Orange Senqu River Commission (ORASECOM)

Project Funding by
German Development Cooperation
SADC Water Sector Cooperation

gtz Partner for the Future. Worldwide.

Orange River Integrated Water Resources Management Plan

Summary of Water Requirements from the Orange River basin

ORASECOM 006/2007
Date Submitted: November 2007

WRP (Pty) Ltd, Jeffares Green Parkman Consultants (Pty) Ltd, Sechaba Consultants, Water Surveys Botswana and Windhoek Consulting Engineers in association

wrp A Miya Group Company
JGP
Sechaba Consultants
Water Surveys (Botswana) (Proprietary) Ltd
WCE

WRP_FC/0810.cdr

Study Name:	Orange River Integrated Water Resources Management Plan
Report Title:	**Summary of Water Requirements from the Orange River**
Submitted By:	WRP Consulting Engineers, Jeffares and Green, Sechaba Consulting, WCE Pty Ltd, Water Surveys Botswana (Pty) Ltd
Authors:	HG Mare
Date of Issue:	August 2007
Distribution:	Botswana: DWA: 2 copies (Katai, Setloboko)
	Lesotho: Commissioner of Water: 2 copies (Ramosoeu, Nthathakane)
	Namibia: MAWRD: 2 copies (Amakali)
	South Africa: DWAF: 2 copies (Pyke, van Niekerk)
	GTZ: 2 copies (Vogel, Mpho)
Reports:	Review of Existing Infrastructure in the Orange River Catchment
	Review of Surface Hydrology in the Orange River Catchment
	Flood Management Evaluation of the Orange River
	Review of Groundwater Resources in the Orange River Catchment
	Environmental Considerations Pertaining to the Orange River
	Summary of Water Requirements from the Orange River
	Water Quality in the Orange River
	Demographic and Economic Activity in the four Orange Basin States
	Current Analytical Methods and Technical Capacity of the four Orange Basin States
	Institutional Structures in the four Orange Basin States
	Legislation and Legal Issues Surrounding the Orange River Catchment
	Summary Report

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

1 INTRODUCTION

1.1 General

The Orange River originates in the Lesotho Highlands and flows in a westerly direction 2 200 km to the west coast where the river discharges into the Atlantic Ocean (see **Figure 1-1)**. The Orange River basin is one of the largest river basins south of the Zambezi with a catchment area of approximately 0.9 million km^2.

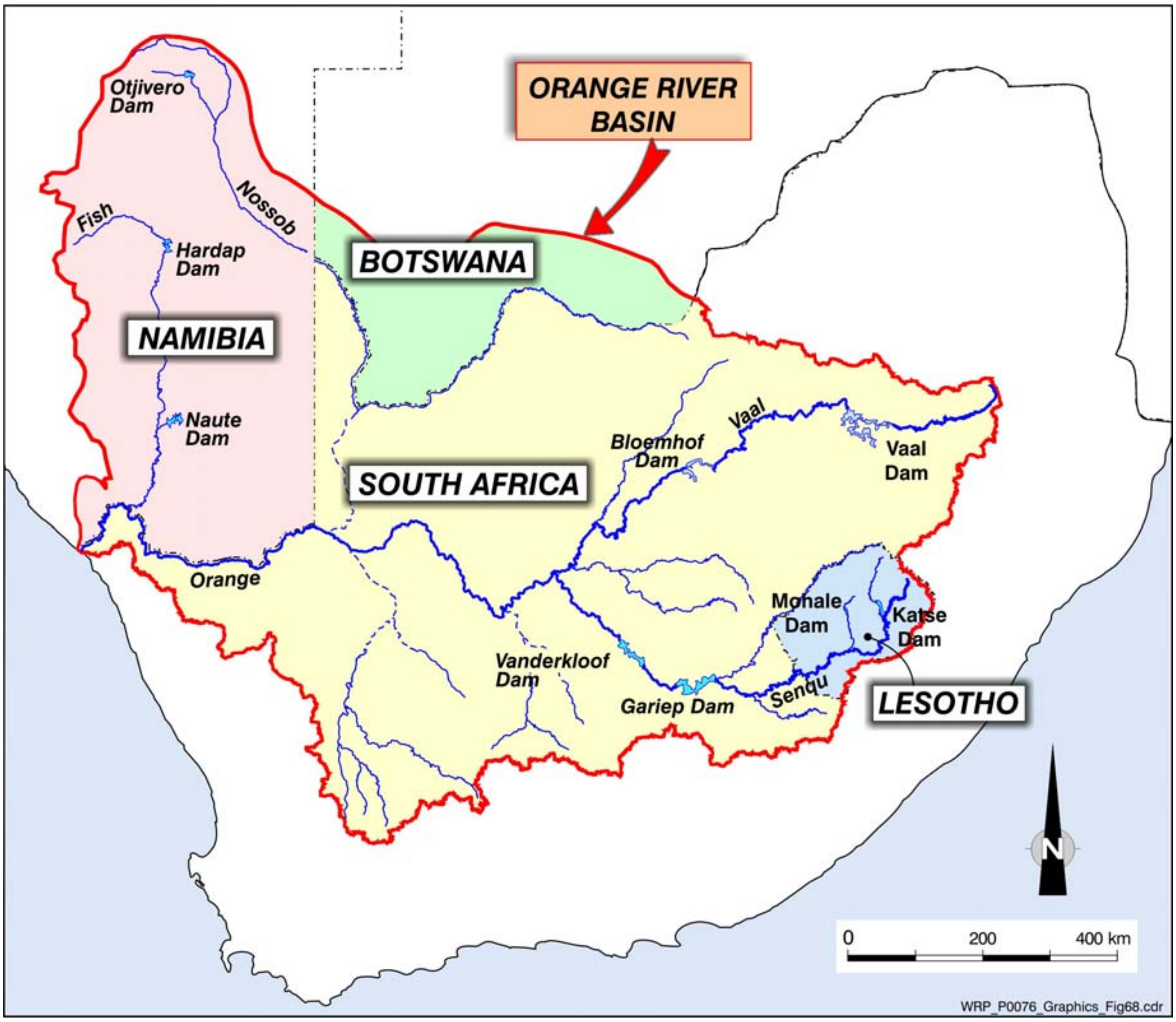


Figure 1-1: Orange River

It has been estimated that the natural runoff of the Orange River basin is in the order of 11 600 million m^3/a of which approximately 4 000 million m^3/a originates in the Lesotho Highlands and approximately 900 million m^3/a from the contributing catchment downstream of the Orange/Vaal confluence which includes part of Namibia and a small portion in Botswana feeding the Nossob and Molopo rivers. Whether or not these two rivers directly contribute to the Orange River is an outstanding issue which will be addressed during the study. The remaining 6 700 million m^3/a originates from the areas contributing to the Vaal, Caledon, Kraai and Middle Orange rivers.

It should be noted that much of the runoff originating from the Orange River downstream of the Orange Vaal confluence is highly erratic (coefficient of variability greater than 2) and cannot be relied upon to support the various downstream demands unless further storage is provided.

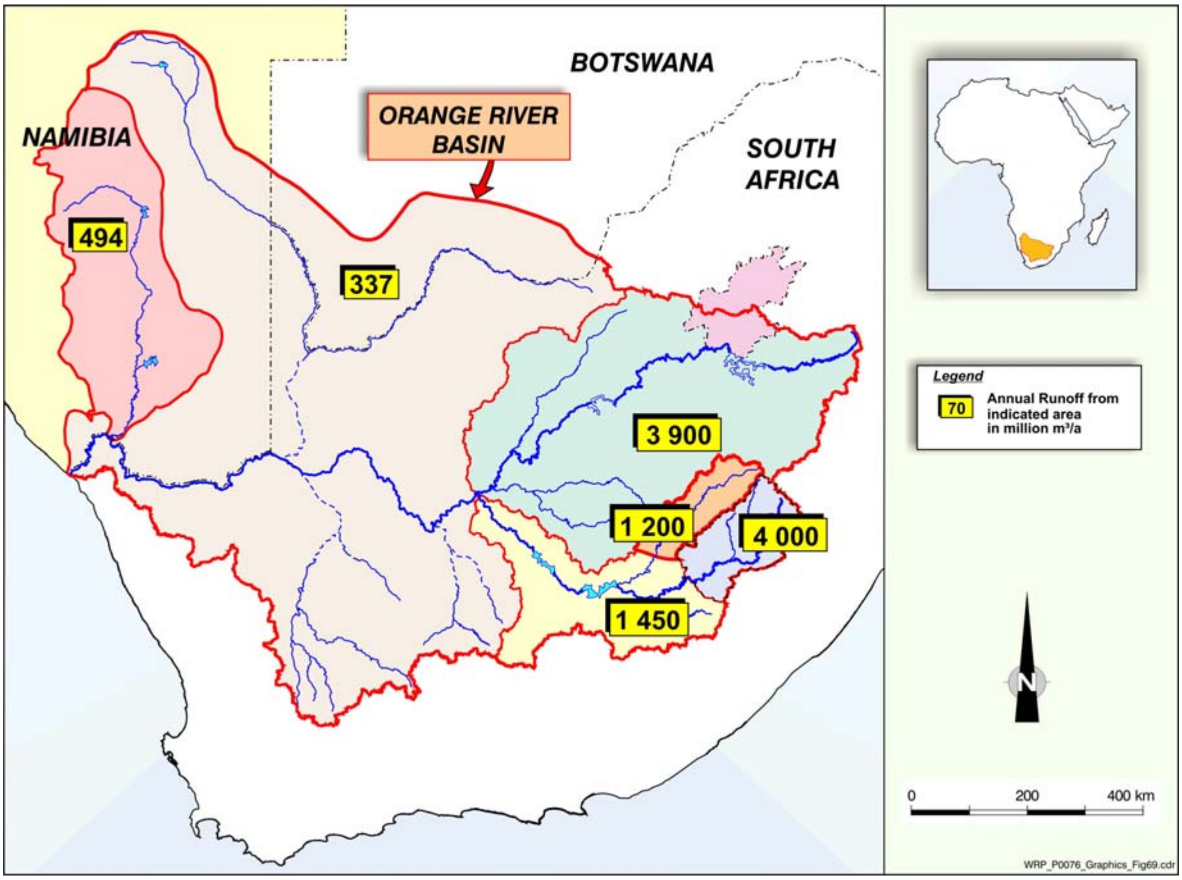


Figure 1-2: Approximate Water Balance for Natural Runoff in the Orange River Basin

The water flowing into the Orange River from the Fish River in Namibia (near the river mouth) could theoretically be used to support some of the downstream demands, particularly the environmental demands at the river mouth. To date, however, the contributions from the Fish River (in Namibia) cannot be utilised to support any downstream demands since these demands are currently supplied with water from Vanderkloof Dam which must be released well in advance since the water takes 2 to 6 weeks to reach the mouth (some 1 400 km away). Any water flowing into the Orange River from the Namibian Fish River will therefore add to the water already released from Vanderkloof Dam since it is currently not possible to stop or store the additional water once it has been released.

The figures indicated in **Figure 1.2** refer to the natural runoff which would have occurred had there been no developments in the catchment. The actual runoff reaching the river mouth (estimated to be in the order of 5 500 million m^3/annum) is considerably less than the natural value (over 11 000 million m^3/annum). The difference is due mainly to the extensive water utilisation in the Vaal River basin, most of which is for domestic and industrial purposes. Large volumes of water are also used to support the extensive irrigation (estimated to be in the order of 1 800 million m^3/annum) and some mining demands (approximately 40 million m^3/annum) occurring along the Orange River downstream of the Orange/Vaal confluence as well as some irrigation in the Lower Vaal catchment and Eastern Cape area supplied through the Orange/Fish Canal. In addition to the water demands mentioned above, evaporation losses from the Orange River and the associated riparian vegetation account for between 500 million m^3/a and 1 000 million m^3/a depending upon the flow of water (and consequently the surface area) in the river (Mckenzie et al, 1993, 1994 and 1995). An approximate water balance for the Orange River is given in **Table 1-1** to provide perspective on the various demands supported from the river.

Several new developments have already been commissioned or have been identified as possible future demand centres for water along the Lower Orange River. In Namibia such developments include the Haib copper mine, Skorpion lead and zinc mine (already developed), the Kudu gas fired power station at Oranjemund and several irrigation projects for communal and commercial irrigation along the northern riverbank. Similar potential also exists on the South African side of the river with particular need to develop irrigation for previously disadvantaged farmers. In Lesotho there is considerable development planned for the Lesotho Lowlands area and also the potential for further transfers from the Lesotho Highlands Water Project. In Botswana, the developments that may influence the Orange River are restricted mainly to groundwater abstraction.

Table 1-1: Orange River Water Balance at 2005 Development Level

Water Balance Component	Volume (million m³/a)
Environmental Requirement	900 (1)
Namibia	120 (2)
Lesotho & Transfers to RSA	820 (3)
RSA Orange River Demand	2 560 (4)
RSA Vaal River Demand	1 560 (5)
Evaporation & losses	1 750 (6)
Spillage	3 780 (7)
Total	**11 490**
Spillage under natural conditions	10 900

Notes (1) - Includes natural evaporation losses from Orange River.
(2) - Includes water use from Orange & Fish rivers.
(3) – With Full Phase 1 of LHWP active.
(4) – Includes transfers to the Eastern Cape.
(5) – Vaal Demand supplied from locally generated runoff.
(6) – Excludes evaporation losses from the as it is already included in component 1.
(7) – Average spillage at 2005 development level

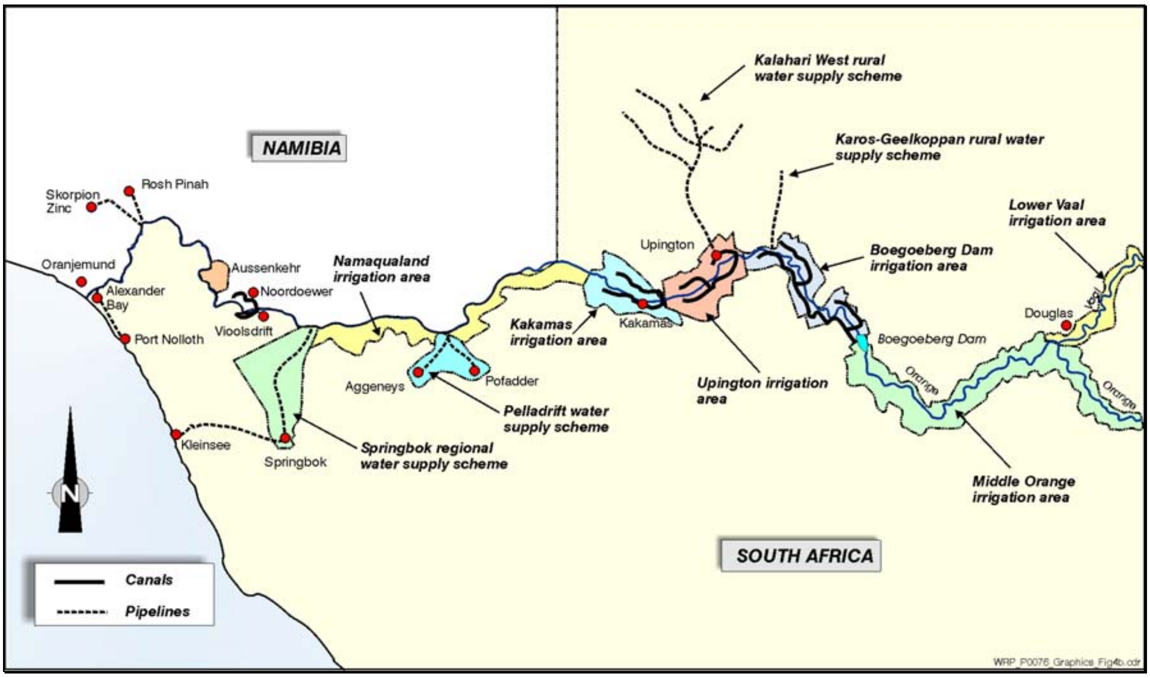


Figure 1-3: Major Water Demands along the Lower Orange River.

In Lesotho, the first phase of the Lesotho Highlands Water Project was recently completed and represents one of the largest water transfer schemes in the world. Some details of the scheme are shown in **Figure 1.5.** It should be noted that the water transfers shown in the figure are approximate values only and are likely to change due to revision of environmental requirements etc.

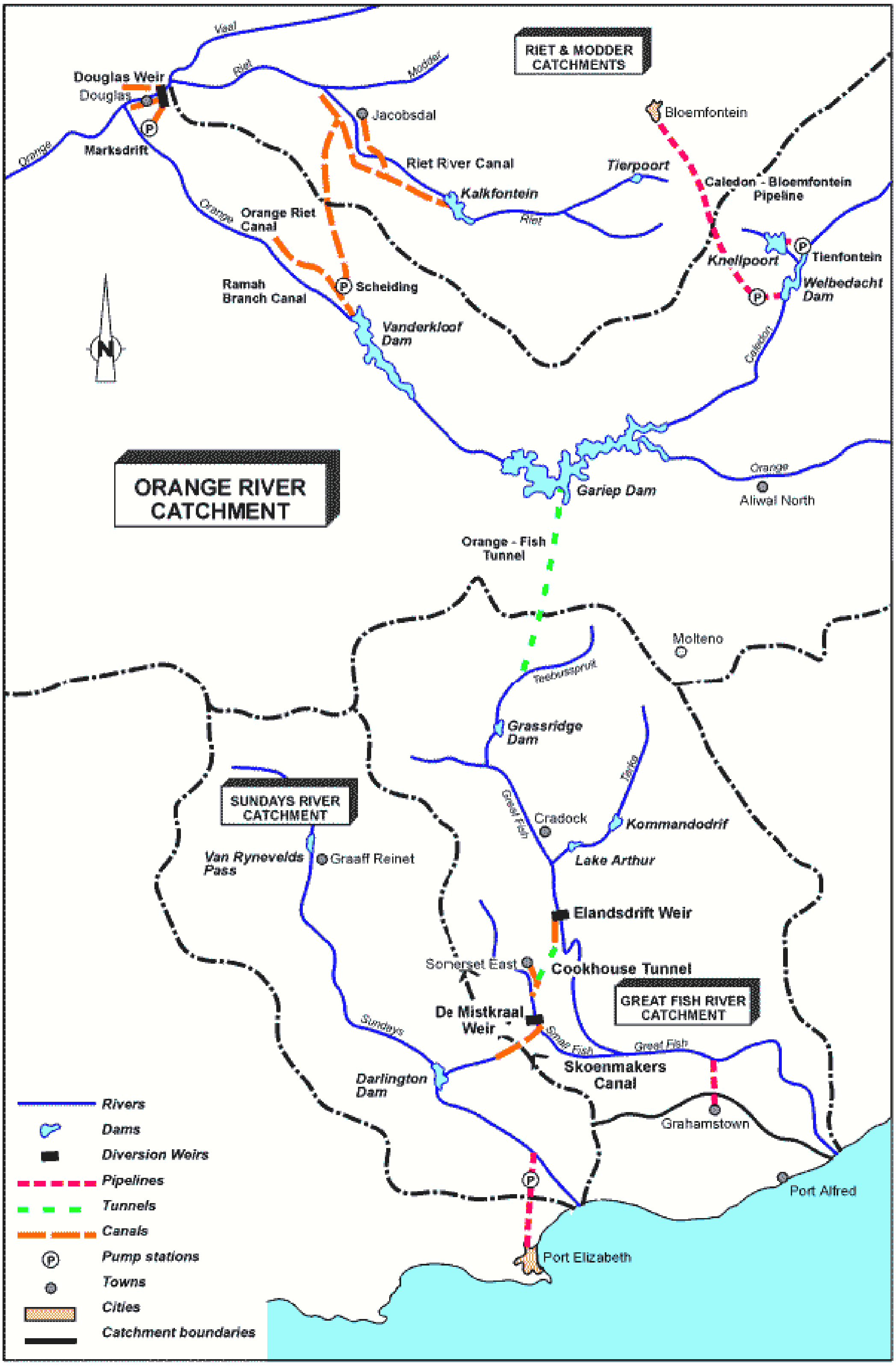


Figure 1-4: Major Water Transfer Schemes from Gariep and Vanderkloof dams.

