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DEPARTMENT: WATER AFFAIRS AND FORESTRY

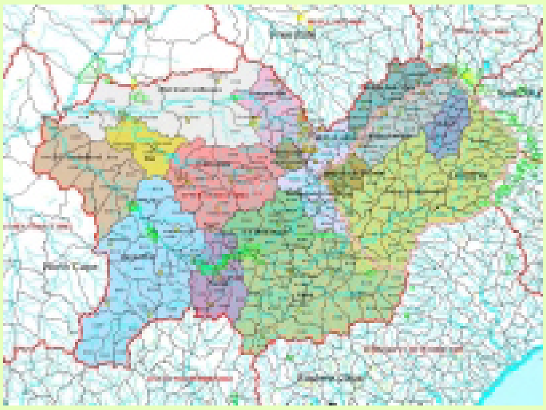
Directorate: Water Resources Planning

UPPER ORANGE
WATER MANAGEMENT AREA

WATER RESOURCES SITUATION ASSESSMENT

MAIN REPORT
FINAL: AUGUST 2002

VANDERKLOOF



CONFLUENCE OF THE VAAL AND ORANGE RIVERS

COMPILED BY:

STEWART SCOTT

Title:	**Upper Orange Water Management Area: Water Resources Situation Assessment – Main Report – Volume 1 of 3**
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UPPER ORANGE 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 Upper Orange Water Management Area, which occupies portions of the Free State, Northern Cape and Eastern 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 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 1998, (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, 1998 (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, 1998 (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.

PREFACE

The Orange/Vaal River Basin extends over four countries, covering an area of 964 000 km². Almost 600 000 km² of the basin falls within South Africa, mainly covering the central part, and which represents nearly half of the surface area of the country. It incorporates the whole of Lesotho (where the main river is known as the Senqu), reaches to the southern part of Botswana, and drains most of the southern half of Namibia. From its origin in the highlands of Lesotho, the Orange River passes through different landscapes and highly varied climatic regions on its 2 300 km journey to the Atlantic Ocean. As a consequence, runoff from the different sub-catchments in the basin is disproportionate to the size of the catchment areas, as illustrated by the fact that approximately 40% of the MAR of the Orange River Basin is contributed by catchments in Lesotho which cover only 4% of the land area of the basin. This is in contrast to the downstream desert reaches of the Orange River where evaporation losses are in excess of the runoff from local tributaries.

The Vaal River forms the main tributary to the Orange River. It originates on the plateau west of the Drakensberg escarpment and drains much of the central highveld of South Africa.

Within South Africa, the Orange/Vaal River Basin includes 5 of the 19 Water Management Areas (WMA). These are the Upper Vaal, Middle Vaal, Lower Vaal, Upper Orange and Lower Orange WMAs. The small portion of the Crocodile West and Marico WMA that falls within the Orange/Vaal River Basin has no significant effect on the water resources situation of the basin. Great differences occur with respect to the hydro-meteorological characteristics as well as nature and level of development in these WMAs. The Vaal River is probably the most developed and regulated river in Southern Africa, while some of the largest dams in Africa have been built in Lesotho and on the main stem of the Orange River. Although linked together by the natural watercourses, a particular characteristic of the Orange/Vaal WMAs is the extensive intercatchment transfer of water within WMAs as well as interbasin transfers between these and other adjoining WMAs. The relative location of the Orange/Vaal WMAs together with a schematic representation of the main transfers of water, are given in **Diagram 1**.

An additional five WMAs are directly linked to the Orange River Basin (and the Orange/Vaal WMAs) through interbasin transfers, while the impacts of water resource management within the basin also indirectly extend to other WMAs and to the neighbouring countries of South Africa outside the basin (Zimbabwe, Swaziland and Mozambique). The main interdependencies among the Orange/Vaal (and other interlinked) WMAs relate to flow volume, flow regime and water quality.

A summarised description of the main features of each of the Orange/Vaal WMAs, effecting other WMAs and countries, follows:

Diagram 1: Layout of the Orange / Vaal River Basin

Upper Vaal WMA

This is the most developed, industrialised and populous of the Orange/Vaal WMAs. From a water resource management perspective it is a pivotal WMA in the country. Large quantities of water are transferred into the WMA from the Usutu to Mhlatuze and the Thukela WMAs as well as from the Senqu (Orange) River in Lesotho. Similarly large quantities of water are released along the Vaal River to the Middle Vaal and Lower Vaal WMAs and are also transferred to the Crocodile West and Marico, and the Olifants WMAs.

Middle Vaal WMA

The Middle Vaal WMA is dependant on water releases from the Upper Vaal WMA for meeting the bulk of the water requirements by the urban, mining and industrial sectors within its area of jurisdiction, with local resources mainly used for irrigation and smaller towns. Water is also transferred via the Vaal River through this WMA, from the Upper Vaal WMA to the Lower Vaal WMA. Water quality in the Vaal River is strongly influenced by usage and management practices in the Upper Vaal WMA.

Lower Vaal WMA

Over 90% of the water used in the Lower Vaal WMA is sourced through releases from the Upper Vaal WMA and from Bloemhof Dam on the Vaal River, on the border with the Middle Vaal WMA. About 80% of the water use in this WMA is for irrigation (mainly at the Vaalharts irrigation scheme). Essentially only irrigation return flows, which are of high salinity, and unregulated flood flows from the Vaal River, reach the confluence with the Orange River.

Upper Orange WMA

Close to 60% of the water resources generally associated with the Upper Orange WMA, originate from the Senqu River in Lesotho. Developments in Lesotho can therefore have a significant impact on the Upper Orange WMA. The two largest storage reservoirs in South Africa, created by the Gariep and Vanderkloof Dams, are located in this WMA. Two thirds of the total yield realised by the dams in Lesotho and in the Upper Orange WMA together, is transferred to the Upper Vaal and Fish to Tsitsikamma WMAs, and released to the Lower Orange WMA as well as for use by Namibia.

Lower Orange WMA

Water requirements in the Lower Orange WMA are far in excess of the yield available from resources within the WMA, and about 95% are supplied by water released from the Upper Orange WMA. High evaporation losses from the Orange River, which are of the same order, as the water requirements in the WMA, are characteristic of the region. Namibia also abstracts water from the Orange River.

Summarising remarks

From a national point of view, the Orange/Vaal River system can be regarded as the most important river system in South Africa, not only because of its size and strategic central location, but because it sustains about half the economic production and a large proportion of the population of the country. It is evident that water resource management in the Orange/Vaal WMAs should be well co-ordinated and be viewed in an integrated systems context. Therefore none of the water resources situation assessment reports for the five WMAs in the Orange/Vaal River Basin should be interpreted in isolation, but rather as part of a suite of reports. Management of water resources in the basin should also be within the framework of the Orange-Senqu River Commission (ORASECOM) recently established by South Africa, Lesotho, Botswana and Namibia. Furthermore, impacts on water resources in other WMAs as well as in the neighbouring countries (other than the Orange co-basin countries), as a result of interbasin transfers, should also be of primary consideration in the management of the Orange/Vaal River Basin and river system.

The reader of this report is requested to take cognisance of the inter-relationships between the three Vaal WMA's, as set out in their respective WMA reports. The surplus yields passing from the Upper Vaal WMA has considerable bearing on the passage of water flowing through the Middle and Lower Vaal WMA's and further downstream to the Lower Orange WMA and influence the calculation of surplus yields that could be used for future development.

The report numbers for the four water management areas are as follows :

- Upper Vaal WMA : 08000/00/0101 (Stewart Scott).
- Middle Vaal WMA : 09000/00/0101 (Stewart Scott).
- Lower Vaal WMA : 10000/00/0101 (BKS).
- Lower Orange WMA : 14000/00/0101 (V3).

SYNOPSIS

1. Introduction

The National Water Act, 1998 (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.

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 and the national database should, in addition to contributing to the establishment of the National Water Resources Strategy, provide a tool for collaborative planning of water resources development and utilisation by the central government and the future catchment management agencies.

The study was carried out as a desktop exercise using data from reports, electronic databases (WR90) and data supplied by associated studies, local authorities and DWAF. The study considers conditions as they were in 1995.

2. Physical features

The Upper Orange River catchment has its headwaters in the Maluti Mountains in the Lesotho Highlands and is known as the Senqu River in Lesotho. Lesotho is not part of the Upper Orange WMA but it contributes to the water resources of the Upper Orange WMA. The Modder-Riet Rivers are tributaries of the Vaal but form part of the WMA. The Caledon River forms the north-western boundary of Lesotho with South Africa and is a major tributary of the Orange River. The Caledon River joins the Orange a short distance upstream of Gariep Dam. Upstream of this confluence the Orange River is joined by the Kraai River at Aliwal North. This WMA covers a catchment area of 103 671 km^2 . Lesotho has been included in the study area and covers 30 492 km^2 . The total area is 134 163 km^2 .

The following table describes the key areas.

LOCATION OF KEY POINT			DESCRIPTION
PRIMARY CATCHMENT		QUATERNARY CATCHMENT NO.	
NO.	KEY AREA NAME AND POINT		
C	Kalkfontein- C51J outlet	C51A-J	Kalkfontein Dam
	Riet – C51K outlet	C51K	Confluence of Riet and Modder
	Riet / Modder confluence – C51M outlet	C51L-M, C52H-L	Remaining C5 Tertiary catchment
	Rustfontein - C52A outlet	C52A	Rustfontein Dam
	Krugersdrift – C52G outlet	C52B-G	Rustfontein to Krugersdrift
D	Katse – D11K outlet	D11A-K	Katse Dam
	Senqu – D18L outlet	D15A-H, D16A-L,D17A-M, D18A-L	Senqu and M? catchments in Lesotho
	Orange u/s Gariep Dam – D14K outlet	D12A-F, D13A-M,D14A-K	U/s Gariep Dam
	Caledon – Lesotho – D22L outlet	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, 22E, D22F, D22H*, D22J, D22K, D22L*	Upper Caledon River catchment in Lesotho
	Caledon - South Africa – D22L outlet	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	Upper Caledon River catchment in South Africa (Free State)
	Welbedacht – Lesotho – D23G outlet	D23A*, D23B, D23E*, D23F*, D23G*	Welbedacht Dam catchment in Lesotho
	Welbedacht – South Africa-D24C outlet	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	Welbedacht Dam catchment in South Africa (Free State)
	Caledon d/s Welbedacht – D24L outlet	D24D-L	Remaining D24 Tertiary catchment
	Gariep – D35K outlet	D35A-K	D35 Tertiary catchment
	Vanderkloof – D31E outlet	D31A-E, D32A-K, D34A-G	D/s Gariep Dam to Vanderkloof Dam
	Orange d/s Vanderkloof – D33K outlet	D33A-K	D33 Tertiary catchment

Note: * Quaternary catchment area within Lesotho and RSA

With its sources in the high mountains of Lesotho, the Orange remains deeply incised for most of its journey. The catchment slopes from the east, where elevations exceed 3 000 m, to about 1 200 m in the west, at its confluence with the Vaal River. The steep mountainous areas in the east are replaced by undulating topography downstream of the Orange/Kraai confluence and in the lower reaches of the Caledon valley.

Climatic conditions vary considerably from east to west across the Upper Orange WMA. Excluding Lesotho, the mean annual temperature ranges between 18 °C in the west to 12 °C in the east and averages about 15 °C for this area as a whole. In Lesotho, the mean annual temperature ranges from 14 °C to below 8 °C in the more mountainous parts towards the east with an average of about 11 °C for the country as a whole. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. Rainfall is strongly seasonal with most rain occurring in the summer period (October to April). The peak rainfall months are December to March. Rainfall occurs generally as convective thunderstorms and is sometimes accompanied by hail. The overall feature of mean annual rainfall over the Upper Orange WMA is that it decreases fairly uniformly westwards from the eastern escarpment regions across the central plateau area. The MAP (excluding Lesotho) ranges from a high of 800 mm in the east to a low of 300 mm in the west with an average of about

500 mm. For Lesotho, it ranges from about 500 to over 1 200 mm in the more mountainous areas.

Extrusive igneous rocks of the Stormberg series (part of Karoo system) cover the eastern high-lying areas. The north-western part of this WMA is described as compact, dominantly argillaceous strata with small pockets of compact tillite and compact sedimentary and extrusive rocks near the WMA boundary. Compact arenaceous and argillaceous strata (fine sedimentary rocks of the Karoo system) underlie the remainder of the Upper Orange WMA

Soil depths are generally moderate to deep over the upper Orange catchment. There are six main soil/texture/relief types that predominate and these are distributed across the catchment as follows:

- Sandy Loam: In the upper Caledon valley and to the south of the Orange in the western part of the catchment of moderate to deep depth and undulating relief.
- Clay Soil: Confined to the mountainous areas in the eastern portion of the Lesotho of moderate to deep depth and steep relief.
- Sandy Soil : Confined to areas around Bloemfontein and Petrusburg of moderate to deep relief and flat relief.
- Clay Loam (flat relief) : Confined to the north-western part of the catchment of moderate to deep depth.
- Clay Loam (Steep relief) : Confined to the south-eastern part of the WMA of moderate to deep depth.
- Clay Loam (undulating relief) : The predominant soil type in the remainder of the catchment of moderate to deep depth.

Lesotho consists almost entirely of the “pure grassveld” veld type (which requires moderate to high rainfall) interspersed with a bit of “temperate and transitional forest and scrub”. There is also a bit of “false karoo” along its western edge where it is drier. Moving north to the Modder-Riet catchment, there is still some “pure grassveld” in the east but most of this catchment is “false karoo” and “false bushveld”. In the south and south-western parts of this WMA one finds mainly “false karoo” together with “karoo and karroid” and “false bushveld”

3. Development Status

The total urban and rural population in this WMA is about 1 250 000 million (1995 figures) fairly evenly split between urban and rural. Lesotho has a total urban and rural population of about 2 million. The northern central part of the WMA including Bloemfontein , Botshabelo and Thaba Nchu (Krugersdrift key area) accounts for about 75% of the urban total in this WMA. In Lesotho, the north-western strip along the Caledon River including Maseru (Caledon – Lesotho key area) accounts for about 75% of the urban population in Lesotho The rural population in the Upper Orange WMA is relatively small. About 80% of the rural population in Lesotho is in the area comprising tertiary catchments D15 to D18 (Senqu key area) and the north-western strip along the Caledon River (Caledon – Lesotho) key area.

Bloem Water provides the vast majority of potable water in this WMA.

Urbanisation accounts for about 27% of the total land use of about 1 262 km^2. Irrigation accounts for about 67% and alien vegetation covers about 5%. Just under 1 % is afforested.

The following table shows land use per key area as well as population. Irrigation is of key importance and there are numerous irrigation schemes in this WMA. The Modder/Riet sub-catchment (secondary catchment C5) accounts for just over 50% of the total land use (for irrigation, afforestation, alien vegetation and urbanisation).

CATCHMENT						Irrigation (field area) (km²)	Afforestation (km²)	Alien vegetation (km²)	Urban (km²)	Other (km²)	Total (km²)	Population
PRIMARY		SECONDARY		TERTIARY								
No.	Description	No.	Description	No.	Key Area Description							
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	38,2	0	2,6	0,0	10 219,2	10 260,0	33 557
			Riet	C51	Riet (C51K)	136,4	0	1,8	0,0	3 493,8	3 632,0	19 924
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	63,8	0	48,1	41,0	14 437,1	14 590,0	76 062
			Rustfontein	C52	Rustfontein (C52A)	3,6	0	0	0,0	933,4	937,0	9 423
			Krugersdrift	C52	Krugersdrift (C52B-G)	19,1	0	1,0	297,0	5 076,9	5 394,0	642 006
	Total in Modder / Riet (C) primary catchment					**2801**	**0**	**67**	**338,0**	**34 160,4**	**34 813,0**	**780 972**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0	0	0,5	0,0	3 359,5	3 360,0	133 701
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	25,7	0	4,4	0,0	21 289,9	21 320,0	531 756
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	171,1	0	0,3	0,0	18 298,6	18 470,0	223 964
		D2	Caledon – Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	7,8	0,0	0	10,2	5 150,3	5 168,3	1 084 100
			Caledon – RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	13,4	9,6	0	7,6	4 564,1	4 594,7	105 770
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	5,2	0	0	0,0	1 796,6	1 801,8	252 200
			Welbedacht - RSA	D23	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	39,0	0	0	0,0	4 844,2	4 883,2	33 220
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	46,4	0	0	0,0	5 389,6	5 436,0	15 607
		D3	Gariep	D35	Gariep (D35A-K)	22,4	0	0,8	0,0	5 614,8	5 638,0	19 589
			Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	63,5	0	2,9	0,0	19 013,6	19 080,0	40 399
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	150,2	0	7,7	0,0	9 440,1	9 598,0	20 351
	Total in D primary catchment					**544,7**	**9,6**	**16,6**	**17,8**	**98 761,3**	**99 349,0**	**1923**
Total in Lesotho in D primary catchment						**[38,7]**	**[0]**	**[5,0]**	**[10,2]**	**[30 438,1]**	**30 492,0**	**[1053]**
Total in Free State in C and D primary catchments						**421,9**	**9,6**	**53,8**	**345,6**	**55 439,1**	**56 270,0**	**1678**
Total in Northern Cape in C and D primary catchments						**174,2**	**0**	**8,7**	**0**	**25 391,1**	**25 575,0**	**1208**
Total in Eastern Cape in D primary catchment						**171,0**	**0**	**2,6**	**0**	**21 652,4**	**21 826,0**	**1703**
TOTAL IN WMA (South Africa only)						**767,1**	**9,6**	**65,1**	**345,6**	**102 483,6**	**103 671,0**	**1 239 872**

Note: * Quaternary catchment area within Lesotho and RSA.

4. Existing Water Related Infrastructure

Agriculture is one of the key users of water in the Upper Orange WMA and there are several schemes comprising dams, canals, pumpstations etc to supply Government Water Schemes (GWS) and irrigation boards in the area.

Domestic and industrial water supply is also extremely important. The Modder River is fully utilised in its upper reaches and this has necessitated transferring water from the Orange and the Caledon Rivers. There are three main transfer schemes, namely: the Caledon – Modder transfer which supplies Bloemfontein, Dewetsdorp and smaller users from Welbedacht Dam, the Orange-Riet transfer which supplies irrigation in the Riet River catchment from the Vanderkloof Dam and the Caledon-Modder (Novo) transfer which is supplying growing demands in the Bloemfontein area. The new Rustfontein purification works is supplying Thaba Nchu and Botshabelo. There are numerous other purification works for small towns as well as sewage disposal works.

The Orange-Fish tunnel transfers water from Gariep Dam to the Eastern Cape (which is outside the Upper Orange WMA).

There are seven major dams in the Upper Orange catchment, namely: Gariep, Vanderkloof, Welbedacht, Rustfontein, Kalkfontein, Groothoek and Mockes. There are two major hydroelectric powerstations at Gariep and Vanderkloof Dams

The following table shows the combined capacities of individual town and regional potable water supply schemes by key area**.**

CATCHMENT						TOWN AND REGIONAL WATER SUPPLY SCHEMES			
PRIMARY		SECONDARY		TERTIARY		Number of People Supplied (1)	% of Key Area Population	CAPACITY	
No.	Description	No.	Description	No.	Key Area Description			($10^6 m^3/a$)	(ℓ/capita/d)
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	22 350	67	not available	208
			Riet	C51	Riet (C51K)	13 900	70	not available	461
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	52 400	69	not available	262
			Rustfontein	C52	Rustfontein (C52A)	7 250	77	not available	95
			Krugersdrift	C52	Krugersdrift (C52B-G)	610 700	95	not available	266
	Sub-total in C primary catchment					**706 600**	**91**	**not available**	**95 to 461**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0	Not applicable	Not applicable	Not applicable
			Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	unknown	unknown	not available	54
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	81 050	36	not available	93
		D2	Caledon - Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	unknown	unknown	not available	87
			Caledon - RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	68 150	64	not available	189
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	unknown	unknown	not available	53
			Welbedacht - RSA	D23	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	16 750	50	not available	190
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	9 750	63	not available	314
		D3	Gariep	D35	Gariep (D35A-K)	15 550	80	not available	277
			Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	30 950	77	not available	210
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	12 650	62	not available	210
	Total in D primary catchment					**931 330**	**51**	**not available**	**53 to 314**
Total in Lesotho in D primary catchments						**[unknown]**	**[unknown]**	**[not available]**	**53 to 87**
Total in Free State in C and D primary catchments						**830 800**	**84**	**not available**	**93 to 461**
Total in Northern Cape in C and D primary catchments						**37 650**	**76**	**not available**	**210**
Total in Eastern Cape in D primary catchments						**73 000**	**36**	**not available**	**93 to 277**
TOTAL IN WMA (only South Africa)						**941 450**	**76**	**not available**	**93 to 461**

Note : (1) Assumed that the South African urban population is supplied from individual and regional water supply schemes.

* Quaternary catchment area within Lesotho and RSA (split provided by DWAF).

5. Water Requirements

The various user sectors in this WMA are as follows and are given in **Table 5.1.1** along with the total water requirements in the WMA in 1995:

- Ecological Reserve (environmental - in-stream flow requirements). This water is not consumed.
- Domestic (urban and rural users).
- Bulk industrial (including thermal power stations) and mining.
- Water transfers.
- Agricultural (including livestock and game).
- Afforestation.
- Alien vegetation.
- Hydropower. This water is not consumed apart from losses. It should be noted that hydropower is a secondary determinant of the weekly releases from Gariep and Vanderkloof Dams, irrigation requirements are the primary concern.

Greater Bloemfontein in the Modder River catchment is the largest urban area in this WMA. In Lesotho, the only significant urban area is the capital city, Maseru. Kimberley is situated on the northern WMA boundary with the Lower Vaal WMA and is considered to be part of the Lower Vaal WMA. Some of the larger urban areas are Thaba Nchu, Botshabelo, Wepener, Dewetsdorp, Reddersburg, Edenburg, Jagersfontein, Trompsburg, Brandfort, Dealesville, Petrusberg, Jacobsdal, Koffiefontein, Oppermans, Fauresmith, Trompsburg, Springfontein, Bethulie, Smithfield, Rouxville, Zastron, Vanstadensrus, Barkly East, Ficksburg, Colesburg, Aliwal North and Phillipolis. The bulk supplier of potable water is Bloem Water which supplies about 40 x 10^6 m^3/a to about 800 000 people.

Rural usage can be categorised into domestic rural use, livestock watering and subsistence irrigation. Apart from Lesotho, there are very little rural domestic water requirements in this WMA. Stock watering is most significant in the Senqu and the Orange u/s Gariep key areas. There is no known subsistence irrigation in this WMA.

There are no strategic bulk water users in this WMA. Even though there some diamond mines in this area - the largest being Debeers Koffiefontein Diamond mine, there is no record of mining operations in this area impacting directly on the hydrology or water quality of the Upper Orange WMA. There are no significant users in the “Other Bulk” category.

Irrigation is the largest user of water in the Upper Orange WMA accounting for about 58 %. The estimated total irrigation use from the Orange River basin is 817 x 10^6 m^3/a, approximately 32 % falls in the Modder/Riet catchment (mainly the Riet and Modder/Riet key areas) and 68 % in the Upper Orange River catchment (mainly in the Orange u/s of Gariep Dam and d/s of Vanderkloof Dam key areas). There are no large areas of irrigation in Lesotho (Refer to **Table 5.5.1**). Approximately 60% of irrigation in the WMA is controlled irrigation with water supplied either from Government Water Schemes (GWS), Government Water Controlled Areas (GWCA) or by Irrigation Boards (IB). The remaining 40 % of irrigation is diffuse irrigation where the water is used for irrigation of low value crops and secondary enterprises. Sources of water range from permanent reliable surface water to lower volume water sources such as groundwater and small farm dams.

There is no dryland agriculture, negligible afforestation and alien vegetation is small with the most significant area being the Riet/Modder confluence key area.

There are two hydroelectric stations in this WMA, namely: Gariep and Vanderkloof which generate peak clipping hydro-power to the Eskom network during releases from the two dams. Both Gariep and Vanderkloof release water through their turbines for other purposes than purely hydropower. The volume also can vary significantly from one year to the next. For these reasons it is not possible to give an accurate account of return flows and losses.

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. Comprehensive irrigation demand management, or water conservation strategies and actions were prepared for the Orange River Replanning Study (ORRS) in 1998 based on the conceptual framework and principle of water demand management detailed in a paper published in 1995.

There are a number of transfer schemes as follows :

- The Caledon – Bloemfontein Scheme. Bloem Water control Welbedacht, Rustfontei and Knellpoort dams as well as the related pumpstations and service reservoirs. The Caledon-Bloemfontein pipeline abstracts water from the Welbedacht dam and supplies various towns such as Bloemfontein, Botshabelo, Thaba Nchu, Dewetsdorp, Reddersburg and Edenburg.

- Bloemwater also operates a pipeline network from Gariep Dam to the southern Free State towns of Trompsburg, Springfontein, Bethulie and Philippolis.

- The Mazelspoort Scheme. Mazelspoort waterworks at the Mazelpoort Weir supplies about 25% of Bloemfontein’s water needs and is owned by the Bloemfontein City Council. There is a service reservoir at Hamilton Park.

- The Orange – Riet Transfer Scheme. Water is abstracted from Vanderkloof Dam to the Riet River catchment via the Orange – Riet canal. The water is primarily used for irrigation but also supplies the urban requirements of Koffiefontein (including mine), Ritchie and Jacobsdal.

- The Caledon – Modder (NOVO) Scheme. The Caledon – Modder (Novo) transfer will become operational in 2000 and will abstract water from Knellpoort Dam to the upper reaches of the Modder basin to supply the growing demands in the Bloemfontein area.

- The Orange – Fish Transfer Scheme transfers water to the Great Fish and Sundays River catchment in the Eastern Cape. Both catchment are water deficient but have fertile soil for irrigation. This scheme also supplies urban consumers, including Grahamstown and Port Elizabeth.

The following table shows the water requirements per user group in 1995. Also included are the water requirements at 1:50 year assurance i.e these requirements are estimated with failure of supply of one year in 50 years.

USER GROUP	ESTIMATED WATER REQUIREMENT (10^6 m^3/a)	REQUIREMENT/USE AT 1:50 YEAR ASSURANCE (10^6 m^3/ a)
Ecological Reserve [(5)]	323,6	757,3
Domestic	[(1)] 89,1	92,1
Bulk industrial [(4)]	1,8	1,9
Neighbouring States	[(6)] [1 115,4]	[264,4]
Agriculture	[(2)] 818,2	678,1
Afforestation	0,4	0,0
Alien vegetation	1,3	0,0
Water transfers [(3)]	568,9	568,9
Hydropower [(7)]	4 990,0	4 990,0
TOTAL (excl. Lesotho)	**6 793,3**	**7 088,3**
TOTAL (incl. Lesotho)	**[7 908,7]**	**[7 352,7]**

(1) Includes urban (85,6 x 10^6 m^3/a) and rural domestic (3,5 10^6 m^3/a) requirements (includes commercial, institutional and municipal requirements).
(2) Includes requirements for irrigation (783,1 x 10^6 m^3/a), dryland sugar cane (0), livestock and game (35,1 x 10^6 m^3/a).
(3) Only transfers out of the WMA are included. Orange – Fish (550,0 x 10^6 m^3/a) and Orange – Vaal (18,9 x 10^6 m^3/a).
(4) Includes thermal powerstations (0), major industries (0), mines (0) and other bulk users.
(5) At outlet of WMA. Totals from Table 5.2.4.1.
Lesotho totals 1 025,2 x 10^6 m^3/a and 171,4 x 10^6 m^3/a respectively.
(6) Lesotho is upstream of the WMA, requirements estimated for:
urban (19,9 x 10^6 m^3/a), rural (17,0 x 10^6 m^3/a), livestock and game (19,2 x 10^6 m^3/a), irrigation (33,4 x 10^6 m^3/a), ecological reserve (1 025,2x 10^6 m^3/a), and alien vegetation (0,7 x 10^6 m^3/a).
(7) Most of this water is available to downstream users.

The following table shows the urban and rural domestic water requirements in 1995

CATCHMENT						URBAN (10^6 m^3/a)	RURAL (10^6 m^3/a)	TOTAL (10^6 m^3/a)	1:50 YEAR ASSURANCE (10^6 m^3/a)	HUMAN RESERVE (10^6 m^3/a)
PRIMARY		SECONDARY		TERTIARY						
No.	Description	No.	Description	No.	Key Area Description					
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	1,7	0,1	1,8	1,9	0,3
			Riet	C51	Riet (C51K)	2,3	0,1	2,4	2,5	0,2
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	5,0	0,3	5,3	5,4	0,7
			Rustfontein	C52	Rustfontein (C52A)	0,3	0,0	0,3	0,3	0,1
			Krugersdrift	C52	Krugersdrift (C52B-G)	59,3	0,4	59,7	61,4	5,9
	Total in Modder / Riet (C) primary catchment					**68,5**	**0,9**	**69,5**	**94**	**7,1**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,0	1,1	1,1	1,2	1,2
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	2,1	4,7	6,8	7,7	4,9
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	5,1	1,6	6,7	6,9	2,1
		D2	Caledon – Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	16,3	8,9	25,2	27,6	9,9
			Caledon – RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	4,7	0,4	5,1	5,5	1,0
			Welbedacht- Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	1,5	2,3	3,8	4,0	2,3
			Welbedacht- RSA	D23-D24	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	1,2	0,2	1,4	1,5	0,3
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	1,1	0,1	1,2	1,3	0,1
		D3	Gariep	D35	Gariep (D35A-K)	1,6	0,1	1,7	1,7	0,2
			Vanderkloof	D31, 32, 34	Vanderkloof (D31A-E, D32A-K, D34A-G)	2,4	0,1	2,5	2,6	0,1
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	1,0	0,1	1,0	1,1	0,1
	Total in D primary catchment					**37,0**	**19,6**	**56,5**	**61,1**	**22,5**
Total in Lesotho in D primary catchment						**[19,9#]**	**[17,0#]**	**[36,9#]**	**[40,5]#**	**[18,3#]**
Total in Free State in C and D primary catchments						**77,9**	**1,9**	**79,8**	**82,6**	**9,0**
Total in Northern Cape in C and D primary catchments						**2,8**	**0,1**	**2,9**	**2,9**	**0,5**
Total in Eastern Cape in D primary catchment						**4,9**	**1,5**	**6,4**	**6,6**	**1,8**
TOTAL IN WMA						**85,6**	**3,5**	**89,1**	**92,1**	**11,3**

Note: (1) Includes bulk conveyance and distribution losses within TLCs.

(2) The social reserve is the minimum water requirement of the population, estimated at 25 ℓ/capita/day (DWAF criterion).

Lesotho requirements are estimates only.

- * Quaternary catchment area within Lesotho and RSA (split provided by DWAF).

Regarding losses, the distribution losses include losses due to leaking pipes and reservoirs as well as unaccounted or unmetered for water. The distribution losses can range from 5% of urban water supplied too as high as 35% of urban water supplied in urban centres where proper maintenance is not done and where there is unmetered water supplied. Generally losses due to the distribution system are of the order of 10%.

In semi-arid area wastewater is regarded as a supplementary source of water. The return flows generated from this WMA supplement the base flow of the Orange river, thus benefiting all downstream users. Return flows from urban areas can be divided into three categories:

- The return flows from urban water systems can manifest in two distinct ways:

  As wastewater (effluent) concentrated by means of waterborne sewage that is treated and released into the surface river network.

  As wastewater diffused locally by means of pit toilets (eg. Loflos, aquaprivies, etc), septic tanks / french drains, or more complex methods such as soil bucket systems or disposal via evaporation from oxidation ponds

  Effluent return flows amount to 25,6 $x10^6m^3$/a.

- Return flow due to leakage of clean water

  There are no known clean returns.

- Stormwater returns

  Return flow due to impervious urban areas (into storm water system). The urban areas in this WMA total 356 km^2 . The return flow generated from these areas is 17,7 $x10^6m^3$/a.

  The total urban effluent return flow to the river system is 43,3 $x10^6m^3$/a.

The return flow generated by rural consumers is negligible and in most cases can be taken as zero.

Irrigation return flow totals 62,6 $x10^6m^3$/annum.

The following table summarises water requirements per key area.

CATCHMENT						STREAMFLOW REDUCTION ACTIVITIES		WATER USE (10^6 m^3/a)		WATER REQUIREMENT (10^6 m^3/a)						ECOLOGICAL RESERVE (10^6 m^3/a)	TOTAL (10^6 m^3/a)
PRIMARY		SECONDARY		TERTIARY													
No.	Description	No.	Description	No.	Key Area Description	AFFORES-TATION	DRYLAND SUGAR CANE	ALIEN VEG.	RIVER LOSSES	BULK	IRRI-GATION	RURAL	URBAN	WATER TRANSFERS OUT[1]	HYDRO-POWER		
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	0,0	0,0	0,0	0,0	0,0	27,5	2,9	1,8	0,0	0,0	8,4	64
		C5	Riet	C51	Riet (C51K)	0,0	0,0	0,0	0,0	0,0	118,4	1,0	2,4	0,0	0,0	0,0	129
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	0,0	0,0	0,0	0,0	0,0	51,3	5,6	5,1	0,0[4]	0,0	0,0	02,0
		C5	Rustfontein	C52	Rustfontein (C52A)	0,0	0,0	0,0	0,0	0,0	2,3	0,5	0,3	11,6	0,0	0,9	39
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	0,0	0,0	0,0	0,0	1,9	15,5	3,0	61,0	0,0	0,0	1,9	104
	Sub-total in Modder / Riet (C) primary catchment					**0,0**	**0,0**	**0,0**	**0,0**	**1,9**	**215,0**	**13,0**	**70,6**	**11,6**	**0,0**	**11,2**	**3443**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,0	0,0	0,0	0,0	0,0	0	3,3	0,0	0,0	0,0	16,3	19,6
		D1	Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	0,0	0,0	0,0	0,0	0,0	21,4	18,2	2,2	0,0	0,0	151,3	193,1
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	0,0	0,0	0,0	0,0	0,0	109,7	10,6	5,2	0,0	0,0	185,7	311,2
		D2	Caledon - Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	0,0	0,0	0,0	0,0	0,0	7,2	13,7	17,0	0,0	0,0	3,7	41,6
		D2	Caledon - RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	0,4	0,0	0,0	0,0	0,0	11,6	3,6	5,0	0,0	0,0	3,7	23,9
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	0,0	0,0	0,0	0,0	0,0	4,8	3,6	1,6	0,0	0,0	0,1	10,1
		D2	Welbedacht – RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	0,0	0,0	0,0	0,0	0,0	33,0	3,4	1,3	39,8	0,0	0,0 (-0,8)	77,5
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	0,0	0,0	0,0	0,0	0,0	36,1	2,1	1,2	0,0	0,0	0,0 (-2,1)	39,4
		D3	Gariep	D35	Gariep (D35A-K)	0,0	0,0	0,0	0,0	0,0	14,3	1,3	1,6	550,0	2 635,0	265,7	3497,9
		D3	Vanderkloof	D31,32,34	Vanderkloof (D31A-E, D32A-K, D34A-G)	0,0	0,0	0,0	69,0	0,0	51,7	3,2	2,5	70,7	2 355,0	291,0	2843,1
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K) l	0,0	0,0	0,0	0,0	0,0	171,6	1,6	1,0	18,9	0,0	0,0 (-594,8)	193,1
	Total in D primary catchment					**0,0**	**0,0**	**0,0**	**69,0**	**0,0**	**461,4**	**64,6**	**38,6**	**679,4**	**4 990,0**	**917,5**	**7 220,5**
Total in Lesotho in D primary catchments						**[0,0]**	**[0,0]**	**[0,0]**	**[0,0]**	**[0,0]**	**[33,4]**	**[38,8]**	**[20,8]**	**[0,0]**	**[0,0]**	**[171,4]**	**[264,4]**
Total in Free State in C and D primary catchments						**0,0**	**0,0**	**0,0**	**13,8**	**1,9**	**430,8**	**25,3**	**80,3**	**361,8**	**2 495,0**	**478,9**	**3 887,8**
Total in Northern Cape in C and D primary catchments						**0,0**	**0,0**	**0,0**	**55,2**	**0,0**	**105,5**	**8,6**	**2,9**	**54,2**	**1 178,0**	**145,5**	**1 549,9**
Total in Eastern Cape in D primary catchments						**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**106,7**	**4,9**	**5,2**	**275,0**	**1 317,0**	**132,9**	**1 841,7**
TOTAL IN WMA (South Africa only)						**0,0**	**0,0**	**0,0**	**69,0**	**1,9**	**643,0**	**38,8**	**88,4**	**691,0[2]**	**4 990,0**	**757,3**	**7 279,4[3]**

Note: * Quaternary catchment area within Lesotho and RSA (split provided by DWAF).

(1) Only potable water transfers considered.

(2) Total transfers (including between key areas) = 691 x 10^6 m^3/a, transfers out of WMA are: 550 x 10^6 m^3/a (Orange – Fish), 18,9 x 10^6 m^3/a (Orange – Vaal) – total of 568,9 x 10^6 m^3/a. Transfers within the WMA between key areas = 122,1 x 10^6 m^3/a.

(3) Total requirement in 1995 at 1:50 assurance: 7 279,4 x 10^6 m^3/a – 122,1 x 10^6 m^3/a = 7 157,3 x 10^6 m^3/a because the internal transfers are accounted for in the water requirements of key areas.

(4) Small effluent transfer from this key area.

6. Surface Water Resources

Mean annual runoff (MAR) from the Upper Orange River catchment is approximately 6 981 x 10^6m^3. When expressed as an equivalent unit runoff from the net catchment area of 113 306 km^2 , the MAR averages out at about 62 mm. However, the pattern of runoff over the catchment is one of a fairly rapid decline from east to west, in accordance with the east to west decline of rainfall associated with an increase in evaporation rates. Unit runoff varies from over 400 mm/a in the Lesotho highlands to as little as 2 mm/a in the vicinity of the Vaal / Orange confluence.

The developed yield from surface water in 1995 totals 3 520,4 x 10^6m^3. The developed yield from groundwater in 1995 is 71,3 x 10^6m^3 and the potential yield is 612,7 x 10^6m^3. If the relationship between surface water and groundwater is taken into account, the total developed yield is 3 591,7 x 10^6m^3 and the total potential yield is 4 133,1 x 10^6m^3. Surface water yields have not had the ecological Reserve deducted from them i.e the yield is calculated as if the ecological Reserve is zero.

The following table shows the water resources per key area.

CATCHMENT						SURFACE WATER RESOURCES ($10^6m^3/a$)			SUSTAINABLE GROUNDWATER EXPLOITATION POTENTIAL NOT LINKED TO SURFACE WATER ($10^6m^3/a$)(1)		TOTAL WATER RESOURCE ($10^6m^3/a$)	
PRIMARY		SECONDARY		TERTIARY		NATURAL MAR	1:50 YEAR DEVELOPED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD IN 1995	DEVELOPED IN 1995	TOTAL POTENTIAL	1:50 YEAR DEVELOPED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD IN 1995
No.	Description	No.	Description	No.	Key Area Description							
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	239,6	74,2	74,2	1,4	74,3	75,6	148,5
		C5	Riet	C51	Riet (C51K)	4,1	91,8	91,8	0,7	14,1	92,5	105,9
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	17,9	0	0	2,3	63,8	2,3	63,8
		C5	Rustfontein	C52	Rustfontein (C52A)	30,7	9,1	9,1	0,7	5,6	9,8	14,7
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	114,4	125,6	125,6	1,4	36,1	127,0	161,7
	Total in Riet / Modder (C) primary catchment					**406,7**	**300,7**	**300,7**	**6,5**	**193,9**	**307,2**	**494,6**
D	Orange	D1	Katse	D11	Katse (D11A-K)	767,0	6,5	6,5	0,0	10,1	6,5	16,6
		D1	Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	3245,0	47,2	47,2	0,1	71,5	47,3	118,7
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	956,3	150,6	150,6	10,5	151,1	161,1	301,7
		D2	Caledon – Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	645,5	28,3	28,3	0,1	29,6	28,4	57,9
		D2	Caledon-RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	340,5	27,7	27,7	0,5	39,1	28,2	66,8
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	107,3	10,9	10,9	0,5	9,1	11,4	20,0
		D2	Welbedacht – RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	197,1	55,8	55,8	3,5	32,9	59,3	88,7
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	112,0	37,5	37,5	0,8	41,0	38,3	78,5
		D3	Gariep	D35	Gariep (D35A-K)	64,2	2 539,2	2 539,2	1,8	42,4	2 541,0	2 581,6
		D3	Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	118,9	408,9	408,9	32,8	111,8	441,7	520,7
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	20,5	0	0	14,9	0,5	14,9	0,5
	Total in D primary catchment					**6 574,3**	**3 312,6**	**3 312,6**	**65,5**	**539,1**	**3 378,1**	**3 851,7**
Total in Lesotho in D primary catchment						**[4 764,8]**	**[92,9]**	**[92,9]**	**[0,7]**	**[120,3]**	**[93,6]**	**[213,2]**
Total in Free State in C and D primary catchments						**1 221,6**	**1 895,7**	**1 895,7**	**33,6**	**340,6**	**1 929,3**	**2 236,3**
Total in Northern Cape in C and D primary catchments						**90,2**	**204,5**	**204,5**	**27,0**	**104,9**	**231,5**	**309,4**
Total in Eastern Cape in D primary catchment						**904,4**	**1 420,2**	**1 420,2**	**10,7**	**167,2**	**1 430,9**	**1 587,4**
TOTAL IN WMA (South Africa only)						**2 216,2**	**3 520,4**	**3 520,4**	**71,3**	**612,7**	**3 591,7**	**4 133,1**

Note: * Quaternary catchment area within Lesotho and RSA.
(1) Refer to Table 6.2.1

7. Water Balance

The following is a summary of the water balance for each key area :

- **KALKFONTEIN KEY AREA**

This key area has a surplus of about 38,5 x $10^6m^3/a$. The area is rural in nature and has significant irrigation (mainly diffuse) requirements (68 % of total requirements). Edenburg and Jagersfontein are the most significant urban centres in the area. Water is imported by Bloem Water from Welbedacht Dam (Welbedacht key area) and Gariep Dam, to supply the needs of Edenburg, Reddersburg and Trompsburg TLCs.

- **RIET KEY AREA**

This key area receives 38,5 x 10^6m^3 from the upstream Kalkfontein key area the result is a surplus of about 21,6 x 10^6m^3. The area is rural in nature and has significant controlled irrigation requirements (97 % of total requirements). Koffiefontein TLC and the associated Debeers Diamond Mine is the most significant urban centre in the area. Water is imported for irrigation from the Vanderkloof key area from Vanderkloof Dam via the Orange-Riet Canal.

- **RIET/MODDER CONFLUENCE KEY AREA**

This key area receives about 21,6 x 10^6m^3 from the upstream Riet key area and about 46 x 10^6m^3 from the upstream Krugersdrift key area. The result is a surplus of about 18 x 10^6m^3. The area is rural in nature and has significant controlled irrigation requirements (81 % of total requirements). Bloemspruit and Bainesvlei TLCs in the east of the key area are the most significant urban centres in the area. Both these centres receive water from Welbedacht Dam via the Bloem Water network.

- **RUSTFONTEIN KEY AREA**

This key area has a deficit of about 6,0 x 10^6m^3. While the area is rural in nature, its main requirement is an export from Rustfontein Dam of 11,6 x 10^6m^3 to supply Botshabelo and Thaba Nchu TLCs in the Krugersdrift key area (74 % of total requirements). Dewetsdorp TLC is the only significant urban centre in the area and receives some of its water from Welbedacht Dam via the Bloem Water transfer network.

- **KRUGERSDRIFT KEY AREA**

This key area has a surplus of about 46 x $10^6m^3/a$. The area is dominated by the urban requirements of Bloemfontein, Botshabelo and Thaba Nchu TLC's. Urban requirements are 73 % of total requirements. To meet the requirements of these centres, water is imported from the Welbedacht key area (Welbedacht Dam), Rustfontein key area (Rustfontein Dam) and from the Middle Vaal WMA (Erfenis Dam to supply Brandfort TLC). The contributions from Welbedacht and Rustfontein Dams are reflected in the surface water yield figure of this key area (**Table 7.2.3**). Urban return flows from these urban centres (stormwater returns and effluent returns) are significant (39,9 x 10^6m^3) but have been excluded from the water balance as information indicates that this water is re-used locally (Basson, 2001).

- **KATSE KEY AREA**

This key area has a deficit of about 13 x $10^6 m^3/a$ caused mainly by the ecological reserve requirement (84 % of total requirements). The area is rural in nature with livestock farming the main activity in the area. The construction of the LHWP Katse Dam in this area since 1995 will contribute significantly to the water resources of the area. This will mean that the balance will alter and must be reviewed.

- **SENQU KEY AREA**

This key area has a deficit of about 143 x $10^6 m^3/a$ caused by the high ecological reserve requirement (79 % of total requirements). This area is rural in nature with livestock farming and irrigation in the lower reaches of the Senqu, the main activities in the area. Mohaleshoek and Moyeni were selected to represent urban centres in the area. The construction of the LHWP Mohale Dam in this area since 1995 means that there will be significant changes to the water resources of the area and that the balance will alter and must be reviewed.

- **ORANGE U/S GARIEP KEY AREA**

This key area has a deficit of about 139,0 x $10^6 m^3/a$ and is dominated by ecological Reserve requirements (60 % of total requirement. The area is rural in nature and has significant diffuse irrigation requirements (35 % of total requirements). Aliwal North and Burgersdorp TLCs are the most significant urban centres in the area. There is no known significant import or export of water from this key area.

- **CALEDON-LESOTHO KEY AREA**

This key area has a deficit of about 10,6 x $10^6 m^3/a$. This area is the most populated area of Lesotho and it is dominated by urban (41% of total requirements) and rural (32% of total requirements) requirements. Maseru, Buthu Buthu and Leribe were selected to represent the urban centres in the area. The balance should be reviewed if more reliable requirement data becomes available.

- **CALEDON– SOUTH AFRICA KEY AREA**

This key area has a small surplus of about 7 x $10^6 m^3/a$. Being mainly rural in nature the requirements are dominated by irrigation and rural requirements (62% of total requirements). Ficksburg and Ladybrand TLCs are the most significant urban centres in the area. There is no known significant import or export of water from this key area. The surplus yield (spillage) contributes to the downstream Welbedacht key area.

- **WELBEDACHT-LESOTHO KEY AREA**

This key area has a small surplus of about 2 x $10^6 m^3/a$. Mainly rural in nature the area is dominated by irrigation and rural (82 % of total requirement) requirements. Makateng was selected to represent the urban centres in the area. The balance should be reviewed if more reliable usage data becomes available. The surplus yield (spillage) contributes to the downstream Welbedacht key area.

- **WELBEDACHT–SOUTH AFRICA KEY AREA**

This key area has a deficit of about 6 x $10^6 m^3/a$. This area is mainly rural in nature but is dominated by Bloem Water Transfers from Welbedacht Dam to supply urban centres in the adjacent Modder / Riet catchment. Transfers and irrigation requirements make up 51% and 48% respectively of total requirements in this key area. Wepener TLC is the most significant urban centre in the area. This area does not contribute to the downstream water resources.

- **CALEDON DOWNSTREAM WELBEDACHT KEY AREA**

This key area has a small surplus of about 3 x $10^6 m^3/a$. The area is mainly rural in nature and is dominated by irrigation requirements (92% of total requirements). Rouxville and Smithfield TLCs are the most significant urban centres in the area. There is no known significant import or export of water from this key area. This area does not contribute to the downstream water resources.

- **GARIEP KEY AREA**

This key area has a surplus of about 1 415 x $10^6 m^3/a$. This area is mainly rural in nature and its most significant feature is the Gariep Dam. The area is dominated by the hydropower water requirements of the Gariep Hydropower Station (about 75 %). However a significant portion of this requirements is re-usable (2 371 x $10^6 m^3/a$) and is available to downstream users. The most important inter-basin transfer also occurs from the Gariep Dam, namely the about 550 x $10^6 m^3/a$ Orange – Fish transfer to the Fish Tsitsikama WMA. The ecological reserve requirements are also significant. Bethulie and Venterstad TLCs are the most significant urban centres in the area.

- **VANDERKLOOF KEY AREA**

This key area receives about 1 415 x $10^6 m^3/a$ from the upstream Gariep key area, the result is a surplus of about 927 x $10^6 m^3/a$. Like the upstream Gariep key area this area is mainly rural in nature and its most significant feature is the Vanderkloof Dam. The area is dominated by the hydropower water requirements of the Vanderkloof Hydropower Station (83 %). However a significant portion of this requirements is re-usable (1 913 x $10^6 m^3/a$) and is available to downstream users. There is a significant transfer, namely the Orange – Riet River transfer from Vanderkloof Dam to the adjacent Riet key area to augment irrigation water requirements. The ecological reserve requirement is also significant. Colesberg and Noupoort TLCs are the most significant urban centres in the area.

- **ORANGE DOWNSTREAM VANDERKLOOF KEY AREA**

This key area receives about 927 x $10^6 m^3/a$ from the upstream Vanderkloof key area, the result is a surplus of about 796 x $10^6 m^3/a$. The area is rural in nature and has significant irrigation requirements (89% of total requirements). There is a significant transfer, namely the Orange – Vaal transfer from Marksdrift in the Orange River to the Douglas weir area to augment irrigation water requirements. Hopetown TLC is the most significant urban centre in the area.

The following table shows the water balance per key area.

CATCHMENT						AVAILABLE 1 IN 50 YEAR YIELD IN 1995 $(10^6\ m^3/a)$			WATER TRANSFERS AT 1:50 YEAR ASSURANCE $(10^6\ m^3/a)$		RETURN FLOWS AT 1:50 YEAR ASSURANCE $(10^6\ m^3/a)$		WATER REQUIREMENTS[(1)] AT 1:50 YEAR ASSURANCE $(10^6\ m^3/a)$[(2)]	WATER BALANCE AT 1:50 YEAR ASSURANCE $(10^6\ m^3/a)$
PRIMARY		SECONDARY		TERTIARY		SURFACE WATER[($)]	GROUND-WATER USE IN 1995	TOTAL	IMPORTS[(1)]	EXPORTS[(1)]	RE-USABLE	TO SEA		
No.	Descript-ion	No.	Description	No.	Key Area Description									
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	(+) 74,2	(+) 1,4	(+) 75,6	(+) 0,7	0,0	(+) 2,8	0	(-) 40,6	(+) 38,5[(3)]
		C5	Riet	C51	Riet (C51K)	(+) 91,8 [+70,7][($)]	(+) 0,7	(+) 92,5	(+) 0,0	0,0	(+) 12,4	0	(-) 121,8	(+) 21,6[(3,4)]
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	(+) 0,0	(+) 2,3	(+) 2,3	(+) 3,8	0,0	(+) 6,4	0	(-) 62,0	(+) 18,1[(4,5)]
		C5	Rustfontein	C52	Rustfontein (C52A)	(+) 9,1	(+) 0,7	(+) 9,8	(+) 0,0	(-) 11,6	(+) 0,0	0	(-) 4,0	(-) 5,8[(6)]
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	(+) 125,6 [+47,1][($)]	(+) 1,4	(+) 0	(+) 2,3	0,0	[(+) 39,9][6]	0	(-) 83,3	(+) 46,0[(6,5)]
	Total in Modder / Riet (C) primary catchment					**(+) 300,7**	**(+) 6,5**	**(+) 307,2**	**(+) 6,8**	**(-) 11,6**	**(+) 21,6**	**0**	**(-) 0**	
	Yield to Lower Vaal WMA (surplus):													**(+) 18,1**
D	Orange	D1	Katse	D11	Katse (D11A-K)	(+) 6,5[(7)]	(+) 0,0	(+) 0	0,0	0,0	(+) 0,0	n/a	(-) 19,6	[(-) 13,1]
		D1	Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	(+) 47,2[(7)]	(+) 0,1	(+) 0	0,0	0,0	(+) 2,1	n/a	(-) 193,1	[(-) 143,7]
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	(+) 150,6	(+) 10,5	(+) 0,1	0,0	0,0	(+) 11,0	n/a	(-) 311,2	[(-) 139,1]
		D2	Caledon – Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	(+) 28,3	(+) 0,1	(+) 0	0,0	0,0	(+) 2,6	n/a	(-) 41,6	[(-) 10,6]
		D2	Caledon – RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	(+) 27,7	(+) 0,5	(+) 0	0,0	0,0	(+) 2,6	n/a	(-) 23,9	[(+) 6,9[(8)]]
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	(+) 10,9	(+) 0,5	(+) 0	0,0	0,0	(+) 0,5	n/a	(-) 10,1	[(+) 1,8[(8)]]
		D2	Welbedacht-RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	(+) 55,8	(+) 3,5	(+) 0	0,0	(-) 39,8	(+) 3,3	n/a	(-) 37,7	[(-) 6,2[(8)]]
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	(+) 37,5	(+) 0,8	(+) 0	0,0	0,0	(+) 3,7	n/a	(-) 39,4	[(+) 2,6]
		D3	Gariep	D35	Gariep (D35A-K)	(+) 2 539,2[(9)]	(+) 1,8	(+) 0	0,0	(-) 550,2	(+) 2 372,4	n/a	(-) 2 917,9	(+) 1 445,3[(10)]
		D3	Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	(+) 408,9	(+) 32,8	(+) 0	0,0	(-) 70,9	(+) 1 913,2	n/a	(-) 2 772,4	(+) 956,9[(10,11)]
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K) l	(+) 0,0	(+) 14,9	(+) 0	(+) 0,2	(-) 18,9	(+) 17,2	n/a	(-) 174,2	(+) 796,1[(11)]
	Total in Upper Orange (D) primary catchment					**(+) 3 312,6**	**65,5**	**(+) 70**	**(+) 0,2**	**(-) 679,8**	**(+) 4 328,6**	**n/a**	**(-) 6 541,1**	
Total in Lesotho in D primary catchment						**[92,9]**	**[0,7]**	**[(+) 108]**	**[0,0]**	**[0,0]**	**[(+) 5,2]**	**[n/a]**	**[(-) 264,4]**	**#**
Total in Free State in C and D primary catchments						**2 025,7**	**33,6**	**2 059,3**	**0,2**	**350,4**	**2 178,2**	**n/a**	**3 526,0**	**#**
Total in Northern Cape in C and D primary catchments						**204,5**	**27,0**	**231,5**	**0,0**	**54,3**	**969,6**	**n/a**	**1 495,7**	**#**
Total in Eastern Cape in D primary catchment						**1 420,2**	**10,7**	**1 430,9**	**0,0**	**275,1**	**1 197,2**	**n/a**	**1 566,7**	**#**
TOTAL IN WMA (South Africa only)						**(+) 3 650,4**	**(+) 71,3**	**(+) 3 721,7**	**(+) 0,2**	**(+) 679,8**	**(+) 4 345,0**	**n/a**	**6 588,4**	
Surplus yield to Lower Orange WMA:														**(+) 796,1**

See overleaf for notes:

Notes:

* Quaternary area within Lesotho and RSA.
# Provincial split not readily available.
$ Available surface water yield represents a net value that includes large transfers and accounts for evaporation losses in the receiver key areas. For example the Orange-Riet Transfer of 70,7 x 10^6 m^3/a is included in the net surface yield of the Riet key area.

(1) Potable water transfers only.
(2) Requirements include ecological reserve, river losses, urban, rural; irrigation, bulk, alien vegetation and afforestation.
(3) Surplus yield from Kalkfontein key area to downstream Riet key area.
(4) Surplus yield from Riet key area to downstream Riet Modder confluence key area.
(5) Surplus yield from Krugersdrift key area to downstream Riet Modder Confluence.
(6) Urban returns in this key area are re-used locally (according to Dr M. Basson, BKS, 2001, NWRS workshop).
(7) Before construction of Katse and Mohale Dams (Lesotho Highlands Project).
(8) Surplus yield from Caledon (RSA) key area and Welbedacht (Lesotho) key area to the downstream Welbedacht (RSA) key area.
(9) Calculated net surface water yield includes yields from all upstream areas and Gariep Dam.
(10) Surplus yield from Gariep key area to downstream Vanderkloof key area.
(11) Surplus yield from Vanderkloof key area to downstream Orange d/s Vanderkloof key area.
[ ] These balances –if positive (surplus) are included in “Surface Water” for the Gariep key area.

8. Costs of Water Resource Development

The ORRS reports deal extensively with options for future use of Orange River water (refer to “Hydrology and System Analysis – Orange River Basin PD000/00/4697). A summary of these options follows :

- Raising Gariep Dam. Raising by 5m, 10m and 15m scenarios were analysed. A reduced minimum operating level (MOL) was also investigated.
- A reduced minimum operating level at Vanderkloof Dam.
- A new dam – Bosberg Dam to transfer water to the Vaal River system and to support Gariep and Vanderkloof when their MOL'' are reached. Supply to the Vaal system (Caledon – Vaal transfer) has been investigated.
- A new dam – Torquay Dam to balance hydropower releases from Vanderkloof Dam.
- A new dam – Boskraai Dam in the Kraai catchment with a similar purpose to Bosberg Dam.
- Lesotho Highlands Phase 1B– Matsoku Weir and Mohale Dam are planned to start transferring water to Katse in 2001 and 2003 respectively.
- New dams as part of further phases of Lesotho Highlands - Mashai Dam, Tsoelike and Ntoahae are planned for the future.
- There are some other new dams which have been considered in the Lower Orange WMA such as Vioolsdrift, Molopo and Boegoeberg.

There are numerous combinations of certain of the above developments and scenarios, which have been dealt with in detail in the abovementioned report. The costing of all these numerous options is therefore an extremely detailed task and will not be dealt with in this report.

There are no known potential wellfields that could be developed on a major scale.

9. Conclusions and Recommendations

In the Upper Orange WMA, irrigation is the largest consumptive user of water. The result is that a number of schemes have been developed to transfer water to catchments that require augmentation of their natural water resources. The Orange-Fish Transfer is the most important of these schemes. At the 1:50 level of assurance as at 1995, the Upper Orange WMA yields about 553 x $10^6 m^3$ to the Lower Orange WMA. This surplus should, however, not be viewed in isolation but be considered with resources and requirements of the Lower Orange WMA. The surplus from the Modder/Riet catchment is used up by irrigation in the vicinity of Douglas and does not contribute to the Lower Orange WMA.

Surface water in the Modder/Riet sub-catchment has not been fully developed and there is also potential for the exploitation of groundwater which ranges from about 2% to 10%. Surface water in the Upper Orange sub-catchment has been fully developed but there is also potential for the exploitation of groundwater which ranges from about 2% to 20% (with the exception of downstream of Vanderkloof Dam where the groundwater appears to be almost fully exploited).

In the Katse and Senqu key areas, it appears that the surface water yields are unrealistically low (DWAF data).

Hydro-power accounts for 98% of the return flow with irrigation and urban returns making up the balance.

CATCHMENT						TOTAL YIELD	IMPORTS (1)	EXPORTS (1)	RE-USABLE	WATER REQUIRE-MENTS (1) AT 1:50 YEAR ASSURANCE (10^6 m^3/a)(2)	WATER BALANCE AT 1:50 YEAR ASSURANCE (10^6 m^3/a)
PRIMARY		**SECONDARY**		**TERTIARY**							
No.	**Descript-ion**	**No.**	**Description**	**No.**	**Key Area Description**						
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	(+) 75,6	(+) 0,7	0,0	(+) 2,8	(-) 40,6	(+) 38,5 (3)
		C5	Riet	C51	Riet (C51K)	(+) 92,5	(+) 0,0	0,0	(+) 12,4	(-) 121,8	(+) 21,6 (3,4)
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	(+) 2,3	(+) 3,8	0,0	(+) 6,4	(-) 62,0	(+) 18,1 (4,5)
		C5	Rustfontein	C52	Rustfontein (C52A)	(+) 9,8	(+) 0,0	(-) 11,6	(+) 0,0	(-) 4,0	(-) 5,8 (6)
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	(+) 0	(+) 2,3	0,0	[(+) 39,9] 6	(-) 83,3	(+) 46,0 (6,5)
	Yield to Lower Vaal WMA (surplus):										**(+) 18,1**
D	Orange	D1	Katse	D11	Katse (D11A-K)	(+) 0	0,0	0,0	(+) 0,0	(-) 19,6	[(-) 13,1]
		D1	Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	(+) 0	0,0	0,0	(+) 2,1	(-) 193,1	[(-) 143,7]
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	(+) 0,1	0,0	0,0	(+) 11,0	(-) 311,2	[(-) 139,1]
		D2	Caledon – Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	(+) 0	0,0	0,0	(+) 2,6	(-) 41,6	[(-) 10,6]
		D2	Caledon – RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	(+) 0	0,0	0,0	(+) 2,6	(-) 23,9	[(+) 6,9 (8)]
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	(+) 0	0,0	0,0	(+) 0,5	(-) 10,1	[(+) 1,8 (8)]
		D2	Welbedacht-RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	(+) 0	0,0	(-) 39,8	(+) 3,3	(-) 37,7	[(-) 6,2 (8)]
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	(+) 0	0,0	0,0	(+) 3,7	(-) 39,4	[(+) 2,6]
		D3	Gariep	D35	Gariep (D35A-K)	(+) 0	0,0	(-) 550,2	(+) 2 372,4	(-) 2 917,9	(+) 1445,3 (10)
		D3	Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	(+) 0	0,0	(-) 70,9	(+) 1 913,2	(-) 2 772,4	(+) 926,9 (10,11)
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K) l	(+) 0	(+) 0,2	(-) 18,9	(+) 17,2	(-) 174,2	(+) 766,1 (11)
TOTAL IN WMA (South Africa only)						**(+) 3 721,7**	**(+) 0,2**	**(+) 679,8**	**(+) 4 345,0**	**6 588,4**	
Surplus yield to Lower Orange WMA:											**(+) 796,1**

Notes:

* Quaternary area within Lesotho and RSA.

\# Provincial split not readily available.

$ Available surface water yield represents a net value that includes large transfers and accounts for evaporation losses in the receiver key areas.
For example the Orange-Riet Transfer of 70,7 x 10^6 m^3/a is included in the net surface yield of the Riet key area.

(6) Potable water transfers only.

(7) Requirements include ecological reserve, river losses, urban, rural; irrigation, bulk, alien vegetation and afforestation.

(8) Surplus yield from Kalkfontein key area to downstream Riet key area.

(9) Surplus yield from Riet key area to downstream Riet Modder confluence key area.

(10) Surplus yield from Krugersdrift key area to downstream Riet Modder Confluence.

(6) Urban returns in this key area are re-used locally (according to Dr M. Basson, BKS, 2001, NWRS workshop).

(7) Before construction of Katse and Mohale Dams (Lesotho Highlands Project).

(11) Surplus yield from Caledon (RSA) key area and Welbedacht (Lesotho) key area to the downstream Welbedacht (RSA) key area.

(12) Calculated net surface water yield includes yields from all upstream areas and Gariep Dam.

(13) Surplus yield from Gariep key area to downstream Vanderkloof key area.

(11) Surplus yield from Vanderkloof key area to downstream Orange d/s Vanderkloof key area.

[ ] These balances –if positive (surplus) are included in “Surface Water” for the Gariep key area.

Although every effort has been spent in obtaining accurate data, manipulation of this data and checking and verification thereof, the information presented in this report is dependent on the accuracy and quality of the numerous reports and documentation previously compiled by other organisations. It is therefore likely that some information may have to be revised in the future. A great deal of effort was spent on the metadata for the project database in order to make future enhancements as efficient a process as possible.

The following recommendations were made:

- While information on controlled irrigation can be considered reliable this data is not reliable at quaternary catchment scale and represents an estimate only. In order to improve on quaternary catchment based information a study should be undertaken to determine the areal distribution of crops at quaternary catchment scale.

  In addition more information is required on the extent and requirement of diffuse irrigation in the WMA. For example in the Kraai catchment (D13) all irrigation is diffuse. Available information seems to indicate that irrigation is widespread but there is no information on the actual water usage in these areas of essentially opportunistic irrigation.

- The available information on livestock and game was for 1988 and 1990. In addition this data was only available at magisterial district level and like irrigation the data at quaternary catchment level must be considered unreliable.

- A survey of a number of TLC's was undertaken to try and determine urban water requirements. This exercise was fairly successful and should be extended to the remaining TLC's. Most small TLC's were not surveyed and their water requirements were estimated using default usage. In the opinion of the Situation Assessment Consultant the default usages are too high for most small towns and as a consequences urban requirements have been inflated.

- The situation assessment consultant did review river losses, however this data appears to have been ignored. This is possibly a result of problems with the river losses sub-model of WSAM.

- Information on allocations, authorisations and permits needs to be centralised and reviewed by an organisation (persons) skilled in the interpretation of these allocations. Thus allowing an assessment of the available resources and the volumes committed to various users.

- Information concerning conveyance losses (most kinds) were generally not readily available. While defaults were provided and these were used extensively a study of this crucial 'use' is recommended.

- If the water resources and water requirements of Lesotho are deemed to be important, they need to be reviewed as the current quality of urban and rural data in the database represent a first estimate only and is considered poor. In addition the LHWP will alter the water balance in a number of key areas and will require review.

- The negative values obtained for ecological water requirements do not make sense and should be investigated.

- Effluent and stormwater returns in the Greater Bloemfontein – Botshabelo area are significant. However according to Dr Basson of BKS, returns from these areas do not contribute to the baseflow of the Modder catchment. The solution could be to increase irrigation (diffuse) in the area or change consumption to 100 %. This issue has not been resolved and must be reviewed in the future.

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DIAGRAMS

ABBREVIATIONS AND ACRONYMS

CCWR	Computing Centre for Water Research
CMA	Catchment Management Agency
DWAF	Department of Water Affairs and Forestry
ELSU	Equivalent Large Stock Units
GIS	Geographic Information System
GJTMC	Greater Johannesburg Transitional Metropolitan Council
GWS	Government Water Scheme
IRP	Integrated Resource Planning
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MD	Magisterial District
MLC	Metropolitan Local Council
NWA	National Water Act
NWSR	National Water Supply Regulation
SABS	South African Bureau of Standards
TLC	Transitional Local Council
TRC	Transitional Regional Council
WMA	Water Management Area
WR90	Water Resources 1990
WSA	Water Services Act
WSAM	Water Situation Assessment Model

GLOSSARY OF TERMS

AEMC

Attainable Ecological Management Class (A-D). A class indicating the management objectives of an area which could be attained within 5 years. Values range from Class A (largely natural) to Class D (largely modified).

ANASTOMOSED

A river made up of multiple channels with stable islands, usually with a bedrock substrate.

BIOTA

A collective term for all the organisms (plants, animals, fungi. bacteria) in an ecosystem.

CONDENSED AREA

The area considered in the alien vegetation component whereby alien vegetation which sparsely occurs in a large area, is redefined as a smaller area with a maximum concentration/density

CAIRN

Mound of rough stones as a monument or landmark.

CAUCASION

Of the White race.

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 Class A (highly sensitive, no risks allowed) to Class D (resilient systems, large risk allowed).

DESC

Default Ecological Status Class.

DIURNAL

During the day.

ENVIRONMENTALLY SENSITIVE AREA

A fragile ecosystem which will be maintained only by conscious attempts to protect it [Concise Oxford Dictionary (COD) of Geography].

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. (a measure of a river for conservation, including natural, socio-economic and cultural aspects).

EDAPHIC

1. Pertaining to the influence of soil on organisms.

2. Resulting from or influenced by factors inherent in soil rather than by climatic factors.

EISC

Ecological importance and sensitivity class.

EPHEMERAL RIVERS

Rivers where no flow occurs for long periods of time.

ENDANGERED

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 diminished and/or degraded that they are deemed to be in immediate danger of extinction.

ENDEMIC

Occurring within a specified locality; not introduced (Concise Oxford Dictionary of Geography.)

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).

HETROGENEOUS

Not uniform. Disparate. Consisting of dissimilar parts or ingredients.

INVERTEBRATE

An animal without a backbone - includes insects, snails, sponges, worms, crabs and shrimps.

LOTIC

Flow water.

PESC

Present Ecological Status Class (A-F). 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 Class A (largely natural) to Class F (critically modified).

PETROGLYPH

A carving or inscription on a rock.

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.

RED DATA BOOK

A book that lists species that are threatened with extinction. The concept was initiated by the International Union for the Conservation of Nature, and has since become adopted by many countries. The "Red" stands for "Danger". The categories reflect the status of the species only within the area under review, and it is sometimes the case that species, which are threatened in one region may have secure populations in other areas.

RESERVE

The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act 108 of 1997) for people, who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource as indicated in NWA, 1998.

RESILIENCE

The ability of an ecosystem to maintain structure and patterns of behaviour in the face of disturbance (Holling 1986, in Costanza et al 1992), or the ability to recover following disturbance.

RESOURCE QUALITY

The quality of all the aspects of a water resource including:

(a) the quantity, pattern, timing, water level and assurance of instream flow;

(b) the water quality, including the physical, chemical and biological characteristics of the water;

(c) the character and condition of the instream and riparian habitat; and

(d) the characteristics, condition and distribution of the aquatic biota.

RESOURCE QUALITY OBJECTIVE

Quantitative and auditable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of resource protection.

SPATIO — TEMPORARY ROBUST

Does not change significantly with time in relation to spatial distribution.

STROMATOLITE

A rocky cushion-like growth formed by the growth of lime-secreting blue-green algae, thought to be abundant 200 million years ago, when blue-green algae were the most advanced form of life on earth.

SWALES

A small earth wall guiding surface runoff away from the stream back onto the fields.

TAXON (plural: TAXA)

General term for a taxonomic group in a formal system of nomenclature, whatever its rank. A taxonomic group refers to the systematic ordering and naming of plants and animals according to their presumed natural relationships. For example, the taxa Simuliidae, Diptera, Insecta and Arthropoda are examples of a family, order, class and phylum respectively.

TROPHIC

Pertaining to nutrition.

VADOSE ZONE

Relating to or resulting from water or solutions that are above the permanent groundwater level.

VULNERABLE

Species believed likely to move into the endangered category in the near future if the causal factors continue operating. Included are species of which all or most of the population are decreasing because of overexploitation, extensive destruction of habitat, or other environmental disturbance. Species with populations which have been seriously depleted and whose ultimate security is not yet assured, and species with populations that are still abundant but are under threat from serious adverse factors throughout their range.

CHAPTER 1: INTRODUCTION

1.1 PURPOSE OF THE STUDY

The National Water Act, 1998 (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 water 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. This report is in respect of the Upper Orange Water Management Area (Upper Orange WMA), which occupies portions of the Free State, Northern Cape and Eastern Cape provinces. Lesotho is also included. 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, February 2000) 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 selected points in each water management area was also calculated

The basic hydrological data used was that contained in the report, The Surface Water Resources of South Africa, 1990, which was published by the Water Research Commission (Stewart Scott, 1990). The data was modified to take account of the Vaal River System Analysis Update Study (BKS et al, 1997). Land-use data was obtained from reports on the Vaal River System Analysis Update Study, from the report on the Surface Water Resources of South Africa, 1990, from the Vaal River Irrigation Study (Loxton et al., 1999a,b) and a number of other reports as indicated in the **References Section**.

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 Upper Orange WMA by the national demographic study (DWAF, March 2000), 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 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 Upper Orange 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 Upper Vaal WMA 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 Upper Orange WMA covers 103 671 km^2 and is part of the Orange River watercourse. Lesotho has been included in the study area and covers 30 492 km^2. The total area is 134 163 km^2 as shown in **Figure 2.1.1**.

The study area is shown in **Figure 2.1.2**.

The Upper Orange WMA falls within the Orange River basin which is the largest river basin in South Africa. The Modder-Riet River catchment which is geographically part of the Lower Vaal catchment is included in the Upper Orange WMA because the water resources of the Modder-Riet are augmented by numerous transfers from the Orange River and its catchments. The rest of the Vaal River catchment comprises the most important tributary of the Orange River but is treated as separate WMA's. The WMA extends from the headwaters of the Caledon and Orange Rivers in the east to the confluence of the Orange and the Vaal Rivers, downstream of Vanderkloof Dam in the west. The water resources and requirements of Lesotho are determined as they affect the water resources management of the Upper Orange WMA. The Upper Orange WMA is upstream of the Lower Orange WMA. The Lower Orange WMA. The Lower Orange WMA delivers water to Namibia.

Greater Bloemfontein in the Modder River catchment is the largest urban area in this WMA. Kimberley is situated on the northern WMA boundary with the Lower Vaal WMA and is considered to be part of the Lower Vaal WMA. Other significant urban areas are Thaba Nchu, Botshabelo, Wepener, Dewetsdorp, Reddersburg, Edenburg, Jagersfontein, Trompsburg, Brandfort, Dealesville, Petrusberg, Jacobsdal, Koffiefontein, Oppermans, Fauresmith, Trompsburg, Springfontein, Bethulie, Smithfield, Rouxville, Zastron, Vanstadensrus, Barkly East, Ficksburg, Colesberg, Aliwal North and Phillipolis.

In Lesotho, the only significant urban area is the capital city, Maseru.

The Upper Orange WMA is shown in **Figure 2.1.2.**

The Upper Orange River has its headwaters in the Maluti Mountains in the Lesotho Highlands and is known as the Senqu River in Lesotho. The Modder-Riet Rivers are tributaries of the Vaal River but form part of the WMA. The Caledon River forms the north-western boundary of Lesotho with South Africa and is a major tributary of the Orange River. The Caledon River joins the Orange River a short distance upstream of Gariep Dam. Upstream of this confluence the Orange River is joined by the Kraai River at Aliwal North. The main tributaries joining the Orange River downstream of Gariep Dam are the Stormberg and Seacow Rivers. These two tributaries are small in terms of water resources.

The Upper Orange WMA in this report includes the whole the Modder-Riet catchment comprising tertiary catchments C51 and C52, the Caledon catchment comprises parts of tertiary catchments D21, D22, D23 (which also include parts of Lesotho) and D24 as well as D12, D13 and D14 tertiary catchments and the D3 secondary catchment.

Lesotho comprises tertiary catchments D11, D15, D16, D17,D18 and parts of D21, D22 and D23.

With its sources in the high mountains of Lesotho, the Orange River remains deeply incised for most of its journey. The catchment slopes from the east, where elevations exceed 3 000 m, to about 1 200 m in the west, at its confluence with the Vaal River. The steep mountainous areas in the east are replaced by undulating topography downstream of the Orange/Kraai River confluence and in the lower reaches of the Caledon River valley.

The Topography and River Catchments are shown in **Figure 2.1.3**.

The hydrological sub-catchments showing numbered quaternary sub-catchments, key area boundaries, rivers, dams and main towns are shown in **Figure 2.1.4**.

Table 2.1 shows the key areas, key points, quaternary catchments and a description of the key area.

TABLE.2.1: KEY AREAS.

LOCATION OF KEY POINT			DESCRIPTION
PRIMARY CATCHMENT		QUATERNARY CATCHMENT NO.	
NO.	KEY AREA NAME AND POINT		
C	Kalkfontein- C51J outlet	C51A-J	Kalkfontein Dam
	Riet – C51K outlet	C51K	Confluence of Riet and Modder
	Riet / Modder confluence – C51M outlet	C51L-M, C52H-L	Remaining C5 Tertiary catchment
	Rustfontein - C52A outlet	C52A	Rustfontein Dam
	Krugersdrift – C52G outlet	C52B-G	Rustfontein to Krugersdrift
D	Katse – D11K outlet	D11A-K	Katse Dam
	Senqu – D18L outlet	D15A-H, D16A-L,D17A-M, D18A-L	Senqu and M? catchments in Lesotho
	Orange u/s Gariep Dam – D14K outlet	D12A-F, D13A-M,D14A-K	U/s Gariep Dam
	Caledon – Lesotho – D22L outlet	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, 22E, D22F, D22H*, D22J, D22K, D22L*	Upper Caledon River catchment in Lesotho
	Caledon - South Africa – D22L outlet	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	Upper Caledon River catchment in South Africa (Free State)
	Welbedacht – Lesotho – D23G outlet	D23A*, D23B, D23E*, D23F*, D23G*	Welbedacht Dam catchment in Lesotho
	Welbedacht – South Africa- D24C outlet	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	Welbedacht Dam catchment in South Africa (Free State)
	Caledon d/s Welbedacht – D24L outlet	D24D-L	Remaining D24 Tertiary catchment
	Gariep – D35K outlet	D35A-K	D35 Tertiary catchment
	Vanderkloof – D31E outlet	D31A-E, D32A-K, D34A-G	D/s Gariep Dam to Vanderkloof Dam
	Orange d/s Vanderkloof – D33K outlet	D33A-K	D33 Tertiary catchment

Note: * Quaternary catchment area within Lesotho and RSA (split provided by DWAF).

2.2 CLIMATE

Climatic conditions vary considerably from east to west across the Upper Orange WMA.

Temperature

The mean annual temperature in the WMA ranges between 18 °C in the west to 12 °C in the east and averages about 15 °C for this area as a whole. In Lesotho, the mean annual temperature ranges from 14 °C to below 8 °C in the more mountainous parts towards the east with an average of about 11 °C for the country as a whole. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. The following table summarises temperature data for the Upper Orange WMA for these two months (Schulze et al, 1997).

TABLE 2.2.1 : TEMPERATURE DATA

Month	Temperature (°C)	Average	Range
January	Mean temperature	22 (16)	7 – 25 (5-22)
	Maximum temperature	29 (23)	12 – 32 (9-30)
	Minimum temperature	15 (9)	2-17 (0-15)
	Diurnal range	12 (14)	10 – 15 (9-15)
July	Mean temperature	8.5 (5)	0-10 (-5-10)
	Maximum temperature	17 (12)	6 –19 (0-19)
	Minimum temperature	0 (-2)	-6 – 5 (-10 –5)
	Diurnal range	17 (14)	12 – 14 (10 – 14)

Note : ( ) designates Lesotho

Frost occurs throughout the Upper Orange WMA in winter, typically over the period mid May to early September. In Lesotho, frost generally starts in mid March and ends in the latter part of September The average number of frost days per year for the Upper Orange WMA (excluding Lesotho) is about 43 and for Lesotho it is 90.

Rainfall

Rainfall is strongly seasonal with most rain occurring in the summer period (October to April). The peak rainfall months are December to March. Rainfall occurs generally as convective thunderstorms and is sometimes accompanied by hail. The average hail day frequency for the Upper Orange WMA (excluding Lesotho) is about one to four per annum (at any single location) and the mean lightning flash density is 2-7 per km^2 per annum. For Lesotho, the average hail day frequency is five to greater than seven per annum (at any single location) and the mean lightning flash density is 4-14 per km^2 per annum

The overall feature of mean annual rainfall over the Upper Orange WMA is that it decreases fairly uniformly westwards from the eastern escarpment regions across the central plateau area. The MAP (excluding Lesotho) ranges from a high of 800 mm in the east to a low of 300 mm in the west with an average of about 500 mm. For Lesotho, it ranges from about 500 mm to over 1 200 mm in the more mountainous areas. The average coefficient of variation (CV) is about 21 – 22% over the whole Upper Orange WMA.

For the driest year in five (80% exceedance probability) the annual rainfall (excluding Lesotho) is about 420 mm and for Lesotho it is about 590 mm. For the wettest year in five (20% exceedance probability) the annual rainfall (excluding Lesotho) is about 630 mm and can be as high as 1 700 mm towards the south-east. For Lesotho, it is about 790 mm and can be as high as 1 800 mm in the escarpment areas.

Humidity and evaporation

In accordance with the rainfall pattern the relative humidity is higher in summer than in winter. Humidity is generally highest in February (the daily mean over the Upper Orange WMA (excluding Lesotho) ranges from 60% in the west to 72% in the east) and lowest in August (the daily mean ranges from of 51% in the west to 70% in the east). For Lesotho, in February it ranges from about 49 to 76% and in August from about 53 to 71%.

Excluding Lesotho, average potential mean annual gross evaporation (as measured by Class A-pan) ranges from 1 200 mm in the east to a high of 2 680 mm in the dry western parts. For Lesotho it ranges from about 1 000 to 2 100 mm. Excluding Lesotho, the highest Class A-pan gross evaporation is in January (range 100 mm to 350 mm) and the lowest evaporation is in June (75 to 106 mm). For Lesotho, for January it ranges from about 75 to 267 mm and for June it ranges from about 75 to 90 mm.

The gross irrigation requirements (based on rainfall and Class A-pan gross evaporation) assume a perennial crop with a uniform crop factor of 0,8. The requirement takes into account effective rainfall plus conveyance losses and spray drift losses (both assumed to be 10%). Excluding Lesotho, the median gross irrigation requirement ranges from 734 mm/a in the dry western parts to 2 000 mm/a in the eastern escarpment areas. For Lesotho it ranges from about 650 to 1 370 mm/a. The minimum monthly requirement is in June which for the Upper Orange WMA excluding Lesotho is 84 mm and for Lesotho itself is 75 mm. The maximum monthly requirement is in September which for the Upper Orange WMA excluding Lesotho is 169 mm and for Lesotho itself is 127 mm..

Figure 2.2.1 shows the distribution of MAP with an inset of a histogram showing monthly distribution of rainfall.

Figure 2.2.2 shows the distribution of mean annual gross Symons Pan evaporation with an inset showing the seasonal distribution.

2.3 GEOLOGY

The geology of the WMA showing the main rock types is given in **Figure 2.3.1**. Extrusive igneous rocks of the Stormberg series (part of Karoo system) described by mafic/basic lavas in **Figure 2.3.1** cover the eastern high-lying areas. The north-western part of this WMA is described as compact, dominantly argillaceous strata with small pockets of compact tillite and compact sedimentary and extrusive rocks near the WMA boundary. Compact arenaceous and argillaceous strata (fine sedimentary rocks of the Karoo system) underlie the remainder of the Upper Orange WMA

2.4 SOILS

Figure 2.4.1 shows a generalised soils map of the WMA using some 16 broad soil groupings (which was obtained from the WR90 study). 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.

Soil depths are generally moderate to deep over the Upper Orange WMA. There are six main soil/texture/relief types that predominate and these are distributed across the catchment as follows:

- Sandy Loam: In the upper Caledon valley and to the south of the Orange in the western part of the catchment of moderate to deep depth and undulating relief.
- Clay Soil: Confined to the mountainous areas in the eastern portion of the Lesotho of moderate to deep depth and steep relief.
- Sandy Soil: Confined to areas around Bloemfontein and Petrusburg of moderate to deep relief and flat relief.
- Clay Loam (flat relief): Confined to the north-western part of the catchment of moderate to deep depth.
- Clay Loam (Steep relief): Confined to the south-eastern part of the WMA of moderate to deep depth.
- Clay Loam (undulating relief): The predominant soil type in the remainder of the catchment of moderate to deep depth.

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 (1988) 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 WMA 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	
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	

DETAILED VELD TYPES	NO.	SIMPLIFIED VELD TYPE
Central Upper Karoo	27	
Western Mountain Karoo	28	
Arid Karoo	29	
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 Transition	53	
Turf Highveld to Highland Sourveld Transition	54	
Bakenveld to Turf Highveld Transition	55	
Highland Sourveld to Cymbopogon – Themeda Veld Transition	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

Lesotho consists almost entirely of the "pure grassveld" veld type (which requires moderate to high rainfall) interspersed with a bit of "temperate and transitional forest and scrub". Moving north to the Modder-Riet catchment, there is still some "pure grassveld" in the east but most of this catchment is "false karoo" and "false bushveld". In the south and south-western parts of this WMA one finds mainly "false karoo" together with "karoo and karroid" and "false bushveld"

The Acock's veld types are shown in **Figure 2.5.2.1**.

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, 1989 (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, 1999 (Act No. 36 of 1999). 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 recognized 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.

2.6.2 River Classification

The water resources of South Africa are to be protected in terms of the National Water Act, 1998 (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.**

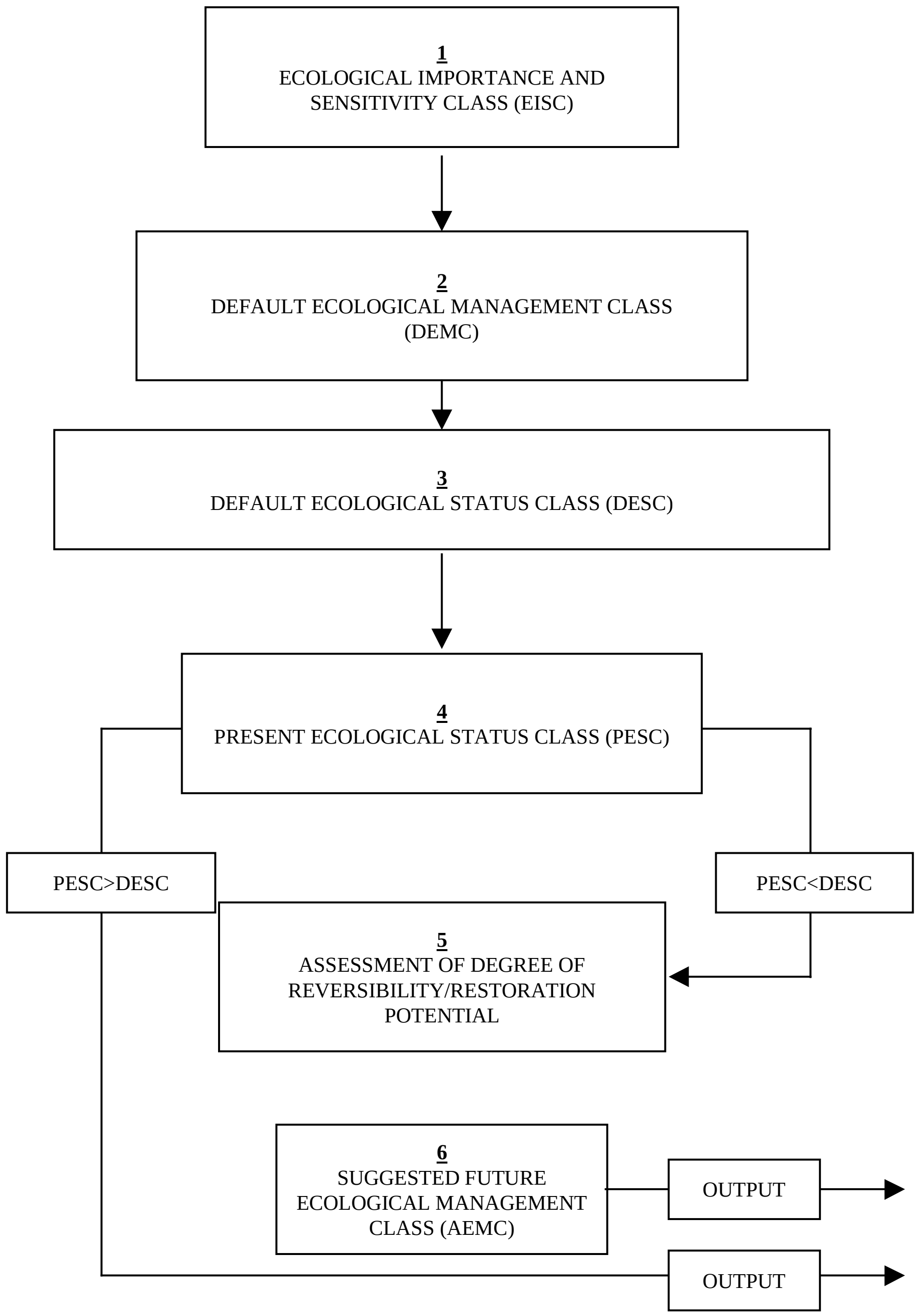


Diagram 2.6.2 1: Procedure followed to Determine the River Classifications

<u>EISC</u>		<u>DEMC</u> and <u>DESC</u>
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

<u>PESC</u>	<u>PESC: SUGGESTED ATTAINABLE IMPROVEMENT</u>
	<u>Acceptable range of AEMC:</u>
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 mainstream 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 assessed during meetings or 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 mainstream 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 catchment 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 mainstream 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 was 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 species diversity was 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 mainstream 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.

Each of the above attributes that were used to estimate the present ecological status were scored, from which the mean was calculated. This mean was used to assign a present ecological status class to the mainstream 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 ecological significance/conservation importance of the river systems falling within the Upper Orange WMA, as exemplified by their Ecological Importance and Sensitivity Classes (EISC), are summarised 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. Definitions of these EISC are given in **Section 2.6.2**. The EISC of a river, as reflected in the DESC, 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 default ecological management class (**Figure 2.6.3.1**) showed that the majority of the catchment could be tolerated as class C (moderately modified) with eight quaternary catchments in the southern part of the WMA even being of class D (largely modified). Interspersed were quaternary catchments where a class B (largely natural) could be tolerated. The present ecological status class (**Figure 2.6.3.2**) showed no class A (unmodified, natural) quaternary catchments and only twelve quaternary catchments in class B. The largest portion of the WMA showed class C with the remainder being Class D and eight quaternary catchments of class E-F (seriously/critically modified) mainly in the northern part of the WMA and upstream of Gariep Dam and Vanderkloof Dam. The suggested future management class (**Figure 2.6.3.3)** showed the worst class as being class D. Portions of classes D and C from **Figure 2.6.3.2** showed improvement to class B scattered all over the WMA.

2.6.4 Natural Heritage Sites, Proclaimed Game and Nature Reserves and 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 Upper Orange 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 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 Upper Orange 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 UPPER ORANGE WMA.

AREA NAME	CATEGORY	QUATERNARY CATCHMENT AND PROVINCE
Kalkfontein Dam Nature Reserve	Habitat and Wildlife Management Area	C51J (Free State)
Rustfontein Dam Nature Reserve	Habitat and Wildlife Management Area	C52A (Free State)
Soetdoring Nature Reserve	Habitat and Wildlife Management Area	C52G (Free State)
Buffelspruit Nature Reserve	Habitat and Wildlife Management Area	D14A (E. Cape)
Die Berg Nature Reserve	Habitat and Wildlife Management Area	D14E/F (E. Cape)
Doornkloof Nature reserve	Habitat and Wildlife Management Area	D31E/D32K (N Cape)

AREA NAME	CATEGORY	QUATERNARY CATCHMENT AND PROVINCE
Gariep Dam Nature Reserve	Habitat and Wildlife Management Area	D35K (Free State)
Golden Gate Highlands Nat. Park	Habitat and Wildlife Management Area	D21A/D (Free State)
Karringmelkspruit Vulture Res.	Habitat and Wildlife Management Area	D12D/F,D24B (Free State)
Mynhardt Game Reserve	Habitat and Wildlife Management Area	D35A (Free State)
Oviston Nature reserve	Habitat and Wildlife Management Area	D35K (E. Cape)
Rolfontein Nature reserve	Habitat and Wildlife Management Area	D31E (N. Cape)
Tussen die Riviere Game farm	Habitat and Wildlife Management Area	D14J/K,D24J/L (Free State)
Welbedacht Dam Nature Reserve	Habitat and Wildlife Management Area	D23J (Free State)

Notes :

(1) Sehlabathebe National Park (Habitat and Wildlife Management Area) is in the quaternary catchment D17J in Lesotho.

(2) Information from (Readers Digest, 1990)

This list should only be viewed as a guide to the protected areas, since as the status of protected areas is constantly changing and new areas are receiving protection, the list cannot be comprehensive. It is the developer's responsibility to ascertain the location of any protected areas adjacent to the development and to ensure that activities do not impact on these areas

Details of these areas are as follows:

Kalkfontein Dam Nature Reserve is situated next to the dam of the same name. The 162 ha reserve is too small for game and the main attraction is the abundance of yellowfish in the dam.

Rustfontein Dam Nature Reserve is located close to the dam wall, 45 km south east of Bloemfontein. The 1 000 ha reserve is home to black wildebeest, blesbok and springbok.

Soetdoring Nature Reserve surrounds Krugersdrift Dam, 40 km north west of Bloemfontein. The 4 117 ha reserve has lion, cheetah and brown hyena in special camps. The rest of the reserve has eland, gemsbok, zebra, red hartebeest and springbok.

Buffelspruit Nature Reserve is located next to Aliwal North and has an area of 900 ha. Main species include springbok, blesbok, gemsbok, red hartebeest, black wildebeest, eland, impala and a variety of waterfowl.

Die Berg Nature Reserve is situated on the Dorpsberg next to Burgersdorp. The 411 ha reserve is on rugged terrain and is being stocked with game previously found in the area.

Doornkloof Nature Reserve is situated on the southern shore of Vanderkloof Dam and along the Seekoei River. The 8 765 ha reserve is characterised by false upper karoo vegetation with patches of Orange River broken veld. The most important animal species is the black rhino.

Gariep Dam Nature Reserve is situated on the northern shore of Gariep Dam. The 11 237 ha reserve is home to springbok, black wildebeest, red hartebeest and ostrich.

Golden Gate Highlands National Park is situated south east of Bethlehem and south west of Harrismith. The 6 300 ha reserve is known for its spectacular scenery, mainly in the sandstone sediments of the Maluti Mountains. Mammal species include eland, black wildebeest, mountain reedbuck, grey rhebok, blesbok, zebra, springbok and oribi. Bird species include the black eagle and bearded vulture.

Karringmelkspruit Vulture Reserve is located 12 km from Lady Grey in the Witteberg. The 70 ha reserve is characterised by sheer-sided ravines rising from sandy plains. About 500 cape vultures live and breed in the reserve.

Mynhardt Game Reserve is located at Bethulie's town dam. The 160 ha reserve has black wildebeest, blesbok, zebra, gemsbok, impala and springbok.

Oviston Nature Reserve is situated on the south side of Gariep Dam. The reserve is used to breed animals for other conservation areas and is home to springbok, black wildebeest, mountain reedbuck, grey rhebok, red hartebeest, blesbok, steenbok, zebra, kudu and eland.

Rolfontein Nature Reserve is situated on the southern shore of Vanderkloof Dam and along the Seekoei River. The 15 000 ha reserve was established to preserve the mountain Karoo ecosystem and is characterised by grassy flats, dolerite koppies and wooded kloofs. Mammal species include eland, gemsbok, black wildebeest, red hartebeest, blesbok, springbok, zebra and white rhino.

Tussen die Riviere Game Farm is situated between the confluence of the Orange and Caledon Rivers. The 21 000 ha reserve has rocky ridges, occasional plateau and grassy plains. Mammal species include mountain reedbuck, duiker, steenbok, eland, kudu, gemsbok, zebra, black wildebeest, red hartebeest, blesbok, springbok and white rhino. Controlled hunting is allowed in winter.

Welbedacht Dam Nature Reserve surrounds Welbedacht Dam. The 1 200 ha reserve has springbok but other species are being introduced.

Sehlabathebe National Park is situated in the south east corner of Lesotho. The 6 500 ha reserve is characterised by mountains and grassveld. Mammal species include mountain reedbuck, black wildebeest, baboon and jackal. Four dams in the reserve have a variety of fish and birds.

Other conservation areas which contain endangered animals and plant species are Moolmanshoek, Benfontein, Grootfontein, Evening Star, Neohenricia siebettii-vygie area, Cape Vulture defined areas and Balloch.

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, 1969 (Act No. 28 of 1969) provides for the protection and conservation of cultural resources including all archaeological sites. In addition, the Environment Conservation Act, 1989 (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.
No general listing of the sites of palaeontological, archaeological and historical significance within the Upper Orange WMA is available. Some information was, however, obtained (Morris and National Monuments Council brochure). There are some archaeological sites near the Orange/Vaal Rivers confluence. 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 DWAF 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, 1975 (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 is likely to supersede 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

It became clear decades ago that not more than a fraction of the Orange River's waters were likely to be beneficially used within its own valley and, over the years many schemes were put forward for harnessing the river.

The initial comprehensive plan envisaged the following:

- The building of several major dams in the main stream and diversion by tunnel of significant proportions of the water resources into the Fish and Sundays valleys of the Cape Midlands.
- The transfer of large quantities of water to the central Karoo and into the Kalahari by an extensive system of canals.
- A cascade of hydro power stations at all major changes of gradient of both the main river and the diversion links.

Much of the original plan has been either excised or considerably modified. The scheme at present comprises:

Gariep Dam, with its 240 MW hydro power station; the 81-km long Orange-Fish tunnel, diverting water at rates of up to about 40 m^3/s from Gariep Dam to the Cape Midlands and ultimately to Port Elizabeth.

Vanderkloof Dam, some distance downstream of Gariep Dam, with its 160 MW hydro power station and diversion canal conveying water to the south-western Free State.

The original concept of conveying water from Gariep Dam to Bloemfontein was abandoned in favour of the subsequently built Welbedacht Dam in the Caledon River with a pipeline to Bloemfontein. Water is also transferred from the Caledon River into off-channel storage at Knellpoort Dam, which then feeds water into Welbedacht Dam and by 2000 to the upper Modder River (Novo scheme).

