Study Name:	Orange River Integrated Water Resources Management Plan
Report Title:	Review of Existing Infrastructure in the Orange River Catchment
Submitted By:	WRP Consulting Engineers, Jeffares and Green, Sechaba Consulting, WCE Pty Ltd, Water Surveys Botswana (Pty) Ltd
Authors:	A Jeleni, H Mare
Date of Issue:	November 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

ABBREVIATIONS

DWAF	Department of Water Affairs and Forestry (RSA)
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
LHWP	Lesotho Highlands Water Project
LORMS	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
ORASECOM	Orange Senqu River Commission
ORP	Orange River Project (Gariep & Vanderkloof dams and the associated supply area)
ORRS	Orange River Development Project Replanning Study
PWC	Permanent Water Commission (Between Namibia & RSA)
RDM	Resource Directed Measures
RSA	Republic Of South Africa
SCC	Storage Control Curves
WC/WDM	Water Conservation & Water Demand Management
WMA	Water Management Area
WRPM	Water Resources Planning Model
WRYM	Water Resources Yield Model

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.

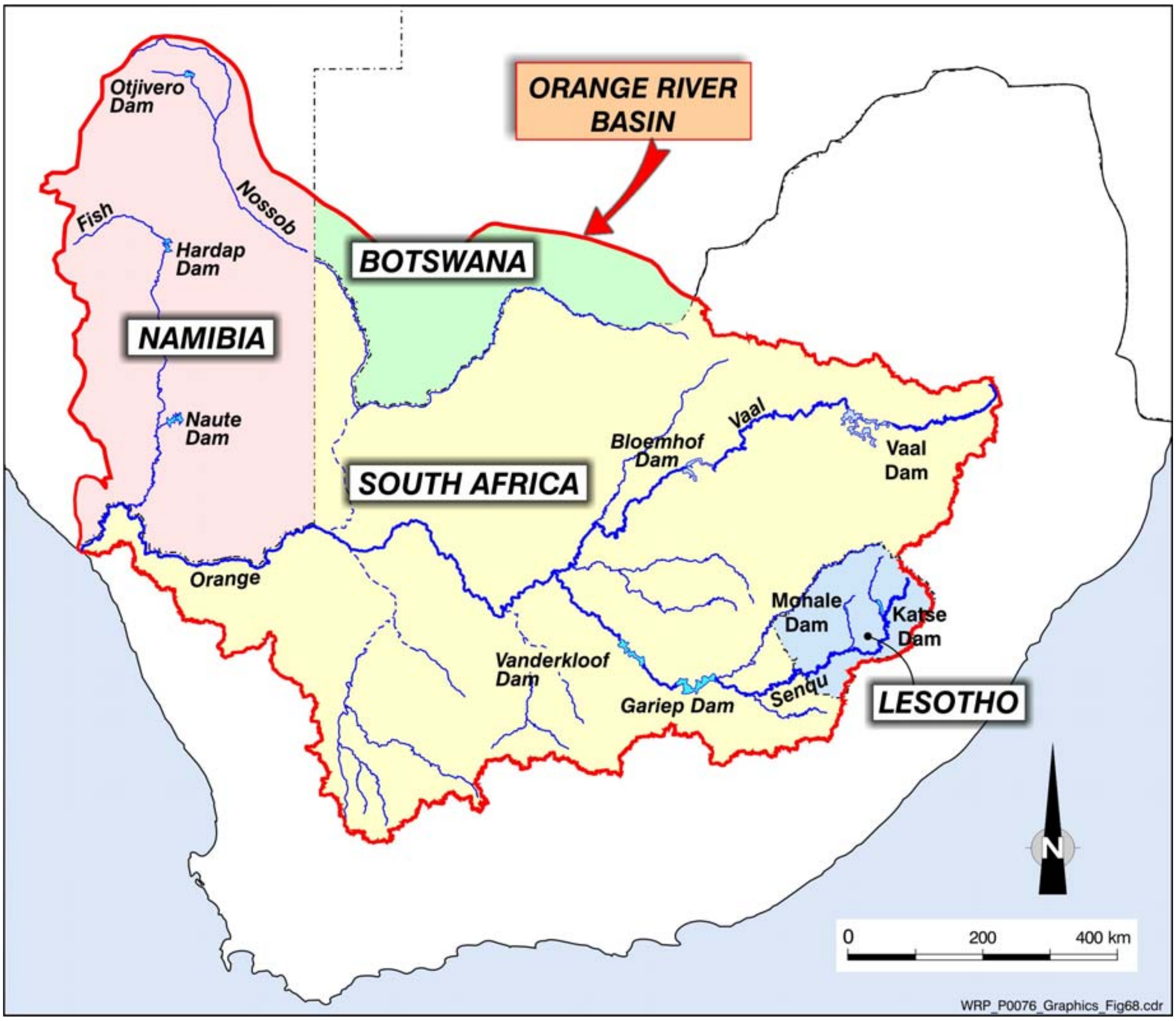

Figure 1-1: Orange River

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.

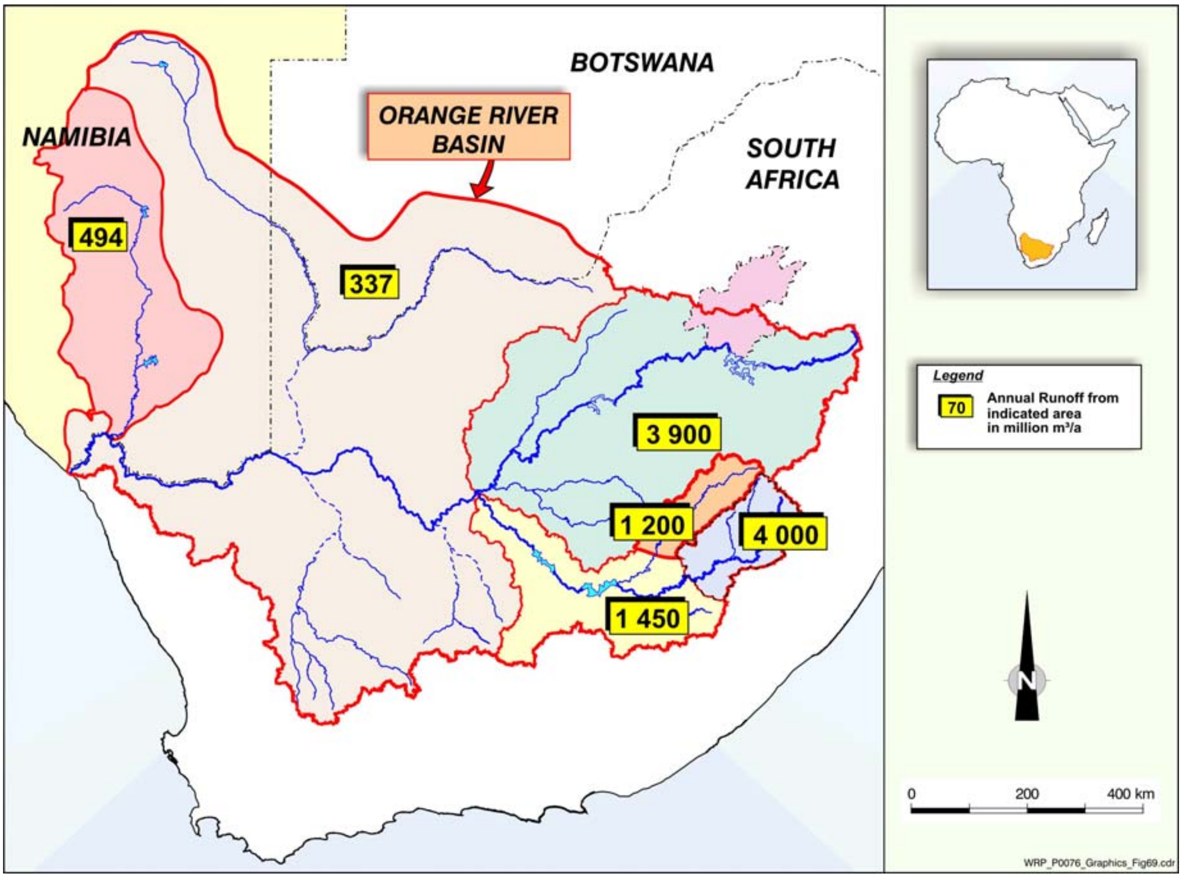

Figure 1-2: Approximate Water Balance for Natural Runoff in the Orange River Basin

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.

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

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.

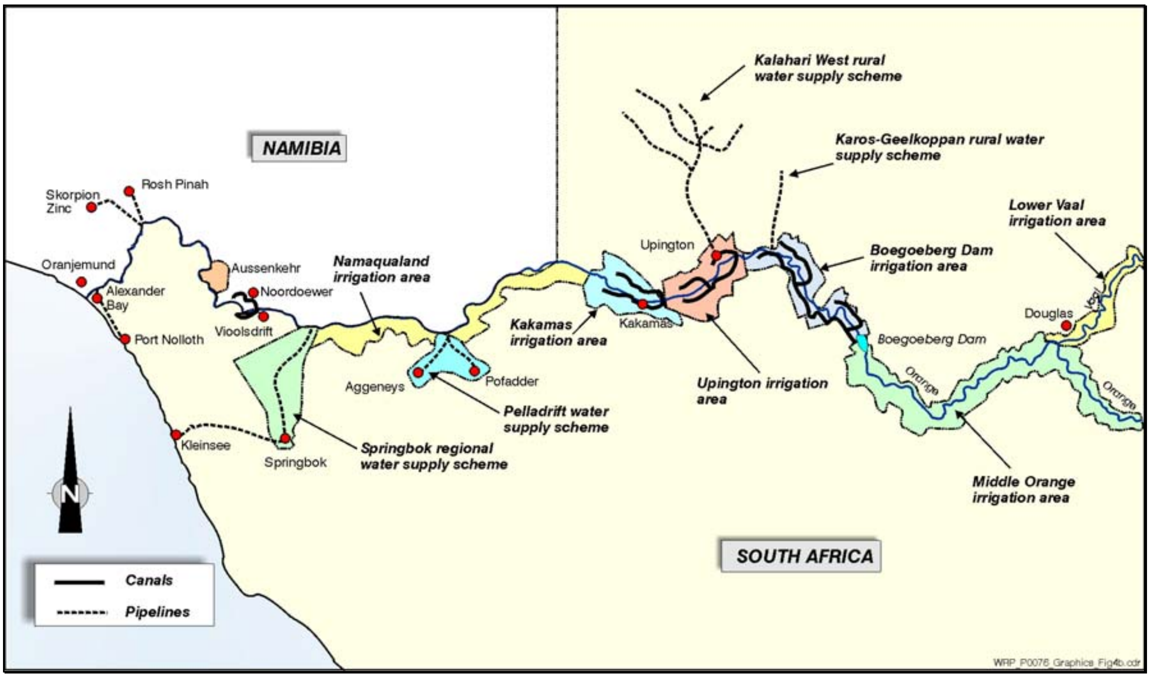

Figure 1-3: Major Water Demands along the Lower Orange River.

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.

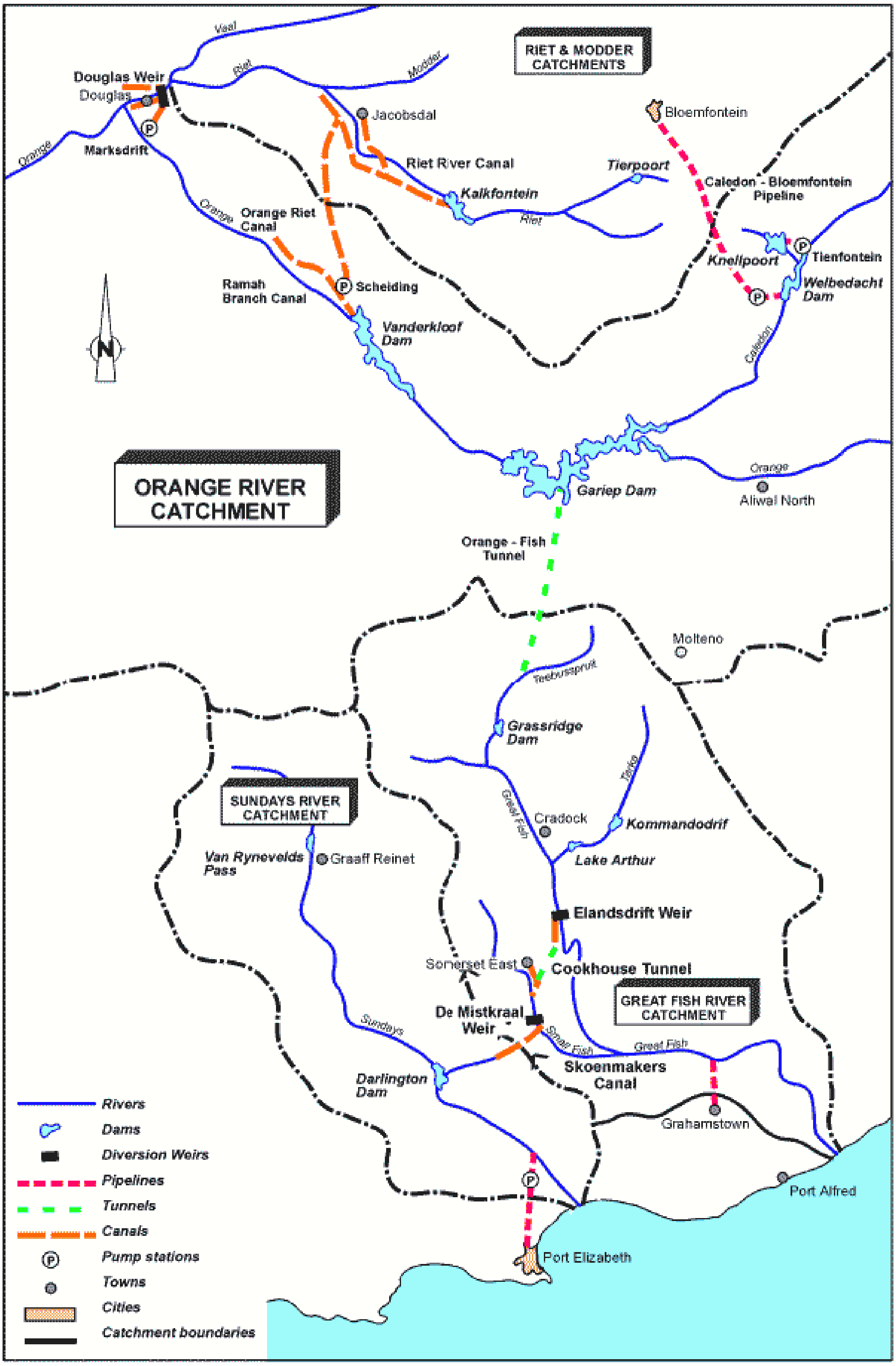

Figure 1-4: Major Water Transfer Schemes from Gariep and Vanderkloof dams.

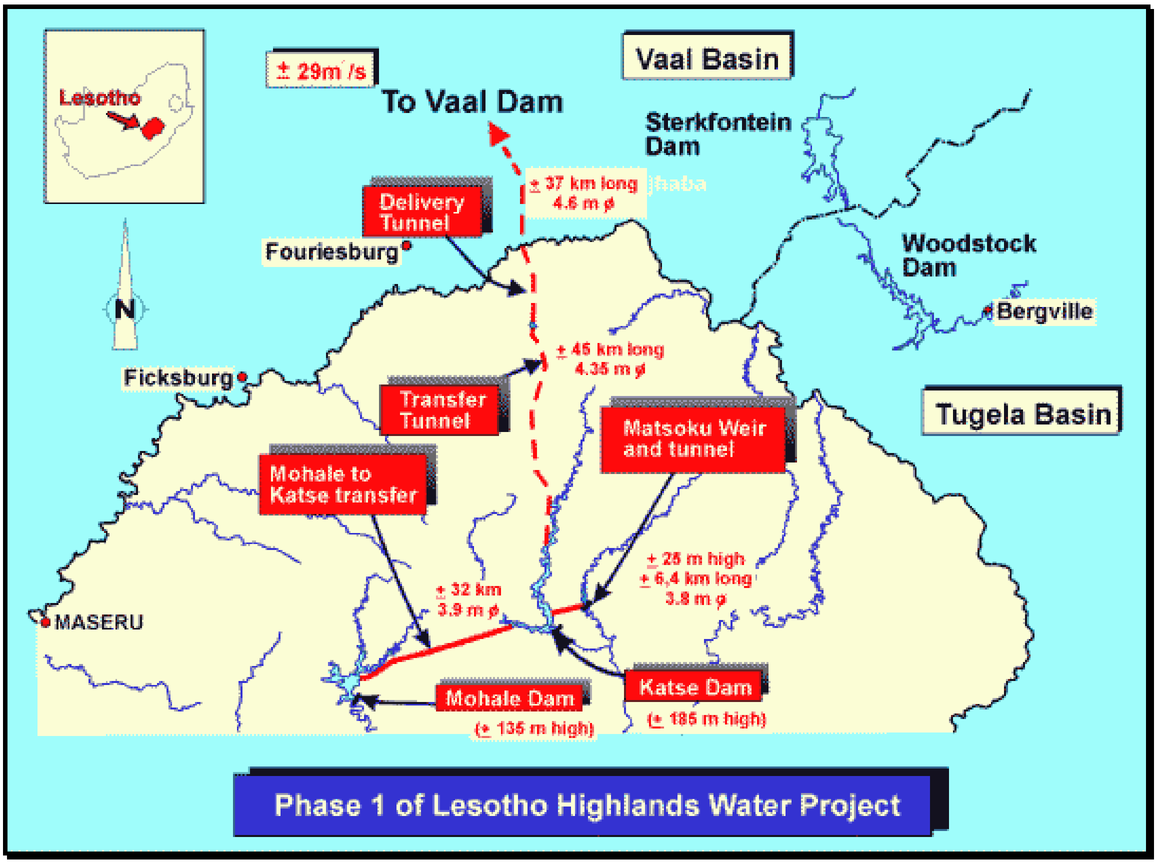

Figure 1-5: Phase 1 of the Lesotho Highlands Water Project.

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

The purpose of this report is to summarise the physical characteristics of the various existing sub-systems in the Orange River Basin and to describe the operating rules adopted to manage them. A general description of the study area will be given in **Section 2** of the report. **Section 3** gives summary of the physical characteristics of the sub-systems with **Section 4** providing details on the operation of the current system. Conclusions and recommendations are given in **Section 5.**

2 GENERAL DESCRIPTION OF THE SYSTEM

The total Orange-Senqu River Catchment, as defined for this study, extends over four countries (Botswana, Lesotho, Namibia, and the Republic of South Africa), covering an area of 985 000 km². Almost 59% (580 000 km²) of the basin falls within South Africa, 26% (260 000 km²) in Namibia, 12% (120 000 km²) Botswana and 3% (25 000 km²) in Lesotho. It incorporates the central part of the RSA, which represents nearly half of the surface area of the RSA, the whole of Lesotho (where the main river is known as the Senqu), reaches to the southern part of Botswana, and drains most of the southern half of Namibia.

From its origin in the highlands of Lesotho, the Orange River passes through different landscapes and highly varied climatic regions on its 2 300 km journey to the Atlantic Ocean. A map of the study area (Orange River Basin) is shown in **Figure 1-1.**

The major tributaries to the Orange-Senqu River are:

- The Vaal River which originates on the plateau west of the Drakensberg escarpment and drains much of the central highveld of South Africa
- The Caledon River, forming the north-western boundary of Lesotho with the Republic of South Africa (RSA)
- The Kraai River draining from the North Eastern Cape in South Africa
- The Ongers and Sak rivers draining from the northern parts of the Karoo, in South Africa
- The Kuruman and Molopo rivers draining the Cape Province north of the Orange River in South Africa as well as the southern parts of Botswana, and
- The Fish River draining the southern part of Namibia.

2.1 South Africa

Within South Africa, the Orange-Senqu catchment can be sub-divided into two main water supply systems, i.e. the Integrated Vaal River System and the Larger Orange River System. The total Integrated Vaal River System comprises all the sub-systems of the Vaal River System, i.e., the Komati-Olifants, Usutu-Olifants, Assegaai-Vaal, Buffalo- Vaal, Tugela-Vaal, Senqu-Vaal and the Vaal River with all its tributaries down to the confluence with the Riet River, but excluding the Riet-Modder river catchment. The Larger Orange River System comprises the Caledon (Caledon/Modder Transfer Scheme), the Orange

River Project (Gariep and Vanderkloof Dams with their total supply area), as well as all the water supply schemes in the Riet/Modder catchment and the larger water supply schemes within tributaries of the Orange River downstream of Vanderkloof Dam.

The Integrated Vaal River System is operated almost independently from the Orange River System. The only link between the two large systems, is the spills from the Vaal System entering Douglas Weir in the Lower Vaal just before the confluence of the Orange and Vaal rivers.

The Vaal River originates on the plateau west of the Drakensberg escarpment and drains much of the central highveld of South Africa. The major dams on the Vaal River are the Vaal Dam, Vaal Barrage, Grootdraai Dam and Bloemhof Dam. The following are the tributaries to the Vaal River: the Klip, Wilge, Liebenbergsvlei Mooi, Schoonspruit, Harts, and Riet Rivers

The Vaal River basin boasts South Africa’s earliest major multi-purpose scheme, which is also the first major inter-basin transfer scheme, viz. the Vaal River Development scheme, of which the main storage unit is the Vaal Dam. Constructed during the mid-nineteen thirties, Vaal Dam was designed to serve both the Reef Complex and the Vaal-Harts Irrigation Scheme (involving diversion of water from the Vaal River into the Harts River valley). Although for many years most of the water from the Vaal River went to Vaal-Harts, the major share now goes to Rand Water for distribution throughout its supply area. Bloemhof Dam, built in 1970, helped to relieve Vaal Dam of part of the downstream load. Considerable quantities of water are exported beyond the boundaries of the Vaal River basin – to Pretoria, Rustenburg and the northern parts of Rand Water’s supply area and to Eskom power stations.

The Upper Orange River as defined in this report comprises the Orange River upstream of Marksdrift located just upstream of the confluence of the Vaal and Orange River as well as the Riet-Modder catchment. Although the Riet and Modder rivers is tributaries of the Vaal River, there is almost no infrastructure linkage between the two rivers with the Vaal, while several transfers takes place from the Upper Orange to Riet-Modder catchment. For this reason it was decided to include the Riet-Modder cachment as part of the Upper Orange. The two largest dams in the RSA, Vanderkloof and Gariep dams are situated in this section of the Orange River. These two dams are utilised for river flow control, flood control, hydro power generation and storage of water for urban and irrigation use.

Water is transferred from the Gariep Dam via the Orange-Fish tunnel to supplement the irrigation and urban water demands along the Great Fish and Sundays rivers, as well as in Port Elizabeth. Water is also transferred from Vanderkloof Dam to supplement the irrigation demands along the Riet River. The third transfer scheme comprises the transfer of water from the Orange River at Marksdrift into the Douglas Weir on the Vaal River.

The Caledon River forms for most of its length the north-western border of Lesotho, between Lesotho and the RSA. The two major dams within the Caledon River Catchment are the Welbedacht Dam and the Knellpoort Dam. The Welbedacht Dam is situated on the Caledon River while the Knellpoort Dam is situated on the Rietspruit River, a tributary of the Caledon River. The Knellpoort Dam is operated as an off-channel storage dam by pumping water from the Caledon River into the dam.

The Knellpoort Dam was built to augment the storage capacity of Welbedacht Dam and to transfer water to the upper reaches of the Modder River. The storage capacity of Welbedacht Dam has reduced significantly due to siltation. Water from the Welbedacht Dam is pumped to the Welbedacht water purification works from where potable water is pumped to supplement the water supply from the Modder River to Bloemfontein. Water is also supplied from this system to De Wetsdorp and Botshabelo.

The Lower Orange River as defined in this report comprises the Orange River from the confluence with the Vaal River to the Atlantic Ocean. The major tributaries draining into this section of the Orange River are: the Ongers and Sak rivers from the northern Karoo; the Kuruman and Molopo rivers from the Cape Province north of the Orange and the southern part of Botswana; and the Fish River from the southern part of Namibia.

These rivers are draining arid and semi arid areas. Water is mainly abstracted for irrigation along the river at various points and to a lesser extent for urban use and stock watering purposes.

Ongers River - joins the Orange River just upstream of Prieska. **Hartebeest River** - joins the Orange River approximately 80 km downstream of Upington. The Carnarvonleegte, Fish, Riet, Rhenoster and Sak Rivers are the main tributaries of the Hartebees River and together they drain the majority of the Hantam and southern portion of the Benede-Orange District Council regions. These rivers have seasonal flow which is captured by pans or irrigation dams. The Ongers River also has seasonal flow and most of its potential runoff is stored in the Smartt Syndicate Dam due west of De Aar.

Molopo River - joins the Orange River approximately 120 km downstream of Upington. The Nossob and Kuruman rivers join the Molopo River near the most southern point of the RSA/Botswana boundary. The Kuruman, Molopo and Nossob Rivers, which drain the Kalahari and northern Benede-Orange District Council regions, are not considered to make a meaningful contribution to the surface water resources.

Within South Africa, the Orange/Vaal River Basin consists of five of the 19 Water Management Areas (WMAs), and **Sections 2.1.1** to **2.1.5** are devoted to the description of each of the five individual Water Management Areas (WMAs) in the Vaal and the Orange systems. **Figure A-12** shows the location of the WMAs in the Vaal River System (Upper, Middel and Lower Vaal WMAs) and the Larger Orange River System (Upper and Lower Orange WMAs).

2.1.1 Upper Vaal WMA

The Upper Vaal WMA is located upstream of the confluence of the Vaal and the Mooi rivers and extends to the headwaters of the Vaal, Klip, Wilge and Liebenbergsvlei rivers. The Upper Vaal WMA is the most developed, industrialised and populous of all the Orange/Vaal WMAs, and from a water resource management perspective it is a pivotal WMA in South Africa. Large quantities of water are transferred into this WMA from the Usutu and Thukela WMAs, as well as the Senqu (Orange) River in Lesotho. Large quantities of water are released along the Vaal River to support users in the Middle Vaal and Lower Vaal WMAs and are also transferred to the Crocodile West, Marico, and the Upper Olifants catchments to supply large urban/industrial demand centres and Eskom power stations with water.

2.1.2 Middle Vaal WMA

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

2.1.3 Lower Vaal WMA

Over 90% of the water used in the Lower Vaal WMA is sourced through releases from the Upper Vaal WMA, and from Bloemhof Dam, which is located on the border with the Middle

Vaal WMA, on the Vaal River. About 80% of the water used in this WMA is for irrigation (mainly at the Vaalharts irrigation scheme) purposes. Essentially, only irrigation return flows, which are of high salinity, and unregulated flood flows from the Vaal River, reach the confluence of the Vaal River with the Orange River.

2.1.4 Upper Orange WMA

Close to 60% of the water resources generally associated with the Upper Orange WMA, originate from the Senqu River in Lesotho. Developments in Lesotho can therefore have a significant impact on the Upper Orange WMA. The two largest storage reservoirs in South Africa (Gariep and Vanderkloof dams), are located in this WMA. Two thirds of the total yield (4 655 mcm/a) realised together by the dams in Lesotho and in the Upper Orange WMA, is transferred/ (reserved for transfer) to the Upper Vaal (835 mcm/a), Fish to Tsitsikamma WMAs (600 mcm/a), and released to the Lower Orange WMA (2 035 mcm/a) also as part of Namibian demands along the border.

2.1.5 Lower Orange WMA

Surface water resources in the Lower Orange WMA are highly dependant on the releases from the Gariep and Van der Kloof dams in the Upper Orange WMA. There are a few small dams in the WMA, but nothing of significant storage capacity except for the Smartt Syndicate (99.3 × 106 m^3), Van Wyksvlei (143 × 106 m^3) and Boegoeberg (20.4 × 106 m^3) dams. Water requirements in the Lower Orange WMA are far in excess of the yield available from resources within this WMA, and about 95% are supplied by water released from the Upper Orange WMA. High river requirements, which include evaporation directly from the Orange River and evapotranspiration from vegetation in and along the river, occur in this WMA. Namibia also abstracts water from the Orange River along the common border.

2.2 Botswana (Molopo/Nossob Rivers)

The Molopo and Nossob rivers form the northern boundary between the RSA and Bostwana. The Molopo originates in Botswana and the RSA and flows in a south west where it first joins the Nossob and later the Kuruman rivers. The Nossob originates in Namibia in the most northern part of the Orange River Basin and flows south west joining the Auob from Namibia and later the Molopo River. The confluence of the Molopo and Nossob is at the most southern tip of Bostwana. No physical structures such as dams or weirs are found in the Molopo and Nossob rivers within and along the Botswana border.

Flow from the Molopo is not reaching the Orange River as sand dunes near Noenieput have blocked its course for at least the last 1 000years.

2.3 Namibia (Fish, Nossob and Auob Rivers)

The Fish River rises to the south of Windhoek and flows in a generally southwards direction over a distance of 636 kilometres before it joins the Orange River approximately 100 km upstream of the river mouth. The Fish River is the largest river from Namibia within the Orange River basin and contributes a reasonable volume (494 million m^3/a) to the flow in the Lower Orange River. Flow in this river is sporadic and varies between almost zero million m^3/a to as high as 5 300million m^3/a. Hardap and Naute dams, two of the largest dams in Namibia is located in this catchment, and is used for urban as well as irrigation supply.

The Nossob rises in the most northern part of the Orange Basin within Namibia. It starts of as the Black and White Nossob which after its confluence is refered to as the Nossob River. Water is mainly utilised in the northern catcment areas through the Daan Viljoen and Otjivero Dams for urban water supply purposes.

The Auob River rises in the north western part of the Orange Basin close to Windhoek, with its main tributaries the Olifants, Skaap and Oanob rivers. Shortly after the confluence of the Olifants River the Auob enters the RSA where after it joins the Nossob at the RSA Botswana border. Two dams, Nauspoort and Oanob dams are located in the upper reaches of the Oanob and are used for urban water supply purposes.

2.4 Lesotho (Senqu River)

The Senqu River, with its tributaries, drains most of the Lesotho Highlands. The Senqu River has as its main tributaries in Lesotho the Malibamatsu, Mokhotlong, Tsoelike, Makhaleng and Senqunyane Rivers. It covers approximately 24 500 km^2 (approximately two thirds of the total surface area of Lesotho) and extends from Oranjedraai in the south towards Mont-aux-Sources on the north-eastern border of Lesotho. It is bordered by the Drakensberg Mountains along the eastern boundaries and by the Maluti Mountains along the western boundary. As soon as the Senqu River crosses the Lesotho border to enter the RSA, the River is known as the Orange River. The origin of the Orange River is thus in fact the Senqu River with its upper reaches draining water from the high rainfall areas in the Lesotho Highlands. Two major dams in the Senqu catchment is the Katse Dam located in the Malibamutso River and Mohale Dam in the Senqunyane River. The full phase 1 of the Lesotho Highlands Water Project (LHWP) comprises of Katse and Mohale dams and Matsoku Weir with its interlinking tunnels and transfer tunnels to the Upper Vaal catchment. The full phase 1 was completed in 2005 and the purpose of this scheme is to transfer water from the Senqu River System to the Vaal River System and to generate electricity for Lesotho.

Transfers from Katse and Mohale dams to the Vaal Dam are based on an agreement between Lesotho and the RSA. According to the agreement, the transfer is to increase over time until it reaches the maximum long-term transfer volume of 835 million m^3 per annum. This maximum long-term transfer volume (877 mcm/a) will then each year be transferred to Vaal Dam regardless of the storage levels in the Vaal or Orange River systems.

3 INFRASTRUCTURE INVENTORY

3.1 Vaal River System

For the Vaal River System it is important to distinguish between the Main Vaal System and the smaller sub-systems in the Vaal. The Main Vaal System consists basically of four major storage dams in the Vaal River Basin, i.e. the Grootdraai Dam, Sterkfontein Dam, Vaal Dam and Bloemhof Dam. These dams are located on the main stem of the Vaal River with the exception of Sterkfontein Dam which is located on the Wilge River tributary. Added to the main system is several transfer schemes (see **Section 3.1.1**) which together with the main system forms the Integrated Vaal River System.

Within the Vaal River Basin there is however also several smaller sub-systems which are all operated independently from the main system. These smaller sub-systems are not used to support the Main Vaal System and it is only the spillage from the smaller sub-systems that reaches the Main Vaal System.

3.1.1 Upper Vaal System

The Upper Vaal System comprises the Vaal River Catchment down to and including the Vaal Barrage (see **Figure A-1** in **Appendix A**). The major impoundments in this sub-system are the Vaal Dam, Grootdraai Dam, Sterkfontein Dam, Saulspoort Dam and the Vaal Barrage (see **Figure A-4** in **Appendix A**) for the location of these dams. The combined gross storage in these dams is 5 655.2 million m^3, and represents 253% of the incremental MAR under natural conditions. The two main rivers feeding the Vaal Dam are the Vaal and the Wilge rivers. The following major tributaries drain into these two rivers: the Klip, Watervals, Venterspruit, Little-Vaal, Liebenbergsvlei, Blesbokspruit, Klip(south of Johannesburg) and Suikerbosrand rivers.

