTENTIAL (mm)	oGEPo EXPLOITATION POTENTIAL ($M.m^3/a$)	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (ℓ/s)	SUM OF BOREHOLE YIELDS ($M.m^3/a$)	MUNICIPAL USE ($M.m^3/a$)	RURAL USE ($M.m^3/a$)	LIVESTOCK USE ($M.m^3/a$)	IRRIGATION USE ($M.m^3/a$)	TOTAL USE FACTOR	oGWSo TOTAL USE ($M.m^3/a$)	TOTAL USE (mm/a)
E23D	750	5.1	3.83	0.84	0.5	2.6	1.92	10	8.41	0.09	0.0000	0.0000	0.0045	0.1068	0.4000	0.0445	0.1
E23E	564	8.0	4.51	1.11	0.5	4.0	2.25	22	24.42	0.26	0.0000	0.0000	0.0034	0.2580	0.4000	0.1046	0.2
E23F	473	3.5	1.66	2.51	0.6	2.1	0.99	3	7.54	0.08	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E23G	747	4.7	3.53	5.68	0.7	3.3	2.47	6	34.06	0.36	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E23H	660	4.1	2.71	3.05	0.7	2.9	1.90	3	9.14	0.10	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E23J	895	3.6	3.25	0.20	0.3	1.1	0.97	0	0.00	0.00	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E23K	572	3.1	1.79	0.23	0.3	0.9	0.54	2	0.45	0.00	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E24A	255	31.9	8.14	3.80	0.7	22.3	5.70	1	3.80	0.04	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E24B	468	9.7	4.54	2.03	0.6	5.8	2.72	13	26.40	0.28	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E24C	784	7.5	5.84	0.80	0.5	3.7	2.92	65	52.13	0.55	0.0000	0.0000	0.0000	0.5835	0.4000	0.2334	0.3
E24D	997	6.2	6.15	1.00	0.5	3.1	3.07	0	0.00	0.00	0.0000	0.0000	0.0000	0.4772	0.4000	0.1909	0.2
E24E	671	8.5	5.71	0.82	0.5	4.3	2.86	70	57.74	0.61	0.0000	0.0000	0.0000	0.1168	0.4000	0.0467	0.1
E24F	582	7.8	4.55	1.65	0.6	4.7	2.73	51	83.92	0.88	0.0000	0.0000	0.0000	0.5572	0.4000	0.2229	0.4
E24G	633	5.7	3.63	1.54	0.6	3.4	2.18	36	55.36	0.58	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E24H	483	3.2	1.53	2.35	0.6	1.9	0.92	6	14.07	0.15	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E24J	1078	14.3	15.40	4.82	0.7	10.0	10.78	33	159.09	1.67	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E24K	652	16.4	10.67	1.02	0.5	8.2	5.33	59	60.47	0.64	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E24L	516	32.1	16.54	3.17	0.7	22.4	11.58	25	79.14	0.83	0.3000	0.0000	0.0006	1.6625	0.3000	0.5889	1.1
E24M	529	30.4	16.10	1.05	0.5	15.2	8.05	35	36.77	0.39	0.0000	0.0000	0.0101	0.2017	0.4000	0.0847	0.2
E31A	2865	0.9	2.63	0.71	0.5	0.5	1.31	95	67.00	0.70	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E31B	1476	3.0	4.43	0.94	0.5	1.5	2.21	8	7.49	0.08	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E31C	1572	2.9	4.63	1.21	0.5	1.5	2.31	36	43.52	0.46	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E31D	839	0.8	0.65	1.00	0.5	0.4	0.33	39	39.04	0.41	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E31E	478	2.3	1.10	0.98	0.5	1.1	0.55	8	7.81	0.08	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E31F	525	3.4	1.79	1.85	0.6	2.0	1.07	56	103.80	1.09	0.0600	0.5144	0.0000	0.0000	0.5000	0.2872	0.5
E31G	1238	0.7	0.89	0.72	0.5	0.4	0.44	86	62.19	0.65	0.0000	0.0000	0.0027	0.0000	1.0000	0.0027	0.0
E31H	726	1.7	1.22	0.38	0.4	0.7	0.49	21	8.03	0.08	0.0000	0.0000	0.0010	0.0000	1.0000	0.0010	0.0
E32A	1118	7.3	8.20	1.28	0.5	3.7	4.10	153	195.70	2.06	0.0000	0.0000	0.0000	1.7328	0.4000	0.6931	0.6
E32B	828	6.8	5.66	1.80	0.6	4.1	3.40	106	190.87	2.01	0.0000	0.0000	0.0000	2.7085	0.3000	0.8126	1.0
E32C	638	7.9	5.03	1.66	0.6	4.7	3.02	117	194.44	2.04	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E32D	616	6.0	3.71	1.27	0.5	3.0	1.85	56	71.16	0.75	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0
E32E	1001	12.6	12.59	1.14	0.5	6.3	6.30	114	130.07	1.37	0.0000	0.0000	0.0000	2.9174	0.3000	0.8752	0.9

QUATERNARY	AREA (km^2)	HARVEST POTENTIAL (mm)	oGHPi HARVEST POTENTIAL ($M.m^3/a$)	AVERAGE YIELD BOREHOLES (ℓ/s, 8hrs/day)	fGECi EXPLOITATION FACTOR	EXPLOITATION POTENTIAL (mm)	oGEPo EXPLOITATION POTENTIAL ($M.m^3/a$)	NO OF BORES WITH YIELD DATA	SUM OF YIELDS (ℓ/s)	SUM OF BOREHOLE YIELDS ($M.m^3/a$)	MUNICIPAL USE ($M.m^3/a$)	RURAL USE ($M.m^3/a$)	LIVESTOCK USE ($M.m^3/a$)	IRRIGATION USE ($M.m^3/a$)	TOTAL USE FACTOR	oGWSo TOTAL USE ($M.m^3/a$)	TOTAL USE (mm/a)
E33A	1355	0.8	1.11	0.66	0.4	0.3	0.44	65	42.73	0.45	0.0000	0.0000	0.0303	0.0000	1.0000	0.0303	0.0
E33B	702	1.3	0.88	2.23	0.6	0.8	0.53	14	31.28	0.33	0.0000	0.0000	0.0209	0.0000	1.0000	0.0209	0.0
E33C	980	5.7	5.54	1.03	0.5	2.8	2.77	32	32.85	0.35	0.0000	0.0000	0.0264	0.0000	1.0000	0.0264	0.0
E33D	1559	1.6	2.44	0.85	0.5	0.8	1.22	159	135.90	1.43	0.0000	0.0000	0.0487	0.0000	1.0000	0.0487	0.0
E33E	1282	1.3	1.60	0.99	0.5	0.6	0.80	68	67.22	0.71	0.1500	0.0000	0.0397	0.0000	1.0000	0.1897	0.1
E33F	725	12.3	8.95	4.02	0.7	8.6	6.26	191	767.92	8.07	0.0000	0.0000	0.0134	0.0000	1.0000	0.0134	0.0
E33G	894	8.5	7.56	2.41	0.6	5.1	4.54	61	146.81	1.54	0.1900	0.0000	0.0156	0.0000	1.0000	0.2056	0.2
E33H	719	2.1	1.52	0.82	0.5	1.1	0.76	64	52.64	0.55	0.0000	0.0000	0.0188	0.0000	1.0000	0.0188	0.0
E40A	941	7.8	7.34	1.64	0.6	4.7	4.40	176	288.41	3.03	0.0000	0.0000	0.0000	3.0550	0.4000	1.2220	1.3
E40B	707	7.9	5.62	1.98	0.6	4.8	3.37	122	241.36	2.54	0.5600	0.2735	0.0000	0.2991	0.4000	0.4530	0.6
E40C	530	16.5	8.74	1.91	0.6	9.9	5.24	123	234.95	2.47	0.0900	0.0000	0.0000	0.0000	1.0000	0.0900	0.2
E40D	544	24.8	13.49	1.46	0.5	12.4	6.75	12	17.55	0.18	0.0000	0.0000	0.0015	0.0000	1.0000	0.0015	0.0
F60A	572	4.4	2.51	0.72	0.5	2.2	1.25	130	93.05	0.98	0.0000	0.0000	0.0090	0.0000	0.7000	0.0063	0.0
F60B	320	2.8	0.89	0.72	0.5	1.4	0.44	45	32.46	0.34	0.0400	0.0000	0.0090	0.0000	0.7000	0.0343	0.1
F60C	622	2.7	1.67	0.76	0.5	1.3	0.83	68	51.59	0.54	0.0000	0.0000	0.0102	0.0000	0.7000	0.0071	0.0
F60D	481	2.5	1.21	0.34	0.4	1.0	0.49	71	23.89	0.25	0.0000	0.0000	0.0194	0.0000	0.7000	0.0136	0.0
F60E	795	2.5	1.99	0.35	0.4	1.0	0.80	0	0.00	0.00	0.0000	0.0000	0.0164	0.0000	0.7000	0.0115	0.0
G30A	503	37.6	18.94	1.35	0.5	18.8	9.47	41	55.33	0.58	0.0000	0.0000	0.1440	1.7973	2.6500	5.1444	10.2
G30B	658	35.2	23.14	3.11	0.7	24.6	16.20	10	31.08	0.33	0.1000	0.0000	0.0006	1.4785	2.6500	4.1846	6.4
G30C	351	33.8	11.86	2.69	0.6	20.3	7.11	16	42.98	0.45	0.0000	0.0000	0.0006	1.8526	2.6500	4.9110	14.0
G30D	534	35.6	19.02	1.91	0.6	21.4	11.41	8	15.31	0.16	0.0000	0.0000	0.0704	1.9322	2.6500	5.3069	9.9
G30E	352	21.6	7.61	1.82	0.6	13.0	4.57	32	58.15	0.61	0.1700	0.0000	0.0484	0.5948	2.5000	2.0330	5.8
G30F	780	26.4	20.57	4.36	0.7	18.5	14.40	196	854.72	8.98	0.0000	0.0000	0.0137	1.4109	2.6500	3.7752	4.8
G30G	647	23.0	14.89	2.19	0.6	13.8	8.93	168	368.59	3.87	0.0601	0.0000	0.0090	1.6400	2.6500	4.5291	7.0
G30H	1077	11.0	11.79	1.22	0.5	5.5	5.90	209	254.16	2.67	0.0000	0.0000	0.0346	0.0627	2.5000	0.2433	0.2
TOTALS	**56758**	**1474.8**	**635.68**	**210.09**				**3783**	**7170.76**	**75.39**	**1.7201**	**0.7879**	**0.6277**	**34.3817**		**45.4915**	

GROUNDWATER CONTRIBUTION TO BASE FLOW PER QUATERNARY CATCHMENT

	vMARi				oGBFi		fGBDo			fGPQi	$_{0}$GWM$_{0}$
QUATERNARY	MEAN ANNUAL RUNOFF (M.m^3/a)	BASE FLOW SCHULTZ (mm/a)	BASE FLOW PITTMAN (mm/a)	BASE FLOW HUGHES (mm/a)	BASE FLOW SCHULTZ (M.m^3/a)	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUND WATER UTILISATION	IMPACT OFGROUND WATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER (X10^6 m^3/annum)
E10A	95.40	14.95	56.60	133.90	2.00	0.18	0.18	UNDER-UTILISED	LOW	0.85	6.81
E10B	36.60	3.64	42.70	100.13	0.74	0.04	0.04	UNDER-UTILISED	LOW	0.85	10.52
E10C	34.70	3.14	31.50	74.22	0.60	0.05	0.05	UNDER-UTILISED	LOW	0.85	7.19
E10D	58.10	3.93	25.50	58.91	0.92	0.04	0.04	UNDER-UTILISED	LOW	1.00	12.34
E10E	62.20	2.24	17.90	39.48	0.82	0.08	0.08	UNDER-UTILISED	LOW	1.00	7.25
E10F	62.40	2.13	17.00	37.24	0.82	0.06	0.06	UNDER-UTILISED	LOW	0.85	8.15
E10G	82.00	2.13	17.00	38.14	1.08	0.06	0.06	UNDER-UTILISED	LOW	0.85	9.35
E10H	39.20	3.05	23.70	55.76	0.49	0.09	0.09	UNDER-UTILISED	LOW	0.85	3.29
E10J	35.20	1.65	8.50	19.25	0.77	0.05	0.05	UNDER-UTILISED	LOW	0.83	9.65
E10K	5.00	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	1.44
E21A	34.88	5.07	24.40	56.91	0.96	0.27	0.27	UNDER-UTILISED	LOW	1.00	2.46
E21B	26.94	3.37	16.40	36.71	0.75	0.27	0.27	UNDER-UTILISED	LOW	1.00	1.98
E21C	24.93	2.82	14.80	32.56	0.66	0.22	0.22	UNDER-UTILISED	LOW	0.40	0.83
E21D	45.37	5.06	24.90	58.53	1.22	0.10	0.10	UNDER-UTILISED	LOW	1.00	8.71
E21E	19.59	1.75	9.20	20.41	0.51	0.14	0.14	UNDER-UTILISED	LOW	0.40	1.04
E21F	16.55	1.11	6.20	13.42	0.42	0.05	0.05	UNDER-UTILISED	LOW	0.40	1.46
E21G	30.56	3.03	15.20	35.93	0.81	0.08	0.08	UNDER-UTILISED	LOW	0.70	4.89
E21H	38.10	2.52	12.60	29.51	1.02	0.06	0.06	UNDER-UTILISED	LOW	0.85	10.79
E21J	18.78	1.51	8.20	18.22	0.48	0.05	0.05	UNDER-UTILISED	LOW	0.80	3.51
E21K	21.47	1.46	8.80	19.24	0.48	0.05	0.05	UNDER-UTILISED	LOW	0.85	5.11
E21L	1.34	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.29
E22A	8.12	0.00	0.00	0.31	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.64	1.74
E22B	6.75	0.00	0.00	0.24	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.33	0.81
E22C	13.41	0.00	0.00	1.73	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	1.00	4.08
E22D	3.92	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.00	0.00
E22E	6.49	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.50	2.40
E22F	0.96	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.61
E22G	1.11	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.44
E23A	7.69	0.00	0.00	0.32	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.70	2.59

	vMARi				oGBFi		fGBDo			fGPQi	oGWMo
QUATERNARY	MEAN ANNUAL RUNOFF ($M.m^3/a$)	BASE FLOW SCHULTZ (mm/a)	BASE FLOW PITTMAN (mm/a)	BASE FLOW HUGHES (mm/a)	BASE FLOW SCHULTZ ($M.m^3/a$)	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUND WATER UTILISATION	IMPACT OFGROUND WATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER ($X10^6$ m^3/annum)
E23B	5.92	0.00	0.00	0.14	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.50	1.44
E23C	1.80	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.27
E23D	4.67	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.77
E23E	6.60	0.00	0.00	0.35	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.50	1.13
E23F	0.52	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.40
E23G	3.16	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.99
E23H	3.63	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.76
E23J	1.18	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.39
E23K	0.53	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.21
E24A	17.31	0.00	10.70	8.17	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.85	4.84
E24B	10.27	0.00	0.00	2.06	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	1.09
E24C	10.24	0.00	0.00	1.31	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	1.17
E24D	5.68	0.00	0.00	0.40	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	1.23
E24E	5.81	0.00	0.00	0.61	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.56	1.59
E24F	4.17	0.00	0.00	0.39	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	1.09
E24G	3.81	0.00	0.00	0.21	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.20	0.44
E24H	4.01	0.00	0.00	0.30	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.37
E24J	20.34	0.00	0.00	1.95	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.27	2.94
E24K	10.18	0.00	0.00	1.27	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.56	2.96
E24L	23.36	0.92	7.10	13.12	0.48	0.03	0.03	UNDER-UTILISED	LOW	0.40	4.63
E24M	9.82	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.67	5.37
E31A	0.29	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.53
E31B	1.62	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.40	0.89
E31C	0.55	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.20	0.46
E31D	0.31	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.00	0.00
E31E	0.61	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.00	0.00
E31F	1.00	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.38	0.41
E31G	0.39	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.10	0.04
E31H	0.78	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.00	0.00
E32A	3.77	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.60	2.46
E32B	1.82	0.00	0.00	0.00	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGIBLE	0.57	1.94

	vMARi				oGBFi		fGBDo			fGPQi	oGWMo
QUATERNARY	MEAN ANNUAL RUNOFF ($M.m^3/a$)	BASE FLOW SCHULTZ (mm/a)	BASE FLOW PITTMAN (mm/a)	BASE FLOW HUGHES (mm/a)	BASE FLOW SCHULTZ ($M.m^3/a$)	BASE FLOW FACTOR	CORRECTED BASE FLOW FACTOR	ESTIMATED EXTENT OF GROUND WATER UTILISATION	IMPACT OFGROUND WATER ABSRTACTION ON SURFACE WATER	PORTION POTABLE	MAX UTILISABLE GROUND WATER ($X10^6$ m^3/annum)
E32C	2.98	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.60	1.81
E32D	1.15	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.43	0.79
E32E	2.62	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.31	1.97
E33A	1.00	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.00	0.00
E33B	0.32	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.00	0.00
E33C	0.99	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.09	0.25
E33D	1.23	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.02	0.02
E33E	0.82	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.07	0.06
E33F	3.30	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.71	4.46
E33G	2.54	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.47	2.14
E33H	0.62	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.00	0.00
E40A	7.38	0.00	0.00	0.09	0.00	0.00	0.00	MODERATELY-UTILISED	NEGLIGIBLE	0.30	1.31
E40B	5.98	0.00	0.00	0.04	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.50	1.68
E40C	6.76	0.00	0.00	0.28	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.50	2.62
E40D	6.95	0.00	0.00	0.28	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.89	6.00
F60A	0.13	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.12	0.15
F60B	0.17	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.00	0.00
F60C	0.21	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.03	0.03
F60D	0.20	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.10	0.05
F60E	0.29	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.25	0.20
G30A	4.76	0.00	0.00	0.07	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.28	2.60
G30B	18.87	0.73	4.30	8.68	0.48	0.02	0.02	UNDER-UTILISED	LOW	1.00	16.20
G30C	11.28	0.77	4.80	9.32	0.27	0.02	0.02	UNDER-UTILISED	LOW	0.85	6.05
G30D	11.89	0.00	0.00	1.72	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.94	10.74
G30E	1.86	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.50	2.28
G30F	6.82	0.00	0.00	0.25	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.85	12.22
G30G	1.74	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.68	6.04
G30H	3.26	0.00	0.00	0.00	0.00	0.00	0.00	UNDER-UTILISED	NEGLIGIBLE	0.29	1.68
TOTALS	**1108.03**				**16.78**						**251.89**

OLIFANTS/DORING WATER MANAGEMENT AREA

APPENDIX G.5 : WATER QUALITY INFORMATION

Quaternary	Station no	Mean (mg/ℓ)	Maximum (mg/ℓ)	Mean colour	Maximum colour	Overall colour
E10A	No					Blue
E10B	No					Blue
E10C	No					Blue
E10D	No					Blue
E10E	E1H013Q01	51	121	Blue	Blue	Blue
E10F	No					Blue
E10G	No					Blue
E10H	No					Blue
E10J	E1R002Q01	50	91	Blue	Blue	Blue
E10K	E1R001Q01	66	126	Blue	Blue	Blue
E21A	No					
E21B	No					
E21C	No					
E21D	No					
E21E	No					
E21F	No					
E21G	E2H007Q01	72	135	Blue	Blue	Blue
E21H	No					Blue
E21J	No					Blue
E21K	No					
E21L	No					Blue
E22A	No					Blue
E22B	No					Blue
E22C	No					Blue
E22D	No					Blue
E22E	No					Blue
E22F	No					Blue
E22G	E2H002Q01	56	106	Blue	Blue	Blue
E23A	No					
E23B	No					
E23C	No					
E23D	No					
E23E	No					
E23F	No					
E23G	No					
E23H	No					
E23J	No					
E23K	No					
E24A	No					
E24B	No					
E24C	No					
E24D	No					
E24E	No					
E24F	No					
E24G	No					
E24H	No					

Quaternary	Station no	Mean (mg/ℓ)	Maximum (mg/ℓ)	Mean colour	Maximum colour	Overall colour
E24J	No					
E24K	No					
E24L	No					
E24M	E2H003Q01	205	905	Blue	Yellow	Green
E31A	No					
E31B	No					
E31C	No					
E31D	No					
E31E	No					
E31F	No					
E31G	No					
E31H	No					
E32A	No					
E32B	No					
E32C	No					
E32D	No					
E32E	No					
E33A	No					
E33B	No					
E33C	No					
E33D	No					
E33E	No					
E33F	No					
E33G	No					
E33H	No					
E40A	No					
E40B	No					
E40C	No					
E40D	No					
F60A	No					
F60B	No					
F60C	No					
F60D	No					
G30A	No					
G30B	No					
G30C	No					
G30D	G3H001Q01	2298	5384	Purple	Purple	Purple
G30E	No			Purple	Purple	Purple
G30F	No					
G30G	No					
G30H	No					

APPENDIX H

WATER RESOURCES

APPENDIX H.1	**Data sources.**
APPENDIX H.2	**Data default values used in WRSA report.**