Water is transferred from the Orange River at Marksdrift by way of canals to irrigate land in the lower Riet and Vaal River catchments.

Releases from Gariep and Vanderkloof Dams are used to supply extensive irrigation development in the middle Orange River catchment, situated between Buchuberg and Kakamas.

For several decades past there have been sporadic investigations into possibilities for diversion of water from the headwaters of the Orange River. Originally the focus was on hydro power generation and later to meet rising demands for water in the Reef Complex, which was fast outstripping the resources of the Vaal River.

Initial plans envisaged the diversion of water from the upper Orange River (in Lesotho) into the Caledon River for hydro-power generation, the so called Oxbow project. However the emphasis gradually changed from hydropower generation to inter-basin transfer. The recently completed first phase of the Lesotho Highlands Water Project (LHWP) can divert up to 20 m^3/s in long tunnels from Katse Dam in the Malibamatso River to the Ash River tributary of the Upper Vaal River catchment. The next phase of the LHWP, involving a further dam (Mohale) on the Sinquanyana River and a weir to divert water from the Matsuko River into Katse Dam, is currently under construction.

In the Riet and Modder River catchments, the following dams have been constructed to supply a number of irrigation schemes:

- Kalkfontein Dam and Tierpoort Dam on the Riet River.
- Rustfontein Dam and Mockes Dam upstream of Krugersdrif Dam on the Modder River.
- Krugersdrif Dam on the Modder River.

Groothoek Dam and Rustfontein Dam also supply urban demands (Botshabelo and Thaba Nchu). Water is also pumped from Mazelspoort Weir to Bloemfontein.

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 focussed 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

Information on historical growth trends is not readily available. However migration to urban areas is a significant trend in the South African portion of this WMA because of the perception that job opportunities are greater and services are better. In addition significant numbers of farm workers have been displaced to the urban area because of land claim concerns. Migrants (including undocumented migrants) from neighbouring Lesotho probably are a significant portion of the population.

3.2.4 Population Size and Distribution in 1995.

The population of the WMA has been split into urban and rural populations for South Africa and for Lesotho. Quaternary catchment urban and rural population data for South Africa was obtained from the National Demographic Study (Schlemmer et al. , 2001*).* Quaternary catchment urban and rural population of Lesotho was estimated by the WRSA consultant and is not considered reliable.

This data has been reproduced in **Figure 3.2.4.1** (shown as pie diagrams) and in **Appendices A.1 (urban data) and A.2 (rural data).** The quaternary catchment data has been summarised in **Table 3.2.4.1** into key area and provincial, urban and rural population data.

TABLE 3.2.4.1: POPULATION IN 1995

CATCHMENT						POPULATION IN 1995		
PRIMARY		SECONDARY		TERTIARY		URBAN	RURAL	TOTAL
No.	Description	No.	Description	No.	Key Area Description			
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	22 350	11 207	33 557
			Riet	C51	Riet (C51K)	13 900	6 024	19 924
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	52 400	23 662	76 062
			Rustfontein	C52	Rustfontein (C52A)	7 250	2 173	9 423
			Krugersdrift	C52	Krugersdrift (C52B-G)	610 700	31 306	642 006
	Total in Modder / Riet (C) primary catchment - RSA					**706 600**	**74 372**	**780 972**
D	Orange	D1	Katse	D11	Katse (D11A-K) – Lesotho	0	133 701	133 701
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L) – Lesotho	105 870	425 886	531 756
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	81 050	142 914	223 964
		D2	Caledon – Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	515 250	568 850	1 084 100
			Caledon - RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	68 150	37 620	105 770
			Welbedacht – Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	75 360	175 840	252 200
			Welbedacht - RSA	D23	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	16 750	16 470	33 220
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	9 750	5 857	15 607
		D3	Gariep	D35	Gariep (D35A-K)	15 550	4 039	19 589
			Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	30 950	9 449	40 399
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	12 650	7 701	20 351
	Total in Upper Orange (D) primary catchment					**931 330**	**1 528 326**	**2 459 656**
	Total in Upper Orange (D) – RSA					**234 850**	**224 050**	**458 900**
	Total in Upper Orange (D) – Lesotho#					**[696 480]**	**[1 304 277]**	**[2 000 757]**
Total in Free State in C and D primary catchments						**830 [A1]800**	**159 672**	**990 472**
Total in Northern Cape in C and D primary catchments						**37 650**	**11 739**	**493 89**
Total in Eastern Cape in D primary catchment						**73 000**	**127 010**	**200 010**
TOTAL IN WMA (South Africa only&)						**941 450**	**298 421**	**1 239 871**

Notes:

*** Quaternary catchment area within Lesotho and RSA.**
& Lesotho is not part of the Upper Orange WMA
 # Lesotho population data is not reliable, estimate only.

In 1995, about 1 239 872 people were estimated to be living in the Upper Orange WMA. A significant proportion (76 %) of the RSA population is urbanised. The urban population of this WMA is dominated by the urban population of the Modder / Riet River catchment (86 %) which has the urban centres of Greater Bloemfontein, Botshabelo and Thaba Nchu. The Upper Orange River catchment has an almost equal split of the urban and rural populations. This area is more rural in nature and is dominated by the rural population of the area above Gariep dam (Orange u/s of Gariep Dam).

The population of Lesotho was estimated to be about 2 000 000 in 1995 and is mainly rural in nature. The rural urban split used by the WRSA consultant is 65 % urban and 35 % rural. The urban population was combined into six centres and is dominated by the population of Maseru.

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 Upper Orange Water Management Area (WMA) in terms of the following aspects:

- The present economic development of the Upper Orange WMA on a sectoral basis, taking into account the context of economic development in South Africa.
- The comparative advantages of the Upper Orange 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, and the immigration of mainly Mozambicans, especially to Mpumalanga and the Northern Province, 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 Upper Orange WMA was R28,7bn in 1997. The most important magisterial districts in terms of contribution to GGP in this WMA are shown below:

- Bloemfontein 63,8%.
- Thaba Nchu 4,2%.
- Ficksburg 2,9%.
- Aliwal North 2,7%.
- Other 26,4%.

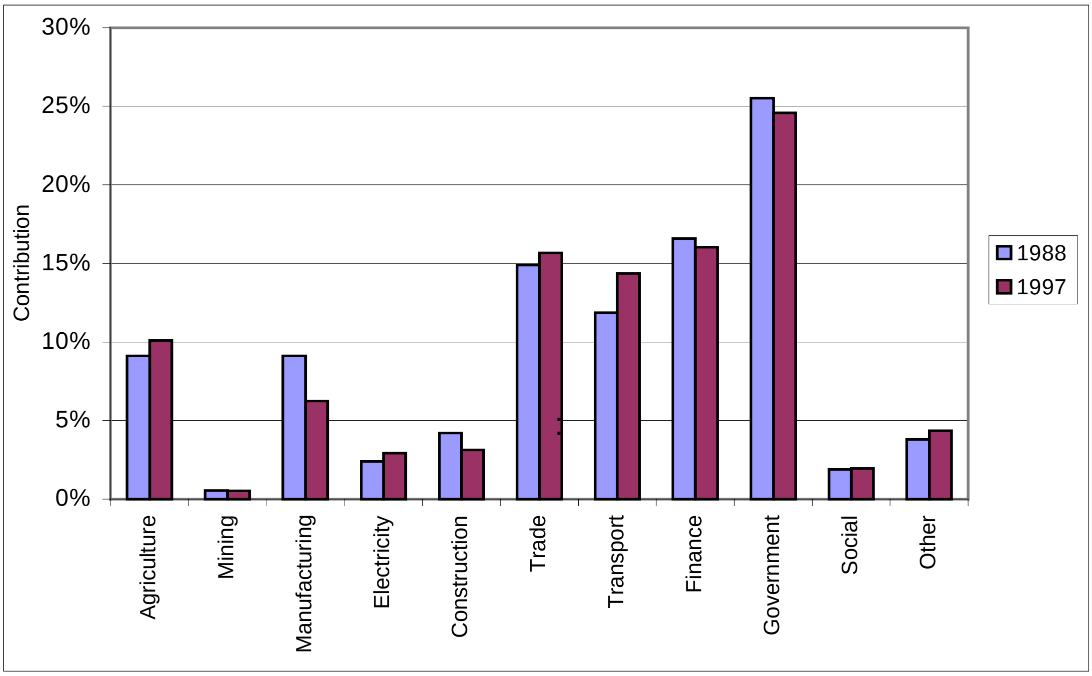
Economic Profile

The composition of the Upper Orange WMA economy is shown in **Diagram 3.3.4.1**. The most important sectors in terms of contribution to GGP are shown below:

- Government 24,6%.
- Finance 16,0%.
- Trade 15,7%.
- Transport 14,4%.

- Other 29,3%.

Diagram 3.3.4.1: Contribution by Sector to Economy of Upper Orange Water Management Area, 1988 and 1997 (%)



The importance of the trade sector could be attributed to the presence of a number of important commercial centres such as Bloemfontein, Thaba Nchu and Aliwal North. These centres do not only serve the local population, but also the surrounding communities in the district.

The main financial services centre in this WMA is Bloemfontein, providing services to the local population as well as surrounding areas. This financial services sector is an important service producer to other economic activities and the demand for business and financial services will be enhanced by growth in other economic activities.

Bloemfontein as the capital of the Free State fulfils an important government function with many provincial government departments located in this area. The activities of the University of the Free State, the Free State Technikon, the Appeal Court and the major hospitals in Bloemfontein also enhance the role of this sector.

The transport sector in Bloemfontein makes a major contribution to the economy of this WMA, and is supported by the Bloemfontein Airport, and railway station, as well as transport companies taking advantage of the fact that Bloemfontein is a major modal interchange and stop-over for cargo travelling on the route from Gauteng or Durban to Cape Town or Port Elizabeth.

Manufacturing occurs mainly in Bloemfontein, but Thaba Nchu is the second most important manufacturing centre. The Musgrave armaments factory is situated here.

The hydroelectric plants at the Gariep and Vanderkloof dams contribute to electricity production by providing 240 and 160 MW power respectively to surrounding areas.

The Ficksburg area near the Lesotho border has a unique combination of climate and growing conditions for the cultivation of cherries, and Ficksburg is the venue of the annual Cherry Festival. Another tourist attraction is the Golden Gate National Park in the north-easternmost corner of this WMA.

Economic Growth

The average annual economic growth by sector is shown in **Diagram 3.3.4.2**. Between 1987 and 1997, the highest average growth rates were recorded in the following sectors:

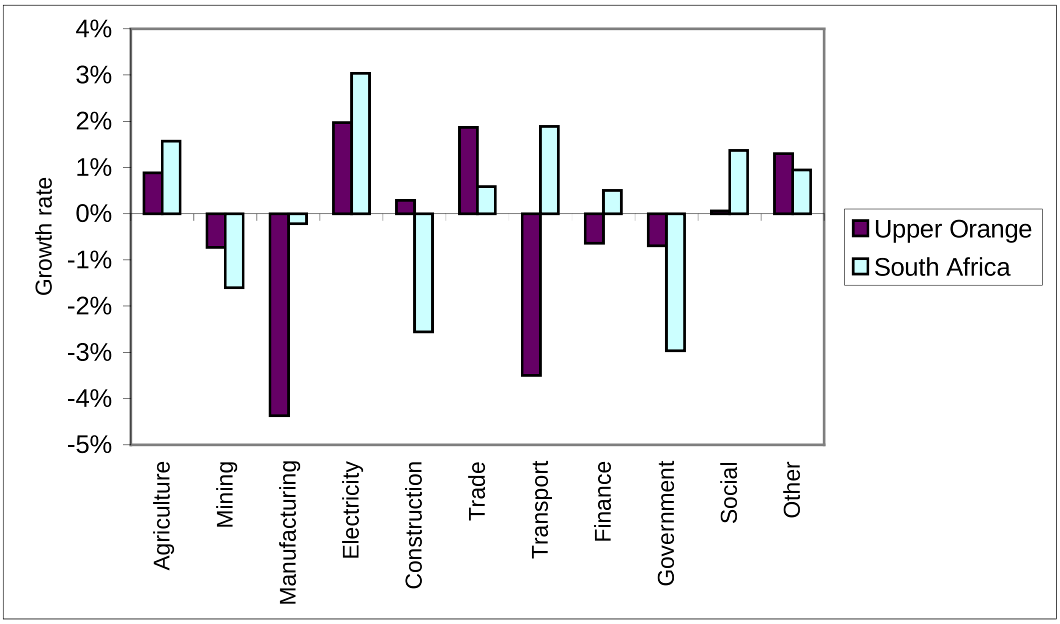
- Trade 1,9%.
- Agriculture 0,9%.

One of the factors that contributed to the growth in the agricultural sector is the fact that the sector has become more diversified, with more farmers concentrating on new agricultural products such as cut flowers, sunflowers and apples. The capital gains or profits on these products are higher than for example dryland grain farming. An increase in irrigation, especially for maize and wheat purposes was also noted. This contributed to an increase in production, and hence to the positive growth rate recorded in the agricultural sector. Another reason that contributed to the growth of this sector is the North East Cape Forests project which was initiated by Anglo American Corporation, De Beers Holdings and Mondi Ltd, in 1989. The Industrial Development Corporation started participating in this sector in 1994. Approximately 600 direct jobs with the potential for another 2 000 have been created.

The growth in the trade sector can be attributed to commercial development that took place, especially in Bloemfontein with the development of a number of new shopping centres.

Although the manufacturing sector recorded negative growth, the development of Thaba Nchu Industrial Development Zone (IDZ) could contribute to growth in the manufacturing sector, especially agro-industries in the Upper Orange WMA.

Diagram 3.3.4.2: Average Annual Economic Growth by Sector of Upper Orange Water Management Area and South Africa, 1988-1997



Labour

Of the total labour force of 376 000 in 1994, 31,1% were unemployed, which is higher than the national average of 29,3%. Fifty nine percent (58,8%) are active in the formal economy. Thirty three percent (32,5%) of the formally employed labour force work for government, while 17,1%, are involved in agriculture, and 11,7% in trade.
During the period 1980 – 1994 employment growth was recorded in the electricity sector (0,2% per annum); financial services (1,8% per annum); manufacturing (3,3% per annum); construction (1,7% per annum); and trade 0,7% per annum).

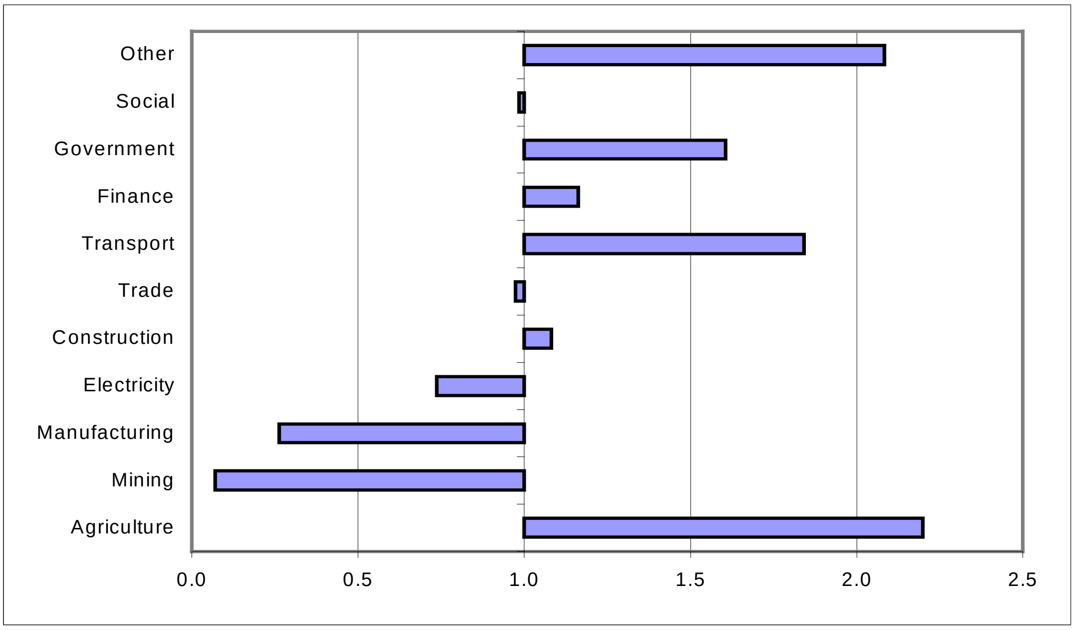
3.3.5 Comparative Advantages

A geographic area is said to have a comparative advantage in the production of certain goods and services if it can produce them at a lower cost per unit than another region while maintaining the same quality. When this is the case, production of such goods tend to become relatively more concentrated in the region which has the comparative advantage. The location quotient is a measure of the relative concentration of economic activities in a region as compared with another region, or as compared with a larger region of which it forms part. A location quotient for an economic sector with a value of more than one implies that the sector contributes a larger percentage to a sub-region's GGP than that sector contributes to the larger area of which the sub-region forms part. The location quotient can, however, not be equated with comparative advantage, and provides only an indication.

Diagram 3.3.5.1 shows the location quotients for Upper Orange WMA. The Figure shows that, based on the location quotients for 1997, the Upper Orange WMA economy is relatively more competitive than the remainder of South Africa in the following economic activities:

- Agriculture 2,2.
- Transport 1,8.
- Finance 1,2.
- Government 1,6.
- Other 2,1.

Diagram 3.3.5.1: Upper Orange Gross Geographic Product Location Quotient by Sector, 1997



The agricultural sector fulfils an important role in the economy of the Upper Orange WMA. The agricultural sector is well diversified and has expanded to include other activities such as the cultivating of flowers, sunflowers and apples. The positive growth recorded in this sector also contributes to its importance.

The comparative advantage of the transport sector can largely be attributed to the N1 and N3 leading into this WMA. This increases the accessibility and consequently improves import and export activities. The transporting of especially agricultural products to off-set points is an important activity contributing to the comparative advantage of this sector in national context.

The significance of the financial sector can be attributed to the importance of especially Bloemfontein that accommodates regional head offices of important financial institutions. Bloemfontein is a regional service centre that provides a spectrum of business and financial services to its local population as well as to a large subregional population in its hinterland.

The comparative advantage of the government and social services sector can largely be ascribed to the presence of a large number of government institutions including those in the former homelands, as well as education and health facilities in this WMA.

Although the “Other” sector does not make a significant contribution to production, it recorded positive growth and has a large comparative advantage. Activities classified under this sector includes private households, extraterritorial organisations, representatives of foreign governments and other activities not adequately defined.

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 colonizing 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 19th 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, 1956 (Act No 54 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, 1998 (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, 1997 (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.
- 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, 1997No. 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.
- 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, 1956 (Act No 54 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, 1956 (Act No 54 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, 1997 (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.
- 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, 1997 (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, 1991 (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, 1995 (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, 1994 (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, 1989 (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, 1998 (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, 1983 (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 uses 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 WUA's 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 CMA's 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.

Bloem Water is the major supplier of potable bulk water in this WMA. **Appendix A.1** lists all Local Council's as at 1995. **Figure 3.4.8.1** shows magisterial district and district council boundaries in 1995 and **Figure 3.4.8.2** shows the institutional boundaries related to water supply (e.g. water board boundaries and TLC/TRC boundaries).

The following District Councils exist in this WMA:

- Bloem Area.
- Stormberg.
- Drakensberg.
- Goldfields.
- Eastern Free State.
- Kalahari.
- BoKaroo.

The following controlled irrigation schemes/boards and controlled areas exist:

Modder / Riet River catchment (C)

- Tierpoort Irrigation Board.
- Kalkfontein Irrigation Board.
- Riet River GWS.
- Orange-Riet Canal Irrigation Control Area.
- Scholtzburg Irrigation Board.
- Ritchie Irrigation Board.
- Lower Riet Irrigation Board.
- Modder River GWS (Loxton et al., 1999b).

Upper Orange River catchment (D)

- Caledon Irrigation Area.
- Upper Orange Irrigation Area (u/s Gariep Dam, d/s Oranjedraai).
- Between Gariep and Vanderkloof Irrigation Area.
- Vanderkloof to Vaalkoppie Irrigation Area.
- Middle Vaal GWS (BKS, 1997m).

3.5 LAND USE

3.5.1 Introduction

Much of the Upper Orange WMA is devoted to agriculture activity. Agricultural activity ranges from commercial farming, which includes extensive irrigation, dryland agriculture and livestock farming. The commercial farming is concentrated mainly in the valley of the Caledon River (RSA side), along the Orange River from the Lesotho border to Vanderkloof Dam and in the Modder-Riet River catchment. Subsistence farming is practiced in the east, on both sides of the RSA/Lesotho border and generally involves cultivation and livestock. The natural or undeveloped areas are confined to the mountainous areas along the southern and south-eastern boundary of the WMA and the Lesotho highlands.

Afforestation is insignificant, there is some mining but no other industrialisation and the WMA is not extensively urbanised.

Greater Bloemfontein in the Modder catchment is the largest urban area in this WMA. Kimberley is situated on the northern WMA boundary with the Lower Vaal WMA and is considered to be part of the Lower Vaal WMA. Other significant urban areas are Thaba Nchu, Botshabelo, Koffiefontein, Ficksburg, Aliwal North and Colesberg. In Lesotho, the main urban area is the capital city, Maseru

Figure 3.5.1.1 shows catchment boundaries, rivers and dams, urban complexes and towns, large industries and afforested areas. **Table 3.5.1.1** lists areas irrigation, urbanisation, afforestation and alien vegetation infestation for key areas and provinces. There is no dryland sugarcane.

TABLE 3.5.1.1: LAND USE BY DRAINAGE AREAS

CATCHMENT						Irrigation (field area) (km^2)	Afforestation (km^2)	Alien vegetation (km^2)	Urban (km^2)	Other(1) (km^2)	Total (km^2)
PRIMARY		SECONDARY		TERTIARY							
No.	Description	No.	Description	No.	Key Area Description						
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	38,2	0	2,6	0,0	10 219,2	10 260,0
			Riet	C51	Riet (C51K)	136,4	0	1,8	0,0	3 493,8	3 632,0
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	63,8	0	48,1	41,0	14 437,1	14 590,0
			Rustfontein	C52	Rustfontein (C52A)	3,6	0	0	0,0	933,4	937,0
			Krugersdrift	C52	Krugersdrift (C52B-G)	19,1	0	1,0	297,0	5 076,9	5 394,0
	Total in Modder / Riet (C) primary catchment					**261,1**	**0**	**53,5**	**338,0**	**34 160,4**	**34 813,0**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0	0	0,5	0,0	3 359,5	3 360,0
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	25,7	0	4,4	0,0	21 289,9	21 320,0
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	171,1	0	0,3	0,0	18 298,6	18 470,0
		D2	Caledon – Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	7,8	0,0	0	10,2	5 150,3	5 168,3
			Caledon – RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	13,4	9,6	0	7,6	4 564,1	4 594,7
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	5,2	0	0	0,0	1 796,6	1 801,8
			Welbedacht - RSA	D23	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	39,0	0	0	0,0	4 844,2	4 883,2
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	46,4	0	0	0,0	5 389,6	5 436,0
		D3	Gariep	D35	Gariep (D35A-K)	22,4	0	0,8	0,0	5 614,8	5 638,0
			Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	63,5	0	2,9	0,0	19 013,6	19 080,0
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	150,2	0	7,7	0,0	9 440,1	9 598,0
	Total in D primary catchment					**544,7**	**9,6**	**16,6**	**17,8**	**98 761,3**	**99 350,0**
Total in Lesotho in D primary catchment						**[38,7]**	**[0]**	**[5,0]**	**[10,2]**	**[30 438,1]**	**[30 492,0]**
Total in Free State in C and D primary catchments						**421,9**	**9,6**	**53,8**	**345,6**	**55 439,1**	**56 270,0**
Total in Northern Cape in C and D primary catchments						**174,2**	**0**	**8,7**	**0**	**25 391,1**	**25 575,0**
Total in Eastern Cape in D primary catchment						**171,0**	**0**	**2,6**	**0**	**21 652,4**	**21 826,0**
TOTAL IN WMA (South Africa only)						**767,1**	**9,6**	**65,1**	**345,6**	**102 483,6**	**103 671,0**

Note: * Quaternary catchment area within Lesotho and RSA (split provided by DWAF).
(1) Includes area of dryland sugar cane (0), dryland crops, nature reserves and rural settlements. This data is not readily available.

3.5.2 Irrigation

Irrigated Area

The total irrigated area and various crop areas for each key area are shown in **Section 3.5.2.** Both harvested area (which includes re-use of irrigable areas for different seasons) and field area (physical maximum crop area under irrigation at any one time) have been shown. A map depicting the extent of the existing irrigation is shown in **Figure 3.5.1.1 and Appendix D.1** lists harvested crop area data.

The harvested irrigated area is defined as the maximum area under irrigation during any stage of the year. Due to the regionalised distribution of the prescribed crop factors given in the report (Loxton et al., 1999a), it was found unrealistic to simply determine the maximum irrigated area on the basis of the month with maximum crop area. To solve this problem in a realistic fashion the irrigated area was accepted as the maximum of the mid-summer crop area and the mid-winter crop area. Considering the given full range of crop factors available, mid-summer was defined as January/February while mid-winter was defined as July/August. Using this approach it was ensured that maximum but realistic allowance was made for double cropping, where appropriate.

Harvested Irrigation area data for this WMA was extrapolated from the Vaal River Irrigation Study (Loxton et al., 1999b), from the ORRS Evaluation of Irrigation water use (BKS et al., 1997 and from Department of Agriculture's, 1990 Food Survey database (Department of Agriculture, 1990).

Irrigation data from the Vaal River Irrigation Study (Loxton et al., 1999b) was used to determine harvested irrigated crop area and field area irrigation data in the Modder/Riet River sub-catchment (tertiary C5).

Irrigation data for the Upper Orange River sub-catchment was determined from the ORRS study and from the DOA food survey data. All irrigation had to be disaggregated into quaternary catchment data. The disaggregation represents an estimate and was undertaken as follows:

- Each irrigation area was reviewed. Where available the irrigated harvested crop area was noted (refer to Table 7.2 of the report (Loxton et al., 1999b) and Table 4.2, (BKS et al, 1997m).
- The main river channel quaternary catchments in each area were noted (the assumption being that most irrigation is from the main river channel) and where applicable, maps of the irrigation areas were reviewed (**Figure 11.11** of the report (Loxton et al., 1999b)).

TABLE 3.5.2.1: IRRIGATION LAND USE

CATCHMENT						IRRIGATED AREA BY CROP CATEGORY [1] (Km2)				
PRIMARY		SECONDARY		TERTIARY		Perennial	Summer	Winter	Total harvested area[2]	Total field area[3]
No.	Description	No.	Description	No.	Key Area Description					
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	19,9	18,3	15,9	54,1	38,2[M/S]
			Riet	C51	Riet (C51K)	29,6	106,8	83,6	220,0	136,4[M/F]
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	12,9	40,3	50,9	104,1	63,8[M]
			Rustfontein	C52	Rustfontein (C52A)	2,6	0,9	1,0	4,5	3,6[M]
			Krugersdrift	C52	Krugersdrift (C52B-G)	13,7	4,8	5,4	23,9	19,1[M]
	Sub-total in Modder / Riet (C) primary catchment					**78,7**	**171,1**	**156,8**	**406,6**	**[261,1]**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0	0	0	0	0
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	0	25,7	0	25,7	25,7[S/F]
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	137,7	33,4	27,6	198,7	171,1[S/F]
		D2	Caledon – Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	0	7,8	0	7,8	7,8[S]
			Caledon – RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	11,1	2,3	1,8	15,2	13,4[S]
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	0	5,2	0	5,2	5,2[S]
			Welbedacht - RSA	D23	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	30,5	8,5	6,9	45,9	39,0[S]
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	29,1	17,3	16,3	62,7	46,4[S]
		D3	Gariep	D35	Gariep (D35A-K)	11,0	11,4	2,9	25,3	22,4[S]
			Vanderkloof	D31, 32 and 34	Vanderkloof (D31A-E, D32A-K, D34A-G)	19,5	44,0	37,3	100,8	63,5[S]
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	13,5	112,0	136,7	262,2	150,2[M/S]
	Sub-Total in Upper Orange (D) primary catchment					**252,4**	**267,6**	**229,5**	**749,5**	**[544,7]**
Total in Lesotho in D primary catchment						**[0]**	**[38,7]**	**[0]**	**[38,7]**	**[38,7]**
Total in Free State in C and D primary catchments						**173,9**	**232,4**	**215,6**	**621,9**	**[421,9]**[A2]
Total in Northern Cape in C and D primary catchments						**29,5**	**130,8**	**144,7**	**305,0**	**[174,2]**
Total in Eastern Cape in D primary catchment						**127,7**	**36,8**	**26,0**	**190,5**	**[171,0]**
TOTAL IN WMA (South Africa only)						**331,1**	**400,0**	**386,3**	**1 117,4**	**[767,1]**

Note: *Quaternary catchment area within Lesotho and RSA (split provided by DWAF).

(1) No undifferentiated crops in the area. Crop area data obtained from Tables 7.2 and 8.2 (Loxton et al., 1999b), ORRS (BKS et al., 1997m) and DOA, (1990 Food Survey).

(2) Total crop area irrigated in 1995.

(3) Physical crop area under irrigation in 1995. Calculated as perennial crop area + summer or winter crop area (which ever is the larger area).

(M/S/F) Mechanical, sprinkler and flood irrigation systems.

For example the irrigation area known as the Modder GWS has a scheduled irrigation field area of 35,33 km^2 (harvested crop area in 1995 of 40,75 km^2), and the main river channel quaternary catchments from which irrigation is most likely to occur are C52H, C52K and C52J. No information on the physical location of irrigation in the GWS was known. As a result the harvested area per quaternary catchment was estimated equally for each quaternary catchment (i.e. 13,58 km^2 / quaternary catchment). This means that the key area harvested irrigation area data can be considered reliable but quaternary catchment irrigation data represents a rough estimate only and must be considered to be less accurate.

Irrigation Methods

The most common irrigation methods used in the WMA are flood irrigation, sprinkler systems and mechanical systems. In general the irrigation methods used for a specific crop type do not vary significantly between different catchments.

The information on the irrigation methods used in the study area was obtained from the report (Loxton et al., 1999b,). **Table 3.5.2.1** highlights the irrigation methods for key areas.

Enterprise Returns

It is generally recognised that future growth in irrigation will be severely limited by the availability of water. In the more water-scarce areas it may even become necessary to curtail irrigation to meet the growing demands of domestic and urban water users. In order to do this it will be necessary to base such decisions on sound economic principles such as 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 the purpose of this study. These categories also represent an appropriate grouping for the purpose of assurance of irrigation water supply. **Table 3.5.2.2** shows typical crops within each category that are grown within this WMA.

TABLE 3.5.2.2: ASSURANCE CATEGORIES FOR IRRIGATED CROPS

Category	Crop Examples
Low	Maize, wheat, soya bean, dry bean, groundnut and pasture for small stock
Medium	Vegetables, potatoes, coffee, cotton, pineapple, seed production and pasture for dairying and ostrich
High	Citrus, deciduous fruit and nuts, sub-tropical fruit and nuts, grapes and speciality vegetables

Efficiency of water use

There is scope for improving the efficiency of irrigation systems. For example farmers in controlled schemes should be encouraged to build concrete lined reservoirs (DWAF, 1999). There is also a need to upgrade and maintain distribution systems.

Canal conveyance losses in the Modder GWS are significant (30 %) because of the ‘poor’ state of distribution canals (DWAF, 1999).

3.5.3 Dryland Farming

The main dryland crops that are cultivated are maize, wheat and fodder pastures (kikuyu and rye). No dryland sugarcane production occurs in the WMA because the climate, topography and soils of the study area are not suitable. The extent of dryland cultivation is not known.

3.5.4 Livestock and game farming

Introduction

The livestock species reviewed, included cattle (beef and milk), sheep, goats, pigs, horses, donkeys and mules, while game species reviewed, ranged from black wildebeest to zebra. This data was available from several sources at magisterial district scale. All livestock and game species had to be converted to “equivalent large stock units” (ELSUs), before disaggregation to quaternary catchment scale.

There was no livestock and game data for Lesotho, however a preliminary estimate of about 935 500 equivalent large stock units was made.

Sources of information

Livestock and game data for the Upper Orange WMA was obtained from two main sources, namely:

- Department of Agriculture (Department of Agriculture, 1990), 1990 Food Survey, digital data provided by Glen Agricultural Station. This data is available on a primary catchment basis per magisterial district.
- Central Statistical Services (CSS), produced a “Census of Agriculture, 1988” on a magisterial district basis and is similar to that provided by the Department of Agriculture. Data on pigs, horses, mules and donkeys is available from this survey. The main disadvantages of this data is that unlike the “Glen” data it is not presented per primary catchment and game is not broken down into species.

It was assumed that livestock and game data for 1988 and 1990 can be used to represent 1995 figures as the general consensus is that agriculture has reached a threshold and that numbers are unlikely to change significantly. Furthermore the 1988 and 1990 data represents both mature and immature livestock and game numbers, therefore these numbers can be extrapolated to represent mature livestock and game numbers for 1995. The CSS livestock data was used if the Food Survey data (Department of Agriculture, 1990), looked suspect or if data was missing. For example the Food Survey database did not provided data on pig numbers while the CSS survey did.

Conversion of data

The first step involved converting the different livestock and game species into Equivalent Large Stock Units (ELSUs). The ELSU conversion factors used for the various species of livestock and game is provided in **Appendix F3**. This conversion table was provided by the DWAF. Unconverted magisterial district data for livestock and game species is also provided in **Appendix F.3**.

The disaggregation of ELSUs from Magisterial District (MD) to quaternary catchment resolution was based on a uniform spatial distribution of ELSUs within a MD. The actual disaggregation was carried out pro-rata to the areas of the quaternary catchments within the MD. Judgement was, however, exercised where there was additional information.

Appendix F.3 lists ELSUs at quaternary catchment scale. The average water use by ELSUs is taken at 45 ℓ/ELSU/day. The overall ELSUs for key areas and provinces for 1995 are given in **Table 3.5.4.1**. **Section 5.3.3** provides information on the water requirements of livestock in the WMA.

Cattle and sheep farming and livestock are dominant in the WMA at both commercial and subsistence levels. Mixed livestock farming takes place to the north of the Orange River. Sheep farming dominates the areas to the south of the Orange River.

TABLE 3.5.4.1: 1995 LIVESTOCK AND GAME POPULATIONS.

CATCHMENT						NUMBER OF ELSU
PRIMARY		SECONDARY		TERTIARY		
No.	Description	No.	Description	No.	Key Area Description	
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	136 068
			Riet	C51	Riet (C51K)	43 283
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	257 594
			Rustfontein	C52	Rustfontein (C52A)	21 541
			Krugersdrift	C52	Krugersdrift (C52B-G)	130 588
	Total in C primary catchment					**589 074**
D	Orange	D1	Katse	D11	Katse (D11A-K)	103 207
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	617 501
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	434 868
		D2	Caledon - Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	158 876
			Caledon - RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	151 145
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F, D23G*)	55 931
			Welbedacht - RSA	D23	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	155 904
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	98 695
		D3	Gariep	D35	Gariep (D35A-K)	60 807
			Vanderkloof	D31,D32,D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	158 826
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	75 043
	Total in Upper Orange (D) primary catchment					**2 070 803**
Total in Lesotho in D primary catchment						**[935 516]**
Total in Free State in C and D primary catchments						**1 120 112**
Total in Northern Cape in C and D primary catchments						**432 146**
Total in Eastern Cape in D primary catchment						**172 103**
TOTAL IN WMA (South Africa only)						**1 724 361**

Note: * Quaternary catchment area within Lesotho and RSA.

3.5.5 Afforestation and indigenous forests

Although rainfall is adequate for afforestation in the eastern portion of the Upper Orange WMA, the steep topography is not suitable for the large scale development of commercial forests. There is only about 9,66 km^2 under commercial plantation, all of which is situated in the upper Caledon River valley, most of which is planted to Wattle. There are no significant areas of indigenous forest in this WMA. **Table 3.5.5.1** gives a breakdown afforestation per key area.

TABLE 3.5.5.1 : AREAS OF AFFORESTATION AND INDIGENOUS FOREST.

CATCHMENT						AFFORESTATION				INDIGENOUS FOREST (km^2)
PRIMARY		SECONDARY		TERTIARY		Eucalyptus (km^2)	Pine (km^2)	Wattle (km^2)	Total (km^2)	
No.	Description	No.	Description	No.	Key Area Description					
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	0	0	0	0	0
			Riet	C51	Riet (C51K)	0	0	0	0	0
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	0	0	0	0	0
			Rustfontein	C52	Rustfontein (C52A)	0	0	0	0	0
			Krugersdrift	C52	Krugersdrift (C52B-G)	0	0	0	0	0
	Total in Modder / Riet (C) primary catchment					**0**	**0**	**0**	**0**	**0**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0	0	0	0	0
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	0	0	0	0	0
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	0	0	0	0	0
		D2	Caledon - Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L)	0	0	0	0	0
			Caledon - RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	2,4	1,8	5,4	9,6	0
			Welbedacht - Lesotho	D23	Welbedacht (D23A, D23B, D23E, D23F, D23G)	0	0	0	0	0
			Welbedacht - RSA	D23	Welbedacht (D23A, D23C, D23D, D23E, D23F, D23G, D23H, D23J, D24A-C)	0	0	0	0	0
			Caledon d/s Welbedacht	D24	D/s Welbedacht (D24D-L)	0	0	0	0	0
		D3	Gariep	D35	Gariep (D35A-K)	0	0	0	0	0
			Vanderkloof	D31,D32,D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	0	0	0	0	0
			Orange d/s Vanderkloof	D33	Orange d/s Vanderkloof (D33A-K)	0	0	0	0	0
	Total in Upper Orange (D) primary catchment					**2,4**	**1,8**	**5,4**	**9,6**	**0**
Total in Lesotho in D primary catchment						**[0]**	**[0]**	**[0]**	**[0]**	**[0]**
Total in Free State in C and D primary catchments						**2,4**	**1,8**	**5,4**	**9,6**	**0**
Total in Northern Cape / Eastern Cape in C and D primary catchments						0	0	0	0	0
TOTAL IN WMA (only South Africa)						**2,4**	**1,8**	**5,4**	**9,6**	**0**

Note: * Quaternary catchment area within Lesotho and RSA.

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 m^3/a by Le Matre (Le Matre et al, 1999) 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 Matre estimated that the impact 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 occur 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.

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 data base 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 20m.
- 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.

Data on alien vegetation eradication schemes was not readily available.

Infestation by alien vegetation is given in **Table 3.5.6.1**.

TABLE 3.5.6 1: INFESTATION BY ALIEN VEGETATION.

CATCHMENT						CONDENSED AREA OF ALIEN VEGETATION
PRIMARY		SECONDARY		TERTIARY		
No.	Descrip-tion	No.	Description	No.	Key Area Description	
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	2,6
			Riet	C51	Riet (C51K)	1,8
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	48,1
			Rustfontein	C52	Rustfontein (C52A)	0,0
			Krugersdrift	C52	Krugersdrift (C52B-G)	1,0
	Total in Modder/Riet (C) primary catchment					**53,5**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,5
			Senqu	D15-D18	Senqu D11 (D15A-H, D16A-L, D17A-M, D18A-L)	4,4
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	0,3
		D2	Caledon – Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*) – Lesotho	0
			Caledon – RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	0
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	0
			Welbedacht - RSA	D23	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	0
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	0
		D3	Gariep	D35	Gariep (D35A-K)	0,8
			Vanderkloof	D31,32,34	Vanderkloof (D31A-E, D32A-K, D34A-G)	2,9
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	7,7
	Total in Upper Orange (D) primary catchment					**16,6**
Total in Lesotho in D primary catchment						**[5,0]**
Total in Free State in C and D primary catchments						**53,8**
Total in Northern Cape in C and D primary catchments						**8,7**
Total in Eastern Cape in D primary catchment						**2,6**
TOTAL IN WMA (South Africa only)						**65,1**

Note: * Quaternary catchment area within Lesotho and RSA.

3.5.7 Urban Areas

Greater Bloemfontein in the Modder River catchment is the largest urban area in this WMA. Kimberley is situated on the northern WMA boundary with the Lower Vaal WMA and is considered to be part of the Lower Vaal WMA. Other significant urban areas include Thaba Nchu, Botshabelo, Wepener, Dewetsdorp, Reddersburg, Edenburg, Jagersfontein, Trompsburg, Brandfort, Dealesville, Petrusberg, Jacobsdal, Koffiefontein, Oppermans, Fauresmith, Springfontein, Bethulie, Smithfield, Rouxville, Zastron, Vanstadensrus, Barkly East, Ficksburg, Colesberg, Aliwal North and Phillipolis.

In Lesotho, the main urban area is the capital city, Maseru.

All urban areas are listed in **Appendix A.**1 and are shown in **Figure 3.5.1.1**. A total urban area of 356 km^2 was estimated from WR90 data. The data from WR90 represents the 1990 situation and it is expected that the urban areas are underestimated for all areas within the WMA.

3.6 MAJOR INDUSTRIES AND POWER STATIONS

Bloemfontein is the only significant industrial area.

Only thermal power stations (that have preferential access to water after allowing for the social reserve and IFR's) are classed as strategic bulk users. There are no strategic bulk users in this WMA.

3.7 MINES

3.7.1 Introduction

Mining operations in South Africa encompass a wide range of activities, which include the extraction, dressing and beneficiation of naturally occurring minerals, whether in solid, liquid or gaseous form to render the material marketable or to enhance the market value of the material. Mining operations include underground and surface mines, quarries and the operation of oil and gas wells.

3.7.2 Mining operations

In the Upper Orange WMA the main products of mining operations are diamonds and salt. There are however no significant direct water requirements by mines in this WMA. The most significant mine is De Beers Koffiefontein, which seems to receive its water from the Koffiefontein TLC.

Data about mines was obtained from a number of sources including:

- Council of Geoscience, SAMINDABA database (SA Mining Database).
- Reports on the "Vaal River Systems Analysis Update" Study (BKS et al, 1998d,e,f)

Discharges from mines are not significant in this WMA. The economy of the Upper Orange WMA is not influenced by the mining sector (<1,0 % of GGP, - refer to **Section 3.3.4**), but urban centres such as Koffiefontein rely on the presence of mines for their existence.

3.8 WATER RELATED INFRASTRUCTURE

There are two hydroelectric power stations in the Upper Orange WMA, namely Gariep and Vanderkloof. Refer to **Sections 4.4 and 5.10** for details.

There are three main water transfers as described in **Section 4.4**.

Major infrastructure has been shown on the GIS map in **Figure 4.1.1** and a schematic diagram showing major infrastructure has been shown in **Figure 4.1.2**. Refer to **Chapter 4** for further details.

CHAPTER 4: WATER RELATED INFRASTRUCTURE

4.1 OVERVIEW

The Orange River is a major contributor along with the Modder and Riet Rivers to supplying water to agriculture, domestic and industrial users in the Upper Orange WMA. Agriculture is one of the key users of water in the Upper Orange WMA and there are several Government Water Schemes (GWS) and irrigation boards in the area. There are two major hydroelectric powerstations at Gariep and Vanderkloof Dams. The Modder River is fully utilised and this has necessitated transferring water from the Orange and the Caledon Rivers. There are three main transfer schemes, namely: the Caledon – Modder transfer which supplies Bloemfontein, Dewetsdorp and smaller users from Welbedacht Dam, the Orange-Riet transfer which supplies irrigation in the Riet River catchment from the Vanderkloof Dam and the Caledon-Modder (Novo) transfer which will supply growing demands in the Bloemfontein area. The new Rustfontein purification works is supplying the Thaba Nchu and Botshabelo urban areas.

Figures 4.1.1 and 4.1.2 show water related infrastructure such as dams, water treatment works, reservoirs, sewage treatment works, pipelines, irrigation schemes, etc. Some of the infrastructure has been shown schematically on the GIS map in **Figure 4.1.1**. A full schematic diagram has been given in **Figure 4.1.2**.

Table 4.1.1 provides a summary of potable water supply schemes per key area and for the provinces. Urban consumption in the Upper Orange WMA ranges from 95 ℓ/capita/day (Rustfontein key area) to 46 ℓ/capita/day (Riet key area). Urban consumption in Lesotho is estimated to range from 53 ℓ/capita/day to 87 ℓ/capita/day.

In 1995 there were seven major dams in the Upper Orange catchment, namely Gariep, Vanderkloof, Welbedacht, Knellpoort, Rustfontein, Krugersdrift and Kalkfontein. Details of these major dams together with other smaller dams have been recorded in **Table 4.3.1**. Details of weirs have been included in **Appendix E.1**. There is a large network of reservoirs, pumpstations and pipelines, details of which have been provided in **Appendices E.2, E.3 and E.6**. Details of sewage treatment works have been included in **Appendix E.4**. Details of groundwater abstractions have been included in **Appendix E.5**. Details of canals and tunnels have been provided in **Appendices E.7 and E.8**. There was no readily available information of hazardous waste sites in this WMA.

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

CATCHMENT						TOWN AND REGIONAL WATER SUPPLY SCHEMES			
PRIMARY		SECONDARY		TERTIARY		Number of People Supplied(1)	% of key Area Population	CAPACITY	
No.	Description	No.	Description	No.	Key Area Description			($10^6 m^3/a$)	(ℓ/capita/d)
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	22 350	67	not available	208
			Riet	C51	Riet (C51K)	13 900	70	not available	461
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	52 400	69	not available	262
			Rustfontein	C52	Rustfontein (C52A)	7 250	77	not available	95
			Krugersdrift	C52	Krugersdrift (C52B-G)	610 700	95	not available	266
	Sub-total in C primary catchment					**706 600**	**91**	**not available**	**95 to 461**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0	Not applicable	Not applicable	Not applicable
			Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	unknown	unknown	not available	54
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	81 050	36	not available	93
		D2	Caledon - Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	unknown	unknown	not available	87
			Caledon - RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*)	68 150	64	not available	189
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	unknown	unknown	not available	53
			Welbedacht - RSA	D23	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	16 750	50	not available	190
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	9 750	63	not available	314
		D3	Gariep	D35	Gariep (D35A-K)	15 550	80	not available	277
			Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	30 950	77	not available	210
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	12 650	62	not available	210
	Total in D primary catchment					**931 330**	**51**	**not available**	**53 to 314**
Total in Lesotho in D primary catchments						**[unknown]**	**[unknown]**	**[not available]**	**53 to 87**
Total in Free State in C and D primary catchments						**830 800**	**84**	**not available**	**93 to 461**
Total in Northern Cape in C and D primary catchments						**37 650**	**76**	**not available**	**210**
Total in Eastern Cape in D primary catchments						**73 000**	**36**	**not available**	**93 to 277**
TOTAL IN WMA (only South Africa)						**941 450**	**76**	**not available**	**93 to 461**

Note : (1) Assumed that the South African urban population is supplied from individual and regional water supply schemes.

* Quaternary catchment area within Lesotho and RSA (split provided by DWAF).

4.2 MAJOR WATER SUPPLY SCHEMES

4.2.1 Bloem Water supply area

Bloem Water supplies about 100 x 10^6 m^3/a to about 580 000 people and is the main supplier of bulk potable water to urban centres in the Modder / Riet River sub-catchment.

The Caledon-Bloemfontein transfer scheme abstracts water from the Welbedacht dam and supplies by main pipeline (107 km) and secondary pipelines various towns such as Greater Bloemfontein, Botshabelo, Thaba Nchu, Dewetsdorp, Reddersburg and Edenburg. With the completion (end 1999) of the 100 Mℓ Rustfontein Water Treatment Works, water will also be pumped to Botshabelo and Thaba Nchu.

Bloem Water controls Welbedacht, Rustfontein and Knellpoort dams as well as the related pumpstations. The design and operating capacity of the purification works at Welbedacht is 145 Mℓ/day. There are 10 service reservoirs, namely:

De Hoek, Uitkyk, De Wetsdorp, Botshabelo, Thaba Nchu, Boesmanskop, Grootvlei, Bloemspruit, Brandkop and De Brug.

The Thaba Nchu and Botshabelo reservoirs have capacities of 156 Mℓ and 52 Mℓ respectively while the remaining eight reservoirs have a combined capacity of 263 Mℓ.

Bloemwater also operates a pipeline network from Gariep Dam to the southern Free State towns of Trompsburg, Springfontein, Bethulie and Philippolis (since 1999).

4.2.2 The Mazelspoort Scheme

Mazelspoort waterworks at the Mazelspoort Weir supplies about 25% of Bloemfontein’s water needs and is owned by the Bloemfontein City Council. There is a service reservoir at Hamilton Park of capacity 57 Mℓ.

4.2.3 The Orange – Riet Transfer Scheme

The Orange – Riet transfer scheme abstracts water from Vanderkloof Dam to the Riet River catchment via the Orange – Riet canal (112,6 km). The water is primarily used for irrigation but also supplies the urban requirements of Koffiefontein (including mine), Ritchie and Jacobsdal.

4.2.4 The Orange – Vaal Transfer Scheme

The Orange – Vaal Transfer Scheme transfers water from Marksdrift out of this WMA to supply irrigation areas along the Vaal River.

4.2.5 The Caledon – Modder (NOVO) Scheme

The Caledon – Modder (Novo) transfer will become operational in 2000 and will abstract water from Knellpoort Dam to the upper reaches of the Modder River catchment to supply the growing demands in the Bloemfontein area.

4.2.6 The Orange – Fish Transfer Scheme

The Orange – Fish Tunnel transfers water to the Great Fish and Sundays River catchments in the Eastern Cape. Both catchments are water deficient and have fertile soil for irrigation. This scheme also supplies urban consumers, including Grahamstown and Port Elizabeth.

4.3 MAIN WATER RESOURCE INFRASTRUCTURE

Gariep and Vanderkloof dams are the two largest dams in this WMA. These two dams reduce the incidence of floods in the Lower Orange by about 50%.

Other major dams are Welbedacht and Knellpoort Dams in the Caledon catchment and Krugersdrif, Rustfontein, and Kalkfontein Dams in the Modder-Riet River catchment. **Table 4.3.1** gives details of all major dams in the Upper Orange WMA. Using WR90 data, storages in this WMA have been shown graphically for selected areas in **Diagram 4.3.1**.

Water supply schemes have been given in **Table 4.3.2** and major potable water supply schemes have been summarised in **Table 4.3.3**. There are numerous controlled irrigation schemes in the Upper Orange WMA. Details are provided in **Table 4.3.4** and are shown on the schematic diagram in **Figure 4.1.2**.

Sedimentation is a major problem in Welbedacht Dam on the Caledon River; its capacity has decreased from 114 x 10^6 m^3 to about 15 x 10^6 m^3 when last estimated in 1994. The construction of Katse and Mohale Dam (Lesotho Highlands Water Project) will re-distribute sedimentation in the Upper Orange River catchment. 1995 figures do not reflect these changes, as construction is post 1995.

TABLE 4.3.1: MAIN DAMS IN THE UPPER ORANGE WMA.

NAME	LIVE STORAGE CAPACITY ($10^6m^3/a$)	DOMESTIC SUPPLIES ($10^6m^3/a$)	IRRIGATION ($10^6m^3/a$)	OTHER ($10^6m^3/a$)	OWNER
Upper Orange sub-catchment:					
Gariep	5 340,6	2,5	540,0	4 152,5	DWAF
Vanderkloof	3 171,3	0,6	291,4	2 314,9	DWAF
Bethulie	4,6	0	0	0	Municipality
Caledon sub-catchment:					
Welbedacht	41,96 (2)	42,4	0	0	DWAF
Knellpoort	130,3	0	0	0	DWAF
Armenia	13,2	0	1,1	0	DWAF
Egmont	9,3	0	0,7	0	DWAF
Modder / Riet sub-catchment					
Kalkfontein	318,9		42,6	0	DWAF
Tierpoort	34,5				DWAF
Krugersdrif	73,2				DWAF
Rustfontein	72,2				DWAF
Groothoek	11,906	2,9	0	0	DWAF
Mockes	6,0				Bloemfontein

Note: (1) Domestic, irrigation and other supply taken from reservoir records for the 1995 hydrological year. Live storage also taken from reservoir records (where available) otherwise "List of Hydrological Gauging Stations (Volume 2) July 1990".
(2) Welbedacht Dam's live storage has been considerably reduced to to siltation.

Storage in major and minor dams has been given in **Diagram 4.3.1** (Minor dams are shown above major dams). Dams on the Orange and Caledon and major tributaries thereof have been designated as major dams and others as minor dams. Lesotho has not been included because the only major dam is Katse which was constructed after 1995 and there are no minor dams.

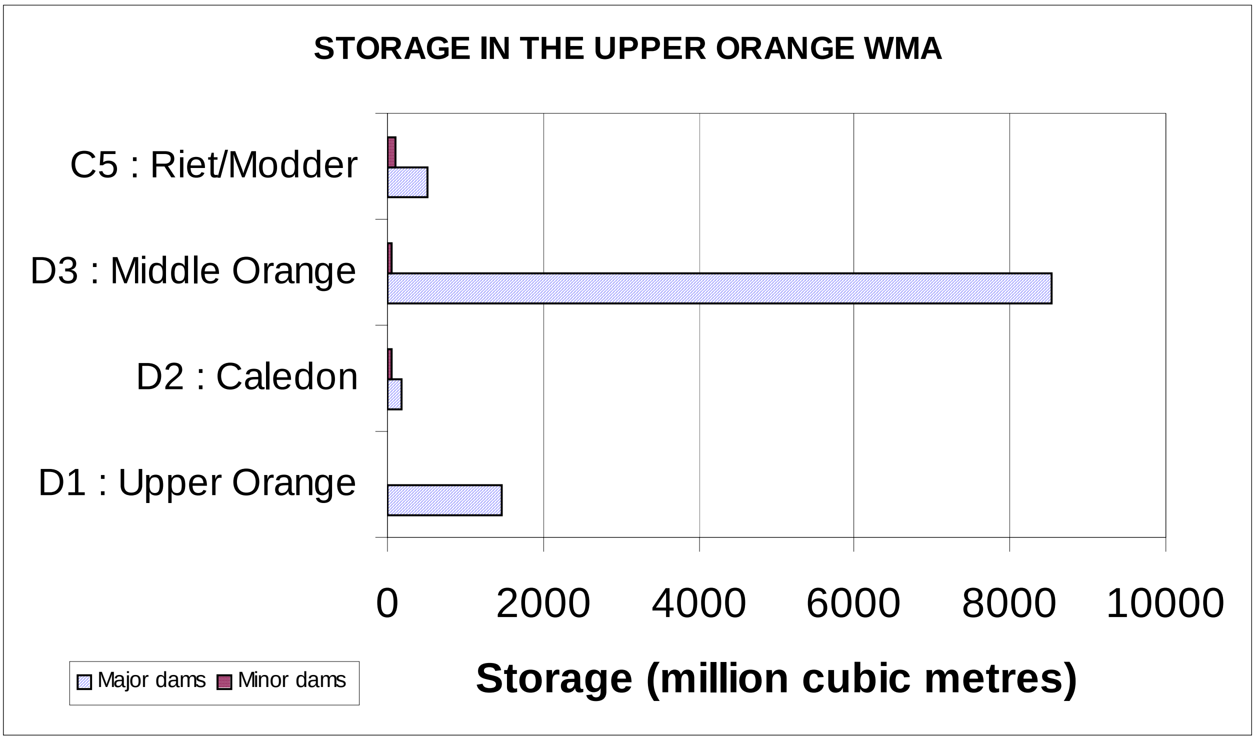


Diagram 4.3.1: Storage in the Upper Orange WMA

TABLE 4.3.2 : REGIONAL WATER SUPPLY SCHEMES : BULK WATER SUPPLY INFRASTRUCTURE

WATER TREATMENT WORKS			RAW WATER SOURCE				
NAME	CAPACITY (Mℓ/d)	OWNER/OPERATOR	NAME	CAPACITY/SUPPLY (10^6 m^3/a)	CAPACITY/SUPPLY (Mℓ/d)	ADDITIONAL YIELD ALLOCATED TO OTHER USERS($10^6 m^3/a$)	OWNER AND OPERATOR
Bethulie	D 4,0 O 1,4	Municipality	Orange River Boreholes	Unknown	Unknown	unknown	Municipality
Botshabelo	D 100	Bloem Water	Rustfontein Dam	Unknown	Unknown	unknown	Bloem Water
Brandfort	Unknown	Municipality	Sand-Vet GWS	Y 0,61	Y 1,66	unknown	Municipality
Clarens	O 1,0	Municipality	Clarens and Gryp Dams	O 0,05 Y0,04	O 0,01 Y 0,12	unknown	Municipality
Clocolan	D 3,46	Municipality	Moperri Dam	O 12,0	O 32,9	unknown	Municipality
Fauresmith	Unknown	Municipality	Jagersfontein Boreholes	Unknown	Unknown	0	Municipality
Ficksburg	Unknown	Municipality	Meulspruit Dam	Y 133,2	Y 364,8	0	Municipality
Gariep Dam	Unknown	Bloem Water	Gariep Dam	Unknown	Unknown	0	Bloem Water
Hobhouse	Unknown	Municipality	Armenia Dam	Y 1,98	Y 5,42	0	Municipality
Jacobsdal	D 960 O 960	Municipality	Kalkfontein Dam Boreholes	Unknown	Unknown	0	Municipality
Jagersfontein	Unknown	Municipality	Boreholes	Unknown		0	
Koffiefontein	Unknown	Municipality	Riet River GWS	Unknown	Unknown	0	DWAF
Ladybrand (Genoe WTW)	D 0,6 O 0,8	Municipality	Caledon River Cathcartdrift Dam	Y 0,79	Y 2,17	0	Municipality
Luckoff	D 0,44 O 0,44	Municipality	Orange-Riet canal	Unknown	Unknown	0	DWAF

WATER TREATMENT WORKS			RAW WATER SOURCE				
NAME	CAPACITY (Mℓ/d)	OWNER/OPERATOR	NAME	CAPACITY/SUPPLY		ADDITIONAL YIELD ALLOCATED TO OTHER USERS($10^6 m^3$/a)	OWNER AND OPERATOR
				(10^6 m^3/a)	(Mℓ/d)		
Maseru	unknown	Municipality	Caledon River	O 35	O 95,8	unknown	Municipality
Oppermans	O 0,3	Municipality	Boreholes	Unknown	Unknown 1,5	unknown	Municipality
Reddersburg	D 0,47	Bloem Water	Welbedacht Dam	Y 0,10	Y 0,29	unknown	Bloem Water
Rosendal		Municipality	Rosendal Dam	0,13	Unknown	unknown	Municipality
Rouxville		Municipality	Kalkoenkrans Dam Boreholes	Y 1,10	Y 3,0	unknown	Municipality
Smithfield	D 1,4	Municipality	Smithfield Dam Boreholes	Unknown O 0,8	Unknown O 2,2	unknown	Municipality
Thaba Nchu (Groothoek)	D 18 O 8	Bloem Water	Groothoek Dam Boreholes	O 1,6 O 6,6	O 4,4 O 18,13	unknown	Bloem Water
Thaba Patchoa		DWAF	Armenia Dam Boreholes	Unknown	Unknown	unknown	DWAF
Trompsburg		Bloem Water	Gariep Dam	Unknown	Unknown	unknown	Bloem Water
Tweespruit	O 1,0	Municipality	Lovedale Dam	Unknown	Unknown	unknown	Municipality
Vanstadensrus		Municipality	Boreholes	Unknown	0,64	unknown	Municipality
Wepener		Bloem Water	Welbedacht Dam Boreholes	Unknown	Unknown	unknown	unknown
Welbedacht	D 145 O 145	Municipality	Welbedacht Dam	42,4 Y 39,7	Y 108,0	unknown	Municipality
Zastron		Municipality	Kloof Dam Montagu Dam	Y 0,43	Y 1,18	unknown	Municipality

Notes :
1. The Rustfontein treatment works supplies water to Botshabelo and Thaba Nchu.
2. D denotes design capacity and O denotes operational capacity.
3. Y denotes Municipal Yearbook.

TABLE 4.3.3: POTABLE WATER SUPPLY SCHEMES IN THE UPPER ORANGE WMA

Scheme Name	Raw water source	Population supplied	Scheme Capacity		
			(10^6 m^3/a)	(Mℓ/day)	Limiting factor
Welbedacht (Caledon – Bloemfontein supply)	Caledon River into Welbedacht Dam	±280 000	53,0	145	#
Botshabelo/ Thaba Nchu supply area	Rustfontein and Groothoek Dams	±276 000	36,5	100	#
Mazelspoort	Modder River at Mazelspoort Weir	±90 000	47,8	130	#
Bloem Water – Southern supply area	Gariep Dam and Orange River	±17 000	#	#	#

Note : # Not readily available

TABLE 4.3.4 : CONTROLLED IRRIGATION SCHEMES IN THE UPPER ORANGE WMA

SCHEME/BOARD/ CONTROL AREA NAME	SCHEDULED AREA (ha)	1995 CONTROLLED IRRIGATED AREA (ha)	PRODUCE	WATER SOURCE	GUIDELINE QUOTA (m^3/ha/a)	AVAILABLE YIELD (10^6 m^3/a)	1995 AVERAGE ANNUAL USE (10^6 m^3/a)	THEORETICAL REQUIREMENT OF CURRENT AREA IRRIGATED (10^6 m^3/a)
MODDER / RIET SUB-CATCHMENT (C5 SECONDARY CATCHMENT):								
Tierpoort Irrigation Board	708	665	Lucerne	Tierpoort Dam/ Kaffir River	9 000	-	6,0	6,4
Kalkfontein Irrigation Board	3 526	3 526	Annual low value	Kalkfontein Dam/ Riet River	11 000	-	27,9	38,8
Riet River GWS	8 084	8 084	Annual low value	Orange Riet transfer	11 000	-	69,1	88,9
Orange Riet Canal Irrigation Control Area	3 787	3 787	Wheat, grazing pastures, maize and lucerne	Vanderkloof Dam/ Orange River	11 000	-	38,7	41,7
Ritchie Irrigation Board	97	97	Fodder and high value	Orange River via Orange – Riet transfer	9 140	-	0,8	0,9
Scholtzburg Irrigation Board	637	637	Annual low value	Orange River via Orange – Riet transfer	9 140	-	6,3	5,8
Lower Riet River Irrigation Board	3 938	3 938	Wheat, grazing pastures, maize and lucerne	Riet River	11 000	-	37,9	43,3
Modder River GWS	3 536	3 533	Wheat, grazing pastures, maize and lucerne	Krugersdrift Dam/ Modder River	8 385	-	22,9	29,7
Total	**24 313**	**24 495**					**209,6**	**255,5**
CALEDON SUB-CATCHMENT (CALEDON – RSA KEY AREA)								
Irrigation upstream of Welbedacht	1 440	3 692	Lucerne, fodder	Welbedacht and Armenia Dams and Caledon River	6 100 / 7 620	-	34,0	9,6
Irrigation upstream of Gariep and downstream of Welbedacht	4 775	3 482	Wheat, grazing pastures, maize and lucerne	Caledon River	8 000	-	35,6	38,2
Total	**6 215**	**7 175**					**69,6**	**47,8**
UPPER ORANGE SUB-CATCHMENT (REMAINING AREA IN THE UPPER ORANGE WMA EXCLUDING THE C5 SECONDARY CATCHMENT, THE CALEDON – RSA KEY AREA AND LESOTHO								
Irrigation upstream of Aliwal North	1 574	1 550	Fodder	Orange River	8 000		12,6	12,9
Irrigation upstream of Gariep and downstream of Aliwal North	2 559	1 940	Fodder	Orange River	8 000		20,5	16,2
Irrigation between Gariep and Vanderkloof Dams	2 316	2 316	Maize, fodder	Orange River	11 000		25,5	22,5
Irrigation d/s Vanderkloof Dam	19 857	19 857	Maize, wheat	Vanderkloof Dam	10 000 / 11 000		212,3	206,0
Total	**26 306**	**25 663**					**270,9**	**257,6**
WMA - TOTALS	**56 834**						**550,1**	**560,9**

Source of data:

- Vaal River Irrigation Study, Table 8.2 (Loxton et al., 1999b).
- ORRS, Evaluation of Irrigation water use, Table 4.4 (BKS et al, 1997l), 1997.

4.4 HYDRO-POWER AND PUMPED STORAGE SCHEMES

Hydro-power stations are shown on **Figure 4.1.1**. Gariep Dam (formerly Hendrik Verwoerd) and Vanderkloof Dam (formerly PK Le Roux) were completed in 1971 and 1976 respectively and apart from generating hydro power, they also supply water for domestic and irrigation purposes.

The Orange River hydro power stations (Gariep and Vanderkloof) generate peak clipping hydropower to the Eskom network with water supplied to downstream users at three different assurance levels. High assurance water, which includes unavoidable river losses, is supplied at an annual assurance of 99,5%. Medium assurance water is supplied at 99% and low assurance at 95% annually. Of the total demand, 44% is high assurance, 24% medium, and 32% low assurance water. Being peaking stations, the load factor of each station is normally about 10%, but they are sometimes operated at 100% load factor (24 hours per day) during high flows.

The effect that these two power stations have is that water is released twice a day, from 06:00 to 09:00 and 18:00 to 21:00, which results in a significant change of water level in the Orange river downstream of the two dams. Each day there is consequently a strong fluctuation of flow immediately below the dams. This has a pronounced adverse impact on the river biota, which gradually reduces to normal over a distance of about 200 km. The dams further affect the temperature regime in the water, which is detectable up to an estimated 180km downstream.

Technical and location details of the power stations are summarised in **Table 4.1.1**, **Appendices F.5 and F.7**.

There are no pumped storage schemes in this WMA.

TABLE 4.4 1: HYDRO-POWER STATIONS.

CHARACTERISTIC		STATION	
		Gariep	**Vanderkloof**
Location:	Latitude Longitude	25º30’26” S 30º37’23” E	24º44’55” S 29º59’29” E
Rated capacity		360 MW	240 MW
Peak capacity (generator limitation)		385 MW	255 MW
Rated head		52 m	59 m
Load factor		Normally 10%	Normally 10%

CHAPTER 5: WATER REQUIREMENTS

5.1 SUMMARY OF WATER REQUIREMENTS

The various user sectors in this WMA are as follows:

- Ecological Reserve (environmental - in-stream flow requirements). This water is not consumed.
- Domestic (urban and rural users).
- Bulk industrial (including thermal power stations) and mining.
- Water transfers.
- Agricultural including (livestock and game).
- Afforestation.
- Alien vegetation.
- Hydropower. This water is not consumed apart from losses. It should be noted that hydropower is a secondary determinant of the weekly releases from Gariep and Vanderkloof Dams; irrigation requirements are the primary concern.

Table 5.1.1 summarises the 1995 water requirements and the equivalent requirement at 1:50 year assurance.

The estimated total water requirements in 1995 are estimated to be about 7 900 x $10^6 m^3$ (dominated by hydropower requirements). The upstream water requirements of Lesotho were estimated to be about 1 115 x 10^6 m^3 in 1995 (dominated by ecological reserve requirements). Lesotho is mainly within the Upper Orange catchment but outside the Upper Orange WMA, however the requirements of Lesotho are needed as they influence the water resources of the WMA.

Distribution losses and conveyance losses are included in the values given for water requirements, including water transfers, but return flows have not been subtracted. Water requirements for aquatic ecosystems are given as the requirement at the outlet to the WMA. Water requirements for hydropower have been included but it should be noted that a large proportion of this requirement is re-usable as a return flow and that this is dealt with under the water balance.

Not all water is required at the same assurance, for example, water for urban requirements must be provided at a much higher assurance than water for irrigation requirements. Refer to **Appendix F.9** for the assurance of supply for various users. The assurance of supply is taken into account in determining the equivalent requirement at 1:50 year assurance.

Figure 5.1.2 shows water requirements at 1:50 year assurance for the user groups at selected key points. A pie diagram showing all the water requirements within the WMA is included as an inset. The most significant water requirements within the WMA are hydropower water requirements (64 %) and ecological Reserve requirements (17%). **Table 5.1.2** summarises water requirements of the user groups for the key areas and for the provinces.

TABLE 5.1.1: WATER REQUIREMENTS PER USER GROUP IN 1995

USER GROUP	ESTIMATED WATER REQUIREMENT (10^6 m^3/a)	REQUIREMENT/USE AT 1:50 YEAR ASSURANCE (10^6 m^3/ a)
Ecological Reserve (5)	323,6	757,3
Domestic	(1) 89,1	92,1
Bulk industrial (4)	1,8	1,9
Neighbouring States	(6) [1 115,4]	[264,4]
Agriculture	(2) 818,2	678,1
Afforestation	0,4	0,0
Alien vegetation	1,3	0,0
Water transfers (3)	568,9	568,9
Hydropower (7)	4 990,0	4 990,0
TOTAL (excl. Lesotho)	**6 793,3**	**7 088,3**
TOTAL (incl. Lesotho)	**[7 908,7]**	**[7 352,7]**

(1) Includes urban (85,6 x 10^6 m^3/a) and rural domestic (3,5 10^6 m^3/a) requirements (includes commercial, institutional and municipal requirements).
(2) Includes requirements for irrigation (783,1 x 10^6 m^3/a), dryland sugar cane (0), livestock and game (35,1 x 10^6 m^3/a).
(3) Only transfers out of the WMA are included. Orange – Fish (550,0 x 10^6 m^3/a) and Orange – Vaal (18,9 x 10^6 m^3/a).
(4) Includes thermal powerstations (0), major industries (0), mines (0) and other bulk users.
(5) At outlet of WMA. Totals from Table 5.2.4.1.
Lesotho totals 1 025,2 x 10^6 m^3/a and 171,4 x 10^6 m^3/a respectively.
(6) Lesotho is upstream of the WMA, requirements estimated for:
urban (19,9 x 10^6 m^3/a), rural (17,0 x 10^6 m^3/a), livestock and game (19,2 x 10^6 m^3/a), irrigation (33,4 x 10^6 m^3/a), ecological reserve (1 025,2x 10^6 m^3/a), and alien vegetation (0,7 x 10^6 m^3/a).
(7) Most of this water is available to downstream users.

TABLE 5.1.2: WATER REQUIREMENTS PER USER GROUP FOR KEY AREAS AND PROVINCE AT 1:50 YEAR ASSURANCE#.

CATCHMENT						USERS								
PRIMARY		SECONDARY		TERTIARY		DOMESTIC USERS(1) (10^6m^3)		BULK USERS(2) ($10^6m^3/a$)	AGRICULTURAL USERS ($10^6m^3/a$)		AFFOREST-ATION ($10^6m^3/a$)	ALIEN VEGETATION ($10^6m^3/a$)	WATER TRANSFERS(3) ($10^6m^3/a$)	HYDRO-POWER ($10^6m^3/a$)
No.	Description	No.	Description	No.	Key Area Description	Urban	Rural		Irrigation	Livestock				
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	1,8	0,1	0,0	27,5	2,8	0,0	0,0	0,0	0,0
			Riet	C51	Riet (C51K)	2,4	0,1	0,0	118,4	0,9	0,0	0,0	0,0	0,0
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	5,1	0,3	0,0	51,3	5,3	0,0	0,0	0,0	0,0
			Rustfontein	C52	Rustfontein (C52A)	0,3	0,0	0,0	2,3	0,5	0,0	0,0	11,6	0,0
			Krugersdrift	C52	Krugersdrift (C52B-G)	61,0	0,4	1,9	15,5	2,6	0,0	0,0	0,0	0,0
	Total in Modder/Riet (C) primary catchment					**70,6**	**0,9**	**1,9**	**215,0**	**12,1**	**0,0**	**0,0**	**11,6**	**0,0**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,0	1,2	0,0	0,0	2,1	0,0	0,0	0,0	0,0
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	2,2	5,5	0,0	21,4	12,7	0,0	0,0	0,0	0,0
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	5,2	1,7	0,0	109,7	8,9	0,0	0,0	0,0	0,0
		D2	Caledon – Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	17,0	10,6	0,0	7,2	3,1	0,0	0,0	0,0	0,0
			Caledon – RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	5,0	0,5	0,0	11,6	3,1	0,0	0,0	0,0	0,0
			Welbedacht – Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	1,6	2,4	0,0	4,8	1,2	0,0	0,0	0,0	0,0
			Welbedacht – RSA	D23-D24	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	1,3	0,2	0,0	33,0	3,2	0,0	0,0	39,8	0,0
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	1,2	0,1	0,0	36,1	2,0	0,0	0,0	0,0	0,0
		D3	Gariep	D35	Gariep (D35A-K)	1,6	0,1	0,0	14,3	1,2	0,0	0,0	550,0	2 635,0
			Vanderkloof	D31,32,34	Vanderkloof (D31A-E, D32A-K, D34A-G)	2,5	0,1	0,0	51,7	3,1	0,0	0,0	70,7	2 355,0
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	1,0	0,1	0,0	171,6	1,5	0,0	0,0	18,9	0,0
	Total in Upper Orange (D) primary catchment					**38,6**	**22,5**	**0,0**	**461,4**	**42,1**	**0,0**	**0,0**	**679,4**	**4 990,0**
Total in Lesotho in D primary catchments						**[20,8]**	**[19,7]**	**[0,0]**	**[33,4]**	**[19,1]**	**[0,0]**	**[0,0]**	**[0,0]**	**[0,0]**
Total in Free State in C and D primary catchments						**80,3**	**2,3**	**1,9**	**430,8**	**23,0**	**0,0**	**0,0**	**361,8**	**2 495,0**
Total in Northern Cape in C and D primary catchments						**2,9**	**0,0**	**0,0**	**105,5**	**8,6**	**0,0**	**0,0**	**54,2**	**1 178,0**
Total in Eastern Cape in D primary catchment						**5,2**	**1,4**	**0,0**	**106,7**	**3,5**	**0,0**	**0,0**	**275,0**	**1 317,0**
TOTAL IN WMA (South Africa only)						**88,4**	**3,7**	**1,9**	**643,0**	**35,1**	**0,0**	**0,0**	**691,0**	**4 990,0**

Note: # 50 year assurance data from DWAF spreadsheet .
* Quaternary area within Lesotho and RSA.
(1) Includes indirect urban requirements.
(2) Includes thermal power stations (0), major industries (0), mines (0) and other bulk users.
(3) Only potable water transfers out of key areas or provinces given, if a river is a provincial border then transfers from the river is divided equally between provinces.

5.2 ECOLOGICAL COMPONENT OF 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 instream 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 this WMA fall within certain Desktop Reserve Parameter Regions as shown below:

Catchment	Desktop Reserve Parameter Regions
C51, C52	8
D11	13
D12	8, 9 and 11
D13	8, 9 and 11
D14	8 and 11
D15	11 and 20
D16	13
D17	13 and 20
D18	9, 11 and 13
D21, D22 and D23	20
D24	8 and 20
D31	8 and 11
D32	8
D33	4, 8 and 11
D34, D35	8 and 11

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

Indications are that the management and other indices (classes) produced, given the limitations of this procedure, represent a relatively accurate picture of the ecological state of the analysed rivers.

The vast majority of quaternary catchments analysed generated C management classes, i.e moderately modified aquatic ecosystems that will require 20-40% MAR. Bearing in mind that assessments were only done at quaternary catchment outlets, there are no A class rivers and only about 15% were designated as B class. This points to the relatively poor state of aquatic ecosystems.

5.2.4 Presentation of results

Table 5.2.4.1 shows the results for key points. Note that the key points considered coincide with catchment or sub-catchment outlets, or with the other specific criteria adopted for the WMA and that the key points shown are at the outlets of the key areas from the list given in **Chapter 7** (**Table 7.2.1**). Note also that there can be intra-quaternary catchment variation in class and state, so there may be intra-tertiary or intra-key point variation. The quaternary information for present ecological status class is contained in **Appendix F.1**.

The water requirements for the Ecological Component of the Reserve are summarised for the key points for the key areas in **Table 5.2.4.1** and **Figure 5.2.4.1**.

TABLE 5.2.4.1: WATER REQUIREMENT FOR ECOLOGICAL COMPONENT OF THE RESERVE.

KEY POINT	PRESENT ECOLOGICAL STATUS CLASS(PESC)	ECOLOGICAL WATER REQUIREMENTSFOR PESC		
		% VIRGIN MAR	VOLUME (m^3 x 10^6/a)	IMPACT ON EXISTING YIELD AS 1:50 YEAR YIELD (m^3 x 10^6/a)
Katse Dam (D11K)	C[A1]	22,7	174,1	16,3
Senqu (D18L)	C	23,4	759,3	151,3
Orange u/s Gariep (D14K)	D	16,5	157,8	185,7
Caledon – SA (D22L)	D	12,8	43,6	3,7
Caledon – Lesotho (D22L)	D	12,8	82,6	3,7
Welbedacht RSA (D24C)	D	11,7	23,1	0 (-0,8)
Welbedacht – Lesotho (D23G)	D	8,6	9,2	0,1
Caledon d/s Welbedacht (D24L)	B	20,7	23,2	0 (-2,1)
Gariep (D35K)	E-F (use default D)	15,6	10,0	265,7
Vanderkloof (D31E)	E-F (use default D)	15,3	18,2	291,0
Orange D/S Vanderkloof (D33K)	D	15,0	3,1	0 (-594,8)
Rustfontein (C52A)	C	10,7	3,3	0,9
Krugersdrift (C52G)	C	11,0	12,6	1,9
Kalkfontein (C51J)	C	11,0	26,4	8,4
Riet (C51K)	C	7,4	0,3	0,0
Riet/Modder confluence (C51M)	C	11,0	2,0	0,0

Note: (-) Negative values for Reserve taken as zero.

5.2.5 Discussion and Conclusions

With regard to limitations of the results, Kleynhans (Kleynhans, CJ, 1999) has provided the following comments:

- An aspect that has become glaringly obvious is the paucity of knowledge on many of South Africa’s rivers. While the regional experts were able to supply useful input on many river systems, there were also many systems that had little or no published ecological data and were not familiar to the relevant regional experts. There is a need therefore, to provide some sort of forum for the continual updating of the information and data.

- The database and data needs to be modified as and when additional (research) information becomes available. An allowance, to a certain extent, is made for this by Kleynhans’s (Kleynhans, CJ, 1999) assertion that “...it can be expected and considered mandatory that the information required for the determination of the ecological component of the Reserve under these situations should improve in confidence and detail compared to that of the desktop estimate, e.g. in all probability information beyond desktop level will be required.”

- Related to the above point, it would be useful if there could be some sort of linkage between quaternary confidence ratings and the generation of the various indices. It became apparent, during the regional workshops, that the difference in assessment expertise and experience between the regional experts needed to be levelled. Confidence ratings perhaps need to play a greater role in determining a particular management class. At present they are merely recorded in the EcoInfo Programme, and their relative importance have perhaps been understated. A role for confidence ratings within the algorithmic sequences of means and medians that Kleynhans (Kleynhans, CJ, 1999) developed to determine the quaternary management classes should be investigated, particularly for any future versions of this procedure.

This procedure for the determination of the ecological Reserve for the WSAM constitutes a solid, workable foundation that may provide a springboard for the development of other procedures, for instance for the rapid determination method. Although general and conservative in nature, it does provide a synthesis of flow related (ecological) data and a means for providing a general estimate of ecological flow requirements.

5.3 URBAN AND RURAL

5.3.1 Introduction

Since political change occurred in 1994 and with the new National Water Act, 1998 (Act No. 36 of 1998) in place, new considerations emerged in urban and rural water use and return flows. About 1 200 new water service systems have been augmented based on the Reconstruction and Development Program (RDP). Although some of these new trends have not actually been implemented yet, it can be stated that the demand for water in urbanised areas is generated mainly by the following criteria:

- Population growth.
- Price of water development and services.
- Technological choices based on the socio-economic situation of various water users.
- Climate.

There are many other variables such as mandatory restrictions, water use legislation, subsidies, etc., which can significantly influence the demand for water, however, all these factors are of a secondary nature.

The reconciliation of water requirements generated primarily by the growth in population, urbanisation and technology changes with available water resources is an essential component of any planning process.

In general the development and management of regional water resources in this WMA over the last four decades were influenced by political decisions with the result that the industrial and mining sectors tended to receive priority.

The result is well developed water supply infrastructure in certain areas that are managed by large public and private water providers e.g. municipalities, water boards etc. In the rural areas the only real development is related to farming. As a result, the development of rural, semi-urban and even some small urban community water supply was lacking. This situation in the 1990's has been aggravated by the influx of the rural population into the vicinity of formal urban settlements resulting in numerous informal settlements without water supply and sanitation facilities.

Table 5.3.1 summarises the urban and rural domestic water requirements for key areas.

TABLE 5.3.1: 1995 URBAN AND RURAL DOMESTIC WATER REQUIREMENTS.

CATCHMENT						URBAN (1) (10^6 m^3/a)	RURAL (1) (10^6 m^3/a)	TOTAL (10^6 m^3/a)	1:50 YEAR ASSURANCE (10^6 m^3/a)	HUMAN RESERVE (10^6 m^3/a)
PRIMARY		SECONDARY		TERTIARY						
No.	Description	No.	Description	No.	Key Area Description					
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	1,7	0,1	1,8	1,9	0,31
			Riet	C51	Riet (C51K)	2,3	0,1	2,4	2,5	0,18
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	5,0	0,3	5,3	5,4	0,69
			Rustfontein	C52	Rustfontein (C52A)	0,3	0,0	0,3	0,3	0,09
			Krugersdrift	C52	Krugersdrift (C52B-G)	59,3	0,4	59,7	61,4	5,86
	Total in Modder / Riet (C) primary catchment					**68,6**	**0,9**	**69,5**	**71,5**	**7,13**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,0	1,1	1,1	1,2	1,22
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	2,1	4,7	6,8	7,7	4,85
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	5,1	1,6	6,7	6,9	2,04
		D2	Caledon – Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	16,3	8,9	25,2	27,6	9,90
			Caledon – RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	4,7	0,4	5,1	5,5	0,97
			Welbedacht- Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	1,5	2,3	3,8	4,0	2,30
			Welbedacht- RSA	D23-D24	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	1,2	0,2	1,4	1,5	0,30
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	1,1	0,1	1,2	1,3	0,14
		D3	Gariep	D35	Gariep (D35A-K)	1,6	0,1	1,7	1,7	0,18
			Vanderkloof	D31, 32, 34	Vanderkloof (D31A-E, D32A-K, D34A-G)	2,4	0,1	2,5	2,6	0,37
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	0,9	0,1	1,0	1,1	0,19
	Total in D primary catchment					**36,9**	**19,6**	**56,5**	**61,1**	**22,46**
Total in Lesotho in D primary catchment						**[19,9#]**	**[17,0#]**	**[36,9#]**	**[40,5#]**	**[18,27#]**
Total in Free State in C and D primary catchments						**77,9**	**1,9**	**79,8**	**82,6**	**9,04**
Total in Northern Cape in C and D primary catchments						**2,8**	**0,1**	**2,9**	**2,9**	**0,45**
Total in Eastern Cape in D primary catchment						**4,9**	**1,5**	**6,4**	**6,6**	**1,83**
TOTAL IN WMA (South Africa only)						**85,6**	**3,5**	**89,1**	**92,1**	**11,32**

Note: (1) Includes bulk conveyance and distribution losses within TLCs.

(2) Human reserve is the minimum water requirement of the population, estimated at 25 ℓ/capita/day (DWAF criterion).

Lesotho requirements are estimates only.

* Quaternary area within Lesotho and RSA.

5.3.2 Urban

Introduction

Even though most of the population in this WMA is urbanised this WMA is not heavily urbanised. Most urbanisation has taken place in the vicinity of Bloemfontein. The bulk of potable water is delivered by Bloem Water and is sold to local councils and subsequently to the end users for residential, municipal and commercial purposes. The end users vary significantly in size of water use and technological level of water utilisation. Some urban centres in this WMA are abstracting water from local sources, e.g. Aliwal North from the Orange River.

A study by Schlemmer (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 and indirect use by the commercial, industrial, institutional and municipal sectors that relate to the direct use.

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 (**Table 5.3.2.1**). The populations of the urban centres that had been determined were allocated to these categories by Schlemmer (Schlemmer, et al, 2001), on the basis of socio-economic category characteristics of each centre. Refer to **Section 3.2** and **Appendix A.1** for details of urban demographic data.

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/capita/day)
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

These default categories of estimated unit water use were reviewed by the situation assessment consultants and adjusted if information for 1995 was available. Generally data of total urban usage (excluding losses) was available. Refer to **Section 5.3.3** for details regarding sources of urban data. This urban usage data was used to override the default data.

Table 5.3.2.2 summarises the direct water use 'pattern' for the different residential categories within key areas and **Appendix F.**8 lists per capita water use for all TLC's. The water use pattern for the Modder / Riet sub-area of the WMA is almost the same as the national default water pattern. The water use pattern for the Upper Orange sub-catchment of the WMA is generally 20 % higher than the national default water pattern.

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 5.3.2.3**.

TABLE 5.3.2.2: DIRECT WATER USE: ESTIMATED UNIT WATER USE FOR RESIDENTIAL CATEGORIES FOR KEY AREAS.

Key area	Res_Cat 1 Water use (ℓ/ c / d)	Res_Cat 2 Water use (ℓ/ c / d	Res_Cat 3 Water use (ℓ/ c / d	Res_Cat 4 Water use (ℓ/ c / d	Res_Cat 5 Water use (ℓ/ c / d	Res_Cat 6 Water use (ℓ/ c / d	Res_Cat 7 Water use (ℓ/ c / d
Modder / Riet sub-catchment :							
Kalkfontein	303,2	303,2	151,6	85,4	9,6	5,8	85,4
Riet	379,5	379,5	189,5	107	11,5	7,5	107
Riet/Modder	301	301	150	85	9	6	85
Rustfontein	179	179	89	50	6	3	50
Krugersdrift	397,1	397,1	198,6	111,8	12,4	7,4	111,8
Average for sub-catchment :	**312**	**312**	**156**	**112**	**12**	**7**	**112**
Senqu				44			
Orange u/s Gariep	293,5	293,5	146,5	82,4	9,1	5,5	82,4
Caledon – Lesotho				60			
Caledon – RSA	303,7	303,7	151,8	85,3	9,5	5,3	85,3
Welbedacht – Lesotho				40			
Welbedacht – RSA	504,2	504,2	252,2	142	15,8	9,4	142
Caledon d/s Welbedacht	545	545	272	153	17	10	153
Gariep	422,5	422,5	211,25	118,75	13,25	7,75	118,75
Vanderkloof	318,8	318,8	159,2	89,5	10,0	6,0	89,5
Orange d/s Vanderkloof	282,0	282,0	141,0	79,3	8,7	5,3	79,3
Upper Orange average usage	**381**	**381**	**191**	**89**	**12**	**7**	**107**
Default usage	**320**	**320**	**160**	**90**	**10**	**6**	**90**

TABLE 5.3.2.3: 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 by the DWAF on the basis of available information for these classes, and are given in **Table 5.3.2.4**. Water use information for the various categories of indirect water use was generally not available. The recommended ‘pattern’ of indirect use was not adjusted in the urban sub-model.

TABLE 5.3.2.4: INDIRECT WATER USE AS A COMPONENT OF TOTAL DIRECT WATER USE.

URBAN CENTRE CLASSIFICATION	COMMERCIAL	INDUSTRIAL	INSTITUTIONAL	MUNICIPAL
Metropolitan	0,2	0,3	0,15	0,08
Cities	0,2	0,3	0,15	0,08
Towns Industrial	0,2	0,3	0,15	0,08
Towns Isolated	0,2	0,3	0,15	0,08
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

However for most urban centre there was generally information about total indirect water use. Where applicable this total figure over-rides the default indirect total in the urban sub-model but the pattern of usage by the various indirect categories remained as given in **Table 5.3.2.4**.

The ratio of direct to indirect water usage is different depending on the classification of the urban centre. Generally large TLCs and MLCs have a ratio of 58 % direct usage to 42 % indirect usage. Smaller TLC’s have a ratio of 72 % direct usage to 28 % indirect usage.

Appendix F.8 provides direct – indirect water use ratio details for all urban centres.

Unaccounted for Water Use: In most urban water systems the total bulk water supplied is generally well documented and is often the more reliable measurement of water used by a TLC. The difference between metered water and bulk water supplied is generally referred to as unaccounted-for-water and is made up of physical leakages within the water distribution system and in some situations also of un-metered or under-metered water. unaccounted for water is has been treated as a component of direct and indirect urban water requirements.

In the Upper Orange WMA unaccounted for water can be significant in the larger TLCs and MLCs. Unaccounted for water is estimated to range from 15 % to 25 % (Barta, 2000).

Water losses

Water losses in urban areas can be divided into two components:

- **Bulk conveyance losses**

Bulk supply losses consist of purification and transmission losses. Purification losses in this WMA are affected by high turbidities caused by the silt content in many of the rivers in this WMA. Purification losses range from 3% to 12% (Bloem Water, 1999). Transmission losses can be in the order of 3% to 6% of bulk water supplied.

The main bulk water supplier is Bloem Water and bulk water losses within the supply area range from 9,5% to 16,5% (Bloem Water, 1999).

For towns that supply their own bulk water little information is available. These losses are estimated to range from about 5% (in the case of TLCs without water treatment works) to about 8 % (in the case of the average TLC that has both purification losses (about 3%) and transmission losses (about 5%). The range of bulk water losses in this WMA are listed in Table **5.3.2.5**.

TABLE 5.3.2.5: LOSSES BY BULK WATER SUPPLIERS.

Bulk Water supplier	Purification losses (%)	Transmission losses (%)	Total losses (%)
Bloem Water:			
Welbedacht Dam	8 to 10 %	6,5 %	14,5 to 16,5 %
Groothoek Dam	8 to 10 %	6,5 %	14,5 to 16,5 %
Rustfontein Dam	3 %	6,5 %	9,5 %
Gariep Dam	5 %	6 %	10 %
TLC's that supply themselves (treatment works)	3 %	5 %	8 %
TLC's (no treatment works)	0 %	5 %	5 %

- **Losses in the water distribution system of an urban area**

Within the water distribution system of an urban area, there are losses associated with the distribution of water (unavoidable, estimated at 10 %) and losses that are caused by the maintenance of the distribution infrastructure (pipes and reservoirs). In many cases the poor maintenance of infrastructure results in significant losses.

Information about distribution losses is not readily available and in many instances the DWAF recommended default of 20% had to be applied. In the Upper Orange WMA the distribution losses can range from about 5% (Fauresmith TLC) to 25% (Smithfield, Noupoort).

Return Flow

The evaluation of return flows to determine consumptive uses is a critical component of the urban water cycle. The return flows from urban areas can be divided into three categories:

- Effluent return flows from direct users (residential) and indirect users (municipal, industrial, etc).
- Return flows due to leakage of clean water.
- Stormwater returns.

Effluent Return flows

The return flows from urban water systems can manifest in two distinct ways:

- As wastewater (effluent) concentrated by means of waterborne sewage that is treated and released into the surface river network. Effluent generated from residential and industrial areas is directly proportional to the water used. The water returned is further dependent on the standard of living of an area (level of sewage service) and the type of industries.

- As wastewater diffused locally by means of pit toilets (eg. Loflos, aquaprivies, etc), septic tanks / french drains, or more complex methods such as soil bucket systems or disposal via evaporation from oxidation ponds.

In South Africa wastewater is often regarded as a supplementary source of water. The return flows generated from the urban water service systems in the Bloemfontein, Botshabelo and Thaba Nchu TLC's, supplement the base flow of the Modder River, thus benefiting all downstream users. Urban return flows in the Upper Orange sub-catchment of the WMA are insignificant.

Although concentrated treated waterborne sewage is gradually increasing, vast amounts of diffuse untreated effluent are still released locally. Previous research has shown that some 16 % of total urban water supply is diffused annually (Barta, 1993). This water is generally untreated and is polluting to a large extent the local groundwater and surface water resources.

The return flows generated in the urban water services systems are commonly metered by the water services authorities for its quality and quantity. The sewage flows are measured both before and after treatment so that any stormwater ingress during the summer season can be identified. The actual return flows metered after treatment include this amount of stormwater.

The proportion of urban water that does not contribute to effluent returns is a function of the sewage infrastructure within the various urban categories. Default consumption factors for direct and indirect urban usage were defined by the DWAF and are listed in **Table 5.3.2.6**.

These factors had to adjusted (calibrated) in the following circumstances:

- For urban centres with no known returns these factors were all increased to 1,0 reflecting that consumption or usage is 100%. The smaller TLC's generally fell into this category. Many of these TLC's have some sewerage infrastructure but effluent is returned to evaporation ponds and in some cases re-used as irrigation for sports fields and parks.

- For a number of the urban centres the 1995 sewage returns were known. The sewage generated using the default consumption factors was reviewed against the known sewage. If the generated figure was within about 10% of the known figure the consumption factors were not adjusted. If adjustment was required the following calibration procedure was followed:

    1. The consumption factor for residential category four was adjusted. This category is defined as having no to minimal sewage infrastructure. For Ficksburg and Ladybrand TLC and Maseru and Leribe this factor was adjusted upwards from 0,8 to factors of 0,85 to 1,0 (no sewage system). For Smithfield TLC this factor was reduced indicating the presence of a more adequate sewage system.

    2. If further adjustments were required the industrial consumption factor was adjusted. This adjustment was considered acceptable because some industries do not return water to the system but rather to evaporation ponds.

    3. For Koffiefontein and Jacobsdal TLC'S adjustments to other consumption factors was required. This was caused because the two TLC's have different consumption patterns that had to be combined. There are no known returns from Jacobsdal TLC but Koffiefontein TLC does return treated effluent to the Riet River.

TABLE 5.3.2.6: DWAF DEFAULT CONSUMPTION FACTORS FOR URBAN WATER USERS.

CATEGORY		CONSUMPTION FACTOR
Direct : 1	Full service : Houses on large erven > 500m^2	0,45
Direct : 2	Full service: Flats, Town Houses, Cluster Houses	0,2
Direct : 3	Full service : Houses on small erven <500m^2	0,35
Direct : 4	Small houses, RDP houses and shanties with water connection but minimal or no sewage service	0,8
Direct : 5	Informal houses and shanties with service by communal tap only, no sewage service	1,0
Direct : 6	No service from any water distribution system	1,0
Direct : 7	Other/Miscellaneous	0,5
Industrial	Full service	0,15
Commercial	Full service; sewage service dependent on toxicity of returns.	0,4
Institutional	Full service	0,1
Municipal	No sewage service	1,0

Appendix F.8 lists the consumption factors for all urban centres. **Table 5.3.2.7** summarises urban requirements for the key areas of this WMA. Total urban effluent returns for 1995 are estimated at about 25,6 x $10^6 m^3$.

Return flow due to leakage of clean water

Return flow due to leakage of clean water arises from distribution losses together with seepage from private and municipal watering (irrigation) that finds its way to streams in the area. Clean returns are expected in urban areas with high unaccounted-for-water and which are located near streams.

Due to the semi-arid nature of this WMA it is assumed that there are no significant clean returns.

Stormwater returns

Additional rainfall runoff is created due to the impervious areas created in urban areas. On average one eighth of the urban areas in the WMA are effectively paved and it is assumed that 84% of rain falling on these areas runs off into the river system. (WR90 values). **Appendix D.2** lists the urbanised centres and the area urbanised (km^2). The impervious area in the WMA is about 356 km^2 and the return flow generated from these areas in 1995 is 17,7 x$10^6 m^3$.

It should be noted that most sewage works are designed to receive 115% of known returns (BKS, 1999). This over-design is to accommodate the ingress of stormwater into the sewerage system during the rainy season.

Table 5.3.2.7 gives the urban water requirements, losses and return flow information per key area.

Sources of data

In order to calculate urban water use to the required level of detail, it was necessary to obtain information from the relevant water supply authorities, e.g. Transitional Local Councils (TLC's), Water Boards etc. A number of TLC's were selected by Markdata and were surveyed by the Situation Assessment Consultant. The survey was done by means of a questionnaire and supplemented by personal communication via telephone and telefax.

All TLC's were taken to be totally within whichever quaternary the majority of the TLC is located.

Other sources of information were also investigated such as municipal yearbooks and existing reports. Various problems were experienced with all the sources of information. It was difficult to obtain the level of detail required, it was difficult to compare information from different sources due to different dates of records and other conceptual differences and there was also a lack of co-operation from some information sources. About 70% of the questionnaires were eventually returned and of these 20% could not be used. Information on waterborne influent and effluent were obtained directly from the TLC's.

Additional information was obtained from the Vaal River System Analysis (BKS et al, 1998d,e,f) reports, from the Orange River Development Project Replanning Study (BKS, 1991 through to BKS, 1997s) reports and situation assessment reports, e.g. DWAF report for Modder and Riet Rivers (Ninham Shand, 1999b).

