Water Demand Projections and Synthesis of Planned Infrastructure Investments

Integrated Water Resources Management Plan for the Orange-Senqu River Basin

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Report No. ORASECOM 012/2014

The ***Support to Phase 3 of the ORASECOM Basin-wide Integrated Water Resources Management Plan*** Study was commissioned by the Secretariat of the Orange-Senqu River Basin Commission (ORASECOM) with technical and financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) in delegated cooperation with the UK Department for International Development (DFID) and the *Australian Department of Foreign Affairs and Trade (DFAT)* implemented through Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)°.

Prepared by

in association with

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Integrated Water Resource Management Plan for the Orange-Senqu River Basin

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Integrated Water Resources Management Plan for the Orange-Senqu River Basin – Phase 3

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1. Introduction

1.1 CONTEXT AND OBJECTIVES OF THE STUDY

1.1.1 General Context

Southern Africa has fifteen (15) transboundary watercourse systems of which thirteen exclusively stretch over SADC Member States. The Orange–Senqu is one of these thirteen. The Southern African Development Community (SADC) embraces the ideals of utilising the water resources of these transboundary watercourses for the regional economic integration of SADC and for the mutual benefit of riparian states. The region has demonstrated a great deal of goodwill and commitment towards collaboration on water issues. Thus, SADC has adopted the principle of basin–wide management of the water resources for sustainable and integrated water resources development. The proposed ORASECOM basin-wide IWRM fits in to this background.

1.1.2 Water resources context

The Orange - Senqu River originates in the highlands of Lesotho on the slopes of its highest peak, Thabana Ntlenyana, at 3 482m, and it runs for over 2 300km to its mouth on the Atlantic Ocean. The river system is one of the largest river basins in Southern Africa with a total catchment area of more than 850,000km^2 and includes the whole of Lesotho as well as portions of Botswana, Namibia and South Africa. The natural mean annual runoff at the mouth is estimated to be in the order of 11,500Mm^3, but this has been significantly reduced by extensive water utilisation for domestic, industrial and agricultural purposes to such an extent that the current flow reaching the river mouth is now in the order of half the natural flow. The basin is shown in Figure 1-1.

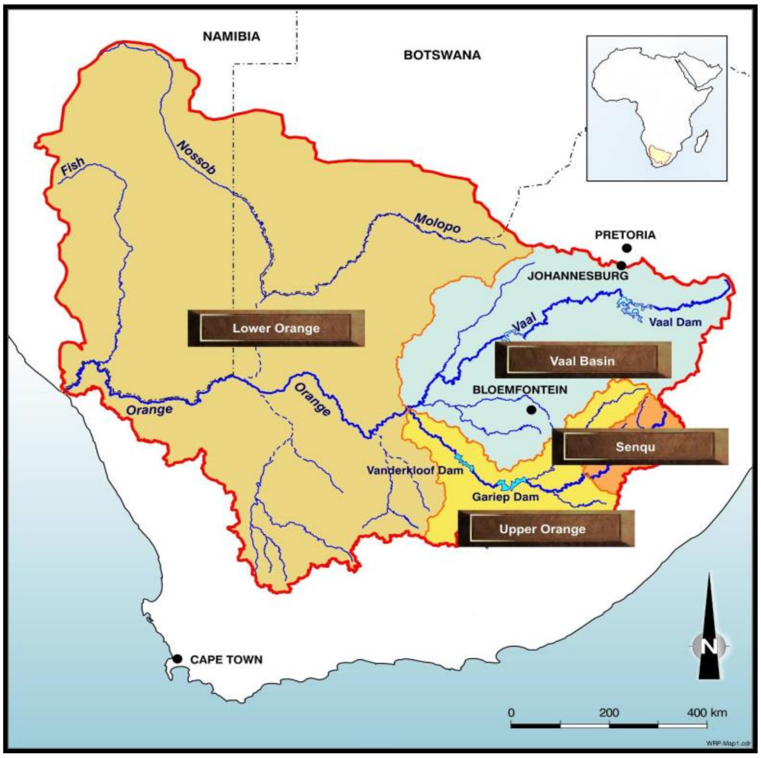

Figure 1-1: Orange – Senqu River Basin

Regulation and Inter-basin transfers

The Orange-Senqu system is regulated by more than thirty-one major dams. Two of these dams are situated in Lesotho, five in Namibia and 24 in South Africa. The largest five reservoirs are those formed by the Gariep, Vanderkloof, Sterkfontein, Vaal and Katse Dams with capacities ranging from 1 950 Mm^3 to 5 675 Mm^3. The Orange-Senqu river basin is a highly complex and integrated water resource system with numerous large inter-basin transfers which allow water to be moved from one part of the basin to another as well as into and out of neighbouring basins. For example, the Sterkfontein Dam (2 617Mm^3) is supplied from the adjacent Tugela basin and the Katse-Mohale dams system (2 910Mm^3) located in Lesotho augment the Vaal Dam (2 122Mm^3) which supplies water to the industrial heartland of South Africa. The Gariep Dam (5 675 Mm^3) and Vanderkloof Dam (3 237 Mm^3) on the Orange River downstream of Lesotho are the largest reservoirs in the Orange-Senqu river system respectively. Both dams are used to regulate the river flow for irrigation purposes as well as to generate hydro-electricity during the peak demand periods with a combined installed capacity of 600 MW. Releases from Vanderkloof Dam into the Orange River are dictated by the downstream flow requirements.

The tributaries downstream of the Vaal confluence are the Molopo-Nossob sub-basin system. Surface flow from this system has not reached the main stem of the Orange River in living memory. Further downstream, the Fish River sub-basin, entirely located within Namibia accounts for the two (Hardap, Naute Dams) of the five dams regulating the flows from Namibia into the Orange River.

The most important and highly utilised tributary of the Orange-Senqu system is the Vaal River which supplies water to the industrial heartland of Southern Africa, the Vaal Triangle including Pretoria. The Vaal River System also provides water to 12 large thermal power stations which produce more than 90% of South Africa's electricity, as well as water to some of the world's largest gold, platinum and coal mines.

The Orange-Senqu river basin is clearly one of the most developed and certainly most utilised river basins in the SADC region, with at least 9 major intra - and inter - basin water transfer schemes.

The complexity of this transboundary system and the resultant need for a sophisticated management system in the Orange-Senqu river basin is one of the key drivers of the proposed project to develop an Integrated Water Resources Management Plan for the basin.

1.1.3 Phase 3 of the Basin-wide IWRM Plan

The basin-wide Integrated Water Resources Management (IWRM) Plan will provide a framework for management, development and conservation of water resources in the Orange-Senqu River Basin, serving to advise Parties on optimising overall water resource utilisation.

Since the establishment of ORASECOM in 2000, a significant number of studies have been completed or are in process and have provided the building blocks for the Basin-wide IWRM Plan. Phase I of the ORASECOM IWRM planning programme was implemented between 2004 and 2007 and focused on collating existing information that described the water resources of the Basin. Phase II of the IWRM Planning Programme (2009 to 2011) focused on bridging the planning gaps identified in Phase I. A Transboundary diagnostic analysis (TDA) has been carried out under the ongoing UNDP-GEF project and National and Strategic Action Plans are in the process of being finalised.

Strategically, ORASECOM has approached the point where, with some exceptions, sufficient preparatory work has been done to move towards drafting a Basin-Wide IWRM Plan. Representatives of the four member countries have tentatively defined an “overall objective” for preparing a Basin-wide IWRM Plan:

“To provide a framework for sustainable development and management of the water resources, taking into account the need for improved distribution and equitable allocation of benefits, in order to contribute towards socio-economic upliftment of communities within the basin, and ensure future water security for the basin States.”

The plan will set out the actions necessary to achieve the strategic objectives of ORASECOM as well as those of the basin States. Some of these will be short term and others longer term. In the context of IWRM planning, once approved, “the Plan” will signify a transition from planning to implementation of the actions that are determined in the Plan. Moreover it will signify the transition of ORASECOM from a reactive to a pro-active mode, technically competent advisor to the Parties as envisaged in the ORASECOM Agreement.

The IWRM Plan will include an implementation plan that identifies activities that will be implemented collectively by all the Parties through ORASECOM and the existing bilateral institutions and those that will be implemented separately by the Parties. The IWRM Plan will be forward looking (10 years in scope) and provide a framework that enables the basin to realise economic and social benefits associated with better water resources management. In addition, the IWRM Plan should strive to link the water sector with national economic growth and poverty alleviation strategies based on the fact that IWRM is not an end in itself but rather a means to achieve economic and social development.

In summary, the objective of this consultancy is to develop a comprehensive 10 year IWRM Plan for the whole of the Orange-Senqu Vaal River Basin. The IWRM Plan will include an implementation plan that identifies activities that will be implemented collectively by all the Parties through ORASECOM and the existing bilateral institutions and those that will be implemented separately by the Parties.

1.2 This Report

1.2.1 Rationale

This study consists of five Work Packages to address all the requirements and actions for the preparation, tabling and approval of the IWRMP. This report focus on Work Package 4c-i, which is one of the sub-work packages of Work Package 4. Work package 4 comprises the following sub-work packages, effectively the technical studies component of the Phase 3 work.

- **Work Package 4a: Conduct an economic analysis of water use based on water accounting**.
- **Work Package 4b: Consolidate water demands and infrastructure development plans.** The task comprises consolidation into a database, updating and filling of gaps for some parts of the basin.
- **Work Package 4c-i: Update the basin planning model and conduct a model based situation analysis**. 4c-Part i comprises the modelling work that has to be done before any new scenarios can be investigated
- **Work Package 4c-ii: Application of the basin planning model for testing and evaluation of scenarios**
- **Work Package 4d: Update ORASECOM Water Information System**: All information collected as well as results generated will be consolidated in the WIS.
- **Work Package 4e: Consolidate available knowledge on environmental flow requirements and water quality assessments**. The consolidation work will form part of the SAP work but the results will be required for consolidation in the water resources models.
- **Work Package 4f: Consolidate knowledge on economic approaches to water management**

These Sub-Work Packages are critical to finalising the inputs required for the drafting of the IWRM Plan

1.2.2 Objective of the report

The work described in this report is carried out under the "Consolidation of an Orange-Senqu River Basin-wide IWRM Plan" project and covers "Work Package 4b: Consolidation of water demands and infrastructure development plans". Work package 4b is set up to ensure that the most up-to-date and accurate water demand and -infrastructure information is being used in the water resource modelling (WRYM and WRPM) work that feeds into the IWRM plan.

The work has been designed to utilize and incorporate data from existing databases that have been developed during various projects in the past and to review and where possible improve this data with newly collected and up to date data taken from new reports and collected from stakeholders. Furthermore, a variety of infrastructure assets including related demands are under development or are planned in the basin with the need for respective information and demand projections to be included.

The work includes the most up to date and comprehensive dataset for both current and projected water demands as well as return flows. The updated database ensures that the modelling that feeds into the IWRM plan development uses the most accurate data. Considering that much work has already been done in the basin, this report, where appropriate, does not repeat the descriptions or analysis but utilizes, quotes, or refers to these sources.

1.2.3 Overview of report contents

The report is structured in five sections starting with this introduction as Section 1. The four main sections that follow then include:

- Section 2: The provision of a situational overview (situational analysis) collating existing information based on available data from the Orange River basin Water Resources Planning Model as well as filling specific gaps and updating the so far available knowledge using a broad range of sources. These include e.g. water sales figures, extraction licenses, recent studies and similar. Data was further collected through consultation with various stakeholders and authorities. Based on this data, the section describes the hydrology and river network of the Orange Senqu River basin, gives an overview of the current water demands in the basin from different users and describes the river infrastructure that is implemented to alter the river flow to better suit users' needs (i.e. specifically dams, weirs and transfer schemes. The section further looks into future trends in the basin that could have an effect on water demand and water availability, including population growth, economic development and climate change as the main drivers for water resources related changes in the basin.
- Section 3: A projection of water demands and a synthesis of planned infrastructure development. The water demand projections are mainly based on ongoing activities (needs/political controlled). The infrastructure developments follow these needs, considering potential future changes in flow regime. The descriptions are provided on a country by country basis, for each describing irrigation-, mining-, industry-, domestic- and environmental aspects and demands, including their spatio-temporal context. The information feeds into the demands database (Section 4) as well as into the development scenarios and scenario modelling (Section 5).
- Section 4: Description of the database that has been set up as the core activity of this work package. The section describes the restructuring of the existing demand database available from the Orange River basin Water Resources Planning Model. It further describes the updating and/or gap filling including data sources of demands and including their related infrastructure. Through annual overviews up to the year 2040 future developments are considered, with e.g. closing old- and opening new mines, construction of new dams and expansion of irrigated areas. These further developments are obviously estimated – albeit using best available knowledge – and should be updated periodically in the future. Further efforts have been spent researching and including the various elements of the hydrological cycle, specifically bed losses, return flows, etc. While very little data was available regarding these aspects, best estimates have been used to assess and include them.
- Section 5: Looking into possible development scenarios this section lists most likely developments in the basin, outlines the need for further assessments and indicates the way forward for detailed scenario assessment, infrastructure design and optimizing the river basin operation.

2. The Orange – Senqu Basin

2.1 River Network & Hydrology

The total catchment of the Orange River (including the Vaal) as shown in Figure 1 extends over approx. 1,000,000 km² with 64% of the area being in South Africa, 25% in Namibia, 8% in Botswana and 3% in Lesotho (ORASECOM, 2007[1]). The Orange River has a total length of 2,200 km, rising in the Moluti mountains in Lesotho at an altitude of over 3,000 m and flowing westwards through South Africa and then along the South African / Namibian border to the Atlantic Ocean. In Lesotho the river is known as the Senqu River.

The main tributary of the Orange River is the Vaal River, covering approximately 200,000 km² and supporting about 37 % of South Africa's economic activity. The greatest demand for water in this intensively used catchment is for irrigation, followed by mining and industrial use, with a similar proportion going to urban and domestic use (Basson et al. 1997[2]) Especially the greater Johannesburg areas is depending heavily on the Vaal waters and the water transfers from the Lesotho Highland Water Project, i.e. from the Senqu River. The Vaal River is controlled through the Vaal Dam, the Vaal Barrage and Bloemhof Dam. From these schemes it also provides water to the Crocodile- and Olifants River.

The Senqu River catchment, i.e. the headwaters of the Orange-Senqu River in Lesotho, is modified by the Lesotho Highland Water Project with Katse Dam, Mohale Dam and Matsoku Weir as well as the related transfer schemes altering the river flow and providing inter basin water transfer to the Vaal River as indicated above. Further downstream the main uses of the Orange River include the provision of water for irrigation and water for hydropower. Main dams along its course include Gariep Dam and Vanderkloof Dam, both in South Africa (Jeleni & Mare, 2007[3]).

From the border of Lesotho to below the Vanderkloof Dam the river bed is deeply incised. In its middle section, the land is flatter, and the river is used extensively for irrigation. At its downstream end, along the Namibian border, the river is once again incised. Close to its mouth into the Atlantic Ocean the river is completely obstructed by rapids and sand bars and is generally not navigable for long stretches.

The hydrology of the Orange-Senqu River is strongly influenced by the intra-annual rainfall distribution with rapid runoff and evaporation during the rainy season. During the dry winter months the volume of the water in the river is considerably reduced. At the source of the Orange-Senqu the rainfall is approximately 2,000 mm per year but precipitation decreases as the river flows westward. At its mouth the rainfall is less than 50 mm per year. The factors that support evaporation, on the other hand, increase in westerly direction. In the wet summer season the Orange-Senqu Rivers flows increase strongly and carry large amounts of sediments that constitute a long-term challenge to engineering projects on the river (Earle et al., 2005[4]).

1 ORASECOM, 2007, Orange River Integrated Water Resources Management Plan: Review of Existing Infrastructure in the Orange River Catchment. By WRP Consulting Engineers, Jeffares and Green, Sechaba Consulting, WCE Pty Ltd, and Water Surveys Botswana (Pty) Ltd. ORASECOM, Gaborone, Botswana

2 Basson, M.S., Van Niekerk, P.H. and Van Rooyen, J.A., 1997, Overview of Water Resources Availability and Utilisation in South Africa, Department of Water Affairs and Forestry, Pretoria.

