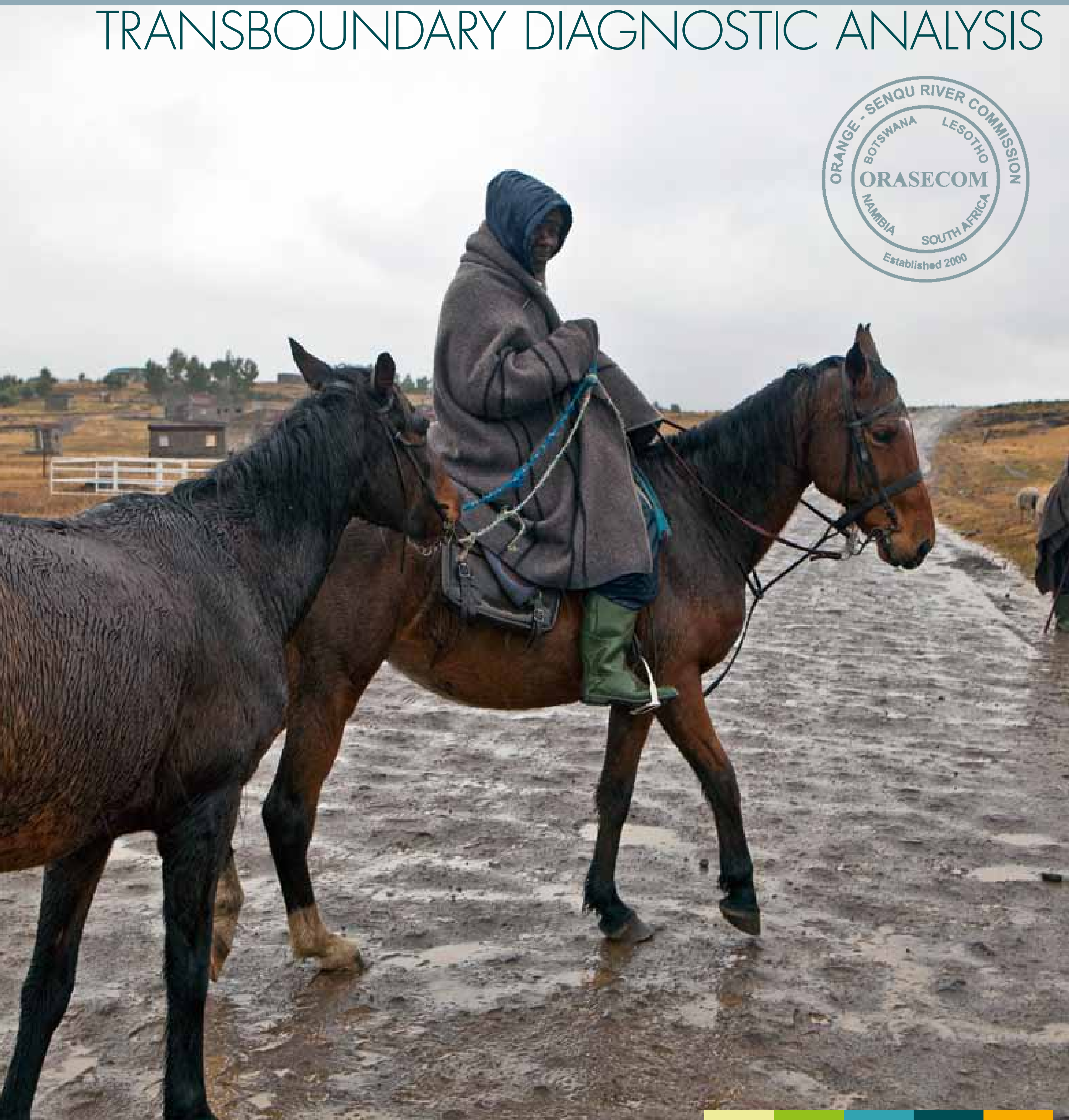
ORANGE–SENQU RIVER BASIN
TRANSBOUNDARY DIAGNOSTIC ANALYSIS



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ORANGE–SENQU RIVER BASIN TRANSBOUNDARY DIAGNOSTIC ANALYSIS
ORASECOM Report 002/2014

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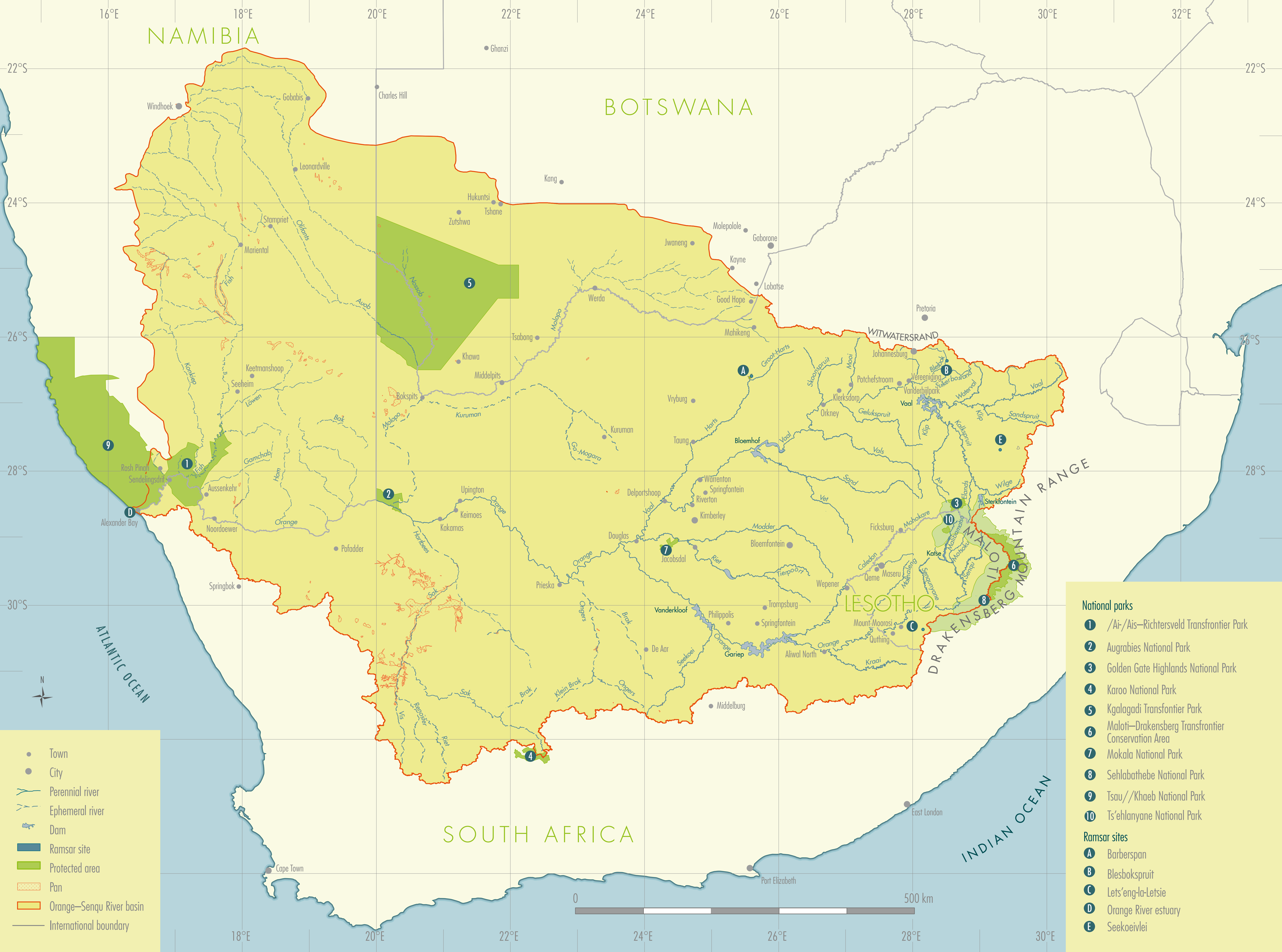

NAMIBIA
BOTSWANA
SOUTH AFRICA
LESOTHO
ATLANTIC OCEAN
INDIAN OCEAN
WITWATERSRAND
MALOTI
DRAKENSBERG MOUNTAIN RANGE
16°E
18°E
20°E
22°E
24°E
26°E
28°E
30°E
32°E
22°S
24°S
26°S
28°S
30°S
Windhoek
Gobabis
Charles Hill
Ghanzi
Kang
Leonardville
Hukuntsi
Tshane
Zutshwa
Stampriet
Mariental
Jwaneng
Molepolole
Gaborone
Kayne
Lobatse
Good Hope
Mahikeng
Werda
Tsabong
Khawa
Middelpits
Bokspits
Keetmanshoop
Seeheim
Pretoria
Johannesburg
Potchefstroom
Vereeniging
Vanderbijlpark
Klerksdorp
Orkney
Vryburg
Kuruman
Taung
Bloemhof
Warrenton
Springfontein
Riverton
Kimberley
Delportshoop
Douglas
Jacobsdal
Bloemfontein
Ficksburg
Sterkfontein
Katse
Maseru
Qeme
Wepener
Trompsburg
Philippolis
Springfontein
Vanderkloof
Mount Moorosi
Quthing
Aliwal North
Gariep
De Aar
Middelburg
Prieska
Upington
Keimoes
Kakamas
Pofadder
Rosh Pinah
Sendelingsdrif
Aussenkehr
Alexander Bay
Noordoewer
Springbok
East London
Port Elizabeth
Cape Town
Nossob
Auob
Molopo
Kuruman
Ga-Mogara
Fish
Olifants
Konkiep
Löwen
Gamchab
Hom
Bak
Orange
Hartbees
Sak
Vis
Renoster
Riet
Brak
Klein Brak
Ongers
Seekoei
Kraai
Caledon
Tierpoort
Modder
Riet
Vaal
Harts
Groot-Harts
Skoonspruit
Mooi
Gelukspruit
Blesbok
Suikerbosrand
Waterval
Klip
Kalkspruit
Sandspruit
Vals
Sand
Vet
Wilge
Elands
As
Mohokare
Malibamatso
Matsoku
Senqu
Makhaleng
Senqunyane
Hlotse
Vaal
5
2
1
9
7
4
3
10
6
8
A
B
C
D
E
N
0
500 km
Town
City
Perennial river
Ephemeral river
Dam
Ramsar site
Protected area
Pan
Orange–Senqu River basin
International boundary
National parks
1 /Ai-/Ais–Richtersveld Transfrontier Park
2 Augrabies National Park
3 Golden Gate Highlands National Park
4 Karoo National Park
5 Kgalagadi Transfrontier Park
6 Maloti–Drakensberg Transfrontier Conservation Area
7 Mokala National Park
8 Sehlabathebe National Park
9 Tsau//Khaeb National Park
10 Ts'ehlanyane National Park
Ramsar sites
A Barberspan
B Blesbokspruit
C Lets'eng-la-Letsie
D Orange River estuary
E Seekoeivlei

ORANGE–SENQU RIVER BASIN

TRANSBOUNDARY DIAGNOSTIC ANALYSIS

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FOREWORD

The Orange–Senqu River basin is one of the largest in southern Africa. It rises in the highlands of Lesotho in the east, draining significant parts of South Africa, Botswana and Namibia on its westward journey to the Atlantic Ocean. The climate of the basin varies from temperate in the east to hyper-arid in the far west and is subjected to regular droughts and floods.

The waters of the Orange–Senqu River provide a lifeline for the most economically active region in southern Africa, supporting large-scale irrigation, industry and the domestic needs of several million inhabitants. Numerous dams and transfer schemes, as well as access to groundwater resources in the west of the basin, ensure the constant availability of water resources to sustain these activities. However, these operations come at a cost.

Extensive water abstraction for urban, industrial and agricultural purposes has significantly altered the natural flow of the river system. The frequency, size and duration of floods are also affected. These changes adversely affect the health of the river, the resources and ecosystems it supports and the services they provide. To maintain these important ecological functions and secure resources in the long term, it is essential that the Orange–Senqu is managed effectively, efficiently and sustainably. ORASECOM promotes such an integrated approach to water management.

In order to achieve this approach, it is vital that the four basin nations agree on transboundary problems and the underlying causes and their impacts, based on in-depth scientific studies involving all stakeholders. To this end, a study, described in the *Orange–Senqu River Basin Preliminary Transboundary Diagnostic Analysis* (TDA), was conducted with assistance from international cooperating partners, UNDP–GEF, and adopted by ORASECOM in 2008. The issues around environmental and socio-economic impacts and governance of water resources based on these multi-sectoral investigations were identified and examined through causal chain analyses.

This document is based on the preliminary TDA and consolidates its findings and recommendations, including information from more recent studies on water balance, sediment loads, water quality, climate change, environmental flow requirements and irrigated agriculture. More importantly, it includes validation of its results and a review of the revised causal chain analyses by recognised experts from each of the basin states.

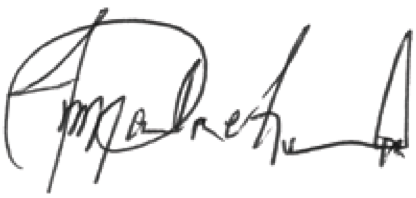
The four main transboundary challenges that have been distilled in this TDA are the increasing demand on water resources, ongoing changes to hydrological regimes, declining water quality and land degradation. While these problems do not necessarily reflect the situation in all the basin states, they are generally cross-cutting, and if not addressed, have the potential of becoming transboundary in nature. The main transboundary problems are considered largely as the result of inappropriate resource uses and practices, while common underlying causes are found to be attributable to related social and economic drivers, which include population pressure, climate change and a diversity of natural and economic drivers.

All four basin states – Botswana, Lesotho, Namibia and South Africa – are members of ORASECOM, which provides them with a forum for consultation and coordination for the sustainable management of the Orange–Senqu River basin's water resources, and are party to a number of relevant international and regional conventions and protocols. They have also all adopted or are in the process of adopting an integrated water resources management (IWRM) approach through the reform of their respective water sectors. The basin states also share common challenges that hamper the implementation of IWRM to a greater or lesser degree:

The TDA provides an important basis for the elaboration of the basin-wide *Strategic Action Programme for the Orange–Senqu River Basin* that will constitute the environmental component of the IWRM plan for the basin. This, in turn, supports the development of National Action Plans in each of the countries. Based on sound factual information derived from thorough participatory and consultative processes, this approach allows the respective countries to collectively set basin-wide objectives and targets to be met over a ten-year period.

We trust that this document will provide a solid base from which important integrated decisions can be made on the future sustainable management and operations of the water resources of the Orange–Senqu River basin at all levels. We believe that it will form the foundation of ongoing research, analysis and monitoring to ensure the wellbeing of this crucial lifeline for the economic growth and social security of the inhabitants of the basin.

OT Obakeng, Head of Delegation, Botswana



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ABBREVIATIONS AND ACRONYMS

a	annum
A1B	a type of emission scenario (see Glossary)
AMD	acid mine drainage
Anon.	anonymous
As	arsenic
BMC	basin management committee
BP	before present
C	Celsius
Ca	calcium
CC	climate change
CCA	causal chain analysis
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
Cl	chlorine
cm	centimetre(s)
CMA	catchment management agency
CSIR	Council for Scientific and Industrial Research (South Africa)
DDT	dichloro-diphenyl-trichloroethane
DRIFT	Downstream Response to Imposed Flow Transformation
DWA	Department of Water Affairs (South Africa or Botswana)
DWAF	Department of Water Affairs and Forestry (Namibia)
EC	electrical conductivity
EFR	environmental/ecological flow requirement(s)
EIA	environmental impact assessment
EMP	environmental management plan
et al.	and others (et alii)
EWR	ecological water requirement(s)
g	gram(s)
GCC	global climate change
GCM	global circulation model
GDP	gross domestic product
GEF	Global Environment Facility
GWh	gigawatt-hour(s)
GWP-SA	Global Water Partnership Southern Africa
ha	hectare(s)
IAP	invasive alien plant
ICOLD	International Commission on Large Dams
IFR	in-stream flow requirements
I_{geo}	geoaccumulation index
IMC	Inter-Ministerial Committee on Acid Mine Drainage
IPCC	Intergovernmental Panel on Climate Change
IRD	Institut de recherche pour le developpement
IWRM	integrated water resources management
JIA	Noordoewer–Vioolsdrift Joint Irrigation Authority

K	potassium
kg	kilogram(s)
km	kilometre(s)
km^2	square kilometre(s)
kW	kilowatt(s)
kWh	kilowatt-hour(s)
ℓ	litre(s)
LHDA	Lesotho Highlands Development Authority
LHWP	Lesotho Highlands Water Project
m	metre(s)
MAE	mean annual evaporation
mamsl	metres above mean sea level
MAP	mean annual precipitation
MAR	mean annual runoff
mg	milligram(s)
mg/ℓ	milligram(s) per litre
mℓ	millilitre(s)
mm	millimetre(s)
Mm^3	million (mega) cubic metre(s)
MoU	memorandum of understanding
Mn	manganese
MPI	metal pollution index
mS/m	milliSiemens per metre
Na	sodium
n/a	not applicable
NAD	Namibia Dollar
NamWater	Namibia Water Corporation
NAP	National Action Plan
NASA	National Aeronautics and Space Administration (United States of America)
NASS	Namibian Scoring System
NDP	national development plan
ORASECOM	Orange–Senqu River Commission
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pers. comm.	personal communication
PES	present ecological state
PFOS	perfluorooctane sulfonate
POP	persistent organic pollutant
pp.	pages
REC	recommended ecological category
s	second(s)
SACU	Southern African Customs Union
SADC	Southern African Development Community
SAP	Strategic Action Programme
SASS	South African Scoring System
SO_4	sulphates
sp.	species (singular)
spp.	species (plural)
SRES	Special Report on Emissions Scenarios

t	metric tonne(s) (1,000 kg)
TAL	total alkalinity
TDA	Transboundary Diagnostic Analysis
TDS	total dissolved solids
TFCA	transfrontier conservation area
TWh	terawatt-hour(s)
UCT	University of Cape Town
UN	United Nations
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNDP–GEF	United Nations Development Programme – Global Environment Facility
UNFCCC	United Nations Framework Convention on Climate Change
UNOPS	United Nations Office for Project Services
USD	United States Dollar
WMA	water management area
WRB	Water Resources Board
WRC	Water Research Commission
WRM	water resources management
WRSM2000	Water Resources Simulation Model
WRYM	Water Resources Yield Model
WUA	water-users' association
WUC	Water Utilities Corporation (Botswana)
ZAR	South African Rand

EXECUTIVE SUMMARY


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EXECUTIVE SUMMARY

Introduction

The Orange River rises as the Senqu in the highlands of Lesotho, some 3,400 m above mean sea level and more than 2,300 km from its mouth on the west coast of southern Africa. With a total catchment area of approximately a million square kilometres, the Orange–Senqu River basin is one of the largest in Africa, encompassing the whole of Lesotho and areas of Botswana, Namibia and South Africa. The region is largely classified as semi-arid and subject to increasing water stress.

The river system is not only transboundary, it also forms some of the borders between these basin states. The Orange–Senqu River Commission (ORASECOM) was established by the governments of the four basin states to promote equitable and sustainable development of the resources of the Orange–Senqu River basin.

Summary of basin characteristics

Country	Proportion (%) of basin area	Contribution to natural runoff (%)	Proportion (%) of basin population	Water use in 2005 (Mm³)
Botswana	7.9	0.3	0.3	negligible
Lesotho	3.4	41.5	15.4	20
Namibia	24.5	5.2	2.6	76
South Africa	64.2	53.0	81.7	5,389

Source: ORASECOM, 2008

The main purpose of this Transboundary Diagnostic Analysis (TDA) is to provide a scientific and technical basis for the identification and prioritisation of key issues concerning the degradation of aquatic ecosystems in the Orange–Senqu River basin. It is intended as a decision-support tool for the Orange–Senqu basin states and stakeholders to identify areas of future action to address key issues.

It is aimed at, amongst others, civil society, industry, governments, academia and environmental groups in the four basin states.

During the development of a preliminary TDA (ORASECOM, 2008), extensive intersectoral discussions involving all four basin states identified the priority transboundary issues as:

- stress on surface and groundwater resources
- altered water flow regime
- deteriorating water quality
- land degradation
- spread of alien invasive plants and animals.

Building on the results and recommendations of the preliminary TDA, a number of studies were carried out, the information and findings of which are compiled in this document. An important step in the development of this TDA involved validation of findings by recognised experts and institutions in the basin. Revised causal chain analyses were reviewed at national meetings of experts and institutional representations in each of the four basin states. The outcomes of these meetings were subsequently incorporated into this document.

Based on this TDA, strategic planning documents – National Action Plans (NAPs) for each of the basin states, and a basin-wide Strategic Action Programme (SAP) – are currently being developed. These will outline appropriate and agreed management responses to address the problems identified here.

Opposite: Autumn scene in Golden Gate National Park, Free State Province, South Africa, near the source of the Caledon River

Basin description

Geographical setting

The temporal and spatial variability of rainfall across the basin is the main driving factor regarding the availability of water in the system. Temperature also varies considerably across the basin. The climate in the basin changes from being relatively temperate in the east at the source of the river, to hyper-arid in the west at its mouth. Assuring water to sustain agriculture and other economic activities and domestic needs, necessitates bulk storage and transmission of water to places and at times when it would otherwise not be available. Such development of the river system is also the underlying cause of many of the ensuing transboundary issues.

Mean annual temperatures, precipitation (MAP) and evaporation (MAE)

	January average range (° C)	July average range (° C)	MAP (mm)	MAE (mm)*
Senqu†	7–25	0–10	500–1,600	1,000–2,100
Upper Orange‡	16–32	2–18	300–800	1,200–2,680
Lower Orange‡	20–37	4–23	20–300	2,420–3,280
Upper Vaal	20–24	0–16	500–1,000	1,600–2,200
Middle Vaal	16–32	1–18	300–700	1,800–2,600
Lower Vaal	15–32	1–20	200–500	2,646–2,690
Namibia	18–37	6–22	0–250	1,950–3,800
Molopo and Nossob‡‡	20–38	0–23	Molopo headwaters 400–600 middle 200–400 western parts 0–200	1,250–1,650

* A-pan evaporation
† Lesotho part of upper Orange–Senqu
‡ South Africa
‡‡ Botswana part of the basin
Sources: DWA, 2002a, 2002b, 2002c, 2005; Mendelsohn et al. 2002; ORASECOM, 2008

Biomes

The basin area can be broadly divided into five biomes that share similar physical features – climate, geology and soil – and plant and animal life:

The cooler and wetter Drakensberg–Maloti Highlands in Lesotho, are important for their high-altitude flora estimated at about 3,100 species, of which 30% is endemic to these mountains. The wetland systems of bogs and marshes also play a crucial role in the hydrological cycle of the Orange–Senqu basin through their retention and slow release of water.

The relatively high-rainfall Highveld Grasslands include some of the most important agricultural areas and highest population density in the basin. Vleis form during seasonal flooding and are important conservation areas. Three of these are internationally recognised and have been declared Ramsar sites.

The Southern Kalahari Savannah, which is characterised by deep wind-blown sands forming vegetated linear dunes, overlies a variety of geological and soil types, and is interspersed with pans. The main form of land use in the area is extensive livestock farming causing land degradation around settlements.

The Nama Karoo covers a vast area on the central plateau in the drier western half of southern Africa. It merges into Succulent Karoo in the west and Highveld Grasslands in the east and is used extensively for small-stock farming.

The Succulent Karoo in the far western, driest area of the basin has the highest number of plant species for an arid area in the world. Consequently, it is recognised as a biodiversity hotspot; much of it is protected through park networks. The Orange River mouth is in this biome and is a declared Ramsar site in both Namibia and South Africa.

Aquatic ecosystems

There are five broad types of aquatic ecosystems in the Orange–Senqu basin: rivers and streams, highland sponges, pans and vleis, the estuary, and groundwater aquifers. Others include pools, springs, human-made reservoirs and storage weirs.

As a result of extensive development and use of the river's water resources there is less water flowing in the river and its tributaries. This, combined with human settlement and activities along the river, have altered the morphology of the riverbed, banks and land alongside it and very little pristine riparian habitat is left. The riparian belt has become prone to invasion by alien species, which together with deforestation further disrupts the hydrological cycle of the river.

The retention and slow release of water of highland sponges help stabilise stream flow, attenuate floods, reduce sedimentation loads and absorb nutrients. These ecosystem services are at risk because sponges and bogs are becoming degraded through overgrazing and overharvesting of resources. Species diversity is declining and soil is exposed to wind and water erosion.

Many pans have become ringed by sizeable human settlements making them less accessible for wildlife. Increased reliance on livestock has caused the area around the pans and water points to become denuded and degraded, and dunes have remobilised. A number of vleis have been declared Ramsar sites, which, with other wetlands, are threatened by pollution and degradation from mining, farming and industrial activities.

Apart from the direct effects of diamond mining in the area, reduced flows and an altered hydrological regime further impact the Orange River estuary (a Ramsar site) and the opening and closing of the mouth to the sea. At present the estuary is classified as 'largely modified'. Mitigation is predominantly dependent on reducing winter flows of the river, reducing nutrient input downstream of Vioolsdrift and the removal of non-flow related impacts in the immediate area of the estuary.

Although groundwater resources are limited in comparison to surface water, the extent, quality and contribution they possibly make to the water balance is not well understood. Reduced flows, salinisation and pollution are all threats to the quality and quantity of groundwater. While the transboundary implications of groundwater use are not particularly significant at present, improved understanding of this valuable resource is essential to protect it for the future.

Social and economic factors

The basin has an estimated population of 14.3 million people, but supports 19 million people through water transfers to adjacent basins. South Africa has by far the major proportion of the basin's people, with high population densities in its eastern areas. All four basin states have undergone significant urbanisation, but population growth rates have slowed because of decreasing fertility and increased mortality as a result of high HIV/Aids prevalence rates.

Most of the South African part of the basin is farmed commercially. Rain-fed commercial farming ranges from maize and wheat production on the grasslands in the east, to increasingly extensive rangeland-based livestock systems in the west. The rest of the Orange–Senqu basin is characterised by small towns and villages, widely scattered throughout the region, serving mainly mining and/or agricultural land uses. Tourism has become an important use of land throughout the basin, but especially in the more arid western areas, displacing or complementing more extensive agricultural pursuits.

The South African economy is overwhelmingly dominant, contributing 93% of the combined gross domestic product (GDP) of the four countries. GDP per capita is highest for South Africa and lowest for Lesotho. The following four sectors dominate:

- agriculture
- mining and quarrying
- manufacturing and utilities, and
- services (which includes government).

All four basin states have inequitable distribution of income and the majority of the populations of the four basin states can be described as poor. While the basin has adequate agricultural production to feed its population, more than a third of its inhabitants suffer from malnutrition caused by insufficient food security at the household level.

Whereas water security is an important influence on food security, increased agricultural production and/or sufficient income generation to purchase food also play major roles. Water transfers from the basin to surrounding basins increase agricultural production, but this does not directly benefit vulnerable communities. The supply of water for food security in rural communities can be improved through better on-farm management, improved performance of irrigation services, augmentation of water supplies and rainwater harvesting.

Economic evidence suggests that scarce water in the basin should be reallocated from irrigated agriculture to urban and industrial uses. Redistribution of wealth and attention to improving water quality were also found to be important for enhancement of social wellbeing.

Water resources

The Orange–Senqu is the largest river system in southern Africa south of the Zambezi. The main river rises in the highlands of Lesotho, while its largest tributary, the Vaal, rises further north in the Drakensberg of Mpumalanga Province in eastern South Africa. Each has a number of tributaries. These rivers flow westwards across the subcontinent joining at Douglas. In the more arid lower reaches of the river, tributaries are ephemeral and contribute relatively little runoff to the main river system. This natural trend in water availability from east to west has helped determine patterns of settlement and economic development.

Water supply required to meet the demands of the densely populated north-eastern areas of the basin and those of large-scale irrigation schemes has been assured through the construction of numerous dams and a series of transfer schemes, mostly on the upper Orange–Senqu and Vaal river systems. It is consequently regarded as the most developed river system in southern Africa. Further downstream groundwater is of major importance and is used for rural domestic supplies, livestock watering and to supply many towns and villages.

Groundwater occurrence is determined largely by geology, and its flow by topography, which usually mimics surface contours. Sparse data and limited data sharing hamper a mutual understanding of the Orange–Senqu's groundwater resources and its development potential.

Groundwater and surface water are closely linked even when separated spatially. Each contributes to the other and with these interactions play an important role in the hydrology of a region. An obvious concern regarding the abstraction of water – either from the ground or rivers – is the likelihood that removal of water from one resource will reduce the amount of water available to the other. Similarly, water quality problems experienced in one resource will affect the other.

The Orange–Senqu can be divided into three main sub-basins – the Vaal, upper Orange–Senqu and lower Orange. Each of these can be further divided into areas practical for the purposes of water management.

Currently, the Orange–Senqu system hosts some 300 built structures, among them a number of large dams and inter- and intra-basin transfer schemes. These store and move bulk water, assuring supply to meet human demands.

Water in the Orange–Senqu basin is used for irrigation and other farming activities, industrial activities, mining, power generation, and urban and rural domestic requirements. Of all the water used in 2010, about 93% was used in South Africa, of which 70% was in the irrigation sector.

Power generation is currently confined to South Africa and Lesotho. This is done by wet- and dry-cooled coal-fired thermal power and hydropower generation. The water demand for, and management of, power generation from this basin poses a challenge especially in coordinating peak demands with other water requirements.

High demands on the water of the Orange–Senqu River system are estimated to have reduced the amount of water reaching the mouth to 37% of the average annual natural flow of 11,300 Mm^3. As a consequence of the river's development, there have also been changes in the patterns of flow. These changes to the hydrological regime of the river system, particularly in its lower reaches, are dramatic. In planning how to meet increasing demands in the future, it is important to have a good understanding of the balance – yield and demand – of water in the system.

Water quality in both rivers and reservoirs is greatly affected by suspended sediments (and associated pollutants) resulting from erosion through land degradation, and alterations and barriers along watercourses. Loss in storage because of sedimentation reduces the ability of reservoirs to supply water and control floods.

Improved understanding of sediment loads in the basin is required to manage them effectively and sustainably. Suspended sediment sampling should be carried out especially in the lower river reaches where sediment load data are limited. Knowledge of long-term fluvial morphology and associated changes is essential in the optimal design and management of river basin projects.

The dams in the basin are built primarily for water supply, but play an important role in drought and flood management, which could become increasingly important in the light of climate change. There are no dams specifically built for flood control but, as a general rule, the larger the capacity in relation to inflow, the greater the attenuation of floods. While all four countries have disaster management plans, these could be more detailed and follow a more integrated approach.

All dams in the basin are built for the purpose of managing water supply which, in its broadest sense, can be construed as drought management. However, all dams have an impact on the flow regime of the rivers on which they are built. By manipulating dam releases and prioritising water-use sectors, the impacts of drought can be minimised.

The environment

Land use and degradation

The condition of the terrestrial environment of a river basin plays a vital role in determining the condition, in terms of the quantity and quality, of a river basin's water resources.

Land degradation as a result of overgrazing, which is often accompanied by the invasion of alien species, is common to all the biomes in the basin. It generally renders the land less productive, reduces biodiversity and affects water balance.

Land ownership issues are strongly related to land degradation and frequently stand in the way of sustainable land management and development in rural areas. These issues include the lack of land tenure rights, limited management control over natural resources and either a lack of, or a failure to implement appropriate rural development and agriculture policies.

It is becoming increasingly evident that for many areas the biggest threat to the terrestrial and aquatic environments is poverty and lack of development rather than development itself. A shortage of land and associated resources leads to non-sustainable land management practices, the direct causes of degradation.

Any solution to land degradation requires intervention to help create alternative off-farm livelihoods and/or to organise and encourage rational urbanisation, which will ultimately make the provision of social services less costly.

While land degradation is taking place throughout the basin, the degradation of the river's headwaters deserves special attention in view of the close linkages between the terrestrial and aquatic ecosystems in these areas. Degradation of the terrestrial environment translates rapidly into degradation of the aquatic environment, impacting the downstream environment and users.

The main transboundary impacts of degradation of the Lesotho highlands relate to changes to the hydrological regime. In particular, increased levels of soil erosion, reduced infiltration and loss of wetland storage are translated into reduced base flow, increased levels of flooding and higher sediment loads.

Land degradation is also a concern in south-western Botswana, which is dominated by linear, vegetated dunes. With the advent of borehole technology in the 1960s, wells were replaced by boreholes and many pans have become ringed by sizeable human settlements. This has made the pans less accessible to wildlife, and overgrazing of livestock around the pans and livestock watering boreholes has led to loss of vegetation and remobilisation of the dunes.

Invasive alien plants

Alien invasive species are species introduced from another geographical location that establish themselves, grow and propagate. They often have adverse economic, environmental, hydrological and ecological effects on the habitats they invade and the indigenous vegetation found there.

Large numbers of species are found in the higher-rainfall areas of the basin, especially in the Vaal and upper Orange–Senqu sub-basins. Invasions are particularly severe along the rivers in the basin. A number of species are problematic, but the most frequently recorded invasive alien is *Salix babylonica* (weeping willow), followed by *Prosopis glandulosa* (mesquite). These plants are closely associated with overall ecosystem degradation. Other relevant factors associated with the spread of invasive plants in the basin include changes in hydrological regime, reduced flows and poor water quality. Each of these contributes to the alteration of the natural ecosystem, disturbing natural habitat and creating a niche for alien species to take hold and proliferate.

Along the Orange River, the proliferation of invasive alien plants is estimated to reduce river yield by as much as 13% in the upper catchment and 7.8% in the lower catchment. Effective clearing could reclaim these water resources for other uses.

Numerous factors operating in the catchment may limit or even counteract restoration actions in specific reaches invaded by alien plants. Restoration should therefore be planned and implemented in an integrated way, respecting both the upstream-downstream linkages and socio-economic factors. The latter implies a strong degree of inter-disciplinary partnerships.

Irrigated agriculture

The area in the basin converted to irrigation may seem relatively small at 385,300 ha, however its impact on the basin's water resources is significant, using approximately 60% of the water supplied in the basin. Most irrigation in the basin takes place in South Africa. However, in recent years there has been a rapid growth in irrigation on the Namibian side of the lower Orange River, especially in the cultivation of high-value crops such as table grapes and dates.

There have been a number of irrigation initiatives in Lesotho and these continue with a view to increasing food security, but at present and for the foreseeable future use a minimal amount of water. There is no irrigation in the Botswana area of the basin.

Relatively low-value field crops, such as maize and wheat, and fodder crops such as lucerne, make up over 80% of irrigated crops. Higher value field crops, such as potatoes, vegetables and certain annual fruit crops such as sweet melon, make up only about 10%.

For years, irrigation has been seen by many as the biggest culprit of inefficient water use. While wastage has been and continues to be an issue, the role that irrigation plays in providing employment and food security is often overlooked. A recent study (ORASECOM, 2011f) showed that there has been significant improvement in the performance of the sector in recent years. This can be ascribed to new laws and policies and their gradual implementation, increasing electricity costs, and an increased level of awareness among farmers.

Future trends in irrigated agriculture are likely to include cultivation of higher value crops; increased levels of technology; an increased integration of previously disadvantaged farmers into the sector; a move towards irrigation as a business rather than an agricultural activity; and heightened compliance to policy and economic realities.

Water quality

The key water quality issues in the Orange–Senqu River system have been identified as nutrient enrichment, primarily linked to increased phosphorus and nitrogen concentrations; increased salinity from acid mine drainage and irrigation return flows; microbial contamination from urban settlements and poorly operated wastewater treatment works; and elevated sediment concentrations resulting from run-off from degraded land. In general, water quality issues are most serious in the Vaal sub-basin.

Nutrient enrichment is perhaps the most significant water quality problem. Sources of nitrogen and phosphorus are from untreated or undertreated human waste and from agricultural return flows. Blooms of floating microscopic algae increase the costs of water treatment in nutrient-enriched water sources and can promote the formation of carcinogenic substances in the treated drinking water. Certain toxic algal blooms have caused livestock deaths. Floating aquatic weeds can cover entire rivers and dams and can block water intakes and affect the recreational use of water.

In the Witwatersrand area, especially, mining activities have exposed metal-containing sulphide ores which produce sulphuric acid when they come into contact with water. The result is extremely acidic water with high concentrations of salts and metals. As mines became uneconomical and closed down, they were no longer dewatered. Recharge of groundwater in subsurface mine workings continued and the water table of acid mine drainage rose, threatening to decant and degrade surface waters. The current treatment of this water through dilution with good quality water and removal of salts is not thought to be sustainable in the long term, and new solutions need to be found.

Intensive irrigation also raises salinity because of fertiliser residues in return flows back to the rivers, or into the groundwater.

Microbial contamination from faecal matter is caused by failing wastewater treatment works and reticulation systems, as well as densely populated, but poorly serviced settlements. The little available data on microbial contamination across the basin shows, however, that while there is significant contamination in and around the main urban centres, it is localised. Notably, cholera has been recorded in settlements in the urban areas that are not provided with safe drinking water, indicating that even though the problem is localised, it can have significant impacts on the people of the basin.

Ecosystem health

Ecosystems have a certain capacity to absorb change and recover from damage. However, when the damage is too severe, an ecosystem loses this resilience and becomes vulnerable.

The abundance and types of aquatic organisms naturally vary along the length of the Orange–Senqu River. To assess the system's health, river monitoring programmes rely on the availability of similar 'reference' sites in their 'natural state', but this poses a problem for the Orange–Senqu, as it is affected by human activities along virtually its entire length. In the absence of unaffected 'reference sites', impacts have to be set against expert knowledge of the rivers and what should occur naturally.

In southern Africa, aquatic ecosystems have adapted to large inter-annual variability in flows; they can cope with low flow conditions in droughts and recover from them. Flow that is constantly higher than natural flows can also have significant impacts on ecosystem functioning.

To determine recommended flows that are needed to maintain aquatic ecosystems at a desired condition in different parts of the basin, the impact on the availability of water for social and economic requirements needs to be taken into account. System-wide water availability needs to be modelled and storage infrastructure needs to be assessed to identify what releases can actually be delivered. Such studies have been carried out for many areas of the basin, but these require collation and evaluation for the development of a basin-wide environmental flow regime.

The four basin states are committed to establishing basin-wide environmental flows in this way. This is important for the long-term health of the river system, particularly the estuary.

Climate change

The naturally high inter-annual and intra-annual variability of both precipitation and runoff in the Orange–Senqu basin makes it difficult to distinguish these periodicities from long-term climate change trends. The limited availability of long-term climate records for many areas of the basin makes this even more difficult.

A global climate change downscaling exercise was recently carried out for the basin (ORASECOM, 2011c). Projected temperature increases are unevenly distributed across the basin and the seasons. Compared with global averages, however, greater warming throughout the basin is expected in all seasons. The largest increases are expected in the central and northern areas, especially in summer. A decrease in annual precipitation is expected over most of the basin, with a possible increase over the headwaters. There is likely to be an increase in extreme events. The combination of these effects on runoff is difficult to assess.

The impacts on vegetation and agriculture are likely to be significant. Rain-fed cultivation will become more difficult in the north-eastern areas of the basin and livestock in the central, northern and western areas more subject to temperature stress. Biomes are likely to shift, which has implications for biodiversity conservation with the potential loss of specialist plant species and suitability for agricultural activities. Issues around sediment loads and mass balance are bound to be exacerbated by land-use changes within the basin.

In many areas of the basin, particularly subsistence farming areas, adaptive capacity to both climate variability and change is exacerbated by existing development challenges, including poverty. Initiatives that are aimed at reducing vulnerability and enhancing resilience to extreme events through efficient catchment management will be particularly important.

Climate change is an evolving science, and models in different countries are constantly being improved and updated. A fairly broad envelope of possible changes is conceivable. While it is important to continually assess the potential changes and their effects, adaptation initiatives are required within the basin in order to minimise the adverse effects of climate change.

Governance

The Orange–Senqu River basin is the most developed transboundary river basin in the Southern African Development Community (SADC) region. It is home to the largest international water transfer scheme in the world, as well as several other inter-basin transfers. The basin's water resources are of critical importance to the region's economy.

The basin is managed within a wide-ranging framework of international agreements. These comprise bilateral and multilateral water management agreements, other multilateral environmental agreements and a number of economic cooperation agreements with indirect impacts on basin management. All of the basin states have adopted or are in the process of adopting an IWRM approach through the reform of their respective water sectors.

The basin states are in agreement that the management of the basin's water resources should be carried out with the full participation of all affected states within it. The Orange–Senqu River Commission (ORASECOM) provides a forum for consultation and cooperation for this.

The major water users in the Orange–Senqu change over the length of the river. Urban-industrial uses predominate in the upper Vaal area, while irrigation is the dominant water use in all the other areas. The four basin states, while at different levels of industrial development, have as a whole seen a reduction in the role that agriculture plays in their national incomes.

Strategies to address poverty and food insecurity through water use differ between the basin states. At the moment, there is no standardised approach to using water to promote growth and development, and this must underlie the implementation of integrated water resources management principles in the basin in the future.

The application of economic principles is becoming increasingly important for water management and there is a need to further develop benefit-sharing strategies in the Orange–Senqu basin.

SADC's Revised Protocol (of which the basin states are signatories) is a regional framework agreement for the management of shared watercourses. It contains a comprehensive set of substantive and procedural rules for the management of shared watercourses in the SADC region.

The Orange–Senqu basin states have concluded a basin-wide watercourse agreement, the ORASECOM Agreement. This agreement is the primary agreement for the basin with SADC's Revised Protocol only providing interpretational guidance and gap filling. The ORASECOM Agreement contains the core of the substantive law obligations of the Orange–Senqu basin states with respect to the management of the basin.

The third type of agreement applicable to the basin is the bilateral agreement, which can broadly be categorised into two types: those with the sole purpose of establishing a bilateral watercourse institution, and those concluded with respect to a specific bilateral infrastructure project.

Several other international environmental agreements are applicable to the management of the Orange–Senqu River basin. The Ramsar Convention promotes the conservation of wetlands and establishes obligations for protection of so-called 'Ramsar sites'. The UN Convention on Biodiversity stipulates riverine and aquatic habitat protection as a core element of biodiversity conservation.

Economic agreements within SADC also play an important role. In particular, the SADC Protocol on Trade (establishing a SADC-wide free-trade area) and the agreement establishing the Southern African Customs Union shape the economic landscape in which the Orange–Senqu basin states operate and influence their economic policies.

The basin states are strongly committed to develop and manage the basin on the basis of a jointly agreed basin-wide IWRM plan and there is an ongoing process of developing such a plan. This process provides opportunities to effectively integrate other existing plans (e.g. biodiversity plans, TFCA management plans), but these are not yet adequately aligned and integrated with basin management. Furthermore, there is no standardised approach to using water to promote growth and development.

The basin states share common challenges to a greater or lesser degree that hamper the implementation of IWRM:

- shortcomings in policy and legislation – outdated legislation, gaps with respect to different aspects of water resource management, translation of policies into laws, potential conflicts between policies from different sectors;
- insufficient intersectoral cooperation and coordination;
- insufficient integration and coordination between national-, regional- and local-level bodies;
- limited institutional capacity and inadequate financial resources;
- weak knowledge management.

Equitable utilisation on a basin-wide scale has not yet been defined in terms of the basin. There is a risk of conflict over water use if downstream interests are not appropriately balanced with upstream interests and integrated into benefit-sharing arrangements.

Assessment of issues

Priority transboundary and common or shared problems were identified through a consultative process during the preliminary TDA. Building on this, ecological and socio-economic impacts and immediate, underlying and root causes were examined. A preliminary causal chain analysis (CCA) was produced for four prioritised issues that were identified during national consultations with all four basin states. These were:

- increasing demand on water resources

- changes to hydrological regime
- declining water quality
- land degradation.

Changes in sediment dynamics and quality and invasion by alien species were additional issues identified and were incorporated into the transboundary problems, as and where appropriate.

One of the most useful aspects of the TDA is the CCA, which is developed for each problem. It graphically relates the transboundary problem to ecological and socio-economic impacts, provides an analysis of what has caused it, and offers potential interventions to address it. To help identify and understand the causes, they have been examined by economic sector and divided into immediate, and underlying and root causes. On analysing the problems it became clear that they cannot be regarded in isolation from each other. The direct and underlying causes of these four issues and their ecological and socio-economic impacts are interwoven. The impact of one problem is very often the cause of another.

The main sectors linked to the causes of the transboundary problems were identified as agriculture, energy, industry, mining and urban. Some of the causes are, however, cross-cutting; the most significant one being related to the need for the storage and transfer of water.

These CCAs should form the basis for development of the NAP and the basin-wide SAP interventions. Therefore, potential points of intervention to address the problems have also been included in the CCAs.

Increasing demand for water

As a result of high and increasing demands for water, especially in the upper area of the basin and for irrigation in the drier areas, there is less water flowing through the system and less water to dilute pollutants. Ecologically, these factors have led to the degradation of wetland and riverine habitats, including ephemeral rivers and the estuary.

Although there are limited options to increase abstraction and use of surface water in the basin, a number of interventions to improve the efficiency and management of its supply and use are suggested, including managing demand and examining the potential of alternative sources.

Limited understanding of resource potential in the basin, especially of groundwater, is a key concern. Rainfall, flow, and groundwater resource monitoring, analysis and evaluation need to be improved. There is also a need to improve the water balance model of the basin. The boundaries of sub-systems, and inputs and outputs of transfer systems need to be better defined, especially in the quantification of inter-basin transfers.

Key transboundary elements to this problem include:
- transfer of water out of the system;
- water wastage and leakage;
- inefficient use of water, especially for irrigation;
- dilution of acid mine drainage;
- lack of provision for basin-wide environmental flows;
- limited data for planning and modelling;
- limited management of demand;
- limited research and implementation of alternative sources and improved technologies;
- limited awareness on the value of water.

Changes to hydrological regime

As a consequence of upstream development, the hydrological regime of the river has changed dramatically. Apart from the mean annual runoff being reduced to half the estimated natural flow, the pattern of flow is different to that of the natural river. There is less variability in flow from one year to the next, fewer floods, and, within the year, there is a less distinct seasonal pattern.

Key transboundary elements of changes include:
- storage and transfer of water for abstraction as required without provision for environmental flow requirements;
- reduced flows and flushing – volume and frequency;
- higher winter flows;
- changes in degradation and aggradation and resultant river morphology and sediment balance;
- changes in balance of riparian and aquatic ecosystems, especially the estuary;
- loss of ecosystem goods and services;
- reduced water quality;
- lack of basin-wide flood and drought warning networks.

The establishment of basin-wide environmental releases is central to mitigating these problems. Greater coordination between development industries, especially, and the water sector is also required.

To create a better understanding of what the environment requires, there is a need to increase the number of hydrological monitoring stations, especially downstream of Upington, and environmental monitoring throughout the basin.

Declining water quality

The key water quality issues in the Orange–Senqu River system have been identified as nutrient enrichment, increased salinity, microbial contamination and changes in sediment load. In addition, radionuclides, heavy metals and persistent organic pollutants, while they do not currently pose a basin-wide risk, do show high concentrations in certain localised areas, and precaution should prevail.

At a time when the types and sources of pollution are increasing, reduced volumes of water in the system prevent their effective dilution, compounding the water quality problem.

Upgrading infrastructure, improving monitoring and enforcing compliance will go a long way to addressing the issues. However, research is also required to establish the extent of some of the pollution concerns and to determine best practices for addressing them. To implement such interventions, capacity and skills need to be developed. There is also a need to implement a 'polluter pays' principle and/or volume-based pricing to help overcome the costs of monitoring and remediation.

Land degradation

Inappropriate land management in different parts of the Orange–Senqu basin has led to a variety of land degradation issues, including loss of wetland storage and aquifer recharge, increased sediment loads, deteriorating water quality, increased distribution and abundance of alien invasive plants, loss of biodiversity, and lowered land productivity.

The main sectors linked to the immediate causes of land degradation are agriculture (at commercial and subsistence levels) and mining. Cross-cutting causes relate to the disturbance and degradation of areas and spread of alien invasive species. However, the problem is not only related to agriculture, but any activities that disturb and require clearing of land. These include construction, mining, crop cultivation (especially in fragile ecosystems) and when environmental management or rehabilitation plans are not implemented.

A conflict of interest between interventions aimed at poverty eradication and ecosystem health is a common issue in all four basin states, as well as issues around land tenure systems and dual grazing rights.

Potential interventions are aimed at improving land management practices, identifying alternative livelihoods and rehabilitation of degraded areas through an integrated and participatory approach. It requires changes in policy, as well as practice.

Deterioration of aquatic ecosystems

Ecosystem functioning is impaired for virtually the entire Orange–Senqu River system. The aquatic ecosystems are vital for maintaining the integrity and health of the system in the long term and the goods and services it provides.

Five broad aquatic ecosystems are threatened: highland sponges, pans and vleis, riparian belt, the estuary and groundwater aquifers. Making provision for environmental flows; improving monitoring and land and water management practices; increasing awareness; enforcing regulation; and integrating these with current operational systems are likely to improve the condition of the river basin as a whole.

Conclusion and recommendations

The TDA provides the basis to develop strategic plans to address problems identified in the basin and in each of the basin states. The basin-wide SAP and NAPs should identify and expand on agreed management responses to the environmental problems identified in this document.

A number of potential points of intervention have been identified. The objectives of the interventions should be to address the prioritised transboundary environmental issues and help support governance challenges. These are summarised as follows:

- Improve understanding of available resources by increasing the basin-wide monitoring network of relevant variables at strategic monitoring stations and enhancing the analysis and sharing of information through ORASECOM's Water Information System.
- Create additional yields of water in the system by improving the efficiency of water use and resource management, especially in the irrigation sector, and exploring alternative sources.
- Improve water quality by identifying and monitoring hotspots, addressing issues with innovative solutions and by encouraging compliance.

Mitigate the adverse effects of the changed hydrological regime by developing basin-wide environmental flow scenarios and implement an integrated management plan for the Orange River estuary.