From the information obtained from the various sources, data for parameters related to urban water use and return flow were estimated for all urban centres in this WMA

TABLE 5.3.2.7: 1995 URBAN WATER REQUIREMENTS BY KEY AREA AND PROVINCE.

CATCHMENT – PRIMARY No.	PRIMARY Desc-ription	SECONDARY No.	SECONDARY Description	TERTIARY No.	TERTIARY Key Area Description	URBAN WATER REQUIREMENTS: DIRECT (10^6 m^3/a)	URBAN WATER REQUIREMENTS: INDIRECT (10^6 m^3/a)	LOSSES: BULK CONVETANCE LOSSES (%)	LOSSES: DISTRI-BUTION LOSSES (%)	LOSSES: TOTAL LOSSES (10^6 m^3/a)	TOTALS: TOTAL (10^6 m^3/a)	TOTALS: TOTAL AT 1:50 YR ASSURANCE (10^6 m^3/a)	RETURN FLOWS: EFFLUENT (10^6 m^3/a)	RETURN FLOWS: IMPERV-IOUS URBAN AREA (10^6 m^3/a)	RETURN FLOWS: TOTAL RETURN FLOW (10^6 m^3/a)	RETURN FLOWS: RETURN FLOW AT 1:50 YR ASSURANCE (10^6 m^3/a)
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	0,9	0,3	8 to 12	5 to 25	0,5	1,7	1,8	0	0	0	0
			Riet	C51	Riet (C51K)	0,9	0,8	8	20	0,6	2,3	2,4	0,6	0	0,6	0,6
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	2,5	1,0	5 to 13	18 to 20	1,5	5,0	5,1	0	1,3	1,3	1,3
			Rustfontein	C52	Rustfontein (C52A)	0,16	0,06	7	7	0,04	0,3	0,3	0	0	0	0
			Krugersdrift	C52	Krugersdrift (C52B-G)	26,5	15,2	8 to 16,5	8 to20	17,6	59,3	61,0	24,0	15,9	39,9	39,9
	Total in Modder / Riet (C) primary catchment					**31,0**	**17,3**	**5 to 16,5**	**5 to 25**	**20,3**	**68,6**	**70,6**	**24,6**	**17,2**	**41,8**	**41,8**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,0	0,0	n/a	n/a	0,0	0,0	0,0	0	0	0	0
			Senqu	D15-18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	1,6	0,0	5	20	0,5	2,1	2,2	0	0	0	0
			Orange u/s Gariep	D12-14	Orange (D12A-F, D13A-M, D14A-K)	2,6	1,4	5 to 8	8 to 20	1,1	5,1	5,2	0	0	0	0
		D2	Caledon – Lesotho	D21-22	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	11,9	0,0	5 to 8	20	4,4	16,3	17,0	1,2	0,7	1,9	1,9
			Caledon – RSA	D21-22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	2,4	1,1	8	9 to 20	1,2	4,7	5,0	0,9	0,5	1,4	1,4
			Welbedacht – Lesotho	D23-24	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	1,1	0,0	5	20	0,4	1,5	1,6	0	0	0	0
			Welbedacht – RSA	D23-D24	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	0,6	0,2	8 to 16,5	15 to 20	0,4	1,2	1,3	0	0	0	0
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	0,6	0,2	8	17 to 24	0,3	1,1	1,2	0,1	0	0,1	0,1
		D3	Gariep	D35	Gariep (D35A-K)	0,8	0,3	5 to 11	15 to 20	0,5	1,6	1,6	0	0	0	0
			Vanderkloof	D31,32,34	Vanderkloof (D31A-E, D32A-K, D34A-G)	1,2	0,7	5 to 8	10 to 25	0,5	2,4	2,5	0	0	0	0
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	0,4	0,2	8	20	0,3	0,9	1,0	0	0	0	0
	Total in D primary catchment					**23,2**	**4,1**	**5 to 16,5**	**8 to 25**	**9,6**	**36,9**	**38,6**	**2,2**	**1,2**	**3,4**	**3,4**
Total in Lesotho in D primary catchment						**[14,6#]**	**[0,0#]**	**[5 to 8#]**	**[18 to 20#]**	**[5,3#]**	**[19,9#]**	**[20,8#]**	**[1,2#]**	**[0,7#]**	**[1,9#]**	**[1,9#]**
Total in Free State in C and D primary catchments						**35,7**	**19,3**	**5 to 16,5**	**5 to 25**	**22,8**	**77,8**	**80,3**	**25,6**	**17,7**	**43,3**	**43,3**
Total in Northern Cape in C and D primary catchments						**1,4**	**0,7**	**5 to 8**	**10 to 25**	**0,7**	**2,8**	**2,9**	**0,0**	**0,0**	**0,0**	**0,0**
Total in Eastern Cape in D primary catchment						**2,5**	**1,4**	**5 to 8**	**8 to 20**	**1,1**	**5,0**	**5,2**	**0,0**	**0,0**	**0,0**	**0,0**
TOTAL IN WMA (South Africa only)						**39,6**	**21,4**	**5 to 16,5**	**5 to 25**	**24,6**	**85,6**	**88,4**	**25,6**	**17,7**	**43,3**	**43,3**

Note: * Quaternary area within Lesotho and RSA
Lesotho requirements are estimates only.

5.3.3 Rural

Rural usage can be categorised into domestic rural use, livestock watering and subsistence irrigation. The rural domestic water requirements are relatively insignificant in this WMA. This is not the case in Lesotho. There is no known significant subsistence irrigation in the WMA.

Water Requirements

Domestic rural water requirements

There was little information available on the 1995 rural domestic requirements in this WMA. There is no significant rural infrastructure in the WMA. The usage is estimated to be 25 ℓ/capita/day. **Section 3.2.4** has information on the rural population in the WMA. **Table 5.3.3.1** summarises the daily rural domestic usage for various rural categories and **Table 5.3.3.2** summarises the rural domestic usage for key areas for 1995 and at 1: 50 year assurance.

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

USER CATEGORY	UNIT WATER REQUIREMENTS			
	Direct use (ℓ/capita/d)	Distribution losses (%)		Total (ℓ/capita/d
		(%)	(ℓ/capita/d)	
Rural	25	20	6,2	31,2
Advanced rural	25	20	6,2	31,2
Developing urban	25	20	6,2	31,2
Commercial farming	25	20	6,2	31,2

Note: DWAF defaults used, no other information available.

TABLE 5.3.3.2: 1995 RURAL WATER REQUIREMENTS BY KEY AREA.

CATCHMENT						RURAL WATER REQUIREMENT ($m^3 \times 10^6/a$)					LOSSES #		TOTALS		RETURN FLOW	
PRIMARY		SECONDARY		TERTIARY		DOMESTIC (10^6 m^3/a)	RURAL PER CAPITA (ℓ/cap/day)	SUBS. IRR. (10^6 m^3/a)	LIVESTOCK AND GAME (10^6 m^3/a)	TOTAL (10^6 m^3/a)	(%)	(10^6 m^3/a)	TOTAL (10^6 m^3/a)	TOTAL AT 1:50 ASSURANCE (10^6 m^3/a)	RETURN FLOW (10^6 m^3/a)	RETURN FLOW AT 1:50 ASSURANCE (1) (10^6 m^3/a)
No.	Description	No.	Description	No.	Key Area Description											
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	0,1	31	0,0	2,2	2,3	20	0,6	2,9	2,9	0	0
			Riet	C51	Riet (C51K)	0,06	31	0,0	0,7	0,8	20	0,2	1,0	1,0	0	0
			Riet/Modder	C51-52	Riet/Modder confluence (C51L-M, C52H-L)	0,2	31	0,0	4,3	4,5	20	1,1	5,6	5,6	0	0
			Rustfontein	C52	Rustfontein (C52A)	0,02	31	0,0	0,35	0,4	20	0,1	0,5	0,5	0	0
			Krugersdrift	C52	Krugersdrift (C52B-G)	0,3	31	0,0	2,15	2,4	20	0,6	3,0	3,0	0	0
	Total in Modder / Riet (C) primary catchment					**0,7**	**31**	**0,0**	**9,7**	**10,4**	**20**	**2,6**	**13,0**	**13,0**	**0,0**	**0,0**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,9	23	0,0	1,7	2,6	20	0,6	3,2	3,2	0	0
			Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	3,8	30	0,0	10,2	14,0	20	3,4	17,4	17,6	0	0
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	1,3	31	0,0	7,2	8,5	20	2,1	10,6	10,6	0	0
		D2	Caledon-Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	7,1	43	0,0	2,6	9,7	20	2,5	12,2	13,3	0	0
			Caledon -RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	0,34	31	0,0	2,5	2,8	20	0,7	3,5	3,5	0	0
			Welbedacht–Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	1,8	35	0,0	0,9	2,7	20	0,7	3,4	3,4	0	0
			Welbedacht-RSA	D23-D24	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	0,15	31	0,0	2,6	2,7	20	0,7	3,4	3,4	0	0
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	0,05	31	0,0	1,6	1,7	20	0,4	2,1	2,1	0	0
		D3	Gariep	D35	Gariep (D35A-K)	0,04	31	0,0	1,0	1,0	20	0,3	1,3	1,3	0	0
			Vanderkloof	D31, 32, 34	Vanderkloof (D31A-E, D32A-K, D34A-G)	0,1	31	0,0	2,6	2,7	20	0,5	3,2	3,2	0	0
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	0,07	31	0,0	1,2	1,3	20	0,3	1,6	1,6	0	0
	Total in Upper Orange (D) primary catchment					**15,6**	**23 to 43**	**0,0**	**34,1**	**49,7**	**20**	**12,2**	**61,9**	**63,2**	**0,0**	**0,0**
Total in Lesotho in D primary catchment						**[13,6]**	**[23 to 43]**	**[0,0]**	**[15,4]**	**[29,0]**	**[20]**	**[7,2]**	**[36,2]**	**[37,5]**	**[0,0]**	**[0,0]**
Total in Free State in C and D primary catchments						**1,5**	**31**	**0,0**	**18,5**	**20,0**	**20**	**5,0**	**25,0**	**25,1**	**0,0**	**0,0**
Total in Northern Cape in C and D primary catchments						**0,1**	**31**	**0,0**	**7,1**	**7,2**	**20**	**1,7**	**8,9**	**9,1**	**0,0**	**0,0**
Total in Eastern Cape in D primary catchment						**1,1**	**31**	**0,0**	**2,8**	**3,9**	**20**	**0,9**	**4,8**	**4,5**	**0,0**	**0,0**
TOTAL IN WMA (only South Africa)						**2,7**	**23 to 43**	**0,0**	**28,4**	**31,1**	**20**	**7,6**	**38,7**	**38,7**	**0,0**	**0,0**

Note: * Quaternary area within Lesotho and RSA.

This loss is applicable to all categories of rural water requirements.

(1) Assurance values estimated from data supplied by the DWAF.

Livestock and game requirements

Livestock and game farming is a relatively small activity within the WMA. The source of water for this activity is derived mainly from boreholes (groundwater) and from small farm dams. **Table 5.3.3.2** summarises the livestock requirements. Livestock water requirements are most significant in the Senqu and the Orange u/s Gariep key areas.

Refer to **Section 3.5.4** and **Appendix F.3** for details about livestock and game species, sources of data and the conversion of livestock species to Equivalent Large Stock Units (ELSU).

The average water use by a ELSU was estimated at 45 ℓ/LSU/day.

Water losses

Information on rural distribution losses for 1995 was not readily available. The recommended default of 20 % (DWAF, default parameters) was applied throughout this WMA. **Tables 5.3.3.1 and 5.3.3.2** summarise rural losses.

Return flow

The return flows generated by rural consumers are negligible and in most cases can be taken as zero.

5.4 BULK WATER USERS

5.4.1 Introduction

This section deals with the water requirements of strategic, industrial and mining bulk water users that have individual bulk water systems, or that receive water directly from water boards, or the DWAF. Industries, power stations and mines supplied with potable water by municipalities are included in urban water requirements.

The bulk water requirements for each bulk water sector are described in terms of the requirement (on-site), the associated conveyance losses and return flows to the Upper Orange WMA.

5.4.2 Strategic

Strategic bulk water users are those that require a high assurance (99,5%) of supply, e.g. Eskom. There are no operational thermal power stations in this WMA.

5.4.3 Mining

Water requirements

The largest mine in the WMA is De Beers Koffiefontein Diamond mine. The water requirements of this mine appears to be supplied by the Koffiefontein TLC and is part of the indirect urban requirement of the TLC.

5.4.4 Other bulk water users

Water requirements

This category includes large and small industrial users, mothballed power stations (water required for maintenance) and small Bloem Water consumers. The assurance of supply for these users ranges from 95 % to 98 % (**Appendix F.9**). For further details on other bulk water users refer to **Section 3.6.3** and **Appendix F.5**.

Bloem Water small consumers are mostly supplied along the Caledon – Bloemfontein pipeline. These users include institutions and domestic users in the Krugersdrift key area. A requirement of 1,8 x $10^6 m^3/a$ was estimated from information provided by Bloem Water.

Water losses

Conveyance losses by other bulk users are in the order of 16,5 % (consumers supplied from Welbedacht Dam).

Return flows

There no known return flows from other bulk users in this WMA.

5.5 NEIGHBOURING STATES

5.5.1 General

Within the Upper Orange catchment is the neighbouring state of Lesotho. Lesotho does not have any water requirements that need to be satisfied as it is situated upstream of the Upper Orange WMA. Lesotho is a "water rich" country that has since 1998, exported water from the Lesotho Highlands Water Project to the Upper Vaal River catchment to supply the "water hungry" industrial heartland of South Africa.

For the purposes of the water balance of the Upper Orange WMA the 1995 water requirements of Lesotho were estimated. The 1995 water requirements for the urban, rural and agricultural sectors in Lesotho are presented in **Tables 5.3.1, 5.3.3.1. and 5.6.2.1** respectively. The data presented represents a first estimate of the water requirements of Lesotho. The overall water requirement estimates for the various sectors are considered to be a fair reflection of the 1995 situation (Ninham Shand, 1996 and 1998; ORRS, 1997), but the population data totals and distributions are not.

5.5.2 Lesotho urban requirements

- Lesotho has been divided into eight districts, which are shown in **Table 5.5.1**. In three districts there is no urbanised population, in the other four districts outside the Maseru district 30 % of the population is urbanised and are all represented in the most significant urban centre of this district. The district of Maseru has a higher urban population that has been divided into two main urban centres.

TABLE 5.5.1: CATCHMENTS, DISTRICTS AND URBAN CENTRES OF LESOTHO.

Catchment	District	Urban centre
Mohokare (Caledon) catchments:		
Upper Mohokare	Upper Mohokare	Butha Buthu
Middle Mohokare	Maseru	Maseru
		Leribe
Lower Mohokare	Maketeng	Maketeng
Senqu (Orange) catchments:		
Upper Senqu	Mokhotlong	No urban centre
Senqunyane	Thaba Tseka	No urban centre
Middle Senqu	Quacha's Nek	No urban centre
Lower Senqu	Quthing	Moyeni
Upper / Lower Makhaleng	Mohales Hoek	Mohales Hoek

Note: District and urban centres from Europa World Year Book, 1998.

- The urban usage consists only of direct (residential) usage and is represented in one residential usage category, namely category 4 of **Table 5.3.2.6**. This category generally has small houses, no paving and poor water supply and sewage infrastructure. Any indirect usage and bulk users are assumed as part of the direct residential usage, due to lack of information about these sectors.

Total urban requirements in 1995 were estimated to be about 19,9 x $10^6 m^3$.

- With the exception of Maseru there are no significant return flows from the urban areas. Urban bulk water transmission losses are set at 5 % and distribution losses within urban areas at 20 % (WSAM defaults).

In 1995, Maseru returned approximately 1,9 x $10^6 m^3$ (sewage and stormwater returns) to the Caledon River (BKS, 1997).

5.5.3 Lesotho rural requirements

- With the exception of Maseru district the rural population ranges from 70 % to 100% in all the other districts. The distribution of the rural population at quaternary catchment level was taken to be proportional to the area of the quaternary within a district. For example if the quaternary catchment area is 15 % of district area the quaternary population is 15 % of the district population etc.
- For three of the Senqu catchments the unit rural water requirement was estimated below the South African human reserve requirement of 25 ℓ/capita/d.
- The livestock distribution and requirements were estimated in similar way. The equivalent large stock unit requirement is set at 45 ℓ/capita/d.

Total rural requirements in 1995 were estimated to be about 36,2 x $10^6 m^3$.

5.5.4 Lesotho agricultural requirements

- While there is some water requirement data for agriculture (for irrigation), there is no information on area irrigated or crops irrigated. The area irrigated was determined using the equivalent requirement per hectare per annum data for the Caledon-SA and Orange u/s Gariep key areas (BKS, 1997ℓ). A mixture of summer crops was selected.

Total irrigation requirements in 1995 were estimated to be about 33,4 x $10^6 m^3$.

5.6 IRRIGATION

5.6.1 Introduction

Irrigation is the most significant user of water in the Upper Orange WMA. There are no large areas of irrigation in Lesotho.

Detailed observed data on water use for irrigation was not available therefore irrigation water requirements were estimated from available information on irrigated areas or reaches, typical quotas and assurances of supply. The sources of information on irrigation water use in this WMA are the Vaal River Irrigation Study (Loxton et al., 1999b) and the Evaluation of Irrigation Water Use (BKS et al., 1997ℓ).

Typical quotas and calculated crop water use data are provided in both studies. **Section 3.5.2** details how irrigated area data was disaggregated to quaternary catchment area data. **Table 5.6.2.1** summarises the irrigation water requirements in 1995 for key areas in the WMA.

Approximately 65 % of the irrigation in this WMA is controlled or scheduled irrigation with water supplied either from Government Water Schemes (GWS), Government Water Control Areas (GWCA) or by Irrigation Boards (IB). In the Modder / Riet sub-catchment about 88 % of irrigation is controlled or scheduled. The remaining 35 % of irrigation is diffuse in nature where water is used for the supplementary irrigation of generally low value crops and secondary enterprises. Sources of water range from permanent reliable surface water to less reliable water sources such as groundwater and small farm dams. This opportunistic irrigation is likely to use less water/ha/a on average. The quotas for scheduled areas adjacent to diffuse areas were extrapolated to these areas.

5.6.2 Water Use Patterns

The water requirement for irrigation was calculated by means of the irrigation pre-processor of the Water Situation Assessment Model and was based on the following well known equation.

IRR(1-CLI) = AIR*(EVT*CRC-REF)*0,001*LER/IRC

Where

IRR:	Irrigation water requirement ($10^6 m^3/a$)
AIR:	Irrigation area (km^2)
EVT:	Evapotranspiration (A-Pan equivalent in mm/m)
CRC:	Crop factor
REF:	Effective rainfall (mm/m)

LER: Leaching factor
IRC: Irrigation efficiency
CLI: Irrigation conveyance loss (Proportion of IRR)

The processor calculates the irrigation water requirement for every crop separately for each of the 12 months, using the appropriate quaternary mean monthly data obtained from the CCWR. This seemingly detailed methodology is essential to eliminate considerable errors that can be made by combining crop factors. The final annual water requirements are then obtained by simple summation of the various crop water requirements.

However a second method has been used to calculate the 1995 irrigation requirement using the quota information for this WMA, from the "Vaal River Irrigation Study" (Loxton et al., 1999b) and from the ORRS irrigation report (BKS et al., 1997ℓ).

The quotas are listed in **Appendix D.1** in the summary table called Irrigation Water Requirements. Two types of quotas were identified in the Vaal River Irrigation Study and are shown in the summary table. They are the typical or guideline quotas, which were used to calculate the average water allocation for an irrigation area and the calculated crop water use, which was used to determine the actual crop water use during 1995.

Assurance of supply for irrigation ranges from 80 % (1 in 5 year assurance) to 98 % (1 in 50 year assurance) and also varies according to value of crop. Higher value crops receive greater assurance of supply in the scheduled irrigation areas.

The irrigation requirement using the typical quotas and field area was 825,1 x 10^6m^3. The actual crop water use in 1995 was 783,1 x 10^6m^3 indicating that 1995 was a dry year in which restrictions of varying severity were applied.

In the case of controlled irrigation, the scheduled area of irrigation is known and the water quota per hectare per annum is known (quota includes conveyance losses). These are multiplied to obtain the annual water requirement for a particular irrigation scheme.

In reality the amount of water transferred is often considerably lower or higher than the actual requirement, this is due to the "priority" of irrigation within a catchment area (often due to water restriction). For example the annual average volume of water released between 1993 to 1999 from the Kalkfontein Dam for the Kalkfontein IB was 18,75 x 10^6m^3/a. This is considerably less than the allocation of 35,5 x 10^6m^3/a and also the calculated crop water use of 24,14 x 10^6m^3/a (DWAF, 1999).

In the Modder River GWS the annual average volume of water released from Rustfontein Dam into the Modder River for irrigation from 1997 to 1999 was 39,29 x 10^6m^3/a. This is considerably more than both the water allocation of 29,65 x 10^6m^3/a and the calculated crop water use of 22,94 x 10^6m^3/a.

Figure 5.6.2.1 shows irrigation water requirements at 1:50 assurance per key area. **Table 5.6.2.1** summarises the 1995 irrigation requirements for all key areas in the WMA. The sources of irrigation water for the various irrigation areas are listed in **Table 5.6.2.2.**

5.6.3 Water losses

Water losses as a result of irrigation can be broken down into two components, both of which are included in the water requirements shown in **Table 5.6.2.2**.

Conveyance losses to field edge

This is the loss (leakage and evaporation) experienced during conveyance of water from the source, (i.e. river, dam or borehole) via canals, dams or pipelines, to the field edge of the area under irrigation. This loss is expressed as a portion of the field edge irrigation water use. Information on conveyance losses was not readily available and have been estimated.

In the Upper Orange WMA conveyance losses are of the order of 10% for run of river abstractions and range from 15 to 30 % for systems with canals and pipelines. System conveyance losses are directly related to the state of repair of irrigation conveyance infrastructure and whether canals are lined or unlined. For example the Orange – Riet transfer canal is concrete lined and well maintained and losses are estimated at 15 % (BKS et al., 1997ℓ). However, the condition of the Modder River GWS canal is poor and losses are estimated at 30% (BKS et al., 1997ℓ). These loss estimates are shown separately in **Table 5.6.2.1**.

Irrigation efficiency

The following irrigation efficiencies are commonly adopted:

- Flood irrigation 65%.
- Sprinkler systems 75%.
- Mechanical systems 80%.
- Micro systems 85%.
- Drip systems 90%.

Where more than one method is used in an area, the efficiencies must be combined to determine an average for the area. The dominant irrigation method in the Modder / Riet sub-catchment (C5 tertiary catchment) of this WMA is mechanical (centre pivot) application while the sprinkler method of application is dominant in the Upper Orange sub-catchment. Average application losses range around 20% to 25 %.

The above losses are included in the field edge requirements and the

Refer to **Section 3.5.2.** and **Table 3.5.2.**1 for more details.

5.6.4 Return flows

Return flows as a result of irrigation can be broken down into two components, namely: leaching beyond the root zone and additional return flow. There was no information on these components in this WMA. Estimated return flows are shown in **Table 5.6.2.1**.

Return flow due to leaching beyond the root zone.

Irrigation water not used by the plant is returned to the groundwater or streams due to leaching and is largely dependent on the soil characteristics and additional leaching water applied because of water quality. Information about leaching applications and these return flows was not readily available therefore a leaching factor of 1,0 resulting in zero return flow from leaching was used throughout the WMA.

TABLE 5.6.2.1: IRRIGATION WATER REQUIREMENTS

CATCHMENT						FIELD EDGE WATER REQUIREMENT	CONVEYANCE LOSSES		TOTAL THEORETICAL WATER REQUIREMENT(1)	TOTAL ACTUAL WATER USE(2)	TOTAL ACTUAL WATER USE AT 1:50 ASSURANCE	RETURN FLOW	RETURN FLOW AT 1:50
PRIMARY		SECONDARY		TERTIARY									
No.	Description	No.	Description	No.	Key Area Description	(10^6 m^3/a) *	(%)	(10^6 m^3/a)	(10^6 m^3/a)	(10^6 m^3/a))	(10^6 m^3/a)	(%)	(10^6 m^3/a)
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	30,0	10	3,0	37,2	33,0	27,5	10	2,8
			Riet	C51	Riet (C51K)	123,5	15	18,5	175,2	142,0	118,4	10	11,8
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	50,8	10 to 30	10,8	73,8	61,6	51,3	0	5,1
			Rustfontein	C52	Rustfontein (C52A)	2,5	10	0,3	2,7	2,8	2,3	0	0
			Krugersdrift	C52	Krugersdrift (C52B-G)	16,9	10	1,7	14,3	18,6	15,5	0	0
	Total in Riet / Modder (C) primary catchment					**223,7**	**10 to 30**	**34,3**	**303,2**	**258,0**	**215,0**	**10**	**19,7**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0	0	0	0	0	0	0	0
			Senqu	D15-D18	Senqu – (D15A-H, D16A-L, D17A-M, D18A-L)	19,3	10	2,1	21,4	21,4	21,4	10	2,1
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	123,4	10	13,7	135,9	137,1	109,7	10	11,0
		D2	Caledon –Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	6,5	10	0,7	7,2	7,2	7,2	10	0,7
			Caledon – RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	12,6	10	1,4	11,6	14,0	11,6	10	1,2
			Welbedacht – Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	4,3	10	0,5	4,8	4,8	4,8	10	0,5
			Welbedacht – RSA	D23-D24	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	35,6	10	4,0	31,0	39,6	33,0	10	3,3
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	38,9	10	4,4	37,1	43,3	36,1	10	3,6
		D3	Gariep	D35	Gariep (D35A-K)	16,1	10	1,8	17,9	17,9	14,3	10	1,4
			Vanderkloof	D31,32 and 34	Vanderkloof (D31A-E, D32A-K, D34A-G)	60,5	10	6,7	76,1	67,2	51,7	10	5,2
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	182,7	10 to 15	23,3	212,3	206,0	171,6	10	17,2
	Total in Upper Orange (D) primary catchment					**499,9**	**10 to 15**	**58,6**	**555,3**	**558,5**	**461,4**	**10**	**46,2**
Total in Lesotho in D primary catchment						**[30,1]**	**[10]**	**[3,3]**	**[33,4]**	**[33,4]**	**[33,4]**	**[10]**	**[3,3]**
Total in Free State in C and D primary catchments						**464,7**	**10 to 30**	**60,0**	**552,8**	**524,7**	**430,8**	**10**	**41,9**
Total in Northern Cape in C and D primary catchments						**113,7**	**10 to 15**	**14,7**	**135,3**	**128,4**	**105,5**	**10**	**10,3**
Total in Eastern Cape in D primary catchment						**115,1**	**10**	**14,9**	**137,0**	**130,0**	**106,7**	**10**	**10,4**
TOTAL IN WMA [South Africa only]						**693,5**	**10 to 30**	**89,6**	**825,1**	**783,1**	**643,0**	**10**	**62,6**

Note : For the C catchment, Vaal River Irrigation Study was used. For the D catchment the ORRS study information was used.

1. Guideline water quotas for Riet Modder from Loxton et al., 1999b and for Orange from BKS et al., 1997ℓ.
2. Calculated crop water use for Riet Modder from Loxton et al., 1999b and for Orange from BKS et al., 1997ℓ.

* Quaternary area within Lesotho and RSA.

TABLE 5.6.2.2: SOURCE OF IRRIGATION WATER

KEY AREA DESCRIPTION	IRRIGATION AREA[(1)]	SOURCE OF IRRIGATION WATER.
Modder / Riet sub-catchment :		
Kalkfontein	Tierpoort IB (controlled)	Tierpoort Dam
	Kalkfontein Irrigation Area (diffuse)	Riet River u/s Kalkfontein Dam
	Tierpoort Irrigation Area (diffuse)	River u/s Tierpoort Dam
Riet	Kalkfontein IB (controlled)	Kalkfontein Dam and Riet River
	Riet River Settlement (Riet River GWS) (controlled)	Vanderkloof Dam (Orange River)
	Orange / Riet Canal (controlled)	Vanderkloof Dam (Orange River)
	Scholtzburg Irrigation Area (controlled)	Vanderkloof Dam (Orange River)
Riet / Modder confluence	Lower Riet River IB (controlled)	Vanderkloof Dam & Riet River
	Ritchie Irrigation Area (controlled)	Vanderkloof Dam & Riet River
	Modder River GWS (controlled)	Krugersdrift Dam & Modder R.
Rustfontein	Rustfontein Dam GWCA (diffuse)	Rustfontein Dam
Krugersdrift	Rustfontein to Krugersdrift Dams (diffuse)	Modder River (including sewage returns)
Caledon sub-catchment :		
Caledon – Lesotho	Caledon – Lesotho (diffuse)	Caledon River
Caledon u/s Welbedacht Dam	Caledon – RSA (controlled)	Welbedacht, Armenia Dams and Caledon River
Caledon d/s Welbedacht Dam	Caledon – RSA (controlled)	Caledon River
Upper Orange sub-catchment :		
Senqu – Lesotho	Senqu (diffuse)	Senqu River
Orange u/s Gariep	U/s Aliwal N & d/s Oranjedraai (controlled & diffuse)	Orange, Kraai and Stormberg Rivers
Gariep	U/s Gariep and d/s Aliwal North (controlled)	Gariep Dam and Orange River
Vanderkloof	U/s Vanderkloof Dam, d/s Gariep Dam	Orange River
Orange d/s Vanderkloof	Vanderkloof / Ramah canals	Vanderkloof Dam & Orange River
	Vanderkloof to Vaalkoppie	Vanderkloof Dam & Orange River
	Boegat to Torquay	Orange River
	Torquay to Orange-Vaal confluence	Orange River

Note: (1) Irrigation areas from Vaal River Irrigation Study, Tables 7.2 / 8.2 (Loxton et al., 1999b) and ORRS, Table 4.2 (BKS et al., 1997ℓ).

Additional return flow

The return flow from irrigation can further increase due to the increased rainfall runoff due to the higher level of soil moisture when compared with the natural state. This increased return flow can be calculated for a seasonal or yearly crop. Based on the climatic conditions and the different crops under irrigation in the WMA the additional return flow generated was estimated to be of the order of 10%. Irrigation returns along the Riet, Caledon and Orange Rivers are considered to add to the available water. Return flows as a result of irrigation are shown in **Table 5.6.2.1**. Any returns in the Modder River upstream of the Krugersdrift Dam are 'used' by diffuse irrigators and therefore do not contribute to the water resource (Basson, MJ, 2000).

5.7 DRYLAND SUGARCANE

There is no dryland sugarcane in this WMA.

5.8 WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

Losses from rivers, wetlands and dams consist primarily of evaporation losses from the river, wetland or dam surface area, but also include seepage losses. The naturalised catchment hydrology often implicitly accounts for channel losses under natural conditions.

Of interest are the additional channel losses that are associated with releases from reservoirs. These losses expressed as incremental losses arising from river regulation (i.e. the additional loss associated with maintaining a fully wetted channel throughout the year). These losses influence the water balance of a system and have to be taken into account in determining releases from dams and the yield of the system.

Regulated river reaches that flow through semi-arid and arid regions can experience substantial transmission losses primarily through the process of evaporation from the water surface. In this WMA, the Orange River from Vanderkloof Dam to the Orange / Vaal River confluence is regarded as regulated. Channel losses along this reach range according to the amount of flow in the Orange River. When the flow is low (60 m^3/s) additional channel losses of 54,4 x $10^6m^3/a$ occur and when the flow is high (400 m^3/s) additional channel losses of 83,3 x $10^6m^3/a$ occur (WRC, 1998).

Total losses from dams, rivers and wetlands range from 630 x $10^6m^3/a$ to 659 x $10^6m^3/a$ of which evaporation from dams and wetlands (>80 %) are the most significant. Information on evaporation losses from dams and wetlands in the WMA was provided by the DWAF. **Table 5.8.**1 summarises the water losses from rivers, wetlands and dams for the key areas.

There is the potential for increased channel losses in the Riet and Modder Rivers, arising from the Novo transfer to the Upper Modder River, which is expected to become operational in 2001. These river losses in the Upper Modder River are expected to be in the order of 15% to 25% (Bloem Water, 1999).

In the absence of information, estimates were based on the potential evapotranspiration loss from free water surfaces and riparian vegetation. Estimates of the incremental losses were based on comparisons of calculated river losses based on naturalised flow sequences with calculated losses assuming a fully wetted channel reach.

TABLE 5.8.1: WATER LOSSES FROM RIVERS, WETLANDS AND DAMS

CATCHMENT						LOSSES FROM RIVERS AND WETLANDS (10^6 m^3/a)	EVAPORATION FROM DAMS (10^6 m^3/a)	TOTAL (10^6 m^3/a)
PRIMARY		SECONDARY		TERTIARY				
No.	Description	No.	Description	No.	Key Area Description			
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	0,0	54,5	54,5
			Riet	C51	Riet (C51K)	0,0	0,8	0,8
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	0,0	1,8	1,8
			Rustfontein	C52	Rustfontein (C52A)	0,0	9,7	9,7
			Krugersdrift	C52	Krugersdrift (C52B-G)	0,0	20,4	20,4
	Total in Modder / Riet (C) primary catchment					**0,0**	**87,2**	**87,2**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,0	0,0	0,0
			Senqu	D15-D18	Senqu –(D15A-H, D16A-L, D17A-M, D18A-L)	0,0	0,6	0,6
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	0,0	14,2	14,2
		D2	Caledon - Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	0,0	0,4	0,4
			Caledon - RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	0,0	1,9	1,9
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	0,0	0,4	0,4
			Welbedacht - RSA	D23-D24	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	0,0	45,5	45,5
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	0,0	5,0	5,0
		D3	Gariep	D35	Gariep (D35A-K)	0,0	280,0	280,0
			Vanderkloof	D31,32,34	Vanderkloof (D31A-E, D32A-K, D34A-G)	0,0	139,1	139,1
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)(1)	69,0	1,2	85,2
	Total in Upper Orange (D) primary catchment					**69,0(1)**	**488,3**	**557,3**
Total in Lesotho in D primary catchment						**[0,0]**	**[1,4]**	**[1,4]**
Total in Free State in C and D primary catchments						**13,8**	**356,3**	**370,1**
Total in Northern Cape in C and D primary catchments						**55,2**	**70,6**	**125,8**
Total in Eastern Cape in D primary catchment						**0,0**	**147,2**	**147,2**
TOTAL IN WMA (South Africa only)						**69,0(1)**	**574,1**	**643,1**

Note: * Quaternary catchment area within Lesotho and RSA.
(1) WRC Report, Evaporation Losses from SA Rivers, 1998. Average losses estimated. Losses range from 54.4 x $10^6 m^3/a$ (flow = 60 m^3/s) to 83,3 x $10^6 m^3/a$ (flow = 400 m^3/s).

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) (Department of Water Affairs and Forestry, 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 afforestation in the incremental catchment on the yield of the catchment.

In terms of overall requirements, the reduction in yield from afforestation is negligible, as this WMA is not really suited to forestry. **Table 5.9.1** summarises the runoff reduction from forestry for key areas.

TABLE 5.91: 1995 WATER USE BY AFFORESTATION.

CATCHMENT						REDUCTION IN RUNOFF		REDUCTION IN YIELD	
PRIMARY		SECONDARY		TERTIARY		(10^6 m^3/a)	(mm/a)	(10^6 m^3/a)	(mm/a)
No.	Description	No.	Description	No.	Key Area Description				
D	Orange	D2	Caledon - RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	0,4	42	0.0	0.0
			Sub-total (Free State)			0,4	42	0.0	0.0
TOTAL IN WMA						**0,4**	**42**	**0.0**	**0.0**

Note. * Quaternary area within Lesotho and RSA.

5.10 HYDROPOWER AND PUMPED STORAGE

There are two hydroelectric stations in the Upper Orange WMA, namely Gariep and Vanderkloof Hydropower Stations. There are no pump storage schemes in this WMA. Details of the 1995 water requirements of the hydropower stations are provided in **Table 5.10.1** and **Appendices F5 and F7**.

Both Gariep and Vanderkloof Hydropower Stations release water through their turbines for other purposes than generating electricity, which is a secondary determinant. The primary determinant is for irrigation requirements. The volume released can vary significantly from one year to the next.

TABLE 5.10.1 : WATER RQUIREMENTS FOR HYDRO-ELECTRIC POWER STATIONS AND PUMP STORAGE SCHEMES.

CHARACTERISTIC	STATION	
	GARIEP	VANDERKLOOF
Quaternary sub-catchment	D35K	D31E
Sources of water	Orange River	Orange River
Peak capacity (generator limitation)	385 MW	255 MW
Load factor	Normally 10%	Normally 10%
Normal water use	2 635 x 10^6 m³/a	2 355 x 10^6 m³/a
Assurance of supply	High 99,5% Med 99,0% Low 95,0%	High 99,5% Med 99,0% Low 95,0%
Evaporation losses	264 x 10^6 m³/a	235 x 10^6 m³/a

Not all hydropower releases may be re-usable downstream because the pattern in which it is released may not suit the requirements of the ecological Reserve or of other users. The unusable portion of the releases is estimated to be 10 % of the volume released from the Vanderkloof hydropower station. Releases from Gariep hydropower station are taken up in the downstream Vanderkloof Dam. Evaporation losses that occur when water is released through the turbines are estimated at 10 % of the water released for the generation of hydropower (DWAF default). **Table 5.10.2** summarises water losses and returns.

TABLE 5.10.2: 1995 HYDRO-POWER WATER LOSSES AND RETURN FLOWS.

SCHEME CHARACTERISTIC	HYDRO-POWER SCHEME	
	GARIEP	VANDERKLOOF
Quaternary catchment	D35K	D31E
Water released	2 635 x $10^6m^{3/}a$	2 355 x $10^6m^{3/}a$
Evaporation	10 %	10 %
Return flow	2 371 x $10^6m^{3/}a$	2 120 x $10^6m^{3/}a$
Unusable return flow	-	212 x $10^6m^{3/}a$
Usable return flow	2 371 x $10^6m^{3/}a$	1 908 x $10^6m^{3/}a$

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.

Table 5.11.1 summarises the 1995 water use by alien vegetation for key areas. Runoff reduction by alien vegetation is insignificant in the WMA.

TABLE 5.11.1: 1995 WATER USE BY ALIEN VEGETATION.

CATCHMENT						AVERAGE REDUCTION IN RUNOFF		REDUCTION IN SYSTEM 1:50 YEAR YIELD	
PRIMARY		SECONDARY		TERTIARY		(10^6 m^3/a)	(mm/a)	(10^6 m^3/a)	(mm/a)
No.	Description	No.	Description	No.	Key Area Description				
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	0,0	0,0	0,0	0,0
			Riet	C51	Riet (C51K)	0,0	0,0	0,0	0,0
			Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	1,0	0,1	0,0	0,0
			Rustfontein	C52	Rustfontein (C52A)	0,0	0,0	0,0	0,0
			Krugersdrift	C52	Krugersdrift (C52B-G)	0,0	0,0	0,0	0,0
	Total in Modder / Riet (C) primary catchment					**1,0**	**0,1**	**0,0**	**0,0**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,1	0,0	0,0	0,0
			Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	0,6	0,0	0,0	0,0
			Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)-	0,0	0,0	0,0	0,0
		D2	Caledon - Lesotho	D21-D23	Caledon (D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*)	0,0	0,0	0,0	0,0
			Caledon - RSA	D21-D22	Caledon (D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H, D22L*)	0,0	0,0	0,0	0,0
			Welbedacht - Lesotho	D23	Welbedacht (D23A*, D23B, D23E*, D23F*, D23G*)	0,0	0,0	0,0	0,0
			Welbedacht - RSA	D23-D24	Welbedacht (D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C)	0,0	0,0	0,0	0,0
			Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	0,0	0,0	0,0	0,0
		D3	Gariep	D35	Gariep (D35A-K)	0,0	0,0	0,0	0,0
			Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	0,1	0,0	0,0	0,0
			Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	0,2	0,0	0,0	0,0
	Total in Upper Orange (D) primary catchment					**1,0**	**0,0**	**0,0**	**0,0**
Total in Lesotho in D primary catchment						**[0,7]**	**[0,0]**	**[0,0]**	**[0,0]**
Total in Free State in C and D primary catchments						**1,0**	**0,1**	**0,0**	**0,0**
Total in Northern Cape in C and D primary catchments						**0,2**	**0,0**	**0,0**	**0,0**
Total in Eastern Cape in D primary catchment						**0,1**	**0,0**	**0,0**	**0,0**
TOTAL IN WMA (South Africa only)						**1,3**	**0,1**	**0,0**	**0,0**

Note. * Quaternary area within Lesotho and RSA.

5.12 WATER CONSERVATION AND WATER DEMAND MANAGEMENT

5.12.1 Introduction

The Department of Water Affairs and Forestry is entrenching and insisting on efficient water management and water 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 Water 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 water 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 water 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 water demand management can be achieved.

This section describes the National Water Conservation and Water 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 water 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 water 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.

Environment

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 10 % of total water use in the Upper Orange WMA. Irrigation losses are often quite significant and it is estimated that often no more than 75% (sprinkler) 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

Afforestation is negligible in the Upper Orange WMA

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, 1997 (Act No. 108 of 1997) and the National Water Act, 1998 (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 Management 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, 1997 (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, 1998 (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 water 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 Africa 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 resources 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 water demand measures

There are a number of categories of water conservation and water 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 water demand management strategy

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

- Create a culture of water conservation and water 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 water 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 water 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 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 water 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.

From analyses of return flows in Gauteng it is concluded that the ratio of return flow to water use is not materially altered by the imposition of water restrictions. In other words, if the supply is reduced by (say) 20%, it can be assumed that the return flow will also be reduced by 20%.

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 ratio of return flow to water use is not materially changed by changes in water use.

The measures implemented during the drought in the mid-1980's 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 Upper Orange WMA

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.

Comprehensive irrigation water demand management, or water conservation strategies and actions were prepared for the Orange River Replanning Study (ORRS) in 1998 based on the conceptual framework and principle of water demand management detailed in a paper published in 1995 (Johnson, 1995).

5.13 WATER ALLOCATIONS

5.13.1 Introduction

In terms of Section 34 of the old Water Act, 1956 (Act No. 54 of 1956), Water Courts were established to apportion water and to determine individual water rights. In order to control the use of water, the Minister, subject to the conditions of various sections of the old Water Act, also issued permits or authorisations to water users.

The various types of allocations made in terms of the old Water Act are summarised below. Allocation information that is readily available is detailed in **Appendix C**.

5.13.2 Allocations and permits which could have been issued under the old Water Act.

Authorisations in terms of Section 9B & 9C of the Water Act

A permit was required for the construction, operation or enlargement of any water work, which will enable more than 110 ℓ/s of water to be abstracted or diverted from a public stream (river). A permit was required for the impoundment on any piece of ground of more than 250 000 m^3 of water from a public stream.

Any dam having a storage capacity greater than 50 000 m^3 and a wall height greater than 5m was deemed to be a dam with a safety risk and no person was allowed to design, construct, operate, alter, enlarge or use such a dam without a permit.

All such dams had to be registered at the Dam Safety Office of DWAF. Data about these dams can be obtained from the Dams Safety Database, DWAF.

Appendix C.1 lists some of the information on dams that was extracted from the Dam Safety database (the volume of information is too great to include it all). No attempt has been made to determine abstractions from these dams, which are not readily available from the database.

Authorisations in terms of Sections 11 and 12 of the old Water Act

Section 11: Use of water for industrial purposes was subject to permission of Water Court, except where water was supplied by a local authority or by the Minister from a Government Water Scheme, or where water was allocated from a Government Water Control Area.

Section 12: If use of water for industrial purposes was greater than 150 m^3 on any one day, a permit of authority was required for the use of the water regardless of the source of the water. This permit had to accompany the application to the Water Court as provided for in Section 11.

Data about these permits can be obtained from the PCPolman database at DWAF. Examples of these types of permits can be found in **Appendix C.2**. No attempt has been made to determine abstractions or discharges for the WMA.

Authorisations in terms of Section 13 of the old Water Act

A local authority requires a permit to construct, alter or enlarge any water work by means of which more than 5 000 m^3/d could be abstracted or diverted from a public stream. Section 13/3 stated that a local authority required a permit to construct, alter or enlarge any water work by means of which more than 125 000 m^3 of public water could be impounded.

Examples of these types of permits can be found in **Appendix C.1** and have been extracted from the Dam Safety database. No attempt has been made to determine abstractions from these dams.

Authorisations in terms of Section 30 (2) of the old Water Act

The Minister can control the abstraction of underground water in a Subterranean Water Control Area (SWCA). There are no known SWCAs in this WMA.

Authorisations in terms of Section 56 (3) of the old Water Act

The Minister may supply water from a Government water work

Authorisations in terms of Section 62 and 63 of the old Water Act

Control of public water in a Government Water Control Area (GWCA) vested in the Minister and no person was allowed to construct, alter, enlarge or use a water work for abstraction except under permit from the Minister. The Minister could allow the abstraction from a Government Water Control Area for irrigation purposes to anyone within or outside the control area.

5.13.3 Water control areas/irrigation boards and irrigation areas in the Upper Orange WMA

There are a number of Government Water Control Areas, irrigation boards and irrigation areas in this WMA, namely:

- Riet River GWS (consisting of the Riet River Settlement, Scholtzburg Irrigation Area, Ritchie Irrigation Area, Orange / Riet Canal Area).
- Rustfontein Dam Catchment GWCA.
- Modder GWS.
- Lower Riet River IB.
- Orange u/s Gariep Dam GWCA.
- Orange d/s Gariep Dam u/s Vanderkloof Dam GWCA.
- Orange d/s Vanderkloof Dam u/s Orange-Vaal Confluence GWCA.
- Caledon u/s Welbedacht Dam GWCA.
- Caledon d/s Welbedacht Dam u/s Gariep Dam GWCA.

5.13.4 Permits and other allocations

Comprehensive and reliable information on permits, authorisations and allocations was not readily available.

A summary of the irrigation scheduling and quotas (Article 63 permits) from Government Water Schemes is provided in **Table 4.3.4**. The Riet River GWS is the largest Government Water Scheme is the Modder / Riet sub-catchment and the Orange d/s Vanderkloof Dam to Orange-Vaal Confluence GWCA is the largest Government Water Control area in the Upper Orange sub-catchment of the WMA.

Data for Section 56 (3) water allocations to other users from Government Water Schemes was provided by the DWAF for the Free State Province in the WMA. Section 56 (3) allocations for key areas in the Eastern Cape and Northern Cape

Provinces are not known. The most significant allocations are for Bloem Water and for the Orange – Fish Transfer. Bloem Water has permits to abstract 168 x 10^6 m^3/a from the Caledon catchment, 44,1 x $10^6 m^3$/a from the Modder catchments and 1,5 x $10^6 m^3$/a from the Orange River.

TABLE 5.13.4.2: ARTICLE 56(3) - ALLOCATIONS FROM GOVERNMENT WATER SCHEMES.

Scheme	Source Catchments	Allocation ($10^6 m^3$/a)
Caledon sub-catchment (Caledon – RSA key area):		
Bloem Water	D23	168,0
Bloem Water allocations (small users)	D23 and C51, 52	* (14,7)
Upper Orange sub-catchment – (area excluding the C5 secondary catchment, Caledon sub-catchment and Lesotho):		
Orange – Fish Transfers	D35	550,0
Bloem Water	D35, C51	1,5
Smaller users	D35, 34, 33, 32, 31	6,5
Modder-Riet sub-catchment (C5 secondary catchment):		
Bloem Water – Modder River	C52	44,1
Small users – Modder / Riet Catchments	C51, 52	2,5
Koffiefontein, Jacobsdal and Debeers Koffiefontein Diamond Mine.	C51	6,4

Note : * Part of the 168,0 for Bloem Water

5.13.5 Allocations in Relation to Water Requirements and availability

Due to the fact that information was not readily available from all sources, it was impossible to compare allocations with water requirements and or water resources.

5.14 WATER TRANSFERS

5.14.1 Introduction

The water resources of a catchment can be exported by pipeline or canal out of the catchment. This transfer out is described as a water requirement from the catchment's water resources. Conversely the water resources of a catchment can be augmented by the import of water by canal or pipeline. This transfer is described as contributing to the resource or source of supply of the catchment.

Water transfers to augment the supply of water for rural, urban, bulk and agricultural requirements are categorised as follows:

- Transfers to or from neighbouring states (there are none within the Upper Orange WMA, but the Lesotho Highlands Transfer to the Upper Vaal WMA in 2000 will be from the Orange River catchment and will affect the water resources of the Upper Orange WMA).
- Transfers between Water Management Areas (e.g. Orange – Fish Transfer).
- Transfers within WMAs are transfers between quaternary catchments (e.g. transfers by Bloem Water from Welbedacht in the Caledon River to various MLCs and TLCs in the Modder / Riet sub-catchment).

There is one small import of water to the Upper Orange WMA, from Erfenis Dam in the Middle Vaal WMA to Brandfort TLC. There is a major export of water from Gariep Dam to the Fish River catchment via the Orange Fish Tunnel.

Figure 5.14.1 shows the positions of the major water transfer schemes and the quantity of water transferred per annum under average conditions at 1995 levels of development. All known inter-basin transfers (including effluent transfers) are listed in **Appendix F.4**.

5.14.2 Transfers to and from neighbouring states.

The Lesotho Highlands Water Project in Lesotho has a significant effect on the water resources of the Upper Orange WMA since the water is transferred from the catchment of the Orange River. Although not operational in 1995 the scheme is included due to its importance in meeting the future water requirements of the Upper Vaal WMA. The transfer of water from Katse Dam in Lesotho to Liebenbergspruit in the Upper Vaal WMA commenced in 1998. **Table 5.14.2.1** summarises the expected transfers from the various components of this scheme.

TABLE 5.14.2.1: TRANSFERS TO AND FROM NEIGHBOURING STATES.

DESCRIPTION OF TRANSFER	SOURCE WMA	RECEIVER WMA	TRANSFER QUANTITY SOURCE WMA ($10^6 m^3/a$)		
			NET TRANSFER	LOSSES$^{(1)}$	TOTAL
Lesotho Highlands Water Project	Katse Dam	Upper Vaal WMA, Liebensbergvlei	334,9 (1998)	29,1	364,0
Lesotho Highlands Water Project	Katse Dam & Mohale Dam	Upper Vaal WMA, Liebensbergvlei	1 104,0 (2003)	96,0	1 200,0

Note: System losses estimated at 8 % (from Katse Dam to receiver area near Bethlehem).
Lesotho information from Lesotho Highlands Water Authority, Mohale Consultants group.

5.14.3 Transfers Between WMA

There are two major inter-basin exports from this WMA namely the Orange-Fish and Orange-Vaal Transfer Schemes. These schemes have been briefly described in **Section 4.2.** and are listed in **Table 5.14.3.1** .

TABLE 5.14.3.1: TRANSFERS BETWEEN WMA's AT 1995 DEVELOPMENT LEVELS.

DESCRIPTION OF TRANSFER	SOURCE WMA	RECEIVER WMA	TRANSFER QUANTITY SOURCE WMA ($10^6 m^3/a$)		
			TRANSFER	LOSSES	TOTAL
Orange-Fish Transfer Scheme	Gariep Dam	Fish River WMA, Theebosspruit	506,0	44,0	550,0
Orange-Vaal Transfer Scheme	Orange River	Lower Vaal WMA, Douglas Weir	17,4	1,5	18,9

Note: Losses estimated at 8 %.

5.14.4 Transfers Within Water Management Area

Within the WMA there are numerous transfers between and within quaternary catchments. The Orange – Riet irrigation transfers and the Bloem Water bulk water transfers represent the great majority of these transfers. Significant transfers are summarised in **Table 5.14.4.1** and all known transfers are listed in **Appendix F.4**. Transfers out of the Vanderkloof key area in 1995 were in the region of 71 x $10^6 m^3$, mostly to the Riet key area for irrigation requirements. Transfers from the Caledon catchment out of the Welbedacht key area in 1995 were in the region of 40 x $10^6 m^3$, mostly to the Krugersdrift key area for urban requirements in the Greater Bloemfontein area.

TABLE 5.14.4.1: AVERAGE TRANSFERS WITHIN THE UPPER ORANGE WMA AT 1995 DEVELOPMENT LEVELS.

DESCRIPTION OF TRANSFER	SOURCE	DESTINATION	QUANTITY ($10^6 m^3/a$)
BLOEM WATER TRANSFERS:			
Bloem Water Southern Transfers	Gariep Dam	Springfontein; Trompsburg, Bethulie TLCs	(-) 1,0
Bloem Water Nothern Transfers Tienfontein pump station	Caledon River	Knellpoort Dam	(+) 94,7
Caledon –Bloemfontein	Welbedacht Dam	Bloemfontein MLC	(-) 33,6
Caledon –Bloemfontein	Welbedacht Dam	Reddersburg; Edenburg; Dewetsdorp and Wepeners TLCs and other bulk users	(-) 2,4
RIET / MODDER TRANSFERS:			
Mazelspoort	Mockes Dam	Bloemfontein MLC	(-) 12,0
Rustfontein WTW	Rustfontein Dam	Botshabelo and Thaba Nchu	(-) 11,6
Orange - Riet Transfer Scheme (import)	Vanderkloof Dam via Orange/ Riet Canal	Riet River Government Water Scheme, Orange / Riet Canal, Ritchie IB, Scholzburg IB etc.	(-) 70,9

Note: A (+) in the transfer column indicates a surplus in destination catchment that WSAM will route through the system while a (-) represents the supply of a requirement in the receiving quaternary.

5.14.5 Effluent transfers

There is one known transfer of effluent (1,6 x $10^6 m^3/a$) within this WMA, from Bainesvlei and Bloemspruit TLC's to water treatment works in Bloemfontein.

5.15 SUMMARY OF WATER REQUIREMENTS, LOSSES AND RETURN FLOWS

The 1995 water requirements, water losses and return flows for the various user categories in the WMA are summarised in **Table 5.15.1**. The summary excludes Lesotho water requirements. Irrigation water requirements (about 11 %) and transfers (about 8 %) are the most significant consumptive users of water in the WMA. While hydropower requirements dominate water requirements (about 70 % of total requirement) of this WMA they are of secondary importance to irrigation. Losses from hydropower generation (about 80 %) represent the most significant losses in the WMA. Returns flows are dominated by utilisable returns from hydropower generation (98 %).

Pie diagrams of on-site water requirements, losses and return flows are given in **Diagrams 5.15.1, 5.15.2 and 5.15.3**.

TABLE 5.15.1: SUMMARY OF UNASSURED 1995 WATER REQUIREMENTS, LOSSES AND RETURN FLOWS (excludes Lesotho).

CATEGORY		ON-SITE WATER REQUIREMENT (10^6 m^3/a)	CONVEYANCE LOSSES[(2)]		GROSS WATER REQUIREMENT (10^6 m^3/a)	RETURN FLOW (10^6 m^3/a)
			(%)	(10^6 m^3/a)		
Irrigation		693,5	10 to 30	89,6	783,1	62,6
Urban (Direct and indirect users)		61,0	5 to 25	24,6	85,6	43,3[(1)]
Rural (Domestic, livestock and subsistence irrigation)		31,1	20	7,6	38,7	0,0
Bulk	a) Strategic (Power Stations)	0,0	0,0	0,0	0,0	0,0
	b) Mining	0,0	0,0	0,0	0,0	0,0
	c) Other (Industrial etc,)	1,6	16,5	0,2	1,8	0,0
Hydro-power		4 279	10 % (evaporation) 10 % (unutilisable)	711,0	4 990,0	4 279,0
Transfers (export)		523,4	8	45,5	568,9	0,0
Alien vegetation		1,3	not applicable	n/a	1,3	0,0
Afforestation (runoff reduction)		0,4	n/a	n/a	0,4	0,0
Rivers, wetlands, dams		643,1	n/a	n/a	643,1	0,0
TOTAL WMA		**6 234,4**		**878,5**	**7 112,9**	**4 384,9**

Note :

(1) Urban returns includes effluent returns (25,6) and stormwater returns (17,7).

(2) Losses associated with the conveyance and distribution of potable water.

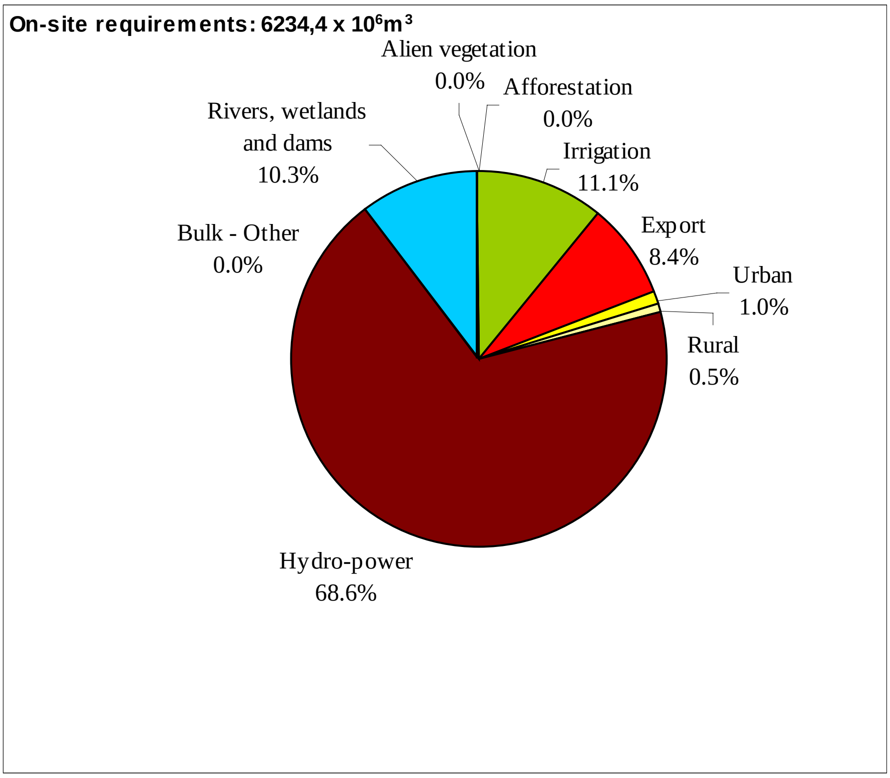


Diagram 5.15.1: Water requirements (excluding losses) in the Upper Oran e WMA in 1995.

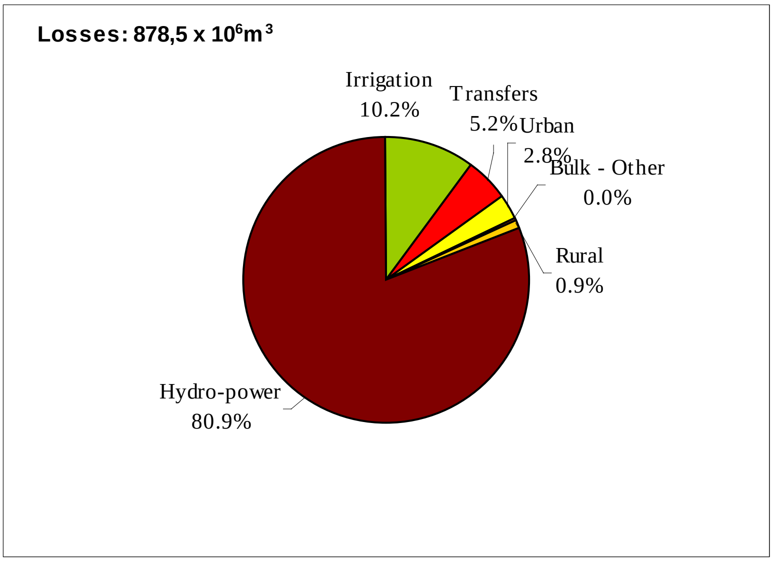


Diagram 5.15.2: Conveyance losses in the Upper Orange WMA in 1995.

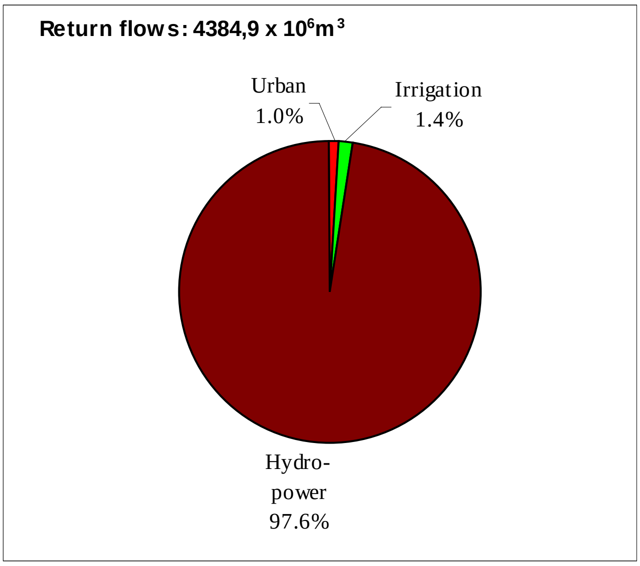


Diagram 5.15.3: Returns flows in the Upper Orange WMA in 1995.

CHAPTER 6: WATER RESOURCES

6.1 EXTENT OF WATER RESOURCES

The Upper Orange River Catchment is defined as that portion of the catchment upstream of the confluence of the Orange and Vaal rivers. Mean annual runoff (MAR) from the Upper Orange River catchment is approximately 6 981 x 10^6m^3. When expressed as an equivalent unit runoff from the net catchment area of 113 306 km^2 , the MAR averages out at about 62 mm. It should be noted that the net catchment area referred to in Table 6.3.2.3 differs significantly from the gross catchment area given in Table 6.3.3.2 due to the fact that there are endoreic areas (which do not contribute towards runoff) in the Modder/Riet sub-catchment as well as downstream of Vanderkloof Dam (Tertiary catchment D33). However, the pattern of runoff over the catchment is one of a fairly rapid decline from east to west, in accordance with the east to west decline of rainfall associated with an increase in evaporation rates. Unit runoff varies from over 400 mm in the Lesotho highlands to as little as 2 mm in the vicinity of the Vaal / Orange River confluence. Equivalent figures for mean annual rainfall (MAP) are 1 200 mm (east) and 300 mm (west) and, for mean annual gross Symons Pan evaporation (MAE) – 1 300 mm (east) and 2 300 mm (west).

Table 6.1.1 gives a summary of the surface and groundwater water resources per key area. . The net 1:50 year yield of the total water resource as developed in 1995 is given in **Figure 6.1.1.**

TABLE 6.1.1: WATER RESOURCES

CATCHMENT						SURFACE WATER RESOURCES ($10^6 m^3/a$)			SUSTAINABLE GROUNDWATER EXPLOITATION POTENTIAL NOT LINKED TO SURFACE WATER ($10^6 m^3/a$)[1]		TOTAL WATER RESOURCE ($10^6 m^3/a$)	
PRIMARY		SECONDARY		TERTIARY		NATURAL MAR	1:50 YEAR DEVELOPED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD IN 1995	DEVELOPED IN 1995	TOTAL POTENTIAL	1:50 YEAR DEVELOPED YIELD IN 1995	1:50 YEAR TOTAL POTENTIAL YIELD IN 1995
No.	Description	No.	Description	No.	Key Area Description							
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	239,6	74,2	74,2	1,4	74,3	75,6	148,5
		C5	Riet	C51	Riet (C51K)	4,1	91,8	91,8	0,7	14,1	92,5	105,9
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	17,9	0	0	2,3	63,8	2,3	63,8
		C5	Rustfontein	C52	Rustfontein (C52A)	30,7	9,1	9,1	0,7	5,6	9,8	14,7
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	114,4	125,6	125,6	1,4	36,1	127,0	161,7
	Total in Riet / Modder (C) primary catchment					**406,7**	**300,7**	**300,7**	**6,5**	**193,9**	**307,2**	**494,6**
D	Orange	D1	Katse	D11	Katse (D11A-K)	767,0	6,5	6,5	0,0	10,1	6,5	16,6
		D1	Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	3245,0	47,2	47,2	0,1	71,5	47,3	118,7
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	956,3	150,6	150,6	10,5	151,1	161,1	301,7
		D2	Caledon – Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	645,5	28,3	28,3	0,1	29,6	28,4	57,9
		D2	Caledon-RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	340,5	27,7	27,7	0,5	39,1	28,2	66,8
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	107,3	10,9	10,9	0,5	9,1	11,4	20,0
		D2	Welbedacht – RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	197,1	55,8	55,8	3,5	32,9	59,3	88,7
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	112,0	37,5	37,5	0,8	41,0	38,3	78,5
		D3	Gariep	D35	Gariep (D35A-K)	64,2	2 539,2	2 539,2	1,8	42,4	2 541,0	2 581,6
		D3	Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	118,9	408,9	408,9	32,8	111,8	441,7	520,7
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	20,5	0	0	14,9	0,5	14,9	0,5
	Total in D primary catchment					**6 574,3**	**3 312,6**	**3 312,6**	**65,5**	**539,1**	**3 378,1**	**3 851,7**
Total in Lesotho in D primary catchment						**[4 764,8]**	**[92,9]**	**[92,9]**	**[0,7]**	**[120,3]**	**[93,6]**	**[213,2]**
Total in Free State in C and D primary catchments						**1 221,6**	**1 895,7**	**1 895,7**	**33,6**	**340,6**	**1 929,3**	**2 236,3**
Total in Northern Cape in C and D primary catchments						**90,2**	**204,5**	**204,5**	**27,0**	**104,9**	**231,5**	**309,4**
Total in Eastern Cape in D primary catchment						**904,4**	**1 420,2**	**1 420,2**	**10,7**	**167,2**	**1 430,9**	**1 587,4**
TOTAL IN WMA (South Africa only)						**2 216,2**	**3 520,4**	**3 520,4**	**71,3**	**612,7**	**3 591,7**	**4 133,1**

Note: * Quaternary area within Lesotho and RSA.
(1) Refer to Table 6.2.1

6.2 GROUNDWATER RESOURCES

Groundwater is an important part of the total water resources of South Africa and must be seen as part of the total hydrological cycle. The information provided here gives an overview of the groundwater resources, it's interaction with surface water, the present use, (1995) and it's 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 Ground Water 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 then reduced by an exploitation factor, determined from borehole yield data, to obtain an exploitation potential ie the portion of the Harvest Potential which can practically be exploited (**see Table 6.2.1 and Figure 6.2.2**).

Groundwater, surface water interaction was determined by evaluating the base flow or more specifically the contribution of 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 impact on surface water has been qualitatively evaluated (**see Figure 6.2.3**) ie where the contribution is 0 the impact will be negligible where the contribution is $\leq$ 30% of the baseflow the impact will be low where the contribution is 30% - 80% of the baseflow, the impact will be moderate and a high impact has been evaluated where the contribution to baseflow is > 80%.

The existing groundwater use was determined by Baron and Seward 2000. The information was then verified at a workshop held in the WMA by the Water Resources Situation Assessment team. This provided local input to the groundwater use numbers provided by Baron and Seward which were then adjusted accordingly (**see Table 6.2.1 and Figure 6.2.4**).

The groundwater balance then compares existing groundwater use to Harvest and Exploitation Potential to determine the extent to which the groundwater resources are utilized (**see Figure 6.2.5**) ie, if total use was greater then the Harvest Potential, the catchment was considered over-utilized, if the total use was greater than the exploitation potential but less than the Harvest Potential, the catchment was considered heavily utilized, if the total use was more than 2/3 of the Exploitation Potential the catchment was considered moderately-utilized and if the total us was less than 2/3 of the exploitation potential the catchment was considered under-utilized.

TABLE 6.2.1: GROUNDWATER RESOURCES

CATCHMENT						GROUNDWATER EXPLOITATION POTENTIAL $(10^6 m^3/a)$	GROUNDWATER USE IN 1995 $(10^6 m^3/a)$	UNUSED GROUNDWATER EXPLOITATION POTENTIAL IN 1995 $(10^6 m^3/a)$	GROUNDWATER CONTRIBUTION TO SURFACE BASE FLOW $(10^6 m^3/a)$	PORTION OF GROUNDWATER EXPLOITATION POTENTIAL NOT CONTRIBUTING TO SURFACE BASE FLOW $(10^6 m^3/a)$
PRIMARY		SECONDARY		TERTIARY						
No.	Description	No.	Description	No.	Key Area Description					
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	75,7	1,4	74,3	0,0	75,7
		C5	Riet	C51	Riet (C51K)	14,8	0,7	14,1	0,0	14,8
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	66,1	2,3	63,8	0,0	66,1
		C5	Rustfontein	C52	Rustfontein (C52A)	6,3	0,7	5,6	0,0	6,3
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	37,5	1,4	36,1	0,0	37,5
	Total in Modder / Riet (C) primary catchment					**200,4[1]**	**6,5[1]**	**193,9[1]**	**0,0[1]**	**200,4[1]**
D	Orange	D1	Katse	D11	Katse (D11A-K)	10,1	0,0	10,1	0,0	10,1
		D1	Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	71,6	0,1	71,5	13,2	58,4
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	161,6[1]	10,5[1]	151,1[1]	95,0[1]	66,6
		D2	Caledon - Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	29,7	0,1	29,6	0,0	29,7
		D2	Caledon RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	39,6[1]	0,5[1]	39,1[1]	19,0[1]	20,6
		D2	Welbedacht - Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	9,6	0,5	9,1	0,0	9,6
		D2	Welbedacht - RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	36,4[1]	3,5[1]	32,9[1]	2,9[1]	33,5
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	41,8[1]	0,8	41,0[1]	0,0[1]	41,8
		D3	Gariep	D35	Gariep (D35A-K)	44,2[1]	1,8[1]	42,4[1]	0,0[1]	44,2
		D3	Vanderkloof	D31, D32, D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	144,6[1]	32,8	111,8[1]	0,0[1]	144,6
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K)	15,4	14,9	0,5	0,0	15,4
	Total in D primary catchment					**604,6**	**65,5**	**539,1**	**130,1**	**474,5**
Total in Lesotho in D primary catchment						**[121,0]**	**[0,7]**	**[120,3]**	**[13,2]**	**[107,8]**
Total in Free State in C and D primary catchments						**374,2**	**33,6**	**340,6**	**24,9**	**349,3**
Total in Northern Cape in C and D primary catchments						**131,9**	**27,0**	**104,9**	**0,0**	**131,9**
Total in Eastern Cape in D primary catchment						**177,9**	**10,7**	**167,2**	**92,0**	**85,9**
TOTAL IN WMA [South Africa only]						**684,0**	**71,3**	**612,7**	**116,9**	**567,1**

Note: * Quaternary area within Lesotho and RSA.
(1) Data provided by K. Haupt, all other data provided by the DWAF.

6.3 SURFACE WATER RESOURCES

6.3.1 Streamflow data

The basis for the analysis of surface water resources for all WMAs 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.

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 purpose of the Water Situation Assessment Model it was decided to adjust the WR90 quaternary naturalised flows to reflect the CSIR afforestation-related streamflow reduction effects. An investigation to determine a method of making the adjustments without serious time or cost implications was conducted (Ninham Shand, 1999). The selected method consisted of the following steps:

(1) The afforestation water use time series based on the Van der Zel 15-year rotation curve was generated.

(2) This time series (the result of (1)) was then subtracted from the Van der Zel-based naturalised flow time series generated for the whole calibration catchment.

(3) The naturalised flow from the afforested portion of the catchment (Van der Zel-based) was used to obtain an afforestation water use time series based on the CSIR curves. This result was added to the result of (2), yielding a time series of adjusted (CSIR-based) naturalised flows.

These adjusted flows have been used for the catchments that contain afforestation.

A validation of this adjustment method was carried out for five gauged catchments from three geographically different regions, which had full hydrological studies available from recent basin studies. Calibration configurations were obtained from these studies. An identical configuration was set up to include the CSIR afforestation-related flow reduction function, and the Pitman model was recalibrated. This resulted in two “calibrated” sets of Pitman model parameters for each catchment, the one using the Van der Zel, and the other using the CSIR afforestation-related streamflow reduction functions.

Monthly naturalised flows were simulated using the two calibrated parameter sets. The CSIR series was used as the “true” series for validation and compared with the Van der Zel time series after it was adjusted as described above.

Differences between the MAR's of the adjusted (CSIR-based) naturalised flows and the re-calibrated “true” naturalised flows were within 5%, which was considered to be acceptable.

Based on the three steps described above, the WR90 naturalised flow series were then adjusted for all the afforested quaternary catchments in the country. If the runoff reduction due to afforestation estimated by means of the CSIR curves was lower than the runoff reduction estimated by means of the Van der Zel curves, the virgin runoff of WR90 would have been reduced and vice versa. The difference between the adjusted MAR's and the original WR90 values ranges between a reduction of 18% and an increase of 28%. For most of the catchments the difference varies between zero and an increase of 7%.

The proposed methodology ensures that the calculated runoff from an afforested catchment (which would be observed at a streamflow gauge) is the same, irrespective of the afforestation water use model that has been used.

The most important limitations of the method described above are:

- The updated afforestation water use was estimated by means of the CSIR curves (as described in (3)), but the uncorrected naturalised flows based on the original Van der Zel curves were used as an input into this calculation. As a refinement, one could consider the possibility of repeating the process, but this time estimating afforestation water use, not using the original WR90 naturalised flows, but rather the newly adjusted ones. This could then be used to make a second estimate of the CSIR-based natural flows. Further re-iterations of this process might improve the accuracy.

- Catchments upstream of some calibration gauges contained quaternaries with and without afforestation. Changing the MAR's of only afforested quaternary catchments therefore made the naturalised MAR of the total catchment less accurate, as the MAR's of unafforested catchments were not adjusted.

The better solution is to re-calibrate all affected catchments. However, as was explained above, at this stage it was considered inappropriate. It is recommended that a sensitivity analysis be done in order to determine whether these limitations have a significant effect on the results.

In the Upper Orange River catchment in Lesotho, where rainfall data are sparse, it was not possible to reconcile the high runoff recorded with the mean annual rainfall (MAP) data received from the Department of Agricultural Engineering, University of Natal. Accordingly, the MAP information was obtained from the Lesotho Highlands Feasibility Study.

A number of gauges in Lesotho were considered to be unreliable. However, the gauges at Oranjedraai (D1H009) - close to the Lesotho/RSA border – and at Aliwal North (D1H003) on the Orange River were considered to be very good.

In the Caledon River catchment only Welbedacht Dam (D2R004) on the Caledon, supplemented by Jammerdrift (D2H001) and Egmont Dam (D2R001) on the Witspruit were useful and reliable.

Downstream of the Orange/Caledon Rivers confluence the only reliable gauges are at Gariep Dam (D3R002) and at Vanderkloof Dam (D3R003) on the Orange River. However, these gauges cannot help to assess local runoff, which in any case is negligible. Gauges D3R001 (Bethulie Dam), D3H015 (on the Seekoei River) and D3H003 (downstream of Vanderkloof Dam) were identified as being unreliable.

The hydrology as used in the Orange River Replanning Study undertaken for the Department of Water Affairs and Forestry, hereinafter referred to as the ORRS, is currently accepted as the definitive hydrology for the Orange River catchment (BKS et al., 1991a,b and 1995a). The hydrology was not revised in the ORRS but was adopted from preceding studies as follows:

- Lesotho Highlands: latest hydrological data as used in the Vaal Augmentation Planning Study (DWAF, 1995).
- Caledon catchment: hydrology as established for the Orange River System Analysis (BKS et al., 1991a).
- Remainder of Upper Orange: hydrology as established for the Orange River System Analysis (BKS et al., 1991b).

These studies encountered similar problems to those documented by the WR90 team. A number of additional problems were addressed and are described below.

Recorded turbine releases at Vanderkloof Dam were thought to be underestimated and the calculated inflows to Gariep Dam were unreliable during low-flow periods, particularly when the dam was at or near full capacity. There was also conflict between Gariep Dam outflows and Vanderkloof Dam inflows. These problems were addressed by carrying out a combined mass balance for the two dams, checking the results against flows recorded at gauges upstream and adjusting the records accordingly. Although the adjusted records relied to some extent on judgement, they represent the best estimate available to date.

In the Modder/Riet River catchment the following problems exist:

- There is no record available at Douglas Weir (C9R003). This is a serious omission as this gauge is on the Vaal River, just upstream of the confluence with the Orange River.
- There are no records for Mockes Dam on the Modder River.
- Tierpoort Dam on the Kaffer River (C5R001) has an unreliable record. This deficiency could be overcome by installing an additional gauge (or gauges) upstream of Kalkfontein Dam (C5R002) in the Riet River catchment.

Assessment of MAR

As stated in the previous section, only the WR90 information is presented at a quaternary catchment level. However, as the ORRS study was undertaken at a greater level of detail, the hydrological assessments should be the more reliable. Accordingly, the ORRS estimates of MAR were used to verify/adjust the WR90 data on the basis of comparisons at key points in the Upper Orange River catchment.

Prior to any adjustments an assessment was made concerning the impact on MAR of the different periods adopted in the WR90 and ORRS studies. WR90 covered the period 1920 to 1989 and ORRS covered the period 1920 to 1992. The additional three years included by ORRS had a minimal impact, resulting in reductions of about one percent in MAR. It was, therefore, considered unnecessary to make any adjustments to cater for the different periods.

The method of adjustment is very simple, as shown below:

Let MK_{WR90} = Incremental MAR at key point from WR90
MK_{ORRS} = Incremental MAR at key point from ORRS
MQ_jK_{WR90} = MAR of jth Quaternary in incremental catchment

Then, for each of the quaternaries making up the incremental catchment, the adjusted MAR is as follows:

MQ_jK_{ADJ} = Adjusted MAR of jth Quaternary in incremental catchment
$= MQ_jK_{WR90} \times MK_{ORRS} / MK_{WR90}$

Table 6.3.1.1 summarises the adjustments made on the basis of MAR comparisons at key points. The adjusted MAR's of each quaternary are given in **Appendix G.1**.

TABLE 6.3.1.1: ADJUSTMENT OF QUATERNARY CATCHMENT NATURAL MAR'S IN THE UPPER ORANGE CATCHMENT.

Gauge point	Quaternary catchments making up incremental catchment	Incremental MAR (10^6m^3)		Adjustment ratio
		WR90	ORRS	
Upper Orange River catchment (excluding Modder/Riet River catchment)				
Katse	D11A – D11F	518,9	582,8	1,123
Matsoku	D11G,H	133,6	99,0	0,741
D1H011	D13A – D13L	651,4	676,3	1,038
D1H003	D12; D13M	181,8	229,4	1,262
Polihali	D16A – D16M	798,8	522,1	0,654
Taung	D11J,K, D16M	270,4	259,5	0,960
Mohale	D17A,B	242,8	303,3	1,249
Malatsi	D17C – D17F	448,4	364,0	0,812
Tsoelike	D17G – D17K	305,2	361,7	1,185
Ntoahae	D17L,M	112,1	147,3	1,314
D1H009	D15; D18	1 306,3	1 426,9	1,092
D2R004	D21, D22, D23	1 243,5	1 216,8	0,979
D3R003	D31, D32, D34	115,2	147,4	1,280
D3R002	D14, D24, D35	335,1	397,2	1,185
Vaal	**D33**	7,9	7,9	1,000
Total / Average	**D1; D2; D3**	**6 546,7**	**6 741,5**	**1,030**
Modder/Riet River Catchment				
C5R001	C51D	27,0	23,8	0,881
C5R002	C51A,B,C,E,F,G,H,J	179,8	215,9	1,201
C5H016	C51K,L	4,5	6,4	1,422
C5R003	C52A	27,9	30,7	1,100
C5R004	C52B – C52G	148,7	114,4	0,769
C5H018	C52H – C52L	8,9	14,4	1,618
Total / Average	**All C51 and C52 quaternary catchments**	**396,8**	**405,6**	**1,317**

It was not considered necessary to adjust MAR's due to afforestation effects because there is negligible afforestation in this WMA. The original WR90 MAR's were used for the determination of non-dimensionalised yield curves. This does not give rise to any inconsistency because they are non-dimensionalised.

Table 6.3.1.2 summarises the natural MAR at the tertiary catchment level and give a comparison between the original MAR's of the WR90 study and the adjusted values. Reasons are given for cases where the adjusted MAR differs substantially from the WR90 estimate.

TABLE 6.3.1.2: TERTIARY CATCHMENT NATURAL MAR IN THE UPPER ORANGE CATCHMENT

Tertiary Number	Description (river)	Net area (km^2)	MAR ($10^6 m^3$)		
			WR90	Adjusted	Change
Upper Orange River catchment (excluding Modder/Riet River catchment)					
D11	Madibamatso	3 360	766,9	791,5	+24,6
D12	Orange (u/s Kraai)	2 967	164,7	207,9	+43,2[1]
D13	Kraai	9 354	668,5	697,9	+29,4
D14	Stormberg	6 145	123,1	145,9	+22,8
D15	Kornet	3 360	522,0	570,2	+48,2[2]
D16	Upper Orange (Senqu)	4 520	830,2	671,8	-158,4[3]
D17	Sinqunyane	7 179	1 108,5	1 176,3	+67,8[4]
D18	Orange (u/s border)	6 260	784,3	856,7	+72,4[5]
D21	Upper Caledon	3 563	518,5	507,4	-11,1
D22	Middle Caledon	6200	467,3	457,3	-10,0
D23	Middle Caledon	5 507	257,7	252,2	-5,5
D24	Lower Caledon	6 614	158,9	188,4	+29,5
D31	Orange (Vanderkloof)	4 396	33,9	43,4	+9,5
D32	Seacow	9 081	41,0	52,5	+11,5
D33	Orange (u/s Vaal)	3 404	7,9	7,9	0,0
D34	Orange (d/s Gariep)	5 020	40,3	51,6	+11,3
D35	Orange (Gariep)	5 638	53,1	62,9	+9,8
TOTAL	**Total Upper Orange**	**92 568**	**6 546,7**	**6 741,5**	**+194,8**
Modder/Riet River Catchment					
C51	Riet	12 166	212,4	247,1	+34,7
C52	Modder	8 572	185,6	159,5	-26,1
TOTAL	Modder / Riet catchment	20 738	398,0	406,6	+8,6
TOTAL	**Upper Orange WMA**	**113 306**	**6 944,7**	**7 148,1**	**+203,4**

Notes:
1. Small differences in incremental MAR between D1H009 and D1H003
2. WR90 calibrated on D1H006 (Kornetspruit), which may be unreliable
3. Based mainly on assessment of MAR at Polihali Dam
4. Based mainly on assessment of MAR at Mohale Dam
5. Small differences in incremental MAR between D1H009 and u/s stations.

The adjusted mean annual natural surface runoff is shown in **Figure 6.3.1**.

Diagram 6.3.1 gives a comparison of MAR at the secondary catchment level. The diagram shows the adjusted MAR's of the secondary catchments to be similar to the WR90 values. Catchments D1 and D3 show a slight increase while the MAR for catchments C5 and D2 remain virtually the same.

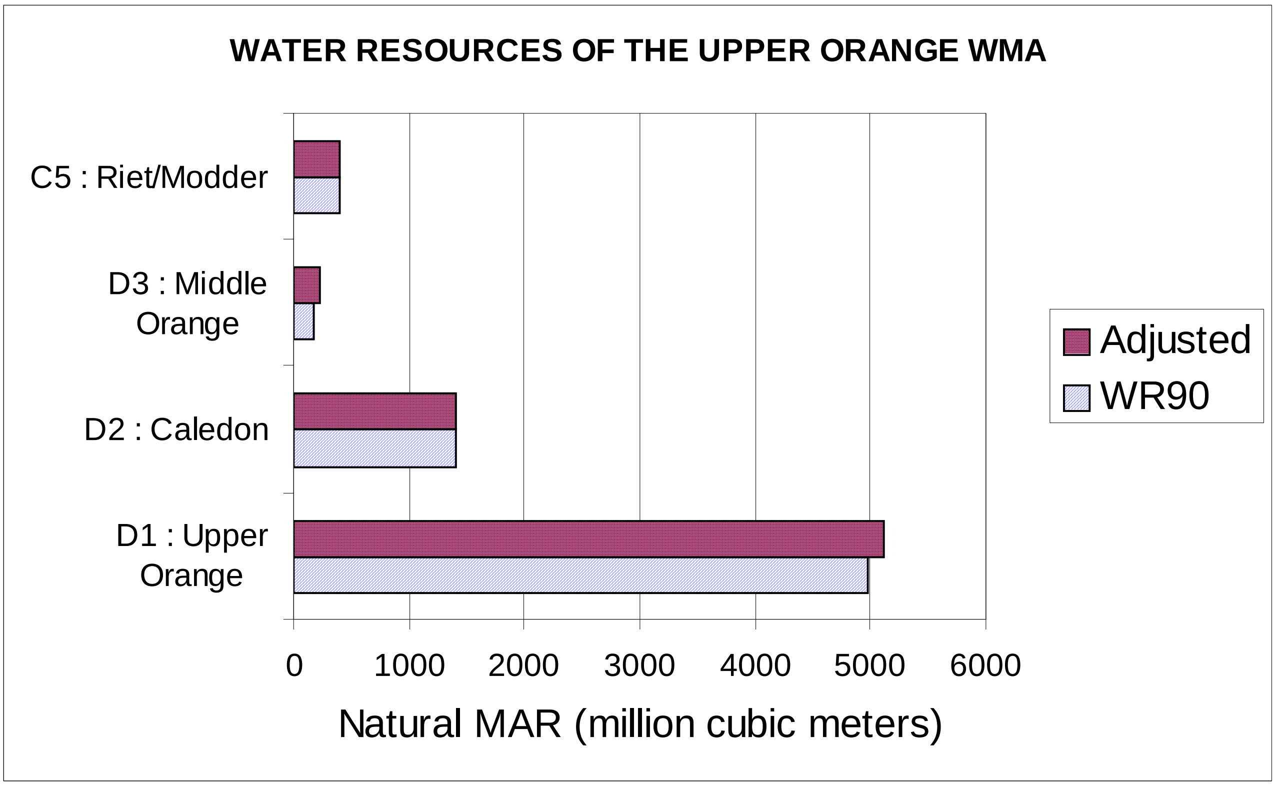


Diagram 6.3.1: Water Resources of the Upper Orange WMA

6.3.2 Yield Analysis

Table 6.3.2.1 shows the comparison between actual dam storage (major and farm dams) and postulated dam storage based on estimates of maximum feasible storage for the tertiary catchments in the Upper Orange WMA.

TABLE 6.3.2.1: COMPARISON BETWEEN POSTULATED DAM STORAGE AND ACTUAL STORAGE.

Tertiary Number	Description	Existing Storage (10^6m^3)	Postulated maximum net storage (10^6m^3)
Upper Orange River catchment (excluding Modder/Riet River catchment)			
C51	Riet	424	622
C52	Modder	202	399
Modder/Riet River Catchment			
D11	Katse	1 478	989
D12	U/S Gariep – D12	7	361
D13	Kraai	10	1 128
D14	U/S Gariep – D14	19	324
D15	Lesotho – D15	2	892
D16	Lesotho – D16	0	840
D17	Lesotho - Mohale	851	1 470
D18	Lesotho – D18	0	1 285
D21	Caledon – D21	1	788
D22	Caledon – D22	8	794
D23	Welbedacht	183	504
D24	D/S Welbedacht	29	410
D31	Vanderkloof	3 195	130
D32	Seekoei	25	157
D33	D/S Vanderkloof	1	24
D34	Gariep-Vanderkloof	11	155
D35	Gariep	5 353	188
TOTAL		**11 796**	**11 460**

Note : It is unrealistic to compare existing storage and postulated storage in this WMA. Some key areas show a higher existing storage than postulated storage because of major dams, e.g Gariep and Vanderkloof Dams. In other key areas, existing storage is lower than postulated storage but this does not mean that the key area is underdeveloped.

In order to estimate the total potential yield available from the catchments within the WMA, future storage dams of a particular maximum net storage capacity have been postulated based on a maximum feasible storage (Stewart Scott, 1998). The net incremental storage capacities that have been adopted within the WMA are given in **Appendix G.1** for all the quaternary catchments.

These range from 125% of the MAR in the higher rainfall quaternary catchments to 300% of the MAR in the drier quaternary catchments 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 size have been derived for the entire South Africa and which will provide consistent results throughout the country.

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 6.3.2.1**. 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 6.3.2.1**. This is illustrated by means of the typical net storage-gross yield relationships shown in **Diagram 6.3.2.1** 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 125%, 150%, 200%, 250% or 300% of the MAR as appropriate.

The Modder/Riet River sub-catchment is still under-developed but the Orange River sub-catchment is fully developed.

Table 6.3.2.2 gives details on surface water resources.

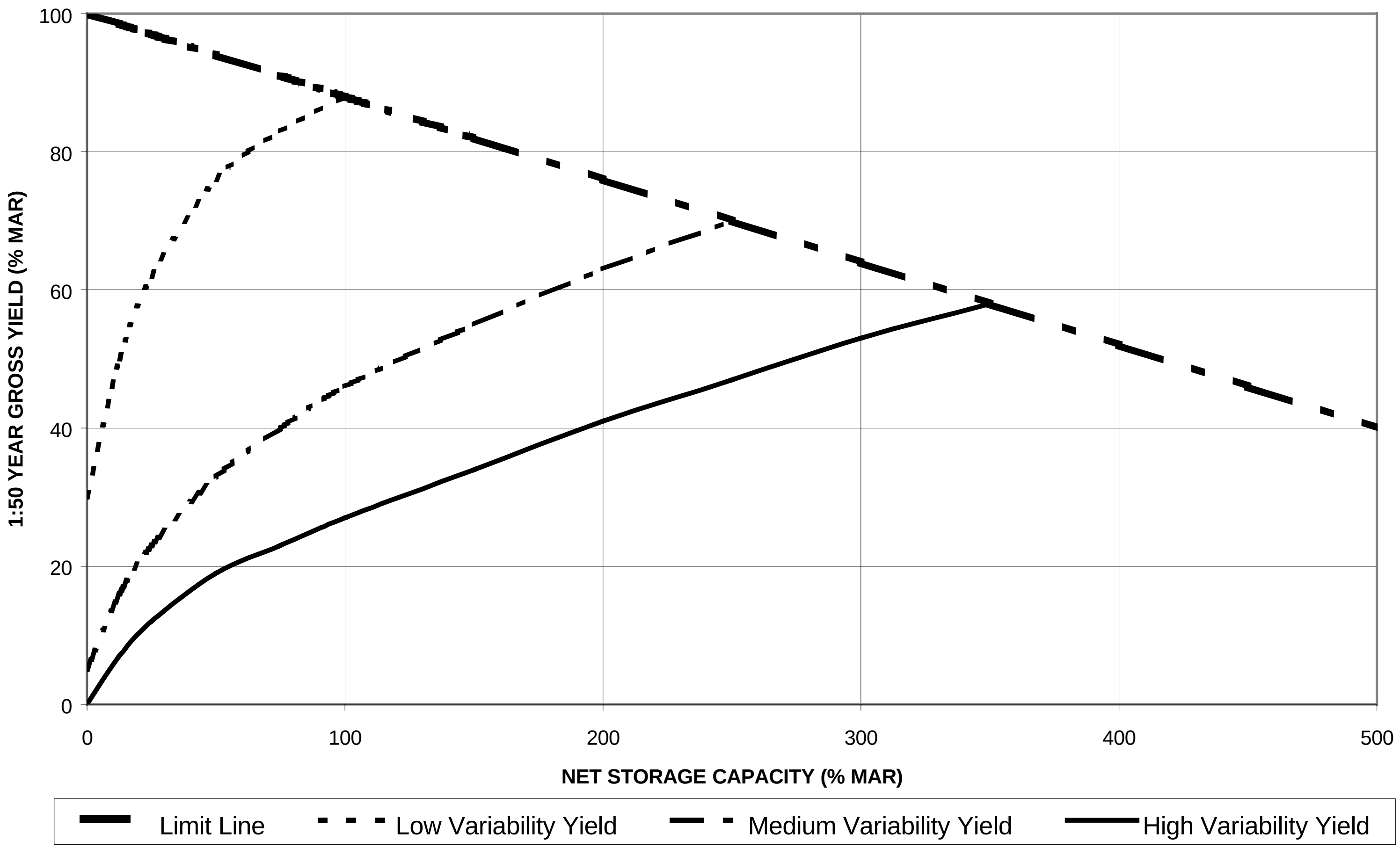


DIAGRAM 6.3.2.1: DAM STORAGE LIMITS

TABLE 6.3.2.2: SURFACE WATER RESOURCES

CATCHMENT						CATCHMENT AREA (km^2)	MEAN ANNUAL PRECIPITATION (mm/a)	MEAN ANNUAL EVAPORATION (mm/a)	NATURAL MAR		YIELD (1:50 YEAR) (1)	
PRIMARY		SECONDARY		TERTIARY					INCREMENTAL (10^6 m^3/a)	CUMULATIVE (10^6 m^3/a)	DEVELOPED IN 1995 (10^6m^3/a)	TOTAL POTENTIAL (10^6 m^3/a)
No.	Description	No.	Description	No.	Key Area Description							
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	10 260,0	417,7	1 816,0	239,6	239,6	74,2	74,2
		C5	Riet	C51	Riet (C51K)	3 632,0	350,0	2 000,0	4,1	243,7	91,8	91,8
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	14 590,0	404,5	2 153,0	17,9	261,6	0	0
		C5	Rustfontein	C52	Rustfontein (C52A)	937,0	543,0	1 600,0	30,7	30,7	9,1	9,1
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	5 394,0	507,7	1 663,0	114,4	145,1	125,6	125,6
	Total in Modder/Riet (C) primary catchment					**34 813,0**	**540,7**	**1 846,4**	**406,7**	**406,7**	**300,7**	**300,7**
D	Orange	D1	Katse	D11	Katse (D11A-K)	3 360,0	909,0	&	767,0	767,0	6,5	6,5
		D1	Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	21 320,0	801,6	1 437,5	3 245,6	3 490,0	47,2	47,2
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	18 470,0	579,6	1 637,0	956,3	4 968,9	150,6	150,6
		D2	Caledon – Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	5168,3	796,2	1 430,0	645,5	645,5	28,3	28,3
		D2	Caledon – RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	4594,7	745,0	1 405,0	340,5	340,5	27,7	27,7
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	1801,8	654,6	1 525,0	107,3	752,8	10,9	10,9
		D2	Welbedacht – RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	4883,2	601,3	1 548,0	197,1	537,6	55,8	55,8
		D2	Orange d,/s Welbedacht	D24	D/S Welbedacht (D24D-L)	5 436,0	474,3	1 624,0	112,0	1 402,0	37,5	37,5
		D3	Gariep	D35	Gariep (D35A-K)	5 638,0	397,4	1 725,0	64,2	6 435,0	2 539,2	2 539,2
		D3	Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	19 080,0	336,7	1 900,0	118,9	6 554,0	408,9	408,9
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K) l	9 598,0	300,8	2 075,0	20,5	6 574,0	0,0	0,0
	Total in D primary catchment					**99349,0**	**534,0**	**1 702,0**	**6 574,3**	**6 574,3**	**3 312,6**	**3 312,6**
Total in Lesotho in D primary catchment						**30492,0**	**790**	**1 403**	**4 644,3**	**#**	**[92,9]**	**[92,9]**
Total in Free State in C and D primary catchments						**56270,0**	**462**	**1 636**	**1 221,6**	**#**	**1 895,7**	**1 895,7**
Total in Northern Cape in C and D primary catchments						**25575,0**	**319**	**1 963**	**90,2**	**#**	**204,5**	**204,5**
Total in Eastern Cape in D primary catchment						**21826,0**	**397**	**1 658**	**1 025,1**	**#**	**1 420,2**	**1 420,2**
TOTAL/AVERAGE IN WMA						**134 163**	**550**	**1 703**	**2 336,9**	**#**	**3 520,4**	**3 520,4**

Note: * Quaternary area within Lesotho and RSA.
& Not readily available
# Not applicable

Using WR90 information, present day gross yields (1995) were determined for selected areas and have been shown in **Diagram 6.3.2.2**. These figures are gross yield and therefore cannot be compared with the net yields in **Table 6.3.2.2**.