There are a number of small to medium dams in the catchment, mainly to supply water for local towns and/or irrigation. These dams are, for modelling purposes in general, combined into a number of so called dummy dams, which represents the combined effect of the small dams within a sub-catchment. The gross full supply storage of these small dams in the Upper Vaal sub-system has been determined to be 191.53 million m^3.

The Vaal Dam is the main storage reservoir (with a live storage capacity of 2 442.53 million m^3) for water supply to the Gauteng area and other consumers downstream of the Vaal Barrage. The Rand Water Board, some of the Eskom power stations and some smaller consumers, abstract water directly from the Vaal Dam. There are also releases from the Vaal Dam to supply consumers between the Barrage and Bloemhof Dam.

Sasol Secunda Complex and some of the Eskom power stations in the Upper Olifants Catchment are supplied from the Grootdraai Dam. However, Matla, Kendal and Kriel power stations are primarily supplied from the Inkomati and Usutu systems, but they can be supplemented from the Grootdraai Dam in case of emergency.

To meet the spiralling water demands within the Vaal River basin, various water transfer schemes have been implemented, and are as follows:

- **Thukela--Vaal Transfer Scheme:** transferring water from Woodstock Dam and Driel Barrage in the Upper Tugela Catchment to the Upper Vaal WMA, with a maximum transfer capacity 19 m^3/s.
- **The Heyshope to Grootdraai Transfer Scheme**: transferring water from Heyshope Dam in the Upper Usutu Catchment to the Upper Vaal WMA, with a design capacity of 10 m^3/s. It is, however, currently limited to 3.8 m^3/s by the pumping station and the rising mains.
- **The Zaaihoek Transfere Scheme**: transferring water from the Zaaihoek Dam in the Slang River in the Buffalo Catchment to the Upper Vaal WMA, with a maximum transfer capacity of 2.79 m^3/s.
- **The Vaal–Olifants Transfer Scheme (Grootdraai)**: transferring water from Grootdraai Dam in the Upper Vaal WMA to the Upper Olifants Catchment, with a maximum transfer capacity of 6.5 m^3/s.
- **The Inkomati Transfer system**: transferring water from Nooitgedacht and Vygeboom dams in the Komati west Catchment to the Upper Olifants Catchment with a design capacity of 5.76 m^3/s.
- **The Lesotho Highlands Transfer System:** transferring water from Katse and Mohale Dams in Lesotho to the Upper Vaal WMA, with a maximum transfer capacity of 35.7 m^3/s.
- **Vaal River Eastern Sub-system Augmentation Project (VRESAP):** Transferring water from Vaal Dam to the Sasol Secunda complex and the Eskom Power stations in the Upper Olifants Catchment, with a maximum transfer capacity of 5.07 m^3/s.

Figure A-4 in **Appendix A** shows a base map with the transfer schemes.

Dams

Table 3.1 shows a list of dams in the Upper Vaal sub-system with their storage capacities.

Table 3.1: Main dams in the Upper Vaal System

Name	Gross Storage (mcm)	Live Storage Capacity (mcm)	Dead Storage (mcm)
Saulspoort	16.867	16.867	0
Driekloof		32,226	
Sterkfontein	2616.951	2 482.32	134.631
Grootdraai	356.02	318.01	38.01
Vaal Dam	2609.8	2 442.52	167.28

Note: * Driekloof Dam is a small dam located within the tail end of Sterkfontein Dam and is part of the Tugela-Vaal Transfer Scheme for balancing purposes.

Major Water Schemes forming part of the Main Vaal System

a) Vaal River Eastern Sub-system Augmentation Project (VRESAP)

VRESAP is aimed at stabilising and extending industrial water supply to Sasol Secunda Complex and the Eskom power stations in Upper Olifants. The scheme is expected to be operational by 2008. The water is to be pumped from the Vaal Dam, using the new abstraction works, to an upgraded existing diversion structure at Knoppiesfontein. From Knoppiesfontein the water will gravitate to Trichardtsfontein and Bosjesspruit dams, supplying Eskom and Sasol Secunda complex respectively (See **Figure A-5** in **Appendix A**). The abstraction structure is designed to be able to deliver its full volume of 5.4 m^3/s with the water level of Vaal Dam at its minimum operating level.

The system consists of:

- Abstraction works, including a low-lift pump station at the Vaal Dam, near the Vaal Marina
- A dual purpose, balancing dam and desilting works
- A high-lift pump station just above the desilting dams
- The pipelines include the 115 km X 1.9 m-diameter rising main and another 5.6 km gravity line from Knoppiesfontein to Bosjesspruit-varying between 1.2 m and 1 m in diameter
- A 100 000 m^3 surge tank at the highest point along the pipeline route

- An upgraded concrete diversion structure at Knoppiesfontein.

b) Grootdraai Dam Sub-system

Grootdraai Dam is the main storage dam in this sub-system. Thuthuka Power station in the Upper Vaal WMA is solely supplied with water from Grootdraai Dam, via a dedicated supply infrastructure. Matla power station in the Upper Olifants Catchment receives water from Grootdraai Dam, via Rietfontein pump station to supply demand shortfalls, when the Usutu system cannot meet the full demand. Both Kendal and Kriel power stations in the Upper Olifants Catchment can be supplied via Rietfontein in the event that the Usutu system is unavailable. Although this scheme can, in emergencies, also provide most of Eskom's remaining power stations in the Upper Olifants Catchment with water during times of water shortage, it is not practical to do so, due to unfavourable water quality.

Water is pumped from the Grootdraai Dam, by the Grootdraai pump station, to Vlakfontein via two steel rising mains from where it gravitates via the Vlakfontein-Grootfontein canal to the Grootfontein pump station. From the Grootfontein pump station the water is pumped to Knoppiesfontein diversion tank where the water is diverted to the Bossiespruit Dam and to Trichardsfontein Balancing Dam. Bossiesspruit Dam releases the water to Sasol Secunda Complex. From Trichardtsfontein balancing dam the water is released into the Rietfontein Weir. From here, the Rietfontein Pumpstation pumps the water to Matla where it can be distributed to Kriel and Kendal as and when required. Water can be released from Rietfontein Weir to flow via the Steenkoolspruit to Witbank Dam in support of Duvha power station. **Figure 3-1** provides a schematic layout of the relative elevations of this sub-system's components with general layout and location given in **Figure 3-2**.

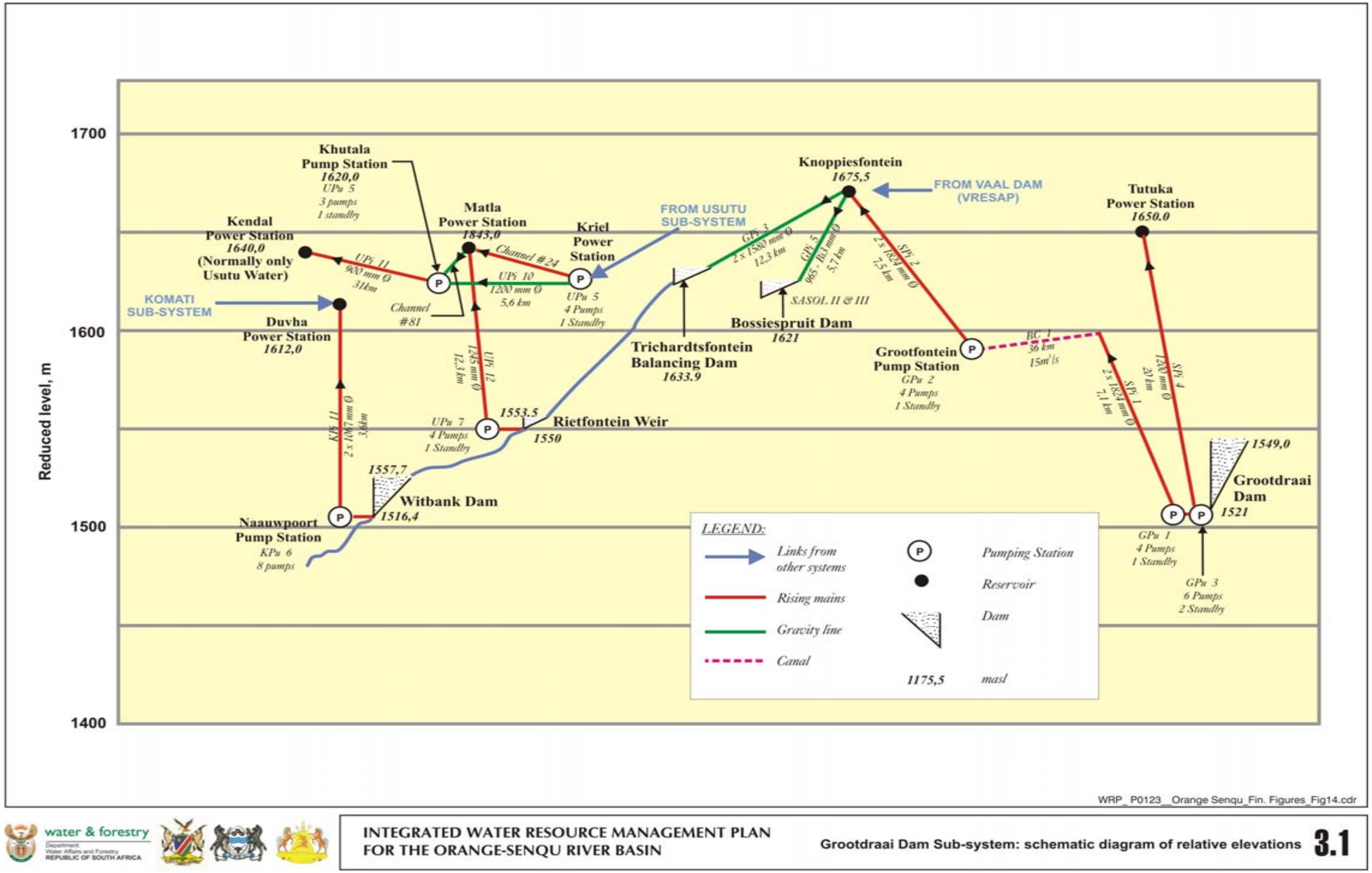

Figure 3-1: Grootdraai Dam Sub-system: schematic diagram of relative elevations

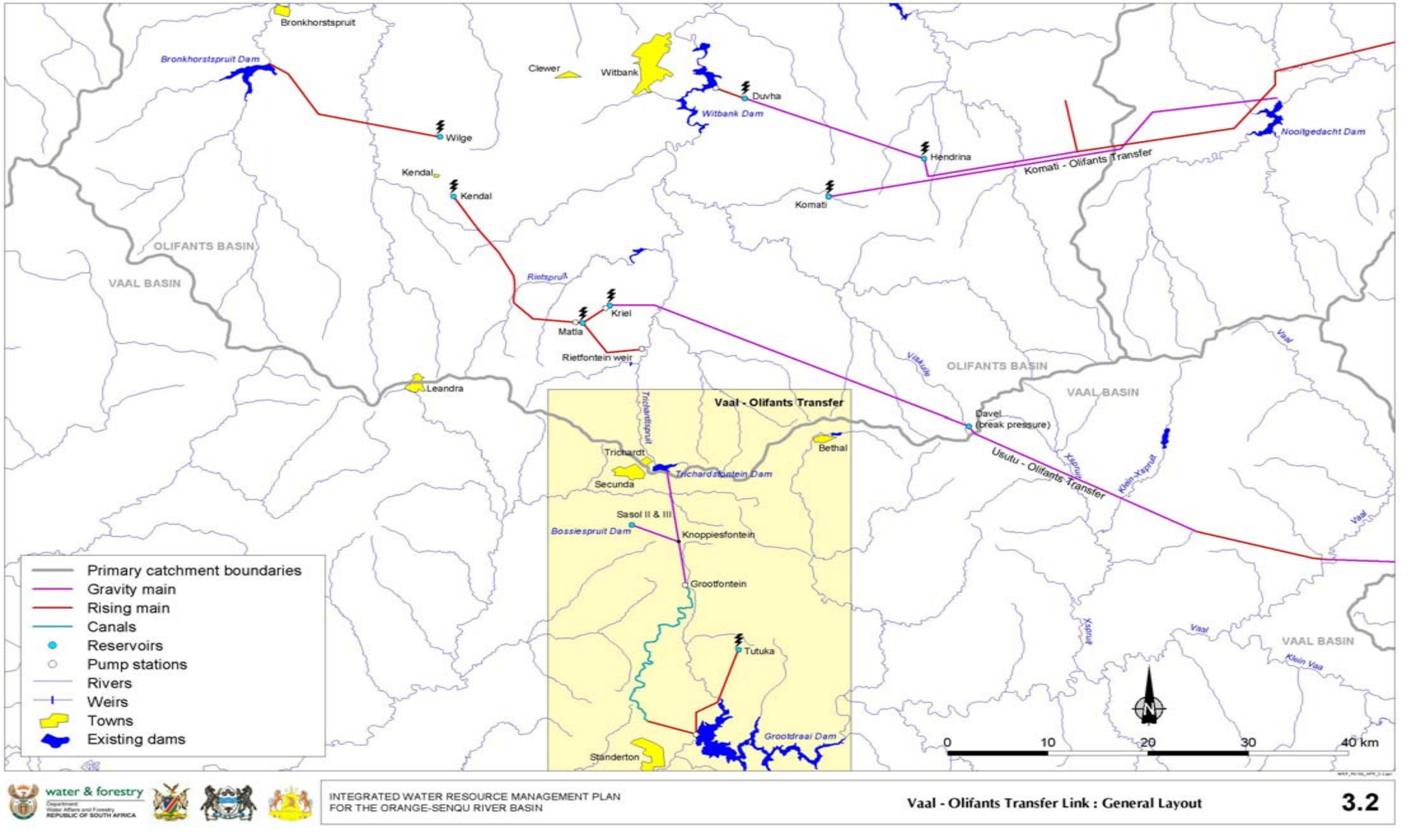

Figure 3-2: Vaal-Olifants Transfer Link: General Layout

c) Vaal Dam Sub-system

Rand Water is the major supplier of water within this sub-system and has two major off-takes from the Vaal River, one at Zuikerbosch and the other at Vereeniging *(*see **Figure 3.3** for the layout of the RWB abstraction system*)*.

The Zuikerbosch water purification works mainly supplies the East Rand and Pretoria, while the Vereeniging works supplies the greater Johannesburg, Vereeniging – Sasol area and the West Rand. Water is abstracted form the Lethabo weir by the intake station to supply Lethabo power station, Vereeniging (where Rand water's off-take is located) and Heilbron. Water is also abstracted directly from Vaal Dam and transferred to the Zuikersbosch abstraction point of Rand Water. The Rand Water scheme is discussed in detail as follows:

Rand Water Supplier

Rand Water, as the major water supplier in the sub-system, has a vast network of pipelines (**Figure 3-4**) used to distribute the water to the various demand centres. Water can be abstracted at the two main abstraction points as indicated below:

- Zuikerbosch pumping station; receiving water from the Vaal River, via a canal from Vaal Dam and from the Lethabo intake station.
- Vereeniging pumping station; receiving water from the Vaal Barrage.

The abstraction point from the Vaal Barrage has however for the last approximately 20years not been used and will need upgrading before it can be utilised again. Water supply from Vereeniging and Suikerbosch pump stations meet at the Daleside Reservoir and continue to Zwartkopjes pumpstation where there are quite a number of pipelines branching off in different directions. Areas supplied along this route include Vereeniging and the Vaal Magisterial District (MD), Meyerton and De Deur, Walkerville and Randvaal MD's. This network is mostly a managed system which is operated in different ways to meet demands which may vary depending on a number of factors. Some reservoirs are not fully utilised, pipelines can be pressurised to supply more water, water can be diverted to meet emergency demands if certain infrastructure is out of commission, etc. There are five major routes used by Rand water as follows:

- Vereeniging pumpstation to Heilbron (pumping main) supplying Vanderbijlpark, Sasolburg and Heilbron areas.

- Vereeniging and Zuikerbosch pumpstations to Zwartkoppies and Zuurbekom pumpstations to Libanon and Blyvooruitzicht reservoirs to Khutsong (gravity main). Included are boreholes at Zuurbekom, which are also managed by Rand Water. Supplying areas of southern Johannesburg, Soweto, the Westonaria and Carletonville MD's and Khutsong.
- Vereeniging and Zuikerbosch pumpstations to Zwartkoppies pumpstation through Pretoria to the Hartebeespoort area and Mamelodi (gravity main). Supplying areas in the Alberton, Germiston, Kyalami and Pretoria MD's, Mamelodi, Atteridgeville, Soshanguve and the Hartebeespoort area.
- Vereeniging and Zuikerbosch pumpstations to Zwartkoppies and Bloemendal pumpstations to Wildebeesfontein (gravity main). Supplying areas in the Alberton, Germiston, Boksburg, Benoni, Brakpan, Springs, Nigel and Heidelberg MD's and to Devon, Leandra and Evander.
- Vereeniging and Zuikerbosch pumpstations to Zwartkoppies to Rustenburg (gravity main) Supplying areas of Greater Johannesburg and the Randfontein, Krugersdorp and Magaliesburg MD's and Rustenburg.

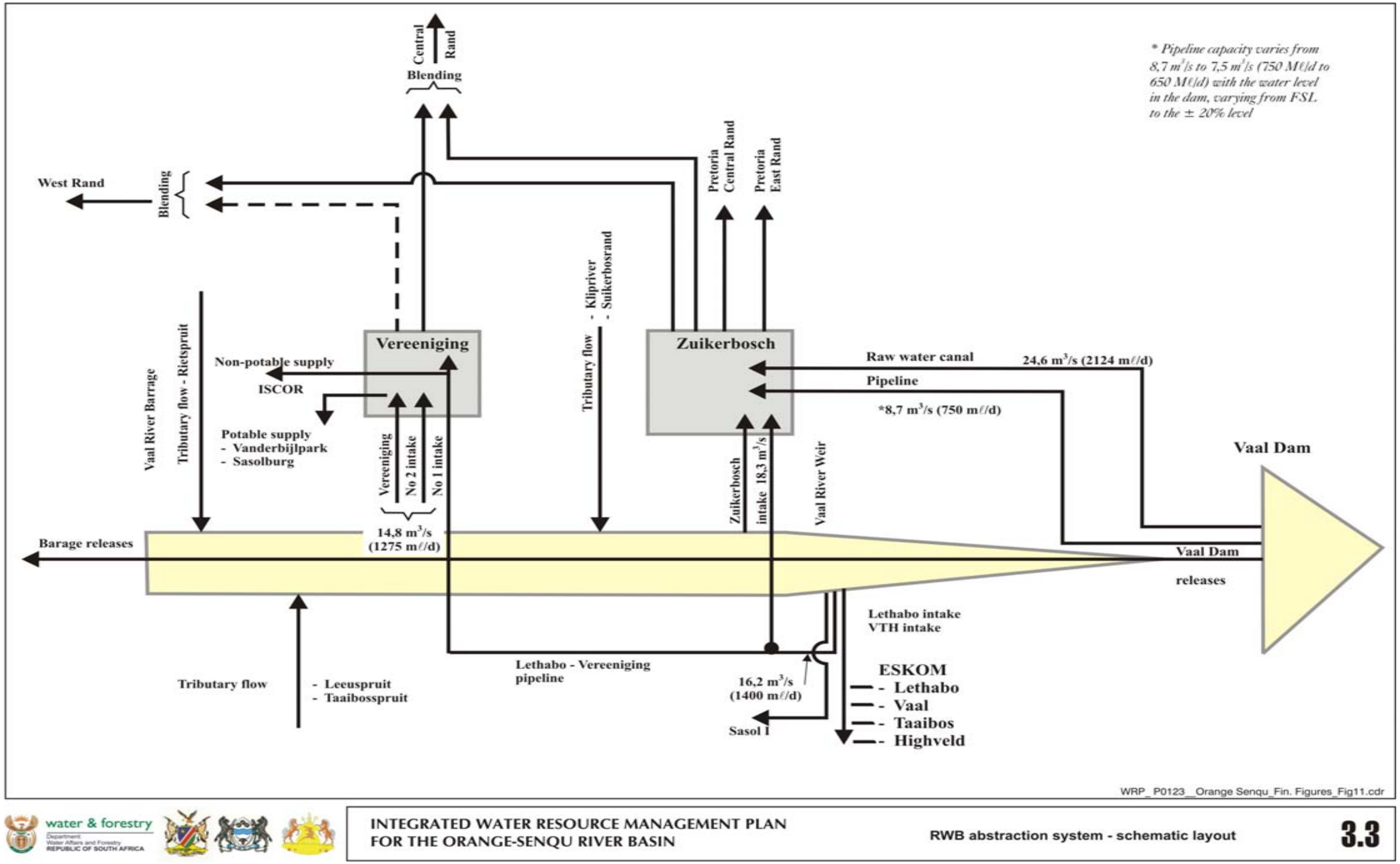

Figure 3-3: RWB abstraction system – schematic layout

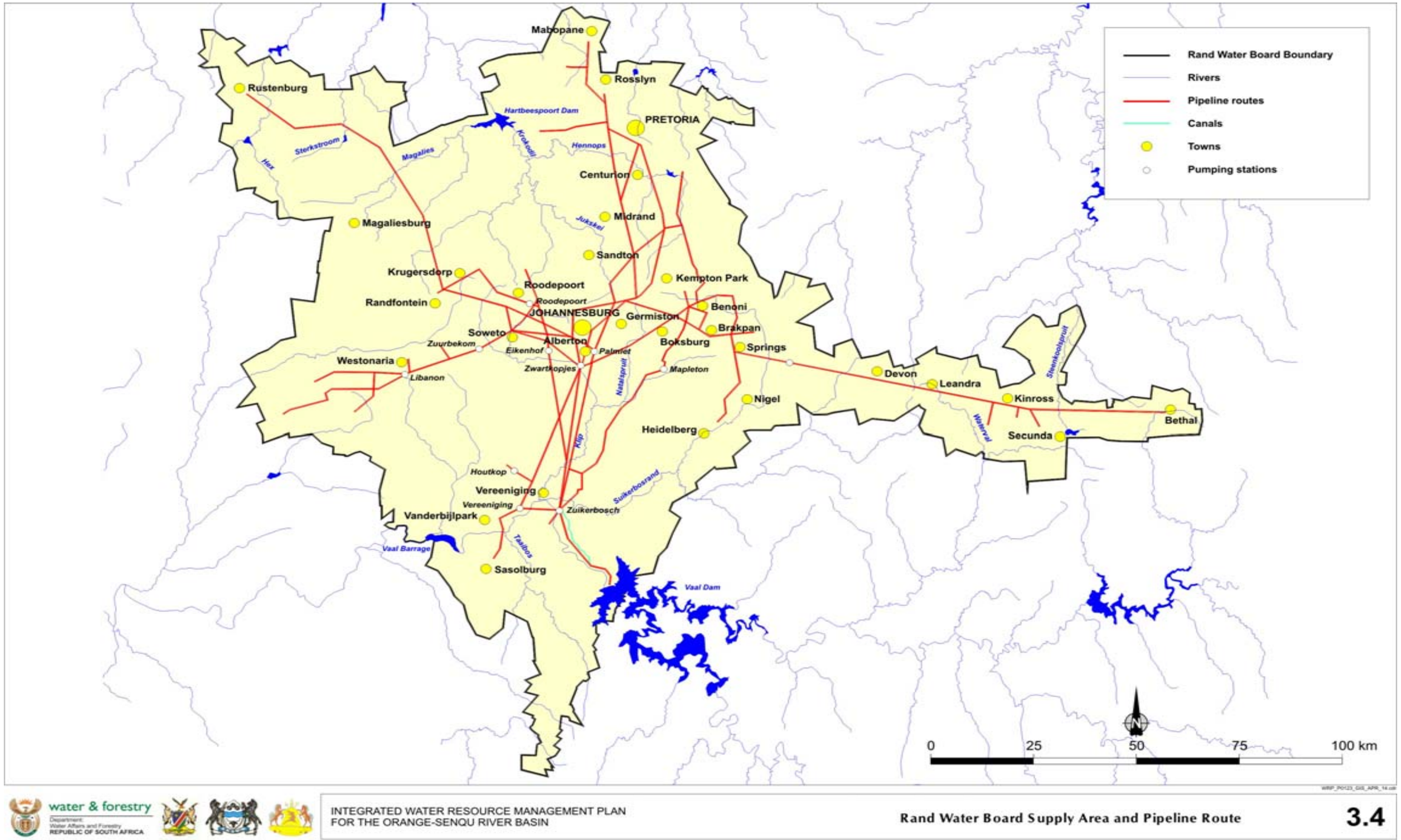

Figure 3-4: Rand Water Board Supply Area and Pipeline Route

d) Thukela-Vaal Transfer Scheme

Also feeding the Vaal Dam via the Wilge River is the Sterkfontein Dam (Drakensberg pump storage scheme). The pump storage scheme consists of the Woodstock Dam, Driel Barrage, Kilburn Dam, Driekloof Dam and a series of pump stations, pipelines, canals, and tunnels. Water is transferred from Driel Barrage in the Upper Tugela Catchment to Driekloof Dam in the Upper Vaal WMA, from where it flows directly into Sterkfontein Dam.

The purpose of this scheme is twofold:

- To transfer water from the Tugela River basin to the Vaal River basin; and
- To generate electricity during periods of peak power demand

Water is pumped from the Driel barrage to the main canal from where it flows to the Jagersrust Forebay. Water is also diverted from the upper reaches of the Tugela River and its tributaries and from the Putterill, Clifford chambers and Khombe weirs via a smaller canal system into the main canal. From Jagersrust, the water is pumped to the Kilburn Dam. During the first phase water was pumped directly via the T'Zamenkomst tunnel and canal to the Sterkfontein Dam, in the second phase the high lift pumps at Jagersrust were removed and replaced by low lift pumps and the water is first pumped into the Kilburn Dam. From Kilburn Dam the water is pumped via the Eskom Pumped Storage Scheme to the Driekloof Dam. The water spills in a weekly cycle into the Sterkfontein Dam, from where it can be released to the Vaal Dam when required. The Driekloof and Kilburn dams act as the head and tail ponds respectively for the Pumped Storage Scheme.

The Woodstock Dam is, however, built only to ensure the water supply to the pumps at the Driel barrage, thus, no water is pumped directly from the Woodstock Dam. The yield from the Spioenkop Dam compensates for water abstracted from the upper reaches of the Tugela River, and the dam stabilises the flow in the lower Tugela River.

The original overall capacity of the transfer system was 11 m^3/s. This capacity has been increased to 20 m^3/s on average, to be able to fill Sterkfontein Dam in a shorter time period. This is, however, not an assured flow. The canal, from Driel to Jagersrust, has a constant section and its design capacity is 20 m^3/s. The capacity of the Mpandweni Siphon is, however, limited to 19 m^3/s. All the super structures for the first section, up to Mpandweni, are positioned for capacity of 19 m^3/s. The layout of the system is shown in **Figure 3-5** and **Figure 3-6** shows the relative elevations and location of the various components of the scheme.

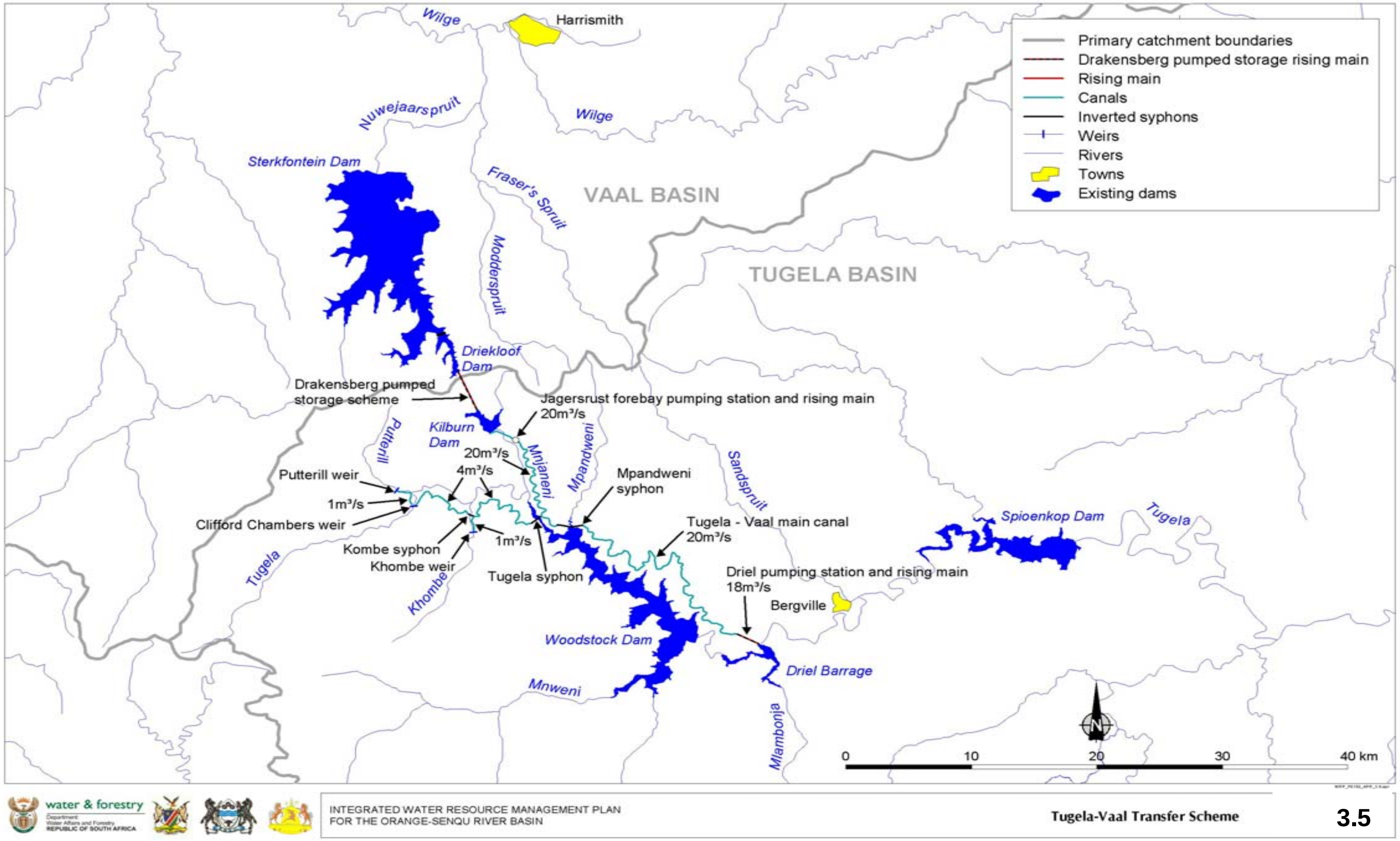

Figure 3-5: Tugela-Vaal Transfer Scheme

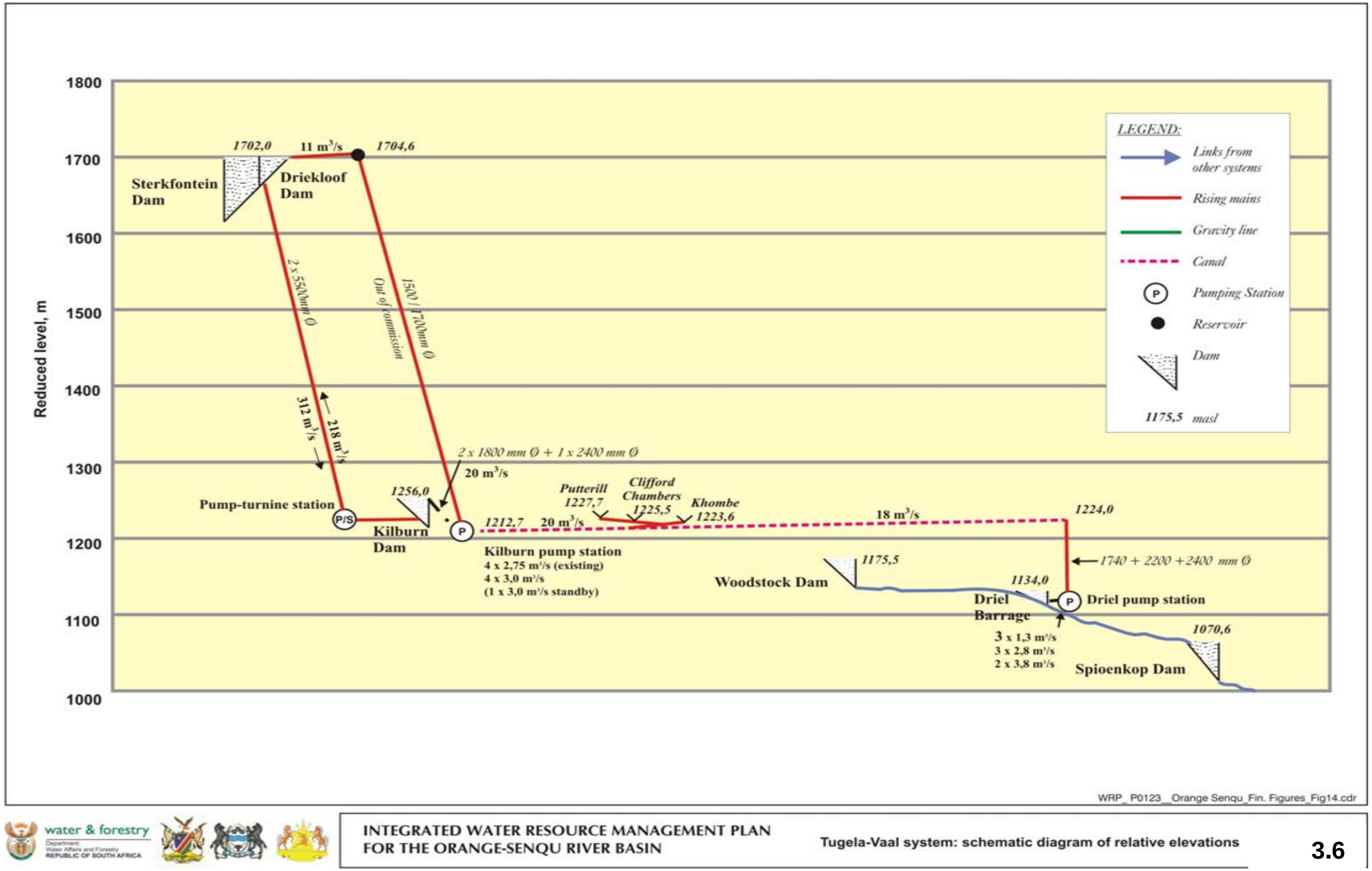

Figure 3-6: Tugela-Vaal system: schematic diagram of relative elevations

e) The Heyshope Scheme

The Heyshope Sub-system is located in the Usutu River Basin and more specifically in the Assegaai River, one of the main tributaries of the Usutu River. The Heyshope System consists of the Heyshope Dam, Geelhoutboom Balancing Dam with pumps and canals system, transferring water from the Heyshope Dam in the Assegaai River to the Upper Vaal WMA, as well as to Morgenstond Dam in the Usutu River Basin. The main purpose of the Heyshope Dam is to support Grootdraai Dam in the Vaal River Basin and also to support the Usutu System in critical periods with transfers to Morgenstond Dam. The water is pumped from Heyshope Dam into the Heyshope Canal, from where it flows into the Geelhoutboom Balancing Dam. From the Geelhoutboom balancing Dam, water is pumped and diverted into Morgenstond Dam via a canal, and also into the Balmoral Canal. From the Balmoral Canal, water is transferred into the upper reaches of the Little Vaal River from where it flows into Grootdraai Dam. Grootdraai Dam is mainly used to supply the Sasol Secunda Complex as well as Eskom power stations in the Upper Olifants Catchment. **Figure 3-7** shows the layout of this sub-system, and **Figure 3-8** gives relative elevations of all the transfer components.