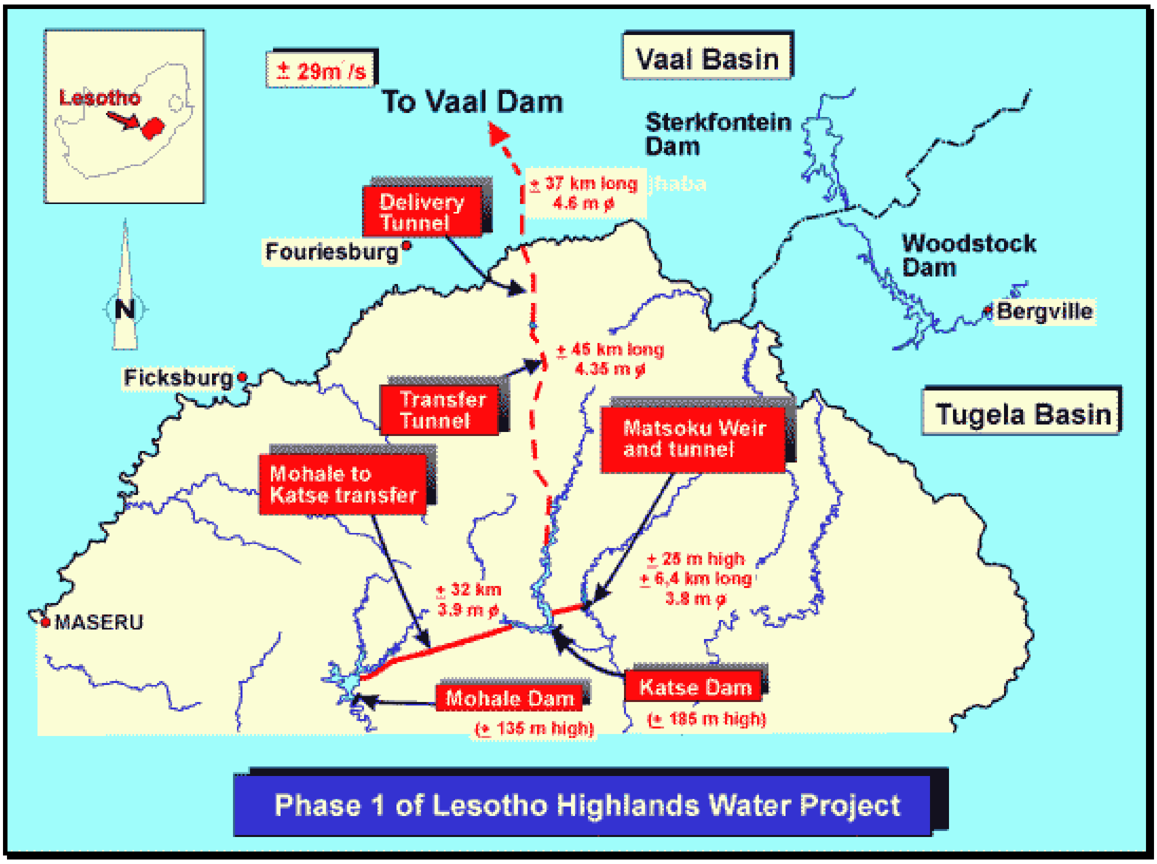


Figure 1-5: Phase 1 of the Lesotho Highlands Water Project.

1.2 Objective of the study

In view of the existing and possible future developments which will influence the availability of water in the Orange River, a project has been initiated by ORASECOM and commissioned and funded by GTZ involving all four basin states (Botswana, Lesotho, Namibia and South Africa. The main objective of the project is to facilitate the development of an Integrated Water Resources Management Plan for the Orange River Basin. The plan will in turn facilitate the following specific objectives:

- Maximise benefits to be gained from Orange River water;
- Harmonise developments and operating rules;
- Foster peace in the region and prevention of conflict;
- Encourage proper and effective disaster management;

- Ensure that developments are sustainable and encourage the maintenance of bio-diversity in the basin, and
- Management of potential negative impacts of current and possible future developments.

In order to achieve the above objective it is envisaged that the resulting Water Resources Development Plan will be founded on the following four basic principles:

- Reasonable utilisation of available water resources;
- Equitable accrual of benefits to basin states;
- Sustainable utilisation of water resources, and
- Minimisation of harm to the environment.

The strategy to be adopted by the project team to meet the objectives should involve the following:

- Sharing of information on existing and proposed future developments;
- Facilitation of a common understanding of key issues based on comparable technical and institutional capacity;
- Development of comparable legislation and institutional structures;
- Adoption of comparable standards and management approaches;
- The development of a Water Resource Management Plan for the future development and management of the water resources of the Orange River.

It is anticipated that the development of the Water Resource Management Plan will be undertaken in phases and the remainder of this document refers to the work involved with Phase 1 of the project. Phase 1 will involve the following:

- A desktop study to establish the status quo within the basin and to create an agreed base from which the subsequent phases of the project can be developed;
- To facilitate capacity building where possible in order to strengthen expertise throughout the four basin states;
- To identify and highlight deficiencies in the knowledge base which must be addressed before the Water Resource Management Plan can be finalised. Some fieldwork may be required in subsequent phases of the project;
- To develop a preliminary Water Resource Management Plan which can be used as the basis from which the final plan can ultimately be developed;

- To develop a draft scope of work for subsequent phases of the project from which a Terms of Reference can be developed by the Client.
- An inaugural meeting to discuss the project and in particular the expected content for the Inception Report was held in Botswana on 8 February 2004.

1.3 Purpose and Structure of this Report

This report is used to summarise the findings from the Water Requirements Task. A description of the data base inventory will be given in **Section 2** of the report. **Section 3** will include a summary of the demands and return flows captured in the excel data base prepared for the current and future demands. Conclusions and recommendations are given in **Section 4.**

2 DATA BASE INVENTORY

2.1 General

This component of the Water Requirements task involved the compiling of the latest available water demand and return flow data from reports of relevant studies. An initial database was developed in Excel which will later in the study be incorporated in the Access database which is developed as part of Task 2 of this study. The preliminary Excel data base was populated with water demand data per main water use sector for each of the selected geographic areas, as obtained from existing reports. Details of the database inventory will be given in the sections to follow.

2.2 Description of the database inventory

For the purpose of the database inventory, the study area was divided into different sub-catchments mainly according to those defined in the available study reports. These sub-catchments were sorted first according to the two major river catchments, the Vaal River and Orange River catchment, and then according to the main sub-catchments within each major river catchment. The Vaal River catchment is divided into five main sub-catchments as described in **Table 2.1** and shown in **Figure A-1** of **Appendix A**.

Table 2-1 : Main sub-catchments in the Vaal River catchment

Main Sub-catchment		Description
Name	Area (km²)	
Upper Vaal	38 638	Vaal River catchment from Vaal Dam and upstream
Vaal Barrage	8 651	Vaal River catchment between Vaal Dam & Vaal Barrage
Middle Vaal	60 836	Vaal River catchment between Vaal Barrage and Bloemhof Dam
Lower Vaal	53 787	Vaal River catchment downstream of Bloemhof Dam excluding the the Riet and Modder River catchments
Riet/Modder	27 627	The combined Riet and Modder River catchments
Total	**189 539**	**Total Vaal River Catchment**

The Orange River catchment (excluding the Vaal River catchment) is divided into seven main sub-catchments which also take into account the country wherein it is located. The Orange River main sub-catchments is described in **Table 2.2** and shown in **Figure A-1** of **Appendix A.**

The sub-catchments as per main sub-catchment are given in **Table 2.3** for both the Vaal and Orange River catchments and are shown in **Figure A-1** of **Appendix A**. Several data elements were covered in the inventory with regards to the following data categories: i.e. catchment area, water resource, water requirements for urban/industrial, mines, power stations, strategic industries, irrigation, rural domestic, livestock, ecological requirements, losses and groundwater use. For each of the sub-catchments as defined in **Table 2.3** metadata were provided for all the selected data elements as and when it was available from existing documents.

Table 2-2: Main sub-catchments in the Orange River catchment

Main Sub-catchment		Description
Name	**Area (km²)**	
Senqu	24 752	Upper reaches and origin of the Orange River in Lesotho
Upper Orange	48 595	Orange River upstream of Vanderkloof Dam and downstream of Welbedacht Dam and the Lesotho Border at Oranjedraai.
Caledon	15 245	Caledon River catchment from Welbedacht Dam and upstream (includes parts of RSA and Lesotho)
Lower Orange RSA	326 173	Orange River catchment downstream of Vanderkloof Dam and the Vaal River confluence excluding the Lower Orange Areas located in Botswana and Namibia
Lower Orange Botswana	71 000	The Orange River catchment located in Botswana
Lower Orange Namibia	164 166	The Orange River catchment located in Namibia excluding the Fish River (Namibia)
Fish River Namibia	95 680	The total Fish River catchment in Namibia
Total	**745 611**	**Total Orange River Catchment excluding Vaal River**

Details of the data elements included in the inventory for each of the data categories are given in **Table 2.4.** The gross and net areas are given for the sub-catchments. The gross area refers to the total area in km² of the sub-catchment and the net area to the area that contributes to the river runoff. Information with regards to the net area was unfortuanatelly not always available from existing reports. In some areas which are relatively flat, part of the sub-catchment drains to local pans, so that only a portion of the runoff will be reaching the river. Only the area that contributes to runoff draining to the river is regarded as the effective area and is referred to as the net catchment area. There will most probably also be non contributing or endoreic areas in Namibia and Botswana, although no data was available in this regard.

The water resource data element refers to the surface water resource that is utilised to supply the indicated demands. The water requirements for the main water use sectors were given for the 2005, 2015 and 2025 development levels. Seven water uses sectors were defined and include urban/industrial, mines, power stations, strategic industries, irrigation, rural domestic and rural livestock. In addition to the seven water use sectors, the ecological requirements and the main losses from water supply systems were added. Groundwater use data is very seldom found in the existing reports. Detail of the actual water use sectors utilising the groundwater was not always given, however it was clear that the bulk of the groundwater was used to supply rural, smaller towns and some irrigation requirements.

Table 2-3 : Sub-catchments within each main sub-catchment

Vaal River Basin		Orange River Basin (excluding Vaal)	
Main sub-catchment	**Sub-catchment name & reference no.**	**Main sub-catchment**	**Sub-catchment name & reference no.**
Upper Vaal	R1-Delangesdrift	Senqu	L1-Katse Dam
	R2-Frankfort		L2-Malatsi possible Dam
	R3-Grootdraai Dam		L3-Mashai possible Dam
	R4-Sterkfontein Dam		L4-Matsoku Weir
	R5-Vaal Dam		L5-Mohale Dam
Vaal Barrage	R6-Vaal Barrage		L6-Ntoahe possible dam
	R7-Klip River		L7-Tsoelike possible dam
	R8-Suikerbosrand River		L8-Oranjedraai
Middle Vaal	R9-Allemanskraal Dam		*L9-Makhaleng 1
	R10-Bloemhof Dam		*L10-Makhaleng 2
	R11-Boskop Dam	Upper Orange	R36-Aliwal Noord
	R12-Erfenis Dam		R37-Gariep Dummy Dam
	R13-Klerkskraal Dam		R38-Vanderkloof Dam
	R14-Possible Klipbank Dam		R39-Kraai River
	R15-Klipdrift Dam		R40-Gariep Dam
	R16-Koppies Dam	Caledon	L11-Hlotse possible dam
	R17-Possible Kromdraai Dam		L12-Katjiesberg possible dam
	R18-Johan Neser Dam		R41-Knellpoort Dam
	R19-Possible Rietfontein Dam		R42-Waterpoort possible dam
	R20-Rietspruit Dam		R43-Welbedacht Dam
	R21-Lower Sand/Vet River		+L13-Hlotse possible dam 1
Lower Vaal	R22-Wentzel Dam		+L14-Hlotse possible dam 2
	R23-Baberspan		[$]L15-Ngoajane possible dam 1

Vaal River Basin		Orange River Basin (excluding Vaal)	
Main sub-catchment	**Sub-catchment name & reference no.**	**Main sub-catchment**	**Sub-catchment name & reference no.**
	R24-Taung Dam		$L16- Ngoajane possible dam 2
			$L17- Muela Dam
	R25-Spitskop Dam	Lower Orange RSA	R44-Boegoeberg Weir
	R26-Lower Harts		R45-Vioolsdrift/Mouth
	R27-Vaalharts Weir	Lower Orange Botswana	B1- Nossop & Molopo catchment
	R28-De Hoop Weir		
	R29-Douglas Weir	Lower Orange Namibia	N1-Daan Viljoen Dam
Riet/Modder	Aucampshoop		N2-Otjivero Dam
	Kalkfontein Dam		N3-Nossop remainder
	Krugersdrift Dam		N4-Nauaspoort Dam
	Rustfontein Dam		N5-Oanob Dam
	Tierpoort Dam		N6-Auob remainder
	Tweerivier		N7-Tsamab Dam
			N8-Dreihoek Dam
			N9-Quaternary 442 & 481 & remainder of 482 & 483
			N10-Quaternary484
			N11-Quaternary485
		Fish River Namibia	N12-Hardap Dam
			N13-Konkiep
			N14-Lower Fish possible dam
			N15-Naute Dam
			N16Seeheim

Notes : * - As part of the Lesotho Lowlands Study the Oranjedraai sub-catchment were sub-divided into these two sub-catchments.

+ - As part of the Lesotho Lowlands Study the Hlotse sub-catchment were sub- divided into these two sub-catchments.

$ - As part of the Lesotho Lowlands Study the Katjiesberg sub-catchment were sub-divided into these three sub-catchments.

Table 2-4: Data elements included in the inventory

Data Category	Data elements	
Catchments area	Gross area in km²	
	Net area in km²	
Water Resource	Resource used to supply the particular demand	
Water Requirements	Urban/Industrial	Demand in million m^3/a for 2005, 2015 & 2025 development level
	Mines	Demand in million m^3/a for 2005, 2015 & 2025 development level
	Power Stations	Demand in million m^3/a for 2005, 2015 & 2025 development level
	Strategic Industries	Demand in million m^3/a for 2005, 2015 & 2025 development level
	Irrigation	Demand in million m^3/a for 2005, 2015 & 2025 development level
	Rural Domestic	Demand in million m^3/a for 2005, 2015 & 2025 development level
	Rural Livestock	Demand in million m^3/a for 2005, 2015 & 2025 development level
	Ecological Requirement	Requirement in million m^3/a
	Losses	Current loss in million m^3/a level
Groundwater use	Groundwater use	Water use in million m^3/a for 1995 development level

3 WATER REQUIREMENTS AND RETURN FLOWS

3.1 General

Most of the water requirements in the Orange River Basin are supplied through two major water supply systems i.e. the Integrated Vaal River System and the Orange River Project (Gariep and Vaderkloof dams). Several transfer schemes are in place to augment the Vaal River (See **Figure A-3** in **Appendix A**) as the demand within the Vaal River basin by far exceeds the water available from the Vaal River alone. A simplified schematic of the Integrated Vaal River and Orange River system is shown in **Figure 3.1**. From this figure all the transfers from other sub-systems to the main Vaal System as well as from the Orange River to other sub-systems are clearly shown. Within the Vaal River System there are numerous smaller sub-systems which are operated as individual stand alone schemes used to supply local requirements. These sub-systems are not used to support the main Vaal River System, but affect the yield of the main system due to the reduced base flow in the tributaries and spills from the sub-system reservoirs.

The Orange River originates in the Lesotho Highlands where it is known as the Senqu River and only when it enters the RSA is it referred to as the Orange River. In contrast to the Vaal River System the Orange River System is used to support users in neighbouring catchments (See **Figure A-4** in **Appendix A** and **Figure 3.1**). From the Lesotho Highlands Project (Katse and Mohale dams) water is transferred to the Vaal System to augment Vaal Dam, from Gariep Dam water is transferred via the Orange/Fish tunnel to the Eastern Cape mainly in support of irrigation, from Vanderkloof Dam water is transferred to the Riet/Modder catchment also mainly for irrigation purposes and finally from Welbedacht and Knellpoort dams in the Caledon River catchment water is transferred to the Modder River catchment to supply urban/industrial requirements of Bloemfontein, Botchabelo and others. Within the greater Orange River System various smaller sub-systems are found which are also operated as individual stand alone schemes not used to support the Orange River Project, similar to those in the Vaal River System. These sub-systems are not all located in the RSA but several are located in Namibia, with some in Lesotho and none in Botswana, except for the groundwater use in Botswana.

It was therefore decided to split this section into five main sections i.e. the Vaal River System, the Orange River System, sub-systems in Namibia, sub-systems in Lesotho and the water demands in Botswana.

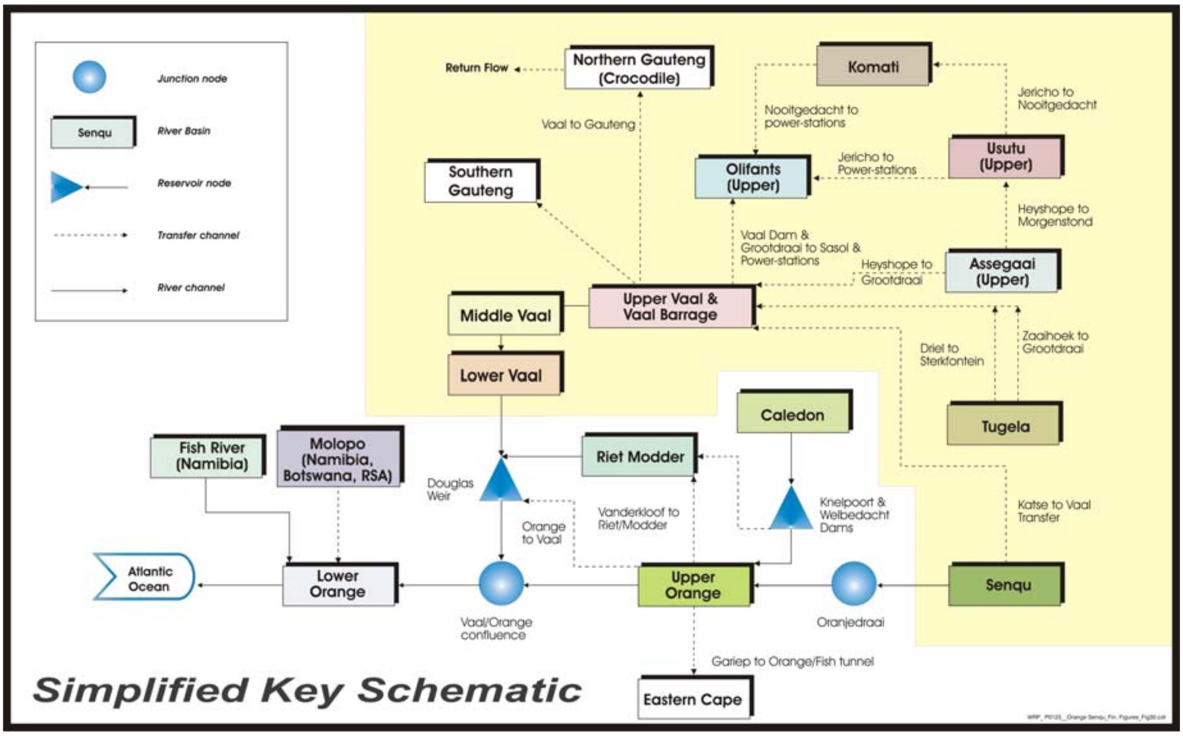


Figure 3-1: Simplified schematic of the Integrated Vaal River and Orange River system

3.2 Vaal River System (RSA)

3.2.1 Main system

Being the principal source of water supply to Gauteng, the Vaal River system is perhaps South Africa's most important system, but certainly the most over-utilised river system. The Main Vaal River System comprises of four major storage dams in the Vaal River Basin, i.e. the Grootdraai Dam, Sterkfontein Dam, Vaal Dam and Bloemhof Dam (See **Figures A-1 & A-5** in **Appendix A**).