Reverse environmental degradation and improve land use, especially in the catchment of the Senqu River, but other degraded areas too, by scaling up piloted rehabilitation efforts and introducing alternative livelihood options and local-level monitoring systems. Implement basin-wide management of alien invasive plants.

Support activities to facilitate the implementation of basin-wide IWRM, such as building capacity, and strengthening regional monitoring, information networks and financial mechanisms.

1. INTRODUCTION


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1.1 ORANGE–SENQU RIVER BASIN BACKGROUND SETTING

The Orange River rises as the Senqu in the highlands of Lesotho, some 3,400 m above mean sea level and more than 2,300 km from its mouth on the west coast of southern Africa. With a total catchment area of approximately a million square kilometres, the Orange–Senqu River basin is one of the largest in Africa, encompassing the whole of Lesotho and areas of Botswana, Namibia and South Africa. The many tributaries of this westward-flowing river include the Vaal River in South Africa and the ephemeral Fish River in Namibia.

Rainfall decreases from east to west across the basin. While Lesotho covers only 3% of the total basin area, it contributes about 40% of the total basin runoff. The large catchment area in South Africa accumulates over half the runoff. The Namibian portion of the basin only contributes 5% of the runoff because of the arid climate in these lower reaches. As a result of its physical characteristics and climatic conditions, the Molopo tributary in Botswana has not contributed any surface runoff to the main river in living memory (ORASECOM, 2007b).

Above: Streams in Lesotho, such as this, collectively contribute more than 40% of the basin's natural runoff.

The basin supports more than 19 million people and the river system plays a vital role in sustaining livelihoods and stimulating economic growth (Earle et al., 2005). Water is abstracted for urban, industrial and agricultural use and augmented through a complex system of more than 70 reservoirs. These are linked by intra- and inter-basin water transfer schemes, which move water both into and out of the basin. Hydroelectric power is harnessed at some sites, but is limited because water is required for other purposes.

The combined effect of abstraction and evaporation is a reduction of more than 60% in the average natural runoff of 11,300 Mm^3 a year. The frequency, size and duration of floods are also affected. These changes in flow and the effects of land use in the basin adversely affect the quality of the water, the health of the river and the resources and ecosystems it supports, and the services these provide.

Demand for water is predicted to increase with economic growth and development, affirming the need for effective, efficient and sustainable water resources management to maintain these important ecological functions and secure the basin's resources in the long term. The governments of the four basin states are well aware of the critical scarcity of water resources in southern Africa and are committed to working together to protect these shared water resources and develop them in a sustainable and equitable way for the benefit of all their people. To this end, the Orange–Senqu River Commission – ORASECOM – was established through a formal agreement between the four governments in 2000. The Commission advises Orange–Senqu basin states on the development, utilisation and conservation of the water resources of the basin.

In support of ORASECOM, UNDP–GEF's Orange–Senqu Strategic Action Programme was developed to assist in identifying transboundary issues and then develop national and basin-wide plans to address them.

During preparation of the UNDP–GEF-funded programme, a preliminary Transboundary Diagnostic Analysis (TDA) of the basin was developed. ORASECOM adopted this document in April 2008 (ORASECOM, 2008). The preliminary TDA focused on transboundary problems, highlighting the main environmental threats to the basin and ascertaining their root causes.

This report finalises the TDA by addressing a number of knowledge gaps and revisiting the causal chain analyses (CCAs), which relate the environmental problems to their impacts and immediate and underlying causes.

Opposite: Maletsunyane Falls in Maseru District, Lesotho, is one of the highest waterfalls in the world.

ORASECOM: THE ORANGE–SENQU RIVER COMMISSION

The Orange–Senqu River Commission – ORASECOM – was established by the governments of Botswana, Lesotho, Namibia and South Africa to promote equitable and sustainable development of the resources of the Orange–Senqu River. This joint commitment was sealed through an 'Agreement for the Establishment of the Orange–Senqu Commission' signed in November 2000 in Windhoek.

It was the first agreement to establish an international river basin institution on a shared river in the Southern African Development Community (SADC) since the Revised Protocol on Shared Watercourses was signed. The ORASECOM Agreement conforms to best international practices regarding joint management of shared rivers, having been drafted in line with the 1997 United Nations Convention on the Law of Non-navigational Uses of International Watercourses.

The highest body of ORASECOM is the Council consisting of delegations from each country, supported by various 'Task Teams' that manage projects, and a Secretariat. The Council serves as technical advisor to the basin states on matters related to development, utilisation and conservation of water resources of the Orange–Senqu basin. The Secretariat, established by agreement with South Africa in 2006 and hosted there, coordinates ORASECOM activities, implements ORASECOM decisions and is the focal point of the institution.

ORASECOM provides a forum for consultation and coordination between its basin states – Botswana, Lesotho, Namibia and South Africa – to promote integrated water resources management (IWRM) within the Orange–Senqu River basin. The IWRM approach helps to manage and develop water resources in a sustainable and balanced way, taking into account social, economic and environmental interests. A primary mechanism of achieving IWRM in the Orange–Senqu River basin is the development of a basin-wide IWRM plan that will provide the cooperation framework for the management and development of water and related resources. The National Action Plans and basin-wide Strategic Action Programme being developed on the basis of this TDA will form the environmental component of that plan.

1.2 REGIONAL SIGNIFICANCE OF THE BASIN

The Orange–Senqu River basin is the largest river basin and water resource south of the Zambezi in a region that is largely classified as semi-arid and subject to increasing water stress. It is important to regional cooperation because it is located in the four territories of Botswana, Lesotho, Namibia and South Africa. The river system is not only transboundary, it also forms some of the borders between these basin states.

The largest part of the basin (64.2%) falls within South Africa and includes the Vaal and Orange water management areas (WMAs). Much of south-western Botswana and southern Namibia are included in the basin and cover significant areas (7.9% and 24.5%, respectively), although they contribute relatively small amounts of water to surface runoff (0.3% and 5.2%, respectively). The whole of Lesotho falls within the basin, making up 3.4% of the basin area, and contributes over 40% of the surface runoff. These four countries rely to varying degrees on the system's water resources for agriculture, industry (mining and manufacturing), energy, domestic needs, conservation and tourism.

Urban and industrial demands are geographically concentrated in the upper, eastern parts of the basin, mostly in the Vaal sub-basin, which forms the economic hub of South Africa and, indeed, of the southern African sub-region. Historically and currently, the Vaal and Orange–Senqu systems have provided the source of water, minerals and energy on which economic development in the region has been based. In spite of significant development and high socio-economic expectations in this area, the greatest quantities of water are used in the agricultural sector for crop irrigation.

Other areas of the basin are significant for their biodiversity and importance to conservation. The Drakensberg–Maloti mountain range is a biodiversity hotspot of high-altitude flora, of which 30% of an estimated 3,100 species is endemic to this area. This endemic zone also supports an extensive network of high-altitude wetland bogs and sponges, crucial in the hydrological cycle of the Senqu River. At the other end of the system, the lower Orange River passes through Succulent Karoo biome, which contains the highest diversity of arid flora globally and is also a declared biodiversity hotspot.

In addition, the river system supports a number of declared Ramsar sites – wetlands of international importance – including the Orange River mouth, shared between Namibia and South Africa. Other Ramsar sites in the Orange–Senqu River basin include Barberspan, Blesbokspruit and Seekoeivlei Nature Reserve in South Africa, and Lets'eng-la-Letsie in Lesotho. These sites are among those protected through the national protected area networks of each country and three transfrontier co-management areas in the basin.

As a result of development and high rates of abstraction, some of these wetlands and areas of conservation importance are under threat. The volumes of water, and frequency and timing of floods have been altered. Furthermore, water quality is impaired in many areas by seepage, runoff and point-source discharges of municipal, industrial and agricultural effluents, and by high sediment loads from land degradation in many areas of the basin.

Only integrated planning of water resources at the basin level can address the environmental and socio-economic development needs in the basin. Consequently, integrated, inter-country efforts are urgently required to comprehensively evaluate the degree of ongoing degradation of the Orange–Senqu and to take action to halt and reverse damaging trends where necessary.

Table 1: Summary of basin characteristics

Country	Proportion (%) of basin area	Contribution to natural runoff (%)	Proportion (%) of basin population	Water use in 2005 (Mm³)
Botswana	7.9	0.3	0.3	negligible
Lesotho	3.4	41.5	15.4	20
Namibia	24.5	5.2	2.6	76
South Africa	64.2	53.0	81.7	5,389

Source: ORASECOM, 2008

The continuous collection and analysis of streamflow data from gauging stations such as this, is essential to quantify available yields for managing and developing the basin's water resources.

1.3 ABOUT THIS TDA DOCUMENT

This document is based on findings and recommendations of the *Orange–Senqu River Basin Preliminary Transboundary Diagnostic Analysis* that was adopted by ORASECOM in 2008 (ORASECOM, 2008). It consolidates information from that document and more recent studies, particularly those pertaining to water balance, sediment loads, water quality, climate change and irrigated agriculture.

1.3.1 Purpose and objectives

The main purpose of this TDA is to provide a scientific and technical basis for the identification and prioritisation of key issues concerning the degradation of aquatic ecosystems in the Orange–Senqu River basin. It is intended as a decision-support tool for the Orange–Senqu basin states and stakeholders to identify areas of future action to address key issues. It is aimed at, amongst others, civil society, industry, governments, academia and environmental groups in the four basin states.

The TDA covers the areas of each of the four Orange–Senqu River basin states – Botswana, Lesotho, Namibia and South Africa. It provides an overview of the basin, covering its geographical characteristics, specifically focusing on its surface and subsurface water resources. The document also discusses the terrestrial environment and activities directly and indirectly affecting the quality and health of the basin's riparian and wetland environments. In addition, it includes a summary of the policy, legal and institutional arrangements within the basin.

Chapter 4 provides an analysis of priority transboundary concerns based on the information presented, and in consultation with experts and stakeholders. It discusses the ecological and socio-economic impacts of these problems and their immediate, underlying and root causes. These CCAs, developed for each of the priority problems, also identify potential points of intervention.

1.3.2 Description of the TDA process

Five main steps in the TDA process can be summarised as follows:

- identification and initial prioritisation of transboundary problems;
- production of the preliminary TDA through gathering and interpreting information on environmental impacts and socio-economic consequences of each problem and developing preliminary causal chain analyses;
- filling in knowledge gaps and initiating pilot projects to address issues following recommendations of the preliminary TDA;
- reworking the CCAs in the light of new information and identifying points of intervention;
- reviewing and validation.

The first step in the process was to agree on the transboundary problems. Initial stakeholder consultation highlighted the main problems, which were revisited by a 'TDA Technical Task Group' of experts from the basin states who examined their transboundary relevance and scope, and determined preliminary priorities. A combination of consultants, ORASECOM members, government officials, institutional representatives and basin residents worked together to reach consensus on the identification and analysis of common and transboundary problems as quickly as possible. The priority transboundary problems were identified as:

- stress on surface and groundwater resources
- altered water flow regime
- deteriorating water quality
- land degradation
- spread of alien invasive plants and animals.

Fragile soils clinging to steep slopes in the mountainous headwaters of the Senqu River are highly erodable and recognised as one of the underlying causes of land degradation in the basin.

© Ian Smith

Six thematic reports were drafted by consultants who formed the basis for the preliminary TDA and development of CCAs. A stakeholder analysis including interviews with 36 stakeholder groups and interviews with more than 400 stakeholders showed that there was concern about the following major issues:

- water quantity
- impacts of climate change on water regime
- water regime influences on biodiversity
- water quality
- other social and economic issues impacting project design and implementation.

An important step in the development of this TDA involved validation of the results by recognised experts and institutions in the basin. Apart from the involvement of stakeholders and experts in the development of the preliminary TDA, the revised CCAs were reviewed at national meetings of experts and institutional representations in each of the four basin states. The outcomes of these meetings were subsequently incorporated into the document. Drafts of this document have also been made widely available for comment.

© Kevin Roberts

Sampling the lower Orange River during the basin-wide survey

ADDRESSING PRELIMINARY RECOMMENDATIONS

Many of the recommendations made in the preliminary TDA have since been carried forward.

- The environmental flow requirements of the lower Orange and Fish rivers have been assessed (ORASECOM, 2011e; Louw et al., 2014).
- Work towards detailing a water resource balance for the basin has been carried forward (Bailey, 2011; ORASECOM, 2011a).
- Initial basin-wide assessments of pollutants, including persistent organic pollutants (POPs) and heavy metals have been carried out (ORASECOM, 2011g, i, 2013).
- A global climate change downscaling exercise was carried out for the Orange–Senqu basin (ORASECOM, 2011c).
- The effects of the Orange–Senqu on the Benguela Current Large Marine Ecosystem were examined (ORASECOM, 2012).
- Community-based management approaches to improve land and water resources management are being piloted.

Building on the results and recommendations of the preliminary TDA, the information and findings from the above-mentioned studies and initiatives have been taken into account in the compilation of this document. The information was also used in the revision of CCAs for each of the transboundary concerns where available.

1.3.3 Where to from here?

This document will provide the basis for strategic planning to address problems identified at both national and basin-wide levels. Planning documents – National Action Plans (NAPs) and a basin-wide Strategic Action Programme (SAP) – are currently being developed. These will outline appropriate and agreed management responses to address the problems identified here.

The basin-wide SAP for the Orange–Senqu River basin will focus largely on environmental concerns, and will identify policy, legal and institutional actions and investments needed to address the priority transboundary water-related environmental problems, thereby forming the environmental component of the Orange–Senqu Integrated Water Resources Management (IWRM) Plan. The NAPs will respond to the specific circumstances and priorities of each basin country and national aspects of the wider SAP. They will integrate basin-wide actions into national planning processes and budgets.

2. BASIN DESCRIPTION

2.1 GEOGRAPHICAL SETTING

The Orange–Senqu River basin is approximately 1,000,000 km^2 in size covering areas of Botswana, Namibia and South Africa and the whole of Lesotho. It is bounded on its western, southern and eastern sides by the Great Escarpment of southern Africa. The area is drained by two main river systems that rise in the more temperate eastern and higher areas of the escarpment and flow westwards through increasingly arid areas before discharging into the Atlantic Ocean. The Orange–Senqu River, which rises in the Maloti Mountains of Lesotho, and the Vaal, which rises further north in the Drakensberg Mountains of eastern South Africa, merge before being joined by a number of other tributaries draining the arid regions of western South Africa and southern Namibia.


© Barry Tuck/Shutterstock

Snow-capped mountains in the highlands of Lesotho

Figure 1: Topography of southern Africa and the Orange–Senqu River basin

2.1.1 Climate

The basin extends across almost the full width of southern Africa, from 30° E to 17° E – approximately 1,000 km – with a significant east-west aridity gradient. The river system rises at the summit of the Maloti-Drakensberg escarpment in Lesotho and South Africa with a mean annual rainfall of 1,600–1,800 mm and relatively low evaporation rates, but discharges into the sea in hyper-arid western reaches of the sub-continent where less than 50 mm of rain falls on average per year and the potential evaporation rate is high.

Rainfall is strongly seasonal over most of the basin, with most rain falling in summer between October and April. In the eastern areas, the rain season starts as early as September, usually occurring as convective thunderstorms, which are sometimes accompanied by hail. Snowfalls are relatively common during

Opposite: Irrigation places the greatest demand on the basin's water resources.

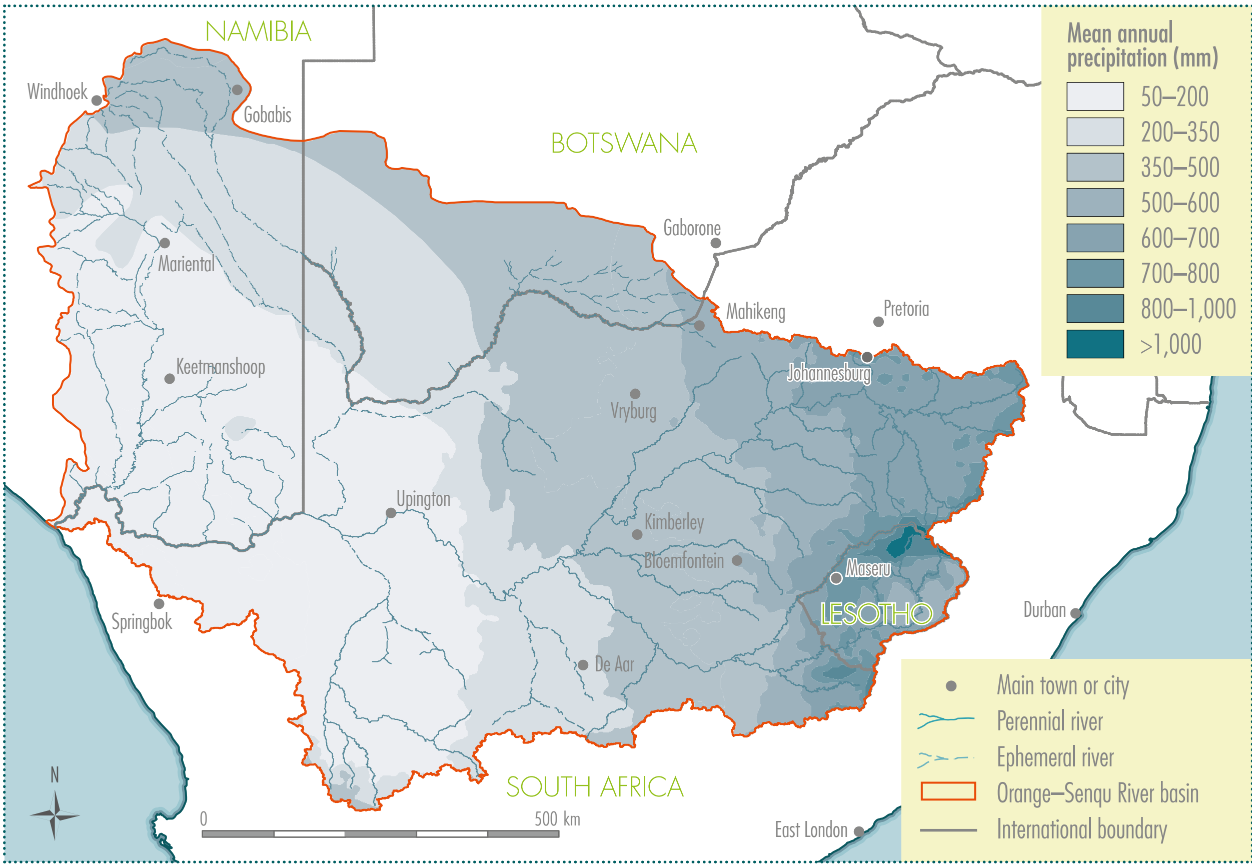

Figure 2: Mean annual precipitation

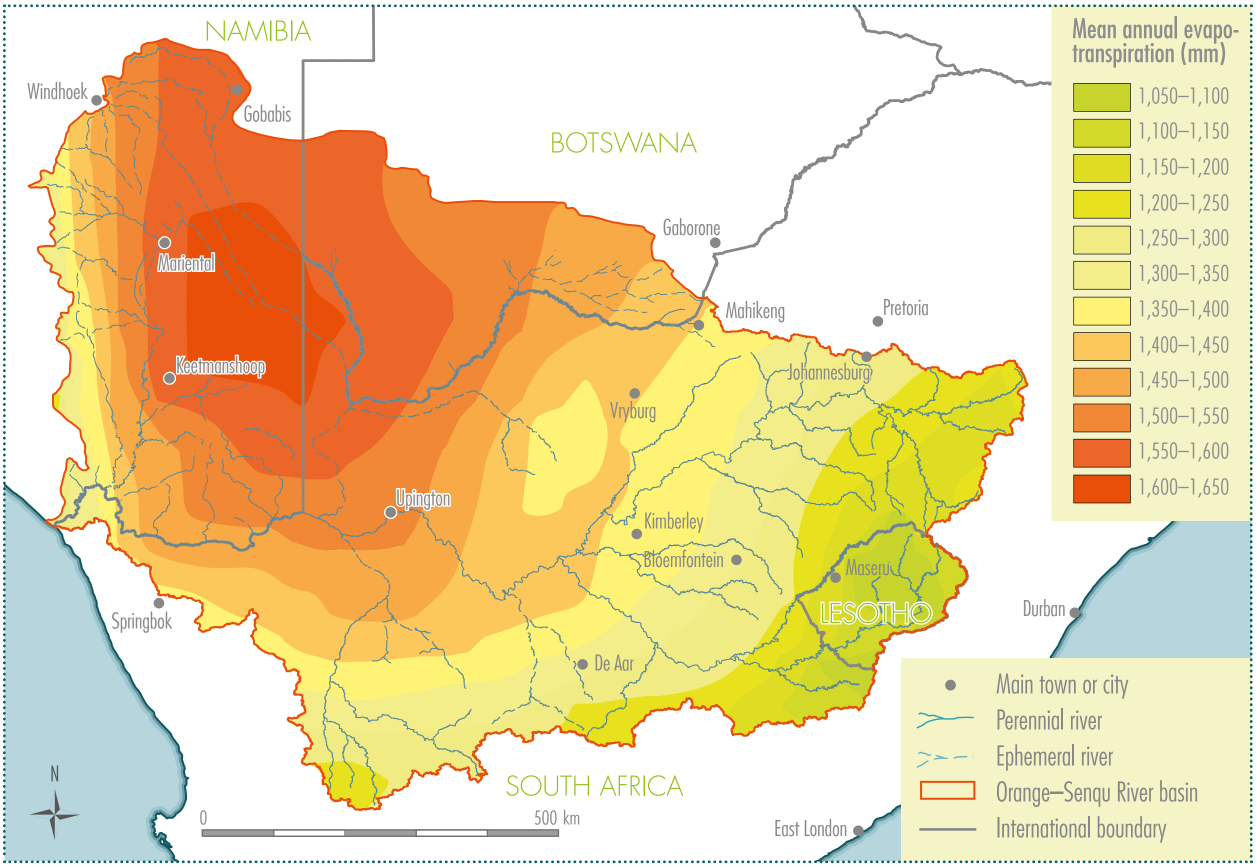

Figure 3: Mean annual evapo-transpiration

winter in the Lesotho highlands. In the west, the rain season is later and shorter (January to April), with much of the precipitation in the far western areas falling during the winter months. Here, advective fog off the cold Atlantic Ocean is also an important source of water for plants and animals.

Rainfall is highly variable throughout the basin, but increasingly so in the more arid western areas, where annual rainfalls can be well above or below the long-term average figures. Variability of precipitation in low-rainfall regions is a critical factor in understanding the climate, as it helps explain the natural year-to-year situation and to an extent the scarcity of water resources. The basin as a whole is prone to extended periods of lower rainfall as experienced, for example, in the late 1960s, mid-1980s and 1990s. Periods of relatively high rainfall also occur, such as those in the 1970s and more recently, in the early 2000s and the exceptional rains of the 2010/11 season.

Precipitation and its temporal and spatial variation is the main driving factor regarding the availability of water in the system. Assuring water to sustain agriculture and other economic activities and domestic needs, necessitates bulk storage and transmission of water to places and at times when it would otherwise not be available. Such development of the river system is also the underlying cause of many of the ensuing transboundary problems.

Temperature varies considerably across the basin, from temperatures well below 0° C in winter in Lesotho, increasing westwards, with extremes in excess of 45° C in the low-lying areas of the Orange River valley.

The average annual temperature, rainfall and evaporation figures are presented according to water management areas (WMAs) in the basin as shown in Table 2.

Much of the rain in the basin falls as summer thunderstorms, sometimes severe and causing temporary flooding.

Table 2: Mean annual temperatures, precipitation (MAP) and evaporation (MAE)

	January average range (° C)	July average range (° C)	MAP (mm)	MAE (mm)*
Senqu†	7–25	0–10	500–1,600	1,000–2,100
Upper Orange‡	16–32	2–18	300–800	1,200–2,680
Lower Orange‡	20–37	4–23	20–300	2,420–3,280
Upper Vaal	20–24	0–16	500–1,000	1,600–2,200
Middle Vaal	16–32	1–18	300–700	1,800–2,600
Lower Vaal	15–32	1–20	200–500	2,646–2,690
Namibia	18–37	6–22	0–250	1,950–3,800
Molopo and Nossob‡‡	20–38	0–23	Molopo headwaters 400–600 middle 200–400 western parts 0–200	1,250–1,650

* A-pan evaporation

† Lesotho part of upper Orange–Senqu

‡ South Africa

‡‡ Botswana part of the basin

Sources: DWA, 2002a, 2002b, 2002c, 2005; Mendelsohn et al., 2002; ORASECOM, 2008

2.1.2 Geology

The present landscape of the basin was formed by geological events that occurred over millions of years. After a period of continental erosion, thick layers of sedimentary material in the form of sand, silt and mud were deposited on mainly granite, basalt and dolomite host rock. The deposition of sand and silt was followed by periods of active lava flows that deposited on top of the sedimentary material.

The youngest volcanic material is represented by basalt lavas of the Karoo Supergroup that can be up to 1,500 m thick and currently form the top of the

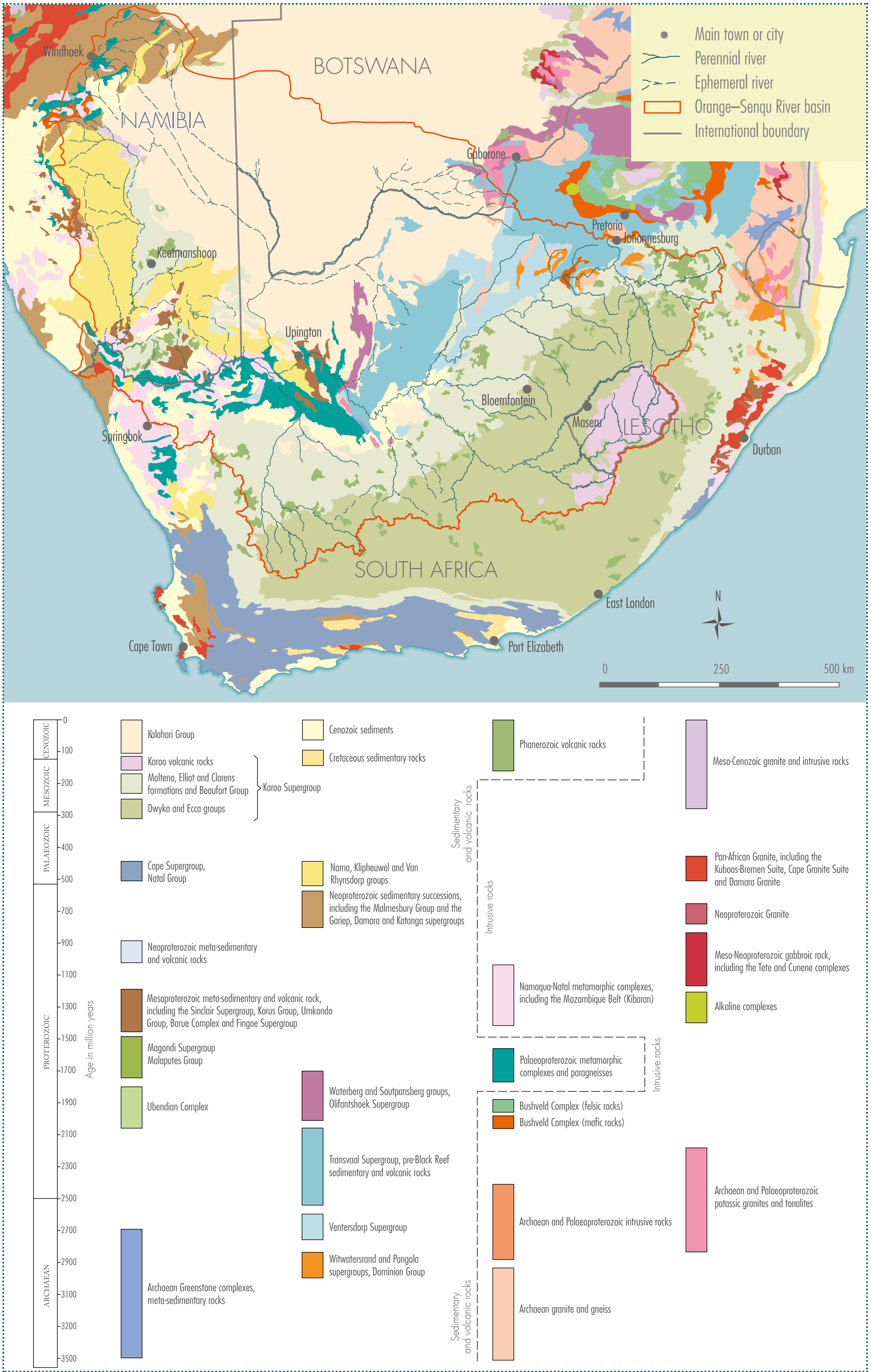

Figure 4: Geology of southern Africa

Drakensberg and Maloti mountains and eastern headwaters of the river system. This is underlain by the Molteno and Beaufort beds, also of the Karoo Supergroup, which are exposed in the southern areas of the basin. The northern parts of the basin, over eastern Namibia and Botswana, are covered with younger Kalahari sands, while slightly older Nama sedimentary rocks make up much of Namibia's Fish River sub-basin. Older rocks are exposed in the central areas of the basin in a south-western and then western-running band from the Witwatersrand to the lower Orange River, with some of the oldest known rocks exposed in the Orange River valley near the confluence with the Fish River.

Periods of erosion have followed the various periods of deposition and the Orange–Senqu River, with all its tributaries, has carved and shaped the landscape over a long time to its present form. The geology of the basin not only determines the geomorphology, but also the minerals present and the resultant soils.

This canyon on Namibia's ephemeral Fish River is claimed to be the second largest in the world.

Soils

Most of the basin is covered in sands or weakly developed soils. With the exception of the main Kalahari component, most of the basin is regarded as being medium to high risk in terms of soil erosion. The soils in Lesotho, classed as Mountain Black Clays, are easily eroded by cultivation and overgrazing.

Influence on groundwater

The geology of the basin affects the distribution, availability, quantity and quality of groundwater in the region. Two main types of aquifers govern the occurrence and distribution of groundwater in the basin, namely shallow alluvial primary aquifers along sections of the rivers, and a variety of deeper hard-rock secondary aquifers. Most aquifers of the basin are situated in hard rock.

The sandstone aquifers of the Beaufort Group are considered to be weak primary aquifers. Secondary aquifers are formed in weathered rock, fractures or faults. The rocks influence water quality by the salts and minerals that the water comes into contact with, as well as how the rock reacts chemically with pollutants and acid. Groundwater is of major importance in the dry lower Orange sub-basin, where it is used to supply smaller rural towns, rural domestic use, stock watering, tourist establishments and, in some cases, irrigation and mining activities.

This satellite image shows the Witwatersrand and Magaliesberg separating the Orange–Senqu basin to the south from the Limpopo basin to the north.

Hard rock aquifers associated with the basin include:

- Dolerite intrusions: Numerous dolerite dykes and sills – dark, fine-grained, intrusive igneous rock – have intruded as lava flows into the sediments of the Karoo Supergroup throughout the basin. The dolerite host rock or the baked contact zones between the dolerite and the surrounding country rock are fractured, forming secondary aquifers. Dolerite intrusions in competent host rocks, such as thick sandstones, have generally higher groundwater potential than intrusions in less-competent rocks such as shales. The highest groundwater yields occur where a fractured dolerite contact zone is overlain by saturated alluvium or crossed by a watercourse, which would facilitate and promote aquifer recharge.
- Fractured sedimentary rocks: Tectonic stress, for example, and resultant folding and faulting, have caused fractures in the sedimentary rocks, which form secondary aquifers. Fracturing is most pronounced in competent, hard sandstone units, such as those found in the Beaufort Group.
- Weathered zone: Secondary porosity created in weathered zones may also act as aquifers. Shales and mudstones are more easily eroded than sandstones, for example, and is often developed within the shales of the Ecca Group.
- Karstic fractured aquifers: These are represented by the Transvaal dolomite units, which are relatively small in areal extent and are found mainly in the northern ephemeral rivers sub-basin area.

Drakensberg–Maloti Highlands

Highveld Grasslands

Southern Kalahari Savannah

2.1.3 Biomes

The basin area can be broadly divided into five biomes that share similar physical features – climate, geology and soil – and plant and animal life.

Drakensberg–Maloti Highlands

The highlands form a distinctly cooler and wetter habitat of alpine grasslands and low, woody, heather communities in the highest areas (2,200–3,482 mamsl). This biome receives the greatest rainfall and is important for its high-altitude flora estimated at about 3,100 species, of which 30% is endemic to these mountains.

The eastern alpine areas of Lesotho also support a network of unique high-altitude bogs and sponges found nowhere else in the world. These wetland systems include hydrophilous, aquatic and semi-aquatic communities, with a high proportion of endemic species. They also play a crucial role in the hydrological cycle of the Orange–Senqu through their retention and slow release of water, which helps stabilise stream flow, attenuate floods, reduce sedimentation loads and absorb nutrients. The tributaries rising in these highlands depend on this network of wetlands for their base flow.

These grasslands and wetlands are fragile and under pressure from cultivation in unsuitable areas, overgrazing and over-harvesting of plants. Degradation and severe soil erosion are evident in some areas. Less than 1% of the area is protected. There is, however, the Lets'eng-la-Letsie Wetlands Protected Area, a Ramsar site, and the Maloti–Drakensberg Transfrontier Conservation Area.

Highveld Grasslands

This undulating grassland area in the east of the basin lies between approximately 1,500 m and 2,100 m above mean sea level (mamsl). It receives relatively high rainfall and provides good agricultural land. Much of it has been converted to farming and is an important agricultural area of South Africa. It is also the most densely populated part of the basin, including Gauteng and the Witwatersrand. The remaining natural grasslands are restricted to a number of relatively small protected areas. They are susceptible to invasion by willows (*Salix* spp.), poplars (*Populus* spp.) and wattles (*Acacia* spp.), especially along rivers.

Vleis form during seasonal flooding and are important conservation areas. Three of these are Ramsar sites: Barberspan, Blesbokspruit and Seekoeivlei.

Southern Kalahari Savannah

This biome is well developed over the northern regions of the basin in South Africa, Botswana and eastern Namibia. Altitude varies between 600 and 1,400 mamsl. It is characterised by deep wind-blown sands forming vegetated linear dunes interspersed with pans. These young sand deposits produce little or no runoff from rainfall. Ephemeral drainage courses flow briefly after exceptional rainfall events, but are subject to invasion by alien plants, in particular *Prosopis* spp.

The area is covered with generally open, lightly wooded sandveld savannah. Rainfall is low (~250 mm per year on average), which coupled with near-annual fires and grazing, keep the grass layer dominant. Almost all plant species found in this biome are adapted to survive fires.

The main form of land use in the area is extensive livestock farming – mostly small stock. Land degradation is evident around settlements, watering points and pans, where stock densities are high. Wildlife is still relatively abundant in this sparsely populated area, but tourism and other wildlife-based livelihood activities, which would demand less water, are not well developed. A large area of this biome is protected within the Kgalagadi Transfrontier Park managed by Botswana and South Africa.

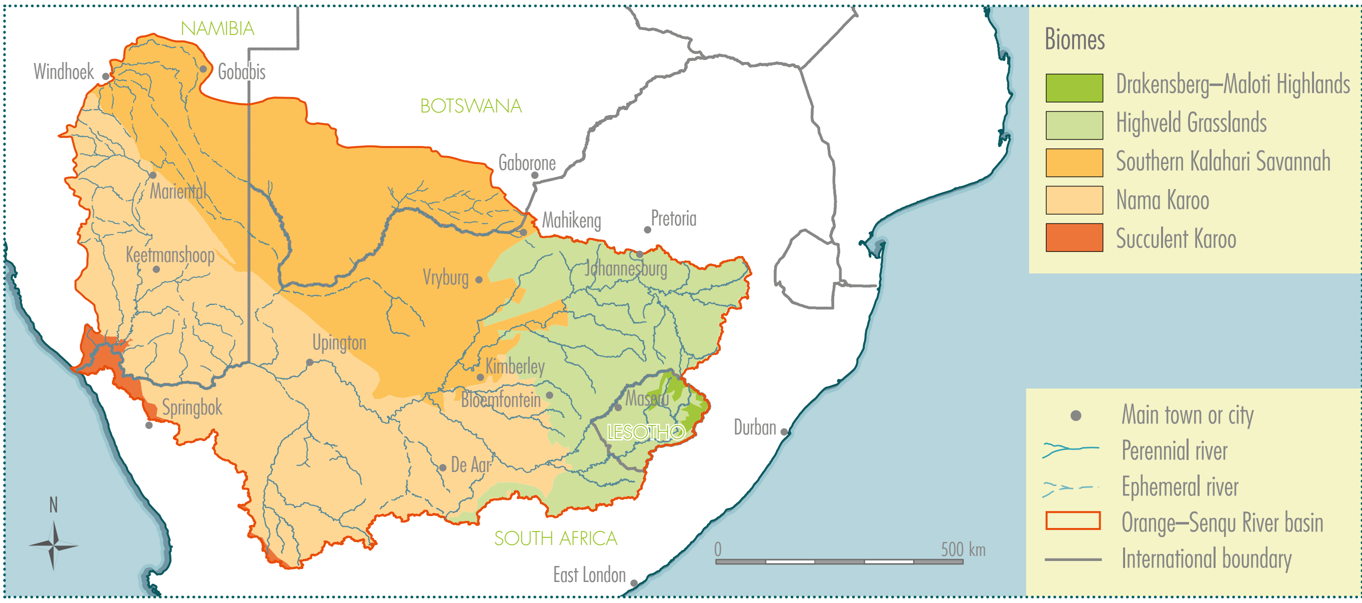

Figure 5: Biomes. Mucina and Rutherford (2006) also recognise a narrow band of desert running along the lower Orange River from approximately 19.5° E to the river mouth, not shown here.
Source: ORASECOM, 2008

Nama Karoo

The Nama Karoo covers a vast area on the central plateau (500–2,000 mamsl) in the drier western half of southern Africa. It merges into Succulent Karoo in the west and Highveld Grasslands in the east. The underlying geology is varied and the distribution of this biome is determined primarily by rainfall, which varies between 100 mm and 520 mm per year and falls mainly in summer. The western areas of the biome are prone to extended droughts.

The dominant vegetation is a grassy, dwarf shrubland, with trees along ephemeral watercourses. The ratio of grasses to shrubs varies according to soil and rainfall. Grasses tend to be more common in depressions and on sandy soils, especially after good rains, and less abundant on clayey and stony soils. Most of the grasses, like the shrubs, are dormant for much of the time, only sprouting rapidly in response to rainfall events. Overgrazing rapidly increases the relative abundance of shrubs. The amount and nature of the vegetation is usually insufficient to carry fires.

Extensive small-stock farming is the major land use in this biome. Sparse vegetation and high erodibility of soils pose a major problem where overgrazing occurs. The rivers and floodplains are particularly susceptible to *Prosopis* invasions. There are very few rare or Red Data Book plant species in this biome. A small proportion of the biome is formally protected in national parks.

Nama Karoo

Succulent Karoo

Succulent Karoo is found in the far western, driest area of the basin where rainfall averages between 20 and 100 mm per year. Altitude is mostly below 800 m. The vegetation is primarily determined by the presence of low winter rainfall and summer aridity, moderated by coastal fog, an important source of moisture for some plants. Rainfall here is generally less erosive than the convective summer storms that fall elsewhere in the basin.

The vegetation is dominated by succulent, dwarf shrubs, of which the vygies (Mesembryanthemaceae) and stonecrops (Crassulaceae) are particularly prominent. Grasses are rare, except in some sandy areas. The area is renowned for its mass flowering displays in spring. The number of plant species is very high and unparalleled elsewhere in the world for an arid area. Consequently, the Succulent Karoo includes significant biodiversity hotspots, such as the Richtersveld, parts of the southern Sperrgebiet and lower Orange River valley areas. The biome is largely protected through park networks, including the /Ai-/Ais–Richtersveld Transfrontier Park, Tsau//Khaeb (Sperrgebiet) National Park and the Orange River mouth, a Ramsar site declared in both Namibia and South Africa.

Succulent Karoo

The rivers and streams in the eastern areas of the basin are usually perennial.

The highland sponges retain water and release it slowly, stabilising stream flow.

Ephemeral pan, Botswana

2.1.4 Aquatic ecosystems

There are five broad types of aquatic ecosystems in the Orange–Senqu basin: rivers and streams, highland sponges, pans and vleis, the estuary, and groundwater aquifers. Others include pools, springs, human-made reservoirs and storage weirs.

Rivers and streams

The Orange–Senqu River system comprises a number of streams and tributaries. As one moves further west to more arid areas these become more ephemeral, only flowing after heavy rain falls.

The development of dams, weirs and canals, rural and urban settlements, agriculture, and mining dominate the riparian zone along the river and its main tributaries. Large demands on the water resources also mean that less water flows through the system and hydrological flows and sediment balance have been altered. Consequently, the morphology of the riverbed, banks and land alongside have been altered extensively and very little pristine riparian habitat is left. The riparian belt has become prone to invasion by alien species, which together with deforestation disrupts the hydrological cycle of the river.

Highland sponges

At the river system's source there is an extensive network of high altitude wetland bogs and sponges, crucial in the hydrological cycle of the entire river. Their retention and slow release of water helps stabilise stream flow, attenuate floods, reduce sedimentation loads and absorb nutrients. The sponges and bogs are becoming degraded through overgrazing and overharvesting of resources, as well as the proliferation of ice rats (*Otomys sloggetti robertsi*). The steep terrain and harsh climatic conditions, particularly at high altitude, exacerbate the situation creating a fragile ecosystem. Species diversity is declining and soil is exposed to wind and water erosion.

Pans and vleis

The sand and calcrete habitats of the Kalahari are dotted throughout by a number of small, closed basins, or pans. These play an important role in the Kalahari, especially for wildlife. Their relatively high silt to clay content offers minerals and otherwise unobtainable soluble salts, as well as standing water following rain. Many pans have become ringed by sizeable human settlements making them less accessible to wildlife. Increased reliance on livestock for livelihoods has caused the area around the pans and livestock watering boreholes to become denuded and degraded, and dunes have remobilised.

In the wetter grassland areas of the basin, a number of seasonal freshwater lakes, vleis and pans provide a number of goods and services within the system and form important areas for wetland birds and other species. Barberspan, Blesbokspruit and Seekoeivlei, for example, are declared Ramsar sites, recognised as wetlands of international importance. These and other such wetlands are threatened by pollution and degradation from mining, farming and industrial activities.

Estuary

The Orange River estuary has been declared a Ramsar site in both Namibia and South Africa. It is an extensive area of freshwater lagoons, marshes, sandbanks and reed beds important for resident and migrant waterbirds. There are large diamond mining operations and associated small towns on both sides of the river.

Apart from direct effects of activities in the area such as encroaching tailings dams, pollution and road embankments, drastically reduced flows and an altered hydrological regime further impact the estuary and the opening and closing of the mouth to the sea. In 1995, the estuary was added to the Montreux Record as a result of the collapse of the salt marsh, which once supported a large diversity of wildlife. Interventions to re-establish the salt marsh have been taken in recent years, but the site remains on the Montreux Record.

At present the estuary is classified as 'largely modified'. Mitigation is very dependent on the flow patterns, particularly seasonality, and the removal of non-flow related impacts. In practice it will not be possible to reverse the flow modifications and anthropogenic developments to the extent that would improve the ecological category to a desired unmodified or slightly modified state. At best it is considered that a moderately modified state could be attained – where a loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.

The salt marsh at the Orange River estuary

ORANGE RIVER ESTUARY

The Orange–Senqu River drains into the Atlantic Ocean on the border between South Africa and Namibia where it forms a large estuarine delta with extensive salt marshes. Freshwater inflows from the river affect the coastal waters at the river mouth, while tidal inflows affect the salinity of the estuary. Together the estuary, salt marshes and the near-coastal zone make up the 'transitional waters' of the Orange–Senqu River System.

The salt marshes of these transitional waters are generally regarded as the sixth most important wetland system in southern Africa in terms of waterfowl numbers. The Orange River estuary was designated as a Ramsar site by South Africa in 1991 and by Namibia in 1995, making the estuary the first trans-border wetland to be included on the list. The estuary wetland is a haven for migratory birds supporting large populations of waterfowl (14 of which are rare or endangered species), marine invertebrates, mammals and fish. As such, it provides a unique habitat on an otherwise wave-exposed and very arid coastline.

The delta type river mouth has a braided channel system during low flow months. It consists of a floodplain, tidal basin, sandbanks, the river mouth and a salt marsh on the south bank of the river mouth. The Orange River usually flows directly into the Atlantic Ocean, but during low flow periods a sand bar can form across the mouth to block the river. The river then rises in level and spills over the salt marsh area. As it is dominated by fresh water, the wetland has few estuarine characteristics.

In this satellite photograph, the Orange River estuary can be seen discharging into the Atlantic Ocean.

Source: NASA Earth Observatory image created by Jesse Allan using data from the University of Maryland's Global Land Cover Facility

© UNOPS/Christoph Mor

This artesian groundwater well in Stampriet, Namibia, supports the irrigation of fruit and vegetable cultivation.

Aquifers

These largely hidden resources deserve special mention. They cannot be regarded separately from the river and other aquatic ecosystems because they are linked, and degradation of one contributes to the degradation of the other. In addition, many rural areas of the basin and the drier western areas of the basin are almost wholly dependent on groundwater sources to meet their supply needs.

Although groundwater resources are limited in comparison to surface water, the extent, quality and contribution they possibly make to the water balance is not well understood. There are insufficient data regarding this hidden resource. The concern is that in some areas abstraction is not sustainable and that it is impacting water levels. Lowering of groundwater levels hampers the ability of plants to take up water and leads to the desiccation of springs and, consequently, destruction of habitats. Invasions by the alien plant *Prosopis* is considered a significant threat to groundwater sources in the western areas of the basin.

Salinity is often naturally high in groundwater, especially in the Nama Karoo biome. Salinisation as a result of increasing total dissolved solids (TDS), nitrates and fluorides is another concern. In extreme cases, over-abstraction can also reduce fluid pressure in confined and artesian aquifers and cause aquifer deformations through the compaction of geological material. Heavy metals can also leach out into the groundwater and find their way into surface water courses.

Groundwater sources are also highly susceptible to pollution from land-use activities through seepage and runoff, even in sparsely populated rural settings. Reversing pollution problems in groundwater is much more difficult than dealing with similar issues in surface sources.

In the region as a whole, the transboundary implications of groundwater use are not particularly significant. A major factor, however, is that reduced flows in the lower Orange River will inevitably lead to a significant reduction in aquifer resources close to the river.

Improving understanding of groundwater sources through monitoring and implementing regulations on the abstraction and protection of groundwater resources would go a long way to addressing these concerns.

Groundwater is used for stock watering in the lower Orange sub-basin.

© UNOPS/Leonie Marinovich

2.1.5 Socio-economic background

The basin has been populated from the earliest days of humankind, and hominid fossils (*Australopithecus africanus*) have been recovered from within the basin in the Taung area. Humans of the later Stone Age (after 125,000 years ago) lived in the basin, and these were later represented by the San hunter-gatherers who left evidence in rock paintings and petroglyphs throughout the Karoo and in the mountains of Lesotho.

The San were the only inhabitants of the basin until some 2,500 years ago, when the Khoikhoi pastoralists arrived in the central basin, moving westwards to the arid coast. Agro-pastoralist Bantu-speaking peoples migrated into the Vaal basin some 1,500 years ago and spread south and west as far as about the current 200 mm isohyet (Earle et al., 2005). After 1690, European semi-nomadic livestock farmers spread into the basin from the south-west. European settlement intensified in the late 19th Century, accompanied by the development of extensive commercial livestock farming, rain-fed crop and livestock production in the east, and irrigated farming along the Orange and Vaal rivers.

Much of the basin is best-suited to small-stock farming.

Demographic trends

The basin has an estimated population of 14.3 million people. However, it supports 19 million people if one takes into account those living outside of the basin, but are supported by it through inter-basin transfers (Earle et al., 2005). South Africa has by far the major proportion of the basin's people, with high population densities in its eastern areas, but significantly fewer people in the arid west. Much of the Lesotho highlands area is sparsely populated, but the Caledon River valley is densely settled on both sides of the Lesotho–South African border. All four basin states have undergone significant urbanisation, but population growth rates have slowed because of decreasing fertility and increased mortality because of high HIV/Aids prevalence rates.

More water is used for irrigation than for all the other requirements.

Land use and economy

Most of the South African part of the basin is farmed commercially. Rain-fed commercial farming ranges from maize and wheat production on the grasslands of the east, to increasingly extensive rangeland-based livestock systems in the west. Cattle and sheep are important in the east, while the arid land in the west is primarily suitable for sheep and goats. The Orange and Vaal rivers and some of their tributaries have significant intensive, commercial, irrigated agriculture along their middle and lower reaches. The rest of the Orange basin is characterised by small towns and villages, widely scattered throughout the region, serving mainly mining and/or agricultural land uses.

Tourism has become an important use of land throughout the basin, displacing or complementing more extensive agricultural pursuits. In some areas, landowners have invested in wildlife and developed wildlife and scenery-based tourism products marketed through lodges and guest farms. In certain areas, particularly the drier western parts of the basin, tourism can have a financial and economic advantage over agriculture, providing incentives for some land-use change.

Gauteng's industrial, mining and residential conurbation (Johannesburg, Vereeniging, Vanderbijl Park areas) straddles the northern watershed of the Vaal system. With 9 million people, Gauteng uses some 20% (the second largest user) of all water used in the basin (ORASECOM 2007c).

The Orange–Senqu's water resources support the industrial and economic hub of Gauteng.