APPENDIX H.1

DATA SOURCES

Data type	Responsible organisation
Afforestation	CSIR
Alien vegetation	CSIR
Industrial, urban and strategic water use	WRSA consultants
Groundwater	WSM Consulting Engineers
Dams	DWAF
Transfer schemes	WRSA consultants
Run-of-river yields	Arcus Gibb
Population	Markdata
Ecological Reserve	IWR, Prof Hughes
Irrigation - Areas and crop types - Efficiency and losses - Evapotranspiration and crop factors	 WRSA consultant WRSA consultant WRP
Storage-draft-frequency curves	WRP

APPENDIX H.2

DATA DEFAULT VALUES USED IN THE WRSA REPORT

PARAMETER	DESCRIPTION	DEFAULT VALUE
FBMLi	Mining losses (factor)	0,1
FBOLi	Other industrial losses (factor)	0,1
FBSLi	Strategic losses (factor)	0,05
FIHCi	Irrigation conveyance losses- High category irrigation (factor)	0,1
FIMCi	Irrigation conveyance losses- Medium category irrigation (factor)	0,1
FILCi	Irrigation conveyance losses- Low category irrigation (factor)	0,1
FIPLi	Irrigation efficiency Low category irrigation (factor)	0,75
FilPMi	Irrigation efficiency Medium category irrigation (factor)	0,75
FilPHi	Irrigation efficiency High category irrigation (factor)	0,75
ORTLi	Rural losses (factor)	0,2

THE DATA AT QUATERNARY CATCHMENT RESOLUTION

For the record – not part of appendix

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D11A	278	278	7	10	203	56434	0.0565	0.0426	255	71024	0.0712	0.0536
D11B	236	236	7	10	203	47908	0.0480	0.0589	255	60294	0.0604	0.0741
D11C	292	292	7	10	203	59276	0.0594	0.0549	255	74601	0.0748	0.0691
D11D	319	319	7	10	203	64757	0.0649	0.0774	255	81499	0.0817	0.0975
D11E	322	322	7	10	203	65366	0.0655	0.1018	255	82266	0.0824	0.1281
D11F	413	413	7	10	203	83839	0.0840	0.0749	255	105514	0.1057	0.0943
D11G	320	320	7	10	203	64960	0.0651	0.1368	255	81755	0.0819	0.1722
D11H	359	359	7	10	203	72877	0.0730	0.1420	255	91718	0.0919	0.1787
D11J	440	440	7	10	203	89320	0.0895	0.1485	255	112412	0.1126	0.1869
D11K	381	381	7	10	203	77343	0.0775	0.1565	255	97339	0.0975	0.1970
0	**3360**	**3360**				**682080**	**0.6834**	**0.0863**		**858423**	**0.8601**	**0.1087**
D12A	369	369	6	13	335	123615	0.1239	0.2878	422	155574	0.1559	0.3622
D12B	385	385	6	13	335	128975	0.1292	0.1969	422	162320	0.1626	0.2478
D12C	343	343	6	13	335	114905	0.1151	0.5597	422	144612	0.1449	0.7044
D12D	355	355	6	12	335	118925	0.1192	0.6649	422	149671	0.1500	0.8368
D12E	712	712	6	12	335	238520	0.2390	0.7200	422	300186	0.3008	0.9062
D12F	803	803	6	13	335	269005	0.2695	0.9797	422	338553	0.3392	1.2330
0	**2967**	**2967**				**993945**	**0.9959**	**0.4791**		**1250916**	**1.2534**	**0.6030**
D13A	475	475	6	13	335	159125	0.1594	0.2239	422	200265	0.2007	0.2817
D13B	533	533	6	13	335	178555	0.1789	0.2420	422	224718	0.2252	0.3046
D13C	517	517	6	13	335	173195	0.1735	0.3160	422	217972	0.2184	0.3977
D13D	635	635	6	13	335	212725	0.2132	0.3679	422	267722	0.2683	0.4630
D13E	1031	1031	6	13	335	345385	0.3461	0.2673	422	434680	0.4355	0.3364
D13F	970	970	6	13	335	324950	0.3256	0.3358	422	408961	0.4098	0.4226
D13G	1125	1125	6	13	335	376875	0.3776	0.7118	422	474311	0.4753	0.8958
D13H	1144	1144	6	13	335	383240	0.3840	1.2843	422	482322	0.4833	1.6163
D13J	1167	1167	6	13	335	390945	0.3917	1.1828	422	492019	0.4930	1.4886

Quat. Number	**Gross area (km2)**	**Net area (km2)**	**Sediment region**	**Erodibility index**	**Sediment (t/km2/a)**	**Sediment yield (t/a)**	**Sediment vol(MCM)**	**Volume (%MAR)**	***Sediment (t/km2/a)***	***Sediment yield (t/a)***	***Sediment vol(MCM)***	***Volume (%MAR)***
D13K	397	397	6	13	335	132995	0.1333	0.2641	422	167379	0.1677	0.3324
D13L	682	682	6	13	335	228470	0.2289	0.9037	422	287538	0.2881	1.1373
D13M	678	678	6	13	335	227130	0.2276	1.0546	422	285851	0.2864	1.3272
0	**9354**	**9354**				**3133590**	**3.1399**	**0.4499**		**3943737.7**	**3.9516**	**0.5662**
D14A	764	764	6	12	335	255940	0.2565	1.0205	422	322110	0.3228	1.2843
D14B	324	324	6	13	335	108540	0.1088	1.3492	422	136602	0.1369	1.6981
D14C	722	722	6	13	335	241870	0.2424	1.3106	422	304402	0.3050	1.6494
D14D	680	680	6	13	335	227800	0.2283	1.9450	422	286695	0.2873	2.4479
D14E	663	663	6	13	335	222105	0.2225	2.1580	422	279527	0.2801	2.7159
D14F	541	541	6	13	335	181235	0.1816	1.2767	422	228091	0.2285	1.6067
D14G	605	605	6	13	335	202675	0.2031	1.0383	422	255074	0.2556	1.3068
D14H	697	697	6	13	335	233495	0.2340	1.5790	422	293862	0.2944	1.9872
D14J	515	515	6	13	335	172525	0.1729	1.5681	422	217129	0.2176	1.9735
D14K	634	634	6	13	335	212390	0.2128	1.6937	422	267301	0.2678	2.1316
0	**6145**	**6145**				**2058575**	**2.0627**	**1.4136**		**2590792**	**2.5960**	**1.7790**
D15A	437	437	7	10	203	88711	0.0889	0.0749	255	111646	0.1119	0.0942
D15B	393	393	7	10	203	79779	0.0799	0.0773	255	100405	0.1006	0.0973
D15C	276	276	7	10	203	56028	0.0561	0.1036	255	70513	0.0707	0.1304
D15D	437	437	7	12	203	88711	0.0889	0.0842	255	111646	0.1119	0.1060
D15E	619	619	7	12	203	125657	0.1259	0.1097	255	158144	0.1585	0.1380
D15F	352	352	7	12	203	71456	0.0716	0.2366	255	89930	0.0901	0.2978
D15G	485	485	7	12	203	98455	0.0987	0.3474	255	123909	0.1242	0.4372
D15H	361	361	7	12	203	73283	0.0734	0.4943	255	92229	0.0924	0.6221
0	**3360**	**3360**				**682080**	**0.6834**	**0.1199**		**858422.63**	**0.8601**	**0.1509**
D16A	159	159	7	10	203	32277	0.0323	0.0762	255	40622	0.0407	0.0960
D16B	249	249	7	10	203	50547	0.0506	0.0925	255	63615	0.0637	0.1164
D16C	438	438	7	10	203	88914	0.0891	0.2732	255	111902	0.1121	0.3438
D16D	339	339	7	10	203	68817	0.0690	0.1114	255	86609	0.0868	0.1402
D16E	434	434	7	10	203	88102	0.0883	0.1763	255	110880	0.1111	0.2219
D16F	277	277	7	10	203	56231	0.0563	0.1105	255	70769	0.0709	0.1391
D16G	290	290	7	10	203	58870	0.0590	0.1269	255	74090	0.0742	0.1597
D16H	345	345	7	10	203	70035	0.0702	0.2191	255	88142	0.0883	0.2758

Quat. Number	**Gross area (km2)**	**Net area (km2)**	**Sediment region**	**Erodibility index**	**Sediment (t/km2/a)**	**Sediment yield (t/a)**	**Sediment vol(MCM)**	**Volume (%MAR)**	***Sediment (t/km2/a)***	***Sediment yield (t/a)***	***Sediment vol(MCM)***	***Volume (%MAR)***
D16J	374	374	7	10	203	75922	0.0761	0.1584	255	95551	0.0957	0.1993
D16K	329	329	7	10	203	66787	0.0669	0.1116	255	84054	0.0842	0.1404
D16L	533	533	7	10	203	108199	0.1084	0.1819	255	136172	0.1364	0.2290
D16M	753	753	7	10	203	152859	0.1532	0.1152	255	192379	0.1928	0.1450
0	**4520**	**4520**				**917560**	**0.9194**	**0.1369**		**1154782.8**	**1.1571**	**0.1722**
D17A	638	638	7	10	203	129514	0.1298	0.0629	255	162998	0.1633	0.0791
D17B	442	442	7	10	203	89726	0.0899	0.0710	255	112923	0.1131	0.0894
D17C	525	525	7	10	203	106575	0.1068	0.1379	255	134129	0.1344	0.1735
D17D	748	748	7	10	203	151844	0.1521	0.1356	255	191101	0.1915	0.1707
D17E	605	605	7	10	203	122815	0.1231	0.1276	255	154567	0.1549	0.1606
D17F	582	582	7	10	203	118146	0.1184	0.2451	255	148691	0.1490	0.3084
D17G	849	849	7	10	203	172347	0.1727	0.1584	255	216905	0.2173	0.1994
D17H	852	852	7	10	203	172956	0.1733	0.1701	255	217671	0.2181	0.2140
D17J	437	437	7	10	203	88711	0.0889	0.0890	255	111646	0.1119	0.1120
D17K	383	383	7	10	203	77749	0.0779	0.1533	255	97850	0.0980	0.1929
D17L	590	590	7	10	203	119770	0.1200	0.1611	255	150735	0.1510	0.2027
D17M	528	528	7	10	203	107184	0.1074	0.1475	255	134895	0.1352	0.1857
0	**7179**	**7179**				**1457337**	**1.4603**	**0.1241**		**1834111.9**	**1.8378**	**0.1562**
D18A	599	599	7	10	203	121597	0.1218	0.1259	255	153034	0.1533	0.1584
D18B	327	327	7	10	203	66381	0.0665	0.1668	255	83543	0.0837	0.2100
D18C	466	466	7	12	203	94598	0.0948	0.1972	255	119055	0.1193	0.2482
D18D	766	766	7	10	203	155498	0.1558	0.1393	255	195700	0.1961	0.1753
D18E	376	376	7	10	203	76328	0.0765	0.1376	255	96062	0.0963	0.1731
D18F	446	446	7	12	203	90538	0.0907	0.2071	255	113945	0.1142	0.2607
D18G	492	492	7	13	203	99876	0.1001	0.1160	255	125698	0.1259	0.1460
D18H	384	384	7	13	203	77952	0.0781	0.1551	255	98105	0.0983	0.1952
D18J	859	859	7	12	203	174377	0.1747	0.1561	255	219460	0.2199	0.1964
D18K	935	935	7	13	203	189805	0.1902	0.1290	255	238877	0.2394	0.1623
D18L	610	610	7	12	203	123830	0.1241	0.1919	255	155845	0.1562	0.2415
0	**6260**	**6260**				**1270780**	**1.2733**	**0.1486**		**1599323.1**	**1.6025**	**0.1871**
D21A	309	309	6	10	335	103515	0.1037	0.1688	422	130277	0.1305	0.2124
D21B	394	394	6	10	335	131990	0.1323	0.1495	422	166114	0.1664	0.1882

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D21C	212	212	6	9	335	71020	0.0712	0.2287	422	89381	0.0896	0.2878
D21D	252	252	6	9	335	84420	0.0846	0.2762	422	106246	0.1065	0.3476
D21E	268	268	6	9	335	89780	0.0900	0.3430	422	112991	0.1132	0.4317
D21F	480	480	6	9	335	160800	0.1611	0.4945	422	202373	0.2028	0.6223
D21G	278	278	6	9	335	93130	0.0933	0.4354	422	117208	0.1174	0.5480
D21H	381	381	6	9	335	127635	0.1279	0.3292	422	160633	0.1610	0.4143
D21J	359	359	6	10	335	120265	0.1205	0.1620	422	151358	0.1517	0.2039
D21K	326	326	6	10	335	109210	0.1094	0.1772	422	137445	0.1377	0.2230
D21L	304	304	6	9	335	101840	0.1020	0.2519	422	128169	0.1284	0.3170
0	**3563**	**3563**				**1193605**	**1.1960**	**0.2357**		**1502195.6**	**1.5052**	**0.2967**
D22A	636	636	6	9	335	213060	0.2135	0.5977	422	268144	0.2687	0.7522
D22B	457	457	6	9	335	153095	0.1534	0.4794	422	192676	0.1931	0.6033
D22C	486	486	6	9	335	162810	0.1631	0.3321	422	204902	0.2053	0.4180
D22D	628	628	6	9	335	210380	0.2108	0.5729	422	264771	0.2653	0.7211
D22E	498	498	6	10	335	166830	0.1672	0.3266	422	209962	0.2104	0.4111
D22F	633	633	6	9	335	212055	0.2125	0.4105	422	266879	0.2674	0.5166
D22G	969	969	6	9	335	324615	0.3253	0.6144	422	408540	0.4094	0.7733
D22H	541	541	6	9	335	181235	0.1816	0.5043	422	228091	0.2285	0.6347
D22J	652	652	6	10	335	218420	0.2189	0.3533	422	274890	0.2754	0.4447
D22K	324	324	6	10	335	108540	0.1088	0.3859	422	136602	0.1369	0.4857
D22L	376	376	6	11	335	125960	0.1262	0.5836	422	158525	0.1588	0.7345
0	**6200**	**6200**				**2077000**	**2.0812**	**0.4551**		**2613980.5**	**2.6192**	**0.5728**
D23A	608	608	6	12	335	203680	0.2041	0.5334	422	256339	0.2569	0.6713
D23B	597	597	6	12	335	199995	0.2004	0.4911	422	251701	0.2522	0.6181
D23C	861	861	3	12	82	70602	0.0707	0.1730	103	88855	0.0890	0.2177
D23D	565	565	6	12	335	189275	0.1897	0.8614	422	238210	0.2387	1.0841
D23E	702	702	6	12	335	235170	0.2356	0.8219	422	295970	0.2966	1.0343
D23F	352	352	6	12	335	117920	0.1182	0.6037	422	148407	0.1487	0.7598
D23G	512	512	6	12	335	171520	0.1719	0.6553	422	215864	0.2163	0.8248
D23H	776	776	6	12	335	259960	0.2605	1.3243	422	327169	0.3278	1.6667
D23J	534	534	6	12	335	178890	0.1792	1.1169	422	225140	0.2256	1.4057

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
0	**5507**	**5507**				**1627012**	**1.6303**	**0.6465**		**2047654.1**	**2.0517**	**0.8136**
D24A	310	310	6	12	335	103850	0.1041	0.5452	422	130699	0.1310	0.6862
D24B	470	470	6	12	335	157450	0.1578	0.6896	422	198157	0.1986	0.8679
D24C	398	398	6	12	335	133330	0.1336	0.9886	422	167801	0.1681	1.2442
D24D	598	598	6	12	335	200330	0.2007	1.3334	422	252123	0.2526	1.6781
D24E	489	489	6	12	335	163815	0.1641	1.3315	422	206167	0.2066	1.6757
D24F	567	567	6	12	335	189945	0.1903	1.0849	422	239053	0.2395	1.3653
D24G	626	626	6	13	335	209710	0.2101	0.9379	422	263928	0.2645	1.1804
D24H	736	736	6	12	335	246560	0.2471	1.3026	422	310305	0.3109	1.6394
D24J	1032	1032	6	12	335	345720	0.3464	1.6795	422	435101	0.4360	2.1137
D24K	877	877	6	12	335	293795	0.2944	1.7489	422	369752	0.3705	2.2011
D24L	511	511	6	12	335	171185	0.1715	1.8793	422	215443	0.2159	2.3651
0	**6614**	**6614**				**2215690**	**2.2201**	**1.1787**		**2788526.9**	**2.7941**	**1.4834**
D31A	1160	1160	5	12	30	34800	0.0349	0.2128	38	43797	0.0439	0.2678
D31B	996	757	5	13	30	22710	0.0228	0.5438	38	28581	0.0286	0.6844
D31C	677	677	5	12	30	20310	0.0204	0.4541	38	25561	0.0256	0.5715
D31D	1108	833	5	12	30	24990	0.0250	0.2575	38	31451	0.0315	0.3241
D31E	969	969	5	12	30	29070	0.0291	0.3395	38	36586	0.0367	0.4273
0	**4910**	**4396**				**131880**	**0.1321**	**0.3048**		**165975.8**	**0.1663**	**0.3836**
D32A	716	716	5	12	30	21480	0.0215	0.5253	38	27033	0.0271	0.6611
D32B	582	582	5	13	30	17460	0.0175	0.3693	38	21974	0.0220	0.4648
D32C	850	850	5	12	30	25500	0.0256	0.5117	38	32093	0.0322	0.6440
D32D	851	851	5	12	30	25530	0.0256	0.5400	38	32130	0.0322	0.6796
D32E	1157	1157	5	13	30	34710	0.0348	0.9054	38	43684	0.0438	1.1395
D32F	1443	1443	5	13	30	43290	0.0434	0.5841	38	54482	0.0546	0.7351
D32G	1045	1045	5	12	30	31350	0.0314	0.4304	38	39455	0.0395	0.5417
D32H	572	572	5	12	30	17160	0.0172	0.4476	38	21596	0.0216	0.5634
D32J	1114	1041	5	12	30	31230	0.0313	0.5128	38	39304	0.0394	0.6454
D32K	824	824	5	12	30	24720	0.0248	0.4606	38	31111	0.0312	0.5797
0	**9154**	**9081**				**272430**	**0.2730**	**0.5204**		**342863.12**	**0.3435**	**0.6550**
D33A	593	472	5	12	30	14160	0.0142	0.9903	38	17821	0.0179	1.2463
D33B	1018	323	5	12	30	9690	0.0097	1.1770	38	12195	0.0122	1.4813

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D33C	805	520	5	12	30	15600	0.0156	0.9679	38	19633	0.0197	1.2182
D33D	952	311	5	12	30	9330	0.0093	1.4309	38	11742	0.0118	1.8008
D33E	1554	343	5	12	30	10290	0.0103	1.3347	38	12950	0.0130	1.6797
D33F	863	77	5	12	30	2310	0.0023	1.7295	38	2907	0.0029	2.1766
D33G	1406	400	5	12	30	12000	0.0120	1.7610	38	15102	0.0151	2.2163
D33H	1054	468	5	7	80.7	37767.6	0.0378	4.0585	102	47532	0.0476	5.1077
D33J	865	200	5	12	30	6000	0.0060	2.1668	38	7551	0.0076	2.7270
D33K	488	290	5	12	30	8700	0.0087	1.6299	38	10949	0.0110	2.0513
0	**9598**	**3404**				**125847.6**	**0.1261**	**1.6044**		**158383.81**	**0.1587**	**2.0191**
D34A	794	794	5	12	30	23820	0.0239	0.2193	38	29978	0.0300	0.2760
D34B	706	706	5	12	30	21180	0.0212	0.2960	38	26656	0.0267	0.3725
D34C	760	760	5	12	30	22800	0.0228	0.3641	38	28695	0.0288	0.4583
D34D	599	599	5	12	30	17970	0.0180	0.3348	38	22616	0.0227	0.4214
D34E	519	519	5	12	30	15570	0.0156	0.2834	38	19595	0.0196	0.3566
D34F	692	692	5	12	30	20760	0.0208	0.3868	38	26127	0.0262	0.4868
D34G	950	950	5	12	30	28500	0.0286	0.2593	38	35868	0.0359	0.3264
0	**5020**	**5020**				**150600**	**0.1509**	**0.2924**		**189535.61**	**0.1899**	**0.3680**
D35A	254	254	6	12	335	85090	0.0853	1.9440	422	107089	0.1073	2.4465
D35B	260	260	6	13	335	87100	0.0873	2.1655	422	109619	0.1098	2.7253
D35C	943	943	6	13	335	315905	0.3165	2.9344	422	397578	0.3984	3.6931
D35D	586	586	6	13	335	196310	0.1967	3.5307	422	247063	0.2476	4.4435
D35E	312	312	6	13	335	104520	0.1047	2.6773	422	131542	0.1318	3.3695
D35F	557	557	6	12	335	186595	0.1870	2.1607	422	234837	0.2353	2.7193
D35G	552	552	6	13	335	184920	0.1853	3.7217	422	232729	0.2332	4.6839
D35H	498	498	6	12	335	166830	0.1672	2.7651	422	209962	0.2104	3.4800
D35J	1002	1002	5	12	30	30060	0.0301	0.3909	38	37832	0.0379	0.4920
D35K	674	674	5	12	30	20220	0.0203	0.2947	38	25448	0.0255	0.3709
0	**5638**	**5638**				**1377550**	**1.3803**	**2.1929**		**1733697.1**	**1.7372**	**2.7599**
0	0	0										
TOTALS	**99349**	**92568**				**20367562**	**20.4083**	**0.3027**		**25633321**	**25.6846**	**0.3810**