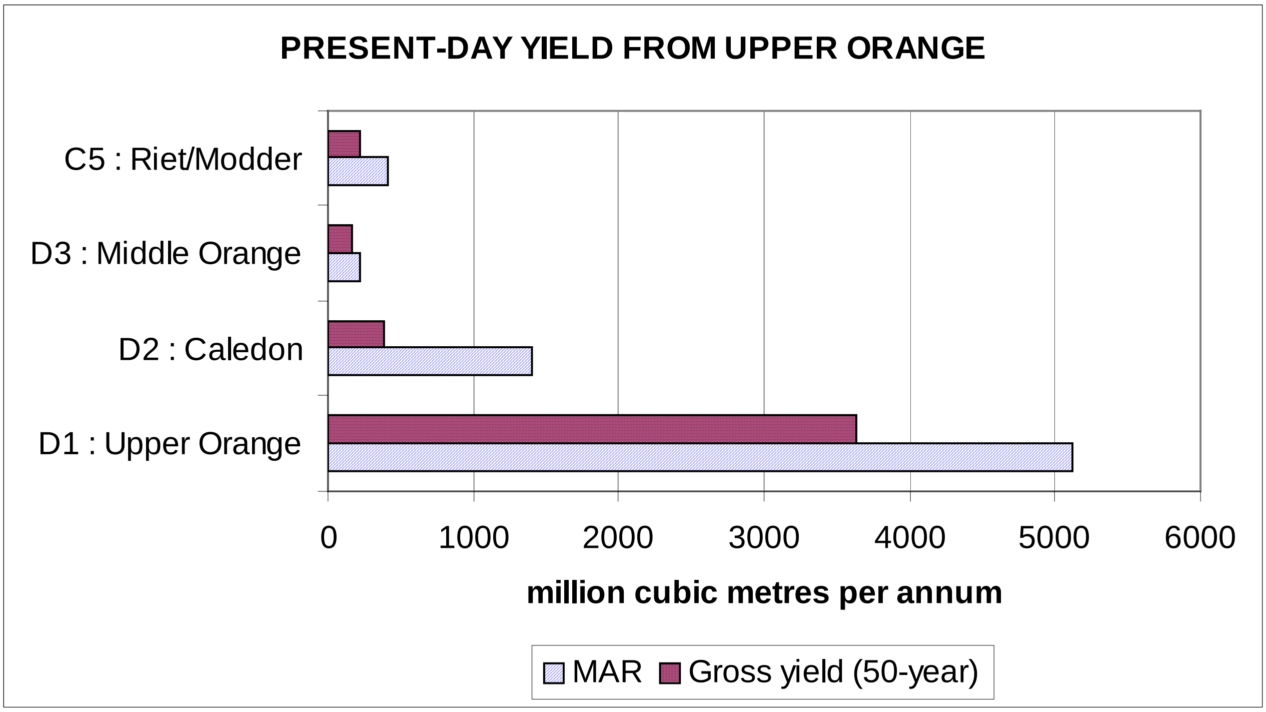


Diagram 6.3.2.2: Present day yield from the Upper Orange WMA.

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 this WMA.

The mineralogical water quality of the surface water bodies is only 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.

There are two water quality monitoring networks in the study area both belonging to DWAF. Water quality monitoring is carried out at streamflow gauging stations and reservoirs. There is also a more informal network of certain points where mine effluent is returned to streams, canals etc. and this monitoring is carried out by various industries and/or mines. In the Upper Orange WMA there are of the order of 55 DWAF flow measuring stations of which some have water quality measurements of varying frequency taken. DWAF have about 11 reservoirs most of which have weekly quality measurements taken. Sampling of water quality should preferably take place at

TABLE 6.3.2.3: NET CATCHMENT AREA

TABLE 6.3.3.2: GROSS CATCHMENT AREA

TABLE 6.3.3.1: KALKFONTEIN KEY AREA

These tables are not accessible in electronic format.

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flow monitoring stations. Sampling frequency can be divided into the following four classes, namely:

- Continuous.
- Weekly.
- Monthly.
- Irregular.

Full details of the water quality monitoring networks for the Modder/Riet River sub-catchment can be found in the reports on the Vaal River Salinity Study: Water quality monitoring requirements for salinity modeling Volume 5. (DWAF, 1993). The rest of the Upper Orange WMA was not covered in this study.

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 WMA.

The mineralogical water quality of the surface water bodies is only described in terms of total dissolved salts (TDS). Data for the assessment were obtained from the water quality data base of the Department of Water Affairs and Forestry.

The surface water quality monitoring stations that were used to provide the data are shown in **Figure 6.4.1.1**.

Only data sets that had data for the last five years (1990 to 1995) were used. The data sets were filtered to monthly data, and various techniques were used to fill in missing values where possible. Only those data sets that spanned at least two years and contained at least 24 data points were eventually selected for analysis. These were used to derive the mean and maximum TDS concentrations.

Details of the TDS and electrical conductivity (EC) for the various catchments are given in **Appendix G.4**.

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 of other uses. The South African Water Quality Guidelines of the Department of Water affairs and Forestry (1996) 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 – 1 800
3	Red	Poor water quality	1 801 – 3 400
4	Purple	Completely unacceptable water quality	>3 400

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. For this purpose the data set was inspected for the worst two-year period observed. 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	Blue
	Green	Green
	Yellow	Green
	Red	Yellow
	Purple	Purple
Green	Green	Green
	Yellow	Yellow
	Red	Yellow
	Purple	Purple
Yellow	Yellow	Yellow
	Red	Red
	Purple	Purple
Red	Red	Red
	Purple	Purple
Purple	Purple	Purple

The water quality of the Upper Orange WMA is summarised in **Table 6.4.1.3** and is shown in **Figure 6.4.1.2.** The surface water class is shown in **Figure 6.4.1.1.**

TABLE 6.4.1.3: SUMMARY OF MINERALOGICAL SURFACE WATER QUALITY OF THE UPPER ORANGE WMA.

Secondary Catchment	No. of Quaternary Catchments &	No of Quaternary Catchments in Class					
		Blue	Green	Yellow	Red	Purple	No Data
C5	25	1	9	3	0	0	12
D1	86	6	0	1	0	0	79
D2	54	6	1	0	0	0	47
D3	45	4	0	1	0	0	40

Note : Of the six stations in secondary catchment D1 of class “Blue”, four of them were in Lesotho.

The mineralogical surface water quality of the Upper Orange WMA is generally good. **Section 6.4.4** deals with the WMA in detail and deals with specific problems.

6.4.2 Mineralogical Groundwater 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 (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 (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 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) and according to Quality of Domestic Water Supplies, Volume I (DWAF, 1998). Water classified as poor and unacceptable (Class 3 and 4) has been considered **not** potable.

In catchments where no information was available estimates of the portion potable were made using Vegters 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 % potable water per quaternary catchment.

6.4.3 Microbiological (or Microbial) 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 G.3** 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 Upper Orange WMA is given in **Figure 6.4.3.1**.

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 resources

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 Upper Orange WMA is given in **Figure 6.4.3.2**. This map shows the degree of potential faecal contamination in groundwater using a rating scale which ranges from low to medium to high.

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

Caledon River:

Salinity in the Caledon River is generally good and well suited to irrigation use and transfer to the Modder and Riet Rivers. Local microbial pollution or contamination can be anticipated below sewage treatment works. A case in point is the Caledon River below Maseru. The Caledon River is characterised by severe sedimentation problems. (For example, much of the storage capacity of Welbedacht Dam has already been lost to sedimentation).

Orange River:

Salinity in the Orange River both upstream, within and below Gariep and Vanderkloof Dams is good and well suited for all uses. Severe sedimentation occurs upstream of these major dams, but is reduced substantially by dam storage.

Modder and Riet Rivers:

The water quality of the runoff into Rustfontein Dam in the upper Modder River is good with an average TDS concentration of 254 mg/ℓ. However evaporative concentration can elevate peak TDS concentrations to 400 mg/ℓ. High metal concentrations have been observed in Rustfontein Dam, possibly due to de-oxygenation of the water column.

Increasing aridity and the impact of Thaba Nchu, Bloemfontein and Botshabelo effluent discharges raised the average TDS in Krugersdrift Dam to 347 mg/ℓ, with peak concentrations during drought conditions exceeding 900 mg/ℓ. This is further increased by cascading evaporative concentration in the downstream riparian irrigation scheme supported by this dam down to the Modder-Riet confluence, with peak concentrations reaching 1 200 mg/ℓ at Tweerivier.

Local microbial and nutrient pollution occurs in the streams downstream of Thaba Nchu and Botshabelo and in the Modder River. Diffuse source pollution contributes to these pollutant loads. Despite storage in the small Mockes Dam and high turbidity, eutrophication problems can occur in Mazelspoort weir, a principal source of water supply to Bloemfontein. The Bloemspruit, which receives effluent from Bloemfontein's Bloemspruit sewage treatment works, can exhibit local eutrophication, but the impact is limited by the absence of significant dams. The Welvaart sewage treatment works discharges the remainder of Bloemfontein's effluent to the Kaalspruit. Much of this flow is lost in this arid stream and the remainder enters the Modder River below the last major dam (Rustfontein Dam). Hence eutrophication effects are limited. High turbidity in the Modder River and the long distance from Mazelspoort weir reduces the potential for eutrophication of Rustfontein Dam.

The Upper Riet River catchment is relatively undeveloped. Despite this, increasing aridity leads to an average TDS concentration in Kalkfontein Dam of 390 mg/ℓ, with recorded peaks exceeding 800 mg/ℓ. The long retention time arising from the large size of the dam relative to its MAR contributes to evaporative concentration.

Irrigation is the main development between Kalkfontein Dam and the Riet-Vaal River confluence just upstream of Douglas. Salinity induced by irrigation return seepage is the main water quality problem. This is especially apparent lower down the Riet River, where the flow to the Vaal River all but ceases during low flow conditions. The Orange River importation via the Vanderkloof canal to the Riet River partially alleviates the high TDS concentrations. However, evaporative concentration and cascading riparian irrigation use raises TDS concentrations to a very high average of 840 mg/ℓ, with peaks reaching 2 400 mg/ℓ in the lower Riet River at Aucampshoop weir.

This has a severe deleterious effect both on local riparian irrigation and on irrigation from Douglas Weir on the Lower Vaal River.

Eutrophication and microbial pollution problems can be expected to increase in the Bloemfontein-Botshabelo area as the urban population increases. The salinity of Rustfontein Dam could be improved once Caledon River water is imported via Knellpoort Dam and the Novo pump scheme. This is unlikely to have much effect on Krugersdrift Dam and downstream Modder-Riet irrigation because most of the imported water will be used to supply urban areas. Since the area of irrigation is unlikely to increase, salinity levels should remain largely unaltered. However, the salinity of the lower Riet River could be substantially improved if a previously investigated scheme for increasing the flow of Orange River water through this river via the Vanderkloof canal were to be commissioned.

Water quality issues are shown in **Figure 6.4.4.1**.

6.5 SEDIMENTATION

Introduction

Sedimentation was analysed according to river basin (by the consultant using data from Rooseboom) i.e the Upper Orange Basin and Vaal Basin. For the Upper Orange WMA, details of the Modder / Riet River catchment have been included in separate tables.

Sediment yield from the Upper Orange catchment varies from about 30 tonnes/km^2/a in areas of very low runoff to about 350 tonnes/km^2/a in the central regions. The average sediment yield for the Upper Orange River catchment as a whole is approximately 205 tonnes/km^2/a (refer to **Appendix G.2**, sediment yield (t/a) divided by the total gross area (km^2)). The total sediment load is of the order of 20 million tonnes/a, which is equivalent to an average annual volume of about 15 million cubic metres of sediment deposition. This volume amounts to about 0,2 % per year of the mean annual runoff. For the Modder/Riet catchment the average sediment yield is approximately 124 tonnes/km^2/a. The total sediment load is of the order of 4 million tonnes/a, which is equivalent to an average annual volume of about 3 million cubic metres after 25 years of deposition. This volume also amounts to about 0,7 % per year of the mean annual runoff for the Modder/Riet River catchment.

Sedimentation is a major problem in Welbedacht Dam, its capacity has decreased from 114 million m^3 to about 15 million m^3 when last estimated in 1994. Reservoir sedimentation rates are given in **Table 6.5.1**.

The construction of Katse and Mohale Dam (Lesotho Highlands Water Project) will re-distribute sedimentation in the Upper Orange River catchment. 1995 figures do not reflect these changes as construction is post 1995.

Sources of information

The primary source of information was the report entitled "The development of the new sediment yield map of Southern Africa" (Rooseboom et al., 1975). The results of this investigation were incorporated into the "Surface Water Resources of South Africa 1990" (WR90) set of reports (Steffen et al, 1994). The WR90 reports were the most convenient to use as the sediment map was superimposed on the quaternary catchment sub-divisions.

Another useful source of data is to be found in the periodic surveys of major reservoir basins, undertaken by DWAF. This information can be used to detect the rate of decrease in storage capacity over time, which can be attributed to the accumulation of sediment in the reservoir basins.

Sediment yield from map by Rooseboom et al

The sediment map is based on two layers of information. The first layer divides the country into nine sediment yield regions with an associated medium yield, expressed in tonnes/km^2/annum. The second layer depicts the erodibility index, which varies between 1 (highest erodibility) to 20 (lowest erodibility). These indices have been grouped into three classes, namely HIGH (1 to 8), MEDIUM (9 to 15) and LOW (16 to 20). Each sediment yield region has factors to apply to the medium yield, depending on whether the erodibility is high or low. (A factor of unity is applied in cases of medium erodibility.)

Each region has a family of confidence bands to indicate how, in most regions, the degree of confidence deteriorates as the catchment area decreases. However, as this study covers the entire Upper Orange River catchment only the mean yield has been used.

Sediment yield for each quaternary catchment was determined using the data from the sediment map. The results of this analysis appear in **Appendix G.2** and a brief summary of the results is given below.

Upper Orange River

Total sediment yield:	20,368 million tonnes/a
Gross catchment area:	99 349 km^2
Average yield:	205 tonnes per km^2 /a

Modder / Riet River

Total sediment yield:	4,332 million tonnes/a
Gross catchment area:	34 815 km^2
Average yield:	124 tonnes per km^2 /a

Sediment yields from reservoir basin surveys

An important factor in the conversion of sediment volumes determined from basin surveys into mass is the variable density of sediment deposits. In order to overcome this problem an indirect method was developed by Rooseboom (1975) for converting volume into mass, which overcomes the difficulties involved in estimating average density at a given stage. The sediment volume in a reservoir (with high sediment trap efficiency) after a period of time has been found to follow a logarithmic relationship for accumulations longer than about 10 years. It was found that for a number of South African and USA reservoirs it was possible to express the volume of sediment deposit after t years (V_t), in relation to the sediment volume after 50 years (V_{50}), as follows:

$$V_t = V_{50} \times 0{,}376 \times \ln (t/3{,}5)$$

By means of this equation it is possible to convert the volume after t years into an equivalent volume after 50 years and vice versa. Choice of the 50 year volume as a reference is arbitrary but it is possible to estimate the average density after 50 years more accurately than after say 10 years. A density of 1 350 kg/m^3 for the 50 year sediment was found to be appropriate for South African reservoirs.

The formula given above was used to determine the equivalent sediment volume after 25 years. The appropriate density after 25 years accumulation was then determined proportionately. For the Upper Orange and the Modder/Riet River catchments it was found to be 998 kg/m^3. Sediment yield (in tons/km^2/a) was then determined using the densities for the 25 year accumulation period.

The calculations for sediment yields based on available reservoir surveys are set out in **Table 6.5.1**, which list the dam name, record period, sediment volume at end of period (V_t), equivalent 50-year volume (V_{50}), net catchment area, equivalent 25-year volume (V_{25}) and average sediment yield. Also listed for purposes of comparison are the sediment yields derived from Rooseboom's map (as published in WR90).

TABLE 6.5.1: RECORDED RESERVOIR SEDIMENTATION RATES FOR RESERVOIRS IN THE UPPER ORANGE CATCHMENT.

MODDER/RIET Dam name	Year Constructed or last raised	Year of last Survey	Original capacity (10^6 m^3)	Surveyed capacity (10^6 m^3)	Sediment volume (10^6 m^3)	Number of years	V50 (10^6 m^3)	Volume per year (10^6 m^3/a)	Net Catchment Area (km^2)	Sediment Yield (m^3/km^2/a)	V25 (10^6 m^3)	Sediment yield (t/km^2/a)	Yield from map (t/km^2/a)
Kalkfontein	1938	1979	360,3	323,6	36,7	41	39,66	0,79329	8391	94,54	29,32	94,35	335
Rustfontein	1954	1988	77,74	72,21	5,53	34	6,47	0,12938	940	137,63	4,78	137,36	335
Krugersdrift	1970	1989	85,62	73,19	12,43	19	19,54	0,39084	5375	72,71	14,45	72,57	82
Tierpoort	1922	1979	38,39	34,34	4,05	57	3,86	0,07721	922	83,74	2,85	83,57	335
						Totals	**70**	**1,39071**	**15628**	**88,99**	**51**	**88,81**	**124**

UPPER ORANGE Dam name	Year Constructed or last raised	Year of last Survey	Original capacity (10^6 m^3)	Surveyed capacity (10^6 m^3)	Sediment volume (10^6 m^3)	Number of years	V50 (10^6 m^3)	Volume per year (10^6 m^3/a)	Net Catchment Area (km^2)	Sediment Yield (m^3/km^2/a)	V25 (10^6 m^3)	Sediment yield (t/km^2/a)	Yield from map (t/km^2/a)
Egmont	1938	1976	12,964	9,783	3,181	38	3,55	0,07095	314	225,95	2,62	224,60	335
Armenia	1974	1986	14,686	14,159	0,527	12	1,14	0,02275	858	26,52	0,84	26,36	82
Welbedacht	1973	1994	116,62	15,14	101,48	21	150,63	3,01261	14387	209,40	111,35	208,14	335
Bethulie	1922	1978	6,672	1,989	4,683	56	4,49	0,08984	255	352,32	3,32	350,21	335
Gariep	1970	1991	5958	5343	615	21	912,87	18,25734	54935	332,34	674,84	330,35	335
Vanderkloof	1976	1991	3237	3187	50	15	91,38	1,82753	19093	95,72	67,55	95,14	30
						Totals	**1164,1**	**23,28102**	**89842**	**259,13**	**857**	**257,58**	**205**

Note: For the “Yield from map” refer to Appendix G2, , sediment yield (t/a) divided by the gross area(km^2) .

The surveyed sedimentation rates display a wide variation among the reservoirs, ranging from as low as 26 tonnes/km^2/a to as high as 350 tonnes/km^2/a. This wide range is attributable more to the inaccuracies inherent in assessing small differences between successive surveys than to actual differences in sediment yield. Another factor, which affects short record periods in particular, is the high variation in sediment load from year to year. Significant sediment deposits are associated with the major floods; thus several years may elapse with negligible sediment volumes being deposited.

The average sediment yield for all reservoirs in the Upper Orange River catchment was calculated to be 258 tonnes/km^2/a, which is about 26% above the figure derived from the sediment map. For the Modder/Riet River catchment the average sediment yield was calculated to be about 89 tonnes/km^2/a, which is about 76% of the figure derived from the sediment map.

Reconciliation of sediment yields from surveys and map

The discrepancy between the two estimates of sediment yield appeared to be unacceptably large. Accordingly, Prof. Rooseboom was approached for advice. His comments on the discrepancy are summarised in point form below:

- The sediment map is unreliable in this area (i.e. upper Orange).
- The sediment yield upstream of Gariep Dam should be about 600 tonnes/km^2/a.
- There is very little data downstream of Gariep Dam but the sediment yield could be of the order of 400 tonnes/km^2/a.
- Records at Prieska (downstream of the Orange/Vaal River confluence) show a drop in sediment load over the period 1930 to 1970, during which time the average yield was halved.

Rooseboom's comments indicate that the sediment yields derived from the reservoir surveys are the more reliable, as they are much closer to his estimates. Furthermore, they are not affected to a significant degree by the (apparently) higher sediment regime prior to 1970. In the light of the foregoing it was decided to increase the sediment yields derived from the map by the ratio 258/205 (i.e. by the ratio total survey yield: total map yield) for the Upper Orange River catchment. **Table 6.5.2 (a)** summarises the sediment data at the tertiary catchment level for the Upper Orange River catchment. For the Modder/Riet River catchment it was decided to accept the discrepancy due to the fact that for the Vaal River Basin as a whole the differences were not that high. **Table 6.5.2 (b)** summarises the sediment data at the tertiary catchment level for the Modder/Riet River catchment. **Appendix G.2** contains details of sediment load calculations for each quaternary catchment (WR90 information).

TABLE 6.5.2 (A): SEDIMENT YIELD FROM TERTIARY CATCHMENTS IN THE UPPER ORANGE CATCHMENT.

Tertiary Number	Description (river)	Net area (km^2)	Sediment yield		
			($t/km^2/a$)	($10^6 t/a$)	($10^6 m^3/a$) *
D11	Malibamatso	3 360	255	0,858	0,860
D12	Orange (u/s Kraai)	2 967	422	1,251	1,253
D13	Kraai	9 354	422	3,944	3,952
D14	Stormberg	6 145	422	2,591	2,596
D15	Kornet	3 360	255	0,858	0,860
D16	Upper Orange (Senqu)	4 520	255	1,155	1,157
D17	Sinqunyane	7 179	255	1,834	1,838
D18	Orange (u/s border)	6 260	255	1,599	1,603
D21	Upper Caledon	3 563	422	1,502	1,505
D22	Middle Caledon	6 200	422	2,614	2,619
D23	Middle Caledon	5 507	422	2,048	2,052
D24	Lower Caledon	6 614	422	2,789	2,794
D31	Orange (Vanderkloof)	4 396	38	0,166	0,166
D32	Seacow	9 081	38	0,343	0,344
D33	Orange (u/s Vaal)	3 404	47	0,158	0,159
D34	Orange (d/s Gariep)	5 020	38	0,190	0,190
D35	Orange (Gariep)	5 638	307	1,734	1,737
TOTAL	**Total Upper Orange**	**92 568**	**277**	**25,633**	**25,685**

TABLE 6.5.2 (B): SEDIMENT YIELD FROM TERTIARY CATCHMENTS IN THE MODDER/RIET CATCHMENT.

Tertiary Number	Description	Net area (km^2)	Sediment yield		
			($t/km^2/a$)	($10^6 t/a$)	($10^6 m^3/a$) *
C51	Riet	12 166	298	3,630	3,637
C52	Modder	8 572	82	0,703	0,704
TOTAL	**Modder / Riet catchment**	**20 738**	**380**	**4,333**	**4,341**

* Average volume after 25 years deposition.

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 water resource and the sum of all the water requirements and losses. While the water requirements and losses are easily abstracted from the database (or can be calculated by the WRSA consultant), to estimate the water resource 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 modeling, 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 modeled correctly.

The approach taken to determine the water balance was therefore to remove the above questionable components out of the WSAM modeling procedure. This is done relatively easily. The above impacts (ecological Reserve, etc.) were then determined external 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.

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 worksheet were structured so a 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 Appendices 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.

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.

The water balance produced by the WSAM, as described in **Section 7.1.2** above, was mostly deemed to be correct. In the few instances where it was clearly incorrect an adjustment was made based on the results of other studies. These changes have been documented. A few adjustments were made to the model to allow for the following.

<u>Runoff into minor dams</u>

It appears as if the WSAM assumes that the runoff into minor dams is equal to the entire incremental flow generated within a quaternary catchment. Considering the definition of a minor dam, i.e. a dam that is not situated on the main stream of the catchment, this is not possible. An assumption was made that only 50% of the runoff of a catchment flows into minor dams and this assumption was applied throughout the WMA.

Impact of afforestation and alien vegetation on catchment yield

The WSAM seems to determine the impact of afforestation and alien vegetation on yield in a realistic manner. However, it does not report correctly on what this impact is. This problem was resolved by adopting zero afforestation and alien vegetation in the catchments when running the WSAM and calculating these impacts external to the model. The impacts on the yield of the catchments were then accounted for external to the model when determining the water balance.

- The available water resource was then assumed to be the difference between the water balance and the water requirements that are supplied from the catchment.
- In some cases, there are negative balances within the quaternary catchments making up a key area. These negative balances are not routed through the system, and it was therefore necessary to sum these negative balances and subtract them from the water resource.
- In some cases the WSAM did not model the yield of major dams correctly and the yield curves were adjusted to approximate the yield as obtained from more detailed studies.

7.2 OVERVIEW

Key areas were selected on the basis that they represented major dams, tertiary catchments or the outflows from tributaries into major rivers. Table 7.2.1 lists the selected key areas for the Upper Orange WMA.

The 1995 water requirements (at 1:50 year assurance) for key areas are summarised in **Table 7.2.2**. The total water requirements (consumptive and non-consumptive) for this WMA were estimated to be about 7 157 x $10^6 m^3/a$. (dominated by hydropower requirements). **Table 7.2.3** summarises the water balance for key areas. There is a surplus yield (spillage) from the Upper Orange sub-area of the WMA to the downstream Lower Orange WMA of about 766 x $10^6 m^3/a$. From the Modder / Riet sub-area there is a surplus yield of about 18 x $10^6 m^3/a$ to the downstream Lower Vaal and Lower Orange WMAs.

There are two major transfers out of this WMA, namely the Orange-Fish Transfer and the Orange-Vaal Transfer.

The cumulative water use and availability at 1:50 year assurance at each key area outlet has been shown by pie diagrams (in units of 10^6 m^3/a) in **Figure 7.2.1**. Categories shown are consumptive requirements (hydropower, urban, rural, irrigation, bulk, afforestation and exports), ecological Reserve requirement and losses. Where there is a surplus of water (includes imports and re-usable return flows), a larger circle has been superimposed on the pie diagram and where there is a deficit; a smaller circle has been superimposed. The water resources situation assessment in each key area is described below.

TABLE 7.2.1: KEY POINTS FOR YIELD DETERMINATION.

LOCATION OF KEY POINT			DESCRIPTION
PRIMARY CATCHMENT		QUATERNARY CATCHMENT NO.	
NO.	KEY AREA NAME AND POINT		
C	Kalkfontein- C51J outlet	C51A-J	Kalkfontein Dam
	Riet – C51K outlet	C51K	Confluence of Riet and Modder
	Riet / Modder – C51M outlet	C51L-M, C52H-L	Remaining C5 Tertiary catchment
	Rustfontein - C52A outlet	C52A	Rustfontein Dam
	Krugersdrift – C52G outlet	C52B-G	Rustfontein to Krugersdrift
D	Katse – D11K outlet	D11A-K	Katse Dam
	Senqu – D18L outlet	D15A-H, D16A-L,D17A-M, D18A-L	Senqu and Maphutsaneng catchments in Lesotho
	Orange u/s Gariep – D14K outlet	D12A-F, D13A-M,D14A-K	U/s Gariep Dam
	Caledon – Lesotho – D22L outlet	D21A*, D21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	Upper Caledon River catchment in Lesotho
	Caledon - RSA – D22L outlet	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	Upper Caledon River catchment in South Africa (Free State)
	Welbedacht – Lesotho – D23G outlet	D23A*, D23B, D23E*, D23F*, D23G*	Welbedacht Dam catchment in Lesotho
	Welbedacht – RSA- D24C outlet	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	Welbedacht Dam catchment in South Africa (Free State)
	Caledon d/s Welbedacht – D24L outlet	D24D-L	Remaining D24 Tertiary catchment
	Gariep – D35K outlet	D35A-K	D35 Tertiary catchment
	Vanderkloof – D31E outlet	D31A-E, D32A-K, D34A-G	D/s Gariep Dam to Vanderkloof Dam
	Orange d/s Vanderkloof – D33K outlet	D33A-K	D33 Tertiary catchment

Note: * Quaternary area within Lesotho and RSA.

TABLE 7.2.2: 1995 WATER REQUIREMENTS BY KEY AREA (AT 1:50 YEAR ASSURANCE).

CATCHMENT						STREAMFLOW REDUCTION ACTIVITIES (10^6 m^3/a)		WATER USE (10^6 m^3/a)		WATER REQUIREMENT (10^6 m^3/a)						ECOLOGICAL RESERVE (10^6 m^3/a)	TOTAL (10^6 m^3/a)
PRIMARY		SECONDARY		TERTIARY													
No.	Description	No.	Description	No.	Key Area Description	AFFORES-TATION	DRYLAND SUGAR CANE	ALIEN VEG.	RIVER LOSSES	BULK	IRRI-GATION	RURAL	URBAN	WATER TRANSFERS OUT[1]	HYDRO-POWER		
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	0,0	0,0	0,0	0,0	0,0	27,5	2,9	1,8	0,0	0,0	8,4	40,6
		C5	Riet	C51	Riet (C51K)	0,0	0,0	0,0	0,0	0,0	118,4	1,0	2,4	0,0	0,0	0,0	121,8
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	0,0	0,0	0,0	0,0	0,0	51,3	5,6	5,1	0,0[4]	0,0	0,0	62,0
		C5	Rustfontein	C52	Rustfontein (C52A)	0,0	0,0	0,0	0,0	0,0	2,3	0,5	0,3	11,6	0,0	0,9	15,6
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	0,0	0,0	0,0	0,0	1,9	15,5	3,0	61,0	0,0	0,0	1,9	83,3
	Sub-total in Modder / Riet (C) primary catchment					**0,0**	**0,0**	**0,0**	**0,0**	**1,9**	**215,0**	**13,0**	**70,6**	**11,6**	**0,0**	**11,2**	**323,3**
D	Orange	D1	Katse	D11	Katse (D11A-K)	0,0	0,0	0,0	0,0	0,0	0	3,3	0,0	0,0	0,0	16,3	19,6
		D1	Senqu	D15-D18	Senqu (D15A-H, D16A-L, D17A-M, D18A-L)	0,0	0,0	0,0	0,0	0,0	21,4	18,2	2,2	0,0	0,0	151,3	193,1
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	0,0	0,0	0,0	0,0	0,0	109,7	10,6	5,2	0,0	0,0	185,7	311,2
		D2	Caledon - Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	0,0	0,0	0,0	0,0	0,0	7,2	13,7	17,0	0,0	0,0	3,7	41,6
		D2	Caledon - RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	0,4	0,0	0,0	0,0	0,0	11,6	3,6	5,0	0,0	0,0	3,7	23,9
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	0,0	0,0	0,0	0,0	0,0	4,8	3,6	1,6	0,0	0,0	0,1	10,1
		D2	Welbedacht – RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	0,0	0,0	0,0	0,0	0,0	33,0	3,4	1,3	39,8	0,0	0,0 (-0,8)	77,5
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	0,0	0,0	0,0	0,0	0,0	36,1	2,1	1,2	0,0	0,0	0,0 (-2,1)	39,4
		D3	Gariep	D35	Gariep (D35A-K)	0,0	0,0	0,0	0,0	0,0	14,3	1,3	1,6	550,2	2 635,0	265,7	3 468,1
		D3	Vanderkloof	D31,32,34	Vanderkloof (D31A-E, D32A-K, D34A-G)	0,0	0,0	0,0	69,0	0,0	51,7	3,2	2,5	70,7	2 355,0	291,0	2 843,1
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K) l	0,0	0,0	0,0	0,0	0,0	171,6	1,6	1,0	18,9	0,0	0,0 (-594,8)	193,1
	Total in D primary catchment					**0,0**	**0,0**	**0,0**	**69,0**	**0,0**	**461,4**	**64,6**	**38,6**	**679,6**	**4 990,0**	**917,5**	**7 220,7**
Total in Lesotho in D primary catchments						**[0,0]**	**[0,0]**	**[0,0]**	**[0,0]**	**[0,0]**	**[33,4]**	**[38,8]**	**[20,8]**	**[0,0]**	**[0,0]**	**[171,4]**	**[264,4]**
Total in Free State in C and D primary catchments						**0,0**	**0,0**	**0,0**	**13,8**	**1,9**	**430,8**	**25,3**	**80,3**	**362,0**	**2 495,0**	**478,9**	**3 888,0**
Total in Northern Cape in C and D primary catchments						**0,0**	**0,0**	**0,0**	**55,2**	**0,0**	**105,5**	**8,6**	**2,9**	**54,2**	**1 178,0**	**145,5**	**1 549,9**
Total in Eastern Cape in D primary catchments						**0,0**	**0,0**	**0,0**	**0,0**	**0,0**	**106,7**	**4,9**	**5,2**	**275,0**	**1 317,0**	**132,9**	**1 841,7**
TOTAL IN WMA (South Africa only)						**0,0**	**0,0**	**0,0**	**69,0**	**1,9**	**643,0**	**38,8**	**88,4**	**691,2[2]**	**4 990,0**	**757,3**	**7 279,6[3]**

Note:
- * Quaternary catchment area within Lesotho and RSA (split provided by DWAF).
- (1) Only potable water transfers considered.
- (2) Total transfers (including between key areas) = 691 x 10^6 m^3/a, transfers out of WMA are: 550 x 10^6 m^3/a (Orange – Fish), 18,9 x 10^6 m^3/a (Orange – Vaal) – a total of 568,9 x 10^6 m^3/a. Transfers within the WMA between key areas = 122,3 x 10^6 m^3/a.
- (3) Total requirement in 1995 at 1:50 assurance: 7 279,4 x 10^6 m^3/a – 122,1 x 10^6 m^3/a = 7 157,3 x 10^6 m^3/a because the internal transfers are accounted for in the water requirements of key areas.
- (4) Small effluent transfer from this key area.

TABLE 7.2.3: WATER REQUIREMENTS AND AVAILABILITY.

CATCHMENT						AVAILABLE 1 IN 50 YEAR YIELD IN 1995 ($10^6 m^3/a$)			WATER TRANSFERS AT 1:50 YEAR ASSURANCE ($10^6 m^3/a$)		RETURN FLOWS AT 1:50 YEAR ASSURANCE ($10^6 m^3/a$)		WATER REQUIREMENTS[1] AT 1:50 YEAR ASSURANCE ($10^6 m^3/a$)[2]	WATER BALANCE AT 1:50 YEAR ASSURANCE ($10^6 m^3/a$)
PRIMARY		SECONDARY		TERTIARY		SURFACE WATER[5]	GROUND-WATER USE IN 1995	TOTAL	IMPORTS [1]	EXPORTS [1]	RE-USABLE	TO SEA		
No.	Descript-ion	No.	Description	No.	Key Area Description									
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	(+) 74,2	(+) 1,4	(+) 75,6	(+) 0,7	0,0	(+) 2,8	0	(-) 40,6	(+) 38,5[3]
		C5	Riet	C51	Riet (C51K)	(+) 91,8 [+70,7][5]	(+) 0,7	(+) 92,5	(+) 0,0	0,0	(+) 12,4	0	(-) 121,8	(+) 21,6[3,4]
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	(+) 0,0	(+) 2,3	(+) 2,3	(+) 3,8	0,0	(+) 6,4	0	(-) 62,0	(+) 18,1[4,5]
		C5	Rustfontein	C52	Rustfontein (C52A)	(+) 9,1	(+) 0,7	(+) 9,8	(+) 0,0	(-) 11,6	(+) 0,0	0	(-) 4,0	(-) 5,8[6]
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	(+) 125,6 [+47,1][5]	(+) 1,4	(+) 127,0	(+) 2,3	0,0	[(+) 39,9][6]	0	(-) 83,3	(+) 46,0[6,5]
	Total in Modder / Riet (C) primary catchment					**(+) 300,7**	**(+) 6,5**	**(+) 307,2**	**(+) 6,8**	**(-) 11,6**	**(+) 21,6**	**0**	**(-) 311,7**	
	Yield to Lower Vaal WMA (surplus):													**(+) 18,1**
D	Orange	D1	Katse	D11	Katse (D11A-K)	(+) 6,5[7]	(+) 0,0	(+) 6,5	0,0	0,0	(+) 0,0	n/a	(-) 19,6	[(-) 13,1]
		D1	Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	(+) 47,2 [7]	(+) 0,1	(+) 47,3	0,0	0,0	(+) 2,1	n/a	(-) 193,1	[(-) 143,7]
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	(+) 150,6	(+) 10,5	(+) 161,1	0,0	0,0	(+) 11,0	n/a	(-) 311,2	[(-) 139,1]
		D2	Caledon – Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	(+) 28,3	(+) 0,1	(+) 28,4	0,0	0,0	(+) 2,6	n/a	(-) 41,6	[(-) 10,6]
		D2	Caledon – RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	(+) 27,7	(+) 0,5	(+) 28,2	0,0	0,0	(+) 2,6	n/a	(-) 23,9	[(+) 6,9 [8]]
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	(+) 10,9	(+) 0,5	(+) 11,4	0,0	0,0	(+) 0,5	n/a	(-) 10,1	[(+) 1,8 [8]]
		D2	Welbedacht-RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	(+) 55,8	(+) 3,5	(+) 59,3	0,0	(-) 39,8	(+) 3,3	n/a	(-) 37,7	[(-) 6,2 [8]]
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	(+) 37,5	(+) 0,8	(+) 38,3	0,0	0,0	(+) 3,7	n/a	(-) 39,4	[(+) 2,6]
		D3	Gariep	D35	Gariep (D35A-K)	(+) 2 539,2[9]	(+) 1,8	(+) 2 541,0	0,0	(-) 550,2	(+) 2 372,4	n/a	(-) 2 917,9	(+) 1 445,3 [10]
		D3	Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	(+) 408,9	(+) 32,8	(+) 441,7	0,0	(-) 70,9	(+) 1 913,2	n/a	(-) 2 772,4	(+) 956,9 [10,11]
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K) l	(+) 0,0	(+) 14,9	(+) 14,9	(+) 0,2	(-) 18,9	(+) 17,2	n/a	(-) 174,2	(+) 796,1 [11]
	Total in Upper Orange (D) primary catchment					**(+) 3 312,6**	**65,5**	**(+) 3 378,1**	**(+) 0,2**	**(-) 679,8**	**(+) 4 328,6**	**n/a**	**(-) 6 541,1**	
Total in Lesotho in D primary catchment						**[92,9]**	**[0,7]**	**[(+) 93,6]**	**[0,0]**	**[0,0]**	**[(+) 5,2]**	**[n/a]**	**[(-) 264,4]**	**#**
Total in Free State in C and D primary catchments						**2 025,7**	**33,6**	**2 059,3**	**0,2**	**350,4**	**2 178,2**	**n/a**	**3 526,0**	**#**
Total in Northern Cape in C and D primary catchments						**204,5**	**27,0**	**231,5**	**0,0**	**54,3**	**969,6**	**n/a**	**1 495,7**	**#**
Total in Eastern Cape in D primary catchment						**1 420,2**	**10,7**	**1 430,9**	**0,0**	**275,1**	**1 197,2**	**n/a**	**1 566,7**	**#**
TOTAL IN WMA (South Africa only)						**(+) 3 650,4**	**(+) 71,3**	**(+) 3 721,7**	**(+) 0,2**	**(+) 679,8**	**(+) 4 345,0**	**n/a**	**6 588,4**	
Surplus yield to Lower Orange WMA:														**(+) 796,1**

See overleaf for notes:

Notes:

- * Quaternary area within Lesotho and RSA.
- # Provincial split not readily available.
- $ Available surface water yield represents a net value that includes large transfers and accounts for evaporation losses in the receiver key areas. For example the Orange-Riet Transfer of 70,7 x 10^6 m^3/a is included in the net surface yield of the Riet key area.
- (1) Potable water transfers only.
- (2) Requirements include ecological reserve, river losses, urban, rural; irrigation, bulk, alien vegetation and afforestation.
- (3) Surplus yield from Kalkfontein key area to downstream Riet key area.
- (4) Surplus yield from Riet key area to downstream Riet Modder confluence key area.
- (5) Surplus yield from Krugersdrift key area to downstream Riet Modder Confluence.
- (6) Urban returns in this key area are re-used locally (according to Dr M. Basson, BKS, 2001, NWRS workshop).
- (7) Before construction of Katse and Mohale Dams (Lesotho Highlands Project).
- (8) Surplus yield from Caledon (RSA) key area and Welbedacht (Lesotho) key area to the downstream Welbedacht (RSA) key area.
- (9) Calculated net surface water yield includes yields from all upstream areas and Gariep Dam.
- (10) Surplus yield from Gariep key area to downstream Vanderkloof key area.
- (11) Surplus yield from Vanderkloof key area to downstream Orange d/s Vanderkloof key area.
- [ ] These balances –if positive (surplus) are included in “Surface Water” for the Gariep key area.

7.3 KALKFONTEIN KEY AREA

This key area has a surplus of about 38,5 x 10^6m^3/a. The area is rural in nature and has significant irrigation (mainly diffuse) requirements (68 % of total requirements). Edenburg and Jagersfontein are the most significant urban centres in the area. Water is imported by Bloem Water from Welbedacht Dam (Welbedacht key area) and Gariep Dam, to supply the needs of Edenburg, Reddersburg and Trompsburg TLCs.

The surplus is transferred down the Riet River to the Riet key area. Releases are made from the Kalkfontein Dam to meet the scheduled requirements of the downstream Kalkfontein Irrigation Board. Due to downstream irrigation requirements the potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources. Currently less than 2 % of exploitable groundwater is exploited (**Table 6.2.1**), however the WRSA consultant is of the opinion that the estimate of groundwater in use is an underestimate. It appears that this key area is about two-thirds developed with regard to surface water (**Table 6.3.3.1**).

7.4 RIET KEY AREA

This key area receives 38,5 x 10^6m^3 from the upstream Kalkfontein key area the result is a surplus of about 21,6 x 10^6m^3. The area is rural in nature and has significant controlled irrigation requirements (97 % of total requirements). Koffiefontein TLC and the associated Debeers Diamond Mine is the most significant urban centre in the area. Water is imported for irrigation from the Vanderkloof key area from Vanderkloof Dam via the Orange-Riet Canal.

The surplus is transferred downstream the Riet River to the Riet/Modder confluence key area.

The potential for water resources development is dependent on the availability of water from the Orange River and to the exploitation of local groundwater resources. Currently about 5 % of the exploitable groundwater is being exploited (**Table 6.2.1**). It appears that this key area is about two-thirds developed with regard to surface water (**Table 6.3.3.1**).

7.5 RIET/MODDER CONFLUENCE KEY AREA

This key area receives about 21,6 x 10^6m^3 from the upstream Riet key area and about 46 x 10^6m^3 from the upstream Krugersdrift key area. The result is a surplus of about 18 x 10^6m^3. The area is rural in nature and has significant controlled irrigation requirements (81 % of total requirements). Bloemspruit and Bainesvlei TLCs in the east of the key area are the most significant urban centres in the area. Both these centres receive water from Welbedacht Dam via the Bloem Water network.

The surplus is transferred downstream to the Riet, Vaal and Orange confluence area to be used by irrigators in the Douglas area.

The potential for water resources development is dependent on the availability of water from the Orange River (Orange-Riet Transfer) and the upstream Krugersdrift key area (Novo Transfer) and to the exploitation of local groundwater resources. Currently less then 5 % of the exploitable groundwater is being exploited (**Table 6.2.1**). It appears that this key area is about two-thirds developed with regard to surface water (**Table 6.3.3.1**).

7.6 RUSTFONTEIN KEY AREA

This key area has a deficit of about 6,0 x $10^6 m^3$. While the area is rural in nature, its main requirement is an export from Rustfontein Dam of 11,6 x $10^6 m^3$ to supply Botshabelo and Thaba Nchu TLCs in the Krugersdrift key area (74 % of total requirements). Dewetsdorp TLC is the only significant urban centre in the area and receives some of its water from Welbedacht Dam via the Bloem Water transfer network.

The surface water resources of this key area will be augmented from 2001 when the first phase (2,7 m^3/s) of the Novo Transfers becomes operational. There is limited groundwater resources exploitation potential in this area, currently about 10 % of exploitable groundwater is being exploited (**Table 6.2.1**). It appears that this key area is about one-half developed with regard to surface water (**Table 6.3.3.1**).

7.7 KRUGERSDRIFT KEY AREA

This key area has a surplus of about 46 x $10^6 m^3/a$. The area is dominated by the urban requirements of Bloemfontein, Botshabelo and Thaba Nchu TLC's. Urban requirements are 73 % of total requirements. To meet the requirements of these centres, water is imported from the Welbedacht key area (Welbedacht Dam), Rustfontein key area (Rustfontein Dam) and from the Middle Vaal WMA (Erfenis Dam to supply Brandfort TLC). The contributions from Welbedacht and Rustfontein Dams are reflected in the surface water yield figure of this key area (**Table 7.2.3**). Urban return flows from these urban centres (stormwater returns and effluent returns) are significant (39,9 x $10^6 m^3$) but have been excluded from the water balance as information indicates that this water is re-used locally (Basson, 2001).

This key area does contribute to the yield of the lower Modder / Riet confluence key area. Releases are made from the Kalkfontein Dam to meet the scheduled irrigation requirements of the downstream Modder GWS.

There is limited groundwater resources exploitation potential in this area, currently less than 5 % of exploitable groundwater is being exploited (**Table 6.2.1**). It appears that this key area is about one-half developed with regard to surface water (**Table 6.3.3.1**). This key area should also benefit from the Novo Transfer Scheme.

7.8 KATSE KEY AREA

This key area has a deficit of about 13 x $10^6 m^3/a$ caused mainly by the ecological reserve requirement (84 % of total requirements). The area is rural in nature with livestock farming the main activity in the area. The construction of the LHWP Katse Dam in this area since 1995 will contribute significantly to the water resources of the area. This will mean that the balance will alter and must be reviewed.

The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources which is less than 1 % of exploitable groundwater (**Table 6.2.1**).

7.9 SENQU KEY AREA

This key area has a deficit of about 143 x $10^6 m^3/a$ caused by the high ecological reserve requirement (79 % of total requirements). This area is rural in nature with livestock farming and irrigation in the lower reaches of the Senqu, the main activities in the area. Mohaleshoek and Moyeni were selected to represent urban centres in the area. The construction of the LHWP Mohale Dam in this area since 1995 means that there will be significant changes to the water resources of the area and that the balance will alter and must be reviewed.

The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources which is less than 1 % of exploitable groundwater (**Table 6.2.1**).

7.10 ORANGE U/S GARIEP KEY AREA

This key area has a deficit of about 139,0 x $10^6 m^3/a$ and is dominated by ecological Reserve requirements (60 % of total requirement. The area is rural in nature and has significant diffuse irrigation requirements (35 % of total requirements). Aliwal North and Burgersdorp TLCs are the most significant urban centres in the area. There is no known significant import or export of water from this key area.

The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources which is about 7% of exploitable groundwater (**Table 6.2.1**). This key area should benefit from the LHWP dams and the balance will need to be reviewed.

7.11 CALEDON-LESOTHO KEY AREA

This key area has a deficit of about 10,6 x $10^6 m^3/a$. This area is the most populated area of Lesotho and it is dominated by urban (41% of total requirements) and rural (32% of total requirements) requirements. Maseru, Butha Buthu and Leribe were selected to represent the urban centres in the area. The balance should be reviewed if more reliable requirement data becomes available.

The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources which is less than 5% of exploitable groundwater (**Table 6.2.1**).

7.12 CALEDON–SOUTH AFRICA KEY AREA

This key area has a small surplus of about 7 x $10^6 m^3/a$. Being mainly rural in nature the requirements are dominated by irrigation and rural requirements (62% of total requirements). Ficksburg and Ladybrand TLCs are the most significant urban centres in the area. There is no known significant import or export of water from this key area. The surplus yield (spillage) contributes to the downstream Welbedacht key area.

The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources which is less than 2% of exploitable groundwater (**Table 6.2.1**).

7.13 WELBEDACHT-LESOTHO KEY AREA

This key area has a small surplus of about 2 x $10^6 m^3/a$. Mainly rural in nature the area is dominated by irrigation and rural (82 % of total requirement) requirements. Makateng was selected to represent the urban centres in the area. The balance should be reviewed if more reliable usage data becomes available. The surplus yield (spillage) contributes to the downstream Welbedacht key area.

The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources which is about 5% of exploitable groundwater (**Table 6.2.1**).

7.14 WELBEDACHT–SOUTH AFRICA KEY AREA

This key area has a deficit of about 6 x $10^6 m^3/a$. This area is mainly rural in nature but is dominated by Bloem Water Transfers from Welbedacht Dam to supply urban centres in the adjacent Modder / Riet catchment. Transfers and irrigation requirements make up 51% and 48% respectively of total requirements in this key area. Wepener TLC is the most significant urban centre in the area. This area does not contribute to the downstream water resources.

The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources which is about 10% of exploitable groundwater (**Table 6.2.1**).

7.15 CALEDON DOWNSTREAM WELBEDACHT KEY AREA

This key area has a small surplus of about 3 x $10^6m^3/a$. The area is mainly rural in nature and is dominated by irrigation requirements (92% of total requirements). Rouxville and Smithfield TLCs are the most significant urban centres in the area. There is no known significant import or export of water from this key area. This area does not contribute to the downstream water resources.

The potential for water resources development within the key area is mostly limited to the exploitation of groundwater resources which is less than 2% of exploitable groundwater (**Table 6.2.1**).

7.16 GARIEP KEY AREA

This key area has a surplus of about 1 415 x $10^6m^3/a$. This area is mainly rural in nature and its most significant feature is the Gariep Dam. The area is dominated by the hydropower water requirements of the Gariep Hydropower Station (about 75 %). However a significant portion of this requirements is re-usable (2 371 x $10^6m^3/a$) and is available to downstream users. The most important inter-basin transfer also occurs from the Gariep Dam, namely the about 550 x $10^6m^3/a$ Orange – Fish transfer to the Fish Tsitsikama WMA. The ecological reserve requirements are also significant. Bethulie and Venterstad TLCs are the most significant urban centres in the area.

This key area is fully exploited by Gariep Dam. The potential for water resources development is therefore limited to the exploitation of groundwater resources which is about 5% of exploitable groundwater (**Table 6.2.1**). The surplus is transferred downstream the Orange River to the Vanderkloof key area.

7.17 VANDERKLOOF KEY AREA

This key area receives about 1 415 x $10^6m^3/a$ from the upstream Gariep key area, the result is a surplus of about 927 x $10^6m^3/a$. Like the upstream Gariep key area this area is mainly rural in nature and its most significant feature is the Vanderkloof Dam. The area is dominated by the hydropower water requirements of the Vanderkloof Hydropower Station (83 %). However a significant portion of this requirements is re-usable (1 913 x $10^6m^3/a$) and is available to downstream users. There is a significant transfer, namely the Orange – Riet River transfer from Vanderkloof Dam to the adjacent Riet key area to augment irrigation water requirements. The ecological reserve requirement is also significant. Colesberg and Noupoort TLCs are the most significant urban centres in the area.

This key area is fully exploited by Vanderkloof Dam. The potential for water resources development is therefore limited to the exploitation of groundwater resources which is about 20% of exploitable groundwater (**Table 6.2.1**). The surplus is transferred down the Orange River to the Orange d/s Vanderkloof key area.

7.18 ORANGE DOWNSTREAM VANDERKLOOF KEY AREA

This key area receives about 927 x $10^6 m^3/a$ from the upstream Vanderkloof key area, the result is a surplus of about 796 x $10^6 m^3/a$. The area is rural in nature and has significant irrigation requirements (89% of total requirements). There is a significant transfer, namely the Orange – Vaal transfer from Marksdrift in the Orange River to the Douglas weir area to augment irrigation water requirements. Hopetown TLC is the most significant urban centre in the area.

Groundwater appears to be almost fully exploitable (**Table 6.2.1**) as does surface water. The surplus is transferred down the Orange River to the Lower Orange WMA.

CHAPTER 8: COSTS OF WATER RESOURCE DEVELOPMENT

8.1 METHODOLOGY

The ORRS reports deal extensively with options for future use of Orange River water - refer to "Hydrology and System Analysis – Orange River Basin PD000/00/4697 (BKS et al., 1997). A summary of these options follows:

- Raising Gariep Dam. Raising by 5m, 10m and 15m scenarios were analysed. A reduced minimum operating level (MOL) was also investigated.

- A reduced minimum operating level at Vanderkloof Dam.

- A new dam – Bosberg Dam on the Orange River upstream of the Kraai River to transfer water to the Vaal River system and to support Gariep and Vanderkloof when their MOL are reached. Supply to the Vaal system (Caledon – Vaal transfer) has been investigated.

- A new dam – Torquay Dam to balance hydropower releases from Vanderkloof Dam.

- A new dam – Boskraai Dam in the Kraai River catchment with a similar purpose to Bosberg Dam.

- A new dam – Mohale Dam (Phase 1B) in Lesotho is planned to start transferring water to Katse in 2003. The yield of Mohale Dam is 9,6 m^3/s. The Matsoku Weir (also Phase 1B) was planned to start transferring water to Katse as well (in 2001).

- A new dam - Mashai Dam in Lesotho, which is part of Lesotho Highlands Phase 2, may come into operation in about 2020.

- New dams – Tsoelike (Phase 3) and Ntoahae (Phase 4) are also planned for future implementation.

- There are some other new dams which have been considered in the Lower Orange WMA such as Vioolsdrift (to supply demands normally met by Vanderkloof and Gariep Dams), Molopo and Boegoeberg (reregulation dam to minimise operating losses).

There are numerous combinations of certain of the above developments and scenarios which have been dealt with in detail in the ORRS report. The costing of all these numerous options is therefore an extremely detailed task and will not be dealt with in this report.

Possible new dam locations are shown in the ORRS report, in Appendix G-7.

There are no known potential wellfields that could be developed on a major scale.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

In the Upper Orange WMA, irrigation is the largest consumptive user of water. The result is that a number of schemes have been developed to transfer water to catchments that require augmentation of their natural water resources. The Orange-Fish Transfer is the most important of these schemes. At the 1:50 level of assurance as at 1995, the Upper Orange WMA yields about 796 x $10^6 m^3/a$ to the Lower Orange WMA. This surplus should, however, not be viewed in isolation but be considered with resources and requirements of the Lower Orange WMA. The surplus from the Modder/Riet catchment is used up by irrigation in the vicinity of Douglas and does not contribute to the Lower Orange WMA.

Surface water in the Modder/Riet sub-catchment has not been fully developed and there is also potential for the exploitation of groundwater which ranges from about 2% to 10%. Surface water in the Upper Orange sub-catchment has been fully developed but there is also potential for the exploitation of groundwater which ranges from about 2% to 20% (with the exception of downstream of Vanderkloof Dam where the groundwater appears to be almost fully exploited).

In the Katse and Senqu key areas, it appears that the surface water yields are unrealistically low (DWAF data).

Hydro-power accounts for 98% of the return flow with irrigation and urban returns making up the balance.

The following table summarises available yield and water requirements. It should be noted that because this report is based on the 1995 situation, the Lesotho Highlands scheme has not been included (1998).

TABLE 9.1: SUMMARY OF YIELD AND WATER REQUIREMENTS

CATCHMENT						TOTAL YIELD	IMPORTS [1]	EXPORTS [1]	RE-USABLE	WATER REQUIRE-MENTS[1] AT 1:50 YEAR ASSURANCE $(10^6\ m^{3}/a)$[2]	WATER BALANCE AT 1:50 YEAR ASSURANCE $(10^6\ m^{3}/a)$
PRIMARY		SECONDARY		TERTIARY							
No.	Descript-ion	No.	Description	No.	Key Area Description						
C	Vaal	C5	Kalkfontein	C51	Kalkfontein (C51A-J)	(+) 75,6	(+) 0,7	0,0	(+) 2,8	(-) 40,6	(+) 38,5[3]
		C5	Riet	C51	Riet (C51K)	(+) 92,5	(+) 0,0	0,0	(+) 12,4	(-) 121,8	(+) 21,6[3,4]
		C5	Riet/Modder	C51-C52	Riet/Modder confluence (C51L-M, C52H-L)	(+) 2,3	(+) 3,8	0,0	(+) 6,4	(-) 62,0	(+) 18,1[4,5]
		C5	Rustfontein	C52	Rustfontein (C52A)	(+) 9,8	(+) 0,0	(-) 11,6	(+) 0,0	(-) 4,0	(-) 5,8[6]
		C5	Krugersdrift	C52	Krugersdrift (C52B-G)	(+) 127,0	(+) 2,3	0,0	[(+) 39,9][6]	(-) 83,3	(+) 46,0[6,5]
	Yield to Lower Vaal WMA (surplus):										**(+) 18,1**
D	Orange	D1	Katse	D11	Katse (D11A-K)	(+) 6,5	0,0	0,0	(+) 0,0	(-) 19,6	[(-) 13,1]
		D1	Senqu	D15-D18	Senqu - (D15A-H, D16A-L, D17A-M, D18A-L)	(+) 47,3	0,0	0,0	(+) 2,1	(-) 193,1	[(-) 143,7]
		D1	Orange u/s Gariep	D12-D14	Orange (D12A-F, D13A-M, D14A-K)	(+) 161,1	0,0	0,0	(+) 11,0	(-) 311,2	[(-) 139,1]
		D2	Caledon – Lesotho	D21-D23	D21A*, 21B, D21C*, D21H*, D21J, D21K, D21L, D22C*, D22D*, D22E, D22F, D22H*, D22J, D22K, D22L*	(+) 28,4	0,0	0,0	(+) 2,6	(-) 41,6	[(-) 10,6]
		D2	Caledon – RSA	D21-D22	D21A*, D21C*, D21D, D21E, D21F, D21G, D21H*, D22A, D22B, D22C*, D22D*, D22G, D22H*, D22L*	(+) 28,2	0,0	0,0	(+) 2,6	(-) 23,9	[(+) 6,9 [8]]
		D2	Welbedacht – Lesotho	D23	D23A*, D23B, D23E*, D23F*, D23G*	(+) 11,4	0,0	0,0	(+) 0,5	(-) 10,1	[(+) 1,8 [8]]
		D2	Welbedacht-RSA	D23-D24	D23A*, D23C, D23D, D23E*, D23F*, D23G*, D23H, D23J, D24A-C	(+) 59,3	0,0	(-) 39,8	(+) 3,3	(-) 37,7	[(-) 6,2 [8]]
		D2	Caledon d/s Welbedacht	D24	D/S Welbedacht (D24D-L)	(+) 38,3	0,0	0,0	(+) 3,7	(-) 39,4	[(+) 2,6]
		D3	Gariep	D35	Gariep (D35A-K)	(+) 2 541,0	0,0	(-) 550,2	(+) 2 372,4	(-) 2 947,9	(+) 1415,3 [10]
		D3	Vanderkloof	D31, D32 and D34	Vanderkloof (D31A-E, D32A-K, D34A-G)	(+) 441,7	0,0	(-) 70,9	(+) 1 913,2	(-) 2 772,4	(+) 926,9 [10,11]
		D3	Orange d/s Vanderkloof	D33	D/S Vanderkloof (D33A-K) l	(+) 14,9	(+) 0,2	(-) 18,9	(+) 17,2	(-) 174,2	(+) 766,1 [11]
TOTAL IN WMA (South Africa only)						**(+) 3 721,7**	**(+) 0,2**	**(+) 679,8**	**(+) 4 345,0**	**6 588,4**	
Surplus yield to Lower Orange WMA:											**(+) 766,1**

Notes:

* Quaternary area within Lesotho and RSA.

\# Provincial split not readily available.

$ Available surface water yield represents a net value that includes large transfers and accounts for evaporation losses in the receiver key areas. For example the Orange-Riet Transfer of 70,7 x 10^6 m^3/a is included in the net surface yield of the Riet key area.

(1) Potable water transfers only.

(2) Requirements include ecological reserve, river losses, urban, rural; irrigation, bulk, alien vegetation and afforestation.

(3) Surplus yield from Kalkfontein key area to downstream Riet key area.

(4) Surplus yield from Riet key area to downstream Riet Modder confluence key area.

(5) Surplus yield from Krugersdrift key area to downstream Riet Modder Confluence.

(6) Urban returns in this key area are re-used locally (according to Dr M. Basson, BKS, 2001, NWRS workshop).

(7) Before construction of Katse and Mohale Dams (Lesotho Highlands Project).

(8) Surplus yield from Caledon (RSA) key area and Welbedacht (Lesotho) key area to the downstream Welbedacht (RSA) key area.

(9) Calculated net surface water yield includes yields from all upstream areas and Gariep Dam.

(10) Surplus yield from Gariep key area to downstream Vanderkloof key area.

(11) Surplus yield from Vanderkloof key area to downstream Orange d/s Vanderkloof key area.

[ ] These balances –if positive (surplus) are included in “Surface Water” for the Gariep key area.

Although every effort has been spent in obtaining accurate data, manipulation of this data and checking and verification thereof, the information presented in this report is dependent on the accuracy and quality of the numerous reports and documentation previously compiled by other organisations. It is therefore likely that some information may have to be revised in the future. A great deal of effort was spent on the metadata for the project database in order to make future enhancements as efficient a process as possible.

9.2 RECOMMENDATIONS

The following recommendations refer to required improvements in the quality of quaternary level data.

- While information on controlled irrigation can be considered reliable this data is not reliable at quaternary scale and represents an estimate only. In order to improve on quaternary based information a study should be undertaken to determine the areal distribution of crops at quaternary catchment scale.

  In addition more information is required on the extent and requirement of diffuse irrigation in the WMA. For example in the Kraai catchment (D13) all irrigation is diffuse. Available information seems to indicate that irrigation is widespread but there is no information on the actual water usage in these areas of essentially opportunistic irrigation.

- The available information on livestock and game was for 1988 and 1990. In addition this data was only available at magisterial district level and like irrigation the data at quaternary catchment level must be considered unreliable.

- A survey of a number of TLC's was undertaken to try and determine urban water requirements. This exercise was fairly successful and should be extended to the remaining TLC's. Most small TLC's were not surveyed and their water requirements were estimated using default usage. In the opinion of the Situation Assessment Consultant the default usages are too high for most small towns and as a consequences urban requirements have been inflated.

- The Situation Assessment Consultant did review river losses, however this data appears to have been ignored. This is possibly a result of problems with the river losses sub-model of WSAM.

- Information on allocations, authorisations and permits needs to be centralised and reviewed by an organisation (persons) skilled in the interpretation of these allocations. Thus allowing an assessment of the available resources and the volumes committed to various users.

- Information concerning conveyance losses (most kinds) were generally not readily available. While defaults were provided and these were used extensively a study of this crucial ‘use’ is recommended.

- The water resources and water requirements of Lesotho need to be reviewed, as the current quality of urban, rural and agricultural data in the database represents a first estimate only. It is likely that detailed water requirement data are available because of the Lesotho Highlands Water Project (LHWP data were not made available to the WRSA consultant). In addition the LHWP will alter the water balance in a number of key areas and will require review.

- The negative values obtained for ecological water requirements do not make sense and should be investigated.

- Effluent and stormwater returns in the Greater Bloemfontein – Botshabelo area are significant. However according to Dr Basson of BKS, returns from these areas do not contribute to the baseflow of the Modder catchment. The solution could be to increase irrigation (diffuse) in the area or change consumption to 100 %. This issue has not been resolved and must be reviewed in the future.

REFERENCES

Allen,RG, Pereira,L, Raes, D and Smith, M (1998). Crop Evapotranspiration. FAO Irrigation and Drain,ge Paper 56. UN-FAO, Rome, Italy.

Baron and Seward (2000). Evaluation of the Groundwater use in South Africa. Unpublished DWAF information.

Barta, B (1993) Water utilisation in urban South Africa according to the development regions, Proceedings, 1st Southern Africa water and wastewater conference, Johannesburg, 1993.

Barta, B, 2000. Personal communication

Basson. MJ, 2000 : Personal communication.

Barta, B and Hudson, J (1996) Management of return flows from urban water systems in the Gauteng province, Proceedings, IAHR African Division Biennial Congress, Sun City, 1996.

BKS Inc / Stewart, Sviridov & Oliver (1991) Orange River System Analysis, Caledon River upstream of Welbedacht Dam: Hydrology. DWAF No. PD000/00/1891, PD200/00/0391

BKS Inc / Stewart, Sviridov & Oliver (1991) Orange River System Analysis, Upper Orange River: Hydrology. DWAF No. PD000/00/0691

BKS Inc / Stewart, Sviridov & Oliver (1992) Orange River System Analysis, Demands and Return flows. DWAF No. PD000/00/0491

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1993). Orange River System Analysis: Phase 2. Evaluation of the future water demands on the Orange River Project. Department of Water Affairs, Directorate of Project Planning, Pretoria.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1995). Orange River Development Replanning Study: Hydrology and System Analysis – Eastern Cape Rivers. DWAF No. PD000/00/4795, PN000/00/0595, PQ000/00/0595.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1995). Orange River Development Replanning Study: Refinement of the Instream Flow Requirements for the Orange River. DWAF No. PD000/00/619.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Comparative Economic Impact Analysis of Optimal Water Allocation. DWAF No. PD000/00/6297.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Environmental Overview of the Eastern Cape Rivers. DWAF No. PD000/00/5397, PN000/00/0997, PQ000/00/0997.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Water Demands of the Eastern Cape Region. DWAF No. PD000/00/4397, PN000/00/0397, PQ000/00/0397.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: River Flow Management Workshop: Fish & Sundays Rivers. DWAF No. PD000/00/6597, PN000/00/1797, PQ000/00/1797.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Social Overview - Eastern Cape Region. DWAF No. PD000/00/5197, PN000/00/0897, PQ000/00/0897.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997). Orange River Development Replanning Study: Eastern Cape Region – Calibration of the Water Quality Model. DWAF No. PD000/00/5697.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Existing Water Infrastructure in the Eastern Cape Region. DWAF No. PD000/00/4197.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Existing Water Infrastructure in the Orange River Basin. DWAF No. PD000/00/4297

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Water Demands of the Orange River Basin. DWAF No. PD000/00/4497

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Hydrology and System Analysis - Orange River Basin. DWAF No. PD000/00/4697

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Social Overview – Orange River Basin. DWAF No. PD000/00/5097

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Evaluation of Irrigation water use. DWAF No. PD000/00/4897, PN000/00/0697, PQ000/00/0697.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study: Regional Economic Assessment. DWAF No. PD000/00/5597, PN000/00/1097, PQ000/00/1097.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Agriculture Economic Analysis of Water in the Orange & Fish River Basins. DWAF No. PD000/00/6397.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Allocations of Orange River water: Social implications. DWAF No. PD000/00/6497.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Sedimentation of reservoirs in the Orange River Basin. DWAF No. PD000/00/5497.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Reconnaissance Phase Summary Report. DWAF No. PD000/00/5795, PN000/00/1295, PQ000/00/1295.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1997) Orange River Development Project Replanning Study. Water Quality Aspects: Orange River Basin. Volume 1: Expected Water, Main Report DWAF No. PD000/00/5997.

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1997) Vaal River System Analysis Update. Hydrology of the Upper Vaal Catchment. Department of Water Affairs and Forestry, Pretoria. Report PC000/00/16296.

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1997) Vaal River System Analysis Update. Hydrology of the Barage Catchment. Department of Water Affairs and Forestry, Pretoria. Report PC000/00/16396.

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1997) Vaal River System Analysis Update. Hydrology of the Middle Vaal Catchment. Department of Water Affairs and Forestry, Pretoria. Report PC000/00/16496.

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1997) Vaal River System Analysis Update. Hydrology of the Lower Vaal Catchment. Department of Water Affairs and Forestry, Pretoria. Report PC000/00/16596.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1998) Orange River Development Project. Replanning Study. Main Report. Department of Water Affairs and Forestry, Pretoria.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1998) Orange River Development Project. Replanning Study. Water Demand Management. Department of Water Affairs and Forestry, Pretoria. Report PD000/00/4597, PN000/00/0497, PQ000/00/0497.

BKS (Pty) Ltd / Ninham Shand (Pty) Ltd. (1998) Orange River Development Project. Replanning Study. Potential Dam Development and Hydro Power Options. DWAF Report PD000/00/4997, PN000/00/0797, PQ000/00/0797.

BKS Inc (1998) Augmentation of the Eastern Sub-system of the Vaal River system: Desk Top Study, Vaal River System: Continuous Study. DWAF PC/000/00/19797

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1998) Vaal River System Analysis Update, Hydro-salinity model calibration: Upper Vaal Catchment. DWAF No. PC000/00/18096

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1998) Vaal River System Analysis Update, Hydro-salinity model calibration: Vaal Barrage Catchment. DWAF No. PC000/00/18196

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1998) Vaal River System Analysis Update, Hydro-salinity model calibration: Middle Vaal Catchment. DWAF No. PC000/00/18296

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1998) Evaporation Losses from South African Rivers (on behalf of Department of Water Affairs and Forestry and Water Research Commission.)

BKS Inc / Stewart Scott Inc / Ninham Shand Inc, (1999) Vaal River System Analysis Update, The historical split in demands and return flows between the northern and southern portions of the Rand Water supply area. (Draft). DWAF No. PC000/00/17296

Bloem Water (1999) Personal communication

Botha, SJ and Viljoen, MF (1991) Die finansiele gevolge van waterbeperkings van 1983 tot en met die opheffing daarvan in 1987 vir die Vaal en Rietrivierwatervoorsieningstelsels. Deel 1. Verslag deur die Departement Landbou-Ekonomie, Universiteit van die Oranje-Vrystaat, aan die Waternavorsingskommissie, Pretoria. Verslag 288/1/91.

Burger, JH (1997) Irrigation systems. Chapter 1, Irrigation Design Manual. ARC Institute for Agricultural Engineering, Pretoria.

City Manager: Greater Soweto (1994) Soweto and Diepmeadow. Status Quo Investigation of Water and Sanitation Functions. Volume 1. Final Report by Stewart Scott. Report No. WC0035-01-00-0794. (9)

Department of Agriculture, (1990) Glen data, Food survey

Department of Agriculture, (1998) Census of Agriculture 1998, Central Statistical Services Ref 2.

Department of Agriculture, (1999) Irrigation Design Manual.

Department of Water Affairs and Forestry. (1974/1975) A Pipline to Convey Releases from Vaal Dam Investigation into the Cost.

Department of Water Affairs and Forestry. (1982) Planning for Water Resource Development in the Orange Free State – First Planning Report PD000/00/0182.

Department of Water Affairs and Forestry. (1982) Proposed Orange – Vaal Scheme – Possible Supply via the Proposed Plooysburg Irrigation Scheme Report PC000/00/0483.

Department of Water Affairs and Forestry. (1984) ‘n Bree Oorsig oor Waterbronontwikkeling vir die Vaalriverstelsel. Report No. PC000/00/0584.

Department of Water Affairs and Forestry. Vaalrivier: Rowwe Beramtng van Kostes en Ekonomiese Berekening van Skemas. Report No. PC000/00/2685, PC000/00/3585.

Department of Water Affairs and Forestry. (1985) Vaalrivieropvanggebied. Report No. PC000/00/0885.

Department of Water Affairs and Forestry. (1985) Die Ekonomiese Voordeel vir die Vaalrivierstelsel Indien die Watervoorsiening vir die Douglas-Besproeiingskema vanaf die Vaalrivier na die Oranjerivier Oorgeplaas Word. Report No. PC000/00/2985.

Department of Water Affairs and Forestry. (1985) Vaalrivieropvanggebied Verslag oor Rivierverliese Tussen Vaalharts-Stuwal en Schmidtsdrigt-Stuwal. Report No. PC000/00/3385.

Department of Water Affairs and Forestry. (1985) Vaalrivier-Benaderde Berekening van Kostes en Ekonomiese Berekening vir die Oorbring van Water. Report No. PC000/00/3285.

Department of Water Affairs and Forestry. (1990) Voorstelle vir die Verbetering van Watergehalte Probleme in die Middel-Vaalriviergebied. Report No. PC000/00/9990.

Department of Water Affairs and Forestry. (1990). List of Hydrological Gauging Stations (Volume 2) July 1990.

Department of Water Affairs and Forestry. A to Z of Water Saving Devices (22)

Department of Water Affairs. (1992) Crocodile River (Western Transvaal) Catchment Study. Urban Demands and Return Flows. Report by SS&O and BKS. Report No. PA200/00/1392. (23)

Department of Water Affairs. (1993) Water quality monitoring requirements for salinity modelling, Volume 5 : Riet River catchment

Department of Water Affairs and Forestry. (1994) Water Supply and Sanitation Policy. White Paper. November 1994. (3)

Department of Water Affairs and Forestry. (1995) Vaal Augmentation Planning Study- Orange Vaal Transfer Scheme. Special Reconnaissance Supporting Report. Conveyance Systems: Caledon Cascades Option. - Pump Stations. - Pre-feasibility Supporting Report Goedemoed and Upper Caledon Options. Report No. PC000/00/13294, PD000/00/3994.

Department of Water Affairs and Forestry. (1995) Vaal River System Analysis – Annual Operationg Analysis for the Total Integrated Vaal River System (1996/1997). Report No. PC000/00/19597.

The Department of Water Affairs and Forestry. The working for Water Programme. 1996/97 Annual Report. (21)

DWAF. (1998) Orange River Development Project. Replanning Study. Water Demand management. Report by BKS and Ninham Shand (Pty) Ltd. Report No. PD000/00/4597, PQ000/00/0497, PN000/00/0497. (19)

Department of Water Affairs and Forestry (1998). Quality of Domestic Water Supplies. Volume 1 : Assessment Guide.

Department of Water Affairs and Forestry. (1999) Free State Province. Ist Order Strategy to develop Community Water Supply and Sanitation

Department of Water Affairs and Forestry. (2000). Reservoir records

De Vallier, W and Broadhurst, DW (1997) The development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss. Water Research Commission Report No. 489/1/97. (17)

Eskom (1999) Personal Communication.

Europa World Year Book (39th Edition), 1998 Volume II: Kazakhstan to Zimbabwe. Europa Publications, United Kingdom. (data for Lesotho)

Gaffney Group (1998) Official South African Local Government Yearbook 1997-1998.

Görgens, A (1998). Methodology for incorporation of alien vegetation impacts in the national water balance model. Memorandum to Department of Water Affairs and Forestry.

Greater Johannesburg Transitional Metropolitan Council. (1995) Investigation into Water Supply in Soweto and Diepmeadow. Compiled by Stewart Scott. Report No. WC0035-02-00-1095. (10)

Greater Johannesburg Transitional Metropolitan Council. (1996) Water Quality Impact Assessment of Johannesburg's Southern Wastewater Treatment Works on the Klip River. Compiled by Stewart Scott and Pulles, Howard & De Lange. Volumes 2 & 6. GJTMC Library. Reference No. WWC0065-02-00-0896. (11)

Greater Johannesburg Metropolitan Council. (1997) Water Conservation Policy & Proposals for Implementation. Compiled by Eric Hall & Associates. Report No. WC0062-01-00-0897. (13)

Greater Johannesburg Metropolitan Council. (1998) Metro Bulk Water. Fax from Mr A Cross of 4 September 1998 to Stewart Scott. (14)

Green, G.C. Estimated irrigation requirements of crops in South Africa. Part 2. Highveld region / Free State region / Transvaal region. Memoirs on the agricultural Natural resources of South Africa. No. 2. Department of Agriculture and Water Supply, Pretoria.

Herold, CE, and Taviv, I, (1997). Modelling of long term effects of atmospheric deposition on the salinity of runoff from the Klip River Catchment.

Heyns, PJ (1997) Planning. Chapter 11, Irrigation Design Manual. ARC Institute for Agricultural Engineering, Pretoria.

Hughes, DA and Münster, F (1999). A decision support system for an initial 'low-confidence' estimate of the quantity component of the Reserve for rivers. Unpublished discussion document available at
http://www.ru.ac.za.departments/iwr.

Johnson, EH (1995) Water Demand Management. Water Institute of Southern Africa. Water Sewage & Effluent. Vol. 15, No. 1, pp29-34. (5)

Kleynhans, CJ (1999). A procedure for the determination of the ecological reserve for the purposes of the National Water Balance Model for South African Rivers. Unpublished. Institute for Water Quality Studies, DWAF.

King, J and Louw, D (1998). Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. Aquatic Ecosystem Health and Management, 1, 109-124.

Le Matre, DC, Versfeld, DB, and Chapman, RA (November 1999). The impact of Invading Alien Plants on Surface Water Resources in South Africa: A Preliminary Assessment.

Linsley-Noakes, GC, Louw, M and Allan, P (1995) Estimating daily positive Utah chill units using daily minimum and maximum temperatures. *J. S. Afr. Soc. Hort. Sci.* 5, 19-23.

Loxton, Venn and Associates. (1985) Vaal River Agro-Economic Study. Preliminary Report. Department of Water Affairs, Directorate of Planning, Pretoria. Report PC000/00/1784.

Loxton, Venn and Associates. (1999) Proposed modifications to the irrigation sub-model of the national water balance model (Stewart Scott (Pty) Ltd). Department of Water Affairs and Forestry, Pretoria.

Loxton Venn and Associates, (1999) Vaal River Irrigation Study. DWAF report: PC000/00/21599

Midgley, DC, Pitman, WV and Middleton, BJ. (1994) Surface Water Resources of South Africa 1990. Users Manual. Volume 11: Appendices. Volume 11: Book of Maps. Water Research Commission, Pretoria. Reports 298/1/94, 298/2.1/94 and 298/2.2/94.

Midvaal Water Co. (1999) Personal Communication.

Nel, van Wilgen and Gelderblom (January 1999). The Contribution of Plantation Forestry to the Problem of Invading Alien Trees in South Africa: A Preliminary Assessment.

Ninham Shand (Pty) Ltd. 1999. Interim Adjustment of WR90 Quaternary Naturalised Flows to Reflect CSIR Afforestation-Related Streamflow Reduction Activities.

Ninham Shand (1996): Lesotho Water Projects (TAMS report): Water Resources Management: Policy and Strategies (some relevant extracts). Dept. of Water Affairs and Forestry, Pretoria.

Ninham Shand Inc. (1997) Eastern Cape Water Resources Situation Assessment. DWAF No. PG000/00/0000.

Ninham Shand Inc. (1998) Vaal River System Analysis Update, Hydro-salinity Model Calibration: Lower Vaal Catchment

Ninham Shand (1998): Lesotho Highlands Further Phases. Upper Caledon Option (Overview report). Dept. of Water Affairs and Forestry, Pretoria.

Ninham Shand Inc. (1999) 1st Order Strategy to Develop Community Water Supply & Sanitation (Free State Province) DWAF: Water Services Planning.

Ninham Shand Inc. (1999) Catchment Management Strategy for the Modder & Riet Rivers. Phase 1: Situation Assessment & Draft Management Strategy. DWAF Report.

North West Water Supply Authority. (1996) Survey of Unauthorised Connections on Water Supply Schemes in the North West Province. Report by Stewart Scott. (20)

Official South African Municipal Yearbook, 1995. (16)

Proudlock, TH (1994) Proposed National Water Regulations. Written Contribution to National Water Supply and Sanitation Policy Conference. July 1994. (1)

Pulles, Howard and de Lange (1998) Mooi River Catchment Management Study: Phase 1, Situation Analysis.

Pybus, PJ (1998) Development of a National Framework for Regional Water Supply Management – Discussion Document.

Rand Water, Marketing Department. (1998) Letter dated 5 October 1998 from Mr G Constantinides to Stewart Scott. Reference DWAF-L26. (15)

Rand Water, (1999) Personal communication.

Readers Digest Association of South Africa, Capetown, (1990). Ref Illustrated Guide to the Game Parks and Nature Reserves of Southern Africa, 2nd edition.

Rooseboom. A (1975) "The development of the new sediment yield map of southern Africa"

Schlemmer, L, Stewart, G and Whittles, J (1969) The Socio-Economic Effects of Water Restrictions on Local Authorities, Selected Industrial and Commercial Establishments and other Private Agencies. Water Research Commission Report. No. WRC/68/1/89. (8)

Schreiner, B (1998) Water Demand Management – An Overview. Water Demand Management Workshop. July 1998. CSIR. (4)

Schoeman en Vennote. (1994) As-Liebenbergsvleirivier. Vol. 1. Departement van Waterwese en Bosbou, Subdirektoraat: Watertoedeling, Pretoria. Verslag B0210/2.

Schoeman en Vennote. (1994) Wilgerivier. Vol. 1. Departement van Waterwese en Bosbou, Subdirektoraat: Watertoedeling, Pretoria.

Schoeman en Vennote. (1995) Vaaldamopvang SWBG. Vaalrivier: Grootdraaidam-opnamegebied. Vol. 1. Departement van Waterwese en Bosbou, Subdirektoraat: Watertoedeling, Pretoria.

Schoeman en Vennote. (1996) Ventersdorp Oog Ondergrondse Staatwaterbeheergebied. Resultate van Veldopnames. Vol. 1. Departement van Waterwese en Bosbou, Subdirektoraat: Watertoedeling, Pretoria.

Schulze, RE. (1997) South African Atlas of Agrohydrology and -Climatology. Water Research Commission, Pretoria. Report TT82/96.

Sedibeng Water. (1998) Fax dated 12 October 1998 from ND Basson to Stewart Scott. (18)

Sedibeng Water (1999) Personal Communication.

Seward, P and Seymour, A (1996). Groundwater Harvest Potential of the Republic of South Africa.

Simonic, M (2000). Assessment of the ambient Groundwater Quality on a National scale in the Republic of South Africa. WRC Project K5/841.

Smith, M. 1992. CROPWAT, a computer programme for irrigation planning and management. FAO Irrigation and Drainage Paper 46. FAO, Rome, Italy.

Smith, M, Allen, RG, Monteith, JL, Perrier, A, Perriera, L and Segeren, A (1992) Report on the expert consultation on procedures for revision of FAO guidelines for prediction of crop water requirements. UN-FAO, Rome, Italy.

Steffen, Robertson and Kirsten Inc., Stewart Scott Inc. and Watermeyer, Legge, Piesold and Uhlmann (now Knight Piesold) (1994) “Surface Water Resources of South Africa 1990”

Stewart Scott. (1990) Water Resources of the Republic of South Africa. (SSI Library)

Stewart Scott. (1994) Water Demand Management of South Africa’s Water Resources. Written contribution to National Water Supply and Sanitation Policy Conference. July 1994. (2)

Stewart Scott, (1996) Long Term Salt Balance of the Vaalharts Irrigation Scheme. WRC Report No: 420 / 1 / 96

Stewart Scott (1996) Lower Vet River Water Quality Situation Analysis with Special Reference to the OFS Goldfields. WRC Report No: 523 / 1 /96.

Stewart Scott (1997) East Rand Water Care Company DD5A Regional Water Care Works Hydrological and Water Quality Situation Analysis. Report to East Rand Water Care Company No. DA137959/01

Stewart Scott (1998) : Report by WV Pitman - “Maximum Dam Sizes to be used in Potential Yield Analyses”

Stewart Scott (1999) Blesbokspruit Catchment, Water Quality Management Plan, Phase 1, Status Quo Analysis. DWAF No. 16/4/C212/1

Thomson, RC (1989) Meeting and Telephonic Conversation between Representatives of Rand Water and Stewart Scott. (12)

Van Zyl, JH and Viljoen, MF. (1986) Die sosio-ekonomiese gevolge van waterbeperkings op besproeiingsboerderye, mynbou, elektrisiteitsvoorsiening en die sentrale owerheid. Verslag deur die Instituut vir sosiale en Ekonomiese Navorsing, Universiteit van die Oranje-Vrystaat, aan die Waternavorsings-kommissie, Pretoria. Verslag 288/1/91.

Van Zyl, JH and Viljoen, MF. (1986) Die Sosio-Ekonomiese Gevolge en Waterbeperkings op Besproeiingsboerderye, Mynbou, Electrisiteitsvoorsiening en die Sentrale Owerheid. Waternavorsingskomissie Verslag No. WRC167/1/87. (7)

Vegter, JR (1995). Groundwater Resources of the Republic of South Africa. WRC Project 483.

Versfeld, DB, le Maitre, DC, and Chapman, RA (1997). Alien Invading Plants and Water Resources in South Africa. Report to the Water Research Commission, Pretoria.

Viljoen, MF, Symington, HM & Botha, SJ. (1992) Verwantskap tussen waterbeperkings en finansiele gevolge in die Vaalrivierwatervoorsieningsgebied met spesiale verwysing na besproeiingsboerderye in die Vaalhartsgebied. Deel 2. Verslag deur die Departement Landbou-Ekonomie, Universiteit van die Oranje-Vrystaat, aan die Waternavorsingskommissie, Pretoria. Verslag 288/2/92.
-. 1998/1999 Rates and Tariffs. 1998. Department of Water Affairs and Forestry, Pretoria.

Viljoen, MF (1994) Research Note: The Opportunity Cost of Water for Environmental use During Water Shortages with Reference to the Vaal River system. Agrekon. Vol 33, No. 2, pp91-95. (6)

Williams, JE, Wood, CA and Dombeck, MP (1997). J.E., C.A Woods, .Dombeck (1997). Understanding watershed-scale restoration. Pp 1-16 in: J.E Williams, CA Wood & M.P Dombeck (eds.) *Watershed restoration: principles and practices*. American Fisheries Society, Bethesda, Maryland.

APPENDICES

Note: Blanks indicate that data was not readily available.

APPENDIX A DEMOGRAPHICS

Comprising:

APPENDIX A.1

URBAN POPULATION DATA

Appendix A.1 URBAN POPULATION

Source of RSA population data: Markdata Demographic Study

Quaternary catchment	Province	Transitional councils	Population
Riet / Modder sub-area			
Kalkfontein key area:			
C51A	FS	REDDERSBURG / MATOPORONG	3,700
C51C	FS	EDENBURG / HA-RASEBEI	5,550
C51G	FS	TROMPSBURG / MADIKGETLA	3,800
C51H	FS	JAGERSFONTEIN / ITUMELENG	5,800
C51J	FS	FAURESMITH / IPOPENG	3,500
Total			**22,350**
Riet key area:			
C51K	FS	KOFFIEFONTEIN / DITLHAKE / OPPERMANSGRONDE & JACOBSDAL / RATANANG	13,900
Total			**13,900**
Riet / Vaal key area:			
C51L	FS	RITCHIE / MOTSWEDIMOSA	10,300
C52H	FS	BLOEMSPRUIT; BAINSVLEI; DEALESVILLE / TSWARAGANANG & SOUTP/	36,600
C52K	FS	PETRUSBURG / BOLOKANANG	5,500
Total			**52,400**
Rustfontein key area:			
C52A	FS	DEWETSDORP / MOROJANENG	7,250
Total			**7,250**
Krugersdrift key area			
C52B	FS	BOTSHABELO & THABA NCHU	276,050
C52F	FS	BLOEMFONTEIN / MANGAUNG	323,650
C52G	FS	BRANDFORT / MAJWEMASWEU	11,000
Total			**610,700**
Urban population - Modder/Riet			**706,600**
Caledon sub-area:			
Caledon key area (Lesotho):			
D21H	Lesotho	BUTHA BUTHU	115,650
D22C	Lesotho	LERIBE	99,600
D22H	Lesotho	MASERU	300,000
Total			**515,250**
Caledon key area (South Africa):			
D21D	FS	CLARENS / KGUBETSWANA	2,450
D21G	FS	FOURIESBURG / MASJAING	7,600
D22A	FS	ROSENDAL / MAUTSE	2,300
D22C	FS	FICKSBURG / MEQHELENG	28,900
D22G	FS	CLOCOLAN / HLOHLOLWANE	10,500
D22H	FS	LADYBRAND / MANYATSENG	16,400
Total			**68,150**

Appendix A.1 URBAN POPULATION

Source of RSA population data: Markdata Demographic Study

Quaternary catchment	Province	Transitional councils	Population
Welbedacht key area (Lesotho):			
D23F	Lesotho	MAKETENG	75,360
Total			**75,360**
D23C	FS	TWEESPRUIT / BORWA	4,500
D23D	FS	THABA PATCHOA	1,250
D23E	FS	HOBHOUSE / DIPELANENG	1,850
D23G	FS	WEPENER / THAPELANG / QIBING	8,250
D24C	FS	VANSTADENSRUS	900
Total			**16,750**
d/s Welbedacht key area:			
D24G	FS	ROUXVILLE / RWELELEYATHUNYA	5,150
D24H	FS	SMITHFIELD / MOFULATSHEPE	4,600
Total			**9,750**
Total urban population - Caledon			**685,260**
Total urban population - Caledon [RSA]			**94,650**
Total urban population - Caledon [Lesotho]			**590,610**
Upper Orange sub-area:			
Katse Dam key area: (Lesotho)			
	-	**No urban area**	**0**
Senqu River key area: (Lesotho)			
D15G	Lesotho	MOHALES HOEK	63,330
D18J	Lesotho	MOYENI	42,540
Total			**105,870**
Orange River (u/s Gariep Dam):			
D12C	EC	GREATER HERSHEL	5,450
D12D	EC	ZASTRON / MATLAKENG	9,150
D12E	EC	LADY GREY / KHWEZINALEDI	4,300
D13B	EC	RHODES / ZAKHELE	850
D13D	EC	BARKLY-EAST / NKULULEKO	7,050
D13H	EC	DORDRECHT / SINAKHO	8,400
D13J	EC	JAMESTOWN / MASAKHANE	3,450
D14A	EC	ALIWAL-NORTH / DUKATHOLE	21,050
D14C	EC	MOLTENO / NOMONDE	9,400
D14E	EC	BURGERSDORP / MZAMOMHLE	11,950
Total			**81,050**
Gariep key area:			
D35F	FS	SPRINGFONTEIN / MAPHODI	3,450
D35G	EC	VENTERSTAD / NOZIZWE	4,500

Appendix A.1 URBAN POPULATION			
Source of RSA population data: Markdata Demographic Study			
Quaternary catchment	**Province**	**Transitional councils**	**Population**
D35H	FS	BETHULIE / LEPHOI	6,500
D35K	FS	VERWOERDDAM	1,100
Total			**15,550**
Vanderkloof key area:			
D31B	NC	PHILIPSTOWN / LUKHANYISWENI	2,650
D32F	NC	HANOVER / NOMPUMELELO	3,200
D32G	NC	NOUPOORT / KWAZAMUXOLO	6,950
D34A	NC	NORVALSPONT (Novelspoint)	1,500
D34F	NC	COLESBERG / KUYASA	12,950
D34G	FS	PHILIPPOLIS / PHODING-TSE-ROLO / WATERKLOOF	3,700
Total			**30,950**
d/s Vanderkloof key area:			
D33A	NC	PETRUSVILLE / THEMBINKOSI / VANDERKLOOF	3,300
D33C	FS	LUCKHOFF	2,250
D33G	NC	HOPETOWN	7,100
Total			**12,650**
Urban population - Upper Orange sub-area			**246,070**
Urban population - Upper Orange sub-area [Lesotho]			**105,870**
Urban population - Upper Orange sub-area [SA]			**140,200**
Urban population - Upper Orange WMA [Lesotho]			**696,480**
Urban population - Upper Orange WMA [SA]			**941,450**
Urban population			**1,637,930**
Source of population data for Lesotho: Estimated by Stewart Scott with reference to Europa Encylopedia (1995)			

APPENDIX A.2

RURAL POPULATION DATA

Appendix A.2 RURAL POPULATION

Quaternary catchment	Rural population	Net per capita consumption [l / c / day]	Consumptive use	Comment
Riet / Modder sub-area:				
Kalkfontein key area:				
C51A	1,267	25	1	
C51B	2,138	25	1	
C51C	283	25	1	
C51D	1,907	25	1	
C51E	1,356	25	1	
C51F	820	25	1	
C51G	1,739	25	1	
C51H	986	25	1	
C51J	712	25	1	
Total:	**11,207**			**all in Free State**
Rural requirement (MCM /annum):			**0.10**	
Riet key area:				
C51K	6,024	25	1	
Total:	**6,024**			
Rural requirement (MCM /annum):			**0.06**	**all in Free State**
Riet / Vaal key area:				
C51L	2,336	25	1	
C51M	1,885	25	1	
C52H	4,633	25	1	
C52J	5,686	25	1	
C52K	6,416	25	1	
C52L	2,706	25	1	
Total:	**23,662**			
Rural requirement (MCM /annum):			**0.22**	**all in Free State**
Rustfontein Dam key area:				
C52A	2,173	25	1	
Total:	**2,173**			
Rural requirement (MCM /annum):			**0.02**	**all in Free State**
Krugersdrift Dam key area:				
C52B	14,760	25	1	
C52C	3,461	25	1	
C52D	685	25	1	
C52E	2,280	25	1	
C52F	4,123	25	1	
C52G	5,997	25	1	
Total:	**31,306**			
Rural requirement (MCM /annum):			**0.29**	**all in Free State**
Rural population - Riet Modder			**74372**	**all in Free State**
Rural requirement - Riet Modder:			**0.68**	
Caledon sub-area (Lesotho):				
Caledon key area [Lesotho]				
D21A	28,050	25	1	
D21B	52,043	25	1	
D21C	24,378	25	1	
D21H	34,529	25	1	

Appendix A.2 RURAL POPULATION

Quaternary catchment	Rural population	Net per capita consumption [l / c / day]	Consumptive use	Comment
D21J	47,519	25	1	
D21K	43,098	25	1	
D21L	40,231	25	1	
D22C	38,378	25	1	
D22D	15,984	25	1	
D22E	47,211	25	1	
D22F	59,970	25	1	
D22H	29,307	25	1	
D22J	61,776	25	1	
D22K	30,679	25	1	
D22L	15,694	25	1	
Total:	**568,850**			
Rural requirement (MCM /annum):			**5.19**	
Caledon key area [RSA]:				
D21A	425	25	1	
D21B	1	25	1	
D21C	218	25	1	
D21D	1,267	25	1	
D21E	1,494	25	1	
D21F	3,829	25	1	
D21G	2,331	25	1	
D21H	462	25	1	
D21L	1	25	1	
D22A	3,295	25	1	
D22B	1,356	25	1	
D22C	8,989	25	1	
D22D	3,995	25	1	
D22F	2	25	1	
D22G	7,342	25	1	
D22H	1,116	25	1	
D22L	1,499	25	1	
Total	**37,620**			
Rural requirement (MCM /annum):			**0.34**	**all in Free State**
Welbedacht key area [Lesotho]				
D23A	36,139	25	1	
D23B	57,392	25	1	
D23E	28,913	25	1	
D23F	27,708	25	1	
D23G	24,289	25	1	
D24A	1,399	25	1	
Total:	**175,840**			
Rural requirement (MCM /annum):			**1.61**	
Welbedacht key area [RSA]:				
D23A	919	25	1	
D23C	4,654	25	1	
D23D	1,737	25	1	
D23E	986	25	1	
D23F	178	25	1	
D23G	709	25	1	
D23H	1,562	25	1	

Appendix A.2 RURAL POPULATION

Quaternary catchment	Rural population	Net per capita consumption [l / c / day]	Consumptive use	Comment
D23J	1,007	25	1	
D24A	1,379	25	1	
D24B	2,213	25	1	
D24C	1,126	25	1	
Total:	**16,470**			
Rural requirement (MCM /annum):			**0.15**	**all in Free State**
d/s Welbedacht key area				
D24D	783	25	1	
D24E	504	25	1	
D24F	853	25	1	
D24G	868	25	1	
D24H	630	25	1	
D24J	906	25	1	
D24K	825	25	1	
D24L	489	25	1	
Total:	**5,857**			**all in Free State**
Rural requirement (MCM /annum):			**0.05**	**all in Free State**
Total rural population - Caledon:			**804,637**	
Total rural population - RSA:			**59,947**	**all in Free State**
Total rural population - Lesotho:			**744,690**	
Total rural requirement - RSA:			**0.55**	
Total rural requirement - Lesotho:			**6.80**	
Upper Orange sub-area:				
Katse Dam key area (Lesotho):				
D11A	11,074	25	1	
D11B	9,409	25	1	
D11C	11,603	25	1	
D11D	12,683	25	1	
D11E	12,832	25	1	
D11F	16,443	25	1	
D11G	12,728	25	1	
D11H	14,266	25	1	
D11J	17,500	25	1	
D11K	15,163	25	1	
Total:	**133,701**			
Rural requirement (MCM /annum):			**1.22**	
Senqu key area (Lesotho and RSA):				
D15A	21,727	25	1	
D15B	19,560	25	1	
D15C	13,720	25	1	
D15D	21,729	25	1	
D15E	30,774	25	1	
D15F	17,528	25	1	
D15G	19,323	25	1	
D15H	4,812	25	1	
D16A	3,380	25	1	
D16B	5,273	25	1	
D16C	9,299	25	1	
D16D	7,182	25	1	

Appendix A.2 RURAL POPULATION

Quaternary catchment	Rural population	Net per capita consumption [l / c / day]	Consumptive use	Comment
D16E	9,211	25	1	
D16F	5,866	25	1	
D16G	6,137	25	1	
D16H	7,322	25	1	
D16J	7,934	25	1	
D16K	6,955	25	1	
D16L	11,331	25	1	
D16M	16,013	25	1	
D17A	7,313	25	1	
D17B	5,064	25	1	
D17C	6,013	25	1	
D17D	8,574	25	1	
D17E	6,932	25	1	
D17F	6,671	25	1	
D17G	9,724	25	1	
D17H	9,755	25	1	
D17J	5,005	25	1	
D17K	4,373	25	1	
D17L	6,737	25	1	
D17M	6,054	25	1	
D18A	10,847	25	1	
D18B	5,866	25	1	
D18C	8,427	25	1	
D18D	13,869	25	1	
D18E	6,701	25	1	
D18F	8,798	25	1	
D18G	8,797	25	1	
D18H	6,946	25	1	
D18J	15,546	25	1	
D18K	33,564	25	1	
D18L	23,158	25	1	
Total:	**469,810**			
Total in Lesotho:			**425,886**	
Total in RSA:			**43,924**	
Rural requirement (MCM /annum):			**4.29**	**Eastern Cape and Lesotho**
Rural population Senqu (Lesotho):			**559,587**	
Rural population Senqu (RSA):			**43,924**	
Rural population Senqu			**603,511**	
Rural requirement Senqu (Lesotho):			**5.11**	
Rural requirement Senqu (RSA):			**0.40**	
Orange u/s Gariep Dam key area:				
D12A	15,143	25	1	
D12B	32,944	25	1	
D12C	12,860	25	1	
D12D	1,398	25	1	
D12E	8,424	25	1	
D12F	1,766	25	1	
D13A	287	25	1	
D13B	462	25	1	
D13C	743	25	1	
D13D	872	25	1	

Appendix A.2 RURAL POPULATION

Quaternary catchment	Rural population	Net per capita consumption [l / c / day]	Consumptive use	Comment
D13E	1,249	25	1	
D13F	1,275	25	1	
D13G	2,814	25	1	
D13H	2,660	25	1	
D13J	2,043	25	1	
D13K	802	25	1	
D13L	1,289	25	1	
D13M	1,252	25	1	
D14A	1,179	25	1	
D14B	400	25	1	
D14C	964	25	1	
D14D	795	25	1	
D14E	638	25	1	
D14F	1,004	25	1	
D14G	1,047	25	1	
D14H	1,106	25	1	
D14J	3,015	25	1	
D14K	561	25	1	
Total:	**98,990**			
Rural requirement (MCM /annum):			**0.90**	**Free State and Eastern Cape**
Gariep key area:				
D35A	201	25	1	
D35B	194	25	1	
D35C	771	25	1	
D35D	431	25	1	
D35E	198	25	1	
D35F	397	25	1	
D35G	369	25	1	
D35H	306	25	1	
D35J	726	25	1	
D35K	448	25	1	
Total:	**4,039**			
Rural requirement (MCM /annum):			**0.04**	**Free State and Eastern Cape**
Vanderkloof key area:				
D31A	534	25	1	
D31B	517	25	1	
D31C	557	25	1	
D31D	622	25	1	
D31E	497	25	1	
D32A	205	25	1	
D32B	233	25	1	
D32C	380	25	1	
D32D	217	25	1	
D32E	358	25	1	
D32F	489	25	1	
D32G	516	25	1	
D32H	179	25	1	
D32J	367	25	1	
D32K	255	25	1	
D34A	1,454	25	1	
D34B	443	25	1	

Appendix A.2 RURAL POPULATION

Quaternary catchment	Rural population	Net per capita consumption [l / c / day]	Consumptive use	Comment
D34C	400	25	1	
D34D	257	25	1	
D34E	281	25	1	
D34F	254	25	1	
D34G	436	25	1	
Total:	**9,449**			
Rural requirement (MCM /annum):			**0.09**	**Free State, Eastern and Northern Cape**
d/s Vanderkloof key area:				
D33A	515	25	1	
D33B	587	25	1	
D33C	606	25	1	
D33D	989	25	1	
D33E	1,577	25	1	
D33F	932	25	1	
D33G	760	25	1	
D33H	798	25	1	
D33J	242	25	1	
D33K	696	25	1	
Total:	**7,701**			
Rural requirement (MCM /annum):			**0.07**	**Free State and Northern Cape**
Rural population - Upper Orange			**120,179**	
Rural requirement - Upper Orange			**1.10**	
Rural population - Upper Orange WMA			**1,602,698**	
Rural requirement - Upper Orange WMA			**14.63**	
Rural population - Lesotho			**1,304,277**	
Rural population - Free State			**159,672**	
Rural population - Eastern Cape			**127,010**	
Rural population - Northern Cape			**11,739**	
Source of data:		**Markdata for RSA data, Europa Enclopedia for Lesotho**		

APPENDIX B MACRO ECONOMICS

Comprising:

Appendix B.1 Graphs: Gross Geographic Product, Labour and Shift-share

Appendix B.2 Water Management Areas in National Context

Appendix B.3 Economic Sector Description

Appendix B.4 Economic Information System

APPENDICES

SUPPLEMENTARY ECONOMIC INFORMATION

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 Berg 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 Berg Employment, 1980 and 1994 (%)	Shows the sectoral composition of the formal WMA labour force.
B.5	➾ Contribution by Sectors of Berg 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).