3 Jeleni, A., Mare, H., 2007, Orange River Integrated Water Resources Management Plan - Review of Existing Infrastructure in the Orange River Catchment, ORASECOM

4 Earle, A., Malzbender, D., Turton, A., Manzungu, E., 2005, A Preliminary Basin Profile of the Orange/Senqu River, AWIRU, University of Pretoria, South Africa

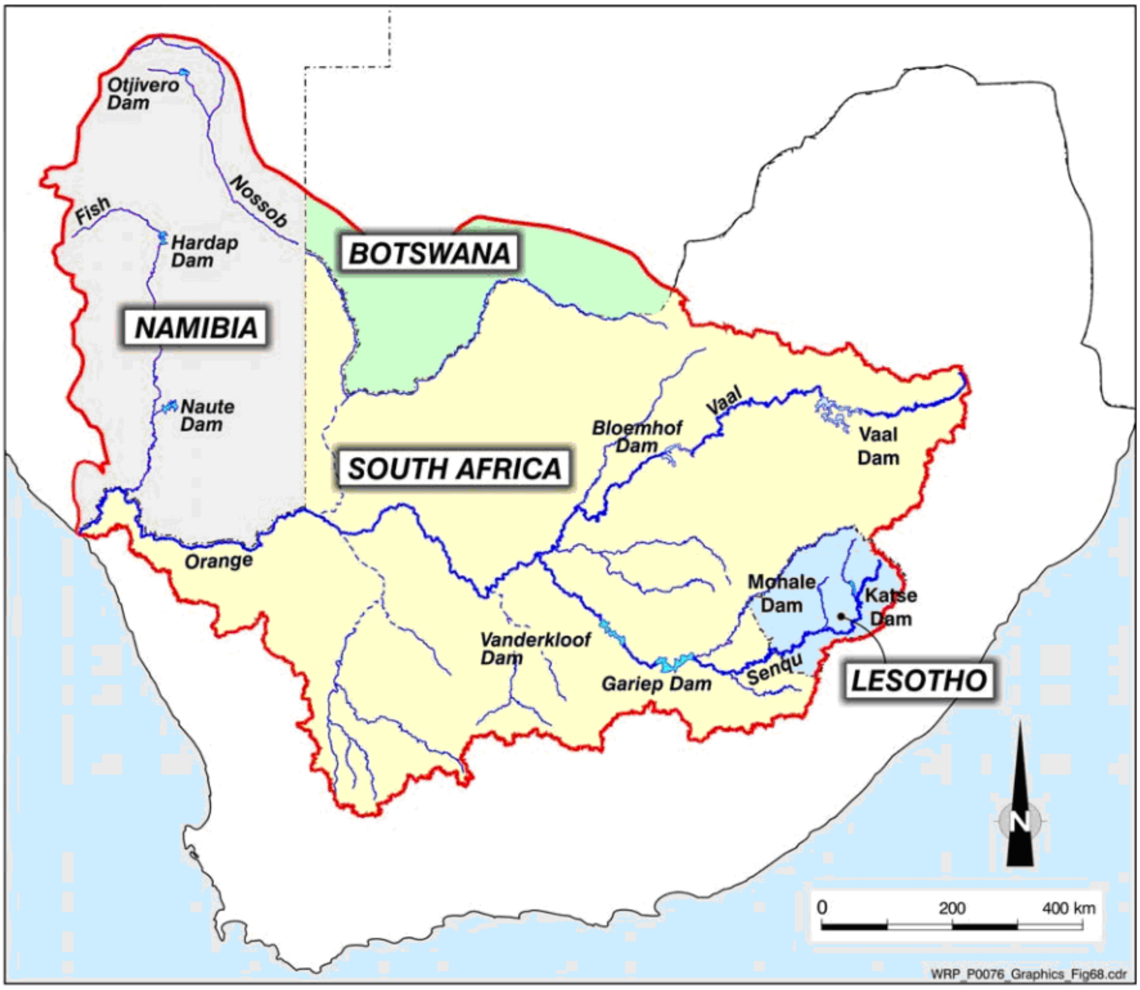

Figure 2-1: The Orange River Basin (Source Maré, Source: Mare, 2007[5])

2.2 Overview of Current Water Demands and Infrastructure

Several water users have a stake in the Orange River basin, either extracting water from river intakes, dams or as non-consumptive users including: Irrigation farming, mining, industries, households as well as hydropower plants. Navigation does not play a role on the Orange River. Infrastructure that has been built in the river to facilitate water use includes dams, hydropower schemes, weirs and river intakes with especially the large dams significantly altering the river flow. In addition to the directly water user related infrastructure water transfer schemes are of particular importance as they divert flows either into or out of the basin or within the basin. The environment with its environmental flow demands is a particular stakeholder. In addition groundwater interaction with respective inter-dependencies between river flow and groundwater play a role.

5 Mare, H., 2007, Orange River Integrated Water Resources Management Plan - Review of Surface Hydrology in the Orange River Catchment, WRP Consulting Engineers, Jeffares and Green, Sechaba Consulting, WCE Pty Ltd, Water Surveys Botswana (Pty) Ltd

2.2.1 Botswana

The part of the Orange River basin which is in Botswana (Figure 2) is the southern portion of the Kgalagadi district of Botswana, covering 12% of the country. This area is part of the Kalahari Desert and there are consequently no large urban centres, no large industries and very limited infrastructures. The main tributary, the Molopo River, does not carry much water along the Botswana section of the river and has not discharged into the Orange River in known history. Despite being connected from a topographical/hydrological perspective, the river channel disappears in the desert before connecting to the Orange main stem.

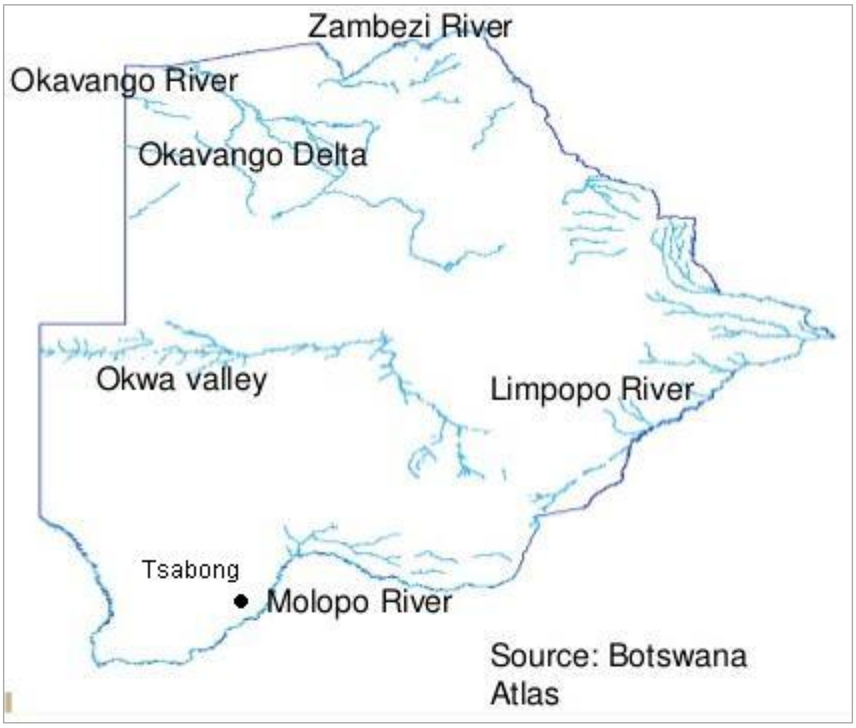

Figure 2-2: Botswana Overview

2.2.1.1 Water management situation

The main water management related institutions in Botswana is the Ministry of Minerals, Energy and Water Affairs (MMEWA). The Ministry is responsible for the national water policy. There are two water supply units under the Ministry, the Department of Water Affairs (DWA), in charge for leading water resources management and providing water supply to villages and the Water Utilities Corporation (WUC), in charge for urban and mining water supply. In the rural areas, the District Councils under the Ministry of Local Government, Lands and Housing (MLGLH), oversee the water supply to rural villages.

The National Water Supply and Sanitation Plan was written in 1999. The main objective was to estimate water demand and availability and the development potential of the water resources. Related legislation comprises the Water Act, the Water Utilities Corporation Act, the Aquatic Weeds (Control) Act and Orders, the Boreholes Act, the Waterworks Act, the Town Councils (Public Sewers) Regulations and the Mines and Minerals Act. The National Water Masterplan was published in 2006.

2.2.1.2 Irrigation

Irrigation in Botswana's part of the Orange Basin is small scale (Chidley, Beuster, & Howard, 2011)[6]. It is mainly fed by groundwater which is recharged through infiltration, from rainfall and streambeds. There are no larger scale irrigation schemes in the Orange basin. Botswana's National Water Masterplan (GoB, 2006)[7] reports no irrigation farming in the basin.

As another agricultural water user, 5 livestock ranches are established in Kgalagadi District (i.e. in the Orange Basin) though being supplied by boreholes.

2.2.1.3 Hydropower

Hydropower is not established in the Orange River basin part of Botswana.

2.2.1.4 Mining

Mining in the Orange River basin part of Botswana is limited to small informal mining as well as one large diamond mine, Jwaneng Mine, operated by Desman since 1982. Mining (raw) water use is approximately 5 Mm^3 in 2011. In addition 2.1 Mm^3 of potable water is used, leading to a total annual consumption of 7.1 Mm^3.

2.2.1.5 Industry

Industry that uses surface water is not established in the Orange River basin part of Botswana. Groundwater using facilities may be existing but not at a large scale. Government of Botswana (2008) [8] reports 1000 m^3 industrial water use per year for Tsabong, the main town in the basin.

2.2.1.6 Domestic

The largest settlement is Tsabong, the administrative centre of the Kgalagadi district, with a population smaller than 10,000 in the year 2011 (United Nations Statistics Division, 2011)[9]. Other smaller settlements are Werda and Bokspits, the rest of the population living in scattered small villages (Water Surveys (Botswana), 2008)[10]. While households along the Molopo may use its surface waters during times when it is available, main supply of domestic water is through shallow wells in the vicinity of the Molopo as well as from groundwater which is assumed to be dependent on surface water infiltration for recharge. Figures for water availability of the individual towns and villages are not available. The accumulated total annual domestic water demand for the southern portion of the Kgalagadi district of Botswana (supplied from Groundwater) was anyhow estimated to be approximately 0.51 Mm^3 in year 2005 (SMEC/EHES, 2006)[11].

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6 Chidley, T., Beuster, H., & Howard, G. (2011). Irrigation GIS Database, Interactive Database and Irrigation Scneario Tool. Pretoria, Republic of South Africa: WRP

7 Government of Botswana, 2006, Ministry of Minerals, Energy & Water Resources, Department of Water Affairs, National Wazer Masterplan Review, Volume 8, Agriculture

8 Central Statistics Office, 2009, Botswana Water Statistics

9 United Nations Statistics Division. (2011). Botswana 2011 Population and Housing Census Project Document. Retrieved December 2013, from Census Knowledge Base:

10 Water Surveys (Botswana). (2008). Costing of the Botswana Water Supply and Demand Clusters. Gaborone, Botswana: Water Surveys (Botswana).

11 SMEC/EHES. (2006). National Water Master Plan Review. Vol 6: Rural Water Supply. Gaborone, Botswana: Department of Water Affairs.

For Tsabong, the main town in Kgalagadi province, which covers large parts of the Orange Basin in Botswana, CSO (2009)[12] reports domestic water consumption development of 118,000-164,000 m³/year for the period 2001-2008. Institutional and commercial water consumption is reported with 74,000-40,000 and 27,000-29,000 m³/year respectively for the same period. Water supply and demand figures reported in the Botswana Water Statistics[13] are listed in Table 2-1.

Table 2-1: Water supply and demand overview for Kgalagadi Province

Village	Population	Supply (m^3/day)	Demand (m^3/day)
Bogogobo	341	29	28
Bray/Hereford	899	-	54
Bokspits	899	101	37
Gachibana	797	34	53
Hukuntsi	4,131	135	315
Huhunkwe	579	49	36
Inalegolo	558	-	38
Kang	4,124	-	532
Khisa	545	-	37
Khuis	851	44	56
Khawa	623	20	42
Kokotsha	1,333	32	85
Kolonkwaneng	762	46	49
Lehututu	1,778	52	122
Lokgwabe	1,435	40	94
Make	366	50	25
Makopong	1,635	75	105
Maleshe	455	26	32
Maralaleng	487	16	34
Maubelo	453	45	30
Middlepits	657	105	105
Monong	172	10	12
Ncaang	175	39	13
Ngwatle	206	-	13
Omaweneno	1,134	75	74
Phepheng	998	68	-
Phuduhudu	621	43	41
Rapplespan	458	29	30
Struzendam	313	33	21
Tsabong	6,591	-	-
Tshane	858	74	63
Ukwi	454	38	32
Vaalhoek	346	33	25
Werda	2,237	189	189
Zutshwa	525	-	36
Draihoek	998	52	66
Total	24,261	948	1,947

[12] Central Statistics Office, 2009, Botswana Water Statistics
[13] Central Statistics Office, 2009, Botswana Water Statistics

2.2.1.7 *Environment*

The Molopo is characterized by its ephemeral nature with the vegetation adapted to these conditions. Environmental flow demands, other than the need for casual flows, cannot be easily quantified.

2.2.1.8 *River and operational requirements*

Losses on the Molopo River are high, reaching magnitudes of 29.4 Mm^3 per year

2.2.2 Lesotho

Lesotho, being referred to as the "water tower" of the Orange-Senqu River basin, has significant water infrastructure in place, comprising weirs, reservoirs, hydropower installations and transfer systems as developed under the "Lesotho Highlands Water Project". Details of current infrastructure are described in the following sub-sections. Proposed structures are described in Section 3.2.

2.2.2.1 *Water management situation*

Institutions involved in the water sector in Lesotho are:

- Lesotho Highlands Development Authority (LHDA)
- Ministry of Agriculture and Food Security (MAFS)

The LHDA is in charge for running the Lesotho Highlands Water project with its main goal to sell water to South Africa.

The main legislation in the water sector is the 1978 Water Resources Act, which regulates the use, control and conservation of water resources. Another important legislation dealing with water resources is the LHWP treaty between Lesotho and South Africa. The treaty regulates the quality and quantity of water delivery to South Africa.

2.2.2.2 *Lesotho Highland Water Project*

The primary goal of the Lesotho Highland Water Project (LHWP) is to provide revenue to Lesotho by transferring water from the catchment of the Senqu/Orange River in Lesotho to meet the growing industrial and domestic demands for water in the Republic of South Africa. Under the current arrangement, 780 Mm^3/year of water are transferred under this project from Lesotho to South Africa (Lesotho Highland Development Authority, 2013)[14].

The main technical components are summarised in Table 2-2. Water from the Senqunyane River is stored by Mohale Dam and diverted to Katse Reservoir which stores water from the Malibamats'o River. The Matsoku Weir diverts additional water from Matsoku River to the Katse Reservoir. Water from the latter reservoir is then diverted to the Muela Reservoir, which acts as a tailwater pond to Muela hydropower station before supplying water to South Africa through Ash River outfall. Muela hydropower station makes use of surplus head in the transfer tunnel system, generating electricity for Lesotho (Lesotho Highland Development Authority, 2013)[15]. An overview is shown in Figure 3.

[14] Lesotho Highland Development Authority. (2013, November). (pers.comm.)
[15] Lesotho Highland Development Authority. (2013, November). (pers.comm.)