LIST OF FIGURES

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Bitterfontein
Nuwerus
Nieuwoudtville
Calvinia
Lutzville
Vanrhynsdorp
Ebenhaezer
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Doringbaai
Lambertsbaai
Graafwater
Clanwilliam
Elandsbaai
Citrusdal
GANNABOS
HEKSRIVIER
GROOT WINTERHOEK
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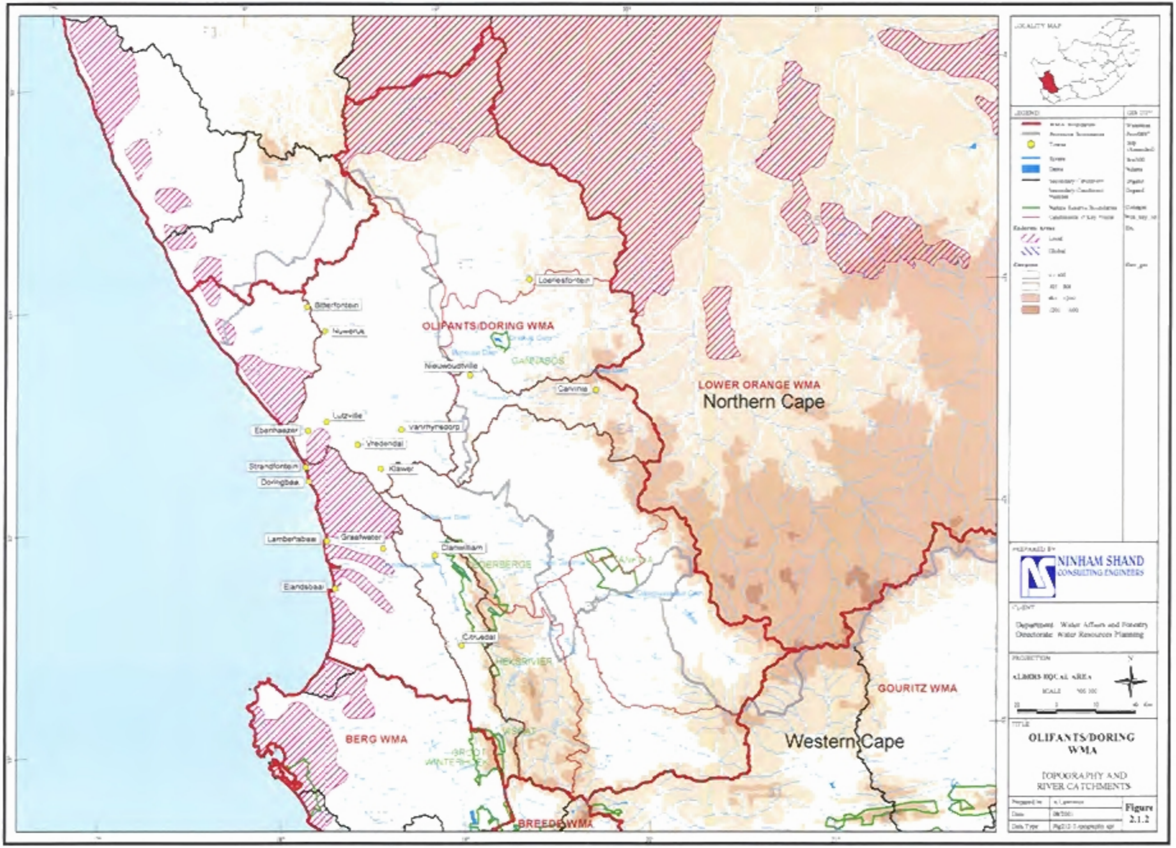
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
OLIFANTS/DORING WMA
THE STUDY AREA
Figure 2.1.1



LOCALITY MAP
LEGEND
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
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Loeriesfontein
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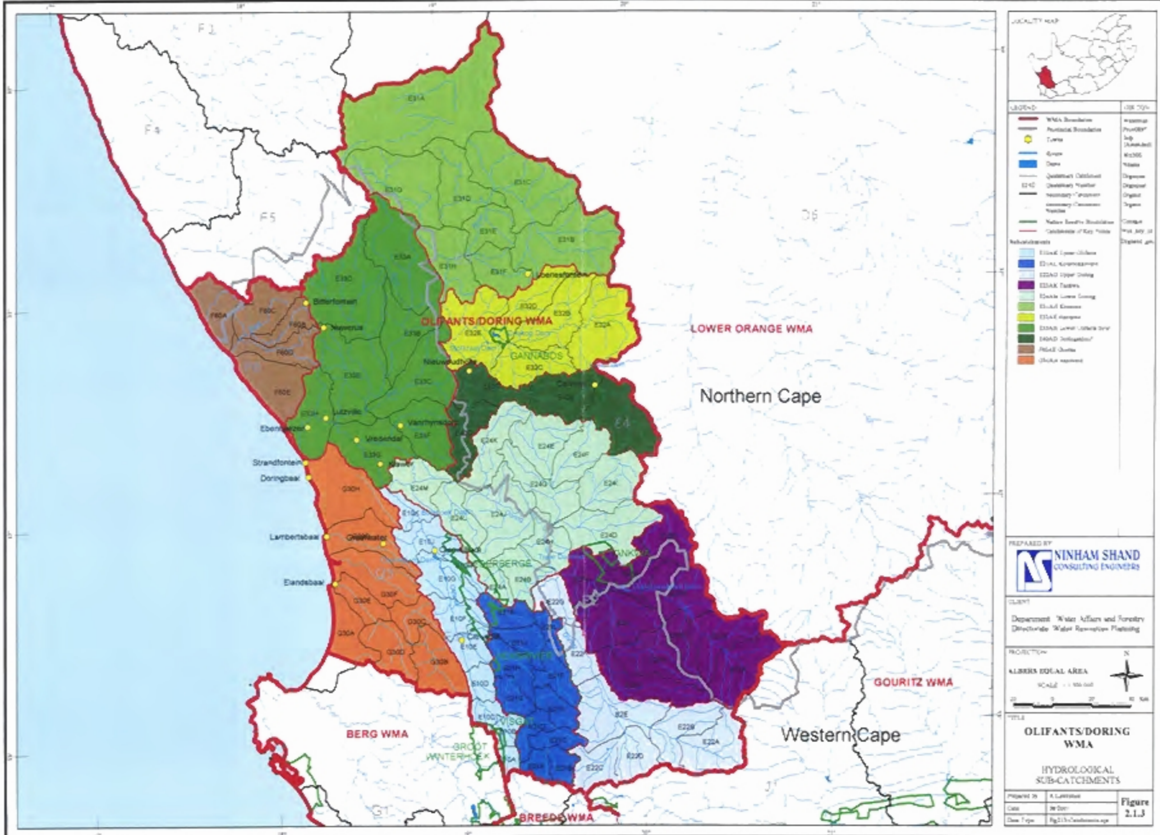
OLIFANTS/DORING WMA
TOPOGRAPHY AND RIVER CATCHMENTS
Figure 2.1.2



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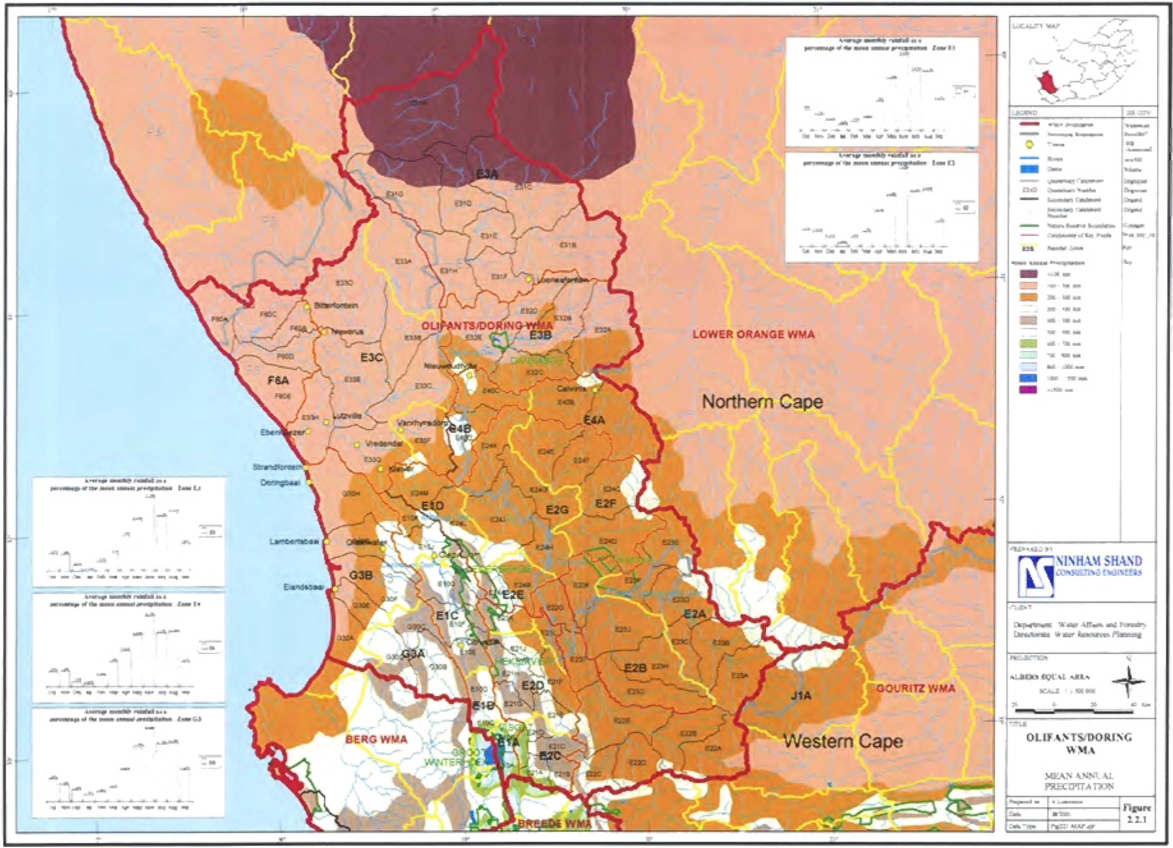
OLIFANTS/DORING WMA
HYDROLOGICAL SUB-CATCHMENTS
Figure 2.1.3



OLIFANTS/DORING WMA
LOWER ORANGE WMA
BERG WMA
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E3A
E3B
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Average monthly rainfall as a percentage of the mean annual precipitation: Zone E3
Average monthly rainfall as a percentage of the mean annual precipitation: Zone E2
LOCALITY MAP
LEGEND
Mean Annual Precipitation
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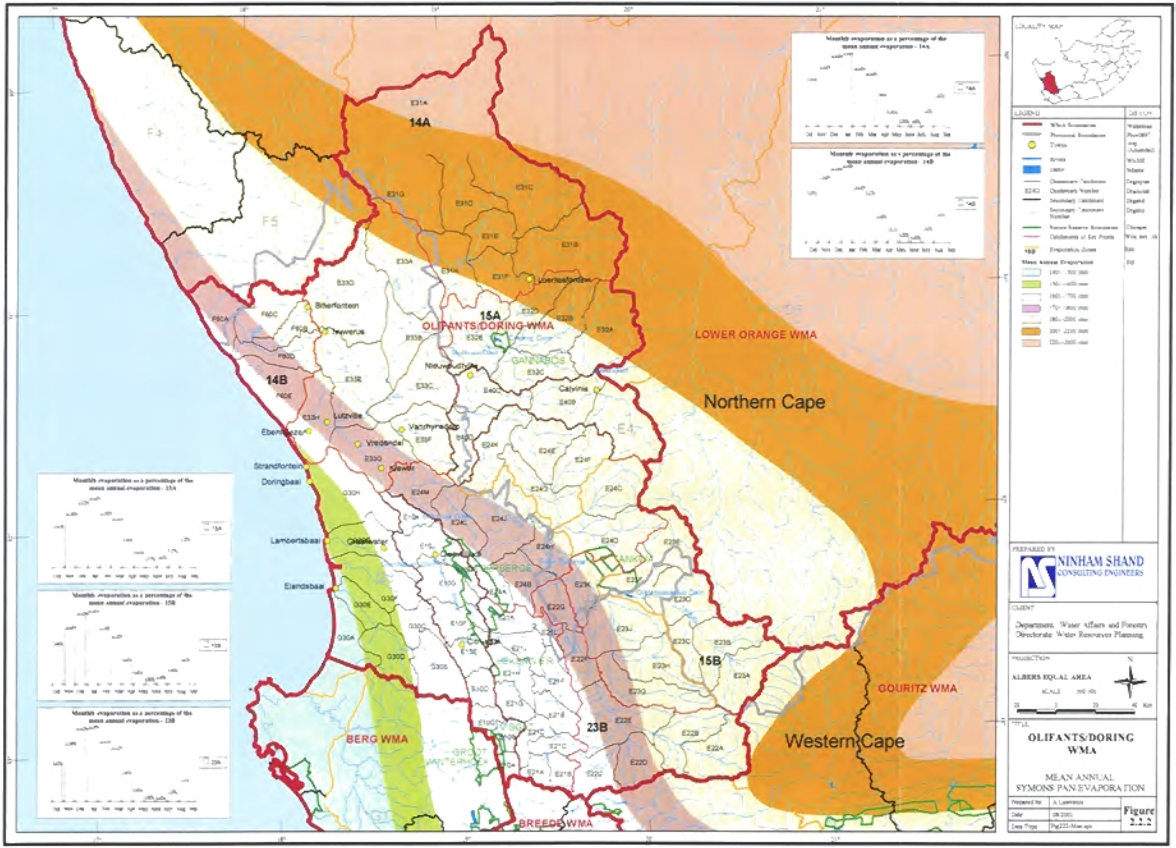
MEAN ANNUAL PRECIPITATION
Figure 2.2.1


14A
14B
15A
15B
23B
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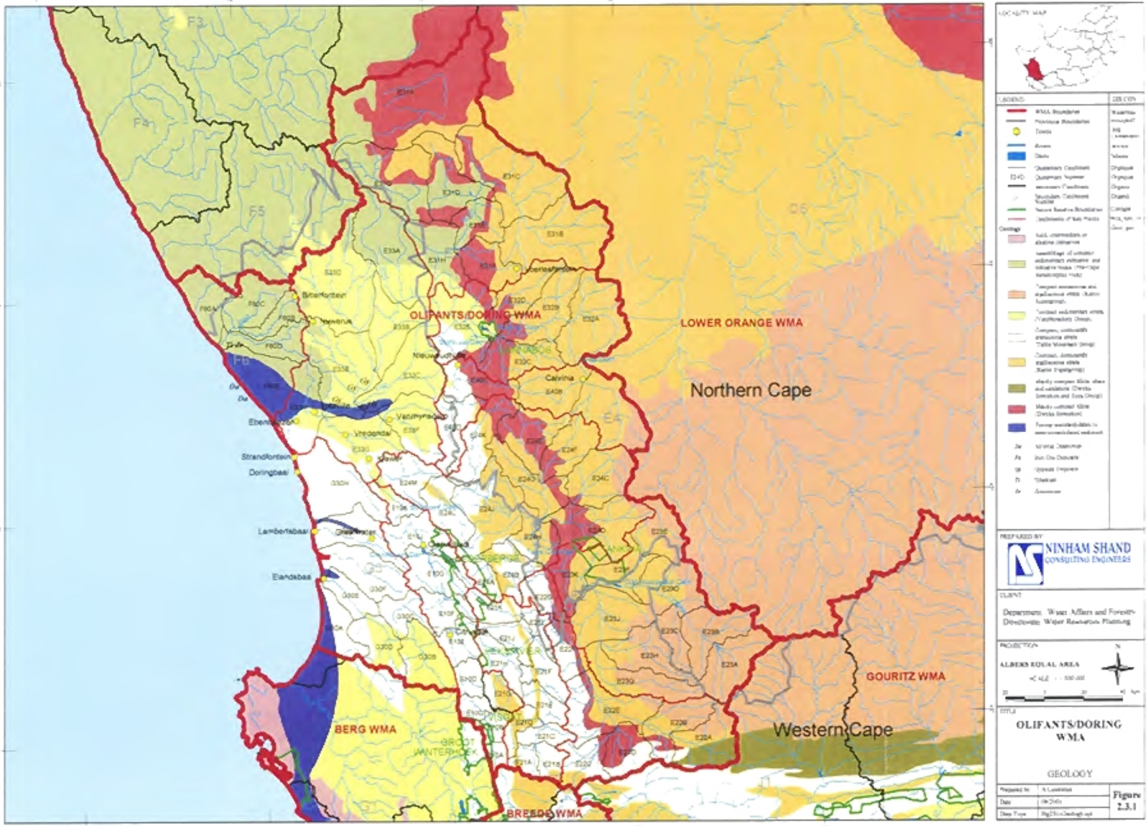
MEAN ANNUAL SYMONS PAN EVAPORATION
Figure 2.2.2



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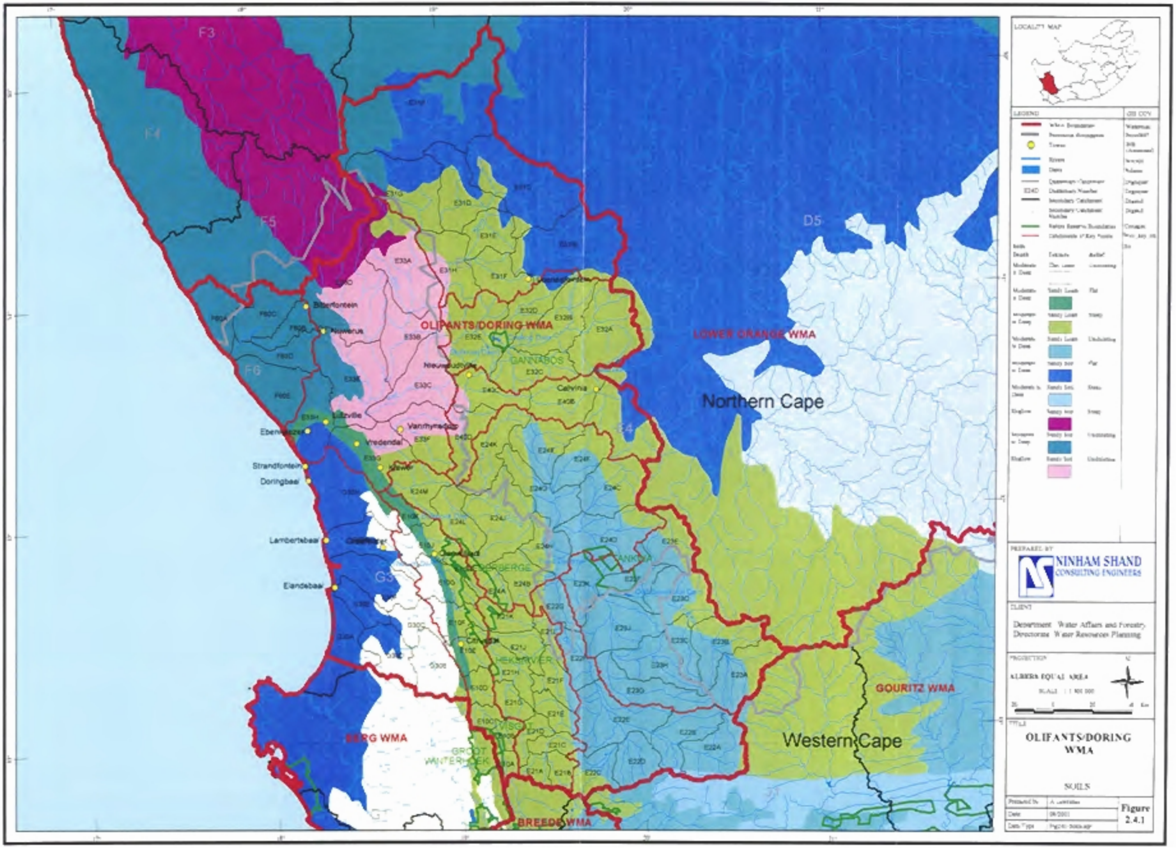
OLIFANTS/DORING WMA
GEOLOGY
Figure 2.3.1