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

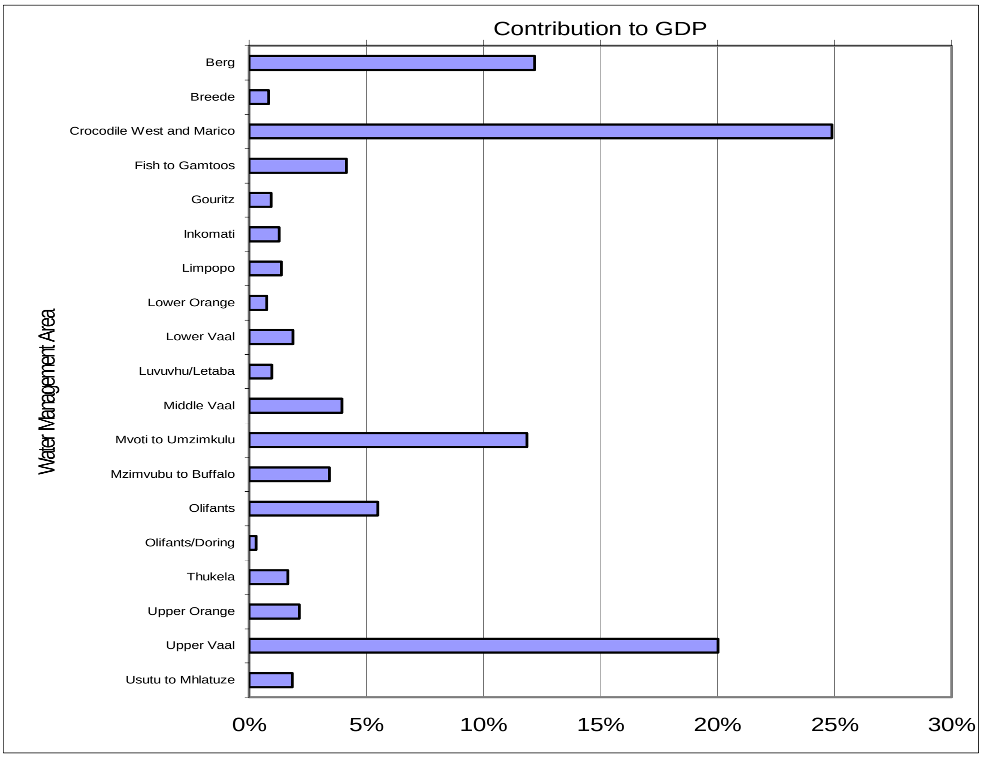
- The largest contribution to the national economy is made by the Crocodile West and Marico WMA which contributes (19.1%) to GDP. This WMA comprises, inter alia, magistrates districts of Pretoria, Johannesburg, Germiston, Kempton Park, Benoni, Thabazimbi and Lichtenburg.

- 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.

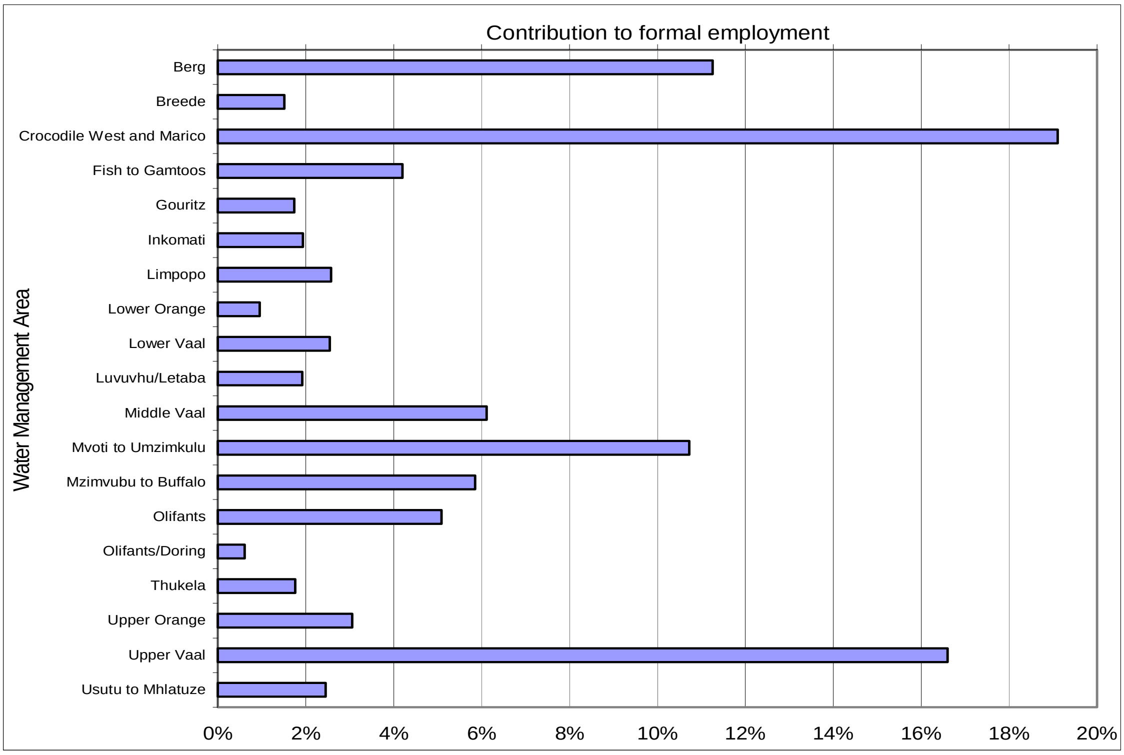
Figure B.1: Total GGP by Water Management Area (% of Country)



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.

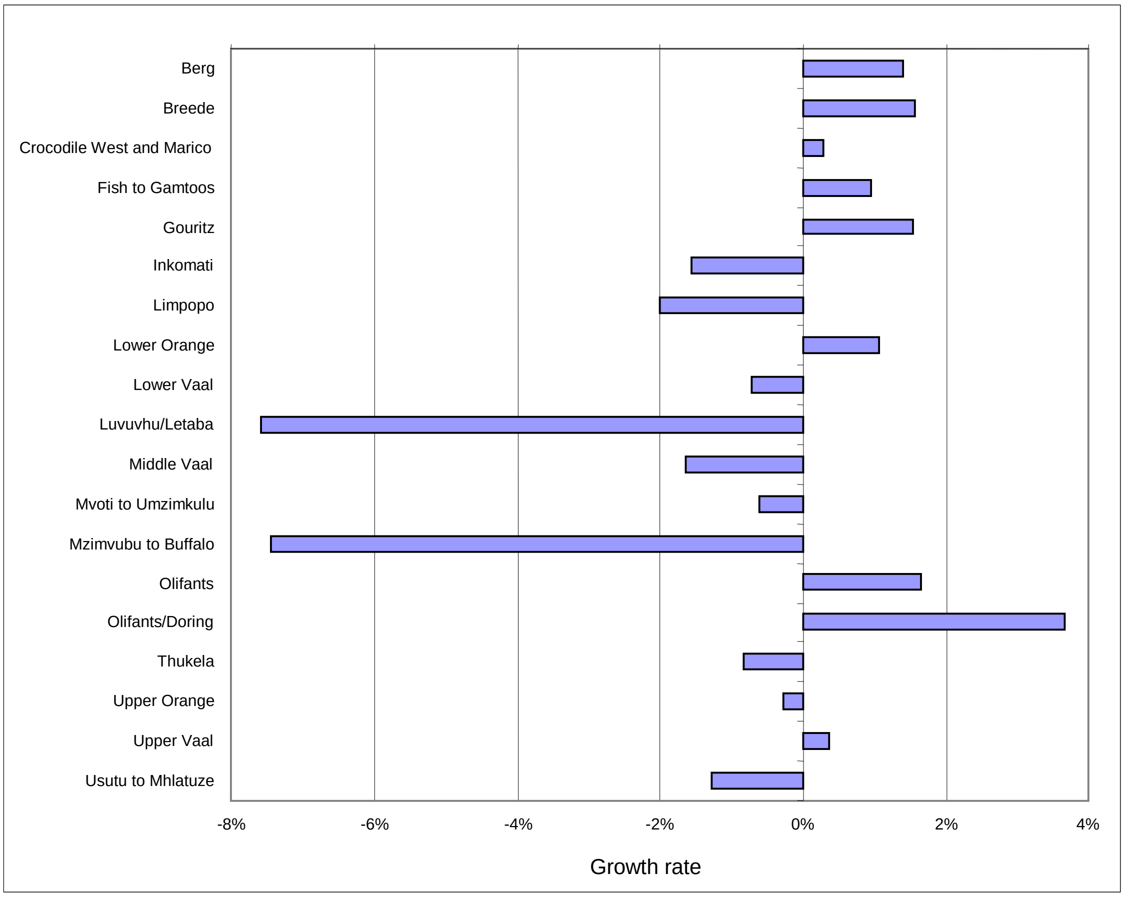
Figure B.2: Formal Employment by Water Management Area (% of country)



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 fertilizer, 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.

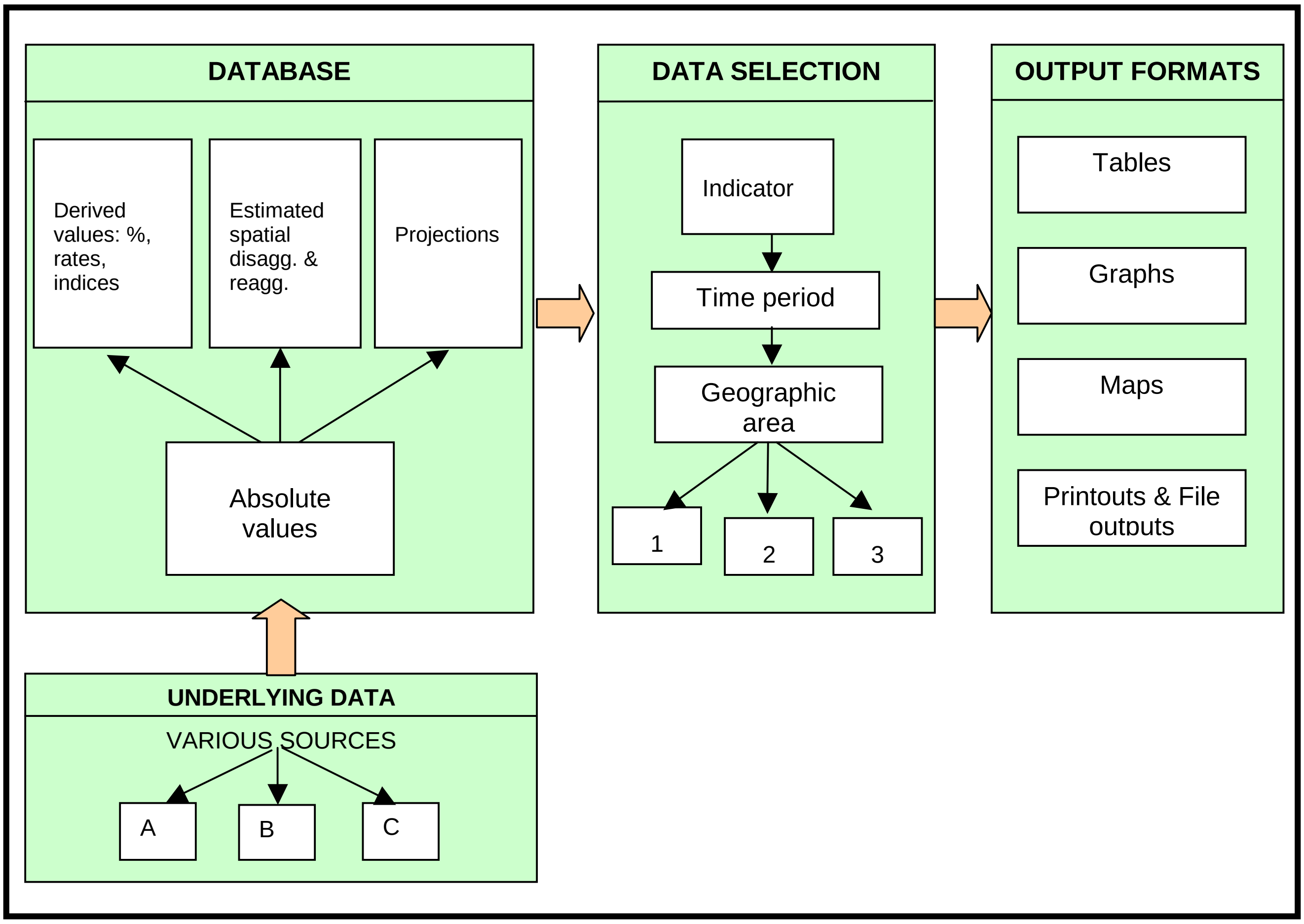
Indicator	Categories	Timespan	Geographic detail
Gross geographic product	Major sectors	1972-1997	Magisterial districts
Labour distribution	Employment/un-employment Major sectors	1980, 1991, 1994	Magisterial districts
Electricity consumption	Economic sectors, domestic	1988-1997	Local authority area, service 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

Comprising:

Appendix C.1 Permit data from DAM SAFETY DATABASE

Appendix C.2 Example of PCPOLMAN DATABASE

Appendix C.3 Section 56(3) permits

APPENDIX C.1

DAM SAFETY DATABASE
(Example of section 9 and 13 permits)

	Section 9b authorisations grant permission to farmers to build dams >250 000 m^3 or for abstractions or diversions > 110 l/sec.							
	DWAF No.	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity ($x10^3m^3$)**	**Dam used for**	**Permit No.**	**Permit Conditions**
	Upper Orange Catchment:							
	MODDER / RIET SUB-AREA							
39	12/2/C510-10	TIERPOORT	BLOEMFONTEIN	KAFFIR RIVER/RIVIER	999	IRRIGATION		
40	12/2/C510-13	OLIEVENFONTEIN	EDENBURG	KROMME SPRUIT TR.	509	IRRIGATION		
41	12/2/C511-31	DAMPLAAS	REDDERSBURG	KAFFIR RIVER/RIVIER	1509	IRRIGATION		
42	12/2/C511-32	VLAKPLAAS-GROOT	BLOEMFONTEIN	-	1600	IRRIGATION		
43	12/2/C512-29	BLUEGUMPOORT BIG	EDENBURG	RIET RIVER/RIVIER TR.	1140	IRRIGATION		
44	12/2/C512-31	WASCHBANK	REDDERSBURG	-	240	IRRIGATION		
45	12/2/C512-34	BOUGAINVILLEA	REDDERSBURG	RIET RIVER/RIVIER TR.	240	IRRIGATION		
46	12/2/C513-29	VISSERSHOEK	PHILIPPOLIS	-	650	IRRIGATION		
47	12/2/C513-32	SAMENSUIPING	TROMPSBURG	VAN ZYL SPRUIT TR.	500	IRRIGATION		
48	12/2/C513-33	LANGZEEKOEGAT	TROMPSBURG	VAN ZYL SPRUIT	3289	IRRIGATION		
49	12/2/C513-34	MORESTER	TROMPSBURG	VANZYL SPRUIT TR.	390	IRRIGATION		
50	12/2/C521-31	DEWETSKOM NO.2-	DEWETSDORP	MODDER RIVER/RIVIER	199	IRRIGATION		
51	12/2/C521-33	KLIPDRIFT	DEWETSDORP	ONDER-KROM SPRUIT	261	IRRIGATION		
52	12/2/C521-34	VREDE	DEWETSDORP	WILDEHONDE SPRUIT	250	IRRIGATION		
53	12/2/C521-42	THE CLIFF	DEWETSDORP	GANNA SPRUIT	1000	IRRIGATION		
54	12/2/C522-01	PALMIETFONTEIN	BRANDFORT	OS SPRUIT	600	IRRIGATION		
55	12/2/C522-02	MOOISPRUIT	BRANDFORT	OS SPRUIT	1750	IRRIGATION		
56	12/2/C522-31	QUIN-SE-DAM	BLOEMFONTEIN	RENOSTERSPRUIT	2100	IRRIGATION		
57	12/2/C524-30	KOOIDAM	JACOBSDAL	MODDER RIVER/RIVIER	260	IRRIGATION		
	UPPER ORANGE SUB-AREA (RSA only)							
78	12/2/D120-01	VAALBANKSPOORT	ROUXVILLE	NUWEJAARS SPRUIT TR.	600	IRRIGATION		
79	12/2/D120-10	VLAKTEFONTEIN-NUWE	LADY GREY	ORANGE RIVER/RIVIER TR.	200	IRRIGATION		
80	12/2/D120-11	VLAKTEFONTEIN OU-NUWE	LADY GREY	GROOT RIVER/RIVIER TR.	300	IRRIGATION		
81	12/2/D120-12	LUSTHOF	ZASTRON	-	440	IRRIGATION		
82	12/2/D120-14	WINDPOORT	ROUXVILLE	NUWEJAAR SPRUIT	225	IRRIGATION		
83	12/2/D120-16	LEEUWFONTEIN NO. 2-	ZASTRON	WINNAAR SPRUIT TR.	241	IRRIGATION		

	Section 9b authorisations grant permission to farmers to build dams >250 000 m^3 or for abstractions or diversions > 110 l/sec.							
	DWAF No.	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity ($x10^3m^3$)**	**Dam used for**	**Permit No.**	**Permit Conditions**
84	12/2/D120-19	BOTHASRAND	ROUXVILLE	NUWEJAAR SPRUIT	300	IRRIGATION		
85	12/2/D132-11	AMERSHAM	WODEHOUSE	HOL SPRUIT	250	IRRIGATION		
86	12/2/D132-12	LION HILL	WODEHOUSE	HOL SPRUIT	783	IRRIGATION		
87	12/2/D132-13	HOLSPRUIT	WODEHOUSE	HOL SPRUIT	1044	IRRIGATION		
88	12/2/D132-15	BLUEHILLS	ALIWAL-NOORD	TELEMACHUS SPRUIT	233	IRRIGATION		
89	12/2/D132-17	SKOORSTEENMANTEL	WODEHOUSE	HOL SPRUIT TR.	250	IRRIGATION		
90	12/2/D132-22	LEEUFONTEIN DAM NO.2	WODEHOUSE	DORDRECHT RIVER/RIVIER	205	IRRIGATION		
91	12/2/D132-24	BAMBOESHOEK	WODEHOUSE	HOL SPRUIT TR.	300	IRRIGATION		
92	12/2/D132-27	BRANDWAG	MOLTENO	STORMBERG SPRUIT TR.	500	IRRIGATION		
93	12/2/D133-01	RONDAVEL	WODEHOUSE	WOLLE SPRUIT TR.	500	IRRIGATION		
94	12/2/D133-04	PINE GROVE DAM NO.1	INDWE	WASBANK SPRUIT TR.	550	IRRIGATION		
95	12/2/D133-05	PINE GROVE DAM NO.2	INDWE	WASBANK SPRUIT TR.	195	IRRIGATION		
96	12/2/D133-06	MOORDENAARSPOORT	WODEHOUSE	WOLWE SPRUIT	250	IRRIGATION		
97	12/2/D133-09	PRIVATE EARTH	LADY GREY	-	545	IRRIGATION		
98	12/2/D133-10	FARM	LADY GREY	BOSSIESLAAGTE SPRUIT	546	IRRIGATION		
99	12/2/D140-05	MOOIVLEI	ALBERT	STORMBERG SPRUIT	460	IRRIGATION		
100	12/2/D140-11	STRYDPOORT	ROUXVILLE	SANDDRIFSPRUIT	2169	IRRIGATION		
101	12/2/D141-17	KROMDRAAI	ROUXVILLE	SANDDRIF SPRUIT	332	IRRIGATION		
102	12/2/D141-21	CLIFTON VALE	ALBERT	ORANGE RIVER/RIVIER TR.	221	IRRIGATION		
103	12/2/D141-23	SILVERMERE	ALBERT	ORANGE RIVER/RIVIER TR.	248	IRRIGATION		
104	12/2/D141-30	OUDEFONTEIN	ALBERT	ORANJE RIVER/RIVIER TR.	780	IRRIGATION		
105	12/2/D141-31	ELIM	ALBERT	PALMIET SPRUIT	300	IRRIGATION		
106	12/2/D142-15	PAARL-NUWE	ALIWAL-NOORD	KLIPPLAAT SPRUIT	200	IRRIGATION		
107	12/2/D142-16	PAARL OU	ALIWAL-NOORD	KLIPPLAAT SPRUIT	240	IRRIGATION		
108	12/2/D142-17	SUURFONTEIN BIG	MOLTENO	WONDERBOOM SPRUIT	783	IRRIGATION		
109	12/2/D142-18	DALKEITH	MOLTENO	STORMBERG SPRUIT TR.	960	IRRIGATION		
110	12/2/D142-19	BERLYN	ALBERT	BARNARD SPRUIT	250	IRRIGATION		
111	12/2/D142-20	KALKOENKRANS	STEYNSBURG	-	250	IRRIGATION		

	Section 9b authorisations grant permission to farmers to build dams >250 000 m^3 or for abstractions or diversions > 110 l/sec.							
	DWAF No.	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity ($x10^3m^3$)**	**Dam used for**	**Permit No.**	**Permit Conditions**
112	12/2/D142-21	HARMSFONTEIN	ALBERT	KOPENPOOTJIES RIVER/RIVIER TR.	2700	IRRIGATION		
113	12/2/D142-22	KOMMANDANTSKOP	KAAP PROVINSIE	-	670	IRRIGATION		
114	12/2/D142-23	KLIPFONTEIN	MOLTENO	WONDERHOEK SPRUIT TR.	209	IRRIGATION		
115	12/2/D142-25	OUDEKLIP-MODDERFONTEIN	MOLTENO	BAMBOESBERG SPRUIT	380	IRRIGATION		
116	12/2/D142-27	HILLSIDE	PRINCE ALBERT	-	300	IRRIGATION		
117	12/2/D142-28	PLAT	ALBERT	KLEIN-BUFFELSVLEI SPRUIT TR.	960	IRRIGATION		
118	12/2/D142-29	OLIFANT	ALBERT	NAAMLOSE WATERBAAN	300	IRRIGATION		
119	12/2/D142-30	BOOMSKRAAP	MOLTENO	BAMBOESBERG SPRUIT TR.	600	IRRIGATION		
120	12/2/D142-31	GOEDEHOOP	MOLTENO	BAMBOESBERG SPRUIT TR.	250	IRRIGATION		
121	12/2/D142-32	POTBERGLEEGTE	MOLTENO	BAMBOESBERG SPRUIT TR.	216	IRRIGATION		
122	12/2/D142-34	LAKESIDE	ALBERT	BAMBOESBERG SPRUIT	1100	IRRIGATION		
123	12/2/D150-01	HOUTCONSTANT	ZASTRON	KOLO-LA-PERE RIVER/RIVIER TR.	1000	IRRIGATION		
124	12/2/D150-02	SPRINGVALLEY	ZASTRON	KOLO-LA-PERERIVIER/RIVER TR.	731	IRRIGATION		
125	12/2/D200-13	KOPPIESKRAAL	SMITHFIELD	VINKELSPRUIT	600	IRRIGATION		
126	12/2/D200-14	LOVEDALE	EXCELSIOR	KLEIN LEEU RIVER/RIVIER	2700	IRRIGATION		
127	12/2/D200-16	NEWBURRY	LADYBRAND	LEEU RIVER/RIVIER	5587	IRRIGATION		
128	12/2/D201-44	VERDUN	FOURIESBURG	LITTLE CALEDON RIVER/RIVIER TR.	250	IRRIGATION		
129	12/2/D201-47	LIBANON	FOURIESBURG	BRANDWATER RIVER/RIVIER TR.	208	IRRIGATION		
130	12/2/D201-59	KRIARDO	FOURIESBURG	GROOT SPRUIT TR.	250	IRRIGATION		
131	12/2/D202-45	CAMPRIDGE	EXCELSIOR	LEEU RIVER/RIVIER	200	IRRIGATION		
132	12/2/D202-52	UPPER RANTSO	FICKSBURG	RANTSHO RIVER/RIVIER TR.	250	IRRIGATION		
133	12/2/D202-58	STOFBERG	LADYBRAND	LEEU RIVER/RIVIER TR.	250	IRRIGATION		
134	12/2/D202-59	GROENVLEI	CLOCOLAN	-	200	IRRIGATION		
135	12/2/D202-60	JEVINGTON	EXCELSIOR	-	300	IRRIGATION		
136	12/2/D202-61	KOPPIE-ALLEEN	FICKSBURG	CALEDON RIVER/RIVIER TR.	259	IRRIGATION		
137	12/2/D202-62	WILGEDRAAI NO. 7-	WEPENER	CALEDON RIVER/RIVIER TR.	450	IRRIGATION		
138	12/2/D202-65	WILGEDRAAI NO. 2-	WEPENER	CALEDON RIVER/RIVIER TR.	250	IRRIGATION		
139	12/2/D202-66	WILGEDRAAI NO. 1-	WEPENER	CALEDON RIVER/RIVIER TR.	1000	IRRIGATION		

	Section 9b authorisations grant permission to farmers to build dams >250 000 m³ or for abstractions or diversions > 110 l/sec.							
	DWAF No.	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity ($x10^3m^3$)**	**Dam used for**	**Permit No.**	**Permit Conditions**
140	12/2/D203-38	ROLANDSECK	ZASTRON	BLAASBALK SPRUIT	5400	IRRIGATION		
141	12/2/D203-44	NOOITGEDACHT	WEPENER	SAND SPRUIT TR.	400	IRRIGATION		
142	12/2/D203-45	MERINOVLEY	DEWETSDORP	RIET SPRUIT	250	IRRIGATION		
143	12/2/D203-47	BEKKERSKRAAL	DEWETSDORP	RIET SPRUIT	500	IRRIGATION		
144	12/2/D203-48	PLATKOP	DEWETSDORP	RIET SPRUIT	1500	IRRIGATION		
145	12/2/D203-53	ABOUKIR	ZASTRON	KLIP SPRUIT TR.	400	IRRIGATION		
146	12/2/D203-54	PELSTERSKRAAL	DEWETSDORP	RIET SPRUIT TR.	250	IRRIGATION		
147	12/2/D203-55	BUSHMANSHOEK	WEPENER	-	210	INSUFFICIENT INFORMATION		
148	12/2/D203-66	SEBELLA	WEPENER	CALEDON RIVER/RIVIER TR.	250	IRRIGATION		
149	12/2/D203-69	ROKEBY	WEPENER	-	259	VEE-/WILDSUIPING		
150	12/2/D203-74	BONHILL	WEPENER	-	420	INSUFFICIENT INFORMATION		
151	12/2/D204-44	KALKHOEK	ZASTRON	CALEDON RIVER/RIVIER TR.	500	IRRIGATION		
152	12/2/D204-45	GROENFONTEIN-SE	SMITHFIELD	GROEN SPRUIT TR.	250	IRRIGATION		
153	12/2/D204-46	WESSELSRUST	SMITHFIELD	WILGEBOOM SPRUIT	250	IRRIGATION		
154	12/2/D204-47	WITKOP	DEWETSDORP	WILGEBOOM SPRUIT TR.	250	IRRIGATION		
155	12/2/D204-49	ALBERT	ROUXVILLE	CALEDON RIVER/RIVIER TR.	310	IRRIGATION		
156	12/2/D204-50	VAALSPRUIT	SMITHFIELD	WILGEBOOM SPRUIT	900	IRRIGATION		
157	12/2/D204-51	GANSPOORT	BETHULIE	SLYK SPRUIT TR.	200	IRRIGATION		
158	12/2/D204-53	FRANKFORT-ROOI	SMITHFIELD	CALEDON RIVER/RIVIER TR.	280	IRRIGATION		
159	12/2/D204-57	SPITZKOP	SMITHFIELD	SKULP SPRUIT	250	IRRIGATION		
160	12/2/D204-58	GROENPOORT	ROUXVILLE	ELDORADO SPRUIT	1600	IRRIGATION		
161	12/2/D204-61	STERKWATER-OU	ROUXVILLE	ELDORADO SPRUIT TR.	200	IRRIGATION		
162	12/2/D204-62	STERKWATER	ROUXVILLE	ELDORADO SPRUIT	2000	IRRIGATION		
163	12/2/D204-66	JERUSALEM	ROUXVILLE	-	250	IRRIGATION		
164	12/2/D310-05	BLOUBOSHOEK	PHILIPPOLIS	ORANJE RIVER/RIVIER TR.	500	IRRIGATION		
165	12/2/D310-07	KLEIN-SCHIETFONTEIN	PHILIPPOLIS	-	280	IRRIGATION		
166	12/2/D310-10	BOSDUIWEKOP	PHILIPSTOWN	HONDEBLAF SPRUIT TR.	2000	IRRIGATION		
167	12/2/D310-11	VENTERSVALLEI	PHILIPSTOWN	-	351	IRRIGATION		

	Section 9b authorisations grant permission to farmers to build dams >250 000 m^3 or for abstractions or diversions > 110 l/sec.							
	DWAF No.	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity ($x10^3m^3$)**	**Dam used for**	**Permit No.**	**Permit Conditions**
168	12/2/D310-12	KNAPSAK	PHILIPPOLIS	KNAPSAK RIVER/RIVIER	1400	IRRIGATION		
169	12/2/D320-01	KRIEGERSPOORT	HANOVER	ELANDSKLOOF RIVER/RIVIER	5355	IRRIGATION		
170	12/2/D320-07	WELGELEGEN-GELDENHUIS	RICHMOND	SEEKOEI RIVER/RIVIER	3800	IRRIGATION		
171	12/2/D320-08	FAUGH-A-BALLAGH	HANOVER	SEEKOEI RIVER/RIVIER	200	IRRIGATION		
172	12/2/D320-09	WELGELEGEN-NAUDE	RICHMOND	SEEKOEI RIVER/RIVIER	5600	IRRIGATION		
173	12/2/D320-11	POEPERSKLOOF	COLESBERG	SEEKOEI RIVER/RIVIER TR.	200	IRRIGATION		
174	12/2/D320-12	ZOETVLEI	RICHMOND	SOETVLEI-SE-LOOP TR.	1240	IRRIGATION		
175	12/2/D320-19	CYPHERWATER	RICHMOND	SEEKOEI RIVER/RIVIER	7500	IRRIGATION		
176	12/2/D320-21	SUNNYDELL	MIDDELBURG	SEEKOEI RIVER/RIVIER	450	IRRIGATION		
177	12/2/D330-20	KLEIN VAN DER KLOOF	FAURESMITH	ORANJE RIVER/RIVIER TR.	1633	GRONBEWARING		
178	12/2/D341-05	ELIM	PHILIPPOLIS	DWARS RIVER/RIVIER TR.	856	IRRIGATION		
179	12/2/D341-06	RIETFONTEINPOORT NO.1-	COLESBERG	VAN DER WALTSFONTEIN SPRUIT	1200	IRRIGATION		
180	12/2/D341-07	RIETFONTEINPOORT NO.2-	COLESBERG	VAN DER WALTSFONTEIN SPRUIT	200	IRRIGATION		
181	12/2/D341-08	ZOOIFONTEIN	PHILIPPOLIS	-	600	IRRIGATION		
182	12/2/D341-11	FONTEINTJE	PHILIPPOLIS	DONKERPOORT SPRUIT	470	IRRIGATION		
183	12/2/D342-05	JAMES BARRY	COLESBERG	OORLOGSPOORT SPRUIT	1000	IRRIGATION		
184	12/2/D342-10	VOLKSKAS	COLESBERG	OORLOGSPOORT SPRUIT	324	IRRIGATION		
185	12/2/D342-12	RIETFONTEIN	COLESBERG	OORLOGSPOORT RIVER/RIVIER TR.	1000	IRRIGATION		
186	12/2/D350-17	SEWEFONTEIN	STEYNSBURG	-	1100	IRRIGATION		
187	12/2/D350-18	STORMFONTEIN	ALBERT	BROEK SPRUIT TR.	1000	IRRIGATION		
188	12/2/D350-19	SOUTHWELL	STEYNSBURG	RIETKUIL RIVER/RIVIER	289	IRRIGATION		
189	12/2/D350-27	SCHOONBEEKSFONTEIN	BETHULIE	-	234	IRRIGATION		
190	12/2/D350-30	GELEGENFONTEIN NO.2-	STEYNSBURG	-	210	IRRIGATION		
191	12/2/D350-31	WINNAARSBAKEN	ALBERT	WINNAARSBAKEN SPRUIT TR.	360	IRRIGATION		
192	12/2/D350-32	ESELZHOEK	ALBERT	BRAND SPRUIT	1480	IRRIGATION		

	Section 13 authorisations: Permission to municipalitities or local councils to build dams >125 000m³ or for abstractions or diversions > 5 000 m³/day.						
	DWAF No:	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity ($10^6 m^3$)**	**Dam used for**	**Permit No.**
	Upper Orange Catchment:						
	MODDER / RIET SUB-AREA						
52	12/2/C510-09	FOURIESPRUIT	EDENBURG	FOURIE SPRUIT	1900	IRRIGATION & MUNISIPAAL EN/OF INDUSTRIAL USE	
53	12/2/C512-30	REDDERSBURG	REDDERSBURG	FOURIE SPRUIT	800	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
54	12/2/C513-38	WOLWAS	JAGERSFONTEIN	PROSES SPRUIT	1000	INLIGTING ONBREEK	
55	12/2/C520-08	MAZELSPOORT	BLOEMFONTEIN	MODDER RIVER/RIVIER	783	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
56	12/2/C520-09	MOCKES	BLOEMFONTEIN	MODDER RIVER/RIVIER	6005	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
57	12/2/C522-29	BRANDKOP RESERVOIR	BLOEMFONTEIN	-	136	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
58	12/2/C523-42	MOOIWATER-VLOEDVERTRAGINGS	BLOEMFONTEIN	BAINSVLEI RIVER/RIVIER	820	FLOOD CONTROL	
	UPPER ORANGE SUB-AREA						
73	12/2/D120-02	KLOOF	ZASTRON	SAND SPRUIT TR.	227	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
74	12/2/D120-07	LADY GREY-DORPS	LADY GREY	WILGE SPRUIT	146	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
75	12/2/D120-15	MONTAGU	ZASTRON	GRYSKOP SPRUIT	4123	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
76	12/2/D132-10	ANDERSON	WODEHOUSE	-	1530	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
77	12/2/D140-02	J.L. DE BRUIN	ALBERT	STORMBERG SPRUIT TR.	1696	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
78	12/2/D140-04	MOLTENO	MOLTENO	STORMBERG SPRUIT	3000	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
79	12/2/D200-15	LUCRETIA	CLOCOLAN	MOPEDI RIVER/RIVIER	786	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
80	12/2/D200-18	SMITHFIELD	SMITHFIELD	GROEN SPRUIT	4550	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
81	12/2/D200-19	VAN STADENSRUS DORPS	WEPENER	WIT SPRUIT	1800	IRRIGATION	
82	12/2/D201-51	MEULSPRUIT	FICKSBURG	MEUL SPRUIT	2600	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
83	12/2/D202-46	CATHCARTDRIFT	LADYBRAND	CALEDON RIVER/RIVIER TR.	1500	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
84	12/2/D202-54	MOPERI	CLOCOLAN	MOPEDI RIVER/RIVIER	10281	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
85	12/2/D204-65	KALKOENKRANS	ROUXVILLE	LEEUW SPRUIT	821	SUPPLY FOR MUNICIPALITY USE &/OR INDUSTRIAL USE	
86	12/2/D350-04	BETHULIE	BETHULIE	BETHULIE SPRUIT	4600	IRRIGATION	
87	12/2/D350-21	VILJOENS	BETHULIE	-	170	INLIGTING ONBREEK	
88	12/2/D350-22	WEMBLEY	BETHULIE	-	700	INLIGTING ONBREEK	

Section 13 authorisations grant permission to industry to build dams >150 000 m^3 or for abstractions > 150m^3/day.							
DWAF No.	**Dam Name**	**Magisterial District**	**RIVER**	**Gross capacity** (x $10^6 m^3$)	**Dam used for**	**Permit No.**	**Permit Conditions**
Upper Orange Catchment:							
12/2/C510-09	FOURIESPRUIT	EDENBURG	FOURIE SPRUIT	1900	IRRIGATION & MUNISIPAAL EN/OF NYWERHEIDSGEBRUIK		
12/2/D141-16	ALKMAAR	ALBERT	PALMIET SPRUIT	177	GRONBEWARING		
12/2/D141-24	GOEDEMOED-SKILPAD	ROUXVILLE	ORANGE RIVER/RIVIER TR.	105	IRRIGATION		
12/2/D141-25	GOEDEMOED-SKAAPKRAAL	ROUXVILLE	ORANGE RIVER/RIVIER TR.	160	IRRIGATION		

APPENDIX C.2

PCPOLMAN DATABASE (example of permits)

Data from PCPOLMAN database (DWAF, Water Quality Section)

SOME ABSTRACTION AND DISCHARGE PERMITS

								Annual abs/disc		Daily abs/disc
Permit no	**File no**	**Name**	**Drainage region**	**PERMIT STATUS**	**QUAT (FLOW TYPE)**	**FLOW**	**ABS / DISCHARGE**	**TOTAL FLOW(m³)**	**TIME**	**FLOW(m³)**
235 B				0	C510/05/V001	FLOW	Q	200000	N	0
988 B	B33/2/350/16	Suid-Westelike Transvaalse Landboukooperasie Bpk	Central Province (Free State)	0	C510/17/L004	FLOW	D	1800	N	0
988 B				0	C510/17/U001	FLOW	D	250	N	0
628 B	B33/2/350/15	Municipality Of Koffiefontein	Central Province (Free State)	0	C510/19/V001	FLOW	Q	620000	D	1500
35 N				0	C520/05/D002	FLOW	A	27727	N	0
331 N	B33/2/350/12	South African Breweries Limited;Hamilton;Bloemfont	Central Province (Free State)	0	C520/05/D002	FLOW	A	0	D	760
331 N				1	C520/05/D002	FLOW	A	277100	D	1230
656 N	B33/2/350/26	Suid Afrikaanse Abattoirkorporasie	Central Province (Free State)	0	C520/05/D002	FLOW	A	143800	D	620
673 N	B33/15/9/1	Hamilton Brouery	Central Province (Free State)	0	C520/05/D002	FLOW	A	121900	D	1000
696 N	B33/2/350/28	Bloemfontein Stadsraad	Central Province (Free State)	0	C520/05/D002	FLOW	A	54800	D	250
699 N	B33/2/350/25	Die DairyBelle Korporasie (Edms) Beperk	Central Province (Free State)	0	C520/05/D002	FLOW	A	255500	N	0
851 N	B33/2/350/10	Corobrick Freestate Limited	Central Province (Free State)	0	C520/05/D002	FLOW	A	112000	N	0
862 N	B33/2/350/35	Central Laundry	Central Province (Free State)	0	C520/05/D002	FLOW	A	138000	D	626
878 N	B33/2/350/40	Rocla (Edms) Bpk-Bloemfontein	Central Province (Free State)	0	C520/05/D002	FLOW	A	29000	D	180
842 B	B33/2/350/2	Munisipaliteit van Bloemfontein	Central Province (Free State)	0	C520/05/E003	FLOW	D	18502000	N	0
882 B	33/2/350/2	City Council Of Bloemfontein	Central Province (Free State)	0	C520/05/E004	FLOW	D	2200000	N	0
842 B	B33/2/350/2	Munisipaliteit van Bloemfontein	Central Province (Free State)	0	C520/05/F001	FLOW	D	3052900	N	0
1323B	B33/350/29	Municipality of Brandfort	Central Province (Free State)	0	C520/17/V002	FLOW	Q	121000	D	330
1100B	B33/2/350/14	Municipality Of Dewetsdorp	Central Province (Free State)	0	C520/20/V005	FLOW	Q	78500	D	215
1101B	B33/2/350/18	Municipality Of Petrusburg	Central Province (Free State)	0	C520/21/V001	FLOW	D	121000	N	0
303 B	33/2/410/6	Zastron Municipality	Central Province (Free State)	0	D120/04/V001	FLOW	Q	121545	D	333
479 B	B33/2/410/7	Municipality Of Barkly East	Eastern Cape Region	0	D130/02/L001	FLOW	Q	109500	D	300
479 B				0	D130/02/V001	FLOW	Q	109500	D	300
1236B	B33/2/410/21	Munisipaliteit Van Dordrecht	Eastern Cape Region	0	D130/03/V002	FLOW	Q	109000	D	300
1531B	B33/2/410/9	Municipality Of Aliwal North	Eastern Cape Region	0	D140/08/L003	FLOW	Q	1205000	N	3000
1531B				0	D140/08/V001	FLOW	Q	1205000	D	3000
671 B	33/2/410/2	Burgersdorp Municipality	Eastern Cape Region	0	D140/09/L001	FLOW	Q	219000	D	600
671 B				0	D140/09/V001	FLOW	Q	219000	D	600
1135B	B33/15/13/5	Oos-Kaap Administrasieraad	Eastern Cape Region	0	D140/10/V001	FLOW	Q	34600	M	2884
226 B	33/2/410/5	Ladybrand Municipality	Central Province (Free State)	0	D200/23/X001	FLOW	Q	1080000	D	0
327 B	MISSING	Clocolan Municipality	Central Province (Free State)	2	D200/27/L011	FLOW	D	104520	N	0
715 B	B33/2/410/11	Municipality Of Rouxville	Central Province (Free State)	0	D200/31/V005	FLOW	Q	100370	D	275
951 B	B33/2/410/10	Municipality Of Smithfield	Central Province (Free State)	0	D200/32/V002	FLOW	Q	23000	D	65
1147B	B33/2/350/39	Orange Free State Province	Central Province (Free State)	0	D200/33/L009	FLOW	Q	26100	N	0
1147B				0	D200/33/V001	FLOW	Q	26100	D	65
437 B	B33/2/410/1	Municipality Of Ficksburg	Central Province (Free State)	0	D201/53/E001	FLOW	E	0	D	620000
617 B	B33/2/430/2	Municipality Of Noupoort	Eastern Cape Region	0	D320/02/V001	FLOW	D	587800	N	0
522 B	B33/2/430/3	Municipality Of Colesburg	Eastern Cape Region	0	D340/03/L001	FLOW	E	140000	N	0
522 B				0	D340/03/V001	FLOW	Q	140000	D	384
1328B	B33/2/1600/1	Hendrik Verwoerddam Dorp (Rioolsuiweringswerke)	Central Province (Free State)	0	D350/23/V002	FLOW	Q	145000	D	400
1486B	B33/2/430/15	Hendrik Verwoerddam Dorp	Central Province (Free State)	0	D350/23/X001	FLOW	Q	145000	D	360

APPENDIX C.3

Section 56(3) permits

ABSTRACTIONS FROM ORANGE RIVER

Data checked by Mrs K Broere, DWAF, GWS, Room 631 (Sedibeng)

Permit Type	River	Quat	Source of allocation	User	Permit No.	Amount (m^3/annum)	Sector	Source of data
Section 56 (3)	**Orange River**	**D35K**	**Gariep Dam**	**Transfer to Eastern Cape: Gariep Dam - Fish Ri**	**Various**	**550000000**	**Agric + urb. / ind. /inst.**	**Nimhan Shand**
Section 56 (3)	**Orange River**	**D35K**	**Gariep Dam**	**Bloem Water - Bethulie; Trompsburg & Springf**	**26/77/12/1/96**	**1500000**	**Mun/Ind**	**DWAF**
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	Vanderkloof Municipality	23/77/12/2/86	1200000	Mun/Ind	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	FS Provicial Administration (Holiday resort)	11/77/12/1/78	1022000	Instituitional	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	FS Provicial Admin: Nature Conservation	42/77/12/1/80	960000	Institutional	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	FS Provicial Administration	38/77/1/77	720000	Institutional - golf course	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	Venterstad Municipality	41/77/12/1/80	600000	Mun/Ind	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	Dept: Correctional Services - Goedemoed Prison	35/1/77/12/1/7	480000	Institutional	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	Phillipolis Municipality (Bloem Water)	34/77/12/1/97	383000	Mun/Ind	DWAF
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	Hopetown Municipality	43/77/12/2/78	300000	Mun/Ind	DWAF
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	Orania Town Council	77/77/12/2/92	252000	Mun/Ind	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	PDK Lubbe	112/77/12/1/8	220000	Domestic / stock (20ha)	DWAF
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	Colesberg Municipality	37/77/12/2/86	146000	Mun/Ind	DWAF
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	Vanderkloof Municipality	139/77/12/2/8	75000	Mun/Ind	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	SA Railways (Norvalspont Station)	12/77/12/1/78	36500	Institutional	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	SA Railways (Norvalspont Station)	34/77/1/77	36000	Institutional	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	Mr Davenport	100/77/12/91	30000	Domestic / stock	DWAF
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	Cape Provincial Administration	65/77/12/2/92	30000	Institutional	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	FS Nature Conservation : "Tussen die riviere" Rese	63/77/12/1/88	20000	Institutional	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	DGM Southey	35/77/1/77	10944	Domestic / stock	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	CJ Robbertze	26/77/12/1/80	5973	Domestic / stock	DWAF
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	JJ Fourie	100/77/12/2/7	2484	Domestic	DWAF
Section 56 (3)	Orange River	D35K	Gariep Dam	FS Nature Conservation	97/77/12/1/83	1825	Institutional	DWAF
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	Van der Merwe / de Lange Delwerye	85/77/12/2/85	1460	Mine	DWAF
Permit 56 (3)	Orange river	D31E	Van der Kloof Dam + canals	Dept: Nature & Environment (Cape)	90/77/12/2/80	100	Institutional	DWAF
						6533286		

Article 63 Scheduling and Quotas in Government Water Schemes

Scheme	Catchments	Scheduling (ha)	Quota ($10^6 m^3$)
Upper Orange WMA			
Upper Orange (excl. Lesotho)	D12, D13, D14, D15		
U/S Aliwal North, D/S Oranjedraai	D12, D15	1574.6	12.6
U/S Gariep Dam, D/S Aliwal North, U/S Aliwal North, Kraai	D13, D14	2559.7	20.5
Sub-total		4134.3	33.1
Caledon	D21, D22, D23, D24		
Caledon U/S Welbedacht Dam	D21, D22, D23,	1440	34
Caledon U/S Gariep Dam, D/S Welbedacht Dam	D24	4775.1	38.2
Sub-total		6215.1	72.2
Middle Orange	D31, D32, D34, D35		
U/S Vanderkloof Dam, D/S Gariep Dam	D32, D34, D35	2316	25.5
Vanderkloof/Ramah canals	D31	5001	55.0
Sub-total		7317	80.5
Modder/Riet	C51, C52		
Upstream Kalkfontein Dam	C51	0	0
Kalkfontein Irrigation Board, Canal	C51	3046	33.51
Kalkfontein Irrigation Board, river	C51	480	5.28
Tierpoort IB	C51	708	6.37
Upstream Tierpoort Dam	C51	0	0
Rustfontein Dam Catchment GWCA	C52	0	0
Rustfontein Dam to Krugersdrift Dam	C52	0	0
Modder River GWS	C52	3536	29.65
Riet River Settlement	C51	7812	85.93
Scholtzburg Irrigation Area	C51	637	5.82
Ritchie Irrigation Area	C51	97	0.89
Lower Riet River IB	C51	3938	43.32
Total		**20254**	**210.77**

* ORRS Report PD000/00/4897, Evaluation of Irrigation use, and LVA report 1999.

Article 56(3) Allocations from Government Water Schemes

Scheme	**Catchments**	**Allocation ($10^6 m^3$)**
Upper Orange WMA		
Upper Orange (excl. Lesotho)	D11, D12, D13, D14, D15, D16, D17, D18	No data
Caledon	D21, D22, D23, D24	
Bloemwater allocation		120.3
Municipalities & Industries	Allocations by Bloemwater	(9.8)
Institutions	“	(4.76)
Mining	“	(0.0)
Domestic; irrigation & stockwatering	“	(0.11)
Sub-total		120.3
Middle Orange	D31, D32, D34, D35	
Municipalities & Industries		4.46
Institutions		3.31
Mining		0.0015
Domestic; irrigation & stockwatering		0.27
Sub-total		8.0415
Modder/Riet (excl. Caledon water allocations to Bloemwater)	C51, C52	
Bloemwater	C52	28.5
Municipalities & Industries		18.08
Institutions		0.54
Mining		3.15
Domestic; irrigation & stockwatering		0.67
Sub-total		50.94
Total		179.28

APPENDIX D LAND USE DATA

Comprising:

Appendix D.1 Irrigation land use

Appendix D.2 Urban area

APPENDIX D.1

IRRIGATION LAND USE DATA

(Summary data and quaternary data)

(Crop area data from WSAM, Irrigation sub-model)

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
UPPER ORANGE WMA:							
Riet / Modder sub-area							
Kalkfontein sub-area							
C51A	Cotton	Low	Line Nr (45)*(1.00)	0.14	0.1	0.78	1
C51A	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.06	0.1	0.78	1
C51A	Grapes - table	High	Line Nr (2)*(1.00)	0.08	0.1	0.78	1
C51A	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.78	1
C51A	Lucerne	Low	Line Nr (9)*(1.00)	1.49	0.1	0.78	1
C51A	Maize	Low	Line Nr (32)*(1.00)	2.24	0.1	0.78	1
C51A	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.78	1
C51A	Rye grass	Low	Line Nr (46)*(1.00)	0.05	0.1	0.78	1
C51A	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.02	0.1	0.78	1
C51A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.27	0.1	0.78	1
C51B	Cotton	Low	Line Nr (45)*(1.00)	0.14	0.1	0.78	1
C51B	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.06	0.1	0.78	1
C51B	Grapes - table	High	Line Nr (2)*(1.00)	0.08	0.1	0.78	1
C51B	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.78	1
C51B	Lucerne	Low	Line Nr (9)*(1.00)	1.49	0.1	0.78	1
C51B	Maize	Low	Line Nr (32)*(1.00)	2.24	0.1	0.78	1
C51B	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.78	1
C51B	Rye grass	Low	Line Nr (46)*(1.00)	0.05	0.1	0.78	1
C51B	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.02	0.1	0.78	1
C51B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.27	0.1	0.78	1
C51C	Cotton	Low	Line Nr (45)*(1.00)	0.14	0.1	0.78	1
C51C	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.06	0.1	0.78	1
C51C	Grapes - table	High	Line Nr (2)*(1.00)	0.08	0.1	0.78	1
C51C	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.78	1
C51C	Lucerne	Low	Line Nr (9)*(1.00)	1.49	0.1	0.78	1
C51C	Maize	Low	Line Nr (32)*(1.00)	2.24	0.1	0.78	1
C51C	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.78	1
C51C	Rye grass	Low	Line Nr (46)*(1.00)	0.05	0.1	0.78	1
C51C	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.02	0.1	0.78	1
C51C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.27	0.1	0.78	1
C51D	Kikuyu	Low	Line Nr (8)*(1.00)	0.74	0.1	0.78	1
C51D	Lucerne	Low	Line Nr (9)*(1.00)	1.26	0.1	0.78	1
C51E	Kikuyu	Low	Line Nr (8)*(1.00)	2.45	0.2	0.8	1
C51E	Lucerne	Low	Line Nr (9)*(1.00)	4.2	0.2	0.8	1
C51F	Cotton	Low	Line Nr (45)*(1.00)	0.14	0.1	0.78	1
C51F	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.06	0.1	0.78	1
C51F	Grapes - table	High	Line Nr (2)*(1.00)	0.08	0.1	0.78	1
C51F	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.78	1
C51F	Lucerne	Low	Line Nr (9)*(1.00)	1.49	0.1	0.78	1
C51F	Maize	Low	Line Nr (32)*(1.00)	2.24	0.1	0.78	1
C51F	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.78	1
C51F	Rye grass	Low	Line Nr (46)*(1.00)	0.05	0.1	0.78	1
C51F	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.02	0.1	0.78	1
C51F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.27	0.1	0.78	1
C51G	Cotton	Low	Line Nr (45)*(1.00)	0.14	0.1	0.78	1
C51G	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.06	0.1	0.78	1
C51G	Grapes - table	High	Line Nr (2)*(1.00)	0.08	0.1	0.78	1
C51G	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.78	1
C51G	Lucerne	Low	Line Nr (9)*(1.00)	1.49	0.1	0.78	1
C51G	Maize	Low	Line Nr (32)*(1.00)	2.24	0.1	0.78	1
C51G	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.78	1
C51G	Rye grass	Low	Line Nr (46)*(1.00)	0.05	0.1	0.78	1
C51G	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.02	0.1	0.78	1
C51G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.27	0.1	0.78	1
C51H	Cotton	Low	Line Nr (45)*(1.00)	0.14	0.1	0.78	1
C51H	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.06	0.1	0.78	1
C51H	Grapes - table	High	Line Nr (2)*(1.00)	0.08	0.1	0.78	1
C51H	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.78	1
C51H	Lucerne	Low	Line Nr (9)*(1.00)	1.49	0.1	0.78	1
C51H	Maize	Low	Line Nr (32)*(1.00)	2.24	0.1	0.78	1
C51H	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.78	1
C51H	Rye grass	Low	Line Nr (46)*(1.00)	0.05	0.1	0.78	1
C51H	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.02	0.1	0.78	1
C51H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.27	0.1	0.78	1
C51J	Cotton	Low	Line Nr (45)*(1.00)	0.14	0.1	0.78	1
C51J	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.06	0.1	0.78	1
C51J	Grapes - table	High	Line Nr (2)*(1.00)	0.08	0.1	0.78	1
C51J	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.78	1
C51J	Lucerne	Low	Line Nr (9)*(1.00)	1.49	0.1	0.78	1
C51J	Maize	Low	Line Nr (32)*(1.00)	2.24	0.1	0.78	1
C51J	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.78	1
C51J	Rye grass	Low	Line Nr (46)*(1.00)	0.05	0.1	0.78	1
C51J	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.02	0.1	0.78	1
C51J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.27	0.1	0.78	1
Total				**54.1**			
Riet key area:							
C51K	Cotton	Low	Line Nr (45)*(1.00)	5.27	0.15	0.8	1
C51K	Grapes - table	High	Line Nr (2)*(1.00)	3.11	0.15	0.8	1
C51K	Kikuyu	Low	Line Nr (8)*(1.00)	0.98	0.15	0.8	1
C51K	Lucerne	Low	Line Nr (9)*(1.00)	24.72	0.15	0.8	1
C51K	Potato	Medium	Line Nr (37)*(1.00)	3.36	0.15	0.8	1
C51K	Rye grass	Low	Line Nr (46)*(1.00)	3.66	0.15	0.8	1
C51K	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.81	0.15	0.8	1
C51K	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	72.67	0.15	0.8	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
C51K	Field (groundnut)	Low	Line Nr (42)*(1.00)	10.05	0.15	0.8	1
C51K	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	11.76	0.15	0.8	1
C51K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	83.59	0.15	0.8	1
Total				**220.0**			
Riet / Vaal key area:							
C51L	Cotton	Low	Line Nr (45)*(1.00)	0.95	0.15	0.79	1
C51L	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.75	0.15	0.79	1
C51L	Kikuyu	Low	Line Nr (8)*(1.00)	0.8	0.15	0.79	1
C51L	Lucerne	Low	Line Nr (9)*(1.00)	3.01	0.15	0.79	1
C51L	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.09	0.15	0.79	1
C51L	Maize	Low	Line Nr (32)*(1.00)	6.25	0.15	0.79	1
C51L	Potato	Medium	Line Nr (37)*(1.00)	1.3	0.15	0.79	1
C51L	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	2.62	0.15	0.79	1
C51L	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	16.5	0.15	0.79	1
C51M	Cotton	Low	Line Nr (45)*(1.00)	0.95	0.15	0.79	1
C51M	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.75	0.15	0.79	1
C51M	Kikuyu	Low	Line Nr (8)*(1.00)	0.65	0.15	0.79	1
C51M	Lucerne	Low	Line Nr (9)*(1.00)	2.7	0.15	0.79	1
C51M	Maize	Low	Line Nr (32)*(1.00)	6.25	0.15	0.79	1
C51M	Potato	Medium	Line Nr (37)*(1.00)	1.3	0.15	0.79	1
C51M	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	2.05	0.15	0.79	1
C51M	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	16.5	0.15	0.79	1
C52H	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.07	0.3	0.79	1
C52H	Grapes - table	High	Line Nr (2)*(1.00)	0.13	0.3	0.79	1
C52H	Kikuyu	Low	Line Nr (8)*(1.00)	0.17	0.3	0.79	1
C52H	Lucerne	Low	Line Nr (9)*(1.00)	1.5	0.3	0.79	1
C52H	Pecan nut	High	Line Nr (14)*(1.00)	0.07	0.3	0.79	1
C52H	Maize	Low	Line Nr (32)*(1.00)	4.55	0.3	0.79	1
C52H	Potato	Medium	Line Nr (37)*(1.00)	0.3	0.3	0.79	1
C52H	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.81	0.3	0.79	1
C52H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	5.98	0.3	0.79	1
C52K	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.07	0.3	0.79	1
C52K	Grapes - table	High	Line Nr (2)*(1.00)	0.13	0.3	0.79	1
C52K	Kikuyu	Low	Line Nr (8)*(1.00)	0.17	0.3	0.79	1
C52K	Lucerne	Low	Line Nr (9)*(1.00)	1.5	0.3	0.79	1
C52K	Pecan nut	High	Line Nr (14)*(1.00)	0.07	0.3	0.79	1
C52K	Maize	Low	Line Nr (32)*(1.00)	4.55	0.3	0.79	1
C52K	Potato	Medium	Line Nr (37)*(1.00)	0.3	0.3	0.79	1
C52K	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.81	0.3	0.79	1
C52K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	5.98	0.3	0.79	1
C52L	Field (groundnut)	Low	Line Nr (42)*(1.00)	0.07	0.3	0.79	1
C52L	Grapes - table	High	Line Nr (2)*(1.00)	0.13	0.3	0.79	1
C52L	Kikuyu	Low	Line Nr (8)*(1.00)	0.17	0.3	0.79	1
C52L	Lucerne	Low	Line Nr (9)*(1.00)	1.5	0.3	0.79	1
C52L	Pecan nut	High	Line Nr (14)*(1.00)	0.07	0.3	0.79	1
C52L	Maize	Low	Line Nr (32)*(1.00)	4.55	0.3	0.79	1
C52L	Potato	Medium	Line Nr (37)*(1.00)	0.3	0.3	0.79	1
C52L	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.81	0.3	0.79	1
C52L	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	5.98	0.3	0.79	1
Total				**104.2**			
Rustfontein Dam key area:							
C52A	Kikuyu	Low	Line Nr (8)*(1.00)	0.1	0.1	0.79	1
C52A	Lucerne	Low	Line Nr (9)*(1.00)	2.48	0.1	0.79	1
C52A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.73	0.1	0.79	1
C52A	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.18	0.1	0.79	1
C52A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1	0.1	0.79	1
Total				**4.5**			
Krugersdrift key area:							
C52B	Kikuyu	Low	Line Nr (8)*(1.00)	0.13	0.1	0.79	1
C52B	Lucerne	Low	Line Nr (9)*(1.00)	3.3	0.1	0.79	1
C52B	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.98	0.1	0.79	1
C52B	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.23	0.1	0.79	1
C52B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.34	0.1	0.79	1
C52D	Kikuyu	Low	Line Nr (8)*(1.00)	0.13	0.1	0.79	1
C52D	Lucerne	Low	Line Nr (9)*(1.00)	3.3	0.1	0.79	1
C52D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.98	0.1	0.79	1
C52D	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.23	0.1	0.79	1
C52D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.34	0.1	0.79	1
C52E	Kikuyu	Low	Line Nr (8)*(1.00)	0.13	0.1	0.79	1
C52E	Lucerne	Low	Line Nr (9)*(1.00)	3.3	0.1	0.79	1
C52E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.98	0.1	0.79	1
C52E	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.23	0.1	0.79	1
C52E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.34	0.1	0.79	1
C52G	Kikuyu	Low	Line Nr (8)*(1.00)	0.13	0.1	0.79	1
C52G	Lucerne	Low	Line Nr (9)*(1.00)	3.3	0.1	0.79	1
C52G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.98	0.1	0.79	1
C52G	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.23	0.1	0.79	1
C52G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.34	0.1	0.79	1
Total				**23.9**			
Total harvested crop area in Modder / Riet sub-area: (all in Free State)				**406.6**			
Caledon sub-area							
D21A	Kikuyu	Low	Line Nr (8)*(1.00)	0.03	0.1	0.75	1
D21A	Lucerne	Low	Line Nr (9)*(1.00)	0.05	0.1	0.75	1
D21A	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.02	0.1	0.75	1
D21A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.01	0.1	0.75	1
D21A	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.01	0.1	0.75	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
D21A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.02	0.1	0.75	1
D21E	Kikuyu	Low	Line Nr (8)*(1.00)	0.2	0.1	0.75	1
D21E	Lucerne	Low	Line Nr (9)*(1.00)	0.35	0.1	0.75	1
D21E	Potato	Medium	Line Nr (37)*(1.00)	0.02	0.1	0.75	1
D21E	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.14	0.1	0.75	1
D21E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.08	0.1	0.75	1
D21E	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.04	0.1	0.75	1
D21E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.11	0.1	0.75	1
D21F	Kikuyu	Low	Line Nr (8)*(1.00)	0.31	0.1	0.75	1
D21F	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.21	0.1	0.75	1
D21F	Lucerne	Low	Line Nr (9)*(1.00)	0.53	0.1	0.75	1
D21F	Potato	Medium	Line Nr (37)*(1.00)	0.03	0.1	0.75	1
D21F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.12	0.1	0.75	1
D21F	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.08	0.1	0.75	1
D21F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.17	0.1	0.75	1
D21G	Kikuyu	Low	Line Nr (8)*(1.00)	0.18	0.1	0.75	1
D21G	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.12	0.1	0.75	1
D21G	Lucerne	Low	Line Nr (9)*(1.00)	0.31	0.1	0.75	1
D21G	Potato	Medium	Line Nr (37)*(1.00)	0.02	0.1	0.75	1
D21G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.07	0.1	0.75	1
D21G	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.04	0.1	0.75	1
D21G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.1	0.1	0.75	1
D21H	Kikuyu	Low	Line Nr (8)*(1.00)	0.08	0.1	0.75	1
D21H	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.06	0.1	0.75	1
D21H	Lucerne	Low	Line Nr (9)*(1.00)	0.15	0.1	0.75	1
D21H	Potato	Medium	Line Nr (37)*(1.00)	0.01	0.1	0.75	1
D21H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.03	0.1	0.75	1
D21H	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.02	0.1	0.75	1
D21H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.05	0.1	0.75	1
D22A	Kikuyu	Low	Line Nr (8)*(1.00)	0.34	0	0.75	1
D22A	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.22	0	0.75	1
D22A	Lucerne	Low	Line Nr (9)*(1.00)	0.58	0	0.75	1
D22A	Potato	Medium	Line Nr (37)*(1.00)	0.04	0	0.75	1
D22A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.13	0	0.75	1
D22A	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.08	0	0.75	1
D22A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.18	0	0.75	1
D22B	Kikuyu	Low	Line Nr (8)*(1.00)	0.33	0	0.75	1
D22B	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.22	0	0.75	1
D22B	Lucerne	Low	Line Nr (9)*(1.00)	0.57	0	0.75	1
D22B	Potato	Medium	Line Nr (37)*(1.00)	0.04	0	0.75	1
D22B	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.13	0	0.75	1
D22B	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.08	0	0.75	1
D22B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.18	0	0.75	1
D22C	Kikuyu	Low	Line Nr (8)*(1.00)	0.06	0.1	0.75	1
D22C	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.04	0.1	0.75	1
D22C	Lucerne	Low	Line Nr (9)*(1.00)	0.1	0.1	0.75	1
D22C	Potato	Medium	Line Nr (37)*(1.00)	0.01	0.1	0.75	1
D22C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	2.62	0.1	0.75	1
D22C	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.01	0.1	0.75	1
D22C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.03	0.1	0.75	1
D22D	Kikuyu	Low	Line Nr (8)*(1.00)	0.3	0.1	0.75	1
D22D	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.2	0.1	0.75	1
D22D	Lucerne	Low	Line Nr (9)*(1.00)	0.51	0.1	0.75	1
D22D	Potato	Medium	Line Nr (37)*(1.00)	0.03	0.1	0.75	1
D22D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	2.71	0.1	0.75	1
D22D	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.07	0.1	0.75	1
D22D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.16	0.1	0.75	1
D22G	Kikuyu	Low	Line Nr (8)*(1.00)	0.81	0.1	0.75	1
D22G	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.53	0.1	0.75	1
D22G	Lucerne	Low	Line Nr (9)*(1.00)	1.38	0.1	0.75	1
D22G	Potato	Medium	Line Nr (37)*(1.00)	0.09	0.1	0.75	1
D22G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.3	0.1	0.75	1
D22G	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.2	0.1	0.75	1
D22G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.44	0.1	0.75	1
D22H	Kikuyu	Low	Line Nr (8)*(1.00)	0.33	0.1	0.75	1
D22H	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.22	0.1	0.75	1
D22H	Lucerne	Low	Line Nr (9)*(1.00)	0.56	0.1	0.75	1
D22H	Potato	Medium	Line Nr (37)*(1.00)	0.03	0.1	0.75	1
D22H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	2.72	0.1	0.75	1
D22H	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.08	0.1	0.75	1
D22H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.18	0.1	0.75	1
D22L	Kikuyu	Low	Line Nr (8)*(1.00)	0.3	0.1	0.75	1
D22L	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.2	0.1	0.75	1
D22L	Lucerne	Low	Line Nr (9)*(1.00)	0.51	0.1	0.75	1
D22L	Potato	Medium	Line Nr (37)*(1.00)	0.03	0.1	0.75	1
D22L	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.11	0.1	0.75	1
D22L	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.07	0.1	0.75	1
D22L	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.16	0.1	0.75	1
Total				**23.0**			
Total SA:				**15.2**			
Total Lesotho:				**7.8**			
Key area: Welbedacht [Upper Orange WMA]							
D23A	Kikuyu	Low	Line Nr (8)*(1.00)	0.33	0.1	0.75	1
D23A	Lucerne	Low	Line Nr (9)*(1.00)	0.57	0.1	0.75	1
D23A	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.22	0.1	0.75	1
D23A	Potato	Medium	Line Nr (37)*(1.00)	0.04	0.1	0.75	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
D23A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	2.72	0.1	0.75	1
D23A	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.08	0.1	0.75	1
D23A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.18	0.1	0.75	1
D23C	Kikuyu	Low	Line Nr (8)*(1.00)	0.82	0.1	0.75	1
D23C	Lucerne	Low	Line Nr (9)*(1.00)	1.39	0.1	0.75	1
D23C	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.54	0.1	0.75	1
D23C	Potato	Medium	Line Nr (37)*(1.00)	0.09	0.1	0.75	1
D23C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.31	0.1	0.75	1
D23C	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.2	0.1	0.75	1
D23C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.44	0.1	0.75	1
D23D	Kikuyu	Low	Line Nr (8)*(1.00)	0.59	0.1	0.75	1
D23D	Lucerne	Low	Line Nr (9)*(1.00)	1.01	0.1	0.75	1
D23D	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.39	0.1	0.75	1
D23D	Potato	Medium	Line Nr (37)*(1.00)	0.06	0.1	0.75	1
D23D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.22	0.1	0.75	1
D23D	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.14	0.1	0.75	1
D23D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.32	0.1	0.75	1
D23E	Citrus (Valencia, navel, easy peelers , lemon, grapefruit)	High	Line Nr (4)*(1.00)	0.64	0.1	0.75	1
D23E	Kikuyu	Low	Line Nr (8)*(1.00)	0.97	0.1	0.75	1
D23E	Lucerne	Low	Line Nr (9)*(1.00)	1.65	0.1	0.75	1
D23E	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.75	1
D23E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	2.96	0.1	0.75	1
D23E	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.24	0.1	0.75	1
D23E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.52	0.1	0.75	1
D23F	Kikuyu	Low	Line Nr (8)*(1.00)	0.2	0.1	0.75	1
D23F	Lucerne	Low	Line Nr (9)*(1.00)	0.34	0.1	0.75	1
D23F	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.13	0.1	0.75	1
D23F	Potato	Medium	Line Nr (37)*(1.00)	0.02	0.1	0.75	1
D23F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.07	0.1	0.75	1
D23F	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.05	0.1	0.75	1
D23F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.11	0.1	0.75	1
D23G	Kikuyu	Low	Line Nr (8)*(1.00)	0.81	0.1	0.75	1
D23G	Lucerne	Low	Line Nr (9)*(1.00)	1.38	0.1	0.75	1
D23G	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.53	0.1	0.75	1
D23G	Potato	Medium	Line Nr (37)*(1.00)	0.09	0.1	0.75	1
D23G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.3	0.1	0.75	1
D23G	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.2	0.1	0.75	1
D23G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.44	0.1	0.75	1
D23H	Kikuyu	Low	Line Nr (8)*(1.00)	2.13	0.1	0.75	1
D23H	Lucerne	Low	Line Nr (9)*(1.00)	3.64	0.1	0.75	1
D23H	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	1.41	0.1	0.75	1
D23H	Potato	Medium	Line Nr (37)*(1.00)	0.23	0.1	0.75	1
D23H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.8	0.1	0.75	1
D23H	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.52	0.1	0.75	1
D23H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.15	0.1	0.75	1
D23J	Kikuyu	Low	Line Nr (8)*(1.00)	1.66	0.1	0.75	1
D23J	Lucerne	Low	Line Nr (9)*(1.00)	2.84	0.1	0.75	1
D23J	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	1.1	0.1	0.75	1
D23J	Potato	Medium	Line Nr (37)*(1.00)	0.18	0.1	0.75	1
D23J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	0.63	0.1	0.75	1
D23J	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.41	0.1	0.75	1
D23J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.9	0.1	0.75	1
D24A	Kikuyu	Low	Line Nr (8)*(1.00)	0.43	0.1	0.75	1
D24A	Lucerne	Low	Line Nr (9)*(1.00)	0.91	0.1	0.75	1
D24A	Potato	Medium	Line Nr (37)*(1.00)	0.05	0.1	0.75	1
D24A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.75	0.1	0.75	1
D24A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.75	0.1	0.75	1
D24B	Kikuyu	Low	Line Nr (8)*(1.00)	0.38	0.1	0.75	1
D24B	Lucerne	Low	Line Nr (9)*(1.00)	0.81	0.1	0.75	1
D24B	Potato	Medium	Line Nr (37)*(1.00)	0.04	0.1	0.75	1
D24B	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.66	0.1	0.75	1
D24B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.66	0.1	0.75	1
D24C	Kikuyu	Low	Line Nr (8)*(1.00)	0.84	0.1	0.75	1
D24C	Lucerne	Low	Line Nr (9)*(1.00)	1.8	0.1	0.75	1
D24C	Potato	Medium	Line Nr (37)*(1.00)	0.09	0.1	0.75	1
D24C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.48	0.1	0.75	1
D24C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.48	0.1	0.75	1
Total:				**51.1**			
Total SA				**45.9**			
Total Lesotho:				**5.2**			
Key area: D/s Welbedacht							
D24D	Kikuyu	Low	Line Nr (8)*(1.00)	1.14	0.1	0.75	1
D24D	Lucerne	Low	Line Nr (9)*(1.00)	2.42	0.1	0.75	1
D24D	Potato	Medium	Line Nr (37)*(1.00)	0.12	0.1	0.75	1
D24D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2	0.1	0.75	1
D24D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2	0.1	0.75	1
D24E	Kikuyu	Low	Line Nr (8)*(1.00)	0.94	0.1	0.75	1
D24E	Lucerne	Low	Line Nr (9)*(1.00)	2	0.1	0.75	1
D24E	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.75	1
D24E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.65	0.1	0.75	1
D24E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.65	0.1	0.75	1
D24F	Kikuyu	Low	Line Nr (37)*(1.00)	1.06	0.1	0.75	1
D24F	Lucerne	Low	Line Nr (9)*(1.00)	2.27	0.1	0.75	1
D24F	Potato	Medium	Line Nr (37)*(1.00)	0.11	0.1	0.75	1
D24F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.87	0.1	0.75	1
D24F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.87	0.1	0.75	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
D24G	Kikuyu	Low	Line Nr (8)*(1.00)	1.27	0.1	0.75	1
D24G	Lucerne	Low	Line Nr (9)*(1.00)	2.71	0.1	0.75	1
D24G	Potato	Medium	Line Nr (37)*(1.00)	0.14	0.1	0.75	1
D24G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.24	0.1	0.75	1
D24G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.24	0.1	0.75	1
D24H	Kikuyu	Low	Line Nr (8)*(1.00)	1.4	0.1	0.75	1
D24H	Lucerne	Low	Line Nr (9)*(1.00)	2.99	0.1	0.75	1
D24H	Potato	Medium	Line Nr (37)*(1.00)	0.15	0.1	0.75	1
D24H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.46	0.1	0.75	1
D24H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.46	0.1	0.75	1
D24J	Kikuyu	Low	Line Nr (8)*(1.00)	1.93	0.1	0.75	1
D24J	Lucerne	Low	Line Nr (9)*(1.00)	4.11	0.1	0.75	1
D24J	Potato	Medium	Line Nr (37)*(1.00)	0.2	0.1	0.75	1
D24J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.39	0.1	0.75	1
D24J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	3.39	0.1	0.75	1
D24K	Kikuyu	Low	Line Nr (8)*(1.00)	0.9	0.1	0.75	1
D24K	Lucerne	Low	Line Nr (9)*(1.00)	1.91	0.1	0.75	1
D24K	Potato	Medium	Line Nr (37)*(1.00)	0.1	0.1	0.75	1
D24K	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.58	0.1	0.75	1
D24K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.58	0.1	0.75	1
D24L	Kikuyu	Low	Line Nr (8)*(1.00)	0.64	0.1	0.75	1
D24L	Lucerne	Low	Line Nr (9)*(1.00)	1.37	0.1	0.75	1
D24L	Potato	Medium	Line Nr (37)*(1.00)	0.07	0.1	0.75	1
D24L	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.13	0.1	0.75	1
D24L	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.13	0.1	0.75	1
Total				**62.7**			
Total irrigation in Caledon:				**136.8**			
Irrigation in Lesotho				**13.0**			
Irrigation in RSA (all in Free State)				**123.8**			
Upper Orange sub-area							
Senqu key area:							
D15D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	4.03	0.1	0.7	1
D15E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	4.03	0.1	0.7	1
D15G	Kikuyu	Low	Line Nr (8)*(1.00)	0.29	0.1	0.7	1
D15G	Lucerne	Low	Line Nr (9)*(1.00)	0.09	0.1	0.7	1
D15G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	4.12	0.1	0.7	1
D15G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.08	0.1	0.7	1
D15H	Kikuyu	Low	Line Nr (8)*(1.00)	0.82	0	0.7	1
D15H	Lucerne	Low	Line Nr (9)*(1.00)	0.26	0	0.7	1
D15H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.26	0	0.7	1
D15H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.22	0	0.7	1
D18C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	4.53	0.1	0.75	1
D18F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	4.53	0.1	0.75	1
D18J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (33)*(1.00)	4.53	0.1	0.75	1
Total:				**27.8**			
Total Lesotho:				**25.7**			
Total SA (add to Orange u/s Gariep):				**2.1**			
Orange u/s of Gariep Dam key area:							
D12A	Kikuyu	Low	Line Nr (8)*(1.00)	0.56	0.1	0.7	1
D12A	Lucerne	Low	Line Nr (9)*(1.00)	0.18	0.1	0.7	1
D12A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.18	0.1	0.7	1
D12A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.15	0.1	0.7	1
D12C	Kikuyu	Low	Line Nr (8)*(1.00)	0.21	0.1	0.7	1
D12C	Lucerne	Low	Line Nr (9)*(1.00)	0.07	0.1	0.7	1
D12C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.07	0.1	0.7	1
D12C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.06	0.1	0.7	1
D12D	Kikuyu	Low	Line Nr (8)*(1.00)	0.99	0.1	0.7	1
D12D	Lucerne	Low	Line Nr (9)*(1.00)	0.31	0.1	0.7	1
D12D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.31	0.1	0.7	1
D12D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.26	0.1	0.7	1
D12E	Kikuyu	Low	Line Nr (8)*(1.00)	2.79	0.1	0.7	1
D12E	Lucerne	Low	Line Nr (9)*(1.00)	0.88	0.1	0.7	1
D12E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.88	0.1	0.7	1
D12E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.74	0.1	0.7	1
D12F	Kikuyu	Low	Line Nr (8)*(1.00)	5.35	0.1	0.7	1
D12F	Lucerne	Low	Line Nr (9)*(1.00)	1.69	0.1	0.7	1
D12F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.69	0.1	0.7	1
D12F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.4	0.1	0.7	1
D13A	Kikuyu	Low	Line Nr (8)*(1.00)	1.76	0.1	0.7	1
D13A	Lucerne	Low	Line Nr (9)*(1.00)	0.57	0.1	0.7	1
D13A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.57	0.1	0.7	1
D13A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.47	0.1	0.7	1
D13B	Kikuyu	Low	Line Nr (8)*(1.00)	1.98	0.1	0.7	1
D13B	Lucerne	Low	Line Nr (9)*(1.00)	0.65	0.1	0.7	1
D13B	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.65	0.1	0.7	1
D13B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.53	0.1	0.7	1
D13C	Kikuyu	Low	Line Nr (8)*(1.00)	3.05	0.1	0.7	1
D13C	Lucerne	Low	Line Nr (9)*(1.00)	1	0.1	0.7	1
D13C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1	0.1	0.7	1
D13C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.82	0.1	0.7	1
D13D	Kikuyu	Low	Line Nr (8)*(1.00)	2.48	0.1	0.7	1
D13D	Lucerne	Low	Line Nr (9)*(1.00)	0.81	0.1	0.7	1
D13D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.81	0.1	0.7	1
D13D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.67	0.1	0.7	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
D13E	Kikuyu	Low	Line Nr (8)*(1.00)	3.83	0.1	0.7	1
D13E	Lucerne	Low	Line Nr (9)*(1.00)	1.25	0.1	0.7	1
D13E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.25	0.1	0.7	1
D13E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.03	0.1	0.7	1
D13F	Kikuyu	Low	Line Nr (8)*(1.00)	3.96	0.1	0.7	1
D13F	Lucerne	Low	Line Nr (9)*(1.00)	1.3	0.1	0.7	1
D13F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.3	0.1	0.7	1
D13F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.07	0.1	0.7	1
D13G	Kikuyu	Low	Line Nr (8)*(1.00)	5.6	0.1	0.7	1
D13G	Lucerne	Low	Line Nr (9)*(1.00)	1.83	0.1	0.7	1
D13G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.83	0.1	0.7	1
D13G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.51	0.1	0.7	1
D13H	Kikuyu	Low	Line Nr (8)*(1.00)	6.59	0.1	0.7	1
D13H	Lucerne	Low	Line Nr (9)*(1.00)	2.15	0.1	0.7	1
D13H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.15	0.1	0.7	1
D13H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.77	0.1	0.7	1
D13J	Kikuyu	Low	Line Nr (8)*(1.00)	7.25	0.1	0.7	1
D13J	Lucerne	Low	Line Nr (9)*(1.00)	2.37	0.1	0.7	1
D13J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.37	0.1	0.7	1
D13J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.95	0.1	0.7	1
D13K	Kikuyu	Low	Line Nr (8)*(1.00)	1.92	0.1	0.7	1
D13K	Lucerne	Low	Line Nr (9)*(1.00)	0.63	0.1	0.7	1
D13K	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.63	0.1	0.7	1
D13K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.52	0.1	0.7	1
D13L	Kikuyu	Low	Line Nr (8)*(1.00)	3.85	0.1	0.7	1
D13L	Lucerne	Low	Line Nr (9)*(1.00)	1.26	0.1	0.7	1
D13L	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.26	0.1	0.7	1
D13L	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.04	0.1	0.7	1
D13M	Kikuyu	Low	Line Nr (8)*(1.00)	4.45	0.1	0.7	1
D13M	Lucerne	Low	Line Nr (9)*(1.00)	1.45	0.1	0.7	1
D13M	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.45	0.1	0.7	1
D13M	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.2	0.1	0.7	1
D14A	Kikuyu	Low	Line Nr (8)*(1.00)	5.94	0.1	0.7	1
D14A	Lucerne	Low	Line Nr (9)*(1.00)	1.87	0.1	0.7	1
D14A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.87	0.1	0.7	1
D14A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.55	0.1	0.7	1
D14B	Kikuyu	Low	Line Nr (8)*(1.00)	2.05	0.1	0.7	1
D14B	Lucerne	Low	Line Nr (9)*(1.00)	0.64	0.1	0.7	1
D14B	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.64	0.1	0.7	1
D14B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.53	0.1	0.7	1
D14C	Kikuyu	Low	Line Nr (8)*(1.00)	4.86	0.1	0.7	1
D14C	Lucerne	Low	Line Nr (9)*(1.00)	1.53	0.1	0.7	1
D14C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.53	0.1	0.7	1
D14C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.27	0.1	0.7	1
D14D	Kikuyu	Low	Line Nr (8)*(1.00)	3.75	0.1	0.7	1
D14D	Lucerne	Low	Line Nr (9)*(1.00)	1.18	0.1	0.7	1
D14D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.18	0.1	0.7	1
D14D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.98	0.1	0.7	1
D14E	Kikuyu	Low	Line Nr (8)*(1.00)	5.42	0.1	0.7	1
D14E	Lucerne	Low	Line Nr (9)*(1.00)	1.71	0.1	0.7	1
D14E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.71	0.1	0.7	1
D14E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.41	0.1	0.7	1
D14F	Kikuyu	Low	Line Nr (8)*(1.00)	4.62	0.1	0.7	1
D14F	Lucerne	Low	Line Nr (9)*(1.00)	1.46	0.1	0.7	1
D14F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.46	0.1	0.7	1
D14F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.2	0.1	0.7	1
D14G	Kikuyu	Low	Line Nr (8)*(1.00)	5	0.1	0.7	1
D14G	Lucerne	Low	Line Nr (9)*(1.00)	1.58	0.1	0.7	1
D14G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.58	0.1	0.7	1
D14G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.3	0.1	0.7	1
D14H	Kikuyu	Low	Line Nr (8)*(1.00)	5.72	0.1	0.7	1
D14H	Lucerne	Low	Line Nr (9)*(1.00)	1.8	0.1	0.7	1
D14H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.8	0.1	0.7	1
D14H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.49	0.1	0.7	1
D14J	Kikuyu	Low	Line Nr (8)*(1.00)	4.1	0.1	0.7	1
D14J	Lucerne	Low	Line Nr (9)*(1.00)	1.29	0.1	0.7	1
D14J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.29	0.1	0.7	1
D14J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.07	0.1	0.7	1
D14K	Kikuyu	Low	Line Nr (8)*(1.00)	5.1	0.1	0.7	1
D14K	Lucerne	Low	Line Nr (9)*(1.00)	1.61	0.1	0.7	1
D14K	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.61	0.1	0.7	1
D14K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	1.33	0.1	0.7	1
Total (Eastern Cape and FS)				**196.6**			
Gariep key area:							
D35A	Kikuyu	Low	Line Nr (8)*(1.00)	0.56	0	0.75	1
D35A	Lucerne	Low	Line Nr (9)*(1.00)	0.26	0	0.75	1
D35A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.85	0	0.75	1
D35A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.22	0	0.75	1
D35B	Kikuyu	Low	Line Nr (8)*(1.00)	1.11	0	0.75	1
D35B	Lucerne	Low	Line Nr (9)*(1.00)	0.52	0	0.75	1
D35B	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.69	0	0.75	1
D35B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.43	0	0.75	1
D35C	Kikuyu	Low	Line Nr (8)*(1.00)	2.25	0	0.75	1
D35C	Lucerne	Low	Line Nr (9)*(1.00)	1.05	0	0.75	1
D35C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.41	0	0.75	1
D35C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.88	0	0.75	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
D35D	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0	0.75	1
D35D	Lucerne	Low	Line Nr (9)*(1.00)	0.02	0	0.75	1
D35D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.06	0	0.75	1
D35D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.02	0	0.75	1
D35E	Kikuyu	Low	Line Nr (8)*(1.00)	0.16	0	0.75	1
D35E	Lucerne	Low	Line Nr (9)*(1.00)	0.08	0	0.75	1
D35E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.25	0	0.75	1
D35E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.06	0	0.75	1
D35F	Kikuyu	Low	Line Nr (8)*(1.00)	1.22	0	0.75	1
D35F	Lucerne	Low	Line Nr (9)*(1.00)	0.57	0	0.75	1
D35F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.86	0	0.75	1
D35F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.48	0	0.75	1
D35G	Kikuyu	Low	Line Nr (8)*(1.00)	0.12	0	0.75	1
D35G	Lucerne	Low	Line Nr (9)*(1.00)	0.06	0	0.75	1
D35G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.18	0	0.75	1
D35G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.05	0	0.75	1
D35H	Kikuyu	Low	Line Nr (8)*(1.00)	0.82	0	0.75	1
D35H	Lucerne	Low	Line Nr (9)*(1.00)	0.38	0	0.75	1
D35H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.25	0	0.75	1
D35H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.32	0	0.75	1
D35J	Kikuyu	Low	Line Nr (8)*(1.00)	0.27	0	0.75	1
D35J	Lucerne	Low	Line Nr (9)*(1.00)	0.13	0	0.75	1
D35J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.42	0	0.75	1
D35J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.11	0	0.75	1
D35K	Kikuyu	Low	Line Nr (8)*(1.00)	0.93	0	0.75	1
D35K	Lucerne	Low	Line Nr (9)*(1.00)	0.43	0	0.75	1
D35K	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.41	0	0.75	1
D35K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.36	0	0.75	1
Total (Eastern Cape and FS)				**25.3**			
Vanderkloof key area:							
D31A	Cotton	Low	Line Nr (45)*(1.00)	0.02	0	0.75	1
D31A	Grapes - table	High	Line Nr (2)*(1.00)	0.05	0	0.75	1
D31A	Kikuyu	Low	Line Nr (8)*(1.00)	0.16	0	0.75	1
D31A	Lucerne	Low	Line Nr (9)*(1.00)	0.39	0	0.75	1
D31A	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.01	0	0.75	1
D31A	Potato	Medium	Line Nr (37)*(1.00)	0.07	0	0.75	1
D31A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	4.76	0	0.75	1
D31A	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.16	0	0.75	1
D31A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	6.04	0	0.75	1
D31B	Cotton	Low	Line Nr (45)*(1.00)	0.01	0	0.75	1
D31B	Grapes - table	High	Line Nr (2)*(1.00)	0.03	0	0.75	1
D31B	Kikuyu	Low	Line Nr (8)*(1.00)	0.11	0	0.75	1
D31B	Lucerne	Low	Line Nr (9)*(1.00)	0.26	0	0.75	1
D31B	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.01	0	0.75	1
D31B	Potato	Medium	Line Nr (37)*(1.00)	0.05	0	0.75	1
D31B	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.12	0	0.75	1
D31B	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.1	0	0.75	1
D31B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	3.97	0	0.75	1
D31C	Cotton	Low	Line Nr (45)*(1.00)	0.01	0	0.75	1
D31C	Grapes - table	High	Line Nr (2)*(1.00)	0.02	0	0.75	1
D31C	Kikuyu	Low	Line Nr (8)*(1.00)	0.07	0	0.75	1
D31C	Lucerne	Low	Line Nr (9)*(1.00)	0.17	0	0.75	1
D31C	Potato	Medium	Line Nr (37)*(1.00)	0.03	0	0.75	1
D31C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.12	0	0.75	1
D31C	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.07	0	0.75	1
D31C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	2.7	0	0.75	1
D31D	Cotton	Low	Line Nr (45)*(1.00)	0.01	0.1	0.75	1
D31D	Grapes - table	High	Line Nr (2)*(1.00)	0.03	0.1	0.75	1
D31D	Kikuyu	Low	Line Nr (8)*(1.00)	0.11	0.1	0.75	1
D31D	Lucerne	Low	Line Nr (9)*(1.00)	0.26	0.1	0.75	1
D31D	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.01	0.1	0.75	1
D31D	Potato	Medium	Line Nr (37)*(1.00)	0.05	0.1	0.75	1
D31D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	3.19	0.1	0.75	1
D31D	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.1	0.1	0.75	1
D31D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	3.98	0.1	0.75	1
D31E	Cotton	Low	Line Nr (45)*(1.00)	0.05	0.1	0.75	1
D31E	Grapes - table	High	Line Nr (2)*(1.00)	0.14	0.1	0.75	1
D31E	Kikuyu	Low	Line Nr (8)*(1.00)	0.44	0.1	0.75	1
D31E	Lucerne	Low	Line Nr (9)*(1.00)	1.05	0.1	0.75	1
D31E	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.02	0.1	0.75	1
D31E	Potato	Medium	Line Nr (37)*(1.00)	0.19	0.1	0.75	1
D31E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	12.8	0.1	0.75	1
D31E	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.4	0.1	0.75	1
D31E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	16.28	0.1	0.75	1
D32C	Kikuyu	Low	Line Nr (8)*(1.00)	0.25	0	0.75	1
D32C	Lucerne	Low	Line Nr (9)*(1.00)	0.12	0	0.75	1
D32C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.39	0	0.75	1
D32C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.1	0	0.75	1
D32F	Kikuyu	Low	Line Nr (8)*(1.00)	0.18	0	0.75	1
D32F	Lucerne	Low	Line Nr (9)*(1.00)	0.08	0	0.75	1
D32F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.27	0	0.75	1
D32F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.07	0	0.75	1
D32G	Kikuyu	Low	Line Nr (8)*(1.00)	0.49	0	0.75	1
D32G	Lucerne	Low	Line Nr (9)*(1.00)	0.23	0	0.75	1
D32G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.74	0	0.75	1
D32G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.19	0	0.75	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
D32H	Kikuyu	Low	Line Nr (8)*(1.00)	0.62	0	0.75	1
D32H	Lucerne	Low	Line Nr (9)*(1.00)	0.29	0	0.75	1
D32H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.94	0	0.75	1
D32H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.24	0	0.75	1
D32J	Kikuyu	Low	Line Nr (8)*(1.00)	1.45	0	0.75	1
D32J	Lucerne	Low	Line Nr (9)*(1.00)	0.68	0	0.75	1
D32J	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.21	0	0.75	1
D32J	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.57	0	0.75	1
D32K	Kikuyu	Low	Line Nr (8)*(1.00)	1.09	0	0.75	1
D32K	Lucerne	Low	Line Nr (9)*(1.00)	0.51	0	0.75	1
D32K	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.65	0	0.75	1
D32K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.42	0	0.75	1
D34A	Kikuyu	Low	Line Nr (8)*(1.00)	1.4	0.1	0.75	1
D34A	Lucerne	Low	Line Nr (9)*(1.00)	0.65	0.1	0.75	1
D34A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.13	0.1	0.75	1
D34A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.55	0.1	0.75	1
D34B	Kikuyu	Low	Line Nr (8)*(1.00)	0.57	0.1	0.75	1
D34B	Lucerne	Low	Line Nr (9)*(1.00)	0.27	0.1	0.75	1
D34B	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	0.87	0.1	0.75	1
D34B	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.22	0.1	0.75	1
D34C	Kikuyu	Low	Line Nr (8)*(1.00)	0.84	0.1	0.75	1
D34C	Lucerne	Low	Line Nr (9)*(1.00)	0.4	0.1	0.75	1
D34C	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.28	0.1	0.75	1
D34C	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.33	0.1	0.75	1
D34D	Kikuyu	Low	Line Nr (8)*(1.00)	0.67	0.1	0.75	1
D34D	Lucerne	Low	Line Nr (9)*(1.00)	0.31	0.1	0.75	1
D34D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.02	0.1	0.75	1
D34D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.26	0.1	0.75	1
D34E	Kikuyu	Low	Line Nr (8)*(1.00)	0.87	0.1	0.75	1
D34E	Lucerne	Low	Line Nr (9)*(1.00)	0.41	0.1	0.75	1
D34E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.32	0.1	0.75	1
D34E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.34	0.1	0.75	1
D34F	Kikuyu	Low	Line Nr (8)*(1.00)	0.79	0.1	0.75	1
D34F	Lucerne	Low	Line Nr (9)*(1.00)	0.37	0.1	0.75	1
D34F	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	1.19	0.1	0.75	1
D34F	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.31	0.1	0.75	1
D34G	Kikuyu	Low	Line Nr (8)*(1.00)	1.78	0.1	0.75	1
D34G	Lucerne	Low	Line Nr (9)*(1.00)	0.83	0.1	0.75	1
D34G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	2.71	0.1	0.75	1
D34G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	0.7	0.1	0.75	1
Total (FS and NC)				**100.8**			
Orange d/s Welbedacht Dam key area:							
D33A	Cotton	Low	Line Nr (45)*(1.00)	0.08	0.15	0.75	1
D33A	Grapes - table	High	Line Nr (2)*(1.00)	0.25	0.15	0.75	1
D33A	Kikuyu	Low	Line Nr (8)*(1.00)	0.8	0.15	0.75	1
D33A	Lucerne	Low	Line Nr (9)*(1.00)	1.9	0.15	0.75	1
D33A	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.04	0.15	0.75	1
D33A	Potato	Medium	Line Nr (37)*(1.00)	0.34	0.15	0.75	1
D33A	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	23.19	0.15	0.75	1
D33A	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.72	0.15	0.75	1
D33A	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	29.5	0.15	0.75	1
D33D	Grapes - table	High	Line Nr (2)*(1.00)	0.02	0.1	0.8	1
D33D	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.8	1
D33D	Lucerne	Low	Line Nr (9)*(1.00)	1.01	0.1	0.8	1
D33D	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.05	0.1	0.8	1
D33D	Potato	Medium	Line Nr (37)*(1.00)	0.35	0.1	0.8	1
D33D	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	7.51	0.1	0.8	1
D33D	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.41	0.1	0.8	1
D33D	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	8.81	0.1	0.8	1
D33E	Grapes - table	High	Line Nr (2)*(1.00)	0.04	0.1	0.8	1
D33E	Kikuyu	Low	Line Nr (8)*(1.00)	0.04	0.1	0.8	1
D33E	Lucerne	Low	Line Nr (9)*(1.00)	1.62	0.1	0.8	1
D33E	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.08	0.1	0.8	1
D33E	Potato	Medium	Line Nr (37)*(1.00)	0.56	0.1	0.8	1
D33E	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	11.98	0.1	0.8	1
D33E	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.65	0.1	0.8	1
D33E	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	14.03	0.1	0.8	1
D33G	Grapes - table	High	Line Nr (2)*(1.00)	0.07	0.1	0.8	1
D33G	Kikuyu	Low	Line Nr (8)*(1.00)	0.08	0.1	0.8	1
D33G	Lucerne	Low	Line Nr (9)*(1.00)	3.07	0.1	0.8	1
D33G	Stone fruit - fresh (peaches, plums, apricots, etc.)	High	Line Nr (4)*(1.00)	0.15	0.1	0.8	1
D33G	Potato	Medium	Line Nr (37)*(1.00)	1.06	0.1	0.8	1
D33G	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	22.72	0.1	0.8	1
D33G	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	1.23	0.1	0.8	1
D33G	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	26.62	0.1	0.8	1
D33H	Grapes - table	High	Line Nr (2)*(1.00)	0.02	0.1	0.8	1
D33H	Kikuyu	Low	Line Nr (8)*(1.00)	0.42	0.1	0.8	1
D33H	Lucerne	Low	Line Nr (9)*(1.00)	2.25	0.1	0.8	1
D33H	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	22.43	0.1	0.8	1
D33H	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	29.67	0.1	0.8	1
D33K	Grapes - table	High	Line Nr (2)*(1.00)	0.32	0.1	0.8	1
D33K	Kikuyu	Low	Line Nr (8)*(1.00)	0.1	0.1	0.8	1
D33K	Lucerne	Low	Line Nr (9)*(1.00)	1.1	0.1	0.8	1
D33K	Summer staple crops (maize, groundnut, soya and other beans, etc.)	Low	Line Nr (32)*(1.00)	18.49	0.1	0.8	1
D33K	Vegetables -green bean, brassicas, cucurbits, pea, onion, tomato, lettuce, carrot, etc	Medium	Line Nr (55)*(1.00)	0.28	0.1	0.8	1
D33K	Winter staple crops (wheat, barley, etc.)	Low	Line Nr (34)*(1.00)	28.06	0.1	0.8	1

Quaternary catchment	Crop Irrigated	Economic value	SAPWAT crop factor	Harvested Area (km^2)	Conveyance loss factor (Refer to section 5.6.3)	Application efficiency	Leaching factor (Refer to section 5.6.4)
Total:				**262.2**			
Total irrigation in Upper Orange sub-area:				**612.7**			
Irrigation in Lesotho				**25.7**			
Irrigation in RSA				**587.0**			
Total irrigation in Upper Orange WMA:				**1156.1**			
Irrigation in Lesotho (all)				**38.7**			
Irrigation in RSA				**1117.4**			

APPENDIX D.2

URBAN AREAS

Urban areas in the Upper Orange WMA

Quaternary	Urban centre	Urban area	Runoff coefficient	Proportion of
		km^2	for paved areas	impervious area
Krugersdrift key area:				
C52B	Thaba Nchu & Botshabelo TLCs	21	0.84	0.125
C52F	Greater Bloemfontein TLC	200	0.84	0.125
C52G	Greater Bloemfontein TLC	76	0.84	0.125
Total:		297		
Riet / Modder key area:				
C52J	Bainesvlei / Bloemspruit TLCs	41	0.84	0.125
Total:		41		
Caledon key area:				
D22C	Ficksburg TLC	7.6	0.84	0.125
D22H	Maseru TLC	10.2	0.84	0.125
Total:		17.8		
Total urbanised area in WMA:		355.8		

Source of data:

1. Water Research Commission (1994) Surface Water Resources of South Africa : 1990;
   WRC Report No. 298/2.1/94, Volume II, Appendices, Appendix 5.4
   WRC Report No. 298/3.1/94, Volume II, Appendices, Appendix 5.4

APPENDIX E WATER RELATED INFRASTRUCTURE

Comprising:

Appendix E.1 Weir details

Appendix E.2 Reservoir details

Appendix E.3 Pumpstation details

Appendix E.4 Watewater treatment works details

Appendix E.5 Boreholes details

Appendix E.6 Pipelines details

Appendix E.7 Canal details

Appendix E.8 Tunnel details

APPENDIX E.1

WEIR DETAILS

Weir name	River name	Position of weir Latitude	Longitude	Full supply gross storage capacity (10^6 m^3)	Full supply surface area (km^2)
Hoopstad Weir		27°50'45"	25°54'32"		
Prince Willie		28°28'24"	26°41'09"		
Roodewal	Kraai	30°49'50"	26°55'17"		
Glen Weir	Modder	28°56'56"	26°19'18"		
Mazelspoort	Modder	29°02'	26°25'	0.783	0.10
Scholtzburg Weir	Modder				
Aliwal North	Orange	30°40'47"	26°42'45"		
Oranjedraai	Orange	30°20'10"	27°21'34"		
De Eerste Poort	Seekoei	30°32'03"	24°57'43"		
Diep Kloof	Strombergspruit	31°00'03"	26°21'11"		

APPENDIX E.2

RESERVOIR DETAILS

Name of reservoir	Storage capacity (Ml)	Name of reservoir	Storage capacity (Ml)
Bethulie (4)	1.50	Newbury	5.59
Bloemfontein (26)	428.98	Petrusberg (4)	0.46
Boesmankop		Philippolis (3)	2.20
Bosdenwekop	2.000	Reddersburg (5)	2.02
Brandfort (4)	6.90	Rosendal (3)	0.20
Brankop	0.136	Rouxville (2)	2.00
Clarens (2)	1.00	Serowalo	0.75
Clocolan (3)		Smithfield	4.64
De Brug		Soutpan	
De Hoek		Trompsburg (5)	1.64
Dealesville		Tweespruit (3)	
Dewetsdorp	1.50	Uitkyk	
Edenburg (2)	2.20	Van Wyksvlei?	143.08
Fauresmith (4)	0.45	Victoria West?	3.66
Ficksburg (2)	5.40	Wepener (2)	4.0
Fouriesburg (4)	0.80	Zastron (5)	3.5
Groenpoort	1.080		
Grootvlei			
Hamilton Park			
Hobhouse (4)			
Jacobsdal (5)	4.86		
Jagersfontein (4)	3.54		
JL de Bruin	2.15		
Knapsak	1.40		
Koffiefontein (3)	2.80		
Kriegerspoort	5.36		
La Riche	10.44		
Ladybrand (2)	8.40		
Langzeekoeigat	3.32		
Lovedale	2.74		
Luckoff (2)	1.16		

Note :

1. The bulk storage reservoirs listed in the table are mainly reinforced concrete.
2. The figure within the bracket indicates the amount of reservoirs existing in the particular town stated.
3. Source: Water Affairs document: 1st Order Strategy to Develop Community Water Supply & Sanitation.