Grootdraai Dam is used to supply Standerton, Sasol II & III, Tutuka Power station as well as part of the water requirement of Duvha, Matla, Kendal and Kriel power stations located in the Olifants River catchment. Grootdraai Dam is supported by transfers mainly from Heyshope Dam in the Assegaai River but also to a lesser extent from Zaaihoek Dam in the Slang River located within the Thukela catchment.

Sterkfontein Dam is located in the upper reaches of the Wilge River a tributary of the Vaal River, and stores the water transferred from Woodstock Dam and Driel Barrage in the Thukela River. Sterkfontein Dam is mainly used to support Vaal Dam, as and when required. This support only occurs when Vaal Dam is at very low levels.

Vaal Dam and Vaal Barrage are located at the downstream end of the Upper Vaal catchment and are used to supply Gauteng with water. Water is also released from Vaal Dam to support users between Vaal Dam and Bloemhof Dam as well as to support Bloemhof Dam with water. The main users between Vaal Dam and Bloemhof Dam include Rand Water, Sasol 1, Midvaal WC, Sedibeng Water and irrigation along the Vaal River.

The Vaalharts Irrigation Scheme is the main user in the Lower Vaal WMA and is supplied with water from Bloemhof Dam. Water is released from Bloemhof Dam into the river and is diverted into the Vaalharts main canal at the Vaalharts Weir. Releases from Bloemhof Dam are also used to supply water to Kimberley, the Vaal Gamagarra Water Supply Scheme as well as irrigation along the Vaal River between Bloemhof Dam and the conluence of the Vaal and Riet River.

The demands imposed on the main Vaal System are summarised in **Table 3.1** with details given in the excel data base. The total demand imposed on the main Vaal System is 2 790 million m^3/a in 2005 and increases over time to 3 212 million m^3/a by 2025. This excludes the ecological requirement as it is a non consumptive requirement, but do include the river evaporation requirements. The ecological requirements are based on desktop estimates recently determined by the DWAF (RSA) RDM office, using the DSS program (DWAF, 2006c). These environmental requirements are only first order indications of what the ecological reserve will be, and are thus currently not supplied by means of any releases from the reservoirs.

Table 3-1: Demands imposed on the main Vaal River System

Description	Demand (million m^3/a) for given year		
	2005	2015	2025
Urban/Industrial			
Rand Water	1 307.86	1 498.48	1 665.23
Sedibeng	40.95	41.33	41.92
Midvaal CO	35.00	35.00	35.00
Others	59.25	80.94	80.77
Sub-total	1 443.06	1 638.59	1 804.10
Mining			

Vaalreefs	1.54	1.82	2.15
Sub-total	1.54	1.82	2.15
Power Stations			
Supplied from Vaal only	101.02	131.19	140.17
Supplied partially from Vaal	125.12	154.93	157.04
Sub-total	226.43	286.12	297.21
Strategic Industries			
Sasol	116.29	137.94	153.94
Mittal Steel	17.35	16.62	16.62
Sub-total	133.64	154.56	170.56
Irrigation			
Vaalharts	327.80	327.80	327.80
Other	210.49	162.63	162.63
Sub-total	538.29	490.43	490.43
Rural			
Vaal Gamagara scheme	13.70	13.70	13.70
Sub-total	13.70	13.70	13.70
Losses			
Canal	127.02	127.02	127.02
Transfers	40.10	40.10	40.10
Operational	115.35	115.35	115.35
Other	73.75	73.75	73.75
	356.22	356.22	356.22
Ecological Requirements			
Ecological requirement **	737.45	737.45	737.45
River evaporation requirement	78.1	78.1	78.1
Total for Main Vaal System*	2790.77	3019.54	3212.47

Note *: The total excludes the ecological requirement as it is a non consumptive demand

**: This represents the ecological requirement at the downstream end of the Vaal River at Douglas

Rand Water is by far the largest water user from the Main Vaal System, utilising approximately 47% of the total demand imposed on the Main Vaal System. The Rand Water supply area is located partly in the Vaal River catchment (51% on a demand basis) and the rest to the North mainly in the Crocodile West River catchment (49% on a demand basis). This means that approximately half of the return flows generated from the urban industrial area will not flow back into the Vaal River basin but will in fact be transferred to the Crocodile West River basin.

The water demand growth projections were obtained from the ''Vaal River System: Large Bulk Water Supply Reconciliation Strategy'' study (DWAF,2006a & b), which is the latest projections available. Several growth projection scenarios are given in the ''First Stage Reconciliation Strategy'' report (DWAF, 2006a) from the Vaal Reconciliation Study and the most likely scenario, referred to as Scenario B was selected for the purpose of this study. Scenario B is based on the August 2006 population estimate of Stats RSA and excludes the effects of water conservation and water demand management options, but includes the expected eradication of unlawful irrigation use.

The decrease in the irrigation projections is therefore due to the expected eradication of unlawful irrigation mainly in the Upper Vaal WMA. The process of validation and verification of existing registered irrigation water use is currently still ongoing in the Vaal River basin, and actions with regards to the eradication of unlawful use can only commence, once it has been completed.

Monthly Requirements

In system yield analysis it is of importance to include the monthly distribution pattern of the demands as it also affects the yield available from a system. If the monthly demand pattern is in phase with the monthly runoff distribution, the system will be able to produce a slightly higher yield than one would have if the distribution pattern is totally out of phase. In the case of irrigation demands, one normally has a higher variation in the monthly demand distribution than with typical urban industrial demands. Irrigation demands in general also vary considerably from year to year. During wet years less irrigation water is required due to the higher contribution from rainfall and during dry years a higher irrigation demand is required due to low rainfall. This high irrigation requirement also occurs during the critical period of the reservoir yield analysis, and therefore decreases the available yield.

Monthly distribution of various demands imposed on the Vaal System and sub-systems are summarised in **Table 3.2**.

Table 3-2: Examples of monthly demand distributions for demands within the Vaal River catchment for 1994 development

Channel No	Monthly and annual requirement (million m³)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Urban abstractions from Suikerbosrant River East Daggafontein, Marievale and Ergo Daggafontein	0.25	0.33	0.36	0.41	0.38	0.40	0.49	0.49	0.46	0.42	0.45	0.40	4.81
Klerkskraal Dam Irrigation demand	2.35	2.12	2.18	2.15	1.89	2.22	2.09	1.99	1.98	2.08	2.08	2.24	25.38
Boskop Dam Irrigation demand	5.06	4.26	4.68	4.95	4.10	4.24	3.66	3.88	3.50	4.11	4.64	5.14	52.23
Klipdrift Dam Irrigation demand	0.54	0.33	0.30	0.57	0.48	0.43	0.31	0.28	0.23	0.35	0.58	0.58	5.00
Demand supplied from Koppies Dam mainly irrigation	1.07	0.72	0.71	1.03	0.83	0.84	0.57	0.71	0.26	0.48	1.32	1.38	9.92
Allemanskraal Dam Irrigation demand	4.20	2.70	2.49	3.27	2.77	3.01	1.55	1.39	1.82	1.98	3.24	4.02	32.44
Erfenis Dam Irrigation demand	5.07	3.50	3.05	3.97	3.03	3.18	1.79	1.95	2.29	2.65	3.90	4.90	39.28
Mine return flow to Boskop Dam	1.74	1.69	1.66	1.81	1.38	1.64	1.36	1.52	1.27	1.52	1.40	1.26	18.25

3.2.2 Smaller sub-systems within the Vaal River Basin

The total demand imposed on the smaller sub-systems within the Vaal River Basin accumulates to a significant volume of 1 055 million m^3/a, for the year 2005. This comprises of almost 25 percent of the total water demand in the basin. The focus on water supply in the smaller subsystems is on irrigation with almost 64 percent of the total demand allocated to irrigation. Excluding the Vaalharts Irrigation Scheme, which receives water from the main Vaal System, there are another twelve irrigation schemes located in the tributary catchments of the Vaal River. These irrigation schemes contribute to only 35 percent of all the irrigation in the smaller sub-systems, at the 2005 development level. The rest of the irrigation is referred to as diffuse irrigation, as it is typically irrigation that is scattered all over the river basin, and which is not part of an organised irrigation scheme. The bulk of this irrigation is located in the Upper Vaal and Vaal Barrage catchments. Based on the preliminary findings of the current validation and verification studies, it seems that a large portion of this irrigation is unlawful. The unlawful irrigation needs to be eradicated, which is the reason for the decrease in the irrigation demand projection between the years 2005 and 2015. The process of the elimination of unlawful irrigation will most probably start as soon as the validation and verification of water use in the Upper Vaal WMA has been completed.

Table 3-3: Demands imposed on the smaller systems within the Vaal River Basin

Description	Demand (million m^3/a) for given year		
	2005	2015	2025
Urban/Industrial			
Bloemfontein & Botchabelo	68.76	78.10	90.80
Kroonstad & Lindley	12.29	11.76	10.52
Potchefstroom	15.49	17.16	18.82
Others	59.60	60.74	60.85
Sub-total	156.14	167.76	180.99
Mining			
Balfour & Ergo	5.95	6.22	6.35
Sub-total	5.95	6.22	6.35
Power Stations			
Majuba supplied from Zaaihoek	19.19	25.58	24.15
Sub-total	19.19	25.58	24.15
Rural Domestic Requirements			
Upper Vaal	9	9	9
Vaal Barrage	1.2	1.2	1.2
Middle Vaal	5.6	5.6	5.6

Description	Demand (million m^3/a) for given year		
	2005	2015	2025
Lower Vaal	3.16	3.16	3.16
Riet-Modder	1	1	1
Sub-total	19.96	19.96	19.96
Livestock			
Upper Vaal	34	33	32
Vaal Barrage	4.3	4.3	4.3
Middle Vaal	35.9	35.9	35.9
Lower Vaal	25.58	25.58	25.58
Riet-Modder	12	12	12
Sub-total	111.78	110.78	109.78
Irrigation			
Irrigation Schemes			
Allemanskraal Irrigation	36.99	36.99	36.99
Boskop Irrigation	28.59	28.59	28.59
Erfenis Irrigation	39.28	39.28	39.28
Klerkskraal Irrigation	6.66	6.66	6.66
Klipdrift Irrigation	7.12	7.12	7.12
Klerksdorp Irrigation	10.25	10.25	10.25
Koppies Irrigation	5.8	5.8	5.8
Schoonspruit Irrigation	18.68	18.68	18.68
Spitskop Irrigation	12.81	12.81	12.81
Kalkfontein Canal Scheme	33.5	33.5	33.5
Tierpoort Irrigation Scheme	6.4	6.4	6.4
Modder River G.W.S.	29.4	29.4	29.4
Sub-total	235.48	235.48	235.48
Diffuse Irrigation			
Upper Vaal	183.85	61.93	61.93
Vaal Barrage	70.35	25.28	25.28
Middle Vaal	87.54	80.28	80.28
Lower Vaal	9.52	9.52	9.52
Riet-Modder	85.4	85.4	85.4
Sub-total	436.66	262.41	262.41
Sub-total	672.14	497.89	497.89
Losses			
Mine dewatering	13.80	13.80	13.80
Caledon/Modder transfer & system	12.40	12.40	12.40
Weltand & bedlosses	44.11	44.11	44.11
Sub-total	70.31	70.31	70.31
Ecological Requirements **			
Allemanskraal Dam	15.38	15.38	15.38
Boskop Dam	20.24	20.24	20.24
Erfenis Dam	16.75	16.75	16.75

Description	Demand (million m^3/a) for given year		
	2005	2015	2025
Klipdrift Dam	3.37	3.37	3.37
Koppies Dam	10.98	10.98	10.98
Johan Neser Dam	11.62	11.62	11.62
Spitskop Dam	23.22	23.22	23.22
Tweerivier	72.15	72.15	72.15
Total for the sub-systems in Vaal	1 055.47	898.50	909.43

Note *: The total excludes the ecological requirement as it is a non consumptive demand
**: These represent the ecological requirement at the downstream end of the sub-systems

The total groundwater use within the Vaal River basin is estimated at 215 million m^3/a at 1995 development level. The bulk of the groundwater use is taking place in the Lower Vaal WMA (45% of total use) followed by the Middle Vaal WMA with almost 33% of the total groundwater use. All the demands listed in **Table 3.3** are supplied from surface water resources, with the exception of the rural domestic and livestock water requirements, which are mainly supplied from groundwater.

3.2.3 Return flows

Most of the return flows generated in the Vaal River basin originate from the Southern Gauteng urban/industrial area which is supplied by Rand Water. For this area, approximately 51% of the gross demand returns to the Vaal River. The return flows from the Northern Gauteng area flows into the Crocodile West River basin. Approximately 49% of the demand in the Northern Gauteng ends up as return flows in the Crocodile River basin, reaching a volume of almost 270 million m^3/a in the year 2005.

Mine dewatering mainly takes place in the catchment between Vaal Dam, and the confluence of the Vaal and Schoonspruit rivers. The volumes from mine dewatering is significant and already accumulated to a total of 114 million m^3/a in the year 2005.

As result of the highly populated and industrialised Gauteng area, increased runoff due to paved areas reached a volume of approximately 100 million m^3/a in 2005. A summary of the return flows from the urban, industrial and mining sectors are given in **Table 3.4**.

Table 3-4: Summary of Urban/Industrial and Mining related return flows

Description	Return flows (million m3/a) for given year		
	2005	**2015**	**2025**
Southern Gauteng (Rand Water)	335	392	438
Midvaal Water Company	1	1	1
Sedibeng Water	2	2	2
Other towns and industries	85	97	107
Mine dewatering	114	121	121
Increased urban runoff	101	107	121
Total	**638**	**720**	**790**

Return flows from irrigation is generally in most studies assumed to be in the order of 10% of the irrigation demand. This is not always true as it is dependant on several factors such as the soil type, location of the irrigation fields, type of irrigation system used, type and condition of the main distribution system, management practices, etc. More detailed analyses on return flows from the main irrigation schemes in the Vaal River Basin were recently undertaken as part of the Vaal River Reconciliation study (DWAF,2006b), which resulted in return flows varying between 4% to 22% (See **Table 3.5**).

Table 3-5: Return flows from main irrigation schemes

Irrigation Scheme	Gross inflow (million m³/a)	Return flows (million m³/a)	Percentage Return flow
Vaalharts Scheme	392.95	49.03	12
Klerksdorp Scheme	4.93	0.25	5
Schoonspruit Scheme	24.10	5.31	22
Mooi River Scheme	165.50 [illegible]	97.08 [illegible]	*59 (4) (4)*
Erfenis Canal Scheme	43.92	3.89	9
Erfenis River Scheme	9.76	0.38	4
Allemanskraal Canal Scheme	40.56	6.63	16
Total	**681.72 (589.60)***	**162.57 (68.45)***	**24 (12)***

Notes:*- A very high percentage of the Mooi River Scheme return flows is as result of the large volume of tail water flow from the canal end. When the effect of the tail water flow is removed the result is given by the value in brackets.

3.3 Orange River System

3.3.1 The Main Orange System (Mainly RSA)

The Main Orange System consists of two major storage dams, i.e. Gariep and Vanderkloof Dam (See **Figures A-1 & A-6** in **Appendix A**). This system is also referred to as the Orange River Project (ORP). Gariep Dam with a gross storage of 5 342 million m^3 is the largest storage dam in the Orange River Basin and Vanderkloof Dam with a gross storage of 3 186 million m^3 the second largest. The two dams are used to supply all the demands along the Orange River from Gariep Dam to the Orange River mouth. These demands include all the irrigation, urban, mining, environmental requirements, river evaporation requirements and operational losses. Large volumes of water are also transferred from the two dams to neighbouring catchments (See **Figure A-4**). These transfers include the following:

- The transfer through the Orange-Fish tunnel from Gariep Dam to the Eastern Cape to support large irrigation developments, as well as some urban/industrial requirements.
- The transfer through the Orange-Riet canal from Vanderkloof Dam to the Riet-Modder catchment, mainly for irrigation purposes.
- Orange-Vaal transfer from the diversion weir at Marksdrift in the Orange River downstream of Vanderkloof Dam. Water is diverted into a canal from Marksdrift Weir to Douglas Weir in the Lower Vaal River just before the confluence of the Vaal and Orange rivers. This scheme mainly supply water for irrigation purposes and is also used to improve the water quality in the Douglas Weir at the downstream end of the Vaal River.
- Relatively small transfer from the Lower Orange along the common border between the RSA and Namibia. This transfer is used to supply water to the towns of Springbok and Kleinsee, for urban and mining purposes.

Water is released directly into the Orange River from Gariep and Vanderkloof Dams to supply all the downstream users. These river releases are used to simultaneously generate hydropower for Eskom. Only the transfers through the Orange-Fish tunnel and through the Orange-Riet canal are not part of the releases into the river, and can therefore not be used to generate hydropower. At times when there is surplus water available in the two major dams, the surplus is utilised to generate hydropower. During times when spillage occurs from the dams the maximum possible flow is routed through the turbines, to generate hydropower.

A summary of the demands imposed on the Orange River main system (Orange River Project) is given in **Table 3.6**, with details provided in the excel data base. The total demand imposed on the main Orange System is 3 250 million m^3/a in 2005 and increases over time to 3 652 million m^3/a by 2025. This includes the ecological requirement of 289 million m^3/a, which is currently released from Vanderkloof Dam, but excludes the high ecological requirement of 1 062 million m^3/a on average, as obtained from preliminary work done in the Lower Orange River Management Study (LORMS) (PWC,2004). The results from the LORMS were obtained from using the latest technology available in this regard, although it was done at an intermediate level of detail. The LORMS result will be closer to the final expected ecological reserve that must still be determined and implemented.

Irrigation is by far the largest water use sector in the Main Orange System using almost 60% of the total demand imposed on the ORP. Losses represent approximately 10% of the total demand, and the operational loss is the largest loss component. The high operational loss is due to the long distance of approximately 1 300km over which the demands are spread along the Orange River and supplied with releases from Vanderkloof Dam. It takes on average, 1 month for the releases to reach the most downstream users.

Although there is a separate section on the Namibian water requirements, some of the Namibia water requirements are included in Table 3.6 as they are supplied from the ORP.