Table 2-2: Technical characteristics of main river structures

Structure	River	Main characteristics
Mohale Dam	Senqunyane	Dam height of 145 m Reservoir capacity of 810 Mm^3
Matsoku Weir	Matsoku	Can divert up to 55 m^3/s to Katse Reservoir
Katse Dam	Malibamats'o	Dam height of 185 m Reservoir capacity of 1,950 Mm^3
Muela Dam	Nqoe	Dam height of 55 m Tailpond of the project with a reservoir capacity of 5.9 Mm^3
Tunnel Mohale - Katse		Length of 32.0 km
Tunnel Matsoku - Katse		Length of 6.4 km
Tunnel Katse – Muela		Length of 45.0 km
Tunnel Muela – Ash River outfall		Length of 37.0 km

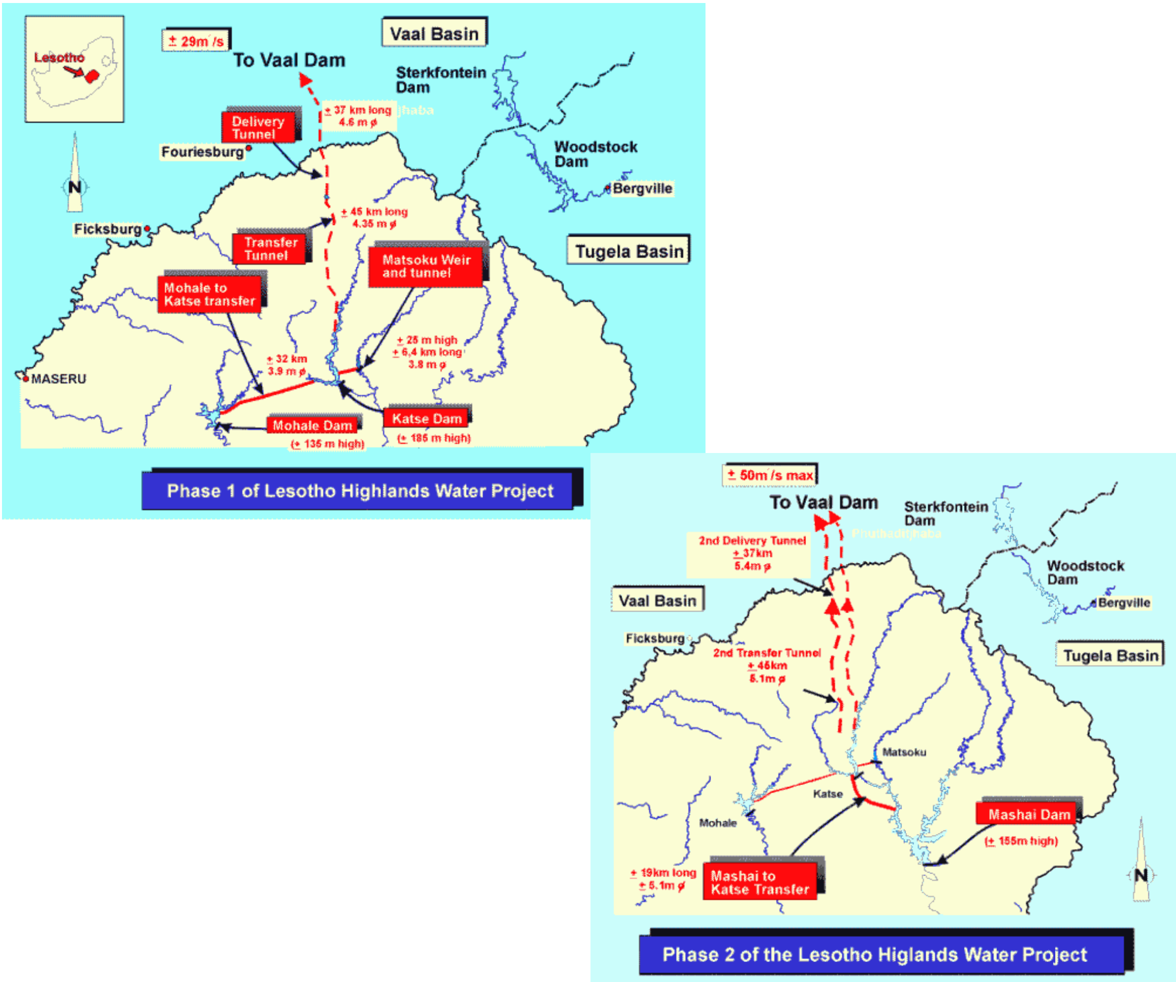


Figure 2-3: Overview of Lesotho Highlands Water Project water transfer infrastructure

2.2.2.3 *Irrigation*

Due to its mountainous terrain, Lesotho has little arable land, estimated to total to about 36,000 ha (WRP, 2012)[16]. It has no large scale irrigation schemes but a number of small scale schemes (up to about 50 ha in size). The total irrigation area which is currently operational is estimated to be about 1,000 ha (Ministry of Agriculture, 2013, *pers. comm.*), although no more precise data is available.

The crops being irrigated are typically vegetables such as cabbage, tomato, spinach and carrots (WRP, 2012)[17]. The associated crop water requirement is approximately 8,600 m^3/ha/year (Ministry of Agriculture, 2013)[18]. With an average irrigation efficiency assumed as 60%, a typical irrigation demand would equals approximately 14,300 m^3/ha/year, or a total irrigation water demand for Lesotho of approximately 14.3 Mm^3/year. The distribution of this demand is reported in Table 2-3.

Table 2-3: Approximate characteristics of irrigation in Lesotho (Ministry of Agriculture, 2013)[19].

Nearby urban centre	Approximate water demands (Mm^3/year)
Leribe	0.26
Mafeteng	6.96
Maseru	3.42
Marija	3.69
Total Lesotho	14.33

2.2.2.4 *Hydropower*

Lesotho only has one large hydropower plant which is the Muela hydropower station (72 MW) constructed as part of the Lesotho Highlands Water Project (Lesotho Electricity Company, 2013)[20]. The hydropower station is included into the Katse-Vaal transfer, utilizing surplus elevation suitable for hydropower production. Muela hydropower has no own reservoir but uses water transferred from Katse Dam through a 45 km long transfer tunnel. The hydropower station respectively has no consumptive water demand as such, but the generated electricity is a by-product of the water transfer.

The main interconnected grid of LEC which supplies power to eight of the ten districts of Lesotho is supplied with power from Muela hydropower plant and Eskom Maseru Bulk intake with electricity imported from South Africa. In addition, the Letseng Diamond Mine and the district of Mokhotlong are supplied by Eskom from Clarens in South Africa and Qacha's Nek is supplied from Eskom Kokstad in South Africa.

16 WRP. (2012). 1st Annual State of Water Resources Report (1 April 2010 - 31 March 2011). Pretoria, Republic of South Africa: WRP.

17 WRP. (2012). 1st Annual State of Water Resources Report (1 April 2010 - 31 March 2011). Pretoria, Republic of South Africa: WRP.

18 Ministry of Agriculture. (2013, November). (pers.comm.)

19 Ministry of Agriculture. (2013, November). (pers.comm.)

20 Lesotho Electricity Company. (2013, November). (pers.comm.)

In addition to the Muela Scheme, there are, or have been four small-scale hydropower schemes in Lesotho. All five schemes are shown in Figure 2-4 .

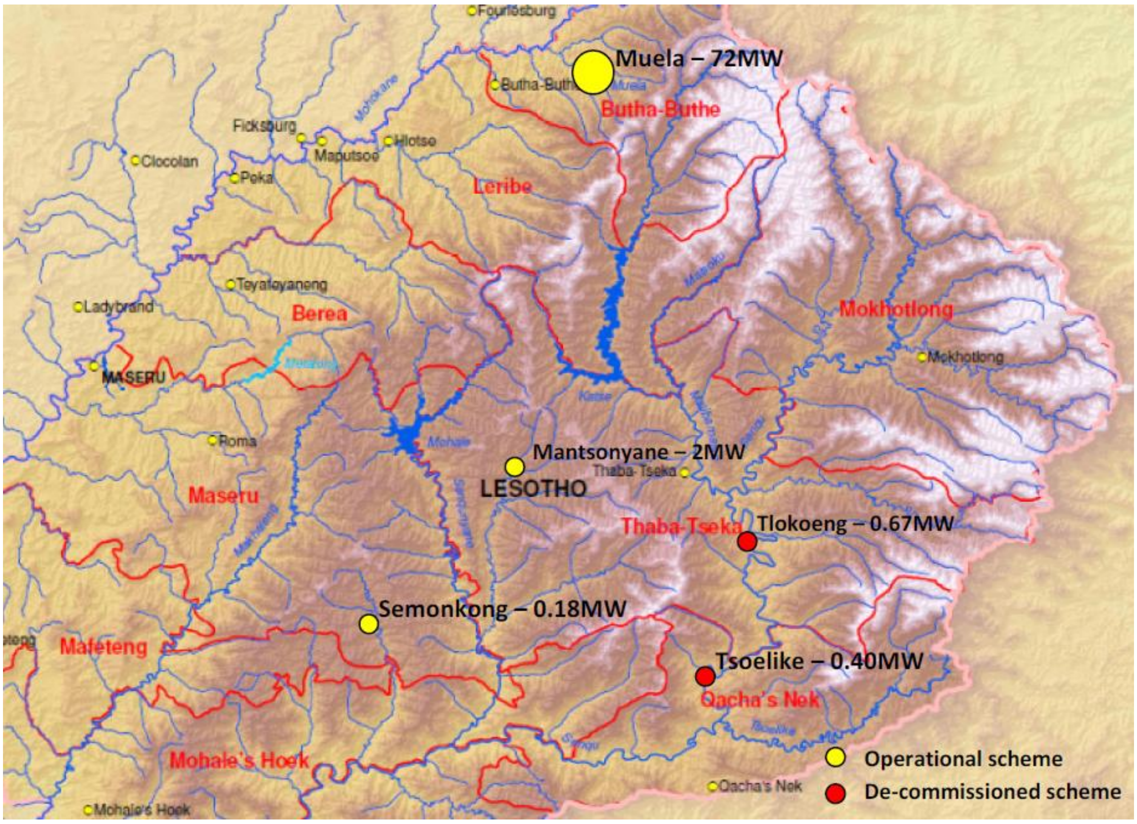


Figure 2-4: Location of hydropower schemes in Lesotho (WRP, 2012[21])

The Semonkong scheme was commissioned in 1988 on the Maletsunyane River and supplies about 26 consumers in the Semonkong development area. In 1989 a 2 MW mini hydro plant situated along the Mantsonyane river was inaugurated and is connected to the National grid as well as supplying areas such as Roma, Molimo-Nthuse and Thaba-Tseka at times when the main grid is inoperative. During normal operation it is utilized for peak lopping, thus reducing the cost of electricity to LEC.

In 1990 two more mini hydro plants were commissioned. These were the Tlokoeng scheme on the Khubelu River and the Tsoelike scheme in Qacha's Nek. These two schemes operated at a very limited scope and have been or are being de-commissioned. All hydropower plants are operated by LEC but it is currently planned to privatize the Semonkong scheme. Once this happens, LEC will operate and manage only the Muela and Maletsunyane schemes

[21] Office of Commissioner of Water and WRP; (2012); First State of Water resources report. Maseru

2.2.2.5 *Mining*

Two types of mining operations are in place in Lesotho. The predominant type is diamond with 5 official mines located in the mountainous part of the district of Butha-Buthe and Mokhotlong, the largest one being Letseng (Figure 2-5). The mining activities require water for washing the extractions but this water is recycled on-site hence the overall water consumption is very small (Ministry of Mines, 2013)[22].

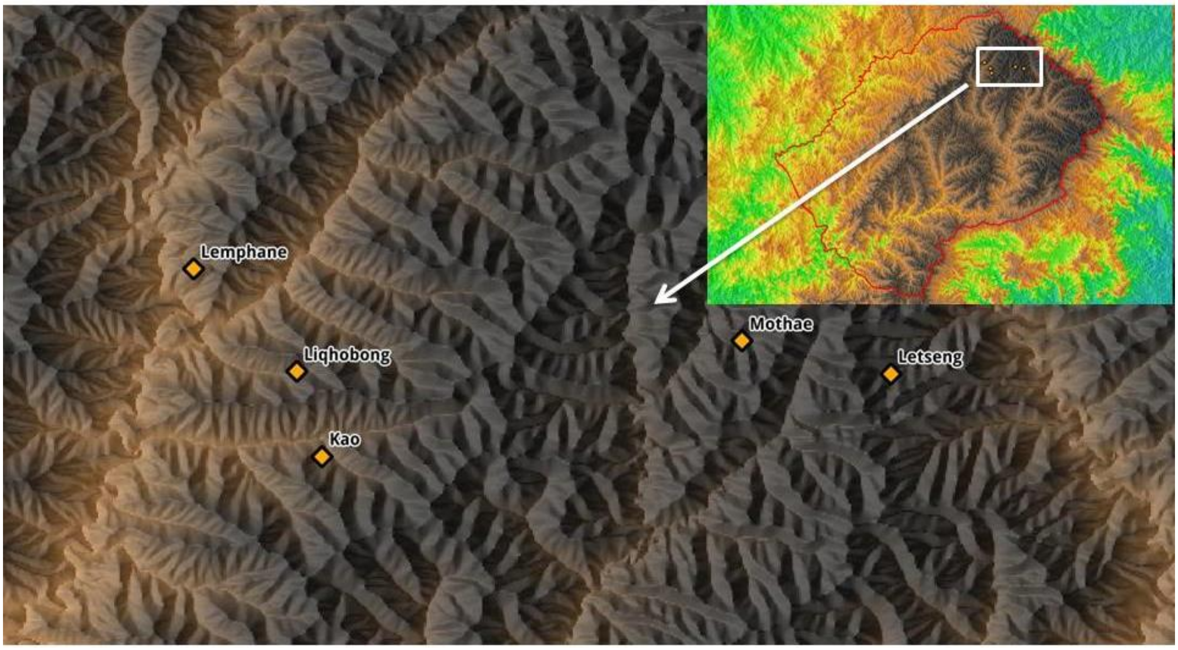


Figure 2-5: Location of the 5 official diamond mines in Lesotho.

Another type of mining operating in Lesotho is the extraction of construction aggregates. Similar to diamond mining, aggregate mining requires water to wash the extractions but the water is recycled on-site and eventually the amount of water being consumed is very small (Ministry of Mines, 2013)[23].

2.2.2.6 *Domestic and Industry*

The Lesotho's Water And Sewerage Company (WASCO) supplies water to urban zones (domestic water) as well as to industries. Maseru city has by far the largest domestic requirement. As an example, during the financial year 2012/2013 WASCO supplied about 3.08 Mm^3 (Table 2-4). The next lower domestic demand is for the town Maputsoe and is significantly smaller, using the same example, during the financial year 2012/2013 WASCO supplied about 0.25 Mm^3. In total WASCO supplies 17 urban zones for a total supply of domestic water of about 4.65 Mm^3 during the example period (Table 2-4).

[22] Ministry of Mines. (2013, November). (pers.comm.)

[23] Ministry of Mines. (2013, November). (pers.comm.)