The South African economy is overwhelmingly dominant, contributing 93% of the combined gross domestic product (GDP) of the four countries. GDP per capita is highest for South Africa and lowest for Lesotho. The following four sectors dominate:

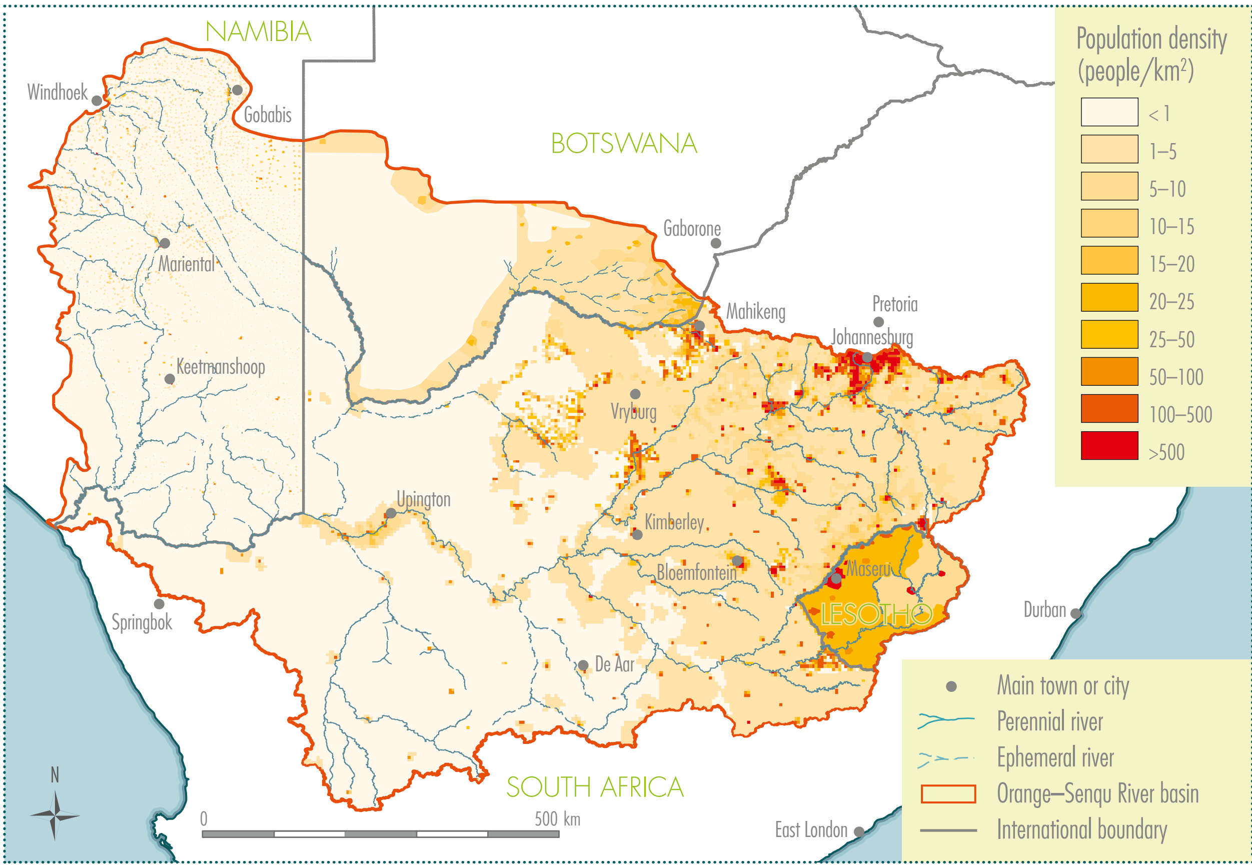

Figure 6: Population density

A row of standpipes at Aussenkehr is the only source of potable water for many thousands of workers at Aussenkehr, Namibia.

- agriculture, forestry and fishing
- mining and quarrying
- manufacturing and utilities
- services (which includes government).

Economic evidence suggests that, for economic efficiency, scarce water in the basin should (all things being equal) be reallocated from irrigated agriculture to urban and industrial uses (DWA, 1998). DWA (1997) examined the expected social impacts of such a reallocation and came to the conclusion that it would have significant positive net benefits socially. Redistribution of wealth, and attention to improving water quality, were also found to be important for enhancement of social wellbeing.

Social welfare and health

All four basin states have inequitable distribution of income and the majority of the populations of the four basin states can be described as poor. Urban areas have lower infant mortality rates and better medical services and facilities than rural areas.

The human development index rose between 1970 and 1990, but has since declined in all countries. Similarly, life expectancy between 2000 and 2005 is much lower in all countries than it was between 1970 and 1975. Other indices, such as adult literacy and access to improved water sources, reflect general improvement over time, in line with the economic growth trends. In South Africa the general level of human development is highest in the urban centre of Gauteng, and lowest in the arid west, where traditional, small-scale rain-fed land uses are typical.

FOOD SECURITY AND WATER

While the basin has adequate agricultural production to feed its population, more than a third of its inhabitants suffer from malnutrition caused by insufficient food security at the household level. Among these, women, children and the elderly are particularly affected. In both South Africa and Namibia, food insecurity is also a reflection of these countries' poverty and income inequality (in urban and rural environments, as well among race and gender).

Food security concerns are particularly prevalent during droughts. In the regionally dry year of 2002, some 650,000 people in Lesotho required emergency food assistance (Lesotho National Vulnerability Assessment Committee, 2002). While water security is an important influence on food security, increased agricultural production and/or sufficient income generation to purchase food also play major roles.

Water transfers from the basin to surrounding basins increase agricultural production, but this does not directly benefit vulnerable communities. The supply of water for food security in rural communities can be improved through better on-farm management, improved performance of irrigation services, augmentation of water supplies and rainwater harvesting (FAO, 2003).

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Ipeleng Morgan Bonmamye, 46, is a small-scale farmer who grows barley and maize on his ten-hectare allotment in the Vaalharts Irrigation Scheme in North West Province, South Africa.

Botswana has a relatively stable food security situation despite the serious problems resulting from the seven-year drought of 1981–87, but is reliant on imports. Some of the past policies aimed at achieving household food security, such as the Financial Assistance Policy and the drought subsidies for livestock, led to environmental degradation of some communal lands (Moepeng, n.d.). The National Policy on Agriculture is currently under review.

In Lesotho, the goal of increasing food security through water security is being achieved by educating farmers on tillage methods (which conserves soil moisture), choosing drought- and frost-resistant crops, encouraging reduction of livestock herd sizes, as well as developing irrigation water infrastructure (Mphale and Rwambali, n.d.). Research has shown that certain seasonal climate forecasts, tailor-made for small-scale farmers, can also help improve food security (Ziervogel and Calder, 2003).

In Namibia, most food security reports focus on the flood and drought risks in northern Namibia where most of the crop production takes place. However, in the Orange–Senqu basin here, water security for livestock and new opportunities for irrigation development are the main issues for these farmers. The country's national food security programme (GRN, 2007) has four pillars, namely:

- food availability, to be addressed by sustainable utilisation of water resources, developing irrigation and increased aquaculture;
- food access, to be addressed by improving access to water resources;
- food utilisation and nutritional requirements;
- stability in equitable food provision from improved disaster management, climate change adaptation and combating desertification.

In South Africa, increased water security and thus food security for subsistence and small-scale farmers is envisaged through support for the development of small-scale irrigation (DOA, 2002). Government policy is to support emerging farmers with reallocation of land and water rights. Rainwater harvesting (which is more viable in certain areas than others) and groundwater use are being advocated and researched. The adoption rate of special programmes has so far been very low (Mwenge Kahinda et al., 2008).

With climate variability increasing, vulnerability in terms of food security may increase in parts of the basin. However, as De Wit (2010) argues, addressing the underlying, systemic causes of food insecurity in southern Africa will go a long way towards absorbing shocks brought about by expected increases in climate variability and longer-term climate changes.

BOTSWANA: GEOGRAPHICAL CHARACTERISTICS

Botswana is a landlocked, semi-arid country that lies within the greater Kalahari basin – a depositional basin between 900 and 1,000 mamsl (UNDP, 2008a). It is relatively flat, with gentle undulations and occasional rocky outcrops. The country can be broadly divided into four major zones: hardveld, sandveld, lacustrine and alluvial. Of the four zones, the hardveld and sandveld are mainly used for farming; the hardveld is mostly used for mixed farming while the sandveld is extensively used for livestock production (MEWT, 2006). Tourism, centred in the Okavango water system, is another important economic activity, as is mining.

The climate is arid and semi-arid, with low rainfall and high rates of evapo-transpiration. The country is also characterised by frequent and long drought periods (MEWT, 2006).

The Botswana section of the Orange–Senqu basin covers 8% of the total basin, mainly falling within Kalahari Savannah – an area that receives the least amount of rainfall in the country. The average annual precipitation in that part of Botswana is 295 mm per year, much less than the mean annual rainfall for Botswana of approximately 400 mm per year (FAO, 2005). Runoff from Botswana has not contributed any surface runoff to the Orange–Senqu River in living memory (ORASECOM, 2007b).


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The Molopo and the Nossob rivers (which form the border between southern Botswana and South Africa) are the major surface drainage features in the area and are the main tributaries of the Orange River in Botswana. These rivers are ephemeral, flowing occasionally after heavy rainfall events, however, their waters have not reached the Orange River for the past thousand years. Generally, the Molopo River rarely retains surface water, due to the arid and semi-arid climatic conditions that prevail in the area. The Kalahari's sandy soils, which have poor water retention capacities, also exacerbate the problem (ORASECOM, 2008). Communities living in this portion of the basin depend on groundwater sources for their water supply and to sustain their livelihoods.


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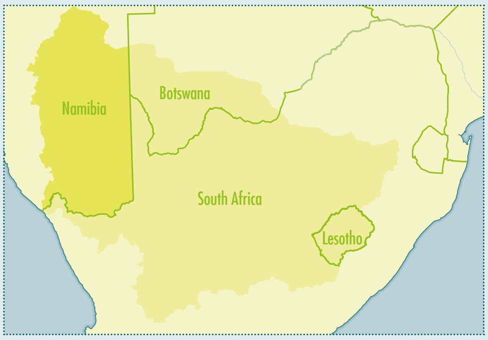
LESOTHO: GEOGRAPHICAL CHARACTERISTICS

Lesotho is characterised by bare rock outcrops of the Maloti Mountains and deep river valleys, with altitudes that range from 1,500 m to 3,482 mamsl (MNR, 2007). The country is divided into four physiographic regions: the lowlands, covering mainly the western part of the country; the mountains, covering 59% of the total area of the country; foothills covering 15%; and the Senqu River valley covering 9% of the country and forming a narrow strip of land that flanks the banks of the Senqu River. The entire country falls within the Orange–Senqu basin and forms the headwaters for the Orange River tributary, with the Senqu River being the main tributary from Lesotho.

Compared to the other three basin states, Lesotho has a relative abundance of water resources (MNR, 2007). Precipitation, influenced by the country's topography, is highly variable both temporally and spatially, and droughts and floods are very common occurrences. The mean annual rainfall is 788 mm, which ranges from less than 300 mm in the western lowlands to 1,600 mm in the north-eastern highlands. Elevations above 3,000 mamsl receive enough snow during winter to cover the ground for several months, with sub-freezing temperatures (MNR, 2007).

Grazing is considered open-access and common property in Lesotho and sustainable management practices are consequently seldom in place and difficult to enforce. The sandstone-derived soils are highly erodible and soil erosion is a major problem. Soil loss occurs primarily as sheet and rill erosion in many cultivated fields, but also as gullies that transverse Lesotho's rangelands and cultivated fields (MNR, 2007). It is also one of the areas of the basin that is most heavily invaded by alien vegetation (le Maitre et al., 2013). Apart from agriculture, mining and textile industries are important components of Lesotho's economy.

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NAMIBIA: GEOGRAPHICAL CHARACTERISTICS

Much of southern Namibia is drained by tributaries of the Orange River. The area covers three desert systems: the Succulent Karoo in the extreme south-west, the Nama Karoo in the central and southern parts, and the southern Kalahari in the east.

The total rainfall averages about 272 mm for the country. However, it ranges from less than 50 mm along the coast, to a high of approximately 350–400 mm in the far north-eastern areas of the basin (DWAF, 2010). Much of the rainwater is lost through evaporation, especially in the more arid western and southern areas (Manning and Seely, 2005). The only perennial rivers in Namibia are shared, transboundary watercourses that are situated on the country's borders, of which the Orange River is one. The Fish River, the country's largest ephemeral river system with a mean annual runoff of 480 Mm^3 at its confluence with the Orange River, is the main tributary to the Orange–Senqu in Namibia (MET, 2011). The Orange–Senqu River forms the southern border of Namibia with South Africa, entering the Atlantic Ocean at Oranjemund.

Most of the basin in Namibia is freehold farmland, with some communal farmland areas too. Because of the low and highly variable rainfall in this area, livestock carrying capacity varies considerably from year to year. As a result, over 75% of central and southern Namibia is rated as 'high to very high risk' for conventional farming. Apart from some very limited and intensive crop production under irrigation, the vast majority of the land is used for extensive small-stock farming and increasingly, wildlife-based industries within indigenous ecosystems. The south-western area of the basin in Namibia is an active mining area for base metals and diamonds.

In 1999, close to 50% of water supplied in Namibia as a whole was provided from groundwater resources, with about 20% from perennial rivers and 30% from ephemeral rivers (DWAF, 2010). Total water demand is expected to rise from 330 Mm^3 per year in 2008 to 600 Mm^3 per year by 2020 (DWAF, 2010). The share of perennial river water is expected to increase as a result of increasing irrigation agriculture along these rivers (DWAF, 2010).


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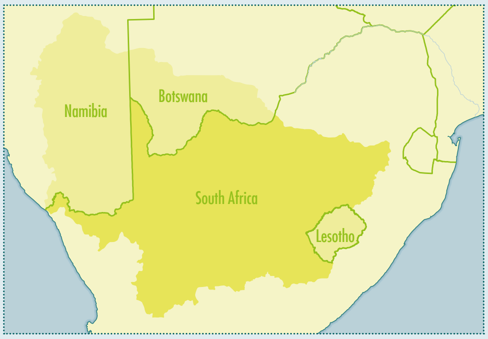
SOUTH AFRICA: GEOGRAPHICAL CHARACTERISTICS



The climate in South Africa varies from sub-humid along the eastern coastal area to desert and semi-desert in the west. The average rainfall for the country is about 450 mm per year and about 365 mm for the area within the Orange–Senqu basin. Evaporation rates are high, especially in the central and western areas (DWA, 2003).

The Orange is the largest river in South Africa and (with the Vaal River) drains almost two-thirds of the interior plateau of the country, which includes much of the densely populated Gauteng Province. This is the largest proportion of the basin (64%) and incorporates all five biomes. The basin population in South Africa is estimated to be around 11 million (82% of the total basin population). High levels of urbanisation and industrialisation have altered the land extensively and very little pristine riparian habitat exists.

Land is largely privately owned. Irrigation and dry-land crop production of cash crops such as maize, wheat and sunflower are extensive in many of the central areas. To protect crops against flooding, levees have been constructed in many parts of the river valley. This disturbs the ecology of the floodplains and prevents natural flooding of systems that require it for survival.

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Mining takes place most notably in the Vaal sub-basin and the lower Orange River. Extensive earth-moving activities with minimal rehabilitation or environmental considerations have degraded much of the habitat along the rivers, which has become susceptible to invasion by alien species.

Protected areas in the South African part of the Orange–Senqu River basin make up just 3% of the area. Of this, one park – the Kgalagadi Transfrontier Park – makes up 80% of the area. This is a remarkably small proportion of land, given that protected areas make up some 10% of South Africa and that the Orange River basin comprises such a large proportion of the country. South Africa shares the Kgalagadi Transfrontier Park with Botswana and the /Ai-/Ais–Richtersveld Transfrontier Park with Namibia. Areas around many resevoirs in the basin are protected as provincial nature reserves. These reserves, such as Rolfontein and the Gariep Dam Nature Reserve, are used for recreation and conservation, with wildlife having been introduced to restore populations to historic numbers and species and as part of provincial biodiversity conservation objectives.

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2.2 WATER RESOURCES

The Orange–Senqu is the largest river system in southern Africa south of the Zambezi. It rises in the highlands of Lesotho, while its largest tributary, the Vaal River, rises further north in an area of the Drakensberg grasslands bounded by Breyten, Carolina and Chrissiesmeer, Mpumalanga. With headwaters less than 250 km from of the Indian Ocean, these rivers flow westwards across the subcontinent, joining at Douglas, south-west of Kimberley, before continuing their 2,300 km journey to the Atlantic Ocean as one river.

Much of the Orange–Senqu basin is semi-arid to arid, with only the highlands of Lesotho and the eastern escarpment classified as temperate and where annual average precipitation exceeds evaporation. The rainfall deficit increases westwards to such a degree that the climate of the lower Orange is classified as arid and hyper-arid. In these lower reaches of the river, tributaries are ephemeral, flowing only after substantial rainfalls, and contributing relatively little runoff to the main river system. This natural trend in water availability from east to west has helped determine patterns of settlement and economic development.

The most economically active and densely populated area of southern Africa is found in the eastern areas of the basin. Water supply required to meet these demands and those of large-scale irrigation schemes has been assured through the construction of numerous dams and a series of transfer schemes, mostly on the upper Orange–Senqu and Vaal river systems. It is consequently regarded as the most developed river system in southern Africa. Further downstream, in the lower Orange, although dams, smaller transfer schemes and irrigation schemes play a role, groundwater is of major importance. Groundwater often constitutes the only source of water across large areas of these arid reaches, and is used for rural domestic supplies, livestock watering and to supply many towns and villages.

2.2.1 Ground and surface water interaction

Groundwater and surface water are closely linked even when separated spatially. Each contributes to the other and with these interactions play an important role in the hydrology of a region (USGS, 2009). Most commonly, groundwater contributes to a stream or river's base flow, and can be a significant contributor to surface water recharge, especially in higher rainfall regions.

The interaction is often bidirectional, depending on the elevation of the groundwater. If the groundwater level is low, groundwater can be recharged by the surface water body; alternatively, if the groundwater level is high it contributes to the surface water body. Such interactions are expected with the peat bogs or 'highland sponges' in Lesotho, which help to regulate water flow. In shallow alluvial aquifers or riverbed sand aquifers, this interaction normally depends on the seasonal cycle of rainfall, runoff and water level in the river banks. Aquifers are dependent on surface runoff for recharge, while recharge of surface waters, especially pools, does occur in normally dry riverbeds from springs (Hughes et al., 2007).

An obvious concern regarding the abstraction of water – either from the ground or rivers – is the likelihood that removal of water from one resource will reduce the amount of water available to the other. Water quality problems are currently experienced in the Vaal and the middle and lower Orange River, where water-logging has resulted from irrigation activity along these riverbanks and the saturated zone reaches the surface.

2.2.2 River systems and sub-basins

The Orange–Senqu basin can be divided into three main sub-basins, the Vaal, upper Orange–Senqu and lower Orange (Figure 7). Each of these can be further divided into areas practical for the purposes of water management.

Vaal sub-basin

The Vaal sub-basin flows through the largest and most important economic region of South Africa before joining the Orange River. The Vaal River and its main tributaries, namely the Wilge, Suikerbosrand, Klip, Mooi, Schoonspruit, Renoster, Vet and Harts rivers, support numerous reservoirs, with the most important being the Vaal and Bloemhof dams.

The Vaal River serves the Reef Complex and the Vaalharts Irrigation Scheme. The major share goes to Rand Water for distribution. Water is not only imported from the Usutu and Thukela WMAs, as well as from the Senqu in Lesotho, but is also exported out of the catchment to major domestic centres and to Eskom power stations. Because of the many return flows and developed nature of the Vaal River and its tributaries, water quality is deteriorating and is becoming an increasing concern.

Upper Orange–Senqu sub-basin

The Senqu River and its tributaries, namely the Makhaleng, Malibamatso, Matsoku, Phuthiatsana and Senqunyane rivers, form the source of the Orange draining the highlands of Lesotho. Two large reservoirs, the Katse and Mohale, and the Matsoku Diversion Weir, form the first phase of the Lesotho Highlands Water Project (LHWP). It transfers water to the Vaal River and generates electricity for Lesotho. The first phase was fully implemented in 2005.

The Gariep and Vanderkloof dams, the two largest dams in South Africa, are situated on the upper Orange. They are central structures of the Orange River Project and provide water for irrigation and urban requirements via a number of transfer schemes. They are also used to generate hydropower and to control floods.

The Mohokare-Caledon River forms the north-western border between Lesotho and South Africa for most of its length before joining the Orange River upstream of the Gariep Dam. The river supplies Bloemfontein and other towns via a series of dams and pipelines. The Kraai tributary, which drains the north-eastern Cape, joins the Orange at Aliwal North.

Lower Orange sub-basin

This is the largest of the sub-basins, but contributes the least amount of runoff to the Orange–Senqu through a number of ephemeral tributaries originating in Botswana, Namibia and South Africa.

The main tributaries in the lower Orange sub-basin are the Ongers and Sak rivers (which drain the northern Karoo), the Kuruman and Molopo rivers (which drain the North West and Northern Cape provinces and southern parts of Botswana), and the Fish River (which drains southern Namibia).

The Kuruman River has its source in South Africa and flows westwards, draining a large area, until it meets the Molopo River. The Molopo flows along the South Africa–Botswana border in a south-westerly direction and joins the Nossob. The Nossob and Auob rivers drain south-eastern Namibia before their confluence in western Botswana. Flow from the Molopo is blocked from reaching the Orange River by sand dunes. There are no dams or weirs on the Molopo or Nossob rivers in Botswana or Namibia. There is, however, a dam – the Disaneng Dam – on the Molopo River in South Africa, near Mahikeng.

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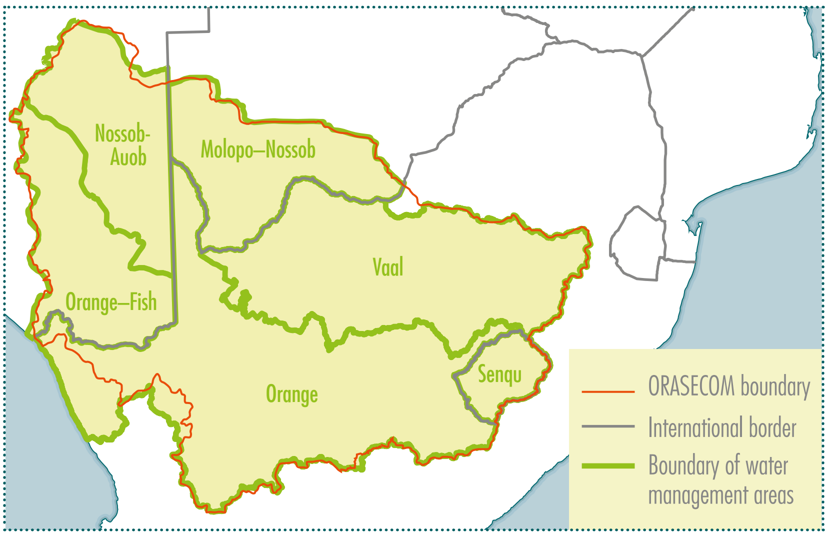
The surface waters of the Orange–Senqu take on a different character along its length, shown here by streams feeding the Vaal (top) and the Senqu (middle), and the lower Orange River (bottom).

Figure 7: The basin can be divided into three main sub-basins: the Vaal, upper Orange–Senqu and lower Orange. The lower Orange is the largest sub-basin, but contributes the least amount of water to the river system via ephemeral tributaries from the north and south.

Figure 8: The Orange–Senqu basin is divided into a number of areas for management purposes. The Senqu comprises the whole of Lesotho. In South Africa the reduction in water management areas (WMAs) will see the current Upper Vaal, Middle Vaal and Lower Vaal combined as the Vaal WMA and the Upper Orange and Lower Orange being combined as the Orange WMA. Eleven basin management areas have been delimited in Namibia, two of which fall within the Orange–Senqu – the Orange–Fish and Nossob–Auob. Note that the boundaries of these management areas as defined by the basin states are not contiguous with the area considered as the Orange–Senqu basin.



The Fish River is the largest river rising in Namibia. It rises to the south of Windhoek and flows in a mostly southerly direction over a distance of about 636 km before it joins the Orange River about 100 km upstream of the river mouth. Flow in this river varies considerably. There are a number of dams in the Orange–Senqu basin in Namibia that supply domestic and irrigation requirements, with Hardap and Naute Dams being the largest. Apart from the Fish, Auob and Nossob rivers, other small tributaries draining southern Namibia flow directly into the Orange.

The Orange River estuary is a small geographic area of about 30 km² extending from the mouth to 9.5 km upstream. It is recognised as an ecologically important area that has been designated as a Ramsar site by both Namibia and South Africa. The estuary comprises the river channel between sand banks, a tidal basin, the river mouth confined by a sandbar and a salt marsh towards the south bank.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Barely appearing as watercourses, ephemeral streams that drain large areas in the lower Orange sub-basin are often only noticeable by the trees growing along their shallow channels.

Table 3: Catchment areas comprising the basin

Major catchment	Catchment area (km²)
Vaal	196,438
Upper Orange	99,277
Lower Orange	
South Africa	243,313
Molopo–Nossob*	356,788
Fish	81,630
Total	**977,446**

*Catchment in Namibia and Botswana
Sources: Areas as reported for South Africa and Lesotho by WRC (2008a) and for Namibia and Botswana by ORASECOM (2011b)

Hardap Dam on the ephemeral Fish River, Namibia, after exceptional rainfalls in its catchment in February 2006. Releases from the dam during this period caused flooding of the irrigation scheme and the town of Mariental downstream.


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Water supply required to meet the many demands placed on the resources of the Orange–Senqu has been assured through the construction of numerous dams and a series of transfer schemes. Shown here are the Mohale Dam in Lesotho (top); the Gariep Dam on the upper Orange River, which supplies the Eastern Cape Province, generates hydropower and supplies water for irrigation (middle); and the Bloemhof Dam, which supplies the Vaalharts Irrigation Scheme (bottom).

HARNESSING THE BASIN'S SURFACE WATERS

Currently, the Orange–Senqu system hosts some 300 built structures, among them a number of large dams and inter- and intra-basin transfer schemes. These store and move bulk water, assuring supply to meet human demands. A summary of this infrastructure is shown diagrammatically on the inside back cover of this publication and ORASECOM (2013a) provides a detailed catalogue of it.

There are six major reservoirs in the basin with storage capacities over 1,000 Mm^3, and over 50 other important supply reservoirs. The Gariep and Vanderkloof in the upper Orange sub-basin are the largest dams in the basin. Both have large hydroelectric power stations and also supply water to users in this area, particularly to support agriculture. They are central to the Orange River Project, which supports the demands for the lower Orange sub-basin. The Vaal Dam is the fourth largest. It is managed by Rand Water and supplies water to the upper reaches of the Vaal sub-basin.

Table 4: Reservoirs in the basin with capacities exceeding 1,000 Mm^3

Dam	Gross storage (Mm^3)*	Live storage (Mm^3)†	Dead storage (Mm^3)
Gariep	5,342.9	4,710.0	632.9
Vanderkloof	3,188.6	2,173.2	1,015.4
Sterkfontein	2,617.0	2,482.3	134.7
Vaal	2,609.8	2,442.5	167.3
Katse	1,950.0†	1,518.6	431.4
Bloemhof	1,218.1	1,229.5	0

* *Source:* SANCOLD, 2009
† *Source:* ORASECOM, 2007a

Due to the high demand for water there are many transfer schemes in both the Vaal and the Orange river systems. The Lesotho Highlands Water Project (LHWP) is an ambitious project to augment South Africa's water supply and generate electricity for Lesotho. Five phases are envisaged. The Katse and Mohale dams, the Matsoku Diversion Weir, tunnels and a hydropower station form the first phase. Phase II is underway and involves the Polihali Dam. Apart from the LHWP, a number of small water supply schemes provide irrigation and domestic water in Lesotho.

The upper Vaal sub-basin is the most developed, industrialised and densely populated part of the basin and large quantities of water are transferred here using various systems. The most important of these systems transfers water from the Katse Dam in the Lesotho Highlands to a tributary of the Wilge River and on to the Vaal Dam. The Thukela-Vaal Transfer Scheme channels water from the Tugela River to the Sterkfontein Dam near Harrismith, ultimately supplementing the Vaal Dam. Water is also transferred to the Vaal Dam from the Usutu River, which rises in Mpumalanga and flows eastwards through Swaziland and Mozambique.

Large quantities of water are released along the Vaal River to supply major urban and industrial demand centres and Eskom power stations in the middle and lower areas of the Vaal sub-basin.

The middle area of the Vaal sub-basin is dependent on water releases from the upper Vaal to supply urban, mining and industrial sectors.

Figure 9: Reservoirs in the basin

Over 90% of the water used in the lower Vaal area originates from the upper Vaal and from Bloemhof Dam. About 80% of this is for irrigation, mainly through the Vaalharts Irrigation Scheme – the largest irrigation scheme in South Africa – as well as a number of smaller schemes.

Considerable return flows from wastewater treatment works and irrigation schemes flow back into the Vaal River causing severe water quality problems.

Although there is relatively little development in the lower Orange sub-basin, water is used for irrigation, mines and domestic requirements. The Kalahari-West, Pelladrift and Springbok water supply schemes provide water to a number of towns and mines. Water is also supplied via a number of weirs and canals on the Orange River to various irrigation schemes.

In Namibia, water is taken from the Orange River via a canal system for the Noordoewer–Vioolsdrift irrigation area and also provides for some domestic and mining requirements.

There is no development on the river systems in the Botswana part of the basin.

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Top: On the Orange River, 130 km downstream of Gariep Dam, the Vanderkloof Dam supports requirements to the mouth, approximately 1,400 km away, by controlling flow; it is also used to generate electricity and stores water for urban and irrigation use.

Bottom: Boegoeberg Dam is currently the western-most dam on the Orange River. It supplies water for irrigation via a 172-km-long canal.

2.2.3 Groundwater

Groundwater occurrence is determined largely by geology, and its flow by topography, which usually mimics surface contours. It is a renewable resource replenished by surface water sources, usually rainfall or stream flow, by:

- infiltration of precipitation
- seepage of standing and river waters through beds and banks
- leakage from adjacent groundwater sources
- artificial recharge from irrigation, pipeline leakage, direct injection, etc.

The recharge process and rate is influenced by the geological nature of the aquifer, the volume, intensity and pattern of rainfall, surface temperatures and rate of evapo-transpiration, and vegetation and soils. Annual average rates of recharge decrease from east to west across the Orange–Senqu basin. The upper parts of the basin have mean annual recharge figures of 25–100 mm, while those further west where there is a higher dependency on groundwater are less than 5 mm.

Vaal sub-basin

In the largest part of the Vaal River sub-basin the Karoo Supergroup is the most prominent host rock. It forms highly productive aquifers with a potential of 10,000–25,000 m^3/km^2 per year and up to 50,000 m^3/km^2 per year in the northern and western areas of the sub-basin. Dykes and sills were formed mostly by diabase (a type of rock) during the intrusive process into the Karoo Supergroup. The water-bearing contact zones these form with shale or sandstone are well known and targeted when drilling.

Groundwater is extensively used in the Vaal River sub-basin, with 26–100+ boreholes per 10 km^2 (conservative figure), especially in areas such as the southern parts of Johannesburg, Krugersdorp, Koster and Swartruggens. Many villages

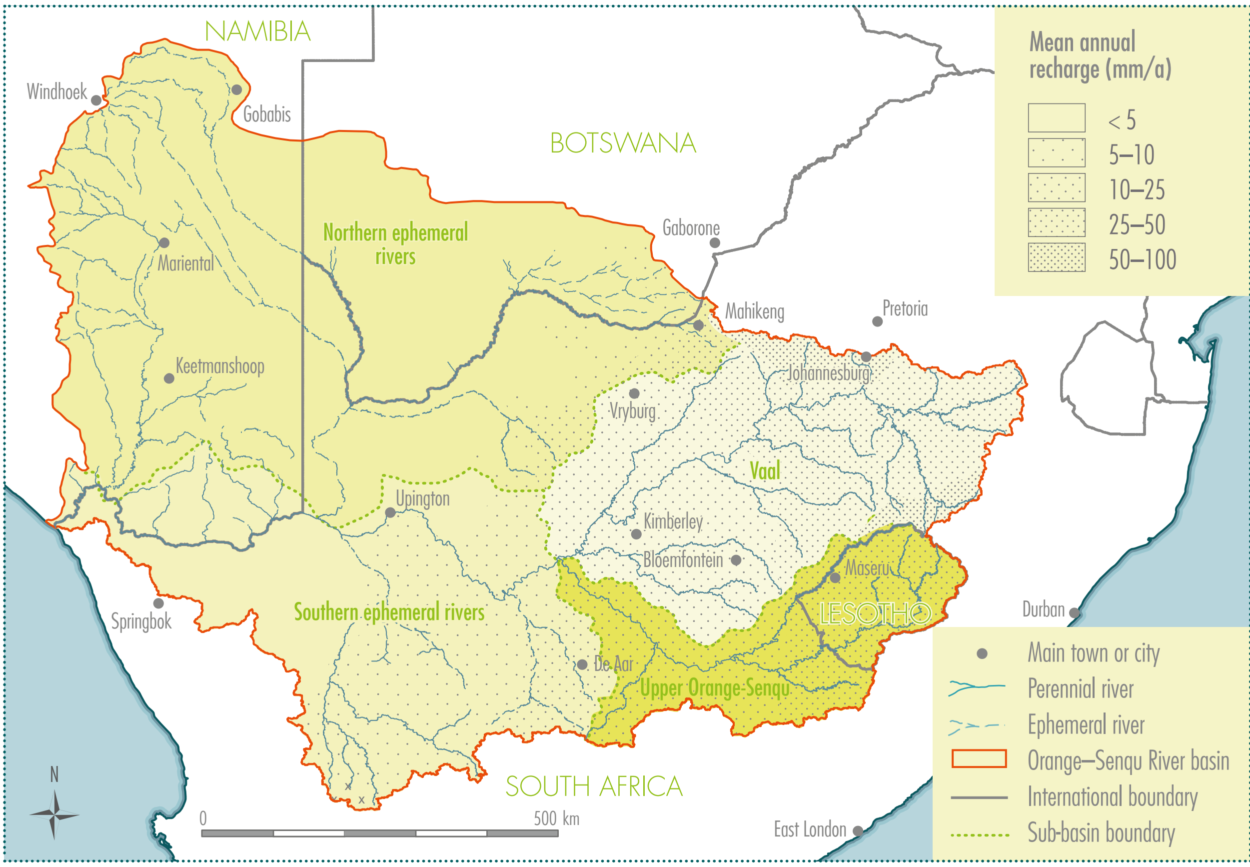

Figure 10: Average rates of groundwater recharge

partially, or entirely, rely on groundwater as a domestic water source; commercial and subsistence farmers use groundwater as their sole water source. The mining sector abstracts large groundwater volumes in processes such as slimes dam operations, dewatering of mines and washing plants. They also pump surface water back into the ground. During these processes, the risk of groundwater contamination is high and needs careful management.


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Many farmers in the arid western reaches of the basin pump groundwaters into small open tanks, thus making water available for livestock and wildlife.

Upper Orange–Senqu sub-basin

Groundwater occurs within the fractured Karoo Supergroup sedimentary and basalt rock aquifers, alluvial sediments and within fracture and dolerite intrusion zones in this sub-basin. Numerous dolerite dykes and sills have intruded the sediments of the Karoo Supergroup throughout the sub-basin. Fractures in the dolerite itself, or in the baked contact zones between the dolerite and the surrounding country rock, act as secondary aquifers. No large porous aquifers are found in the upper Orange sub-basin. Recharge rates, and therefore sustainable yields, are relatively low especially over the lower, drier parts of this sub-basin. In localised areas, however, for example where lime bogs are found, higher recharge rates do take place.

There are two prominent areas where borehole densities are high: the western part of Lesotho, from Ficksburg area to Wepener in the south; and the agricultural area north of the Gariep Dam, which includes villages such as Springfontein, Trompsburg and Philippolis.

Lower Orange sub-basin

Low recharge rates as a result of low rainfall and hard geological formation underlying much of the area make aquifer characteristics (borehole yields and storage of groundwater) unfavourable as a source of water. However, as little to no runoff is expected in many of the rivers away from the main watercourse, groundwater is the most widely used resource in this part of the Orange–Senqu basin. It is mainly used for rural domestic supply, stock watering and supply to the towns and villages in the area.

The Karoo Supergroup, which forms a large part of the southern parts of this sub-basin, consists of shales, sandstone and mudstone with dolerite intrusions. Where intruded dolerite sheet and dyke structures are weathered along geological contact zones, they form ideal positions for water abstraction in this arid area of the basin. Further north, Kalahari sands cover large areas of the sub-basin, inhibiting the development of drainage features to a large extent, while groundwater is found in porous and unconsolidated sedimentary strata in the north-west.

The alluvial material found at the Orange River mouth consists of a complex mix of unconsolidated superficial deposits, conglomerates, limestone, sandstone, marl and high-level gravel. It forms the ideal aquifer for shallow sandpits and boreholes. Deeper boreholes tap water from the fractured hard rock formations that consist of greywacke, quartzite and lava. Fresh water is found at the top of the aquifer with more saline water at a deeper level.

Groundwater potential or natural recharge of much of the area has not yet been fully determined. It is estimated that between 1% and 2% of rainfall actively recharges groundwater in Namibia. As a result, groundwater is often brackish because of high salt concentrations. Much of the groundwater abstracted near rivers is induced recharge from the river.

Groundwater availability in the coastal region is also extremely limited as a result of the lack of rainfall and risk of seawater intrusion into coastal aquifers. Low recharge rates often result in brackish groundwater.

Controlling the climate under sheltered greenhouse conditions helps reduce evapo-transpiration and water requirements.

Transboundary aquifers

Almost all the country borders are underlain by low-yielding aquifers. Coupled with low demand for water in these areas, the risk of over-pumping or pollution leading to dispute is low. However, two distinct and extensive transboundary aquifers exist – both located on the Karoo system.

The first, the Karoo Sedimentary Aquifer, is located in Lesotho, and the eastern Free State and parts of the Eastern Cape in South Africa. The low rates of transmission and consequent low borehole yields of the Karoo Supergroup rocks straddling the Lesotho–South Africa border suggest that the transboundary impact of groundwater abstraction is likely to be small. The area is designated as a 'major groundwater basin' with medium recharge on the world transboundary aquifer map, yet it is likely to need management approaches that are different to those applied to transboundary aquifers with much higher transmission rates.

The second, the South-east Kalahari–Karoo Aquifer, is shared by Namibia, Botswana and South Africa. It is predominantly used in Namibia for stock watering, increasingly for irrigation and to supply rural domestic households and small villages. Water occurs in the Auob and Nossob sandstone of the Ecca Group (Lower Karoo Sequence), as well as in the overlying Kalahari. The formations dip slightly towards the south-east and, in general, the water quality deteriorates in that direction. The so-called 'salt block' extends from the south-eastern section of the basin in Namibia into Gordonia in South Africa. Namibia is likely to have the largest increasing demand from the system in the future. Although the system is large, because of present uncertainty about recharge, the sustainability of irrigating large areas is uncertain.

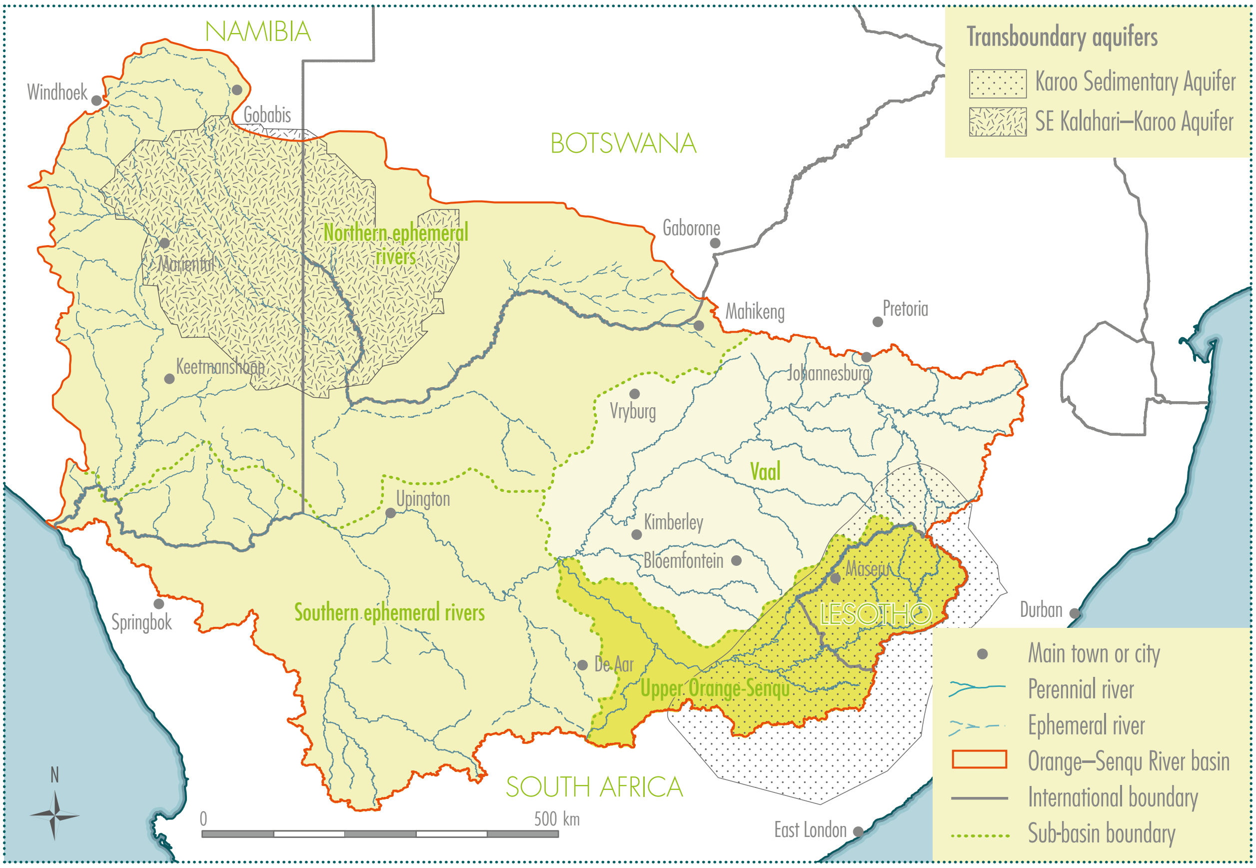


Figure 11: Transboundary aquifers in the basin

SHARING WATER, WORKING TOGETHER

Sparse data and limited data sharing, and lack of technical cooperation, training and research between the basin states on hydrogeology, hampers a mutual understanding of the Orange–Senqu's groundwater resources. The development potential of each aquifer needs to be assessed against factors such as surface water and groundwater interactions, recharge rates and groundwater-dependent ecosystems. Such assessments will inform the joint development and management of these resources to the mutual benefit of the basin states. Cross-border cooperation is imperative to establish and ensure sustainable cooperative utilisation of shared aquifer resources and avert potential future disputes. Agreement between scientists is a necessary precursor to broader transboundary governance agreements with regard to shared water resources. Recent initiatives by ORASECOM promise closer integration (Cobbing et al., 2008).

The interaction between surface and groundwater is complex and not well understood in most places. There is an increasing focus on modelling surface water and groundwater interactions, and different methods are being compared. The models, however, are only as good as the data on which they are based. Robust data gathered through long-term rainfall, runoff and groundwater monitoring programmes, as well as an understanding of the geology are essential.

Freshwater springs in the Nama Karoo, such as this one at Hobas on the plateau above the Fish River in southern Namibia, provide important refuges for a myriad of plant and animal life.

Colourful Barberton daisies (*Gerbera jamesonii*) are commercially grown in greenhouses by the Rehoboth Community Trust and are watered using groundwater from the ephemeral Oanob River in Namibia.

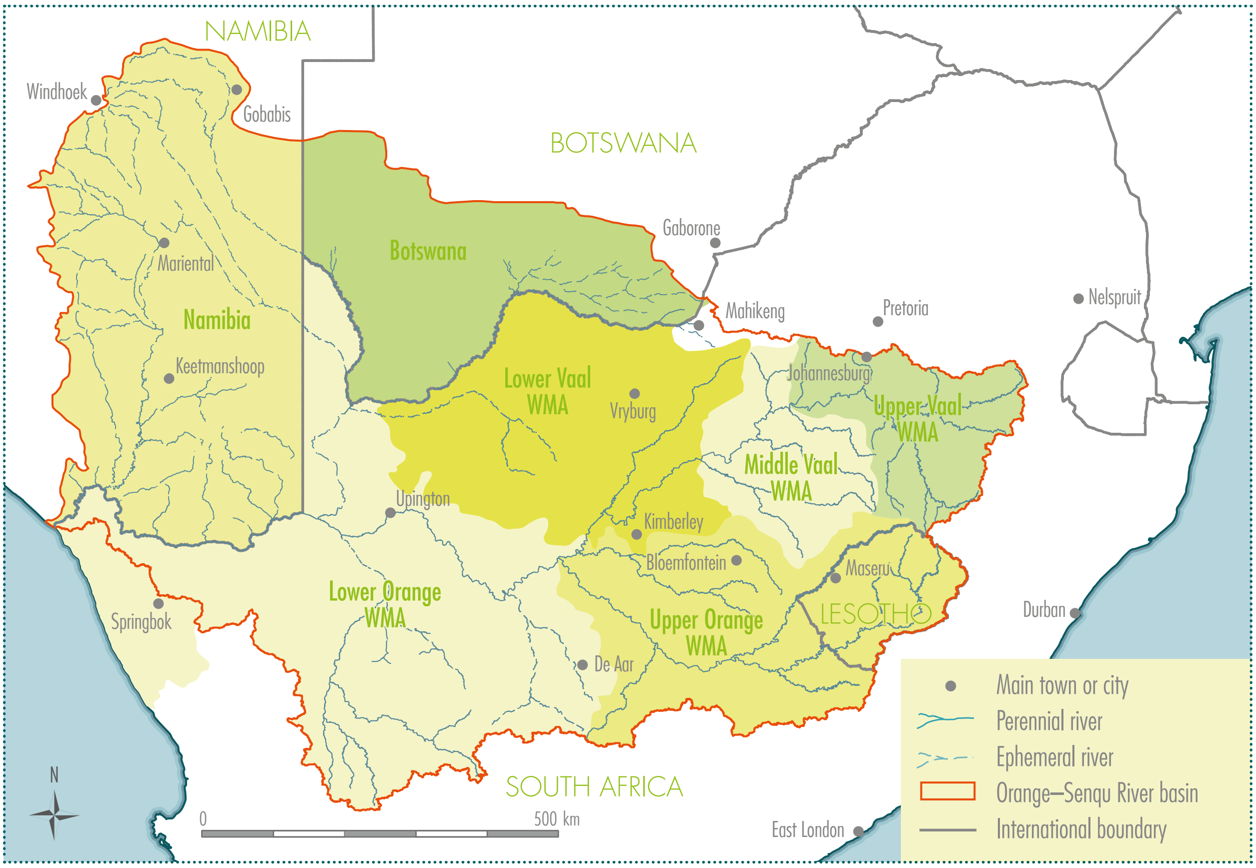


Figure 12: Map and charts showing the water required by the various management areas of the basin, 2000

2.2.4 Water requirements

Water in the Orange–Senqu River basin is used for irrigation, urban domestic and industrial activities, mining, power generation, and rural domestic and farming activities. Of all water demand in 2010, about 93% was in South Africa, of which 70% was from the irrigation sector.

To give an indication of growth in water demand, figures were analysed for 2000 and 2010, as shown in Table 5. Water requirements appear to have grown from 4,232 Mm^3 in 2000 to 5,718 Mm^3 in 2010, an increase of about 35%. However, the actual increase is probably less than this. The 2000 and 2010 figures were obtained from different sources with different objectives, so do not make an ideal comparison. Those for 2010 were prepared from a modelling perspective. It is also not clear whether losses and environmental demands were part of the 2000 figures, and if so, to what extent these were considered. No figures were available for Botswana in 2000, so the 2010 figure was used.

Table 5: Water requirements at 2000 and 2010 development levels

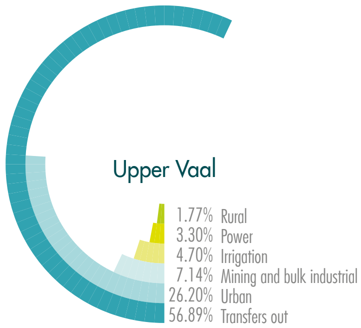
	Point demands (net Mm^3/a)*		Irrigation average demands (net Mm^3/a)		Total (Mm^3/a)	
Water management area	2000	2010	2000	2010	2000	2010
Upper Vaal	931	871	114	257	1,045	1,128
Middle Vaal	211	280	159	143	370	423
Lower Vaal	118	178	525	469	643	647
Upper Orange–Senqu	188	185	780	1,339	968	1,524
Lower Orange	43	84	977	1,558	1,020	1,642
Molopo–Nossob (Botswana)	Unknown	135	Unknown	1	Unknown	136
Fish (Namibia)	8	172	42	46	50	218
Total†	1,634	1,905	2,598	3,813	4,232	5,718

Sources: All 2000 figures, except those for Namibia, from DWA 2002d, e, f, g and h. For Namibia, DWA 2005. All 2010 figures, from ORASECOM (2011a) with adjustments for irrigation and removal of the Orange–Fish transfer.

* Net point demands are gross point demands with return flows subtracted

† Using the relatively small 2010 figures for Molopo

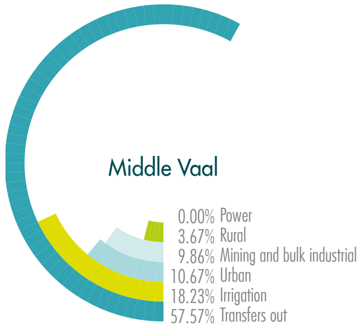
Information from 2000 gave a clear indication of which groups were using the water. Figure 12 clearly shows the high demands of the irrigation sector. Re-allocation of water from one water-use sector to another is probable in the future.