Table 3-6: Demands imposed on the main Orange River System (Orange River Project)

Description	Demand (million m^3/a) for given year		
	2005	2015	2025
Urban/Industrial/Mining			
RSA			
Orange-FishTransfer (Eastern Cape)	20.00	20.00	41.30
Orange-Riet Transfer	0.30	0.40	0.50
Orange Vaal Transfer	1.20	1.40	1.70
Upper Orange	2.10	2.30	2.50
Lower Orange	36.10	47.20	47.90
Springbok-Kleinsee transfer	4.60	5.60	6.90

Sub-total RSA	64.30	76.90	100.80
Namibia			
Directly from river in common border	15.92	46.72	47.69
Sub-total Namibia	15.92	46.72	47.69
Sub-total urban/industrial/mining	80.22	123.62	148.49
Irrigation			
RSA			
Orange-FishTransfer (Eastern Cape)	607.30	651.00	651.00
Orange-Riet Transfer	183.80	183.80	183.80
Orange Vaal Transfer	80.20	80.20	80.20
Upper Orange	84.40	84.40	84.40
Upper Orange Growth	0.00	44.00	44.00
Lower Orange	936.00	936.00	936.00
Lower Orange Growth	0.00	60.00	60.00
Sub-total RSA	1 891.70	2 039.40	2 039.40
Namibia			
Current along common border	62.70	62.70	62.70
Growth along common border	0.00	94.80	175.30
Sub-total Namibia	62.70	157.50	238.00
Sub-total Irrigation	1 954.00	2 092.80	2 173.30
Losses			
Canal	27.00	27.00	27.00
Transfers	34.70	34.70	34.70
Operational	270.00	270.00	270.00
Sub-total	331.70	331.70	331.70
Ecological Requirements			
Ecological requirement *	1 062.00	1 062.00	1 062.00
Currently released &	288.90	288.90	288.90
River evaporation requirement	615.00	615.00	615.00
Sub-total	903.90	903.90	903.90
Power Stations			
Hydro Power at Gariep & Vanderkloof dams	Utilises releases to meet downstream requirements for hydro power generation purposes. Only when surplus water is available, will additional water be allocated for power generation purposes		
Total for Main Orange System*	3 270.32	3 556.22	3 661.60

Note : * - The total excludes the ecological requirement of 1 062 as it represents the average flow required at the river mouth. This is an indication of what the reserve should be and is not currently supplied.
& - This is the volume currently released from Vanderkloof Dam for ecological purposes.

Results from the LORMS (PWC, 2004) indicated that the operational losses can be reduced by approximately 80 million m^3/a when real time modelling is introduced to improve the control and management of releases from Vanderkloof Dam. A re-regulating dam at Vioolsdrift can reduce these losses by approximately 170 million m^3/a.

The river evaporation and evapo-transpiration (from natural vegetation) requirement along the Orange River downstream of Vanderkloof Dam accumulates to a significant volume of 615 million m^3/a, or 19% of the total demand. This is a natural water requirement and forms part of the ecological requirements.

The urban/industrial/mining requirement along the Orange River is relative small and comprises of only 2.5% of the total demand.

Monthly Requirements

In system yield analysis it is of importance to include the monthly distribution pattern of the demands as it also affects the yield available from a system. If the monthly demand pattern is in phase with the monthly runoff distribution, the system will be able to produce a slightly higher yield than one would have if the distribution pattern is totally out of phase. In the case of irrigation demands, one normally has a higher variation in the monthly demand distribution than with typical urban industrial demands. Irrigation demands can also vary considerably from year to year. During wet years, less irrigation is required due to the higher contribution from rainfall and during dry years, a higher irrigation demand is required due to low rainfall. This high irrigation requirement also occurs during the critical period of the reservoir yield analysis, and therefore decreases the available yield.

Monthly distribution of various demands imposed on the greater Orange River System is summarised in **Table 3.7**.

Table 3-7:Monthly Demands distribution for demands within the greater Orange River System at 2005 Development Levels (million cub. m/a)

DESCRIPTION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	ANNUAL
AREA 1 UPSTREAM OF GARIEP													
CALEDON RSA URB DMD	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	4.200
URBAN DMD KRAAI NODE	0.892	0.892	0.892	0.892	0.892	0.892	0.892	0.892	0.892	0.892	0.892	0.892	10.700
CALEDON LESOTHO URBAN DMD	0.917	0.917	0.917	0.917	0.917	0.917	0.917	0.917	0.917	0.917	0.917	0.917	11.000
BOTSHABELO DMD	1.264	1.264	1.264	1.264	1.264	1.264	1.264	1.264	1.264	1.264	1.264	1.264	15.169
BLOEMFONTEIN DMD	4.243	4.298	4.564	5.011	4.034	3.901	3.424	3.448	3.221	3.358	3.815	4.112	47.430
LHWP TRANSFER	65	65	65	65	65	65	65	65	65	65	65	65	780
AREA 2 GARIEP TO ORANGE/VAAL CONFLUENCE													
ORANGE RIVER IRR: (Vanderkloof to Torquay)	19.386	3.295	4.801	12.614	9.799	13.413	11.244	1.338	4.712	6.703	11.922	17.471	116.70
HOPETOWN DMD	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	2.000
ORANGE RIVER EVAPORATION REQUIREMENTS REACH 1a	4.6294	5.7038	6.2015	6.1857	4.6294	3.7051	2.5122	1.9039	1.3667	1.58	2.3305	3.5076	44.2558
DOUGLAS DMD	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	1.200
IRR FROM DOUGLAS WEIR & CANAL	13.294	3.347	4.033	6.642	4.219	3.850	2.975	0.650	3.117	4.399	7.764	11.409	65.70
RICHIE URB	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.300
RAMAH & VANDERKLOOF IRR	9.252	3.177	4.723	8.030	4.299	4.829	3.975	0.681	2.176	3.062	5.388	7.910	57.502
GARIEP TO VANDERKL URBAN	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	0.175	2.100
ORANGE RIVER IRR: (Torquay to Orange-Vaal Confl.)	5.997	1.019	1.485	3.902	3.031	4.150	3.478	0.414	1.458	2.073	3.688	5.405	36.10
ORANGE RIVER LOSSES REACH 1b	1.2306	1.5162	1.6485	1.6443	1.2306	0.9849	0.6678	0.5061	0.3633	0.42	0.6195	0.9324	11.7642

DESCRIPTION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	ANNUAL
TOTAL SYSTEM OPERATING LOSSES	15.89	15.38	15.89	15.89	14.53	34.16	50.65	34.16	21.67	20.23	15.89	15.64	270.00
AREA 3 RIET/ MODDER													
THABA N'CHU DMD	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	0.267	3.200
KALKFONTEIN URBAN DEM	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	1.700
AREA 4 ORANGE RIVER : (Orange/Vaal confl. to 20 degree Longitude)													
PRIESKA URB	0.161	0.186	0.208	0.249	0.202	0.198	0.159	0.138	0.135	0.118	0.131	0.143	2.027
ORANGE RIVER EVAPORATION REQUIREMENTS REACH 2	13.22	16.31	17.72	17.67	13.22	10.59	7.19	5.44	3.9	4.5	6.67	10.02	126.45
IRR MID ORANGE	22.434	3.814	5.556	14.597	11.339	15.523	13.012	1.549	5.453	7.757	13.796	20.219	135.048
UPINGTON RIVER IRR ABS.	7.242	8.280	10.096	13.617	7.021	4.573	3.008	0.462	1.408	1.768	2.636	3.932	64.043
KAKEMAS RIVER IRR ABS	3.558	4.703	5.147	6.573	3.119	2.122	1.435	0.114	0.770	0.918	1.224	1.797	31.480
BOEGOEBERG IRR	11.543	13.197	16.092	21.703	11.190	7.289	4.794	0.736	2.244	2.819	4.202	6.267	102.076
UPINGTON IRR	11.566	13.574	15.694	20.991	10.660	7.515	5.132	0.636	2.387	2.951	4.255	6.307	101.669
KEIMOES IRR	7.329	8.601	9.944	13.300	6.754	4.761	3.252	0.403	1.513	1.870	2.696	3.997	64.419
ORANGE RIVER EVAPORATION REQUIREMENTS REACH 3	13.68	16.87	18.34	18.28	13.68	10.96	7.44	5.63	4.04	4.66	6.9	10.37	130.85
KAKEMAS URB DMD	0.193	0.232	0.265	0.288	0.256	0.228	0.170	0.153	0.141	0.141	0.152	0.162	2.380
KAKEMAS IRR DMD	12.013	15.880	17.377	22.193	10.531	7.163	4.844	0.383	2.600	3.098	4.134	6.068	106.284
ORANGE RIVER EVAPORATION REQUIREMENTS REACH 4	3.88	4.78	5.2	5.18	3.88	3.11	2.11	1.6	1.15	1.32	1.96	2.94	37.11
UPINGTON AND OTHERS URB DMD	1.432	1.722	1.971	2.143	1.902	1.692	1.262	1.133	1.045	1.047	1.126	1.204	17.680

DESCRIPTION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	ANNUAL
NAMAQWALAND IRR U/S NAMIBIA	1.105	1.461	1.599	2.042	0.969	0.659	0.446	0.035	0.239	0.285	0.380	0.558	9.779
AREA 5 ORANGE RIVER : (20 °Longitude to river mouth) RSA													
NAMAQWALAND IRR D/S NAMIBIA	4.014	4.902	5.916	7.635	3.738	2.106	1.279	0.278	0.768	0.952	1.398	2.109	35.096
URB. DMD SPRINBOK AND PELLADRIFT	0.391	0.448	0.442	0.474	0.476	0.423	0.389	0.344	0.328	0.317	0.335	0.373	4.740
VIOOLSDRIFT AND MINOR IRR	0.771	1.209	1.529	2.059	1.004	0.269	0.156	0.094	0.058	0.071	0.113	0.194	7.528
ALEXANDER BAY IRR	1.104	0.640	0.681	1.500	1.146	1.490	1.225	0.226	0.249	0.338	0.578	0.870	10.045
SPRINGBOK OR NAMAKWA WATER BOARD	0.345	0.389	0.450	0.482	0.471	0.402	0.403	0.378	0.316	0.327	0.345	0.291	4.600
URB.DMD. ALEX.BAY	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	0.608	7.300
AREA 5 ORANGE RIVER : (20 °Longitude to river mouth) Namibia													
PELLADRIF NAMIBIA IRR	2.151	2.626	3.169	4.089	2.002	1.128	0.685	0.150	0.411	0.510	0.749	1.129	18.80
VIOOLSDRIF NAMIBIA IRR	1.997	3.132	3.962	5.334	2.600	0.697	0.404	0.244	0.151	0.185	0.292	0.502	19.50
ORANJEMUND & ROSH PINAH	0.705	0.746	0.662	1.040	0.748	0.739	0.729	0.571	0.581	0.538	0.639	0.582	8.280
HAIB MINE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ARIAMSVLEI ETC.	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NOORDOEWER, ASSENKEHR	0.014	0.016	0.014	0.021	0.018	0.015	0.015	0.012	0.011	0.010	0.011	0.012	0.170
MINES ROSH PINAH ETC.	0.571	0.571	0.571	0.571	0.571	0.571	0.571	0.571	0.571	0.571	0.571	0.571	6.850
AREA 5 ORANGE RIVER : (20 degree Longitude to river mouth)Combined RSA and Namibia													
ORANGE RIVER EVAPORATION REQUIREMENT REACH 5	15.05	18.55	20.17	20.1	15.05	12.05	8.19	6.19	4.45	5.13	7.59	11.4	143.92
ORANGE RIVER EVAPORATION REQUIREMENT REACH 6	5.67	6.99	7.6	7.57	5.67	4.54	3.08	2.33	1.67	1.93	2.86	4.29	54.2

DESCRIPTION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	ANNUAL
ORANGE RIVER EVAPORATION REQUIREMENT REACH 7	6.95	8.57	9.32	9.29	6.95	5.57	3.78	2.86	2.06	2.37	3.51	5.27	66.5
RIVER MOUTH ENVIRONMENTAL + IFR (Currently released)	32.141	31.104	32.141	32.141	29.290	32.141	31.104	24.106	15.552	9.374	9.374	10.368	288.85
AREA 6 NAMIBIA FISH RIVER													
HARDAP IRRIGATION	3.711	3.586	3.194	5.717	5.125	3.936	4.170	2.498	1.914	2.081	2.948	2.819	41.700
NAUTE IRRIGATION	0.413	0.399	0.355	0.636	0.570	0.438	0.464	0.278	0.213	0.232	0.328	0.314	4.640
HARDAP URBAN	0.087	0.086	0.083	0.104	0.092	0.081	0.077	0.072	0.065	0.067	0.066	0.069	0.950
NAUTE URBAN	0.159	0.186	0.151	0.220	0.202	0.145	0.174	0.148	0.145	0.124	0.141	0.155	1.950

3.3.2 Other sub-systems within the Orange River Basin (RSA)

The largest of the other sub-systems within the Orange River basin, is the Lesotho Highlands Water Project (LHWP), which is used to transfer water to the Integrated Vaal River System. This transfer has almost reached its maximum of 877 million m^3/a. This volume is continuously transferred to the Vaal System, irrespective of the water situation and dam levels in the RSA (see **Table 3.8**). Although the LHWP is located in Lesotho, details of the transfers are also included in **Table 3.8** as it is used to supply water primarily to the RSA.

Table 3-8: Demands imposed on the other sub-systems within the Orange River Basin

Description	Demand (million m^3/a) for given year		
	2005	2015	2025
Transfers			
LHWP	780	877	877
Caledon/Modder	55	70	83
Sub-total	835	947	960
Urban/Industrial/Mining			
Caledon RSA	4.2	4.7	5.2
Upper Orange	10.7	12.8	15.3
Lower Orange	5.96	5.96	5.96
Sub-total	20.86	23.46	26.46
Rural Domestic Requirements			
Caledon RSA	0.70	0.70	0.70
Upper Orange	2	2	2
Lower Orange	10.04	10.04	10.04
Sub-total	12.74	12.74	12.74
Livestock			
Caledon RSA	6.30	6.30	6.30
Upper Orange	15.2	15.2	15.2
Lower Orange	23.86	23.86	23.86
Sub-total	45.36	45.36	45.36
Irrigation			
Caledon RSA	70.4	70.4	70.4
Upper Orange from main river	33.1	33.1	33.1
Upper Orange Diffuse	288.91	288.91	288.91
Lower Orange	11.64	11.64	11.64
Sub-total	404.05	404.05	404.05
Losses			
Knelpoort support to Welbedaght	3.70	3.70	3.70
Sub-total	3.70	3.70	3.70

Description	Demand (million m^3/a) for given year		
	2005	2015	2025
Ecological Requirements **			
Matsoku Weir	20.5	20.5	20.5
Katse Dam	65.86	65.86	65.86
Mohale Dam	30.44	30.44	30.44
Total for the sub-systems in Orange*	541.71	559.31	575.31

Note: * - The total excludes ecological requirement and transfers out of the Orange system as the ecological requirements is not a consumptive demand and the demands supplied by means of the transfers are already included in the Vaal System demands.

The total demand from the sub-systems in the Orange River basin accumulates to 542 million m^3/a, and if transfers are included it increases to 1 322 million m^3/a. For the purpose of this study the total demand for the sub-systems is referred to as 542 million m^3/a, as the demands supplied by means of the transfers from the sub-systems are already included in the Integrated Vaal River System. Irrigation is the largest water user in the sub-systems and comprises of 75% of the total demand of 542 million m^3/a, followed by the transfers from the Caledon 55 million m^3/a, or 10% of the total demand.

The total water use from groundwater is estimated at 115 million m^3/a for the 1995 development level. The bulk of the groundwater use (59%) is located in the Lower Orange where surface water resources are limited beyond the Orange River itself. Most of the demands listed in **Table 3.8** are supplied from surface water resources. The only exception is the rural domestic and livestock water requirements, which are mainly supplied from groundwater resources.

Hydro-power is generated by means of the releases from Gariep and Vanderkloof dams to supply the downstream requirements. This is therefore a non-consumptive demand, and is not added to the total demand. Only during times when there is a surplus short-term yield available from Gariep and Vanderkloof dams, is the surplus allocated to Escom to generate additional hydro-power over and above that generated by means of the normal releases. Currently the total demand imposed on the main Orange System, has reached the long-term yield available from the Orange River Project, and surplus conditions very seldom occur. During periods when the dams are spilling, the maximum possible volume is released through the hydro-power turbines, to utilise the spills far as possible for this purpose.

3.3.3 Return flows

The return flows from the Urban/Industrial and mining sector is relatively small in the Orange River Basin. Some of the water supply systems such as Pelladrift and Namakwa supply water to towns located far from the Orange River and return flows will not reach the river. Most of the smaller towns, direct their return flows to evaporation ponds or pan areas, preventing these flows to return to the main river. The mines re-circulate their water to a large extent and their waste water is generally evaporated through evaporation ponds. Bearing in mind that the urban industrial demand in the Orange only represents 2.5% of the total Orange demand, the return flows from this sector are negligible.

Return flows from irrigation are however a considerable amount. The total expected return flow to reach the Orange River is in the order of 200 million m^3/a. These return flows are to a large extent used by irrigators further downstream along the Orange River, and results in less water being released from Vanderkloof Dam.

Table 3-9: Return flow estimations from main irrigation areas

Irrigation area/scheme	Gross demand (million m³/a)	Return flows (million m³/a)	Percentage Return flow
Irrigation from Orange & Caledon rivers u/s of Gariep Dam	112	8	7%
Irrigation from ORP: Gariep to Orange Vaal confluence	570	46	8%
Irrigation from ORP: Orange Vaal confluence to Namibian border	777	134	17%
Irrigation from ORP: Orange along the RSA / Namibian border	111	19	17%
Irrigation from ORP: Eastern Cape Rivers supplied through Orange/Fish tunnel.	747	261	35%
Total*	1 570	207	13%

Notes:*- Return flows from the Eastern Cape irrigation is not included in the total as it has no effect on the flows in the Orange River.

The irrigation return flows from the Sundays and Fish River in the Eastern Cape will obviously not contribute to flow in the Orange River, although these irrigation areas are supplied from the ORP.

3.4 Namibia Water Requirements

3.4.1 Background

In the year 2000 an analysis was done of the present and future water demand in Namibia and the information in that report will be used to provide an overview of the present and future water requirements of Namibia within the Orange River Basin.

The Orange River basin covers an area of approximately 260 000 square kilometres in Namibia and there are three main catchment areas. These ephemeral catchments are the Fish River and it tributaries (Konkiep, Lowen), the Nossob River and its tributaries (Auob, Black Nossob, White Nossob, Olifants) as well as the lower Orange which has a number of seasonal watercourses (Ham, Hom, Haib, Gamchab) flowing into the Orange River along the common border with South Africa. There is also an endoreic river system, the Oanob River in the Auob catchment of the Nossob River (See **Table 3.10** & **Figure A-1** in **Appendix A**)

Table 3-10 : Surface area of the Orange River Basin in Namibia

CATCHMENT	SURFACE AREA (km^2)
Nossob River	103 858
Fish River	95 680
Orange	60 308
TOTAL	259 846

3.4.2 Population

The Census Office in the National Planning Commission in Namibia carries out a national population census every ten years, and the last census was completed in 2001. However, when the water demand report mentioned above was prepared the census statistics were not yet available and the information of the 1991 census was used to prepare the report.

At that time it was expected that the increase in the population would generally have been affected by increasing urbanization from people outside the basin, due to better health care, and the adverse effects of HIV/AIDS. It was therefore estimated that the population in the basin would increase from about 156 900 in 1991 to 189 078 in 1999. Based on those estimates, further estimates were made for the years 2005, 2015 and 2025. It is therefore estimated that the population will increase from about 202 000 in 2005 to 232 000 in 2025. Please refer to **Table 3.11** for the population statistics in the Orange Basin in Namibia.

According to the 2001 census the number of people in Namibia was about 1 826 900, and about 174 700 people resided in the Orange Basin. This means that in 2001 about 9,5% of the Namibian population resided in the Orange Basin.

Table 3-11: Estimated Population in the Orange River Basin in Namibia

CATCHMENT	POPULATION (Million)			
	1999	2005	2015	2025
Auob	66 962	75 399	80 022	86 177
Fish	64 752	66 791	70 799	76 245
Nossob	37 276	38 450	40 757	43 892
Orange	20 088	22 097	23 754	25 581
TOTAL	189 078	202 737	218 332	231 895

3.4.3 Water Requirements

The water demand in the Orange River Basin in Namibia is mainly due to domestic use in urban and rural areas, livestock watering on commercial and communal farms, irrigation, mining and tourism (See **Table 3.12**).