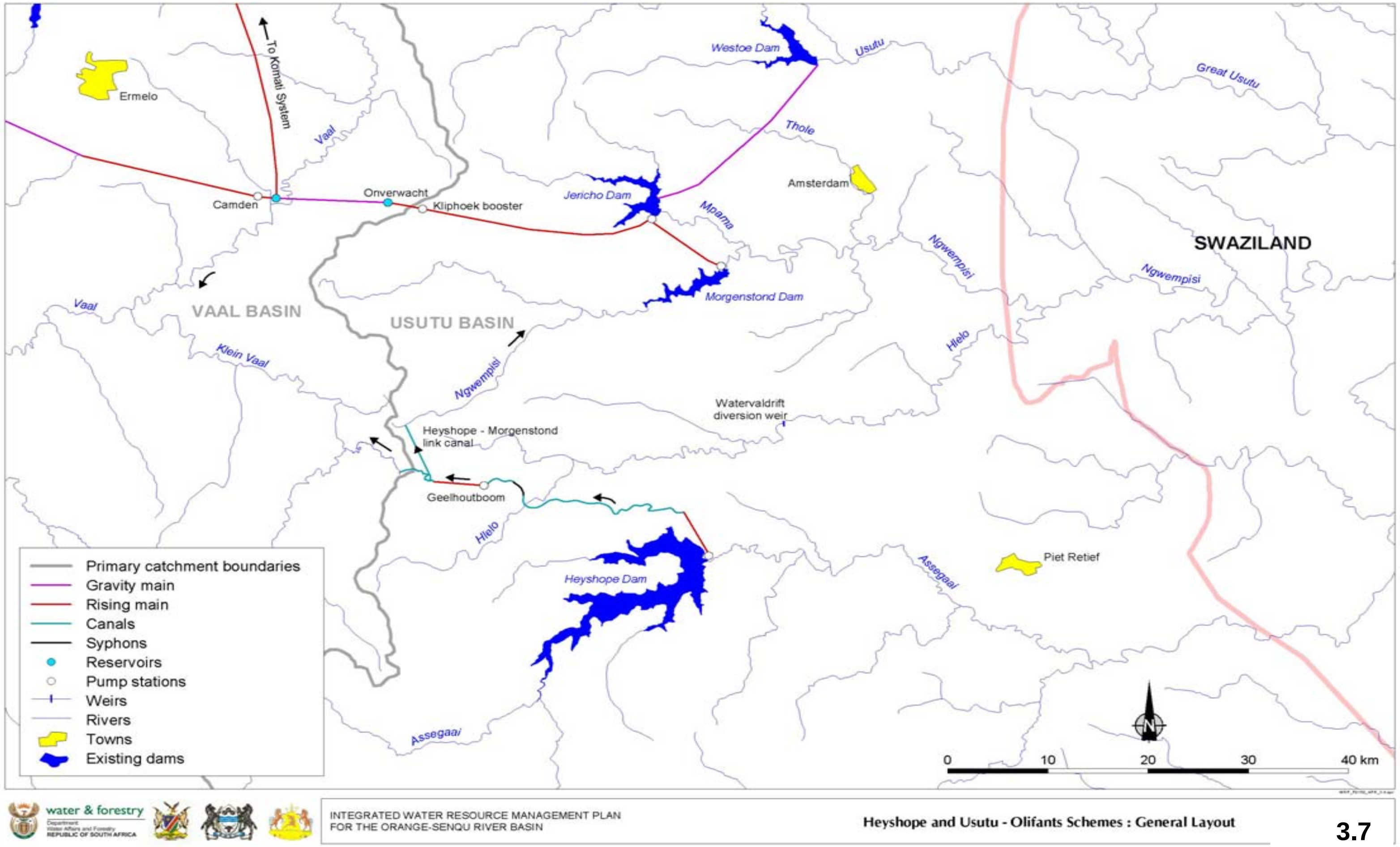

Figure 3-7: Heyshope and Usutu-Olifants Schemes: General Layout

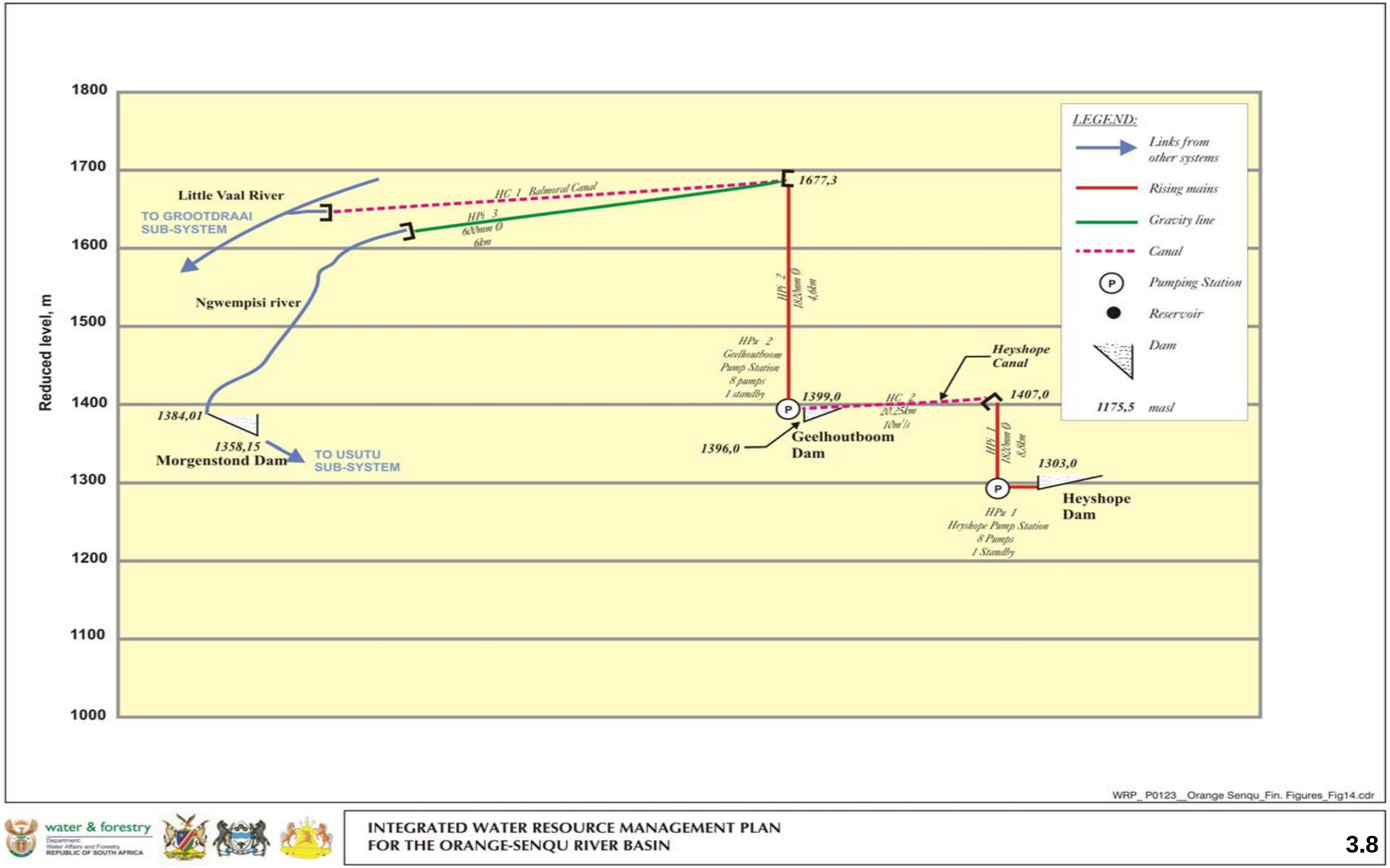

Figure 3-8: Heyshope Sam Sub-system: schematic diagram of relative elevations

f) The Zaaihoek Transfer Scheme

The Zaaihoek Dam Sub-system, also known as the Slang River Government Water Scheme (GWS) or the Buffalo-Vaal Sub-system, supplies water to the Majuba power station, supplement water supply to Volksrust and the Ngagane River GWS, provides compensation water for irrigation, and transfers surplus water to the Vaal River Catchment.

Water for the Ngagane River GWS and for irrigation is released into the Slang River. The water for Majuba, Volksrust and the Vaal River transfer is pumped from Zaaihoek Dam through a rising main to the Uitkyk Reservoir, where there is a provision for diversion to Mahawane Dam to supply Volksrust. From the Uitkyk Reservoir the water flows via a gravity main to Majuba power station. Water that is transferred to the Vaal River is released from this gravity main into the Perdewaterspruit, a tributary of the Schulpspruit, upstream of Amersfoort Dam. The water passes through the Amersfoort Dam before flowing into the Rietspruit River and then into the Vaal River upstream of the Grootdraai Dam. The pump station is designed to deliver 3 m^3/s when water is available to be transferred and 0.34 m^3/s on average (0.44 m^3/s maximum) when water is supplied to Majuba only. The pump station has two separate sets of pumps. One set delivers 3 m^3/s and the other 0.34 m^3/s.

A general layout of the scheme is shown in **Figure 3-9** and **Figure 3-10** shows the relative heights of the system's components.

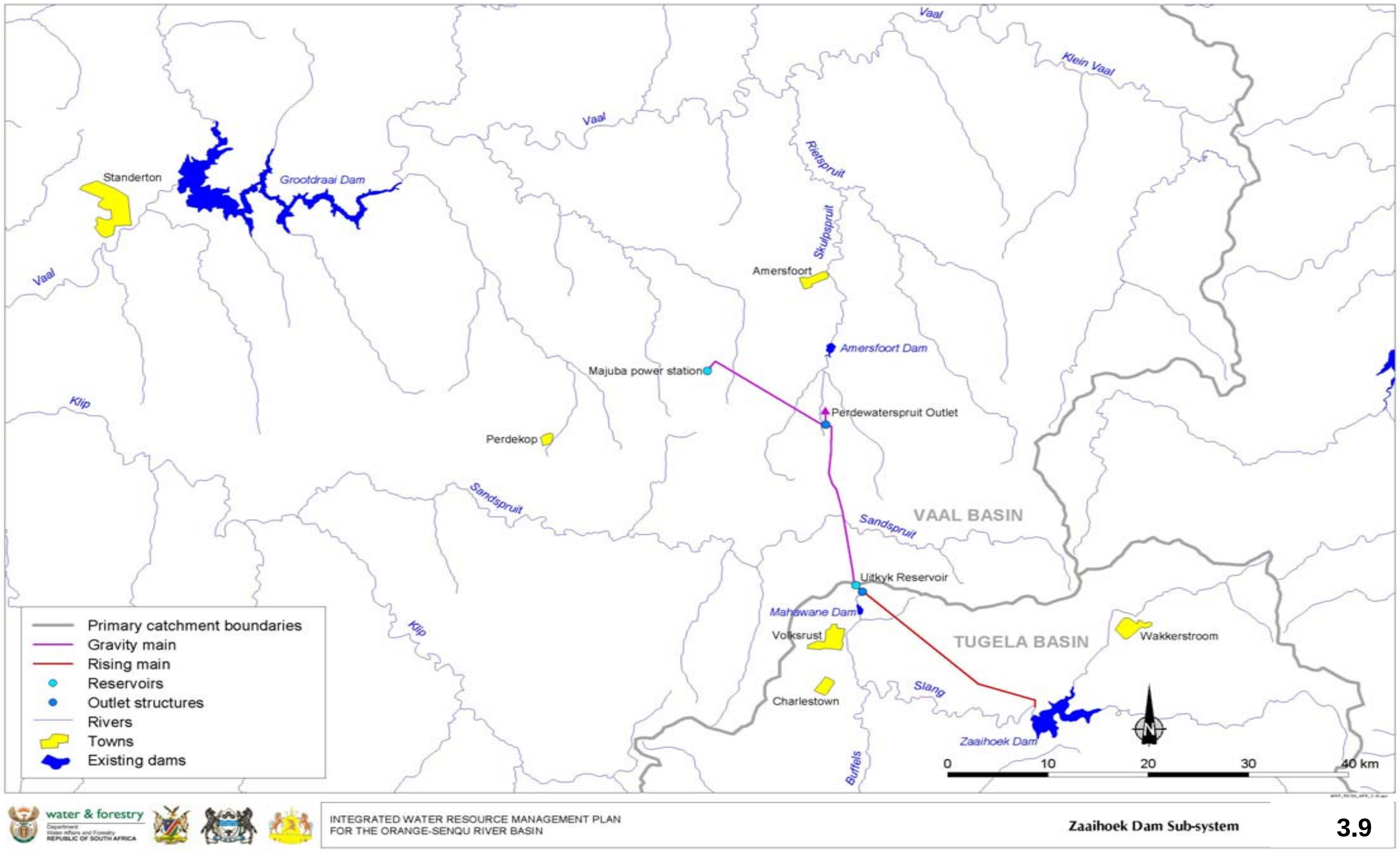

Figure 3-9: Zaaihoek Dam Sub-system

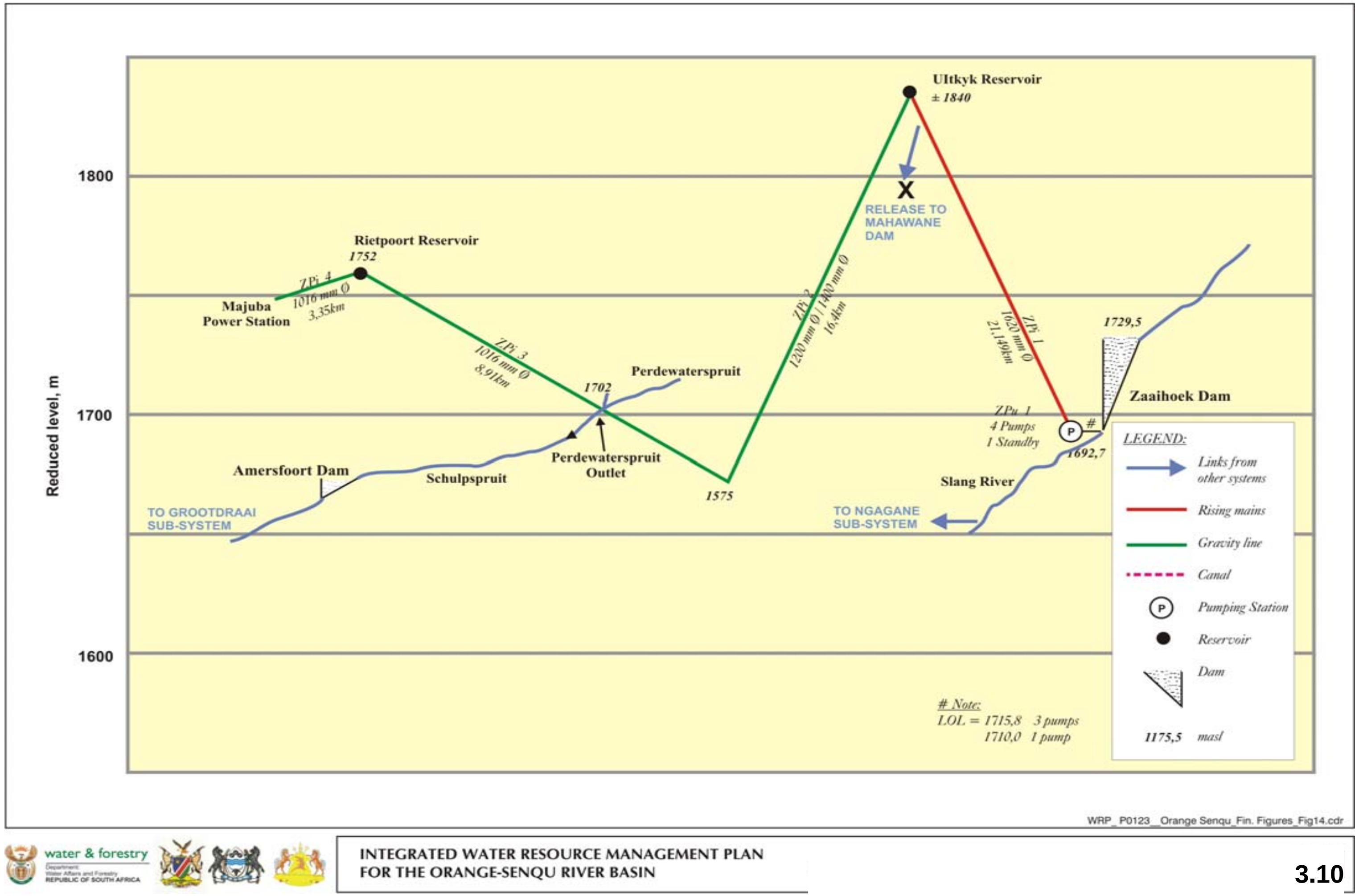

Figure 3-10: Zaaihoek Dam subsystem: schematic diagram of relative elevations

g) Lesotho Highlands Water Project

This scheme is discussed in detail in **Section 3.2.1**.

Small Water Supply Systems not used to support the Main Vaal System

The smaller systems and related dams on the Vaal River Catchment are those that are located on the Vaal River tributaries of which the spills are still captured by the Major Dams on the Vaal River. The smaller systems are however not used to support the Main Vaal System. Base flows from the tributaries into the Vaal River are also reduced due to the impact of the smaller sub-systems in the different sub-catchments. The smaller systems are therefore discussed separately in the sub-sections to follow:

Most of the catchment upstream of Vaal Dam forms part of the Main Vaal System. Only three relatively small dams are found in this area that is not part of the supply to the Main Vaal System. These are Saulspoort Dam in the Ash River, Metsi Matso and Fika Patso Dams in the upper reaches of the Wilge River. Although the transferred water from the LHWP flows into Saulspoort Dam, it is directly released from the dam without storing the water in the dam.

Water Treatment Works

Table 3.2 Shows a list of the treatment works with their capacities, sources of raw water and owners/operators. Most of the treatment works are operated by the municipalities, with a small fraction operated by Rand Water.

Table 3.2: Bulk water supply schemes in the Upper Vaal System

Water Treatment Works				Raw Water Source
Name	Capacity		Owner/Operator	Name
	(Ml/d)	(mcm/A)		
Balfour	Unknown	Unknown	Unknown	Balfour Dam
Bethlehem	D40.0	14.61	Municipality	Saulspoort Dam
Camden Power Station(Mothballed)	Unknown	Unknown	Unknown	Jericho Dam
Camerlia (Frankfort WTW)	Unknown	Unknown	Municipality Frankfort	Wilge River
Deneysville	Unknown	Unknown	Municipality	Vaal Dam
Ermelo	Unknown	Unknown	Unknown	Dams
Eskom Lethabo Power Station	Unknown	Unknown	Unknown	Vaal Barrage

Water Treatment Works				Raw Water Source
Name	Capacity		Owner/Operator	Name
	(Ml/d)	(mcm/A)		
Frankfort	Unknown	Unknown	Municipality	Wilge River
Grootvlei Power Station(monthballed)	Unknown	Unknown	Unknown	Vaal Dam
Harrismith	D10.0	3.65	Harrismith TLC	Sterkfontein Dam Gibson Dam Wilge River
Iscor Klip Works	Unknown	Unknown	Unknown	Vaal Barrage
Iscor Vaal Works	Unknown	Unknown	Unknown	Vaal Barrage
Iscor Vanderbijl Works	Unknown	Unknown	Unknown	Vaal Barrage
Kestell	Unknown	Unknown	Sedibend Water	Boreholes
Majuba Power station	Unknown	Unknown	Unknown	Zaaihoek Dam
Memel	Unknown	Unknown	Municipality	Boreholes
Parys	D12.5	4.56	Municipality	Vaal River
Potchefstroom	Unknown	Unknown	Municipality	Mooi River
Sasolburg	Unknown	Unknown	Rand Water	Vaal Dam
Reitz	Unknown	Unknown	Municipality	Geluk Dam De Mollen Reward Dam Gryp Dam
Sasol I	Unknown	Unknown	Unknown	Vaal Barrage
Sasol II and III	Unknown	Unknown	Unknown	Grootdraai Dam
Standerton	Unknown	Unknown	Unknown	Vaal river
Tutuka Power Station	Unknown	Unknown	Unknown	Grootdraai Dam
Tweeling	D0.96	0.35	Municipality	Unknown
Tubemakers, Stuart and Lloyd	Unknown	Unknown	Unknown	Vaal Barrage
Villiers	D3.5	1.28	Municipality	Vaal River
Vrede	Unknown	Unknown	Municipality	Vrede Dam New Dam on the Spruitsonderdrf
Warden	D2.59	0.95	Municipality	Warden

Notes: D - denotes design, Unknown – This means the data was not available in the existing reports used to obtain information. Where source of water is unknown, the source is generally local rivers.

3.1.2 Middle Vaal Sub-system

The Vaal River Basin downstream of the Vaal Barrage, down to and including the Bloemhof Dam constitutes the Middle Vaal sub-system. The following major tributaries drain into this section of the Vaal River and into the Bloemhof Dam: the Mooi River, Renoster River, Vals River, Sand River, Vet River and the Schoonspruit.

The major dams in this sub-catchment are the Bloemhof Dam, Erfenis Dam, Allemanskraal Dam, Koppies Dam, Serfontein Dam, Rietspruit Dam, Elandskuil Dam, Johan Neser Dam, Klerkskraal Dam, Boskop Dam and Klipdrift Dam. The dams in the Middle Vaal Sub-system are mainly used for irrigation water supply, although some urban/industrial and mining demands are also supplied from these dams. The dams on the tributaries are operated independently from the Vaal River, and only the spillage from the dams, are captured in Bloemhof Dam.

Dams

Table 3.3 lists the main dams in the Middle Vaal with their capacities.

Table 3.3: List of Main dams in the Middel Vaal System

Name	Gross Storage (mcm)	Live Storage Capacity (mcm)	Dead Storage (mcm)
Erfenis	212.20	207.49	4.71
Allemanskraal	179.31	174,2	5.11
Koppies	42.31	41.81	0.50
Klipdrift	13.576	13.576	0
Boskop	21.256	21.018	0.238
Klerkskraal	8.023	7.933	0.09
Lakeside	2.027	2.027	0
Rietspruit	7.28	7.28	0
Johan Neser	5.67	5.67	0
Bloemhof	1241.29	1 239.46	1.83

Major Water Schemes forming part of the Main Vaal System

Two organisations, namely: Midvaal Water Company and Sedibeng Water, abstracts water from the Vaal River within the Middel Vaal Sub-system.

a) Midvaal Water Company

The MidVaal Water Company has a large abstraction point from the Vaal River, in the Klerksdorp – Orkney area. The MidVaal Water Company purifies water from the Vaal River to supply three TLC's; Klerksdorp, Stilfontein and Orkney, and three Gold Mines; Vaal Reefs, Hartbeesfontein and Buffelsfontein. Water is abstracted from the Vaal River through a pump station and diverted into two pipelines, one to the Vaal Reefs general mining, and the other to Klerksdorp, Stilfontein, Orkney, and Hartbeesfontein and Buffelsfontein gold mines.

b) Sedibeng Water

Sedibeng Water has a major abstraction point from the Vaal River at Balkfontein, upstream of Bloemhof Dam. Water from this abstraction point is purified at the Balkfontein Water Purification Works and distributed from there. Sedibeng Water also abstracts water from Allemanskraal Dam via a canal system in the vicinity of Virginia.

c) Bloemhof sub-system

The Bloemhof Dam is the main storage reservoir for the Vaalharts irrigation scheme, irrigators along the Vaal River to Douglas, the Vaal-Gamagara transfer scheme and for Kimberly.

Smaller Water Supply Systems not used to support the Main Vaal System

a) Sand-Vet Scheme

This scheme consists of the Erfenis Dam, Allemanskraal Dam and a series of pipelines, canals and pump stations. Water is released from the Erfenis and the Allemanskraal dams into canals to supply the Sand/Vet GWS down stream (See Figures A-7 & A-8 in Appendix A). The Sand-Vet Irrigation Scheme includes both the Erfenis Irrigation Scheme and the Allemanskraal Irrigation Scheme. These schemes are currently supplied with water from the Erfenis Dam and Allemanskraal Dam, respectively. Erfenis Dam supplies water for the irrigation of 5 489 ha; and any excess water at the canal tail end flows into the Vet River. Downstream of the confluence of the Sand and the Vet River, there is another 1 297 ha of irrigation which is mainly supplied directly from the Vet River. For the Allemanskraal Scheme, water is diverted from Allemanskraal Dam into the main canal. This canal then splits into two separate canals downstream of the dam supplying water for irrigation on the left and the right banks of the Sand River. Any excess water at the tail ends of these canals flows back to the Sand River.

Sedibeng Water abstracts water from Allemanskraal Dam to supply part of the Virginia requirement via pipeline. Virginia also receives water from the Vaal River through the Sedibeng abstraction at Balkfontein. Water from the Allemanskraal Dam is purified at the Virginia Water Purification Works. Water is also transferred to Brandfort TLC in the Upper Orange WMA (Modder River Catchment) by a gravity pipeline which leads to a storage reservoir in Bradford where this water is purified and supplied to the users.

b) Vals River System

This system consists of the Serfontein Dam which is almost completely silted-up. Water is released directly into the Vals River from the dam and is abstracted and pumped into the Kroonstad Municipality dam called the Bloemhoek Dam for urban supply to Kroonstad. Further downstream water is also abstracted by the Vals River Irrigation Scheme.

c) Koppies River System

This system consists of the Koppies Dam from where water is released into the river and into a canal distribution system. Koppies Town abstracts its water from the river downstream of the Koppies Dam, and further downstream water is abstracted from both the canal system and the river for the Weltevrede IB and Koppies River GWS. Water is also abstracted from the river to supply Viljoenskroon with potable water, and the excess water flows into the Vaal River. Voorpoed mine is in the process of purchasing irrigation water rights to meet the requirements of the mine, and this water will be release from Koppies Dam into the river for their abstraction purposes.

Schoonspruit River System

d) Schoonspruit Catchment sub-systems

The Schoonspruit and Klerksdorp irrigation schemes are both located in this sub-catchment and are operated as two stand alone schemes. The schemes utilizes the Schoonspruit Eye, Kalk Dam, Elandskuil Dam, Rietspruit Dam and the Johan Neser Dam as their sources of water. Approximately fifty percent of the water generated in the Schoonspruit Catchment is coming from the Schoonspruit Eye, which is fed from dolomitic compartments. Elandskuil Dam is used as a balancing dam as it has almost no contribution from rainfall runoff.

The **Schoonspruit Irrigation Scheme** is located close to Ventersdorp and receives its water from the Schoonspruit Eye, Elandskuil Dam and Rietspruit Dam (See **Figure A-9** in **Appendix A**). A weir has been built to divert the Eye's water into a canal on the Right Bank of the Schoonspruit. The scheme is operated so as to divert the maximum capacity into this canal (i.e. 3039m^3/h), which conveys the water to the Ventersdorp Municipality off-take as well as to irrigation located further downstream along the canal system. Further, along the Schoonspruit at Kalk Dam the Municipality of Ventersdorp also abstracts water for agricultural use in the town.

The canal crosses the Schoonspruit just downstream of the Kalk Dam where there is a structure that can reject excess water from the canal into the Schoonspruit as well as allowing water to flow underneath the Schoonspruit by means of a siphon (pipes) into a canal on the left bank of the Schoonspruit. This canal supplies irrigation water down to the Rietspruit Dam (506.7 ha scheduling) as well as supplying water by means of the Elandskuil pipeline to the Elandskuil Dam and canal on the Right Bank of the Schoonspruit. Water from the Rietspruit Dam and Elandskuil Dam is used for the irrigation of 1 279.6ha and 647.6ha respectively.

It seems that the canals are flowing full for most of the time, depending on the flow from the Schoonspruit Eye and the water available in the Rietspruit Dam. The outflow from the canal tail-ends simply flows back into Schoonspruit and is captured in the Johan Neser Dam located further downstream.

The Klerksdorp irrigation scheme was developed around the Johan Neser Dam, which was built in 1914. The major purpose of the dam is to provide water for the irrigation. With time, the water availability has reduced, mainly as a result of upstream developments and increasing groundwater abstractions, utilizing water from the dolomite aquifers feeding the Schoonspruit Eye. The dam is operated by the Klerksdorp Irrigation Board and currently the average area irrigated is much smaller than the scheduled area. The only time the irrigation is not curtailed, is when the Johan Neser Dam is spilling. Some irrigators abstract water directly from the dam basin and directly from the river just upstream of the dam (See **Figure A-10** in **Appendix A**). Water is also supplied to irrigators via a canal system, a pipeline and by means of releases directly into the river downstream of the dam.

e) Mooi River Catchment Sub-systems

There are two sub-systems located in this sub-catchment, the Mooi River Government Water Scheme, and the Klipdrift irrigation scheme located on a tributary of the Mooi River.

The Mooi River Government Water Scheme consists of four major sources of water, namely: Klerkskraal Dam, Boskop Dam, Lakeside Dam, and the Gerhard Minnebron Eye. These components are linked by means of concrete lined canals, referred to as the main canals (See **Figure A-6** in **Appendix A**).

The Klerkskraal Dam is located on the Mooi River, on the northern boundary of the scheme and supplies the irrigation fields via the left and right bank canals of the Mooi River. The left canal discharges back into the Mooi River, about 9 km upstream of the Boskop Dam and the right canal supplies water to numerous irrigation fields and at the end discharges into the Mooi River, just a few hundred metres upstream of the Boskop Dam. Klerskraal Dam is also used to support Boskop Dam when required. The releases for this support are mainly done through the canals and not by releases directly into the river. This is done to minimise conveyance losses.

The Gerhard Minnebron Eye lies on the left bank of the Mooi River, between the Klerkskraal and Boskop dams. This important source is linked to the scheme by the Gerhard Minnebron canal, which ends about 3 km downstream of Boskop Dam, discharging into the Boskop Dam left canal.