Groundwater use

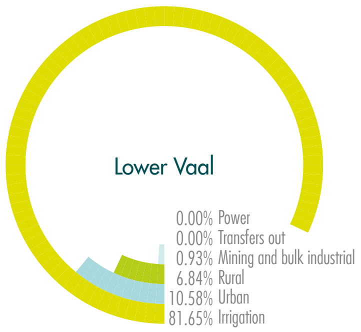
Groundwater use in the basin can be examined by the borehole density distribution. Although the borehole density map cannot effectively represent the volumes of groundwater abstracted, it does indicate reliance on groundwater. The highest number of boreholes is found around urban areas and throughout the agricultural areas of the basin.

Recent estimates put groundwater abstraction in South Africa between 1,771 Mm^3 and 1,900 Mm^3 per year (Baron and Seward, 2001; Hughes, 2005). However, the actual use of groundwater is largely unknown; there is currently no formal data collection on groundwater use in any of the countries in the basin. Throughout the sub-basin, borehole density is in the order of 1–25 boreholes per 10 km^2. In Namibia, groundwater abstraction from the basin is estimated at 13.81 Mm^3 per year and in Botswana at 1.12 Mm^3 per year (Lange et al., 2007).

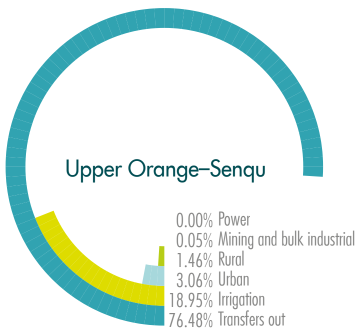


There are a few million people living on subsistence and commercial farms in Namibia, Botswana, Lesotho and South Africa, who use groundwater daily for domestic and animal use. Without groundwater sources, these farms and villages would be unproductive. The overall lack of certainty regarding groundwater yields and its use, and limited awareness by users of the vulnerability of this resource, leaves great room for improvement in its management.

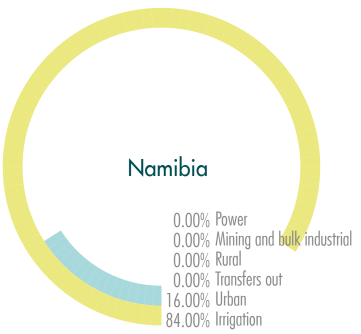
2.2.5 Stream flow and water balance

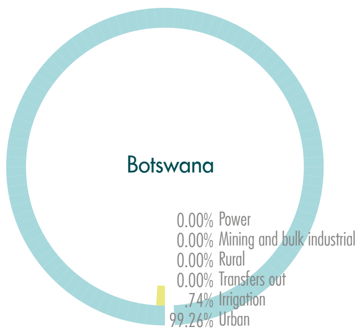


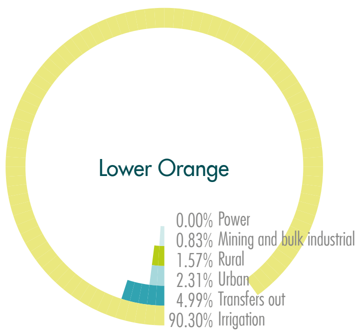
High demands on the water of the Orange–Senqu River system have greatly reduced the amount of water reaching the mouth. In planning how to meet increasing demands in the future, it is important to have a good understanding of the balance – yield and demand – of water in the system. Data and information to facilitate modelling and planning of water resources throughout the basin is generally limited. Even in South Africa, which had relatively good rainfall records, and observed stream-flow and land-use data in the past, the number of rainfall stations and stream-flow stations have declined over the past decade or two. Nevertheless, various hydrological analyses have been carried out.



One such detailed analysis, part of the Water Resources of South Africa study (WR2005), used a rainfall–runoff model called the Water Resources Simulation Model (WRSM2000), also known as the Pitman Model, with a monthly time-step on basin catchments in South Africa, Lesotho and Swaziland. The first step in rainfall–runoff modelling is to calibrate the simulated stream flow that the model determines against the measured, or observed, stream flows. This is done by manipulating so-called calibration parameters that alter the simulated stream







© Carole Roberts

Gauging station at /Ai-/Ais on the ephemeral Fish River, Namibia

flow until it is as close as possible to the observed stream flow. The model uses statistics and graphs to do this calibration.

Observed stream-flow record periods differ from gauging station to gauging station, but adopting this approach allows the generation of values for stream flow where observed flows do not exist. The analyses for South Africa and Lesotho are documented in the recently completed study undertaken for the Water Research Commission (WRC, 2008a, b).

In the Namibian part of the basin, a model called NAMRON was used to do a similar analysis. The contribution to surface flow of the system from Botswana is negligible. The catchments are grouped into sub-basins – or water management areas (WMAs) – as shown in Figure 8.

Key gauges were selected for each catchment. Table 6 gives the observed and simulated stream-flow values at these key locations. Return flows from industry, mining and urban areas are relatively high upstream of the Vaal Barrage, while in the lower Vaal, most of the return flows are from irrigation.

Table 6: Calibration details for key stream-flow gauges

Major catchment	Sub-catchment	Stream-flow gauge	River/dam	Record period	Observed MAR (Mm³/a)	Simulated MAR (Mm³/a)
Vaal	Upper Vaal	C1R001	Vaal Dam	1936–2004	1,882	2,008
	Middle Vaal	C9R002	Bloemhof Dam	1968–2004	2,101	2,158
	Lower Vaal	C9R003	Vaal River (Douglas Weir)	1958–1985	1,517	1,923
Orange	Upper	D3R002	Gariep Dam	1971–2004	6,421	6,500
		D3R003	Vanderkloof Dam	1977–2004	4,745	5,296
	Lower	D8H003	Orange River	1935–1982	9,382	7,588
Molopo–Nossob (Botswana)		No gauges				
Fish (Namibia)		Hardap Dam	Fish River	1962–1990	182	

Sources: WRC, 2008a and b together with supplementary analysis by Dr Bill Pitman for WRP Consulting Engineers; and DWA, 2005 (Namibia)

© UNOPS/Christoph Mor

Irrigated fields on the floodplain of the lower Orange River

The second step in the rainfall-runoff modelling process is the determination of naturalised stream flow. Naturalised stream flow, i.e. the flow without the inclusion of human influences such as dams, irrigation schemes, towns, industry and mines, is important for modelling the yield of dams. This has been determined using a different model, the Water Resources Yield Model (WRYM).

WRYM uses naturalised stream flow produced by WRSM2000 and then includes the effects of land use, which have so-called associated 'penalty structures'. This allows the model to supply certain users before others. In reality, environmental flows are the most important and should be supplied first. They are usually followed by water supply for urban domestic demands, industrial demands, mining demands and lastly irrigation demands. Naturalised stream flow is determined over the full record period, in this case from 1920 to 2004.

Present-day levels of development of competing land uses are generally used to determine the yields of dams. As shown in Table 7, the Upper Orange sub-basin provides almost 60% of the total naturalised stream flow in the basin, the Vaal sub-basins about 32%, collectively, and the ephemeral systems of the arid lower Orange sub-basin provide the remaining 8%. Naturalised flows cannot be compared to either simulated or observed flows because of the land-use component and also because the record periods are usually different.

Altered habitats and degraded banks, coupled with naturally fragile soils, lead to erosion and create a high sediment load for the Senqu River, Lesotho.

Figure 13: Mean annual runoff calculated for each tertiary catchment in the basin

The Vaalharts canal system built in the 1930s supplies an area of 370 km², making it one of the largest irrigation schemes in the world.

Table 7: Naturalised flows of the Orange–Senqu River system, 1920–2004

	WMA/country		Naturalised MAR (Mm³/a)
Vaal	Upper Vaal		2,452
	Middle Vaal		912
	Lower Vaal		201
Orange–Senqu	Upper Orange–Senqu		6,756
	Lower Orange	South Africa	255
		Botswana	44
		Namibia	651
Total			**11,271**

Sources: WRC, 2008a and b (Lesotho and South Africa); ORASECOM, 2011b (Botswana); DWAF hydrology records, 1920–99 (obtained October 2011, Appendices).

The analyses that produced Tables 6 and 7 relate to some degree to the determination of the available water resources. However, it is very important to analyse the water balance of a catchment, i.e. to compare the available water resources with the water demands. Ideally, the demands would be adequately met by the available water resources. Transfers into and out of the basin obviously also need to be accounted for as they influence the water balance.

The next step is to determine the water balance to ascertain whether there is surplus water available or not and, if so, the magnitude thereof. This can vary considerably from year to year in a large basin, especially one subject to variable rainfall, such as that of the Orange–Senqu.

The water balance given in Table 8 shows a relatively small surplus yield, i.e. the flow volume that could be used every year without failure to supply growing demands. 'Spills to sea' is water that is lost, i.e. it is not possible to store this volume with current infrastructure, as dams are full and demands have been met in times of high rainfall which produce floods. This volume cannot be regarded as available yield because it is lost to the sea.

Because a water balance compares what is available against what is required, ecological flow requirements (EFRs) and hydropower requirements (except losses) are not included, as they do not consume water the way urban, industrial and irrigation demands do. Environmental flow and hydropower requirements are, however, included in the determination of yield.

A summary of the water balance for the Orange–Senqu River system for the period 1920 to 2004, is given in Table 8. As different organisations carried out the two studies, the assumptions of naturalised flow values are not the same for Tables 7 and 8. While the discrepancy for the Vaal is relatively small, the difference in the naturalised flow for the Orange River is 6.7% higher in Table 8 than in Table 7. This is probably because losses in the lower part of the Orange are naturally high and very difficult to estimate, making for a wider range of values than in the Vaal system.

Table 8: Water balance summary, 1920–2004

Details	Volume surplus (+) or deficit (-) (Mm³/a)
Natural hydrology Vaal	3,609 (+)
Natural hydrology Orange	8,220 (+)
Thukela transfer inflow	478 (+)
Net demands Vaal	2,205 (–)
Net demands Orange	4,022 (–)
Evaporation and dam storage	1,724 (–)
Spills to sea	4,182 (–)
Surplus yield	174

Source: ORASECOM, 2011b

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While dams, such as the Vanderkloof, are important to assure that water supply demands are met, their cumulative effects and extensive abstraction of water have significantly altered the natural flow of the river.

The volume of water reaching the mouth of the Orange River averages 4,182 Mm^3 per year, although this varies considerably from year to year. This flow is reduced to less than half of the natural flow (37%), a result of abstraction of water from the Vaal River (mainly for domestic and industrial uses), and the Orange River (mainly for irrigation).

There are limited options for constructing new dams, especially if environmental flow requirements of the system are also to be met. Water resource planners are now looking at other interventions such as water conservation and demand management, re-use of water, desalination and water transfers to provide for growing water demands.

2.2.6 Pattern of flow

As a consequence of the river's development, there have been changes, not only in the amount of water reaching the mouth, but also in the patterns of flow. These changes to the hydrological regime of the river system, particularly in its lower reaches, are dramatic.

- The frequency of floods is greatly reduced, and the peak and duration of these conditions are generally halved. Floods, other than extreme events, are 'absorbed' by the upstream storage dams.
- There is less inter-annual variation in total annual flow volumes.
- Average monthly flows show similar orders of reduction and less distinct seasonal patterns.

These changes are significant in terms of long-term degradation of the riverine environment, the availability and reliability of water resources in the lower reaches of the basin, and the sustainability of the ecological functionality of the mouth.

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Cooling towers that rely on the evaporation of water to dissipate heat are increasingly being replaced by dry-cooled systems to reduce the demand on the basin's water resources.

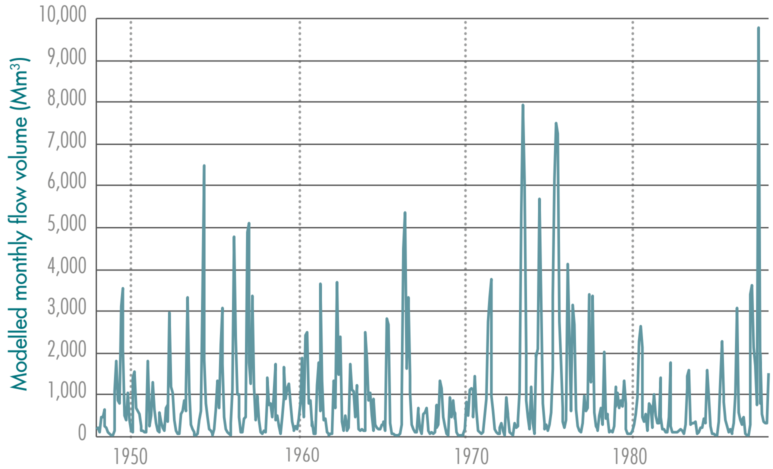
2.2.7 Water and power generation

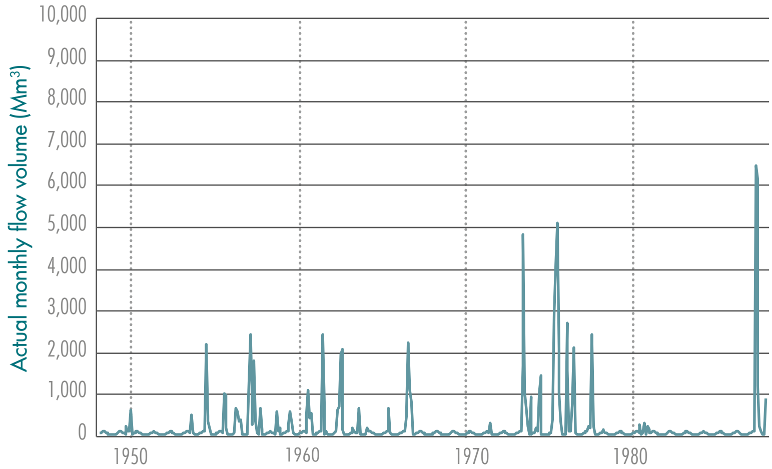
In the Orange–Senqu River basin, power generation is currently confined to South Africa and Lesotho. This is done by wet- and dry-cooled coal-fired thermal power and hydropower generation. The water demand for, and management of, power generation from this basin however, poses a challenge.

There are four thermal power stations in the basin. Lethabo and Tutuka were fully commissioned in 1990 and are modern stations compared with the older Camden and Grootvlei stations. Both Lethabo and Tutuka operate desalination plants, treating mine water, while Lethabo also uses water from the Vaal River and treated wastewater for cooling. During the severe drought in 1982 only one of eight units was run at Camden, as there was not enough available water to cool the station.

Figure 14: Flow patterns show fewer and smaller floods. Modelled monthly flow volumes at Augrabies (1947–87) under natural conditions (top) and with 2005 infrastructure and demands (middle).

Bottom: Average monthly flow at Vioolsdrift before major abstraction and infrastructure development (1935–71) showed higher summer flows and lower winter flows than those since major development of the river occurred (1972–2009).





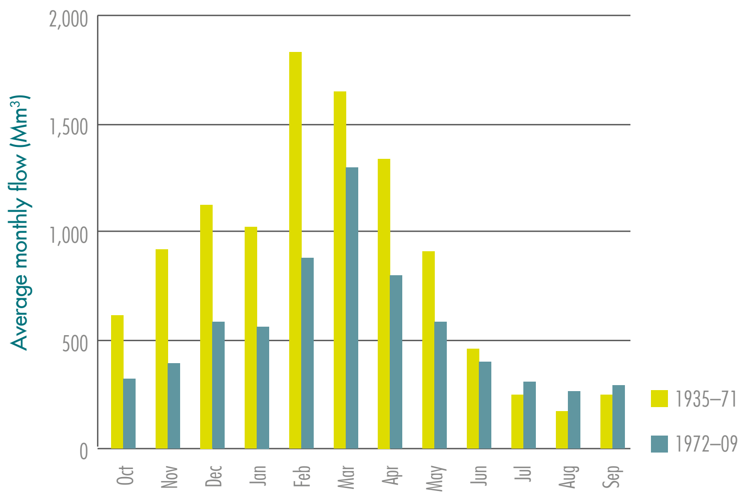


Table 9: Thermal power station raw water consumption

Power station	Power generation (MW)	Cooling	Raw water consumption (m^3/s) Present	After upgrade
Lethabo	3,708	Wet	1.32	0.95
Tutuka	3,654	Wet	1.49	1.28
Camden	1,600	Wet	1.26	1.03
Grootvlei	1,200	Wet and dry	0.87	0.92
Majuba*	4,110	Wet and dry	0.63	n/a

* Water from Zaaihoek Dam in Thukela basin used
Source: Bailey, 2011

Typical water use of thermal power stations is 50 Mm^3 per year for wet-cooled systems and 3.5 Mm^3 per year for dry-cooled systems. A direct relationship exists between energy produced and water consumed. This 'specific water consumption' is used to assess the performance of power stations. In South Africa, Eskom has reduced the specific water consumption (for all generation technologies) from 2.85 ℓ/kWh in 1980 to 1.29 ℓ/kWh in 2003. Its future strategy does not accommodate construction of more wet-cooled power plants.

There are also large hydropower plants on the Orange–Senqu (Table 10). The Gariep and Vanderkloof plants are supported through a combined reservoir capacity of 8,530 Mm^3. During energy production, the stored water is passed through the turbines, which has consequences for downstream settlements. Irrigation, as well as flood control, are key considerations during energy production. The electricity produced by these hydropower stations is cheap, at almost one-fifth the cost of coal-fired power stations. They have an added advantage in that they do not 'consume' the water and it can theoretically be used for other purposes.

© Graeme Williams

Meeting the ever-increasing demands for water and power from limited resources is an ongoing challenge that will require innovative intervention in the long term.

Table 10: Hydropower stations

Station	Sub-basin	Power generation current (MW) Current	Planned
Gariep	Orange–Senqu	360	440
Vanderkloof	Orange–Senqu	240	240
Muela	Orange–Senqu	72	72
Drakensberg (Thukela)	Thukela and upper Vaal	1,000	1,000
Ingula	Thukela and upper Vaal	n/a	1,330

Sources: Bhula, undated; Bailey, 2011

Due to the multi-purpose nature of the Orange River as a whole, a balance has to be maintained between the availability of water resources for irrigation, industrial and urban uses, amongst others, and water resources for power generation. Wet and dry cycles of river flow influence the availability of water and therefore a sophisticated operating model has been developed for optimum management of water for both power generation and water supply purposes. The hydroelectric power stations are predominantly used as peaking power stations as a result of limited water resources and because they can provide a swift response to demand peaks.

Another hydropower plant within the basin, Muela, is part of the LHWP and meets all the current power needs of Lesotho. This plant and a planned pumped-storage scheme in Lesotho have minimal influence on water availability of the broader basin.

The feasibility of upgrading the Gariep plant has been investigated. Most importantly at this stage in South Africa's supply crisis, the upgrade would supply an additional 80 MW of peak and emergency generation to the national grid. Given the fact that hydropower is considered to be renewable energy, it would also be more environmentally friendly. However, it is debatable whether the dam would have sufficient water for enough of the time to justify the cost of the upgrade.

Power generation by conventional hydroelectric power stations is augmented by pumped-storage schemes. These have the advantage of re-using the same water to generate power. A pumped storage scheme has an upper and lower reservoir. During periods of low demand, water is pumped from the lower to the upper reservoir. During periods of peak or emergency demand, water is allowed to run back into the lower reservoir through turbines to generate electricity. This mechanism of creating energy during peak demand periods and drawing energy from the electrical network (pumping) during low-demand periods is very useful for river control. It is even more useful if water can be transferred between rivers.

Because it is necessary to pump the water back after use, pumped-storage power stations can only provide energy for limited time periods. In addition, they are more expensive to operate than conventional hydroelectric power stations because of pumping costs.

There is a pumped-storage power plant at Drakensberg, which is also used as a pump station in the Thukela-Vaal Water Transfer Scheme. Water is transferred from the Thukela WMA to the Upper Vaal WMA and also facilitates the generation of hydroelectricity. The scheme involves Woodstock Dam, Driel Barrage, Kilburn Dam, Driekloof Dam, Sterkfontein Dam and a number of pump stations, pipelines, canals and tunnels.

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Changes in river flow patterns, for example by upstream dams, impact the morphology of the riverbed by altering the interaction between erosion and deposition.

Currently, base-load power is predominantly supplied by coal-fired power stations. However, the drive towards clean emissions and the mitigation of global climate change might require that hydropower (and other renewables) support base-load energy requirements. This could, in turn, pose constraints on other water uses.

2.2.8 Fluvial morphology and sediment balance

Water quality in both rivers and reservoirs is greatly affected by suspended sediment concentration resulting from erosion through land degradation, and alterations and barriers along watercourses. Loss in storage because of sedimentation reduces the ability of reservoirs to supply water for domestic, industrial, irrigation and hydropower uses, and for flood control. Apart from sediment affecting the fluvial morphology of the river, it also affects water quality – either the sediment itself, or pollutants associated with it (Gordon and Muller, 2010).

A river's regime with regard to its width, depth, slope and channel pattern is affected by water discharge and sediment load over time. River flow patterns and structural components such as main channel width and depth can also be affected by the construction of dams upstream and river bank activities. Dams contribute to degradation of the downstream riverbed, which depends on the interaction of erosion and deposition processes. They store sediment leading to decreased sediment transport capacity locally downstream, but by attenuating floods increase riverbed aggradation. Furthermore, an increase in discharge of water from dams results in an increase in the channel width and a decrease in discharge will narrow channel width.

Similarly, the change in the particle size is directly proportional to the change in the main channel width. A decrease in the channel slope results in an increase in the channel width, and vice versa. Table 11 shows some of the observed river width changes after dam construction within the basin (Beck and Basson, 2003).

Table 11: Observed river width change with dam construction

Dam	River	Width before (m)	Width after (m)	% change
Bloemhof	Vaal	92	82	–11
Noordoewer	Orange	222	208	–6
Gariep	Orange	269	255	–5

Source: Beck and Basson, 2003

Denuded slopes are quickly eroded by high rainfall in the upper basin.

Sediment characteristics vary greatly within the basin as a result of varying climatic conditions, land use and geological characteristics. The Orange–Senqu River has an alluvial sand bed, with some reaches of bedrock. The washload (silt and clay) fraction is high during floods (70–80%), especially on the Caledon River.

Floods play an important role in the transport of sediment. They are dependent on the intensity of rainfall, runoff transporting capacity of tributaries and soil-draining capabilities. The notable flood regions within the basin include the Vaal, Harts, Riet, Caledon, Senqu, Ongers, Molopo, Nossob, Fish and Hartbees river sub-basins. Mean annual precipitation of these sub-basins varies from about 850 mm in the Senqu to 140 mm in the arid region of the lower Orange River. Most sediment is transported during floods that are larger than the average runoff.

The role of floods in sediment transport can be explained by the following observations within the basin.

- The relatively arid region of the Molopo River is characterised by sands and dolomites, but the sediment load is limited by few perennial flows, and occasional seasonal floods. Even though more sediment could be available in this sub-catchment or river, the extent of floods limits the actual sediment loads observed at the outlet.
- The runoff from the Lesotho Highlands, on the other hand, contributes almost half the flow in the Orange River (Sene et al., 1998). The maximum instantaneous flow recorded in Lesotho is more than 6,000 m^3 per second. However, because of the number of dams that have been constructed within the Lesotho Highlands, the effect of the floods on sediment load downstream is dependent on the extent of floods, availability of sediment and the trap efficiency of the dams.

Sediment yields and loads

Total average sediment outflow from sub-catchment areas within the basin at selected river gauging stations or dam locations are shown in Table 12.

Table 12: Average long-term sediment yields and loads at some reservoirs in the basin

Station	River	Quaternary catchment	Total catchment area (km^2)	Mean sediment yield ($t/km^2/a$)	Sediment load (t/a)*
Katse Dam	Malibamatso	D11F	1,869	175	327,075
Gariep Dam	Orange	D35K	70,667	392	28,593,406
Vanderkloof Dam	Orange	D31E	84,019	136	2,927,382
Jammersdrift	Caledon	D22L	13,220	621	3,850,200
Vaal Dam	Vaal	C12L	36,638	163	4,850,563
Bloemhof Dam	Vaal	C43D	108,125	38	2,207,724
Upington	Orange	D73F	400,000	205	32,022,745
Hardap Dam	Fish	D46B	13,600	36	489,600
Orange mouth	Orange	D82L	803,000	19	44,322,405

* Sediment trapping in reservoirs has been included

Sources: Gibson, et al. (2010) for South Africa and Lesotho; DWA (2005) for Namibia

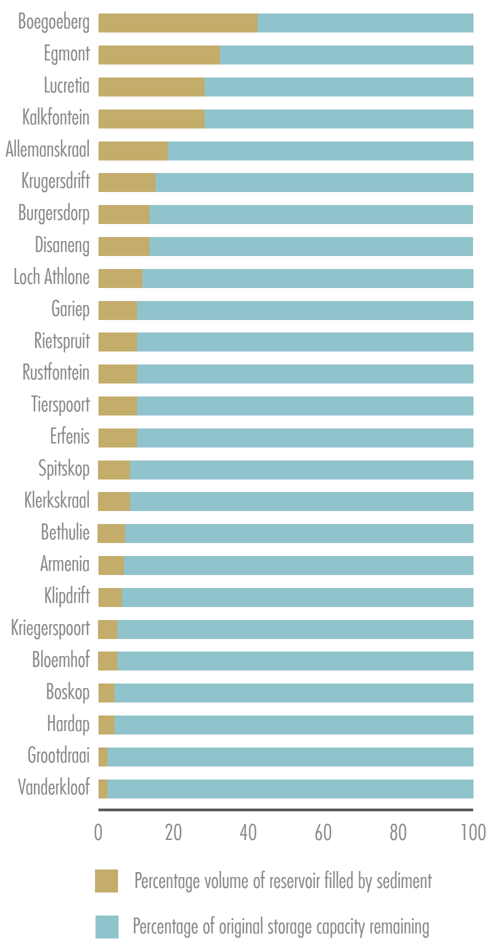

Figure 15: State of reservoir sedimentation: Storage lost as a percentage of original storage capacity

The Senqu River sub-basin has a drainage area of more than 20,000 km² within Lesotho. The sub-catchment consists mainly of basalts. Analysis of suspended sediment data from Lesotho (1976–1982) showed that annual yields ranged from less than 10 t/km² per year in the igneous region to more than 2,000 t/km² per year in the sedimentary region (Makhoalibe, 1984). The low sediment yields in the basaltic regions, have resulted in a notably low average in this region.

The Caledon River drains the densely populated lowlands of Lesotho and the eastern part of the Free State in South Africa. The drainage area in Lesotho is underlain by a sedimentary formation, known as cave sandstone, which is more easily eroded than the basalts of the mountain region. The soils of this sub-basin are highly erodible and the area is overstocked and overgrazed, resulting in some of the highest sediment yield areas in the basin. Measured sediment yield values range from 392 t/km² per year to 1,141 t/km² per year.

The central Karoo is geologically one of the more homogeneous regions in the sub-catchment, with sheep farming the dominant land use. Though the region is geographically large, sediment load data is limited due to the prevailing arid conditions and limited transporting capacity. Six out of the seven catchments in the area have sediment yield values of less than 50 t/km² per year.

Reservoir sedimentation

Most of the dams in South Africa were constructed in the 1960s and 1970s. Surveys to determine reservoir sedimentation and sediment yields are carried out typically every 10–15 years; some critical reservoirs are surveyed more frequently. The analysis of these data for South African dams showed that only 4% of the dams in the basin have lost 40–50% of their storage capacity due to sedimentation, and that 46% lost 5–10% of their capacity (Table 13). Over 80% of the dams in the basin have lost up to 20% of their capacity (Table 13) and are losing capacity at a rate of up to 0.5% per year (Table 14).

Table 13: Reservoir storage* lost as a percentage of the original capacity as a result of sedimentation

Storage lost (%)	% of selected dams	Cumulative % of dams	% of dams (basin)	Cumulative % of dams (basin)
0–5	28	28	24	24
5–10	18	46	40	64
10–20	20	66	20	84
20–30	6	72	8	92
30–40	5	77	4	96
40–50	7	84	4	100
50–60	8	92	0	100
>60	8	100	0	100

* South African dams only
Source: DWA (2006)

Table 14: Annual storage loss in reservoirs due to sediment deposition*

Annual storage loss (%)	% of selected dams	Cumulative % of dams	% of dams (basin)	Cumulative % of dams (basin)
0–0.1	28	28	13	13
0.1–0.2	25	53	24	37
0.2–0.5	31	84	40	77
0.5–1	8	92	23	100
1–1.5	8	100	0	100

* South African dams only
Source: DWA (2006)

Figure 15 shows the observed sediment volumes in the basin reservoirs graphically. Gariep Dam has by far the highest deposited sediment volume.

Analysis of the results showed that the average annual storage loss due to sedimentation in South African reservoirs is approximately 0.3%. This scenario adversely affects the long-term sustainability of the reservoirs. However, the international average annual storage loss due to sedimentation is 0.8% (ICOLD, 2009).

Managing sedimentation

Improved understanding of sediment loads in the basin is required to manage them effectively and sustainably. Suspended sediment sampling should be carried out in river reaches where sediment load data are limited, such as in the lower Orange River, in Botswana and the lower Fish River. Knowledge of long-term fluvial morphology and associated changes is essential in the optimal design and management of river basin projects.

Concerted efforts are needed to deal with specific problematic sediment sources within the basin. An understanding of catchment soil and stream channel erosion is important for predicting sources of sediment, particularly the sub-catchments within the basin that generate more sediment, and how it is transported to the river. This will help identify appropriate catchment management programmes. Soil erosion can be addressed through effective conservation initiatives, which should identify catchment erosion areas significant for conservation action. South Africa has an erosion hazard index that should be considered in conservation planning and management.

Measures to limit sediment deposition in reservoirs should be applied. The construction of more off-channel dams should be considered, as well as sluicing high sediment loads through the reservoir or flushing previously deposited sediments during floods, such as at Welbedacht Dam. This requires water level drawdown during a flood, large outlet gates and excess water.

A silt-laden Orange River in South Africa, close to the Lesotho border

WELBEDACHT DAM: CASE STUDY

(Adapted from de Villiers and Basson, 2007)

Damming results in reduced sediment transport capacity upstream of the dam and sediment deposition occurs, resulting in the loss of live storage capacity. In many cases the sediment deposition also occurs above the full supply level of the reservoir, sometimes more than 10% of the deposited sediment. As sediment deposition is continuous, the sediment delta grows higher and eventually flood levels start to rise. Not only are flood levels affected, but also the drainage from agricultural land, bridge discharge capacity, pump station operation and navigation.

The Welbedacht Dam on the Caledon River was commissioned in 1973. Its original storage capacity was 114 Mm^3, but one third of its capacity was lost within three years because of reservoir sedimentation. Figure 16 shows the historical loss in capacity. A survey in 2002 indicated that less than 10 Mm^3 storage capacity was left. Upstream sedimentation raised the riverbed level and flood levels so much that large parts of Wepener, a town located about 50 km upstream of the dam, had to be expropriated, and the R702 road bridge lost most of its opening and had to be raised as the bed aggraded.

Bloem Water started a flushing operation of the dam in 1991, which decreased the rate of sedimentation. The flushing operation is however not very effective because the five large gates are located about 15 m above the original riverbed level. The flushing canal, upstream of the dam, will eventually reach equilibrium and will be the only storage capacity remaining in the reservoir. In recent years, vegetation has grown on the sediment in the reservoir and this additional hydraulic roughness will raise flood levels even further.

Enough excess water is available for hydraulic flushing at the Welbedacht Dam, but low-level gates should be added to flush effectively. It is estimated that with suitable outlets, the reservoir storage capacity can be restored to 35 Mm^3. However, if the current operation is continued without reconstruction, the ultimate mean storage capacity could be less than 5 Mm^3 and could be lost completely during a single flood for short periods of time, although subsequent flushing would restore some of the capacity.

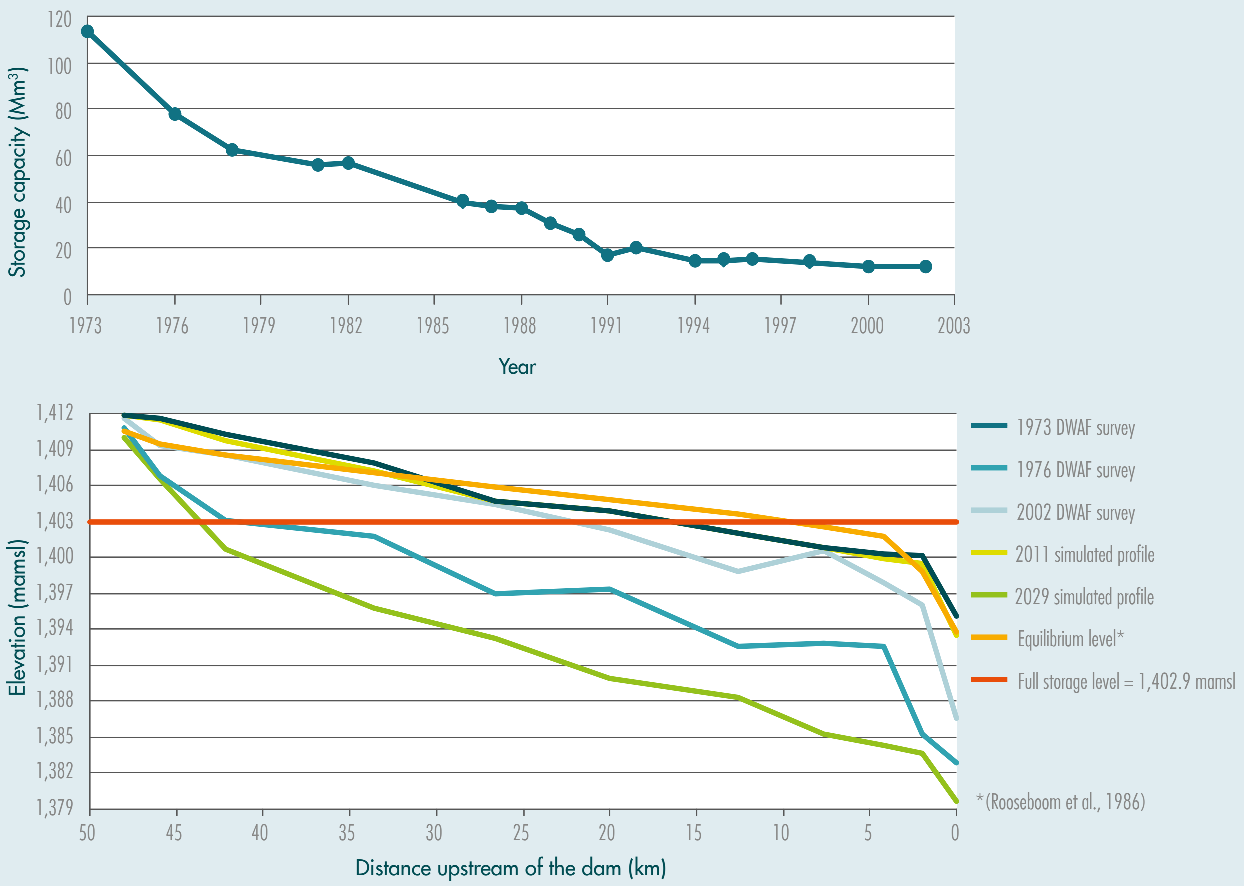

Figure 16: Storage capacity lost at Welbedacht Dam (top) and historical longitudinal bed profiles (bottom)

FLOOD AND DROUGHT MANAGEMENT

The Orange–Senqu catchment is heavily utilised and there are several large dams, particularly along the Orange and on its main tributary, the Vaal. These dams, although designed primarily for water supply, play an important role in flood and drought management. This role could become increasingly important in the light of climate change.

Flood management

There are no dams specifically built for flood control but, as a general rule, the larger the capacity in relation to inflow, the greater the attenuation of floods. Dams with gated spillways have the greatest capacity for flood control, provided they are operated correctly, for example, by releasing water before the flood peak arrives. Grootdraai, Vaal and Bloemhof dams – all on the Vaal – have gated spillways but there are none on the Orange and its tributaries. However, Gariep and Vanderkloof have significant outlet works and hydropower stations in addition to large capacities.

Flood waves move down the Orange and Vaal rivers at an average velocity of about 3 m per second, which translates to approximately 250 km a day. As the total length of the Orange–Senqu is 2,200 km (1,400 km from the Vanderkloof Dam to the mouth), there is a potential lead time of several days to warn people on the lower Orange and Vaal of an impending flood.

Flood forecasting capabilities for Lesotho and Botswana are confined to short- and long-term rainfall, whereas Namibia and South Africa include water-level monitoring. Problems associated with forecasting include lack of rainfall and stream-flow stations, vandalism, communication problems during floods, lack of manpower and limited flood-line information for hazard determination. Currently, there is no established or operational basin-wide flood warning network.

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The Orange River in flood at Augrabies Falls, January 2011 (above). Debris brought down by floods puts infrastructure such as this bridge at risk.

The primary concern for dam operation during floods is the safety of the dam. The second priority is to minimise loss of life and infrastructural impacts. Of particular concern in the basin is the timing of flood peaks downstream of the Orange–Vaal confluence. Every effort is made by the Department of Water Affairs (South Africa) to avoid coincident peaks from the Orange and Vaal rivers occurring at the confluence at Douglas.

While all four countries have disaster management plans, it is felt that these should be more detailed and that a more integrated approach should be pursued. Flood lines for a range of floods should be prepared for all areas susceptible to flooding, and emergency preparedness plans should be compiled for all major dams. Various problems associated with flood forecasting should be investigated and an integrated solution proposed to stakeholders.

Drought management

All dams in the basin are built for the purpose of managing water supply which, in its broadest sense, can be construed as drought management. However, all dams have an impact on the flow regime of the rivers on which they are built. Water from many dams is transferred to consumers who are remote from the river and, in some cases, to adjacent river basins. The Orange–Fish Scheme, which transfers water to the Eastern Cape from the upper Orange–Senqu, is a prime example of such an inter-basin transfer. Dams also release water for hydropower or for consumers situated some distance downstream of the dam, which also increases flow during dry periods.

The most severe droughts over the past 30 years occurred in the early 1980s and early 1990s. By manipulating dam releases and prioritising water use sectors, the impacts of drought can be minimised. Apart from the dams constructed as part of the Lesotho Highlands Water Project (LHWP), all major dams in the Orange–Senqu basin were built before an environmental flow requirement (EFR) became a required release from a reservoir (in South Africa). Environmental flow requirements are designed to maintain the environmental integrity of rivers downstream of dams, but in all cases the EFRs do not exceed the natural flow in the river.

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The Succulent Karoo is home to a rich diversity of plant species and spectacular landscapes.

2.3 TERRESTRIAL ENVIRONMENT

Other than precipitation falling directly onto open water surfaces, all freshwater resources, both surface water and groundwater, are derived from a passage (of long or short duration) through the terrestrial environment. The condition of the terrestrial environment, therefore, plays a vital role in determining the condition, in terms of the quantity (variability and absolute volume) and quality of a river basin's water resources.

Until relatively recent times, changes to the terrestrial environment in the basin have taken place at an evolutionary pace. Only in the last two centuries has change started to accelerate, as population pressure and land use have become significant and even intense in some places. It is argued that the intensification of agriculture over the past 50 years has and will have a detrimental impact on the basin's terrestrial and aquatic ecosystems as a result of large increases in nitrogen and phosphorous fertilisation to increase agricultural output levels. These changes have already had quite dramatic impacts on the diversity, composition and functioning of the natural ecosystems within the basin and on their ability to provide society with a variety of essential ecosystem services.

In a recent study carried out for ORASECOM looking at environmental flow requirements (ORASECOM, 2011e; Louw et al., in prep.), the present ecological state (PES) of the Orange–Senqu River was assessed at a number of key representative points. One of the indicators assessed at each site was the index of habitat integrity (IHI) of the riparian environment, considered to be one of the driving components of the PES. The status of riparian vegetation was also assessed and was, in many cases, found to be significantly altered and showing a diminished PES.

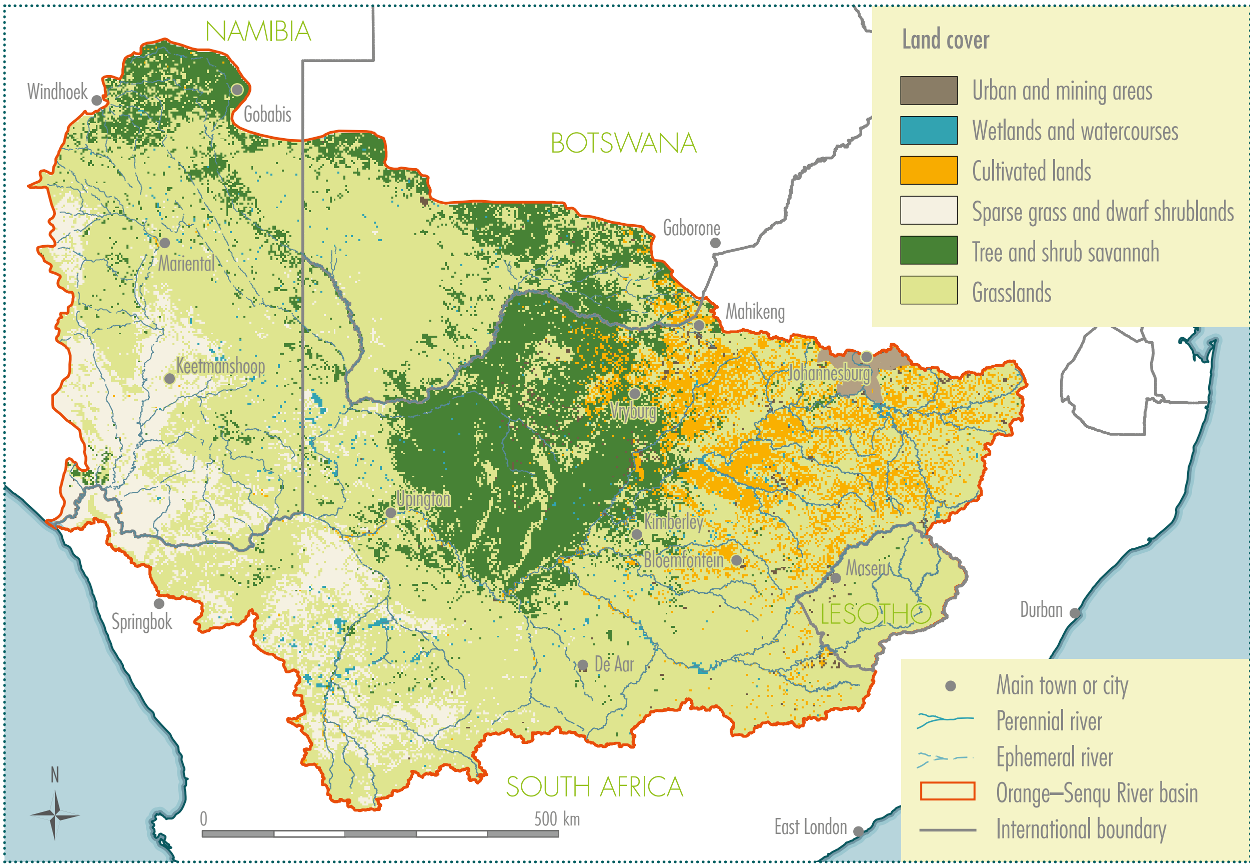
These changes and impacts in the Orange–Senqu River basin are being felt. Traditional farming practices, once sustainable by a relatively small population on available suitable land, are becoming increasingly unsustainable. More and more marginal land is being converted to agriculture, resulting in deforestation, loss of wetlands and erosion of soil from overgrazed rangelands and steep slopes unsuitable for crop farming.

This section examines how the terrestrial environment has changed, what the impacts have been and what the causes are. In so doing certain key areas, namely land degradation and invasive alien species, have been highlighted and investigated in more depth. The irrigation sector, which uses most of the Orange–Senqu's water resources, and is arguably one of the main polluters, is also examined.

2.3.1 Biomes, land use and degradation

The biomes of the Orange–Senqu River basin were introduced earlier and are shown in Figure 5. They represent distinct areas with particular biophysical characteristics. These characteristics make them suitable for different land-use activities and susceptible to different types of pressures and degradation and thus provide a logical point of departure for the analysis of the terrestrial environment.

Related to biomes, is land cover (Figure 17). Across the basin, four different types of land cover dominate: grasslands (64%), bushveld (18%), cultivated areas (7%) and in the more arid western reaches, areas classified as bare ground (10%), which is in fact sparsely vegetated areas of the Nama Karoo and Succulent Karoo, of ecological and conservation importance (ORASECOM, 2011h). There is little to no forest in the Orange–Senqu basin. Other types of land cover include wetlands and water bodies, and those areas that are now either urban or mines.



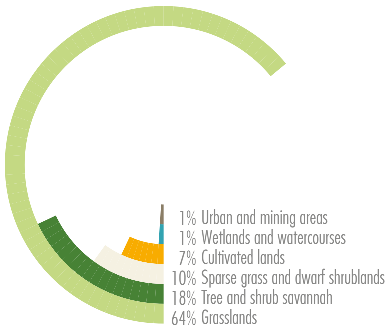


Figure 17: Map of land cover and the chart showing the proportions of each type in the basin

Source: Adapted from Hatfield (in ORASECOM 2011b)

Land degradation as a result of overgrazing, which is often accompanied by the invasion of alien species, is common to all the biomes. It generally renders the land less productive, reduces biodiversity and affects water balance. Such degradation, especially in the upstream areas of the basin, impacts the basin's water resources, both in terms of quantity and quality.

A key problem in the Southern Kalahari Savannah is that the shrub-tree element starts to dominate in areas that are overgrazed, with negative impacts on the availability of grazing lands. Bush encroachment is not limited to this biome. In the Nama Karoo, overgrazing can lead to various species, such as three-thorn (*Rhigozum trichotomum*), bitterbos (*Chrysocoma ciliata*), slapdoring (*Acacia nebrownii*) and sweet-thorn (*Acacia karroo*) proliferating. Many grasses and other palatable species can be lost through this process of degradation.

The Nama Karoo is also particularly susceptible to invasion by non-indigenous – or alien – plant species, such as various cacti (*Opuntia* spp.) and mesquite (*Prosopis* spp.). Mesquite is particularly problematic in the drier western parts of the basin, where it aggressively invades ephemeral watercourses and disturbed alluvial floodplains.

In some areas of the Succulent Karoo biome much soil has been lost through sheet erosion, largely as a consequence of overgrazing. Other localised areas are under pressure from mining. The high species richness and unique global status of the Succulent Karoo demand conservation status, which, within the basin itself, is being addressed by the recent formation of the /Ai-/Ais–Richtersveld Transfrontier Park and proclamation of the Tsau//Khaeb (Sperrgebiet) National Park.

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Extremely arid ecosystems in the western reaches of the basin are counter-intuitively some of the richest with respect to the diversity of species.

Although the area in the basin converted to irrigation (385,321 ha) (ORASECOM, 2011f) may seem relatively small by comparison with the total area of the basin, its impact on the basin's water resources is highly significant. The total amount of water used for irrigation is approximately 3,800 Mm^3 per year, which corresponds to about a third of the basin's total surface water resources.

Three key areas – irrigation, land degradation and invasive alien vegetation are discussed in more detail later in this section.

Land use and economy

While the relationships are not unique, different biomes can be associated with certain land uses, often as a result of inherent advantages and properties. The Highveld Grasslands, for example, are used largely for grazing and arable agriculture, generally under rain-fed conditions. The roles of these grasslands in preventing soil erosion and promoting infiltration are environmentally and hydrologically important, so their pristine condition should be conserved. This is particularly true for the system of grasslands and bogs in the Drakensberg–Maloti Highlands, which are also under pressure and have been degraded through unsustainable farming practices. This biome also supports the most densely populated and highly urbanised areas of the basin – Gauteng and the Witwatersrand.

In the Nama Karoo biome, urbanisation is minimal and agriculture is extensive. Irrigation is confined to the Orange River valley and some pans. Most of the land is used for grazing by sheep (for mutton, wool and pelts) and goats, which can be commensurate with conservation when carrying capacity is respected. Current levels of tourism development are low but there is potential for significant growth based on the presence of transboundary conservation areas and further development of tourism routes.

While much of the Southern Kalahari Savannah vegetation types are used for grazing, mainly by cattle or game, in the southernmost parts of the Kalahari, sheep and goats are the major stock. Urbanisation is not as significant, with centres usually based around economic activity, such as mining and providing services to the agricultural sector. However, rapidly expanding growth points are often under-serviced and are points of localised degradation and of concern.

The Succulent Karoo biome has little agricultural potential due to limited availability of water. The paucity of grasses limits grazing, and low carrying capacity requires extensive supplementary feeds. In a few areas, table and wine grapes, fruit and other crops are cultivated. Tourism is developed to a limited extent with mass spring flower displays a draw card. Mining is important in the north-western areas of this biome.

Barberspan, a 2000-ha expanse of water, is one of the largest bird sanctuaries in South Africa and one of five Ramsar sites in the Orange–Senqu basin. Ramsar sites are wetlands internationally recognised as being important feeding, stopover and breeding sites for migratory birds and waterfowl.