The domestic water demand in the towns and the rural areas has been based on water consumption data and projections of the future demand due to the population increase and the expected improvement in the standard of living. The impact on urbanization due to the migration of people outside the basin and from the rural areas, better health care and the adverse effects of HIV/AIDS have been considered in estimating the future domestic water demand. Namibia is not a highly industrialized country and the industrial water use at mainly service industries has been included in the urban demand.

According to the 2001 census the population in the basin was 174 700 people in 2001, but according to the estimates made on the basis of the 1991 census, the population should have been 193 500. This means that the urban and rural water demand figures for domestic use in the water demand report is on the conservative side, but this can be regarded as insignificant because domestic water use represents only 5, 5% of the total water demand in the basin.

A comprehensive database of livestock numbers (cattle, donkeys, horses, goats, sheep, pigs, and ostriches) exists and could be used to determine the number of livestock in the Orange Basin, as well as the estimated water demand. Due to the limitations in the grazing capacity of the rangeland, it is not expected that there will be a significant increase in stock numbers over time, but it will most probably fluctuate around the present number as a result of the decrease and increase in the availability of grazing due to the seasonal variations in the rainfall.

There are four main areas where irrigation is practised in the Orange Basin within Namibia. These are downstream of the Hardap Dam and the Naute Dam where surface runoff in the ephemeral Fish River basin is used, the Stampriet artesian groundwater basin underlying the Nossob and Auob catchments where groundwater is used and the irrigation schemes on farms along the lower Orange River where perennial water is used. The most notable irrigation schemes are at Noordoewer/Vioolsdrift and Aussenkehr. It is also anticipated that about 1 000 hectares of land will be brought under irrigation at the proposed Tandjieskoppe Irrigation Scheme at Noordoewer in the next few years.

The present water requirements for mining purposes at Oranjemund, Rosh Pinah, Skorpion and a number of small diamond mines along the lower Orange River, as well as small mines in the Rehoboth district is known. New mining development is difficult to anticipate, but the possible development of the proposed Haib copper mine on the lower Orange River near Noordoewer is on hold until the price of copper has increased to the extent that mine is economically viable. The proposed development of the Kudu gas power plant at Oranjemund will also lead to an increase in the water demand, and although provision has been made for such a demand, it is not clear when the project will actually come into operation.

Table 3-12 : Estimated water requirements in the Orange River Basin within Namibia

CONSUMER GROUP	ESTIMATED DEMAND (million m^3/a)		
	2005	2015	2025
Urban	14.74	15.97	17.47
Rural	0.317	0.32	0.324
Livestock	16.42	16.82	16.42
Irrigation	118.81	217.32	303.52
Mining	7.35	37.75	38.23
Tourism	0.56	0.69	0.85
TOTAL	158.20	288.47	376.82

A study was done of the water demand in the tourism industry and information was obtained from bed and breakfast places, guest farms and loges, hotels, resorts and at camping sites.

The environmental water requirements for the ephemeral watercourses in Namibia and along the lower Orange River was not included in the assessment of the estimated future demand by Namibia, Provision has been made at the Oanob Dam near Rehoboth to make ecological water releases because of the envisaged adverse effect the dam would have on the downstream riverine vegetation.

3.5 Botswana Water Requirements

3.5.1 Background

In order to assess the water requirements for domestic use at villages and for stock in the area considered it is important that the accepted boundary line of the Orange River Basin through southern Botswana is unambiguously defined for planning purposes. Due to the featureless landscape of the Kalahari Desert in Botswana, it is difficult to define the boundary along clear topographical features and it will therefore be assumed for the purpose of the water requirement summary, that the basin boundary follows a straight line across Botswana from Pitsane near the upper reaches of the Molopo River on the border between Botswana and South Africa to the border post at Mampunu in Botswana (Buitepos in Namibia) on the border between Botswana and Namibia. All the villages to the south of this line and the stock numbers will therefore be included in the assessment of the domestic and stock water requirements.

This proposed line differs from the rather arbitrary line shown on the map of the basin in **Figure A-1** of **Appendix A** is preferred because settlements like, Lehututu , Ncojane and Mampunu in Botswana, as well as Buitepos and the area to the east of Gobabis in Namibia is now included. Places along the Trans Kalahari Highway such as Lobatse, Kanye, the mining town of Jwaneng and Kang in Botswana are still to the north of the proposed boundary line and therefore not included in the assessment.

The area under consideration is about 120 000km^2 in extent or 49 000 square kilometres more than the area given in the Surface Hydrology Report prepared for this study.

Table 3-13: Catchment data of the Orange River Basin

BASIN STATE	SURFACE AREA OF EACH BASIN STATE (km²)*	SURFACE AREA OF ORANGE RIVER BASIN (km²)*	SHARE OF STATE IN THE BASIN (%)*	SHARE OF BASIN IN EACH STATE (%)*
Botswana	582 000	120 000	12	21
Lesotho	30 000	25 000	3	83
Namibia	824 000	260 000	26	32
South Africa	1 221 000	580 000	59	48
TOTAL	-	985 000	100	-

Note: * - All numbers have been rounded

3.5.2 Water Requirements

The water demand is mainly due to domestic use and stock watering because there are no mining activities or major irrigation activities in the area under consideration.

The Central Statistics Office (CSO) in Botswana carries out a national population census every ten years and the last census was done in 2001. There are about 51 villages in the area and the population in the largest urban centres, Tsabong and Mmathethe, was respectively only 6 591 and 4 415 while 35 minor settlements had less than 1000 people, 9 rural villages had between 1 000 and 2 000 people, and 3 major villages had between 2 000 and 3 000 inhabitants. The total population in the Orange Basin in Botswana was about 55 161 in 2001. The total population in Botswana in 2001 was 1 680 863 and therefore 3,28% of the people in Botswana lived in the Orange Basin. The population density in the basin area was only 0,46 people per km^2 in 2001.

The 2001 population data for the villages in the area defined above had been used to make calculations of the estimated population in the years 2005, 2015 and 2025. It is expected that the increase in the population will generally be affected by increasing urbanization, better health care, the adverse effects of HIV/AIDS and a decline in economic activities. From the estimates in the 2001 population census the annual increase in the population in the Orange Basin will decrease from 1,1 %/annum over the period 2001 to 2010 to 0, 26 %/annum between 2010 and 2020. It was also expected that the population in the minor villages will reduce between 2001 and 2010 due to migration to the rural villages, but will increase again at 0, 2% /annum between 2010 and 2020. A conservative estimate of the future population is shown in **Table 3.14.**

Table 3-14 : Population data

LOCALITY	POPULATION (Million)			
	2001	2005	2015	2025
Urban Centres	11 006	11 586	13 174	13 625
Major Villages	7 644	7 898	8 571	8 757
Rural Villages	9 541	12 904	20 300	20 720
Minor Settlements	26 470	24 527	25 034	25 553
TOTAL	54 661	56 915	67 079	68 655

The impact of this scenario on the water demand has not been quantified by the Government of Botswana and the best information about water demand forecasts is contained in the 1991 Botswana National Water Master Plan, which is currently under revision. According to the information, the average water use in the area under consideration is 75 litres per person per day and this figure will be used to estimate the future water demand.

It has also been assumed that the grazing capacity in the area is on average about 20 hectares per large stock unit and that stock water consumption is about 30 litres per large stock unit per day. The Gemsbok National Park in Botswana covers an area of about 12 700 square kilometres and that means that the available rangeland in the basin is about 107 300 square kilometres. The number of stock is therefore in the order of 536 500 and it is not expected that this number will increase over time, but will most probably fluctuate around the present number as a result of the availability of grazing due to the seasonal variations in the rainfall. The estimated stock water demand at 30ℓ per large stock unit per day is 5, 875 million cubic metres per annum. Please refer to **Table 3.15** for the estimated water demand in the Orange Basin in Botswana.

It should be noted that no water borne sewage systems are at present in use in most of the villages and settlements. Such systems have been planned at Tsabong, Goodhope and Mamunu. Water borne sewage systems and other water intensive projects will cause a major increase in the water demand.

Table 3-15: Estimated water requirement for Botswana

LOCALITY	DEMAND (million m^3/a)		
	2005	2015	2025
Domestic use Livestock	1.56 5.88	1.84 5.88	1.88 5.88
TOTAL	7.43	7.71	7.75

3.6 Lesotho Water Requirements

3.6.1 Population

The 1996 Population Census reported that Lesotho's population in 1996 was 1,968,354, while the 2001 Lesotho Demographic Survey estimated that the country's population was 2.1 million in 2001. Details of the total population, estimated by the 2001 Lesotho Demographic Survey (LDS), are shown in the **Table 3.16**.

Table 3-16 : Distribution of Lesotho's Population by District

District	Total
Butha-Buthe	126,907
Leribe	362,339
Berea	300,557
Maseru	447,599
Mafeteng	238,946
Mohale's Hoek	206,842
Quthing	140,641
Qacha's Nek	80,323
Mokhotlong	89,705
Thaba-Tseka	133,680
TOTAL	**2,127,539**

The HIV/AIDS prevalence rate in Lesotho is at a high level because of Lesotho's highly mobile population and its evolving socio-economic situation. Cultural norms and practices and the high level of poverty also fuel the epidemic. In addition, the highly mobile community is largely young men (to South Africa) and young women (to factories in Lesotho

With HIV/AIDS, the natural growth rate of Lesotho is declining and is projected to continue to decline until it reaches zero growth rates by 2007/2008, and negative rates thereafter. This will result in a slow growth of the population until 2010 after which a slow reduction in population size is projected. The following figure presents the projected population of Lesotho without AIDS and what this is now likely to be in the face of the high rates of infection and expected deaths.

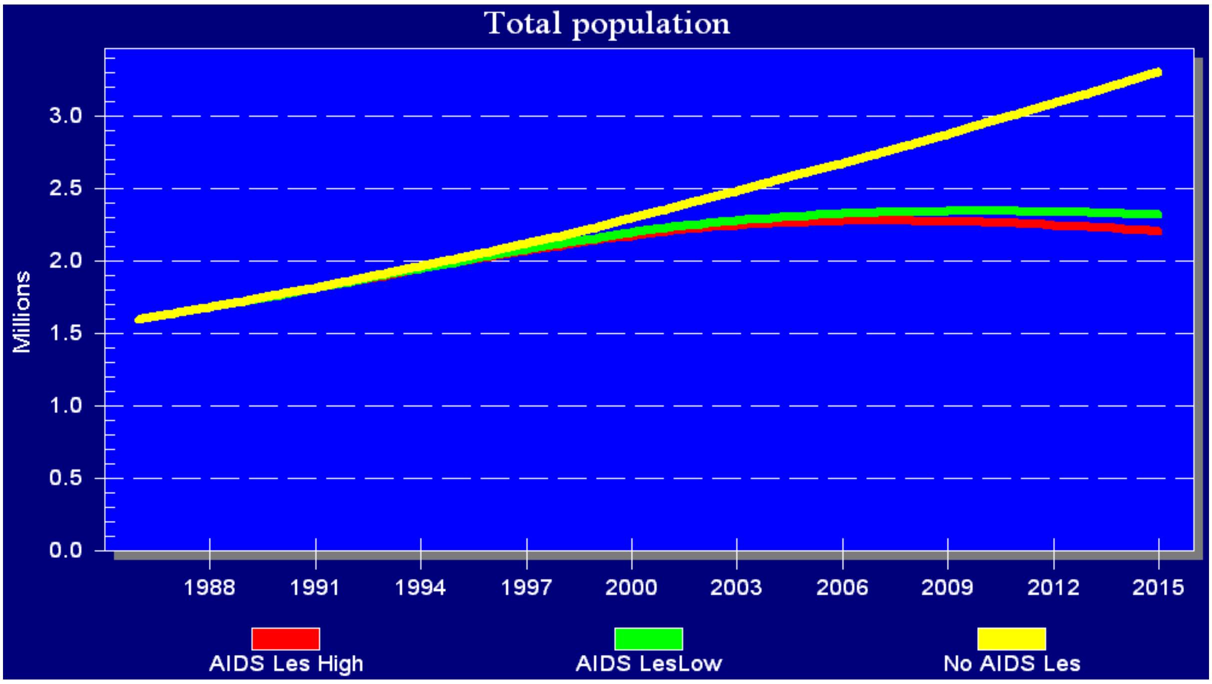


Figure 3-2 : Population With and Without AIDS for Lesotho (1986 - 2015)

The Spectrum population projections for both scenarios estimated that the population would be 2,030,000 and 2,220,000, respectively, for 2001, with the low prevalence scenario consistent with Bureau of Statistics (BOS) projections.

Without HIV/AIDS the population was projected to increase to 3.3 million by 2015 but, due to the impacts of HIV/AIDS, it will only grow to about 2,2 million based on the high HIV prevalence scenario and 2.32 million based on the low HIV prevalence scenario, meaning that Lesotho's population will increase only marginally between now and the end of the decade, and will thereafter decline if no fundamental changes are brought about on a national scale.

3.6.2 Water Requirements

The supply of water to urban areas in Lesotho relies heavily on direct river extraction and pumping from underground sources. In recent years, the rapid economic development in the Lesotho lowlands, with its attendant increase in urban and peri-urban populations and commercial/industrial activities, has placed an increasing demand on the existing water supply and sewerage facilities. . It is estimated that by 2005 as much as 78 percent of Lesotho's 2.3 million people will be living in the Lesotho Lowlands area. Fairly detailed water demand and demand projection data were obtained from the Lesotho Lowlands Study report (Lesotho, 2004). These demand projections are summarised in **Table 3.17**. For the remainder of Lesotho it was assumed that most of the households represent unconnected households with a much lower per capita water use. For this purpose 30 l/c/d was used, which was referred to in the Lesotho Lowland study reports as a recommended volume for good health. I fact the majority of unconnected households in Lesotho currently use even less, in the order of 14 to 18 l/c/d.

Table 3-17 : Summary of urban/Industrial/rural demand projections for Lesotho

Zone & Description		Demand at given development level (million m^3/a)			
		2005	2010	2020	2035
1	Butha Buthe	4.47	6.53	12.17	13.09
2	Hlotse-Maputsoe	5.88	7.74	9.88	12.57
3	Teyateyakeng	2.32	3.04	3.59	3.98
4	Maseru zone	26.61	32.00	43.04	59.53
0	Maseru only	23.88	29.17	39.99	56.05
5	Morija-Matsieng	1.30	1.32	1.38	1.51
6	Mafeteng	4.16	4.49	4.92	5.78
7	Mohales Hoek	2.18	6.85	15.90	16.53
8	Quthing	0.93	0.95	1.02	1.15
	Sub-total	**47.85**	**62.91**	**91.90**	**114.14**
	Remainder	15.01	15.01	15.01	15.01
	Total	**62.87**	**77.93**	**106.91**	**129.15**

Although Lesotho apparently has abundant water resources, its geographical, seasonal and annual distribution is uneven and irrigation is therefore still required. Irrigation in Lesotho is limited and currently only 66ha is irrigated. Previous irrigation projects in Lesotho have considered 2,637ha, but have failed due to lack of co-operation for many reasons.

Water for irrigation must be abstracted from one of two sources, from surface water (rivers) or from groundwater. The greatest potential for substantial quantities of water is however from the rivers. The quantity of water that can be abstracted from rivers is determined by the low flows in the river. Keeve Steyn Inc. conducted a “Hydrological Investigation into Rivers in Lesotho” in 1993. As shown in **Table 3.18**, they concluded that those listed were the maximum areas that could be irrigated at the period of minimum flow with a 15% chance of insufficient water being available (which would lead to crop failure). This is land which could be sustained for irrigation, with a 15%, ie. a 1 in 7 year, chance of crop failure, without regulation of the water source.

Table 3-18 : Maximum Areas Suitable for Irrigation (with a 15% failure chance)

River	Area (hectares)	Water Requirement (million m^3/a)
Hololo	30	0.15
Hlotse	500	5.00
Phuthiatsana North	600	6.00
Phuthiatsana South	350	1.75
Mohokare		Not recommended
Mpetsana	40	0.20
Makhaleng	1 000	10.00
Senqu	1 000	11.50
Total	3 520	34.60

3.6.3 Water Transfers from Lesotho

Over and above the local water requirements in Lesotho, large volumes of water are also transferred to the RSA by means of the Lesotho Highlands Water Project (LHWP).

The Lesotho Highlands Scheme started operating in 1998, and comprises Mohale and Katse dams, Matsoku diversion weir, a series of tunnels and a hydro power station. Water is gravitated through tunnels from Katse Dam (In the Lesotho Highlands) and flows into the Liebenbergsvlei River via Saulspoort Dam (acting only as a weir), down into the Wilge River and eventually flows into the Vaal Dam.

The transfer volume has been phased in over a number of years and has almost reached its maximum of 877 million m^3/a. This volume is continuously transferred to the Vaal System, irrespective of the water situation and dam levels in the RSA. The ecological requirement releases from the two major dams and Matsoku Weir are summarised in **Table 3.19**.

Table 3-19 : Ecological water requirements supplied from LHWP

Description	Requirement (million m^3/a)
Matsoku Weir	20.5
Katse Dam	65.86
Mohale Dam	30.44

3.7 Assurance of Supply

3.7.1 General

In arid and semi arid regions it is generally not economical feasible to develop and operate a water resource system to meet all the demands at all times This means that 100% of the demand can not be supplied for 100% of the time and shortfalls in the supply will occur from time to time. If shortfalls occur frequently, the supply will have a low assurance while relative few shortfalls represent a high assurance in supply. Restrictions in supply during dry periods is therefore one of the few management tools available for operators to cope with the highly variable stream flow conditions.

It is fairly obvious that different types of user groups or categories will require a different assurance of supply. Irrigation will typically be supplied at a lower assurance than water for domestic and industrial purposes and water for strategic industries such as power generation even at a higher assurance. It is also logic to sub-divide the supply to irrigation into different assurance levels, as permanent crops such as export grapes would require a higher assurance than for example a cash crop.

Using only the available historic flow record of 50 to 70 years it is not possible to provide yield results representing the yield available at high assurances such as a 99% or 99.5% assurance, which means a possible failure of 1 in 100years and 1 in 200 years respectively. By using stochastic yield analysis it is possible to determine the system yield at different reliabilities or assurance levels. At low reliability levels the system can typically provide a higher yield than would be available at a high reliability level. The stochastic yield characteristics therefore make it possible to supply the system demands at the required level of assurance in planning and operational analyses as well as in practise.

For the purpose of these analyses it is therefore important to sub-divide the demand of the different user categories into three or four priority classes, which represent different assurance or reliability levels.

3.7.2 Vaal River System

The Integrated Vaal River System is a large and highly complicated system which included several transfer and support schemes. To be able to properly manage and to do planning for this system, annual operating analyses are carried out for the integrated system by using the Water Resource Planning Model (WRPM). The users within the Main Vaal River System are already supplied according to the assurances defined in the WRPM. The combination of assurances of supply as applicable to the different user groups or categories is referred to as the priority classification set for a particular system. The priority classification as applicable to the Integrated Vaal River is given in **Table 3.20**.

Table 3-20 :User Categories and Priority Classifications used for the Vaal System

User Category	Priority Classification & Assurance of Supply		
	Low 95% 1 in 20 year	**Medium 99% 1 in 100 year**	**High 99.5% 1 in 200 year**
Urban/industrial	22%	24%	54%
Industrial (Strategic)	0%	30%	70%
Irrigation	50%	30%	20%
Power Stations	0%	0%	100%

The supply to the user categories were each split into different levels of assurance of supply. In the Vaal System the user categories were split into three levels of assurance of supply, namely the low level (95% assurance of supply), medium level (99% assurance of supply), and the high level (99,5% assurance of supply). In this way a portion of the demand for a specific user category (say urban) can be supplied at a high level of assurance (e.g. domestic consumption), while the remaining portion of the demand can be supplied at a lower level of assurance (e.g. garden watering).