Table 2-4: Water supplied by Lesotho's Water And Sewerage Company (WASCO) to the 6 largest urban centres and the total for Lesotho during the financial year 2012/2013. Based on data obtained from WASCO (10% loss in production is considered, distribution losses are higher)

Urban centre (Mm3/year)	Raw water withdrawn from river (Mm3/year)	Treatment losses (%)	Water produced (Mm3/year)	Distribution losses (%)	Water billed						
					Total	Domestic		Industries		Others (e.g., commercial)	
					(Mm3/year)	(Mm3/year)	(%)	(Mm3/year)	(%)	(Mm3/year)	(%)
Maseru	16.81	10	15.13	32	10.22	3.08	30%	3.10	30%	4.04	40%
Maputsoe	0.80	10	0.72	31	0.50	0.25	50%	0.09	18%	0.16	32%
Mafeteng	0.59	10	0.53	25	0.40	0.23	58%	0.02	5%	0.15	37%
Leribe	0.45	10	0.40	23	0.31	0.17	55%	0.00	0%	0.14	45%
Roma	0.42	10	0.38	24	0.29	0.08	28%	0.00	0%	0.21	72%
Teyateyaneng	0.40	10	0.36	25	0.27	0.19	70%	0.00	0%	0.08	30%
Total Lesotho	21.15	10	19.03	31	13.09	4.65	35%	3.21	25%	5.23	40%

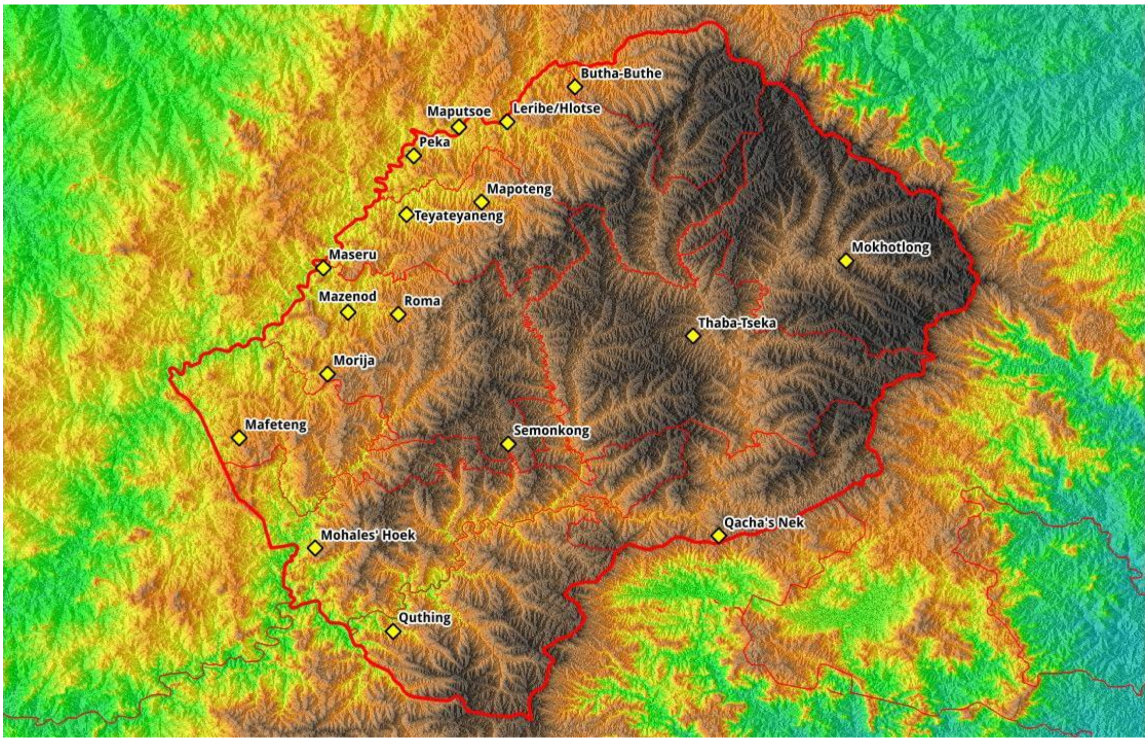


Figure 2-6: The 17 urban centres being supplied by Lesotho's Water and Sewerage Company (WASCO)

In terms of industries, the garment industry is by far the largest sector in Lesotho, amounting to 85% of the industrial activities in year 2010 (though it endured a slow down since the year 2005). The remaining majors sectors are footwear (6% in year 2010) and electronics (3% in year 2010) (LNDC, 2011). WASCO's water supply to industries is largely around Maseru, followed to a much smaller extent around the towns of Maputsoe and Mafeteng (Table 4). At Maseru the amount supplied to industries (ca 3.1 Mm^3) is essentially the same as the volume provided to domestic demand (3.08 Mm^3) during the financial year 2012/2013. During this same period, the total volume of water WASCO supplied to industries in Lesotho, which are all located in Maseru, Maputsoe and Mafeteng, is 3.21 Mm^3.

WASCO also delivers water to other uses located in urban zones, including commercial and government (Table 2-4). Domestic, industrial and others (including commercial and government) water represents respectively 35%, 25% and 40% of the water supplied by WASO during the financial year 2012/2013. This supply, which is the volume of water billed, is smaller than the total volume of water WASCO produces before distribution, due to losses in the distribution system ranging from 33% to 25% with a country average of 31% (Table 2-4). The total water WASCO produced during the financial year 2012/2013 was about 19.0 Mm^3. Moreover, due to an additional loss occuring during the water treatment process, estimated to be about 10% (WASCO, 2013), the total volume of raw water withdrawn from rivers to produce the total treated water was about 21.15 Mm^3 for the same period.

2.2.2.7 Environment

The implementation of the Lesotho Highland Water Project has led to significant changes in the hydraulic regime with the Mohale Dam, the Matsoku Weir and the Katse Dam being in place. Minimum water releases downstream are enforced by the project to satisfy environmental flow requirement, as summarised in Table 2-5.

Table 2-5: Minimum water released by the Lesotho Highland Water Project to satisfy environmental flow requirement (Lesotho Highland Development Authority, 2013)[24].

Structure	River	Minimum release downstream (Mm^3/year)
Mohale Dam	Senqunyane	31.2
Matsoku Weir	Matsoku	34.4
Katse Dam	Malibamats'o	67.7

2.2.2.8 River and operational requirements

Operation of the Lesotho Highlands Water Project results in a certain amount of losses, mainly as a result of seepage and evaporation from the new reservoirs. In general, 10% system losses are assumed. The absolute loss numbers are respectively dependent on the actual water transfers. Assuming the above stated 780 Mm^3/year transfer volume losses would respectively be 78 Mm^3/year.

To support Lesotho's Water and Sewerage Company's supply of domestic and industrial waters in the lowlands of Lesotho, While the bulk of the water from Muela dam is transferred to Ash River outfall in South Africa, the Lesotho Highland Water Project (LHWP) also releases water to the Caledon River through its tributary, the Nqoe River, the original riverbed at Muela Dam. The LHWP uses the reservoirs Muela and Katse to adapt the release to the current hydrological conditions. At Muela Dam, the mean inflow is approximately 5 Mm^3/year. Except during droughts, the dam releases less than this inflow, 1.25 Mm^3/year, and by adapting the water being transferred between Katse Dam and Muela Dam to supply water to South Africa, the remaining water is virtually stored in Katse Dam to a cumulated maximum of 15 Mm^3. During droughts, the LHWP releases water into the Caledon at Muela Dam to meet requirements in the lowlands (in particular at Maseru), to an amount which can exceed 5 Mm^3/year (Lesotho Highland Development Authority, 2013).

[24] Lesotho Highland Development Authority. (2013, November). (pers.comm.)

2.2.3 Namibia

Namibia’s surface water resources within the Orange River basin are relatively limited. All rivers are seasonal in nature with the Fish River being the largest by far. The Auob and Nossob Rivers in the north-east of the basin are part of the Molopo system. Hydraulic infrastructure in Namibia includes weirs, dams and irrigation schemes as well as domestic offtakes related to these schemes. Most water is anyhow supplied from groundwater in a decentralized manner.

2.2.3.1 Water management situation

Institutions involved in water management in Namibia include:

- NamWater, a parastatal institution that is responsible for bulk water supply;
- The Department of Water Affairs (DWA) within the Ministry of Agriculture, Water and Rural Development, which is responsible for all water resource development projects, including irrigation planning and development;
- The National Development Corporation (NDC) that executes new government developments and also manages schemes.

Water boards are responsible for irrigation scheme management. Due to the transboundary nature of the Orange River, joint efforts have been established between Namibia and South Africa in form of a Joint Irrigation Authority between Namibia and South Africa, known as the Noordoewer/Viooldrift Irrigation Board, established 1993.

Namibia’s water legislation is based on the Water Act 54 of 1956 which has colonial roots and assumes principles of well-watered European countries. It is respectively challenging to deal with Namibia’s natural conditions. The water act is under revision aiming to better consider the countries particularities and switch to a Water User Association based management style. In 1995, a National Agricultural Policy was established, mainly to improve irrigation performance. The National Water Policy was adopted in 2000, aiming at the implementation of integrated water resources management.

2.2.3.2 Irrigation

Namibia has several irrigation schemes, fed from the Fish River as well as from the Orange River. The main schemes are listed in Table 2-6. In the Auob/Nossob sub-basin, specifically the Stampriet area, irrigation is reported to take place based on groundwater (ORASECOM, 2011[25]). Farmers who use groundwater boreholes generally do not irrigate on a very large scale. Quantities of water consumptions are not available as licenses and sales figures from Namwater do not reveal irrigation users.

[25] ORASECOM, 2011, The promotion of water conservation and water demand management in the irrigation sector, Support to Phase 2 of the ORASECOM basin wide integrated water resources management plan.

Table 2-6: Main irrigation schemes and their features in Namibia (Source: MoA, 2013)[26]

Scheme	River	Size (ha)	Irrigation demand (m^3/ha/a)*	Main crops	Irrigation method**	Water source
Hardap	Fish	2200	20,000	Maize, Wheat	f,s	River
Naute	Löwen	400	15,000	Dates, Grapes, Fruit	m	River
Aussenkehr	Orange	1500	15,000	Grapes	d,m	River
Noordoewer	Orange	286	15,000	Vegetable, Lucerne	f,s	River
Haakiesdoorn	Orange	250	15,000	Dates, Vegetable	d,m	River
Komsberg	Orange	310	15,000	Grapes, Dates	d,m	River
Stampriet	Auob/ Nossob	1000 approx		Vegetable	s,m,d	Ground water

f=furrow, s=sprinkler, m=micro, d=drip
* Updated figures based on information from Ministry of Agriculture (2013)

2.2.3.3 Hydropower

There are no large hydropower plants in the Namibian part of the basin. A small hydropower installation is located in Hardap Dam.

2.2.3.4 Mining

Namibia has several mines, all located along the Orange River. Main mines are shown in Table 7.

Table 2-7: Main mines in Namibia

Mine	River	Product	Mine water demand (Mm^3/year)	Commission date	Expected closure
Namdeb Auchas & Daberas	Orange	Diamond	1.0	1991	2020
Rosh Pinah	Orange	Zinc, Lead	0.9	1968	2025
Skorpion	Orange	Zinc	4.7	2003	Approx 2018
Oranjemund	Orange	Diamond	6.5	1936	2020

[26] Ministry of Agriculture, 2013, pers.comm.

2.2.3.5 *Industry*

There are no large scale industries within the basin in Namibia. Evidence for industrial water use is not available but the demands are included in the domestic water use figures

2.2.3.6 *Domestic*

Namibia's domestic water demand is supplied from both groundwater and surface water sources. Broadly speaking most of the smaller scale domestic demands are satisfied from groundwater while domestic demand satisfaction from surface water is limited to the vicinity of rivers, dams and irrigation schemes. The domestic demands include demands from small and medium industries.

The main locations for domestic demands in the basin include:

- Mining towns, supplied from Lower Orange River 8.4 Mm^3/year
- Keetmanshoop, supplied from Naute Dam 1.9 Mm^3/year
- Mariental, supplied from Hardap Dam 1.0 Mm^3/year
- Irrigation related domestic demands on Lower Orange 0.3 Mm^3/year
- Towns supplied from Otjivero Dam 0.9 Mm^3/year
- Towns supplied from Viljoen Dam 0.1 Mm^3/year

Detailed demand numbers related to groundwater extraction are not known.

2.2.3.7 *Environment*

Environmental flow requirements in Namibian rivers are difficult to assess due to the seasonal or intermittent nature of the rivers. Efforts for calculating Environmental Flow Requirements (EFR) have been made, e.g. by Lowe, et.al. (2013)[27]. EFR requirements for the Lower Orange are dealt with in another report.

2.2.3.8 *River and operational requirements*

Losses in Namibia's rivers and reservoirs are very high as compared to the total water resource availability and -use in the country. For example, according to Water Resources Planning Model calculations, natural losses along the Namibian part of the Orange River are estimated at 560 Mm^3/year and natural losses along the Fish River at 224 Mm^3/year. Evaporation losses from the Hardap and Naute Dams are considerable.

[27] Louw, Brown, Van Niekerk, 2013, Transboundary Water Management in SADC : Integrated Water Resources Management Plan for the Orange-Senqu River Basin: Testing flow regimes for scenario design, ORASECOM-IWRM-Plan-TF-Rep

2.2.4 South Africa

South Africa has the largest amount of river infrastructure in the Orange basin including weirs, dams, hydropower schemes, irrigation schemes, inter- and intra-basin transfer schemes as well as intakes. Infrastructure is well documented in e.g. the ORASECOM Catalogue of Built Structures. Demand related structures have further been included in a database that has been produced as part of the current project. A summary is provided in the following sections.

2.2.4.1 Water management situation

Different ministries are involved in water management in South Africa:

- The Ministry of Water Affairs and Forestry, through the Department of Water Affairs and Forestry (DWAF), monitors surface water and groundwater resources, formulates the national water strategy and is responsible for the implementation of the Water Act
- The Ministry of Agriculture, through the National and Provincial Departments of Agriculture (NDA and PDA), promotes irrigation engineering concepts and is responsible for agricultural extension with the aim of improving irrigation efficiency

Respective legislation is included in the Water Act 0f 1998 which stipulates water management by Water User Associations (WUA) at the local level. The Water Act further determines that all water use, with the exception of reasonable domestic use must be licensed.

2.2.4.2 Irrigation

For South Africa, 220 irrigation entries have been included in the database. Largest consumers draw up to 608 Mm^3/year of irrigation water (Eastern Cape Irrigation on the Upper Orange), though the average irrigation scheme or -areas demand is 14.5 Mm^3/year and the median demand is 2.8 Mm^3/year. Most irrigation schemes or -areas in South Africa are respectively relatively small. There are 8 schemes with water demands larger than 100 Mm^3/year, 38 schemes larger than 10 Mm^3/year and the remaining smaller than 10 Mm^3/year. Details are provided in Table 2-8. Total irrigation water demands sum up to 3200 Mm^3/year.

Table 2-8: Main irrigation schemes and their features in South Africa that are supplied with water from the basin based on collected information from different sources (see database for details)

River system	Scheme or area	Irrigation demand (Mm^3/a)
Caledon	Total of smaller schemes and areas	64.3
Upper Orange	Total of smaller schemes and areas	163.4
Upper Orange	Eastern Cape Irrigation	577.2
Upper Orange	Irr VDK to Torquay	141.1
Upper Orange	RR239: Orange Riet Canal Irrigation	171.3
Riet/Modder	Total of smaller schemes and areas	214.4
Lower Vaal	Total of smaller schemes and areas	166.8
Molopo	Total of smaller schemes and areas	1.8
Lower Orange Main Stem	Total of smaller schemes and areas	241.5
Lower Orange Main Stem	Middel Orange Irrigation	152.2
Lower Orange Main Stem	Boegoeberg Canal Irrigation	101.4
Lower Orange Main Stem	Upington Canals Irrigation	104.2
Lower Orange Main Stem	Kakamas Canals Irrigation	111.4
Komati Sub-system	Total of smaller schemes and areas	16.6
Usutu Sub-system	Total of smaller schemes and areas	8.5
Upper Vaal : Grootdraai	Total of smaller schemes and areas	20.7
Upper Vaal: Incremental	Total of smaller schemes and areas	159.8
Upper Vaal: Vaal Barrage	Total of smaller schemes and areas	55.9
Middle Vaal: Kromdraai	Total of smaller schemes and areas	7.4
Middle Vaal: Mooi River	Total of smaller schemes and areas	48.5
Middle Vaal: Renoster River	Total of smaller schemes and areas	17.3
Middle Vaal: Vals River	Total of smaller schemes and areas	30.1
Middle Vaal: Schoonspruit	Total of smaller schemes and areas	30.2
Middle Vaal: Sand-Vet	Total of smaller schemes and areas	102.7
Middle Vaal: Vaal River Main	Total of smaller schemes and areas	55.0
Lower Vaal: Vaal River Main	Total of smaller schemes and areas	86.8
Lower Vaal: Harts River	Total of smaller schemes and areas	78.7
Lower Vaal: Harts River	RR379 Vaalharts GWS North Canal & Part Taung Irrigation Demand	270.0

2.2.4.3 Hydropower

South Africa has a developed hydropower infrastructure with hydropower stations implemented in several dams. The main installations are shown in Table 2-9. As the water use is not consumptive the schemes don't have a "water demand" as such

Table 2-9: Main hydropower schemes in South Africa

Scheme	River	Installed capacity	Production	Reservoir capacity	Operation
Gariep Dam	Orange	360 MW	889 GWh/year	5,340 Mm^3	Hydropower priority in combination with Vanderkloof Dam
Vanderkloof Dam	Orange	250 MW	932 GWh/year	3,188 Mm^3	Irrigation priority
Drakensberg Pumped Storage Scheme	Part release into the Vaal, part of the Orange basin		27.6 GWh/ pump storage	275 Mm^3	Demand driven pump storage with chain of reservoirs including Driekloof Dam (branch of Sterkfontain Dam), Kilburn Dam, Woodstock Dam, Driel Barrage

In addition to the hydropower water demands there are several cooling water demands from fossil fuel fired power stations that are included in the database. Most of these power stations are located outside the Orange/Senqu basin but are supplied with transfers from the Vaal in combination with transfers from neighbour river basins. Their water demand from the Orange River basin sums up to 500 Mm^3/year consumptive use.

2.2.4.4 Mining

South Africa has several mining operations with respective water demands, totalling 8.7 Mm^3/year and a median demand of 0.5 Mm^3/year. Main mines are listed in Table 2-10.