The Klipdrift Irrigation Scheme is in the Mooi River Catchment and is supplied with water from the Klipdrift Dam located in the Loopspruit River, a tributary of the Mooi River (See **Figure A-6** in **Appendix A**).

Water Treatment Works

Table 3.4 shows a list of Water Treatment Works with their capacities and owners/operators. Most of them are operated by the municipalities, with a small fraction operated by Rand Water, Sedibeng and the MidVaal WC.

Table 3.4: List of Water Treatment Works in the Middle Vaal System

Water Treatment Works				Raw Water Source
Name	Capacity		Owner/ Operator	Name
	(Ml/d)	(mcm/a)		
Arlington	D0.29	0.11	Municipality	Dam & Boreholes
Bultfontein	Unknown	Unknown	Municipality	Luipaardvlei Dam & boreholes
Edenville	Unknown	Unknown	Municipality	Boreholes
Excelsior	D1.0	0.37	Municipality	Gryp Dam Boreholes
Heilbron	D2.0	0.73	Rand Water	Lang Dam
Hoopstad	D4.25	1.55	Municipality	Vet River
Klerksdorp	Unknown	Unknown	MidVaal WC	Vaal River
Koppies	D2.8	1.02	Municipality	Koppies Dam
Kroonstad	D60.0	21.92	Municipality	Vals River Dams
Lindley	D3.0	1.1	Municipality	Piekniekdraai Dam Vals River
Leeudoringstad	Unknown	Unknown	MidVaal WC	Boreholes
Marquard	D168.0	61.36	Municipality	Marquard Dam Laaispruit Dam
Petrus Steyn	D1.0	0.37	Municipality	Middelpunt Dam Boreholes
Orkney	Unknown	Unknown	MidVaal WC	Vaal River
Snekal	D9.0	3.3	Municipality	Cyferfontein Dam De Put Dam
Steynsrus	D3.0	1.1	Municipality	Steynrus Dam Catch Dam Boreholes
Stilfontein	Unknown	Unknown	MidVaal WC	Vaal River
Theunissen	D8.88	3.24	Municipality	Erfenis Dam
Verkeerdevlei	D0.6	0.22	Municipality	Unknown
Vijoenskroon	D5.0	1.83	Municipality	Rhenoster River
Virginia	Unknown	Unknown	Municipality	Allemanskraal Dam
Vredefort	D2.4	0.88	Municipality	Unknown
Welkom	Unknown	Unknown	Sedibeng Water	Vaal River
Wesselsbron	D3.4	1.24	Sedibeng Water	Unknown
Winburg	D2.46	0.9	Municipality	Rietfontein Dam Wolwas Dam 1&2 Laaispruit

Water Treatment Works				Raw Water Source
Name	Capacity		Owner/ Operator	Name
	(Ml/d)	(mcm/a)		
Wolmaranstad	Unknown	Unknown	Sedibeng Water	Makwassiespruit Boreholes

Notes: D denotes design, Unknown – Indicate that the information was not available from existing reports used to obtain data, Where source of water is unknown, the source is generally local rivers.

3.1.3 Lower Vaal Sub-System

This region comprises the Vaal River Catchment downstream of the Bloemhof Dam down to the confluence of the Vaal River with the Orange River. The major tributary draining into the Vaal River in this region is the Harts River. Although the Riet-Modder Catchment forms part of the Vaal River Basin, it is included as part of the Upper Orange sub-system, mainly due to the fact that there are several transfers from the Orange to support water requirements in the Riet-Modder Catchment. The only connection between the Vaal and Riet-Modder rivers is the spills from the Riet-Modder Catchment into the Vaal River just upstream of Douglas Weir.

The major dams in this sub-catchment are Wentzel Dam, Taung Dam and Spitskop Dam, all located on the Harts River, with Vaalharts Weir on the Vaal River.

Kimberly Municipality and the Vaal-Gamagara Government Regional Water Supply Schemes as well as small towns abstract water for urban/industrial use from the Vaal River. The larger water related schemes which are in place are linked to either irrigation or abstractions from the Vaal River, which is the only abundant source of water within the sub-system. By far, the most significant of these schemes is the transfer of water from the Vaal River to the Vaalharts Irrigation Scheme. Smaller schemes transfer water from the Vaal River to the towns and mines in the arid north-west area and to Kimberley.

Dams

Table 3.5 lists the main dams and weirs in the Lower Vaal with their capacities.

Table 3.5: Main dams and weirs in the Lower Vaal System

Name	Gross Storage (mcm)	Live Storage Capacity (mcm)	Dead Storage (mcm)
Douglas	17.66	16.104	1.56
Vaalharts	48.66	48.66	0
Spitskop	57.89	57.83	0.06
Taung	65.99	65.99	0
Wentzel	6.58	6.58	0

Water Schemes forming part of the Main Vaal System

a) Riverton-Kimberley Scheme

Water is abstracted from the Vaal River at Riverton and purified at the Riverton water treatment plant before being pumped to Kimberley. The rising main consists of, initially, one 900mm diameter pipeline in parallel with a 600mm pipeline. This increases to two 600mm diameter and a single 965mm pipes along the route. The total static head of this rising main is 168m with a maximum capacity of 0.46 m^3/s.

b) Vaal-Gamagara Government Water Schemes

The Vaal-Gamagara Regional Water Supply Scheme was initiated in 1964 to supply water mainly to the mines in the Gamagara Valley in the vicinity of Postmasburg and further north of this town. An abstraction works and low-lift pumping station are located on the Vaal River near Delportshoop, just below the confluence with the Harts River, from where water is pumped to the water purification works situated next to the Vaal River. Purified water is then pumped through a 99km long double rising main to reservoirs on the watershed of the Vaal River Catchment near Clifton. Intermediate pumping stations are situated at Kneukel and Trewil. The pipeline diameters vary from 700mm to 200mm. From the reservoirs at Clifton, water is gravity fed over a distance of 182 km along the route via Postmasburg – Sishen - Hotazel - Black Rock. Branch pipelines of 24 and 5 km long to supply water to the town of Olifantshoek and a reservoir at Beesthoek respectively. The design capacity of the scheme is 36.37 Ml/day with allowance being made to increase this capacity with the addition of booster pumps and reservoirs.

c) Vaalharts Scheme

The most significant water supply scheme in the Lower Vaal is the Vaalharts Irrigation Scheme, the largest irrigation scheme in South Africa. Water is released from Bloemhof Dam to the Vaalharts Weir, situated on the Vaal River between Christiana and Warrenton, from where it is diverted into a canal (See **Figure A-11** in **Appendix A**). The incremental yield of Bloemhof Dam is less than the water requirements of the Vaalharts Scheme and other irrigators along the Lower Vaal. In times of shortages, Bloemhof Dam is therefore supplemented by releases from Vaal Dam. The Vaalharts Scheme therefore forms part of the greater Vaal System. The Vaalharts canal system consists of a main canal of length 18,9km and capacity 48 m^3/s. This follows the right bank of the Vaal River for about 13km before splitting, the main section heading northward through a low saddle into the Harts River Catchment. The smaller branch which continues along the bank of the Vaal is called the Klipdam-Barkley Canal. The main canal splits again into the West Canal (length 20.9km, initial capacity 6.0m^3/s), and the North Canal (length 60,4km, initial capacity 38.8 m^3/s). The North and West canals have numerous takeoffs into secondary canals system with a total length of 183km. This secondary system splits further into a tertiary system, which has a total length of 544km and conveys water up to the boundary of each farm. All these canals are concrete lined. The scheme also has an extensive drainage system to deal with return flows and storm water. Naledi and Greater Taung Municipalities source their water from the Vaalharts scheme, and water is purified at Pudimoe treatment works. Pokwane Municipality also obtain water directly from the Vaalharts canals to supply Jan Kempdorp, Hartswater, and Pampierstad, with water purified at the Jan Kempdorp, Hartswater and Pampierstad treatment works.

Smaller Water Supply Systems not used to support the Main Vaal System

a) Wentzel Dam sub-system

Wentzel Dam is the most upstream dam on the Harts River and relies totally on the natural flow from the Harts. The only existing abstraction from the dam is the Schweizer Reneke town demand, reaching 1.02 million m^3/a at 2006 development level. The dam was originally constructed to supply water to the Schweizer Reneke town and limited areas of scheduled irrigated land. The irrigation allocation has however been taken over by Schweizer Reneke town and hence no irrigation is supplied from the dam.

b) Taung Dam sub-system

Taung Dam is located downstream of Wentzel Dam not far upstream of the town of Taung. The Taung dam was built in the Harts River in 1993 to augment irrigation supplies to the Taung irrigation area and possibly support new irrigation areas in the Pudimoe area. Currently the dam is not utilised at all. The DWAF has however initiated a study to investigate and recommend the best supply options to utilize Taung Dam water.

c) Spitskop Dam sub-system

Spitskop dam was constructed in 1975 in order to supply irrigators along the lower Harts upstream of the Vaal confluence. The dam was reconstructed in 1989 due to damage incurred by floods in 1988. The dam is positioned downstream of the Vaalharts Irrigation Scheme and therefore substantial volumes of return flows seep into the dam. The dam is currently only utilised to supply irrigation along the Harts River downstream of the dam. Due to the large volumes of return flows from the Vaalharts Scheme, the dam is currently under utilised, and water is supplied to the downstream irrigators as required, but within their allocated quotal of 7700 m^3/ha/a. The total area under irrigation from Spitskop Dam is 1,663.1 ha with a total allocation of 12.81 million m^3/a.

The Historic Firm Yield (HFY) has been calculated as 34.81 million m^3/a based on current conditions, but the river losses associated with releases from the dam to irrigators downstream are high. When the return flows from the Vaalharts Sheme is reduced due to improved irrigation and water conservation and demand management practices, the yield from Spitskop Dam can drop significantly. Taking these losses and possible reduction in return flows into account, it is quite possible that no surplus yield will be available from Spitskop Dam.

3.2 Larger Orange-Senqu River System RSA & Lesotho (Infrastructure)

The Orange River is the largest river in South Africa and flows from the Lesotho Highlands in the east where it is known as the Senqu River, to the Atlantic Ocean at Alexander Bay in the west. The Caledon River, forming the north western boundary of Lesotho with the RSA, is a major tributary of the Orange River. Apart from the Vaal River and the Caledon River, other major tributaries draining into the Orange River are the Kraai River (draining from the North Eastern Cape), the Ongers and Sak rivers (draining from the northern Karoo), the Kuruman and Molopo rivers (draining from the dry Northern Cape as well as the southern parts of Botswana) and the Fish River (draining the southern parts of Namibia). In Lesotho the Orange River is known as the Senqu River and the Caledon River as the Mohokare River.

The following sub-sections give details of the infrastructure in the Senqu catchment (Lesotho Highlands), Upper Orange sub-system and the Lower Orange sub-system.

3.2.1 Lesotho Highlands (Senqu River)

Dams

Table 3.6 lists the main dams in the Lesotho Highlands Scheme with their capacities.

Table 3.6: Main dams in Lesotho Highlands water project

Name	Gross Storage (mcm)	Live Storage Capacity (mcm)	Dead Storage (mcm)
Katse	1950	1518.6	431.4
Mohale	946.9	857.1	89.8

Major Water Schemes

a) Lesotho Highlands Water Project

The Lesotho Highlands Scheme which started operating in 1998 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 (See **Figure 3-11**).

The Lesotho Highlands sub-system includes part of the catchment of the Senqu River within the borders of Lesotho. The main tributaries of the Senqu River are the Malibamatsu, Tsoelike and Senqunyane rivers. The Lesotho Highlands Water Project was initiated to transfer water from within Lesotho to South Africa. The initial planning included a series of dams, tunnels and pump stations to be constructed in different phases.

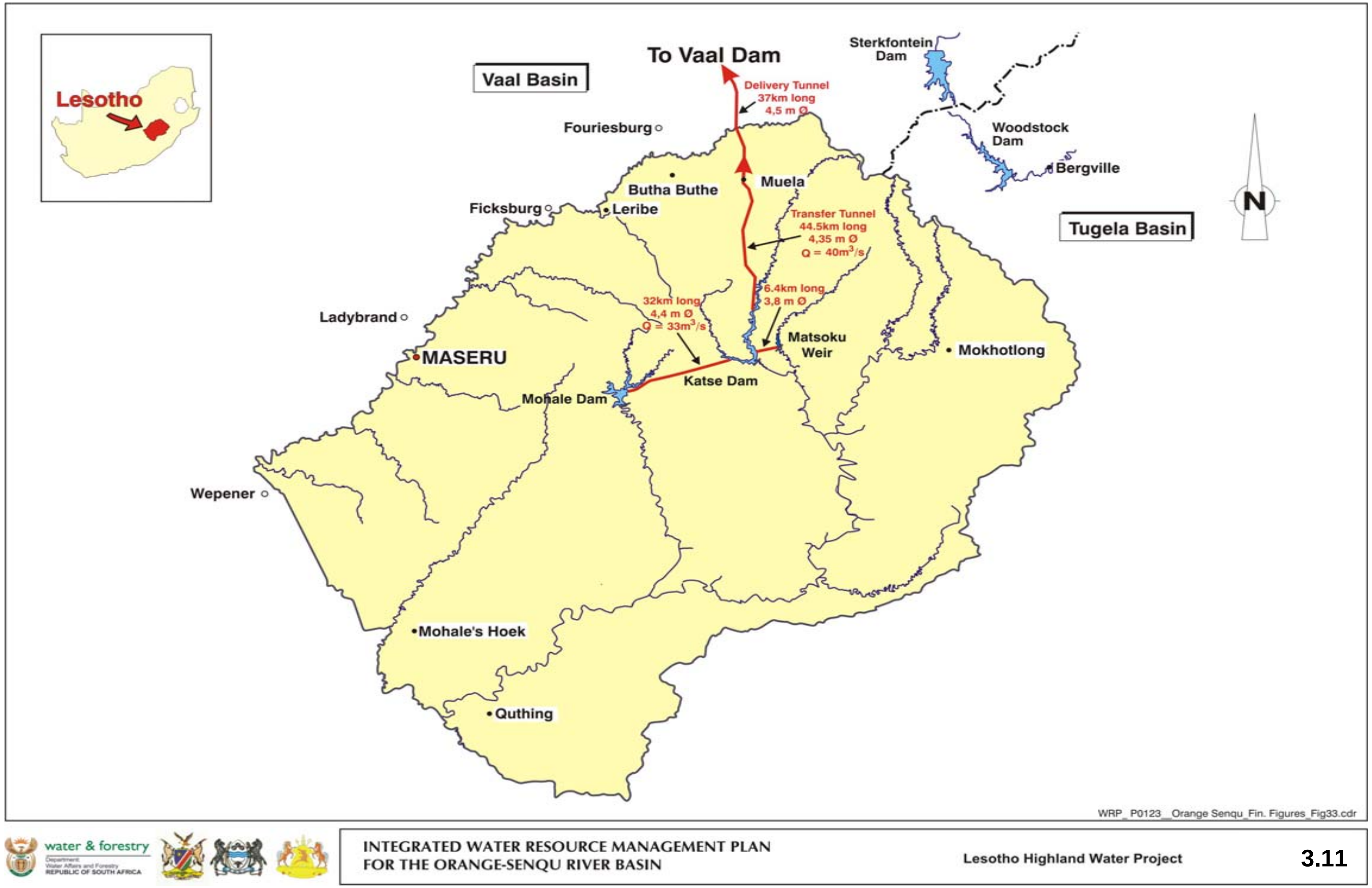

Figure 3-11: Lesotho Highland Water Project

Currently only Phase 1 was completed. Recent studies however indicated that there is not sufficient water to develop all the phases. The possibility of a second phase is currently being investigated, which will most probably be the last phase of the Lesotho Highlands Project.

Phase 1 consists of Katse Dam on the Senqu River, Mohale Dam on the Senqunyane River and Matsoku diversion weir on the Matsoku River. Approximately 80 km of tunnels link Katse Dam to the Upper Vaal WMA, delivering water into the Axle River a tributary of the Liebenbergvlei River, which in turn flows into the Vaal River. The tunnel from Katse to the Axle River, has an internal diameter of 4.35 m, and is discontinued approximately 45 km from Katse Dam, at which point there is a Hydro-electric Power station, generating hydro power for use by Lesotho. The tailrace of the hydro power station discharges into Muela Dam, in which the intake for the delivery tunnel to the Axle River is situated.

Matsoku Weir diverts water from the Matsoku River to the east of Katse Dam, through a 6.4 km, 3.8m diameter tunnel into Katse Dam. Mohale Dam on the Senqunyane River, to the west of Katse Dam, transfers water through a 32 km long gravity tunnel, with an internal diameter of 4.4m, to Katse Dam, from where the water is again transferred through the Katse tunnels to South Africa. The maximum transfer capacity of the tunnels to the RSA is 40m3/s although the in the Treaty between the RSA and Lesotho it was agreed on a 27.8 m3/s transfer for the full phase 1 of the LHWP.

Small Water Supply Systems in Lesotho

The Water and Sewage Authority (WASA) in Lesotho is responsible for water supply and sanitation in the 13 urban areas within Lesotho. In Butha-Buthe, Hlotse, Mapoteng, Maputsoe, Mohale's Hoek, Morija, Peka, Quthing, Roma and Teyateyaneng surface water sources are used and are supplemented by groundwater. Maseru and Mafeteng are supplied from surface water resources only.

Water for the **Maseru Water Treatment Works** is abstracted directly from the Mohokare (Caledon) River. From the treatment plant water is pumped to several reservoirs supplying a number of zones of reticulation within the town. To be able to obtain adequate volumes of raw water during periods of low flow in the river, an off-channel storage, Maqalika Reservoir, is utilized. A pumping station situated alongside the river supply up to 10 000m^3/day to the Maqalika Reservoir with a storage capacity of 3.7 million m^3. Water is pumped from Maqalika Reservoir to the Maseru Water Treatment Works.

The facility has recently been upgraded and new pumps have been installed with a capacity of 47 000 m^3/day. The original 3.7km 400mm dia. AC main pipeline has been duplicated with a 450mm dia. PVC pipe. Plans are in hand to raise Maqalika Dam in order to augment the system yield. When completed, the sustainable average system yield for the Mohokare River abstraction and Maqalika Dam system will be approximately 35 000m^3/day.

Roma is supplied from 6 production boreholes in the Qhobosheaneng Valley and can produce up to 400m^3/day. The boreholes deliver water to a 46m^3 tank from where water is pumped through a 200mm PVC transmission main 2.2km long to the main service reservoir near the centre of the town. Surface water is abstracted from the Liphiring Stream and pumped to the treatment works adjacent to the pumping station. Water is also pumped into an off-channel storage reservoir (Lepae Dam) with a capacity of 45 000m^3. The maximum capacity of the treatment works is 950 m^3/day. A pump delivers the treated water to the main service reservoir through a 200 mm dia. AC pipeline, 3km in length.

Mapoteng is a small trading town situated within the Berea District approximately 20 km to the east of Teyateyaneng. The existing water supply is from a spring some 20 km east of the town in the foothills of the Maluti Mountains. There is an intake harnessing water at the “Makaliso A” spring, which has been evaluated as being capable of supplying 300 m^3/day. The water is conveyed through a 20.4km long pipeline (125mm & 100mm diameter) by gravity to a reservoir in the town. Twelve small villages are also supplied with water along the route of the pipeline, through individual break pressure tanks. There are two storage reservoirs sited on higher ground to the south of Mapoteng, an old 200 m^3 steel tank and a new 1 500 m^3 concrete tank. Water is chlorinated at the inlets.

Peka is supplied from a single source of water comprising the existing Peka water supply scheme. The scheme consists of a number of wellpoints in the Mohokare River, at the west of the town, feeding an intake with low lift pumping to a high lift pumping station. There is no treatment works, but there is provision for gas chlorination. The high lift pumping station supplies water (1 200 m^3/day) through a 5.4km long 200 mm dia. transmission main, to a 588 m^3 concrete ground level storage reservoir at the east of the town.

The water supply to Teyateyaneng water supply scheme comprises two sources and infrastructures, the Phuthiatsana River to the north of Teyateyaneng and the St. Anges wellfield located 3 km to the west of the town. In the Phuthiatsana River, a number of wellpoints are used, individually equipped with submersible pumps supplying 225 m³/day as well as two nearby boreholes along the river bank supplying 235 m³/day. These are operated in combination with an intake of submersible pumps for the abstraction of surface water located by the road bridge, which can supply up to 605 m³/day. A high lift pumping station, of maximum capacity 1 550 m³/day, delivers water though a 5km long 150 mm dia. transmission main, to a booster pumping station situated on the western outskirts of the town. From here the booster pumping station delivers the same quantity of water through a 3.5km long 150 mm dia. transmission main to a 830 m³ reinforced concrete circular ground level storage reservoir at the south of the town.

The second scheme (St. Anges wellfield) comprises four production boreholes delivering 140 m³/day supplying water to a collector tank on the river bank. From here the high lift pumping station delivers the water through a 3.3km long 100 mm dia. transmission main to the 830 m³ storage reservoir at the south of the town.

The **Hlotse (Leribe)** water supply scheme comprises a number of wellpoints in the Hlotse River, at the south-east of the town, with a combined yield of 800 to 950 m³/day as well as four production boreholes in the Hlotse River with a yield of 280 m³/day. Water is supplied to a local treatment works from where it is pumped by means of a high lift pumping station and through a 3.25km long 200 mm dia. transmission main, capable of transferring 2 000 m³/day to a 528 m³ steel ground level storage reservoir in the WASA compound in the centre of the town.

The water supply scheme at **Maputsoe** comprises three sources and infrastructure. The Mohokare River to the west of Maputsoe is one source and has a sub-sand intake collector system, with a low lift pumping station on the bank side, supplying a local collector tank. A new wellpoint system supplies 200 m³/day and a further four wellpoints individually equipped with submersible pumps can supply up to 500 m³/day, all feeding directly to the collector tank. A borehole near to the river intake; supplies 300 m³/day, and also feeds directly to the collector tank. A high lift pumping station delivers through a 3.2km long 200 mm dia. transmission main to a 950m³ reinforced concrete ground level storage reservoir in the WASA compound, located towards the east of the town centre.

Butha-Buthe is currently provided with water from two sources, namely from groundwater abstracted from boreholes and from surface water in the Moroeroe Stream. There is an intake from the Moroeroe Stream adjacent to the treatment works, which is situated some 100 m north of the main road from Butha-Buthe to Qalo and Mohotlong. A weir was later constructed approximately 1 200m upstream of the treatment works from where water can gravitate to the works. The treatment works was designed with a capacity of 280 m^3/day, and is used if and when required. All boreholes but one deliver to a collector sump from where a high lift booster pumping station pumps the collected water to a main storage reservoir through a 315 mm dia. PVC main. The main reservoir is situated to the east of the town on the slopes of a hill at Makopo.

Mafeteng itself is served primarily by the Rasebala Dam, located a few kilometres to the south-east of the town centre, which was built and commissioned in the mid-1990's, and has an estimated yield of some 2 000 m^3/day, and an estimated design life through to the year 2023. This feeds a treatment works with a capacity of some 1 000 m^3/day, but which currently only operates at some 600 m^3/day. Two boreholes are also in operation near to the dam, which, when used conjunctively, produce approximately 250 m^3/day.

Two sources of water are feeding the supply to **Morija.** The first is a number of boreholes in the valley of the Lerato River. The boreholes can deliver up to 325 m^3/day, through a 100/150mm dia collector main, to a collector tank at the western end of the town. The second source is a small soil conservation dam close to the western edge of the town. Water from the dam is pumped through a package treatment plant and can provide up to 80m^3/day.

Mohale's Hoek uses three sources of water to supply its current water requirements. The first and major supply source is the wellpoints in the Makhaleng River, which can produce some 900 m^3/day to the treatment works with a capacity of 800 m^3/day. From here a high lift pumping station delivers water to a booster pump station situated on the western outskirts of the town. The booster pump station delivers water to a 1000m^3 steel reservoir, within the town. Secondly there is a borehole to the east of the town which delivers untreated water to a 100m^3 steel reservoir at a rate of 50m^3/day. The third source is an old well located to the south of the town, delivering untreated water to a 400m^3 reservoir at a rate of up to 150m^3/day.

The source of water for **Quthing** is the Qomoqomong River. Two 200mm porous pipes acting as infiltration galleries feed water to a caisson sump, from where water is pumped to the treatment works. A high lift pumping station with a capacity of 870m^3/day transfers the water to the main storage reservoir through a 150mm dia. 2.3km long pipeline.

3.2.2 Upper Orange Sub-system (RSA)

The Upper Orange Sub-system comprises the Orange Catchment just upstream of the confluence with the Vaal River at Marksdrift as well as the Riet/Modder river catchment, but excluding Lesotho (See **Figure A-1** in **Appendix A**). The Orange River is a major contributor along with the Caledon, Modder and Riet rivers in supplying water to agriculture, domestic and industrial users in the Upper Orange WMA. Agriculture is one of the key users of water in the Upper Orange WMA and there are several Government Water Schemes (GWS) and irrigation boards in the area. Two major hydro-power stations are located at Gariep and Vanderkloof dams.

The Modder River is fully utilised and this has necessitated the transfer of water from the Orange and the Caledon rivers to the Riet/Modder Catchment. There are three large transfer schemes used for this purpose, namely: the Orange-Riet transfer which supplies irrigation water to the Riet River Catchment from the Vanderkloof Dam, the Caledon – Modder transfer which supplies Bloemfontein, Dewetsdorp and smaller users from Welbedacht Dam as well as the Novo transfer scheme which is closely linked to the Caledon-Modder transfer scheme, and is used to supply water to Bloemfontein, Botshabelo and Thaba Nchu with water transferred from Knellpoort Dam.

In the whole of the Upper Orange WMA, there are a number of large water supply schemes as listed below:

The Caledon – Modder Transfer Scheme; Opearted by Bloem Water Company, consisting of Welbedacht, Rustfontein and Knellpoort dams as well as the related pumpstations and service reservoirs. The Caledon-Bloemfontein pipeline abstracts water from the Welbedacht Dam and supplies various towns such as Bloemfontein, Botshabelo, Thaba Nchu, Dewetsdorp, Reddersburg and Edenburg.

The NOVO Transfer Scheme. The Caledon – Modder (Novo) Transfer Scheme transfers water from Knellpoort Dam to Rustfontein Dam in the upper reaches of the Modder River Basin to supply the growing demands in the Bloemfontein area. This transfer scheme is in fact an extention of the older Caledon – Modder transfer scheme.

The Mazelspoort Scheme. Mazelspoort waterworks at the Mazelpoort Weir supplies about 25% of Bloemfontein's water needs and is owned by the Bloemfontein City Council and there is a service reservoir at Hamilton Park. Mazelspoort receives its water by means of releases from Mockes Dam, which is in turn supported from Rustfontein Dam as well as from transfers from Knellpoort Dam.

The Orange River Project. This is by far the largest scheme and includes Gariep and Vanderkloof dams with several sub-systems or smaller schemes included under the Orange River Project supply area. These sub-systems or schemes in the Upper Orange includes the following:

- **The Orange – Riet Transfer Scheme.** Water is supplied from Vanderkloof Dam to the Riet River Catchment via the Orange – Riet Canal. The water is primarily used for irrigation but also supplies the urban requirements of Koffiefontein (including mine), Ritchie and Jacobsdal.
- **The Orange – Fish Transfer Scheme**; transfers water to the Great Fish and Sundays River catchments in the Eastern Cape. Both catchments are water deficient but have fertile soil for irrigation. This scheme also supplies urban consumers, including Grahamstown and Port Elizabeth.
- **Orange-Vaal transfer scheme**; Water is abstracted from the Orange River at Marksdrift Weir to be transferred to Douglas Weir in the Vaal River. The water is used mainly for irrigation purposes and to improve the water quality in the Lower Vaal River.
- **Bloemwater**; also operates a pipeline network from Gariep Dam to the southern Free State towns of Trompsburg, Springfontein, Bethulie and Philippolis.
- **Irrigation abstractions** directly from the Orange River between Gariep and Vanderkloof dams as well as downstream of Vanderkloof Dam to Marksdrift just before the confluence of the Vaal and Orange rivers.
- **Urban/Industrial abstractions** along the Orange River between Gariep Dam and Marksdrift such as Hopetown, Vanderkloof and Orania.
- **Support to the Lower Orange WMA** (See **Section 3.2.3**)

Modder River Government Water Scheme. This scheme is located downstream of the Krugersdrift Dam, which has been operational since 1971. Releases are made directly from the dam into the river in support of downstream irrigation.

Tierpoort Dam Scheme; consisting of the Tierpoort Dam supporting irrigation downstream of the dam through a canal system.

Riet River Government Water Scheme. This irrigation scheme is supplied with water via a left bank canal from Kalkfontein Dam.

Dams

Table 3.7 lists the main dams in the Upper Orange with their capacities.

Table 3.7: Main dams in the Upper Orange System

Name		Live Storage Capacity (mcm)	
Upper Orange sub-catchment			
Gariep	5348.12	4710.03	638.09
Vanderkloof	3188.6	2173.2	1015.4
Bethulie		4.6	
Caledon sub-catchment			
Welbedacht	15.47	15.47	0
Knellpoort	136.95	130.3	6.65
Armenia		13.2	
Egmont		9.3	
Modder/Riet sub-catchment			
Kalkfontein	318.94	318.91	0.03
Tierpoort	34.02	34.00	0.02
Krugersdrift	73.19	73.19	0
Rustfontein	71.22	71.21	0.01
Groothoek		11,906.0	
Mockes		3.31	

Major Water Schemes

a) The Orange River Project

Gariep and Vanderkloof dams with a combined storage capacity of 8 500 million m^3 are the two largest storage dams in South Africa. They were built during the 1970's as part of the Orange River Project and are used to supply water to the whole of the Orange River Project supply area. The Orange River Project supply water to users in the Upper Orange

WMA, the Lower Orange WMA including Namibia as well as to users in the Fish to Tsitsikama WMA in the Eastern Cape. The Orange-Fish, Orange Riet and Orange-Vaal transfer schemes are all smaller sub-systems forming part of the larger Orange River Project as well as the Ramah Canal and Bloemwater pipeline network from Gariep Dam. Over and above these sub-systems in the Upper Orange WMA, there are several other towns and large irrigation areas along the Orange River in the Upper and Lower Orange, which are supplied from Gariep and Vanderkloof dams. Hydro-power is generated at both dams and is utilised by Eskom to increase the generated power into the national electricity grid over the daily peak load periods.

Details of the different components of the Orange River Project in the Upper Orange are given in the paragraphs to follow. Details of the components located in the Lower Orange WMA will be discussed in **Section 3.2.3.**

Orange-Fish Transfer Scheme

The layout of the Orange-Fish Tunnel Transfer Scheme is given in **Figure 3-12**. The capacity of the tunnel, with a total length of about 83 km, is 54 m^3/s. Water is transferred from Gariep Dam via the Orange-Fish tunnel to the Fish and Sundays rivers as well as to Port Elizabeth. A combination of canals, tunnels, balancing dams and natural river courses are used to distribute the water to the irrigators within the Fish-Sundays sub-system to eventually reach the Port Elizabeth abstraction point at the down stream end of the system.