The assurance of supply as applied to the Main Vaal System is however, not imposed on the smaller sub-systems in the Vaal River catchment. The RSA DWAF is currently in the process to develop similar operating rules also for the smaller sub-systems, which include the ability of supplying the users at reasonable and agreed assurance levels. In general it is expected that the demands in the smaller sub-systems are supplied at lower assurances than those indicated in **Table 3.20** for the Main Vaal System in particular for the diffuse irrigation.

3.7.3 Orange River System

User categories that were considered for the Orange River Development Project Replanning Study (ORRS) were urban, industrial, strategic industries, mining, irrigation and environmental. The urban and industrial users were grouped together due to the fact that it was difficult to split the total water demand of a municipality into these two user categories.

The user categories were each split into different levels of assurance of supply. In annual operating analysis for the Orange River Main System each of these user categories is sub-divided into three levels of assurance of supply, namely the low level (95% assurance of supply), medium level (99% assurance of supply), and the high level (99,5% assurance of supply). In this way a portion of the demand for a specific user category (say urban) can be supplied at a high level of assurance (e.g. domestic consumption), while the remaining portion of the demand can be supplied at a lower level of assurance (e.g. garden watering).

Table 3-21: User Categories and Priority Classifications used for the Main Orange System

User Category	Priority Classification & Assurance of Supply		
	Low 95% 1 in 20 year	Medium 99% 1 in 100 year	High 99.5% 1 in 200 year
Urban/industrial	20%	30%	50%
Losses & river evaporation	0%	0%	100%
Irrigation	50%	40%	10%
Ecological Requirements	33%	0%	67%

The reason why river evaporation and conveyance losses are in the high assurance class is because these losses cannot be curtailed and will still exist during dry periods. The most realistic option is therefore to include them in the highest assurance class.

The assurance of supply from the transfers from the Lesotho Highlands transfer Scheme to the Upper Vaal is somewhat lower than 98% assurance. The method of calculating the assurance as used by the RSA and Lesotho differs slightly. Based on the Lesotho method the transfer is supplied at a 98% assurance, while the RSA method shows an assurance somewhat lower than the 98%.

The priority classification for the Caledon/Modder sub-system is given in **Table 3.22**.

Table 3-22: User Categories and Priority Classifications used for the Caldon/Modder Sub-system

User Category	Priority Classification & Assurance of Supply		
	Low **95%** **1 in 20 year**	**Medium** **99%** **1 in 100 year**	**High** **99.5%** **1 in 200 year**
Urban/industrial	20	30	50
Irrigation	50	40	10

The assurance of supply as applied to the Main Orange System is also not imposed on the smaller sub-systems in the Orange River catchment. In general it is expected that the demands in the smaller sub-systems are supplied at lower assurances than those indicated in **Table 3.22** for the Main Orange System and in particular for the diffuse irrigation. Most of the Orange River catchment lays in a much lower rainfall zone than applicable the Vaal River catchment, so that it is expected that the assurance of supply particularly in the Lower Orange smaller sub-systems will be much lower.

3.8 Efficiency of Water Use

3.8.1 Irrigation

The two main components in the overall irrigation efficiency are the conveyance losses and the irrigation system losses. Most literature indicates that an 80% conveyance efficiency (that is 20% loss through conveyance) is justifiable, considering associated capital and maintenance costs required. Conveyance losses as currently experienced in five of the larger irrigation schemes in the Vaal River catchment is summarised in **Table 3.23** as obtained from the report ''*Potential Savings through WC/WDM in the Upper and Middle Vaal Water Management Areas*''.

Table 3-23 : Summary of conveyance losses and possible savings

Scheme	Current Loss (%)	Targeted Loss (%)	Difference	Water Saving Potential (million m^3/a)
Schoonspruit	28.5	20	8.5	2.57
Mooi River	24.7	20	4.7	6.1
Allemanskraal				
Erfenis	24	20	4	1.87
Vaalharts	32	25	7	29.96
Total				40.5

From **Table 3.23** it is clear that substantial savings is possible when conveyance losses are limited to acceptable values.

Irrigation system losses can be reduced by improved management and scheduling practises but is to a large extent limited by the type of irrigation system used. **Table 3.24** summarises the distribution of different irrigation systems as found in the main irrigation schemes within the Vaal River catchment.

Table 3-24 : Percentage of Irrigation systems in the selected five schemes

Type of Irrigation	Irrigation	% of Irrigation systems in Irrigation schemes					
System	Efficiency	Schoonspruit	Erfenis	Allemanskraal	Vaalharts*	Klerksdorp	Mooi
Flood	65.0%	60.0%	3.0%	8.0%	70.0%	25.0%	60.0%
Mechanical	80.0%	15.0%	93.0%	73.0%	10.0%	0.0%	15.0%
Sprinkler	75.0%	25.0%	4.0%	18.0%	15.0%	75.0%	25.0%
Micro	85.0%	0.0%	0.0%	1.0%	3.0%	0.0%	0.0%
Drip	90.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%
Scheme Efficiency		0.70	0.79	0.78	0.69	0.73	0.70

Flood irrigation is still widely used in most of the schemes. With an overall improvement of only 5% in the irrigation efficiency, it will be possible to save approximately 18 million m^3/a.

As part of the Lower Orange River Management Study (LORMS) a report was produced on WC/WDM. This is the most recent work produced on WC/WDM for the Greater Orange River System. Irrigation is the largest water consumer in the Orange and fairly substantial savings can be achieved by means of WC/WDM. Results from the LORMS study is summarised in **Table 3.25**.

Table 3-25: Possible savings through WC/WDM in the irrigation sector

River Reach	Existing Requirement (Million m^3/a)	Possible water savings (Million m^3/a)				Percentage Saving
		Scheduling	Metering & Pricing	Irr System Efficiency	Total	
Caledon and Orange upstream of Gariep Dam	102	7.2	6.7	8.4	22.3	21.9%
Riet/Modder & Orange River to Namibia Border	1 269	63.9	84.3	115.5	263.7	20.8%
Orange River on Common Border between Namibia & RSA	102	3.6	6.9	6.2	16.7	16.9%
Total	1 473	74.7	97.9	130.1	302.7	20.5%

Only estimated conveyance losses in the canal distribution systems in the Orange and Riet/Modder catchments were available from the LORMS reports. These are summarised in **Table 3.26**.

Table 3-26 : Estimated Canal Losses in the Orange and Modder/Riet systems

Description	Estimated canal losses (million m^3/a)	Estimated Return flow (million m^3/a)	Net Canal loss (million m^3/a)	Net loss as % of gross inflow (million m^3/a)
Ramah & Vanderkloof canal	11.03	6.62	4.41	6.0
Orange Riet canal	22,67	1.13	21.54	14.3
Lower Riet	6.35	0.32	6.03	14.3
Kalkfontein Scheme	5.91	3.55	2.36	6.0
Douglas Weir	11.75	3.53	8.22	10.5
Boegoeberg Canal	20.01	12.00	8.01	6.0

Description	Estimated canal losses (million m^3/a)	Estimated Return flow (million m^3/a)	Net Canal loss (million m^3/a)	Net loss as % of gross inflow (million m^3/a)
Upington Canal	17.45	10.47	6.98	6.0
Keimoes Canal	13.47	8.08	5.39	6.0
Kakamas Canal	10.05	6.03	4.02	4.0
Vioolsdrift South	1.59	0.95	0.64	6.0
Vioolsdrif North	1.01	0.60	0.41	6.0
Aussenkehr	1.45	0.87	0.58	6.0
Total	189.07	54.15	68.59	

No detailed investigation was done to determine the seepage, evaporation losses and leakage on the canals. The estimated values are however not sufficient to determine the possible efficiency improvements through canal rehabilitation, as detailed investigations are required combined with observed data.

3.8.2 Urban/Industrial

From the assessment of the scope for WC/WDM that was carried out as part of the "Vaal River System: Large Bulk Water Supply Reconciliation Strategies" study the following 2004/05 demands and related total system losses were obtained as given in **Table 3.27**. The losses refer to all the losses (real and apparent) that occurs in the distribution system up to the consumers metering point. Losses within the internal supply system of the consumers are therefore excluded. From these results it seems that on average approximately 25% losses are experienced within the Rand Water supply area.

It should however be noted that the use of percentages can be very misleading due to the fact that percentage figures are strongly influenced by the consumption. Typically one would see that the percentage losses tend to be higher for the smaller users, although the potential for savings might not be very high for these small users.

Table 3-27 : Losses within the Rand Water supply area

Area	Annual Demand (million cub.m/a)	Total loss (million cub.m/a)	Percentage loss
Johannesburg	470	90.87	19.3
Ekurhuleni	291	69.02	23.7
Tshwane	255	62.67	24.6
Emfuleni	79	36.2	45.8
Rustenburg	26	8.17	31.4
Mogale	24	6.12	25.5
Govan Mbeki	18	9.05	50.3
Matjhabeng	16	9.05	56.6
Randfontein	7	1.9	27.1
Total	1186	293.05	24.7

The WC/WDM report from the “Vaal River System: Large Bulk Water Supply Reconciliation Strategies” study concluded that the projected Rand Water demand can over time be reduced by between 13% to 27% through the implementation of WC/WDM measures..

Urban/industrial demands in the Orange River System are a very small component of the total demand. The impact of WC/WDM within this sector will therefore have a very small impact on the overall water use. The LORMS however did indicate that the biggest potential to improve the efficiency of water use, are within the mining related towns of Alexanderbay, Oranjemund and Rosh Pinah. The residents in these towns receive unmetered water, free of charge, which leads to wastage.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 Vaal River Systems

The water resources of the Vaal River system are an important asset to the RSA and its people supporting major economic activities and a population of almost 12 million people. Demands imposed on the main Vaal System are in general well defined and updated on a regular basis, as part of the annual operating analysis carried out for the integrated Vaal River System. This system is largely utilised to supply water to urban/industrial/mining and power stations (65%), with irrigation (19%) being a much smaller component. Only surface water resources are used to supply these demands.

The resources within the Vaal Basin itself is not sufficient to supply in the large demand of almost 2 800 million m^3/a currently imposed on the system. Several major transfer schemes were therefore introduced to augment the ever increasing demand in the basin. Indications are that intervention will again be required by approximately 2013. The intervention will most probably include a combination of water conservation and demand management actions, together with a transfer scheme.

The ecological requirements for both the main Vaal System as well as for the smaller systems are based on desktop estimates recently determined by the RSA DWAF. These environmental requirements are only first order indications of what the ecological reserve will be, and are thus currently not supplied by means of any releases from the reservoirs.

The demands imposed on the smaller systems within the Vaal River Basin is not supplied or supported from the main Vaal system. It however impacts significantly on the main Vaal System, as large volumes of water is utilised in these smaller systems, which reduces the total volume of water reaching the main system. The total water use from the smaller systems accumulates to 1 055 million m^3/a at 2005 development level. The bulk of the water use in the smaller systems is for irrigation purposes, representing 64% of the total demand. Most of the demands are supplied from surface water resources with the exception of the rural domestic and livestock requirements, which are mainly met from groundwater resources.

Data for demands imposed on the smaller systems and in particular for the diffuse irrigation demands are at a lower confidence level than those available for the main Vaal System. Indications from the verification and validation of registered water use in the Vaal

Basin showed that the diffuse irrigation is significantly more than previously estimated. A large amount of the irrigation use (241 million m^3/a) is expected to be unlawful and need to be eradicated

The confidence level on groundwater use related data is in general much lower than that from surface water. There is not always a clear cut sub-division between whether surface or groundwater resources are used to supply the certain demands, in particular with regards to diffuse irrigation requirements. Reliable data in this regard should become available at the completion of the validation and verification of the registered water use in the RSA.

The bulk of the return flows in the Vaal River basin are generated from the urban/industrial sector in the Gauteng area. Approximately 50% of the total demand is received as return flows from this area, producing in excess of 600 million m^3/a, of which 335 million m^3/a returns to the Vaal River while the remainder (270 million m^3/a) end up in the Crocodile West River catchment. Increased urban runoff due to paved areas and mine dewatering each add another 114 million m^3/a, and 101 million m^3/a respectively. Return flows from the main irrigation schemes accumulates to almost 70 million m^3/a, or approximately 12% of the gross irrigation demand. Although the large volumes of return flows from the Vaal catchment improves the water availability in the catchment, it has a negative effect on the quality of the water, to such an extent that operational measures had to be introduced to improve the quality in certain river reaches.

4.1.2 Orange River Systems

In contradiction to the main Vaal System, the main Orange System or ORP is used to mainly supply water for irrigation purposes (approximately 60% of demand), with a small portion (only 2.5%) of the demand comprising of urban/industrial & mining requirements. Irrigation demands are in general obtained by the quota for the given area times the allocated irrigation area. There is very little observed measured irrigation abstraction data available and the actual true irrigation use will differ from that obtained from the allocated area and quota. Although this data is, as in the case for the Vaal System, also updated on an annual basis as part of the operational analysis, it is not to the same confidence level as that of the Vaal, due to the large irrigation component. Return flows from urban/industrial requirements is almost negligible and those from irrigation amounts to 207 million m^3/a, or 13% of the gross irrigation requirement.

The main Orange River System in not supported or augmented by any other sub-system. Water is in fact transferred from the Orange River Main System to support other sub-systems such as the Eastern Cape, the Riet/Modder, Douglas in the Lower Vaal etc. With the current expected growth in demand, the main Orange River System will require intervention by 2012. This is expected to be accomplished by increased system efficiency in combination with utilising Vanderkloof Dam lower level storage and or a dam at Vioolsdrift.

The river mouth ecological requirement currently released from Vanderkloof Dam amounts to 289 million m^3/a, and is based on fairly old methodology. Recent estimation of the ecological requirement indicated an average requirement of in the order of 1 062 million m^3/a. This ecological requirement has not been implemented as it was not determined at a detailed level and only provided and better indication of what the reserve could be. Ecological requirements as determined and implemented for the LHWP were recently updated and can be used with confidence.

The total demand, transfers included from the other systems in the Orange Basin is in excess of 1 400 million m^3/a, which will have a significant impact on the water availability in the main Orange System. Most of the demands are supplied from surface water resources with the exception of the rural domestic and livestock requirements which are mainly supplied from groundwater. The demands and transfer data with regards to the LHWP and the Caledon/Modder transfer are at a fairly high confidence level. The confidence level with regards to groundwater use is in general much lower than those from surface water resources. The smaller towns as well as diffuse irrigation are in many cases supplied by both surface and groundwater resources, making it difficult to allocate the demand to the correct resource.

4.2 Recommendations

- The confidence in groundwater related data need to be improved in both the Orange and Vaal River Systems. This must include the distinction between groundwater and surface water use in particular when both the resources are used to supply a specific demand centre.
- Ecological requirements given for the Vaal Systems and the Main Orange System should be treated with caution as they are only preliminary values, used to provide an indication of what the reserve could be. These values should be replaced when more recent and up to date estimations are available.

- Unlawful irrigation need to be eradicated and controlled as it has a significant effect on the total water demand imposed on the systems.
- High return flow volumes are available from both the Vaal and Orange River systems. One should be very careful in allocating those return flows for other uses as more efficient use in the systems can lead to significant reductions in return flows.
- Results from Verification / Validation studies should be used to improve the confidence level of data currently used in models, as soon as it becomes available.
- The irrigation demand is in the Orange systems the largest and in the Vaal systems the second largest water consumer. Very little of the irrigation use is however metered. It is recommended that measures should be put in place to encourage the proper metering and recording of irrigation abstractions.
- There is a need to do a proper survey within the Orange River basin in Botswana to determine the location of new settlements, villages and towns, the number of people, the number of livestock the different water uses and the quantity of water used in order to make present and future water demand assessments based on more accurate information.
- There is a need to update the 2000 assessment of the present and future water demand in Namibia with specific reference to the Orange River Basin.

5 REFERENCES

AtlasSWA (1983) **National Atlas of South West Africa.** By JH van der Merwe, 1983

Botswana WSDM(1989) **Rural Village Water Supply Design Manual.** By the Department of Water Affairs Botswana, 1989.

Botswana NWMP(1991) **Botswana National Water Master Plan.** Report prepared by SMEC, WLPU Consultants and Swedich Geological International. 1991.

DWAF (1993) **Orange River System Analysis. Caledon, Modder and Riet Rivers: Yield Analysis.** Report no P D 000/00/1092, P D 200/00/0192, P C 500/00/0792 by BKS Incorporated Consulting Engineers and Stewart Sviridov & Oliver Consulting Engineers for the Department of Water Affairs and Forestry, Pretoria, South Africa, March 1993. Prepared by Project Team.

Census (1994) **1991 Population and Housing Census Namibia.** By Census Office, National Planning Commission, 1994

DWAF (1997) **Orange River Development Project Replanning Study. Hydrology and System Analysis - Orange River Basin.** Report no PD 000/00/4697 by BKS (Pty) Ltd and Ninham Shand (Pty) Ltd for the Department of Water Affairs and Forestry, Pretoria South Africa, May 1997. Prepared by R S McKenzie and H G Maré.

DWAF(2000a) **Vaal River System Analysis Update. Historic and Long-Term Stochastic Yield Analysis of the Grootdraai Dam and Bloemhof Dam sub-systems.** Report no PC 000/00/17696 by BKS (Pty) Ltd, Stewart Scott Inc and Ninham Shand (Pty) Ltd for the Department of Water Affairs and Forestry, Pretoria South Africa, February 2000. Prepared by H G Maré.

DWAF(2000b) **Vaal River System Analysis Update. Historical and Long- Term Stochastic Yield Analysis of the Senqu sub-system.** Report no PC 000/00/17796 by BKS (Pty) Ltd, Stewart Scott Inc and Ninham Shand for the Department of Water Affairs and Forestry, Pretoria, South Africa, February 2000. Prepared by P G Van Rooyen, H G Maré and O Viljoen.

WCE (2000) **Analysis of Present and Future Water Demand in Namibia.** By Windhoek Consulting Engineers, 2000.

Census (2002) **2001 Population and Housing Census.** By Census Office, National Planning Commission, 2002.

DWAF (2002a) **Upper Vaal Water Management Area: Water Resources Situation Assessment – Main Report – Volume 1 of 3**: Report no. P08000/00/0101 by Stewart Scott Consulting Engineers for the Department of Water Affairs and Forestry, Pretoria, South Africa, July 2002. Prepared by Project Team.

DWAF (2002b) **Middle Vaal Water Management Area: Water Resources Situation Assessment – Main Report – Volume 1 of 3**: Report no. P09000/00/0101 by Stewart Scott Consulting Engineers for the Department of Water Affairs and Forestry, Pretoria, South Africa, August 2002. Prepared by Project Team.

DWAF (2002c) **Lower Vaal Water Management Area: Water Resources Situation Assessment – Main Report** : Report no. P10000/00/0301 by BKS (Pty)Ltd for the Department of Water Affairs and Forestry, Pretoria, South Africa, August 2002. Compiled by C Delport & SJL Mallory.

DWAF (2002e) **Upper Orange Water Management Area: Water Resources Situation Assessment – Main Report- Volume 1 of 3** : Report no. P13000/00/0101 by Stewart Scott Consulting Engineers for the Department of Water Affairs and Forestry, Pretoria, South Africa, August 2002. Compiled by WV Pitman, AK Bailey, AB Beater.

DWAF (2002f) **Lower Orange Water Management Area: Water Resources Situation Assessment – Main Report- Volume 1 of 2** : Report no. P14000/00/0101 by V3 Consulting Engineers for the Department of Water Affairs and Forestry, Pretoria, South Africa, March 2002. Compiled by AJ Smook, DJ Pournara, AR Craig.

DWAF (2002g) **Orange River Continuous Studies Task 15. Caledon - Modder River System Planning Analysis: Effect of Updated Water Requirement Projections based on the National Water Resources Strategy Study.** Report no P876615 by BKS Engineering Management for the Department of Water Affairs and Forestry, Pretoria, South Africa, February 2002. Prepared by H G Maré and R Dube.