APPENDIX E.3

PUMPSTATION DETAILS

Name of Pumpstation	Position	Raw or treated water	Peak rated design pumping capacity (m^3/s)	Static head (m)
Betulie (Bloem area)				
Clocolan (E Freestate area)				
Dewetsdorp (Bloem area)			0.08	unknown
Edenburg (Bloem area)				
Ficksburg (E Freestate area)				
Gariep Dam Treatment Works	30°37'30" 25°29'15"			
Highlift			1,68	unknown
Hobhouse (E Freestate area)				
Jacobsdal (Bloem area)	29°08'49" 24°44'05"			
Koffiefontein (Bloem area)				
Ladybrand (E Freestate area)				
Lesaka	Caledon – Bloemfontein pipeline	treated	0.58	unknown
Luckoff (Bloem area)				
Marksdrift	29°09'42" 23°41'47"	raw	6	unknown
Maselpoort	Maselpoort Weir			
Novo	Caledon / Modder divide	raw	10	unknown
Oppermans (Bloem area)				
Reddersburg (Bloem area)				
Rouxville (Bloem area)				
Scheiding	Vanderkloof Dam area	Raw	15	unknown
Smithfield (Bloem area)				
Tienfontein	Welbedacht Dam area	Raw	3	unknown
Trompsburg (Bloem area)				
Tweespruit (E Free state area)				
Vanstadensrus (Bloem area)				
Wepener (Bloem area)				

Name of Pumpstation	Position	Raw or treated water	Peak rated design pumping capacity (m^3/s)	Static head (m)
Zastron (Bloem area)				

APPENDIX E.4

WASTEWATER TREATMENT WORKS DETAILS

Name of Wastewater Treatment Works	Position	Peak rated design flow capacity (Ml/day)	Treatment process description	Effluent disposal process
Aliwal North STW			Biological filters	
Bainsvlei	W of Bloemfontein	5	Bio filters & Activated sludge	discharges into stormwater balancing dams draining the Modder River
Bloemfontein: Bloemspruit STW	29°07'24"S 26°16'51"E	57	Bio-filter & Activated sludge	discharges into the Bloemspruit
Bloemfontein: Suid-oostelike	On road to Dewetsdorp	30	Unknown	-
Bloemfontein Welvaart STW	W of Bloemfontein 29°13'11"S 26°07'21"E	6.5	Activated sludge & Bio filters	discharges into the Kaalspruit
Bloemfontein Langenhovenpark STW		5.0	Activated sludge & Bio filters	-
Bloemfontein Noordelike STW	N of Bloemfontein 29°02'43"S 26°12'13"E	0.75	Conventional	-
Bloemfontein Meriting STW		1.2	Oxidation ponds	-
Bloemfontein Bloemspruit Lugmagbasis STW	W of Bloemfontein	0.55	Conventional	-
Bothshabelo	Bothshabelo	20		discharges into the Klein Modder R.
Brandfort STW		-	Oxidation ponds	No returns
Clarens STW		3.6?	Unknown	Small returns to Klein Caledon R.
Clocolan STW		7.2	Oxidation ponds	No returns, used for irrigation.
Dealesville STW		0.7	Oxidation ponds	No returns
Soutpan STW		0.04	Oxidation ponds	No returns
Ikgomotseng STW		0.3	Oxidation ponds	No returns

Name of Wastewater Treatment Works	Position	Peak rated design flow capacity (Ml/day)	Treatment process description	Effluent disposal process
Dewetsdorp STW		?	Oxidation ponds	No returns
Edenberg STW		?	Oxidation ponds	Reed beds in spruit
Fauresmith STW		?	Oxidation ponds	No returns, used for irrigation.
Ficksburg STW		6.2	Activated sludge	Caledon River
Fouriesburg STW		?	Aerators + dams	No returns, used for irrigation.
Jacobsdal STW		?	Oxidation dams	Evaporation
Hobhouse STW		?	Oxidation dams	Evaporation
Jagersfontein STW		1.2 +	Oxidation dams	Some discharge, mainly evaporation
Koffiefontein STW	Koffiefontein	1.8	Heismann – Verticle	discharges into the Riet River
Ladybrand STW		?	?	Discharges into spruit.
Luckoff		0.44	Oxidation ponds	No returns
Maseru		10		discharges into Caledon R.
Oppermans STW		?	Oxidation ponds	No returrns
Philippolis STW		?	Oxidation ponds	No returrns
Reddersburg STW		0.47	Oxidation ponds	Some discharges into spruit.
Rosendal STW		?	Oxidation ponds	No returns
Rouxville STW		?	Oxidation ponds	No returns
Selosesha STW	Thaba Nchu	6	Activated sludge	discharge into the Sepanespruit
Smithfield STW		0.52	Oxidation ponds	Discharges to Groenspruit
Springfontein STW		?	Oxidation ponds	No returns
Sterkwater STW	SE of Bloemfontein	10	Bio filters & Activated sludge	discharges into the Renosterpruit
Thaba Patchoa STW		?	Oxidation ponds	Evaporation dams

Name of Wastewater Treatment Works	Position	Peak rated design flow capacity (Ml/day)	Treatment process description	Effluent disposal process
Tweespruit STW		?	Oxidation ponds	No returns, used for irrigation
Wepener STW		?	Oxidation ponds	No returns
Zastron STW			Conventional	Unknown.

Note: Source of data: Water Affairs document: 1st Order Strategy to Develop Community Water Supply & Sanitation.

APPENDIX E.5

BOREHOLES DETAILS

Name (no. of boreholes)	**Quaternary**	**Yield (m^3/day)**
Burgersdorp	D14E	
Dewetsdorp (7)	C52A	unknown
Edenburg (1)	C51C	0.1
Fauresmith (3)	C51J	unknown
Fouriesburg (5)	D21G	3499
Hanover	D32F	
Jacobsdal (2)	C51K	unknown
Jagersfontein (2)	C51H	unknown
Oppermans (5)	C51K	1500
Petrusburg (13)	C52K	1814
Philippolis (9)	D34G	unknown
Philipstown	D31B	
Reddersburg (2)	C51A	unknown
Rosendal (4)	D22A	150
Rouxville (2)	D24G	unknown
Smithfield (11)	C51L	2200
Springfontein (4)	D35F	340
Thaba Nchu (855)	**C52B**	**18135**
Thaba Patchoa (3)	D23D	unknown
Trompsburg (3)	C51G	unknown
Van Stadensrus (5)	D24C	636
Wepener (2)	D23G	unknown

Note: Source of data: Water Affairs document: 1st Order Strategy to Develop Community Water Supply & Sanitation.

APPENDIX E.6

PIPELINE DETAILS

Description of bulk supply pipelines	Flow direction	Peak rated design flow capacity (m^3/s)	Gravity or rising main	Diameter (mm)	Raw or treated
Caledon-Bloemfontein / Welbedacht pipeline	From Welbedacht Dam to Bloemfontein and other users	1.85 (120km)	Pumping (De Hoek) & Gravity (Brankop)	1220	Treated
Lesaka	From Caledon – Bloem pipeline to Thaba Nchu and Botshabelo	0.58 (20km)			Treated
Caledon-Modder (Novo)	From Knellpoort Dam to Bloemfontein	1.5 (initial)	Rising main: 13.8km Gravity line: 6.8km		Raw
Leeuwkop – Bloemfontein (mid 1999)	using existing Lesaka pipeline	1.08 (34km)			Treated
Caledon-Bloemfontein pipeline, Edenburg, Reddersburg pipeline	To the south	0.08		200 to 150	Treated
Gariep Dam pipeline	North to Springfontein, Bethulie and Trompsburg	?	Rising main: (Gariep Dam) Gravity main: (Springfontein)	250 to 150	Treated
Serfontein Bridge – Philippolis pipeline (operational in 1999)	Philippolis	?	Rising main (Orange River)		Raw

Note: Source of data : ORRS report and information from Bloemwater.

APPENDIX E.7

CANAL DETAILS

Name	**Peak rated design flow capacity (inlet, outlet) (m^3/s)**
Orange-Riet (Sarel Hayward) (112.6 km)	15,6 (74.6km) to 13,2 (38km)
Vanderkloof	57
Ramah Branch (87.4 km)	9,6 to 1,5
Orange – Vaal (Douglas Canal) (22 km)	**6** to 12 (max)
Kalkfontein Irrigation Canal	7,1

Note: Data from ORRS report: PD000/00/4897.

APPENDIX E.8

TUNNEL DETAILS

Name	Peak rated design flow capacity (inlet, outlet) (m^3/s)	Diameter and length (m) (km)
Orange-Fish Gariep Dam to Teebus Spruit in Fish River Basin	54.0	5.26 m and 82.8 km

APPENDIX F WATER REQUIREMENTS

Comprising:

APPENDIX F.1

ECOLOGICAL STATUS CLASS INDEX

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
C51A	FREE STATE	Fouriespruit	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C51B	FREE STATE	Riet	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C51C	FREE STATE	Riet	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C51D	FREE STATE	Riet	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C51E	FREE STATE	Riet	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C51F	FREE STATE	Riet	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C51G	FREE STATE	Riet	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C51H	FREE STATE	Riet	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C51J	FREE STATE	Riet (upstream portion of Kalkfontein dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C51K	FREE STATE	Riet	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C51L	FREE STATE	Riet	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
C51M	FREE STATE	Riet	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C52A	FREE STATE	Modder (upstream from Rusfontein dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C52B	FREE STATE	Modder	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
C52C	FREE STATE	Trib	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C52D	FREE STATE	Modder	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
C52E	FREE STATE	Modder (esentially dam area-mockes and Maselspoort)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS E - F: NOT AN ACCEPTABLE CLASS
C52F	FREE STATE	Renoster (upstream from Bloemspruit confluence and informal settlement)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C52G	FREE STATE	Modder (after confluence, before Krugerdrif dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
C52H	FREE STATE	Modder	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS D: LARGELY MODIFIED
C52J	FREE STATE	Modder trib.	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
C52K	FREE STATE	Modder	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS D: LARGELY MODIFIED
C52L	FREE STATE	Modder	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS D: LARGELY MODIFIED
D12A	FREE STATE	Orange	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D12B	FREE STATE	Orange TRIB (=D12D)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D12C	FREE STATE	Orange	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D12D	FREE STATE	Trib.	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D12E	FREE STATE	Orange	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D12F	FREE STATE	Orange	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D13A	EASTERN CAPE	Sterk	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D13B	EASTERN CAPE	Bell	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D13C	EASTERN CAPE	Rifle	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D13D	EASTERN CAPE	Langkloof	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D13E	EASTERN CAPE	Kraai (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D13F	EASTERN CAPE	Kraai (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D13G	EASTERN CAPE	Kraai (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D13H	EASTERN CAPE	Holspruit	LOW	CLASS D: LARGE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D13J	EASTERN CAPE	Holspruit	LOW	CLASS D: LARGE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D13K	EASTERN CAPE	Kraai (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D13L	EASTERN CAPE	Kraai (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D13M	EASTERN CAPE	Kraai (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D14A	FREE STATE	Orange	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
D14B	EASTERN CAPE	Stormbergspruit/Trib	LOW	CLASS D: LARGE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D14C	EASTERN CAPE	Stormbergspruit/Trib	LOW	CLASS D: LARGE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D14D	EASTERN CAPE	Stormbergspruit	LOW	CLASS D: LARGE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D14E	EASTERN CAPE	Stormbergspruit	LOW	CLASS D: LARGE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D14F	EASTERN CAPE	Lower Stormbergspruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D14G	EASTERN CAPE	Stormbergspruit - unamed trib (considered as part of main stem)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D14H	EASTERN CAPE	Lower Stormbergspruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D14J	EASTERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D14K	EASTERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D15G	FREE STATE	Trib. (Kornet)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D15H	FREE STATE	Trib. (Kornet)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D18K	FREE STATE	Trib. (Orange)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D18L	FREE STATE	Trib. (Senqu/Kornet?)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D21A	FREE STATE	Trib. (Caledon)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D21B	FREE STATE	Caledon (main stem) LESOTHO	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS E - F: > CLASS E NOT ATTAINABLE IN 5 YR - USE CLASS D AS DEFAULT
D21C	FREE STATE	Caledon (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D21D	FREE STATE	Trib. (Caledon)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D21E	FREE STATE	Trib. (Caledon) = D21D	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL
D21F	FREE STATE	?	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D21G	FREE STATE	Trib. (Caledon)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D21H	FREE STATE	Caledon (main stem)	HIGH	CLASS B: SMALL RISK	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
				ALLOWED		
D21L	FREE STATE	Caledon (main stem) (ACTUALLY IN LESOTHO)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D22A	FREE STATE		HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D22B	FREE STATE	Caledon (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D22C	FREE STATE	Caledon (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D22D	FREE STATE	Caledon (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D22F	FREE STATE	Caledon (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D22G	FREE STATE	Mopeli	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D22H	FREE STATE	Main stem Caledon	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
D22L	FREE STATE	Main stem Caledon	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
D23A	FREE STATE	Main stem Caledon	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
D23B	FREE STATE		MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D23C	FREE STATE	Caledon headwaters? (upstream from Armenia dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D23D	FREE STATE	Main stem Caledon??	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D23E	FREE STATE	Main stem Caledon	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
D23F	FREE STATE	Caledon trib?	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D23G	FREE STATE	Trib. (Caledon)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D23H	FREE STATE	Caledon (TRIB) (PESC = D24H)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D23J	FREE STATE	Caledon (main stem) (pesc=D23F)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D24A	FREE STATE	Caledon trib. (upstream from Egmont dam)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D24B	FREE STATE	Caledon (main stem)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D24C	FREE STATE	Caledon (main stem)	MODERATE	CLASS C: MODERATE	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
				RISK ALLOWED		
D24D	FREE STATE	Caledon (main stem)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D24E	FREE STATE	Caledon (main stem)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D24F	FREE STATE	Caledon (main stem)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D24G	FREE STATE	Caledon (main stem)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D24H	FREE STATE	Skulpspruit (trib Caledon)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D24J	FREE STATE	Caledon (main stem)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D24K	FREE STATE	Trib	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D24L	FREE STATE	Trib (Bossiesprui??)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D31A	NORTHERN CAPE	Trib of Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D31B	NORTHERN CAPE	Hondeblaf	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D31C	NORTHERN CAPE	Hondeblaf?	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D31D	NORTHERN CAPE	Trib of Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D31E	NORTHERN CAPE	Vanderkloof dam	INVALID ENTRIES	WRONG ENTRY	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS E - F: > CLASS E NOT ATTAINABLE IN 5 YR - USE CLASS D AS DEFAULT
D32A	NORTHERN CAPE	Noupoortsruit? (trib of Seekoei)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D32B	NORTHERN CAPE	Trib of Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D32C	NORTHERN CAPE	Trib of Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D32D	NORTHERN CAPE	Trib of Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS B: LARGELY NATURAL	CLASS B: LARGELY NATURAL
D32E	NORTHERN CAPE	Trib of Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D32F	NORTHERN CAPE	Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D32G	NORTHERN CAPE	Elandsfonteinspruit (trib of Seekoei)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
D32H	NORTHERN CAPE	Elands	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D32J	NORTHERN CAPE	Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D32K	NORTHERN CAPE	Seekoei	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS C: MODERATELY MODIFIED
D33A	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D33B	NORTHERN CAPE	Unanmed trib of Orange (probably highly seasonal)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS D: LARGELY MODIFIED
D33C	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D33D	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D33E	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D33F	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D33G	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D33H	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D33J	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D33K	NORTHERN CAPE	Orange (main stem)	HIGH	CLASS B: SMALL RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D34A	NORTHERN CAPE	Main stem Orange (in between Gariep and Vanderkloof)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D34B	NORTHERN CAPE	Oorlogspoorivier?	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D34C	NORTHERN CAPE	Oorlogspoort??	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D34D	NORTHERN CAPE	Oorlogspoort?	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D34E	NORTHERN CAPE	Main stem Orange (in between Gariep and Vanderkloof)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D34F	NORTHERN CAPE	Main stem Orange (in between Gariep and Vanderkloof)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D34G	NORTHERN CAPE	Main stem Orange (in between Gariep and Vanderkloof)	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS D: LARGELY MODIFIED	CLASS B: LARGELY NATURAL
D35A	FREE STATE	Trib draining into Gariep dam	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS B: LARGELY NATURAL

QUATERNARY	PROVINCE	RIVERS	EISC	DEMC	PESC	BEST AEMC
D35B	EASTERN CAPE	Oudagspruit	LOW	CLASS D: LARGE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D35C	EASTERN CAPE	Brookspruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D35D	EASTERN CAPE	Brookspruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D35E	EASTERN CAPE	Brookspruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D35F	FREE STATE	Trib draining into Gariep	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D35G	EASTERN CAPE	Brakspruit	LOW	CLASS D: LARGE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D35H	EASTERN CAPE	Gariep Dam	INVALID ENTRIES	WRONG ENTRY	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS E - F: > CLASS E NOT ATTAINABLE IN 5 YR - USE CLASS D AS DEFAULT
D35J	EASTERN CAPE	Suurbergspruit	MODERATE	CLASS C: MODERATE RISK ALLOWED	CLASS C: MODERATELY MODIFIED	CLASS C: MODERATELY MODIFIED
D35K	FREE STATE	Gariep Dam	INVALID ENTRIES	WRONG ENTRY	CLASS E - F: NOT AN ACCEPTABLE CLASS	CLASS E - F: > CLASS E NOT ATTAINABLE IN 5 YR - USE CLASS D AS DEFAULT

APPENDIX F.2

ECOLOGICAL FLOW REQUIREMENT

(This data is not readily available)

APPENDIX F.3

LIVESTOCK AND GAME DETAILS

Conversion of mature Livestock and Game Populations to Equivalent Large Stock Units (ELSU) (DWAF, Circular 14/98)

.

Livestock species:	Number per ELSU	Game species:	Number per ELSU
Cattle	0.85	Black Wildebeeste	3.3
Sheep	6.5	Blou Wildebeeste	2.4
Goats	5.8	Blesbuck	5.1
Horses	1	Buffalo	1
Donkeys / mules	1.1	Eland	1
Pigs	4	Elephant	0.3
		Gemsbok	2.2
		Giraffe	0.7
		Hippopotamus	0.4
		Impala	7
		Kudu	2.2
		Nyala	3.3
		Ostrich	2.7
		Red Hartebeest	2.8
		Roan Antelope	2
		Sable Antelope	2
		Southern Reedbuck	7.7
		Springbok	10.3
		Tsessebe	2.8
		Warthog	5
		Waterbuck	2.4
		Rhinoceros	0.4
		Zebra	1.6

Appendix F.3 LARGE STOCK UNITS		
Quaternary catchment	Equivalent Large stock units (ELSU)	Daily Water requirement (l/ELSU/d)
Upper Orange WMA:		
Modder / Riet sub-area		
Kalkfontein key area:		
C51A	13,213	45
C51B	23,913	45
C51C	8,577	45
C51D	18,881	45
C51E	13,255	45
C51F	8,709	45
C51G	23,141	45
C51H	17,405	45
C51J	8,974	45
Total:	**136,068**	
ELSU 1995 req. (million cubic meters/a):		**2.24**
Riet key area:		
C51K	43,283	45
Total:	**43,283**	45
ELSU 1995 req. (million cubic meters/a):		**0.71**
Riet / Vaal key area:		
C51L	19,381	45
C51M	17,195	45
C52H	66,907	45
C52J	31,183	45
C52K	85,559	45
C52L	37,369	45
Total:	**257,594**	
ELSU 1995 req. (million cubic meters/a):		**4.23**
Rustfontein key area:		
C52A	21,541	45
Total:	**21,541**	
ELSU 1995 req. (million cubic meters/a):		**0.35**
Krugersdrift key area:		
C52B	8,099	45
C52C	9,489	45
C52D	7,967	45
C52E	31,868	45
C52F	11,471	45
C52G	61,694	45
Total:	**130,588**	
ELSU 1995 req. (million cubic meters/a):		**2.15**
Total Modder / Riet sub-area:	**589,074**	
Total Free State	**552,498**	
Total Northern Cape	**36,576**	
Caledon sub-area:		
Caledon key area (SA)		
D21A	2,053	45
D21C	1,166	45
D21D	815	45
D21E	11,473	45
D21F	20,440	45
D21G	11,904	45
D21H	4,606	45

Appendix F.3 LARGE STOCK UNITS		
Quaternary catchment	**Equivalent Large stock units (ELSU)**	**Daily Water requirement (l/ELSU/d)**
D22A	16,963	45
D22B	16,823	45
D22C	2,963	45
D22D	16,701	45
D22G	31,473	45
D22H	7,217	45
D22L	6,547	45
Total:	**151,145**	
ELSU 1995 req. (million cubic meters/a):		**2.48**
Caledon key area (Lesotho)		
D21A	6,487	45
D21B	12,036	45
D21C	5,638	45
D21H	7,985	45
D21J	10,989	45
D21K	9,967	45
D21L	9,304	45
D22C	12,383	45
D22D	5,157	45
D22E	15,232	45
D22F	19,349	45
D22H	9,456	45
D22J	19,932	45
D22K	9,898	45
D22L	5,064	45
Total:	**158,876**	
ELSU 1995 req. (million cubic meters/a):		**2.61**
Welbedacht (SA):		
D23A	7,209	45
D23B	0	45
D23C	17,760	45
D23D	13,027	45
D23E	14,277	45
D23F	1,547	45
D23G	6,312	45
D23H	51,323	45
D23J	13,034	45
D24A	7,983	45
D24B	13,850	45
D24C	9,582	45
Total:	**155,904**	
ELSU 1995 req. (million cubic meters/a):		**2.56**
Welbedacht (Lesotho):		
D23A	11,495	45
D23B	18,255	45
D23E	9,197	45
D23F	8,813	45
D23G	7,726	45
D24A	445	45
Total:	**55,931**	45
ELSU 1995 req. (million cubic meters/a):		**0.92**
d/s Welbedacht:		
D24D	19,852	45
D24E	8,100	45

Appendix F.3 LARGE STOCK UNITS		
Quaternary catchment	**Equivalent Large stock units (ELSU)**	**Daily Water requirement (l/ELSU/d)**
D24F	12,637	45
D24G	13,825	45
D24H	11,606	45
D24J	18,989	45
D24K	7,811	45
D24L	5,875	45
Total:	**98,695**	
ELSU 1995 req. (million cubic meters/a):		**1.62**
Total Caledon:	**620,551**	
Total Caledon (SA):	**405,743**	**All Free State province**
Total Caledon (Lesotho):	**214,808**	
Upper Orange sub-area		
Katse key area:		
D11A	8,507	45
D11B	7,728	45
D11C	8,913	45
D11D	9,743	45
D11E	9,858	45
D11F	12,631	45
D11G	9,777	45
D11H	10,959	45
D11J	13,443	45
D11K	11,648	45
Total (Lesotho):	**103,207**	
ELSU 1995 req. (million cubic meters/a):		**1.70**
Senqu key area:		
D15A	13,361	45
D15B	12,028	45
D15C	8,437	45
D15D	13,362	45
D15E	18,923	45
D15F	10,778	45
D15G	14,713	45
D15H	10,728	45
D16A	4,859	45
D16B	7,581	45
D16C	13,370	45
D16D	10,323	45
D16E	13,243	45
D16F	8,433	45
D16G	8,824	45
D16H	10,527	45
D16J	11,407	45
D16K	9,999	45
D16L	16,292	45
D16M	23,023	45
D17A	19,513	45
D17B	13,510	45
D17C	16,045	45
D17D	22,877	45
D17E	18,495	45
D17F	17,799	45
D17G	25,943	45
D17H	26,027	45
D17J	13,329	45

Appendix F.3 LARGE STOCK UNITS		
Quaternary catchment	**Equivalent Large stock units (ELSU)**	**Daily Water requirement (l/ELSU/d)**
D17K	11,657	45
D17L	17,969	45
D17M	16,154	45
D18A	18,517	45
D18B	10,007	45
D18C	14,386	45
D18D	23,675	45
D18E	11,423	45
D18F	13,778	45
D18G	15,017	45
D18H	11,857	45
D18J	26,538	45
D18K	10,195	45
D18L	14,156	45
Total (Lesotho / RSA):	**629,078**	
ELSU 1995 req. (million cubic meters/a):		**10.34**
Total (Lesotho):	**617,501**	
Total (RSA) (Eastern Cape):	**11,577**	
Orange u/s Gariep Dam		
D12A	5,914	45
D12B	79	45
D12C	2,252	45
D12D	10,484	45
D12E	15,203	45
D12F	19,610	45
D13A	9,700	45
D13B	10,895	45
D13C	18,224	45
D13D	13,792	45
D13E	21,147	45
D13F	22,415	45
D13G	32,328	45
D13H	36,472	45
D13J	32,718	45
D13K	11,516	45
D13L	17,707	45
D13M	15,050	45
D14A	17,114	45
D14B	9,680	45
D14C	19,925	45
D14D	18,384	45
D14E	11,371	45
D14F	9,126	45
D14G	10,595	45
D14H	12,318	45
D14J	9,290	45
D14K	9,982	45
Total:	**423,291**	
ELSU 1995 req. (million cubic meters/a):		**6.96**
Gariep key area:		
D35A	2,658	45
D35B	3,976	45
D35C	12,504	45
D35D	6,156	45
D35E	2,935	45
D35F	5,859	45

Appendix F.3 LARGE STOCK UNITS		
Quaternary catchment	**Equivalent Large stock units (ELSU)**	**Daily Water requirement (l/ELSU/d)**
D35G	5,139	45
D35H	5,112	45
D35J	9,794	45
D35K	6,674	45
Total:	**60,807**	
ELSU 1995 req. (million cubic meters/a):		**1.00**
Vanderkloof key area:		
D31A	12,982	45
D31B	8,235	45
D31C	5,623	45
D31D	8,935	45
D31E	9,798	45
D32A	3,660	45
D32B	9	45
D32C	5,391	45
D32D	3,944	45
D32E	6,494	45
D32F	9,102	45
D32G	8,417	45
D32H	5,558	45
D32J	10,590	45
D32K	7,866	45
D34A	9,035	45
D34B	6,204	45
D34C	7,455	45
D34D	5,874	45
D34E	5,795	45
D34F	6,803	45
D34G	11,056	45
Total:	**158,826**	
ELSU 1995 req. (million cubic meters/a):		**2.61**
d/s Vanderkloof key area:		
D33A	4,856	45
D33B	8,446	45
D33C	6,239	45
D33D	9,483	45
D33E	3,578	45
D33F	10,082	45
D33G	13,037	45
D33H	4,679	45
D33J	10,986	45
D33K	3,657	45
Total:	**75,043**	
ELSU 1995 req. (million cubic meters/a):		**1.23**
Total ELSUs - Upper Orange sub-area:	**1,450,252**	
Total ELSUs (Lesotho):	**720,708**	
Total ELSUs (RSA):	**729,544**	
Total ELSUs - Free State Province	**1,083,536**	
Total ELSUs - Eastern Cape Province	**432,146**	
Total ELSUs - Northern Cape Province	**208,679**	
Total ELSUs - Lesotho	**935,516**	
Total ELSUs - Upper Orange WMA:	**2,659,877**	
Total ELSU Requirement - Upper Orange WMA:		**43.72**

LIVESTOCK AND GAME DATA FOR MAGISTERIAL DISTRICTS IN THE UPPER VAAL WMA

(Figures from 1990 Food Survey Report by Department of Agric (Glen) & CSS survey of 1988 (where necessary)

PROVINCE	DISTRICT	(DOA) CATTLE	(DOA) SHEEP	(DOA) GOATS	(CSS) GOATS	(CSS) PIGS	(DOA) Horses, mules & donkeys	(CSS) HORSES	(CSS) MULES/ DONKEYS	(Unadjusted) LIVESTOCK	(DOA) Gemsbok	(DOA) Kudu	(DOA) Spring-buck	(DOA) Bles-buck	(DOA) Black Wildebeeste	(DOA) Blue Wildebeeste	(DOA) Eland	(DOA) Impala	(DOA) Waterbuck	(DOA) Zebra	(DOA) Hartebees	(unadjusted) GAME
FREE STATE	**Bethlehem***	73695	118398	746	**2245**	249	0	**674**	**242**	**195503**				12	4							**16**
FREE STATE	**Frankfort**	98920	319794	0	**3025**	0	0	**517**	**26**	**422282**												**0**
FREE STATE	**Harrismith**	216440	424772	**3669**	2444	0	**4540**	1073	112	**649421**			78	194		25	4	115	4	4		**424**
FREE STATE	**Heilbron***	165886	232972	0	0	427	0	**357**	**29**	**399671**												**0**
FREE STATE	**Parys**	21954	32389	0	**223**	142	**258**	49	0	**54966**												**0**
FREE STATE	**Reitz**	79233	168540	**754**	533	498	**1150**	323	18	**250175**												**0**
FREE STATE	**Sasolburg**	31073	40036	0	0	6394	0	**75**	**0**	**77578**												**0**
FREE STATE	**Vrede**	59976	208095	0	**3781**	683	0	**1428**	**81**	**274044**				700								**700**
FREE STATE	**Vredefort***	31512	45125	**2598**	430	150	0	**41**	**0**	**79426**												**0**
GAUTENG	**Alberton**	0	0	0	0	0	0	0	0	**0**												**0**
GAUTENG	**Benoni***	0	0	0	0	0	0	**10**	**0**	**10**												**0**
GAUTENG	**Boksburg**	0	0	0	0	0	0	**78**	**0**	**78**												**0**
GAUTENG	**Brakpan***	0	0	0	0	0	0	0	0	**0**												**0**
GAUTENG	**Germiston**	0	0	0	0	0	0	0	0	**0**												**0**
GAUTENG	**Heidelberg**	28000	17731	**959**	0	11701	25	**169**	**0**	**58560**												**0**
GAUTENG	**Johannesburg***	28105	8074	0	0	0	0	**44**	**0**	**36223**												**0**
GAUTENG	**Nigel**	19635	23259	**230**	0	2987	**154**	97	0	**43144**												**0**
GAUTENG	**Oberholzer***	12520	3630	**150**	0	0	**100**	24	0	**16400**												**0**
GAUTENG	**Randfontein***	0	0	0	0	0	0	**58**	**0**	**58**												**0**
GAUTENG	**Roodepoort***	0	0	0	0	5696	0	0	0	**5696**												**0**
GAUTENG	**Springs**	0	0	0	0	0	0	0	0	**0**												**0**
GAUTENG	**Vanderbijlpark**	19225	20390	**840**	0	4593	**530**	38	0	**45578**				250								**250**
GAUTENG	**Westonaria**	7378	7070	**494**	0	0	**253**	0	0	**15195**												**0**
MPUMALANGA	**Amersfoort**	35232	231736	**2813**	0	247	**1583**	377	31	**271611**												**0**
MPUMALANGA	**Balfour**	0	0	0	0	652	0	**332**	**35**	**1019**												**0**
MPUMALANGA	**Bethal**	117670	383670	**9450**	5196	3070	0	**389**	**16**	**514265**				1000								**1000**
MPUMALANGA	**Delmas***	3800	3454	0	0	1258	**100**	59	0	**8612**												**0**
MPUMALANGA	**Ermelo***	121500	496500	0	384	1453	0	**1229**	**134**	**621066**				2140	105							**2245**
MPUMALANGA	**Highveld Ridge***	20000	80000	0	0	517	0	**99**	**13**	**100629**												**0**
MPUMALANGA	**Standerton**	133000	219100	0	0	2596	279	**570**	**68**	**355334**												**0**
MPUMALANGA	**Volksrust***	43545	146768	0	**5196**	434	0	**552**	**105**	**196600**												**0**
NORTH WEST	**Potchefstroom**	89963	61970	**2900**	1929	32346	**19460**	238	16	**206639**				1000								**1000**
	TOTAL	**1458262**	**3293473**	**25603**	**25386**	**76093**	**28432**	**8900**	**926**	**4899783**	**0**	**0**	**78**	**5296**	**109**	**25**	**4**	**115**	**4**	**4**	**0**	**5635**

APPENDIX F.4

TRANSFER DETAILS

Inter-Basin Transfers

From quat	To quat	From sector	To sector	Description of transfer	From DWAF Maximum Capacity (Million cubic metres per annum)	SS-data 1995 (Million cubic metres per annum)
Transfers into WMA:						
C41G	C52G	SRD	SSU	Brandfort TLC supply: From Erfenis Dam [Vet river GWS]	2.3	2.3
Total imports:					**2.3**	**2.3**
Exports out of WMA:						
D35K	Q12B	SRD	SRD	Orange - Fish Transfer scheme: From Gariep Dam via Orange Fish Tunnel to Thebusspruit	550.0	550
D33K	C92B	SRD	SRD	Orange - Vaal transfer scheme: From Marksdrift [$6m^3/s$] for irrigation [Orange-Vaal IB] in the Douglas area. Max capacity of transfer to $12m^3/s$.	18.9	18.9
Total exports:					**568.9**	**568.9**
Within Basin transfers						
Transfers within Modder / Riet sub-catchment:						
C52A	C52B	SRD	SSU	Bloemwater transfer: Rustfontein Dam to Botshabelo & Thaba'Nchu TLCs	11.6	11.6
C52E	C52F	SRD	SSU	Greater Bloemfontein supply: From Mockes Dam via Maselpoort weir and WTW.	12.0	12.0
C52H	C52F	URF	SRD	Bainesvlei & Bloemspruit TLCs: Export of effluent to Bloemspruit via Bloemspruit STW.	1.6	1.6
Total					**13.6**	**25.2**
Transfer from Caledon River to Modder / Riet sub-catchment						
D23H	C52F	SRD	SSU	Bloem Water transfer: Welbedacht Dam and Knelpoort to Greater Bloemfontein	60.00	33.60
D23J	C52F	SRD	SSO	Bloem Water transfer: From Welbedacht Dam via Bloemfontein - Caledon pipeline to small users.	1.93	1.93
D23J	C52A	SRD	SSU	Bloemwater transfer: From Welbedacht Dam to Dewetsdorp TLC via Bloemfontein - Caledon pipeline	0.05	0.05
D23J	C51C	SRD	SSU	Bloemwater transfer: From Welbedacht Dam to Edenburg TLC via Bloemfontein - Caledon pipeline	0.30	0.30
D23J	C51A	SRD	SSU	Bloemwater transfer: From Welbedacht Dam to Reddersburg TLC via Bloemfontein - Caledon pipeline	0.15	0.15
D23J	C52H	SRD	SSU	Bloemwater transfer: From Welbedacht Dam to Bloemspruit and Bainesvlei TLCs via Bloemfontein - Caledon pipeline	3.79	3.79
Total transfers					**66.22**	**39.82**
Transfers within Caledon catchment:						
D23J	D23G	SRD	SSU	Bloemwater transfer: From Welbedacht Dam to Wepener TLC	0.5	0.5
D23J	D23H	SRD	SRD	Tienfontein transfer: From Caledon River [upstream Welbedacht Dam+E3] to augment Knellpoort Dam ($3m^3$/sec).	30.0	94.7
Total transfers					**30.5**	**95.2**
Vanderkloof Dam transfers:						
D31E	D33C	SRD	SSU	Orange - Riet transfer: From Vanderkloof Dam to Luckhoff TLC [abstracts from Sarel Haywood canal].	0.2	0.2
D31E	C51K	SRD	SRD	Orange - Riet transfer: From Vanderkloof Dam via Sarel Haywood canal to Riet / Modder rivers & Riet River GWS, Scholtzburg IA & RitchieIB. Average transfer for 1993 to 1999.	190.0	70.7
Total transfers					**190.2**	**70.9**
Gariep Dam transfers:						
D35K	D35F	SRD	SSU	Bloemwater transfer: From Gariep Dam to Springfontein TLC.	0.3	0.3
D35K	D35H	SRD	SSU	Bloemwater transfer: From Gariep Dam via Springfontein to Bethulie TLC.	0.5	0.5
D35K	C51G	SRD	SSU	Bloemwater transfer: From Gariep Dam via Springfontein to Trompsburg TLC.	0.2	0.2
D35K	D35G	SRD	SSU	Gariep Dam to Venterstad TLC	0.2	0.2
Total transfers					**1.2**	**1.2**

Note : From DWAF, Upper Orange Tables.xls

APPENDIX F.5

STRATEGIC BULK USER AND OTHER BULK USER DETAILS

1995 Strategic bulk user details.

Strategic bulk user	Location	Main activity	Source of water	On-site requirement ($10^6m^3/a$)	Returns flow	River
Gariep Hydro Electric Power Station	Gariep Dam Wall	Power generation	Gariep Dam	2635	90 %	Orange d/s of dam.
Vanderkloof Hydroelectric Power Station	Vanderkloof Dam Wall	Power generation	Vanderkloof Dam	2355	90 %	Orange d/s of dam.
Muela Hydroelectric Power Station (Lesotho)*	Muela Reservoir	Power generation	Katse Dam	538	90 %	Caledon River ?

Note: * Not operational in 1995.

1995 Other bulk user details.

Bulk user	Main activity	Source of water	Bulk requirement (10^6m^3)	River returned to
Bloem Water Small consumers: UFS research farm, Grootvlei Farms, De Brug etc.	Insitutional , rural & agricultural	Caledon River, Welbedacht Dam	1.6	No known returns

APPENDIX F.6

MINE DETAILS

1995 Mining water requirements.

There are no direct mining water requirements in this WMA. The most significant mine is Debeers Koffiefontein (receives water from Koffiefontein TLC).

APPENDIX F.7

POWER STATIONS DETAILS

Hydroelectric power stations in the Upper Orange WMA

Description	Gariep	Vanderkloof	Muela (Lesotho)*
Quaternary	D35K	D31E	
Location: Latitude Longitude	25º30’26” S 30º37’23” E	24º44’55” S 29º59’29” E	28º46’00” S 28º27’00” E
Rated capacity	360 MW	240 MW	
Peak capacity (generator limitation)	385 MW	255 MW	96
Rated head	52 m	59 m	237
Design head	55 m	61 m	
Maximum discharge capacity	660 m^3/s	360 m^3/s	
Load factor	Normally 10%	Normally 10%	47.39
Average flow through turbines	4100 x 10^6 m^3/a	3470 x 10^6 m^3/a	
Water requirements	2640 x 10^6 m^3/a	2355 x 10^6 m^3/a	538 x 10^6 m^3/a
Proportion not available for downstream IFR or users.	10 %	10 %	?

Note: * Not operational in 1995.

Power stations (coal) operated by local councils

There are none in this WMA.

APPENDIX F.8

URBAN USER DETAILS AND TRENDS

(Trend analysis)
(Per capita usage per residential category for urban areas)
(Consumption factors for urban areas)

TRENDS IN WATER USE IN THE UPPER ORANGE

It is essential to examine trends in the various water use sectors. This is particularly important to the urban water use sector as this sector has been most dynamic in recent years. Table F.8.1 indicates historic trends in water allocation amongst the various water use sectors.

TABLE F.8.1: HISTORIC TREND AND MOST RECENT PERCENTAGE DISTRIBUTION OF WATER AMONGST THE FOREMOST WATER USE SECTORS

Year	Ecology and forestry	Agriculture	Urban sector	Remarks
1975	-	75	25	Ecology sector not recognised yet
1985	10	65	25	
1995	20	50	30	

NB: Urban sector represents the residential, public, commercial, industrial and mining categories.

The actual contributions from the data capture process on the water use of numerous TLCs in the study area enabled only limited analysis of specific variables. The variables well surveyed, which indicate certain trends, are as follows:

- type and size of dwelling and land size/income structure
- composition of area serviced
- water supply standards
- water losses

Residential land and residential house sizes are declining as illustrated in Table F.8.2, subsequently the domestic water use for indoor and outdoor purposes is also declining.

TABLE F.8.2: TRENDS IN URBAN RESIDENTIAL HOUSE AND LAND SIZES

Year	Residential land (m^2)	Residential house size (m^2)	Remarks
1980	1275	190	House with water and sewer connection
1985	1050	150	do. Do
1990	950	175	do. Do
1995	900 (estimate)	150 (estimate)	Housing developed under RDP criteria

NOTE: Source of info: Housing Trust (1993)

The large water services providers are currently using the following unit water use values in the development of water services infrastructure as shown in the following Table F.8.3.

TABLE F.8.3: DESIGN UNIT WATER VALUES USED FOR THE INFRASTRUCTURE DEVELOPMENT

User's income level	Unit range (kℓ/stand/day)	Unit range (kℓ/hectare/day)	Average values from DMS survey (kℓ/unit/day)
Upper income	1.150 – 2.150	-	1.55 (erf >500m^2)
Middle income	0.650 – 1.150	-	0.75 (erf >500m^2)
Low income	0.400 – 0.600	-	1.25 (high density)
Wet Industries		40 – 65	
Dry industries		30 – 40	19.0 (light industry)

Source of info: TLC guidelines for development of municipal infrastructure.

From the survey carried out on major TLC's situated in the study area, it has been determined that there are seven distinct water services categories to be dealt with. Table F.8.4 illustrates 1995 distribution patterns according to seven water services categories.

TABLE F.8.4: TYPICAL WATER SERVICES SITUATION IN THE STUDY AREA IN 1995

Categories of domestic usage	Dwelling and water supply category	Type of sanitation services	Percentage breakdown (%)
1,2,3,4	In-house connection	Full water and waterborne sewerage	27
5	Yard taps (metered and unmetered) Communal standpipes	water connection only	31
6	Backyard shacks	No water connection, communal tap	16
7	Informal/inadequate	None	26

The current management functions of the TLCs and MTCs are stated in the general Proclamation No. 35, 1995 under Section 8(20) read with Section 10(1) of the Local Government Transition Act, 1993 (Act No. 209 of 1993). This Act determines bulk supply of water as one of the powers and duties of the town and metropolitan councils.

The water and sanitation departments of each council are to provide a continuous and reliable supply of bulk water of specified quality for distribution in order to meet the needs of communities.

Summary on urban water use trends

These trends are of lesser significance in the Upper Orange, which is less developed and less relaint on transfers than the Upper Vaal WMA.

The growth for urban water supplies in the provinces increased between 1985 and 1995 about one and half times as shown in Table F.8.5. However, the general short-term trend experienced in very recent years, indicate very low or negative growth for water in some locations. Table F.8.5 gives the trends of source of water supply over a10 year period from 1985 to 1995.

TABLE F.8.5: TRENDS IN WATER SUPPLIES FROM VARIOUS SOURCES IN 1995

Source of water	Water supplies (10^6m^3/annum) 1985	Water supplies (10^6m^3/annum) 1995	Increase over 10 years (%)	Remarks
Local surface and Groundwater	28.6	44.0	154	
Bulk external supply	44.8	63.8	142	
Bulk and local water sources	4.9	7.8	159	RDP systems
Total for all supplies	78.3	115.6	148	

Note : Source of info – Barta, 1999.

The typical characteristics of urban/peri-urban water services situation in this WMA is related to an absence of strong rural water use component in comparison to other WMA's. Rural water services information in this WMA is not readily available.

A significant water services development in this WMA is taking place primarily in the former constituent townships. These townships are now integrated under TLCs and MTCs jurisdiction.

The constraints influencing this WMA's urban/metropolitan water services trends are primarily of the natural, socio-economic and institutional nature. The technical and to some extent environmental restraints also play an important but somewhat secondary role. The water services development and management in this WMA is subjected primarily to the constraints as follows:

- stochastic distribution of precipitation,

- evaporation exceeding precipitation due to highly variable temperature
- patterns (i.e. peak demand variability in water supply)
- high population growth rate (some 2,4% p.a.) and unabated population influx of rural population,
- competition for financial resources between established and growing new communities,
- culture of non-payment for services rendering to a slow-down in maintenance and expansion of existing water services infrastructure,
- direct and indirect subsidisation of least contributing communities,
- ongoing restructuring of local government management structures causing serious discontinuity in development of needed services,
- a pure monopoly of potable water supply of a single water services provider taking over of the entire market demand,
- a fragmentation in management of metropolitan water supply and wastewater
- reclamation causing a lack of interest in a conjunctive management actions,
- a crisis management approach to water services development in an absence of an overall metropolitan master plan,
- a huge demand for electrical energy due to large volumes of water pumped over long distances and excessive pumping heads,
- inadequate methods used in determining of metropolitan demand for water and capacity expansion and timing,
- the demand management principles overlooked in sizing of new capacity,
- inconsistent technology transfer by the metropolitan authorities,
- non-methodological financial management by the metropolitan stakeholders in absence of asset management practices,
- unattended urban hydrology problems with regard to contaminated urban runoff and excessive pumpage of mineralised mining waters.

Most of the above listed constraints contribute directly or indirectly to the present trends in management and development of water services in this WMA. It is anticipated that by means of new water legislation on the background of a wider Local Government Transition Act specifying implementation of the Integrated Development Planning (IDP) principles, many above-mentioned constraints will eventually be eliminated.

APPENDIX F.9

ASSURANCE OF SUPPLY TO USERS IN WMA

(Data on assurance supplied by DWAF and used in WSAM
to determine 1:50 yr assurance quantities)

UPPER ORANGE WMA									
			Per capita consumption per residential category						
Quaternary	Transitional Council	Cat1_SS	Cat2_SS	Cat3_SS	Cat4_SS	Cat5_SS	Cat6_SS	Cat7_SS	Direct : Indirect
Kalkfontein key area:									
C51A	REDDERSBURG	150	150	75	42	5	3	42	72 % : 28 %
C51C	EDENBURG	320	320	160	90	10	6	90	72 % : 28 %
C51G	TROMPSBURG / MADIKGETLA	212	212	106	60	7	4	60	72 % : 28 %
C51H	JAGERSFONTEIN / ITUMELENG	514	514	257	145	16	10	145	72 % : 28 %
C51J	FAURESMITH / IPOPENG	320	320	160	90	10	6	90	72 % : 28 %
		303.2	303.2	151.6	85.4	9.6	5.8	85.4	
Riet key area:									
C51K	KOFFIEFONTEIN / DITLHAKE / OPPERMANSGRONDE	439	439	219	124	13	9	124	54 % : 46%
C51K	JACOBSDAL / RATANANG	320	320	160	90	10	6	90	72 % : 28 %
		379.5	379.5	189.5	107	11.5	7.5	107	
Riet/ Modder key area:									
C51L	RITCHIE / MOTSWEDIMOSA	301	301	150	85	9	6	85	72 % : 28 %
Rustfontein key area:									
C52A	DEWETSDORP / MOROJANENG	179	179	89	50	6	3	50	72 % : 28 %
Krugersdrift key area:									
C52B	BOTSHABELO	342	342	171	96	11	6	96	68 % : 32%
C52B	THABA'NCHU	309	309	155	87	10	6	87	68 % : 32%
C52F	BLOEMFONTEIN / MANGAUNG	324	324	161	92	9	6	92	62 % : 38%
C52G	BRANDFORT / MAJWEMASWEU	1044	1044	522	294	33	20	294	72 % : 28 %
C52H	BLOEMSPRUIT	320	320	160	90	10	6	90	72 % : 28 %
C52H	BAINSVLEI	320	320	160	90	10	6	90	72 % : 28 %
C52H	DEALESVILLE / TSWARAGANANG	320	320	160	90	10	6	90	72 % : 28 %
C52H	SOUTPAN / IKGOMOTSENG	320	320	160	90	10	6	90	72 % : 28 %
C52K	PETRUSBURG / BOLOKANANG	275	275	138	77	9	5	77	72 % : 28 %
		397.1	397.1	198.6	111.8	12.4	7.4	111.8	
Orange u/s Gariep Dam:									
D12C	GREATER HERSHEL	320	320	160	90	10	6	90	72 % : 28 %
D12D	ZASTRON / MATLAKENG	279	279	139	78	9	5	78	72 % : 28 %
D12E	LADY GREY / KHWEZINALEDI	471	471	235	132	15	9	132	72 % : 28 %
D13B	RHODES / ZAKHELE	203	203	101	57	6	4	57	72 % : 28 %
D13D	BARKLY-EAST / NKULULEKO	332	332	166	93	10	6	93	72 % : 28 %
D13H	DORDRECHT / SINAKHO	131	131	65	37	4	2	37	72 % : 28 %
D13J	JAMESTOWN / MASAKHANE	296	296	148	83	9	6	83	72 % : 28 %
D14A	ALIWAL-NORTH / DUKATHOLE	384	384	192	108	12	7	108	58 % : 42%
D14C	MOLTENO / NOMONDE	217	217	108	61	7	4	61	72 % : 28 %
D14E	BURGERSDORP / MZAMOMHLE	302	302	151	85	9	6	85	72 % : 28 %
		293.5	293.5	146.5	82.4	9.1	5.5	82.4	
Senqu key area:									
D15G	MOHALES HOEK (Lesotho)	320	320	160	27	10	6	90	100 % : 0 %
D18J	MOYENI (Lesotho)	320	320	160	61	10	6	90	100 % : 0 %
		320	320	160	44	10	6	90	

UPPER ORANGE WMA									
			Per capita consumption per residential category						
Quaternary	Transitional Council	Cat1_SS	Cat2_SS	Cat3_SS	Cat4_SS	Cat5_SS	Cat6_SS	Cat7_SS	Direct : Indirect
Caledon (RSA) key area:									
D21D	CLARENS / KGUBETSWANA	320	320	160	90	10	6	90	72 % : 28 %
D21G	FOURIESBURG / MASJAING	320	320	160	90	10	6	90	72 % : 28 %
D22A	ROSENDAL / MAUTSE	279	279	139	78	9	5	78	72 % : 28 %
D22C	FICKSBURG / MEQHELENG	406	406	203	114	12	6	114	88 % : 12 %
D22G	CLOCOLAN / HLOHLOLWANE	320	320	160	90	10	6	90	72 % : 28 %
D22H	LADYBRAND / MANYATSENG	177	177	89	50	6	3	50	72 % : 28 %
		303.7	303.7	151.8	85.3	9.5	5.3	85.3	
Caledon (Lesotho) key area:									
D21H	BUTHA BUTHU	320	320	160	39	10	6	90	100 % : 0 %
D22C	LERIBE	320	320	160	70	10	6	90	100 % : 0 %
D22H	MASERU	320	320	160	70	10	6	90	100 % : 0 %
		320	320	160	59.6666667	10	6	90	
Welbedacht (RSA) key area:									
D23C	TWEESPRUIT / BORWA	320	320	160	90	10	6	90	72 % : 28 %
D23D	THABA PATCHOA	320	320	160	90	10	6	90	72 % : 28 %
D23E	HOBHOUSE / DIPELANENG	1193	1193	597	336	37	22	336	72 % : 28 %
D23G	WEPENER / THAPELANG / QIBING	368	368	184	104	12	7	104	72 % : 28 %
D24C	VANSTADENSRUS	320	320	160	90	10	6	90	72 % : 28 %
		504.2	504.2	252.2	142	15.8	9.4	142	
Welbedacht (Lesotho) key area:									
D23F	MAKETENG	320	320	160	40	10	6	90	100 % : 0 %
Caledon d/s Welbedacht key area:									
D24G	ROUXVILLE / RWELELEYATHUNYA	820	820	410	231	26	15	231	72 % : 28 %
D24H	SMITHFIELD / MOFULATSHEPE	271	271	135	76	8	5	76	72 % : 28 %
		545.5	545.5	272.5	153.5	17	10	153.5	
Vanderkloof key area:									
D31B	PHILIPSTOWN / LUKHANYISWENI	320	320	160	90	10	6	90	72 % : 28 %
D32F	HANOVER / NOMPUMELELO	320	320	160	90	10	6	90	72 % : 28 %
D32G	NOUPOORT / KWAZAMUXOLO	249	249	124	70	8	5	70	72 % : 28 %
D34A	NORVALSPONT (Novelspoint)	261	261	130	73	8	5	73	72 % : 28 %
D34F	COLESBERG / KUYASA	320	320	160	90	10	6	90	58 % : 42%
D34G	PHILIPPOLIS / PHODING-TSE-ROLO / WATERKLOOF	443	443	221	124	14	8	124	72 % : 28 %
		318.8	318.8	159.2	89.5	10.0	6.0	89.5	
Orange d/s Vanderkloof Dam:									
D33A	PETRUSVILLE / THEMBINKOSI / VANDERKLOOF	320	320	160	90	10	6	90	72 % : 28 %
D33C	LUCKHOFF	206	206	103	58	6	4	58	72 % : 28 %
D33G	HOPETOWN	320	320	160	90	10	6	90	72 % : 28 %
		282.0	282.0	141.0	79.3	8.7	5.3	79.3	
Gariep key area:									
D35F	SPRINGFONTEIN / MAPHODI	311	311	155	87	10	6	87	72 % : 28 %
D35G	VENTERSTAD / NOZIZWE	292	292	146	82	9	5	82	72 % : 28 %
D35H	BETHULIE / LEPHOI	767	767	384	216	24	14	216	72 % : 28 %

UPPER ORANGE WMA									
			Per capita consumption per residential category						
Quaternary	Transitional Council	Cat1_SS	Cat2_SS	Cat3_SS	Cat4_SS	Cat5_SS	Cat6_SS	Cat7_SS	Direct : Indirect
D35K	VERWOERDDAM	320	320	160	90	10	6	90	72 % : 28 %
		422.5	422.5	211.25	118.75	13.25	7.75	118.75	
		347.9	347.9	173.8	92.4	10.8	6.5	97.9	
Default pattern of usage [Markdata]:		320	320	160	90	10	6	90	
Maximum pattern of usage (RSA)		1193	1193	597	336	37	22	336	
		3.7	3.7	3.7	3.7	3.7	3.7	3.7	
Minimum pattern of usage (RSA)		131	131	65	37	4	2	37	
		0.4	0.4	0.4	0.4	0.4	0.3	0.4	

ASSURANCE OF SUPPLY FOR VARIOUS USER CATEGORIES									
				Assurance Categories					
User Category	**50%**	**80%**	**90%**	**95%**	**98%**	**99%**	**99.5%**	**99.8%**	**99.9%**
Bulk - Strategic (on-site)	0	0	0	0	20	80	0	0	0
Bulk - Mining (on-site)	0	0	0	0	50	50	0	0	0
Bulk - Other (on-site)	0	0	0	20	50	30	0	0	0
Direct Urban category 1	0	0	0	50	20	30	0	0	0
Direct Urban category 2	0	0	0	50	20	30	0	0	0
Direct Urban category 3	0	0	0	30	40	30	0	0	0
Direct Urban category 4	0	0	0	0	20	80	0	0	0
Direct Urban category 5	0	0	0	0	0	100	0	0	0
Direct Urban category 6	0	0	0	0	0	100	0	0	0
Direct Urban category 7	0	0	0	20	30	50	0	0	0
Indirect Urban use	0	0	0	20	30	50	0	0	0
Irrigation high income	0	20	20	30	30	0	0	0	0
Irrigation medium income	0	35	30	20	15	0	0	0	0
Irrigation low income	0	50	40	10	0	0	0	0	0
Rural per capita demand	0	0	0	0	0	100	0	0	0
Rural Livestock consumption	0	0	0	0	20	80	0	0	0
Rural Irrigation subsistence	0	0	0	0	20	80	0	0	0
Per capita volume used for subsistence irrigation	0	0	20	30	30	20	0	0	0
Probability of supply%		Median	% Probability						
1:2 assurance factor		1.23	50						
1:5 assurance factor		1.23	80						
1:10 assurance factor		1.22	90						
1:20 assurance factor		1.113	95						
1:50 assurance factor		1.00	98						
1:100 assurance factor		0.93	99						
1:200 assurance factor		0.88	99.5						
1:500 assurance factor		0.78	99.8						
e.g. for rural domestic use if use =100 Mm^3/a in 1995 the adjusted value will be 100/median for 1:100 = 107.527									
	1:5	1:10	1:20	1:50	1:100	1:200	1:500		
Min	1.121	1.12	1.06		0.847	0.711	0.72		
10Percentile	1.164	1.162	1.083		0.905	0.76	0.826		
25Percentile	1.188	1.186	1.093		0.922	0.774	0.857		
Median	1.227	1.224	1.113	1.00	0.935	0.785	0.881		
75Percentile	1.299	1.295	1.139		0.945	0.794	0.899		
Max	1.654	1.647	1.355		0.962	0.808	0.93		

APPENDIX G WATER RESOURCES

Comprising:

Appendix G.1	Details of postulated dam storages
Appendix G.2	Sediment load per quaternary
Appendix G.3	Groundwater Resources of South Africa
Appendix G.4	Potential vulnerability of surface water and groundwater to microbial contamination.
Appendix G.5	Water quality database

APPENDIX G.1

DETAILS OF POSTULATED DAM STORAGES

Quat.	MAP	MAE	Hydro	Adj. MAR	Postulated dams		Actual dams storage (106m^3)		
number	(mm)	(S - mm)	zone	(10^6m^3)	(%MAR)	(10^6m^3)	Capacity	Farm	Total
MODDER / RIET SUB AREA									
Kalkfontein key area:									
C51A	474	1640	J	22.69	250	56.71	0.00	5.36	5.36
C51B	434	1660	J	52.09	250	130.23	0.00	13.25	13.25
C51C	419	1725	J	15.30	250	38.25	0.00	2.91	2.91
C51D	491	1640	J	23.80	250	59.50	34.55	5.39	39.94
C51E	423	1730	J	20.37	250	50.92	0.00	6.08	6.08
C51F	372	1800	J	11.83	250	29.57	0.00	1.20	1.20
C51G	403	1730	J	41.82	250	104.56	0.00	14.83	14.83
C51H	396	1800	J	38.02	250	95.06	0.00	11.82	11.82
C51J	387	1870	J	13.78	250	34.44	323.69	0.76	324.45
Total				**239.7**		**599.24**	**358.24**	**61.6**	**419.84**
Riet key area:									
C51K	350	2000	M	**4.54**	300	**13.61**	**0.00**	**3.67**	**3.67**
Riet / Modder key area:									
C51L	350	2140	M	1.86	300	5.59	0.00	0.08	0.08
C51M	320	2200	M	1.05	300	3.15	0.00	0.17	0.17
C52H	455	1800	L	3.24	250	8.09	0.00	0.53	0.53
C52J	456	1730	L	6.17	250	15.42	0.00	4.75	4.75
C52K	414	1900	L	2.70	250	6.75	0.00	1.33	1.33
C52L	377	2000	M	2.29	250	5.73	0.00	0.54	0.54
Total				**17.31**		**44.73**	**0.00**	**7.4**	**7.4**
Rustfontein key area:									
C52A	543	1600	J	**30.70**	250	**76.75**	**72.21**	**10.33**	**82.54**
Krugersdrift key area:									
C52B	563	1570	J	28.36	250	70.90	13.24	4.19	17.43
C52C	528	1600	J	14.29	250	35.73	0.00	1.69	1.69
C52D	513	1620	J	10.10	250	25.26	6.01	1.82	7.83
C52E	481	1620	J	15.35	250	38.38	0.00	5.32	5.32
C52F	514	1670	J	12.54	250	31.35	0.00	4.12	4.12
C52G	481	1690	J	33.75	250	84.38	73.44	2.74	76.18
Total				**114.39**		**286.00**	**92.69**	**19.88**	**112.57**
TOTAL MODDER / RIET:				**3915.28**		**1020.35**	**523.14**	**102.88**	**626.02**
UPPER ORANGE SUB-AREA									
Katse key area:									
D11A	1190	1300	A	132.86	125	166.0765	0.00	0.00	0.00
D11B	1026	1300	A	81.54	125	101.9202	0.00	0.00	0.00
D11C	1058	1300	A	108.15	125	135.1916	0.00	0.00	0.00
D11D	914	1300	A	83.78	125	104.7279	0.00	0.00	0.00
D11E	842	1350	A	64.35	125	80.44113	0.00	0.00	0.00
D11F	951	1350	A	112.08	125	140.1051	1478.00	0.00	1478.00
D11G	879	1300	A	47.57	125	59.46669	0.00	0.00	0.00
D11H	852	1300	A	51.43	125	64.28331	0.00	0.00	0.00
D11J	774	1350	A	60.26	125	75.3273	0.00	0.00	0.00
D11K	759	1350	A	49.51	125	61.89313	0.00	0.00	0.00
Total				**791.55**		**989.4329**	**1478.00**	**0.00**	**1478.00**
Orange u/s Gariep Dam									

Quat.	MAP	MAE	Hydro	Adj. MAR	Postulated dams		Actual dams storage (106m^3)		
number	(mm)	(S - mm)	zone	(10^6m^3)	(%MAR)	(10^6m^3)	Capacity	Farm	Total
D12A	627	1600	B	43.04	150	64.55366	0.00	0.00	0.00
D12B	720	1545	B	65.63	150	98.4396	0.00	0.00	0.00
D12C	638	1600	E	20.57	200	41.14271	0.00	0.00	0.00
D12D	605	1575	E	17.92	200	35.84211	0.00	4.79	4.79
D12E	593	1600	E	33.19	200	66.38363	0.00	0.47	0.47
D12F	545	1600	E	27.51	200	55.02521	0.00	1.24	1.24
D13A	809	1475	B	71.22	150	106.8334	0.00	0.00	0.00
D13B	785	1475	B	73.92	150	110.8825	0.00	0.00	0.00
D13C	704	1475	B	54.92	150	82.38318	0.00	0.00	0.00
D13D	676	1525	B	57.93	150	86.89946	0.00	0.07	0.07
D13E	754	1475	B	129.47	150	194.2001	0.00	0.00	0.00
D13F	666	1600	B	96.97	150	145.4554	0.00	0.12	0.12
D13G	631	1600	E	53.05	200	106.1066	0.00	1.41	1.41
D13H	538	1625	E	29.90	200	59.80178	0.00	5.26	5.26
D13J	550	1625	E	33.12	200	66.23878	0.00	0.78	0.78
D13K	732	1575	B	50.46	150	75.68663	0.00	0.10	0.10
D13L	593	1625	E	25.33	200	50.6654	0.00	1.59	1.59
D13M	538	1625	E	21.58	200	43.16198	0.00	0.15	0.15
D14A	493	1675	F	25.13	250	62.82501	0.00	0.49	0.49
D14B	487	1700	E	8.06	200	16.12113	0.00	0.96	0.96
D14C	491	1700	E	18.49	200	36.98378	0.00	3.21	3.21
D14D	443	1700	E	11.74	200	23.47047	0.00	2.78	2.78
D14E	431	1700	E	10.31	200	20.62557	0.00	1.86	1.86
D14F	492	1650	E	14.22	200	28.44906	0.00	3.33	3.33
D14G	520	1650	E	19.56	200	39.11746	0.00	0.37	0.37
D14H	435	1675	F	14.82	250	37.04305	0.00	3.19	3.19
D14J	436	1675	F	11.02	250	27.56003	0.00	0.43	0.43
D14K	427	1675	F	12.57	250	31.4125	0.00	1.84	1.84
Total				**1051.65**		**1813.31**	**0.00**	**34.44**	**34.44**
Senqu key area:									
D15A	974	1450	B	118.73	150	178.0968	0.00	0.00	0.00
D15B	961	1450	B	103.44	150	155.1589	0.00	0.00	0.00
D15C	850	1450	B	54.18	150	81.2659	0.00	0.00	0.00
D15D	927	1450	B	105.51	150	158.2719	0.00	0.00	0.00
D15E	799	1500	B	114.80	150	172.1985	0.00	0.00	0.00
D15F	750	1500	D	30.26	200	60.51251	0.00	0.00	0.00
D15G	670	1500	D	28.40	200	56.79874	0.00	1.73	1.73
D15H	609	1525	D	14.86	200	29.71011	0.00	0.00	0.00
D16A	1186	1300	A	42.42	125	53.02434	0.00	0.00	0.00
D16B	1088	1300	A	54.77	125	68.46594	0.00	0.00	0.00
D16C	725	1350	A	32.62	125	40.7691	0.00	0.00	0.00
D16D	994	1300	A	61.90	125	77.37141	0.00	0.00	0.00
D16E	826	1300	A	50.07	125	62.58342	0.00	0.00	0.00
D16F	997	1300	A	50.98	125	63.72725	0.00	0.00	0.00
D16G	941	1300	A	46.47	125	58.08984	0.00	0.00	0.00
D16H	763	1300	A	32.03	125	40.03378	0.00	0.00	0.00
D16J	879	1350	A	48.04	125	60.05067	0.00	0.00	0.00
D16K	871	1350	A	59.97	125	74.96746	0.00	0.00	0.00
D16L	725	1350	A	59.59	125	74.48766	0.00	0.00	0.00

Quat.	MAP	MAE	Hydro	Adj. MAR	Postulated dams		Actual dams storage (106m^3)		
number	(mm)	(S - mm)	zone	($10^6 m^3$)	(%MAR)	($10^6 m^3$)	Capacity	Farm	Total
D16M	646	1350	A	132.95	125	166.1837	0.00	0.00	0.00
D17A	1000	1375	A	206.37	125	257.9677	0.00	0.00	0.00
D17B	999	1375	A	126.57	125	158.2088	851.00	0.00	851.00
D17C	876	1400	A	77.45	125	96.80958	0.00	0.00	0.00
D17D	899	1450	A	112.19	125	140.242	0.00	0.00	0.00
D17E	920	1450	A	96.44	125	120.5553	0.00	0.00	0.00
D17F	717	1450	A	48.30	125	60.37914	0.00	0.00	0.00
D17G	710	1400	A	109.02	125	136.2705	0.00	0.00	0.00
D17H	691	1400	A	101.91	125	127.3833	0.00	0.00	0.00
D17J	871	1375	A	99.89	125	124.8652	0.00	0.00	0.00
D17K	711	1375	A	50.83	125	63.54352	0.00	0.00	0.00
D17L	679	1400	A	74.50	125	93.12381	0.00	0.00	0.00
D17M	716	1450	A	72.79	125	90.98869	0.00	0.00	0.00
D18A	819	1475	B	96.78	150	145.1645	0.00	0.00	0.00
D18B	736	1475	B	39.87	150	59.80252	0.00	0.00	0.00
D18C	691	1475	B	48.06	150	72.09071	0.00	0.00	0.00
D18D	788	1475	B	111.85	150	167.7748	0.00	0.00	0.00
D18E	792	1475	B	55.60	150	83.39585	0.00	0.00	0.00
D18F	678	1475	B	43.80	150	65.70086	0.00	0.00	0.00
D18G	800	1500	B	86.29	150	129.4356	0.00	0.00	0.00
D18H	714	1500	B	50.35	150	75.53141	0.00	0.00	0.00
D18J	712	1500	B	111.96	150	167.9386	0.00	0.00	0.00
D18K	774	1525	B	147.46	150	221.1874	0.00	0.00	0.00
D18L	663	1525	B	64.66	150	96.99478	0.00	0.00	0.00
Total				**3274.93**		**4487.12**	**851.00**	**1.73**	**852.73**
Caledon key area:									
D21A	978	1275	C	61.45	150	92.17889	0.00	0.00	0.00
D21B	1021	1275	C	88.46	150	132.6906	0.00	0.00	0.00
D21C	883	1275	C	31.12	150	46.67657	0.00	0.00	0.00
D21D	839	1300	C	30.63	150	45.94266	0.00	0.21	0.21
D21E	784	1300	C	26.22	150	39.33749	0.00	0.00	0.00
D21F	725	1325	D	32.59	200	65.17106	0.00	0.46	0.46
D21G	751	1325	D	21.43	200	42.86025	0.00	0.08	0.08
D21H	782	1325	C	38.85	150	58.27232	0.00	0.00	0.00
D21J	991	1300	C	74.37	150	111.5541	0.00	0.00	0.00
D21K	960	1300	C	61.75	150	92.61923	0.00	0.00	0.00
D21L	860	1325	C	40.51	150	60.76761	0.00	0.00	0.00
D22A	682	1375	D	35.72	200	71.43374	0.00	0.51	0.51
D22B	725	1375	D	32.00	200	63.99681	0.00	2.70	2.70
D22C	782	1375	C	49.12	150	73.6844	0.00	0.00	0.00
D22D	694	1400	D	36.79	200	73.58654	0.00	0.56	0.56
D22E	817	1475	C	51.18	150	76.76681	0.00	0.00	0.00
D22F	758	1475	C	51.77	150	77.6475	0.00	0.00	0.00
D22G	688	1450	D	52.94	200	105.8785	0.00	2.39	2.39
D22H	730	1450	D	36.01	200	72.02087	0.00	1.50	1.50
D22J	772	1400	C	61.94	150	92.91279	0.00	0.00	0.00
D22K	750	1400	C	28.18	150	42.27312	0.00	0.00	0.00
D22L	705	1475	D	21.63	200	43.25166	0.00	0.00	0.00
Total				**946.66**		**1581.52**	**0.00**	**8.41**	**8.41**

Quat.	MAP	MAE	Hydro	Adj. MAR	Postulated dams		Actual dams storage (106m^3)		
number	**(mm)**	**(S - mm)**	**zone**	**(10^6m^3)**	**(%MAR)**	**(10^6m^3)**	**Capacity**	**Farm**	**Total**
Welbedacht key area:									
D23A	688	1475	D	38.26	200	76.52217	0.00	0.00	0.00
D23B	705	1475	D	40.81	200	81.61061	0.00	0.00	0.00
D23C	638	1500	D	40.90	200	81.80631	14.20	6.16	20.36
D23D	607	1525	D	22.02	200	44.0345	0.00	0.10	0.10
D23E	615	1525	D	28.67	200	57.3427	0.00	1.70	1.70
D23F	638	1525	D	19.57	200	39.14178	0.00	0.00	0.00
D23G	622	1525	D	26.22	200	52.44998	0.00	0.21	0.21
D23H	519	1600	E	19.67	200	39.33749	0.00	3.37	3.37
D23J	541	1550	D	16.05	200	32.09626	157.00	0.68	157.68
D24A	627	1575	D	19.08	200	38.16916	9.78	0.00	9.78
D24B	591	1575	E	22.88	200	45.75557	0.00	0.40	0.40
D24C	532	1575	E	13.51	200	27.02661	0.00	7.20	7.20
Total				**307.64**		**615.29**	**180.98**	**19.82**	**200.8**
D/s Welbedacht key area:									
D24D	490	1575	E	15.05	200	30.10859	0.00	1.86	1.86
D24E	491	1575	E	12.33	200	24.65585	0.00	0.72	0.72
D24F	519	1575	E	17.54	200	35.08717	0.00	0.75	0.75
D24G	525	1650	E	22.40	200	44.80727	0.00	2.80	2.80
D24H	478	1650	F	18.97	250	47.4151	0.00	5.16	5.16
D24J	447	1650	F	20.63	250	51.56392	0.00	0.00	0.00
D24K	442	1650	F	16.83	250	42.0809	0.00	0.15	0.15
D24L	434	1650	F	9.13	250	22.81852	0.00	0.20	0.20
Total				**132.88**		**298.54**	**0.00**	**11.64**	**11.64**
Vanderkloof key area:									
D31A	396	1900	G	16.39	300	49.16774	0.00	2.91	2.91
D31B	314	1900	G	4.18	300	12.5538	0.00	0.00	0.00
D31C	328	1900	G	4.48	300	13.4443	0.00	2.35	2.35
D31D	377	1900	G	9.72	300	29.16734	0.00	0.00	0.00
D31E	353	1900	G	8.58	300	25.73624	3189.00	0.50	3189.50
D32A	314	1925	G	4.10	300	12.29193	0.00	5.47	5.47
D32B	341	1925	G	4.74	300	14.21255	0.00	0.45	0.45
D32C	316	1925	G	4.99	300	14.98079	0.00	0.00	0.00
D32D	312	1925	G	4.74	300	14.21255	0.00	18.14	18.14
D32E	274	1925	G	3.84	300	11.52369	0.00	0.00	0.00
D32F	305	1900	G	7.43	300	22.27913	0.00	0.26	0.26
D32G	330	1900	G	7.30	300	21.89501	0.00	0.24	0.24
D32H	328	1900	G	3.84	300	11.52369	0.00	0.08	0.08
D32J	315	1900	G	6.10	300	18.30653	0.00	0.38	0.38
D32K	324	1900	G	5.38	300	16.13316	0.00	0.00	0.00
D34A	385	1750	G	10.88	300	32.65045	0.00	5.78	5.78
D34B	361	1800	G	7.17	300	21.51088	0.00	0.35	0.35
D34C	343	1800	G	6.27	300	18.82202	0.00	0.00	0.00
D34D	349	1800	G	5.38	300	16.13316	0.00	1.32	1.32
D34E	364	1800	G	5.51	300	16.51729	0.00	0.00	0.00
D34F	338	1800	G	5.38	300	16.13316	0.00	2.40	2.40
D34G	372	1800	G	11.01	300	33.03457	0.00	0.86	0.86
Total				**147.41**		**442.23**	**3189.00**	**41.49**	**3230.49**
D/s Vanderkloof key area:									

Quat.	MAP	MAE	Hydro	Adj. MAR	Postulated dams		Actual dams storage (106m^3)		
number	(mm)	(S - mm)	zone	(10^6m^3)	(%MAR)	(10^6m^3)	Capacity	Farm	Total
D33A	333	2075	G	1.43	300	4.298145	0.00	0.00	0.00
D33B	315	2075	G	0.82	300	2.474853	0.00	0.00	0.00
D33C	333	2075	G	1.61	300	4.84472	0.00	0.00	0.00
D33D	299	2075	G	0.65	300	1.960084	0.00	0.42	0.42
D33E	307	2100	G	0.77	300	2.317568	0.00	0.00	0.00
D33F	288	2100	G	0.13	300	0.401506	0.00	0.00	0.00
D33G	285	2200	G	0.68	300	2.048364	0.00	0.00	0.00
D33H	298	2200	G	0.93	300	2.797343	0.00	0.00	0.00
D33J	272	2200	G	0.28	300	0.83237	0.00	0.00	0.00
D33K	287	2200	G	0.53	300	1.604508	0.00	0.00	0.00
Total				**7.83**		**23.58**	**0.00**	**0.42**	**0.42**
Gariep key area:									
D35A	435	1700	G	4.39	300	13.15769	0.00	0.23	0.23
D35B	423	1700	G	4.03	300	12.09085	0.00	0.00	0.00
D35C	408	1725	G	10.79	300	32.36081	0.00	2.67	2.67
D35D	390	1725	G	5.57	300	16.71382	0.00	1.54	1.54
D35E	403	1725	G	3.91	300	11.73524	0.00	0.00	0.00
D35F	425	1725	G	8.65	300	25.95977	0.00	0.87	0.87
D35G	387	1750	G	4.98	300	14.93576	0.00	0.05	0.05
D35H	401	1725	G	6.05	300	18.13628	0.00	0.00	0.00
D35J	371	1750	G	7.70	300	23.11486	0.00	0.00	0.00
D35K	385	1725	G	6.88	300	20.62557	5348.00	0.00	5348.00
Total				**62.95**		**188.83**	**5348.00**	**5.36**	**5353.36**
TOTAL UPPER ORANGE SUB-AREA:				**6741.50**		**10439.86**	**11046.98**	**123.31**	**11170.29**
TOTAL UPPER ORANGE WMA:				**7148.14**		**11460.19**	**11570.12**	**226.19**	**11796.31**

APPENDIX G.2

SEDIMENT LOAD PER QUATERNARY

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibilty index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)
Kalkfontein key area:								
C51A	675	675	6	12	335	226125	0.227	0.999
C51B	1691	1691	6	12	335	566485	0.568	1.090
C51C	624	624	6	12	335	209040	0.209	1.369
C51D	922	922	6	12	335	308870	0.309	1.300
C51E	806	806	6	12	335	270010	0.271	1.328
C51F	877	678	6	12	335	227130	0.228	1.924
C51G	1835	1835	6	12	335	614725	0.616	1.473
C51H	1782	1782	6	12	335	596970	0.598	1.573
C51J	1052	699	6	10	335	234165	0.235	1.703
Total	**10264**	**9712**			**335**	**3253520**	**3.261**	
Riet key area								
C51K	**3632**	**1313**	3	7	**153.34**	**201335**	**0.202**	4.448
Riet / Modder key area:								
C51L	2032	540	3	7	153.34	82804	0.083	4.449
C51M	1521	601	3	7	153.34	92157	0.092	8.805
C52H	2373	438	3	9	82	35916	0.036	1.112
C52J	1923	811	3	11	82	66502	0.067	1.080
C52K	4333	557	3	9	82	45674	0.046	1.694
C52L	2406	435	3	10	82	35670	0.036	1.559
Total	14588	3382			105.78	358723	0.360	
Rustfontein key area:								
C52A	**937**	**937**	3	11	**82**	**76834**	**0.077**	0.251
Krugersdrift key area:								
C52B	949	949	3	11	82	77818	0.078	0.275
C52C	600	600	3	11	82	49200	0.049	0.345
C52D	471	471	3	11	82	38622	0.039	0.383
C52E	897	897	3	10	82	73554	0.074	0.480
C52F	688	688	3	11	82	56416	0.057	0.451
C52G	1789	1789	3	10	82	146698	0.147	0.436
Total	**5394**	**5394**			**82**	**442308**	**0.444**	
TOTAL MODDER RIET SUB-AREA:								
	34815	**20738**				**4332720**	**4.344**	
UPPER ORANGE SUB-AREA								
Katse key area:								
D11A	278	278	7	10	203	56434	0.0565	0.0426
D11B	236	236	7	10	203	47908	0.0480	0.0589
D11C	292	292	7	10	203	59276	0.0594	0.0549
D11D	319	319	7	10	203	64757	0.0649	0.0774
D11E	322	322	7	10	203	65366	0.0655	0.1018
D11F	413	413	7	10	203	83839	0.0840	0.0749
D11G	320	320	7	10	203	64960	0.0651	0.1368

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibilty index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)
D11H	359	359	7	10	203	72877	0.0730	0.1420
D11J	440	440	7	10	203	89320	0.0895	0.1485
D11K	381	381	7	10	203	77343	0.0775	0.1565
Total	**3360**	**3360**			**203**	**682080**	**0.6834**	
Orange u/s Gariep Dam								
D12A	369	369	6	13	335	123615	0.1239	0.2878
D12B	385	385	6	13	335	128975	0.1292	0.1969
D12C	343	343	6	13	335	114905	0.1151	0.5597
D12D	355	355	6	12	335	118925	0.1192	0.6649
D12E	712	712	6	12	335	238520	0.2390	0.7200
D12F	803	803	6	13	335	269005	0.2695	0.9797
D13A	475	475	6	13	335	159125	0.1594	0.2239
D13B	533	533	6	13	335	178555	0.1789	0.2420
D13C	517	517	6	13	335	173195	0.1735	0.3160
D13D	635	635	6	13	335	212725	0.2132	0.3679
D13E	1031	1031	6	13	335	345385	0.3461	0.2673
D13F	970	970	6	13	335	324950	0.3256	0.3358
D13G	1125	1125	6	13	335	376875	0.3776	0.7118
D13H	1144	1144	6	13	335	383240	0.3840	1.2843
D13J	1167	1167	6	13	335	390945	0.3917	1.1828
D13K	397	397	6	13	335	132995	0.1333	0.2641
D13L	682	682	6	13	335	228470	0.2289	0.9037
D13M	678	678	6	13	335	227130	0.2276	1.0546
D14A	764	764	6	12	335	255940	0.2565	1.0205
D14B	324	324	6	13	335	108540	0.1088	1.3492
D14C	722	722	6	13	335	241870	0.2424	1.3106
D14D	680	680	6	13	335	227800	0.2283	1.9450
D14E	663	663	6	13	335	222105	0.2225	2.1580
D14F	541	541	6	13	335	181235	0.1816	1.2767
D14G	605	605	6	13	335	202675	0.2031	1.0383
D14H	697	697	6	13	335	233495	0.2340	1.5790
D14J	515	515	6	13	335	172525	0.1729	1.5681
D14K	634	634	6	13	335	212390	0.2128	1.6937
Total	**18466**	**18466**			**335**	**6186110**	**6.199**	
Senqu key area:								
D15A	437	437	7	10	203	88711	0.0889	0.0749
D15B	393	393	7	10	203	79779	0.0799	0.0773
D15C	276	276	7	10	203	56028	0.0561	0.1036
D15D	437	437	7	12	203	88711	0.0889	0.0842
D15E	619	619	7	12	203	125657	0.1259	0.1097
D15F	352	352	7	12	203	71456	0.0716	0.2366
D15G	485	485	7	12	203	98455	0.0987	0.3474
D15H	361	361	7	12	203	73283	0.0734	0.4943
D16A	159	159	7	10	203	32277	0.0323	0.0762
D16B	249	249	7	10	203	50547	0.0506	0.0925
D16C	438	438	7	10	203	88914	0.0891	0.2732
D16D	339	339	7	10	203	68817	0.0690	0.1114
D16E	434	434	7	10	203	88102	0.0883	0.1763
D16F	277	277	7	10	203	56231	0.0563	0.1105
D16G	290	290	7	10	203	58870	0.0590	0.1269
D16H	345	345	7	10	203	70035	0.0702	0.2191
D16J	374	374	7	10	203	75922	0.0761	0.1584

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibilty index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)
D16K	329	329	7	10	203	66787	0.0669	0.1116
D16L	533	533	7	10	203	108199	0.1084	0.1819
D16M	753	753	7	10	203	152859	0.1532	0.1152
D17A	638	638	7	10	203	129514	0.1298	0.0629
D17B	442	442	7	10	203	89726	0.0899	0.0710
D17C	525	525	7	10	203	106575	0.1068	0.1379
D17D	748	748	7	10	203	151844	0.1521	0.1356
D17E	605	605	7	10	203	122815	0.1231	0.1276
D17F	582	582	7	10	203	118146	0.1184	0.2451
D17G	849	849	7	10	203	172347	0.1727	0.1584
D17H	852	852	7	10	203	172956	0.1733	0.1701
D17J	437	437	7	10	203	88711	0.0889	0.0890
D17K	383	383	7	10	203	77749	0.0779	0.1533
D17L	590	590	7	10	203	119770	0.1200	0.1611
D17M	528	528	7	10	203	107184	0.1074	0.1475
D18A	599	599	7	10	203	121597	0.1218	0.1259
D18B	327	327	7	10	203	66381	0.0665	0.1668
D18C	466	466	7	12	203	94598	0.0948	0.1972
D18D	766	766	7	10	203	155498	0.1558	0.1393
D18E	376	376	7	10	203	76328	0.0765	0.1376
D18F	446	446	7	12	203	90538	0.0907	0.2071
D18G	492	492	7	13	203	99876	0.1001	0.1160
D18H	384	384	7	13	203	77952	0.0781	0.1551
D18J	859	859	7	12	203	174377	0.1747	0.1561
D18K	935	935	7	13	203	189805	0.1902	0.1290
D18L	610	610	7	12	203	123830	0.1241	0.1919
Total	**21319**	**21319**			**203**	**4327757**	**4.363**	
Caledon key area:								
D21A	309	309	6	10	335	103515	0.1037	0.1688
D21B	394	394	6	10	335	131990	0.1323	0.1495
D21C	212	212	6	9	335	71020	0.0712	0.2287
D21D	252	252	6	9	335	84420	0.0846	0.2762
D21E	268	268	6	9	335	89780	0.0900	0.3430
D21F	480	480	6	9	335	160800	0.1611	0.4945
D21G	278	278	6	9	335	93130	0.0933	0.4354
D21H	381	381	6	9	335	127635	0.1279	0.3292
D21J	359	359	6	10	335	120265	0.1205	0.1620
D21K	326	326	6	10	335	109210	0.1094	0.1772
D21L	304	304	6	9	335	101840	0.1020	0.2519
D22A	636	636	6	9	335	213060	0.2135	0.5977
D22B	457	457	6	9	335	153095	0.1534	0.4794
D22C	486	486	6	9	335	162810	0.1631	0.3321
D22D	628	628	6	9	335	210380	0.2108	0.5729
D22E	498	498	6	10	335	166830	0.1672	0.3266
D22F	633	633	6	9	335	212055	0.2125	0.4105
D22G	969	969	6	9	335	324615	0.3253	0.6144
D22H	541	541	6	9	335	181235	0.1816	0.5043
D22J	652	652	6	10	335	218420	0.2189	0.3533
D22K	324	324	6	10	335	108540	0.1088	0.3859
D22L	376	376	6	11	335	125960	0.1262	0.5836
Total	**9763**	**9763**			**335**	**3270605**	**3.277**	
Welbedacht key area:								

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibilty index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)
D23A	608	608	6	12	335	203680	0.2041	0.5334
D23B	597	597	6	12	335	199995	0.2004	0.4911
D23C	861	861	3	12	82	70602	0.0707	0.1730
D23D	565	565	6	12	335	189275	0.1897	0.8614
D23E	702	702	6	12	335	235170	0.2356	0.8219
D23F	352	352	6	12	335	117920	0.1182	0.6037
D23G	512	512	6	12	335	171520	0.1719	0.6553
D23H	776	776	6	12	335	259960	0.2605	1.3243
D23J	534	534	6	12	335	178890	0.1792	1.1169
D24A	310	310	6	12	335	103850	0.1041	0.5452
D24B	470	470	6	12	335	157450	0.1578	0.6896
D24C	398	398	6	12	335	133330	0.1336	0.9886
Total	**6685**	**6685**			**335**	**2021642**	**2.026**	
Caledon d/s Welbedacht key area:								
D24D	598	598	6	12	335	200330	0.2007	1.3334
D24E	489	489	6	12	335	163815	0.1641	1.3315
D24F	567	567	6	12	335	189945	0.1903	1.0849
D24G	626	626	6	13	335	209710	0.2101	0.9379
D24H	736	736	6	12	335	246560	0.2471	1.3026
D24J	1032	1032	6	12	335	345720	0.3464	1.6795
D24K	877	877	6	12	335	293795	0.2944	1.7489
D24L	511	511	6	12	335	171185	0.1715	1.8793
Total	**5436**	**5436**			**335**	**1821060**	**1.825**	
Vanderkloof key area								
D31A	1160	1160	5	12	30	34800	0.0349	0.2128
D31B	996	757	5	13	30	22710	0.0228	0.5438
D31C	677	677	5	12	30	20310	0.0204	0.4541
D31D	1108	833	5	12	30	24990	0.0250	0.2575
D31E	969	969	5	12	30	29070	0.0291	0.3395
D32A	716	716	5	12	30	21480	0.0215	0.5253
D32B	582	582	5	13	30	17460	0.0175	0.3693
D32C	850	850	5	12	30	25500	0.0256	0.5117
D32D	851	851	5	12	30	25530	0.0256	0.5400
D32E	1157	1157	5	13	30	34710	0.0348	0.9054
D32F	1443	1443	5	13	30	43290	0.0434	0.5841
D32G	1045	1045	5	12	30	31350	0.0314	0.4304
D32H	572	572	5	12	30	17160	0.0172	0.4476
D32J	1114	1041	5	12	30	31230	0.0313	0.5128
D32K	824	824	5	12	30	24720	0.0248	0.4606
D34A	794	794	5	12	30	23820	0.0239	0.2193
D34B	706	706	5	12	30	21180	0.0212	0.2960
D34C	760	760	5	12	30	22800	0.0228	0.3641
D34D	599	599	5	12	30	17970	0.0180	0.3348
D34E	519	519	5	12	30	15570	0.0156	0.2834
D34F	692	692	5	12	30	20760	0.0208	0.3868
D34G	950	950	5	12	30	28500	0.0286	0.2593
Total	**19084**	**18497**			**30**	**554910**	**0.556**	
Orange d/s Vanderkloof key area:								
D33A	593	472	5	12	30	14160	0.0142	0.9903
D33B	1018	323	5	12	30	9690	0.0097	1.1770
D33C	805	520	5	12	30	15600	0.0156	0.9679
D33D	952	311	5	12	30	9330	0.0093	1.4309

Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibilty index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)
D33E	1554	343	5	12	30	10290	0.0103	1.3347
D33F	863	77	5	12	30	2310	0.0023	1.7295
D33G	1406	400	5	12	30	12000	0.0120	1.7610
D33H	1054	468	5	7	80.7	37767.6	0.0378	4.0585
D33J	865	200	5	12	30	6000	0.0060	2.1668
D33K	488	290	5	12	30	8700	0.0087	1.6299
Total	**9598**	**3404**			**30**	**125847.6**	**0.126**	
Gariep Dam key area:								
D35A	254	254	6	12	335	85090	0.0853	1.9440
D35B	260	260	6	13	335	87100	0.0873	2.1655
D35C	943	943	6	13	335	315905	0.3165	2.9344
D35D	586	586	6	13	335	196310	0.1967	3.5307
D35E	312	312	6	13	335	104520	0.1047	2.6773
D35F	557	557	6	12	335	186595	0.1870	2.1607
D35G	552	552	6	13	335	184920	0.1853	3.7217
D35H	498	498	6	12	335	166830	0.1672	2.7651
D35J	1002	1002	5	12	30	30060	0.0301	0.3909
D35K	674	674	5	12	30	20220	0.0203	0.2947
Total	**5638**	**5638**				**1377550**	**1.3803**	**2.1929**
Total Upper Orange sub-area:								
	99349	**92568**				**20367562**	**20.408**	
Total Upper Orange WMA:								
	134164	**113306**				**24700282**	**24.75**	

APPENDIX G.3

GROUNDWATER RESOURCES OF SOUTH AFRICA

GROUND WATER 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 Existing Ground Water Use

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 (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 (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 (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

Colour Code	Description	TDS Range (mg/l)
Blue	Ideal water quality	<260
Green	Good water quality	260 – 600
Yellow	Marginal water quality	601 – 1 800
Red	Poor water quality	1 801 – 3 400
Purple	Completely unacceptable water quality	>3 400

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 91 000 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 GROUND WATER 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 (3 750 x 10^6 yrs).