F3
F4
F5
F6
D5
G3
OLIFANTS/DORING WMA
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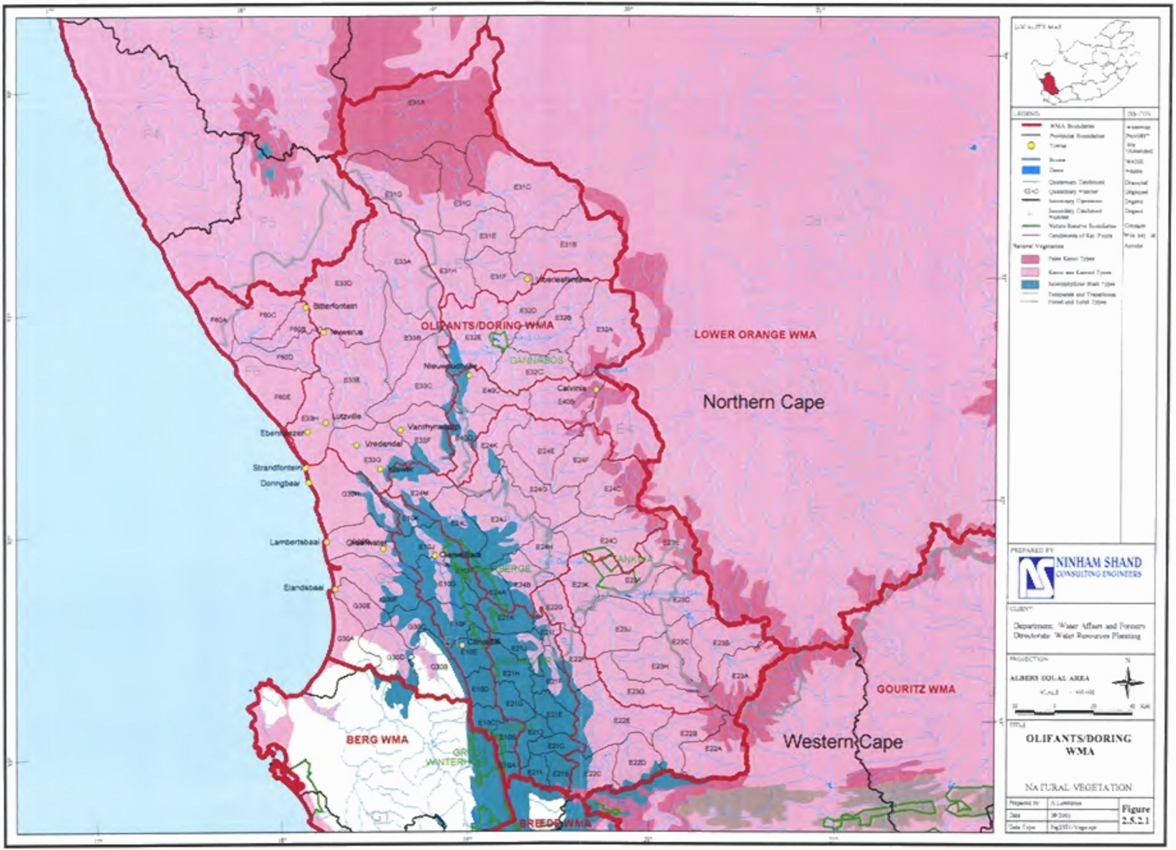
ALBERS EQUAL AREA
OLIFANTS/DORING WMA
SOILS
Figure 2.4.1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TITLE
OLIFANTS/DORING WMA
NATURAL VEGETATION
Figure 2.5.2.1

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OLIFANTS/DORING WMA
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ALBERS EQUAL AREA
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OLIFANTS/DORING WMA
DEFAULT ECOLOGICAL MANAGEMENT CLASSES
Figure 2.6.3.1

OLIFANTS/DORING WMA
LOWER ORANGE WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
Northern Cape
Western Cape
F3
F4
F5
F6
G3
G1
D5
E4
J1
GROOT WINTERHOEK
Bitterfontein
Nuwerus
Nieuwoudtville
Calvinia
Loeriesfontein
Lutzville
Vredendal
Vanrhynsdorp
Ebenhaeser
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Clanwilliam
Elandsbaai
Brak
Sout (Noord)
Olifants
Jakkals
Wadrif
Verlorenvlei 2
Verlorenvlei
Papkuils (Wes)
Kobee
Noordhoek
Bulshoek
Rondegat
Jan Dissels
Driehoek
Sneeuberg Hu Stream
Hoogvertoon
Sederhoutkop
Boschkloof
Krulmans
Wagenbooms River
Beukes
Middelberg-Wes
Tra-Tra
Donkerkloof Tributary
Blomfontein
Matjies
Brandkraals
Bovendale Wagendrift
Wind Heuvel
Oudebaaskraal
Boesmans
Kareeks
Dwarsrivier
Koghmanskloof
LOCALITY MAP
LEGEND
PREPARED BY
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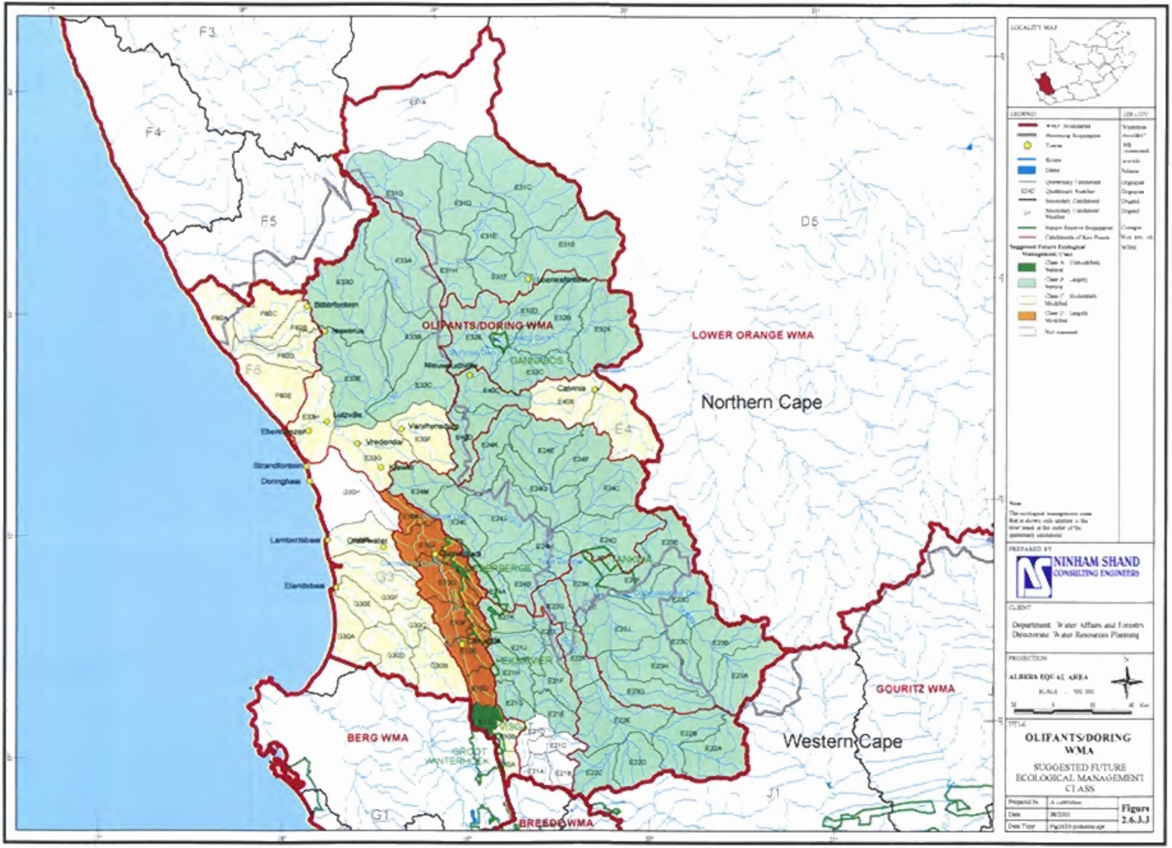
CLIENT
Department Water Affairs and Forestry
Directorate Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
PRESENT ECOLOGICAL STATUS CLASS AND ECOLOGICALLY SENSITIVE SITES
Figure 2.6.3.2



F3
F4
F5
F6
D5
E4
G3
G1
J1
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
GANNABOS
CEDERBERGE
HEKSRIVIER
GROOT WINTERHOEK
Loeriesfontein
Bitterfontein
Nieuwoudtville
Calvinia
Lutzville
Vredendal
Vanrhynsdorp
Klawer
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Clanwilliam
Citrusdal
LOCALITY MAP
LEGEND
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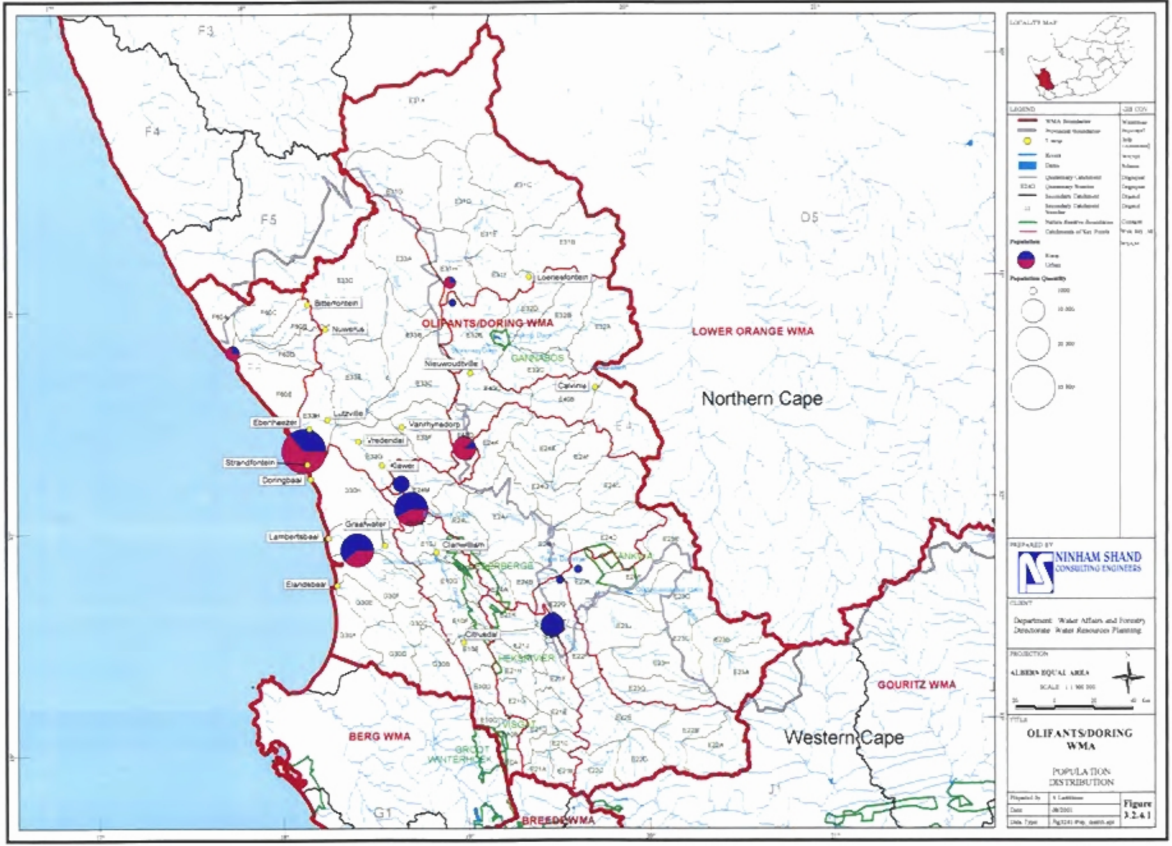
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
SUGGESTED FUTURE ECOLOGICAL MANAGEMENT CLASS
Figure 2.6.3.3


OLIFANTS/DORING WMA
LOWER ORANGE WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
Northern Cape
Western Cape
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F4
F5
D5
G1
J1
E4
Loeriesfontein
Bitterfontein
Nuwerus
Nieuwoudtville
Calvinia
Lutzville
Vanrhynsdorp
Ebenhaezer
Vredendal
Strandfontein
Klawer
Doringbaai
Graafwater
Lambertsbaai
Clanwilliam
Elandsbaai
Citrusdal
GANNABOS
CEDERBERGE
GROOT WINTERHOEK
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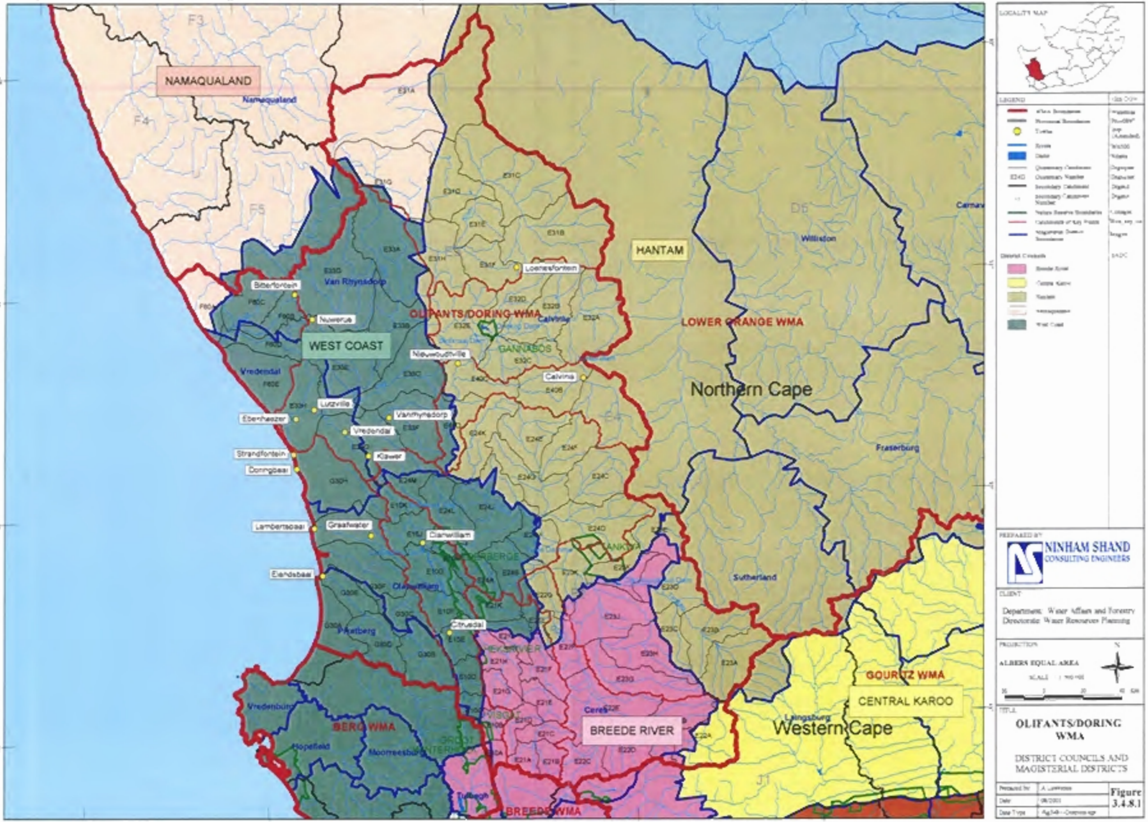
ALBERS EQUAL AREA
OLIFANTS/DORING WMA
POPULATION DISTRIBUTION
Figure 3.2.4.1



NAMAQUALAND
WEST COAST
HANTAM
BREEDE RIVER
CENTRAL KAROO
Northern Cape
Western Cape
OLIFANTS/DORING WMA
LOWER ORANGE WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
Bitterfontein
Nuwerus
Loeriesfontein
Nieuwoudtville
Calvinia
Lutzville
Ebenhaezer
Vanrhynsdorp
Vredendal
Klawer
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Clanwilliam
Elandsbaai
Citrusdal
Williston
Fraserburg
Sutherland
Vredenburg
Hopefield
Moorreesburg
Ceres
Laingsburg
Tulbagh
Piketberg
GANNABOS
LOCALITY MAP
LEGEND
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PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS
Figure 3.4.8.1

OLIFANTS/DORING WMA
LOWER ORANGE WMA
BERG WMA
BREEDE WMA
GOURITZ WMA
Northern Cape
Western Cape
LOERIESFONTEIN
Loeriesfontein
RIETPOORT
Bitterfontein
BITTERFONTEIN/NUWERUS
Nuwerus
Nieuwoudtville
NIEUWOUDTVILLE
Calvinia
CALVINIA
LUTZVILLE
Lutzville
EBENHAEZER
Ebenhaezer
VANRHYNSDORP
Vanrhynsdorp
VREDENDAL
Vredendal
STRANDFONTEIN
Strandfontein
Doringbaai
DORINGBAAI
Klawer
KLAWER
LAMBERTSBAAI
Lambertsbaai
GRAAFWATER
Graafwater
Clanwilliam
CLANWILLIAM
ELANDSBAAI
Elandsbaai
REDELINGHUYS
CITRUSDAL
Citrusdal
PIKETBERG
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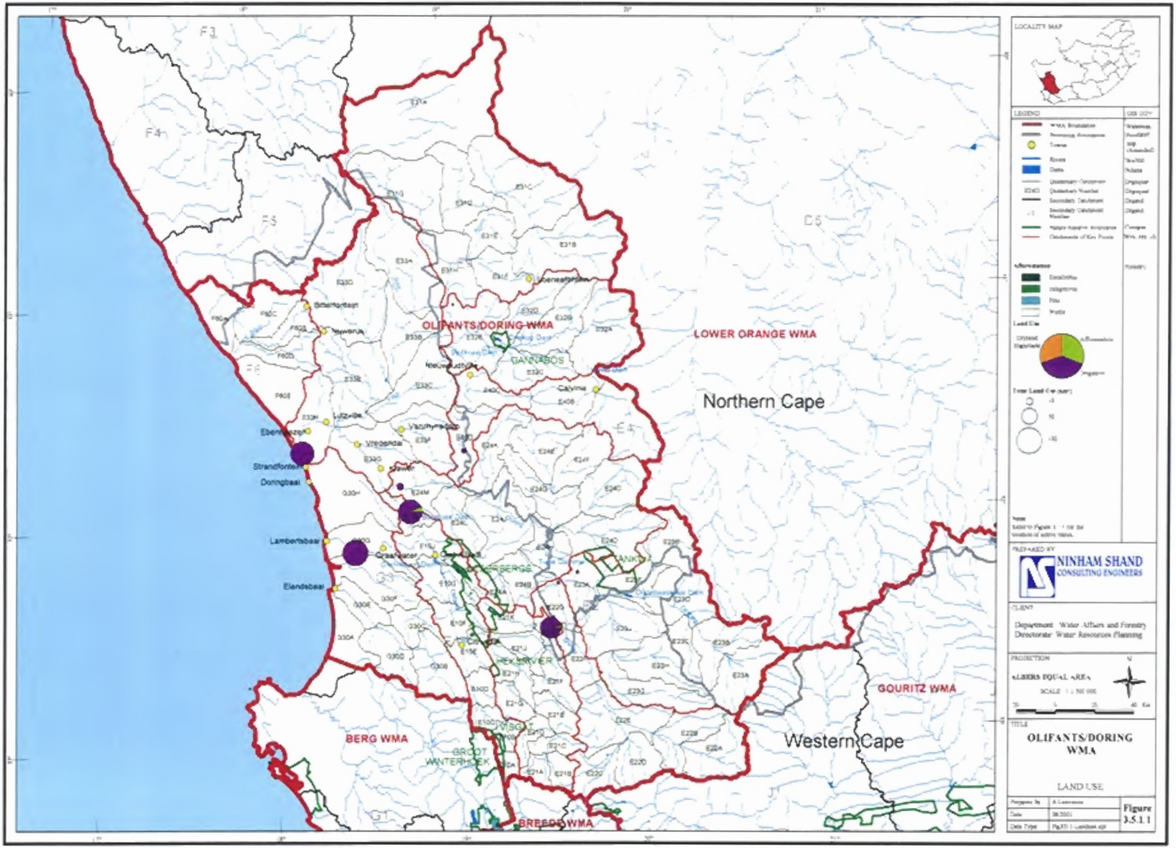
ALBERS EQUAL AREA
OLIFANTS/DORING WMA
INSTITUTIONAL BOUNDARIES RELATED TO WATER SUPPLY
Figure 3.4.8.2


OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
BERG WMA
GOURITZ WMA
BREEDE WMA
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Lutzville
Vredendal
Vanrhynsdorp
Klawer
Nieuwoudtville
Calvinia
Graafwater
Bitterfontein
Nuwerus
GANNABOS
HEKSRIVIER
GROOT WINTERHOEK
LOCALITY MAP
LEGEND
NINHAM SHAND
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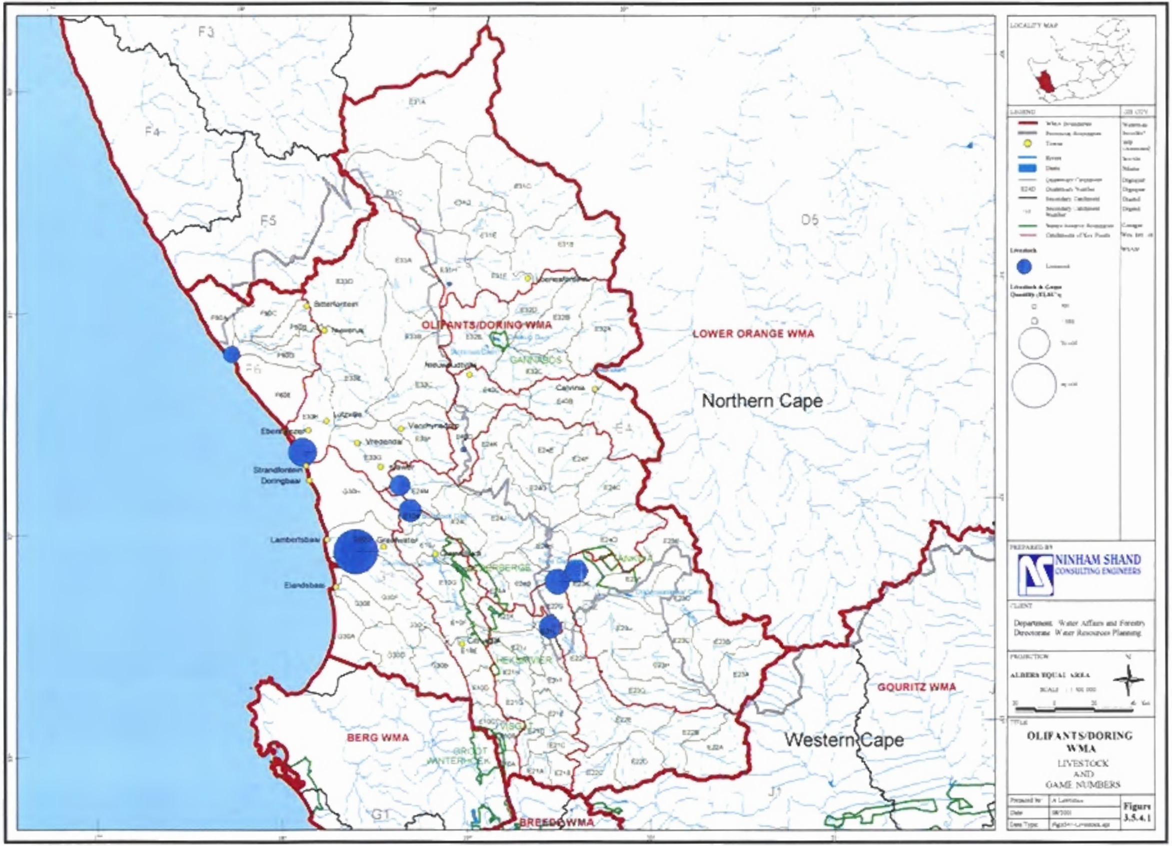
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
LAND USE
Figure 3.5.1.1



Northern Cape
Western Cape
LOWER ORANGE WMA
OLIFANTS/DORING WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
GANNABOS
D5
F3
F4
F5
F6
G1
J1
Bitterfontein
Nuwerus
Nieuwoudtville
Calvinia
Lutzville
Vanrhynsdorp
Vredendal
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
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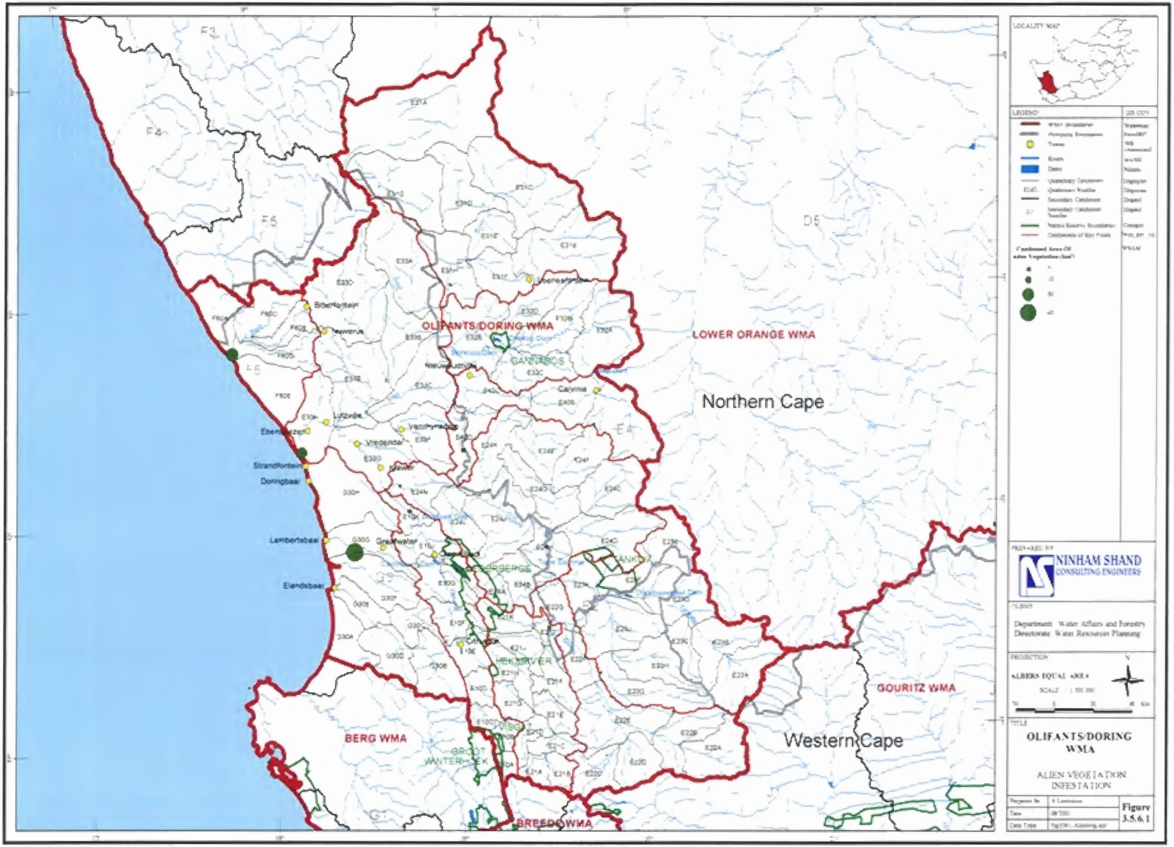
Directorate: Water Resources Planning
ALBERS EQUAL AREA
OLIFANTS/DORING WMA
LIVESTOCK AND GAME NUMBERS
Figure 3.5.4.1



OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
GANNABOS
CEDERBERGE
HEKSRIVIER
GROOT WINTERHOEK
Bitterfontein
Nuwerus
Nieuwoudtville
Loeriesfontein
Calvinia
Lutzville
Vanrhynsdorp
Vredendal
Klawer
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
F3
F4
F6
D5
E4
G1
LOCALITY MAP
LEGEND
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PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
ALIEN VEGETATION INFESTATION
Figure 3.5.6.1

FIGURE 3.7.1: MINES

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F3
F4
F5
D5
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
G1
J1
Lutzville
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Calvinia
Vanrhynsdorp
Klawer
Bitterfontein
GANNABOS
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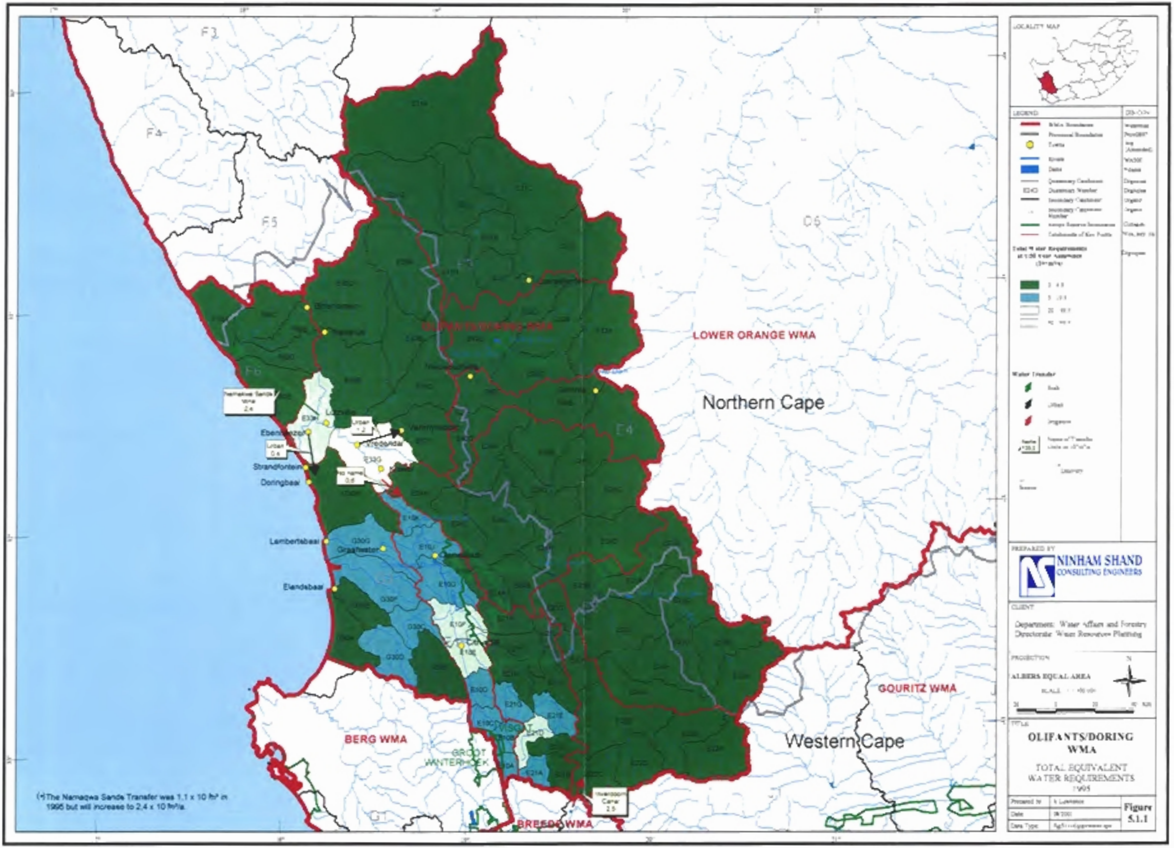
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
WATER RELATED INFRASTRUCTURE
Figure 4.1.1



LOCALITY MAP
LEGEND
F3
F4
F5
F6
C5
E4
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
GROOT WINTERHOEK
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
E33G
G30G
G30F
G30D
E10D
E21G
Water Transfer
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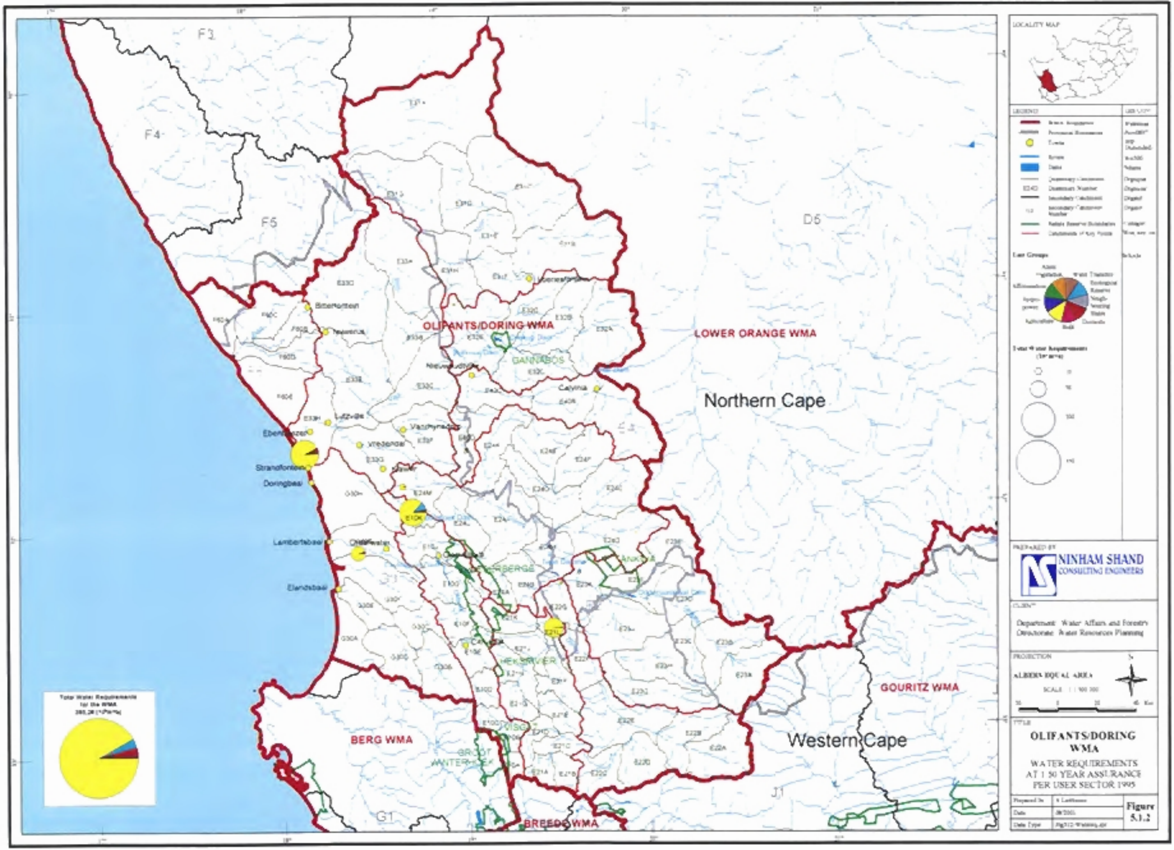
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
TOTAL EQUIVALENT WATER REQUIREMENTS 1995
Figure 5.1.1
(*)The Namaqwa Sands Transfer was 1,1 x 10 m³ in 1995 but will increase to 2,4 x 10 m³/a.


F3
F4
F5
D5
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
GANNABOS
Calvinia
Nieuwoudtville
Bitterfontein
Nuwerus
Lutzville
Vanrhynsdorp
Vredendal
Klawer
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Clanwilliam
CEDERBERGE
HEKSRIVIER
GROOT WINTERHOEK
BERG WMA
BREEDE WMA
GOURITZ WMA
Western Cape
G1
J1
Total Water Requirements for the WMA
LOCALITY MAP
LEGEND
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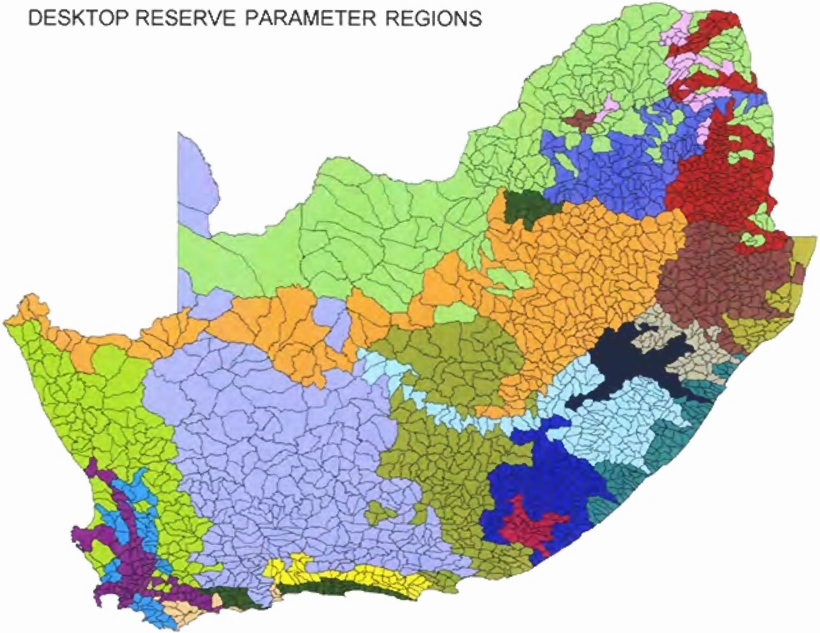
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
WATER REQUIREMENTS AT 1:50 YEAR ASSURANCE PER USER SECTOR 1995
Figure 5.1.2

DESKTOP RESERVE PARAMETER REGIONS



LEGEND

1 Western Cape (wet)
2 Western Cape (dry)
3 Western Karoo
4 Eastern Karoo
5 Southern Cape (dry)
6 Southern Karoo
7 Southern Cape (wet)
8 Eastern Cape (arid)
9 Eastern Cape
10 Amatole
11 T Drainage Region
12 T Drainage Region (coast)
13 Drakensberg
14 Southern Natal
15 Northern Natal
16 Zululand
17 Eastern Escarpment
18 Lowveld
19 Eastern Foothills
20 Vaal
21 Olifants

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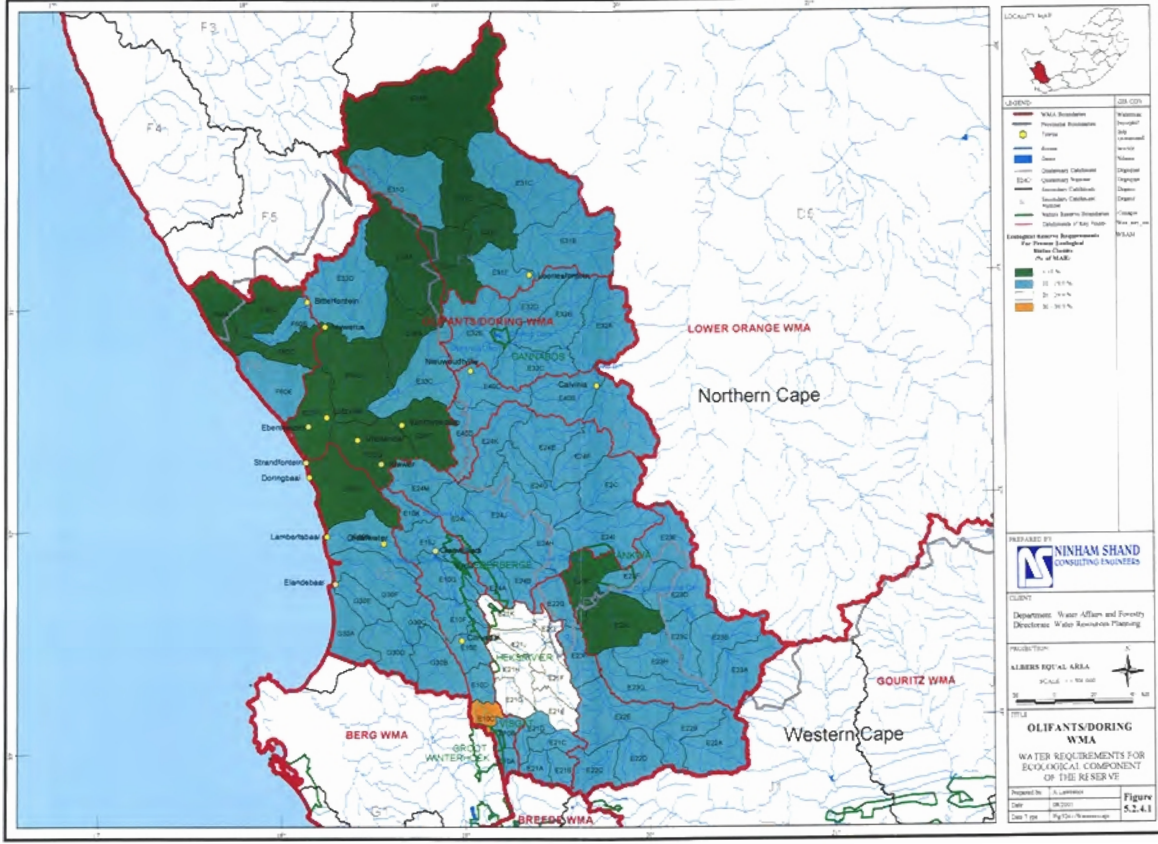
TITLE