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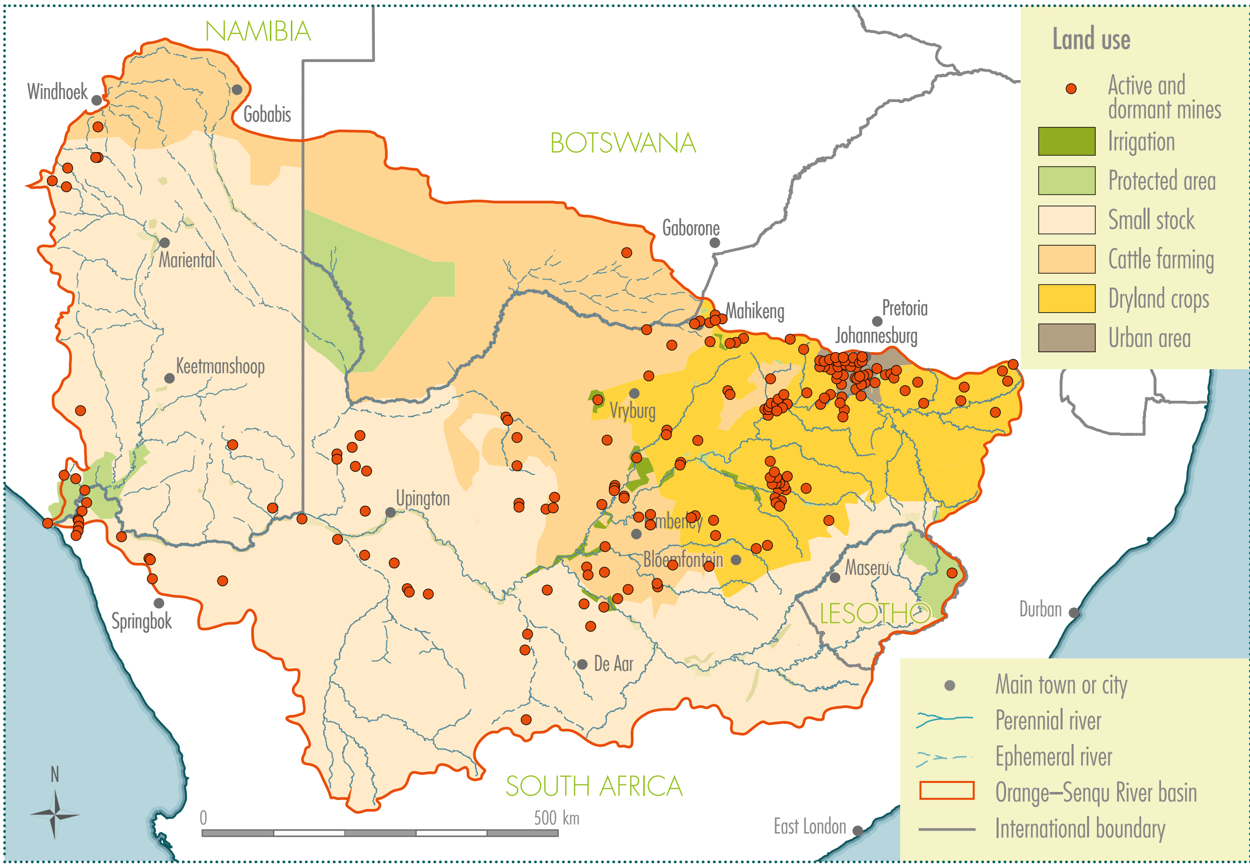

Figure 18: Land use

Mining is economically important in all four basin states, with significant activity in the basin now and in the past (Figure 18). Environmental responsibility of the mining sector, especially of the larger mining concerns, has greatly improved in recent decades, with environmental regulations to tightly control the environmental impacts of these activities. However, decommissioned mines have left a legacy of degradation, which is expensive and difficult to address. At present, implementation of environmental regulations is often limited to larger mining concerns and environmental degradation by small mines is not always sufficiently addressed.

Protected area network

Protected areas play an important role in the conservation of biomes and ecosystems and their function. Within the Orange–Senqu River basin there are a number of national parks – including three transboundary conservation areas – as well as a number of nature reserves, private parks and conservancies. There are also a number of declared Ramsar sites and biodiversity hotspots. Table 15 provides a comprehensive list of protected areas in the Orange–Senqu River basin.

Many of the smaller protected areas are associated with aquatic ecosystems and water supply infrastructure in the basin and play an important role in the conservation of the basin's natural resources. As shown in the Figure 19, there are a few large protected areas, but many are small in comparison to the size of the basin. Large areas of the basin do not fall under formal protection, but some areas are protected by private concessions and parks.

The remote mountainous areas of Lesotho are one of the few places in Africa that the bearded vulture (*Gypaetus barbatus*) is found.

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World heritage sites
1 Maloti-Drakensberg Transfrontier
2 Richtersveld Cultural and Botanical Landscape
3 Vredefort Dome

Transfrontier parks
4 /Ai-/Ais–Richtersveld
5 Kgalagadi
6 Maloti–Drakensberg Conservation Area

National parks
7 Augrabies Falls
8 Golden Gate Highlands
9 Karoo
10 Mokala
11 Sehlabathebe
12 Tsau//Khaeb (Sperrgebiet)
13 Ts'ehlanyane

Nature reserves
14 Abe Bailey
15 Bokong
16 Caledon
17 Gariep
18 Hardap
19 Kalkfontein
20 Koppies Dam
21 Leon Taljaard
22 Maria Moroka
23 Naute
24 Soetdoring
25 Sterkfontein Dam
26 Tussen-die-Riviere
27 Willem Pretorius

Ramsar sites
28 Barberspan
29 Blesbok Spruit
30 Lets'eng-la-Letsie
31 Orange River estuary
32 Seekoeivlei

Figure 19: Main protected areas in the basin

Table 15: Protected areas in the Orange–Senqu River basin*

	Name	Biome	Country	Area (km²)
Ramsar sites				
	Barberspan	Highveld Grasslands, wetland	South Africa	31
	Blesbok Spruit	Highveld Grasslands, wetland	South Africa	19
	Lets'eng-la-Letsie	Drakensberg–Maloti Highlands, wetland	Lesotho	4
	Orange River estuary†	Succulent Karoo, wetland	Namibia	5
	Orange River estuary†	Succulent Karoo, wetland	South Africa	20
	Seekoeivlei Nature Reserve	Highveld Grasslands, wetland	South Africa	48
World heritage sites				
	Maloti–Drakensberg Park	Drakensberg–Maloti Highlands	Lesotho & South Africa	2,493
	Richtersveld Cultural and Botanical Landscape	Succulent Karoo	South Africa	1,600
	Vredefort Dome	geologic interest	South Africa	300
Biodiversity hotspots and centres of endemism				
	Drakensberg–Maloti Ecoregion	Drakensberg–Maloti Highlands	Lesotho & South Africa	
	Succulent Karoo Ecoregion	Succulent Karoo	Namibia & South Africa	
Transfrontier parks				
	/Ai-/Ais–Richtersveld Transfrontier Park	Nama Karoo and Succulent Karoo	South Africa & Namibia	6,045
	Kgalagadi Transfrontier Park	Southern Kalahari Savanna	South Africa & Botswana	37,991
	Maloti-Drakensberg Transfrontier Conservation Area	Drakensberg–Maloti Highlands	South Africa & Lesotho	8,113
National parks				
	Augrabies Falls National Park	Nama Karoo	South Africa	820
	Golden Gate Highlands National Park	Highveld Grasslands	South Africa	340
	Karoo National Park	Nama Karoo	South Africa	768
	Mokala National Park	Nama Karoo	South Africa	196
	Sehlabathebe National Park	Highveld Grasslands	Lesotho	70
	Tsau//Khaeb (Sperrgebiet) National Park	Succulent Karoo	Namibia	26,000
	Ts'ehlanyane National Park	Drakensberg–Maloti Highlands	Lesotho	56
Nature reserves				
	Abe Bailey Nature Reserve	Highveld Grasslands	South Africa	4
	Bokong Nature Reserve	Drakensberg–Maloti Highlands	Lesotho	20
	Caledon Nature Reserve	Highveld Grasslands, wetland	South Africa	23
	Gariep Nature Reserve	Highveld Grasslands, wetland	South Africa	477
	Hardap Recreation Resort	Nama Karoo, wetland	Namibia	252
	Kalkfontein Nature Reserve	Nama Karoo, wetland	South Africa	45
	Koppies Dam Nature Reserve	Highveld Grasslands, wetland	South Africa	34
	Leon Taljaard Nature Reserve	Southern Kalahari Savannah	South Africa	20
	Maria Moroka Nature Reserve	Highveld Grasslands, wetland	South Africa	
	Naute Recreation Resort	Nama Karoo	Namibia	225‡
	Soetdoring Nature Reserve	Highveld Grasslands, wetland	South Africa	75
	Sterkfontein Dam Nature Reserve	Drakensberg–Maloti Highlands, wetland	South Africa	180
	Tussen-die-Riviere Nature Reserve	Highveld Grasslands, wetland	South Africa	220
	Willem Pretorius Game Reserve	Highveld Grasslands, wetland	South Africa	120

*Excludes conservancies and private conservation areas

† Orange River estuary is a declared Ramsar site in both Namibia (August 1995) and South Africa (June 1991). Although a transboundary wetland in that it is an ecologically coherent wetland that extends across the national border, because the authorities on both sides have not formally agreed to collaborate in its management, or notified the Ramsar Secretariat of such intent, it is not considered a 'Transboundary Ramsar Site' (Ramsar 2013).

‡ Currently under expansion; once the boundaries are amended, Naute Recreation Resort will be 345 km².

GONDWANA CAÑON PARK: IMPROVED LAND USE CHANGE

Gondwana Cañon Park in southern Namibia is a privately owned nature park situated in the Nama Karoo just 20 km from the Fish River Canyon covering an area of 1,260 km^2. Rainfall is low (50–100 mm per year on average) and highly variable, and evaporation rates very high (~2,000 mm per year on average). In spite of its very arid climate, the area was used for stock farming for many decades, providing a marginal livelihood for farm owners and their few farmhands. The farmers overgrazed the arid lands, shot wildlife for meat and skins, and poisoned potential predators and, indirectly, scavengers. Over time the land became less productive and the ecosystem less resilient.

After Namibia's independence, tourism to the country increased and alternative land-use options presented themselves. In 1995, 11 farms were purchased to become a private protected area, now known as Gondwana Cañon Park, with the vision of forming a nature park, supporting wildlife and low-impact tourism.

Livestock was removed from the area and wildlife was reintroduced after careful study of what had occurred naturally in the area. This included some species that had become locally extinct as a result of hunting in the 18th and 19th centuries. Water-thirsty orange orchards were removed, as were all invasive alien plants, especially *Prosopis* spp.

A biodiversity and landscape monitoring system shows that biodiversity has increased and land cover in previously severely overgrazed and degraded areas has recovered. These more benign land uses have increased vegetation cover and resulted in less erosion and increased water retention and groundwater recharge. Diesel water pumps were replaced by solar pumps. Wildlife, better suited to local conditions, requires less water than livestock.

The current land use is not only more suitable to the arid conditions of the area than farming, but is almost 50 times more profitable (Barnes and Humavindu, 2003). Tourism has been introduced and a number of job and career opportunities have been created.

By removing internal fences to recreate open landscapes, wildlife is given mobility to find patched water and food resources. Neighbouring land owners and custodians are joining in to expand this concept. Fences are being removed along common boundaries creating large landscapes where wildlife can resume their historic movement patterns in response to rainfall.

Canyon Lodge – just one of the tourist lodges in Gondwana Cañon Park

2.3.2 Land ownership

Land ownership issues are strongly related to land degradation and frequently stand in the way of sustainable land management and development in rural areas. These issues include the lack of land tenure rights, limited management control over natural resources and either a lack of, or a failure to implement, appropriate rural development and agriculture policies.

Many of the underlying causes relate to the fact that policies and practices, which were perhaps appropriate many decades or more ago, are no longer applicable as a result of increased population pressure on the land. The best and most challenging example of this is the farming and land management practices on communal land. Some of the worst levels of poverty and land degradation are to be found on communal land where subsistence farming is practised. Subsistence farming in these areas is arguably a broken system and the communal lands are increasingly becoming the home of the poorest people in the basin.

As population pressure increases, subsistence farmers are driven to poor land management practices.

The major part of freehold land in the basin is used for commercial livestock farming. This activity was heavily subsidised in the past with the result that stock farming was deemed economically viable in these marginal, semi-arid areas. In the southern areas of Namibia, for example, there are many farms where livestock subsidies led to overstocking. The benefits of this policy were short-term and unsustainable and left a legacy of land degradation. In many cases it has become clear that large tracts of land are simply not suitable for farming at all.

A certain amount of freehold land on the banks of and close to the Orange River and its tributaries in South Africa and Namibia is used for irrigation. Although the price of water is subsidised, these farms, if run efficiently, can be both economically and environmentally sustainable.

On the Hardap Irrigation Scheme in Namibia the land is privately owned by farmers, while on the Orange River it is a mix of freehold and government-owned land. The irrigation sector is examined in more detail below.

Socio-economic linkages

It is becoming increasingly evident that for many areas the biggest threat to the terrestrial and aquatic environments is poverty and lack of development rather than development itself. In the past, while population densities remained within certain limits, traditional farming practices and livelihoods coexisted with the environment in a relatively stable way. However, it is now increasingly clear that in many of the most degraded parts of the basin, the two most important driving forces of land degradation are limited land resources and population increase. The result is small farms or more limited access to smaller areas of communal land, low production per person and increasing landlessness. A consequence of land shortage is poverty.

A shortage of land and associated resources leads to non-sustainable land management practices, the direct causes of degradation. Poor farmers are driven to cut trees, cultivate steep slopes without conservation, overgraze rangelands and make unbalanced fertiliser applications. In many cases, the biomass residue that should be used for fertilisation is used as fuel instead, for want of an affordable alternative.

Any solution to land degradation requires a solution to the basic socio-economic development challenges that define poverty in the worst-hit areas. It is difficult to see how the poverty-stricken can escape the cycle, and clearly government intervention is necessary to help create alternative off-farm livelihoods and/or to organise and encourage rational urbanisation, which will ultimately make the provision of social services less costly.


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COMMUNAL LAND TENURE AND SUBSISTENCE FARMING – A BROKEN SYSTEM?

In the Orange–Senqu basin, communal land is generally home to people leading subsistence lifestyles because of both a lack of employment and a natural continuation of traditional agricultural practices and livelihoods. However, many components of the original subsistence system would appear to have broken down. In the past, in this virtually cashless system, resources such as fuel, housing materials, even medicines and of course food, were 'freely' available for everyone. This is no longer true. Resources are so limited that people either have to look far to find them or they have to buy them from merchants. Even when resources are harvested locally, this occurs in an increasingly unsustainable manner.

The basic problem in these areas is that the rural population has become too large for the resources available. However, proven and effective strategies for improving livelihoods in subsistence farming areas do exist, but require both the acceptance and cooperation of the potential beneficiaries. This is a real challenge where land and responsibility is communally owned. It is difficult to introduce, control and manage a more sustainable form of subsistence farming. Having these strategies accepted and applied, however, is the critical first step towards reversing both poverty and environmental degradation in these areas. Without it, as people become increasingly poor, day-to-day solutions that have a price tag for the beneficiary, such as rural electrification to replace fuel wood, become increasingly unaffordable.

The little revenue that people have has to be spent on essentials that should be freely available from the subsistence system, instead of supporting farm operation and maintenance, education and health. Sustainability strategies for subsistence farming can only provide part of the solution. The creation of off-farm activities and the development of urban nodes are essential, but also a challenge in communal areas. Entrepreneurs and investors could play a major role in the provision of employment and improved livelihoods but hesitate to invest when they can't have security of land tenure.

2.3.3 Irrigated agriculture

The extreme range of climatic conditions has resulted in a wide variety of crop types being grown across the basin under both rain-fed conditions and irrigation. In the more temperate north-eastern sections of the catchment, rain-fed crop production occurs widely and is interspersed with irrigated cropping. In these sectors, mixed cropping with field crops such as maize, wheat, potatoes, groundnuts, cotton, soybeans and dry-beans takes place, while the main fodder crops are lucerne, maize-silage and pastures. Limited areas of orchard produce fruit, such as cherries, apples and peaches, in the high altitude areas with adequate winter chill.

Moving westwards, crop production becomes more dependent on irrigation, especially where rainfall is very low or variable. These irrigated areas support permanent orchard and vine crops, such as table, raisin and wine grapes, citrus and dates. Lucerne is also a common crop in the dryer western areas.

Most irrigation in the basin takes place in South Africa. However, in recent years there has been a rapid growth in irrigation on the Namibian side of the lower Orange River, especially in the cultivation of high-value crops such as table grapes and dates.

There have been a number of irrigation initiatives in Lesotho and these continue with a view to increasing food security, but at present and for the foreseeable future use a minimal amount of water. Estimates of the area under irrigation in Lesotho vary between a few hundred hectares and 2,200 ha. There is no significant irrigation in the Botswana part of the basin.

Almost all the irrigation schemes were originally built and managed by government. It is only in recent years, especially with the formation of water-user associations (WUA) in South Africa and Namibia, that operations and management are being privatised. Although many of these associations are still in their infancy or yet to be formed, a positive impact on water management and improved efficiency is already emerging, especially where the water-user association is well-managed.

Most of this irrigation occurs on commercial farms with freehold tenure. The average size of irrigated area per farming unit is about 50 ha. However, there are many farms with larger irrigated areas where consolidation of irrigation units under one owner has taken place, in order to maintain or improve financial viability. This consolidation can, in general, be equated to an improved level of farming efficiency which usually includes better irrigation efficiency as well. A programme to introduce and develop resource-poor farmers on smallholder irrigation schemes is intensifying, but these areas make up only about 10% of total irrigated areas.

Areas under irrigation

Major expansion of the irrigation sector in the basin started in the 1930s and continued for several decades. A number of large-scale schemes using flows supplied from large dams (Gariep and Vanderkloof) were established in the South African part of the Orange–Senqu River basin. These included a transboundary

Along the banks of the Orange River, roughly 100 kilometres inland from where the river empties into the Atlantic Ocean, irrigation projects at Aussenkehr in Namibia take advantage of water from the river to grow grapes. Rainfall alone could not support such farming in this area, which receives less than 50 mm of rain a year, on average. Aussenkehr is emerald green.

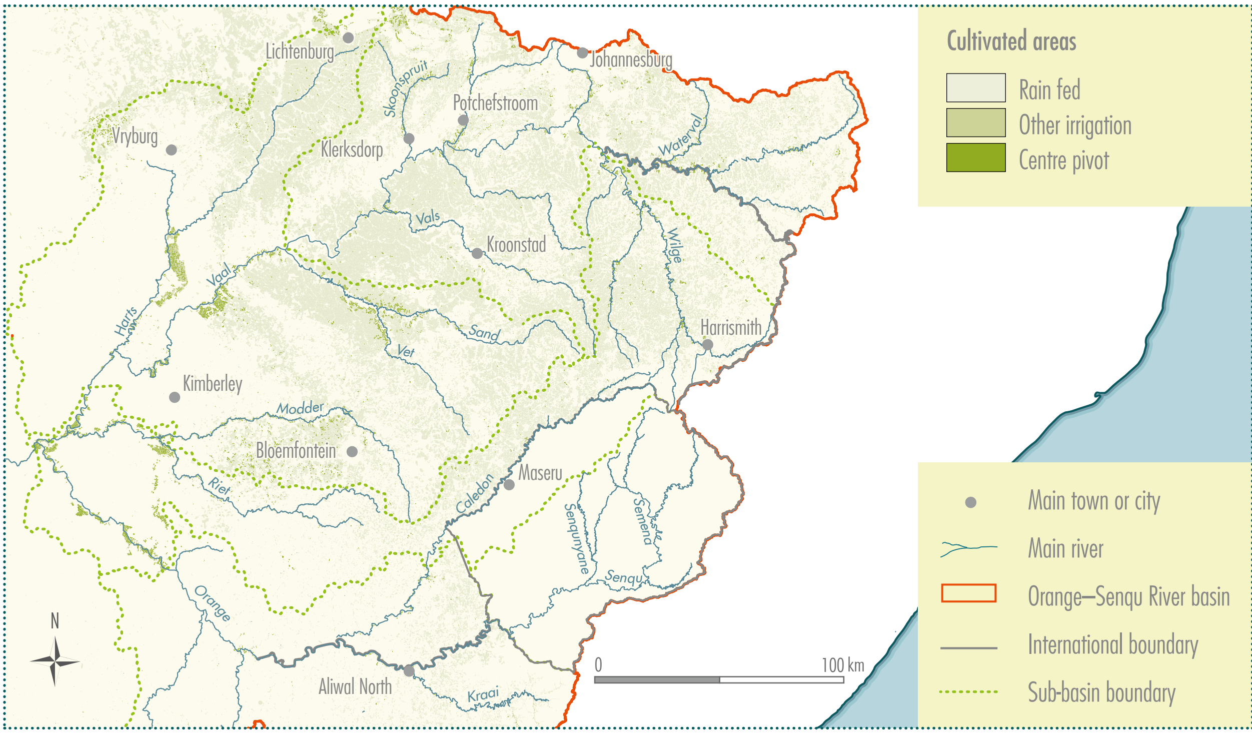


Figure 20: Cultivated areas in the upper Vaal and Orange–Senqu sub-basins. Much of the highveld grassland area is under cultivation. Information on areas in Lesotho under rain-fed cultivation was not available.

Figure 21: Much of the riparian belt along the lower Orange River is under irrigation

scheme at Vioolsdrift and Noordoewer. In 1961, the Hardap Scheme was built on the Fish River in Namibia, mainly with the purpose of irrigation. These were large-scale schemes usually including dams and a network of canals taking water to 'farm edge'.

As part of a recent study carried out on behalf of ORASECOM, the area under irrigation within the basin was estimated, using a combination of available data and the feature mapping of satellite imagery. The total area under irrigation was estimated at 385,321 ha, considerably higher than previous estimates (ORASECOM, 2011f). The higher figure could, in large part, be ascribed to an increase in illegal unlicensed irrigation operations. The net water consumption is estimated at around 3,813 Mm^3 per year or about 34% of the natural mean annual runoff of the Orange–Senqu River system.

Figures 20 and 21 show areas under both rain-fed and irrigated agriculture in the upper and lower parts of the Orange–Senqu basin. In Figure 20 it is clear that very little rain-fed agriculture is possible to the west of a line drawn approximately through Bloemfontein and Wynburg. Predictions on climate change indicate that this line is moving eastwards.

Furrow irrigation

Types of schemes

Much of the basin's irrigation is characterised by a highly sophisticated network of water storage and conveyance infrastructure serving a large number of formal irrigation schemes.

In the case of the Vaal sub-basin, water is allocated to these schemes from over 20 government-controlled dams (including the Vaal and Bloemhof, through to minor dams and weirs) and is distributed to irrigators via canals, pipelines, balancing dams and pumping systems. There is a significant amount of uncontrolled (diffuse) irrigation from the Vaal River and its tributaries and from private farm dams.

In the Orange River portion of the catchment, irrigation water distribution is controlled from the Gariep and the Vanderkloof dams and a number of weir and canal systems along the Orange River. The Vanderkloof canal, which runs for over 100 km from Vanderkloof Dam, is a major artery that supplies high-quality Orange River water to a water-stressed central region of the basin.

Distribution to farmers within schemes is mainly by means of calibrated sluice gates, while in-line flow meters with telemetry are used in some schemes in the central region of the basin. The irrigation distribution infrastructure, particularly the lined open canals, is aging and requires widespread rehabilitation. There are a few exceptions such as the Kakamas WUA where a comprehensive upgrade of bulk infrastructure has taken place.

Centre-pivot irrigation now makes up about 80% of all irrigation systems in the catchment and micro-jet and drip irrigation systems are dominant in orchard and vine crops. Flood irrigation is still practised widely in the basin, particularly on the lower Orange areas such as Boegoeberg, Upington and Kakamas.

It is important to note that the majority of farmers irrigate on the basis of an allocation of irrigation water per hectare and that technical irrigation scheduling is the exception rather than the rule. These are both aspects that are of critical relevance to water conservation and water demand management in the irrigation sector.

Crops

Relatively low-value field crops, such as maize and wheat, and fodder crops, such as lucerne, make up over 80% of irrigated crops in the basin. Higher value field

© John Pallett

Micro-spraying below the canopy of the vineyard

crops, such as potatoes, vegetables and certain annual fruit crops such as sweet melon, make up only about 10%. The low percentage of higher value and more water efficient crops is determined by a number of key factors:

- lack of assurance of irrigation water supply means that farmers are hesitant to convert to capital-intensive permanent crops that do not allow any form of flexibility in times when water allocation cuts may be necessary;
- the present (low) cost of water usually allows farmers to farm profitably using annual field crops, provided management is good;
- high capital cost of establishing orchard and vine crops;
- high-value orchard and vine crops have to be export-orientated for financial viability – a deterrent to farmers in a climate of fluctuating exchange rates;
- high level of management intensity and substantial financial resources and technical skills;
- climatic risks related to floods and droughts;
- deteriorating water quality has become a major concern, particularly in the Vaal River system, and especially for highly sensitive crops such as citrus.

Despite the challenges, there are areas where rapid evolution to intensive and water-efficient irrigation is taking place in the basin. In the Namibian portion of the catchment, where expansion has been more recent, more than half the area under irrigation is dedicated to table grapes and other high-value crops, including dates. Looking at the lower Orange irrigation area from Boegoeberg Dam to Vioolsdrift as another example, the table grape and raisin industry has blossomed on the basis of favourable climatic conditions, relatively high assurance of water supply and the development of sophisticated agri-business operators.

In addition, as the industry expands onto higher-lying previously non-arable ground away from the river, soaring pumping costs have become a significant component of crop production costs. This has led to ever-increasing irrigation efficiency through sophisticated irrigation scheduling.

An economic analysis of crops grown in the basin was undertaken as part of a recent study (Rutherford et al., 2011) carried out for ORASECOM. The analysis was applied to three agro-economic regions, which are broadly described as the eastern, central and western parts of the basin. Gross margins were calculated, representing income from the sale of the produce less all direct costs that can be allocated to production of the specific crop.

The gross margins were based on an average of top producing farmers in the area in an attempt to be representative of typical best practice farming operations in the region. In reality, the management practices among farmers differ substantially, which results in a wide disparity in actual income and production cost of enterprises. The gross margin analysis showed that the crops with the highest net returns per hectare are table grapes, melons and raisins.

Irrigated agriculture and water demand

For years, irrigation has been seen by many as the biggest culprit of inefficient water use. The sector is often viewed as abusing the huge quantities of water provided for it at subsidised rates. While wastage has been and continues to be an issue, the role that irrigation plays in providing employment and food security is often overlooked. The recent ORASECOM study (2011f) showed that while there is still a long way to go, there has been significant improvement in the performance of the sector in recent years. This can be ascribed to new laws and policies and their gradual implementation, increasing electricity costs and an increased level of awareness among farmers.

Changes in the organisational and institutional structure of the water sector in South Africa over the past 15 years have had a significant effect on irrigation within the basin.

Legislation and irrigation

South Africa's Water Act (Act 36 of 1998) provides for a fundamental reform of water resources legislation, for the conservation of a scarce resource and the equitable allocation of water for beneficial use.

Most relevant to the management of the irrigation sector are the catchment management agencies (CMAs) and water-user associations (WUAs). The CMAs are statutory bodies established under the Act to manage water resources within its water management area (WMA). Irrigation schemes fall under government water schemes, irrigation boards or WUAs with the goal that they should all become WUAs over time (Table 40).

A WUA is a cooperative association of water users who wish to undertake water-related activities for their mutual benefit. A WUA has to accommodate all water sectors within their area of jurisdiction. The broad role of a WUA is to enable people within a community to pool their resources to more effectively carry out water-related activities. Members will thus benefit from addressing local needs and priorities.

The Act requires that water conservation and water demand management be driven primarily by WUAs. These are, in turn, required to submit annual business plans to a CMA, or the Department of Water Affairs in the absence of a CMA. The business plans are required to include a water management plan.

The importance of these water management plans cannot be overstated. They set out benchmarks and best management practices for water conservation and water demand management, and a manageable and affordable programme for their implementation by both the WUA and their irrigators over time. A water management plan is therefore the primary tool with which the agricultural sector is expected to implement South Africa's National Water Conservation and Demand Management Strategy.

This approach places the responsibility of water conservation squarely in the hands of the water distributors and their water users and is aligned to three important global trends in water resource management:

- integrated water resources management within catchment boundaries;
- decentralised management, operation and maintenance of water delivery;
- improved management of existing water resources to promote water use efficiency and water conservation.

Normal flood irrigation still predominates in many irrigation schemes, especially along the lower Orange River. Some farmers are laser-levelling their fields to make flood irrigation more water efficient.

SOUTH AFRICAN WATER ACT (1998) – KEY POINTS FOR IRRIGATION

The current South African water legislation documents a number of policies relevant to the irrigation sector. These include:

- a new water allocation system to prioritise stressed areas, to use water pricing and limited-term allocations to balance supply and demand;
- water allocations will no longer be permanent, but will be given for a reasonable period, and provision will be made to enable the transfer or trade of these rights between users;
- to promote the efficient use of water, the policy will be to charge users for the full financial costs of providing access to water, including infrastructure development and catchment management activities;
- all water use will be subject to a catchment management charge which will cover actual costs incurred to property and infrastructure, and siltation;
- to promote equitable access to water for disadvantaged groups for productive purposes such as agriculture, some or all of these charges may be waived for a determined grace period;
- all major water use sectors must develop a water use, conservation and protection policy;
- regulations will be introduced to ensure compliance with the policy in key areas.

In the Namibian part of the basin the formation of WUAs are envisaged under the new Water Resources Management Act of 2013. This new legislation will implement many of the same principles that are being applied in the irrigation sector in South Africa. This policy was promoted, even before the Act was passed, with the establishment of basin management committees in Namibia's portion of the Orange–Senqu basin.

The Hardap Irrigation Scheme, although still reporting unacceptably high application rates, has recently started implementing the volumetric measurement of water delivered to each farmer, and billing accordingly. This will encourage the generalisation of best management practices, such as laser levelling of flood irrigated areas.

Future trends

The following future trends seem likely:

- Continued moves toward the cultivation of high-value crops, especially in the western, drier part of the basin where there is a relative advantage for growing and marketing such crops. This will probably be accompanied by a continued expansion of irrigated areas of these crops, using previously non-arable land further away from the river, and highly efficient, modern irrigation techniques using 'saved' water.
- Increasing levels of technology and automisation of farms growing cereals in the middle and middle upper part of the basin. Increased levels of commercialisation and reduction in labour force in order to improve levels of productivity and maintain profitability. Continued consolidation of farms as less-efficient farmers are bought out.
- Increased share of the commercial irrigation sector by previously disadvantaged and food-insecure farmers and challenge of their integration into this increasingly specialised and technical part of the farming sector.
- Continued move away from irrigation as an agricultural activity to one of a business activity.
- Continued gradual improvement in irrigation efficiencies encouraged by policy and economic realities.

Temperature, humidity and ventilation can be controlled in a polytunnel using various equipment.

IMPROVING WATER MANAGEMENT IN IRRIGATION: PILOTING PRACTICES ACROSS BOUNDARIES


© Francois du Plessis

The Noordoewer–Vioolsdrift Irrigation Scheme straddles the border between Namibia and South Africa on the lower Orange River. It was built at the time of the Great Depression in the 1930s, when Namibia and South Africa were both administered under the South African Government, to create work and stimulate the economy. Today the scheme is managed by the Noordoewer–Vioolsdrift Joint Irrigation Authority (JIA), which was established through a bilateral agreement between Namibia and South Africa in 1992 shortly after Namibia's independence. The JIA consists of eight board members – three irrigators and a government official from each country – and a small maintenance team. The JIA operates and maintains the canal and inverted siphon distribution system using its own funds.

Farmland situated on both sides of the river is privately owned. Over the years the many small farms (originally 5–7 ha) have been consolidated into larger farms (50 ha in South Africa and 71 ha in Namibia, on average) belonging to fewer farmers (12 in South Africa and four in Namibia). Collectively, they grow vegetables, fodder crops and fruit under various irrigation methods (see table below).

Table 16: Area of land under various crops and irrigation methods

Crops	Area (ha)										Total
	Flood	Drip			Micro			Drip & micro	Centre pivot	Sprinkler	
	Open	Tunnel	Shade	Open	Tunnel	Shade	Open	Shade	Open	Open	
Grapes	0	0	0	5.1	0	0	76.9	0	0	0	**82.0**
Dates	1.0	0	0	0	0	0	0	0	0	0	**1.0**
Pomegranates	0	0	0	0	0	0	19.0	0	0	0	**19.0**
Mango	24.3	0	0	0	0	0	0.4	0	0	0	**24.7**
Citrus	0	0	0	0	0	0	1.6	0	0	0	**1.6**
Fodder crops	223.6	0	0	0	0	0	0	0	0	4.3	**227.9**
Vegetables	141.6	4.5	27.5	172.9	3.2	0	0	15.0	42.0	2.6	**409.3**
Total	**390.5**	**4.5**	**27.5**	**178.0**	**3.2**	**0**	**97.9**	**15.0**	**42.0**	**6.9**	**765.5**

Source: Du Plessis (2013)

The UNDP–GEF-funded Orange–Senqu Strategic Action Programme is implementing a project with the JIA to demonstrate how practices, methods, tools and devices, and knowledge and information can contribute to improved water-use efficiency and pollution control in the irrigation sector. Working at both the institutional and farm level, the project shows the importance of measuring different variables in helping farmers make informed decisions for efficient farming. These measurements include:

- atmospheric demand
- soil moisture
- pump flow and energy
- irrigation system efficiency
- canal flow and take-off
- water quality.

The compilation of a water management plan for the JIA is an important component of the project. It will be used by the JIA as a basis implementing strategies to improve the scheme's water efficiency in the future.

Outcomes from the project so far support experience that irrigation efficiencies can be improved significantly when equipped with better information from measurements, training and information transfer. However, it also emphasises the importance of extension and support services, especially in a remote region such as this. The importance of clearer policies regarding incentives for the farmer to invest towards improved system efficiencies is also relevant.

BEST MANAGEMENT PRACTICES: THE ORANGE-RIET WATER USER ASSOCIATION

This water-user association (WUA) was formed on 15 September 2000 and manages 17,050 ha. The WUA operates and maintains the main canal from the Vanderkloof Dam and the Orange-Riet Canal and pump stations. A number of best practices are demonstrated by this WUA:

- All staff members have a sense of awareness of the importance of efficient irrigation water management and conservation.
- The team maintains a high level of service to irrigators and good control of overall water distribution by means of a computerised telemetry system integrated through all levels of water management from bulk flow measurement to the invoicing of irrigators for water used.
- Volumes of water used are measured using water meters purchased by the farmer and belonging to him. Volumetric measurement allows the WUA to operate a 'water bank' for the sale of unused water rights – a huge incentive for efficient water use.
- WUA has a clear set of regulations including, for example:
  - irrigators' responsibilities for setting their own sluices
  - water may be transferred from one property through a rigorous process
  - strict regulations on unlawful abstractions
  - year planner to be supplied by each farmer and record of all crops grown.
- The WUA prepares an annual water management plan which allows for a systematic and practically achievable improvement in water management and water-use efficiency.
- All sluices are measured at the outlet. A record is kept of every irrigator's requests and receipts.
- The WUA prepares an annual disposal report, an annual water accounting report and specific performance indicators.
- Unlawful use of water is monitored using a spot-check system, reported shortages in the canal, telemetric measurement and comparison with benchmark crop water-use figures.

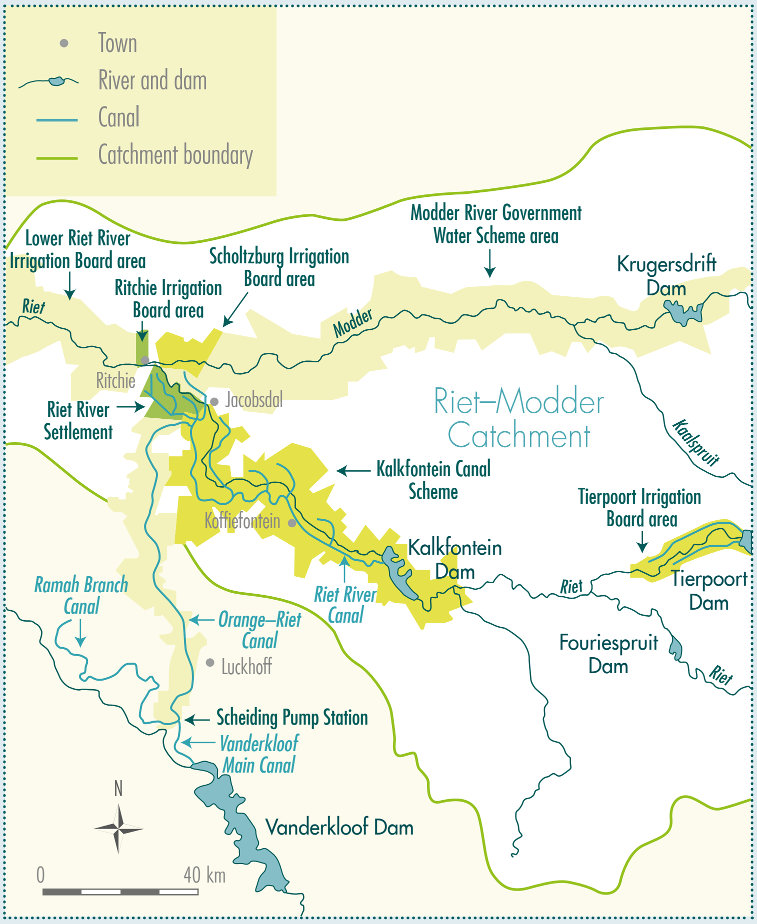


Figure 22: Riet River Government Water Scheme (adapted from ORASECOM, 2007a)

2.3.4 Land degradation

While land degradation is taking place throughout the basin, the degradation of the river's headwaters deserves special attention in view of the close linkages between the terrestrial and aquatic environments in these areas. Degradation of the terrestrial environment in these areas translates rapidly into degradation of the aquatic environment all the way downstream. Localised issues of degradation rapidly turn into transboundary water issues with impacts on both the environment and users.

Largely anthropogenic pressures have inevitably led to major changes to the terrestrial environment. Rapid population growth has led to urbanisation, the intensification of agricultural production and industrialisation in order to meet the demand for food, energy and other commodities, as well as to alleviate poverty and improve standards of living. The increase in the mobility of the basin's residents, as well as those outside it, has resulted in the introduction of many non-native or alien vegetation species. In many cases they have become invasive, competing successfully with the indigenous natural vegetation.

The main transboundary impacts of land degradation relate to changes to the hydrological regime. In particular, increased levels of soil erosion, reduced infiltration and loss of wetland storage are translated into reduced base flow, increased levels of flooding and higher sediment loads. Local impacts on productivity and livelihoods can be devastating. At a time when increasing numbers of people are faced with dividing up the land resource pie into even smaller pieces, they are also faced with the fact that what is left is also less productive.

Soil erosion reduces wetland storage and reduces base flow of the river.

Degradation of headwaters and Lesotho rangelands

In Lesotho, where the headwaters of the river system are found, the natural ecosystems and habitats are over-exploited and over-utilised. Overgrazing of the rangelands, mismanagement of sensitive ecological systems, over-harvesting of medicinal plants, and poor agricultural practices such as ploughing on marginal and sloping lands are just some of the activities leading to loss of biodiversity.

The root cause of biodiversity loss however, is that a rapidly increasing rural population puts greater demands on finite biological resources. Matters are complicated by a land tenure system that effectively gives everybody the right of access to land. Less than 10% of Lesotho can be classified as arable, around 70% can be classified as rangeland and 20% as 'inaccessible or eroded'.

Causes of biodiversity loss in Lesotho are both proximate and fundamental. Most of the population of Lesotho resides in the less mountainous western area of the country. In this area, competition for limited land resources is intense, soil erosion is widespread, and care for the land and its resources is poor. Ninety per cent of household energy needs for cooking and heating are derived from biomass in the form of fuel wood, which is obtained from woody shrubs, and from dung and crop residue in the form of maize stover.

Peat is collected and dried and used as a source of fuel in Lesotho

The uses and benefits of wetlands have been studied in detail. Most importantly, they are used for grazing livestock. However, there are numerous other benefits, with many of the wetland plants supporting livelihoods in a number of ways, as summarised in Table 17.

The high-altitude wetland of Lets'eng-la-Letsie is Lesotho's only Ramsar site.

The ice rat (*Otomys sloggetti robertsi*) has become prolific in wetland areas that are drying; they degrade the peatlands with their extensive burrows.

Table 17: Uses of wetland plants in Lesotho

Local name	Scientific name	Use
Moseha	*Merxmuellera drakensbergensis*	handicrafts (hats, brooms, baskets), ropes, roofing, fodder
Loli	*Scirpus ficinoides*	handicrafts (hats, mats, beer strainers, traditional tray)
Koena	*Mentha aquatica*	medicinal (colds and flu)
Khamakhame	*Rumex lanceolatus*	medicinal (livestock indigestion and constipation)
Rororo	*Juncus glaucus*	roofing, fencing, handicrafts, ropes and fodder
Lesuoane	*Carex cognate*	handicrafts, fodder
Thita-poho	*Fingerhuthia sesleriiformis*	handicrafts (strong brooms)
Tihapi	*Ranunculus multifidus*	medicinal (toothache and septic wounds)
Qobo	*Gunnera perpensa*	medicinal

Source: CEM, undated

Traditionally, grassland conservation was supported by the transhumance of the livestock sector, which would involve moving cattle from the lowlands to the highland areas during the summer and then back to the lowlands in the winter. These summer grazing rights are obtained from the principal chiefs. While this was the practice in the past, it was reported that these days many cattle graze in the highland areas all year round, resulting in overgrazing and damage to the wetland areas. To a large extent the grazing control system has broken down with only 3% of livestock grazing with permits.

The result is decreased vegetation cover, especially within the degraded patches, where there is serious gully erosion, deposition of sediment that destroys the vegetation, and reduced numbers of fish. Because of the eroded patches in the wetlands and associated gullies, the wetlands' morphology is altered. Desiccation of the wetlands means that the water table becomes lower, which encourages encroachment of ice rats (*Otomys sloggetti robertsi*) into the wetland area.

The eastern alpine areas of Lesotho support a network of unique high-altitude bogs and sponges, a system of wetlands found nowhere else in the world (Figure 23). These high altitude wetland systems include hydrophilous, aquatic and semi-aquatic communities, with a high proportion of endemic species. Important wetlands (sometimes referred to as 'sponges') in the alpine areas are also under threat. Livestock trampling and the activities of ice rats, whose numbers have increased as a result of a reduction of natural predators, affect the rates of erosion and water storage, and increase sediment load in the streams that the wetlands feed.

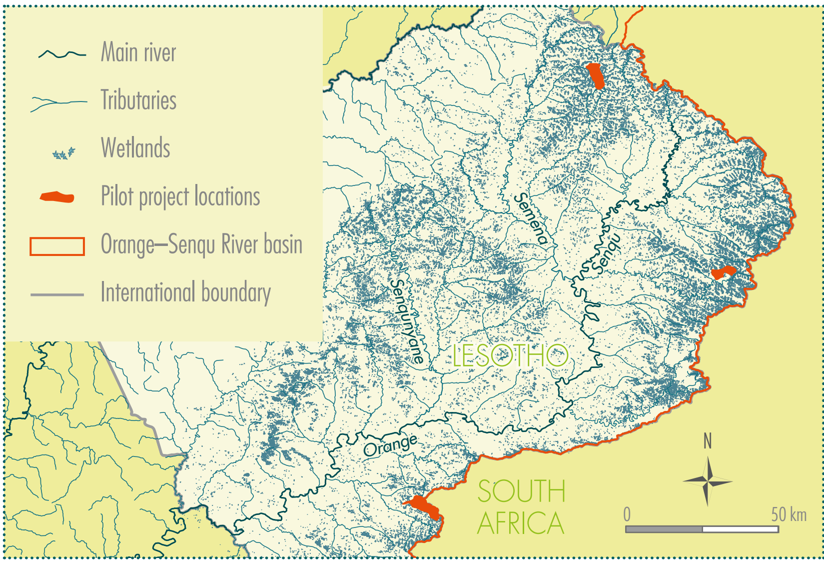


Figure 23: An image showing thousands of wetland sponges feeding the tributaries of the Senqu River in Lesotho

The wetlands of the mountain grasslands are important because of the many critical functions that they perform, including:
- climate regulation – carbon cycling
- absorption of contaminants
- flood control and soil stabilisation
- supporting high levels of genetic and biological diversity
- provision of a critical refuge and breeding ground for many species
- maintenance of groundwater levels
- water purification (particularly in settlement and agricultural areas).

Degradation of the wetlands has a negative impact on the wetlands' ability to fulfil these important functions. In the last few decades, large tracts of the rangelands of Lesotho have been degraded to levels of non-recovery through overgrazing, as a result, in large part, of overstocking. Overgrazing of the rangelands has led to a decrease in diversity of species and invasion of non-palatable species, although this is not as yet widespread.

With the degradation of the rangelands, there is an accompanying invasion of Karoo species such as *Chrysocoma ciliata*. While this invasion is still relatively limited, these shrubs are now being observed in areas where they were not previously known. Although *Chrysocoma ciliata* provides groundcover against rain-induced soil erosion, it is an indicator of deterioration of the rangelands, loss of useful biological components and a sign of increasing desertification.

The wetland systems play a crucial role in the hydrological cycle. Because they retain and slowly release water, these high altitude wetlands assist in flow regulation, attenuating floods, assuring a healthy base flow, reducing sedimentation loads and improving the absorption of nutrients.

The impacts of degradation can best be described and understood through an examination of the vicious cycle of negative impacts causing the degradation of the wetlands, especially of the soils.
- Degradation of organic carbon is taking place as a result of the shorter duration of water-logged conditions which are caused by erosion.
- Organic carbon degradation leads to soil structure degradation, which results in poor soil quality.
- Dry and pulverised soil particles cannot absorb water, which increases the erodibility of the soils.
- Eventually severe erosion takes place, which affects the hydrology of the wetland, which in turn stimulates mole and ice rat activities. Ice rat tunnels, as well as the trampling impact of the domestic animals, contributes to the erosion.
- The desiccation of the organic rich soils puts the wetland plants, which are hydrophytes, under severe stress. Reduced growth, photosynthetic activity and reproduction cause these plants to disappear.
- In turn, the peat soil becomes exposed, erosion starts and the cycle continues.

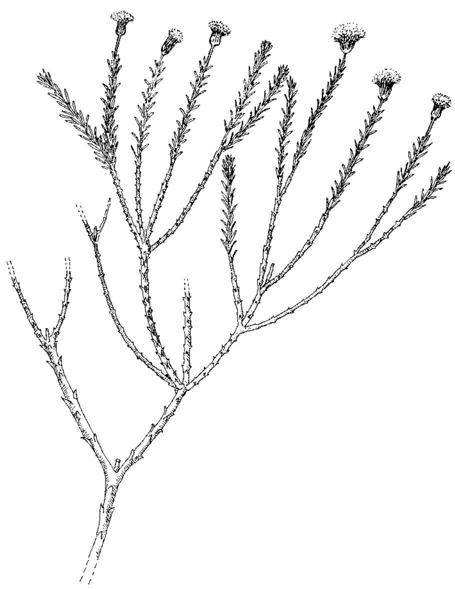
It is the storage capacity of the soils that ultimately defines the health of the wetlands and the grasslands that drain into them.

Before considering potential remedial actions it is useful to summarise the interaction of the driving forces, pressures, changes to the state of the environment using an adapted DPSIR (drivers of change – pressures – state of the environment – impact – responses) framework, as illustrated in Figure 24.

The Wetlands Restoration and Conservation Programme, started in 2008 supported by the Millenium Challenge Account, is an initiative intended to identify measures of improving watershed management to revitalise livelihoods by enhancing economic wellbeing and alleviating widespread poverty within the rural mountain areas. It also aims to devise mechanisms for curbing widespread

Lets'eng-la-Letsie, although a Ramsar site, is also a popular area for grazing livestock.

Chrysocoma ciliata (bitterbos) established on otherwise denuded sands



Bitterbos, *Chrysocoma ciliata*.
Drawn by R Holcroft ©, first published in Killick, 1983

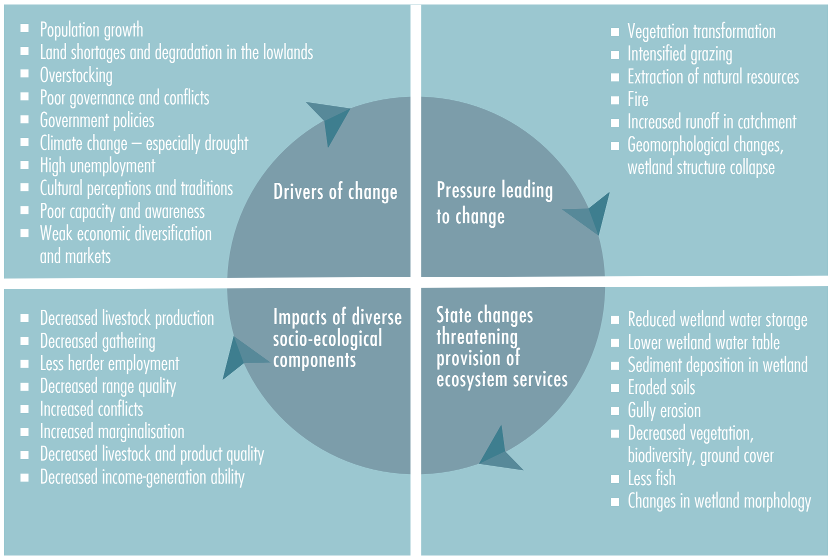


Figure 24: Drivers, pressures, changes of state and impacts of land degradation in the headwaters, Lesotho

overgrazing and degradation of the alpine grasslands and associated wetlands. While it is implemented locally, the benefits are potentially transboundary.

Appropriate institutional organisation is essential and it is recognised that there is a need for managed-resource committees to be established. A grazing plan, based on re-established range management areas according to catchment committee boundaries and the responsibilities of chiefs and catchment committees, also needs to be implemented. A lot of work still has to be done for this to become general practice but the principles are in place and the approach has been shown to be workable. Once successfully implemented this approach would result in:

- resource committees and capacitated herders, livestock owners, grazing associations, catchment committees and chiefs, who would manage rangelands in a sustainable manner;
- district administration support of sustainable land-use planning and capacity-building for effective livestock and range management;
- implementation by the catchment committees in cooperation with the principal chief, livestock owners and grazing associations;
- improved livelihood for the population in the catchment based on sustainable range management.

While there are various instruments in place aimed at ensuring proper management, including policies, institutions, planning and monitoring mechanisms, there are areas of action that need attention if the future sustainability of wetland functions is to be assured. These include:

- technical measures combining expertise with erosion-curbing structures and physical rehabilitation/restoration structures;
- capacity-building and strengthening of herders and grazing associations;
- participatory planning and monitoring of wetland conditions, watersheds and rangelands;
- enforcement of legal instruments.