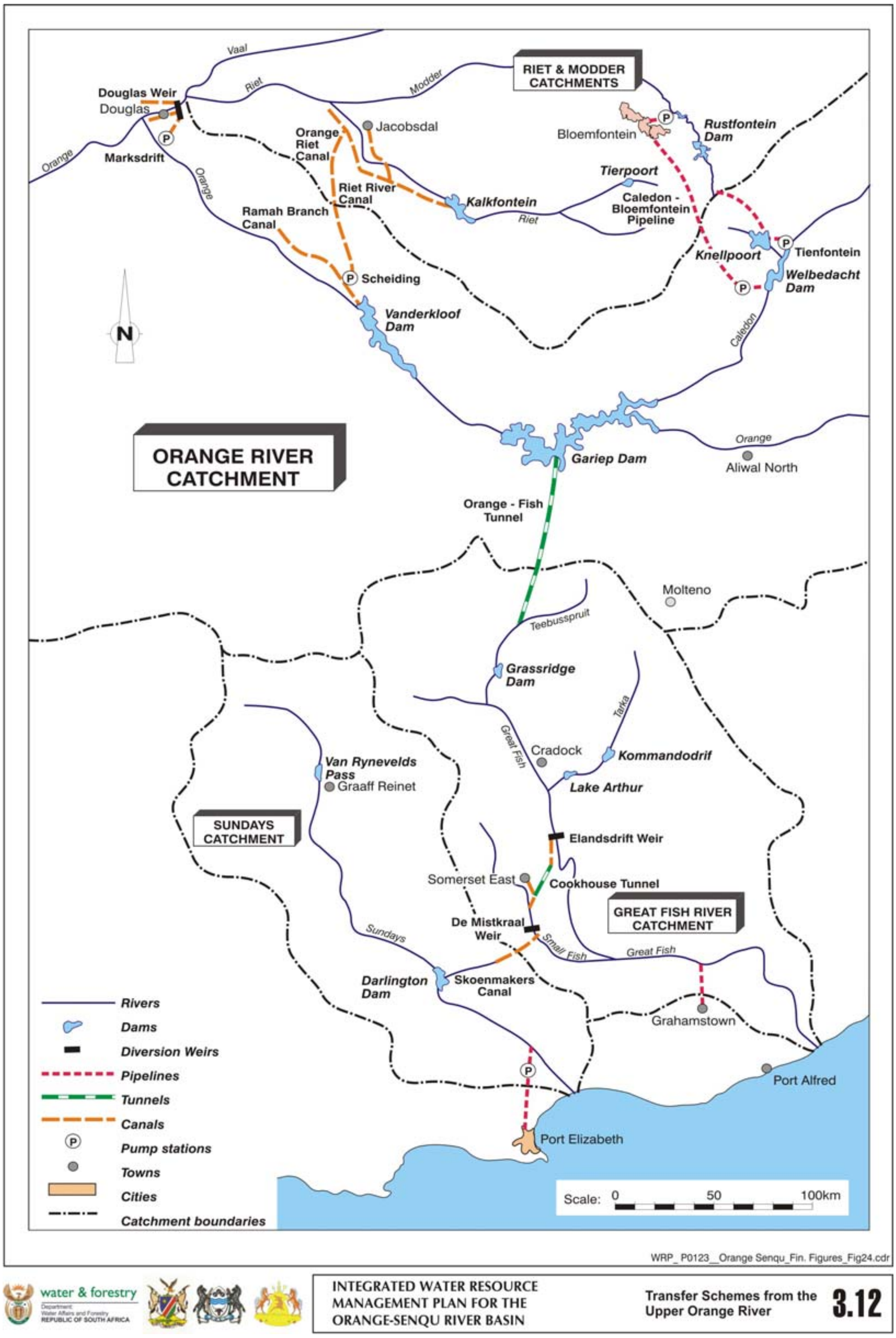

Figure 3-12: Transfer Schemes from the Upper Orange River

Vanderkloof Canals Scheme

This scheme consists of two main canals, namely; The Orange-Riet transfer canal and the Ramah canal, with details given below:

The Orange – Riet Transfer Scheme

The Orange – Riet Transfer Scheme abstracts water from Vanderkloof Dam to be transferred to the Riet River Catchment via the Orange – Riet canal. The water is primarily used for irrigation but also supplies the urban requirements of Koffiefontein (including mine), Ritchie and Jacobsdal. The primary consideration for the construction of the Orange-Riet canal in 1983, as shown in **Figure 3.13**, was the need to steady the supply of sufficient water for both the peak daily as well as the annual water demand. The Orange-Riet transfer scheme forms part of the Orange-Riet Government Water Scheme. Water is released from the Vanderkloof Dam into the Vanderkloof Main Canal. The capacity of the Vanderkloof Main Canal is 57 m^3/s and has a length of 14 km. At the Scheiding pump station water is pumped from the Main Canal into the Orange-Riet Canal. The remainder of the Vanderkloof Canal, running along the Orange River, is known as the Ramah Branch Canal and supplies water to irrigation areas along the right bank of the Orange River.

The Orange-Riet Canal has a total length of 112.6 km and supplies water for irrigation to 3 787 ha of irrigation next to the canal, as well as to the Riet River Settlement near Jacobsdal (7 812 ha), the Scholtzburg Irrigation Board (637.1 ha), Richie Irrigation Board (96,8 ha) and the Lower Riet Irrigation Board (3 937.1ha). Riet River Settlement forms part of the Riet River GWS and also receives water from the Orange. The first 74.6 km of the Orange-Riet Canal has a capacity of 15.6 m^3/s and the last 38 km has a capacity of 13.2 m^3/s. At the end of the Orange-Riet Canal, it splits into two secondary canals, namely the Main Canal and the S350 Canal. Both these canals supply water to the Riet River Settlement. The Main Canal supplies water to the Richie Irrigation Board. The S350 Canal releases water into the Modder River. This water flows into Scholtzburg Weir in the Modder River just upstream of the confluence of the Modder and Riet rivers. The Scholtzburg Irrigation Board abstracts water from this weir for irrigation purposes.

Ramah Canal

The Vanderkloof Main Canal (shown on **Figure 3-13**), on the right bank of the Orange River downstream of Vanderkloof Dam, supplies water to irrigation areas as far as Scheiding pump station. At Scheiding pump station water is pumped through a rising main into the Orange-Riet Canal. The Ramah Branch Canal is the remaining section of the Vanderkloof Main Canal on the right bank of the Orange River, downstream of the Scheiding pump station. The Ramah Canal supplies water to 5 667 ha of irrigation land on the right bank of the Orange River. The Ramah Canal has 3 reaches (i.e. I, II, and III): Ramah I is 17.3 km long with a capacity of 9.6 m^3/s, Ramah II is 48.9 km long with a capacity of 4.2 m^3/s and Ramah III is 21.2 km long with a capacity of 1.48 m^3/s. There are two balancing dams on the Ramah Canal, the first between reaches I and II (340 000 m^3 capacity and 12.68 ha surface area) and the second between reaches II and III (280 000 m^3 capacity and 9.0 ha surface area).

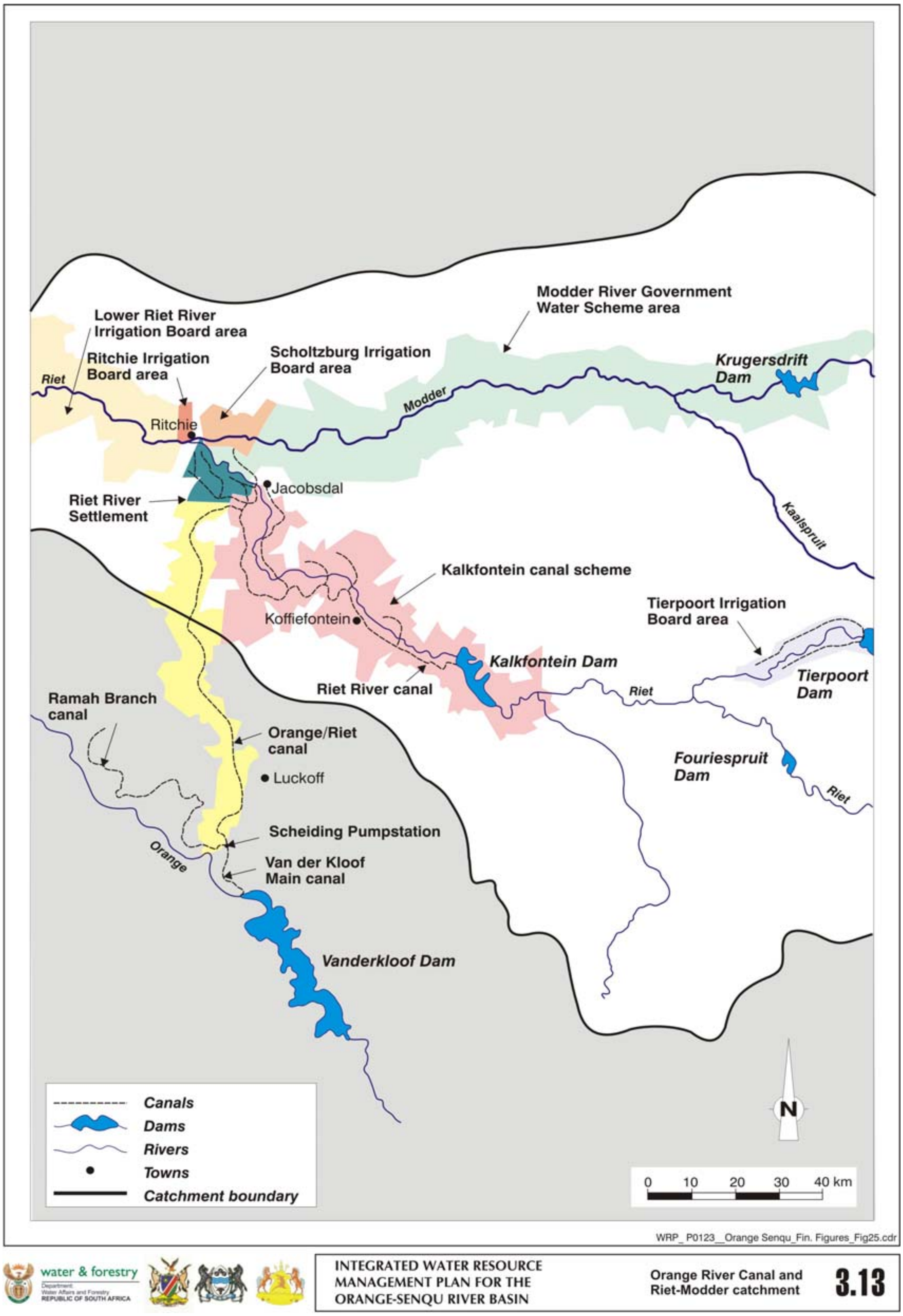

Figure 3-13: Orange River Canal and Riet-Modder catchment

Orange-Vaal transfer scheme

The Orange-Vaal Transfer Scheme has a transfer capacity of 6 m^3/s from the Orange River to the Vaal River (See **Figure 3-14)**. It was originally constructed in 1984 as an emergency scheme to overcome water shortages and salinity problems in the Douglas GWS. This scheme, also known as the Orange-Douglas Government Water Scheme, consists of a pumping station at Marksdrift on the Orange River, a rising main and a 22 km canal, known as the Bosman Canal, terminating at the Douglas Weir on the Vaal River. The total irrigation area for this scheme is 8 113 ha. Douglas Weir was originally completed in 1896 and replaced by a higher concrete structure in 1976. From this weir water is transferred via a 24 km concrete lined canal on the left bank of the Vaal River, the Douglas Canal, to the confluence of the Orange and Vaal rivers. On the right bank of the Vaal River, an unlined canal, the Atherton Canal, supplies water to the Atherton plots. Water quality is a very important issue in this scheme as salinity levels of water flowing into Douglas Weir have increased in recent years. The Orange River water transferred through the Orange-Vaal Transfer Scheme is also used to improve the water quality of the irrigation water of farmers being supplied from the Douglas Weir.

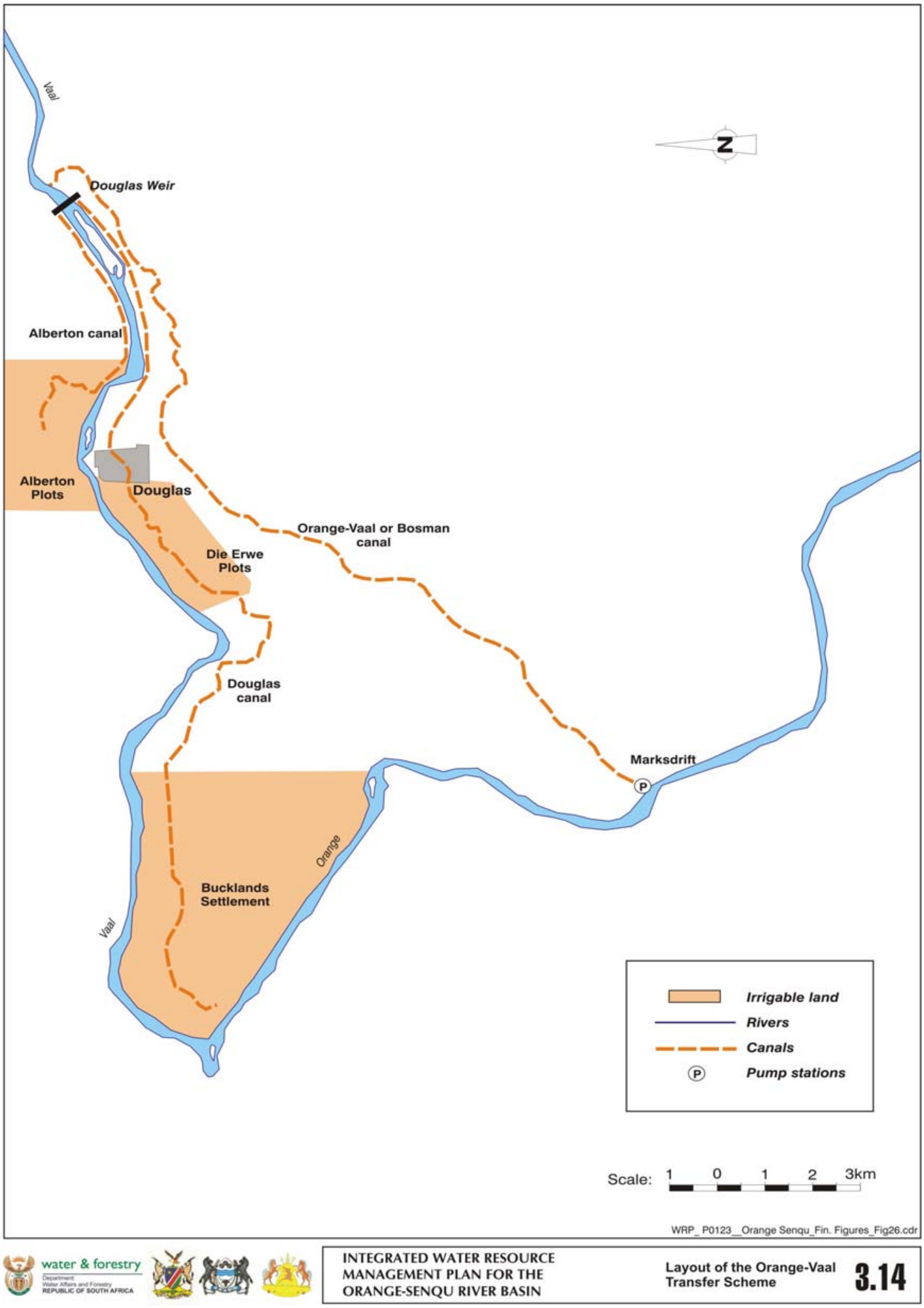

Figure 3-14: Layout of the Orange –Vaal Transfer Scheme

b) The Caledon–Modder and Novo Transfer Scheme

The Caledon River forms, for most of its length, the north-western border of Lesotho with the RSA. The confluence with the Orange River is in the upper reaches of the Gariep Dam. The only major dam on the Caledon River is the Welbedacht Dam. Due to the high silt load in the Caledon River, Welbedacht Dam has lost a large portion of it original capacity. To avert this, Knellpoort Dam was then constructed in one of the small tributaries of the Caledon River and acts as an off channel storage dam. Knellpoort Dam is filled mainly by pumping from the Caledon River using Tienfontein Pumpstation. Natural runoff from the Knellpoort Dam catchment contributes to a very small portion of its yield. Water is released from Knellpoort dam to support Welbedacht Dam when required.

In 2000, the Novo transfer scheme was commissioned to transfer water directly from Knellpoort Dam to Rustfontein Dam in the Modder River Catchemt. The Novo Transfer Scheme is in fact an extention to the already existing Caledon-Modder Transfer Scheme. The two transfers schemes also link directly with the water supply system on the Modder River comprising Rustfontein Dam and Mockes Dam to form one integrated water supply system. The integrated system is used to supply water to various towns such as Bloemfontein, Botshabelo, Thaba Nchu, Dewetsdorp, Reddersburg and Edenburg.

The Caledon-Modder Transfer Scheme (see **Figure 3-15**) therefore consists of two transfer schemes: the original Caledon-Modder transfer scheme and the Novo Transfer Scheme, and are forming one integrated supply system together with the Rustfontein and Mockes storage dams and Mazelspoort Weir (Mazelspoort Scheme) in the Modder River. Details on each transfer scheme are given hereafter:

The Original Caledon-Modder Transfer Scheme

The Caledon-Modder Transfer Scheme facilitates abstraction of water from Welbedacht Dam in the Caledon River. After purification at the Welbedacht Treatment Works, the water is pumped to the end-users through the Welbedacht-Bloemfontein pipeline. This pipeline consists of a 6.55 km pressure pipeline and a 105.5 km gravity pipeline. Potable water is supplied to Dewetsdorp, Botshabelo and other minor consumers by means of secondary pipelines branching off the main pipeline. The capacity of the Welbedacht-Bloemfontein pipeline is 128 Ml/day or 1.48 m^3/s. Sediment deposition has reduced the capacity and yield of Welbedacht Dam significantly. As a result of this reduction in storage at Welbedacht Dam, Knellpoort Dam, an off-channel reservoir, was constructed on the

Rietspruit, a tributary of the Caledon River, to supplement the yield of Welbedacht Dam. Water is pumped via the Tienfontein Pump Station (original capacity was 3 m^3/s) upstream of Welbedacht Dam to Knellpoort Dam in order to supplement Welbedacht Dam. This pump station was upgraded to up to 10 m^3/s capacity, to supply water also via the Novo Transfer Scheme to the Modder River Sub-system.

Novo Transfer Scheme

The Novo Transfer Scheme supplements the Caledon-Modder River sub-system directly from the Knellpoort Dam. It has a total transfer capacity of 2.4 m^3/s. The scheme consists of the Novo Pump Station at Knellpoort Dam, a rising main, a 29.7 km long pipeline and a 12 km long canal to the upper reaches of the Modder River. During the first phase of this scheme, it was utilised to supply water to Rustfontein Dam, which supplements Maselspoort purification plant via Mockes Dam and Mazelspoort Weir, for use by Bloemfontein. In later phases of the Novo Transfer Scheme, a water treatment plant was constructed near Rustfontein Dam. Botshabelo is now supplied with water from this water purification plant near Rustfontein Dam, with the result that more water can then be supplied from Welbedacht Dam to Bloemfontein through the Welbedacht-Bloemfontein pipeline, since Botshabelo was initially also supplied from the Welbedacht-Bloemfontein pipeline.

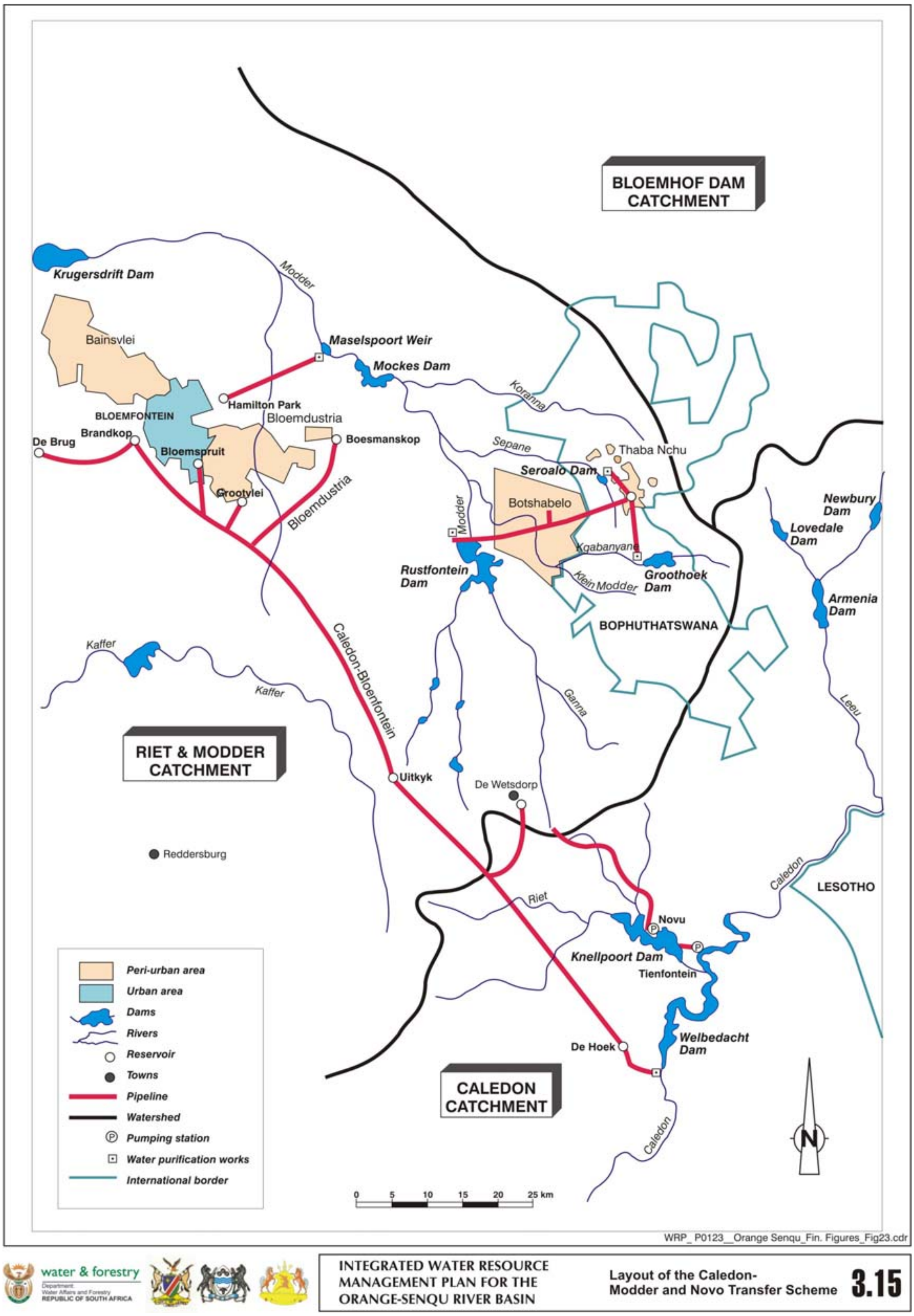

Figure 3-15: Layout of the Caledon-Modder and Novo Transfer Scheme

c) Krugersdrift Dam Scheme

This scheme consists of the Krugersdrift Dam, and a series of storage weirs on Modder River (See **Figure 3-13**). The scheme supplies water to the Modder River Government Water Scheme located downstream of the Krugersdrift Dam, which has been operational since 1971. The dam makes releases to 55 small storage weirs along the lower Modder River from which irrigation water is abstracted. The capacities of the weirs vary from below 5000 m^3 to 1 million m^3. The releases from Krugersdrift Dam are regulated so that they cascade down to fill the furthest downstream weir.

d) Tierpoort Dam Scheme

This scheme consists of the Tierpoort Dam, and two canals on the banks of the Kaffer River (See **Figure 3-13**). The dam was commissioned in 1923 and was reconstructed after it was washed away in the floods of 1988. The dam supplies water to the Tierpoort Irrigation Board Scheme via two canals on either bank of the river.

e) Riet River Government Water Scheme

This scheme consists of the Kalkfontein Dam commissioned in 1938 and a canal system distributing water to the irrigators (See **Figure 3-13**). The dam supplies water to Riet River Government Water Scheme via a left bank canal. The scheme originally supplied the demands of riparian irrigators along the river, the Riet River Settlement, the Scholtzburg and Richie Irrigation Board, as well as the town of Jacobsdal and mining centre of Koffiefontein. However, since the implementation of the Sarel Hayward Canal, which took over the supplies to the Riet River Settlement, the Scholtzburg and Richie Irrigation Board as well as the Town of Richie. The town of Jacobsdal and mining centre of Koffiefontein are supplied still supplied from the Kalkfontein Dam.

Small Water Supply Systems

The smaller systems and related dams on the Orange River tributaries as well as in the Riet-Modder Catchment are operated independently from the ORP. Spills from some of the sub-system dams and flows from unregulated tributaries are still captured by the Major Dams on the Orange River. Base flows from the tributaries into the Orange River are however reduced due to the impact of the smaller sub-systems on the flow from the different sub-catchments. The smaller systems are therefore discussed separately in the sub-sections to follow:

- **Groothoek Dam** is a relative small dam and is only used to supply water to Thaba Nchu. Water for Thaba Nchu is now also supplied from Rustfontein Dam.
- **Armelia Dam Scheme** consists of the Armelia Dam and a canal system on the Leeu River. The dam has been operational since 1954. The scheme supplies water to the Leeu River Irrigation Scheme located below the dam. The water is released into a canal and distributed for irrigation purposes.

Water Treatment Works

Table 3.8 lists Water Treatment Works with their respective capacities and operators. Most of the systems are operated by the municipalities, with a small fraction operated by Bloemwater and DWAF.

Table 3.8: Water Treatment Works in the Upper Orange System

Water Treatment Works				Raw Water Source
Name	Capacity		Owner/ Operator	Name
	(Ml/d)	(mcm/a)		
Bethulie	D4.0	1.46	Municipality	Orange River Boreholes
Botshabelo	D100	36.52	Bloem Water	Rustfontein Dam
Brandfort	Unknown	Unknown	Municipality	Sand-Vet GWS
Clarens	Unknown	Unknown	Municipality	Clarens & Gryp Dams
Clocolan	D3.46	1.26	Municipality	Moperri Dam
Fauresmith	Unknown	Unknown	Municipality	Jagersfontein Boreholes
Ficksburg	Unknown	Unknown	Municipality	Meulspruit Dam
Gariep Dam	Unknown	Unknown	Bloem Water	Gariep Dam
Hobhouse	Unknown	Unknown	Municipality	Armenia Dam
Jacobsdal	D960	350.64	Municipality	Kalkfontein Dam Boreholes
Jagersfontein	Unknown	Unknown	Municipality	Boreholes
Koffiefontein	Unknown	Unknown	Municipality	Riet River GWS
Ladybrand (Genoe WTW)	D0.6	0.22	Municipality	Caledon River Cathcartdrift Dam
Luckoff	D0.44	0.16	Municipality	Orange-Riet Canal
Maseru	Unknown	Unknown	Municipality	Caledon River
Oppermans	Unknown	Unknown	Municipality	Boreholes

Water Treatment Works				Raw Water Source
Name	Capacity		Owner/ Operator	Name
	(Ml/d)	(mcm/a)		
Reddersburg	D0.47	0.17	Bloem Water	Welbedacht Dam
Rosendal	Unknown	Unknown	Municipality	Rosendal Dam
Rouxville	Unknown	Unknown	Municipality	Kalkoenkrans Dam Boreholes
Smithfield	D1.4	0.51	Municipality	Smithfield Dam Boreholes
Thaba Nchu (Groothoek)	D18.0	6.57	Bloem Water	Groothoek Dam,Rustfontein Dam Boreholes
Thaba Patchoa	Unknown	Unknown	Dwaf	Armenia Dam Boreholes
Trompsburg	Unknown	Unknown	Bloem Water	Gariep Dam
Tweespruit	Unknown	Unknown	Municipality	Lovedale Dam
Vanstadensrus	Unknown	Unknown	Municipality	Boreholes
Wepener	Unknown	Unknown	Bloem Water	Welbedacht Dam Boreholes
Welbedacht	D145	52.96	Municipality	Wlebedacht Dam
Zastron	Unknown		Municipality	Kloof Dam Montagu Dam

Notes: D denotes design, Unknown – Indicate that the information was not available from existing reports used to obtain data, Where source of water is unknown, the source is generally local rivers.

3.2.3 Lower Orange Sub-system

This sub-system covers the Orange River Catchment from Marksdrift, just upstream of the confluence between the Orange and Vaal rivers to the Orange River Mouth. The two largest dams in the RSA, the Gariep Dam and Vanderkloof Dam which are part of the Orange River Project are used to supply most of the water requirements in the Lower Orange Sub-system, although they are located in the Upper Orange WMA.. These dams are utilised for flood control, power generation and water supply to irrigation and urban users.

There are several schemes located within the Lower Orange Water Management Area (LOWMA), and in all cases water is sourced from the Orange River Project (see **Figure 3-16**). The following schemes are included:

The Karos-Geelkoppen Rural Water Supply Scheme; provides water for stock watering purposes and is located just upstream of Upington.

The Kalahari-West Rural Water Supply Scheme; draws treated water from the Upington purification plant and pumps it north for stock watering and rural domestic purposes.

The Pelladrift Water Supply Scheme; is operated by the Pella Water Board and provides water to Poffadder, Pella and the mines at Aggenys and Black Mountain.

The Springbok Regional Water Supply Scheme; draws water from Henkriesmond, via the Henkries purification works and supplies the towns of Springbok, Okiep, Carolusberg and Kleinsee as well as some mining requirements in the area.

Urban, Industrial and Mining water requirements are supplied all along the Orange River and includes places such as Prieska, Upington Alexander Bay, Oranjemund, Rosh Pinah, Noord Oewer, Vioolsdrift etc.

The irrigation schemes; mainly consisting of a series of weirs and canals, providing water to riparian farmers on both the left and right bank of the Orange River. The following irrigation schemes are included:

- Douglas Irrigation Scheme.
- Boegoeberg Irrigation Scheme.
- Upington Irrigation Scheme.
- Kakamas Irrigation Scheme
- Onseepkans Irrigation Scheme.
- Namakwaland Irrigation Area.
- Vioolsdrift Irrigation Scheme
- Noordoewer Irrigation Scheme (Namibia)
- Aussenkehr Irrigation Scheme (Namibia)
- Namaqualand Irrigation Area
- Middle Orange Irrigation Area.
- Komsberg to Noordoewer Irrigation Area (Namibia)

There are a number of weirs, on the Orange River such as the Boegoeberg and Neusberg weirs, which are used to divert the Orange River water into irrigation canal systems and to act as flow gauges. A few small dams have been built on some of the tributaries to the Orange River, such as the Smartt Syndicate Dam on the Ongers River, as well as the Van

Wyksvlei Dam on the Carnarvonleegte River. No hydro-power is generated within the Lower Orange WMA.

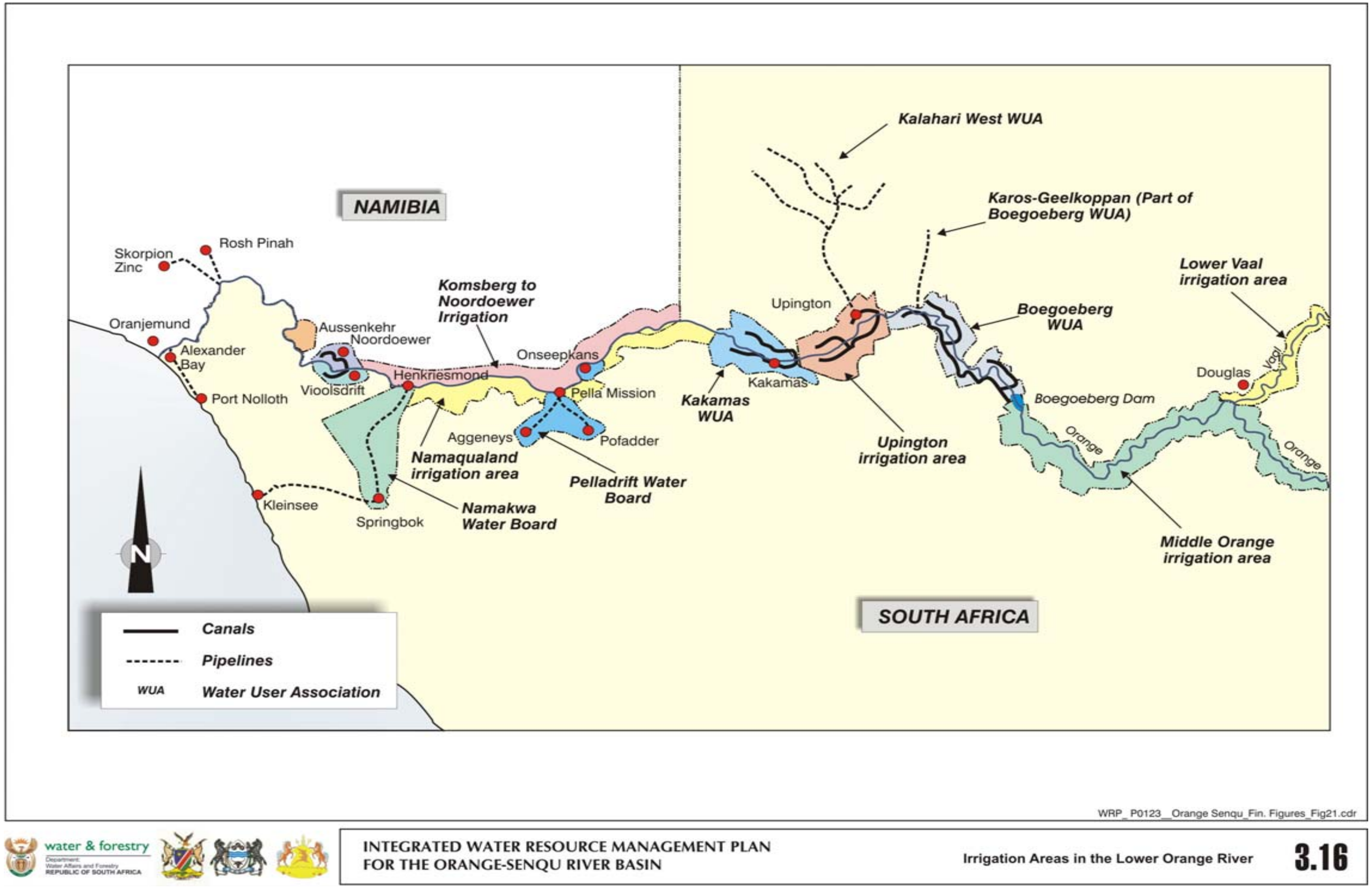

Figure 3-16: Irrigation Areas in the Lower Orange River

Dams

Table 3.9 lists the main dams in the Middle Vaal with their capacities.