OLIFANTS/DORING WMA

DESKTOP RESERVE PARAMETER REGIONS

Figure 5.2.1.1



LOCALITY MAP
LEGEND
F3
F4
F5
D6
LOWER ORANGE WMA
Northern Cape
OLIFANTS/DORING WMA
GANNABOS
Bitterfontein
Nieuwoudtville
Calvinia
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
CEDERBERGE
HEKSRIVIER
GROOT WINTERHOEK
BERG WMA
BREEDE WMA
GOURITZ WMA
Western Cape
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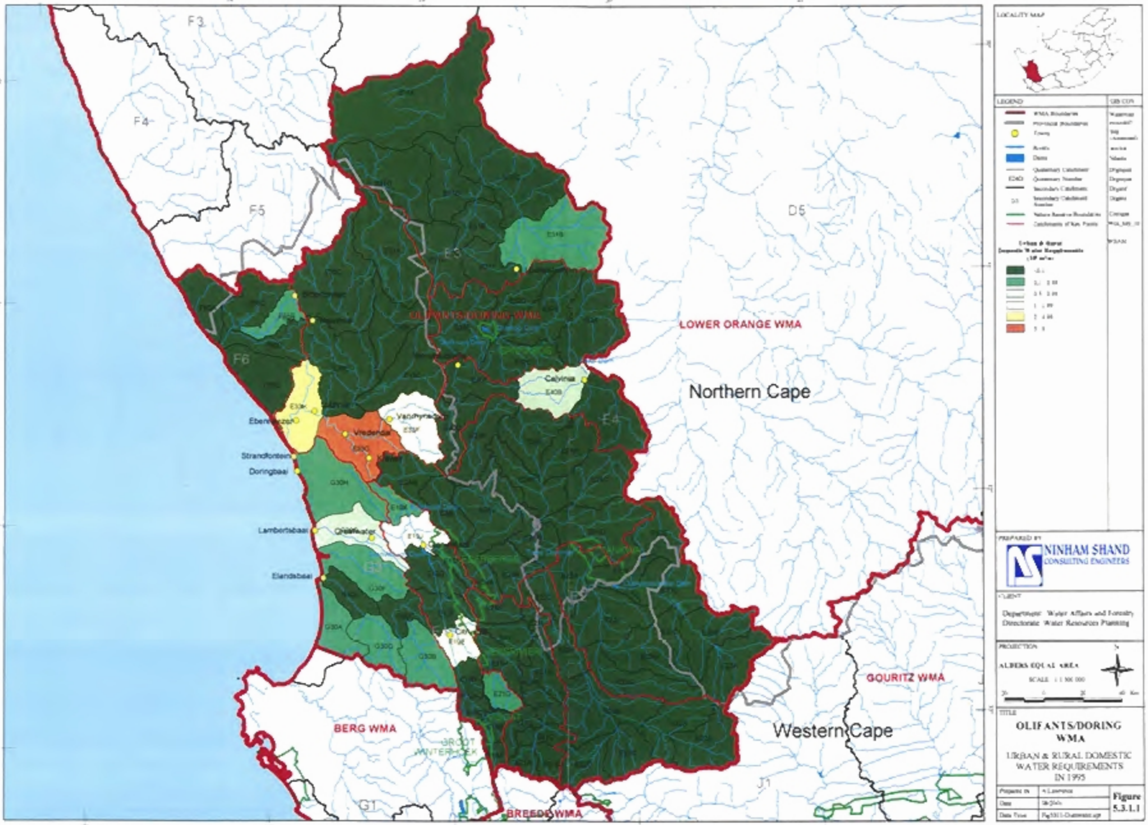
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
WATER REQUIREMENTS FOR ECOLOGICAL COMPONENT OF THE RESERVE
Figure 5.2.4.1



F3
F4
F5
F6
D5
E3
E4
G1
G3
J1
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
GROOT WINTERHOEK
Calvinia
Vanrhynsdorp
Vredendal
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Clanwilliam
Elandsbaai
LOCALITY MAP
LEGEND
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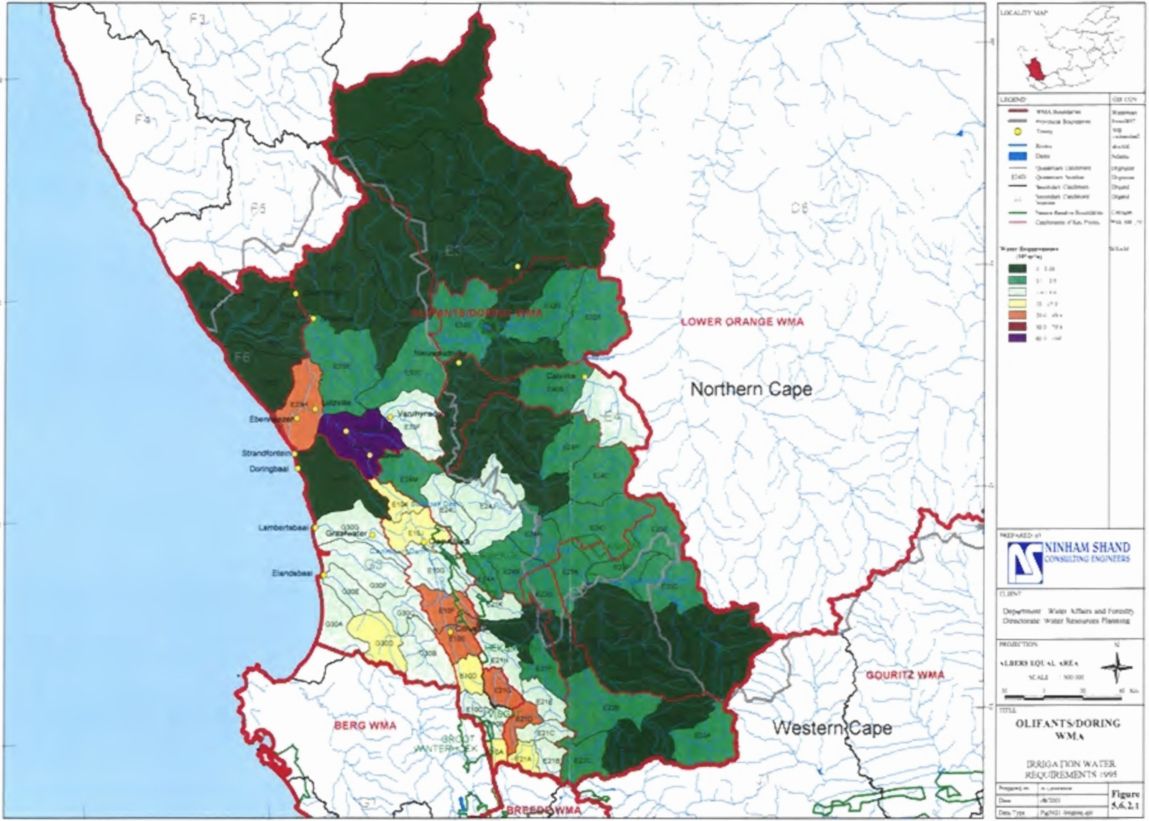
PROJECTION
ALBERS EQUAL AREA
OLIFANTS/DORING WMA
URBAN & RURAL DOMESTIC WATER REQUIREMENTS IN 1995
Figure 5.3.1.1


LOCALITY MAP
LEGEND
Water Requirements
LOWER ORANGE WMA
OLIFANTS/DORING WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
GROOT WINTERHOEK
Lutzville
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
Calvinia
Nieuwoudtville
Vanrhynsdorp
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PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
IRRIGATION WATER REQUIREMENTS 1995
Figure 5.6.2.1

LOCALITY MAP
LEGEND
Water Requirements
F3
F4
F6
D5
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
G1
J1
Bitterfontein
Nuwerus
Nieuwoudtville
Calvinia
Loeriesfontein
Lutzville
Ebenhaezer
Vanrhynsdorp
Vredendal
Klawer
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Clanwilliam
Elandsbaai
Citrusdal
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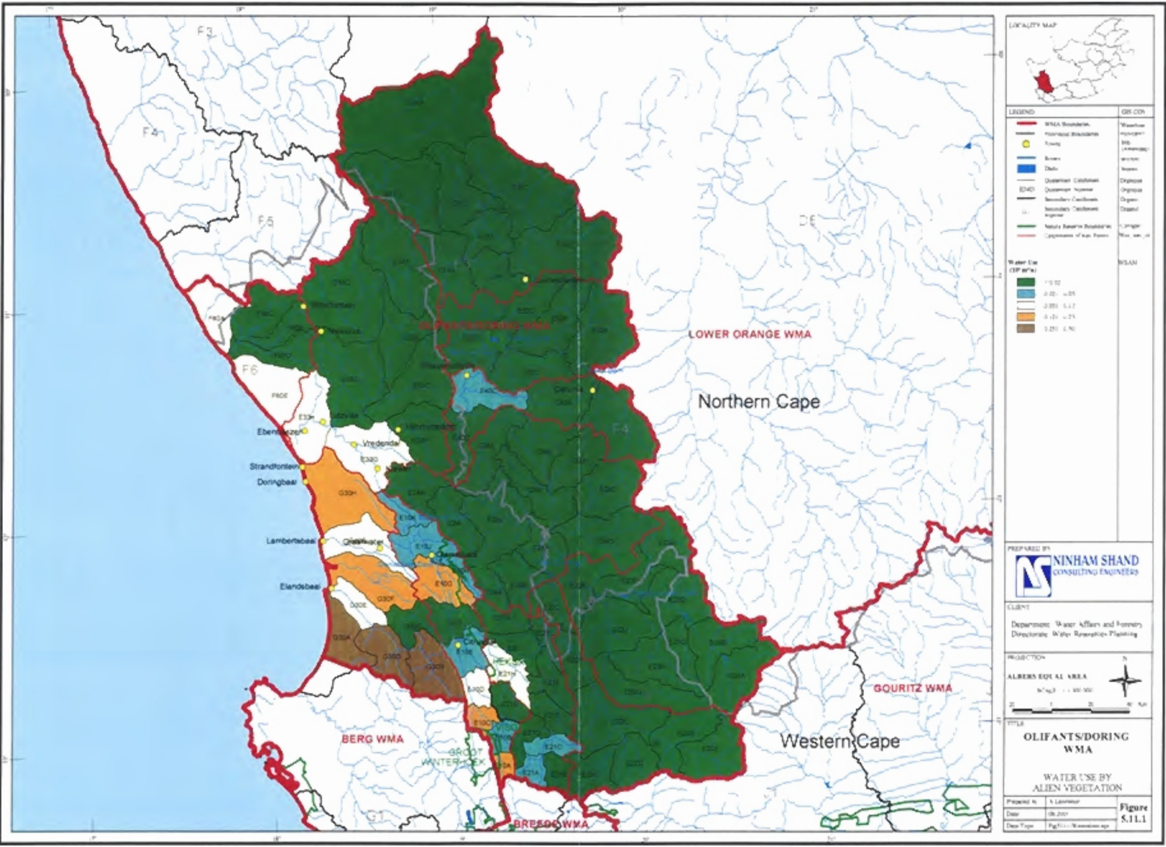
PROJECTION
ALBERS EQUAL AREA
N
TITLE
OLIFANTS/DORING WMA
WATER USE BY AFFORESTATION IN 1995
Prepared by
A Lawrence
Date
Figure 5.9.1


Northern Cape
Western Cape
LOWER ORANGE WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Vredendal
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ALBERS EQUAL AREA
OLIFANTS/DORING
WMA
WATER USE BY
ALIEN VEGETATION
Figure
5.11.1


F3
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D5
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
BERG WMA
GOURITZ WMA
BREEDE WMA
G1
J1
Bitterfontein
Nuwerus
Nieuwoudtville
Calvinia
Lutzville
Vanrhynsdorp
Vredendal
Klawer
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
GANNABOS
(+) The Namaqwa Sands Transfer was 1,1 x 10 ^{6}m³ in 1996 but will increase to 2,4 x 10 ^{6}m³/a
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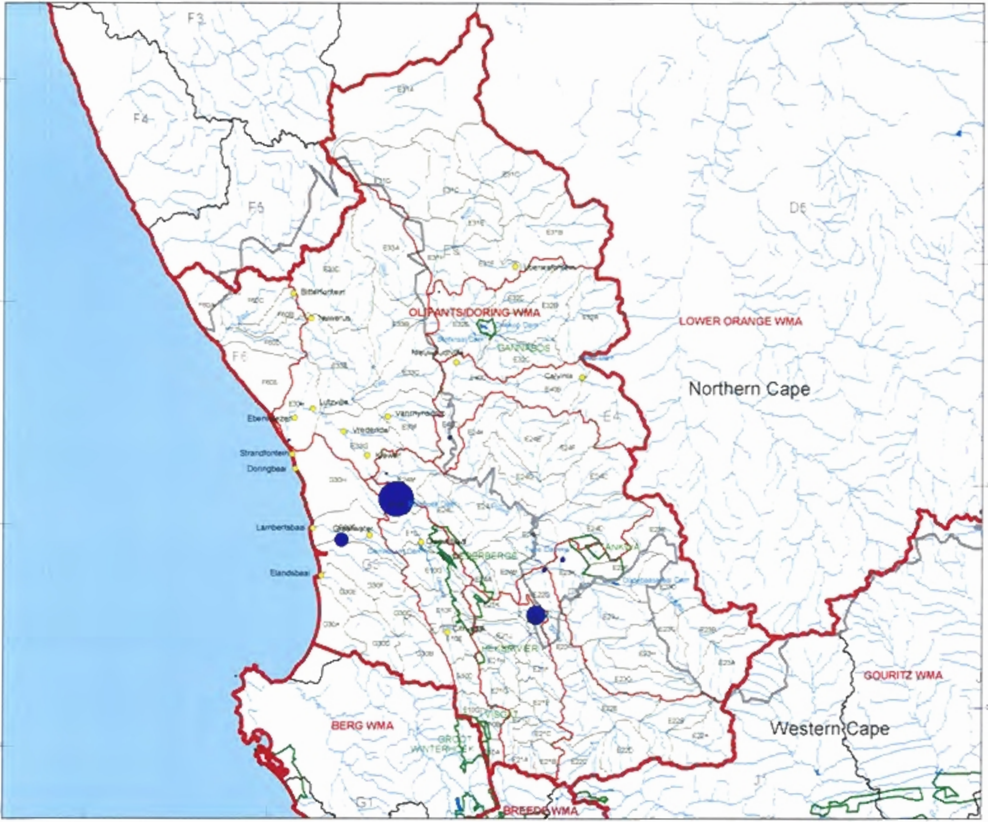
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
WATER TRANSFER SCHEMES
Figure 5.14.1



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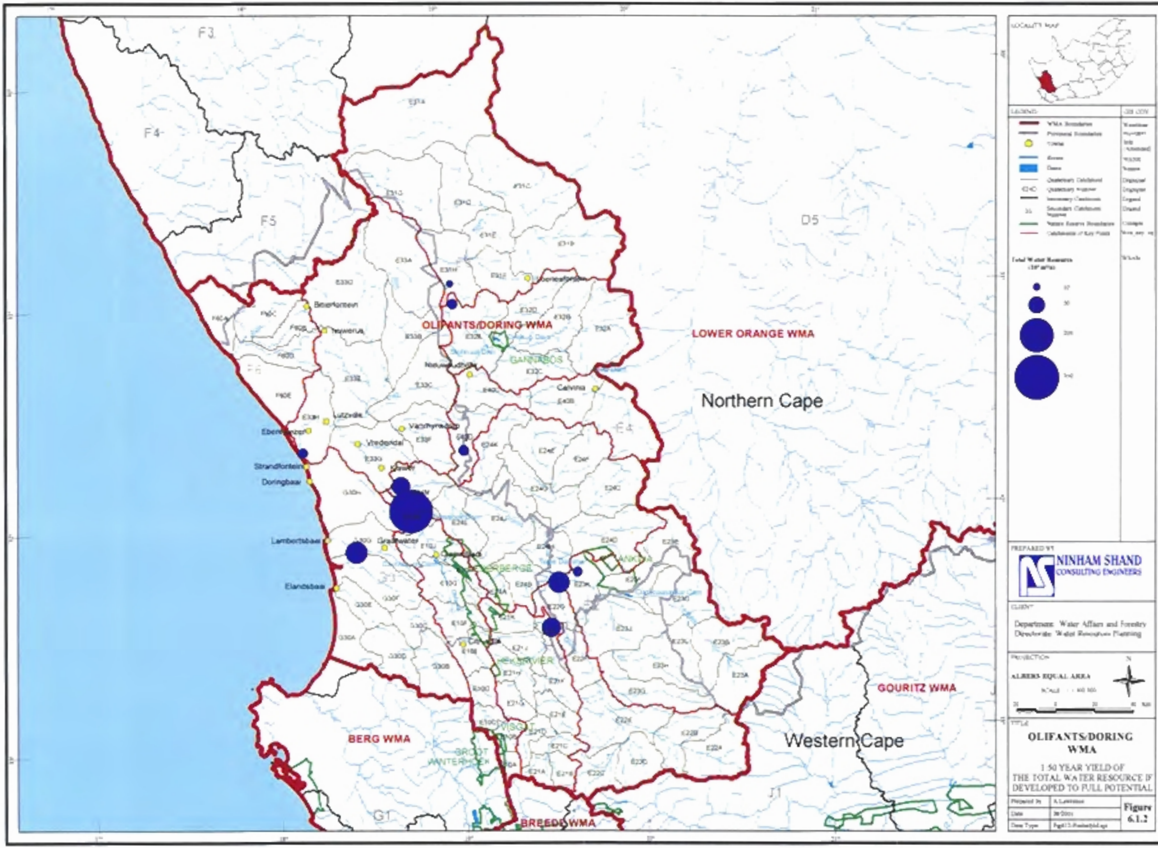
ALBERS EQUAL AREA

OLIFANTS/DORING WMA

1:50 YEAR YIELD OF THE TOTAL WATER RESOURCE AS DEVELOPED IN 1995

Figure 6.1.1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J1
OLIFANTS/DORING WMA
LOWER ORANGE WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
Northern Cape
Western Cape
GANNABOS
Beierfontein
Nieuwoudtville
Calvinia
Lutzville
Vanrhynsdorp
Vredendal
Ebenhaeser
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
Total Water Resource
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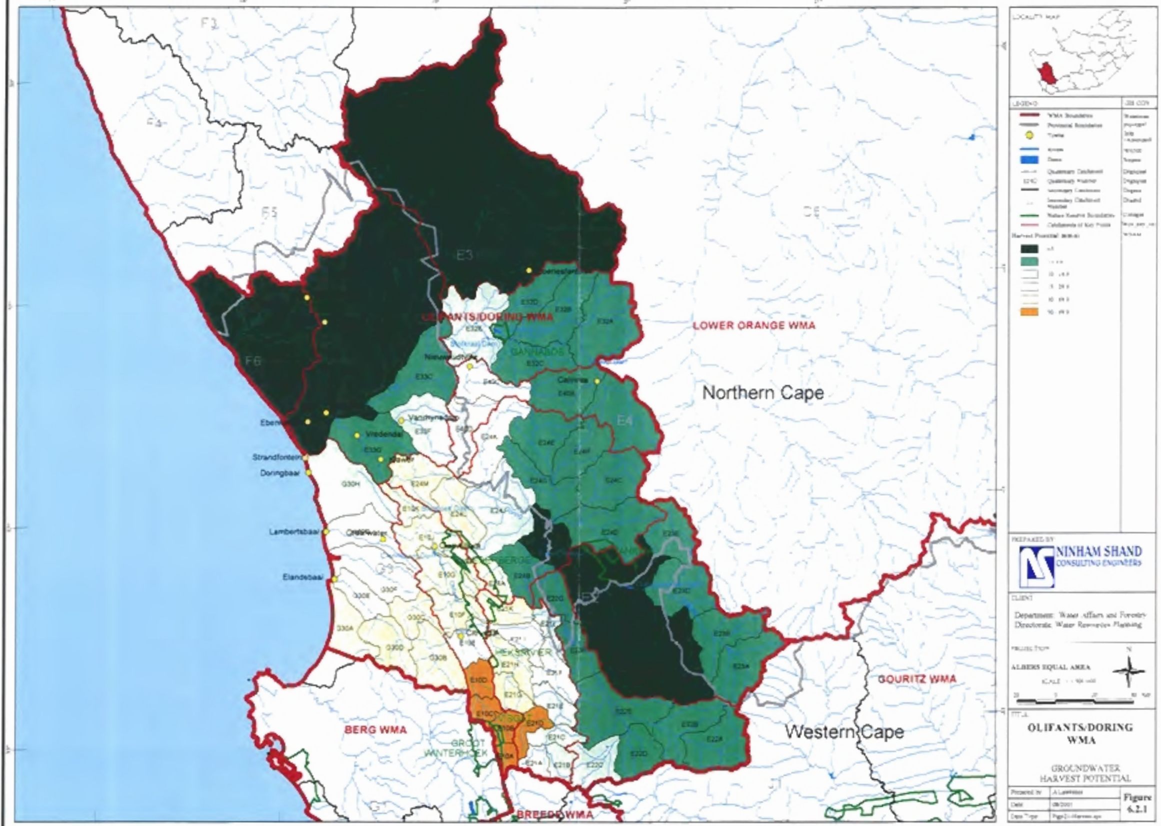
PROJECTION
ALBERS EQUAL AREA
N
TITLE
OLIFANTS/DORING WMA
1:50 YEAR YIELD OF THE TOTAL WATER RESOURCE IF DEVELOPED TO FULL POTENTIAL
Figure 6.1.2


OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
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E4
F6
Vredendal
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Vanrhynsdorp
Calvinia
HEKSRIVIER
GROOT WINTERHOEK
PREPARED BY
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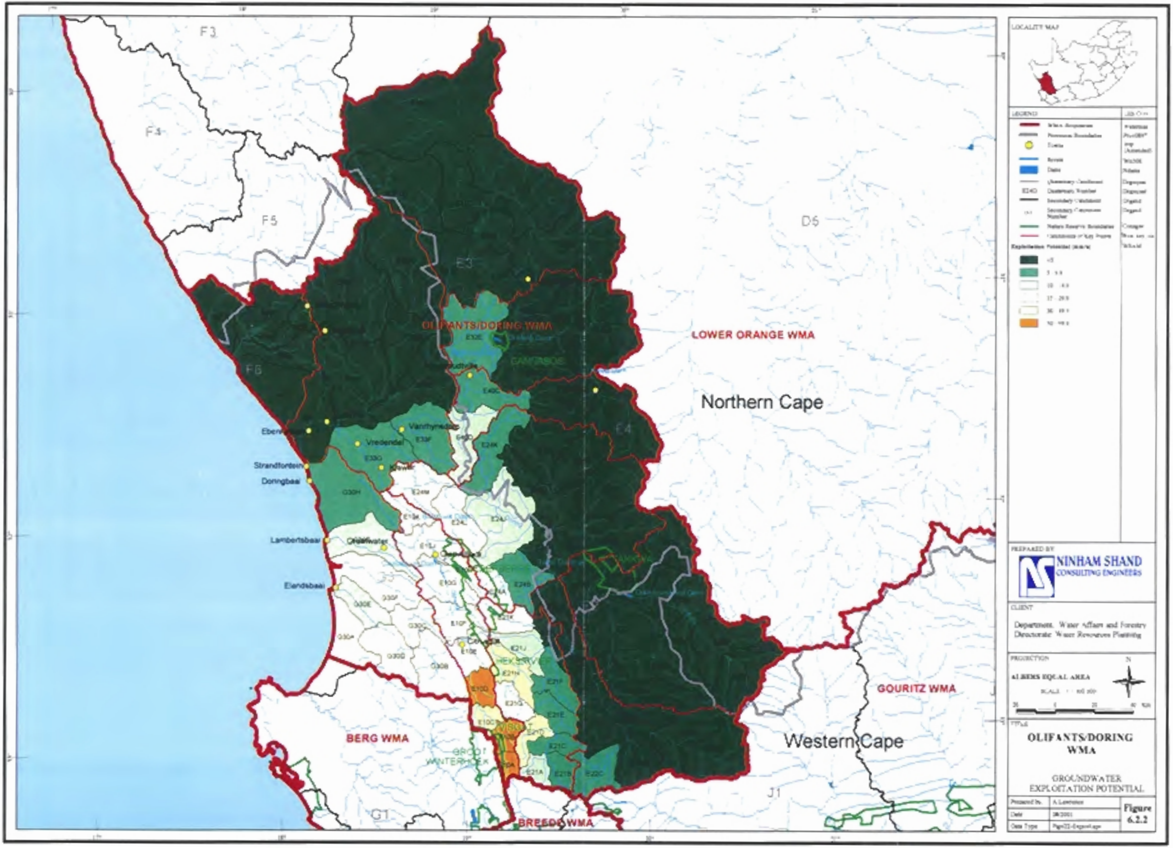
Directorate: Water Resources Planning
ALBERS EQUAL AREA
OLIFANTS/DORING
WMA
GROUNDWATER
HARVEST POTENTIAL
Figure
6.2.1


F3
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F6
E3
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D6
G1
J1
OLIFANTS/DORING WMA
LOWER ORANGE WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
Northern Cape
Western Cape
Vanrhynsdorp
Vredendal
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
LOCALITY MAP
LEGEND
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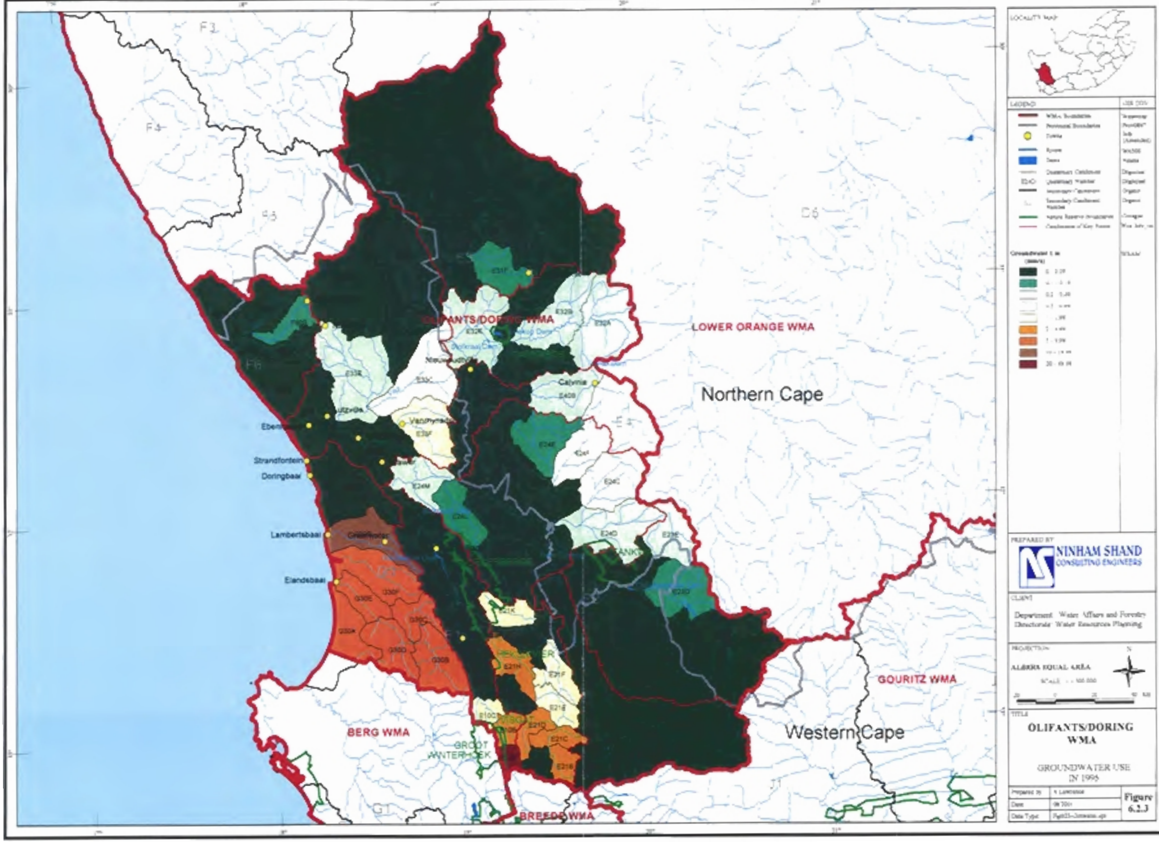
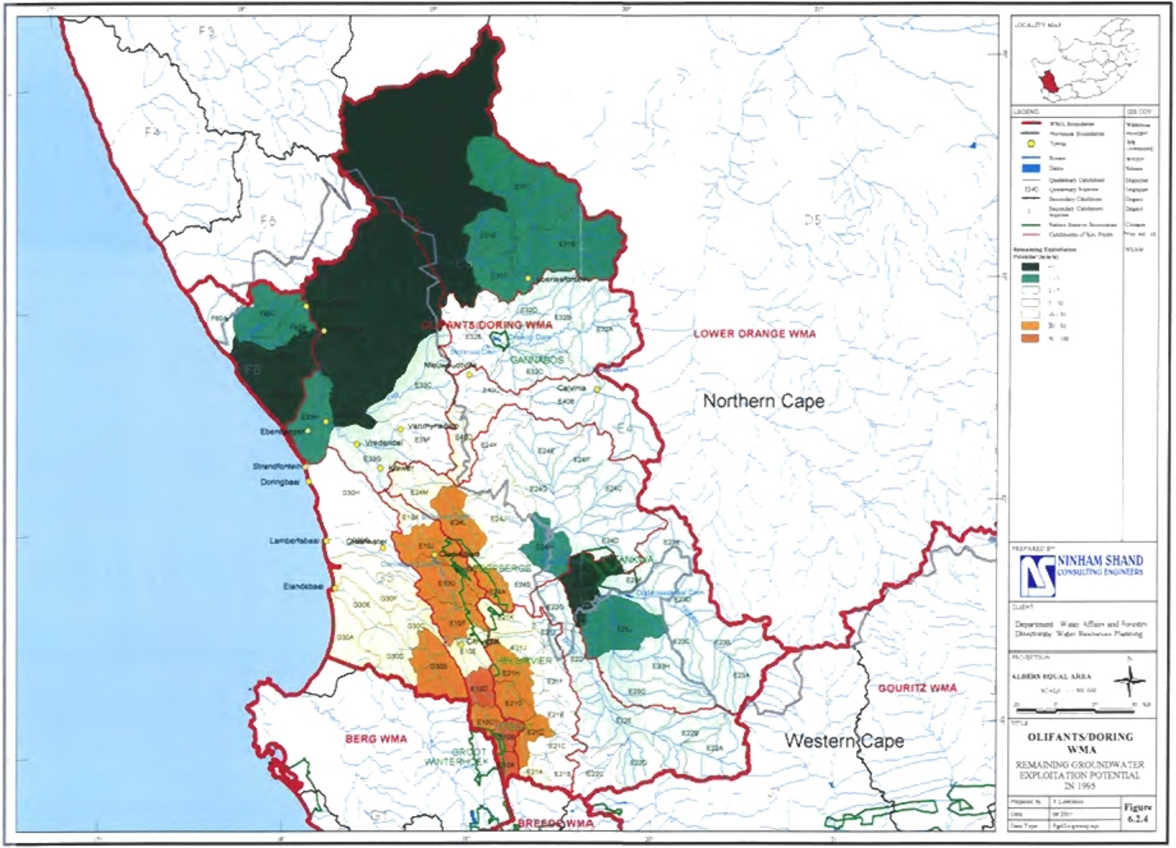
PROJECTION
ALBERS EQUAL AREA
N
OLIFANTS/DORING
WMA
GROUNDWATER
EXPLOITATION POTENTIAL
Figure
6.2.2


OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
Calvinia
Vanrhynsdorp
Nieuwoudtville
Ebenhaeser
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
GROOT WINTERHOEK
NINHAM SHAND CONSULTING ENGINEERS
ALBERS EQUAL AREA
OLIFANTS/DORING WMA
GROUNDWATER USE IN 1995
Figure 6.2.3



OLIFANTS/DORING WMA
REMAINING GROUNDWATER EXPLOITATION POTENTIAL IN 1995
Figure 6.2.4
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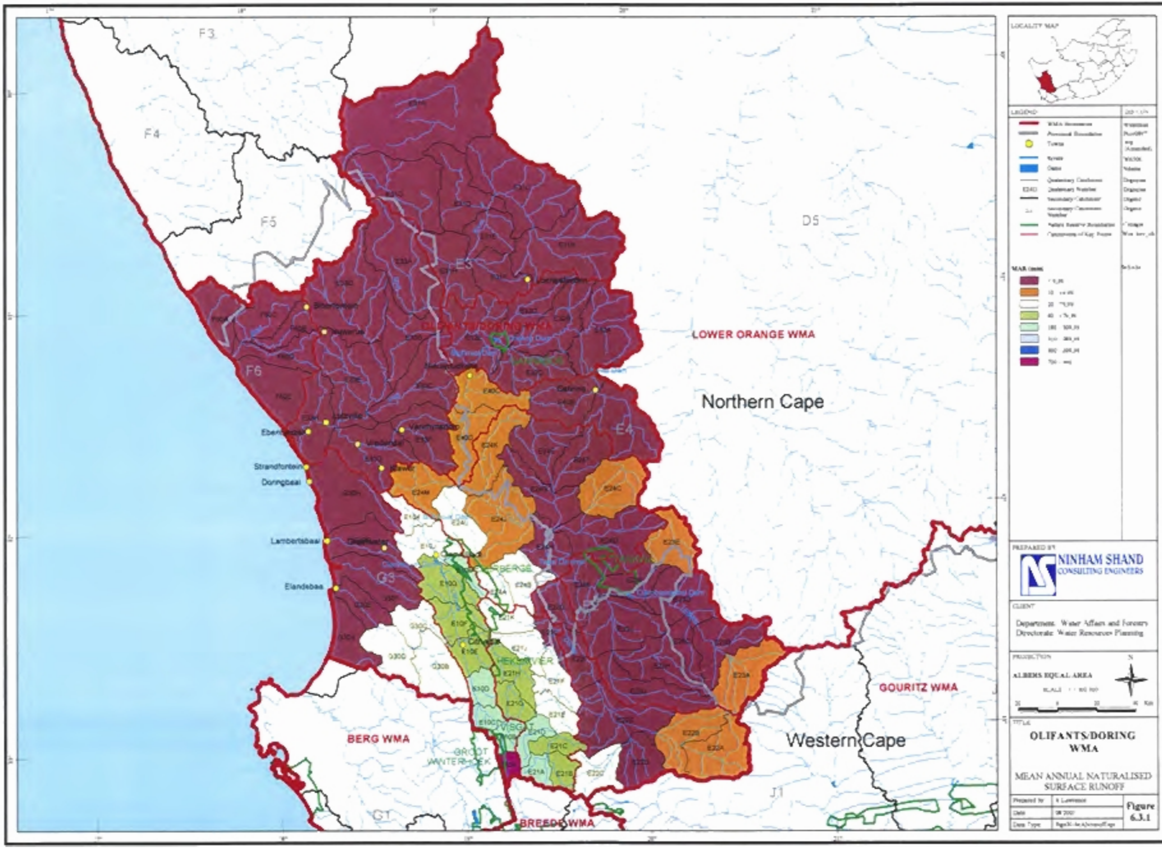
ALBERS EQUAL AREA
Northern Cape
Western Cape
LOWER ORANGE WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
OLIFANTS/DORING WMA
GANNABOS
GROOT WINTERHOEK
Calvinia
Nieuwoudtville
Vanrhynsdorp
Vredendal
Klawer
Ebenhaezer
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Clanwilliam
F3
F4
F5
F6
D5
E4
G1


F3
F4
F5
F6
D5
E3
E4
G3
G1
J1
OLIFANTS/DORING WMA
LOWER ORANGE WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
Northern Cape
Western Cape
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
HEKSRIVIER
GROOT WINTERHOEK
PREPARED BY
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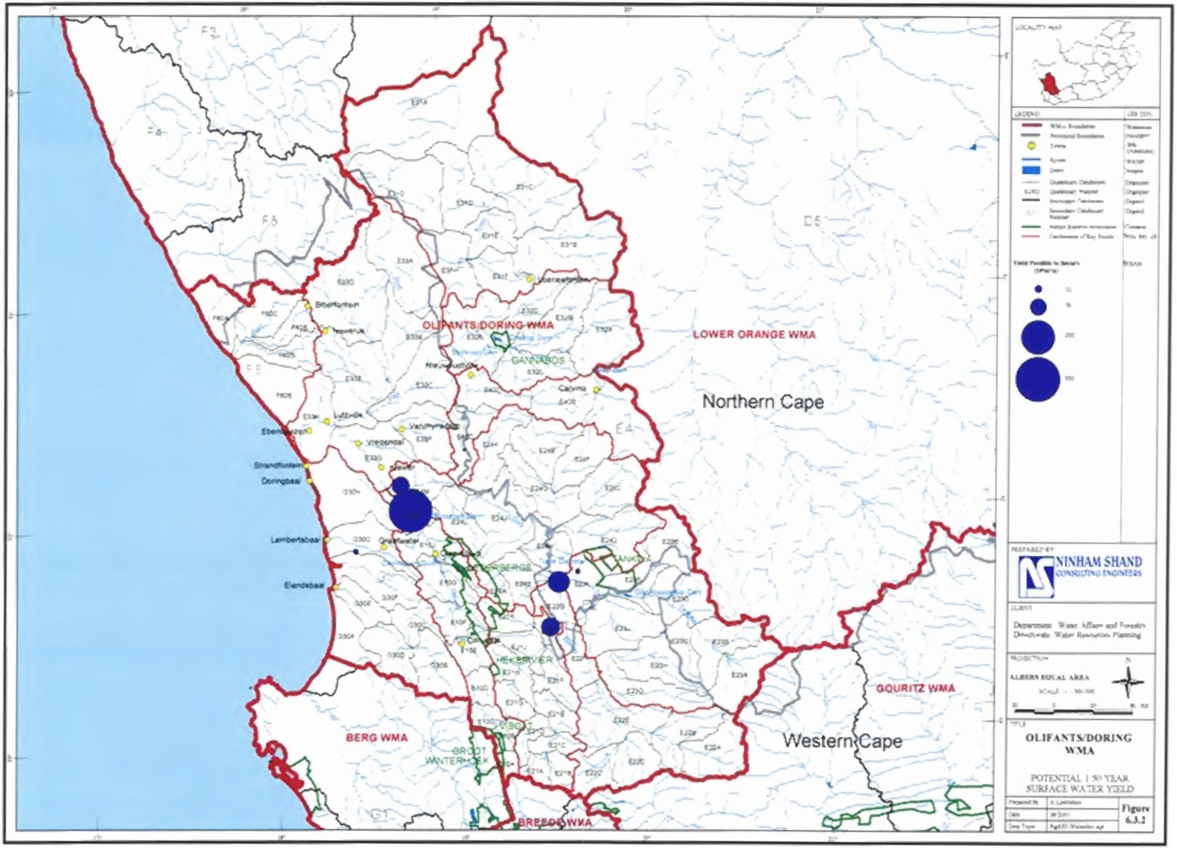
CONSULTING ENGINEERS
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
OLIFANTS/DORING WMA
MEAN ANNUAL NATURALISED SURFACE RUNOFF
Figure 6.3.1



OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
GANNABOS
HEKSRIVIER
GROOT WINTERHOEK
Bitterfontein
Nuwerus
Nieuwoudtville
Calvinia
Lutzville
Vanrhynsdorp
Vredendal
Klawer
Ebenhaeser
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Clanwilliam
Elandsbaai
Citrusdal
Loeriesfontein
D5
E4
F5
F4
G1
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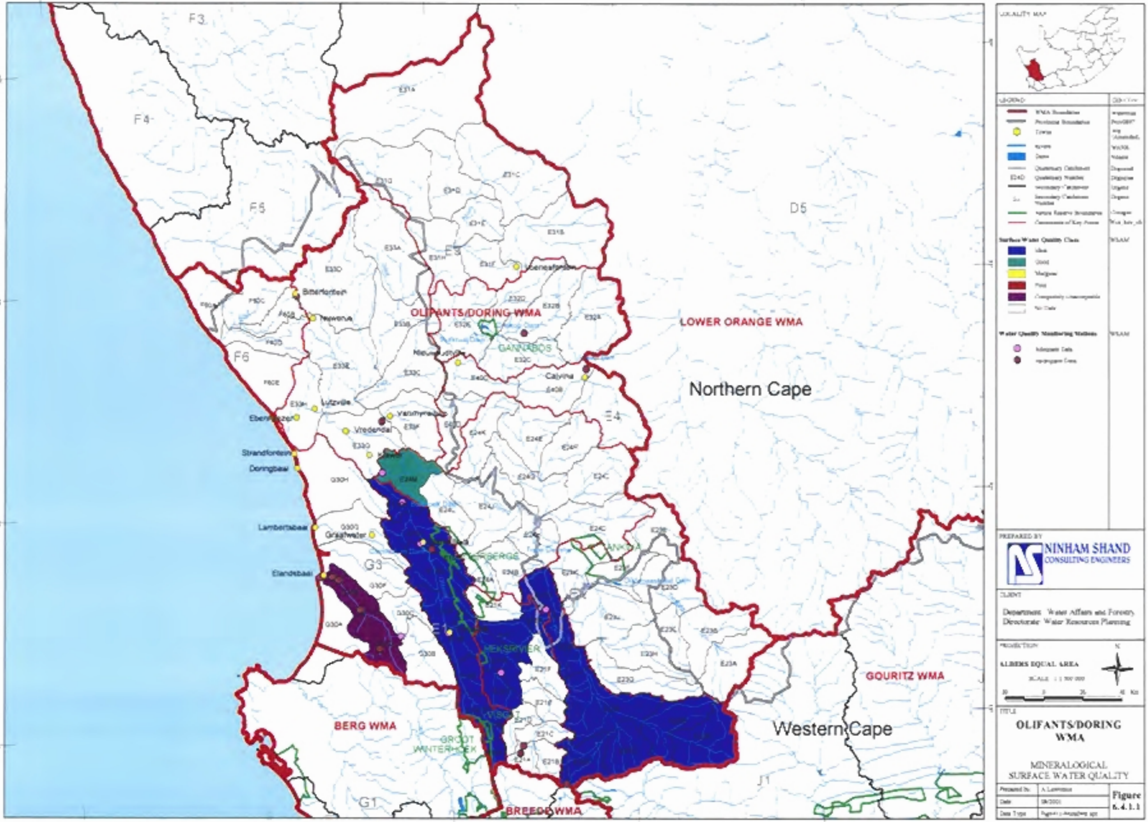
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
POTENTIAL 1:50 YEAR SURFACE WATER YIELD
Figure 6.3.2