Botswana Population(2002) **Population and Housing Census.** By Central Statistics Office, Botswana Government. 2002

DWAF (2004a) **Internal Strategic Perspective for the Vaal River System Overarching (WMAs No. 8, 9 & 10).** Report no. P RSA C000/00/0103 by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 for the Department of Water Affairs and Forestry, Pretoria, South Africa, March 2004.

DWAF (2004b) **Internal Strategic Perspective for the Upper Vaal Water Management Area (WMA No. 8).** Report no. P WMA 08/000/00/0304 by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 for the Department of Water Affairs and Forestry, Pretoria, South Africa, March 2004.

DWAF (2004c) **Internal Strategic Perspective for the Middle Vaal Water Management Area (WMA No. 9).** Report no. P WMA 09/000/00/0304 by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 for the Department of Water Affairs and Forestry, Pretoria, South Africa, July 2004.

DWAF (2004d) **Internal Strategic Perspective for the Lower Vaal Water Management Area (WMA No. 10).** Report no. P WMA 10/000/00/0304 by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 for the Department of Water Affairs and Forestry, Pretoria, South Africa, October 2004.

DWAF (2004e) **Internal Strategic Perspective for the Upper Orange Water Management Area (WMA No. 13).** Report no. P WMA 13/000/00/0304 by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 for the Department of Water Affairs and Forestry, Pretoria, South Africa, April 2004.

DWAF (2004f) **Internal Strategic Perspective for the Lower Orange Water Management Area (WMA No. 14).** Report no. P WMA 14/000/00/0304 by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 for the Department of Water Affairs and Forestry, Pretoria, South Africa, July 2004.

DWAF (2004g) **Internal Strategic Perspective for the Orange River System Overarching (WMAs No. 13 &14).** Report no. P RSA D000/00/0104 by PDNA, WRP Consulting Engineers (Pty) Ltd, WMB and Kwezi-V3 for the Department of Water Affairs and Forestry, Pretoria, South Africa, July 2004.

LESOTHO (2004) **Lesotho Lowlands Water Supply Scheme: Consultancy Services for a Feasibility Study of the Scheme. Main Report Volume1 & 2.** Report by Parkman for the Kingdom of Lesotho & European Commission 8th EDF National Indicative Programme. June 2004.

PWC (2004h) **Hydrology, Water Quality and System Analysis Volume A (Draft 2). Pre-Feasibility Study into Measures to improve the Management of the Lower Orange River and to provide for future developments along the Border between Namibia and South Africa.** Report no PB D 000/00/4303 by Burmeister & Partners, Ninham Shand (Pty) Ltd, Windhoek Consulting Engineers and WRP (Pty) Ltd for the Permanent Water Commission, The Republic of Namibia, The Republic of South Africa, October 2004. Prepared by H G Maré, L C Hattingh, W Kamish and Project Team.

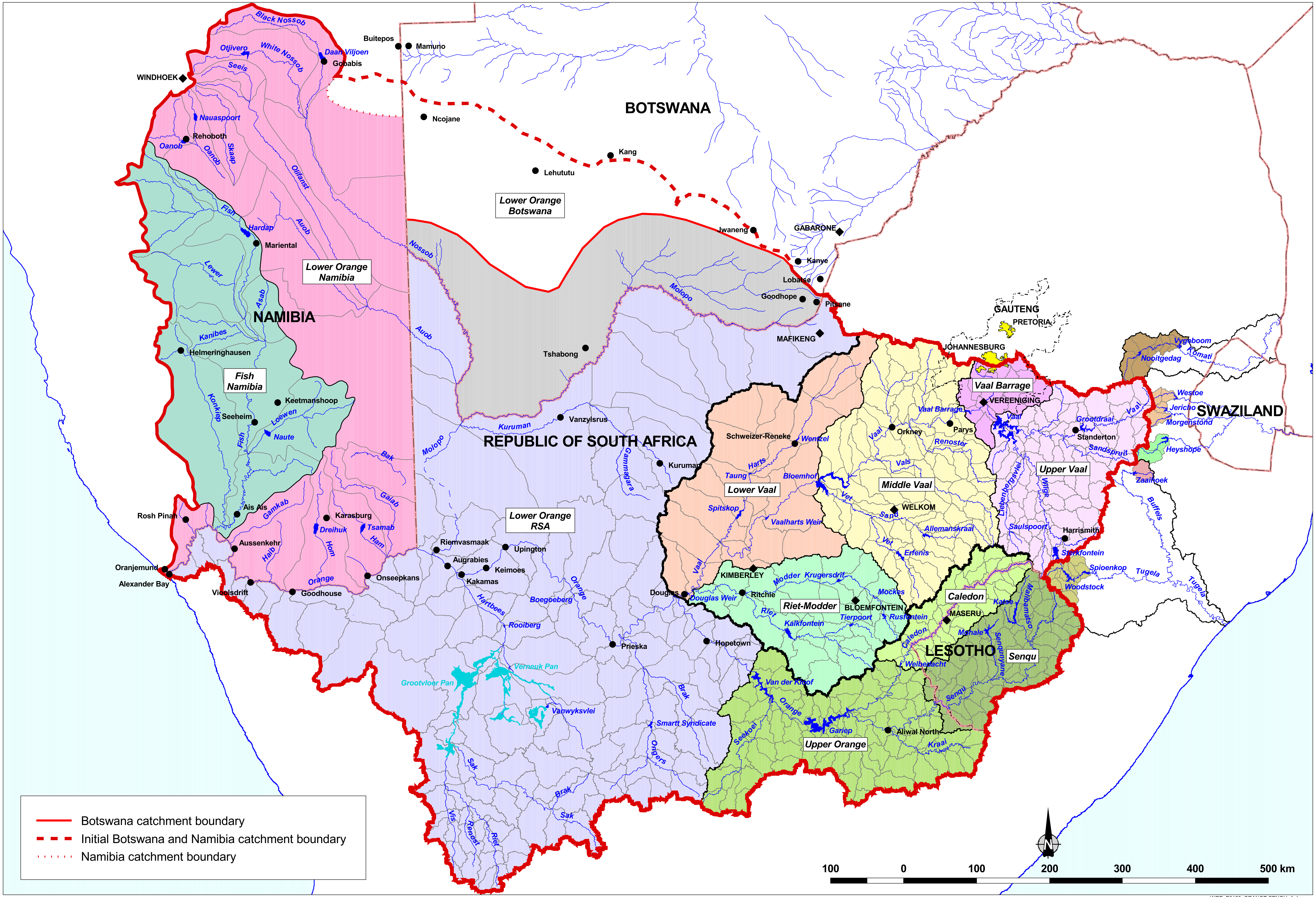
DWAF(2006a) **Vaal River System: Large Bulk Water Supply Reconciliation Strategy: First stage reconciliation study.** Report no P RSA C000/00/4405/07 by DMM Development Consultants, Golder Associates Africa, SRK, WRP Consulting Engineers and Zitholele Consulting for the Department of Water Affairs and Forestry, Pretoria, South Africa, December 2006. Prepared by PG van Rooyen and study Team.

DWAF(2006b) **Vaal River System: Large Bulk Water Supply Reconciliation Strategy: Irrigation water use and return flows.** Report no P RSA C000/00/4405/04 by DMM Development Consultants, Golder Associates Africa, SRK, WRP Consulting Engineers and Zitholele Consulting for the Department of Water Affairs and Forestry, Pretoria, South Africa, December 2006. Prepared by HG Maré.

DWAF(2006c)	**Vaal River System: Large Bulk Water Supply Reconciliation Strategy: Water Resource Analysis.** Report no P RSA C000/00/4405/05 by DMM Development Consultants, Golder Associates Africa, SRK, WRP Consulting Engineers and Zitholele Consulting for the Department of Water Affairs and Forestry, Pretoria, South Africa, December 2006. Prepared by HS Swart.
DWAF(2007)	**Vaal River System: Annual Operating Analysis 2006/2007.** Report no P RSA C000/00/4405/05 by WRP Consulting Engineers for the Department of Water Affairs and Forestry, Pretoria, South Africa, July 2007. Prepared by HS Swart.

Appendix A

Figures



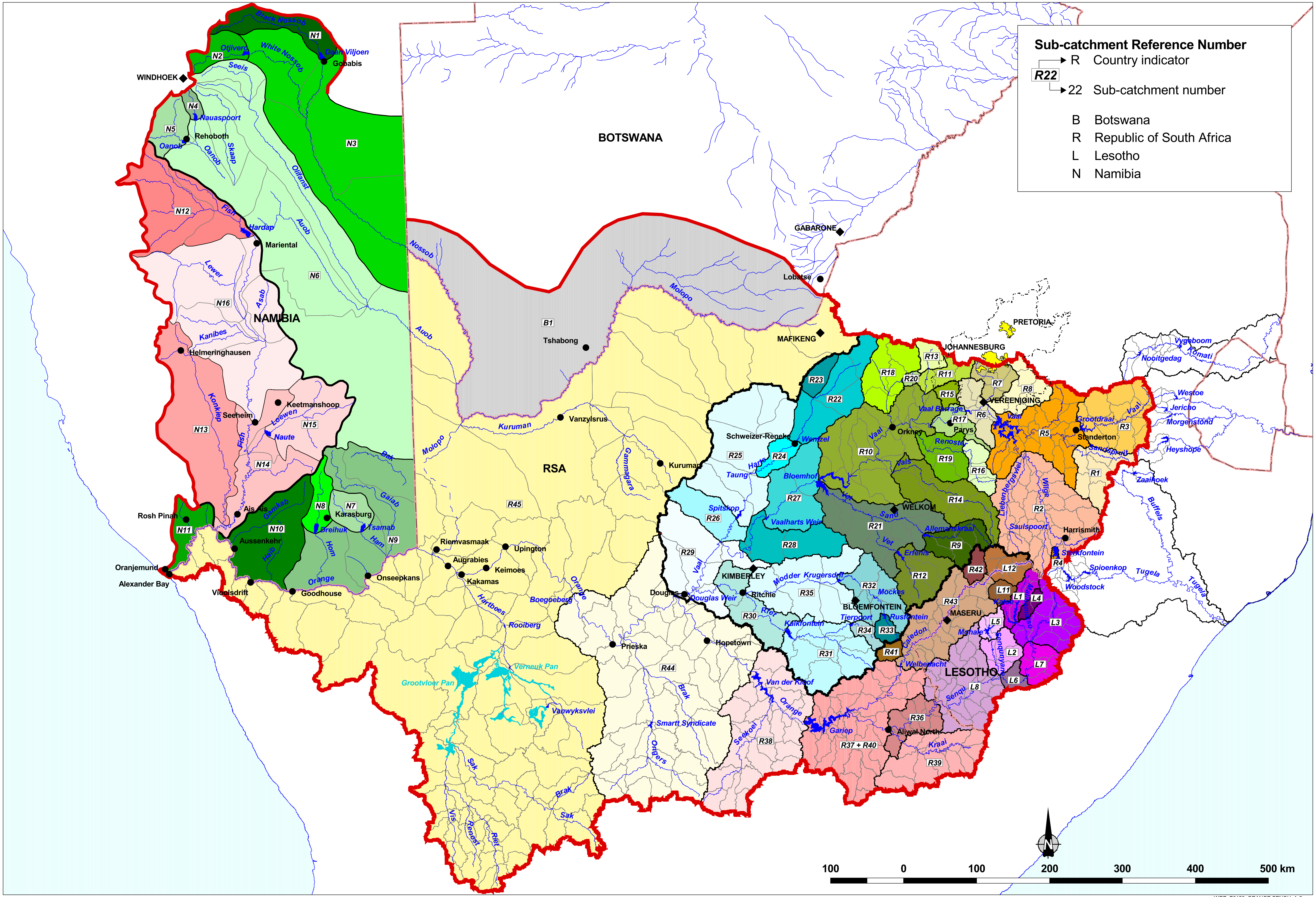
WRP_P0123_ORANGE SENQU_A-1.apr

water & forestry
REPUBLIC OF SOUTH AFRICA

INTEGRATED WATER RESOURCES MANAGEMENT PLAN
FOR THE ORANGE-SENQU RIVER BASIN

Orange River Catchment Base Map and Main Sub-catchments

A-1

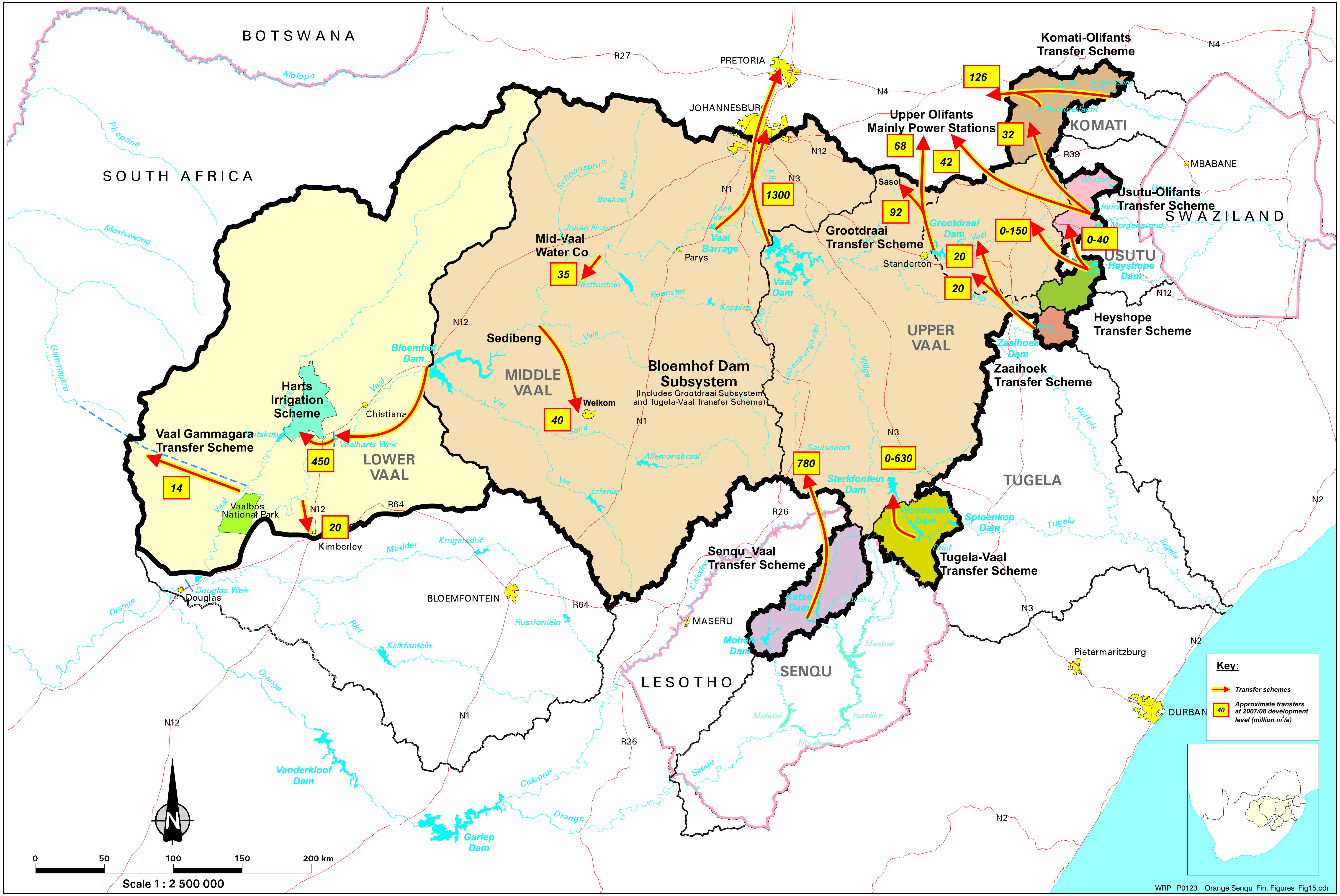


water & forestry
Department: Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