In the remaining 10% of the surface area of South Africa ground water occurs in primary openings ie 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 19 100 x $10^6 m^3/a$ and varies from less than 0,5 mm/a in quaternary catchment D82J to more than 352 mm/a 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 10 100 x $10^6 m^3/a$ and varies from less than 0,2 mm/a in quaternary catchment D82G to more than 211 mm/a in quaternary catchment W12J.

The ground water use, excluding mines and industries, has been estimated to be some 1 040 x $10^6 m^3/a$ 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 > 20 000 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.

APPENDIX G.4

POTENTIAL VULNERABILITY OF SURFACE WATER AND GROUNDWATER TO MICROBIAL CONTAMINATION

WATER RESOURCES SITUATION ASSESSMENTS

DEPARTMENT: WATER AFFAIRS & FORESTRY
DIRECTORATE: WATER RESOURCE PLANNING

POTENTIAL VULNERABILITY OF SURFACE WATER & GROUNDWATER TO MICROBIAL CONTAMINATION

AUGUST 2001

Parsons & Associates	**IWQS**	**Ninham Shand**
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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 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).

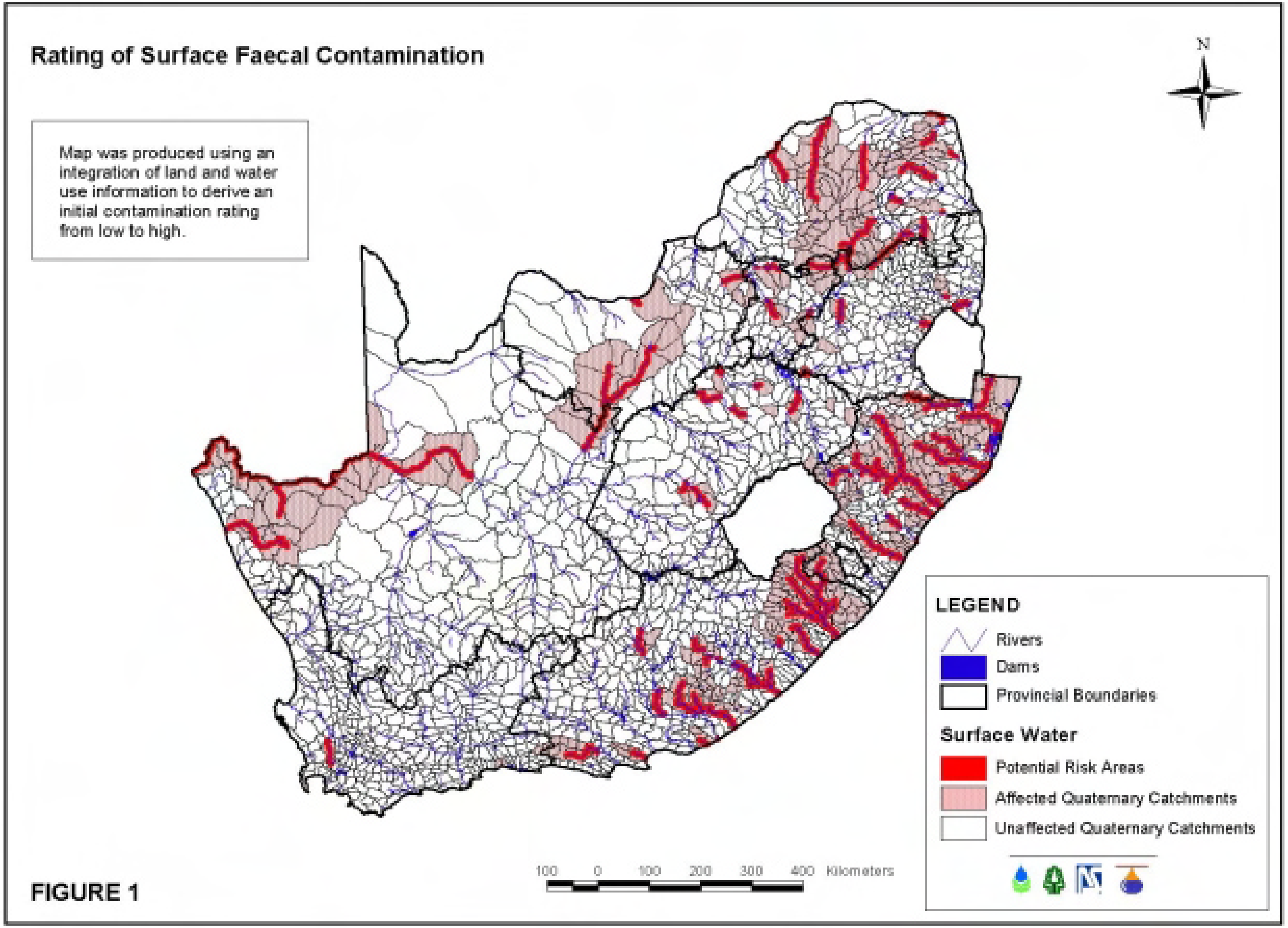
$$OR = 0.4\ TLU + 0.6\ TWU \qquad \text{........ (1)}$$

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:

$$LU = SA + PD \quad \text{........ (3)}$$

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:

$$TLU = (LU_n) \quad \text{........ (4)}$$

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).

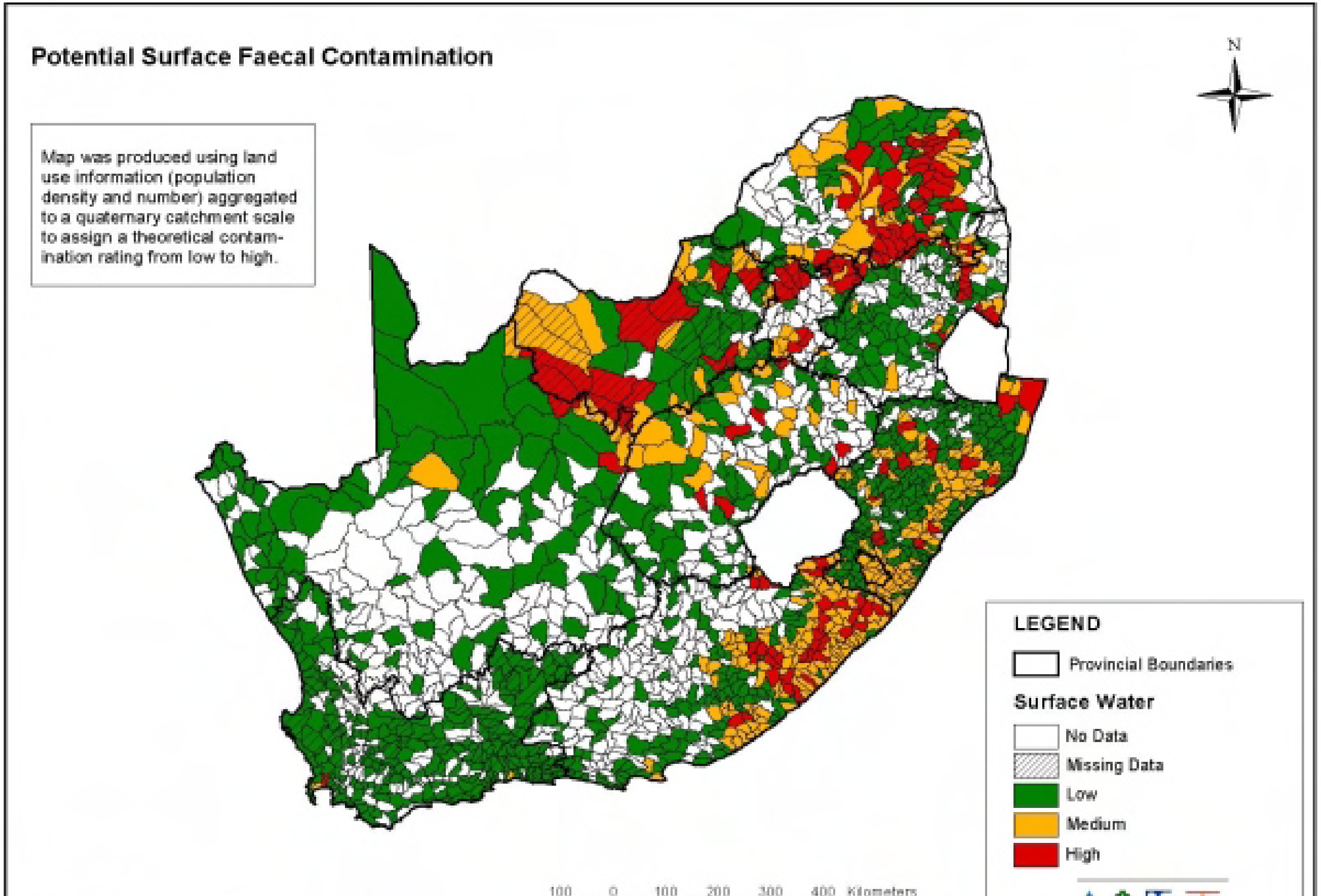

Potential Surface Faecal Contamination
N
Map was produced using land use information (population density and number) aggregated to a quaternary catchment scale to assign a theoretical contamination rating from low to high.
LEGEND
Provincial Boundaries
Surface Water
No Data
Missing Data
Low
Medium
High
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.

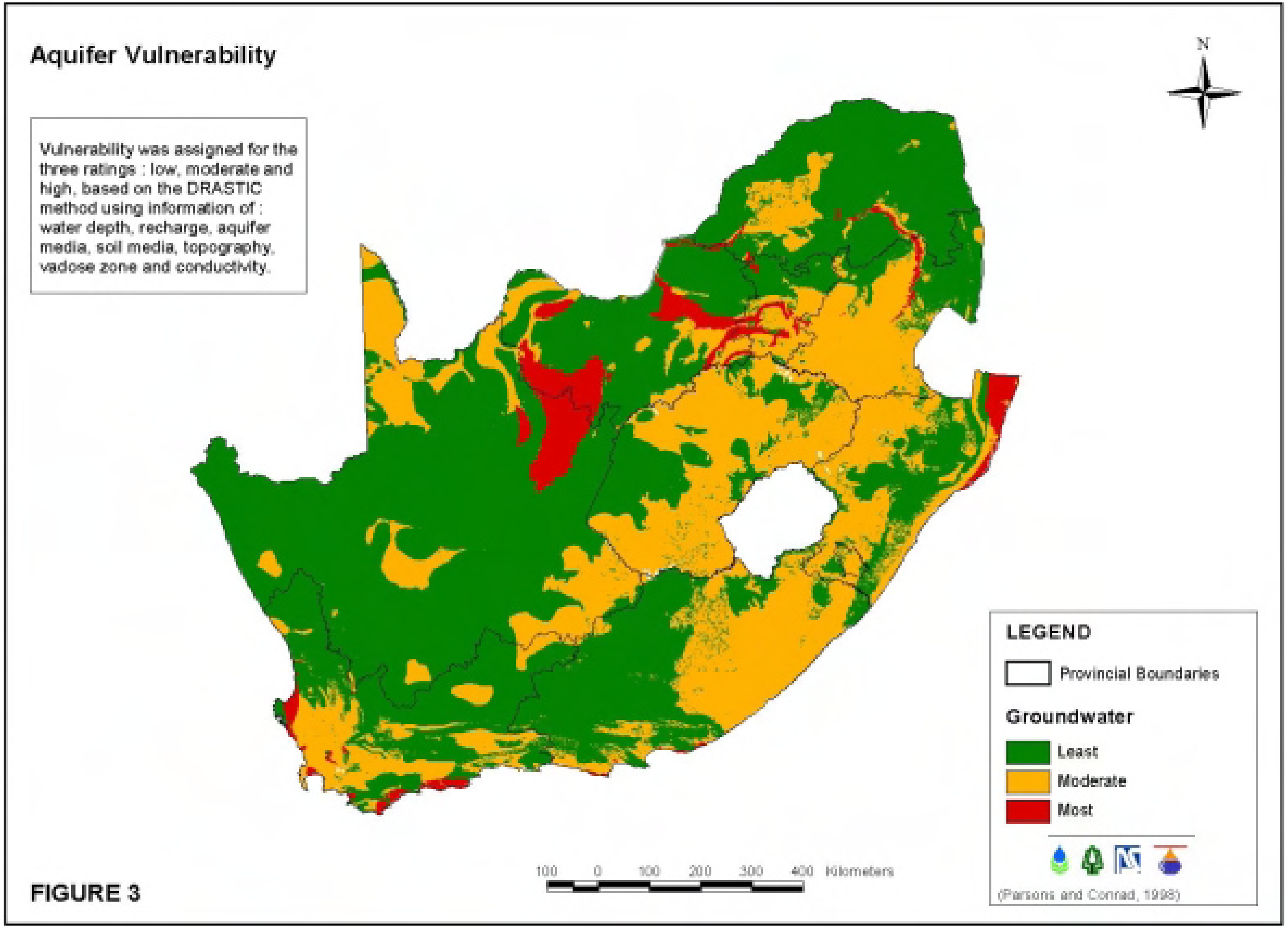
Microbial contamination of groundwater increases in high population density areas and areas with inadequate sanitation. Approximately three quarters of the population of South Africa do not have access to adequate sanitation.

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
100 0 100 200 300 400 Kilometers
(Parsons and Conrad, 1998)

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:

$$I = D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \qquad \text{..... (7)}$$

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,

$$\text{Index} = 5\ D_R + 5\ S_R + 4\ I_R \qquad \text{......... (8)}$$

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.

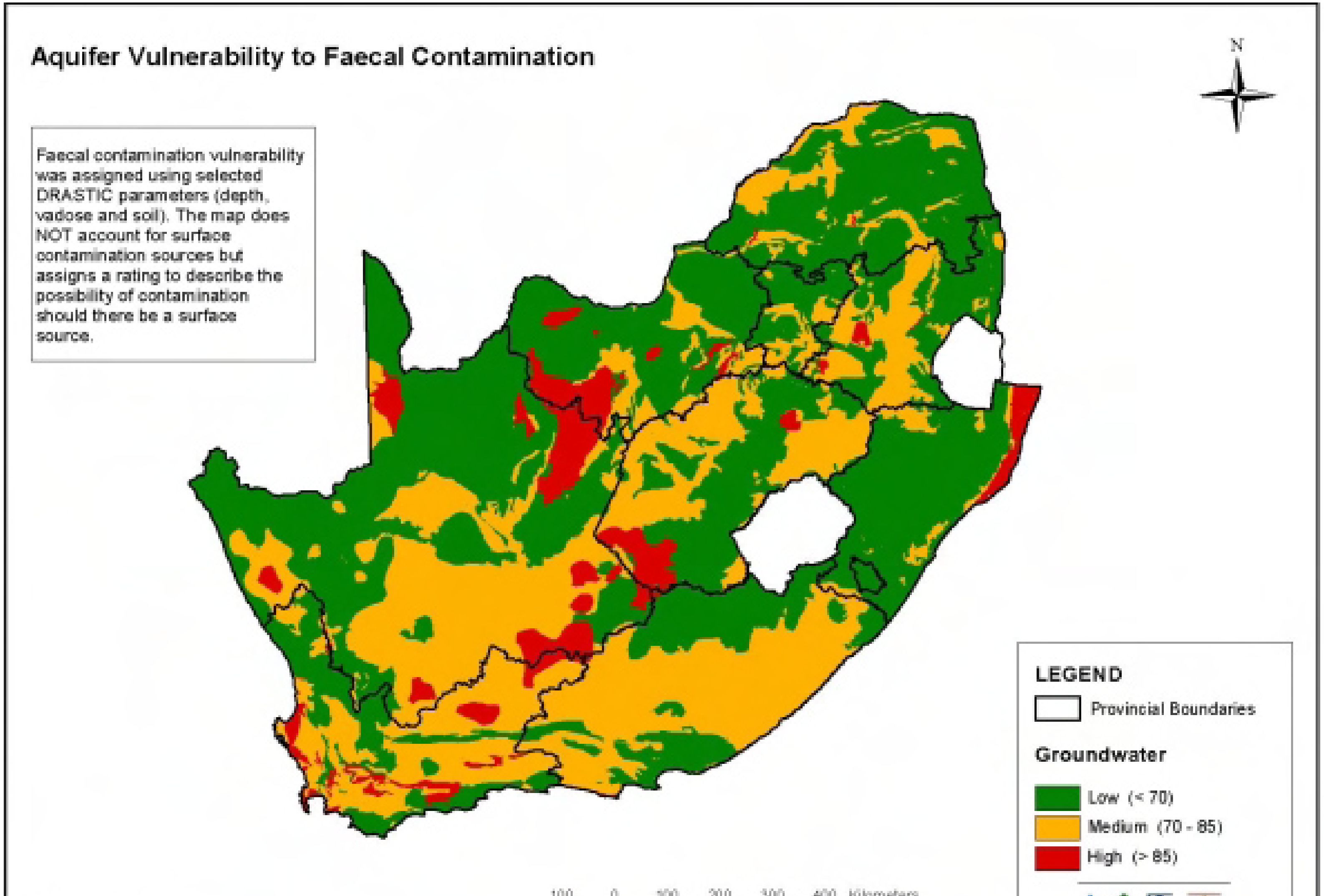

Aquifer Vulnerability to Faecal Contamination
Faecal contamination vulnerability was assigned using selected DRASTIC parameters (depth, vadose and soil). The map does NOT account for surface contamination sources but assigns a rating to describe the possibility of contamination should there be a surface source.
N
LEGEND
Provincial Boundaries
Groundwater
Low (< 70)
Medium (70 - 85)
High (> 85)
100 0 100 200 300 400 Kilometers

FIGURE 4

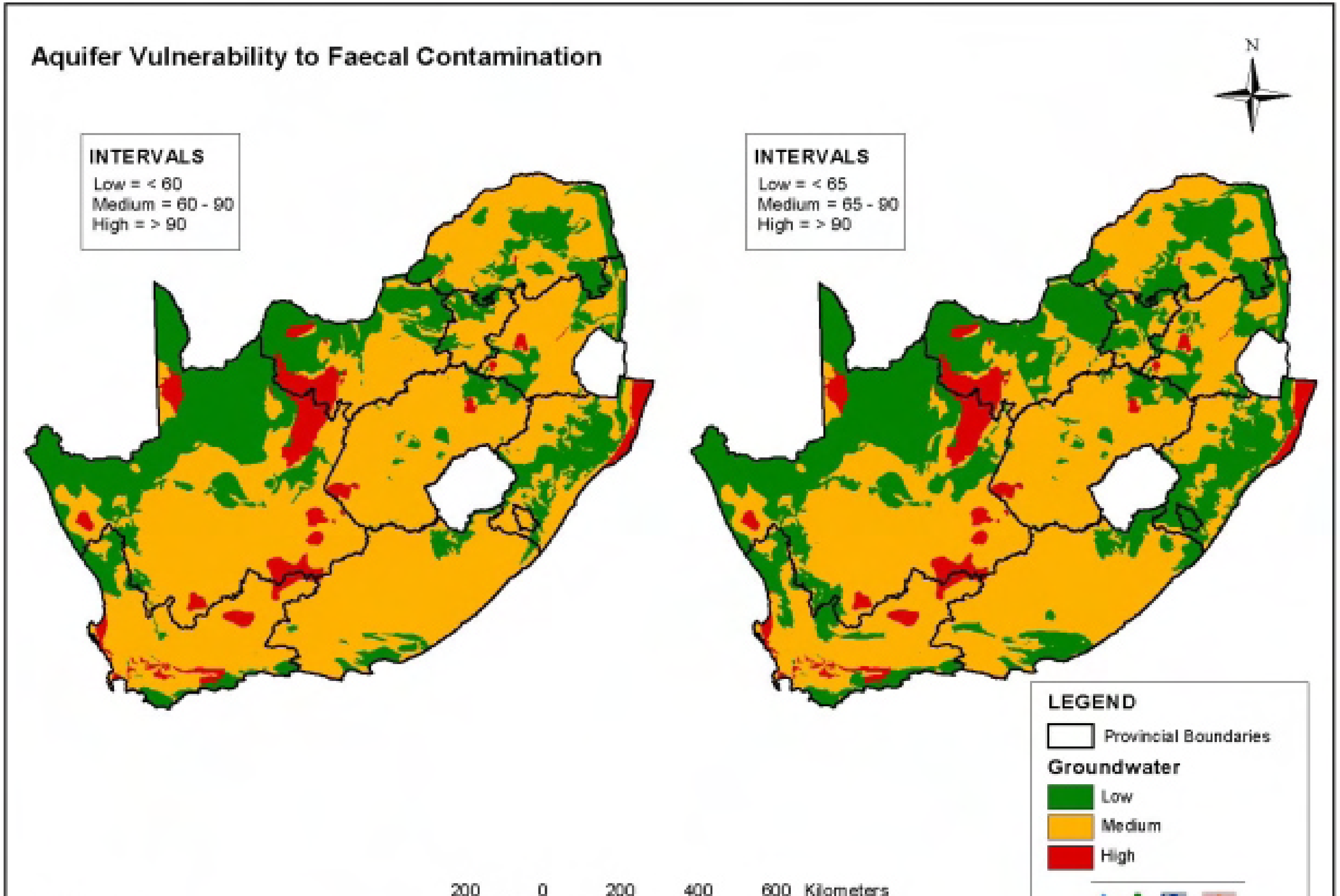

Aquifer Vulnerability to Faecal Contamination
N
INTERVALS
Low = < 60
Medium = 60 - 90
High = > 90
INTERVALS
Low = < 65
Medium = 65 - 90
High = > 90
LEGEND
Provincial Boundaries
Groundwater
Low
Medium
High
200 0 200 400 600 Kilometers

FIGURE 5

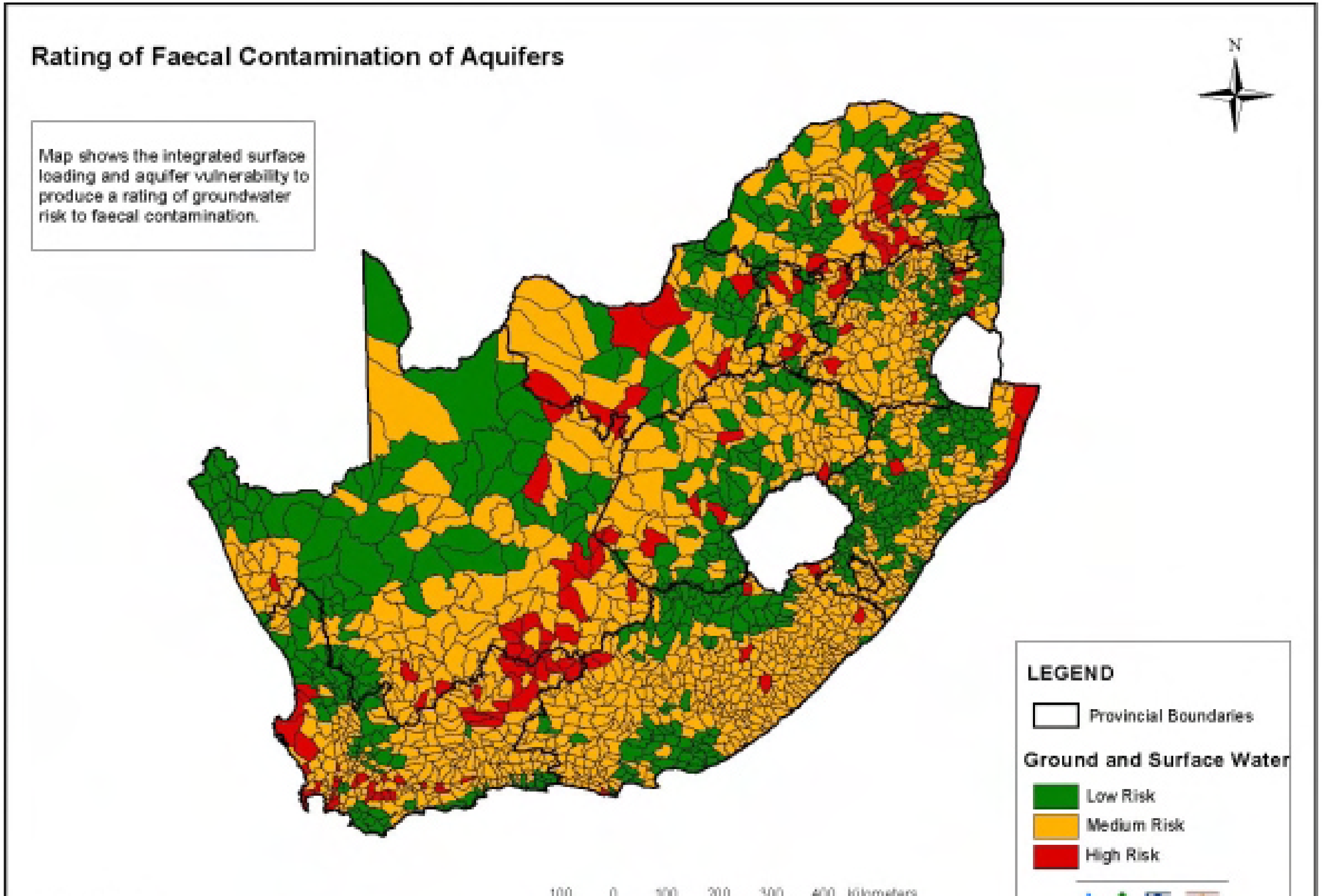

Rating of Faecal Contamination of Aquifers
Map shows the integrated surface loading and aquifer vulnerability to produce a rating of groundwater risk to faecal contamination.
N
100 0 100 200 300 400 Kilometers
LEGEND
Provincial Boundaries
Ground and Surface Water
Low Risk
Medium Risk
High Risk

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.

5. REFERENCES

Aller, L., Bennet, T., Lehr, J.H. and Petty, R.J. (1987). DRASTIC - a standardised system for evaluating groundwater pollution potential using hydrogeologic settings; United States Environmental Protection Agency Report EPA/600/2-87/035.

DWAF (1997). A protocol to manage the potential of groundwater contamination from on site sanitation; Edition 1, National Sanitation and Co-ordination Office and Directorate of Geohydrology, Department of Water Affairs and Forestry, Pretoria.

Goodmin. P and Wright, G. (1991). *Decision analysis for management judgement.* John Wiley & Sons Ltd., Chichester, UK. Pp 7 B 36.

Institute for Water Quality Studies, (1996). *A National Microbiological Monitoring Programme to assess faecal Pollution of South African Surface Water Resources: Conceptual Monitoring Design*. Report to Department of Water Affairs and Forestry, PRETORIA, pp 71

Murray, K. (1998). *National Microbial Monitoring Programme Implementation Manual Version 2 (for discussion purposes).* Draft Report to WRC. pp 92.

Lynch, S.D., Reynders, A.G. and Schulze, R.E. (1994). Preparing input data for a national scale groundwater vulnerability map of South Africa; Water SA, Vol. 20 No. 3, pp 239 - 246.

Lynch, S.D., Reynders, A.G. and Schulze, R.E. (1997). A DRASTIC approach to groundwater vulnerability in South Africa; SA Jour. Sci., Vol. 93, pp 56 - 60.

Parsons, R.P. and Conrad, J.E. (1998). Explanatory notes for the aquifer classification map of South Africa; Report prepared for the Water Research Commission, Department of Water Affairs and Forestry and the SA Oil Industry Environment Committee by Parsons & Associates Specialist Groundwater Consultants cc and the CSIR (Environmentek).

Reynders, A.G. and Lynch, S.D. (1993). Compilation of a national groundwater vulnerability map of South Africa; Conf. Proc. AAfrica Needs Ground Water@ Johannesburg, Sept. 1993, Poster Paper No. 75.

Reynders, A.G. (1997). An investigation of aquifer vulnerability and pollution risk in formulating a ground-water quality protection strategy for South Africa; *unpublished Ph.D thesis in preparation,* University of Orange Free State, Bloemfontein.

Vegter, J.R. (1995). An explanation of a set of national groundwater maps; Report TT 74/95, Water Research Commission, Pretoria.
Venter, F (1998). Personal communication.

Wright, A.H., (1995). Septic tank systems in the South African coastal zone; WRC Report No. 597/1/95, Water Research Commission, Pretoria.

Xu, Y. and Braune, E. (1995). A guideline for groundwater protection for the community water supply and sanitation programme; First Edition, Department of Water Affairs and Forestry, Pretoria.

APPENDIX G.5

WATER QUALITY DATABASE

WATER QUALITY DATA BASE

	Natural conditions:		Urban returns:			Strategic returns:			Other bulk user returns:		
Quaternary catchment	Virgin MAR (10^6m^3) (oMARi)	Average TDS of natural runoff (oTSNi)	Increase in TDS as a result of urban use (oISUi)	Urban effluent returns (10^6m^3)	TLC and river	Increase in TDS as a result of strategic industry use (oISSi)	Return flows by Strategic users (10^6m^3)	Remark	Increase in TDS as a result of other bulk use (oISOi	Return flows by Other Bulk users (10^6m^3)	Remark
Modder Riet sub-catchment:											
Kalkfontein key area:											
C51A	21.61	216	350	0.0	Reddersburg TLC: No returns	1000			1000	0.0	None known
C51B	49.74	216	350		No sewage returns	1000			1000		
C51C	14.59	216	350	0.0	Edenburg TLC: No returns	1000			1000		
C51D	23.76	179	350		No sewage returns	1000			1000		
C51E	19.43	216	350		No sewage returns	1000			1000		
C51F	14.59	216	350		No sewage returns	1000			1000		
C51G	39.87	216	350	0.0	Trompsburg TLC: No returns	1000			1000		
C51H	36.27	216	350	0.0	Jagersfontein TLC: No returns	1000			1000		
C51J	19.77	216	350	0.0	Fauresmith TLC: No returns	1000			1000		
Riet key area:											
C51K	4.09	578	350	0.6	Koffiefontein TLC: Returns to Riet R.	1000			1000		
Riet / Modder confluence key area:											
C51L	2.28	578	350	0.0	Ritchie TLC: No returns	1000			1000		
C51M	1.2	290	350		No sewage returns	1000			1000		
C52H	3.83	507	350	0.0	Bainesvlei / Bloemspruit / Dealesville & Soutpan TLCs: Returns exported to C52F or returned to oxidation dams.	1000			1000		
C52J	3.19	507	350		No sewage returns	1000			1000		
C52K	4.59	507	350	0.0	Petrusburg TLC: No returns	1000			1000		
C52L	2.77	507	350		No sewage returns	1000			1000		
Rustfontein key area:											
C52A	30.67	101	350	0.0	Dewetsdorp TLC: No returns	1000			1000		
Krugersdrift key area:											
C52B	28.36	129	210	3.3	Thaba'nchu & Botshabelo TLCs: Returns to Klein Modder River & Sepanespruit	1000			1000		
C52C	14.29	155	350		No sewage returns	1000			1000		
C52D	10.1	155	350		No sewage returns	1000			1000		
C52E	15.35	155	350		No sewage returns	1000			1000		
C52F	12.54	155	121	19.1	Greater Bloemfontein TLC: Returns to Bloemspruit from Bloemspruit STW [mainly]	1000			1000	0.0	No known returns
C52G	33.76	155	350	0.0	Brandfort TLC: No returns	1000			1000		
Caledon sub-area:											
Caledon key area (RSA & Lesotho):											
D21A	62.76	187	350		No sewage returns	1000			1000		
D21B	90.37	187	350		No sewage returns	1000			1000		
D21C	31.8	187	350		No sewage returns	1000			1000		
D21D	31.26	187	350	0.0	Clarens TLC: Negligible returns to Klein Caledon River.	1000			1000		
D21E	26.84	187	350		No sewage returns	1000			1000		
D21F	33.32	187	350		No sewage returns	1000			1000		
D21G	21.91	187	350	0.0	Fouriesburg TLC: Returns are re-used locally.	1000			1000		
D21H	39.74	187	350	0.0	Butha Buthu (Lesotho): No known returns	1000			1000		
D21J	76	187	350		No sewage returns	1000			1000		
D21K	63.15	187	350		No sewage returns	1000			1000		
D21L	41.39	187	350		No sewage returns	1000			1000		
D22A	36.47	187	350	0.0	Rosendal TLC: No returns (oxidation dams)	1000			1000		
D22B	32.75	187	350		No sewage returns	1000			1000		
D22C	50.24	187	350	0.9	Ficksburg TLC: Returns to Caledon River from STW	1000			1000		
D22D	37.6	187	350		No sewage returns	1000			1000		
D22E	52.34	187	350		No sewage returns	1000			1000		
D22F	52.91	187	350		No sewage returns	1000			1000		
D22G	54.06	187	350	0.0	Clocolan TLC: Returns are re-used locally	1000			1000		
D22H	36.82	187	350	1.2	Maseru (Lesotho): Returns to Caledon River	1000			1000		
D22J	63.34	187	350		No sewage returns	1000			1000		
D22K	28.83	187	350		No sewage returns	1000			1000		
D22L	22.1	187	350		No sewage returns	1000			1000		

WATER QUALITY DATA BASE

	Natural conditions:		Urban returns:			Strategic returns:			Other bulk user returns:		
Quaternary catchment	Virgin MAR (10^6m^3) (oMARi)	Average TDS of natural runoff (oTSNi)	Increase in TDS as a result of urban use (oISUi)	Urban effluent returns (10^6m^3)	TLC and river	Increase in TDS as a result of strategic industry use (oISSi)	Return flows by Strategic users (10^6m^3)	Remark	Increase in TDS as a result of other bulk use (oISOi	Return flows by Other Bulk users (10^6m^3)	Remark
Welbedacht key area (RSA & Lesotho):											
D23A	39.07	187	350		No sewage returns	1000			1000		
D23B	41.67	187	350		No sewage returns	1000			1000		
D23C	41.78	187	350	0.0	Tweespruit TLC: No returns	1000			1000		
D23D	22.51	187	350	0.0	Thaba Patchoa TLC: No returns	1000			1000		
D23E	29.32	187	350	0.0	Hobhouse TLC: No returns	1000			1000		
D23F	20.03	187	350	0.0	Maketeng (Lesotho): No known returns	1000			1000		
D23G	26.81	187	350	0.0	Wepener TLC: No returns (oxidation dams)	1000			1000		
D23H	20.07	187	350		No sewage returns	1000			1000		
D23J	16.42	187	350		No sewage returns	1000			1000		
D24A	16.06	91	350		No sewage returns	1000			1000		
D24B	19.33	91	350		No sewage returns	1000			1000		
D24C	11.36	91	350	0.0	Vanstadensrus TLC: No returns	1000			1000		
Orange d/s Welbedacht key area:											
D24D	12.65	91	350		No sewage returns	1000			1000		
D24E	10.42	91	350		No sewage returns	1000			1000		
D24F	14.75	91	350		No sewage returns	1000			1000		
D24G	18.89	91	350	0.0	Rouxville TLC: Negligible returns	1000			1000		
D24H	15.97	91	350	0.07	Smithfield TLC: Returns to Caledon River from STW	1000			1000		
D24J	17.4	91	350		No sewage returns	1000			1000		
D24K	14.17	91	350		No sewage returns	1000			1000		
D24L	7.71	91	350		No sewage returns	1000			1000		
Upper Orange sub-area:											
Katse key area:											
D11A	118.3	100	350		No sewage returns	1000			1000		
D11B	72.63	100	350		No sewage returns	1000			1000		
D11C	96.28	100	350		No sewage returns	1000			1000		
D11D	74.57	100	350		No sewage returns	1000			1000		
D11E	57.33	100	350		No sewage returns	1000			1000		
D11F	99.81	100	350		No sewage returns	1000			1000		
D11G	64.19	100	350		No sewage returns	1000			1000		
D11H	69.42	100	350		No sewage returns	1000			1000		
D11J	62.84	100	350		No sewage returns	1000			1000		
D11K	51.63	100	350		No sewage returns	1000			1000		
Senqu key area:											
D15A	108.7	100	350		No sewage returns	1000			1000		
D15B	94.7	100	350		No sewage returns	1000			1000		
D15C	49.55	100	350		No sewage returns	1000			1000		
D15D	96.62	100	350		No sewage returns	1000			1000		
D15E	105.1	100	350		No sewage returns	1000			1000		
D15F	27.71	100	350		No sewage returns	1000			1000		
D15G	26.01	100	350	0.0	Mohales Hoek (Lesotho): No known returns	1000			1000		
D15H	13.59	100	350		No sewage returns	1000			1000		
D16A	64.9	100	350		No sewage returns	1000			1000		
D16B	83.82	100	350		No sewage returns	1000			1000		
D16C	49.9	100	350		No sewage returns	1000			1000		
D16D	94.72	100	350		No sewage returns	1000			1000		
D16E	76.65	100	350		No sewage returns	1000			1000		
D16F	77.96	100	350		No sewage returns	1000			1000		
D16G	71.09	100	350		No sewage returns	1000			1000		
D16H	49.04	100	350		No sewage returns	1000			1000		
D16J	73.52	100	350		No sewage returns	1000			1000		
D16K	62.5	100	350		No sewage returns	1000			1000		
D16L	62.08	100	350		No sewage returns	1000			1000		
D16M	64.12	100	350		No sewage returns	1000			1000		
D17A	165.2	100	350		No sewage returns	1000			1000		

WATER QUALITY DATA BASE

	Natural conditions:		Urban returns:			Strategic returns:			Other bulk user returns:		
Quaternary catchment	Virgin MAR ($10^6 m^3$) (oMARi)	Average TDS of natural runoff (oTSNi)	Increase in TDS as a result of urban use (oISUi)	Urban effluent returns ($10^6 m^3$)	TLC and river	Increase in TDS as a result of strategic industry use (oISSi)	Return flows by Strategic users ($10^6 m^3$)	Remark	Increase in TDS as a result of other bulk use (oISOi	Return flows by Other Bulk users ($10^6 m^3$)	Remark
D17B	114.1	100	350		No sewage returns	1000			1000		
D17C	95.43	100	350		No sewage returns	1000			1000		
D17D	138.2	100	350		No sewage returns	1000			1000		
D17E	118.8	100	350		No sewage returns	1000			1000		
D17F	59.51	100	350		No sewage returns	1000			1000		
D17G	92.05	100	350		No sewage returns	1000			1000		
D17H	85.97	100	350		No sewage returns	1000			1000		
D17J	84.26	100	350		No sewage returns	1000			1000		
D17K	42.94	100	350		No sewage returns	1000			1000		
D17L	56.73	100	350		No sewage returns	1000			1000		
D17M	55.39	100	350		No sewage returns	1000			1000		
D18A	88.57	100	350		No sewage returns	1000			1000		
D18B	36.54	100	350		No sewage returns	1000			1000		
D18C	43.99	100	350		No sewage returns	1000			1000		
D18D	102.4	100	350		No sewage returns	1000			1000		
D18E	50.92	100	350		No sewage returns	1000			1000		
D18F	40.06	100	350		No sewage returns	1000			1000		
D18G	79.02	100	350		No sewage returns	1000			1000		
D18H	46.14	100	350		No sewage returns	1000			1000		
D18J	102.5	100	350	0.0	Moyeni (Lesotho): No known returns	1000			1000		
D18K	135	100	350		No sewage returns	1000			1000		
D18L	59.2	100	350		No sewage returns	1000			1000		
Orange u/s Gariep key area:											
D12A	34.1	100	350		No sewage returns	1000			1000		
D12B	52.04	100	350		No sewage returns	1000			1000		
D12C	16.3	100	350	0.0	Greater Hershel TLC: No returns	1000			1000		
D12D	14.19	100	350	0.0	Zastron TLC: No returns	1000			1000		
D12E	26.27	100	350	0.0	Lady Grey TLC: No returns	1000			1000		
D12F	21.84	100	350		No sewage returns	1000			1000		
D13A	68.63	100	350		No sewage returns	1000			1000		
D13B	71.24	100	350	0.0	Rhodes TLC: No returns	1000			1000		
D13C	52.86	100	350		No sewage returns	1000			1000		
D13D	55.83	100	350	0.0	Barkly-East TLC: No returns	1000			1000		
D13E	124.7	100	350		No sewage returns	1000			1000		
D13F	93.36	100	350		No sewage returns	1000			1000		
D13G	51.1	100	350		No sewage returns	1000			1000		
D13H	28.8	100	350	0.0	Dordrecht TLC: No returns	1000			1000		
D13J	31.91	100	350	0.0	Jamestown TLC: Returns are re-used locally.	1000			1000		
D13K	48.65	100	350		No sewage returns	1000			1000		
D13L	24.42	100	350		No sewage returns	1000			1000		
D13M	17.07	100	350		No sewage returns	1000			1000		
D14A	21.17	91	350	0.0	Aliwal-North TLC: Returns are re-used locally.	1000			1000		
D14B	6.78	91	350		No sewage returns	1000			1000		
D14C	15.58	91	350	0.0	Molteno TLC: No returns	1000			1000		
D14D	9.92	91	350		No sewage returns	1000			1000		
D14E	8.69	91	350	0.0	Burgersdorp TLC: No returns	1000			1000		
D14F	12.02	91	350		No sewage returns	1000			1000		
D14G	16.45	91	350		No sewage returns	1000			1000		
D14H	12.51	91	350		No sewage returns	1000			1000		
D14J	9.32	91	350		No sewage returns	1000			1000		
D14K	10.63	91	350		No sewage returns	1000			1000		
Gariep key area:											
D35A	9.07	91	350		No sewage returns	1000			1000		
D35B	9.07	91	350		No sewage returns	1000			1000		
D35C	9.07	91	350		No sewage returns	1000			1000		
D35D	4.68	91	350		No sewage returns	1000			1000		

WATER QUALITY DATA BASE

	Natural conditions:		Urban returns:			Strategic returns:			Other bulk user returns:		
Quaternary catchment	Virgin MAR (10^6m^3) (oMARi)	Average TDS of natural runoff (oTSNi)	Increase in TDS as a result of urban use (oISUi)	Urban effluent returns (10^6m^3)	TLC and river	Increase in TDS as a result of strategic industry use (oISSi)	Return flows by Strategic users (10^6m^3)	Remark	Increase in TDS as a result of other bulk use (oISOi	Return flows by Other Bulk users (10^6m^3)	Remark
D35E	3.28	91	350		No sewage returns	1000			1000		
D35F	7.28	91	350	0.0	Springfontein TLC: No returns	1000			1000		
D35G	4.24	91	350	0.0	Venterstad TLC: No returns	1000			1000		
D35H	5.13	91	350	0.0	Bethulie TLC: No returns	1000			1000		
D35J	6.48	91	350		No sewage returns	1000			1000		
D35K	5.85	91	350	0.0	Verwoerddam TLC: No returns	1000	2376	Gariep Hydoele	1000		
Vanderkloof key area:											
D31A	12.82	222	350		No sewage returns	1000			1000		
D31B	4.3	222	350	0.0	Philipstown TLC: No returns	1000			1000		
D31C	3.47	222	350		No sewage returns	1000			1000		
D31D	10.08	222	350		No sewage returns	1000			1000		
D31E	6.71	222	350		No sewage returns	1000	2120	Vanderkloof Hydroelectricit	1000		
D32A	3.22	222	350		No sewage returns	1000			1000		
D32B	3.66	222	350		No sewage returns	1000			1000		
D32C	3.92	222	350		No sewage returns	1000			1000		
D32D	3.74	222	350		No sewage returns	1000			1000		
D32E	3.04	222	350		No sewage returns	1000			1000		
D32F	5.78	222	350	0.0	Hanover TLC: No returns	1000			1000		
D32G	5.66	222	350	0.0	Noupoort TLC: Negligible returns	1000			1000		
D32H	3.02	222	350		No sewage returns	1000			1000		
D32J	5.06	222	350		No sewage returns	1000			1000		
D32K	4.16	222	350		No sewage returns	1000			1000		
D34A	8.5	222	350	0.0	Norvalspont TLC: No returns	1000			1000		
D34B	5.64	222	350		No sewage returns	1000			1000		
D34C	4.91	222	350		No sewage returns	1000			1000		
D34D	4.17	222	350		No sewage returns	1000			1000		
D34E	4.29	222	350		No sewage returns	1000			1000		
D34F	4.19	222	350	0.0	Colesberg TLC: No returns	1000			1000		
D34G	8.58	222	350	0.0	Phillipolis TLC: No returns	1000			1000		
Orange d/s Vanderkloof key area:											
D33A	1.84	222	350	0.0	Petrusville TLC: No returns	1000			1000		
D33B	2.56	222	350		No sewage returns	1000			1000		
D33C	2.5	222	350	0.0	Luckoff TLC: No returns [endoreic area]	1000			1000		
D33D	1.95	222	350		No sewage returns	1000			1000		
D33E	3.53	222	350		No sewage returns	1000			1000		
D33F	1.53	222	350		No sewage returns	1000			1000		
D33G	2.39	222	350	0.0	Hopetown TLC: No returns	1000			1000		
D33H	2.13	222	350		No sewage returns	1000			1000		
D33J	1.22	222	350		No sewage returns	1000			1000		
D33K	0.85	222	350		No sewage returns	1000			1000		

WATER QUALITY DATA BASE

	Mining returns:				Rural returns:		Other data:	
Quaternary catchment	TDS concentration in groundwater discharge (oTFMi)	Increase in TDS as a result of mining water use (oISMi)	Mine Groundwater decant/dewatering ($10^6 m^3$) (oBMGi)	Remark	Increase in TDS as a result of rural water use	Return flows rural Bulk users ($10^6 m^3$)	Ratio between salt load in return flow to load in water supply (oPSIi)	Reservoir spill TDS/supply TDS (oPSPi)
Modder Riet sub-catchment:								
Kalkfontein key area:								
C51A	3000	1000	0	No known mining returns	150	0.0	0.45	0.83
C51B					150	0.0	0.45	0.83
C51C					150	0.0	0.45	0.83
C51D					150	0.0	0.45	0.64
C51E					150	0.0	0.45	0.83
C51F					150	0.0	0.4	0.83
C51G					150	0.0	0.4	0.83
C51H					150	0.0	0.4	0.83
C51J					150	0.0	0.4	0.83
Riet key area:								
C51K					150	0.0	0.3	0.42
Riet / Modder confluence key area:								
C51L					150	0.0	0.35	0.42
C51M					150	0.0	0.3	0.42
C52H					150	0.0	0.35	0.35
C52J					150	0.0	0.35	0.35
C52K					150	0.0	0.35	0.35
C52L					150	0.0	0.35	0.35
Rustfontein key area:								
C52A					150	0.0	0.45	0.69
Krugersdrift key area:								
C52B					150	0.0	0.45	0.8
C52C					150	0.0	0.45	0.68
C52D					150	0.0	0.45	0.68
C52E					150	0.0	0.45	0.77
C52F					150	0.0	0.45	0.77
C52G					150	0.0	0.45	0.77
Caledon sub-area:								
Caledon key area (RSA & Lesotho):								
D21A					150	0.0	0.2	0.95
D21B					150	0.0	0.2	0.95
D21C					150	0.0	0.2	0.95
D21D					150	0.0	0.2	0.95
D21E					150	0.0	0.2	0.95
D21F					150	0.0	0.2	0.95
D21G					150	0.0	0.2	0.95
D21H					150	0.0	0.2	0.95
D21J					150	0.0	0.2	0.95
D21K					150	0.0	0.2	0.95
D21L					150	0.0	0.2	0.95
D22A					150	0.0	0.2	0.95
D22B					150	0.0	0.2	0.95
D22C					150	0.0	0.2	0.95
D22D					150	0.0	0.2	0.95
D22E					150	0.0	0.2	0.95
D22F					150	0.0	0.2	0.95
D22G					150	0.0	0.2	0.95
D22H					150	0.0	0.2	0.95
D22J					150	0.0	0.2	0.95

WATER QUALITY DATA BASE								
	Mining returns:				Rural returns:		Other data:	
Quaternary catchment	TDS concentration in groundwater discharge (oTFMi)	Increase in TDS as a result of mining water use (oISMi)	Mine Groundwater decant/dewatering (10^6m^3) (oBMGi)	Remark	Increase in TDS as a result of rural water use	Return flows rural Bulk users (10^6m^3)	Ratio between salt load in return flow to load in water supply (oPSIi)	Reservoir spill TDS/supply TDS (oPSPi)
D22K					150	0.0	0.2	0.95
D22L					150	0.0	0.2	0.95
Welbedacht key area (RSA & Lesotho):								
D23A					150	0.0	0.2	0.95
D23B					150	0.0	0.2	0.95
D23C					150	0.0	0.2	0.95
D23D					150	0.0	0.2	0.95
D23E					150	0.0	0.2	0.95
D23F					150	0.0	0.2	0.95
D23G					150	0.0	0.2	0.95
D23H					150	0.0	0.2	0.95
D23J					150	0.0	0.2	0.95
D24A					150	0.0	0.2	0.97
D24B					150	0.0	0.2	0.97
D24C					150	0.0	0.2	0.97
Orange d/s Welbedacht key area:								
D24D					150	0.0	0.2	0.97
D24E					150	0.0	0.2	0.97
D24F					150	0.0	0.2	0.97
D24G					150	0.0	0.2	0.97
D24H					150	0.0	0.2	0.97
D24J					150	0.0	0.2	0.97
D24K					150	0.0	0.2	0.97
D24L					150	0.0	0.2	0.97
Upper Orange sub-area:								
Katse key area:								
D11A					150	0.0	0.2	0.97
D11B					150	0.0	0.2	0.97
D11C					150	0.0	0.2	0.97
D11D					150	0.0	0.2	0.97
D11E					150	0.0	0.2	0.97
D11F					150	0.0	0.2	0.97
D11G					150	0.0	0.2	0.97
D11H					150	0.0	0.2	0.97
D11J					150	0.0	0.2	0.97
D11K					150	0.0	0.2	0.97
Senqu key area:								
D15A					150	0.0	0.2	0.97
D15B					150	0.0	0.2	0.97
D15C					150	0.0	0.2	0.97
D15D					150	0.0	0.2	0.97
D15E					150	0.0	0.2	0.97
D15F					150	0.0	0.2	0.97
D15G					150	0.0	0.2	0.97
D15H					150	0.0	0.2	0.97
D16A					150	0.0	0.2	0.97
D16B					150	0.0	0.2	0.97
D16C					150	0.0	0.2	0.97
D16D					150	0.0	0.2	0.97
D16E					150	0.0	0.2	0.97
D16F					150	0.0	0.2	0.97
D16G					150	0.0	0.2	0.97
D16H					150	0.0	0.2	0.97

WATER QUALITY DATA BASE

	Mining returns:				Rural returns:		Other data:	
Quaternary catchment	TDS concentration in groundwater discharge (oTFMi)	Increase in TDS as a result of mining water use (oISMi)	Mine Groundwater decant/dewatering ($10^6 m^3$) (oBMGi)	Remark	Increase in TDS as a result of rural water use	Return flows rural Bulk users ($10^6 m^3$)	Ratio between salt load in return flow to load in water supply (oPSIi)	Reservoir spill TDS/supply TDS (oPSPi)
D16J					150	0.0	0.2	0.97
D16K					150	0.0	0.2	0.97
D16L					150	0.0	0.2	0.97
D16M					150	0.0	0.2	0.97
D17A					150	0.0	0.2	0.97
D17B					150	0.0	0.2	0.97
D17C					150	0.0	0.2	0.97
D17D					150	0.0	0.2	0.97
D17E					150	0.0	0.2	0.97
D17F					150	0.0	0.2	0.97
D17G					150	0.0	0.2	0.97
D17H					150	0.0	0.2	0.97
D17J					150	0.0	0.2	0.97
D17K					150	0.0	0.2	0.97
D17L					150	0.0	0.2	0.97
D17M					150	0.0	0.2	0.97
D18A					150	0.0	0.2	0.97
D18B					150	0.0	0.2	0.97
D18C					150	0.0	0.2	0.97
D18D					150	0.0	0.2	0.97
D18E					150	0.0	0.2	0.97
D18F					150	0.0	0.2	0.97
D18G					150	0.0	0.2	0.97
D18H					150	0.0	0.2	0.97
D18J					150	0.0	0.2	0.97
D18K					150	0.0	0.2	0.97
D18L					150	0.0	0.2	0.97
Orange u/s Gariep key area:								
D12A					150	0.0	0.2	0.97
D12B					150	0.0	0.2	0.97
D12C					150	0.0	0.2	0.97
D12D					150	0.0	0.2	0.97
D12E					150	0.0	0.2	0.97
D12F					150	0.0	0.2	0.97
D13A					150	0.0	0.2	0.97
D13B					150	0.0	0.2	0.97
D13C					150	0.0	0.2	0.97
D13D					150	0.0	0.2	0.97
D13E					150	0.0	0.2	0.97
D13F					150	0.0	0.2	0.97
D13G					150	0.0	0.2	0.97
D13H					150	0.0	0.2	0.97
D13J					150	0.0	0.2	0.97
D13K					150	0.0	0.2	0.97
D13L					150	0.0	0.2	0.97
D13M					150	0.0	0.2	0.97
D14A					150	0.0	0.2	0.97
D14B					150	0.0	0.2	0.97
D14C					150	0.0	0.2	0.97
D14D					150	0.0	0.2	0.97
D14E					150	0.0	0.2	0.97
D14F					150	0.0	0.2	0.97
D14G					150	0.0	0.2	0.97

WATER QUALITY DATA BASE

	Mining returns:				Rural returns:		Other data:	
Quaternary catchment	TDS concentration in groundwater discharge (oTFMi)	Increase in TDS as a result of mining water use (oISMi)	Mine Groundwater decant/dewatering ($10^6 m^3$) (oBMGi)	Remark	Increase in TDS as a result of rural water use	Return flows rural Bulk users ($10^6 m^3$)	Ratio between salt load in return flow to load in water supply (oPSIi)	Reservoir spill TDS/supply TDS (oPSPi)
D14H					150	0.0	0.2	0.97
D14J					150	0.0	0.2	0.97
D14K					150	0.0	0.2	0.97
Gariep key area:								
D35A					150	0.0	0.2	0.97
D35B					150	0.0	0.2	0.97
D35C					150	0.0	0.2	0.97
D35D					150	0.0	0.2	0.97
D35E					150	0.0	0.2	0.97
D35F					150	0.0	0.2	0.97
D35G					150	0.0	0.2	0.97
D35H					150	0.0	0.2	0.97
D35J					150	0.0	0.2	0.97
D35K					150	0.0	0.2	0.97
Vanderkloof key area:								
D31A					150	0.0	0.2	0.95
D31B					150	0.0	0.2	0.95
D31C					150	0.0	0.2	0.95
D31D					150	0.0	0.2	0.95
D31E					150	0.0	0.2	0.95
D32A					150	0.0	0.2	0.95
D32B					150	0.0	0.2	0.95
D32C					150	0.0	0.2	0.95
D32D					150	0.0	0.2	0.95
D32E					150	0.0	0.2	0.95
D32F					150	0.0	0.2	0.95
D32G					150	0.0	0.2	0.95
D32H					150	0.0	0.2	0.95
D32J					150	0.0	0.2	0.95
D32K					150	0.0	0.2	0.95
D34A					150	0.0	0.2	0.95
D34B					150	0.0	0.2	0.95
D34C					150	0.0	0.2	0.95
D34D					150	0.0	0.2	0.95
D34E					150	0.0	0.2	0.95
D34F					150	0.0	0.2	0.95
D34G					150	0.0	0.2	0.95
Orange d/s Vanderkloof key area:								
D33A					150	0.0	0.2	0.95
D33B					150	0.0	0.2	0.95
D33C					150	0.0	0.2	0.95
D33D					150	0.0	0.2	0.95
D33E					150	0.0	0.2	0.95
D33F					150	0.0	0.2	0.95
D33G					150	0.0	0.2	0.95
D33H					150	0.0	0.2	0.95
D33J					150	0.0	0.2	0.95
D33K					150	0.0	0.2	0.95

WATER QUALITY DATA BASE								
	Mining returns:				**Rural returns:**		**Other data:**	
Quaternary catchment	**TDS concentration in groundwater discharge (oTFMi)**	**Increase in TDS as a result of mining water use (oISMi)**	**Mine Groundwater decant/dewatering ($10^6 m^3$) (oBMGi)**	**Remark**	**Increase in TDS as a result of rural water use**	**Return flows rural Bulk users ($10^6 m^3$)**	**Ratio between salt load in return flow to load in water supply (oPSIi)**	**Reservoir spill TDS/supply TDS (oPSPi)**
LOWER VAAL DATA								
C31A					**150**		**0.5**	**0.33**
C31B					**150**		**0.5**	**0.33**
C31C					**150**		**0.5**	**0.33**

WATER QUALITY DATA BASE

	Mining returns:				Rural returns:		Other data:	
Quaternary catchment	TDS concentration in groundwater discharge (oTFMi)	Increase in TDS as a result of mining water use (oISMi)	Mine Groundwater decant/dewatering ($10^6 m^3$) (oBMGi)	Remark	Increase in TDS as a result of rural water use	Return flows rural Bulk users ($10^6 m^3$)	Ratio between salt load in return flow to load in water supply (oPSIi)	Reservoir spill TDS/supply TDS (oPSPi)
C31F					150		0.5	0.44
C32A					150		0.45	0.28
C32B					150		0.45	0.28
C32C					150		0.45	0.28
C32D					150		0.45	0.28
C33A					150		0.45	0.28
C33B					150		0.45	0.28
C33C					150		0.45	0.28
C91A					150		0.79	0.73
C91A*					150		0	0.73
C91B					150		0.79	0.73
C91C					150		0.76	0.73
C91D					150		0.76	0.73
C91E					150		0.62	0.73
C92A					150		0.62	0.73
C92B					150		0.62	0.73
C92C					150		0.62	0.73

APPENDIX H

SUPPLEMENTARY INFORMATION

APPENDIX H.1

Data type	Responsible organisation
Afforestation	CSIR
Alien vegetation	CSIR
Industrial, urban and strategic water use	WRSA consultants
Ground Water	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 Evapotraspiration and crop factors	 WRSA consultant WRSA consultant WRP
Storage-draft-frequency curves	WRP

APPENDIX H.2

Default values used in the WRSA reports.

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
fiIPMi	Irrigation efficiency – Medium category irrigation (factor)	0.75
fiIPHi	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

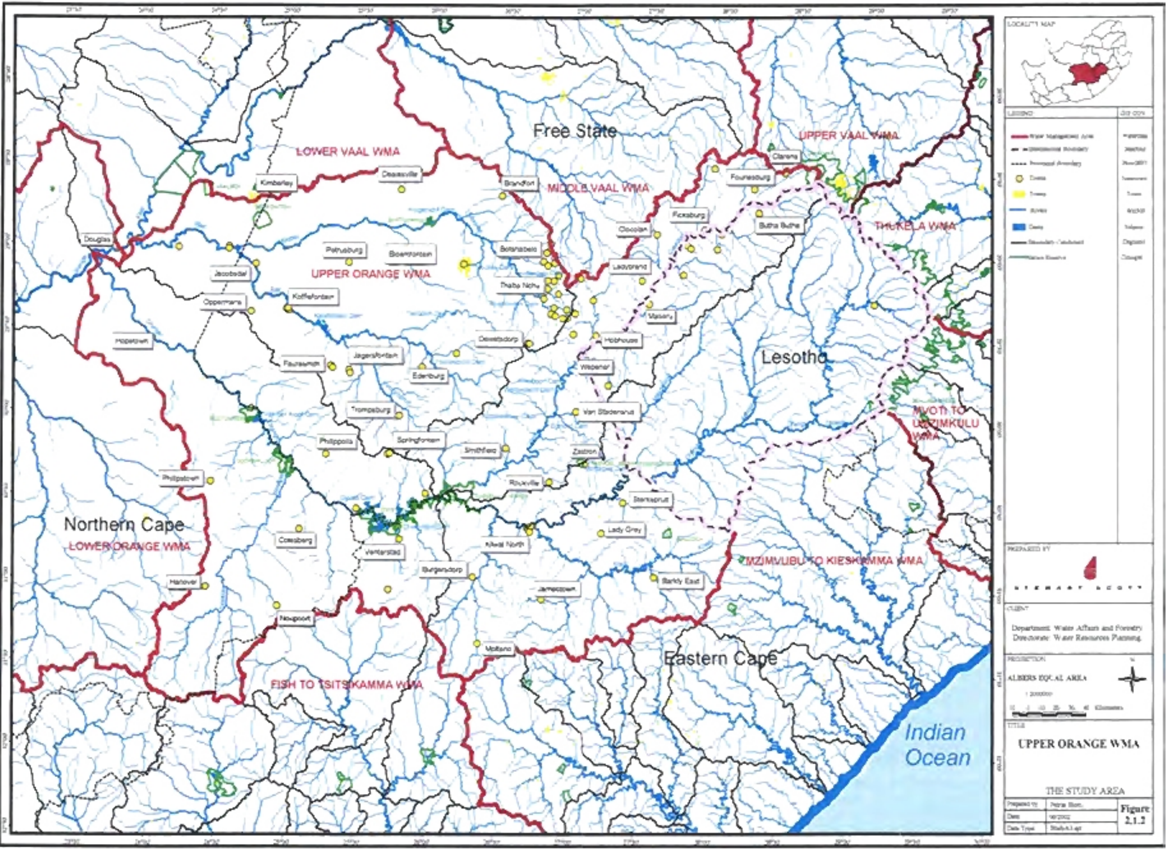
Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D21C	212	212	6	9	335	71020	0.0712	0.2287	422	89381	0.0896	0.2878
D21D	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

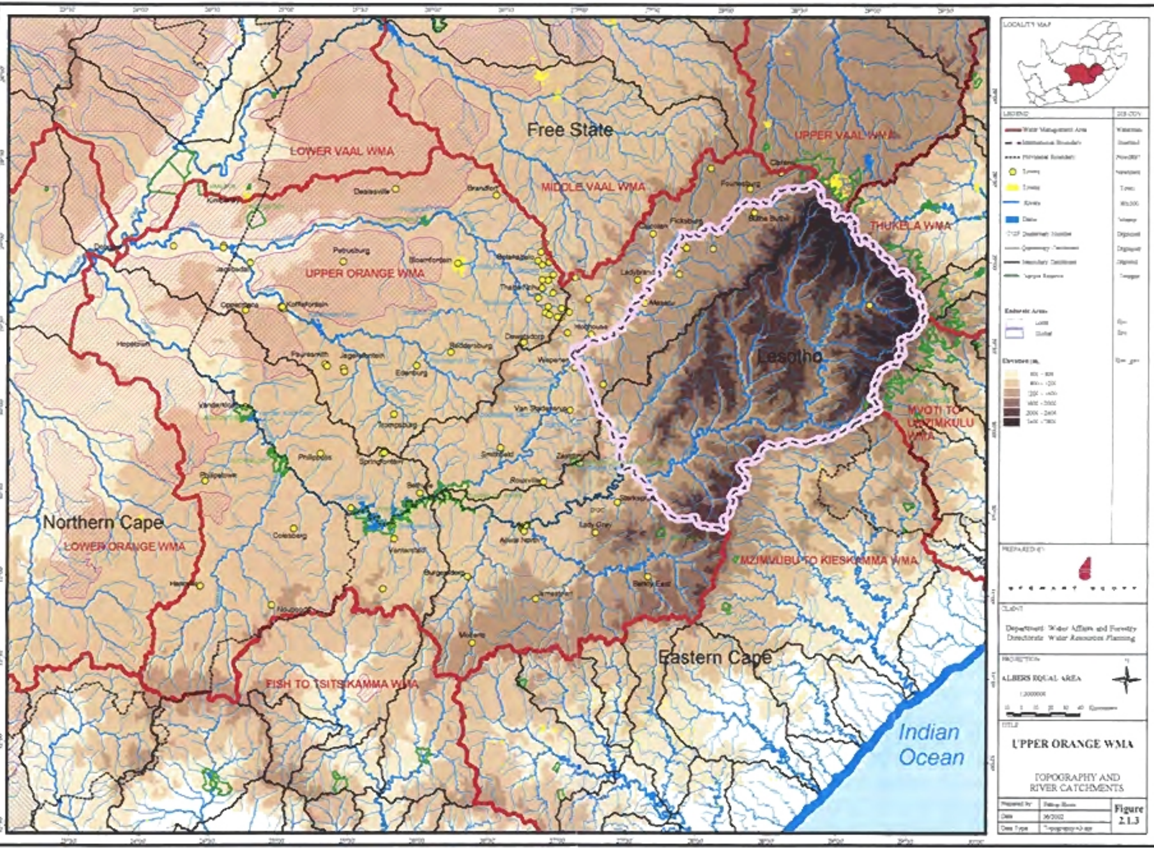
Quat. Number	Gross area (km2)	Net area (km2)	Sediment region	Erodibility index	Sediment (t/km2/a)	Sediment yield (t/a)	Sediment vol(MCM)	Volume (%MAR)	*Sediment (t/km2/a)*	*Sediment yield (t/a)*	*Sediment vol(MCM)*	*Volume (%MAR)*
D33C	805	520	5	12	30	15600	0.0156	0.9679	38	19633	0.0197	1.2182
D33D	952	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**

FIGURES


BOTSWANA
NAMIBIA
LIMPOPO
Northern Province
CROCODILE(WEST) AND MARICO
OLIFANTS
Mpumalanga
Gauteng
LOWER VAAL
North West
MIDDLE VAAL
UPPER VAAL
Free State
THUKELA
Kwazulu Natal
LESOTHO
MVOTI TO UMZIMKULU
LOWER ORANGE
Northern Cape
UPPER ORANGE
MZIMVUBU TO KIESKAMMA
Eastern Cape
FISH TO TSIT'SIKAMMA
GOURITZ
Western Cape
BERG
OLIFANTS/DOORN
Atlantic Ocean
Indian Ocean
Kuruman
Christiana
Kroonstad
Welkom
Bethlehem
Upington
Douglas
Bloemfontein
Springbok
Prieska
Fauresmith
De Aar
Victoria West
Sutherland
LOCALITY MAP
BASE MAP LEGEND
PREPARED BY
STEWART SCOTT
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
N
TITLE
UPPER ORANGE WMA
ORANGE RIVER WATERCOURSE
Prepared by
Date
06/2002
Data Type
Figure 2.1.1



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Lesotho
MVOTI TO UMZIMKULU WMA
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Kimberley
Dealesville
Brandfort
Clarens
Fouriesburg
Ficksburg
Clocolan
Butha Buthe
Douglas
Petrusburg
Bloemfontein
Botshabelo
Ladybrand
Jacobsdal
Thaba Nchu
Koffiefontein
Oppermans
Hopetown
Dewetsdorp
Hobhouse
Jagersfontein
Fauresmith
Edenburg
Wepener
Trompsburg
Van Stadensrus
Philippolis
Springfontein
Smithfield
Zastron
Philipstown
Rouxville
Sterkspruit
Colesberg
Venterstad
Aliwal North
Lady Grey
Burgersdorp
Hanover
Jamestown
Barkly East
Noupoort
Molteno
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
THE STUDY AREA
Figure 2.1.2



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
THUKELA WMA
UPPER ORANGE WMA
Lesotho
MVOTI TO
WMA
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KIESKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
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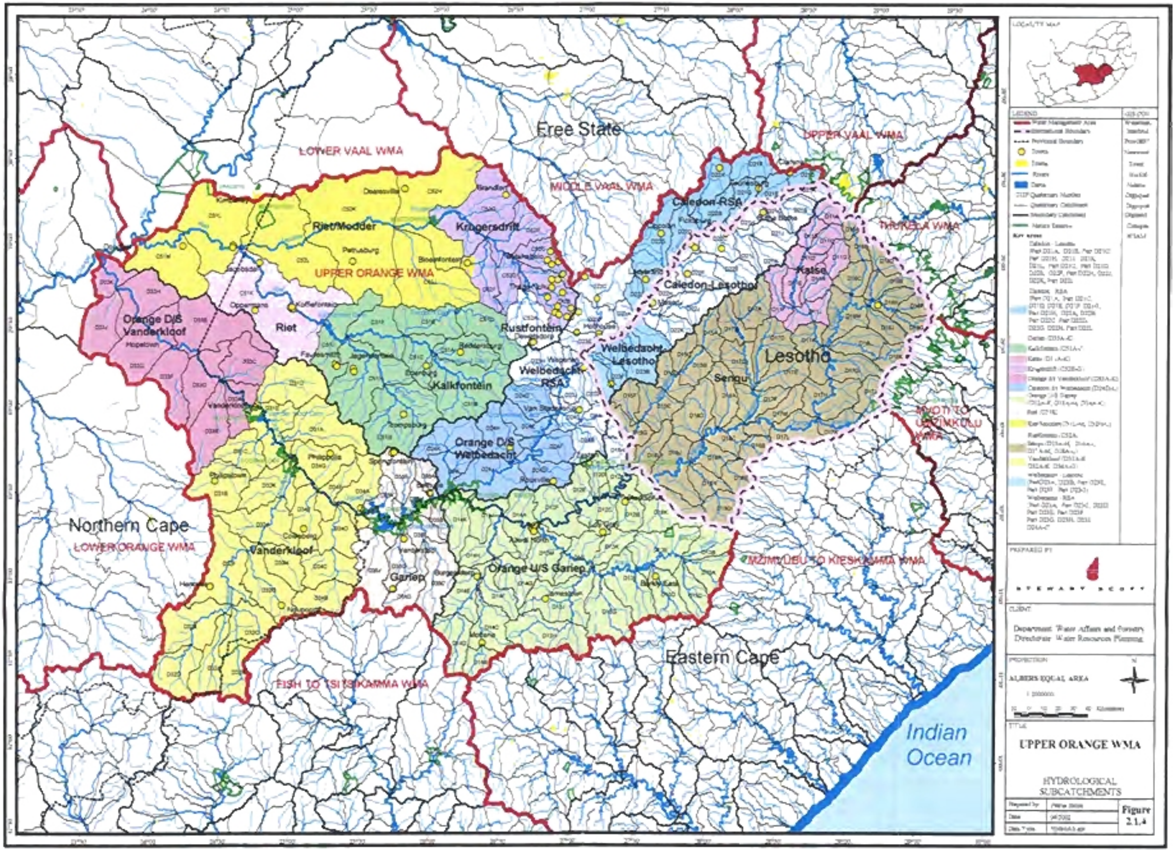
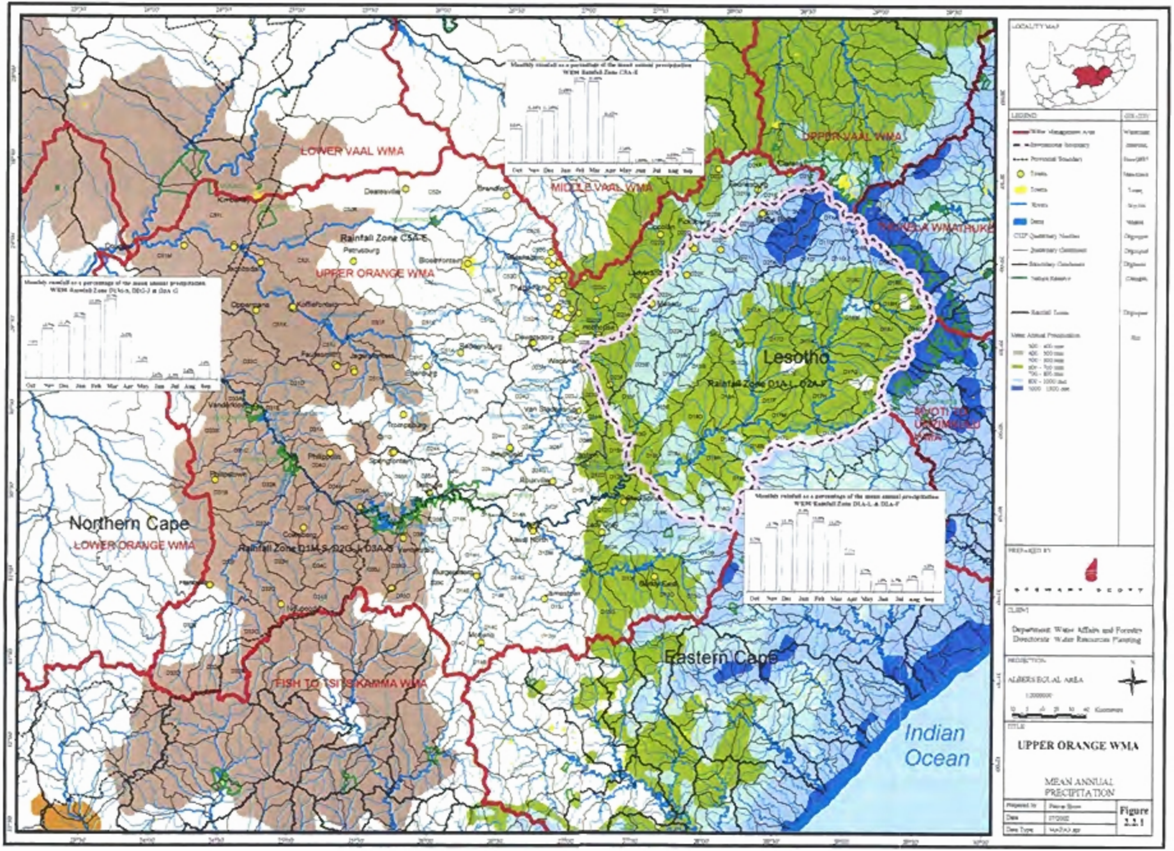
Brandfort
Petrusburg
Bloemfontein
Koffiefontein
Fauresmith
Jagersfontein
Edenburg
Reddersburg
Dewetsdorp
Wepener
Hobhouse
Ladybrand
Ficksburg
Fouriesburg
Clocolan
Butha Buthe
Maseru
Van Stadensrus
Trompsburg
Philippolis
Springfontein
Smithfield
Zastron
Rouxville
Bethulie
Colesberg
Venterstad
Burgersdorp
Aliwal North
Lady Grey
Sterkspruit
Barkly East
Jamestown
Molteno
Noupoort
Hopetown
Philipstown
Hanover
Vanderkloof
Douglas
Jacobsdal
LOCALITY MAP
LEGEND
PREPARED BY
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
UPPER ORANGE WMA
TOPOGRAPHY AND
RIVER CATCHMENTS
Figure
2.1.3


Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
THUKELA WMA
UPPER ORANGE WMA
Riet/Modder
Krugersdrift
Caledon-RSA
Caledon-Lesotho
Katse
Lesotho
Senqu
Orange D/S Vanderkloof
Riet
Rustfontein
Welbedacht Lesotho
Welbedacht RSA
Kalkfontein
Orange D/S Welbedacht
Northern Cape
LOWER ORANGE WMA
Vanderkloof
Gariep
Orange U/S Gariep
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Bloemfontein
Petrusburg
Hopetown
Philippolis
Colesberg
Aliwal North
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
HYDROLOGICAL SUBCATCHMENTS
Figure 2.1.4



LOCALITY MAP
LEGEND
Monthly rainfall as a percentage of the mean annual precipitation
WR90 Rainfall Zone C5A-E
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
LOWER VAAL WMA
UPPER VAAL WMA
MIDDLE VAAL WMA
UPPER ORANGE WMA
Rainfall Zone C5A-E
Petrusburg
Bloemfontein
Koffiefontein
Jagersfontein
Fauresmith
Philippolis
Springfontein
Colesberg
Aliwal North
Burgersdorp
Lesotho
Rainfall Zone D1A-L, D2A-F
Northern Cape
LOWER ORANGE WMA
Rainfall Zone D1M-S, D2G-J, D3A-G
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
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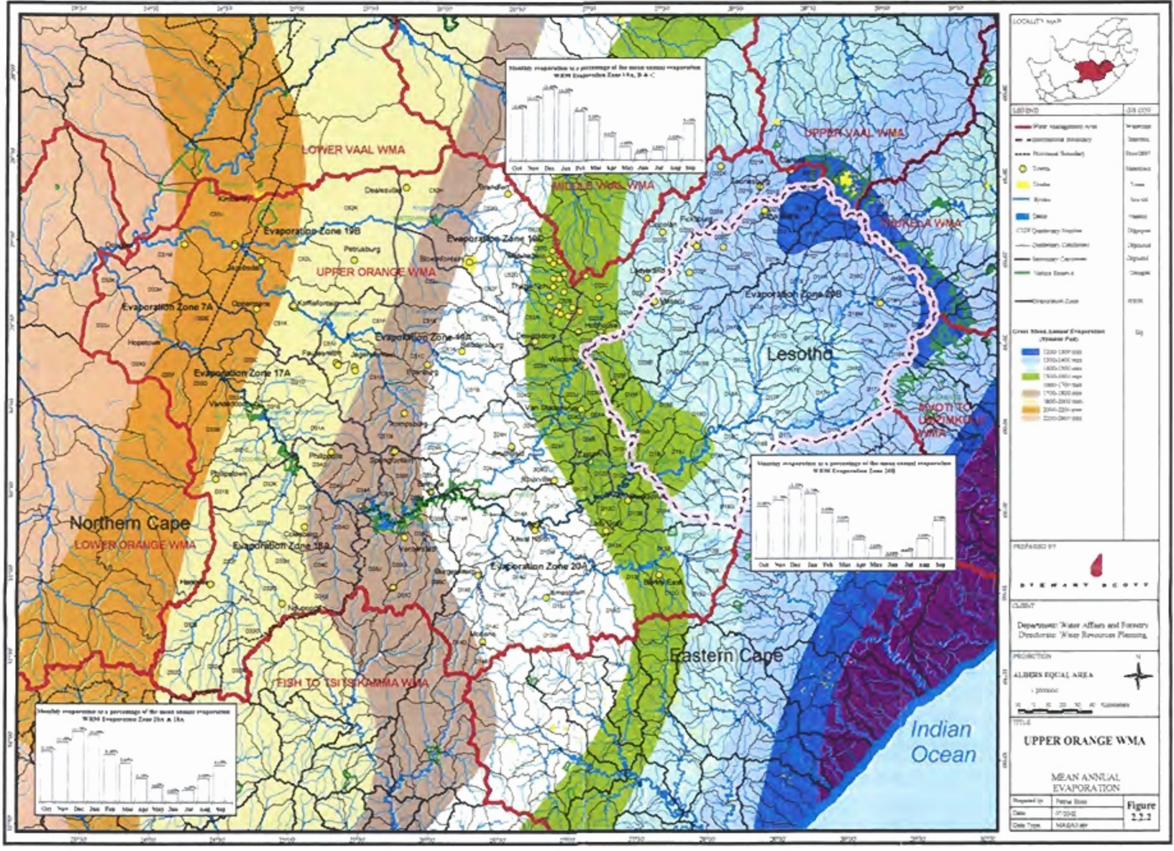
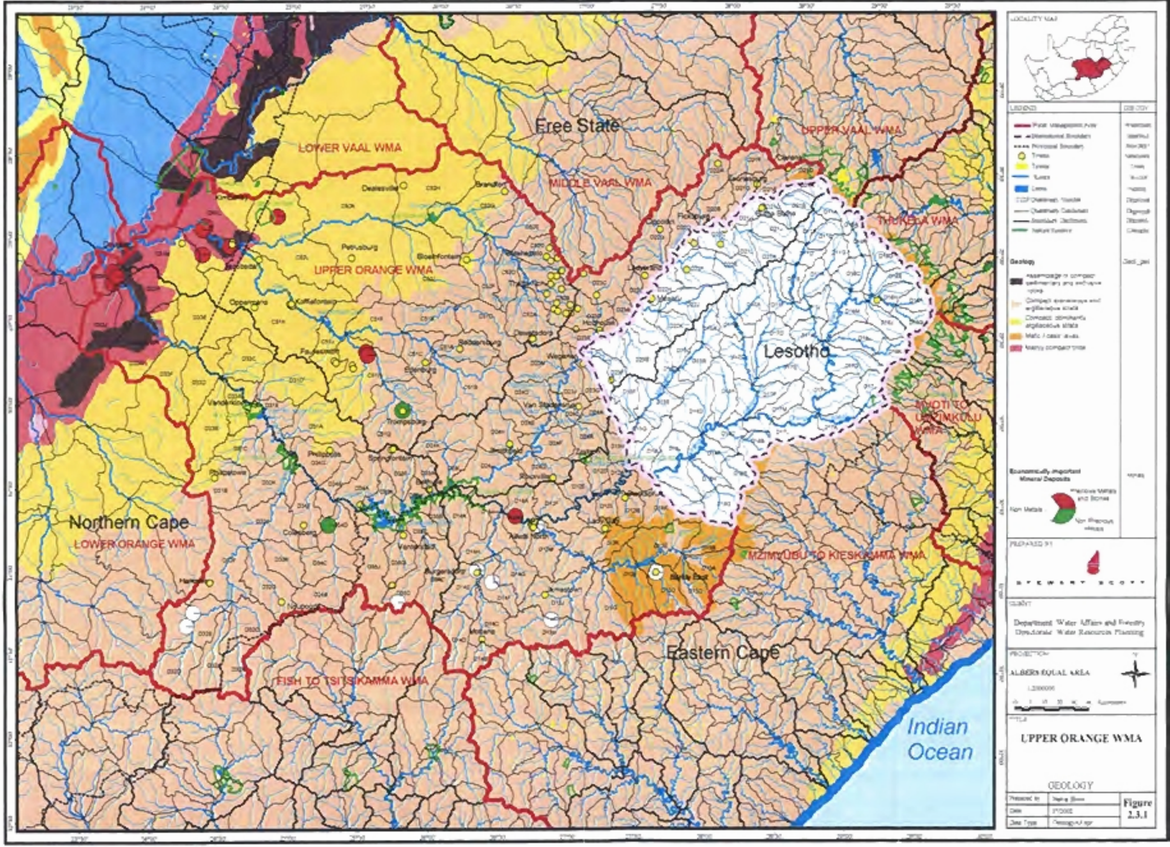
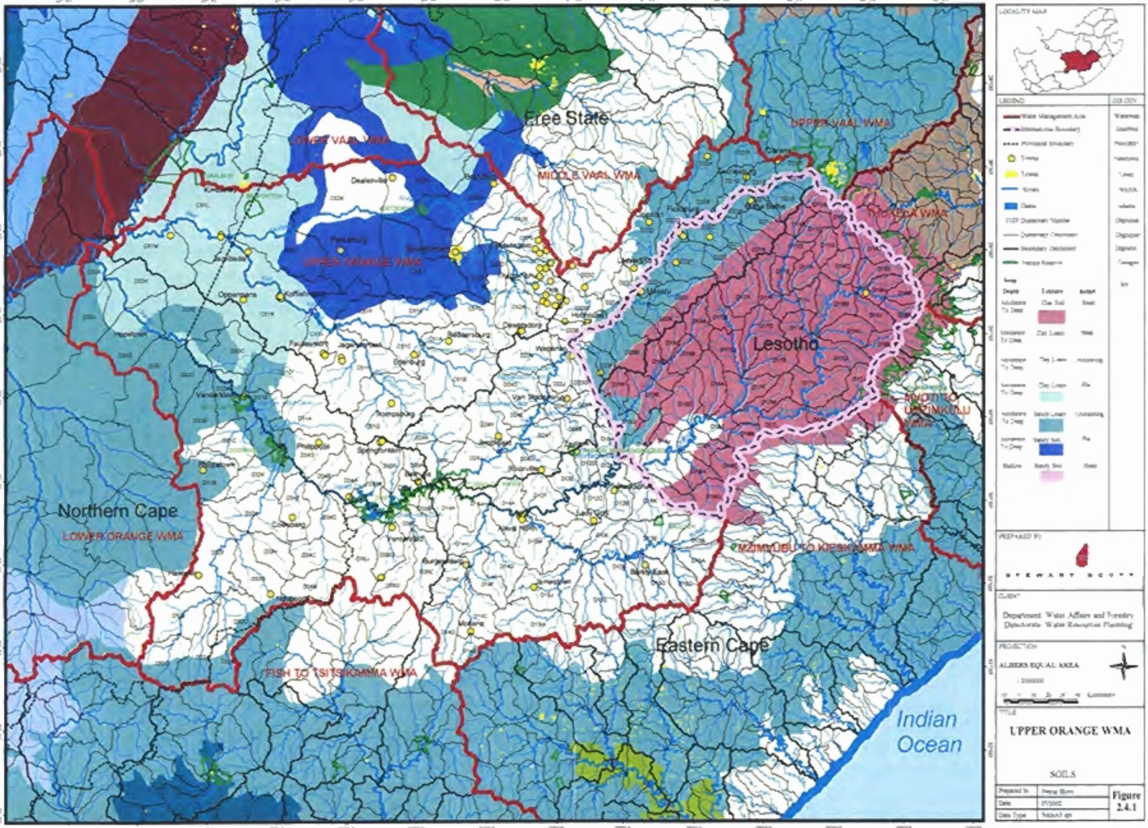
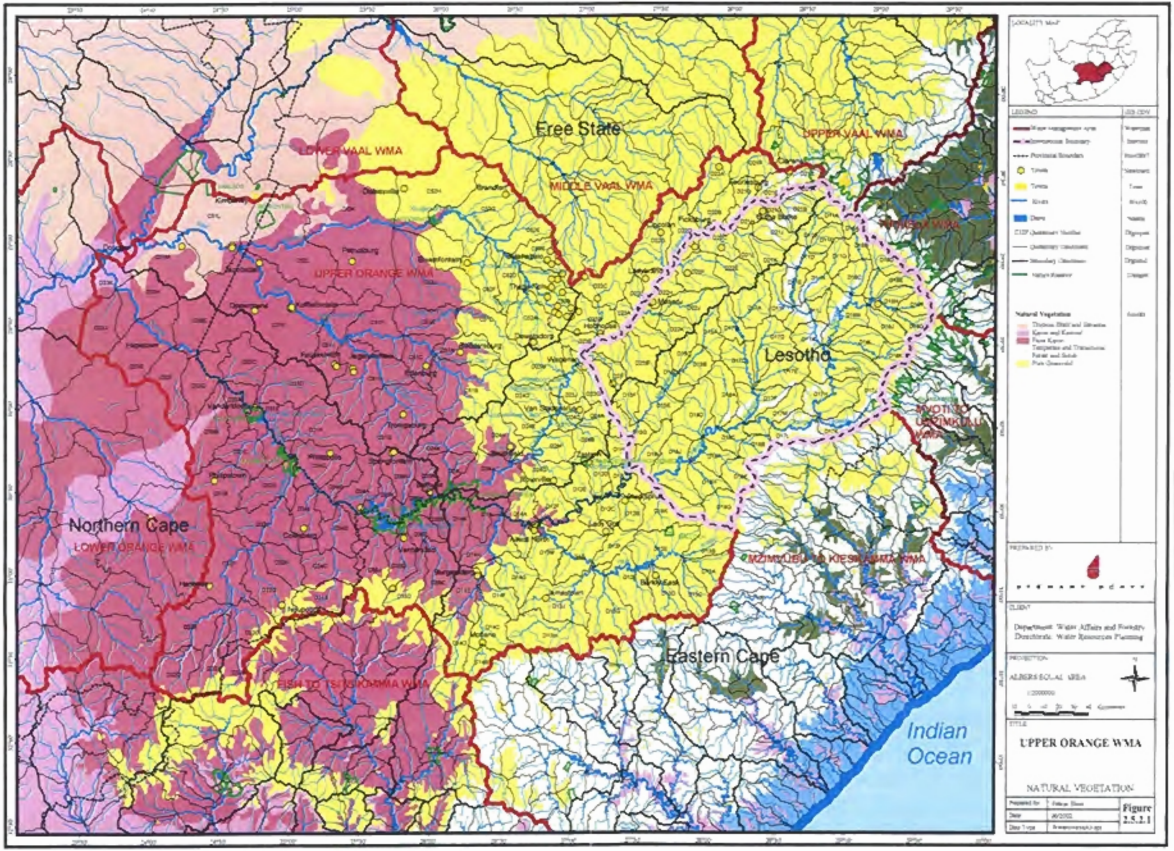
PROJECTION
ALBERS EQUAL AREA
UPPER ORANGE WMA
MEAN ANNUAL PRECIPITATION
Figure 2.2.1

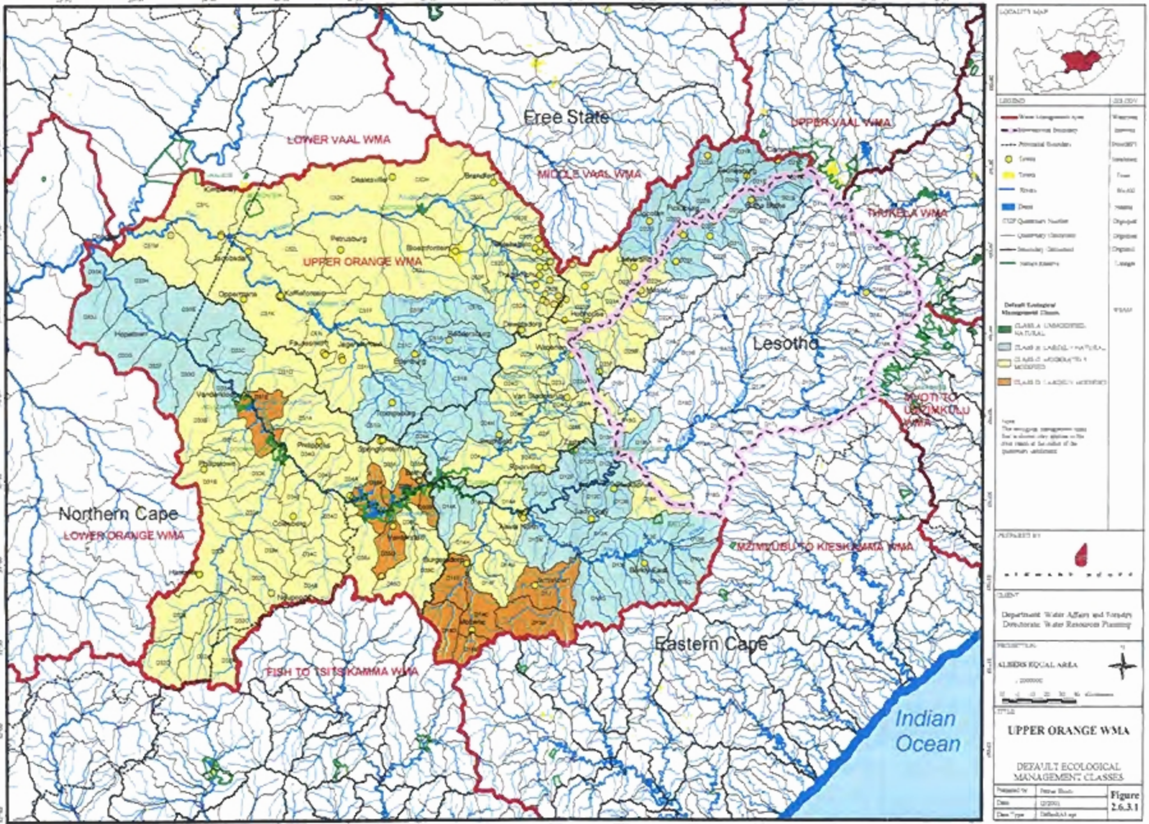

LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
LOWER ORANGE WMA
FISH TO TSITSIKAMMA WMA
Evaporation Zone 19B
Evaporation Zone 19D
Evaporation Zone 7A
Evaporation Zone 18A
Evaporation Zone 17A
Evaporation Zone 18B
Evaporation Zone 20A
Evaporation Zone 20B
Lesotho
Northern Cape
Eastern Cape
Indian Ocean
Kimberley
Petrusburg
Bloemfontein
Dealesville
Hopetown
Philippolis
Colesberg
Hanover
Noupoort
Molteno
Barkly East
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
LEGEND
PREPARED BY
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
UPPER ORANGE WMA
MEAN ANNUAL
EVAPORATION
Figure
2.2.2


Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
THUKELA WMA
UPPER ORANGE WMA
Lesotho
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KIESKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Bloemfontein
Petrusburg
Dealesville
Trompsburg
Geology
Economically important Mineral Deposits
Non Metals
STEWART SCOTT
Department Water Affairs and Forestry
Directorate Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
GEOLOGY
Figure 2.3.1

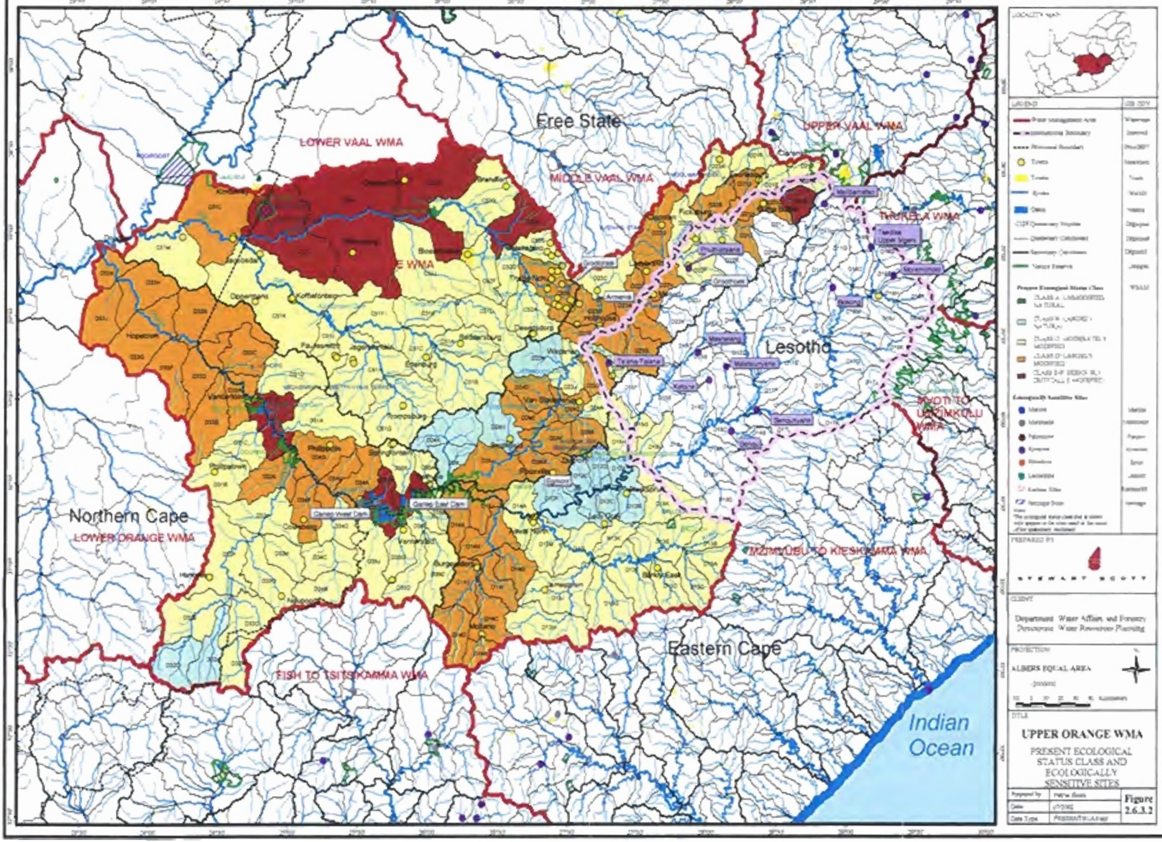

Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Lesotho
MVOTI TO UMZIMKULU WMA
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
LOCALITY MAP
LEGEND
PREPARED BY:
STEWART SCOTT
CLIENT:
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION:
ALBERS EQUAL AREA
UPPER ORANGE WMA
SOILS
Figure 2.4.1