F3
F4
F5
F6
E3
E4
D5
G3
G1
J1
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
BERG WMA
GOURITZ WMA
BREEDE WMA
GANNABOS
Bitterfontein
Nuwerus
Calvinia
Lutzville
Vredendal
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
LOCALITY MAP
LEGEND
Surface Water Quality Class
Water Quality Monitoring Stations
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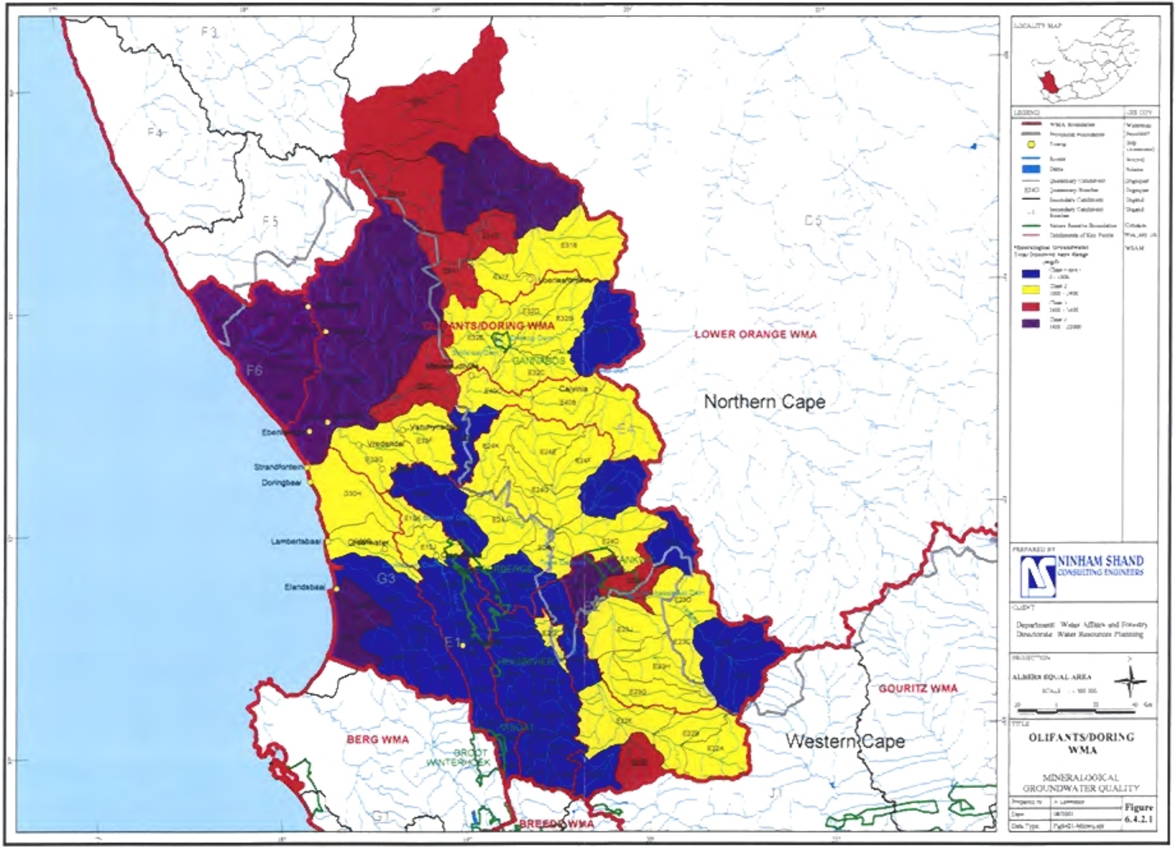
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
MINERALOGICAL SURFACE WATER QUALITY
Figure 6.4.1.1



F3
F4
F5
F6
C5
E4
G3
E1
G1
J1
OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
GANNABOS
GROOT WINTERHOEK
Calvinia
Vredendal
Vanrhynsdorp
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
LOCALITY MAP
LEGEND
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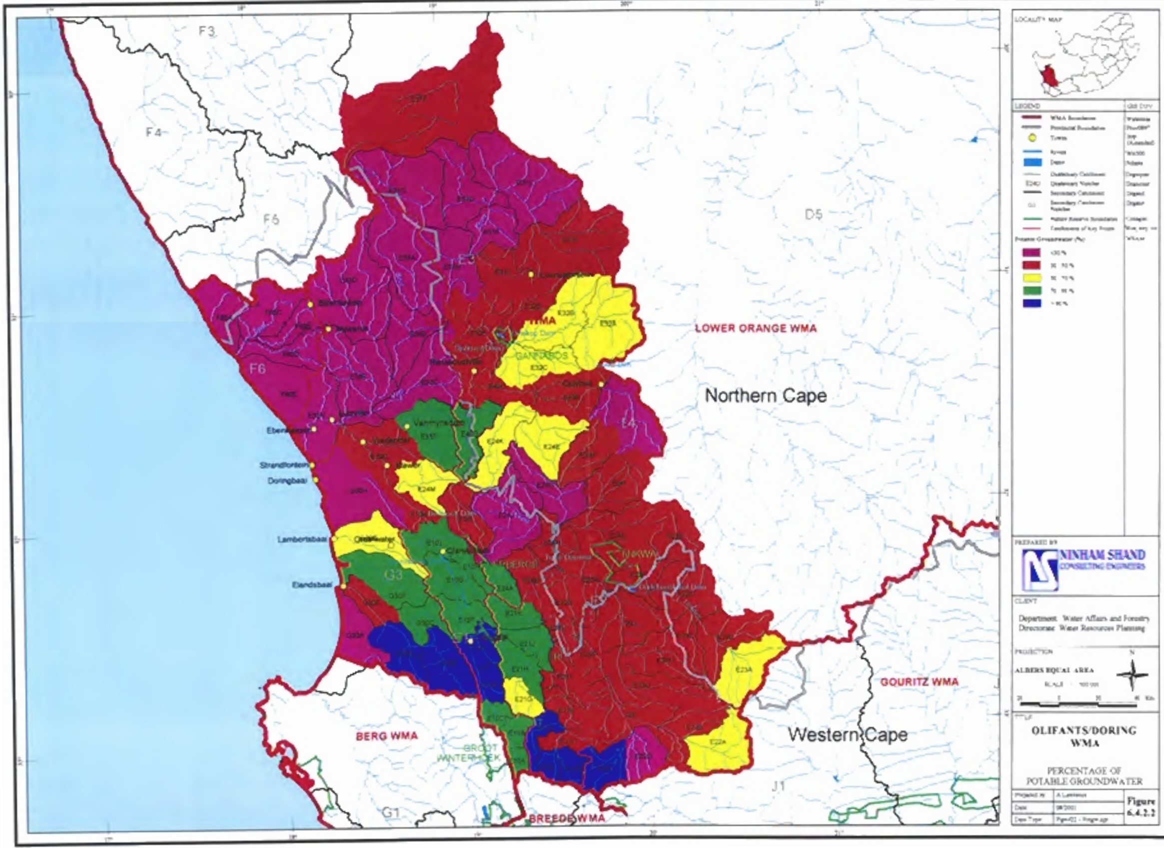
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
MINERALOGICAL GROUNDWATER QUALITY
Figure 6.4.2.1



LOCALITY MAP
LEGEND
Potable Groundwater (%)
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Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
OLIFANTS/DORING
WMA
PERCENTAGE OF
POTABLE GROUNDWATER
Figure
6.4.2.2
Northern Cape
Western Cape
LOWER ORANGE WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
GROOT
WINTERHOEK
F3
F4
F6
D5
E4
G3
G1
J1
Lambertsbaai
Elandsbaai
Strandfontein
Doringbaai
Vanrhynsdorp
Vredendal
Clanwilliam
Nieuwoudtville
Calvinia
GANNABOS

LOCALITY MAP
LEGEND
Potential Surface Water Contamination
No Data
Missing Data
Low
Medium
High
OLIFANTS/DORING WMA
LOWER ORANGE WMA
BERG WMA
GOURITZ WMA
BREEDE WMA
Northern Cape
Western Cape
GANNABOS
HEKSRIVIER
Calvinia
Lutzville
Vredendal
Vanrhynsdorp
Klawer
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Ebenhaeser
Bitterfontein
Nieuwoudtville
Loeriesfontein
Citrusdal
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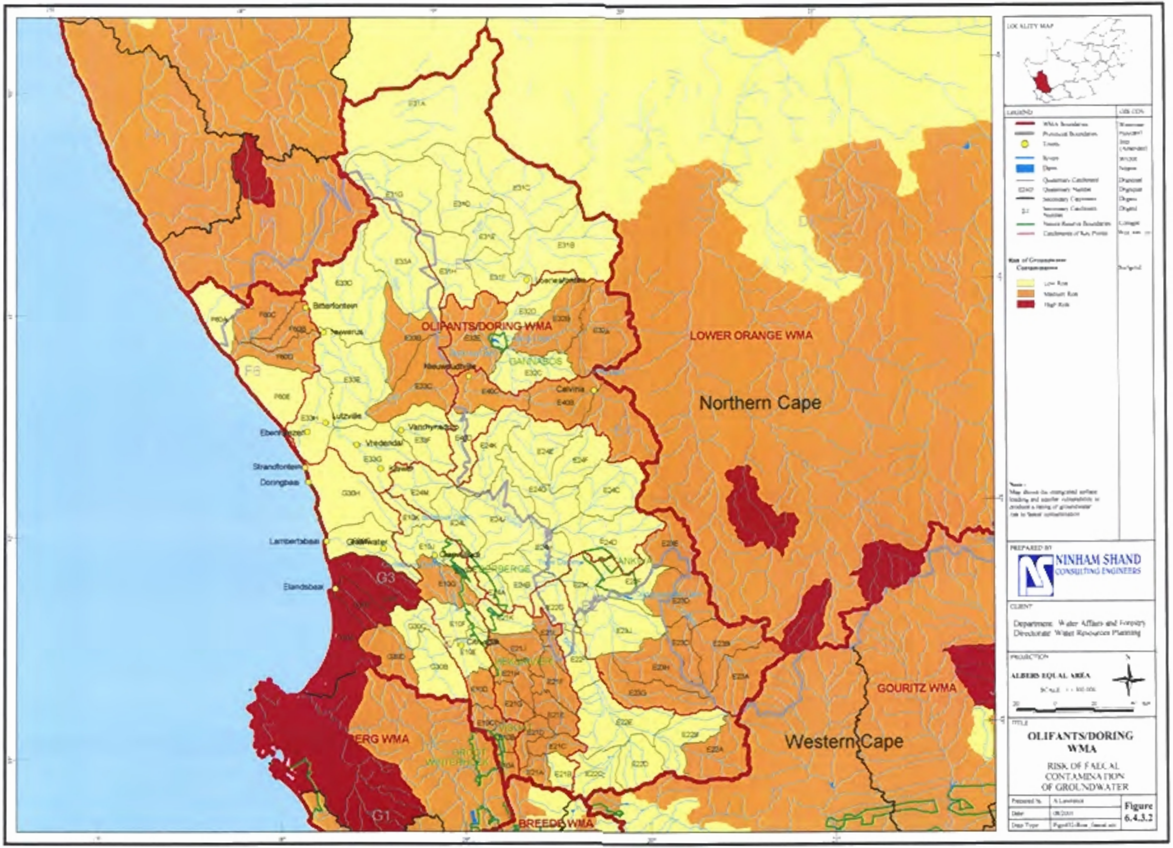
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
POTENTIAL SURFACE FAECAL CONTAMINATION
Figure 6.4.3.1


OLIFANTS/DORING WMA
LOWER ORANGE WMA
GOURITZ WMA
BREEDE WMA
ERG WMA
Northern Cape
Western Cape
F6
G3
G1
GANNABOS
Bitterfontein
Nuwerus
Nieuwoudtville
Calvinia
Lutzville
Ebenhaeser
Vanrhynsdorp
Vredendal
Strandfontein
Doringbaai
Lambertsbaai
Graafwater
Elandsbaai
Loeriesfontein
Clanwilliam
Citrusdal
LOCALITY MAP
LEGEND
Risk of Groundwater Contamination
Low Risk
Medium Risk
High Risk
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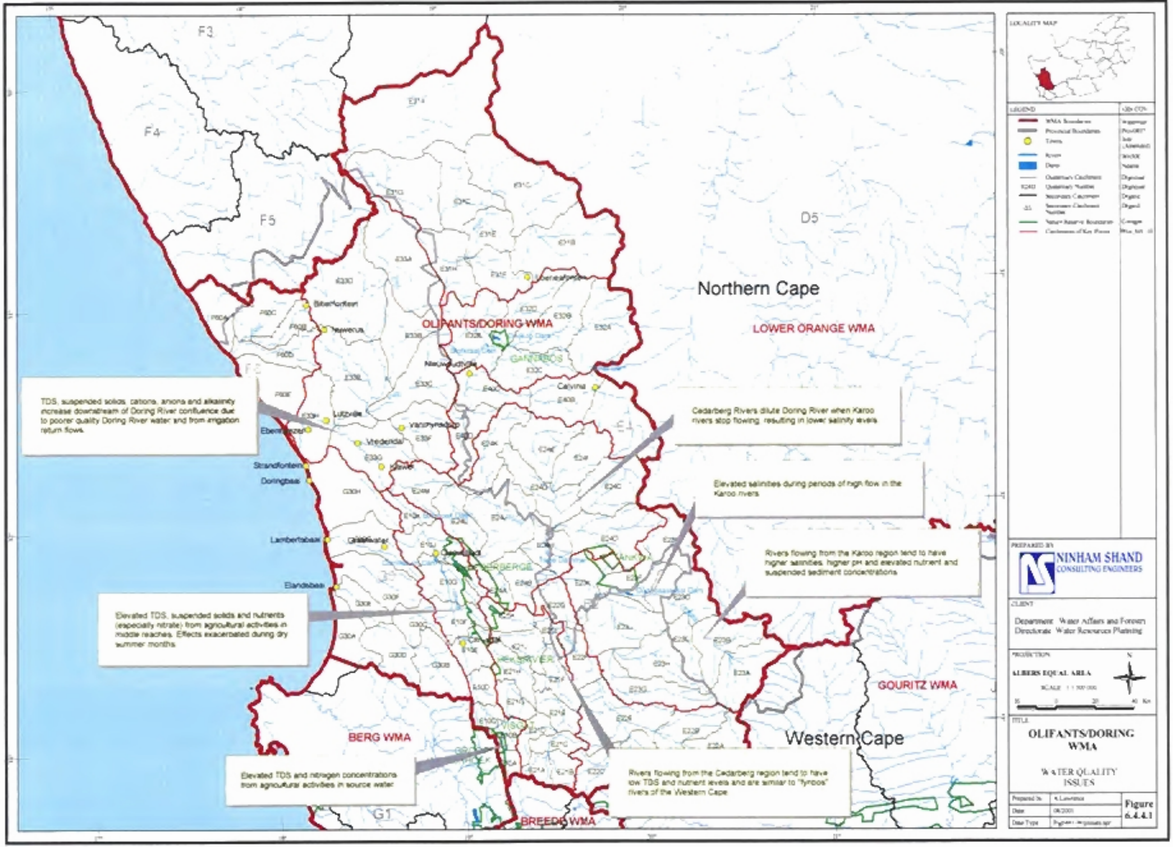
PROJECTION
ALBERS EQUAL AREA
TITLE
OLIFANTS/DORING WMA
RISK OF FAECAL CONTAMINATION OF GROUNDWATER
Figure 6.4.3.2



F3
F4
F5
D5
E1
G1
Northern Cape
Western Cape
OLIFANTS/DORING WMA
LOWER ORANGE WMA
GOURITZ WMA
BERG WMA
BREEDE WMA
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Lutzville
Vredendal
Calvinia
TDS, suspended solids, cations, anions and alkalinity increase downstream of Doring River confluence due to poorer quality Doring River water and from irrigation return flows.
Cedarberg Rivers dilute Doring River when Karoo rivers stop flowing, resulting in lower salinity levels
Elevated salinities during periods of high flow in the Karoo rivers
Rivers flowing from the Karoo region tend to have higher salinities, higher pH and elevated nutrient and suspended sediment concentrations
Elevated TDS, suspended solids and nutrients (especially nitrate) from agricultural activities in middle reaches. Effects exacerbated during dry summer months.
Elevated TDS and nitrogen concentrations from agricultural activities in source water
Rivers flowing from the Cedarberg region tend to have low TDS and nutrient levels and are similar to "fynbos" rivers of the Western Cape
LOCALITY MAP
LEGEND
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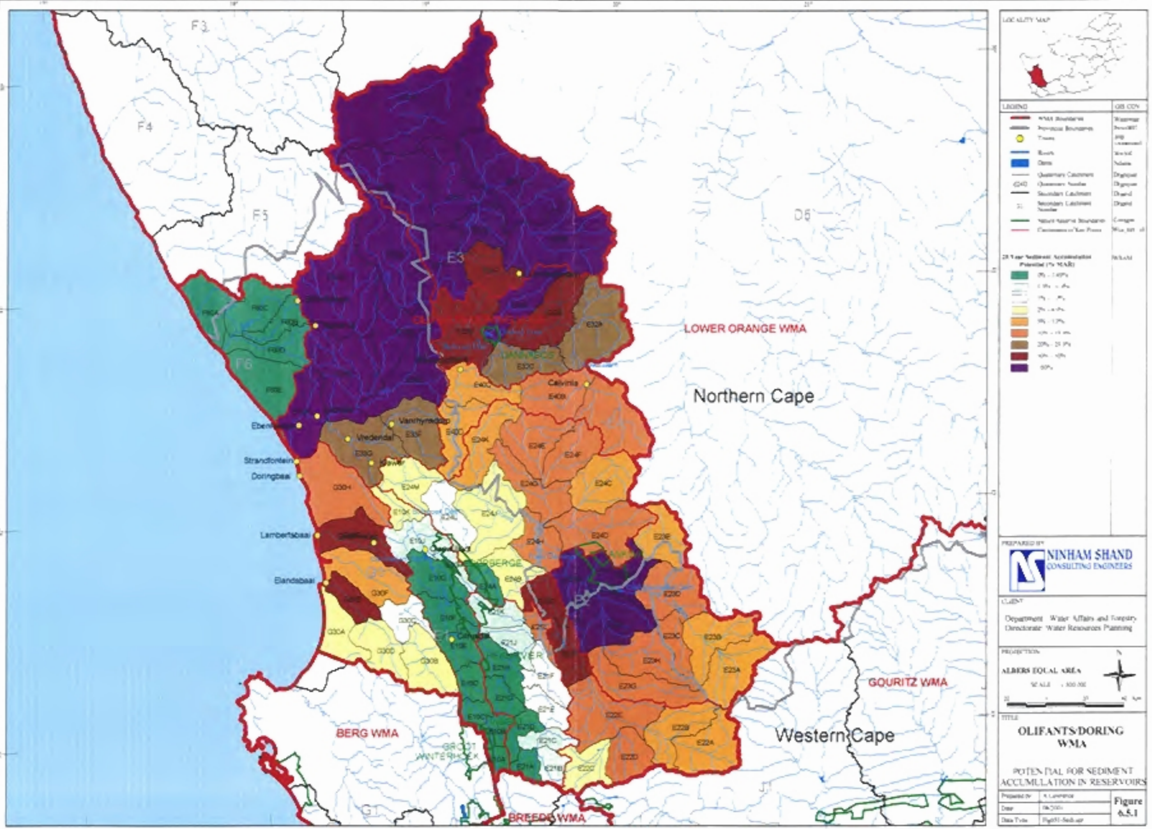
PROJECTION
ALBERS EQUAL AREA
N
TITLE
OLIFANTS/DORING WMA
WATER QUALITY ISSUES
Figure 6.4.4.1


F3
F4
F5
F6
E3
D5
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
Calvinia
Vanrhynsdorp
Vredendal
Klawer
Strandfontein
Doringbaai
Lambertsbaai
Elandsbaai
Citrusdal
E32A
E32C
E40C
E40B
E33F
E33G
E24K
E24E
E24F
E24C
E24G
E24M
E24H
E24D
E23E
E23D
E23B
E23A
E23C
E22C
E22B
E22A
E22D
E22G
G30H
G30F
G30A
G30D
G30B
E10G
E10J
E10K
E10F
E10E
E10D
E10C
E10B
E10A
E21A
E21B
E21C
E21D
E21E
E21F
E21J
E21K
E21H
E21G
E24J
E24A
E24B
F60A
F60C
F60D
F60E
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ALBERS EQUAL AREA
OLIFANTS/DORING
WMA
POTENTIAL FOR SEDIMENT
ACCUMULATION IN RESERVOIRS
Figure
6.5.1


OLIFANTS/DORING WMA
LOWER ORANGE WMA
Northern Cape
Western Cape
GOURITZ WMA
BERG WMA
BREEDE WMA
Bitterfontein
Nuwerus
Nieuwoudtville
Loeriesfontein
Calvinia
Lutzville
Vredendal
Strandfontein
Doringbaai
Klawer
Lambertsbaai
Graafwater
Elandsbaai
Clanwilliam
Citrusdal
CEDERBERG
TANKWA
HEKSRIVIER
GROOT
WINTERHOEK
Total Yield Balance
for the WMA
385
345
LOCALITY MAP
LEGEND
Water Categories
Water Surplus
Water Shortfall
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PROJECTION
GEOGRAPHIC PROJECTION
TITLE
OLIFANTS/DORING
WMA
YIELD BALANCE
OVERVIEW
Figure
7.2.1