INTEGRATED WATER RESOURCES MANAGEMENT PLAN
FOR THE ORANGE-SENQU RIVER BASIN

Minor Sub-catchments and Reference Numbers

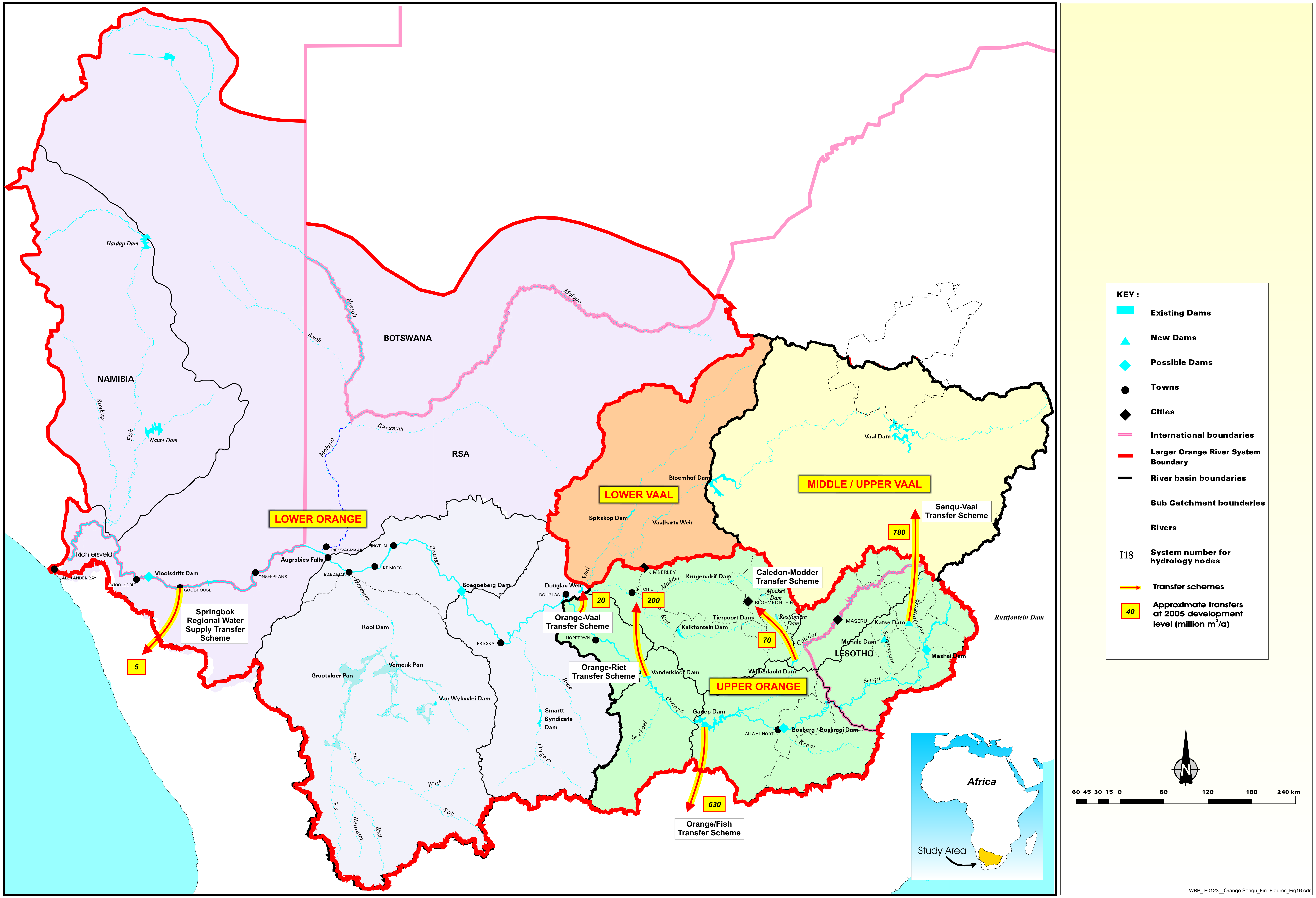
A-2



INTEGRATED WATER RESOURCE MANAGEMENT PLAN
FOR THE ORANGE-SENQU RIVER BASIN

Transfers to and from the integrated Vaal River Water Supply System

A-3

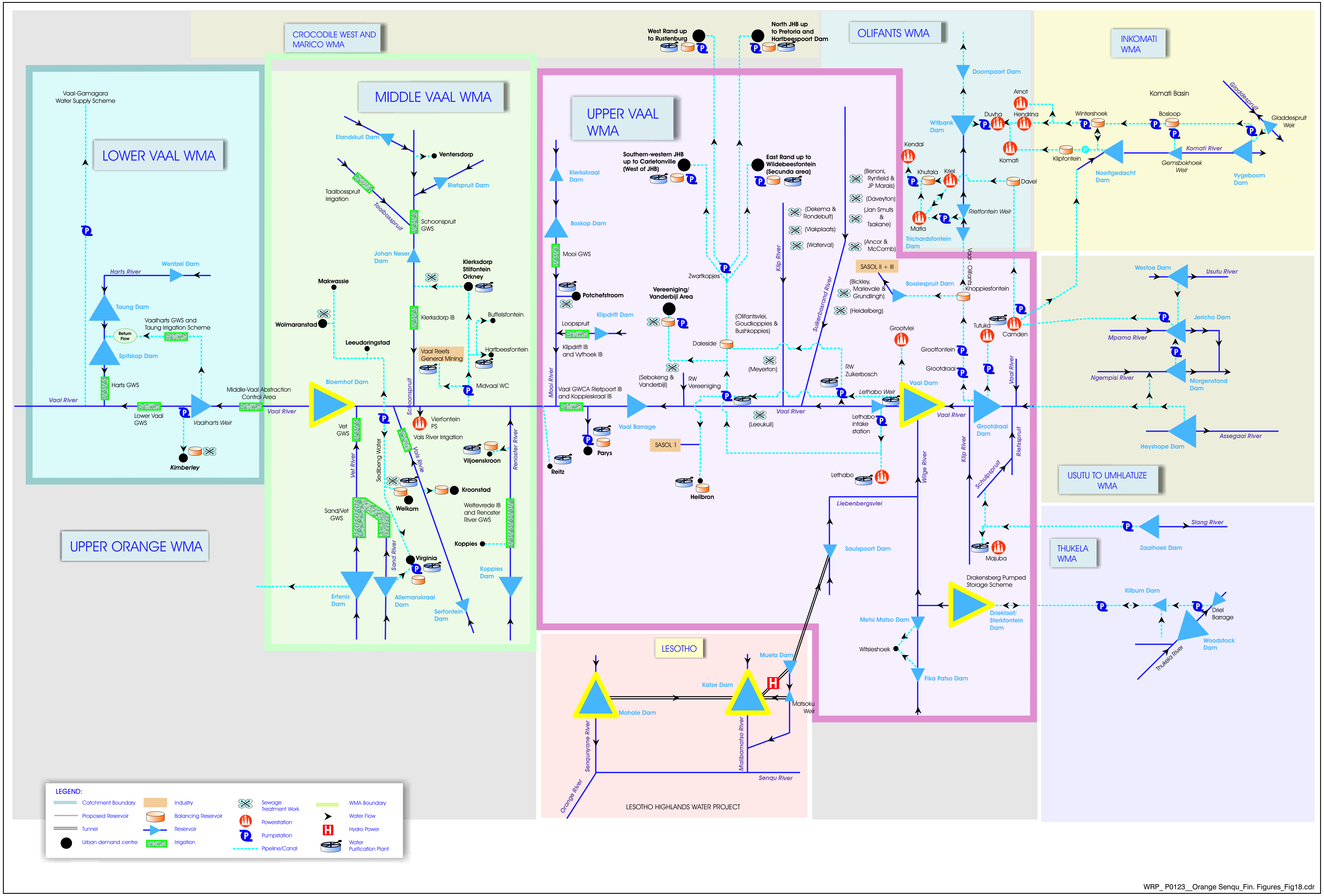


water & forestry
Department: Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

INTEGRATED WATER RESOURCE MANAGEMENT PLAN
FOR THE ORANGE-SENQU RIVER BASIN

Transfers from the Larger Orange River Water Supply System

A-4

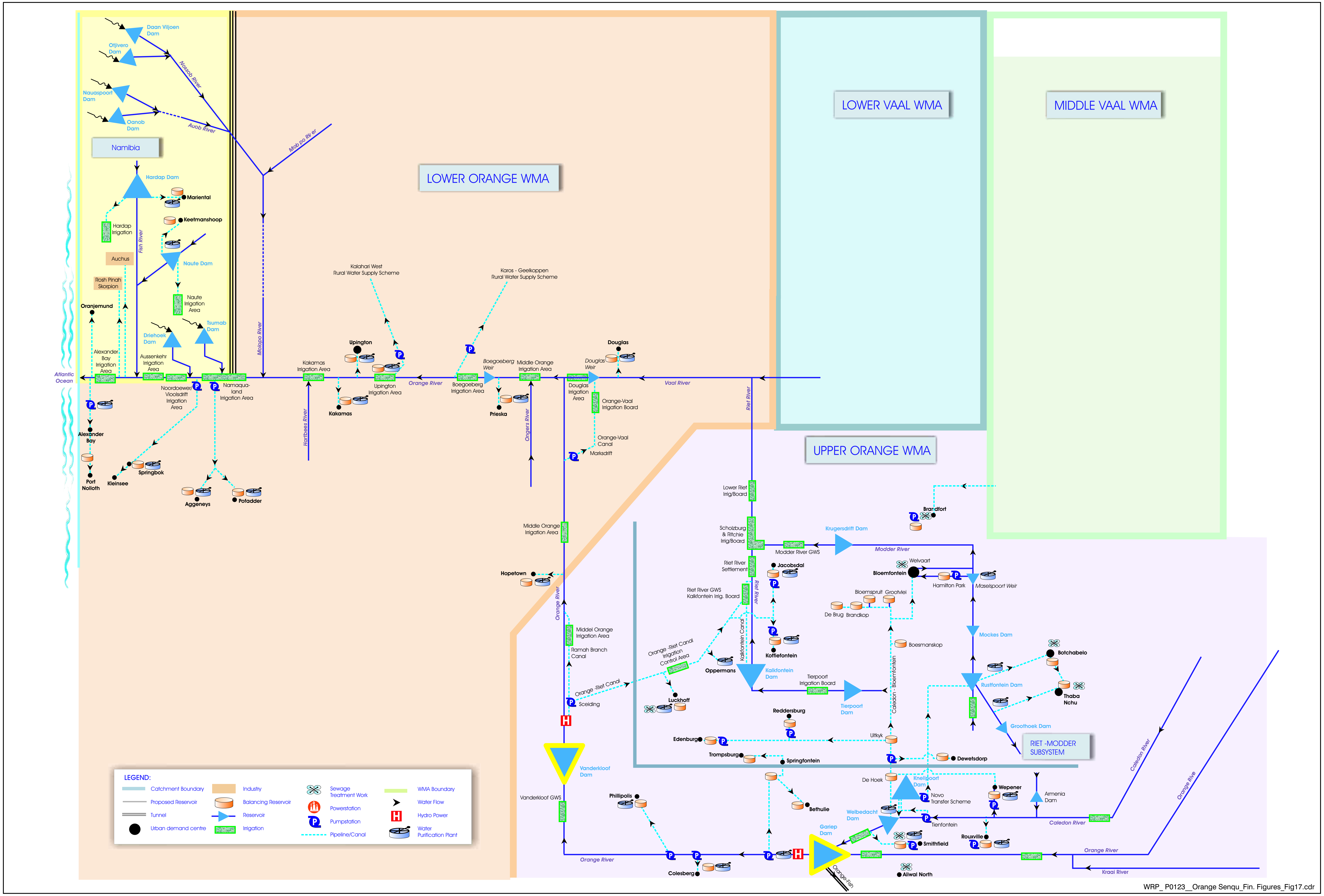


water & forestry
Department: Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

INTEGRATED WATER RESOURCE MANAGEMENT PLAN FOR THE ORANGE-SENQU RIVER BASIN

Schematic of the Integrated Vaal River System

A-5

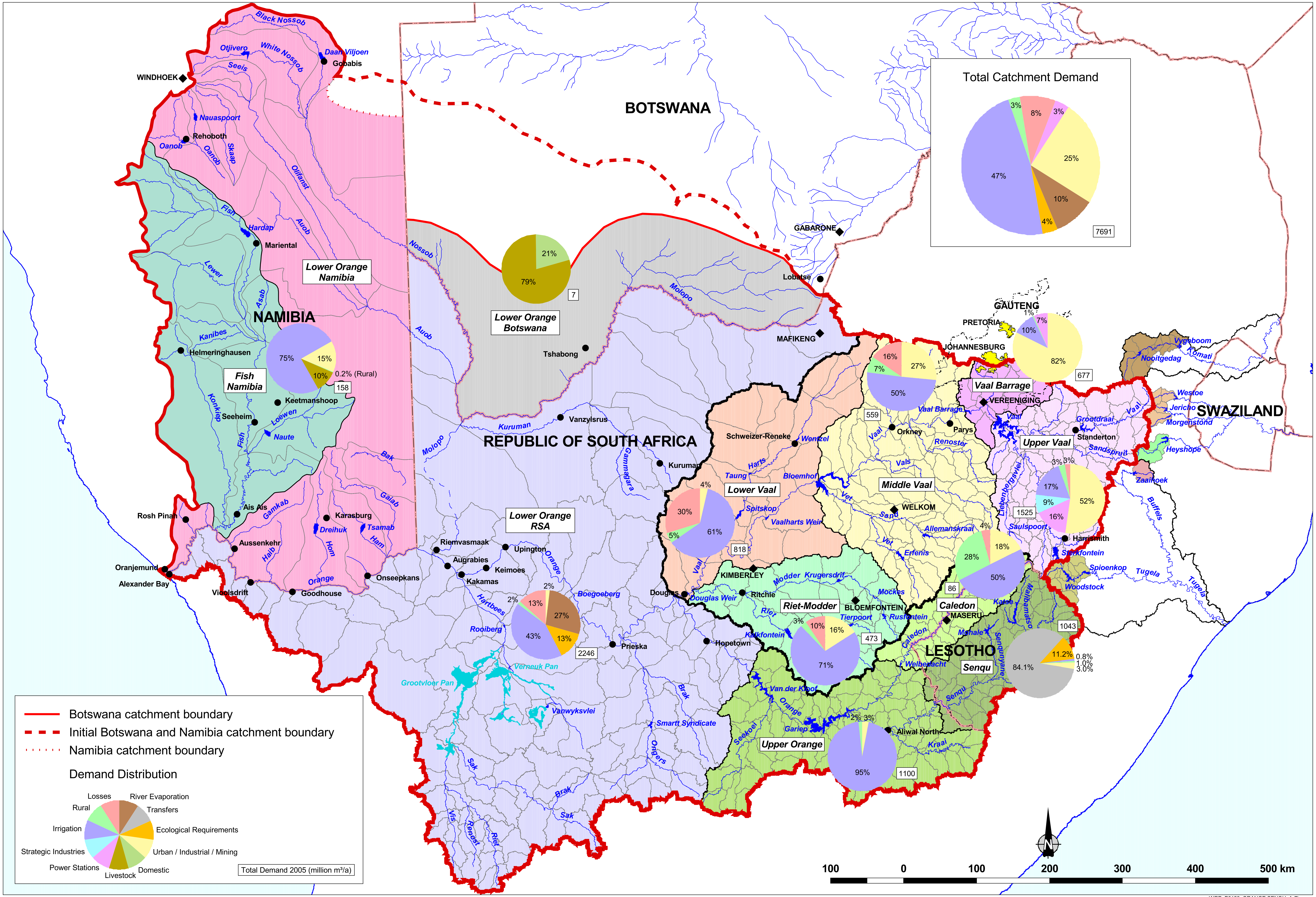


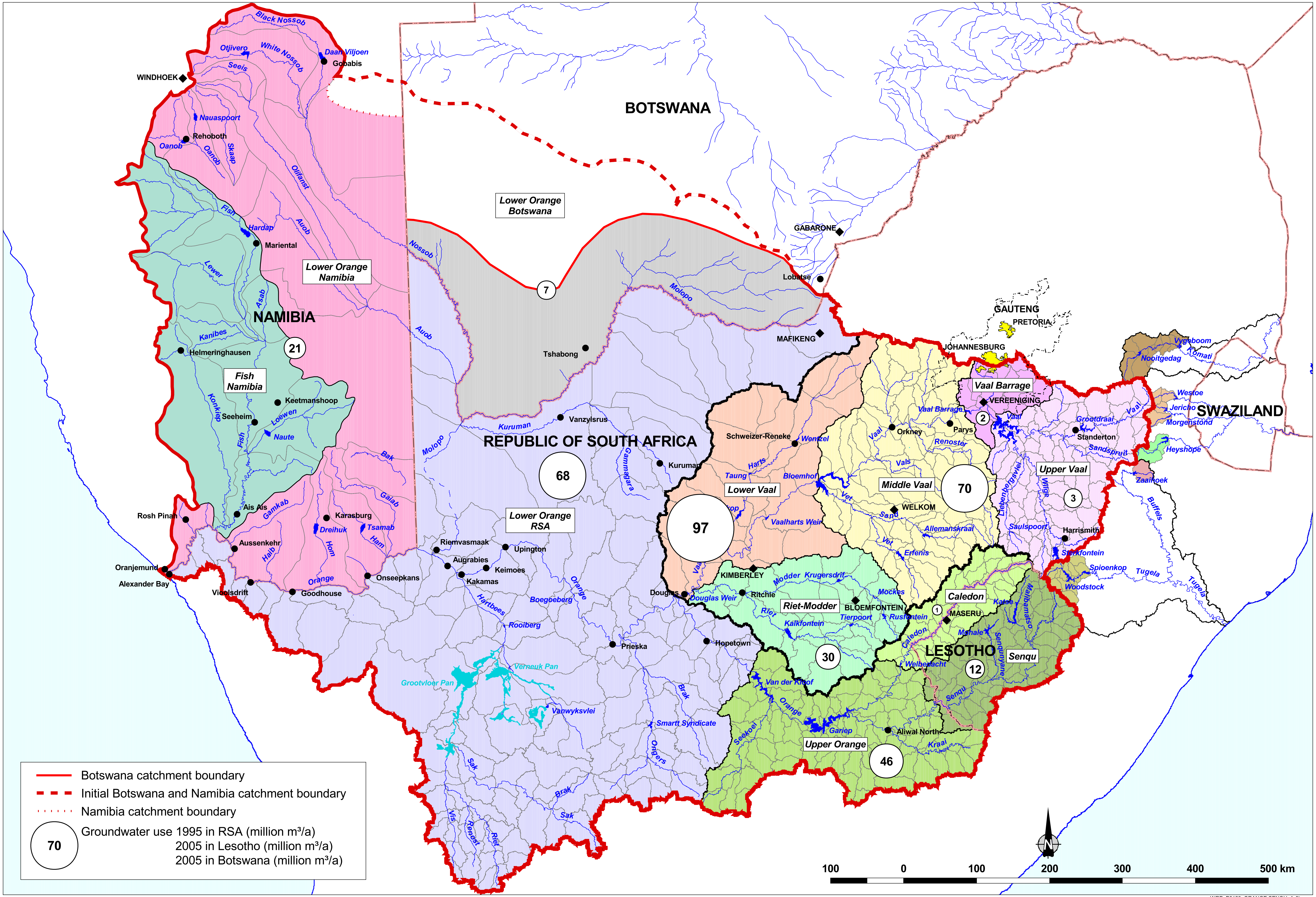
water & forestry
Department: Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

INTEGRATED WATER RESOURCE MANAGEMENT PLAN FOR THE ORANGE-SENQU RIVER BASIN

Schematic of the Larger Orange River System

A-6


BOTSWANA
NAMIBIA
REPUBLIC OF SOUTH AFRICA
LESOTHO
SWAZILAND
GAUTENG
Total Catchment Demand
47%
25%
10%
8%
4%
3%
3%
7691
Lower Orange Namibia
Fish Namibia
Lower Orange Botswana
Lower Orange RSA
Lower Vaal
Middle Vaal
Vaal Barrage
Upper Vaal
Riet-Modder
Caledon
Senqu
Upper Orange
75%
15%
10%
0.2% (Rural)
158
21%
79%
7
13%
27%
13%
43%
2%
2%
2246
30%
4%
61%
5%
818
16%
27%
7%
50%
559
1%
7%
10%
82%
677
3%
3%
17%
9%
16%
52%
1525
4%
18%
28%
50%
86
3%
10%
16%
71%
473
84.1%
11.2%
0.8%
1.0%
3.0%
1043
2%
3%
95%
1100
WINDHOEK
Rehoboth
Gobabis
Mariental
Helmeringhausen
Keetmanshoop
Seeheim
Ais Ais
Rosh Pinah
Karasburg
Aussenkehr
Oranjemund
Alexander Bay
Vioolsdrift
Goodhouse
Onseepkans
Riemvasmaak
Augrabies
Kakamas
Keimoes
Upington
Tshabong
Vanzylsrus
Kuruman
GABARONE
Lobatse
MAFIKENG
PRETORIA
JOHANNESBURG
VEREENIGING
Standerton
Parys
Orkney
Schweizer-Reneke
WELKOM
Harrismith
KIMBERLEY
Douglas
Ritchie
BLOEMFONTEIN
MASERU
Prieska
Hopetown
Aliwal North
Black Nossob
White Nossob
Otjivero
Seeis
Daan Viljoen
Nauaspoort
Oanob
Skaap
Olifant
Auob
Fish
Hardap
Lewer
Asab
Kanibes
Konkiep
Loewen
Naute
Bak
Gaiab
Gamkab
Dreihuk
Tsamab
Ham
Hom
Haib
Orange
Nossob
Molopo
Kuruman
Gamagara
Hartbees
Rooiberg
Boegoeberg
Grootvloer Pan
Verneuk Pan
Vanwyksvlei
Sak
Brak
Vis
Renoster
Riet
Smartt Syndicate
Ongers
Harts
Taung
Wentzel
Bloemhof
Spitskop
Vaalharts Weir
Vaal
Vals
Vet
Sand
Allemanskraal
Erfenis
Renoster
Vaal Barrage
Grootdraai
Sandspruit
Liebenbergsvlei
Saulspoort
Sterkfontein
Woodstock
Spioenkop
Tugela
Buffels
Zaaihoek
Heyshope
Morgenstond
Jericho
Westoe
Nooitgedag
Vygeboom
Komati
Modder
Krugersdrif
Mockes
Douglas Weir
Tierpoort
Rustfontein
Kalkfontein
Caledon
Welbedacht
Mohale
Katse
Malibamatso
Senqunyane
Van der Kloof
Gariep
Seekoei
Kraai
Botswana catchment boundary
Initial Botswana and Namibia catchment boundary
Namibia catchment boundary
Demand Distribution
Losses
River Evaporation
Rural
Transfers
Irrigation
Ecological Requirements
Strategic Industries
Urban / Industrial / Mining
Power Stations
Domestic
Livestock
Total Demand 2005 (million m³/a)
100
0
100
200
300
400
500 km
N
WRP_P0123_ORANGE SENQU_A-7b.apr



WRP_P0123_ORANGE SENQU_A-8b.apr

water & forestry
Department: Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

INTEGRATED WATER RESOURCES MANAGEMENT PLAN
FOR THE ORANGE-SENQU RIVER BASIN

Distribution of Groundwater Abstraction

A-8