The last of these points is really critical and a major challenge. Much higher advocacy levels are required with stricter enforcement being an absolute necessity. Indeed, completely new enforcement measures need to be considered and financial resources made available to support them. The fact that more than 90% of grazing in some places is taking place without a permit is indicative of how uncontrolled the situation has become.

LAND REHABILITATION EFFORTS IN LESOTHO SHOW PROMISING RESULTS

In Lesotho, the catchment of the Senqu contributes nearly half the Orange–Senqu basin's surface runoff. Overgrazing on the steep slopes in Lesotho's mountainous highlands causes degradation of the vegetation, reduction in the water-retaining capacity of the highland's wetlands ('sponges'), loss of biodiversity, and large-scale erosion.

Remedying unsustainable management practices is a crucial step in improving conditions. A demonstration project under the UNDP–GEF Orange–Senqu Strategic Action Programme empowers local communities to address landscape degradation by implementing locally designed measures. Launched in 2011 and implemented by Serumula Development Association, a Lesotho non-governmental organisation, this project builds on indigenous knowledge and understanding of the challenges at hand and the importance of rangelands in traditional culture, while expanding alternative economic opportunities for the communities involved.

The project works with four village communities near Mount Moorosi, Quthing District, who rely primarily on livestock and livestock products for their livelihoods. The aim is to rehabilitate rangeland and introduce alternative livelihood options.

Local communities were mobilised to actively assist in uprooting invasive shrubs (mainly *Chrysocoma ciliata*), to build erosion-control structures (stone-packs and gabions) along badly eroded slopes, and to reseed cleared areas and other degraded sites with *Eragrostis curvula* (weeping lovegrass). Through hands-on activities, community members learnt how to rehabilitate degraded rangelands, and the importance of managed grazing.

Although improvements in rangeland conditions take time and need to be monitored, positive changes were noticeable within a couple of seasons. The impacts of reseeding *Eragrostis curvula* are encouraging, with good establishment of the grass reported in some areas. Monitoring of this as well as the natural establishment of grasses in areas cleared of shrubs is ongoing. The current practice of using purchased *Eragrostis curvula* seed is practically viable, however it may be more beneficial from the perspective of biodiversity, ecosystems services and also livestock production to consider utilising locally harvested indigenous species of grass for rehabilitation and this is being examined.

Measuring the effectiveness of the erosion control structures, such as stone-packs, takes longer as they have to trap soil before any vegetation can be established above them.

To provide project participants with alternative livelihood options and additional income, small poultry rearing and kitchen garden projects were started. Over 200 participants were introduced to rearing Koekoek chicks for the production of eggs and meat for household consumption, and keyhole, trench and raised-bed vegetable gardens were created around homesteads and at schools in the villages.

© UNOPS/Christoph Mor

Stone-packed walls were built along the slopes to prevent erosion.

© Kevin Kirkman

Eragrostis curvula becoming established in areas cleared of invasive shrubs

© UNOPS/Greg Marinovich

Keyhole gardens, which are easily composted and water efficient, are encouraged for growing vegetables.

Encouraged by the initial results of this demonstration project, the Ministry of Forestry and Land Reclamation has adopted and introduced a similar land rehabilitation project adjacent to the pilot area. In addition, leaders of other villages in the district have requested Serumula to expand their activities to help rehabilitate degraded land in their areas.

Pale Kalahari sands and low rainfall in southern Botswana support sparse vegetation of relatively low nutritive value.

Land degradation in the Kalahari savannahs of southern Botswana

The south-west Kalahari of Botswana is a desert dominated by linear vegetated dunes, 2–30 m high and several hundred metres apart. Some of the highest dunes are immediately adjacent to the Molopo River valley, and tower over the rocky outcrops that dominate the river's banks. In keeping with the other dry watercourses of the Kalahari, the Molopo is believed to have formed during periods of wetter climate and to have incised its course into the relatively subdued Kalahari landscape.

There is evidence of perennial or semi-perennial flow within the Molopo between 16,000–12,000 years BP with additional fluvial events during the mid-Holocene (~6,000 years ago). Earliest references to flows in the Molopo are provided by Bain who crossed the river in 1826, describing it as a 'fine young stream', while Cornwallis-Harris ten years later, described it as having 'a broad shallow bed, covered with turf, traversed by a deep stream about ten yards wide, completely overgrown with high reeds... [with] an abundance of hippo' (Cornwallis-Harris, 1852, p.66, from Nash, 1992, p.143). Today the lower reaches of the Molopo are predominantly dry, but floods are known to have occurred in the Molopo in 1891/92, 1896, 1915, 1917/18, 1933/34 and 1988, extending at most to about 30 km downstream of Makopong (Bullard and Nash, 1998).

The sand and calcrete habitats of the Kalahari are dotted throughout by a number of small, closed basins, or pans, most densely in Kgalagadi District. Pans play an important role within the Kalahari ecosystem and are of vital significance to wildlife. With their relatively high silt to clay content, pans offer both minerals and otherwise unobtainable soluble salts (Child et al., 1971; Parris and Child, 1973; Parris, 1970), as well as standing water following rain. Pans were traditionally used by the San to hunt game that drank there and also became a focus for cattle-keeping over the last century as livestock was watered from wells dug into them.

Groundwater in the southern Kalahari is typically highly saline and the boreholes low-yielding, with groundwater recharge estimated to be as low as 1 mm per year (Mazor, 1982). Plans for livestock expansion in the southern Kalahari have been greatly constrained by the lack of surface and groundwater, with today, many existing boreholes drying up or showing signs of increased salinity and reduced yields.

Southern Kalahari pastures are of very low nutritive value. High crude fibre, low crude protein, low calcium and phosphorus and low dry-matter digestibility are characteristic and major limiting factors for large herbivores in the Kalahari.

The southern Kalahari fauna is adapted to the main limiting factors of arid regions, namely high temperatures during the day and the scarcity of water. The earliest aerial survey of the central and southern Kalahari in Botwana was undertaken by the Countrywide Animal and Range Assessment Project (DHV, 1980). It highlighted the importance of comparatively slight and stochastic events, such as isolated rainfall showers, causing dramatic, short-lived changes in animal distributions. The flushing of green shoots on recently burnt ground, which is known to attract both domestic and wildlife in large numbers (Pratt, 1967), is another well-known example.

DHV (1980) describes the green flush associated with an isolated rainfall event in July 1979 in the southern Kalahari region that led to the concentration of some 40,000 blue wildebeest (*Connochaetes taurinus*) and 25,000 eland (*Taurotragus oryx*). By contrast, the three previous flights over a broader southern Kalahari area had returned an average of 4,500 wildebeest and 6,000 eland (from DHV, 1980, Vol. IV).

Such mobility has been and remains a key strategy for the survival of large ungulates in the Kalahari, particularly for red hartebeest (*Alcelaphus buselaphus*) and blue wildebeest populations. In a drought, the latter need access to surface water. The severe 1982–1986 drought led to spectacular die-offs of 90% of both populations (over half a million animals) as a result of the imposition of veterinary disease control cordon fences across their traditional migratory pathways.

With the advent of borehole technology in the 1960s, wells were replaced by boreholes and many pans have become ringed by sizeable human settlements making them less accessible to wildlife. Furthermore, growing settlements and increased reliance on livestock for livelihoods have caused the area around the pans and livestock watering boreholes to become denuded and degraded with remobilisation of the dunes. Well-intentioned sector-led initiatives, such as those providing cattle and small stock to 'remote area dwellers' to boost livelihoods, have also promoted land degradation and conflict with wildlife in this fragile ecosystem.

The loss of once abundant wildlife populations in the Kalahari has had profound ecological and socio-economic consequences, not least because as DHV (1980, p. 45) points out: 'Enhanced game use is seen as the best way to raise the standard of living of the greatest number of people in the Kalahari, particularly those who are the poorest.' Certainly, the open vistas and resident wild ungulates around unsettled pans could provide a key attraction to tourists and an obvious focus for tourism development in the Kalahari.

As Sandford (1980, p. v) describes: '…in the communal areas a new, more positive approach is required that places less emphasis on destocking, rotational grazing and the difficulties presented by the social structure, and more emphasis upon looking for fresh initiatives.' Projects cannot be short term in their outlook; they should focus on a range of products and sectors to provide a sustainable option once the project is over (Rozemeijer, 2001).

Cisterns constructed in the seasonal pans at Zutshwa help to prolong the availability of this water source.

ADDRESSING LAND DEGRADATION IN SOUTHERN BOTSWANA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In Botswana, a significant challenge facing environmental protection and conservation of natural resources, particularly wildlife resources, is increasing pressure from other forms of land use. Pastoralism is an important livelihood activity in the Kalahari and is increasingly encroaching into the areas adjacent to the national parks and game reserves. These so-called wildlife management areas make up 20% of the land area of Botswana, with wildlife-based economies intended to be the dominant land use within them.

Formulated in the 1970s, the wildlife management areas in Kgalagadi District have never been formally gazetted because of conflict with the surrounding livestock users. This poses a significant challenge to wildlife-based developments in the area and limits the potential for community trusts to benefit from the adjoining Kgalagadi Transfrontier Park. As a result, there is considerable pressure to develop any available groundwater supplies (such as those discovered by mineral prospecting or road development) for livestock keeping. Piosphere or borehole-based land degradation follows, with removal of the vegetation cover leading to remobilisation of sand dunes around water points.

A demonstration project under the UNDP–GEF Orange–Senqu Strategic Action Programme in Botswana works with the communities in the Khawa (near Tsabong) and Zutshwa (near Hukuntsi) villages in Kgalagadi District. Practical work started in mid-2011 and continued to mid 2014.

The rangeland is overgrazed and degraded in most areas around the Khawa village and its watering points. Better rangeland condition occurs further away from the watering points and village where fewer animals graze. The rangeland around Zutshwa is still in a fairly good condition. This can be attributed to lower grazing impacts by livestock as a result of the lack of potable groundwater in the area.

Human–wildlife conflict includes various scenarios in which human strategies affect the free movement of wild animals and vice versa, specifically when the needs and behaviour of wildlife impact negatively on the goals of humans. Participatory rural appraisal and community environmental action plans identified human–wildlife conflict, such as domestic stock being killed by large predators, as one of the priority issues in their communities. Small stock is particularly important to rural female-headed households by providing some income to those who are often the most vulnerable.

A field officer of the UNDP–GEF programme works out of the district's Water Affairs office in Tsabong and oversees implementation, closely coordinating field activities with the Tsabong and Hukuntsi technical advisory committees (inter-departmental working groups on development issues) and collaborating with other land management initiatives in the area.

Related ongoing activities of the project include education and awareness-raising on management issues, in particular improved management of water points and 'kraaling' of livestock at night. Other activities focus on increased mobility of livestock herds that will in turn provide some rest periods for rangelands to recover, and rangeland monitoring; water harvesting and conservation; and development of alternative income-generating opportunities.

A community-based monitoring system to include several biophysical, infrastructural, management and socio-economic aspects is being developed. It is based on management-oriented monitoring systems (pioneered by Stuart-Hill et al., 2005), which has previously been successfully piloted in an adjacent area. In parallel, projects to re-stabilise the dunes adjacent to the village of Khawa with indigenous grasses and woody plants, and others that harvest rainwater in each of the villages are being implemented. Results from these project activities will not only contribute towards the development of a sustainable grazing strategy, but will also be used in the identification and establishment of alternative livelihoods and income-generating activities that are sustainable in the long term.

Deforestation of the riparian belt

Deforestation, in general terms, refers to the removal of woody vegetation cover. Its consequences are loss of habitats and biodiversity, changes in hydrological and nutrient cycles, and reduction in carbon-sinking capacities. It has historically played, and continues to play, a major role in land degradation and has a particular impact on the hydrology and sediment load of the Orange–Senqu River and its tributaries.

There are two main categories of deforestation in the Orange–Senqu basin: clearing of woodlands and bush for agriculture and providing fuel wood and, most significantly, deforestation of the riparian belt woodlands from over-harvesting and clearing for irrigation. Both of these can be accompanied by the invasion of alien species, but this is particularly relevant to the riparian belt.

Deforestation of the catchment in general is clearly an issue that has an impact on the quantity and quality of flows in the tributaries and main stream of the Orange–Senqu basin. However, deforestation of the riparian belt is arguably even more critical, especially when accompanied, as it often is, by the invasion of alien species.

Riparian zones form the interface between aquatic and terrestrial ecosystems. For much of the length of the Orange–Senqu River and its tributaries they are generally relatively narrow, linear features across the landscape. Riparian zones support distinctive vegetation that differs in structure and function from adjacent aquatic and terrestrial ecosystems.

Riparian belt woodland is of particular significance in the semi-arid and arid zones, since many of the features that distinguish the riparian zone and highlight its importance are exaggerated in these areas. Riparian woodland is also more at risk in these zones, since they may represent the only source of firewood in the area. In areas where there has been a rapid growth in population associated with urbanisation or mining, for example, there have been very high levels of deforestation. Because the areas are relatively small they can be decimated quickly. Recovery is often complicated by the presence of highly successful invasive alien competitors that specialise in adapting to disturbed areas.

Maintaining a healthy indigenous riparian zone is important because riparian trees and vegetation are adapted to fluctuations in the water table as river levels alternate between low base flows and floods. Riparian vegetation provides habitat, stabilises riverbanks and filters sediments and nutrients from the surrounding catchment.

Very little information exists on the status of the Orange–Senqu riparian woodland vegetation, although it is clear that the most affected areas are the middle and lower Orange. Here, the aridity of the climate has combined with increased population to exert pressure, especially where informal settlements have grown in association with irrigation and mining activities.

While the ephemeral rivers that cross the Kalahari do not carry much water, they support trees, which provide a valuable source of fuel and fodder.

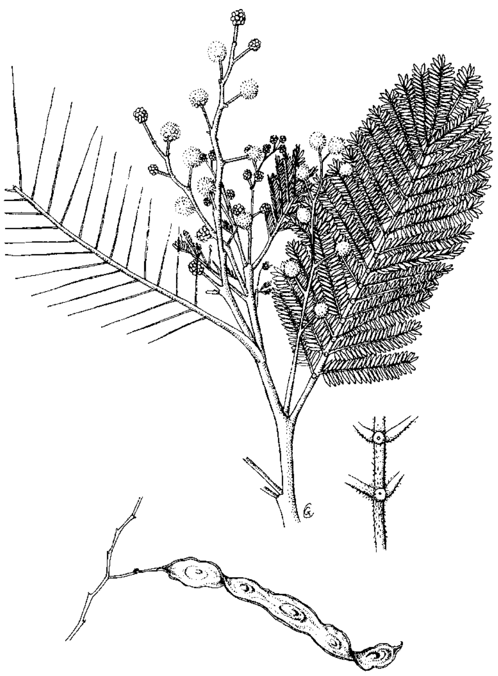
BUSH ENCROACHMENT – ADDING WOODY BIOMASS BUT DIMINISHING LAND PRODUCTIVITY

If deforestation can, in general terms, be referred to as the removal of woody vegetation cover, another form of land degradation specific to the extensive savannah areas of the basin can be seen as adding woody vegetation. This is known as 'bush encroachment', which happens where woody vegetation becomes so thick that it threatens farming lands and the original status of the savannah in which it occurs. It is a particular problem in the highland savannah areas of the basin in South Africa and Namibia, and results in a loss of agricultural productivity (through reduced carrying capacity) and biodiversity. Between 10 and 20 million ha are affected in South Africa, much of which lies within the basin.

Traditionally the causes of bush encroachment have been ascribed to interactions between heavy grazing of grasses by domestic livestock and fire occurrence and intensity. Current thinking, however (Ward, 2005), is that the causes are more complicated and work remains to be done to fully understand them.

Generally indigenous woody plants cause bush encroachment, which is therefore quite different from invasive alien plant infestation. The impact of bush encroachment on water resources is neither well studied nor well understood. Woody vegetation, in general, transpires more water than grasses as shown by many studies. Bockmühl (2009) has presented evidence that bush encroachment can have a negative impact on groundwater recharge in some areas. What is clear is that bush encroachment contributes to rural poverty through land degradation because it curtails availability of rangelands.

Tackling the problem of bush encroachment revolves around two possible strategies that can be complimentary: the sustainable harvesting of invasive woodland and the restoration of rangelands.



Silver wattle, *Acacia dealbata.*

Drawn by G Condy, first published in Henderson et al., 1987, © SANBI

Alien invasive vegetation

Alien invasive species are species introduced from another geographical location that establish themselves, grow and propagate. They often have adverse economic, environmental and/or ecological effects on the habitats they invade and the indigenous vegetation found there. Such invasive species may be either plants (IAPs) or animals and tend to dominate a region, wilderness area or particular habitat by causing loss of natural controls. Since this section deals with the terrestrial environment and in particular land degradation, the focus is on flora rather than fauna, but the interaction between these two elements should not be forgotten.

Not all alien species become widespread and abundant in their new host environment and the majority may have little or no impact on their new habitat. The transition from native in one locality to 'invasive' in another involves the passing of a number of barriers – geographical, environmental, reproductive, dispersal and disturbed habitats (Richardson and van Wilgen, 2004). Consideration of these barriers is useful because it provides both clues to the causal chain, and to the potential preventative or management measures that can be considered to minimise the extent and impact of invasive alien species.

The most damaging species transform ecosystems by:
- using excessive amounts of resources (notably water, light and oxygen)
- adding resources (notably nitrogen)
- promoting or suppressing fire
- stabilising sand movement and/or promoting erosion
- accumulating litter
- accumulating or redistributing salt.

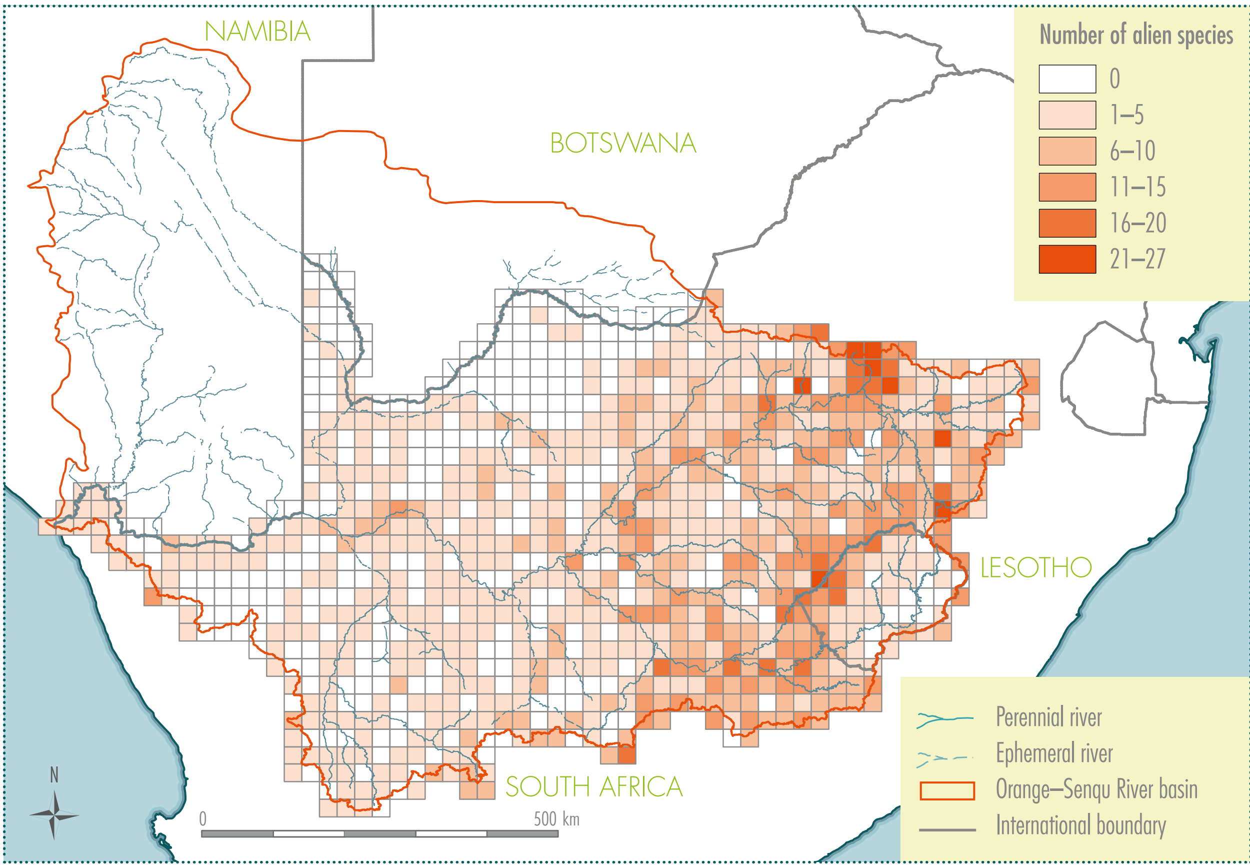


Figure 25: Number of alien plant species recorded for each quarter-degree grid cells in the basin in Lesotho and South Africa (data not available for Botswana and Namibia)

Source: Henderson, 2007

Such changes potentially alter the flow, availability or quality of nutrient resources in biogeochemical cycles. They modify trophic resources within food webs, and they alter physical resources such as living space or habitat, sediment, light and water. Invaders are most likely to have substantial effects on habitats by rapidly changing disturbance regimes.

There are invasions in the mountains and lowlands, but particularly along the rivers. Much of the riparian corridor of the Orange–Senqu River system is degraded through agriculture close to river banks, excavation for small-scale mining, wood-fuel collection and colonisation by IAPs as a cause and effect.

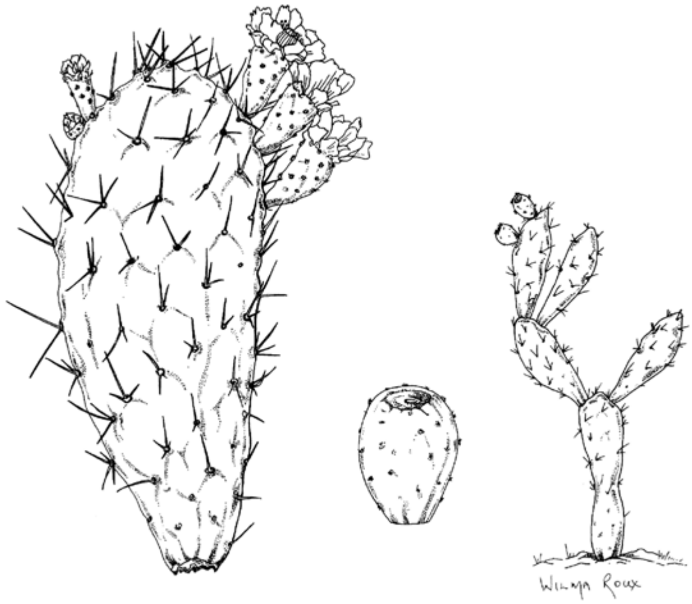
The invasion of IAPs is closely associated with overall ecosystem degradation (MacDougall and Turkington, 2005). Other relevant factors associated with the spread of IAPs in the Orange–Senqu basin include changes in hydrological regime and reduced water quality and flows. Each of these contributes to the alteration of the natural ecological system, disturbing natural habitat and creating a niche for alien species to take hold and proliferate.

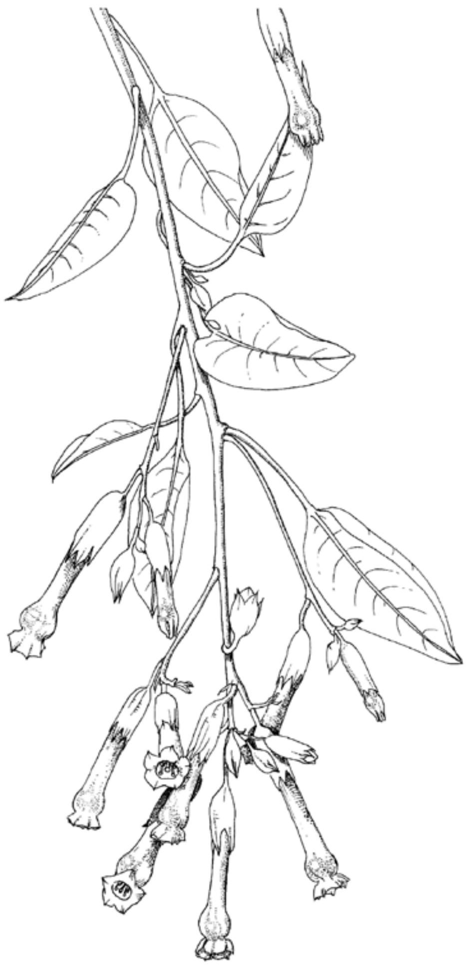
In South Africa and Lesotho the extent and general distribution of invasive alien plants has been mapped by the Southern African Plant Invaders Atlas (SAPIA) and through the National Invasive Plant Survey (NIAPS). The number of invasive plant species extracted from the SAPIA database is shown in Figure 25. Species composition, extent and distribution varies across the basin. Large numbers of species are found in the higher-rainfall areas of the basin, especially in the Vaal and upper Orange–Senqu sub-basins. There are fewer species recorded in the more arid western areas of the basin, which are largely confined to the riparian corridor. The most frequently recorded IAP is *Salix babylonica* (weeping willow), followed by *Prosopis glandulosa* (mesquite).

In the higher rainfall areas of the upper catchment, the most common woody invasive species are *Salix* spp. (willows), *Populus* spp. (poplar), *Acacia dealbata* (silver wattle), *Acacia mearnsii* (black wattle), *Pinus* spp. (pines), *Eucalyptus* spp. (gums), *Melia azedarach* (syringa), as well as wild briar (*Rosa rubiginosa*). Towards the more arid areas in the central and western parts of South Africa, southern Namibia and

Red river gum, *Eucalyptus camaldulensis.*

Drawn by M Steyn ©, first published in Henderson, 1995.





Top left: Sweet prickly pear, *Opuntia ficus-indica.* Drawn by W Roux ©, first published in Henderson, 1995

Top right: Common thorn-apple, *Datura stramonium.* Drawn by ME Connell, first published in Phillips, 1938, © SANBI

Above: Wild tobacco, *Nicotiana glauca.* Drawn by R Weber, first published in Stirton, 1978, © SANBI

Botswana, the primary invasive plants are *Prosopis* and *Eucalyptus* species and a variety of shrubs and herbs, such as *Opuntia* spp. (cacti), *Datura* spp. (thorn-apples), *Nicotiana glauca* (wild tobacco) and *Ricinus communis* (castor-oil bush).

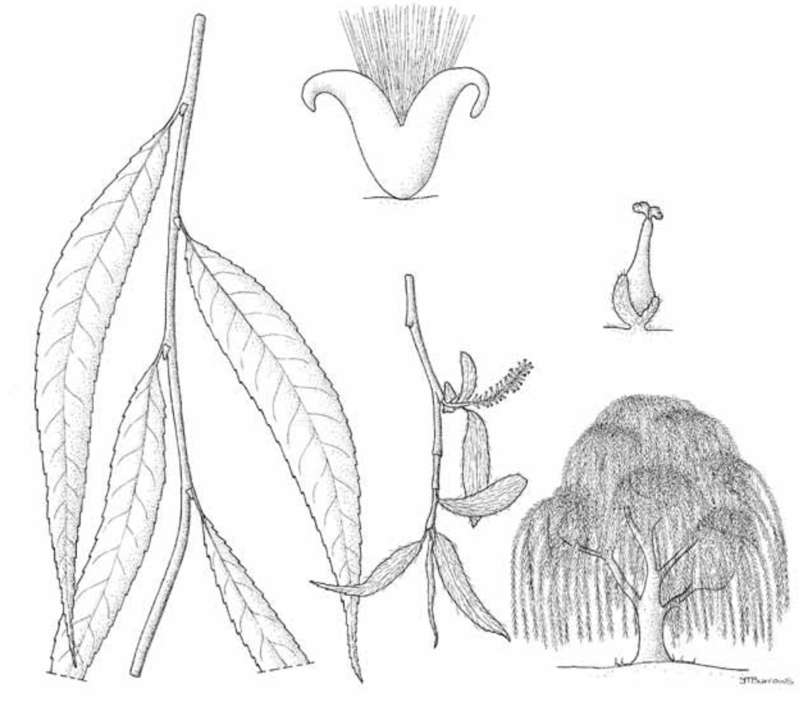
The extent of invasion in the Fish River catchment in Namibia is largely confined to the riparian zone and is relatively limited. However, in the upper and middle parts of the Nossob and Auob rivers, dense stands of *Prosopis* spp. have replaced *Acacia erioloba* and this has been shown to have a major impact on alluvial aquifers in these systems (de Klerk, 2004). It is possible that the *Prosopis* spp. upstream in the Nossob River reduces flooding and groundwater recharge (by impeding flow and using the water) to such an extent that *Acacia erioloba* trees downstream have lower survival rates. Some farmers implement control measures in order to prevent *Prosopis* spp. invasions, especially alongside the Nossob River, but this is dependent on the interest of the individual farmer.

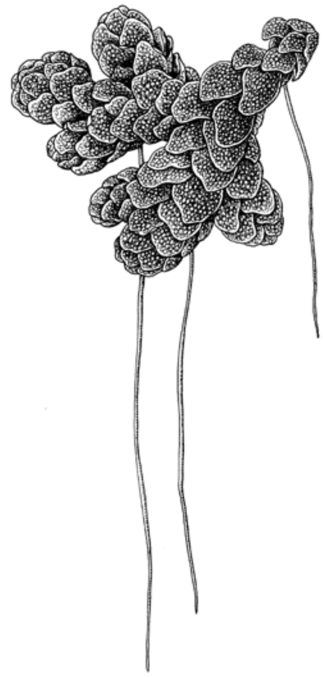
Along the Orange River, the proliferation of IAPs is estimated to reduce river yield by as much as 13% in the upper catchment and 7.8% in the lower catchment (Le Maitre et al., 2000; Le Maitre et al., 2013). Effective clearing could reclaim these water resources for other uses.

Changed flow conditions and nutrient levels have allowed particular species to establish and proliferate. *Phragmites australis* (common reed) occurs throughout the perennial and near-perennial systems along the edges and in shallow sections of the active channels (Heath and Brown, 2007). The reduction in flood frequency, regulation of moderate flood events, and the smoothed flows created by irrigation transfers and dam operation in the system have allowed it to colonise areas along the Orange and Vaal (and their perennial tributaries) where it was previously removed by seasonal flooding.

Aerial photographs have confirmed that the reeds proliferated along the Orange from virtually none in 1976 to infest over 41,000 ha in 1995 (ORASECOM, 2008). In the Fish River downstream of the Hardap Dam, the risk of flooding has been increased by the invasion of reeds, which reduces the capacity of the river channel, requiring continuous efforts to redress the problem.

Increased nutrient levels from sewage effluent and agricultural return flows have led to the proliferation of algae and aquatic IAPs, particularly in the Vaal tributary, as well as promoting the growth of reeds. The most abundant





aquatic IAPs are *Azolla filiculoides* (red water fern) and *Eichhornia crassipes* (water hyacinth), which both prefer slow-flowing waters and high nutrient levels.

In the context of water resources, the issue of invasive alien species in the riparian zone is particularly important. Trees in these moist areas are known to use two or more times as much water as non-riparian trees in the same catchment (Scott and Lesch, 1995).

A number of studies have been carried out in South Africa and Lesotho looking at the consumption of water by invasive alien species, most recently, le Maitre et al. (2013) and Schachtschneider and le Maitre (2013). They estimated that invasive alien species use 1.3% of the mean annual runoff of the upper Orange–Senqu (110 Mm^3 per year) and 3.6% of the runoff of the Mohokare–Caledon (83 Mm^3 per year). For the Vaal sub-basin it was estimated that alien invasive species use 1.5% of the mean annual runoff (64 Mm^3 per year).

For the Orange–Senqu River as a whole this amounts to 257 Mm^3 per year. Of this, 63% is attributable to alien invasive species in Lesotho (161 Mm^3 per year). *Prosopis* accounts for about 8 Mm^3 per year in the Orange–Senqu basin, primarily groundwater in ephemeral river and floodplain aquifers. These figures are based on estimates of naturalised (pre-development) flows. The reductions come to a much greater percentage if modern-day abstractions are taken into account.

As the incremental increase in water consumption by invasive alien species is so high, there is a strong argument for trying to reduce their presence. In essence, these numbers indicate that a high priority should go into dealing with invasive alien trees in Lesotho, while bearing in mind the needs for fuel, construction, etc. Some of the greatest culprits with respect to water consumption in the basin are *Acacia mearnsii*, *A. dealbata* and *Prosopis* spp. So-called 'restoration' projects, such as those carried out under the Working for Water Programme in South Africa, are complicated. They are also expensive, although costs can be reduced drastically if invasions are treated early (Marais and Wannenburgh, 2008).

Numerous factors operating in the catchment may limit or even counteract restoration actions in specific reaches. Restoration should therefore be planned and implemented in an integrated way, respecting both the upstream-downstream linkages and socio-economic factors. The latter implies a strong degree of inter-disciplinary partnerships.

Top left: Weeping willow, *Salix babylonica.*
Drawn by S Burrows ©, first published in Henderson, 1995

Top right: Red water fern, *Azolla filiculoides.*
Drawn by G Condy, first published in Henderson, 1995, © SANBI

Above: Water hyacinth, *Eichhornia crassipes.*
Drawn by R Weber, first published in Stirton, 1978, © SANBI

Drawn by G Condy, first published in Zimmermann, 1991, © SANBI

Honey mesquite, *Prosopis glandulosa* var. *torreyana*

© UNOPS/Leonie Marinovich

PROSOPIS

Adapted from Schachtschneider and le Maitre (2013)

Prosopis species (*P. chilensis*, *P. glandulosa* var. *torreyana*, *P. velutina*) would seem to be the major invaders in the Orange–Senqu basin as a whole, given that there are extensive invasions in South Africa and similar invasions in Namibia and Botswana. Although the invasions are largely concentrated in the arid western part of the basin, they are well established in the arid Southern Kalahari Savannah and extend well into the moister savannahs and grasslands in South Africa.

They were introduced in the late 1800s primarily for their pods, which are used for fodder, but they do have several other uses including firewood, construction timber and for providing shade. Despite several attempts in South Africa and Namibia, their large-scale use for the commercial production of wood or charcoal has not taken off, although there are examples of successful small businesses (Wise et al., 2012). In some areas the trees grow to the size where they have suitable diameter stems and branches for timber, although the white wood is often attacked by borers. Pod yields decline as stand density increases and in dense stands pod production can be limited to the trees on the fringe. There is potential for the generation of bio-energy but their tendency to occur in remote, generally non-electrified areas and the concentration of dense stands in narrow strips along rivers, severely limits their potential and the options for energy production and commercialisation.

There is evidence that there is a rapid increase in the area invaded. Van den Berg (2010) reported an increase in the Northern Cape Province from 127,821 ha in 1974 to 1,473,953 ha in 2007, equivalent to a 7.4% per annum increase (Wise et al., 2012). Should this rate continue, the invaded areas will double every 12 years. Furthermore, they are able to increase in density from an open to a dense, monospecific stand of trees in 10–24 years (Harding and Bate, 1981), leaving little chance for indigenous vegetation.

Prosopis seems equally able to invade intact and disturbed areas, particularly floodplain environments where floods naturally create disturbances and where these invasive plants can have significant impacts on water resources and, thus, on human livelihoods (Wise et al., 2012). Evidence of recent spread and the increasing problems caused by these species are providing strong motivations for research into more effective control measures.

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Dense growth of *Prosopis* in the ephemeral Nossob River in Namibia has formed impenetrable thickets out-competing indigenous species, impeding runoff and reducing groundwater recharge.

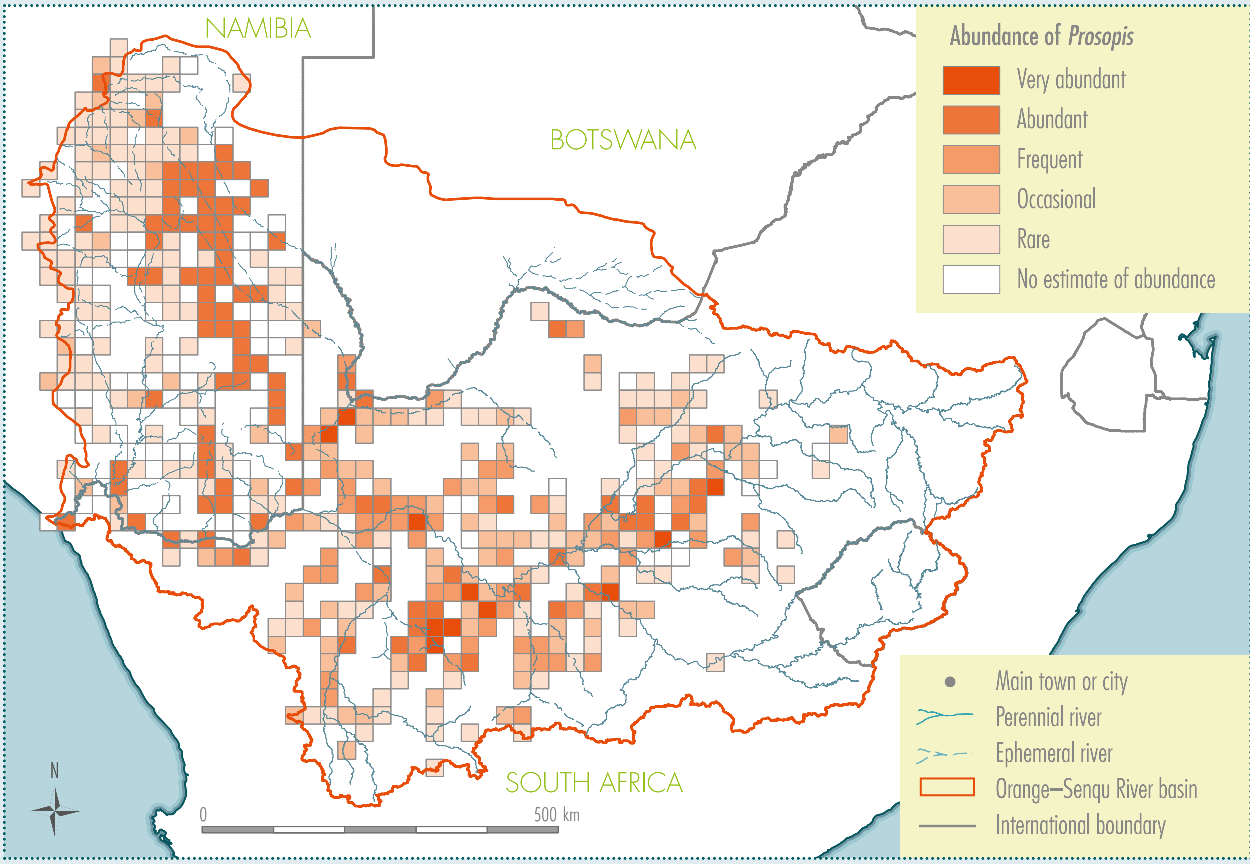


Figure 26: *Prosopis* species occurrence and abundance in quarter-degree grid-cells in South Africa and Namibia. Data were not available for Botswana.
Sources: SAPIA database (Henderson, 1995, 2001); Namibian Tree Atlas database (Curtis and Mannheimer, 2005)

© UNOPS/Greg Marinovich

Foamy streams can be a sign of excess phosphorus from detergents.

2.4 AQUATIC ENVIRONMENT

The transboundary nature of the Orange–Senqu River, together with the unique interaction of its natural and human-made characteristics, makes it one of the most complex river systems in the world. The river is subject to various sources of pollution that impact on water quality: effluent from large water demand centres; increased salinity and agrochemicals from intensive irrigation in the middle reaches of the system; heavy metals from mining; and elevated salt concentrations because of acid mine drainage.

However, having the largest water demand centres situated on the watershed not only means that some water leaves the basin as effluent, but also that many tributaries carry a proportionally high volume of effluent, particularly in the winter months when there is less natural flow in the river. In South Africa, the rivers flowing southward from Johannesburg carry a high volume of effluent from domestic wastewater treatment works, which increases nutrient concentrations in the river. It is estimated that the 500–540 Mm^3 of effluent per year that is returned to rivers in southern Gauteng make up more than 50% of the total flow in the middle Vaal River in some years, with extensive impacts on water quality.

Agencies managing urban pollution often have to deliver basic services to the poor, with limited financial and human resources and inadequate cost recovery. As a result, effluent quality often does not meet the required standards and affects downstream water quality.

Natural flow patterns and river connectivity have been altered across virtually the entire Orange–Senqu basin. Seasonal flows have been disrupted by the transfer schemes, increasing flows in the upper reaches of the basin, and decreasing flows in the lower reaches. The Orange River estuary now receives less than 40% of its pre-development flow, which has had severe impacts on the functioning of the estuarine ecosystem. Large dams throughout the basin have disrupted flow patterns even in the ephemeral rivers of Namibia, and created barriers to fish migration, which in turn affect normal ecosystem functioning.

The Vaal and Riet-Modder catchments are now operated as 'closed systems'. To minimise water spills from these rivers into the Orange during dry periods, water released from upstream storage or transfer schemes is carefully managed to just meet the water demand. The reduced flow in the lower reaches of the Vaal and Riet rivers not only impacts on the health of the aquatic ecosystem, but also on water use for irrigation. Salt concentrations in these parts of the river system are well above target levels set to protect irrigation water users.

In Botswana, over-abstraction from groundwater is leading to the gradual salinisation of water. Both nitrate and nitrite concentrations are also on the increase, with levels now exceeding human drinking water standards in some areas of the basin reliant on groundwater sources. Some communities have been provided with desalinisation treatment systems to counteract this problem, but this is a costly solution.

This section presents a summary of the key issues concerning water quality and the health of aquatic ecosystems.

2.4.1 Water quality

The key water quality issues in the Orange–Senqu River system have been identified as nutrient enrichment, primarily linked to increased phosphorus and nitrogen concentrations; increased salinity from acid mine drainage and irrigation return flows; microbial contamination from urban settlements and poorly operated wastewater treatment works; and elevated sediment concentrations resulting from run-off from degraded land. Other concerns include heavy metals and persistent organic and other pollutants.

Nutrient enrichment

Nutrient enrichment is perhaps the most significant water quality problem in the Orange River basin. Also known as eutrophication, it refers to the increase in plant nutrients in the water, consisting chiefly of nitrogen and phosphorus. These plant nutrients are found in high concentrations in effluent from domestic wastewater treatment works, wash-off from urban areas and in agricultural areas where they are applied to fields as fertilisers.

The nutrients speed up the growth of aquatic plants, and floating and attached algae, which poses a range of problems for aquatic ecosystems and water users. Floating aquatic weeds can cover entire rivers and dams, blocking light and preventing oxygen from dissolving into the water. They can also block water intakes and affect the recreational use of water. Algae attached to rocks on the riverbed can affect ecosystem functioning.

In nutrient-enriched river systems, blooms of floating microscopic algae increase the costs of water treatment and can promote the formulation of carcinogenic substances in the treated drinking water. Certain toxic, algal blooms have been known to cause livestock deaths; the toxins have also been known to cause human health problems by passing through the water treatment process.

Nutrient enrichment is typically assessed by comparing the concentrations of phosphorus and nitrogen compounds in the water to given standards. The nutrient status of the water can then be classified as 'ideal', 'acceptable', 'tolerable' or 'unacceptable'.

Phosphate and nitrogen concentrations in the Lesotho Highlands are generally low; they fall within the 'ideal' or 'acceptable' ranges and remain in this range along the length of the Senqu River. At the Lesotho–South Africa border, nutrient concentrations are still within the 'acceptable' range.

The transfer of water via the Lesotho Highlands Water Project (LHWP) does not seem to have lowered nutrient concentrations in the Wilge River system. At the inflow to the Vaal Dam, nutrient concentrations are high enough to cause significant algal blooms and records show a gradual increase in phosphate concentrations in both the Wilge and Vaal rivers over the past 10 years – a trend most likely associated with increasing problems with wastewater treatment.

The Vaal Dam has been characterised by frequent algal blooms in recent years, but blooms are not solely associated with recent events. In the summer of 1942/43 blooms of the toxic blue-green algae *Microcystis aeruginosa* in the newly constructed dam resulted in thousands of livestock deaths (Rainharvest, 2011), most likely due to the nutrients released from the flooded farmland. Similar summer blooms were noted in the 1970s, and have occurred periodically since then. Summer blooms of *Microcystis* are now typical of the Vaal Dam, many of which are thought to be toxic (DWA, 2011).

Nutrient concentrations further downstream in the Vaal River increase even more. The Klip and Suikerbosrand rivers – the two main tributaries draining south from Johannesburg – carry effluent from 19 wastewater treatment works with a total discharge volume of some 25 Mm^3 per month. During the average winter (May-September), combined flows in these rivers constitute some 28 Mm^3 per month. This means that in the winter months, 90% of the flow in these rivers is from treated domestic effluent. Most of this, around 80%, is discharged into the Klip River. Phosphate and nitrogen concentrations in the Klip River are therefore mostly in the 'unacceptable' range.

Increased nutrients in the water encourages the growth of algae, which in turn increases reduced oxygen content and stream health.

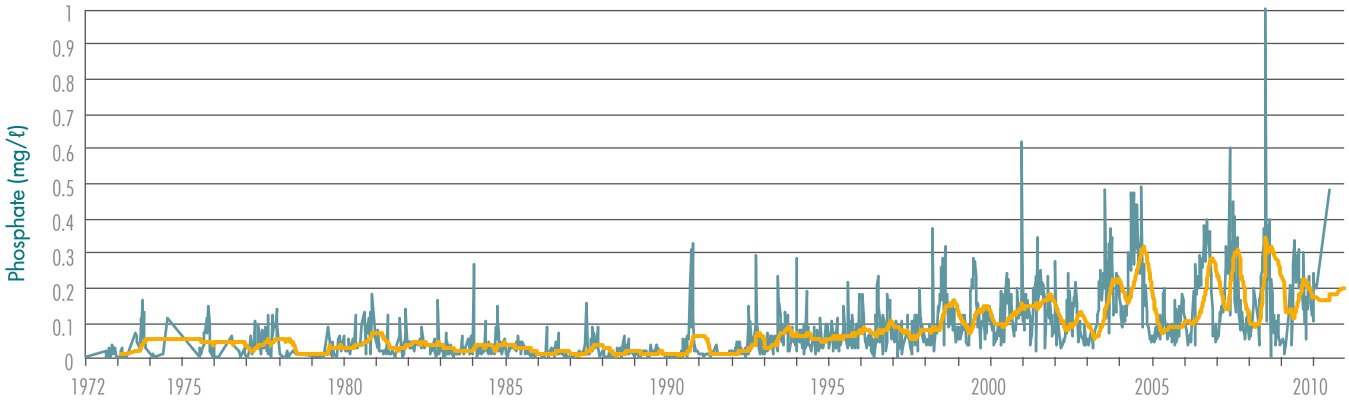


Figure 27: Phosphate concentrations in the Vaal River at Kliplaatdrift. The site is downstream of mining towns in the middle Vaal sub-basin and shows increasing trends in concentrations since the mid 1990s. The orange line represents the 26-point moving average, smoothing out short-term fluctuations.

The Vaal Barrage, which receives the water from these two rivers, is characterised by extensive blooms of toxic *Microcystis aeruginosa*. Apart from the seasonal fluctuation, nutrient concentrations in the Klip River have remained stable over the years, unlike the Suikerbosrand River where concentrations are on the rise.

One possible explanation for the stable nutrient levels in the Klip River could be the well-run Johannesburg South Wastewater Treatment Works. The treatment works discharging to the Suikerbosrand River, on the other hand, perform only adequately. A large proportion of the flow in this region is derived from treated wastewater that will increase as Johannesburg and its surrounding towns grow. Imposing even more stringent effluent discharge standards for nutrients on wastewater treatment works is thus unlikely to reduce nutrient concentrations to even 'acceptable' limits.

Further downstream, the entire length of the middle Vaal River from the Vaal Barrage to the Bloemhof Dam, is characterised by high nutrient concentrations. Phosphate concentrations have been steadily climbing since the mid-1990s, and since 2000 concentrations have been almost continually within the 'unacceptable' range (see Figure 27). At Orkney, 76% of the phosphate concentrations now fall within this category.

Nitrogen concentrations however, do not appear to be as much of a problem, with 85% of the samples taken falling within the 'acceptable' range. The Caledon–Mohokare River, downstream of Maseru in Lesotho, has largely 'unacceptable' phosphorus concentrations with no discernible trends. Nitrogen, on the other hand, falls in the 'ideal' or 'acceptable' range.

Nutrient concentrations in the Orange River, downstream of Lesotho, mostly fall in the 'acceptable' or 'tolerable' ranges. However, phosphorus concentrations are high enough to cause algal blooms in standing water. Blooms of *Microcystis* have been noted in both the Gariep and Vanderkloof dams, creating problems when treating the water to potable standards.

A bloom of algae in the Orange River at Upington caused severe health problems in the town in 2001. Further downstream, blooms of toxic algae are known to have occurred since 2000, raising concerns about the recreational use of the lower Orange River. At Vioolsdrift, 35% of the samples fall in the 'unacceptable' range for phosphorus, and a further 30% in the 'tolerable' range. It is possible that the planned Vioolsdrift Dam may therefore experience blooms of toxic algae. However, no trends in nutrient concentrations are noted in the lower Orange River.

In Namibia, the ephemeral nature of the Fish River makes analysis of the nutrient conditions complicated. The stagnant pools in the river, however, indicate nutrient enrichment – most probably derived from intensive livestock watering. However, irrigation return flows in some areas and untreated domestic wastewater could also play a role.

In parts of the Molopo–Nossob aquifer in Namibia and Botswana, very high nitrate and/or nitrite concentrations that exceed the 45 milligrams per litre (mg/ℓ) limit for human consumption are reported. This is very likely as a result of nutrients derived from irrigation and cattle watering stations. While there is no risk to surface waters or the aquatic environment, people are dependent on groundwater in this area.