Table 2-10: Main mines in South Africa

Mine	River	Product	Mine water demand (Mm^3/year)	Commission date	Expected lifespan
DeBeers / Petra Diamonds (Kalkfontain)	Riet/Modder	Diamond	1.5	1870	unknown
Black Mountain Mines (Pelladrift)	Lower Orange Main Stem	Zinc, Lead	1.9	1980	2030
Alexander Bay Transhex Small Mines	Lower Orange Main Stem	Diamond	5.3	2001	2020

In addition to mine water demand, mines typically produce a return flow that has been considered in the database (industry discharge or industry return flow).

2.2.4.5 Industry

Industrial (or strategic) water demand in South Africa is dominated by processing, manufacturing and energy production with most of the industries being located in the Gauteng Province, the industrial heartland of South Africa. The water demand in Gauteng province outstripped the local resource of the Vaal River many years ago with the result that the area relies heavily on large water schemes which transfer water from adjacent river basins into the Vaal River basin e.g. through the Lesotho Highland Water Project as well as other smaller transfer schemes. The water transfer schemes associated with the Vaal River basin are large by any international standards and the water resource system is one of the most complex and integrated, anywhere in the world (Mckenzie & Wegelin, 2009)[28].

Total industrial demands supplied from the Vaal basin have been established with 221 Mm^3/year in 2013. In comparison, the total demands in the Vaal basin considering all users sum up to about 2,600 Mm^3/year. It anyhow needs to be noted that in the data as collected and compiled in the database, industrial and domestic data are often lumped together, i.e. small scale industries may not be captured in above figures but are included in the domestic demands.

Considering overall South Africa, industrial demands in the basin have been established with 496 Mm^3/year for 2013. The largest industrial user groups are Escom and Sasol with several large demands as shown in Table 11. The latter, in between others, is e.g. showing a single largest demand of 86 Mm^3/year.

Table 2-11: Main industrial water demands in South Africa

River	Number	User	Demand (Mm^3/year)
Upper Vaal, Grootdraai	43	SASOL Secunda	86
Upper Vaal, Grootdraai	48	Eskom Tutuka & DWA 3rd Party Users	34
Upper Vaal, Vaal Barrage	66	Eskom Power Stations (Grootvlei, Lethabo, Kragbron&New) from Vaal Dam	37
Upper Vaal, Vaal Barrage	67	Sasol Sasolburg Complex abstracton from Vaal River	28
Upper Vaal, Vaal Barrage	76	Sasol Sasolburg Complex abstraction from Vaal Dam	15
Upper Vaal, Vaal Barrage	158	Sasol Sasolburg Complex abstraction from Barrage	13
Usutu Sub-system	10	Eskom Matla 2 (Supply from Grootdraai and VRESAP) & Kusile PS	34
Usutu Sub-system	80	Eskom Kriel_1 (Usutu-with support from Grootdraai)	28
Usutu Sub-system	476	Eskom Kriel_2 (Supply from Grootdraai and VRESAP)	27
Komati Sub-system	11	Eskom Duvha2 (Komati with Usutu sub-system support)	32
Komati Sub-system	929	Eskom Hendrina & DWA 3rd Party Users	23

[28] Mckenzie, R.S., Wegelin, W., 2009, Challenges facing the implementation of water demand management initiatives in Gauteng Province, ISSN 0378-4738 = Water SA Vol. 35 No. 2

2.2.4.6 Domestic

Domestic water use in South Africa is distributed between a large number of individual demand centres. Domestic demand is partly including industrial demands and also domestic demands are partly included in mining demands, i.e. not included here as the figures cannot always be separated. In addition, the database is not conclusive as part of domestic water demand is satisfied from groundwater and not accounted for. Based on information stored in the database, total domestic demands for South Africa have been established with 2300 Mm³/year for 2013. Main demand centres are shown in Table 2-12.

Table 2-12: Main domestic demand centres in South Africa

River	Number	User	Demand (Mm³/year)
Upper Vaal: Vaal Barrage	70	Rand Water (Northern Gauteng) & Authorised Industrial Users	523
Upper Vaal: Vaal Barrage	69	Rand Water: Southern Gauteng Users (DC40: Ret Flow to Klip River)	435
Riet/Modder	950	Bloemfontein total	74
Middle Vaal: Vaal River Main Stem	127	Sedibeng Water: Abstraction from Vaal River at Balkfontein	72
Middle Vaal: Vaal River Main Stem	166	MidVaal WC & Vaalreefs Mine: Abstraction from River (DC84)	58
Upper Orange	529	Eastern Cape Urban	34

2.2.4.7 Environment

The South Africa Ecological Reserve (South Africa National Water Act, Act 36 of 1998) has been implemented to address the importance of environmental flows (ORASECOM, 2007)[29]. Current provisional assessments indicate that, as a national average, about 20% of the total river flow is required as ecological reserve which needs to remain in the rivers to maintain a healthy biophysical environment (DWAF, 2003)[30].

ORASECOM (2013)[31] describes environmental flow demands as the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems. The document further describes a background of different environmental flow assessments in the Orange basin and tests the suitability of different test flow regimes for maintaining the Present Ecological State (PES).

Following the different studies, conditions in the basin with regards to maintaining Environmental Flow Requirements (EFR´s) are quite different. In the Senqu basin, EFR´s have been computed as between 13% and 80% of the natural flows, an increase as compared to previous studies (15-40%). Results also show that for most sites actual flows do not reach environmental flow requirements in the future with actual flows being 65-124% of EFR´s. Median results show an achievement rate of 96% of EFR´s. Respectively an over-abstraction is taking place at cost for the environment and potentially impacting ecosystem services. Desired environmental flows are not achieved.

[29] ORASECOM. 2007. Environmental Considerations Pertaining to the Orange River WRP Consulting Engineers, Jeffares and Green, Sechaba Consulting, WCE Pty Ltd, Water Surveys Botswana (Pty) Ltd. 190 pp

[30] DWAF. 2003. Overview of Water Resources Availability and Utilisation. National Water Resources Strategy Report No. P WMA 08/000/00/0203. by BKS (Pty) Ltd.

[31] ORASECOM, 2013, Transboundary Water Management in SADC : Integrated Water Resources Management Plan for the Orange-Senqu River Basin: Testing flow regimes for scenario design

In the Caledon basin, EFR´s range between 19% and 100% of the mean annual flows, depending on site. Test flows meet the target condition during the dry season. In the wet season, the test flows are lower than the target EFR by about 20%. In the Orange River all flow regimes show an improvement during the wet season but are deficient as to reach EFR´s during the dry season. For the Vaal River, ORASECOM (2013)[32] has listed ecological flow requirements of 13%-73% of the mean annual flows based on previous studies. In the Lower Orange and respectively the estuary EFR´s are reported with 14%-40%.

2.2.4.8 River and operational requirements

River and operational requirements are based on the overall operation of the Orange River system catering for several different user requirements considering consumptive and non-consumptive aspects as well as, if applicable, flood regulation, etc. An important aspect of river operation is the consideration of seasonal requirements and particularities of the river system that are included into operation schedules.

Operational requirements related to river and channel flows are reflected in losses and diffuse demands. In addition e.g. changes in runoff and other aspects that cannot be allocated to a specific demand centre have to be considered here.

Losses make up a significant amount of water demands, they occur due to seepage and evaporation. E.g. losses in the Molopo River alone sum up to 4100 Mm³/year, i.e. the entire river flows are lost before reaching the Orange River main stem. Nevertheless a proportion of these losses are recharging the groundwater and are respectively used from there in an unaccounted for manner. In general losses for river reaches and channels are set at between 5% and 25%. Total losses in the Orange River basin are estimated with 4800 Mm³/year. Diffuse demands amount to 80 Mm³/year.

Operational requirements are to some extent dependent on operation priorities for the different assets, i.e. whether dams are operated with e.g. hydropower priority (e.g. Gariep Dam) or irrigation priority (e.g. Vanderkloof Dam).

WATER TRANSFERS

Water transfer demands and yields are assigned to the different transfer schemes that have been built in South Africa. These transfers require significant water amounts, e.g. up to 780 Mm³/year in the Lesotho-Vaal transfer and 303 Mm³/year for the Grootdrai transfer. An overview is given in 13, total current transfer demands amount to 1088 Mm³/year.

Table 2-13: Overview of current and potential water transfers in South Africa

River	Number	User	Demand (Mm³/year)
Senqu	2	Lesotho Vaal Transfer (LHWP)	780
Riet/Modder	2149	Water Quality Releases for Lower Riet	5
Upper Vaal: Grootdraai	42	Supply route from Knoppiesfontein to Trichardtsfontein	303
Upper Vaal: Vaal Barrage	1993	Transfer of raw water from Vaal to Crocodile	(future option)
Lower Vaal: Vaal River Main Stem	1376	Bloemhof Dam Excess Water supplied to Orange River	50
Thukela	385	Transfer from Thukela to Mhlatuze	38

[32] ORASECOM, 2013, Transboundary Water Management in SADC : Integrated Water Resources Management Plan for the Orange-Senqu River Basin: Testing flow regimes for scenario design

2.3 Basin Trends

2.3.1 Population Growth

The demographics in the Orange River basin are dynamic and in general characterized by population growth. The Basin as a whole is home to about 15.7 million people, the majority of which (85%) live in South Africa.

Latest figures show that South Africa has a current population of approximately 53 million (2011 census) and a population growth rate of 1.3%[33] which is relatively low compared to the massive growth during the last century. Projections of the UN indicate a stabilizing population in the upcoming decades[34]. Namibia shows a population of about 2.1 million people (2011 census), with a growth rate of 1.4% which is a reduction from previous years[35]. In Botswana the current population is estimated with about 2 million (2011 census). Current growth rate is 1.9%[36]. Lesotho has a population estimated to be over 2 million. The last census numbers show 1.9 million people in 2006[37]. The annual growth rate is estimated with 0.1%[38]. provides a respective overview.

Table 2-14: Summary of basin country demographics (based on ORASECOM, 2007[39], updated by 2011 census information)

	South Africa	Botswana	Lesotho	Namibia	Total
Total Population	44.8 million	1.7 million	2.1 million	1.8 million	50.5 million
Number in Basin	13.4 million	47,700	2.1 million	163,100	15.7 million
% in Basin	29.8	2.8	100	8.9	
% of Number in Basin	84.9	0.3	13.5	1.3	100
Updated information from 2011 census					
Population	53 million	2 million	2 million	2.1 million	59.1 million
Growth rate	1.3%	1.9%	0.1%	1.4%	

In general a slowing down of population growth is visible over the last decades. Based on this trend a stabilization of the population is anticipated in all basin countries over the coming decades.

ORASECOM (2007)[40] reports that all basin states are undergoing rapid urbanisation driven primarily by high levels of unemployment in rural areas and perceived work opportunities in urban areas. This results in rural areas experiencing out-migration (population declines), whilst urban areas – especially major conglomerates – witness growth rates well in excess of the national averages.

33 Statistics South Africa, 2013, "Mid-year population estimate, 2013"

34 Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2010 Revision

35 "Census Summary Results". National Planning Commission of Namibia, 2011

36 2011 Population and Housing Census. Gaborone: Statistics Botswana.

37 "2006 census". Lesotho Bureau of Statistics

38 CIA. "CIA - The World Factbook - Lesotho"

39 ORASECOM, 2007, Orange River Integrated Water Resources Management Plan – Demographics and Economic Activity in the Four Orange Basin States

40 ORASECOM, 2007, Orange River Integrated Water Resources Management Plan – Demographics and Economic Activity in the Four Orange Basin States

2.3.2 Economic Development

Economic development in the Orange River basin is relatively rapid but also significantly different between the basin states, with a main focus on South Africa's Gauteng region which is the economic hub of southern Africa. Main economic activities in the basin are agriculture, mining and industries.

South Africa is the driving economy in southern Africa. Despite showing strong income inequalities, it is ranked as an upper-middle income economy by the World Bank[41]. The economy is diversified with agriculture, mining, manufacturing, assembly, processing, energy, finances, services, tourism, transportation and trade. Irrigation is the most important water consumer overall, accounting for over 60% of the local water requirements in the entire area. With water demands being higher than naturally available water resources, the Lesotho Highland Water Project was developed to supply water from the Lesotho highlands to South Africa's Gauteng region. The project ensures that South Africa's water demands can be met and is at the same time a major contributor to Lesotho's revenue generation through the water sales and providing hydropower.

Botswana is the state with the highest economic growth rate in the basin, averaging 9% per year. Main activities include agriculture, mining, tourism and trade. A specific notion is that agriculture is the livelihood for the majority of the population while it only generates a small fraction of the gross domestic product. Water from the Orange basin plays a lesser role for the economy in Botswana at the current stage though transfer schemes are under consideration for the future.

Namibia's economy is strongly linked to South Africa and rated as a higher middle income country though having strong inequalities. The economy consists both of subsistence farming as well as market oriented mining, manufacturing and agricultural activities, especially in the Orange basin part of the country and respectively being fully dependent on Orange basin (Fish- and Orange River) surface water resources.

Agriculture, livestock and manufacturing are the basis of the Lesotho economy, while a large proportion of income is also gathered through a migrant workforce employed in South Africa. Nearly two thirds of the country's income is through the agricultural sector, while half of the population earn some income through crop cultivation or animal husbandry. The western lowlands are home to the majority of agriculture in Lesotho. With the reduction of mineworkers, a manufacturing base within Lesotho has been developed. Manufacturing includes agro-processing crops grown in the country as well as the development of an apparel assembly sector. As a result, manufacturing employment has become the largest formal sector employer in Lesotho, exceeding government employment. Income is also gathered through the transfer of water from Lesotho through the Lesotho Highlands Water Project for use in Gauteng and the Free State of South Africa.

Considering the natural resources and human potential in the basin and considering trends it is anticipated that economic growth in the basin countries will continue, which is also reflected by the inclusion of South Africa into the BRICS countries in 2010.

41 http://data.worldbank.org/country/south-africa

2.3.3 Climate Change

INTRODUCTION

The climate in the Orange River basin shows a broad spectrum of conditions, varying from subtropical to near temperate and is largely influenced by latitude, variations in elevation, tropical weather systems, the Indian Ocean to the southeast and the Atlantic Ocean to the southwest. Precipitation falls mostly during the summer months of October to March; winter (June to August) is the dry season

According to the UNDP-GEF (2008http://www.orangesenqurak.com)[42], the climate in the basin can be divided into the following areas.

- The mountainous terrain of the Maloti Mountains of Lesotho - this region experiences a relatively temperate climate, defining the ecosystems and to a large extent the livelihoods possible in this region.
- The undulating dry grasslands of the southern Highveld - a climatic and geographic transition zone from the mountainous regions.
- The western region of southern Africa - containing three desert systems, characterized by harsh arid conditions:
  - The Succulent Karoo – experiencing highly variable and inconsistent rainfall throughout the year
  - The Nama Karoo - receiving mainly summer rainfall and comprising a number of different vegetation types
  - The Southern Kalahari – consisting of deep wind-blown sand, which allows little or no run-off from rainfall

Climate change projections for the basin are well described by ORASECOM (2011)[43]. Assessments have been conducted considering the IPCC A1B scenario.

[42] UNDP-GEF (United Nations Development Programme - Global Environment Facility), 2008, Orange-Senqu River Basin Preliminary Transboundary Diagnostic Analysis

[43] ORASECOM, 2011, Support to Phase 2 of the ORASECOM Basin Wide Integrated Water Resources Management Plan, Work Package 4, Climate Change in the Orange-Senqu River Basin, Projection of Impacts under Plausible Scenarios and Guidelines on Climate Change Adaptation Strategies

TEMPERATURE

The mean annual temperature in the basin as projected for 2031-2060 is expected to increase by 1°C to 2.5°C as compared to the 1971-2000 baseline for the basins coastal area (river mouth) and Kalahari Desert respectively. The increase in Lesotho is expected to be between 1.5°C to 2°C. A basinwide overview is shown in Figure 6.