Table 3.9: Main dams in the Lower Orange System

Name	Gross Storage (mcm)	Live Storage Capacity (mcm)	Dead Storage (mcm)
Boegoeberg	20.74	20.73	0.01
Modderpoort		10	
Ratelfontein		6.91	
Rooiberg		3.65	
Smart syndicate		101.12	
Van Wyksvlei		143.08	
Victoria West		3.66	

Major Water Schemes

a) Douglas Irrigation Scheme

Douglas Irrigation Scheme is located at the downstream end of the Vaal River. This scheme therefore receives water from the Vaal River, but is also supplemented with water from the Orange River via the Orange Vaal Transfer Scheme.

b) Middle Orange Irrigation Area

The Middle Orange Irrigation Area comprises riparian irrigators from Hopetown to Boegoeberg Dam (See **Figure 3-16**). The area from Hopetown to Marksdrift is however included in the Upper Orange WMA. The remainder from Marksdrift to Boegoeberg Weir amount to approximately 15 434 ha and falls within the Lower Orange WMA. Irrigators in this area are not part of a formalised scheme with a common supply system. Irrigators abstracts water directly from the Orange River on an individual basis and are supported with releases from Vanderkloof Dam.

c) Boegoeberg Scheme

Boegoeberg Dam, a 9 m-high concrete gravity structure was built in 1931 some 150 km upstream of Upington in the Orange River, and is the major structure supporting the releases to the Boegoeberg irrigation area. Due to sedimentation, the capacity of the reservoir has decreased from its original 34.7 million m³ to only 20.7 million m³. The

Boegoeberg Canal consists of the 172 km long main canal on the left bank with a capacity of 9.76 m³/s (See **Figure 3-16** and **Figure 3-17**). A syphon and branch canal on the right bank of the Orange River (the Noord-Oranje Canal) conveys water to the area controlled by the Noord-Oranje Irrigation Board. Further downstream, another syphon and canal on the right bank supplies water to the Gariep Settlement. The Boegoeberg Canal on the left bank also supplies water to the Rouxville West Scheme. This former irrigation board canal scheme now forms part of the Boegoeberg GWS. The Karos Weir in the Orange River upstream of the Rouxville West Island Group is no longer functional.

The schematic layout of the Boegoeberg-Karos Government Water Scheme (GWS) is shown on **Figure 3-17**. Details of the Noord-Oranje Canal are given in **Table 3.10**.

Table 3.10: Details of the Noord-Oranje Canal

Reach No.	Length (m)	Capacity (m^3/s)
1	11 600	1.81
2	7 450	1.53
3	6 630	0.91
4	2 360	0.45
5	2 590	0.23
Total	30 630	

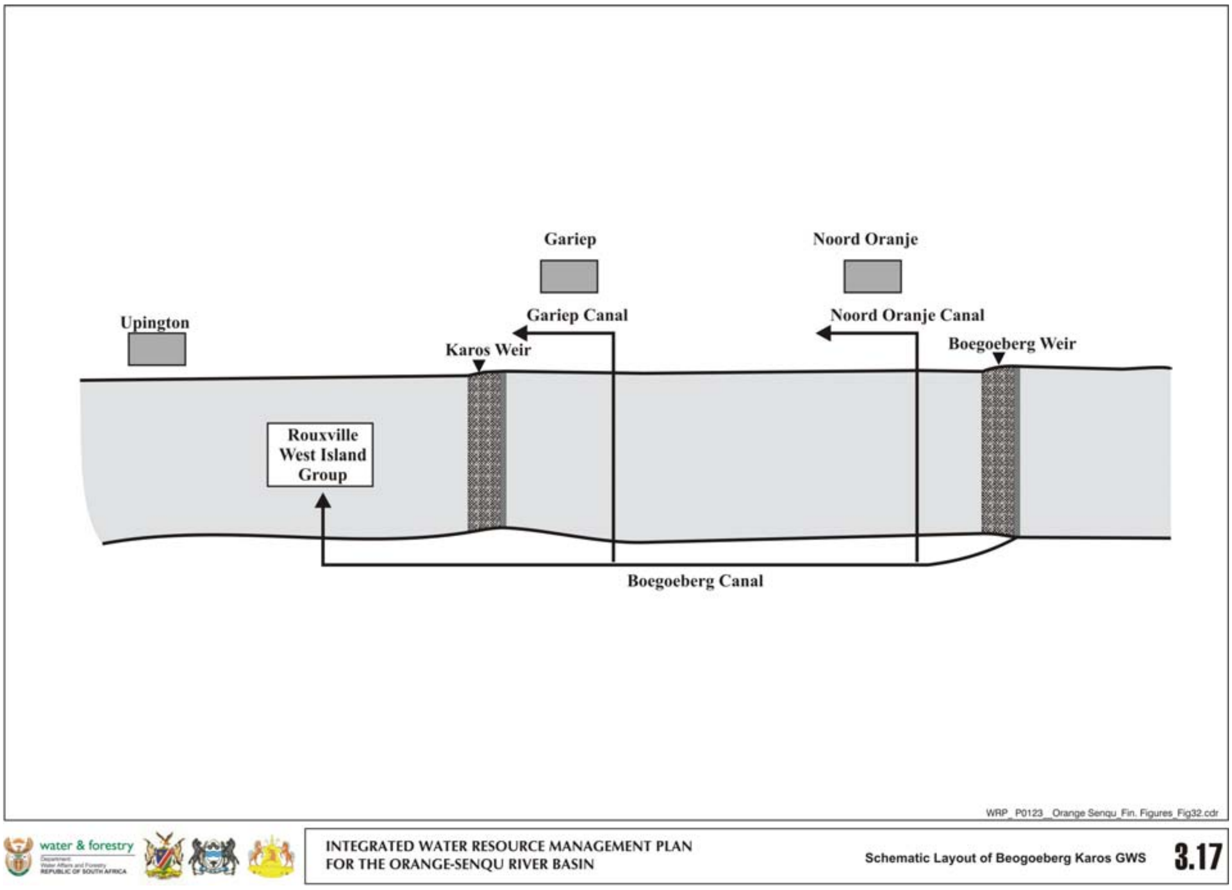

Figure 3-17: Schematic Layout of Boegoeberg Karos GWS

d) Gifkloof Weir (Upington Islands GWS and Upington Irrigation Board Canal)

There are many islands in the Orange River in the vicinity of Upington, where irrigation has been practiced as far back as 1883, when the first canal was constructed. These irrigation areas are now controlled by the Upington Irrigation Board (**Figure 3-18)**. The upstream intake for the Upington Irrigation Board Canal is on the right bank of the Gifkloof Weir at the Rouxville West Island Group. Gifkloof Weir also diverts water to the left bank of the Orange River into the Upington Islands GWS. Both banks of the river and the islands are irrigated and water is supplied via a network of secondary canals and syphons. The left bank canal has an initial capacity of approximately 10 m³/s and supplies water to the Upington Islands Government Water Scheme. A series of secondary canals and syphons supply water to irrigation land on the left and right banks of the river and to the islands in the river.

Steynsvoor Canal, which supplies water to the Steynsvoor Irrigation Board, branches from the end reach of the Upington Island Canal. Water is transferred to this canal on the right bank of the river by means of the Steynsvoor syphon. For details of the canals see **Table 3.11**.

The total length of the main canal is 58.5 km and can be subdivided as shown **in Figure 3-18.** Details of the Irrigation Boards in the Upington Islands GWS are listed in **Table 3.11**. The scheduled area for irrigation from the Upington Main Board canals is 5 846 ha, while 407 ha is scheduled with water abstracted directly from the river. The irrigation areas in the Upington Irrigation Board are 747 ha from canals and 46 ha from the river.

Table 3.11:Details of the Upington Islands Canal

Reach No.	Length (m)	Irrigation Board	Canal Capacity (m^3/s)
1	11 598	Straussburg	9.911
2	6 633	Straussburg Olyvenhoutsdrift South	8.807
3	7 189	Olyvenhoutsdrift South	8.807
4	3 141	Louisvale	8.807
5	10 882	Louisvale	6.230
6	4 937	Louisvale	3.936
7	9 530	Louisvale	1.529
8	4 521	Louisvale Blaauwskop Kanoneiland Upper	0.813
Total	58 521		

Table 3.12: Details of the Irrigation Boards in the Upington Islands GWS

Name	Area under irrigation (ha)			
	Canal	River		Total
		Basic	Bought	
Straussburg	552.4			552.4
Olyvenhoutsdrift South	639.3	12.2	120.0	771.5
Swartkop	971.0	34.0	20.0	1 025.0
Louisvale	1 118.5	25.3	70.3	1 214.1
Blaauwskop	690.2	-	100.4	790.6
Steynsvoor	1 353.7	8.4	16.4	1 378.5
Kanoneiland	520.6	-	-	520.6
Total	5 845.7	79.9	327.1	6 252.7

In the vicinity of Keimoes there are various Irrigation Boards with its own diversions. The scheduled area for the Boards abstracting water from canals is 5 089 ha and 296 ha is scheduled with water abstraction from the river. A further 733 ha of irrigation land is scheduled between Gifkloof Weir and Neusberg Weir to abstract water from the river.

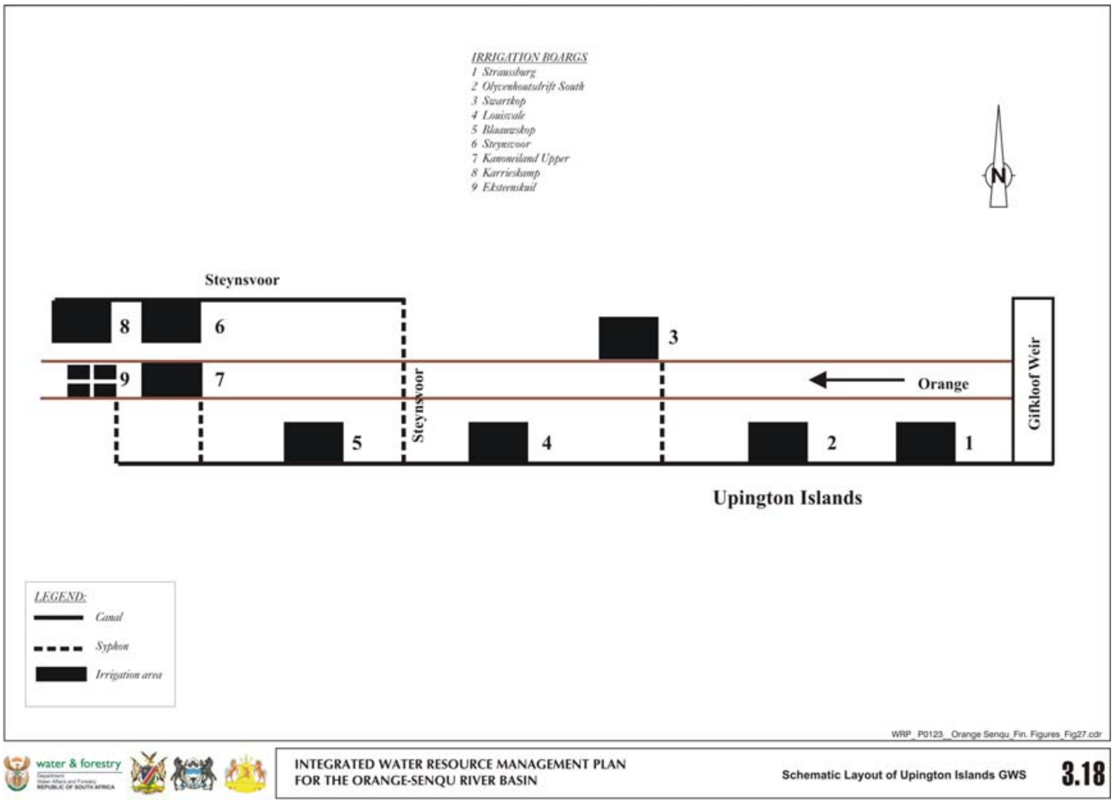

Figure 3-18 : Schematic Layout of Upington Islands GWS

e) Kalahari Rural Water Supply Scheme

This scheme consists of the Kalahari West, Kalahari East and the Karos-Geelkoppan Rural Water Supply Schemes which are discussed in detail as follows:

- **Kalahari West:** This water supply scheme northwest of Upington, was initiated following several years of critical drought in this part of the catchment. The scheme consists of a 51 l/s main pump station at the Upington municipal reservoir, which conveys water through a 250 mm diameter and 20 km long pipeline to the main reservoir (2 500 m³ capacity) near Spitskop. From there, the water flows through a 250 mm diameter gravity pipeline to a balancing reservoir of 100 m³. A 22.5 l/s booster pump station supplies water beyond this point to the primary distribution system. This distribution system consists of 9 reservoirs with capacities ranging from 100 m³ to 730 m³ and pipelines with a total length of 330 km with diameters ranging from 110 mm to 250 mm. A second booster pump station delivers the water to the remainder of the area at a maximum capacity of 16.4 l/s. A secondary distribution system consists of 105 km of pipelines, with diameters between 50 mm and 110 mm, as well as three 80 m³ reservoirs.

- **Kalahari East:** The Kalahari East Rural Water Supply Scheme was constructed in the early nineties to supply water to farmers in the Kalahari, north of Upington, with water for stock watering and domestic use. The scheme was prompted by the successful implementation of the Kalahari West Rural Water Supply Scheme. The scheme sources its water from the Vaal-Gamagara pipeline. The Kalahari East pipeline taps into the Vaal-Gamagara pipeline near Kathu, north-east of Olifantshoek, from where water is pumped through a 32km long rising main heading west to a 4.3 Ml reservoir. From there, water is fed, mostly under gravity, into an extensive pipe network serving an area of 14 120 km^2. The total length of pipeline comprising this network is 1 059km with diameters varying from 450 to 63mm. The scheme is designed to deliver a peak flow of 6.18 Ml/day with provision made to increase this to 8.52 Ml/day.

f) Karos-Geelkoppan Rural Water Supply Scheme

This is a very small scheme, which supplies water to rural communities north of Upington. The actual water supplied by the scheme in 1995 was 0.04 million m^3/annum.

g) Kakamas GWS

The Kakamas GWS consists of the Neusberg Weir and the Rhenosterkop Weir, and are discussed separately in the following subsections:

h) Neusberg Weir

The Neusberg Weir supplies water to the Kakamas Government Water Scheme area. Irrigation in the Kakamas area started in the late nineteenth century and the irrigated areas are on various islands in the Orange River as well as on the alluvial flood plains on both banks of the river. The construction of the South-Furrow and the North-Furrow canal schemes commenced in 1898 and 1908 respectively (See **Figure 3-19**). Both canals were later enlarged and upgraded. Water for both canals is abstracted at the Neusberg Weir, completed in 1993, in the Orange River near Kakamas. The scheduled area for the Kakamas North and South Schemes is 4 317 ha. Kakamas N & S and Augrabies canals 8 336ha)

i) Rhenosterkop Weir (Kakamas GWS)

The Rhenosterkop Canal diverts water below the end of the Kakamas South Furrow by means of a concrete weir, the Rhenosterkop Weir. This weir was built between the left bank and Paarden Island, and has an intake capacity of 7.85 m³/s. The Rhenosterkop Canal leads into the Augrabies Canal, which in turn leads into the Noudonzies Canal. An area of 1 712 ha is scheduled for water supply through the Augrabies canal. Between Augrabies and the Namibian border, 767 ha of irrigation land has scheduled water rights for abstraction directly from the Orange River.

Details of the canal systems of the Kakamas GWS are summarised in **Table 3.13**, and **Figure 3-19** shows a schematic layout of the Kakamas GWS.

Table 3.13: Details of the canal system of the Kakamas GWS

Reach No.	Length	Capacity (m^3/s)
North Furrow		
1	17 400	7.45
2	7 200	4.09
3**	2 300	0.19
Total	26 900	
South Furrow		
1	9 300	6.81
2	700	4.43
3	6 350	3.16
4	6 900	2.07
5	9 350	0.84
Total	32 600	
Rhenosterkop, Augrabies and Noudonzies Canals		
1	500	7.85
2	5 050	5.25
3	2 000	3.05
4	6 200	1.05

5	3 650	0.88
6	4 100	0.37
Total	21 500	

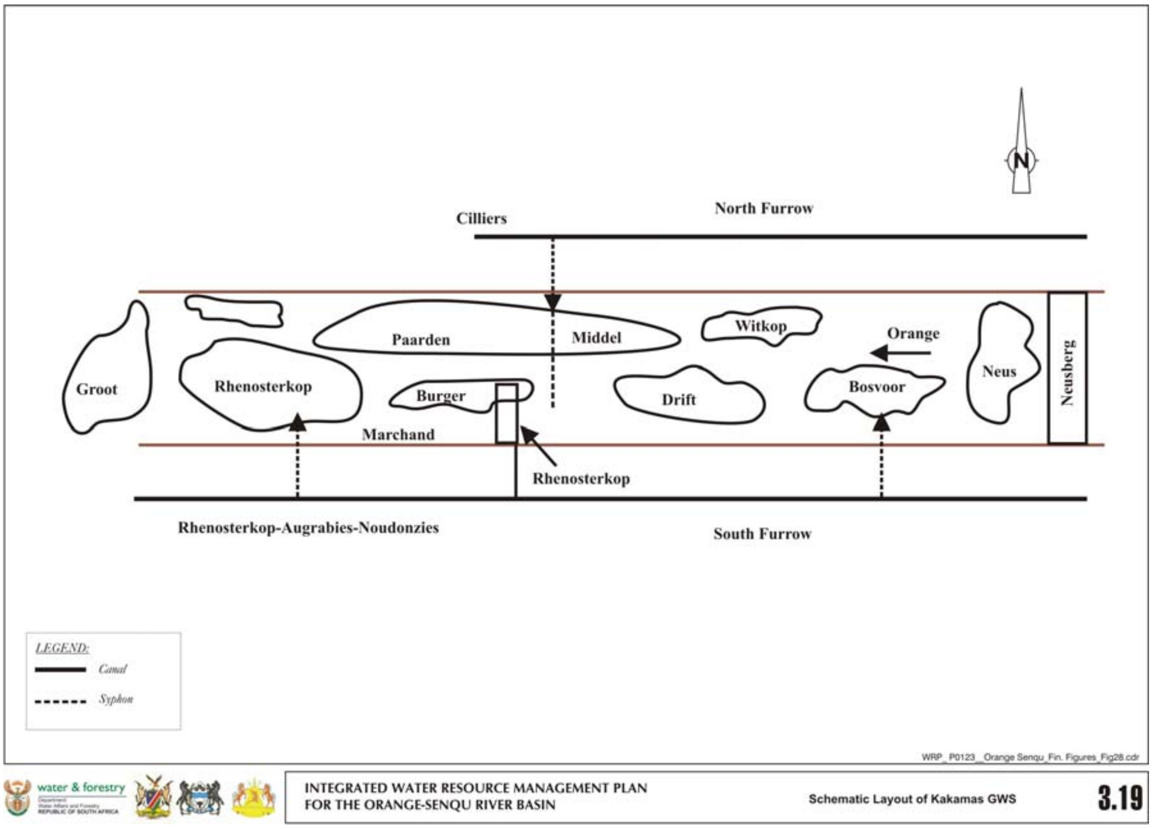

Figure 3-19 : Schematic Layout of Kakamas GWS

j) Keimoes Canal Irrigation Area

Keimoes irrigation area consists of various Irrigation Boards with its own diversions from the Keimoes Canal which obtains its water from the Orange. The scheduled area for the Boards abstracting water from canals is 5 089 ha and 296 ha is scheduled with water abstraction from the river.

k) Onseepkans Irrigation Area

Onseepkans irrigation area is supplied through a canal on the left bank of the Orange River. The capacity of this canal is unknown, but it supplies water to 314 ha of irrigation land (See **Figure 3.16**).

l) Namakwaland Irrigation Area

The water for the Namakwaland Irrigation Area is abstracted from the Orange River. Water is released from Van der Kloof Dam to supply users in this area. The scheduled area is about 2 439 ha (See **Figure 3.16**).

m) Pelladrift Water Supply Scheme

The Pelladrift Water Supply Scheme supplies water to Pofadder, Aggenys, Black Mountain Mine and Pella Mission. Water is abstracted from the Orange River through an abstraction works at Pella Mission. The scheme was first implemented in 1979, before which the various towns made use of groundwater. This scheme is owned and operated by Pelladrift Water (See **Figure 3.16**) and has an allocation of 4.48 million m^3/a from the Orange River.

n) Namakwa Water Board Water Supply Scheme

This scheme was constructed due to insufficient water resources from boreholes. The works comprises of abstraction works on the Orange River at Henkriesmond, the purification works at Henkries, several pump stations as well as pipelines to reservoirs at the bulk consumers. Springbok, Okiep, Nababeep, Steinkopf, Concordia, Carolusburg and Kleinsee are supplied with purified water from this scheme. The scheme consists of an inlet plus pump station in the Orange River, supplying water to a Sedimentation Dam. From this dam water is pumped through a 475 mm rising main of 9.5 km length to Henkries, where the water is treated and pumped over a distance of 35.2 km through a 419 mm pipeline. A booster pump has been installed to help supply the water to a reservoir of 6 800 m^3 at Eenrietberg. From this reservoir at Eenrietberg water is released under gravity over a distance of 54.5 km, to supply water to the users at Concordia, Okiep reservoir (11 200 m^3), Springbok and Nababeep. Kleinsee is supplied via a pipeline from the Springbok Reservoir. This scheme is owned and operated by Namakwa Water (See **Figure 3-16**).

o) Vioolsdrift and Noordoewer Irrigation Area (RSA and Namibia)

Vioolsdrift and Noordoewer irrigation areas are supplied through a canal system fed by the Vioolsdrift Weir on the Orange River. The canal originates on the left bank. All land on the northern (right) bank is inside Namibia. The capacity of the first reach of 13 km of the canal is 1,28 m^3/s. This canal is also referred to as the Vioolsdrift canal. Within this reach a syphon feeds some water to the Noupoort Canal on the north (right) bank, supplying water to three plots. The water is then fed through the Vioolsdrift syphon to the right bank. The length of second reach (called the Noordoewer Canal), is 8 km with a capacity of 0.99 m^3/s. At the Rooiwal syphon, water is transferred to the left bank canal, called the Rooiwal Canal. At the end of the Noordoewer Canal, after the syphon, the canal extends a further 4 km with a capacity of 0.09 m^3/s. This canal is referred to as the Duifieloop Canal.

The Rooiwal Canal has a capacity of 0.71 m^3/s and is 1.7 km long. The Rooiwal Canal splits into two canals: the Duin Canal, 2.5 km in length with a capacity of 0.26 m^3/s, and the Swartbas Canal, 2.5 km long with a capacity of 0.45 m^3/s. The Swartbas syphon transfers water to the Modderdrift main canal on the right bank, 2.5 km in length with a capacity of 0.26 m^3/s. At the end of the Modderdrift main canal, the capacity of the canal reduces to 0.09 m^3/s for 2.4 km. This canal is called the Modderdrift North Branch Canal. At the point where the Modderdrift main canal reduces in capacity, some water is transferred to the left bank through the Modderdrift syphon. This left bank canal, the Modderdrift South Branch Canal, is 3.1 km long with a capacity of 0.40 m^3/s. The scheduled area for Vioolsdrift (RSA) amounts to 600 ha and for the Noordoewer (Namibia) area 284 ha. This scheme has been transferred to, and is operated by, the Vioolsdrift and Noordoewer Joint Water Authority. **Figure 3-20** shows a schematic layout of the Vioolsdrift and Noordoewer Irrigation Area.

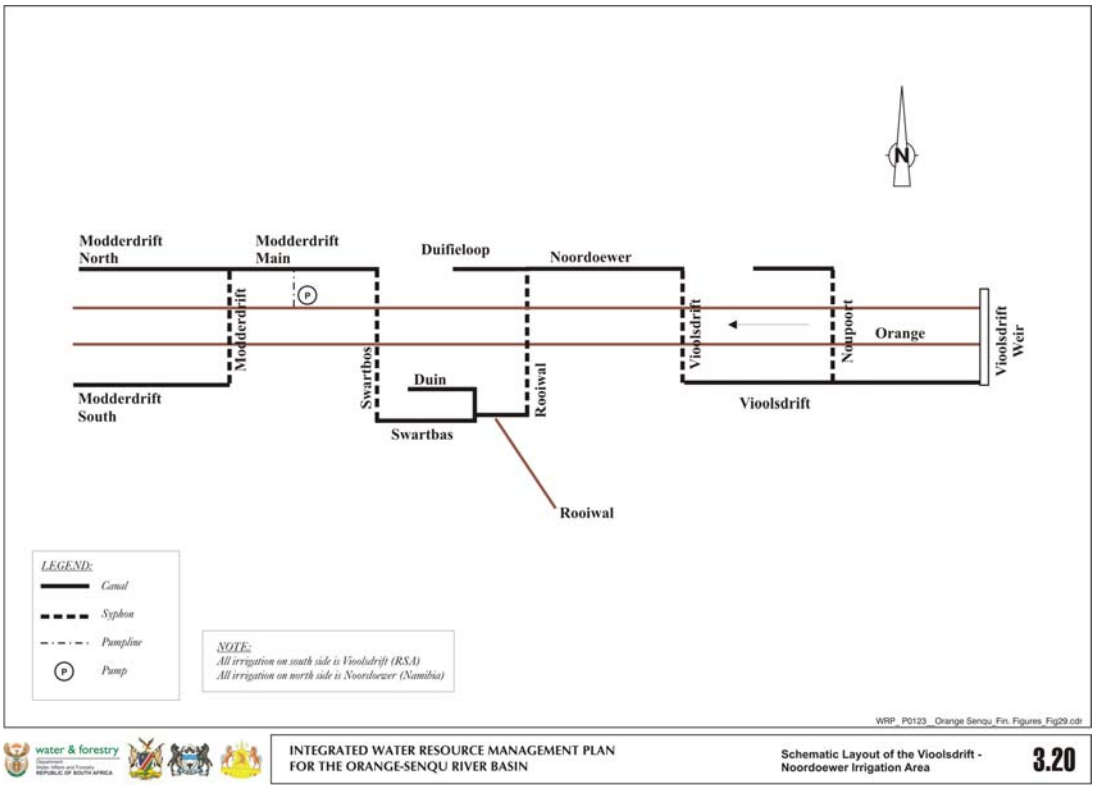

Figure 3-20 : Schematic Layout of the Vioolsdrift-Noordoewer Irrigation Area

p) Alexander Bay

Well points in the Orange River near Oppenheimer Bridge are used to supply the domestic and mining water requirements of Alexander Bay, as well as Port Nolloth to the south. There is also 761ha of irrigated land on the left bank upstream of Oppenheimer bridge, supplied with water from the Orange River by means of direct river abstractions.

q) Namibian urban and mining from the Orange River

Water for Oranjemund domestic purposes is abstracted from the alluvial aquifer at the Orange River mouth. The mining processes at Oranjemund only use seawater. The water supplied to Rosh Pinah and the Skorpion Mine is abstracted with pumpsets in a vertical water tower. The water abstracted at Noordoewer and Rosh Pinah is purified before distribution for domestic use. There is also a raw water pipeline from the abstraction tower to the Skorpion Mine.

r) Namibian irrigation from the Orange River

The Noordoewer Vioolsdrift irrigation scheme is a combined Namibia/RSA scheme and was already described on page 92 of this report.

At the other places such as the irrigation farms and small mines the water is abstracted with a mobile pump set that can be moved away when the water level in the river rises. Approximately 2 600 ha (excluding Noordoewer) are irrigated by riparian abstraction on the right bank of the Orange River. The largest development of this type is at Aussenkjer, between Noordoewer and the Fish River Confluence.

Small Water Supply Systems

Smart Syndicate

This scheme consists of the Smart Syndicate Dam with gross storage of 101 million m^3 and supplies water to 1 818 ha of irrigation. However, due to the low assurance of supply only 16% of the total area is irrigated on average

Water Treatment Works: Table 3.14 lists Water Treatment Works with their respective capacities and operators. Most of the systems are operated by the municipalities.

Table 3.14: Summary of Water Treatment Works in the Lower Orange

Water Treatment Works				Raw Water Source
Name of Town	Capacity (Ml/d)	Capacity (mcm/a)	Owner	
Upington Municipality	60	21.92	Kharahais Waterboard	Orange River
Pelladrift	Unknown assumed 5.16)	1.88	Pella Water Board	Orange River
Henkries	10	3.65	Namakwa water	Orange River
Karos Geelkoppen	No information	No information	KarosGeelkoppan Water Board	Orange River
Prieska	15,0	5.48	Siyathemba municipality	Orange River
Strydenburg	No information	No information	No information	No information
Vosburg	No information	No information	No information	No information
Britstown	No information	No information	No information	No information

Name of Town	Water Treatment Works			Raw Water Source
	Capacity		Owner	
	(Ml/d)	(mcm/a)		
De Aar / Bellary	No information	No information	No information	No information
Victoria West	No information	No information	No information	No information
Hutchinson	No information	No information	No information	No information
Richmond	No information	No information	No information	No information
Kenhardt	No information	No information	No information	No information
Copperton/ Proteapark	No information	No information	No information	No information
Vanwyksvlei	No information	No information	No information	No information
Carnarvon	No information	No information	No information	No information
Loxton	No information	No information	No information	No information
Fraserburg	No information	No information	No information	No information
Sutherland	No information	No information	No information	No information
Williston	No information	No information	No information	No information
Brandvlei/ Jonkerskop	No information	No information	No information	No information
Lime Acres	No information	No information	No information	No information
Griekwastad	No information	No information	No information	No information
Niekerkshoop	No information	No information	No information	No information
Douglas	No information	No information	No information	No information
Prieska	No information	No information	No information	No information
Westerberg/ Koegasbrug	No information	No information	No information	No information
Marydale	No information	No information	No information	No information
Groblershoop	No information	No information	No information	No information
Upington	No information	No information	No information	No information
Louisvale/Oranjevallei	No information	No information	No information	No information
Klippunt	No information	No information	No information	No information
Kanoneiland	No information	No information	No information	No information
Keimoes / Tierberg	No information	No information	No information	No information
Eksteenskuil	No information	No information	No information	No information
Kakamas / Lutzburg / Cillie	No information	No information	No information	No information
Mier	No information	No information	No information	No information
Askham	No information	No information	No information	No information
Augrabies	No information	No information	No information	No information
Marchand	No information	No information	No information	No information
Pella	No information	No information	No information	No information
Pofadder	No information	No information	No information	No information

Name of Town	Water Treatment Works			Raw Water Source
	Capacity		Owner	
	(Ml/d)	(mcm/a)		
Aggeneys	No information	No information	No information	No information
Black Mountain	No information	No information	No information	No information
Onseepkans	No information	No information	No information	No information
Concordia	No information	No information	No information	No information
Vioolsdrift	No information	No information	No information	No information
Kuboes	No information	No information	No information	No information
Alexander Bay	No information	No information	No information	No information
Port Nolloth	No information	No information	No information	No information
Steinkopf	No information	No information	No information	No information
Nababeep	No information	No information	No information	No information
Okiep	No information	No information	No information	No information
Springbok/Bergsig	No information	No information	No information	No information
Matjieskloof / Simonsig	No information	No information	No information	No information
Kleinzee	No information	No information	No information	No information
Komaggas	No information	No information	No information	No information
Koiingnaas (De Beers Mine)	No information	No information	No information	No information
Kamieskroon	No information	No information	No information	No information
Hondeklipbaai	No information	No information	No information	No information
Kharkams	No information	No information	No information	No information
Garies	No information	No information	No information	No information

Note: Unknown or no information – Data not available from existing reports

3.3 Namibia

3.3.1 Introduction

The water supplied in the Orange River basin in Namibia is obtained from surface water impounded in dams on the ephemeral rivers, surface water abstracted from the perennial Orange River along the common border with South Africa and groundwater sources.

The configuration of the water supply infrastructure is more or less the same at each urban centre, village or minor settlement, depending on whether the water is supplied from a dam, an aquifer or abstracted directly from the perennial Orange River.

3.3.2 Number of Urban Water Supply Schemes

In the analysis that was carried out in the year 2000 regarding the present and future water demand in Namibia, an overview was given on the number of urban water supply schemes. There are at present about 28 major and minor urban water supply schemes in the area under consideration. Please see **Table 3.15** for a summary of the urban centres and the type of water supply scheme.