THE URBAN POLLUTION CHALLENGE

Urban pollution poses unique challenges for water resource managers. Much of the problem derives from household sanitation services, and the costs of providing and maintaining these services are recovered in services payments. Often, the poor struggle to pay for appropriate levels of services and the 'polluter pays' principle is complicated by the inability of the polluter to pay. The 'non-payment' problem however is not limited to the poor, and many commercial enterprises as well as government agencies, are also behind on payments.

In larger centres, cross-subsidisation can provide the resources to effectively manage urban waste services. This is not possible in smaller towns, but the cumulative impacts of these towns on the water resources can become significant – as is the case in the middle Vaal River. These smaller centres face increasing pressures to provide high levels of services. Small towns consequently face a growing challenge to maintain waste and other services with insufficient financial and human resources and limited opportunities for cost recovery.

Larger treatment works are often well managed. However, the majority of the wastewater treatment works in small towns across the Orange–Senqu basin are not performing to standard. The high number of works with critical or very poor performance is a cause for concern, and this has certainly contributed to nutrient enrichment problems. High levels of population growth and urban migration further contribute to the problem.

To complicate matters, urban pollution is often managed by local government. Policing of effluent standards is therefore confused by inter-governmental relations – making prosecution difficult. Urban pollution, and particularly nutrient enrichment is therefore likely to remain a significant problem in the Orange–Senqu basin.

Providing services in ever-expanding urban areas is a challenge for authorities. To encourage them to improve their services in supplying safe drinking water and adequate sanitation services, South Africa's Department of Water Affairs has introduced a certification programme – the Blue Drop for water quality and the Green Drop for sanitation services. Gaining certification indicates that the responsible service provider has achieved the highest possible standards in minimising risk to public health and the environment.

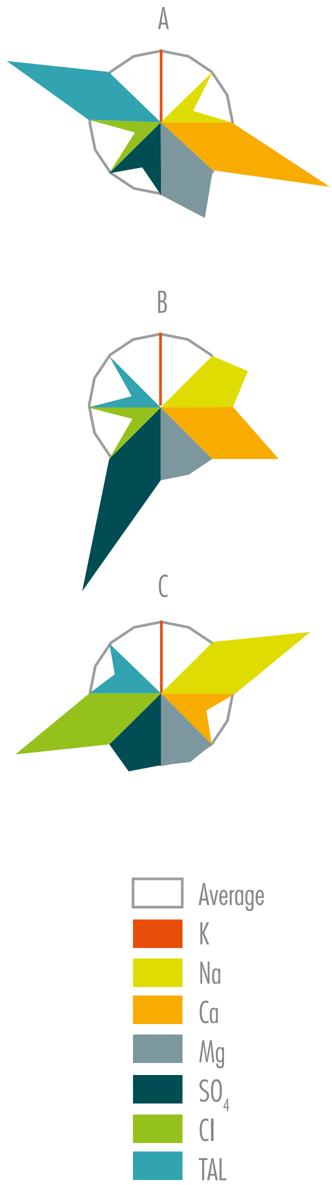


Figure 28: Maucha diagrams show the relative composition of salts making up the salinity typical of a) the upper reaches and most of the Orange River, b) waters polluted from acid mine drainage, c) waters polluted from irrigation return flows
(TAL = total alkalinity)

Salinity

In the Orange–Senqu River basin, the main anthropogenic sources of salts in water resources are (ORASECOM, 2008):

- water pumped from underground mine workings;
- runoff and seepage from areas disturbed by mining and mine waste dumps;
- runoff and seepage from industrial areas;
- irrigation return flows;
- discharge of sewage effluent from wastewater treatment works;
- runoff and seepage from urban areas, especially those without formal sewerage and sanitation systems.

Mining activities increase salt concentrations in water through acid mine drainage (AMD). This occurs when rock containing pyrite is oxidised, resulting in the formation of sulphuric acid. The acidic water produced, contains high levels of salts (mostly sulphates, SO_4) as well as iron and other metals such as uranium and cadmium. Lime is added to raise the pH and neutralise the acidic water that results from AMD. This treatment also precipitates out most of the metals held in solution. However, additional and expensive desalination is then required to remove the salts. Acid mine water can be pumped out of the underground workings to prevent it from rising and contaminating shallow aquifers, wetlands and streams. However, it also enters the river system by leaching out of mine tailings, dams and waste rock dumps.

Intensive irrigation also raises salinity. Irrigated crops need the water that is applied, but not the salt dissolved in that water, so farmers usually apply a little more water than the crops need to carry the excess salt back to the river ('irrigation return flow') or into the groundwater. This also carries some of the applied fertilisers into the water sources.

Irrigation return flow is typified by high concentrations of sodium (Na) and chloride (Cl) salts. The salt load in return flows depends on a number of factors – the salt concentrations in the water applied to the crops, soil type and whether drainage systems have been put in place to carry the saline water away.

Domestic water use increases salinity mostly by introducing Na and Cl salts from foods. Industrial activities also have an effect on the total salt concentration with some industrial processes, such as chemical manufacturing, changing the composition of salts.

Analysis of the relative composition of the different salts in water provides information on the potential sources of these salts. Figure 28 outlines the salt compositions at selected sites in the Orange–Senqu system.

UNDERSTANDING SALINITY

Salinity refers to the concentration of salts dissolved in water. It is commonly measured as total dissolved salts (TDS) in milligrams per litre (mg/ℓ), or as electrical conductivity (EC) as milliSiemens per metre (mS/m).

As with nutrients, the salinity of natural water can also be categorised as 'ideal', 'acceptable', 'tolerable' and 'unacceptable', based on the expected impacts on water users, as shown below.

Category	Ideal	Acceptable	Tolerable	Unacceptable
EC (mS/m)	< 30	50	85	>85

The natural concentration of salts dissolved in water varies widely. All naturally occurring water carries salts that leach out of surrounding soils, rocks and from plant material. Salinity of water also increases as water flows downstream, particularly in the drier regions where rainfall is low and evaporation high. Salts are continuously added through natural (geological) and anthropogenic processes such as mining, industry and agriculture, but are only minimally removed through technological interventions or diluted by precipitation.

Salts have a variety of impacts on the use of water. In very high concentrations, salts make water unsuitable for human consumption. A salinity level of 1,000 mg/ℓ is considered to be moderate and is generally tolerated by humans. However, at levels above 3,000 mg/ℓ (high salinity), fatal intestinal and renal damage can occur. Other effects of salts include the 'salinisation' of irrigated soils, diminished crop yields, increased scale formation and corrosion in domestic and industrial water pipes, and changes in the biotic communities.

© John Pallett

Irrigation return flows usually have high salt concentrations. Centre-pivot irrigation, however, typically uses less water than many surface or furrow irrigation techniques and produces less runoff.

© Greg Marinovich

Mine waters usually have high concentrations of salts as well as heavy metals.

THE ACID MINE DRAINAGE CONUNDRUM FOR SOUTH AFRICA


© Greg Marinovich

Mining activities expose pyrites to water resulting in the formation of sulphuric acid. The acid mine drainage produced contains high levels of salts and metals.

Gold mining has been a key feature of the Witwatersrand for more than 100 years, long before its environmental impacts were considered important. Early mining activities often left waste rock and slimes dams (the waste material after the gold has been removed) in environmentally sensitive areas and with little or no protection of the surface and groundwater from seepage. Over the years, many mines have closed and the original mining companies have long since disappeared. The mining industry has left behind a legacy of 120 abandoned or decommissioned gold mines and 400 km^2 of mining residue. This totals about 6 billion tonnes of crushed rock and metal contaminants.

Mining exposes metal-containing sulphide ores (such as pyrite) to the air. When these oxidized surfaces come into contact with water, sulphuric acid is produced. The result is extremely acidic water with high concentrations of salts and metals, chiefly iron, but including other more toxic metals like uranium.

The geology of the Witwatersrand exacerbates this problem – the overlying, highly permeable dolomitic rocks allow water from the surface to seep into abandoned workings, filling up the former gold bearing seams. Here, the water is exposed to pyrites and forms acid mine water. This has happened in the three large underground basins of the West Rand, Central and East Rand. Over time the rising acidic water table will reach the overlying dolomitic rocks, dissolving them to contaminate the near-surface groundwater. Ultimately the water will reach surface water, decanting into rivers and streams (a process which has already started in places).

Recent public outcry about the rising acid mine water and the consequent threat of uncontrolled decanting prompted the formulation of an Inter-Ministerial Committee on Acid Mine Drainage (IMC) to investigate a permanent solution to the problem. This committee recommended inter alia that:

- water must be pumped from all three basins to maintain water levels below the critical environmental level or the lowest level of underground activity;
- the water should be treated to raise the pH and remove the metal contaminants;
- longer-term solutions to address the contribution of salts to the major river systems should be investigated;
- steps to prevent the ingress of water to the underground workings should be taken.

One of the complicating factors in this process has been determining the liability for the costs of pumping and AMD treatment from the defunct mines. The IMC recommended that an environmental levy, to be paid by the existing mining companies, should be investigated. However, the search for a sustainable solution will most likely be dogged by technical problems.

Many have argued that the acidic 'surface' waters in the underground workings could be flushed out, removing the need for on-going treatment. However, the impacts of recurrent pumping and heat convection currents that would continually mix the water are not known. In addition to the treatment of the acidity of AMD, treatment to remove the salts in the water is expected to be prohibitively expensive and could also leave dangerous residual deposits on the surface.

The dilution of AMD with releases of good quality water from the Vaal Dam could be an option. However, this could place unacceptable demands on water availability in the Orange–Senqu system as a whole, and result in unusable surpluses further downstream in the Vaal River.

A sustainable and cost-effective solution must, consequently, take the impacts on the whole Orange–Senqu into account, and must address potential costs and benefits to all the Orange–Senqu basin states.

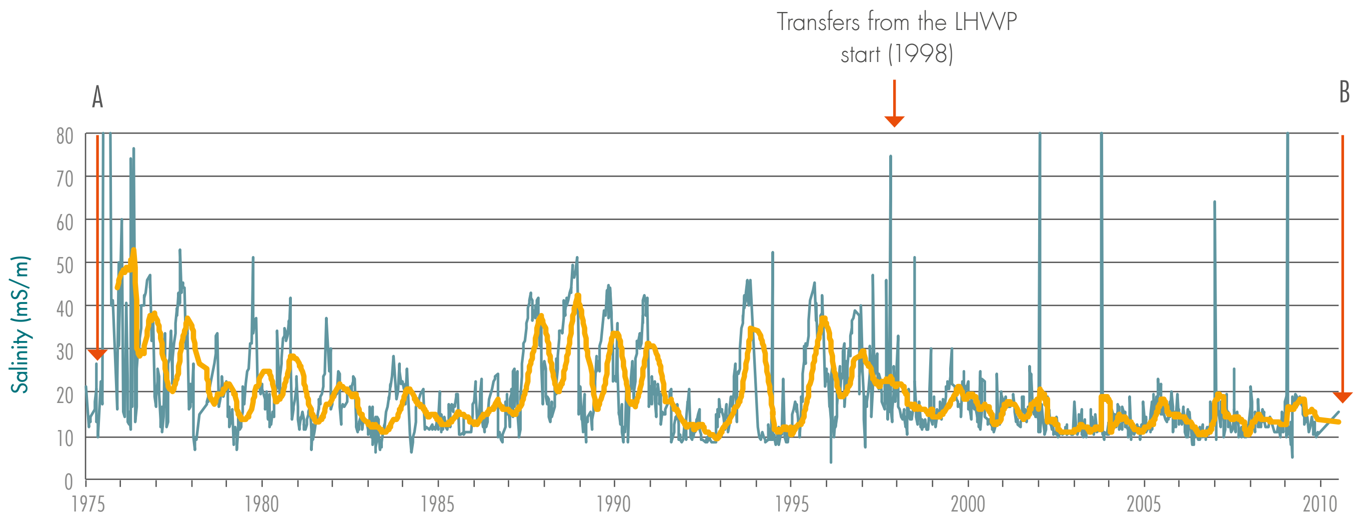
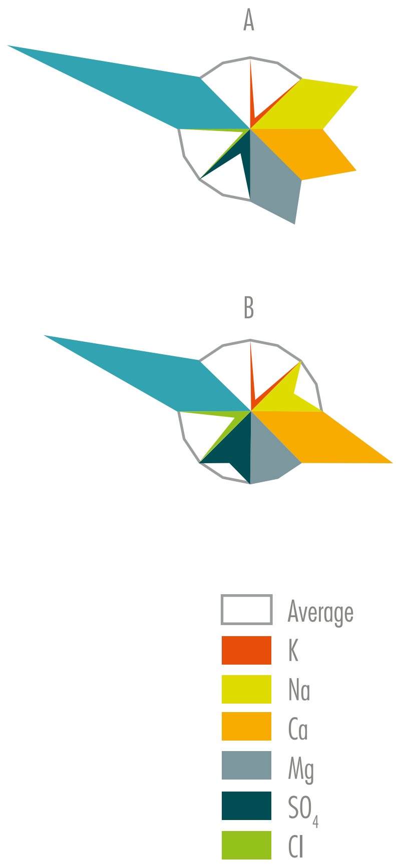


Figure 29: Salinity in the Wilge River inflow to the Vaal Dam as electrical conductivity (EC) in mS/ml, 1975–2010. The orange line represents the 26-point moving average. When water is applied to crops, the plants use the water, but not the salts. These salts then increase the salinity of return flows and the downstream river.



Salinity in the Lesotho Highlands is dominated by calcium carbonate (CaCO3) salts, mostly due to the sedimentary geology of the area, referred to as TAL (total alkalinity) in the Maucha diagrams (Figure 29). It falls within the 'ideal' range and remains there for virtually the entire length of the Orange River, with only the lower Orange experiencing concentrations in the 'tolerable' range. A shift towards Na and Cl salts in the lower Orange would suggest that this is mostly attributed to irrigation return flows.

The Caledon–Mohokare River, between Lesotho and South Africa, experiences late winter peaks of increased salinity, which are most likely due to salts from the clothing manufacturing plants in Maseru. This may impact on the use of water for irrigation and on the water supply to Bloemfontein.

The transfer of water via the LHWP has had notable impacts in reducing the salinity of the Wilge River system. This has in turn decreased the salinity of the Wilge inflow to the Vaal Dam. Seasonal variations in salinity have also been reduced, and salt concentrations now fall almost continuously in the 'ideal' range, as shown in Figure 29.

This pattern is not noted in the Vaal River inflow, which typically ranges from 'ideal' in the summer months to 'acceptable' or 'tolerable' in winter. The salinity of the Vaal Dam is however likely to decrease, as the flow from Lesotho increases when Phase II of the LHWP delivers water in a few years, which will reduce the amount of water required for dilution downstream.

Downstream of the Vaal Dam, AMD contributes sulphate salts to the Vaal River – primarily through the Klip and Suikerbosrand rivers. The salinity of these rivers is frequently in the 'unacceptable' range. However, salinity in the Klip River has gradually improved since 1986 (largely because of the higher volumes of effluent from the wastewater treatment works) and now falls mainly in the 'tolerable' range.

Historically, the Klip River contributed most of the salt load (about 80%) to the Vaal Barrage. This influenced the calculation of the volume of water from the Vaal Dam required for diluting the middle Vaal River to 600 mg/ℓ TDS. Salinity in the Klip has since dropped below this level, thus dilution is no longer necessary.

While the salinity of the Orange River remains within the 'ideal' range along most of its length, salt concentrations gradually increase downstream (Figure 30). At Vioolsdrift, salinity has noticeably increased over time, rising from some 30 mS/m in the late 1970s to 50 mS/m in 2010. This most likely reflects the impact of increased irrigation along the length of the lower Orange, as well as the impacts of the lower flows. The hot, dry weather in this part of the basin also

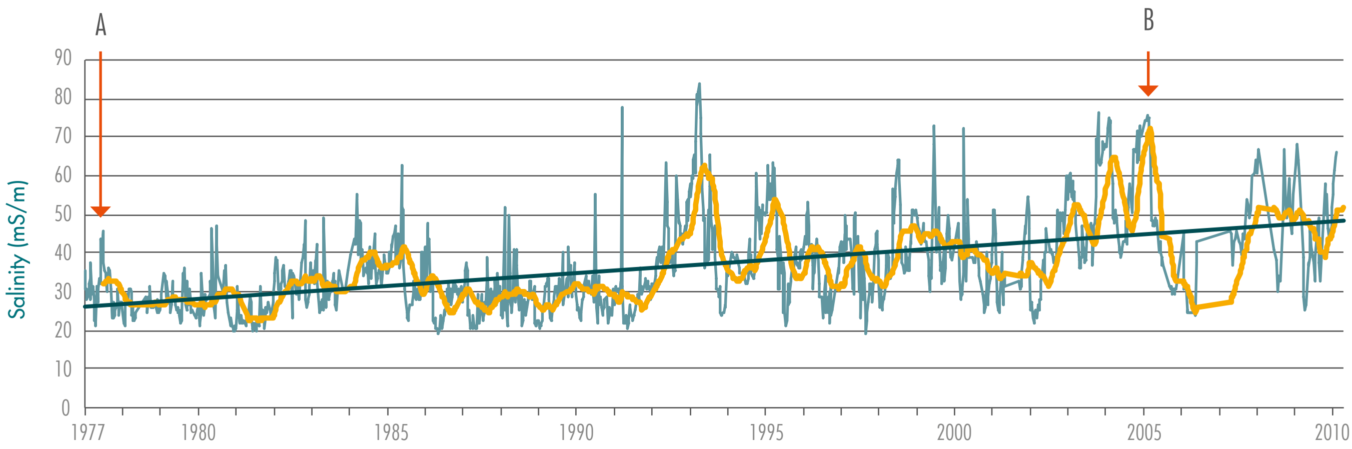
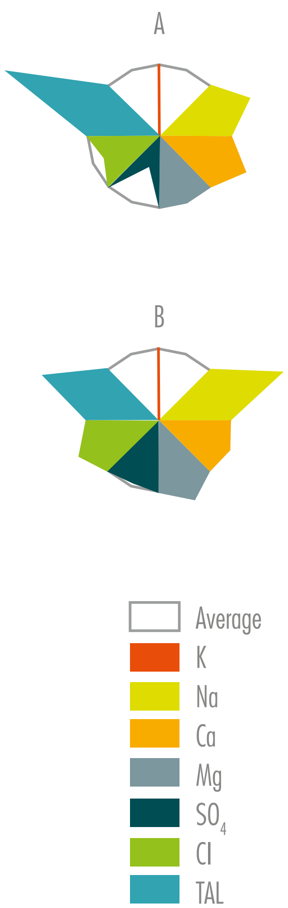


Figure 30: Salinity in the lower Orange River, 1977–2010



means that the salinity impacts on irrigated crops could be significant, especially if overhead sprinklers are used, as the salts in the water remain on the leaves of the plants causing salt burn.

Microbial contamination

Microbial contamination from faecal matter is caused by failing wastewater treatment works and reticulation systems, as well as densely populated but poorly serviced settlements.

Microbial contamination is normally measured as the counts of faecal coliform or *Escherichia coli* bacteria per 100 ml of water. While these organisms are not always pathogenic themselves, they are good indicators of the possible presence of other pathogens like *Giardia*, *Cryptosporidium* and cholera. Worldwide, microbial contamination of untreated drinking water is regarded as the most significant cause of infant mortality. In South Africa, the economic cost of diarrhoeal disease related to contamination of water has been estimated at ZAR32 billion per year (approximately USD3.2 billion, at 2013 exchange rate).

There is little data available on microbial contamination across the basin, and it has not been possible to analyse trends or the spatial extent of the problem. The data show, however, that while there is significant contamination in and around the main urban centres, it is localised. Notably, cholera has been recorded in settlements in urban areas that are not provided with safe drinking water, indicating that even though the problem is localised, it can have significant impacts on the people of the basin.

Heavy metals and persistent organic pollutants

Very little was known about the distribution of persistent organic pollutants (POPs) and metals in the Orange–Senqu River system before a special investigation was launched in 2010 to assess the extent of the problem. This reconnaissance survey was not aimed at investigating specific sources of POPs and heavy metals, but rather at determining the extent of the problem across the whole of the basin (ORASECOM, 2013b). River and wetland sediments, fish tissue and bird eggs were the focus of the survey, as pollutants are known to accumulate in these.

MANAGING SALINITY OF THE VAAL THROUGH BLENDING

Salinity has long been recognised as one of the more significant water quality problems in the Vaal River. During the 1970s and early 1980s, increases in salinity raised concern. Studies highlighting the costs associated with higher salinity prompted the search for an urgent solution.

AMD into the Klip and Suikerbosrand Rivers draining the Johannesburg area seemed to be driving the salinity problem, which led to a proposal to dilute the salts in these rivers with better quality water from the Vaal Dam. Environmental impact studies showed that increased flows could also dilute nutrient concentrations – reducing algal blooms through higher flows, and would contribute to environmental flows. The '600 mg/ℓ TDS Blending Option' was therefore implemented in the late 1980s.

While the dilution did place additional water demands on the system, it also provided valuable resources for downstream water use, and ultimately the programme succeeded in mitigating the overall impacts of salinisation.


© UNOPS/Greg Marinovich

The Klip River (above), which drains some areas of Johannesburg, is responsible with the Suikerbosrand River for the high salt concentrations in the Vaal.

Although the blending option is no longer operational, the decreases in salinity in the Klip River remain stable.

Salinity in the Suikerbosrand River increased in the late 1990s when AMD was pumped out of the Grootvlei mine and into the upper reaches of the river system, peaking at over 2,000 mg/ℓ – well above the 'unacceptable' level. However, the salinity was diluted by the improving quality of the Klip River. More recently, the Grootvlei mine has struggled to finance the 'treatment' of the AMD. Pumping has stopped and salinity in the Suikerbosrand River has decreased, but still falls largely within the 'unacceptable' range.

With additional pumping of large volumes of AMD being planned, fears that the salinity of the middle Vaal River will again rise to unacceptable levels are re-emerging and the dilution mechanism is being revived as an option.

It is difficult to predict the future impacts of pumping more AMD into the Klip and Suikerbosrand rivers on the middle Vaal River without complex mathematical modelling. However, at present, the middle Vaal River is mostly in the 'tolerable' range for salinity. Furthermore, experiences gained with the Grootvlei mine pumping show that the additional water demands for dilution may not be as significant as initially expected.

Further downstream in the Vaal system, salinity is primarily affected by irrigation return flows. Increasing salinity in the groundwater under the Vaalharts Irrigation Scheme gives potential cause for concern.

Salinity in the lower Riet–Modder River system is also affected by irrigation return flows and the operation of the transfers from the Orange River. The Riet and Vaal rivers are operated as closed systems, and only transfer sufficient water from the Orange to satisfy irrigation demands. As a result, irrigators further downstream are using increasingly saline water and are contributing a greater load of salts in their return flows. The consequence is that salinity in the lower Riet River is continually in the 'unacceptable' range, at times exceeding 2,000 mg/ℓ TDS, with significant impacts on crop yields. In 1995, a salinity blending option was proposed to aid this system. The proposed solution showed that the additional costs are modest, but the potential reductions in salinity could be significant.

© Johan van Rensburg

Being at the top of the food chain, fish-eating birds are at risk of building up high levels of POPs and heavy metals, making them susceptible to the effects of these pollutants.

HEAVY METALS, POPS AND BIOACCUMULATION

Persistent organic pollutants (POPs), as their name suggests, persist for long periods in the environment and have a variety of impacts on ecosystems and human health. Heavy metals, such as lead and cadmium can be toxic even in low concentrations and often accumulate in the bottom sediments.

Both POPs and heavy metals bio-accumulate; that is, they are stored in the muscle and fat tissue of organisms living in the environment in which they are present, gradually building up over time. The concentrations of POPs and heavy metals therefore also increase in species higher up the food chain. When people eat fish from polluted rivers, lakes and seas they can ingest large concentrations of these pollutants with potential adverse health effects. Lead and mercury in fish, and the accumulation of the pesticide DDT in bird eggs are well known examples of bioaccumulation.

© UNOPS/Christoph Mor

A member of the team working on the ORASECOM survey of persistent organic pollutants and heavy metals collects fish in Parys on the Vaal River.

Previously, research on POPs in the Orange–Senqu River basin concentrated on pesticides such as DDT. Only recently has more attention been given to POPs such as dioxins and polybrominated diphenyl ethers. Little is known about polycyclic aromatic hydrocarbons (PAHs) in the catchment, and there are very few studies available on levels of elements, including heavy metals, in sediments and biota. A survey was undertaken to assess levels of POPs and heavy metals in water bodies and riverine sediments under the umbrella of ORASECOM's 2010 Joint Basin Survey (ORASECOM, 2011i) and as a contribution to this TDA. During the study, PAHs were added as an additional research topic because of their detrimental effects on humans and wildlife (ORASECOM, 2013b).

Sediments were sampled in September 2010 at 61 sites, 33 of which were in the Vaal River catchment. The remaining 28 sites were along the Orange–Senqu River and its other tributaries, with one site in Namibia and five in Lesotho. Fish tissue was collected from three sites in the Vaal River system and from two sites in the Orange River. Four breeding colonies of aquatic birds were also identified for egg collection, all located in the Vaal River catchment.

The sharp-tooth catfish (*Clarius gariepinus*) was targeted as the preferred species for analysis as it is an omnivore that typically preys on fish, birds, frogs and even small mammals. It is common throughout the basin and is often caught and eaten by communities along the banks of the rivers, thus making it a good indicator of bioaccumulation.

Sediment concentrations of the 21 POPs outlined in the Stockholm Convention were found to be generally low in the Orange–Senqu basin. Some substances were not detected in the sediments at all, and where higher POPs concentrations were found, the problem seemed to be localised. They are perhaps not transported downstream because they are bioaccumulated or broken down very quickly.

The concentrations of organochlorine pesticides were found to be higher in and around the main urban centres in the eastern parts of the basin. The higher concentrations are attributed to the breakdown products of DDT and other pesticides.

Some POPs, notably dioxins and polychlorinated biphenyls (PCBs) occurred in higher concentrations near all the larger urban centres, including Bloemfontein, Maseru and the large urban centres in South Africa's Gauteng and North West provinces. Dioxins mostly originate from burning plastics in solid waste sites – referred to as 'unintentional' production under the Convention. PCBs can also originate from dumped electrical transformers and electrical motors where they are used as coolants.

Both dioxins and PCBs are thought to promote cancer and some are classified by the World Health Organisation as highly hazardous.

The risk of human exposure to POPs in river sediment is negligible. However, there may be some ecological risk associated with bioaccumulation of POPs that reside in the bottom sediments.

In the study commissioned for the TDA, perfluorooctane sulfonate (PFOS) was not found in the sediments in detectable levels. However, fish from the two sampling sites in the central parts of the basin contained PFOS, while bird eggs from Barberspan and especially Bloemhof Dam had surprisingly high levels. A more in-depth, species-specific assessment needs to be done and will be considered in a new sampling event.

Preliminary calculations based on approaches used by the United States Environmental Protection Agency suggest that there may be some exposure risk to humans if they eat the fish on a regular basis over an extended period of time; however more work is required to confirm these findings.

The limited number of sampling opportunities to collect data on POPs in fish tissue and bird eggs (added to the fact that birds are highly mobile), made it difficult to interpret the results of this study. Further research is needed to investigate this and other observed anomalies, which included inexplicably high concentrations of POPs in animal tissues at the lower Vaal, Middle Orange River and Bloemhof Dam sites; and lower than expected concentrations in the heavily industrialised areas of Eldorado Park and Standerton.

THE STOCKHOLM CONVENTION ON PERSISTENT ORGANIC POLLUTANTS

The Stockholm Convention is a United Nations environmental treaty that aims to eliminate or restrict the production, use and/or release of selected persistent organic pollutants (POPs). All four countries in the Orange–Senqu River Basin are signatories to the Stockholm Convention and are therefore bound by its provisions. Specifically, it requires the Orange–Senqu basin states to eliminate or restrict the use of POPs and 'within their capabilities and at the national and international levels undertake monitoring of, and cooperation on, POPs'.

Very little was known about the presence and concentration of the POPs listed under the Stockholm Convention in the Orange–Senqu River system before the Joint Basin Survey. The Stockholm Convention initially covered 12 substances, then in 2009 an additional nine were added and another was listed in 2011. Twenty-one of these were tested for in the survey.

© Greg Marinovich

Maintaining sound slimes dams is essential to avoid contamination of surface and groundwater sources through seepage and spillage.

HEAVY METALS

Heavy metals enter the aquatic environment through various routes, from extensive mining, to the large-scale combustion of coal and the wash-off of oils from roads. They find their way to watercourses where they are either dissolved in the water or trapped in the sediment.

The amount of metals dissolved in water depends on the pH of the water. Acid water (low pH) can have high concentrations of metals in solution. These metals rapidly precipitate once the pH rises and accumulate in the bottom sediments. Natural background values of heavy metals also vary widely depending on the local geology. Sometimes even these background values can exceed the recommended health limits.

Certain metals are nutritionally beneficial and are referred to as trace elements, for example, iron, copper, manganese, and zinc. At low concentrations, these metals – present in food or water – are necessary for healthy living. However, at higher concentrations, trace elements can cause acute or chronic toxicity. Metals bioaccumulate in the soft tissues, usually when larger quantities are present in the food and water. They can also be re-mobilised, even when they are present in river sediments, by the acid in the stomachs of bottom-feeding fish. They are then absorbed in the fish's tissues and can affect people if they eat the fish.

Heavy metal toxicity can affect the brain and central nervous system and may affect the ability of the blood to carry oxygen and trace elements around the body. High concentrations are known to affect the functioning of vital organs such as kidneys and liver, and long-term exposure may result in gradual degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy and multiple sclerosis. High levels of certain metals have also been linked to increased risks of cancer.

A total of 42 different heavy metals were analysed for the TDA survey across all 61 sites. A 'metal pollution index' (MPI) was produced for each site, using the geometric mean of the concentrations of all the metals found in the sample. The calculated MPI then provided an idea of the total metals load in the sample. This approach was a useful way to compare potential metal pollution across the whole basin.

The metal pollution index (MPI) was highest for the Molopo Eye and, when the geoaccumulation index (I_{geo}) values were determined, the same site had the most elements with I_{geo} values indicative of pollution (Figure 31). This site, together with a cluster of sites in the Riet and Modder rivers, also belonged to the 25% of sites with the most elements with the highest concentrations. Shared geology between some of the sites could partially explain this, but in-depth investigation of the area is deemed necessary to determine the exact cause. High levels of elements at two sites in Lesotho are also likely to be due to geology rather than mining or any other anthropogenic activities.

The elemental composition of sediments was difficult to associate with sediment source geology as a result of the very complex geology of the system and the huge drainage area covered. Furthermore, this assessment is based on complete digestion of the sediment, which aims to release the elements into solution so that

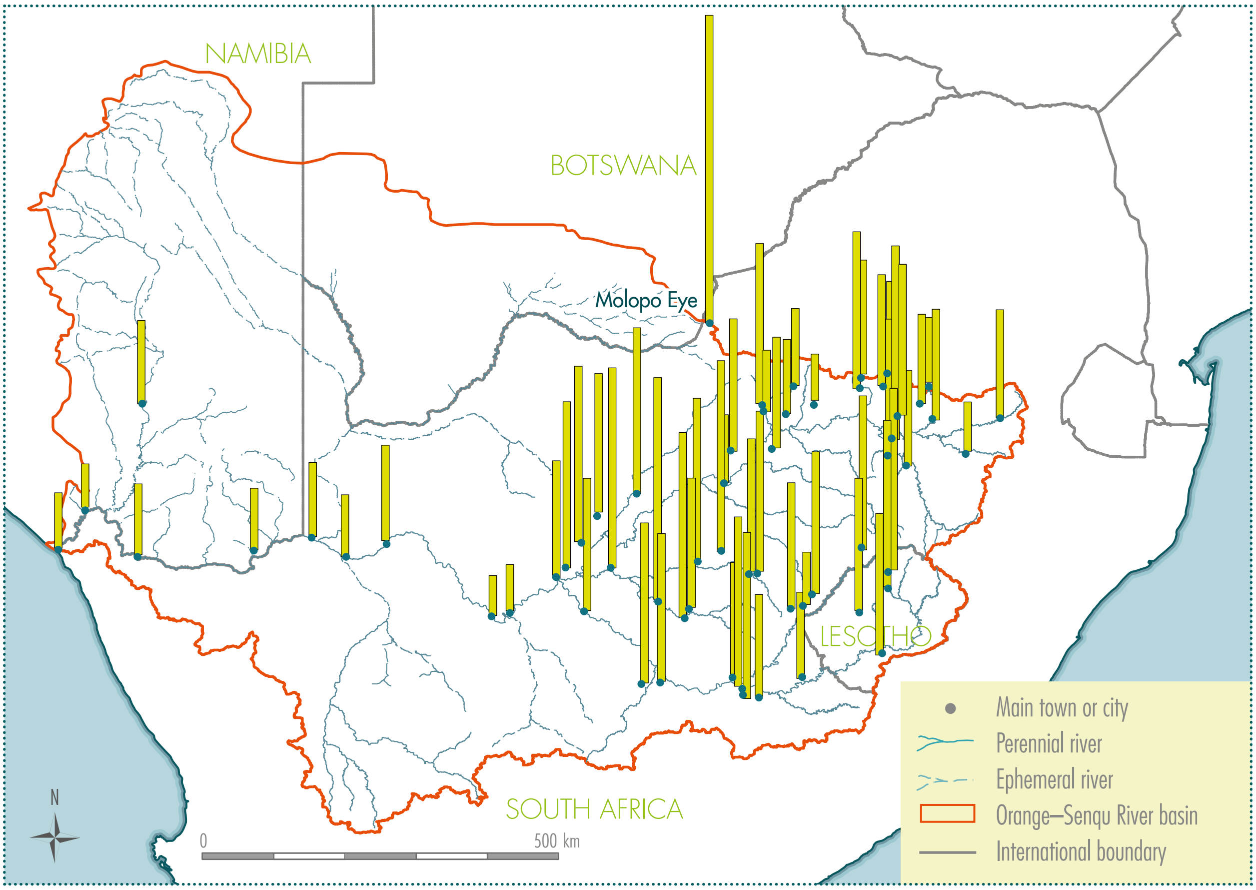


Figure 31: Metal pollution index (MPI) measured in the 2010 survey. Bar size is relative and shows the high MPI for the Molopo Eye.

they can be analysed. In reality, the elements in sediment will not necessarily be present in the surrounding water or be bioavailable.

Nevertheless, the study has identified areas of concern where more in-depth assessments should be done to determine whether high levels of elements are due to natural factors or disturbances – agricultural runoff, industry, urbanisation, mining – or a combination of these factors. Based on elemental analyses and risk assessments of sediments, the areas in the Orange–Senqu River basin that were identified as areas of concern are:

- Molopo Eye due to gallium, chromium, manganese, nickel, silver and selenium;
- Vaal River at Schmidtsdrift due to uranium;
- the areas associated with the Riet River and Koranna Spruit due to a combination of higher than average levels of several elements;
- the Caledon and Malibamatso rivers draining into the Orange–Senqu river due to a combination of higher than average levels of several elements;
- Skoon Spruit due to higher than average levels of iron, nickel and other elements;
- Fish River due to higher than average levels of arsenic.

In fish, levels of elements for which international guidelines and food safety standards are available were found to be within acceptable limits. Platinum was the element most likely to bioaccumulate, assuming that 100% of the measured concentrations in sediment would be bioavailable to fish. In bird eggs, tin had the highest level and also the highest bioaccumulation factor, but this is not necessarily an indication of toxicity. The grey heron seemed to bioaccumulate more elements than other bird species.

The health risk assessment indicated that arsenic and beryllium could potentially pose significant cancer hazards to humans consuming bird eggs and fish. However, the bioaccumulation results for both fish and birds should be treated with caution, as a number of assumptions had to be made in the calculations.

The survey helped identify basin-wide pollutant distribution patterns and identify areas for further work:

- Communities potentially exposed to hazardous levels of PAHs should be identified and the contributing pyrogenic sources investigated, so that interventions to reduce emissions of PAHs can be proposed. Such interventions would also reduce releases of dioxins and PCBs.
- This survey has probably not identified all communities and sites in the basin that are potentially experiencing hazardous exposure to PAHs. Additional areas where relevant sources are known to occur need to be identified.
- Communities that risk exposure to unacceptable levels of elements should also be identified.
- The reasons for unexpectedly high concentrations of certain organic compounds (especially PFOS) in biota in isolated areas need further investigation.
- A monitoring programme should be instituted to track changes, with a selection of samples stored for retrospective analyses.
- Areas of concern identified, should be investigated to determine the sources and processes contributing to high levels of heavy metals and trace elements in water and sediment, as well as their bioavailability.
- These data of background levels of elements are the first of their sort, and need to be curated to allow for future comparisons and trend monitoring.

Radionuclides

Radionuclides are a range of potentially radioactive metals, chiefly uranium, thorium and radium. They are commonly found in gold-bearing rock and pose potential threats through AMD and in the sediments washed from mining

Catching fish (left) and taking samples (right) to analyse for heavy metals and POPs in fish tissue, basin-wide survey, 2010.

residues. Radionuclides, when present in sufficiently high concentrations (above background levels), can increase the risk of cancer after long-term exposure.

There are very few data available on the extent of the radionuclide problem across the whole of the Orange–Senqu basin. However, studies have been undertaken in the rivers draining the main gold mining areas, which indicated that the radiological risk associated with the water was low and there was very little downstream transport.

Transient elevated radioactivity was noted at some sites, but this was not sustained and did not pose a long-term health risk. The studies also noted that radioactivity in the Klip River was closely correlated to the concentrations of uranium in the water, and suggested that uranium concentrations could perhaps be used as a tracer for radioactivity. They did not consider using bottom sediments or fish tissue as possible indicators of contamination – an area of investigation covered in the next section.

2.4.2 Aquatic ecosystem health

Ecosystems have the capacity to absorb change and recover from damage. This resilience to a changing world is crucial. However, when an ecosystem loses its resilience it becomes vulnerable.

Monitoring ecosystem health

The abundance and types of aquatic organisms naturally vary along the length of the Orange–Senqu River. River monitoring programmes rely on the availability of similar 'reference' sites in their 'natural state' in order to assess the system's health, but this poses a problem for the Orange–Senqu as it is affected by human activities along virtually its entire length.

In the absence of unaffected 'reference sites', impacts have to be set against expert knowledge of the rivers and what should occur naturally. It is then possible

Collecting bird eggs (left) and measuring (right) before sending them off for analysis for heavy metals and POPs, basin-wide survey, 2010.

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to determine the condition of river ecosystems on a scale of 'unmodified' or 'natural' to 'seriously modified' in a similar manner to the European, American and Australian systems. This represents an increasing loss of species and ecological functions.

Perhaps the best measure of the condition of the aquatic environment comes from the aquatic life itself. Plants and animals living in rivers and lakes react to even short-term changes in water quality, and their numbers and composition can be affected for months or even years after a pollution event. Monitoring the numbers and types of aquatic organisms can therefore provide a more complete picture of the impacts on a river than sampling chemical water quality alone.

By monitoring the numbers and types of organisms found at a sample site, and then comparing them to what you would expect to find under natural conditions, it is possible to assess river health. Measuring the abundance and type of macro-invertebrates (insects, crustaceans, snails and worms), fish species and algae (diatoms) builds a picture of an ecosystem's health.

Organisms not only respond to changes in water quality but also the flow patterns of rivers, both of which drive changes to aquatic ecosystems. Monitoring of the habitat itself is also important to determine whether a lack of suitable habitat is the result of natural causes or human intervention. Habitat destruction by removal of natural vegetation along the banks of rivers, building dams or weirs in the river, and mining of the rivers' banks and beds are key factors in river health.

BASIN-WIDE WATER QUALITY MONITORING

After the recent basin-wide survey it has been recognised that there is an urgent need to improve knowledge about the scale and extent of water health and quality issues, acceptable water quality standards and how to deal with, especially emerging, pollution issues (ORASECOM 2011i, 2013b). While a monitoring programme was proposed in 2010, this should be reassessed and improved.

A water resource quality monitoring network would allow the spatial and temporal water resource quality status of the basin to be assessed and trends determined. It should include all aspects of the physical, chemical, biological and ecosystem characteristics of water sources that pertain to its quality.

The existing water resources quality monitoring networks of basin states need to be harnessed and basin-wide guidelines for water resource quality need to be developed. South Africa and Lesotho's water resource quality guidelines have been identified as the most advanced for different water users. It is proposed that these will be re-interpreted to produce basin-wide water resource quality guidelines that cater for all aspects of water quality. There should be an emphasis on analysis and regular delivery of information for management.

(From Du Plessis, M, 2013)

There are several river health monitoring programmes in the Orange–Senqu basin. The Lesotho Highlands Development Authority (LHDA) operates a monitoring programme at eight sites in the region using the South African Scoring System (SASS) for macro-invertebrates. This programme, included under the LHWP Treaty, is designed to assess whether environmental flows released from the Katse and Mohale dams are having the desired impacts. The programme scores the ecosystem condition using a range from 'pristine', through to 'non-functional'.

South Africa's River Health Programme uses a number of methods to assess the river ecosystem – the SASS, a fish response assessment index and an index of habitat integrity – each of these methods focuses on the response of the ecosystem to arrive at an integrated view of river health. Recently, diatoms have been included as an indicator means and there are plans to include riparian vegetation assessments. Sampling is undertaken at least twice a year: in autumn and spring for invertebrates, and less frequently for fish and habitat assessments. The programme has identified 132 sites in the South African portion of the Orange–Senqu River system for sampling, but the programme has been expensive and administratively difficult to establish and few of the identified sites have been regularly surveyed.

Namibia has recently started monitoring river health but has not established routine monitoring. Here, the Namibian Scoring System (NASS) is used, which is very similar to the SASS method, but includes several species that are common to northern Namibia. Both the NASS and SASS methods therefore produce the same results for the Orange–Senqu River system. Namibia has also collected data through the Neckartal Dam's Environmental Impact Assessment.

ORASECOM has established a monitoring programme for aquatic ecosystem health at 45 sites throughout the basin, including many sites that are already part of the other programmes to minimise duplication. The ORASECOM programme proposes sampling of macro-invertebrates twice a year (using either SASS or NASS) with a full survey of fish, habitat, riparian vegetation, diatoms, and ecological drivers every five years. The first of these five-yearly surveys was carried out in 2010 (ORASECOM 2011i).

Establishing and maintaining an effective basin-wide water quality monitoring network requires concerted effort, resources and coordination.

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Children identify various freshwater fauna during the MiniSASS workshop in Namibia.

ORANGE–SENQU RIVER LEARNING BOX PROJECT: ACTION LEARNING FOR A LIVING RIVER

Children are the basin's future managers and decision-makers, so efforts are being made to raise their awareness about the Orange–Senqu River basin, its water resources and the challenges of conserving and managing these vital resources.

Educational materials aimed at 10–12-year-old school learners in the basin – the Orange–Senqu River Learning Box – are being developed. In addition, teachers and learners from each of the basin states are being trained to use MiniSASS, a simple water-quality monitoring tool based on the comprehensive South African Scoring System (SASS). They are provided with equipment allowing them to monitor water resources in their area. Training allows them to upload their results to a wiki for the river basin and share their miniSASS results and other environmental data collected.

Ecosystem health in the Vaal River

The upper Vaal River is mostly categorised as 'moderately modified', because of flow modifications from water transferred into the basin. Rivers that are not impacted by these transfers are in a 'largely natural' state. Flow regulation from the Grootdraai Dam in the upper reaches of the Vaal degrades the system to a 'moderately' to 'largely modified' state. Tributaries draining the industrial and mining areas around Secunda show 'largely modified' ecological functioning, mostly as a result of mining and industrial pollution.

© Ruslou Koorts

Large-scale, heavy industry not only places a heavy demand on water resources, it is also a potential source of pollution to the basin's water resources.

PRESENT ECOLOGICAL STATE OF AQUATIC ECOSYSTEMS

In assessing the health of a water body, experts take various abiotic and biotic parameters into account, weight them and give each a score. The overall health score is called the present ecological state (PES). A system of categorisation commonly used in southern Africa for defining PES is shown in the table below. The PES helps determine what the recommended (desired) ecological category should be and determines what interventions should be put in place to reach it. The degree to which the ecological state needs to be elevated above the PES depends on the level of importance and level of protection, or desired protection, of a particular aquatic ecosystem – and what is possible to attain.

Table 18: Definitions of PES categories (after Kleynhans, 1996)

Health score (%)	PES category	Description
90–100	A	Unmodified, natural
80–90	B	Slightly modified: A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
60–80	C	Moderately modified: Loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
40–60	D	Largely modified: A large loss of natural habitat, biota and basic ecosystem functions has occurred.
20–40	E	Seriously modified, highly degraded: The loss of natural habitat, biota and basic ecosystem functions is extensive.
0–20	F	Critically modified, extremely degraded: The system has been critically modified with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

© Graeme Williams

An acidic pond near eMalahleni (Witbank), South Africa, where large tracts of land have been left after decades of mining activity

Downstream of the Vaal Dam, flow regulation maintains the system in a 'largely modified' condition. The Klip River carries a significant proportion of effluent, and is categorised as 'largely modified' because of both poor water quality and flow modification. The Suikerbosrand River system, which receives both domestic effluent and acid mine drainage, is in a 'largely' to 'seriously modified' condition as a result of modification and water quality. The upper reaches of the Suikerbosrand River (upstream of the mining and urban areas) is, however, in a 'largely natural' to 'moderately modified' state.

For the most part, the middle Vaal River is in a 'moderately modified' condition. The ecosystem function is impacted primarily through poor water quality (largely as a result of nutrient enrichment), alien vegetation, and to some extent flow regulation. Tributaries draining the mining and industrial areas from the north have 'largely to seriously modified' ecological functioning, principally as a result of acid mine drainage and nutrient enrichment. The Harts River draining the Vaal Harts irrigation scheme is 'largely modified' because of both water quality and flow related drivers. Livestock watering has altered the river banks in many areas, affecting river ecosystem functioning.

Ecosystem health in the Orange and Senqu rivers

Since regular monitoring in the Lesotho Highlands began in 2006, aquatic ecosystems there have varied from 'natural' to 'seriously modified'. There is some evidence to show that this may be a result of the impacts caused by the construction of the Katse and Mohale dams, but rivers that are unaffected by these dams also occasionally show 'highly modified' states. Most sites sampled in the region seem to be 'largely natural' to 'moderately modified'.

Rivers receiving the water transferred from the Lesotho Highlands are in a 'largely' to 'seriously modified' ecological state, as a result of the increases in flow. The Wilge River upstream of the influx of the water from Lesotho (upstream of the town of Harrismith) is in a largely natural state. However, immediately downstream of the town, the ecosystem functioning is 'largely modified' because of the impact of a municipal wastewater treatment works. The Wilge River nevertheless recovers further downstream to a 'moderately modified' state.

The Orange and Caledon–Mohokare river systems are in a predominantly 'moderately modified' condition, with both flow and water quality drivers

A view of the lower Orange River from the north bank looking upstream shows a green belt of trees along the river banks, many of which are alien invasive species. Changes in flow and increased salinity have a variety of impacts on the aquatic ecosystem here.

© John Pallett

impacting ecosystem functioning. In the smaller rivers, destruction of the riparian vegetation has also driven the condition of the river ecosystem, while weirs and water storage infrastructure have disrupted river continuity for virtually the entire Orange–Senqu system.

In the lower Orange River, changes in flow and increased salinity have had the greatest impacts on aquatic ecosystem functioning, resulting in a 'moderately modified' state.

The Fish River in Namibia is similarly affected by weirs and other structures in the river, flow modifications, and nutrient enrichment from livestock, and is in a 'moderately modified' condition.

© Carole Roberts

The site of the Neckartal Dam, which is currently under construction on the ephemeral Fish River, Namibia. This dam will be the largest dam in Namibia when completed. It will impact the aquatic ecosystems downstream, especially the permanent pools and the recharge of alluvial aquifers, unless environmental flows are carefully implemented.

Ecosystem health of the estuary

The wetland system at the Orange River estuary is heavily impacted by developments throughout the Orange–Senqu basin, as well as activities in the estuary area itself. The significant loss of the salt-marsh area prompted Namibia and South Africa to list the wetland on the Montreux Record, a convention which identifies priority wetlands for positive national and international attention, and places obligations on the countries to take positive action to address the causes of wetland degradation. (So far, only 55 of the 1,952 Ramsar sites worldwide have been listed on the Montreux Record.)

The ecological health of estuaries can be assessed in a similar way to rivers, by determining the abundance and composition of key estuarine species. The ecological health of the Orange–Senqu estuary was last assessed in 2003, and the system was classified as 'largely modified'. At that time researchers suggested that, in the light of its Ramsar status, the system should be improved to at least 'moderately modified' by introducing changes within the estuary, such as restoring freshwater inflows to a more natural pattern.

Like rivers, estuarine ecosystems require freshwater inflows to mimic natural patterns so that they function effectively. Freshwater inflows to the Orange–Senqu estuary, however, are now less than 40% of the natural flows, having been reduced from a natural mean annual runoff (MAR) of 11,300 Mm^3 per year to approximately 4,200 Mm^3 per year. Further reductions are anticipated as water demands increase. The river is now so controlled that the seasonal pattern of water flow has effectively been reversed: winter flows are often higher than those in summer, and flood volumes have been reduced by almost half, having significant impact on the wetland ecosystem.

A delicate balance is at play at the Orange–Senqu river mouth. To ensure a healthy ecosystem in the estuary, both flooding and flushing-out are crucial.

Floods and variable river flows are vital to maintain the careful balance of transitional waters as they deliver valuable nutrients and affect the opening and closing of the estuary mouth. Small floods maintain channels in the wetland area, and larger floods open the mouth by flushing away the accumulated sediments.

Back floods, which result from the build-up of water levels behind a closed mouth, are also essential for estuarine health. Historically, the Orange River mouth closed approximately once every four years. Now, constant low flows keep the mouth open most of the time and when it does close, the mouth is artificially breached to protect mining infrastructure from flooding. This means that salt marshes in the estuary are no longer inundated with water – a process essential for the ecological function that increases the salinity of the marsh and sustains the species that live there.