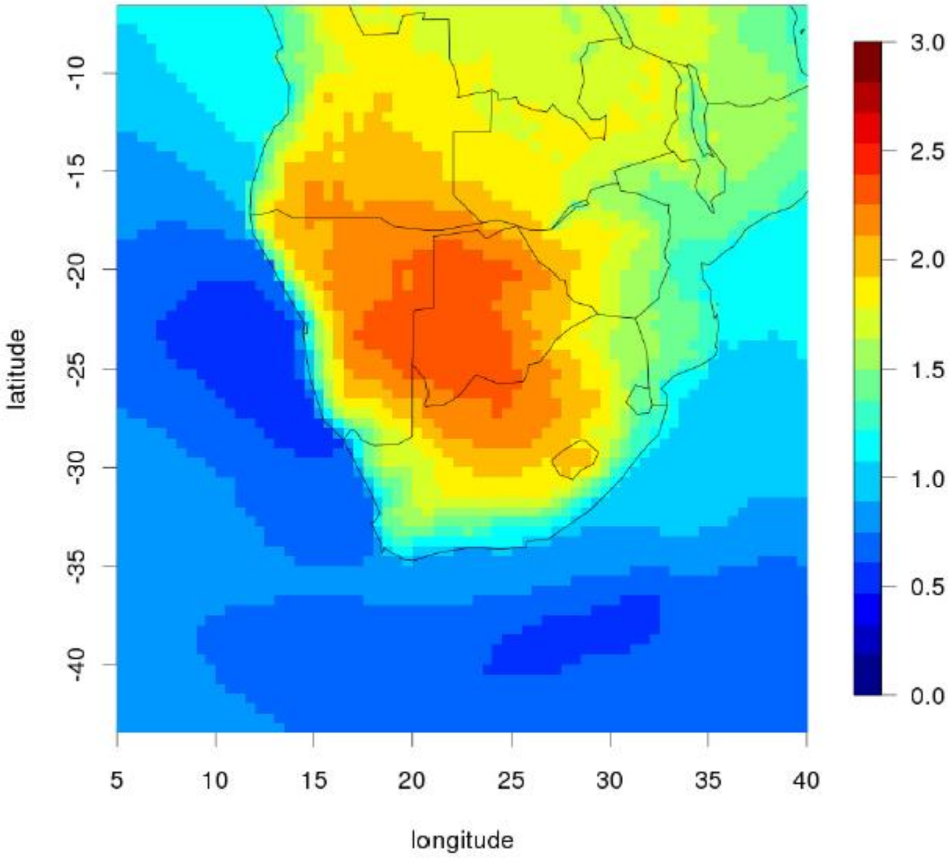


Figure 2-7: Change in the average annual temperature between 2031-2060 and 1971 to 2000

For the different seasons, the projected temperature increase is unevenly distributed. In summer (DJF) and autumn (MAM) a general temperature increase of more than 2.5°C in the northern Orange basin and Namibia is predicted. The largest increase of 3°C is predicted for the summer months around the Kalahari Desert. For the autumn and winter seasons temperature increases are predicted although the magnitude of the increase is less extreme. The temperature increase in these cases is more evenly distributed across the basin with predicted temperature increases of between 1°C and 2°C. Details are shown in Figure 2-8.

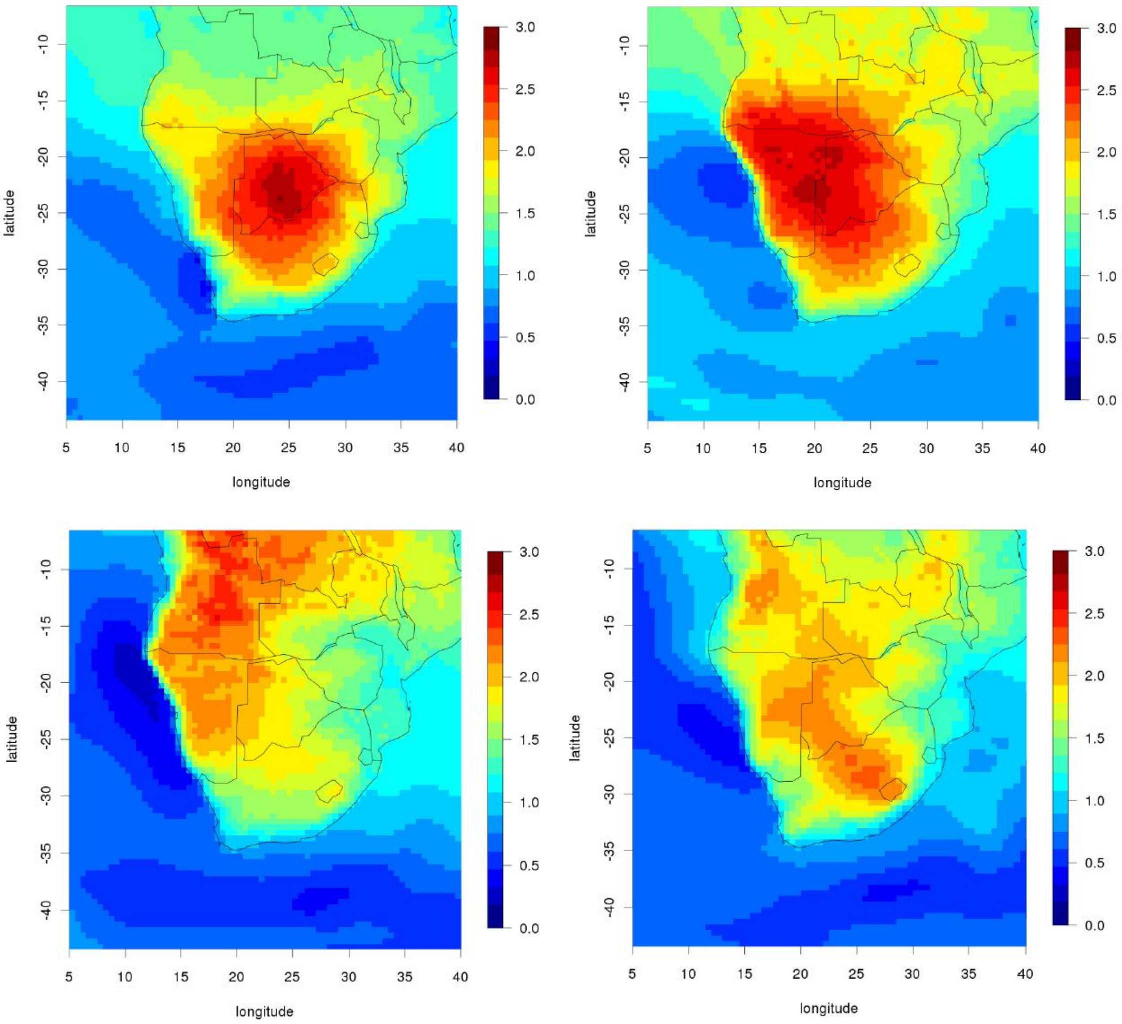


Figure 2-8: Predicted temperature changes for 2031-2060 as compared to 1971-2000 baseline for summer (DJF, top left), autumn (MAM, top right), winter (JJA, bottom left)) and spring (SON, bottom right)

PRECIPITATION

Projections of mean annual rainfall are less certain than temperature projections. Results depend on scenario assumptions and have been evaluated for dry, median and wet conditions for 2051-2060 as compared to current observations by ORASECOM (2011)[44]. Considering a median development scenario, results show a small decrease of annual precipitation (down to -80mm per annum) for most of the Orange/Senqu river basin. The precipitation decrease is evenly spread across the basin. For the dry scenario, a decrease of precipitation is projected for the largest part of the river basin, especially in the area of the Vaal River, with values decreasing down to -140mm per annum. To the contrary, under the wet scenario results show a decrease of precipitation for the largest part of the river basin, with its maximum around the Gariep Dam (down to -100mm per annum). Note that all three scenarios agree in an increase of precipitation in eastern Lesotho and in the east of South Africa, reaching values of up to +80mm per annum while the major part of the basin less rainfall in the future. Details are shown in Figure 2-9.

44 ORASECOM, 2011, Support to Phase 2 of the ORASECOM Basin-Wide Integrated Water Resources Management Plan. Work Package 4: Climate Change in the Orange-Senau River Basin. GCC Downscaling fort he Orange-Senqu River Basin

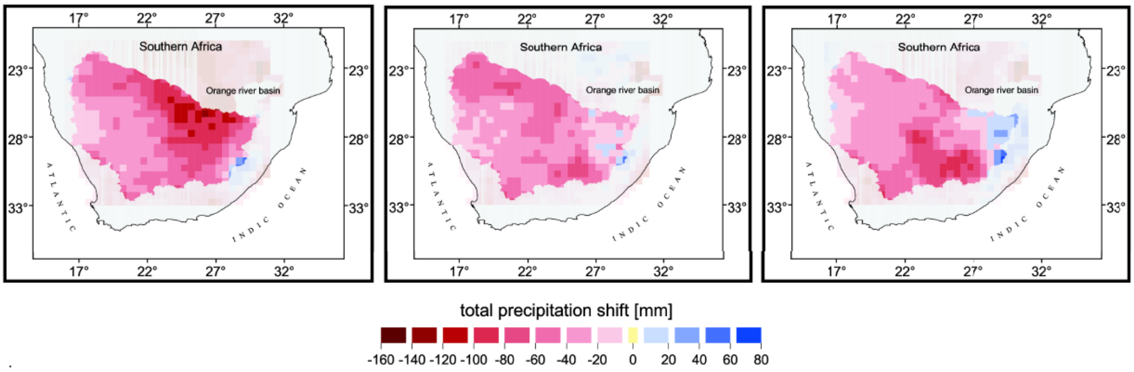


Figure 2-9: Projected precipitation differences between 2051-2060 and 1958-2007 under expected future dry- (left), median- (middle) and wet (right) scenario conditions

Additional Regional Climate Change Information

Model simulations show wide disagreements in projected changes in the amplitude and frequency of future El Niño events, contributing to uncertainty in future climate variability in projections for this region.

The projected increase in temperature is expected to exacerbate the possibility of drying, or even counteract any possible increases in rainfall, through increased evapotranspiration, which would detrimentally affect the agriculture and water resources of the country.

Climate change impacts

Impacts of climate change, i.e. of increasing temperatures and changing rainfall patterns will have a direct effect on quantity and timing of water availability. Water demands and water infrastructure will be affected, mainly in that demands and infrastructures need to be adapted to the changing conditions. Direct impacts may be a change in runoff quantity and runoff timing, increased water losses through evaporation and increased water demands. Details would have to be carefully assessed in a scenario oriented manner. This work will be initiated under Work package 4c.

3. Projected water demands and infrastructure developments

3.1 Botswana

3.1.1 Introduction

Botswana's main water demand areas are located outside the Orange/Senqu basin. Water demands in e.g. Gaborone are currently satisfied through pipeline water from outside the Orange River basin, i.e. from the Shashe River (North-South Carrier project). A future extension proposal aims to transfer water for Gaborone from the Zambezi.

Preliminary investigation work on the possible transfer of water from Lesotho to Botswana is due to start in the near future. Such a transfer of water could be used for a range of applications but until this work has been advanced there is no information available on either the quantity of water that may be made available, or its possible intended use.

3.1.2 Irrigation

The extent of irrigation development in Botswana is constrained by the availability of renewable water resources, especially in the Molopo basin. In the absence of economically feasible storage and reallocation facilities, the irrigation extent is limited. Irrigation using groundwater is very limited with no visible potential for expansion (GoB, 2006)[45]. Respectively, there are no plans for larger scale irrigation scheme development based on surface water resources within the Orange basin.

The National Water Masterplan anyhow states that a potentially large resource for irrigation is available from sand rivers but that further investigations to establish quantities are necessary (GoB, 2006)[46].

3.1.3 Mining

Jwaneng mine is expected to continue its operation unitil about the year 2040, maintaining the current production quantities and respective water use of 5 Mm^3 raw water and 2.1 Mm^3 potable water, i.e. a total of 7.1 Mm^3 yearly.

45 Government of Botswana, 2006, MINISTRY OF MINERALS, ENERGY & WATER RESOURCES, DEPARTMENT OF WATER AFFAIRS. National Water Masterplan Review, Executive Summary

46 Government of Botswana, 2006, MINISTRY OF MINERALS, ENERGY & WATER RESOURCES, DEPARTMENT OF WATER AFFAIRS. National Water Masterplan Review, Executive Summary

3.1.4 Industry

There are no plans for larger scale industry schemes within the Orange basin in Botswana

3.1.5 Domestic

The total annual domestic water demand for the part of the Orange River basin which is in Botswana, i.e., the southern portion of the Kgalagadi district of Botswana, is supposed to grow moderately as shown in Figure 3-1, reaching about 0.8 Mm^3 in year 2040 (SMEC/EHES, 2006).

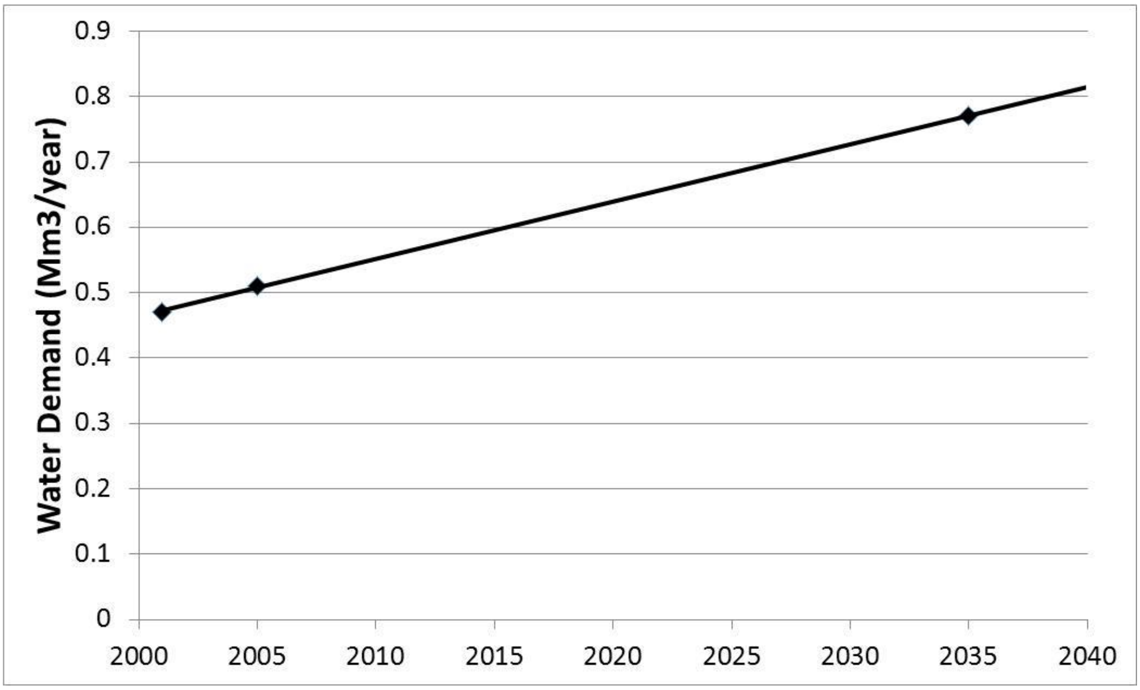


Figure 3-1: Projected domestic water demand for the part of the Orange River basin which is in Botswana, i.e., the southern portion of the Kgalagadi district of Botswana. Based on (SMEC/EHES, 2006)

3.1.6 Environment

As already mentioned, the Molopo is characterized by its ephemeral nature with the vegetation adapted to these conditions. Environmental flow demands, other than the need for irregular flow events, can therefore not be easily quantified.

3.1.7 Transfer

To satisfy future rising water demands in Botswana, a water transfer that would transfer water from the Lesotho highlands into Botswana is under consideration. A reconnaissance level study is scheduled to be carried out in 2014 by the Government of the Republic of Botswana through the Ministry of Minerals, Energy & Water Resources to see whether this project should advance to the feasibility study stage. Further details regarding this undertaking are not available.

3.2 Lesotho

3.2.1 Lesotho Highland Water Project (water transfer)

The Lesotho Highland Water Project comprises the implementation of several large scale infrastructure projects with the main purpose to transfer water from the Senqu system to the Vaal system in order to increase water availability in the Gauteng area, South Africa's industrial heartland. Under Phase 1 of the project Katse Dam, Muela Dam, Mohale Dam and the respective transfer tunnels have already been constructed several years ago. Under Phase II of the Lesotho Highland Water Project which is currently under implementation, Polihali Dam will be constructed with an expected completion by the year 2020. With this new dam in place, water transfer to South Africa will be increased by 15 m^3/s in addition to the existing transfers, resulting in a total transfer to South Africa of about 1,251 Mm^3/year (Lesotho Highland Development Authority, 2013; WRP, 2013).