Table 3.15: Urban Water Supply Schemes in the Orange Basin in Namibia

CATCHMENT	NUMBER OF SCHEMES			
	TOTAL	WATER SUPPLIED FROM		
		DAMS	BOREHOLES	ORANGE RIVER
Auob	7	2	5	0
Fish	13	2	11	0
Nossob	10	2	8	0
Orange	8	1	5	2
TOTAL	28	7	19	2

3.3.3 Typical Layout of the Water Supply Schemes

Water supply from Dams

The water supply schemes obtaining water from dams in the ephemeral rivers are at Rehoboth, Gobabis, Omitara, Keetmanhoop, Mariental, Oamites and Karasburg. A summary of the dam data is provided in **Table 3.16**.

Table 3.16: Summary of Dam Data

River	Dam	Type	Capacity (Mm^3)	95% Assured safe yield (Mm^3/a)	Treatment Capacity (m^3/h)	Demand Centre
Oanob	Oanob	Conrete arch	35	4,2	720	Rehoboth
White Nossob	Otjivero Main	Concrete gravity	9,8	1,4	7,5	Gobabis Omitara
White Nossob	Otjivero Silt Trap	Embankment	7,8	0	0	Main Dam
Black Nossob	Daan Viljoen	Concrete gravity	0,3	0	0	Tilda Viljoen
Black Nossob	Tilda Viljoen	Embankment	0,5	0	400	Gobabis
Fish	Hardap	Rockfill	294	50	350	Mariental
Loewen	Naute	Conrete arc	84	12	450	Keetmanshoop

Hom	Dreihuk	Rockfill and cutoff wall	16	0	50	Karasburg
Usib	Nauaspoort	Embankment	5	0	25	Oamites

a) Oanob Dam (Auob Catchment)

Water is supplied to Rehoboth from the Oanob Dam on the Oanob River which is an endoreic, ephemeral watercourse system in the Auob catchment of the Orange River. The dam is a double curvature arch structure and the full storage capacity of the reservoir is 35 million cubic metres. The 95% assured safe yield of the dam is 4,2 million cubic metres per annum. Raw water is treated at a purification plant with a capacity of 720 cubic metres per hour and the water is stored in two 2 500 megalitre concrete reservoirs at Rehoboth. The 4 kilometre long raw water pipeline from the 54 metre high abstraction tower in the dam to the water treatment plant at Rehoboth is a 400 millimetre diameter fibre-reinforced cement pipe with a capacity of 1 200 litres per second.

b) Otjivero Dam (Nossob Catchment)

Water is supplied to Gobabis and Omitara from the Otjivero Dam on the White Nossob River, as well as from the Daan Vijoen Dam on the Black Nossob River. Raw water from the Daan Viljoen Dam is pumped into the Tilda Vijoen Dam which is a pumped storage dam located next to the Daan Viljoen Dam. The Otjivero Dam has a Main Dam and a Silt Trap Dam. The full storage capacity of the Main Dam is 9,8 million cubic metres and the full storage capacity of the Silt Trap Dam is 7,8 million cubic metres. The 95% ussured safe yield of the system is 1,4 million cubic metres per annum. Raw water is treated at a small purification plant with a capacity of 150 cubic metres per day at the dam to supply Omitara with water and the water for the town is stored in a 500 megalitre concrete reservoir on a hill at the dam. Raw water is also treated at a purification plant with a capacity of 400 cubic metres per hour at Gobabis and the water is stored in two 2 500 megalitre concrete reservoirs at the town. The 110 kilometre long raw water pipeline from the dam to the water treatment plant at Gobabis is a 450 millimetre diameter fibre-reinforced cement pipe with a maximum capacity of 117 litres per second. The water resources for Gobabis are augmented from groundwater as the availability of water from the dams is unreliable.

c) Naute Dam (Fish River Catchment)

Urban: Water is supplied to Keetmanshoop from the Naute Dam on the Loewen River in the catchment of the Fish River. The dam is a double curvature circular arch structure and the full storage capacity of the reservoir is 84 million cubic metres. The 95% ussured safe yield of the dam is 12 million cubic metres per annum. Raw water is treated at the dam in a purification plant with a capacity of 450 cubic metres per hour. The 1, 9 kilometre long raw water pipeline from the dam to the water treatment plant is a 500 millimetre steel pipe (lined and wrapped in bitumen) with a capacity of 124 litres per second. The 44 kilometre long purified water pipeline from the dam to the two 3 000 kilolitre terminal reservoirs at Keetmanshoop is a 380 millimetre diameter steel pipe (lined and wrapped in bitumen) with a capacity of 56, 5 litres per second. There is one booster pump station along the pipeline.

Irrigation: Raw water is also supplied under gravity through a 2 kilometre long 350 millimetre diameter steel pipeline to a 270 hectare irrigation scheme downstream of the dam.

d) Hardap Dam (Fish Catchment)

Urban: Water is supplied to Mariental from the Hardap Dam on the Fish River. The dam is a rockfill embankment with an upstream impervious bituminous concrete blanket and the full storage capacity of the reservoir is 294 million cubic metres. The 95% ussured safe yield of the dam is 50 million cubic metres per annum. Raw water is treated in a purification plant downstream of the dam and supplied into a 2 000 kilolitre reservoir from where the water gravitates about 20 kilometres through a two UPVC pipelines to a terminal reservoir in Mariental. The pipeline on the eastern side of the Fish River is 300 and 250 millimetres in diameter and the line on the western bank of the river is 200 millimetres in diameter.

Irrigation: The dam also supplies raw water to a 2 000 hectares irrigation scheme by means of 16 kilometres of concrete lined canals and distribution pipelines.

e) Nauaspoort (Auob Catchment)

Water is supplied to Oamites from the Nauaspoort Dam on the Usib River which is an endoreic, ephemeral watercourse system in the Auob catchment of the Orange River. The dam is an earthfill embankment with a clay core and the full storage capacity of the reservoir is 5 million cubic metres. The dam has no assured safe yield and the water supply is augmented with a number of boreholes. There is an 18 kilometre long asbestos cement pipeline with a capacity of 15 litres per second from the dam to a 4 000 kilolitre concrete reservoir at Oamites. At Oamites there is a small raw water treatment plant with a capacity of 25 cubic metres per hour.

f) Dreihuk (Lower Orange)

Water is supplied to Karasburg from the Dreihuk Dam on the Hom River which is an ephemeral watercourse flowing into the lower Orange River. The dam has a rockfill embankment on the downstream side and a vertical reinforced concrete seal on the upstream side. The full storage capacity of the reservoir is 16 million cubic metres and the dam has no assured safe yield. The water supply to Karasburg is augmented from the Bondelsdam and a number of boreholes. There is a small water treatment plant with a capacity of 50 cubic metres per hour at Karasburg, about 5 kilometres from the Dreihuk Dam.

g) Water supply from Boreholes

The water supply schemes for the 14 major urban centres comprise a number of boreholes, depending in the size of the supply point and to make provision for standby facilities. The water is pumped from the boreholes by means of diesel engines or electric motors where electricity is available.

The water at the urban centres is normally stored in a concrete ground level reservoir and pumped to an elevated reservoir or pumped directly into a water tower. Gravity fed water reticulation systems are generally well established in the towns and villages. Access to the water is through centrally located standpipes or a yard connection and house connections.

h) Water supply from the Orange River

As the water supply from the Orange River to Namibia along the common border forms part of the total supply from the Orange River Project (Gariep and Vanderkloof dams), the description of the water supply to Namibia from this source is given in **Section 3.2.3.**

i) Rural Water Supply Schemes

There are more than 840 rural water supply schemes in the Orange Basin within Namibia. These rural water schemes comprise one or a number of boreholes, depending in the size of the supply point and to make provision for standby facilities. The water is pumped from the boreholes by means of diesel engines. In some cases where boreholes have run dry at the minor settlements, water is supplied by means of a water tanker.

The borehole water is normally stored in a ground level reservoir or elevated reservoir (mostly plastic tanks) where a reticulation system has been provided. Access to the water is through centrally located standpipes at a water point. Drinking troughs are provided some distance away from a water point to give livestock access to water.

j) Sufficiency of Water Supply Infrastructure

A study was done to determine of the sufficiency of the existing water supply schemes to meet the estimated future water demand. About 12 urban centres had some insufficiency due to borehole yield, or pipeline capacity or pump capacity or reservoir capacity. It seems as if none of the identified constraints cannot be rectified, and the supply of water is assured until at least 2015.

Another source of concern is the fact that water supply losses are as high as 40% in some rural water supply schemes and reticulation networks supplied from the urban water schemes. Considerable work should be done to reduce those losses.

4 OPERATION OF THE CURRENT SYSTEM

4.1 Botswana

The water requirements in Botswana within the Orange River Basin are only supplied from groundwater resources. The requirements are in general relatively small and each supply point is operated as an individual system, requiring no complex operating rules. The main aim is to supply in the basic needs and to make provision for standby facilities.

4.2 Lesotho

The Lesotho Highlands Water Project (LHWP) is the only major water supply scheme in Lesotho. The LHWP is used to supply water to the RSA, mainly Gauteng area and therefore forms part of the Integrated Vaal River System. The operation of the LHWP is therefore described under the Operation of the Integrated Vaal River System.

No large surface storage dams are currently utilized in Lesotho to supply the current water requirements. The Lesotho Lowlands Study which was recently completed, however, investigated various options of possible storage dams to be able to supply in the increasing demand in Lesotho. The current groundwater resources and surface water from runoff river abstractions and wellpoints in river beds is not sufficient to supply in the future demand within Lesotho.

Similar to Botswana, the various schemes are all operated as stand alone schemes and do not require complex operating rules. Although there should be some form of operating procedure to be able to supply the basic water requirements and to protect the resources, no description in this regard were given in the existing reports.

4.3 Namibia

Although a large portion of the Namibian water requirements are supplied from groundwater resources, several medium to large surface water storage dams in Namibia are also used for this purpose. The dams used for water supply purposes in Namibia are listed in **Table 4.1** except for Gariep and Vanderkloof dams which are also utilised to supply Namibian demand along the common border between the RSA and Namibia.

The operating procedures and assurance of supply to the Namibian demands along the common border is as described in general in **Section 4.4.1** and for the Orange River Project in **Section 4.4.3**.

Table 4.1: Summary of Dam data

River	Dam	Type	Capacity (Mm^3)	95% Assured safe yield (Mm^3/a)	Demand Centre
Oanob	Oanob	Conrete arch	35	4,2	Rehoboth
White Nossob	Otjivero Main	Concrete gravity	9,8	1,4	Gobabis Omitara
White Nossob	Otjivero Silt Trap	Embankment	7,8	0	Main Dam
Black Nossob	Daan Viljoen	Concrete gravity	0,3	0	Tilda Viljoen
Black Nossob	Tilda Viljoen	Embankment	0,5	0	Gobabis
Fish	Hardap	Rockfill	294	50	Mariental
Loewen	Naute	Conrete arc	84	12	Keetmanshoop
Hom	Dreihuk	Rockfill and cutoff wall	16	0	Karasburg
Usib	Nauaspoort	Embankment	5	0	Oamites

Detailed operating rules were developed for the Hardap Dam water supply system as part of a recent study completed 'Flood Risk Reduction: Marietal Town and Hardap Irrigation Scheme' for Namibia to reduce flooding and related damage at Mariental and the Hardap irrigation scheme.

The basic principles that were used for the development of the operating rule for Hardap Dam was based on those used in the RSA. For background and more detail on this approach the reader is referred to **Sections 4.4 & 4.4.1**.

Based on this approach, the priority classification as applicable to the Hardap System is summarised in **Table 4.2**. From this table it is evident that the bulk of the irrigation is supplied at an 80% assurance (possibility of not supplying the full demand on average once in 5 years) which is regarded as the low assurance category. The urban requirement is all supplied at the high assurance (95%) category.

Hardap Dam is also partly used for flood absorption purposes to provide some protection for Mariental Town and the irrigation scheme. Flood control at Hardap Dam is therefore currently partly achieved by storing water at levels lower than the full supply level (assuming full supply level is equal to the top of the gates). By doing this a larger portion of the flood is absorbed in Hardap Dam and could then be released after the flood peak, to reduce flooding at Mariental Town, downstream of Hardap

Table 4.2: User Categories and Priority Classifications for Hardap

User Category	Priority Classification & Assurance of Supply		
	Low 80% 1 in 5 year	Medium 90% 1 in 10 year	High 95% 1 in 20 year
Urban/industrial	0%	0%	100%
Irrigation	83%	17%	0%
Canal Losses	50%	50%	0%

Based on the findings of the yield analysis, it was decided that the operational full supply level for Hardap Dam can be reduced to the 70% storage level or 1131.62 masl. With this operational full supply level (FSL) the dam will still be able to supply the users at the required assurance of supply.

During wet periods it also means that as soon as the water level in the dam rises above the operational FSL, water need to be released from the dam into the river, to keep the dam at this level to allow for some flood absorption by the dam during high flow periods.

The operating rule includes the following:

- Each year on 1 May, use the curtailment curve based on short-term stochastic yield characteristics, to determine whether there is a surplus or deficit in the sub-system. When there is a deficit in the sub-system, use this curve (See **Figure 4-1**) to determine the required curtailment level
- If there is a deficit in the sub-system, impose curtailments according to the agreed priority classification as given in **Table 4.2**. First curtail the low assurance use, then the medium, followed by the high assurance use.
- The required curtailment need to be spread evenly over the 12 months, until 30 April of the next year, when the curtailment will be adjusted based on the storage level in the dam on 1 May of that year.
- A storage projection plot for the current year is included and the actual observed storage on the first of each month must be plotted on the storage projection to monitor the behaviour of the system. If the observed storage is plotting outside the projection plot, management need to be informed as additional actions may be required to protect the resource.

- When the water level in the dam rises above the operational FSL of 1131.62 masl., water must be released from the dam into the river to prevent the dam level to raise above the 1131,62 masl level.

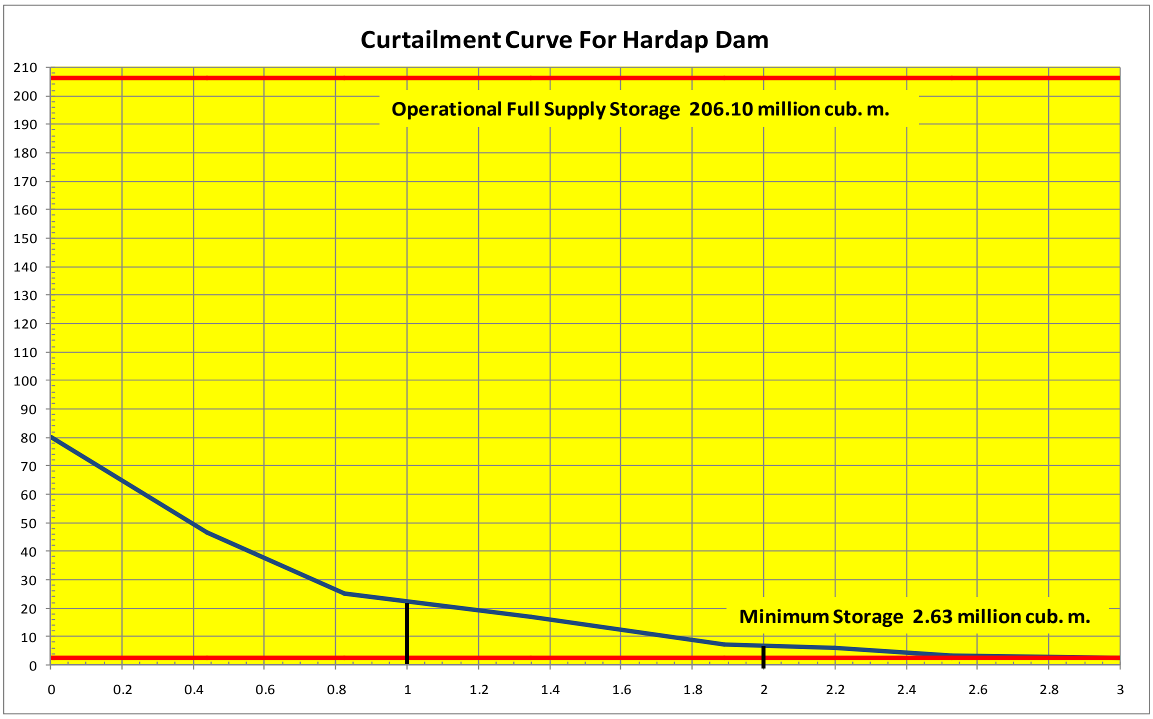

Figure 4-1: Hardap System Curtailment Curve

The 95% assured safe yield is in general used in Namibia for water supply to urban/industrial areas and 80% for irrigation purposes. This assurance is however based on calculations using only the historic flow sequence and therefore differs from the method used by the RSA.

Detail descriptions of the operating rules for the other dams were not available from existing reports. In general, however, restrictions in water supply are imposed on users when the available water in the dam is less than 2 times the annual demand imposed on the dam. This will however differ from scheme to scheme and also depends on the availability and reliability of groundwater resources.

4.4 Republic of South Africa

Two trigger mechanisms are generally used in the operating rules applied in South Africa. The first trigger mechanism used is specific i.e. fixed levels in the dams are selected and used to control the event when supply to a specific user should cease or commence, and to be able to reserve water for users that can only be supplied from this resource. When there is a growing demand imposed on a dam, these fixed levels need to be adjusted often, as a different level will obviously be required when the total demand increased or decreased over time.

The second trigger mechanism is the use of the short-term yield capability of the sub-system which is compared with the demand imposed on the sub-system. When the balance is negative water from another possible resource need to be used or curtailments need to be imposed. This option or trigger mechanism is used in most of the sub-systems and are in some cases combined with trigger mechanism 1 (fixed dam levels). The benefit of the second trigger mechanism is that the short-term yield as well as the demand imposed on the system can be compared at the desired assurance levels of supply.

The following four important principles were in most cases built into the operating rules developed for the Orange and Vaal River systems:

- General operating principle – Operate the system as an integrated system in order to obtain the maximum yield benefit from the system.
- Maintain the assurance of supply to users – This is the primary objective of the operating rules and for the operation of the Orange and Vaal systems.
- Cost saving operating rules – The secondary objective of the operating rules is to implement rules that will, where possible, reduce the cost of water supply.
- Restriction of demands – The operation of the system needs to be based on the principle that demands are restricted during severe drought events.
  - The objective of these restrictions is to reduce supply to less essential use to be able to protect the assurance of supply to more essential use.
  - The basis on which restrictions are implemented is defined by means of the user priority classification definition as explained in **Section 4.4.1**.

In South Africa, operational analyses of the Orange and Vaal River systems are carried out on an annual basis. These analyses are used to determine possible shortages and surpluses in the system and also to advise the operators in advance regarding the adjustments in transfers or curtailments to be imposed, in order to prevent failures in water supply. These adjustment and/or curtailments are undertaken according to the priority classification for a specific system or sub-system. The following section discusses in detail the priority classification as applied in South Africa.

4.4.1 Background on Priority Classification in SA

The Priority Classification is an agreed set of required portions of the water supply at a particular assurance/reliability for different user sectors. Different assurance classes are defined from a low to a high assurance. The requirement for each user sector is sub-divided into the different assurance classes. During drought periods and related water shortages, the water use allocated to the low assurance is curtailed first and that to the high assurance last.

Two models *(i.e the Water Resource Yield Model (WRYM) and the Water Resource Planning Model (WRPM))* are used to determine and manage priority classification. The Water Resources Yield Model (WRYM) is used to determine the system yield for different possible scenarios in the sub-systems, and also to determine the system yield at different reliability levels, by means of stochastic yield analysis. The output results from the WRYM are the yield characteristics for both long and short term periods. At low reliability levels the system can typically provide a higher yield than would be available at a high reliability level.

The Water Resources Planning Model (WRPM) uses the yield characteristics as obtained from the WRYM, in planning and operational analyses, to supply the system demands at the required level of assurance. Irrigation or urban garden watering will for example be supplied at a lower assurance than strategic industries and drinking water. 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 each represent a different assurance or reliability level.

One of the inputs required by the WRPM when analysing a system, is a set of guidelines on how to implement water restrictions in the catchment, as and when required. The method of allocating the supply of available water to users on the basis of the current supply characteristics of the various components of a system, is built into the WRPM. This requires that the different water users should be grouped together into user categories and these categories should be classified according to the required priority for water supply. The user categories can be split into a number of different levels of assurance of supply, and an example of such categories are indicated in **Table 4.3**. In this way a portion of the demand for a specific user category (for instance Domestic/Industrial) 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 low level of assurance (e.g. garden watering).

The WRPM is used to analyse the system and allocate water to maintain the assigned assurance of supply for all the users in the different user categories, subject to any physical constraints that may exist. Restrictions in water supply are applied first to the water use allocated to the low assurance level, which in this case is the 95% assurance level (possibility of a shortage in the supply of an average, once in 20 years). The WRPM will only start to impose curtailments on the level 2 water use (the 99% assurance level), when all of level 1 (the 95% assurance level) has been curtailed. In a similar way, curtailments will each time only be imposed on the higher assurance level, if all the water allocated to the lower assurance level has been curtailed in full. There could be a number of curtailment levels used for the system. For the Integrated Vaal River System there are 3 curtailment levels, and curtailment level 1 represents the curtailments being imposed on the low assurance supply (95%), curtailment level 2 for the medium assurance level (99%) and curtailment level 3 for the high assurance level (99.5%).

Table 4.3:User category and priority classifications for the Integrated Vaal River System

System and User Category	Priority Classification (%)		
	Low (95% assurance) (1:20 year)	Medium (99% assurance) (1:100 year)	High (99,5% assurance) (1:200 Year)
Domestic	30%	20%	50%
Industrial	10%	30%	60%
Irrigation	50%	30%	20%
Strategic Industries	0%	0%	100%
Curtailment level 0	1	2	3

These curtailments are determined by comparing the short-term stochastic yield characteristic curves that were determined with the WRYM for various start storage levels, with the demand imposed on the system. These yield characteristics are then included in the data input files of the WRPM, together with the demands imposed on the system at different assurance levels. The short-term yield is very sensitive to the available storage in the dam at the beginning of a short-term planning period. When the dams are 100% full, the short-term available yield will typically be higher than the long-term stochastic yield at the same assurance level of supply. At the other extreme, when the dams are at a low level at the beginning of the short-term planning period, the short-term yield will be significantly lower than the long-term yield at the same assurance level of supply. Under such conditions it would then be required to curtail the demand to such a level that the water resources are protected and that the water supply will not exceed the predetermined risk of failure as defined for the different user categories.

Table 4.4 below illustrate the procedure on how curtailments are determined and implemented in the River Sub-system. When the agreed priority classification is imposed on the River Sub-system demands, the result will be as shown in **Table 4.4**. For the scenario where the short-term stochastic yield showed that the yield available is more than or equal to the total demand, no curtailments are required and 100% of the demand can be supplied, as indicated in **Table 4.4**. This means that 590 million m³/a is supplied at a low assurance of which 321 million m³/a is for urban/industrial use and 269 million m³/a for irrigation purposes. Another 551 million m³/a is supplied at the medium assurance with the split between urban/industrial, large industrial and irrigation as given in the table. At the high assurance level, 1 215 million m³/a of the demand is allocated with the split between urban/industrial, large industrial, irrigation and strategic industries as shown in **Table 4.4.**

Table 4.4: Priority Classification for the Integrated Vaal River Sub-system demands

User Category	Priority Classification & Assurance of Supply (million m³/a)			Total (million m³/a)
	Low 1:20 year	Medium 1:100 year	High 1 in 200 year	
Urban/Industrial	321	350	787	1 458
Large Industrial	0	40	94	134
Irrigation	269	161	108	538
Strategic Industries	0	0	226	226
Total	590	551	1 215	2356

When the storage level in the dam decreases and the short-term yield indicates that only 1 955 million m³/a can be supplied (83% of total demand), the users allocated to the low assurance are curtailed first. This means that the system needs to be curtailed by (2 356–1 955) = 401 million m³/a. This is less than the total volume allocated to the low assurance and therefore one only needs to curtail the low assurance users, and in this case by 401 million m³/a or 68% of 590 million m³/a, so that only 32% of the demand allocated to the low assurance can be supplied as indicated in **Table 4.5**. For this scenario the medium and high scenarios can all still be 100% supplied so that the supplies to the higher assurance users are protected. Due to the fact that a higher portion of the irrigation demand is allocated to low assurance it can be seen that only 66% of the total irrigation demand is supplied compared to 85% of the Urban/industrial and 100% of the Strategic Industries and Large Industrial water requirement.

Table 4.5: An example of a River Sub-system allocation decision for curtailments

User Category	Priority Classification & Assurance of Supply (million m³/a)			Total Supplied (million m³/a)	Total Demand (million m³/a)
	Low 1:20 year	Medium 1:100 year	High 1 in 200 year		
Total allocated	189	551	1215	1955	2356
Proportion supplied	32%	100%	100%	83%	100%
Allocation to individual users					
Urban/Industrial	103	350	787	1240 (85%)	1458
Large Industrial	0	40	94	134 (100%)	134
Irrigation	86	161	108	355 (66%)	538
Strategic Industries	0.00	0.00	226	226 (100%)	226
Total	189	551	1215	1955	2356

For the scenario where the short-term yield shows that the dam can only supply 942 million m³/a (40% of total demand), then all the users need to be curtailed as shown in **Table 4.6.** This means that only 16 % of the irrigation, 42% of urban/industrial demand, 54% of the large industrial and 78% of the strategic industries can be supplied.

Table 4.6: An example of a River Sub-system allocation decision for curtailments

User Category	Priority Classification & Assurance of Supply (million m³/a)			Total Supplied (million m³/a)	Total Demand (million m³/a)
	Low 1:20 year	Medium 1:100 year	High 1 in 200 year		
Total allocated	0	0	942	942	2356
Proportion supplied	0%	0%	77.5%	40%	100%
Allocation to individual users					
Urban/Industrial	0	0	610	610 (42%)	1458
Large Industrial	0	0	73	73 (54%)	134
Irrigation	0	0	84	84 (16%)	538
Power stations	0.00	0.00	175	175 (78%)	226
Total	0	0	942	942	2356

The following section provides more detail on the actual operation of the Integrated Vaal River System.

4.4.2 Operation of the Integrated Vaal River System

Main System

Being the principal source of water supply to Gauteng, the Vaal River System is perhaps South Africa's most important system – certainly the most over-utilised river system. For the purpose of the operation of the Integrated Vaal River System, it is important to distinguish between the Main Vaal System and the smaller sub-systems in the Vaal. The Main Vaal System consists basically of four major storage dams in the Vaal River Basin, i.e. the Grootdraai Dam, Sterkfontein Dam, Vaal Dam and Bloemhof Dam. These dams are all located on the main stem of the Vaal River with the exception of Sterkfontein Dam which is on the Wilge River tributary. Added to the Main Vaal System is several transfer schemes, which together with the main system forms the Integrated Vaal River System. Considerable volumes of water are transferred to and from neighbouring catchments and this are largely dictated by the population needs, economic activity and infrastructure constraints in the WMAs and sub-systems. To enable these transfers and to meet the spiraling water demands in an efficient manner, specific operating rules were developed and implemented for the various water transfer schemes.

Within the Vaal River Basin there are several smaller sub-systems which are all operated separately from the main system. The details of the smaller sub-systems are included in the system models, but it is only the spillage from these sub-systems that reaches the Main Vaal System. These smaller sub-systems are not used to support the Main Vaal System and are operated separately.

The operation of the Integrated Vaal River System is very complex and operational analyses are carried out on an annual basis using the WRPM. These analyses are used to determine possible shortages and surpluses in the system and to advise the operators to make adjustments in transfers or impose curtailments in advance. This is done according to the required assurance levels applicable to the different users as defined in the priority classification (See **Section 4.4.1**), in order to prevent unacceptable and disastrous failures in the water supply to the users.

The Integrated Vaal River System is not used to support the Orange River System, but is rather operated to minimise spills into the Orange River, as large volumes of water are transferred into the Vaal River System from neighbouring catchments at high cost, to augment the growing demand in the Vaal System. Consequently, water from Sterkfontein Dam will only be released to support the Vaal Dam when the Vaal Dam is at a fairly low level (14% of the full supply storage). Releases from the Vaal Dam, to support Bloemhof Dam, are only made when the Bloemhof Dam is at a low level (6% storage). This operating rule will therefore result in lower storage levels in the Bloemhof and Vaal dams, and will, as a result, reduce evaporation and spillage from the two dams, as well as increase the possibility of the dams to capture local runoff. An additional objective included in the annual operating rule analysis is the dilution and blending operating rule as briefly described hereafter:

- *Dilution and blending operating rules:* A large portion of the runoff into the Barrage is due to effluent return flows, mine dewatering and urban storm-water runoff from the southern Gauteng area. There are two possible options for the abstraction of water by Rand Water, from the Vaal System. The total Rand Water requirement can be supplied directly from Vaal Dam as the first option or secondly as a combination from the Vaal Barrage and Vaal Dam. For option one, where only Vaal Dam water is utilised by Rand Water, the dilution rule is applied. This means that water has to be released from Vaal Dam to maintain the TDS concentration downstream of Vaal Barrage at 600mg/l. This is currently the preferred option. For option two, Rand Water abstracts the maximum possible volume of water from the Vaal Barrage. This water needs to be blended with water directly from Vaal Dam to keep the TDS concentration at 300 mg/l. This is referred to as the blending option and no dilution downstream of Barrage is required for this option.

The following sections describe the operating rules adopted for the interbasin transfer schemes.

- **Thukela-Vaal Transfer Scheme:** transferring water from the Thukela WMA to Upper Vaal WMA through the pump storage scheme, with a typical annual long term transfer of 736 million m^3/a. However, the scheme is currently constrained to 630 million m^3/a by the scheme capacity. Water is transferred at a rate of up to 20 m^3/s as long as water is available from Kilburn Dam and until the Sterkfontein Dam is full, however, only 19 m^3/s can be delivered on a continuous basis due to limitations in the canal transferring water from Driel barrage to Kilburn Dam. The normal operating procedure followed for this transfer scheme, is to keep pumping from the Tugela until both Vaal and Bloemhof dams are full. However, when the system storage is at a relatively high level, reduced pumping options are considered through scenario analysis, to be able to reduce pumping costs. It is important to ensure that reduced pumping options will over the long term not impact negatively on the assurance of supply for the integrated Vaal System.
- **The Heyshope - Grootdraai Transfer Scheme**: transferring water from the Usutu WMA to Upper Vaal WMA, with a maximum transfer capacity 3.8 m^3/s. Water is transferred at this rate as long as Grootdraai Dam is below 90% of the live storage. Buffer storage needs to remain in Heyshope Dam. When this buffer level is reached, transfers from Heyshope to Grootdraai Dam are ceased, and only transfers to the Usutu Sub-system are allowed. The buffer storage is reserved to protect the support to the Usutu sub-system. This buffer storage will change in relation to the commissioning of the Vaal pipeline. The following buffer storage will therefore apply: 58 million m^3 for May 2006 to May 2008, 150 million m^3 for May 2008 to May 2018, and 58 million m^3 for 2018 onwards.