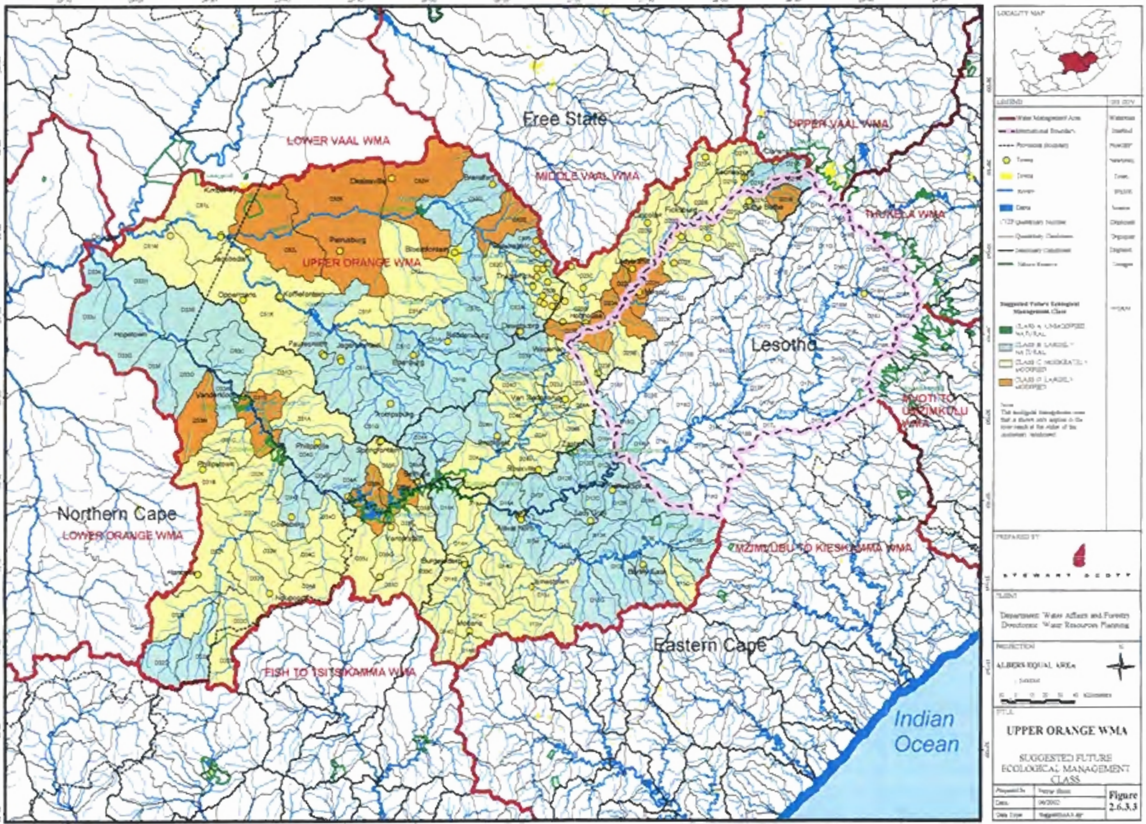
Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
Lesotho
Northern Cape
LOWER ORANGE WMA
FISH TO TSITSIKAMMA WMA
MZIMVUBU TO KEISKAMMA WMA
Eastern Cape
Indian Ocean
Natural Vegetation
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
UPPER ORANGE WMA
NATURAL VEGETATION
Figure 2.5.2.1



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
THUKELA WMA
UPPER ORANGE WMA
Petrusburg
Bloemfontein
Lesotho
MVOTI TO UMZIMKULU WMA
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KIESKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
DEFAULT ECOLOGICAL MANAGEMENT CLASSES
Figure 2.6.3.1



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
THUKELA WMA
Lesotho
MVOTI TO UMZIMKULU WMA
MZIMVUBU TO KEISKAMMA WMA
Eastern Cape
Indian Ocean
FISH TO TSITSIKAMMA WMA
Northern Cape
LOWER ORANGE WMA
Gariep West Dam
Gariep East Dam
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
PRESENT ECOLOGICAL STATUS CLASS AND ECOLOGICALLY SENSITIVE SITES
Figure 2.6.3.2



Free State
LOWER VAAL WMA
UPPER VAAL WMA
MIDDLE VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
Eastern Cape
FISH TO TSITSIKAMMA WMA
Indian Ocean
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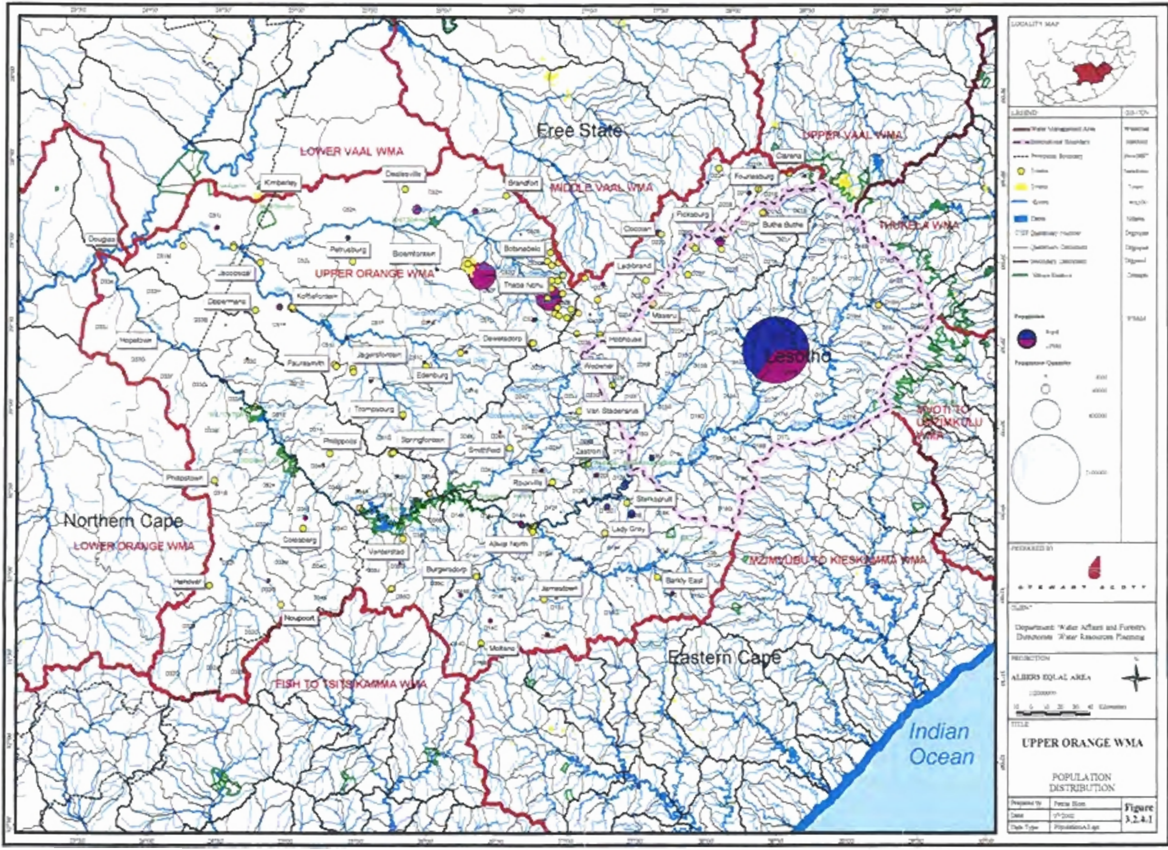
ALBERS EQUAL AREA
UPPER ORANGE WMA
SUGGESTED FUTURE
ECOLOGICAL MANAGEMENT
CLASS
Figure
2.6.3.3



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
MVOTI TO UMZIMKULU WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
LOWER ORANGE WMA
Northern Cape
Eastern Cape
Lesotho
Indian Ocean
Kimberley
Dealesville
Brandfort
Clarens
Fouriesburg
Ficksburg
Clocolan
Butha Buthe
Douglas
Petrusburg
Bloemfontein
Botshabelo
Ladybrand
Jacobsdal
Thaba Nchu
Koffiefontein
Oppermans
Maseru
Dewetsdorp
Hobhouse
Hopetown
Fauresmith
Jagersfontein
Edenburg
Wepener
Van Stadensrus
Trompsburg
Philippolis
Springfontein
Smithfield
Zastron
Philipstown
Rouxville
Sterkspruit
Colesberg
Venterstad
Aliwal North
Lady Grey
Burgersdorp
Jamestown
Barkly East
Hanover
Noupoort
Molteno
LOCALITY MAP
LEGEND
PREPARED BY
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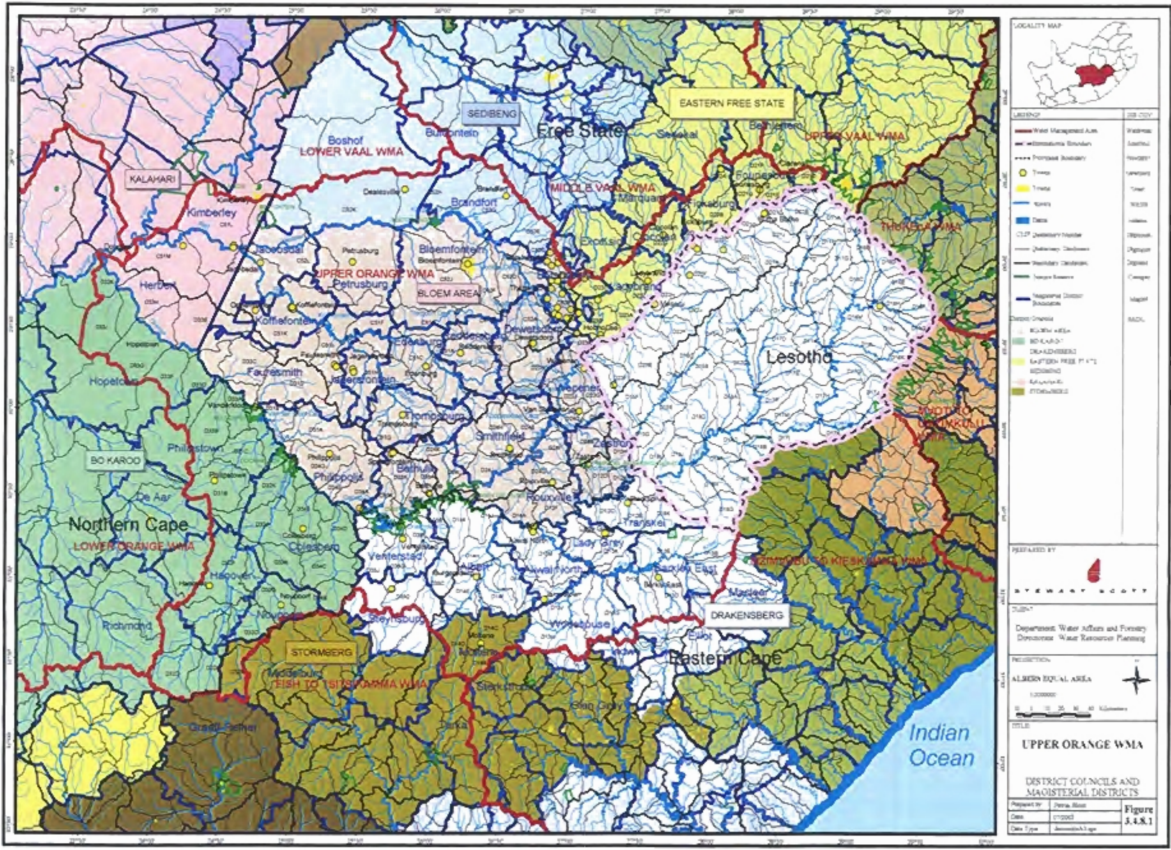
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
UPPER ORANGE WMA
POPULATION DISTRIBUTION
Figure 3.2.4.1



SEDIBENG
EASTERN FREE STATE
Free State
Boshof
LOWER VAAL WMA
Bultfontein
UPPER VAAL WMA
MIDDLE VAAL WMA
Bethlehem
KALAHARI
Kimberley
Brandfort
Bloemfontein
Ficksburg
Ladybrand
UPPER ORANGE WMA
Petrusburg
BLOEM AREA
Herbert
Koffiefontein
Dewetsdorp
Lesotho
Fauresmith
Jagersfontein
Hopetown
Wepener
Trompsburg
Smithfield
Zastron
BO KAROO
Philipstown
Philippolis
Bethulie
Rouxville
De Aar
Northern Cape
LOWER ORANGE WMA
Colesberg
Venterstad
Transkei
Lady Grey
Albert
Aliwal North
Barkly East
Hanover
Maclear
Steynsburg
DRAKENSBERG
Richmond
STORMBERG
Middelburg
FISH TO TSITSIKAMMA WMA
Molteno
Sterkstroom
Elliot
Eastern Cape
Graaff-Reinet
Indian Ocean
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Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
DISTRICT COUNCILS AND MAGISTERIAL DISTRICTS
Figure 3.4.8.1


Free State
Lesotho
Northern Cape
Eastern Cape
Indian Ocean
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
LOWER ORANGE WMA
THUKELA WMA
MVOTI TO UMZIMKULU WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
KIMBERLEY
DEALESVILLE
SOUTPAN
BRANDFORT
ROSENDAL
CLARENS
FOURIESBURG
CLOCOLAN
BLOEMFONTEIN
THABA NCHU
FICKSBURG
LADYBRAND
BOTSHABELO
THABA PATCHOA
DEWETSDORP
HOBHOUSE
WEPENER
VANSTADENSRUS
ZASTRON
STERKSPRUIT
PETRUSBURG
OPPERMANS
KOFFIEFONTEIN
HOPETOWN
FAURESMITH
JAGERSFONTEIN
EDENBURG
REDDERSBURG
LUCKHOFF
ORANIA
VANDERKLOOF
TROMPSBURG
PETRUSVILLE
SMITHFIELD
PHILIPPOLIS
SPRINGFONTEIN
PHILIPSTOWN
BETHULIE
GARIEP
ROUXVILLE
ALIWAL NORTH
COLESBERG
VENTERSTAD
LADY GREY
BURGERSDORP
BARKLY EAST
HANOVER
JAMESTOWN
NOUPOORT
MOLTENO
Douglas
VAALRIVIER
VETVAAL
MALUTI
GARIEP CENTRAL SOUTH
BLOEMFONTEIN
ORANGE WEST
SOUTH EASTERN
ORANJE-KAROO
RHENOSTERBERG
EBOYA
VENTERSTAD
ALBERT
ALIWAL NORTH
GREY
HERSCHEL
MOUNT FLETCHER
BARKLY EAST
MACLEAR
ELLIOT
MOLTENO
STEYNSBURG
MIDDELBURG
STERKSTROOM
TARKASTAD
CENTRALE KAROO
GRAAFF-REINET
DRAKENSBERG
Sedibeng Water
Bloem Water
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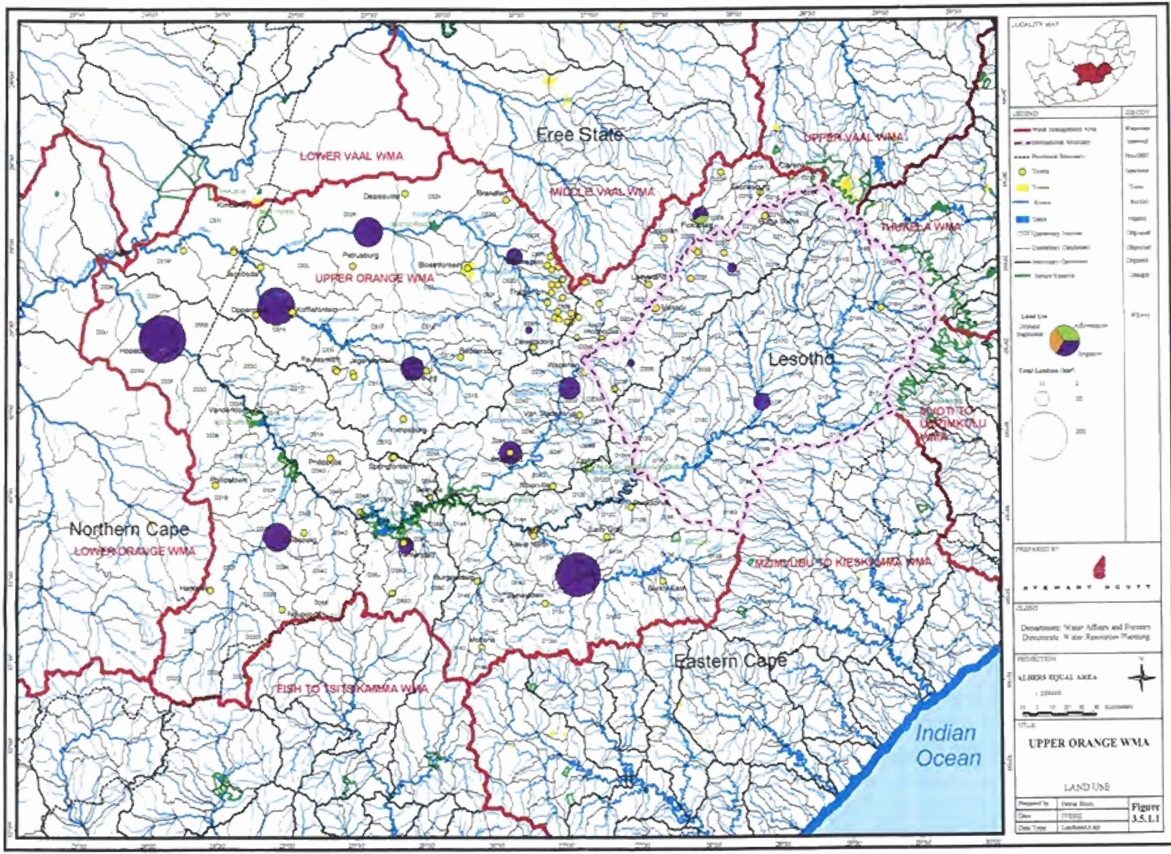
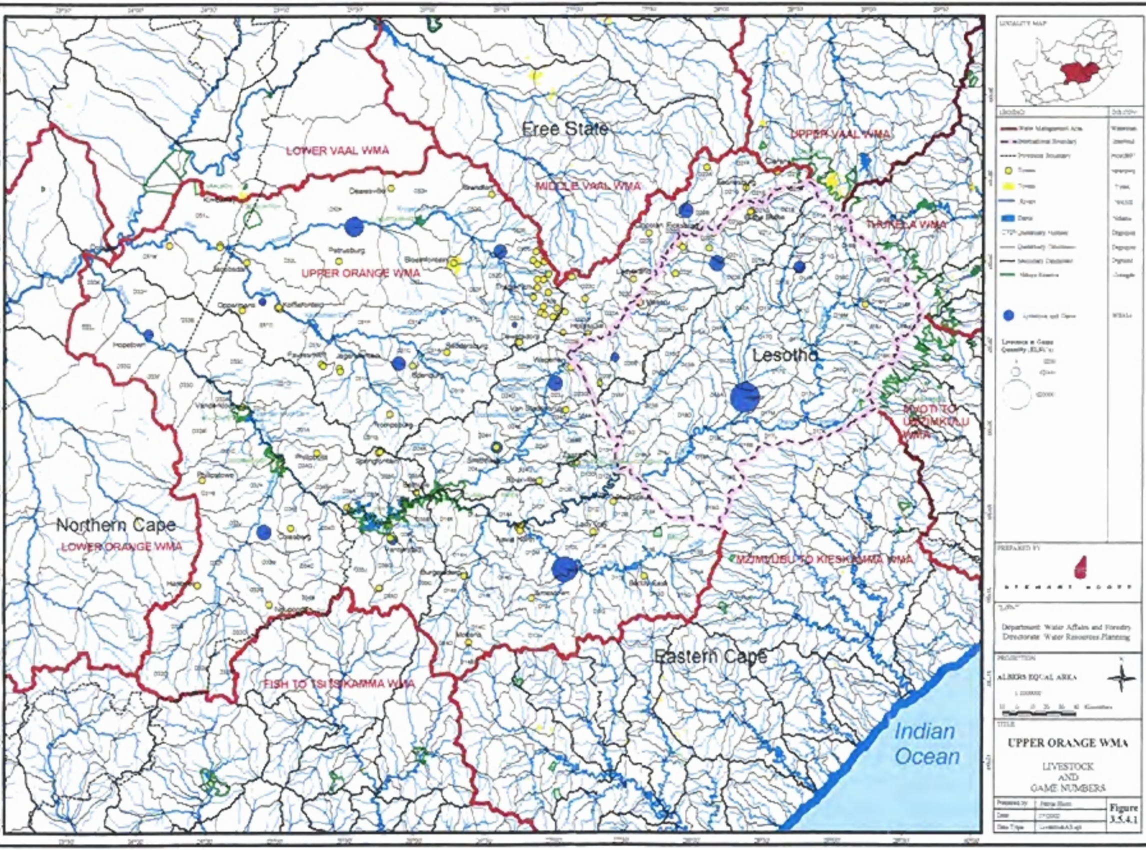
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
INSTITUTIONAL BOUNDARIES RELATED TO WATER SUPPLY
Figure 3.4.8.2



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
THUKELA WMA
UPPER ORANGE WMA
Lesotho
MVOTI TO UMZIMKULU WMA
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Petrusburg
Bloemfontein
Koffiefontein
Hopetown
LOCALITY MAP
LEGEND
Land Use
Total Landuse (km²)
PREPARED BY
CLIENT
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
UPPER ORANGE WMA
LAND USE
Figure 3.5.1.1


Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
PREPARED BY
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
UPPER ORANGE WMA
LIVESTOCK AND GAME NUMBERS
Figure 3.5.4.1

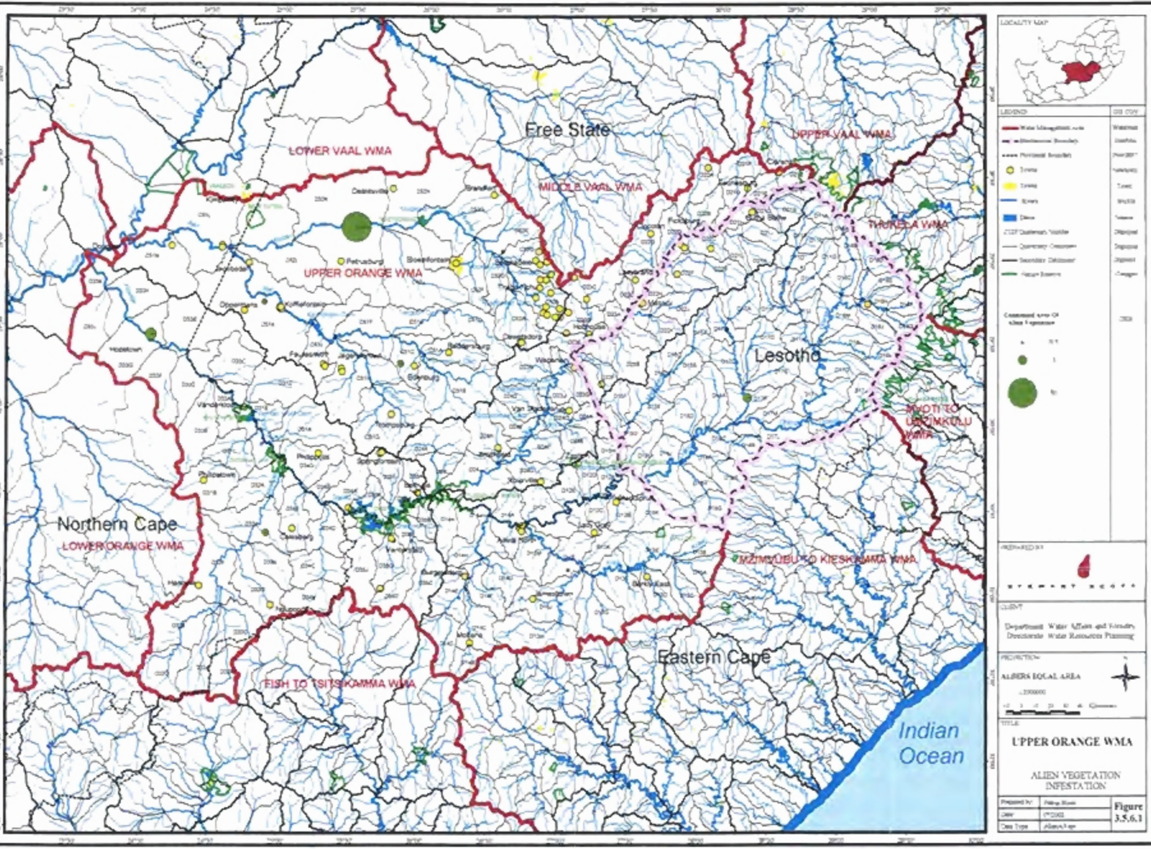

LOCALITY MAP
LEGEND
Free State
Lesotho
Northern Cape
Eastern Cape
Indian Ocean
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
MVOTI TO UMZIMKULU WMA
MZIMVUBU TO KEISKAMMA WMA
LOWER ORANGE WMA
FISH TO TSITSIKAMMA WMA
Petrusburg
Bloemfontein
Hopetown
Philipstown
Colesberg
Springfontein
Philippolis
Venterstad
Burgersdorp
Molteno
Jamestown
Aliwal North
Lady Grey
Barkly East
Zastron
Smithfield
Rouxville
Wepener
Dewetsdorp
Hobhouse
Ladybrand
Ficksburg
Senekal
Fauresmith
Jagersfontein
Koffiefontein
Edenburg
Reddersburg
Trompsburg
Vanderkloof
Hanover
Noupoort
Steynsburg
Edenville
Brandfort
CLIENT
Department Water Affairs and Forestry
Directorate Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
UPPER ORANGE WMA
ALIEN VEGETATION INFESTATION
Figure 3.5.6.1

FIGURE 3.7.1: MINES

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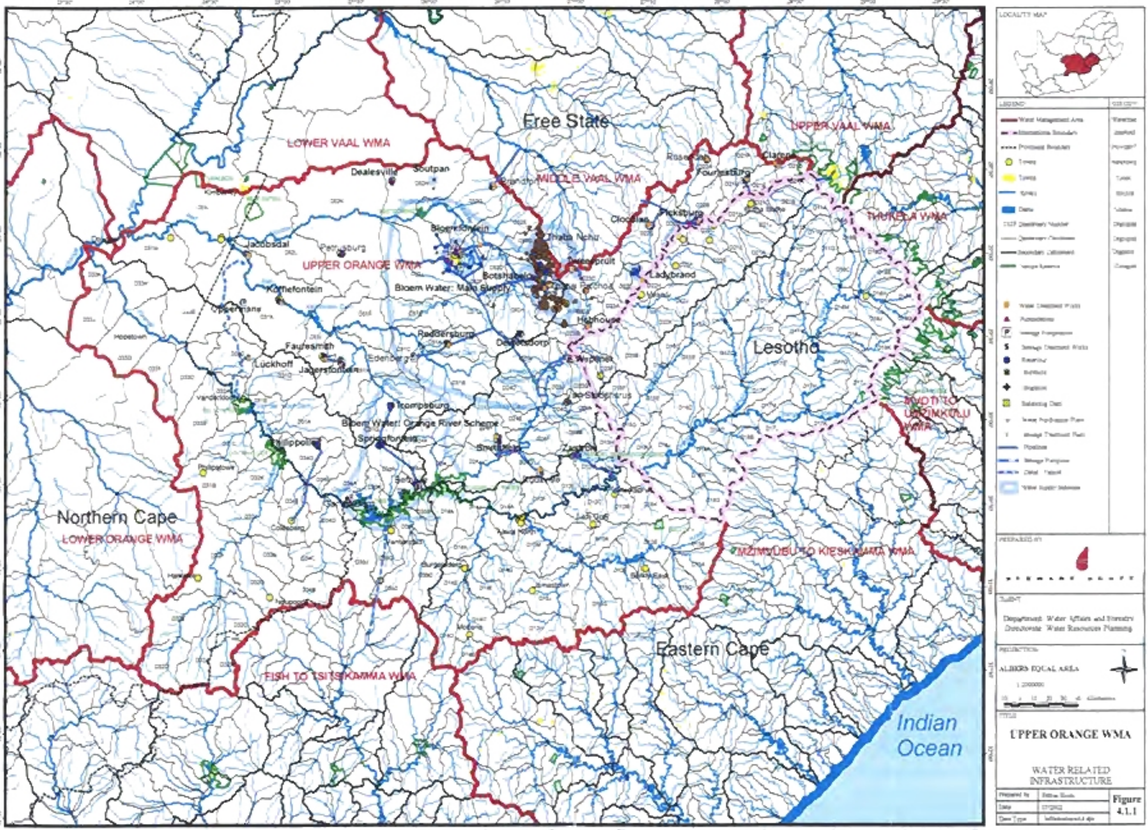
DIRECTORATE: WATER RESOURCES PLANNING



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
MVOTI TO UMZIMKULU WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
LOWER ORANGE WMA
Northern Cape
Eastern Cape
Lesotho
Indian Ocean
Dealesville
Soutpan
Bloemfontein
Thaba Nchu
Botshabelo
Bloem Water: Main Supply
Jacobsdal
Petrusburg
Koffiefontein
Reddersburg
Fauresmith
Luckhoff
Jagersfontein
Dewetsdorp
Hobhouse
Ladybrand
Clocolan
Ficksburg
Trompsburg
Bloem Water: Orange River Scheme
Springfontein
Smithfield
Zastron
Philippolis
LOCALITY MAP
LEGEND
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Department: Water Affairs and Forestry
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
TITLE
UPPER ORANGE WMA
WATER RELATED INFRASTRUCTURE
Figure 4.1.1

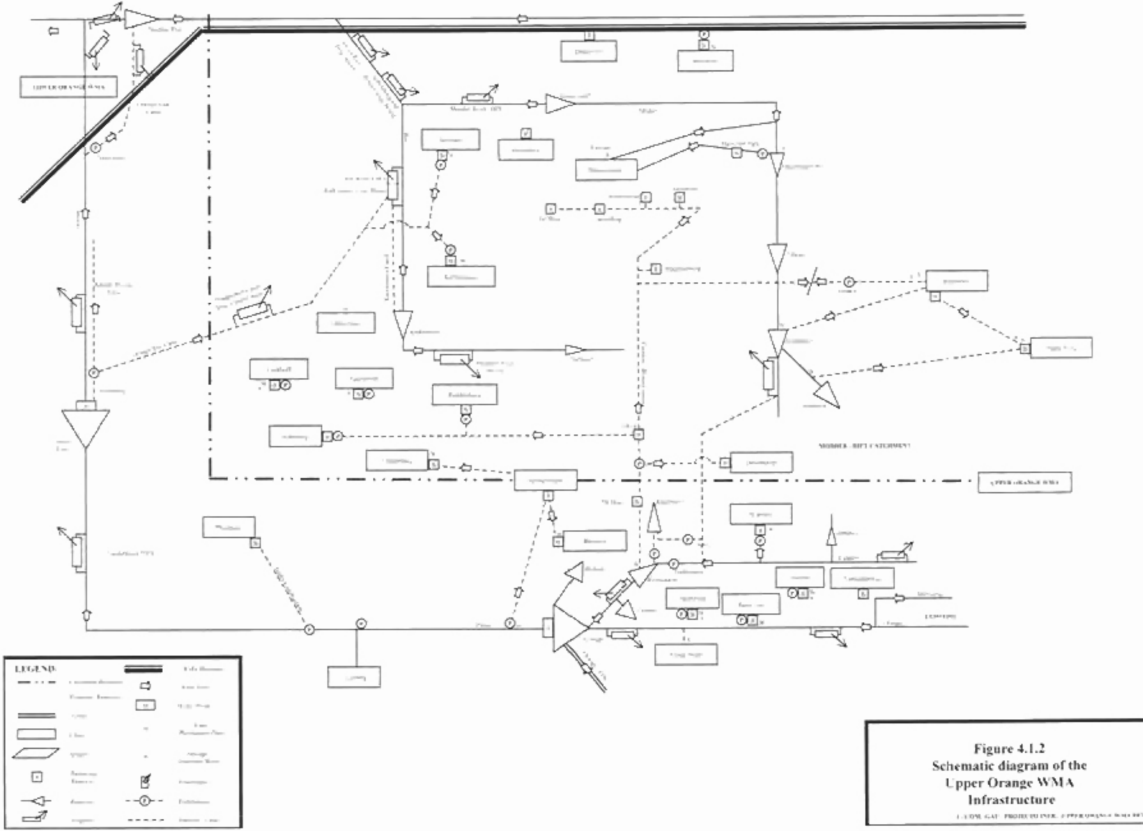
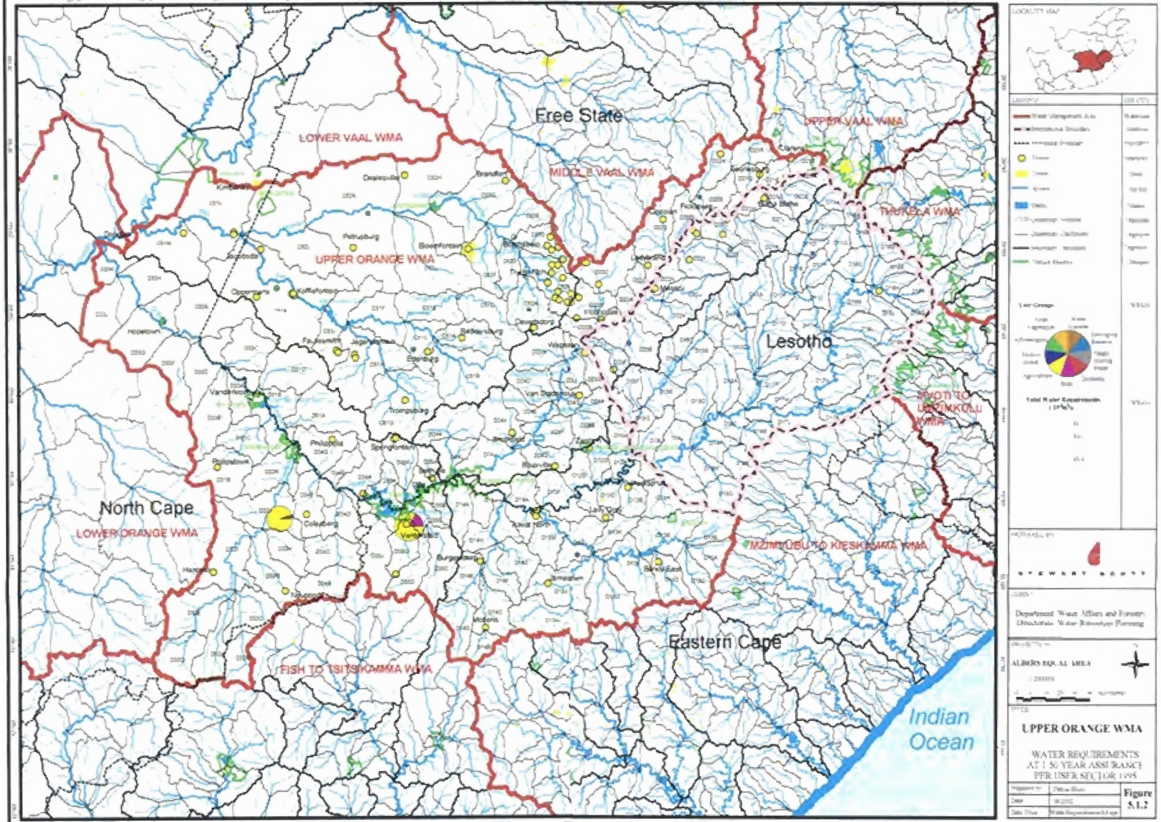
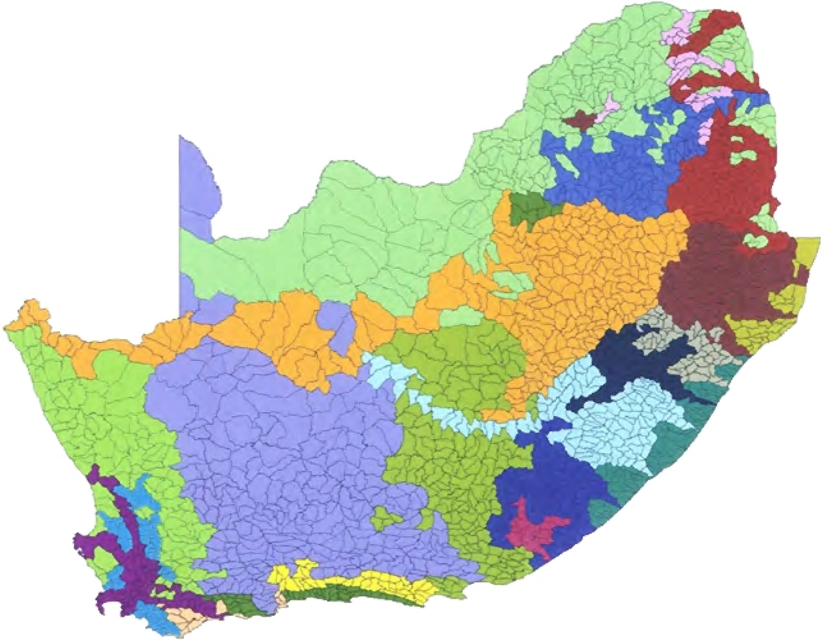


Figure 4.1.2
Schematic diagram of the Upper Orange WMA Infrastructure


Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Lesotho
MVOTI TO UMZIMKULU WMA
North Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Kimberley
Bloemfontein
Petrusburg
Jacobsdal
Koffiefontein
Oppermans
Hopetown
Fauresmith
Jagersfontein
Edenburg
Trompsburg
Philippolis
Springfontein
Colesberg
Venterstad
Burgersdorp
Jamestown
Molteno
Aliwal North
Lady Grey
Barkly East
Zastron
Rouxville
Smithfield
Wepener
Van Stadensrus
Dewetsdorp
Thaba Nchu
Ladybrand
Maseru
Ficksburg
Clocolan
Senekal
Bethlehem
Clarens
Fouriesburg
Vanderkloof
Petrusville
Philipstown
Hanover
Noupoort
Department Water Affairs and Forestry
Directorate Water Resources Planning
ALBERS EQUAL AREA
1:2000000
UPPER ORANGE WMA
WATER REQUIREMENTS
AT 1:50 YEAR ASSURANCE
PER USER SECTOR 1995
Figure 5.1.2



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 Amatola
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

PREPARED BY

STEWART SCOTT

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Directorate: Water Resources Planning

PROJECT TITLE

TITLE

DESKTOP RESERVE
PARAMETER REGIONS

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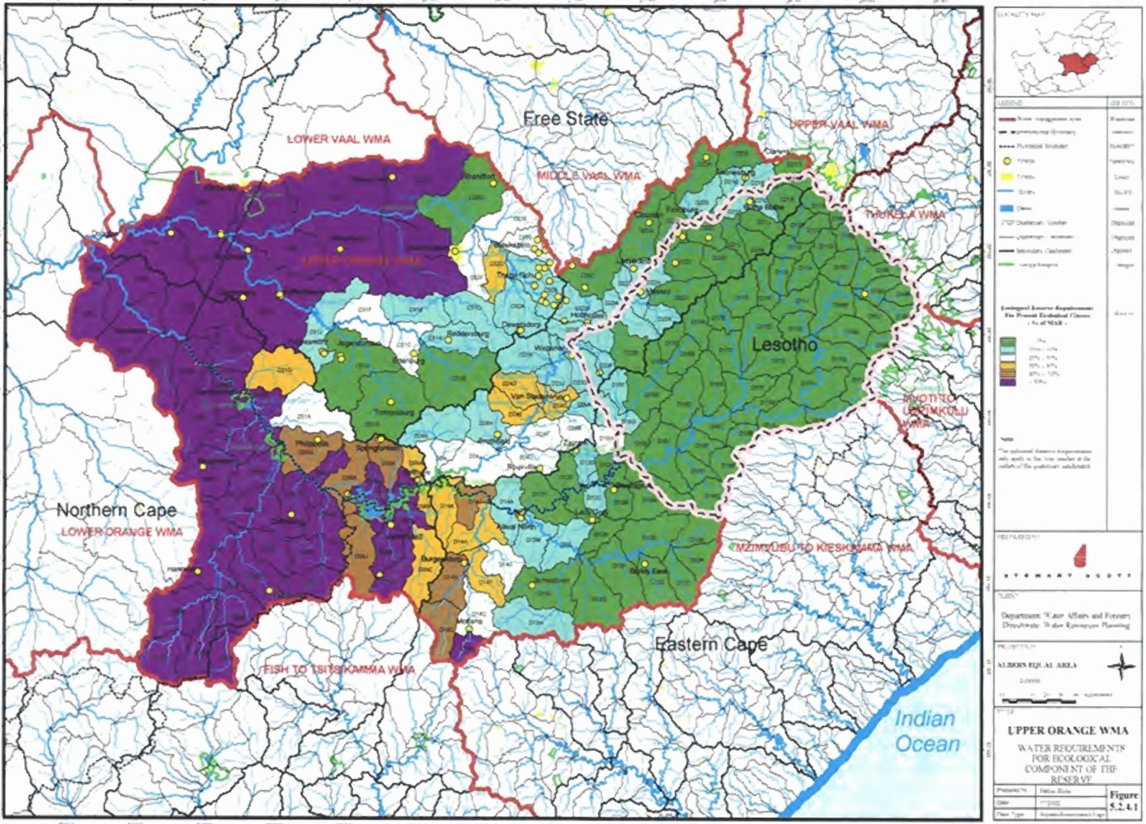
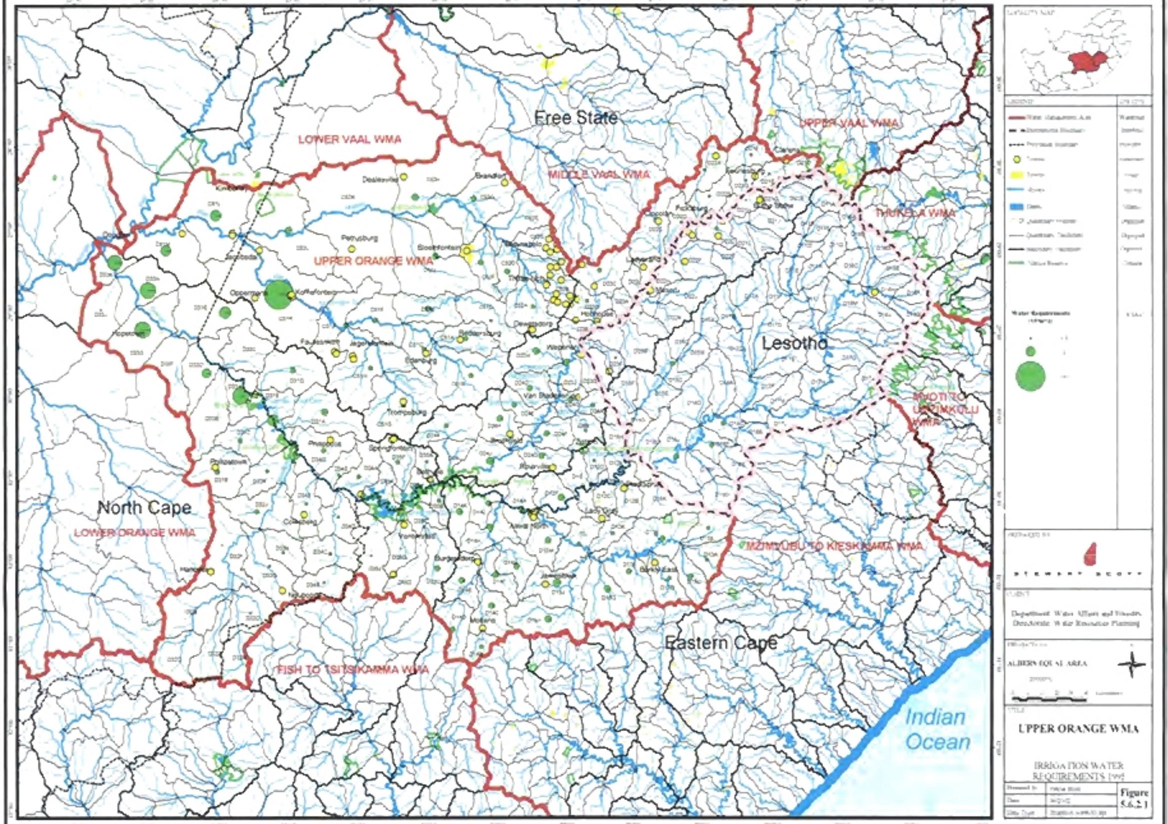
Date	11/2001	
Data Type	Desktop	


Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Lesotho
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Van Stadensrus
Trompsburg
Philippolis
Springfontein
Burgersdorp
Lady Grey
Barkly East
Aliwal North
Zastron
Rouxville
Smithfield
Dewetsdorp
Wepener
Reddersburg
Edenburg
Jagersfontein
Thaba Nchu
Brandfort
Molteno
Ladybrand
Hobhouse
Ficksburg
Clocolan
Fouriesburg
Bethlehem
Albers Equal Area
Department Water Affairs and Forestry
Directorate: Water Resources Planning
UPPER ORANGE WMA
WATER REQUIREMENTS FOR ECOLOGICAL COMPONENT OF THE RESERVE
Figure 5.2.4.1



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Lesotho
MVOTI TO UMZIMKULU WMA
North Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Petrusburg
Bloemfontein
Koffiefontein
Jacobsdal
Trompsburg
Springfontein
Philippolis
Colesberg
Burgersdorp
Aliwal North
Lady Grey
Barkly East
Hopetown
Wepener
Van Stadensrus
Smithfield
Zastron
Rouxville
Edenburg
Jagersfontein
Fauresmith
Ladybrand
Dewetsdorp
Brandfort
Dealesville
Hanover
Noupoort
Middelburg
Molteno
Venterstad
ALBERS EQUAL AREA
UPPER ORANGE WMA
IRRIGATION WATER REQUIREMENTS 1995

Figure 5.6.2.1

Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
LOWER ORANGE WMA
Northern Cape
Eastern Cape
Lesotho
Indian Ocean
Orange - Vaal Transfer
Brandfort Supply
Export of Effluent to Bloemspruit
1.6
Modder Dam - Greater Bloemfontein Supply
12.0
Bloemwater - Greater Bloemfontein and Other Users Supply
Orange - Riet Transfer
Bloemwater - Southern Transfer
1.2
Orange - Fish Transfer
650.0
Lesotho Highlands Water Project
0
Bloemfontein
Kimberley
Brandfort
Dealesville
Petrusburg
Jacobsdal
Koffiefontein
Oppermans
Hopetown
Jagersfontein
Fauresmith
Reddersburg
Edenburg
Trompsburg
Philippolis
Springfontein
Colesberg
Hanover
Noupoort
Venterstad
Burgersdorp
Molteno
Rouxville
Zastron
Wepener
Lady Grey
Barkly East
Sterkspruit
Van Stadensrus
Dewetsdorp
Thaba Nchu
Ladybrand
Ficksburg
Senekal
PREPARED BY
CLIENT
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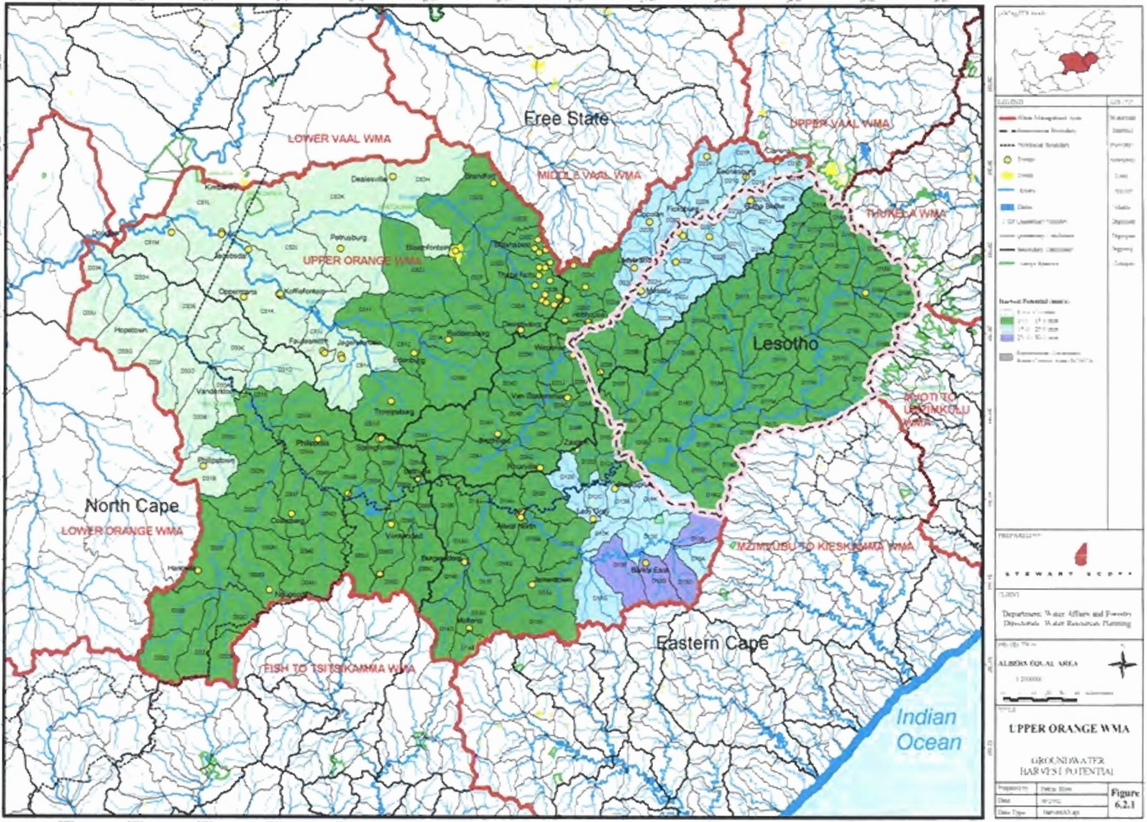
Directorate: Water Resources Planning
PROJECTION
ALBERS EQUAL AREA
UPPER ORANGE WMA
WATER TRANSFER SCHEMES
Figure
5.14.1


Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
THUKELA WMA
UPPER ORANGE WMA
Lesotho
Northern Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
Bloemfontein
Petrusburg
Dealesville
Koffiefontein
Trompsburg
Philippolis
Colesberg
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
NET 1:50 YEAR YIELD OF THE TOTAL WATER RESOURCE AS DEVELOPED IN 1995
Figure 6.1.1



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
THUKELA WMA
UPPER ORANGE WMA
Lesotho
North Cape
LOWER ORANGE WMA
FISH TO TSITSIKAMMA WMA
MZIMVUBU TO KEISKAMMA WMA
Eastern Cape
Indian Ocean
Bloemfontein
Petrusburg
Dealesville
Brandfort
Jacobsdal
Koffiefontein
Oppermans
Hopetown
Fauresmith
Jagersfontein
Edenburg
Reddersburg
Dewetsdorp
Thaba Nchu
Wepener
Van Stadensrus
Trompsburg
Philippolis
Springfontein
Smithfield
Zastron
Rouxville
Philipstown
Colesberg
Venterstad
Aliwal North
Lady Grey
Barkly East
Burgersdorp
Jamestown
Molteno
Noupoort
Hanover
Vanderkloof
Ficksburg
Clocolan
Ladybrand
Maseru
Bethlehem
Harvest Potential (mm/a)
PREPARED BY
STEWART SCOTT
CLIENT
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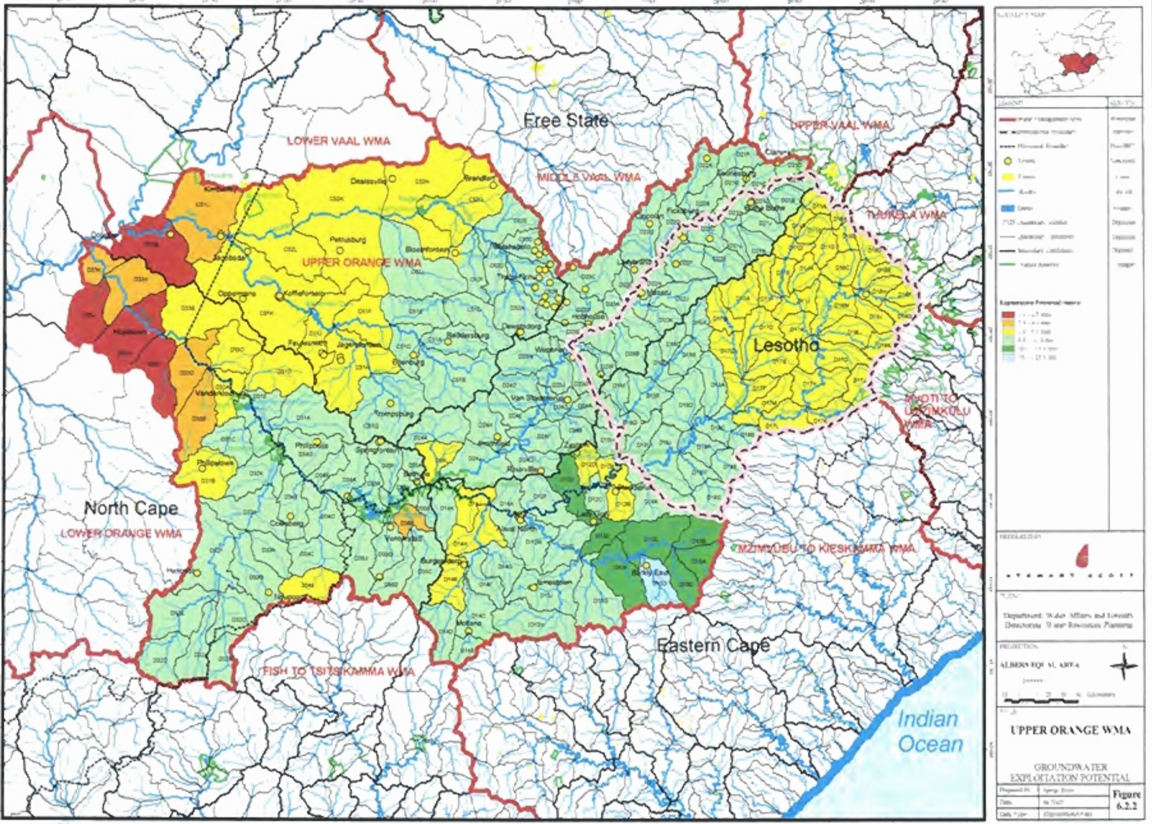
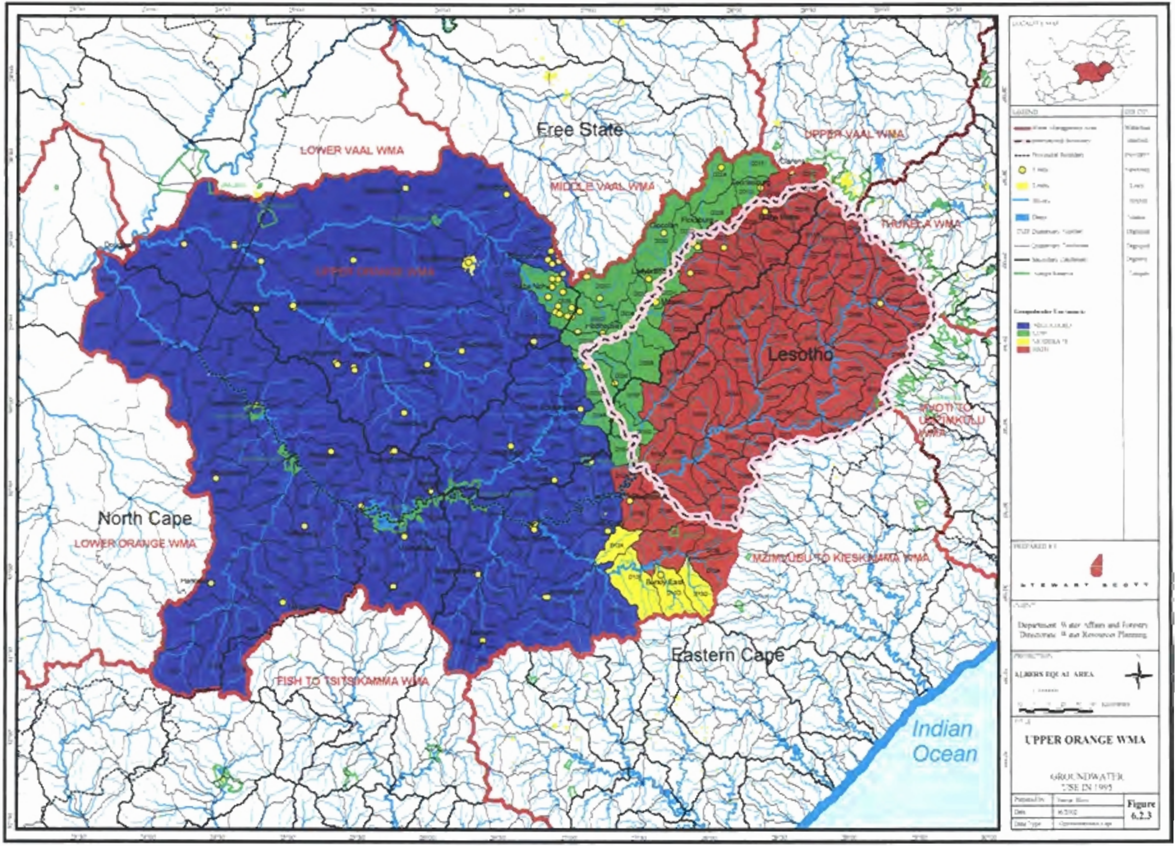
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
GROUNDWATER
HARVEST POTENTIAL
Figure 6.2.1



Free State
LOWER VAAL WMA
MIDDLE VAAL WMA
UPPER VAAL WMA
UPPER ORANGE WMA
THUKELA WMA
Lesotho
MVOTI TO UMZIMKULU WMA
North Cape
LOWER ORANGE WMA
MZIMVUBU TO KIESKAMMA WMA
Eastern Cape
FISH TO TSITSIKAMMA WMA
Indian Ocean
Petrusburg
Bloemfontein
Philippolis
Philipstown
Colesberg
Burgersdorp
Barkly East
Molteno
Department: Water Affairs and Forestry
ALBERS EQUAL AREA
UPPER ORANGE WMA
GROUNDWATER EXPLOITATION POTENTIAL
Figure 6.2.2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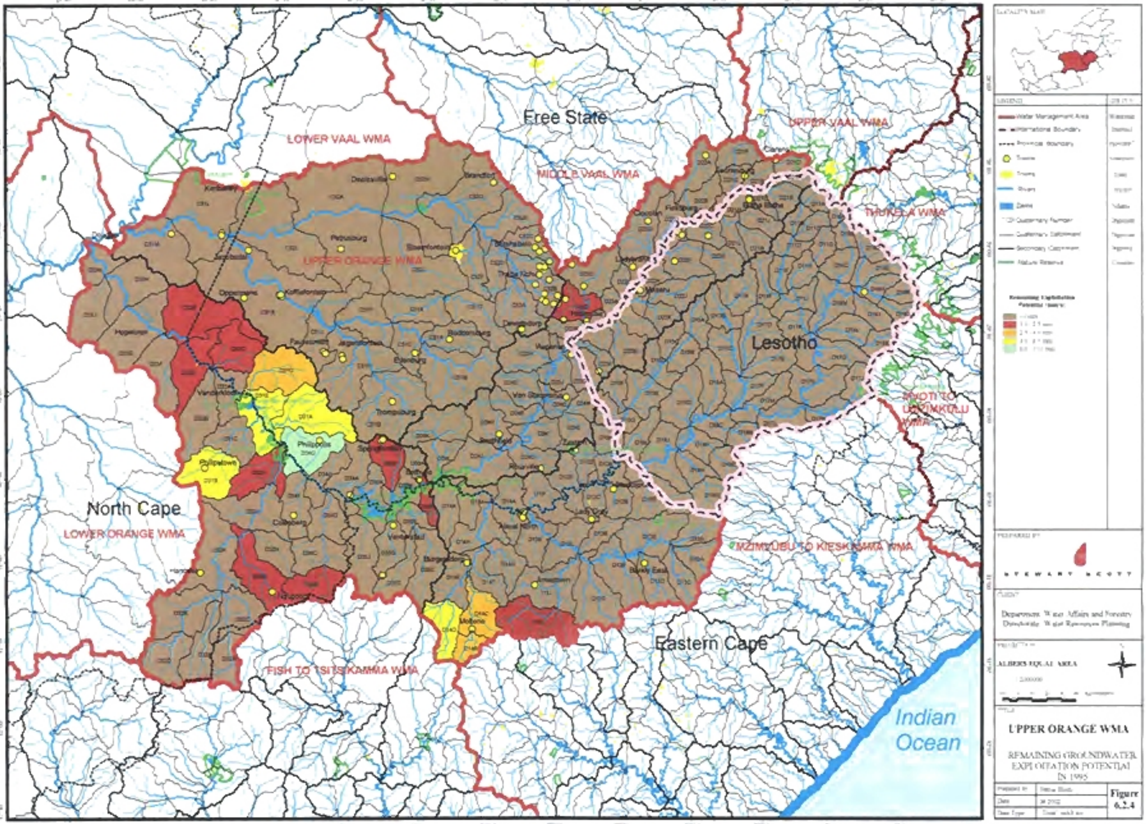
MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
STEWART SCOTT
ALBERS EQUAL AREA
UPPER ORANGE WMA
GROUNDWATER
USE IN 1995
Figure 6.2.3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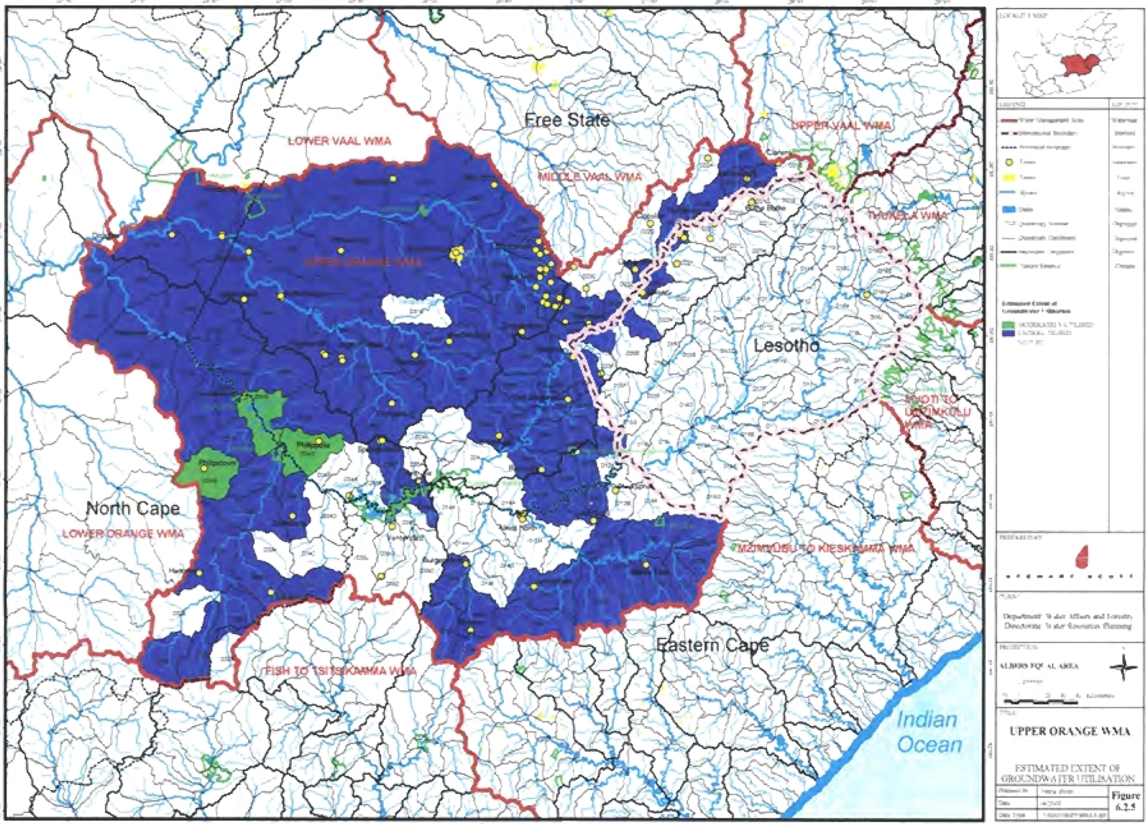
LOWER ORANGE WMA
FISH TO TSITSIKAMMA WMA
MZIMVUBU TO KEISKAMMA WMA
Eastern Cape
Indian Ocean
STEWART SCOTT
Department: Water Affairs and Forestry
ALBERS EQUAL AREA
UPPER ORANGE WMA
REMAINING GROUNDWATER EXPLOITATION POTENTIAL IN 1995
Figure 6.2.4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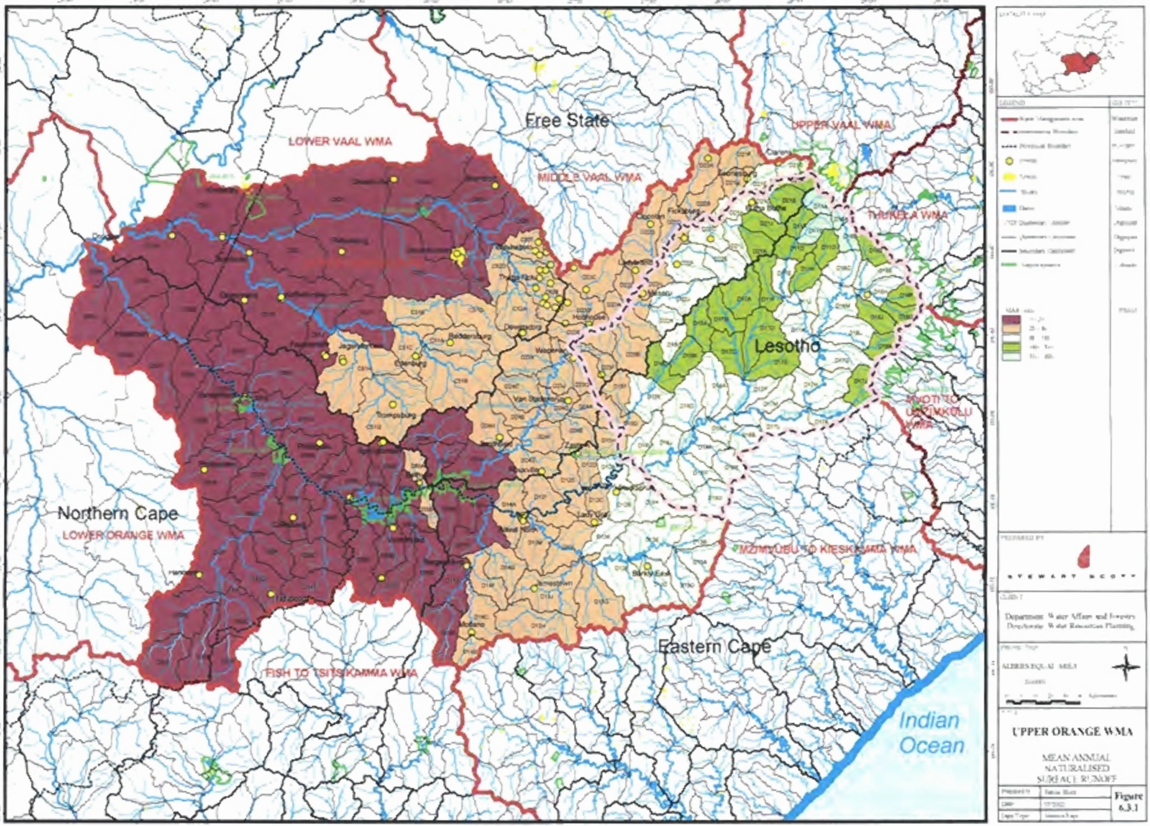
Lesotho
Philippolis
Philipstown
North Cape
LOWER ORANGE WMA
MZIMVUBU TO KEISKAMMA WMA
Eastern Cape
FISH TO TSITSIKAMMA WMA
Indian Ocean
UPPER ORANGE WMA
ESTIMATED EXTENT OF GROUNDWATER UTILISATION
Figure 6.2.5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MZIMVUBU TO KEISKAMMA WMA
FISH TO TSITSIKAMMA WMA
Northern Cape
LOWER ORANGE WMA
Lesotho
Eastern Cape
Indian Ocean
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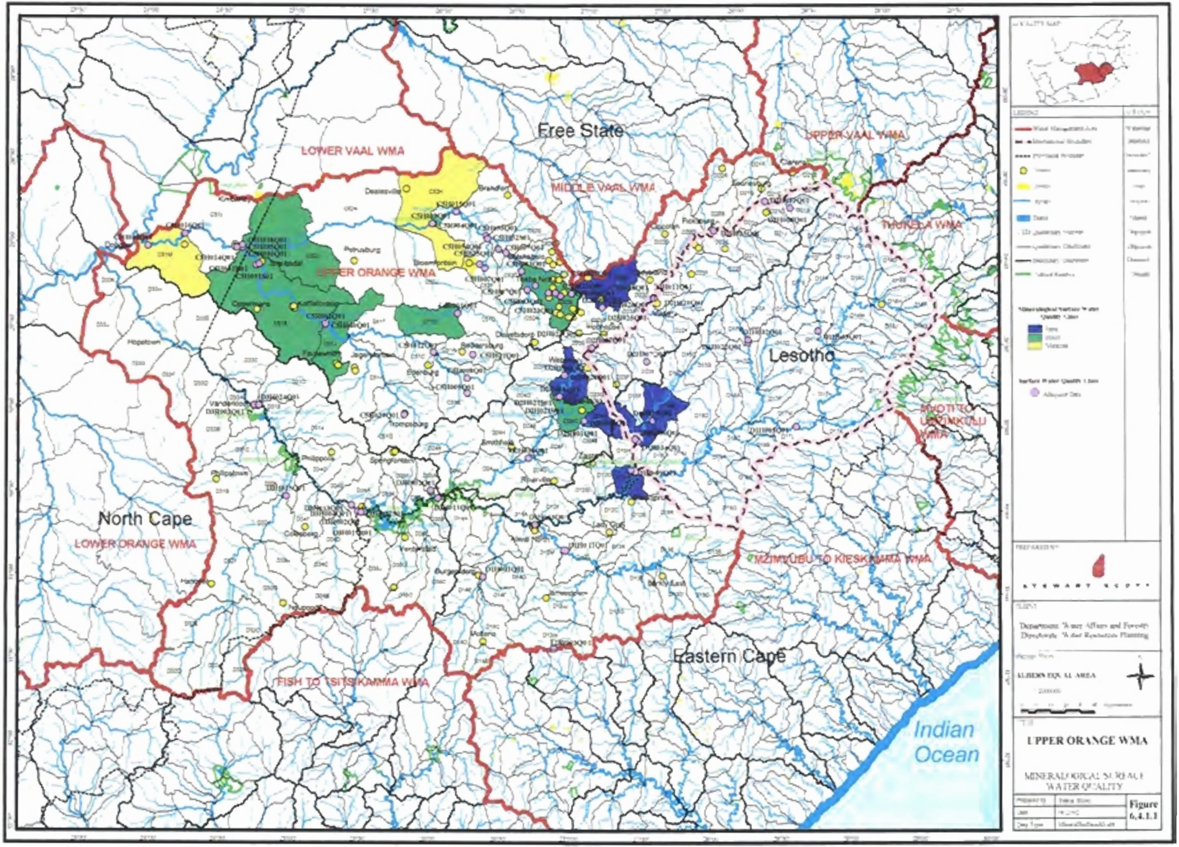
Directorate: Water Resources Planning
UPPER ORANGE WMA
MEAN ANNUAL NATURALISED SURFACE RUNOFF
Figure 6.3.1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Trompsburg
Springfontein
Philippolis
Colesberg
Smithfield
Hopetown
Molteno
Burgersdorp
Lady Grey
STEWART SCOTT
ALBERS EQUAL AREA
UPPER ORANGE WMA
MINERALOGICAL SURFACE WATER QUALITY
Figure 6.4.1.1

FIGURE 6.4.1.2: THE WATER QUALITY OF THE UPPER ORANGE WMA

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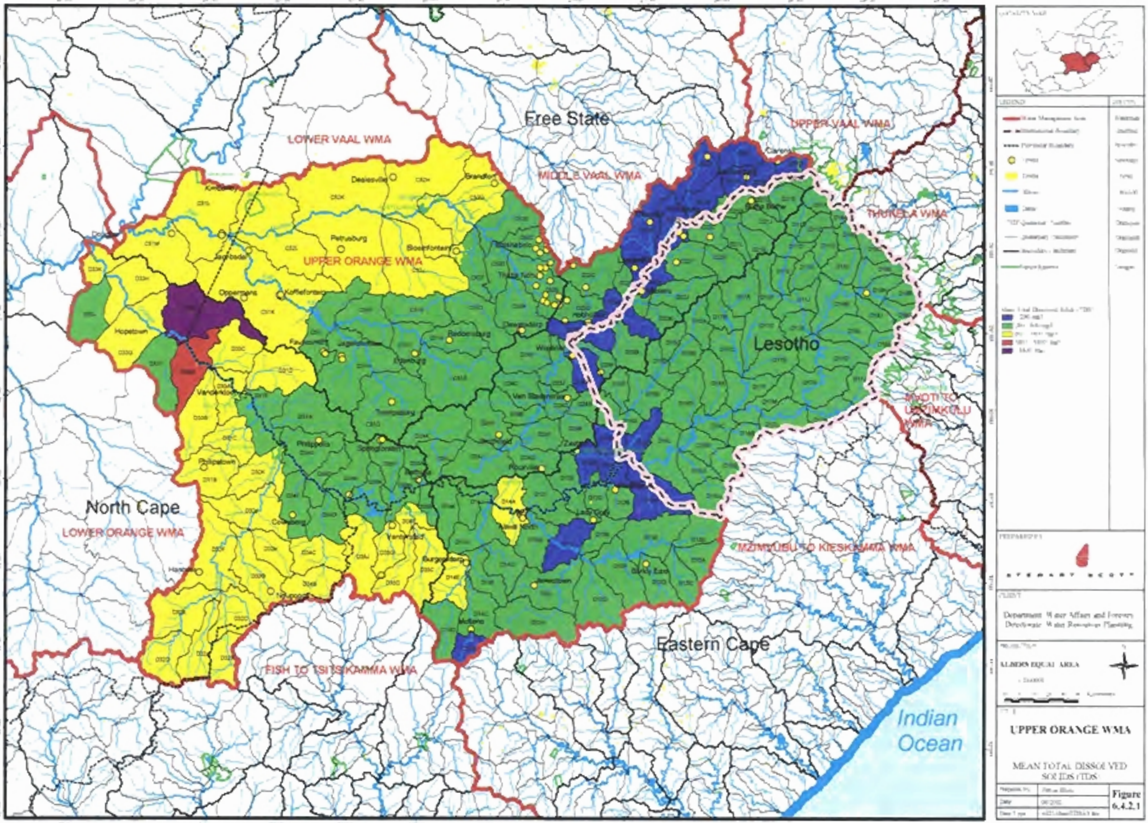
Free State
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UPPER ORANGE WMA
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MVOTI TO UMZIMKULU WMA
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Oppermans
Koffiefontein
Hopetown
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Colesberg
Venterstad
Burgersdorp
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Sterkstroom
Lady Grey
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Hanover
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Wepener
Zastron
Rouxville
Smithfield
Reddersburg
Edenburg
Trompsburg
Van Stadensrus
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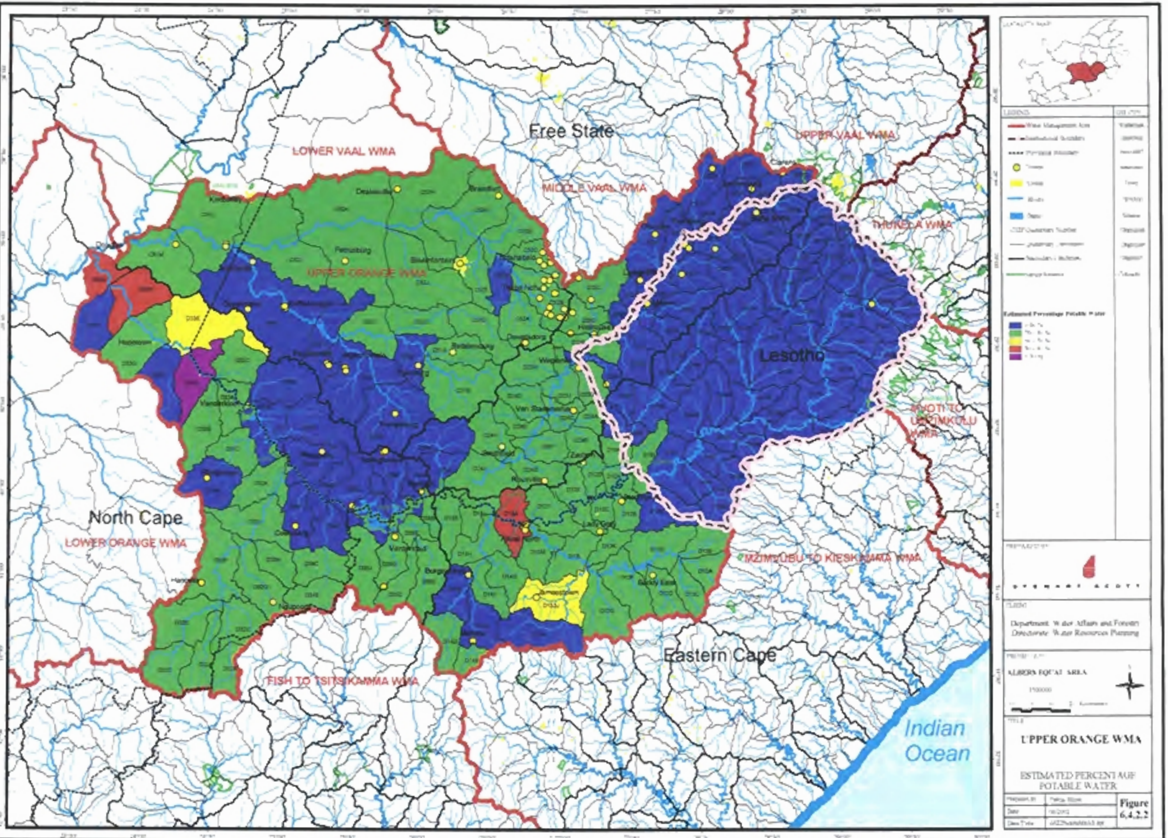
Directorate Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
MEAN TOTAL DISSOLVED SOLIDS (TDS)
Figure 6.4.2.1



Free State
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Lesotho
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LOWER ORANGE WMA
MZIMVUBU TO KIESKAMMA WMA
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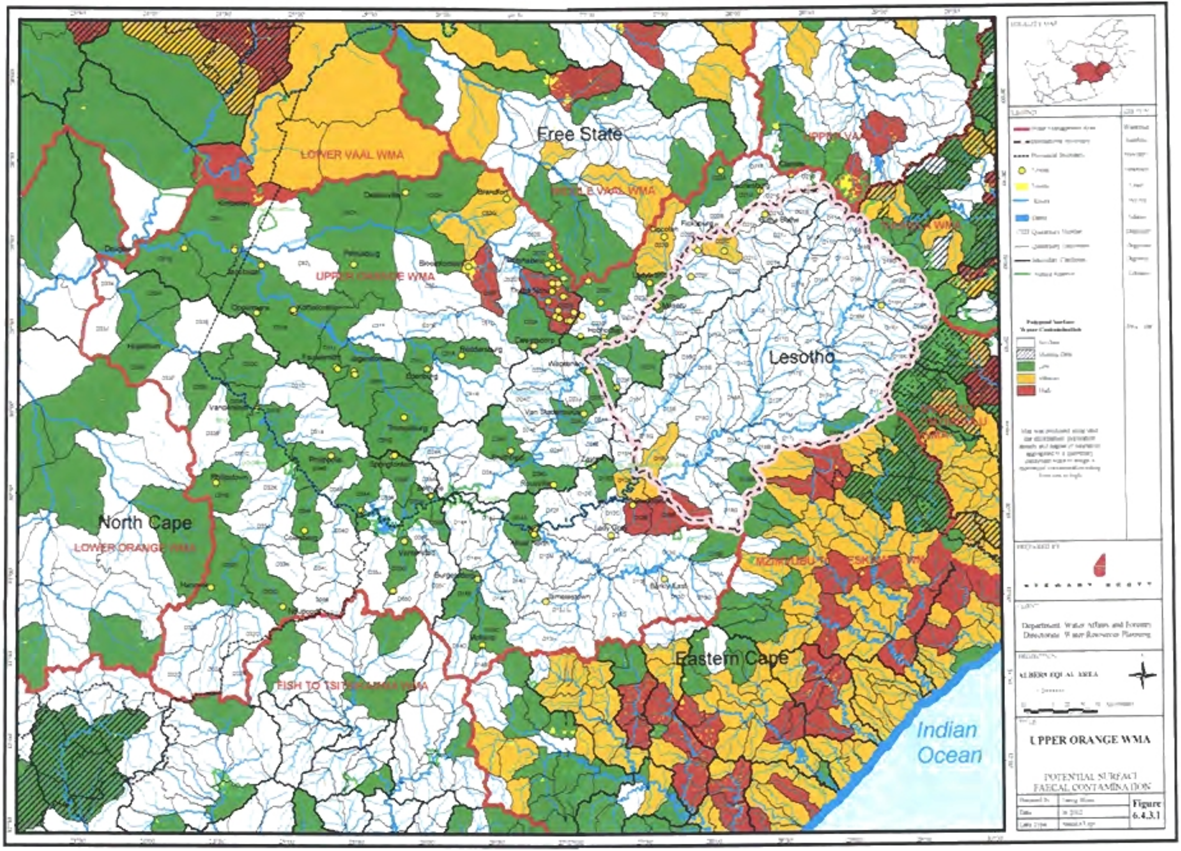
Eastern Cape
Indian Ocean
Petrusburg
Bloemfontein
Estimated Percentage Potable Water
Department: Water Affairs and Forestry
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
ESTIMATED PERCENTAGE POTABLE WATER
Figure 6.4.2.2


Free State
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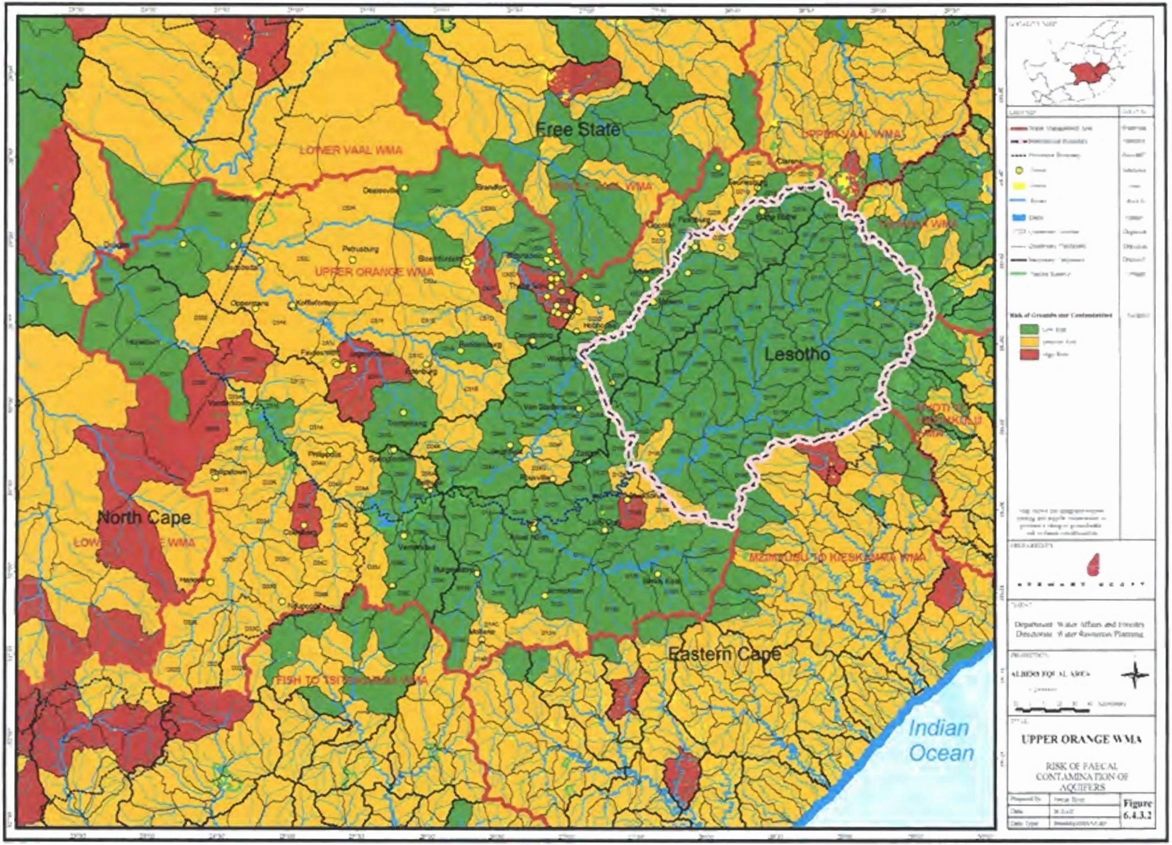
North Cape
LOWER ORANGE WMA
FISH TO TSITSIKAMMA WMA
Eastern Cape
Indian Ocean
UPPER ORANGE WMA
POTENTIAL SURFACE FAECAL CONTAMINATION
Figure 6.4.3.1


Free State
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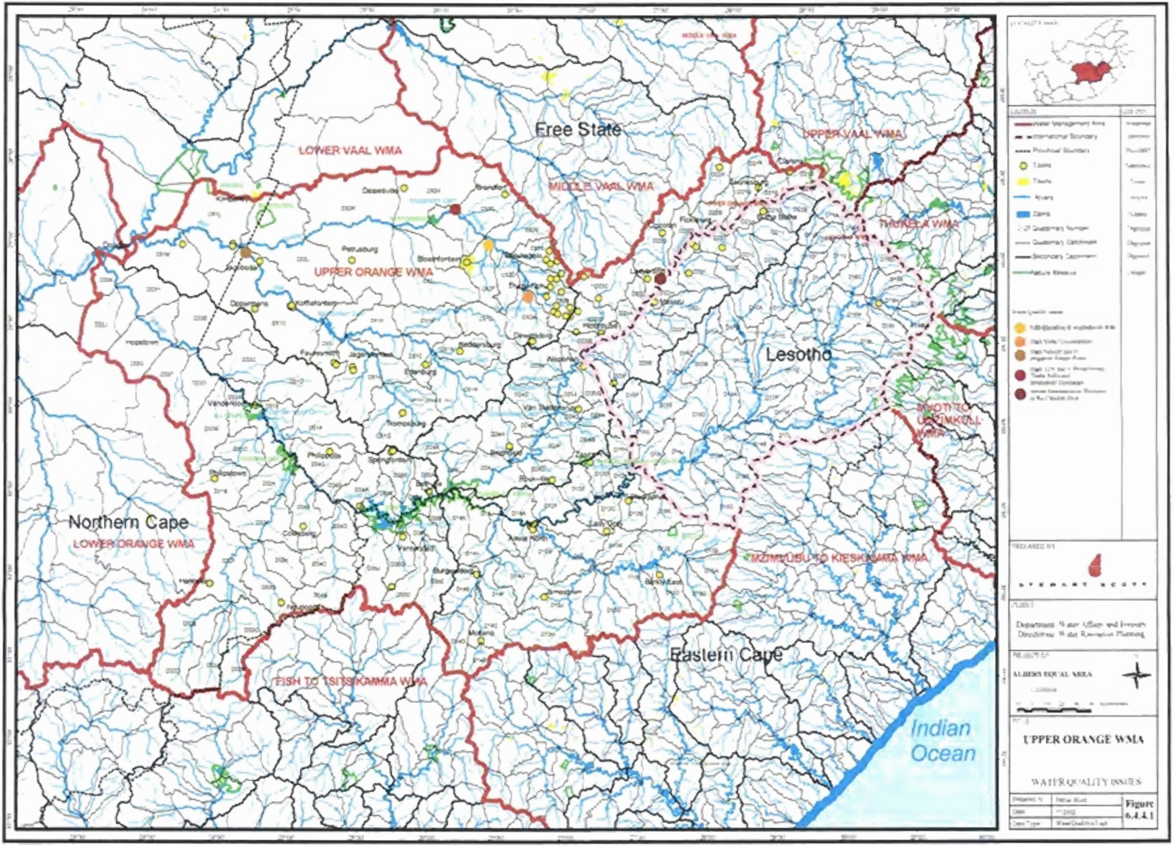
Eastern Cape
MZIMVUBU TO KEISKAMMA WMA
Indian Ocean
Department Water Affairs and Forestry
Directorate Water Resources Planning
UPPER ORANGE WMA
RISK OF FAECAL CONTAMINATION OF AQUIFERS
Figure 6.4.3.2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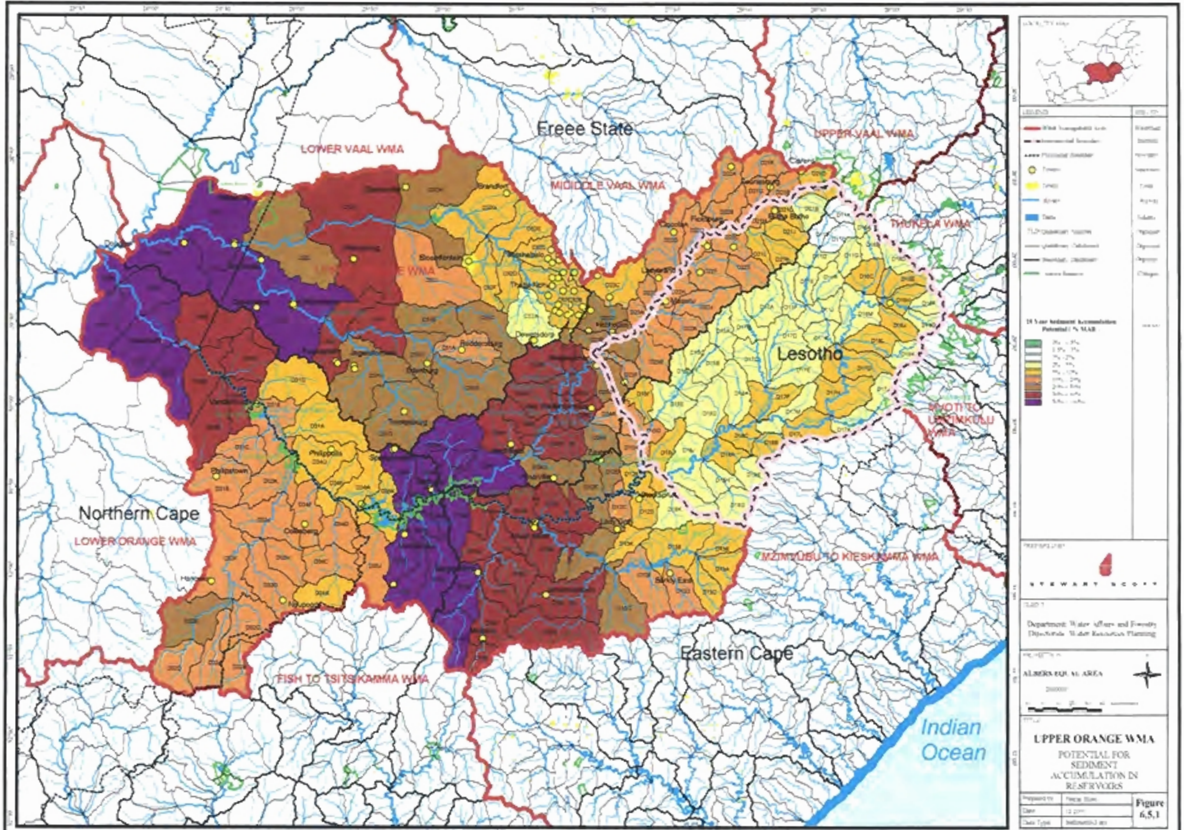
Burgersdorp
Lady Grey
Aliwal North
Jamestown
Molteno
STEWART SCOTT
ALBERS EQUAL AREA
UPPER ORANGE WMA
WATER QUALITY ISSUES
Figure 6.4.4.1



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Reddersburg
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Philipstown
Noupoort
Zastron
Lady Grey
Barkly East
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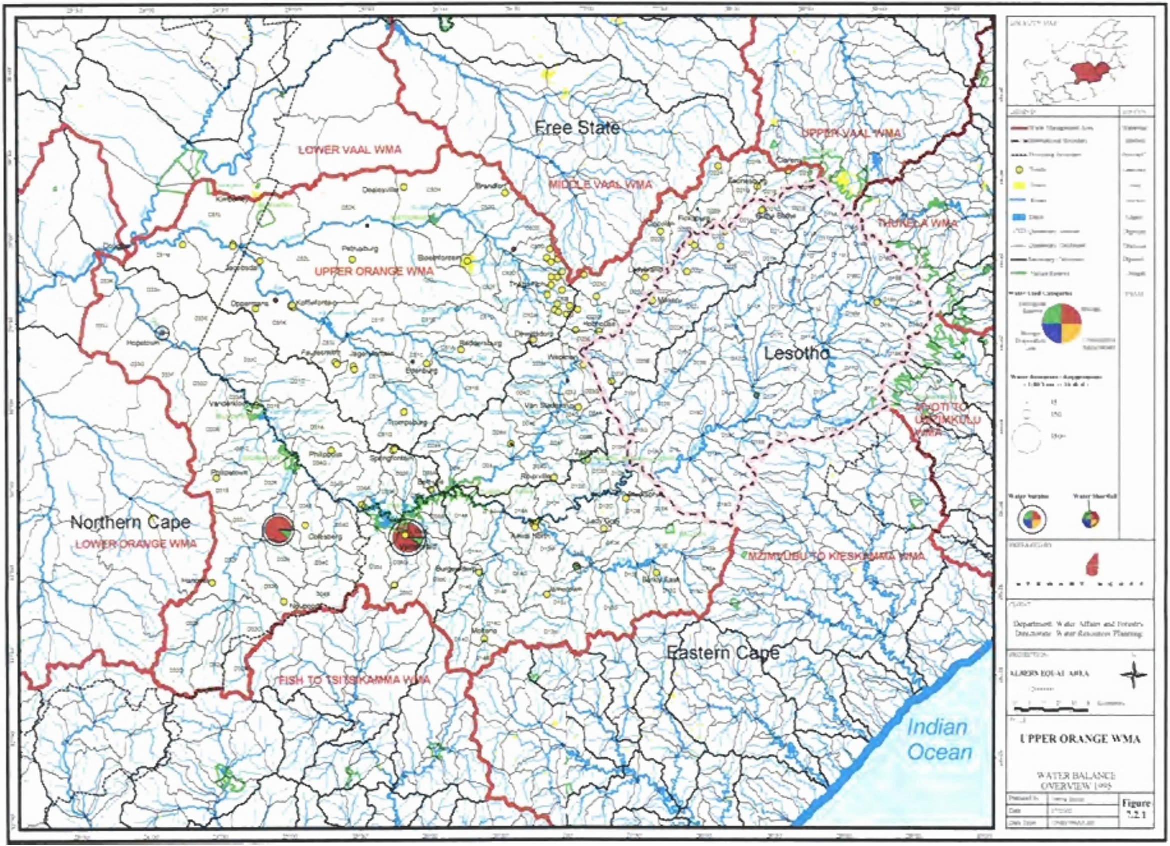
Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
POTENTIAL FOR SEDIMENT ACCUMULATION IN RESERVOIRS
Figure 6.5.1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Directorate: Water Resources Planning
ALBERS EQUAL AREA
UPPER ORANGE WMA
WATER BALANCE
OVERVIEW 1995
Figure
7.2.1