3.2.2 Irrigation

There are no plans for large scale irrigation scheme expansion within Lesotho. The government of Lesotho has invested in irrigation projects in the past but the success rate was not satisfactory. As a consequence, development of irrigation is currently not a focus in Lesotho (Ministry of Agriculture, 2013).

3.2.3 Hydropower

Except for the smaller plant Mantsonyane (2 MW), expected to become operational in year 2014, no additional hydropower plants are planned in Lesotho in the near future (i.e. before year 2020). Further into the future a series of plants may be constructed (Table 3-1) but further studies are required to confirm these future schemes (Lesotho Electricity Company, 2013). The construction of the hydropower plant Muela II (110 MW), planned in the initial stage of the LHWP, is not scheduled for the short or medium term (Lesotho Highland Development Authority, 2013).

Table 3-1: Possible future hydropower plants in Lesotho - not planned for the immediate future (Lesotho Electricity Company, 2013)

Name	Capacity (MW)	Area	Nearby village
Hlotse	6.5	Mahobong	Hamoqathinyane
Khubelu	14.6	Mapholaneng	Ha Rammeleke
Makhaleng 1	1.0	Makhaleng	Ha Joele
Makhaleng 2	1.4	Makhaleng	Likolobeng(Ha Japi)
Makhaleng 3	8.9	Makhaleng	Majoaneng
Makhaleng 4	9.1	Makhaleng	Ha Ntleke
Mokhotlong(Polihali)	19.3	Mokhotlong town	Bafali Ha poso
Phuthiatsana	5.4	Thaba bosiu	Qiloane(Liphokoaneng)
Quthing 1	0.6	Quthing	Molalahlaheng
Quthing 2	2.4	Quthing	Ha Pokisi
Tsoelike	17.7	Ha Rankakala	Ha Moalosi

3.2.4 Mining

Lesotho has plans to expand its mining activities beyond diamond and aggregates, namely for extracting gas, gold, silver and copper, but none of these plans are concrete at the time of writing this report. The immediate focus is to increase the number of diamond mines (Ministry of Mines, 2013).

3.2.5 Domestic and Industry

Lesotho's Water And Sewerage Company (WASCO) is forecasting the future water demands for urban centres, including domestic and industrial demands, which is reported in Figure 3-2. Maseru stays by far the largest water user. The volume of raw water withdrawn from rivers to meet the demand in Maseru is expected to grow by approximately 0.2 Mm³/year, reaching about 22 Mm³ in year 2040. The same figures for the whole of Lesotho are 0.4 Mm³/year and 33 Mm³ respectively.

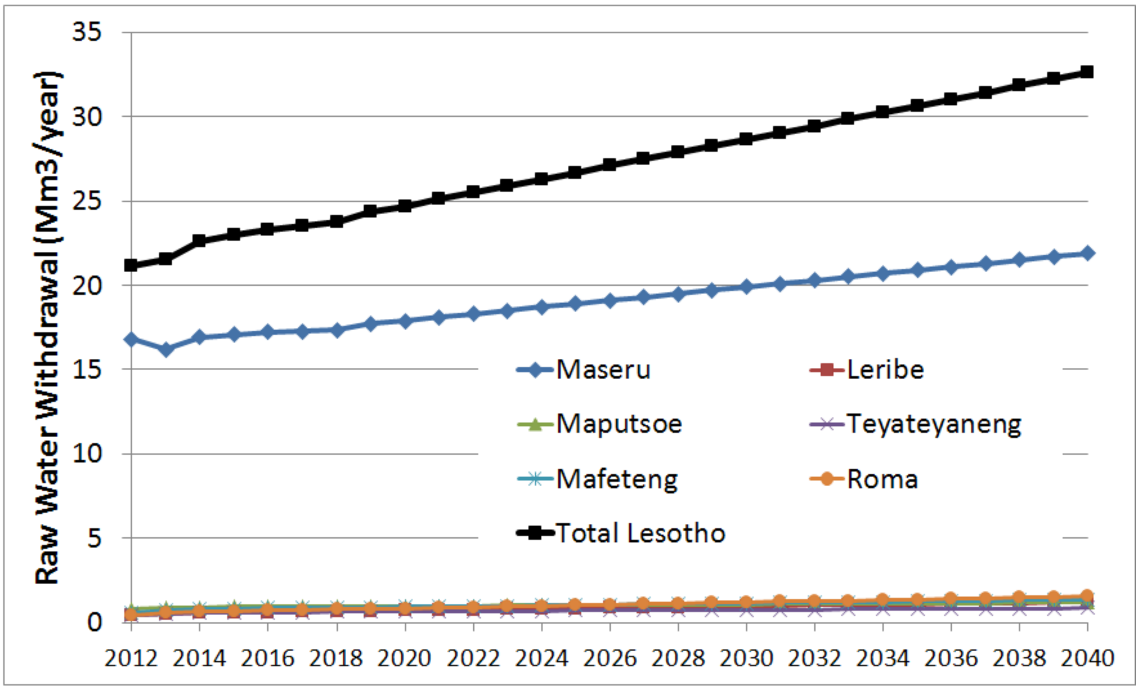


Figure 3-2: Forecast of raw water withdrawal from rivers (before treatment) to meet future water demands (domestic and industrial), of the 6 largest urban centres and for Lesotho in total. Figures based on data obtained from WASCO

To tap surface water for augmenting the supply of domestic and industrial waters to meet increasing future requirements as shown in Figure 3-2, the Lesotho Lowlands Water Supply Project has been designed. The most advanced scheme under construction under this project is the Metolong Dam with a height of 83 m and a reservoir capacity of 63 Mm³. The dam is associated with a water treatment plant with a capacity of 0.075 Mm³/day, expandable to 0.150 Mm³/day in the future. The structure is planned to supply water to five urban centres, namely Maseru, Teyateyaneng, Roma, Mazenod and Morija. At the time of writing this report, the dam was partially built (to a height of about 30 m) and the treatment plant was completed. Partial impounding would be initiated in January 2014 and the treatment plant would be gradually tested (Metolong Authority, 2013).

The Lesotho Water And Sewerage Company (WASCO) will be operating the Metolong dam/reservoir and expects to start gradual supply of domestic and industrial waters from year 2015. It is expected that Metolong will supply all the water for Maseru until year 2025, enabling the rehabilitation of the infrastructures currently supplying Maseru. Following 2025 it is expected that both the rehabilitated infrastructures and the Metolong dam will provide water to Maseru. The rehabilitated system would supply the volume of year 2024 and Metolong would provide the increase in demand from year 2025. This is illustrated in Figure 3-3 (Water And Sewerage Company, 2013).

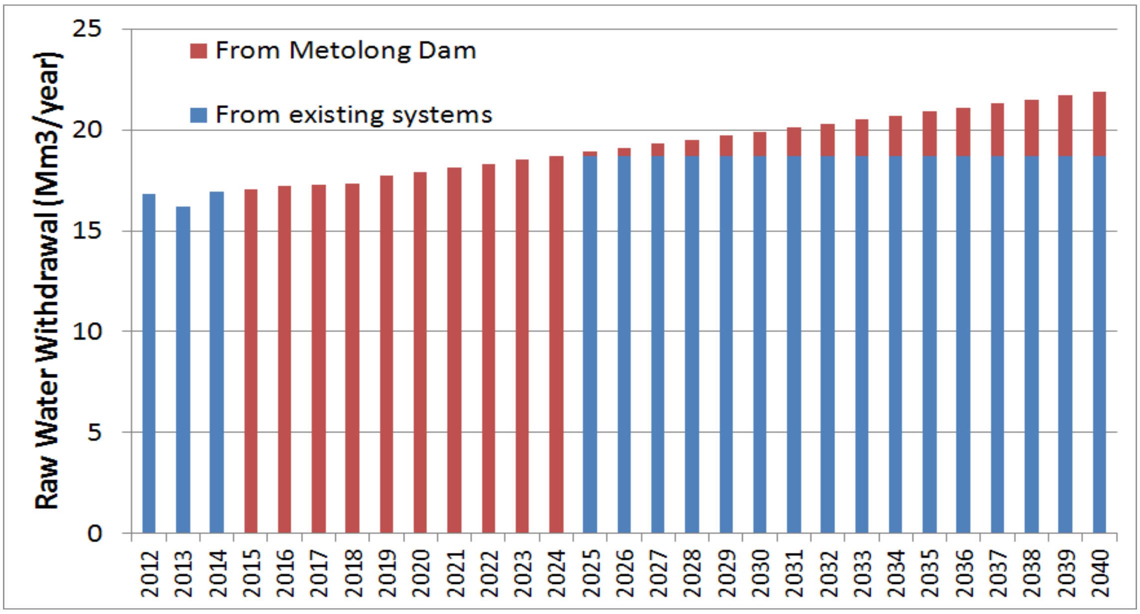


Figure 3-3: Forecast of raw water withdrawal (before treatment) from the existing water production systems and from the Metolong Dam to meet future water demands, including domestic and industrial demands, of Maseru urban zone. Based on data obtained from WASCO.

3.2.6 Environment

The Lesotho Highland Development Authority has suggested to the Lesotho Highland Water Commission to modify the minimum water releases downstream of Mohale Dam and the Katse Dam as summarised in Table 16 – no modification is suggested for Matsoku Weir. There is a little change for Katse Dam while the suggested new minimum release at Mohale Dam is more than doubled (Lesotho Highland Development Authority, 2013). It is not known at the time of writing this report if this change will be accepted by the Commission.

Table 3-2: Suggested new minimum water releases by existing dams of the Lesotho Highland Water Project to satisfy future environmental flow requirements (Lesotho Highland Development Authority, 2013)

Structure	River	Minimum release downstream (Mm^3/year)
Mohale Dam	Senqunyane	68.1
Katse Dam	Malibamats'o	67.2

New minimum flow releases to satisfy environmental flow requirement should be implemented for the new dams Metolong and Polihali, and indicative values are as reported in Table 17. Two figures are quoted by the reference used for Polihali. The first one (91.7 Mm^3/year) is judged to be the most plausible but the second figure (136 Mm^3/year) is reported as well for completeness.

Table 3-3: Suggested minimum water to be released by new dams to satisfy future environmental flow requirement

Structure	River	Minimum release downstream (Mm³/year)	Reference
Metolong Dam	Phuthiatsana	15.4	(Southern Waters Ecological Research and Consulting & Aurecon, 2012)
Polihali Dam	Senqu	1st option: 91.7 2nd option: 136.0	(Louw & Niekerk, 2013)

3.3 NAMIBIA

3.3.1 Irrigation

Namibia is planning for some extensions to its existing irrigation schemes as well as the development of additional irrigation schemes in conjunction with the planned Neckartal Dam in the Fish River basin. The timing is uncertain and had to be estimated. Details are shown in Table 18.

Table 3-4: Main planned expansions included in the database

Scheme	Type	Current size (ha)	Additional size (ha)	Irrigation Demand (m^3/ha/year)	Additional water demand (Mm^3/year)
Neckartal	planned	0	5000	20,000	100
Hardap	existing	2200	no plans	20,000	-
Naute	existing	400	250	15,000	3.8
Aussenkehr	existing	1500	no plans	15,000	-
Noordoewer	existing	286	1000	15,000	15
Haakiesdoorn	existing	250	450	15,000	6.8
Komsberg	existing	310	no plans	15,000	-
Total					125.6

3.3.2 Mining

Mining in Namibia is relatively stable. It is expected that Skorpion mine is probably nearing the end of its operation but that instead Haib mine will be opened. Planning and/or development for this mine are anyhow dormant so that no solid estimate can be made if- or when the mine could become operational. Expected water demand when operational would be 6 Mm^3/year, so slightly larger than Skorpion (4.7 Mm^3/year). In the database it has been assumed that operation will start as from 2015.

A possible future expansion of Rosh Pina mine is the Gergarub mine which has been discussed as a possible future expansion though details are not known yet and projected water demands cannot be quantified.

3.3.3 Industry

There are no detailed plans concerning the expansion of industries in Namibia. It is likely that industries are growing in line with general developments and that demands are included in the domestic demand numbers, growing by 0.01 Mm^3/year.

3.3.4 Domestic

Based on examples in most areas of the world, domestic demands in Namibia are expected to increase in line with population growth. For planning purposes it needs to be kept in mind that large parts of the country are satisfied by groundwater and not surface water so that it can be assumed that changing demands have a negligible effect on surface water demands from the Orange basin.

3.3.5 Environment

Environmental flow requirements (EFR´s) for the Fish- and lower Orange River have been assessed by ORASECOM (2013)[47]. EFR´s for the Fish River are described below, for the lower Orange River in the section bordering South Africa. The main concern in assessing the EFR´s was the development of Neckartal Dam with its respective potential downstream impacts. In order to assess the potential impact of the dam, different release scenarios have been simulated and consequences for different ecological objectives analyzed. Due to the ephemeral nature of the Fish River, the change in percentage of time in which the river contains flowing water was used as an indicator to judge environmental impacts.

Based on the updated estimates of natural runoff from the Fish River carried out as part of the ORASECOM (2013) study, a total potential natural runoff of 613 Mm^3/year is generated from the Fish River basin, but only 571 Mm^3/year of this reaches the Orange River under natural conditions, as an estimated 42 Mm^3/year is lost due to evaporation and riverbed losses.

The EFR analysis shows that out of different tested release scenarios for Neckartal Dam only the 50% (and above) release scenario will fully meet the ecological objectives with an acceptable impact on the ecological state of the river. A 40% release scenario has the potential to meet all the ecological objectives, but with a higher risk of failure. This is the same assumption as for otherways unchanged conditions. An overview is shown in Figure 12.

Release option	*0%*	*20%*	*30%*	*40%*	*50%*
EFR Fish 2	×	×	×	✓	✓
EFR Fish Ai-Ais	×	×	×	✓	✓

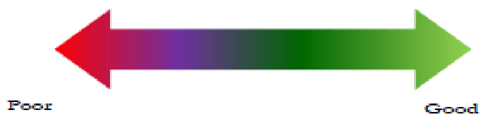


Figure 3-4: Impacts of different Neckartal Dam release options on downstream EFRs

47 ORASECOM, 2013, Research project on environmental flow requirements of the Fish River and the Orange-Senqu River Mouth, UNDP-GEF

As the 40% and 50% release options would have significant impacts on the irrigation yield of Neckartal Dam, an optimised release scenario that minimizes the impacts on both the yield and the ecological status was investigated. Such a release scenario was suggested to be between 30% and 40% release. The scenario entails releasing 40% of the inflow while the storage in the dam is above 60% of its full supply capacity dropping to 30% of the inflow should the storage in the dam drop below 60% of full capacity.

The evaluation of the optimized scenario indicated that it has an even higher risk than the 40% release scenario that the ecological objectives would not be met. However, as the yield was a significant improvement from 40%, release scenario, this release option represents the recommended EFR from Neckartal Dam.

3.4 South Africa

3.4.1 Irrigation

The current irrigation water demand of approx. 3200 Mm³/year is not expected to increase over time though based on current assumptions minor fluctuations can be expected. Rather than increasing water demand the potential for expanding irrigated areas are in improving irrigation efficiency and getting more crop per drop.

3.4.2 Mining

Mines in South Africa have a current expected lifespan until 2020-2030 after which extraction of minerals may become uneconomical and mines may reduce production and eventually close, leading to a reduction in mining water demand. There are ongoing mining explorations the probability of finding new resources is likely. Figures will need to be updated in the future once more certain information is available.

From a current perspective the mining water demand is assumed to increase from the current level of 10 Mm³/year to 24 Mm³/year, mainly due to a significant demand increase of the Black Mountain Mine water demand from 1.9 to 13.9 Mm³/year expected for 2014.

3.4.3 Industry

Industrial water demands in South Africa are expected to increase over the coming years. In the Vaal basin, South Africa's industrial heartland, demands are expected to increase from currently 228 Mm³/year to 286 Mm³/year in 2050. By comparison, the total demands in the Vaal basin considering all users sum up to about 2,600 Mm³/year in 2013 and about 3,200 Mm³/year by 2050 respectively. The latter numbers are important as it is important to understand that in the data as collected and compiled in the database, industrial and domestic data are partly lumped together, i.e. small scale industries may not be captured in the industrial water demand figures but are included in the domestic demands.

Considering all of South Africa, industrial demands are expected to stabilize from 496 Mm³/year for 2013 to 500 Mm³/year in 2050.