- **The Zaaihoek Scheme**: transferring water from the Slang River, a tributary of the Buffalo River in Thukela WMA to the Vaal WMA. The maximum transfer volume to Grootdraai Dam is determined by the difference between the long-term yield of Zaaihoek Dam and the current in-basin water requirements, including the Majuba Power Station requirements. Zaaihoek Dam is the only water resource for Majuba Power Station. Majuba therefore receives priority with regards to its water supply, over any of the other users. Water is transferred to Grootdraai Dam only until Grootdraai Dam has reached 90% of its live storage. The current infrastructure limits the transfer capacity to Grootdraai Dam at a maximum rate of 2.79. Compensation releases need to be made from Zaaihoek Dam as a priority. These releases are based on the normal flow entering the dam, and were determined as 11.4 million m^3/a on average.
- **The Vaal – Olifants Transfer Scheme**: Transferring water from Upper Vaal WMA (Grootdraai Dam) to the Upper Olifants WMA at a maximum rate of 6.5 m^3/s. The transfers are required to supply water to the Sasol – Secunda Complex as well as to power stations located in the Upper Olifants. This is currently the only water resource for the Sasol- Secunda Complex. Komati, Arnot and Hendrina power stations can be supplied from the Komati and Usutu sub-systems. These power stations are first supplied from the Komati and then from the Usutu Sub-system. Camden can only be supplied from the Usutu Sub-system. Duvha can be supplied from all three sub-systems with a maximum of 9 million m^3/a support from the Vaal System, due to water quality problems in Witbank Dam. Duvha will first be supplied from the Komati and Usutu and then from the Vaal Sub-system. Matla, Kriel, and Kendal are supplied first from the Usutu and then from the Vaal Sub-system. The allocation from the different possible resources is based on the short-term stochastic yield characteristics. Compensation releases need to be made from Grootdraai Dam as a priority. These releases are based on the normal flow entering the dam, and are in the order of 20 million m^3/a on average.
- **The Komati-Olifants Transfer Scheme:** Although this scheme does not transfer water directly into or out of the Vaal Catchment, it augments a supply area of the Vaal Catchment in the Upper Olifants WMA for power generation purposes. Water can be transferred at a rate of up to 4.62 m^3/s. The maximum possible volume for the transfer is supplied from Vygeboom Dam with the remainder being supplied from Nooitgedacht Dam. When required, Nooitgedacht Dam is also augmented by

transfers from the Usutu Sub-system. Allowance for compensation releases from Vygeboom Dam (0.65 m^3/s) and Nooitgedacht Dam (0.15 m^3/s) receive priority over any other requirements from the sub-system. (Also see Vaal – Olifants Transfer Scheme for more detail)

- **The Usutu-Olifants Transfer Scheme:** Although this scheme does not transfer water directly into or out of the Vaal Catchment, it augments a supply area of the Vaal Catchment in the Upper Olifants WMA for power generation purposes. Water can be transferred at a rate of up to 3.4 m^3/s. Part of the transfer can be used to support the Komati Sub-system, with the remainder to be used to directly supply the Usutu-Vaal Power Stations. Water is transferred from Jericho Dam which is supported from Morgenstond and Westoe dams. Inter reservoir operating rules determine the support from these two dams to Jericho Dam. Morgenstond Dam can, when required, also be supported by transfers from Heyshope Dam, as soon as Morgenstond Dam is below 35 million m^3 storage. This level will change as soon as VRESAP is implemented. (Also see Vaal – Olifants Transfer Scheme for more detail).
- **The Lesotho Highlands Transfer System:** transferring water from The Lesotho Highlands to the Upper Vaal WMA, with a maximum annual allocation of 867 million m^3/a based on the Lesotho-RSA Treaty. Transfers are to be increased over time until the maximum allocation has been reached. The flow rate is determined annually and is fixed for the whole year regardless of the storage levels in the Vaal River System or in Katse and Mohale dams. It is expected that the transfers will reach the maximum allocation by the 2008/09 planning year. Water can be transferred from Mohale to Katse Dam or visa versa, depending on the difference in the water level of the two dams. When the difference is in excess of 12m, transfers will occur depending on the physical characteristics of the transfer tunnel. Releases in support of the ecological water requirements are a priority from Katse Dam, Matsoku Weir and Mohale Dam.
- **Vaal River Eastern Sub-system Augmentation Project (VRESAP)**: VRESAP is aimed at stabilising and extending industrial water supply to the Sasol - Secunda Complex and the Eskom power stations on the Mpumalanga highveld, The scheme is designed to be able to transfer water at a rate of up to 5.4 m^3/s, even when the water level of the Vaal Dam is at its minimum operating level. The scheme is currently under construction, and the anticipated commissioning date is

November 2008. Priority in supply will be from the VRESAP pipeline when Grootdraai Dam is below 90% of its live storage, and the remainder will then be supplied from Grootdraai Dam. When Grootdraai is above the 90% storage level, the priority of supply will be from Grootdraai Dam and the remainder supplied via the VRESAP pipeline. The volumes to be transferred from each of the resources will be determined by the short-term stochastic yield characteristics.

A significant amount of potable water is provided and distributed by Rand Water, Sedibeng Water and MidVaal Water Company, from the Vaal River System to different areas in the Vaal River Catchment and also outside the bounds of the Vaal River Catchment. The MidVaal Water Company has a major offtake from the Vaal River, in the Klerksdorp – Orkney area. Sedibeng Water has a major offtake from the Vaal River at Balkfontein, upstream of Bloemhof Dam and also abstracts a smaller quantity of water from Allemanskraal Dam. Rand Water has two major offtakes from the Vaal River System, one from Vaal Dam and the other from the Vaal Barrage.

There are also a number of water schemes sourcing their water from the Vaal River System as follows:

- **Vaalharts:** This is the most significant water supply scheme in the Lower Vaal in that it supplies water to the Vaalharts Irrigation Scheme, the largest irrigation scheme in South Africa. Water is sourced from Bloemhof Dam to the Vaalharts weir, situated on the Vaal River between Christiana and Warrenton, from where it is diverted into a canal. The maximum supplied to this scheme is based on the allocated quota plus system distribution losses to be able to supply the water to the edge of the irrigation field. This currently amounts to a total of 442 million m^3/a. In practice, however, approximately 85% of the maximum requirement is diverted from the Vaalharts Weir as the full area is seldom irrigated. The volume diverted from Vaalharts Weir is purely based on the requests from the irrigators. During drought periods, restrictions are imposed based on the priority classification and the short-term yield characteristics.
- **Vaal-Gamagara Scheme:** This Water Supply Scheme was initiated in 1964 to supply water mainly to the mines in the Gamagara Valley in the vicinity of Postmasburg and further north of this town with a maximum allocation of 13.7 million m^3/a. An abstraction works and low-lift pumping station are located on the

Vaal River near Delportshoop, just below the confluence with the Harts River, from where water is pumped to the water purification works situated next to the river. During drought periods, restrictions are imposed based on the priority classification and the short-term yield characteristics.

Smaller Systems

The smaller systems and related dams on the Vaal River tributaries are operated independently from the Main Vaal River System, although spillage from the sub-system dams and flows from unregulated tributaries, are still captured by the Major dams on the Vaal River. Base flows from the tributaries into the Vaal River are also reduced due to the impact of the smaller sub-systems in the different sub-catchments. The smaller systems are therefore discussed separately in the sub-sections to follow:

a) Catchment upstream of Vaal Dam

Most of the catchment upstream of Vaal Dam forms part of the Main Vaal System. Only three relative small dams are found in this area that are operated individually and are not part of the supply to the Main Vaal System. These are Saulspoort Dam in the Ash River, and Metsi Matso and Fika Patso dams in the upper reaches of the Wilge River. Although the transferred water from the LHWP flows into Saulspoort Dam, it is directly released from the dam without storing the water in the dam.

No specific operating rule is documented for any of these smaller dams. In the WRPM analyses a simple operating rule is used for these dams. Based on this operating rule the dam will keep on supplying in the full demand imposed on the dam until the minimum operating level for the dam has been reached. The dam will then only be able to utilise its inflow during the month, less evaporation losses, to supply the demand imposed on the dam.

b) Mooi River Catchment Sub-systems

There are two sub-systems located in this sub-catchment, the Mooi River Government Water Scheme, and the Klipdrift irrigation scheme located on a tributary of the Mooi River.

- **The Mooi River Government Water Scheme** consists of four major sources of water, namely: Klerkskraal Dam, Boskop Dam, Lakeside Dam, and the Gerhard Minnebron Eye. These components are linked by means of concrete lined canals, referred to as the main canals also feeding into the secondary or branch canals. The operating rule currently in use for this scheme is not documented. DWAF is currently in the process to develop short-term stochastic yield characteristics and associated operating rules for this sub-system to be able to operate the resource on a scientific base and to impose restrictions on the water use from this resource during drought conditions. The operating rule currently still used in the WRPM, is to supply the full demand until the minimum operating level in the dams is reached.

- **The Klipdrift Irrigation Scheme** is in the Mooi River catchment and is supplied with water from the Klipdrift Dam located in the Loopspruit, a tributary of the Mooi River. No operating rule is documented. DWAF is currently in the process to develop short-term stochastic yield characteristics and associated operating rules for this sub-system, to be able to operate the resource on a scientific base and to impose restrictions on the water use from this resource during drought conditions. The operating rule currently used in the WRPM analysis is as described for small sub-systems above.

c) Schoonspruit catchment sub-systems

The Schoonspruit and Klerksdorp irrigation schemes are both located in this sub-catchment and are operated as two stand alone schemes. The schemes have the Schoonspruit Eye, Kalk Dam, Elandskuil Dam, Rietspruit Dam and the Johan Neser Dam as their sources of water.

- **The Schoonspruit Irrigation Scheme** receives its water from the Schoonspruit Eye, Kalk Dam, Elandskuil Dam and Rietspruit Dam. A weir has been built to divert the Eye's water into a canal on the Right Bank of the Schoonspruit. The scheme is operated so as to divert the maximum capacity into this canal (i.e. 3039m^3/h), which conveys the water to the Ventersdorp Municipality off-take as well as to irrigation areas located further downstream along the canal system. The canal crosses the Schoonspruit just downstream of the Kalk Dam where there is a structure that can reject excess water from the canal into the Schoonspruit as well as allowing water to flow underneath the Schoonspruit by means of a siphon (pipes) into a canal on the left bank of the Schoonspruit. The canals are flowing full for most of the time, depending on the flow from the Schoonspruit Eye and the water available in the Rietspruit Dam. The outflow at the tail end of the canals simply flows back into Schoonspruit and is captured in the Johan Neser Dam further downstream. The DWAF is currently also in the process of developing proper operating rules for this sub-system, based on the short-term yield characteristics and priority classifications.

- **The Klerksdorp irrigation scheme** was developed around the Johan Neser Dam, which was built in 1914. The major purpose of the dam is to provide water for the irrigation. With time, the water availability has reduced, mainly as result of upstream developments and increasing groundwater abstractions. The dam is operated by the Klerksdorp Irrigation Board and currently the average area irrigated is much smaller than the scheduled area, and the only time when the irrigation supply is not curtailed, is when the dam spills. The operating rule currently used for the dam therefore enforces severe restrictions for most of the time. The operating rule is defined in **Table 6.5**.

Table 4.7: Klerksdorp Irrigation Scheme – curtailment levels

Johan Neser Dam Level	Irrigation Curtailment
≥ 100%	0%
50 – 100%	25%
10 – 50%	50%
≤ 10%	100%

DWAF is currently in the process to develop short-term stochastic yield characteristics and associated operating rules for this sub-system.

d) Renoster River Catchment sub-systems

Koppies Dam is the only Dam in this sub-catchment, except for the farm dams. The Dam supplies water to the irrigators from the Koppies GWS, Koppies urban area and mines. Irrigators abstract water from a canal system as well as directly from the River. Koppies Dam is not allowed to be drawn down below 2.5% due to water quality problems that are experienced under such conditions. Thus, the current operating rule is such that the irrigators starts to be restricted when storage reaches 20% of the full supply capacity, and when the dam falls below 10% of the full supply capacity, the irrigators are not allowed to abstract any water at all, with the remaining 10% reserved for urban and mining use only

DWAF is currently in the process to also develop short-term stochastic yield characteristics and associated operating rules for this sub-system.

e) Vals River Catchment sub-systems

Serfontein Dam is the only water supply scheme in the Vals River catchment and is used to supply part of the Kroonstad town requirement and irrigation water demands. Kroonstad is also supplied by Sedibeng Water with water from the Main Vaal System. No operating rule is documented. In the WRPM water is utilised from Serfontein Dam until the minimum operating level in Serfontein Dam is reached, where after the total water requirement for Kroonstad is supplied from the Main Vaal System.

f) Sand-Vet River catchment sub-systems

The Sand-Vet Irrigation Scheme includes both the Erfenis Irrigation Scheme and the Allemanskraal Irrigation Scheme. These schemes are currently supplied with water from the Erfenis Dam and Allemanskraal Dam, respectively. Erfenis Dam supplies water for the irrigation of 5 489 ha; and any excess water at the canal tail end flows into the Vet River. Downstream of the confluence of the Sand and the Vet River, there is another 1 297 ha of irrigation which is mainly supplied directly from the Vet River. During droughts water is also released from Erfenis Dam in support of the river irrigation, on the condition that there is sufficient water available in Erfenis Dam. For the Allemanskraal Scheme, water is diverted from Allemanskraal Dam into the main canal. This canal then splits into two separate canals downstream of the dam supplying water for irrigation on the left and the right banks of the Sand River. Any excess water at the tail end of these canals flows back to the Sand River.

Marquard, Winburg, Bultfontein and Brandfort are supplied from Erfenis Dam. Virginia has a total allocation of 15.2 million m^3/a from Allemanskraal Dam. Water is first supplied from Allemanskraal to Virginia and the remainder of the Virginia water requirement is supplied by Sedibeng Water from the Main Vaal System.

In the current WRPM setup, these two resources are utilised to supply the demands imposed on the dams until their minimum operating levels are reached, where after only the inflow into the dams can be used to supply part of the demand. During drought periods DWAF Regional Office determine curtailment levels for Allemanskraal and Erfenis dams based on experience, which are then included in the annual WRPM analysis. The DWAF RSA is currently also in the process of developing proper operating rules for these two sub-systems, based on the appropriate short-term yield characteristics and priority classifications.

g) Wentzel Dam sub-system

Wentzel Dam is the most upstream dam on the Harts River and relies totally on the natural flow from the Harts. The only existing abstraction from the dam is the Schweizer Reneke town demand, reaching 1.02 million m^3/a at 2006 development level. In the WRPM analyses the dam is operated to supply the demand until the dam reaches its DSL (which is equal to the zero storage level). The dam was originally constructed to supply water to the Schweizer Reneke town and limited areas of scheduled irrigated land. The irrigation allocation has however been taken over by Schweizer Reneke town and hence no irrigation is supplied from the dam.

h) Taung Dam sub-system

Taung Dam is located downstream of Wentzel Dam not far upstream of the town of Taung. The Taung dam was built in the Harts River in 1993 to augment irrigation supplies to the Taung irrigation area and possibly support new irrigation areas in the Pudimoe area. Currently the dam is not utilised for irrigation purposes. Abstraction points have also not been constructed, but the possibility of extracting water from the two outlet works exists.

DWAF RSA has initiated a feasibility study for the utilisation of Taung Dam. As part of this study operating rules will be developed for the sub-system which will most probably also include Spitskop Dam. These operating rules will include the use of short-term stochastic yield characteristics and priority classifications.

i) Spitskop Dam sub-system

Spitskop Dam was constructed in 1975 in order to supply irrigators along the lower Harts upstream of the Vaal confluence. The dam was reconstructed in 1989 due to damage incurred by floods in 1988. The dam is positioned downstream of the Vaalharts Irrigation Scheme and therefore substantial volumes of return flows seep into the dam. The dam is currently only utilised to supply irrigation along the Harts River downstream of the dam. Due to the large volumes of return flows from the Vaalharts Scheme, the dam is currently under-utilised, and water is supplied to the downstream irrigators as required, but within their allocated quota of 7700 m^3/ha/a. The total area under irrigation from Spitskop Dam is 1,663.1 ha with a total allocation of 12.81 million m^3/a.

The operating rule for Spitskop Dam will also be updated as part of the current Taung Dam Study.

4.4.3 Operation of the Larger Orange River System

Main System (Orange River Project)

For the purpose of the operation of the Main Orange River System, it is important to distinguish between the Main System and the smaller sub-systems in the Orange and Riet-Modder catchment. The Orange River Main System, also referred to as the Orange River Project, consisting mainly of Gariep and Vanderkloof dams, the two largest storage dams in South Africa. The two dams are operated as one system, with the result that water demands downstream of Vanderkloof Dam can be supplied from either of the dams. The System was also constructed for hydropower generation purposes at both dams, and is for this purpose operated by Eskom to supply electricity during peak hours. Under normal circumstances water is released twice a day for relatively short periods, by running the turbines at full capacity, producing maximum river flows in the order of up to 720 m^3/s downstream of the reservoir.

The dams are used to supply all the water requirements along the Orange River from Gariep Dam to the Orange River Mouth. These demands include all the irrigation, urban, mining, environmental requirements, river requirements etc. A constant compensation flow of 16 m^3/s (505 million m^3/a) is currently released to supply irrigators abstracting water from the river between Gariep Dam and Vanderkloof Dam. Large volumes of water are also transferred to other neighbouring catchments. These transfers include the following:

- The transfer from Gariep Dam to the Eastern Cape through the Orange-Fish tunnel to support large irrigation developments and some urban requirements in the Eastern Cape. An annual allocation of 600 million m^3/a is used for this purpose. This water is transferred at a rate of up to 54 m^3/s, which is the maximum capacity of the tunnel.
- The transfer through the Orange-Riet canal from Vanderkloof Dam to the Riet-Modder catchment, is mainly for irrigation purposes.

- Orange-Vaal Transfer through the canal system from Marksdrift Weir in the Orange River to Douglas Weir in the Vaal River, and is also mainly used for irrigation purposes.
- Transfer from the Lower Orange along the common border area to Springbok and Kleinzee for urban and mining use.

Except for the releases through the Orange-Fish tunnel and those into the Vanderkloof Canals, all the releases from Gariep and Vanderkloof Dams, to supply downstream users, are made through the hydropower turbines directly into the Orange River. These river releases are therefore used to simultaneously generate hydropower.

Any spills from the Vaal or Fish Rivers (Namibia) or any local runoff generated in the Lower Orange are not taken into account when releases are made from Vanderkloof Dam to supply the downstream users. This is due to the fact that it is extremely difficult to compensate for Vaal, Fish or any other inflows into the Lower Orange by means of reduced releases from Vanderkloof Dam, as releases take approximately one month to reach the river mouth and the existing flow gauging structures in the Orange and Lower Vaal Rivers are inaccurate for the measuring of low flows.

Operating analyses are carried out on an annual basis for the Orange River System in order to determine the available surplus or deficit in the system for the coming year. If there is a surplus available in the system, the surplus is allocated to Eskom to generate additional hydropower over and above that generated by means of the normal releases for downstream users. Eskom utilises this surplus mainly during the winter months when the power demand is high. However, if there is a deficit in the system, curtailments will be imposed according to the priority classification (see **Table 4.8 & Table 4.9**), first on the low assurance (1 in 20-year) component of the demand.

Table 4.8: User category and priority classifications as used for the Orange River Project

<table>
<tr><th colspan="2" rowspan="2">System and User Category</th><th colspan="6">Priority Classification (%)</th></tr>
<tr><th colspan="2">Low
(95% assurance)
(1:20 year)</th><th colspan="2">Medium
(99% assurance)
(1:100 year)</th><th colspan="2">High
(99,5% assurance)
(1:200 Year)</th></tr>
<tr><td colspan="2">Urban/Industrial/Mining</td><td colspan="2">20%</td><td colspan="2">30%</td><td colspan="2">50%</td></tr>
<tr><td colspan="2">Irrigation</td><td colspan="2">50%</td><td colspan="2">40%</td><td colspan="2">10%</td></tr>
<tr><td colspan="2">River requirements & Losses</td><td colspan="2">0%</td><td colspan="2">0%</td><td colspan="2">100%</td></tr>
<tr><td colspan="2">Environmental requirement</td><td colspan="2">33%</td><td colspan="2">0%</td><td colspan="2">67%</td></tr>
<tr><td>Curtailment level</td><td>0</td><td></td><td>1</td><td></td><td>2</td><td></td><td>3</td></tr>
</table>

Table 4.9: Priority Classification for the Orange River Project with demands

User Category	Priority Classification & Assurance of Supply (million m³/a)			Total (million m³/a)
	Low 1:20 year	**Medium 1:100 year**	**High 1 in 200 year**	
Urban/Industrial/Mining	16	24	40	80
Irrigation	967	774	194	1 935
River evaporation requirements & Losses			947	947
Environmental requirement	97		192	289
Total	1080	798	1 373	3 251

Only when the low assurance demand component has been curtailed by 100%, will curtailments be imposed on the medium assurance (1 in 100-year) demand component, and thereafter on the high assurance (1 in 200-year) demand component.

The minimum operating levels (m.o.l.) for hydropower generation in the dams are currently used as the m.o.l. in both dams. It is only in severe droughts that the dams will be drawn below these levels.

Storage control curves (SCCs) are utilised at both dams to minimise spillage from the dams and to increase hydropower generation during wet periods. Limited volumes of water can be routed through the turbines and it is therefore not possible to route large incoming floods through the turbines, and as soon as the water spills over the crest of the dam wall, the water will be lost for power generation purposes. Therefore, the SCC allow the operator to start running the turbines at maximum capacity, as soon as the water level in the dam rises above the SCC level for the specific month, to be able to utilise incoming floods as much as possible for hydro power generation purposes. When the level drops below the SCC the hydropower releases will again be reduced to be equal to the releases required by the downstream users. Storage control curves (SCCs) for both dams are relatively close to the full supply levels (FSLs) of the dams and are at higher levels in the winter and at lower levels in the summer. As the demand on the ORP increases over time, the SCC will be adjusted to higher levels to maintain the required assurance of supply to the users.

Other larger Sub-systems

a) The Lesotho Highlands Water Project (LHWP)

The LHWP consists of the Katse and Mohale dams as well as the Matsoku Weir which are interlinked and connected to the Upper Vaal System by means of tunnels, canals and streams. The main purpose of the LHWP is to support the Vaal System, thus the sub-system is not used to support Gariep and Vanderkloof Dams. The only releases into the Orange River from Katse and Mohale Dams are for environmental purposes. Although some of these releases will reach Gariep and Vanderkloof Dams, they are needed in the system to be able to also supply the environmental requirements downstream of the two dams. A fixed and agreed volume of water annually up to the maximum of 835 million m^3/a is released from Katse Dam to the Upper Vaal in support of Vaal Dam, irrespective of the water level in Vaal Dam or Bloemhof Dam. Matsoku Weir diverts water to its maximum capacity into Katse Dam whenever flow is available. Mohale Dam transfers water to Katse Dam based on the levels in the two dams. The LHWP is part of the annual operating analysis carried out for the Integrated Vaal River System and the Orange River System.

b) Caledon Modder Sub-system:

Welbedacht and Knellpoort Dams in the Caledon River are part of the Caledon-Modder Transfer System, used to supply part of the water requirements of Bloemfontein, Botshabelo, Thaba Nchu and other small users. Water treated at Welbedacht Dam is transferred directly to Bloemfontein and small users, while raw water from Knellpoort Dam is transferred to Rustfontein Dam in the upper reaches of the Modder River. Rustfontein Dam is then used to supply Botshabelo and Thaba Nchu via the water treatment works at Rustfontein Dam. Raw water is released from Rustfontein Dam to support Mockes Dam, from where water is again released to Maselspoort Weir, where it is abstracted and supplied to Bloemfontein via the water treatment works at Maselspoort.

The operating rule for this sub-system dictates that water is to be taken from Welbedacht Dam first, then from Knellpoort Dam, then from the upper 20% in Mockes Dam, then from Rustfontein Dam until Rustfontein Dam reaches 40% of its live storage. Water is then transferred from Knellpoort Dam through the Novo transfer scheme to Rustfontein Dam, only if Knellpoort Dam is above 60% of it's live storage. When Knellpoort Dam is below the 60% storage level, the remaining 40% in Rustfontein Dam will be used, followed by the remaining 80% in Mockes Dam and as the last resort the remaining water in Knellpoort Dam.

All the water available at Tienfontein pumpstation is pumped to Knellpoort Dam up to the maximum capacity of the pumpstation until Knellpoort Dam is full. Welbedacht and Knellpoort Dams are not used to support Gariep and Vanderkloof Dams.

Smaller Systems

The smaller systems and related dams on the Orange River tributaries and in the Riet-Modder Catchment are operated independently from the ORP, although spillage from some of the sub-system dams and flows from unregulated tributaries, are still captured by the Major Dams on the Orange River. Base flows from the tributaries into the Orange River are however reduced due to the impact of the smaller sub-systems in the different sub-catchments. The smaller systems are therefore discussed separately in the sub-sections to follow:

a) Groothoek Dam

Groothoek Dam is a relatively small dam and is only used to supply water to Thaba Nchu. Water for Thaba Nchu is now also supplied from Rustfontein Dam. Detail on the actual operating rule for Groothoek Dam is not documented. The operating rule followed in the WRPM is to supply the demand imposed on the dam until it reaches its mimimum operating level. Thaba Nchu will then only be supplied from Rustfontein Dam to the maximum capacity of the supply system

b) Kalkfontein System

The system consists of the Kalkfontein Dam and a canal distribution system to supply irrigation with water. Urban and mining requirements of Koffiefontein, Jacobsdal and Koffiefontein Mine are also supplied from Kalkfontein Dam. The operating rule currently used is not documented in the existing reports. In the WRPM setup a simple operating rule is followed which supplies the full demand imposed on the dam until the minimum operating level is reached. At that point priority will be given to the urban and mining demands, and only the water entering the dam will be available to supply the demands. Kalkfontein Dam is not supported from Tierpoort Dam.

c) Krugersdrift System

The system consists for Krugersdrift Dam which is used to supply water to the Modder River GWS (Irrigation) downstream of the dam. Water is released from the dam directly into the river and abstracted by the irrigators from the river at various small weirs across the river. No operating rule is documented for this dam. In the WRPM setup, a simple operating rule is used that allows the total demand to be fully supplied until the minimum operating level in the dam is reached. Only the water flowing into the dam will then be available to supply the irrigators.

d) Tierpoort System

Tierpoort Dam supplies water for 708 ha of irrigation land to the Tierpoort Irrigation Board. Water is supplied to the farmers via unlined canals and, due to the low assurance of supply from the dam; permanent crops are not favoured in this area. No operating rule is documented for this dam and the same operating as used for Krugersdrift Dam in the WRPM is also used for Tierpoort Dam.

e) Smart Syndicate

This scheme consists of the Smart Syndicate Dam with gross storage of 101 million m3 and supplies water to 1 818 ha of irrigation. However, due to the low assurance of supply only 16% of the total area is irrigated on average. No operating rule is documented for this dam

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

5.1.1 Infrastructure

Infrastructure related data obtained from the existing reports already includes a vast amount of data. This data is more than sufficient to provide a clear overall picture of the current infrastructure development in the Orange-Senqu Basin for phase 1 of this study. For detailed modelling purposes however, one would require more information and also to update some of the data, as a fair amount of the data was obtained from old reports. The level of detail required with regards to infrastructure also depends on the level of detail that is required for modelling purposes and what one intends to achieve with the modelling of the Orange-Senqu Basin water supply system.

As only available information from existing reports was captured, the level of detail of the available information differs from area to area and also between the four basin states. Comprehensive infrastructure related data with regards to the main Vaal System, the Orange River Project, the Caledon Modder Transfer Scheme and the Lesotho Highlands Water Project are available although updates on the capacities of the older infrastructure might be required. Less information is in general available for the smaller sub-systems which are operated as stand alone schemes and are not supporting the major schemes mentioned above, and in particular for the drier areas such as the Lower Orange which is currently not modelled to the same level of detail. This also apply to a most of the smaller towns which is in most cases supplied from groundwater resources.

Information on groundwater related infrastructure is in general limited and is most probably due to the relative small scale of the most of the groundwater supply schemes.

5.1.2 Operation of the current System

The operation of the main water supply schemes such as the Integrated Vaal River System, the Orange River Project, the Lesotho Highland Water Project and the Hardap Water Supply Scheme is well defined and is based on well founded scientifically and proven techniques. Long-term and short-term stochastic yield characteristics are used together with the Water Resources Planning (WRPM) and operational model to be able to impose restriction on the water use when required to protect the resources and still supply the different users at their required assurance of supply. Dilution and blending operating rules are also in place in the Integrated Vaal River System to keep the TDS concentrations downstream of Vaal Dam at acceptable levels.

The smaller sub-systems are operated individually using fairly simple operating rules based on specific levels in the storage dam. Most of the operating rules are however not documented clearly in the existing reports and it seems if water are abstracted to supply the full demand until a specific level in the storage dam is reached, where after curtailments are imposed. Details of how this level is determined and how severe curtailments should be, were not given in the existing reports. The assurance of supply from the smaller sub-systems is in most cases not well defined and if it do exist it is based only on the historic sequence which can be misleading, and is often to short to be able to determine volumes available at high assurances. Different methodologies are followed by the four basin states to determine the assurance of the yield from a resource as well as the assurance of supply to the users.

The DWAF in the RSA is currently in the process to develop operating rules for the smaller sub-systems within the Vaal System. These new operating rules are based on the long-term and short-term stochastic yield characteristics of the sub-system and are developed with the aid of the WRPM.

5.2 Recommendations

The level of detail that is required for infrastructure related data for modelling purposes need to be agreed on by the four basin states, bearing in mind that it will be affected by the level of detail as required for the modelling of the total Orange-Senqu basin. The infrastructure data base then need to be updated to the required level. Attention should specifically also be given to the large number of small towns for which very little information exists in current reports.

Diagrams and related capacities need to be updated to reflect the current situation. This is in particular required where the data were obtained from fairly old reports.

Details on the operating rules for most of the smaller systems need to be obtained and new operating rules currently under development need to be captured when available.

It is recommended that the basin states should work towards using similar operating rule principles throughout the Orange-Senqu Basin. This will simplify the operation, modelling and understanding of the total system and improve co-operation between the basin states.

6 REFERENCES

CensusN(1994) **1991 Population and Housing Census.** Report by the Census Office, National Planning Commission Namibia, 1994.

CensusN(2002) **2001 Population and Housing Census.** Report by the Census Office, National Planning Commission Namibia, 2002.

DWA (1963) **Hardap Dam Inauguration.** Report by the Department of Water Affairs Namibia, 1963.

DWA(1972) **The Naute State Water Scheme.** Report by the Department of Water Affairs Namibia, 1972.

DWAF(1985) **Vaal River System Analysis: Description of existing and proposed systems.** Report no. P RSA C000/00/4385 by BKS (Pty) Ltd in association with SS&O for the Department of Water Affairs and Forestry, Pretoria South Africa, November 1985. Prepared MS Meyer.

DWA(1986) **Otjivero – Gobabis Regional State Water Scheme.** Report by the Department of Water Affairs Namibia, 1986.

DWA(1991) **The Oanob Dam State Water Scheme.** Report by the Department of Water Affairs Namibia, 1991.

DWAF(1992) **Orange River System Analysis. Demands and Return Flows.** Report no. PD 000/00/0492 by BKS (Pty) Ltd and Stewart Scott Consulting Engineers for the Department of Water Affairs and Forestry, Pretoria, South Africa, November 1992. Prepared by NW Schäfer.

DWAF(1992) **Orange River System Analysis. Description of the Physical System.** Report no. PD 000/00/0392 by BKS (Pty) Ltd and Stewart Scott Consulting Engineers for the Department of Water Affairs and Forestry, Pretoria, South Africa, November 1992. Prepared by MS Meyer.

DWAF (1997) **Orange River Development Project Replanning Study. Existing water infrastructure in the Eastern Cape region**: Report no PD 000/00/5795 by BKS (Pty) Ltd and Ninham Shand (Pty) Ltd for the Department of Water Affairs and Forestry, Pretoria South Africa, May 1997. Prepared by G Dyke, S L Murray.

DWAF (1997) **Orange River Development Project Replanning Study. Existing water infrastructure in the Orange River basin**: Report no PD 000/00/4297 by BKS (Pty) Ltd and Ninham Shand (Pty) Ltd for the Department of Water Affairs and Forestry, Pretoria South Africa, May 1997. Prepared by JD Rossouw.

DWAF(2001) **Vaal River System: Pre-feasibility Study to determine the Need for Augmentation of the Eastern Sub-system**. Report no P RSA C110/00/0900 by Africon Engineering International, V3 Consulting Engineers, WRP Consulting Engineers, Urban-Econ and AfriDev for the Department of Water Affairs and Forestry, Pretoria, South Africa, December 2001.

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.
DWA(2004)	**10 Years Directorate Rural Water Supply 1993**

to 2003. Report by the Department of Water Affairs Namibia, 2004.

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.

DWAF(2005) **Luvuvhu River System Annual Operating Analysis**: **Development of a Decision Support System and executing of the 2005/2006 annual operating analysis**. Report PNMA 02/000/00/0305 by WRP Consulting Engineers in association with DMM Development Consultants for the Department of Water Affairs and Forestry, Pretoria, South Africa, December 2005.

DWAF(2007) **Feasibility Study For Utilisation Of Taung Dam Water: Main Report.** Report no. P WMA 10/000/00/0407 by WRP consulting Engineers, V3 Consulting Engineers, Golder Associates, Kayamandi Development services, DMM Development Services, and WSM Leshika for the Department of Water Affairs and Forestry, Pretoria, South Africa, July 2007.

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.

DWAF(2007) **Orange River Integrated Water Resources Management Plan: Summary of Water Requirements from the Orange River.** Report no. ORASECOM 006/2007 by WRP Consulting Engineers, Jeffares and Green, Sechaba Consulting, WCE Pty Ltd, and Water Surveys Botswana (Pty) Ltd for the Department of Water Affairs and Forestry, Pretoria, South Africa, November 2007. Prepared by HG Maré, P Heyns.

DWAF(2007) **Orange River Integrated Water Resources Management Plan: Review of Surface Hydrology in the Orange River Catchment.** Report no. ORASECOM 002/2007 by WRP Consulting Engineers, Jeffares and Green, Sechaba Consulting, WCE Pty Ltd, and Water Surveys Botswana (Pty) Ltd for the Department of Water Affairs and Forestry, Pretoria, South Africa, November 2007. Prepared by HG Maré.

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.
ESKOM(1995)	**Orange River System Analysis: Refinement of the Hydro Power Operating Rules.** Report no. P573301 by BKS (Pty) Ltd for ESKOM Hydro and Water Department, South Africa, 1995. Prepared by PG Van Rooyen and HG Maré.
VanderMerwe(1983)	**National Atlas of South West Africa.** Report by JH van der Merwe, 1983.
WCE(2000)	**Analysis of Present and Future Water Demand in Namibia.** Report by Windhoek Consulting Engineers, 2000.

Appendix A

Figures