3.4.4 Domestic

Domestic water demand in South Africa is expected to increase with population growth and development. Considering the current 1.3% population growth rate, South Africa's population may increase from currently 53 million to 88 million. Currently about 30% of South Africa's population live within the Orange basin. Assuming the same percentage for the future, the South African basin population may increase to 26 million. Realistically it can be expected that there will be a strong trend of the increasing population to accumulate in the urban and industrial centres, e.g. in the Gauteng region. It can therefore be expected that the above estimated future population number for the Orange basin in South Africa is underestimated.

The rising population as well as general development will have a direct effect on increasing water demand. Current estimates show an increase in demand from the current 2 300 Mm^3/year to a future 3 600 Mm^3/year for the South African part of the basin.

3.4.5 Transfer schemes

Water transfers to supply additional water from Lesotho to the demand centres in South Africa. Under Phase II of the Lesotho Highland Water Project which is currently under implementation, Polihali Dam will be constructed with an expected completion by the year 2020. With this new dam in place, water transfer to South Africa will be increased by 18 m^3/s in addition to the existing transfers, resulting in a total transfer to South Africa of about 1,350 Mm^3/year (Lesotho Highland Development Authority, 2013).

3.4.6 Environment

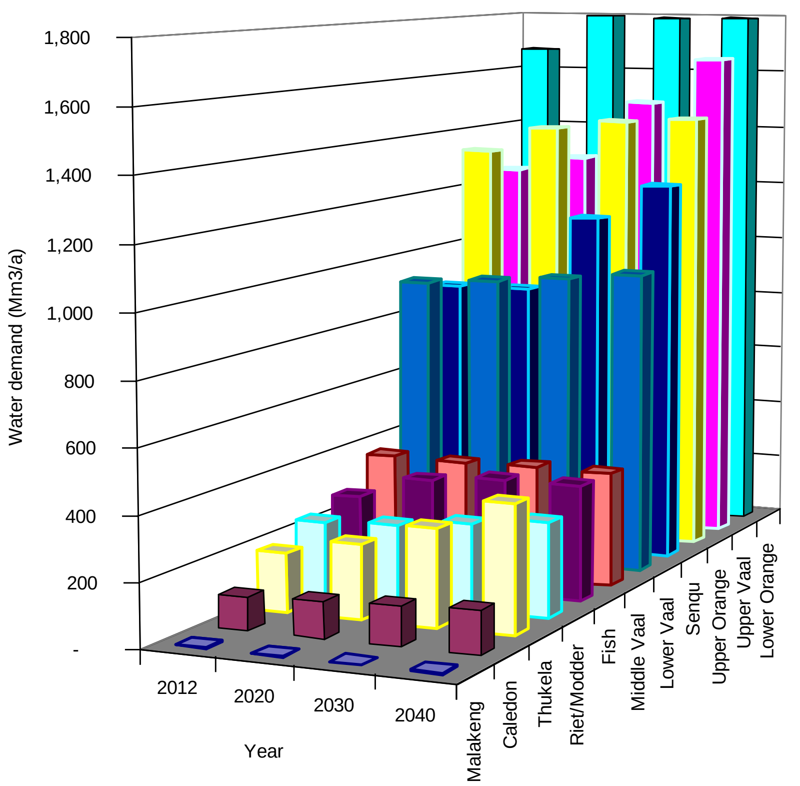
Environmental flow requirements for the Orange River in South Africa are not expected to change significantly over time. Nevertheless, ORASECOM (2013) reports that the Orange River estuary, which has been declared a Ramsar site, is considered to be in a degraded state. Related environmental flow requirements would respectively need to be increased to restore and maintain the estuary's saltmarsh and functional state and respectively to maintain its Ramsar site status. This would require a political decision which is not considered in the current assumptions.

3.4.7 River and operational requirements

River and operational requirements will need some adjustment in the future with climate change and respectively increased higher temperatures leading to higher evaporation losses. These have so far not been calculated but would require detailed consideration in coordination with expected future river system operation.

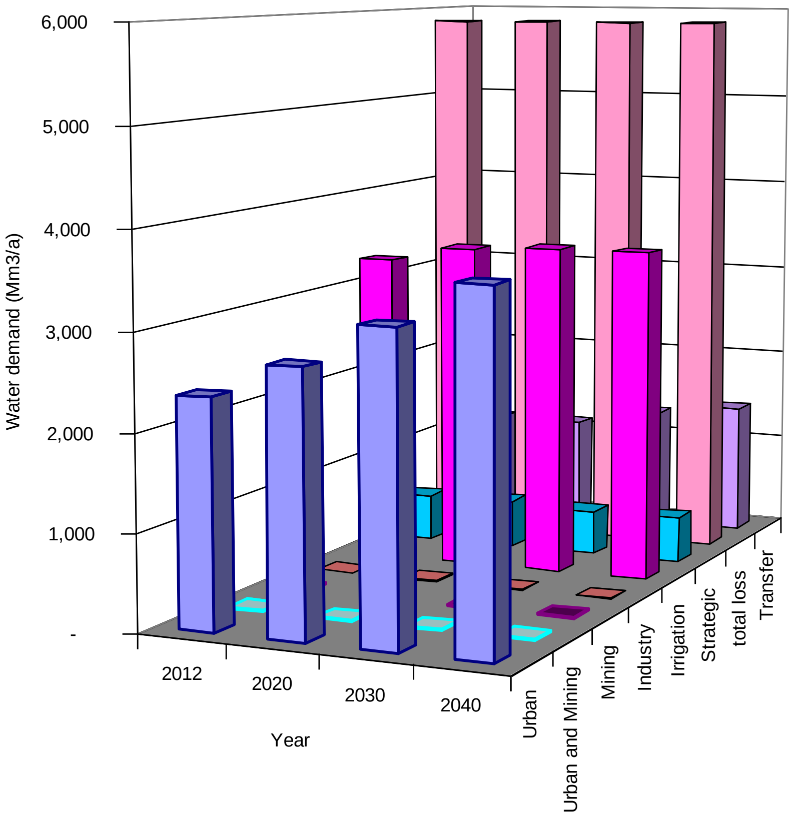
3.5 BASIN OVERVIEW OF PROJECTED WATER DEMANDS

Trends in the Orange-Senqu River basin show a generally increasing trend in water demands while at the same time the available water resources are expected to decrease (Section 2.3.3, climate change). An overview of expected demand increase per sub-basin, sector and country is shown in Figure 2-14 to 2-16 respectively.



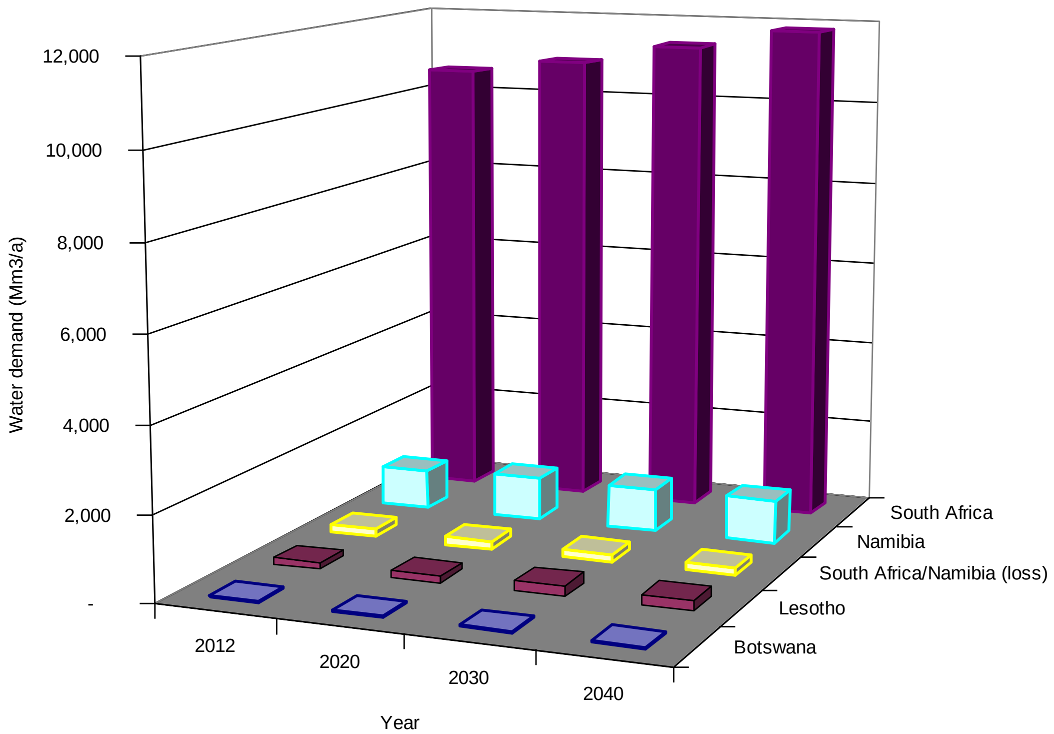
	2012	2020	2030	2040
Malakeng	1	2	2	3
Caledon	105	114	124	135
Thukela	189	238	309	403
Riet/Modder	240	251	273	301
Fish	277	350	371	371
Middle Vaal	369	365	369	368
Lower Vaal	921	939	958	982
Senqu	882	883	1,136	1,253
Upper Orange	1,331	1,418	1,447	1,460

Figure 2-14: Expected water demand increase in the Orange River sub-basins. The strongest absolute increases are projected in the Upper Vaal, Senqu and Thukela sub-basins Strongest relative increase in the Malakeng and Thukela sub-basins. Further details are provided in the water demand database



	2012	2020	2030	2040
Urban	2,348	2,708	3,151	3,601
Urban and Mining	12	11	13	15
Mining	21	24	15	14
Industry	7	7	7	7
Irrigation	3,297	3,460	3,501	3,509
Strategic	496	506	471	483
total loss	5,860	5,862	5,865	5,867
Transfer	1,106	1,102	1,278	1,402

Figure 2-15: Expected water demand increase in the different sectors in the basin. The strongest increase, both in absolute and relative numbers, is projected in urban demand. Further details are provided in the water demand database



	2012	2020	2030	2040
Botswana	37	37	37	37
Lesotho	140	145	243	251
South Africa/Namibia (loss)	180	180	180	180
Namibia	921	1,017	1,029	1,028
South Africa	10,582	10,903	11,380	11,839

Figure 2-16: Expected water demand increase in the different countries in the basin. Strongest absolute demand increase is projected in South Africa, while strongest relative increase is projected in Lesotho.

4. Database setup

The developed Orange River basin database contains 1034 entries and provides information about water demand locations, -types and –figures. The database contains both current and potential future demands, the latter in annual steps up to 2040/2050. It is recommended that the database be updated periodically to capture actual water demands that will occur with the actual development. The modalities for doing this will be included in the IWRM Plan.

The database has been developed as a Microsoft Excel spreadsheet, organized in columns, based on existing water resource modelling (WRYM and WRPM) work. The data structure includes elements as described in Table 19.

Table 4-1: Database structure, main entries and explanations

Entry	Description
- Subsystem name	Tributary name
- WRPM channel number	Number assigned to a specific demand entry
- Channel sub-components	Subcomponent that contributes to a main channel number
- Description	Description of the demand
- Recipient country	South Africa, Botswana, Namibia or Lesotho
- Demand type	E.g. Loss, Irrigation, Mining, Return flow, Urban, Transfer, etc.
- Demand projections to 2040	Projection in annual steps, may be filled linearly or variably
- Comments	Comment on entry

* Further entries in the database are supporting the modelling work

The database includes both existing as well as planned future water demands, e.g. Neckartal Dam in Namibia. Key challenges in development of the database were

a) the different structures of existing datasets that had to be merged as well as

b) different terminology or grouping used in the different datasets.

Combining the different sources therefore had to be carefully checked and in some cases decisions made considering "most likely" developments and respective projection numbers. Other challenges included mixed demand types (e.g. domestic/industrial) not allowing for a specific allocation of demands to a particular sector. Care also had to be taken where unclear descriptions were used by different authors as well as in the inclusion of return flows.

In addition to merging the data sources, entries had to be checked for gaps both in infrastructures and data entries. Such gaps were researched using stakeholder statements, existing literature and web research. Main documents that were used for extracting the required data and information to fill gaps are listed in the reference list.

5. Development scenarios

5.1 Introduction

Development scenarios will be considered as part of the work towards formulation of the IWRM Plan. Based on the team's knowledge built up in compiling this review of current and future demands the various water resource development considerations that may have to be taken into account are briefly presented in this chapter. These depict a range of aspects that may challenge water resources in the future.

The natural mean annual runoff of the Orange-Senqu Basin has been stated as 11,700 Mm³/year (DWA, 2013)[48]. At the same time estimated water demands accumulated for the entire basin sum up to 8,200 Mm³/year for the present and 9,600 Mm³/year for the future. This comparison shows overall sufficient resource availability but does not consider the spatial and temporal aspects of water demand and availability. It does also not take into account the uncertainties of potential additional demands (e.g. the Lesotho-Botswana transfer). The actual demand-availability relation may vary significantly on a spatial scale resulting in scarcity of water resources in particular locations. This is where river infrastructure and their operation play an important role to improve timely availability of water resources.

5.2 Considerations for Development Scenarios

Development scenarios will have to take into account the spatiotemporal particularities and needs to satisfy water demands in the overall basin. Detailed model assessments will need to be conducted to test their suitability, establish design parameters and optimize their operation. This is all planned under Work Package 4c of this study

Main elements of the different development scenarios will take into consideration:

- Increased water transfer from Lesotho Highland Water Project (LHWP) Phase II (Polihali dam in place by approximately 2022 and water delivery then over time increased from 780 million m³/a to 1,217 million m³/a. Phase II of the LHWP will result in a reduction in the yield available from the Orange River Project (ORP) that is using Gariep and Vanderkloof dams as the main resource. Intervention options need to be implemented to address these shortages. Currently the RSA is investigation this through the study named "Development of Reconciliation Strategies for Large Bulk water supply systems; Orange River." As part of this study several options are investigated. These include:
  - Raising of Gariep Dam.
  - Utilising the lower level storage in Vanderkloof dam.
  - Vioolsdrift Dam.
  - Bosberg and or Boskraai Dam in the Upper Orange
  - Possible dams in Lesotho
  - Real time modelling in the Lower Orange and Vaal to reduce operational requirements.

[48] Department of Water Affairs, 2013, http://www.dwaf.gov.za/orange/waterres.aspx Based on 1994 Water Research Commission Reports, DWA, South Africa

  - Water conservation and water demand management in urban/industrial/mining and irrigation sectors.
  - Removal of unlawful irrigation.
  - Supplying water at lower assurance levels.
  - Development of ground water resources
- The Metolong Dam in Lesotho that is currently near completion.
- Consideration of potential Lesotho-Botswana transfer scheme
- Increasing reuse use of return flows and treated acid mine drainage water in the Vaal River system.
- Implementing the reserve (final agreed environmental requirements) in the Vaal sub-system.
- Consideration of overall strong increase in domestic/industrial demands (especially in Vaal basin)
- Contingency for increased economic activities (focus on mining)
- Increased capacity of greater Bloemfontein supply system to supply in the increasing mainly urban/industrial requirement of the Greater Bloemfontein demand centres.
- Development of 12 000 ha allocated to resource poor farmers within the RSA to be supplied from Gariep and Vanderkloof dams. Only a very small portion of this allocation has until know been taken up.
- Vioolsdrift Dam on the lower Orange to be used to reduce operational requirements, to enable proper supply to the river mouth environmental requirements and to support increased irrigation along the lower Orange, mainly for Namibia.
- Neckartal Dam in Namibia Fish River, operational with 5000ha irrigated area
- Implementation of Environmental Flow Requirements (EFR) in the Orange, especially consideration of increased environmental flow requirements to stop degradation of the Orange estuary. The implementation of the latest estimations for the EFR is expected to have a significant impact on the water availability within the system to such an extent that severe shortages in the water supply within the Orange River Project (Gariep and Vanderkloof dams) will be experienced. It will therefore be required to increase the current system yield and or to decrease system demands to be able to fully supply the EFR.
- Development of large solar power stations along the Lower Orange.
- The Square Kilometre Array (SKA) currently under development in the Northern Cape.
- Possible future hydro power plant along the Orange River. It is expected that these developments will have a non-consumptive demand and is therefore not expected to impact on the overall system demand.
- Possible hydraulic fracturing in the Karoo area

It is important that developments in the basin, including changed demand projections, will be updated periodically to adjust the operation of the basin.

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