'Flushing out' of the estuary with fresh water is also important to wash out accumulated salts from time to time. However, with the Vaal River being operated

Flooding of Mariental in 2000 and 2006 was, in part, attributed to the dense reed growth in the Fish River below the dam at Hardap Irrigation Scheme. The growth of the reeds is an indication that the return flows from the irrigation scheme are high in nutrients. One initiative to help avoid flooding of the town again has been to clear the watercourse of reeds. This would, however, not address the underlying water quality issue.

as a closed system and the dams in the Fish and Orange rivers holding small- and medium-sized floods back, flushing out happens infrequently. Currently, only large floods flush the estuary system.

Despite the importance of flushing out the system, the estuary cannot be inundated with river water too often. Constant freshwater inflows decrease salinity in the marshland and impact vegetation and biodiversity.

Changes in flow patterns have important effects on the water chemistry of the estuary. The condition of a constant open river mouth shifts the balance between marine and fresh water and affects the salinity regimes needed to maintain the estuarine ecology. The Orange River mouth largely escapes the severe pollution in the Vaal River system, because of the operation of the Vaal River as a closed system, and because of the assimilation of pollutants along the length of the lower Orange River. Nevertheless, toxic algal blooms in the lower Orange River (most probably driven by nutrients from irrigated agriculture in the region) suggest some level of nutrient enrichment.

The amount of sediment carried down the Orange River is considerably lower than recorded prior to the 1960s. Regulation of the flows and reduction of the flood peaks means that sediment is no longer carried downstream. Historically, much of the sediment carried by the river was derived from the upper portion of the Orange–Senqu system. This sediment is now largely trapped behind the Gariep and Vanderkloof dams, leaving the estuary to be fed predominantly with sediment from the middle Orange River catchment. This is evident from the metals loads in the sediment, which are much lower than those noted upstream of the Vanderkloof Dam.

Sediment carried by the Orange River also plays an important role in the establishment and maintenance of the estuary's wetlands. Sediment brought down by the river replenishes near-shore habitats that are continuously eroded by the ocean's currents. Sediments also carry organic matter and nutrients into the estuary, supporting an abundance of life in the bottom sediments – an important source of food for bottom-feeding fish species.

The flow of nutrients, sediment and detritus from the river plays a valuable role in the numbers of other fish species. Microscopic organisms and invertebrates live off the detritus, and phytoplankton and zooplankton utilise the suspended nutrients. These communities provide food for all life stages of fish. Sediment carried in the water column also offers protection by increasing the turbidity or cloudiness of the water, providing a valuable refuge from predation.

When the river discharges into the sea, sediments are deposited in an underwater delta, and are dispersed by wave action, longshore drift and subsurface currents. Altered flow regimes and sedimentation can affect the broader marine and coastal environment, the most significant of which is the Benguela Current Large Marine Ecosystem. However, the impacts of the altered flow regimes in the Orange River at present are not expected to be significant in these systems (ORASECOM, 2012).

Pollution from within the boundaries of the wetland is however becoming a key factor affecting wetland functioning. Slimes dams constructed adjacent to the salt marshes could be contributing to the hypersalinity measured in the estuary, which in turn is causing die-back of vegetation around the mouth of the estuary. Without the protection of vegetation, the valuable salt marshes are at increasing risk of erosion. Apart from a degree of saline water seepage from the slimes dams, the wetland is also polluted by fine waste particles that are picked up and deposited onto the marshes by the wind.

The area around the Orange–Senqu estuary is very sparsely populated. Diamond mining companies control access to the coast and estuary, and visitors to Alexander Bay in South Africa and Oranjemund in Namibia need permits to holiday in the region. With diamonds now depleted and the commercial fisheries downsizing, it is expected that the region's emphasis will shift from industry to ecotourism. Although low-key at present, ecotourism is a growing industry and a possible source of future socio-economic benefit. However, the region's remoteness will most likely limit its full tourism potential.

PRIORITY INTERVENTIONS FOR MANAGEMENT OF THE ORANGE–SENQU RIVER MOUTH

In a recent study, the present ecological state (PES) of the Orange–Senqu River mouth was determined to be in Category D, largely modified (Rivers for Africa, 2013). As it is a designated Ramsar site, it was recommended that it is elevated to 'its best attainable state', which is estimated as a Category C. To do this, a number of key interventions have been recommended (van Niekerk, 2013):

- Decrease winter baseflows sufficiently to allow closure of the mouth and back-flooding of the salt marshes.
- Remove the remnant causeway to improve circulation during high flow and flood events.
- Remove old earth-moving equipment buried in the sand berm near the mouth of the river.
- Control wind-blown dust and wastewater from mining activities, to reduce smothering of the salt marshes.
- Identify elevated areas that obstruct tidal intrusions and drainage of the floodplain.
- Control fishing efforts on both sides of the estuary through increased compliance, law enforcement and alignment of fishing regulations in South Africa and Namibia.
- Decrease nutrient input from upstream Noordoewer–Vioolsdrift area by improving agricultural practices.

© Antje Burke

Orange River mouth

Environmental flows

The timing, duration and magnitude of flows have profound impacts on the function of river and estuarine ecosystems:

- Changes in flow are important for many aquatic species that require flowing water to survive, move up or downstream or as a signal to start spawning.
- Higher flows wet a greater area of riverbed – increasing the amount of habitat available. They also inundate new habitats along riverbanks and back waters which provide valuable spawning sites.
- High flows also help to oxygenate the water, decrease the retention time in slow-flowing sections of the river, and limit algal blooms.
- Floods help flush out accumulated sediment, while low flows deposit sediments that can help establish new habitats.

Environmental flows describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and wellbeing that depend on these ecosystems (Hirji and Davis, 2009). Countries around the world are increasingly taking environmental flows into account when managing water resources. To maintain a natural or pristine ecological condition, very little water can be abstracted for water use.

The provision of water for the protection of the riverine and estuarine ecosystems, and the control of unwanted consequences of degradation, have long been recognised as key factors in the management of the Orange–Senqu River basin.

In the 1970s and into the 1980s blackfly was controlled using water-flow manipulation (Myburg and Neville, 2003), and in the late 1980s, the Orange River Environmental Task Group was formed to assess the environmental flow requirements of the Orange River between Vanderkloof Dam and the mouth (ORETG, 1990). Since then, environmental flow assessments have been done for various parts of the basin. To our knowledge, however, only those for the upper Orange–Senqu sub-basin in Lesotho are being actively implemented and monitored.

A number of methods have been proposed for determining environmental flows and these provide the scientific basis to assess the links between flow and ecosystem function. However, the final determination of environmental flow is

The Orange River, having offered its water to meet other requirements on its 2,300 km journey, slowly meanders the last few kilometres into the estuary before reaching the cold, fog-shrouded Atlantic waters.

a socio-political decision, based on balancing the likely impacts of different flow regimes on ecosystem functioning with the economic impacts of decreasing the amount of water available for use. All four of the Orange–Senqu basin states have committed to establishing environmental flows in this way.

Environmental flow requirements for the Orange–Senqu system

South Africa's National Water Act (1998) introduces the concept of the 'ecological reserve' – the quality and quantity of water required to sustain aquatic ecosystems. This must be met before water is allocated to other uses. A similar concept of ecological reserves has been adopted in Lesotho's water legislation.

In Namibia, 'resource quality' is defined as the quantity, pattern, timing, level and assurance of stream flow that must be considered when issuing a permit for water use or effluent discharge. The Namibian Water Resources Management Act (2013) also provides for water to be allocated for environmental purposes, and protection of the environment 'to the maximum extent'. Botswana does not yet have legislation that specifically makes provision for environmental flows.

The first legislative recognition of the need to provide for environmental flows in the Orange–Senqu River system was the Lesotho Highlands Treaty. Signed in 1986, the treaty stipulated 'compensation flows' to be released from the Katse and Mohale dams and Motsoku Weir that amount to approximately 2–3% of the natural flows to maintain the system at predetermined conditions. These initial provisions have subsequently been further developed in the Lesotho Highlands Development Authority (LHDA) policy on environmental flows (called in-stream flow requirements, or IFRs, in Lesotho). This represents one of the few examples of an environmental flow requirement being in operation in the basin.

Over the past 15 years, environmental flow assessments have been done for several river reaches in the Orange–Senqu basin, and in some cases more than one study has been done for the same area. These assessments vary in terms of their basic approach, the level of detail at which they were done and the different hydrological baselines used. Studies range from being purely desktop (involving no fieldwork) using monthly hydrological data, to comprehensive studies. The latter include two full field visits to collect biophysical data, hydraulic and biological sampling and daily hydrological data. The impact of reduced freshwater inflows on the estuary has been part of various assessments over the years, but it wasn't until recently that a more detailed environmental flow assessment was done specifically for the estuary (Rivers for Africa, 2013).

A summary of the assessments and key findings are summarised in Table 19. The natural mean annual runoff, PES, the recommended ecological category and the percentage volume of mean annual runoff to maintain the recommended ecological category are given. The locations of the assessments are illustrated in Figure 32. Apart from the environmental flow requirements determined for the Senqu sub-basin, the required flows are not being actively implemented, although some are being met by current flows.

There are key mismatches with respect to mean annual volumes that would need to be resolved before an integrated basin-wide flow regime could be implemented. For example, EFR05 on the Orange River, immediately upstream of the estuary, requires 14% of mean annual runoff to maintain its ecological condition, whereas the estuary requires 39.5%. Such mismatches would be more marked at monthly or daily levels of resolution.

There is a need to synchronise the outputs of these assessments and to use them as a basis for determining and implementing a harmonised basin-wide environmental flow regime.

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Blackfly (*Simulium* spp.) breeds in rivers where there is constant flow of fast-moving water. The larvae, as shown here, attach to rocks and plants and filter out suspended particles. It first became a pest along the lower Orange in the 1970s as a result of the change in flow regime due to construction of major dams upstream. The adult fly is a pest of small livestock farming and can cause huge economic losses in the sector.

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Breaks made in the causeway that crosses the Orange River estuary is one of the measures taken to rehabilitate the salt marsh.

Table 19: Summary of environmental flow studies and key findings (Brown, 2013)

River		Site	Method used	Natural MAR (Mm³)	PES	REC	EFR (Mm³)	EFR (% MAR)
Senqu								
	Senqu	Polihali	DRIFT	730	C	D	136	18.63
	Matsoku	IFR 1	DRIFT	87	A	C	34.8	40.00
	Malibamatso	IFR 2	DRIFT	576	B	D	88.1	15.30
	Malibamatso	IFR 3	DRIFT	774	B	C	224.46	29.00
	Senqu	IFR 4	DRIFT	1,572	B	B	Dependent on IFR 3	
	Senqu	IFR 5	DRIFT	1,924	B	B	Dependent on IFR 3	
	Senqunyane	IFR 7	DRIFT	355	B	D	78.1	22.00
	Senqu	IFR 6	DRIFT	3,330	B	B	Dependent on IFR 3 and 7	
Caledon								
	Caledon	EFR05	HFSR	57	C/D	C/D	14.32	25.17
	Nqoe	IFR 11	n/a	5	B	B	4.8	100.00
	Phuthiatsana	EF Site 1	DRIFT	73	C/D	C/D	15.39	21.09
	Kraai	EFR07	HFSR	683	C	C	135	19.78
	Caledon	EFR06	HFSR	1,348	C	C	259.9	19.28
	Orange	EFR01	n/a	6,737	C	C	None	
Vaal								
	Vaal	EWR 1	desktop	332	B/C	B	130.92	39.40
	Vaal	EWR 2	HFSR	458	C	C	62.27	13.61
	Klip	EWR 6	HFSR	95	B/C	B/C	25.3	26.54
	Vaal	EWR 3	HFSR	858	C	C	122.67	14.30
	Wilge	EWR 7	HFSR	23	A/B	C	10.77	45.89
	Wilge	EWR 8	HFSR	474	C	C	64.45	13.59
	Vaal	EWR 4	desktop	1,977	C	B/C	None	
	Suikerbosrand	EWR 9	HFSR	31	C	B/C	10.85	34.65
	Suikerbosrand	EWR 10	desktop	149	C/D	C/D	61.35	41.10
	Blesbokspruit	EWR 11	desktop	29	D	D	6.18	21.21
	Vaal	EWR 5	desktop	2,288	C/D	C	-	-
	Vaal	EWR 12	HFSR	2,546	D	D	832.79	32.70
	Vaal	EWR 13	HFSR	2,654	C/D	C/D	859.82	32.39
	Vals	EWR 14	HFSR	146	C/D	C/D	24.85	17.05
	Vet	EWR 15	HFSR	413	C/D	C/D	46.10	11.16
	Vaal	EWR 16	HFSR	1,699	D	D	422.24	24.85
	Harts	EWR 17	HFSR	148	D	D	107.20	72.51
	Vaal	EWR 18	HFSR	3,347	C	C	257.39	7.69
	Vaal	EWR 19	HFSR	404	C	2	171.10	42.37
Orange								
	Orange	EFR02	HFSR	10,573	C	C	1,797.00	17.00
	Orange	EFR03	HFSR	10,513	C	B	2,341.00	22.27
	Orange	EFR04	HFSR	10,335	C	B/C	1,478.90	14.31
	Molopo	EFR08	flow plan	10	C	B/C	3.53	34.17
	Fish	EFR 01	HFSR	-	B/C	B	Flood requirements for Hardap Dam	
	Fish	EFR 02	HFSR	613	B/C	B/C	245.20	40.00
	Orange	EFR 05	HFSR	11,373	B/C	B	1,667.32	14.66
	Estuary	Estuary	estuary	11,373	D	C	4,469.77	39.50

REC = recommended ecological category
HFSR = Habitat Flow Stressor Response
DRIFT = Downstream Response to Imposed Flow Transformation
Source: Brown, 2013

Figure 32: The positions of environmental flow assessment sites listed in Table 19, based on Brown (2013)

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The Fish River a few hundred metres upstream of its confluence with the Orange

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The rain season of 2011 was exceptional throughout the basin, with some areas receiving three or four times more rain than on average. Such extreme events are likely to become more common with climate change.

2.5 CLIMATE CHANGE

According to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC, 2007), Africa is expected to experience more rapid warming than the global average during the 21st Century, with the drier subtropics warming more than the moist tropics. It was stated that rainfall in southern Africa is likely to decrease in much of the winter rainfall region and western margins. The likelihood of change in summer rainfall, which is most significant for the Orange–Senqu basin, is less evident.

Global climate change (GCC) models use a very coarse resolution and cannot take into account local climatic variations. Their application to a single river basin or part of one, even when the basin is as large as the Orange–Senqu, is of little practical value. A global climate change downscaling exercise was recently carried out for the Orange–Senqu basin (ORASECOM, 2011c) with the aim of investigating possible climate change at a higher level of resolution through regional downscaling.

2.5.1 GCC downscaling for the Orange–Senqu River basin

The ORASECOM study (2011c) used both dynamic and statistical downscaling methods with a large volume of climate data from all four basin states. The downscaling used the A1B emission scenario (IPCC, 2000), which assumes a globalised world emphasising economic growth and a balanced dependence on fossil and non-fossil fuel energy sources. The future projections compare the period 2031–2060 with 1971–2000.

Projected temperature increase is unevenly distributed across the seasons. In summer and autumn a temperature increase of more than 2.5° C is estimated in the northern part of the basin and Namibia in general. The largest increase of 3° C is predicted for the summer months in the Southern Kalahari Savannah area.

The study also looked at the possible changes to precipitation. Figure 33 shows how the long-term average of the precipitation for the future time period may differ from the present. A major decrease in precipitation is predicted for much of the basin, especially the north-eastern part. However, an increase over the source areas, mainly in the Maloti Mountains of Lesotho, is also predicted.

It should be stressed that the recommendations of the study emphasised the need both for further downscaling work and improved data in order to achieve a better level of confidence in findings.

2.5.2 Vulnerability to climate change

The IPCC report on regional impacts of climate change (Watson et al. 1998), argues that the vulnerability of a region depends to a great extent on its wealth, and that poverty limits adaptive capabilities. In simple terms, vulnerability is highest where there is 'the greatest sensitivity to climate change and the least adaptability'. However, it can also be argued that adaptive capability is better where people are already used to adapting to highly variable climatic conditions, as is the case in many parts of the Orange–Senqu basin. Given the huge natural areal and temporal variation of precipitation, especially in the more arid western parts of the basin, it has proved difficult to detect change in precipitation as a result of climate change at a statistically significant level. The vegetation and land-use practices in the basin have, arguably, been adapted to prolonged drought and climatic extremes for many decades and are thus less vulnerable than might be anticipated.

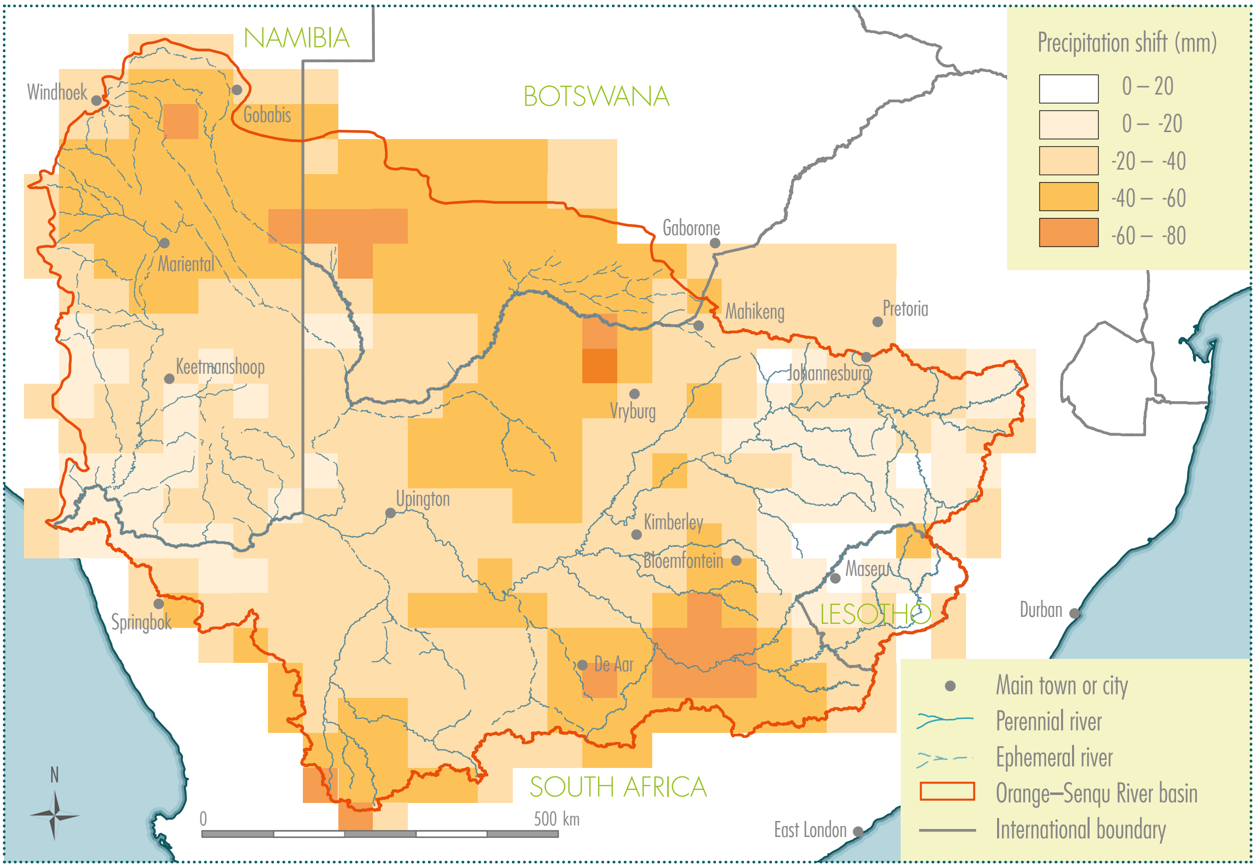

Figure 33: Predicted changes in annual precipitation (ORASECOM, 2011c)

Perhaps vulnerability to increased temperatures is more noteworthy than vulnerability to changes in precipitation. The downscaling has indicated that temperature increases throughout the basin are likely to be significant and have major impacts on vegetation and agricultural activities. There is a high level of confidence in this prediction.

The boxes in this section summarise sectoral vulnerabilities and adaptive capacities as they may be anticipated in the basin, highlighting those areas associated with the terrestrial environment.

CLIMATE CHANGE PARAMETERS

Temperature

- Higher warming is predicted throughout the basin and in all seasons compared with global average.
- Warming will be most severe in the central and western parts of the basin in summer and autumn.
- Winter temperature rise is less marked but still significant.

Precipitation

- Decrease in annual rainfall in most of the basin is predicted, which will be most pronounced in the northern and south-eastern parts.
- Possible increase in precipitation in some headwater areas might occur, especially in Lesotho.
- Distribution of rainfall events may change, typically fewer rain days and more intense storms.

Extreme events

- Possible increase in frequency and intensity of extreme events, including droughts and floods is predicted. Many areas will suffer from both.

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Desiccation of habitats and increasing aridity will move eastwards with climate change.

SECTORAL VULNERABILITIES TO CLIMATE CHANGE

Water resources

- Increased water stress for most parts of the basin is likely to affect all sectors, but irrigation will be particularly vulnerable.
- Possible increase of flows in highland source areas may compensate for those dependent on water directly from the river.
- Natural adaptive capacity or regulatory functions of river systems will have been diminished by deforestation, erosion and damage to wetlands.

Terrestrial ecosystems

- Drying and desertification will move eastwards.
- Areas will switch from one biome to another and biodiversity will be lost.
- Levels of deforestation and degradation of grasslands will increase.
- Soil erosion will increase.
- More animal species will become endangered.

Agriculture and food security

- Agricultural production is likely to be very vulnerable to loss of land, shorter growing seasons and more uncertainty about what and when to plant. Only in upper part of the basin is the vulnerability likely to be limited.
- Food security is likely to worsen and numbers of people at risk from hunger will increase, especially in subsistence farming areas.
- Heat stress on livestock and resultant water requirements will increase.
- Yields from rain-fed crops will be significantly reduced.
- Net revenues from crops are likely to fall.
- Cost of irrigation is likely to increase due to higher application rates (increased evapotranspiration).
- Agricultural activities will be vulnerable to biome switches.

Health

- Spatial and temporal transmission of disease vectors will alter.

2.5.3 Impacts and adaptation in the Orange–Senqu River basin

Climate change implications on water cycle, yield and demand

Climate change has been a feature of earth's climate for aeons. Accordingly, climate change is regarded by different scientists with different perceptions, assumptions and predictions.

The IPCC uses 21 different global circulation models (GCMs), each with their own merits and weaknesses. Each of these models can be fed with different scenarios of greenhouse gas emissions. The GCMs make computations over grid cells of about 50,000 km^2 (250 km x 250 km), and so local geographical details such as mountains and lakes are smoothed in the computations. Downscaling methods are used to translate these model results to a smaller spatial scale. In addition to different GCMs and different greenhouse gas scenarios, there are also different scenarios for climate change because of different downscaling methods.

The University of Cape Town (UCT) leads the research in South Africa and uses nine models for further downscaling. They use percentile curves to analyse the variation in outcomes between different models. These curves give an indication of the percentage of model outputs that are predicting a certain outcome. The whole 'envelope' of different model outputs is then studied.

The naturally high inter-annual and intra-annual variability of both precipitation and runoff in the basin makes it very difficult to observe climate change trends. Such trends can easily be masked by the natural variability. It can also happen the other way around; what is perceived as climate change could be natural variability.

The projected temperature increases are unevenly distributed across the seasons in the basin. During the initial summer period, the increase in temperature over the Lesotho Highlands is at its highest. In the autumn and winter season, an increase in temperature is still predicted, albeit not as extreme. In autumn and winter, the temperature increases are predicted at between 1° C and 2° C by 2100, fairly evenly distributed over the basin.

In any climate change forecast there is a high degree of uncertainty related to the predicted changes in precipitation. According to Knoesen et al. (2009), the differences in results between different GCMs are greater for shorter periods (average seven-day rainfall uncertainty is greater than that for average annual rainfall) and more consistent for longer return periods (1:50 year rainfall predictions are more consistent than 1:2 year rainfall predictions).

Some of the downscaling models that UCT uses give similar monthly rainfall changes. However, consistency between models depends on where and when changes are being assessed (pers. comm. 2011, Mark Tadross, UCT). The uncertainty for temperature changes is less than that for precipitation. The changes in temperature and rainfall (cloud cover) translate into evaporation changes.

Climate change trends can impact on land cover, which will indirectly impact on hydrology. The climate change scenarios are consistent in that, in general, a higher variability in water resources is predicted (often more floods and more droughts).

Institutes outside southern Africa also model climate change in this region, each with their own preferences for models. The greenhouse gas emission scenario 'A1B' was used (for ORASECOM, 2011c, d) as input to GCMs, which assumes

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The adaptive capacity of many residents in the basin to climate variability and climate change is limited. This needs to be taken into consideration when developing strategies to address climate change.

FACTORS AFFECTING ADAPTIVE CAPACITY TO CLIMATE CHANGE

In many areas of the basin, particularly where subsistence farming is the main livelihood, adaptive capacity to both climate variability and climate change is hindered by existing developmental challenges, including:
- little consideration to women and gender, especially in policy planning
- widespread, endemic poverty
- weak institutions
- low levels of education
- low levels of primary health care
- limited access to capital, including markets, infrastructure and technology
- ecosystems degradation.

Other constraints include:
- high level of direct dependence on natural resources
- existing high levels of degradation in some areas.

Positive factors include high levels of technology in the irrigation sector.

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The Richtersveld, South Africa, is likely to become even more arid.

relatively high greenhouse gas emissions. It is unclear which GCMs they used, but a distinction is made between a wet, dry and moderate scenario. The Potsdam Institute for Climate Impact Research conducted the ORASECOM climate change study, using their dynamic downscaling model, the Cosmo Climate-Limited-Area-Modelling and the statistical model STAR II, for downscaling to the southern African region.

The main conclusions of the ORASECOM study (2011c) are:

- Temperature increases are expected throughout the basin, varying from about a 1° C increase at the coast (river mouth), to a maximum of around 3° C in the Southern Kalahari Savannah. The increase in the upper river basin is between 1.5 and 2° C.
- The impacts on runoff are different for different areas:
  - The Lesotho Highlands and source of the Caledon River in South Africa may experience an increase in precipitation. A relatively small increase in precipitation in these key areas could result in a significant increase in runoff, perhaps enough to offset the reduced runoff from the western areas of the basin.
  - Runoff in the Fish River is likely to be adversely affected by the significantly reduced precipitation in that sub-basin, although this may be partially offset by more extreme rainfall events. (It is noted that the discussion on runoff (ORASECOM 2011c) only refers to the impact of precipitation changes.)
  - The considerable increases in predicted temperature would result in increasing potential evaporation and will thus decrease the proportion of rainfall that becomes runoff.
- In the upper-middle catchment area, a significant temperature increase coupled with a significant reduction in precipitation, will make rain-fed farming increasingly difficult.
- In the lower Orange corridor and irrigation areas in Namibia, a significant increase in temperature is expected. The decrease in precipitation is likely to be less than for the middle part of the basin, but will have some impact on irrigation requirements.
- For stock-farming areas in the lower Orange, Namibia and Botswana, a significant increase in temperature will increase heat stress during summer and reduce the risks of very cold nights during winter. Cattle watering requirements will increase. Changes in vegetation are likely to occur due to reduced precipitation, but may be counteracted by the carbon dioxide fertilisation effect on grazing lands.

It is important to note that these conclusions were based on very few different scenarios and models.

The University of KwaZulu-Natal uses rainfall and evaporation scenarios generated by UCT for further hydrological modelling. Their study on the basin (Knoesen et al., 2009) presented the results of one model (ECHAM5), but the scenarios of five models were used for analysis (GCM 3.1, CNR-CM3, ECHAM5/MPI-OM, GISS-ER and IPSL-CM4). The results of this research are very different to those of ORASECOM (2011c). Temperature changes are higher, between 2° C and 3° C for 2046–2065 and 4° C to >7° C for the longer term (2081–2100). The research findings expect an overall increase in rainfall over the basin, not just in the highlands. These differences in scenarios create a completely different picture of the impact on hydrology from that of the ORASECOM (2011c) study.

The above-mentioned differences in insights on climate change, as well as the possibility of a higher frequency of floods and droughts, show that planning of water resources needs to consider the unexpected and should therefore include robust or flexible solutions.

The impact of climate change on sediment load and mass balance is bound to be exacerbated by land-use changes within the basin. The greatest proportion of sediment is transported during floods. On the other hand, during periods of droughts people tend to use land that is close to the river channels, particularly for agricultural activities. This could increase the availability of sediment for transport. In an event of extreme floods, such sediment is transported down the river channel. Therefore, the occurrence of extreme floods could increase the average sediment load over a longer period of time.

It can be concluded that dams that have not yet been adversely affected by sedimentation could potentially be vulnerable as a result of land-use and climate changes. In addition, areas that were not previously affected by floods could be easily inundated during flooding, as a result of increased deposition of sediment in river channels.

More adaption initiatives are required within the basin in order to minimise the adverse effects of climate change and land-use changes on sediment load and mass balance. This can be achieved through raising awareness on the adverse effects of human-induced erosion. In addition, building relevant capacity for management of land and water resources within the basin is required to ensure that there is little or no disturbance of the fluvial morphology.

Governance systems are already in place with regard to climate change adaptation. In view of this, the impact of climate change on sediment load and mass balance can be managed within the existing governance systems that deal with adaptation and sustainable development. Initiatives that are aimed at reducing vulnerability and enhancing resilience to extreme events through efficient catchment management will be particularly important.

Land degradation, erosion and heavy silt loads are likely to become more extensive problems in the future.

Biome shift

Opinions on the degree of sensitivity of biomes in the geographical area of the basin are mixed. According to one recent study (Bergengren et al. 2011), tropical biomes, including rain forest, savannah and desert are tied to specific 'tipping points'. When certain climatic thresholds are crossed the one ecosystem can suddenly switch to another, as intermediate states somehow prove to be non-existent.

Scheiter and Higgins (2009) investigated the impacts of climate change on the vegetation of Africa using an 'adaptive dynamic vegetation modelling approach' . Using this model they carried out forward simulations to 2100 and predicated that large parts of today's savannahs will be replaced by deciduous woodlands under elevated atmospheric CO_2. The model indicated that 34.6% of the continent's grasslands would be transformed into savannahs and 45.3% of the continent's savannahs transformed into deciduous woodlands over the next 90 years. Total biomass stored in each of these biomes will increase.

The model also showed that while today's grasslands shift towards tree dominance, the relative area covered by grasslands only marginally decreases. This is because part of the grassland conversion into savannahs will be offset by a spread of grasslands into some desert areas resulting from the effects of increasing CO_2 and temperature. The model was applied at the continental scale and in the absence of a more detailed application over the project area; the results present an interesting point of departure for consideration of biome shift.

Looking at the Orange–Senqu basin, the study and associated modelling indicate a westward movement of increasing tree biomass at quite significant levels. The transformation of grasslands into savannah results in a reduction in grass biomass over much of the basin. An increase in grass biomass is anticipated only in the upper parts of the Senqu, Caledon and Vaal sub-basins. In terms of overall

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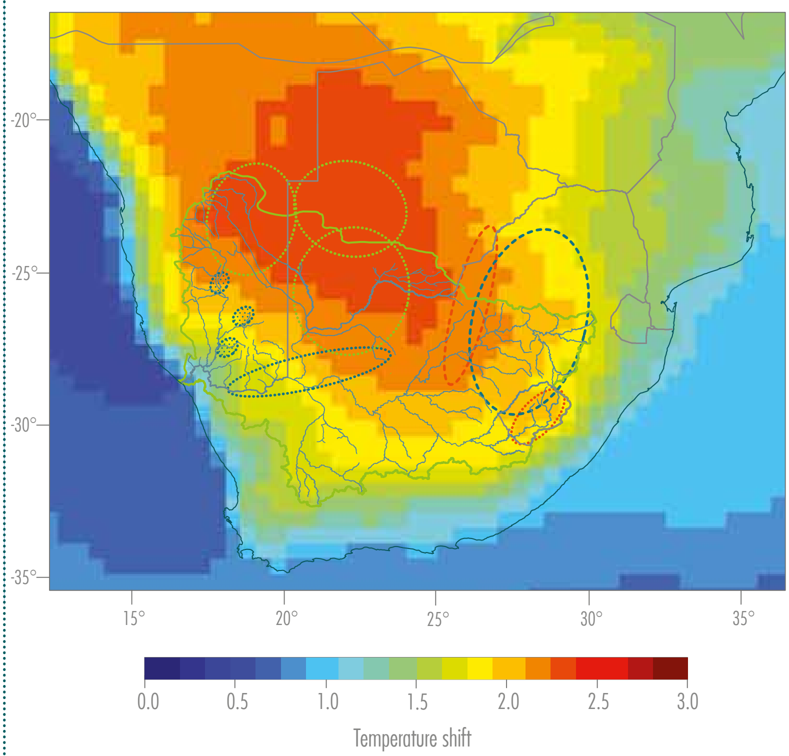
The Wilge River, South Africa, in flood carrying large pieces of debris; note the alien invasive weeping willows, *Salix babylonica*, in the background.

biomass, only the extreme western part of the basin is predicted to experience an overall decrease. The thickening of savannah has already been observed in the basin and the model shows that this will continue.

Shifting of biomes has cascading functional consequences and implications for biodiversity conservation. The potential loss of many specialist savannah plant species is especially concerning, given the apparent spatial extent and speed of this vegetation switch.

Impacts on land use and economic activity

As already indicated, major changes in vegetation as a result of biome shifts and shifts within each biome will certainly have an ongoing impact on agricultural activity, bearing in mind the underlying relationship between biome vegetation



LEGEND

- Western limits of rain-fed farming areas will move eastwards making farming more difficult. This might be partially offset by adaptation measures, but consideration should be given to development of alternative, off-farm livelihoods and irrigation where possible.
- Decreased rainfall in these areas will impact on rain-fed crop and stock farming. Consideration should be given to adaptation measures, such as use of drought-tolerant and high-yielding varieties; soil and water conservation measures; improved agricultural practices; supplementary irrigation; and capacity-building.
- Increased precipitation in headwaters could increase mean annual runoff, which could be negated by reduced snowmelt as a result of higher winter temperatures. Rainfall, snowfall and stream-flow monitoring should be improved.
- Increased temperatures will increase heat stress and watering requirements, compounded by a conversion of grasslands to savannah. Reduced carrying capacity will make farming in some areas uneconomical.
- Risk of reduced runoff into Hardap, Naute and proposed Neckartal dams. Potential for improved reservoir management through real-time rainfall and runoff observation and flood warning.
- Increased temperatures leading to higher evapo-transpiration rates and increased irrigation application rates. Reduced 'crop per drop' could be mitigated through use of different crop varieties, and irrigation efficiency improved through technologies and management.

Figure 34: Potential impacts and adaptive measures

and land use. Just as changes in vegetation will move gradually across the basin, it can be anticipated that the associated agricultural activities will shift as well. Where the relationship between vegetation and agricultural activity is strongest, so also will the impact be greatest.

Livestock carrying capacity will reduce as grass biomass reduces. On the other hand, the impact on arable agriculture, especially irrigated agriculture, is likely to be less marked. Arable agriculture will however be affected by an increase in temperature and changes in precipitation regime.

Figure 34 illustrates the possible impacts of climate change, especially for some of the agricultural practices around the basin.

Livestock-keeping is deeply ingrained in the culture, livelihoods and economy of the Orange–Senqu basin. However, reductions in grass biomass and increases in temperature, that are predicted with climate change, are likely to impact this.

Impacts of climate change on ecosystem health

Climate change as a result of anthropogenic actions is now a widely accepted phenomenon. Global surface temperatures are rising as a result of man's production of greenhouse gases, and this pattern is likely to continue.

Climate change is already having an impact on the Orange–Senqu basin. Surface temperatures have increased by 0.5° C to 1.0° C, extreme rainfall events are more frequent and the length and severity of droughts have increased (particularly in the lower reaches of the river).

Most climate change models suggest that the lower Orange and Fish river systems will experience reduced runoff, which will further exacerbate the problem. Increased evaporation will result in a significant loss of water in the lower Orange River and higher temperatures can be expected to have further detrimental effects on flow along this stretch of the river.

Conversely, climate change models predict that Lesotho, which generates more than 40% of the total runoff in the Orange–Senqu basin, may get wetter. A small percentage increase in the upper basin would represent a much larger volume of water than the predicted reductions in runoff in the lower reaches of the basin. As such, the real impact of climate change on river flows into the estuary will depend on the operation of the Orange–Senqu basin as a whole.

Rising sea levels that are predicted to result from climate change will, nevertheless, have an impact on the estuary. The predicted 1.2 mm per year rise has, so far, been realised over the past three decades and that trend is set to continue at an accelerated pace.

Rising sea levels will almost certainly increase saline intrusion into the estuary, and while this may provide welcome restoration for the currently desiccated salt marshes, it poses a threat to other low-lying marshlands. Seawater intrusion could be expected to kill off plant species that are unable to tolerate the saline conditions; the dieback of this vegetation would then expose the area to erosion.

The effects of climate change in reducing freshwater inflows but increasing seawater intrusion into the estuary will require careful management. It is crucial that any future management plan for the Orange–Senqu basin considers the operation of the system as a whole – including the river's estuarine flow requirements – to address the issues for transitional waters, and deliver benefits to the entire system.

In summary, climate change is an evolving science and models in different countries are constantly being improved and updated. A fairly broad envelope of possible changes is conceivable. While it is important to continually access the potential changes and their effects, more adaptation initiatives are required within the basin in order to minimise the adverse effects of climate change.

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LESOTHO RAINFALL AND VEGETATION PATTERNS

The grasslands of Lesotho are generally short grasslands dominated by a range of grass and non-grass species. Among the non-grasses are a class of shrubs, typified by *Chrysocoma ciliata*, that are thought to be increasing in density, with consequent negative effects on grazing capacity, rainfall infiltration and soil conservation. Acocks, in his surveys during the 1940s and 1950s, described Karoo invasion in these grasslands (Acocks, 1953). Showers (2005) noted that the invasion of *Chrysocoma* in the early 1930s was causing concern among officials at that time.

Invasion of grassland by shrubs is usually ascribed to overgrazing or inappropriate grazing management. There is significant evidence to support this, but there is increasing evidence that rainfall patterns may also play a causative role in the balance between grass and shrubs in grassland.

Several authors have highlighted the role of climate in this regard, including the interaction between grazing and rainfall. In particular, Hoffman and Cowling (1990) raised the notion that periods of higher spring-summer rainfall promote perennial grass at the expense of shrubs, while periods of increased autumn-winter rainfall have the reverse effect. They emphasised the role of grazing in exacerbating these effects. Even rainfall distribution throughout the rainy season is likely to favour perennial grasses, while uneven distribution (severe rainfall events followed by lengthy dry spells) is likely to favour annual grasses and deeper rooted shrubs.

Analysis of 123 years (1888 to 2011) of rainfall records from Middelburg in the Karoo (du Toit, 2013) has revealed some interesting patterns. These seem to coincide with recorded vegetation changes: from grassy Karoo, through increasing shrub and decreasing grass density in the mid-1900s, to increasing grass and decreasing shrub densities in the late 1900s and early 2000s. In particular, the seasonal distribution of rainfall moved from mid-summer through later summer and back to mid-summer during this time; later summer rainfall seemed to favour shrubs and earlier rainfall distribution to favour grasses.

In Lesotho, the variability of rainfall between and within years has been noted by several authors (see Showers, 2005). It seems that most analyses of rainfall data have focused on between-season variability, and not within-season variability, duration and intensity. Detailed analysis of within-season rainfall patterns may allow for comparison of any patterns with vegetation change.

Future predictions of climate change may allow for predictions of grass–shrub balance changes. There is some consensus on rainfall events becoming more extreme and erratic, which may favour shrubs at the expense of grasses. In addition, Schulze (2010) predicts a shift in rainfall patterns towards later summer rain in future. This is also likely to favour shrub development.

The influence of climate on the vegetation composition should be considered in parallel to livestock management and the influence that livestock exert on vegetation.

THE QUIVER TREE – A UNIQUE INDICATOR SPECIES

The quiver tree, *Aloe dichotoma*, is one of the flagship species of southern Namibia and the Northern Cape Province of South Africa, indeed of the western areas of the Orange–Senqu River basin. One of the largest and most striking succulent plants of southern Africa, it is well-adapted to its arid environment, storing water in its succulent leaves, having a shallow root system for quick uptake of water and using crassulacean acid metabolism, which allows it to photosynthesise with minimal water loss. It is on the IUCN's Red List of Threatened Species (IUCN, 2009).

Quiver trees, given the chance, live for about 350 years, growing up to 10 m in height. By studying the size of these trees in a population, it is possible to estimate when wet periods might have occurred allowing seedlings to survive. Researchers can also estimate when and how many tree deaths occurred, because the dead trees decay relatively slowly in their arid habitats.

Temperature records show that average temperatures in the western areas of the basin have increased over the past decades. By the turn of this century, large die-offs of quiver trees had been observed. Foden and her colleagues (2007) have shown that populations in the hotter, more northerly latitudes of the tree's range were dying off, whereas the southerly populations, especially those on the tops of mountains, were flourishing. Furthermore, genetic tests showed that the southernmost populations are younger, suggesting that over time their range is moving towards cooler latitudes. In spite of indications of an apparent shift in the tree's distribution range, no new populations of this slow-growing species have so far been found further south.

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Aloe dichotoma, more commonly know as the quiver tree or kokerboom, is a flagship species of the Nama Karoo and apparently living on the edge of its survival limits.

Only time will tell whether the quiver tree – and other desert plants living on the edge of their survival limits – will be able to make the slow move to outrace climate change.

3. GOVERNANCE ANALYSIS

3.1 OVERVIEW OF FRAMEWORK FOR BASIN-WIDE GOVERNANCE

The Orange–Senqu River basin is the most developed transboundary river basin in the Southern African Development Community (SADC) region. It is home to the largest international water transfer scheme in the world, as well as several other inter-basin transfers. The basin's water resources are of critical importance to the region's economy.

The Orange–Senqu basin states are aware of the need for integrated basin management in order to find sustainable solutions to the challenges facing it. They are in agreement that the management of the basin's water resources should be carried out on a basin-wide scale with the full participation of all affected basin states within it (ORASECOM, 2011b). The Orange–Senqu River Commission (ORASECOM) provides a forum for consultation and coordination between the basin states for this. There are also a number of bilateral agreements between basin states relating to the Orange–Senqu River and the development and use of its water resources.

Katse Dam on the Malibamatso River, Lesotho, was constructed during Phase I of the LHWP to augment South Africa's water supply.

3.1.1 Economic water use in the basin and policy drivers

The water resources of the Orange–Senqu River are of great economic importance for the basin states (perhaps with the exception, to some degree, of Botswana). The policy drivers for basin development in the basin states are strongly linked to their economic dependency on its resources. A recent study (SADC, 2010) estimated the water use per economic sector (as shown in Table 20) and found agriculture is by far the biggest user, followed by domestic consumption, manufacturing and mining.

Table 20: Water use per economic sector in the basin (2000)

Sector	% water use
Agriculture	90.76
Domestic	6.16
Manufacturing	3.59
Mining	0.51

Source: SADC, 2010

Water use is of strategic importance for the respective countries; in particular, Lesotho and South Africa have a high degree of dependency on Orange–Senqu water resources, as well as an interest in the development of joint basin infrastructure. For Lesotho, the royalties for the water transfers to South Africa through the Lesotho Highlands Water Project (LHWP) are a key component of the national budget, creating some degree of fiscal dependency on the scheme. For South Africa, the water transfers from Lesotho are essential to supply adequate water to Gauteng Province, its economic heartland, with more than 12 million domestic consumers.

While economically less dependent on the basin's water resources, Botswana shares a common interest with Lesotho and South Africa in possible future water transfers. Botswana is becoming increasingly water scarce and the possibility of extending water transfers from Lesotho, via the LHWP scheme to Botswana, have been discussed as an option for the future.

In Namibia, the Orange–Senqu River is the only perennial source of water in the country's southern region. The country's primary economic activities in this area are irrigated agriculture, mining and tourism. Namibia's needs have to be

Opposite: Dates are becoming an increasingly important cash crop in the drier western parts of the basin.

balanced with the above-mentioned interests of the other three basin states in further developing the upper parts of the basin, as additional water transfers to South Africa and possibly Botswana would reduce the quantity of water available for downstream needs.

WATER FOR GROWTH AND DEVELOPMENT IN THE BASIN


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River rafting on the lower Orange downstream of Noordoewer–Vioolsdrift is a popular tourist venture.

The major water users in the Orange–Senqu, of which the Vaal forms part, change over the length of the river. Urban-industrial uses predominate in the upper Vaal area, while irrigation is the dominant water use in all of the other areas (ORASECOM, 2007c). A relatively small portion is used for urban purposes. The four basin states, while at different levels of industrial development, have as a whole seen a reduction in the role that agriculture plays in their national incomes (Earle et al., 2005).

Strategies to address poverty and food insecurity through water use differ between the basin states (ORASECOM, 2007c) and the states differ widely in their ability to convert water from the Orange–Senqu system into gross domestic product (GDP) and jobs. At the moment, there is no standardised approach to using water to promote growth and development, and this must underlie the implementation of integrated water resources management (IWRM) principles in the basin in the future.

The application of economic principles is becoming increasingly important for water management in the basin. There is a need to further develop benefit-sharing strategies in the Orange–Senqu basin (SADC, 2010). The Lesotho Highlands Water Project (LHWP) illustrates benefit-sharing in practice through payment for water, purchase agreements for power and financing arrangements. However, this is a bilateral initiative that at present does not take into consideration potential benefits, or compensation for loss of benefits, for other basin states (SADC, 2010).

Hydropower production is another water-dependent activity in the basin. The most significant future hydropower generation opportunities in the Orange–Senqu basin are in Lesotho. The LHWP is already generating enough hydropower to meet almost all the country's needs and offers a profitable source of export earnings. The recently approved Phase II of the project foresees the construction of a 1,200 MW pump-storage scheme in Lesotho. SADC is promoting regional electricity cooperation and power pooling through the extension of grid interconnections to cover all Orange–Senqu basin states and the creation of a regional electricity market.

The Southern African Power Pool (SAPP) is a core component in the New Partnership for Africa's Development's (NEPAD's) regional energy plans. All four basin states belong to SAPP (ORASECOM, 2007g), which potentially provides them with increased options for benefit-sharing in the context of basin management.

The Orange–Senqu River basin states (together with Swaziland) are all members of the Southern African Customs Union (SACU). Within the SACU region, Orange–Senqu basin states trade freely with each other, without levying any customs duties on goods traded between them. At the same time, SACU members apply the same tariffs regime to goods traded from non-Orange–Senqu basin states, regardless of where the goods enter the customs union territory. The total customs revenue is shared between the Orange–Senqu basin states through a common revenue pool based on an agreed formula. This benefit-sharing model is at present not linked to water management. In the future, however, there might be possibilities to link water-use allocations to the SACU revenue-sharing formula and thereby increase the basket of options for water allocation in the basin.

3.1.2 Legal and institutional frameworks

The Orange–Senqu River basin is managed within a wide-ranging framework of international agreements. These comprise bilateral and multilateral water management agreements, other multilateral environmental agreements and a number of economic cooperation agreements with indirect impacts on basin management.

Table 21: International agreements relevant to the management of the Orange–Senqu River basin

Agreements regarding water resources management	Year	Type
Treaty on the Lesotho Highlands Water Project between the Government of the Republic of South Africa and the Government of the Kingdom of Lesotho	1986	Bilateral
Samewerkingsooreenkoms tussen die Regering van die Republiek van Suid-Afrika en die Oorgangsregering van Nasionale Eenheid van Suidwes-Afrika/Namibie Betreffende die Beheer, Ontwikkeling en Benutting van die Water van die Oranjerivier	1987	Bilateral
Protocol 1 to the Treaty on the Lesotho Highlands Water Project: Royalty Manual	1988	Bilateral
Protocol 2 to the Treaty on the Lesotho Highlands Water Project: SACU Study	1988	Bilateral
Protocol 3 to the Treaty on the Lesotho Highlands Water Project: Apportionment of the Liability for the Costs of Phase IA Project Works	1988	Bilateral
Protocol IV to the Treaty on the Lesotho Highlands Water Project: Supplementary Arrangements Regarding Phase IA	1991	Bilateral
Agreement between the Government of the Republic of South Africa and the Government of the Republic of Namibia on the Establishment of a Permanent Water Commission	1992	Bilateral
Agreement on the Vioolsdrift and Noordoewer Joint Irrigation Scheme between the Government of the Republic of South Africa and the Government of the Republic of Namibia	1992	Bilateral
Ancillary Agreement to the Deed of Undertaking and Relevant Agreements Entered into Between the Lesotho Highlands Development Authority and the Government of the Republic of South Africa	1992	Bilateral
Protocol V to the Treaty on the Lesotho Highlands Water Project: Supplementary Arrangements with Regard to Project Related Income Tax and Dues and Charges Levied in the Kingdom of Lesotho in Respect of Phases IA and IB of the Project	1999	Bilateral
Protocol VI to the Treaty on the Lesotho Highlands Water Project: Supplementary Arrangements Regarding the System of Governance for the Project	1999	Bilateral
Agreement between the Governments of the Republic of Botswana, the Kingdom of Lesotho, the Republic of Namibia and the Republic of South Africa on the Establishment of the Orange–Senqu River Commission (ORASECOM)	2000	Multilateral
SADC Revised Protocol on Shared Watercourses	2003*	Multilateral
Other environmental agreements:		
UN Framework Convention on Climate Change (UNFCCC)	1992	Multilateral
UN Convention on Biodiversity (UNCBD)	1993	Multilateral
Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention)	1994	Multilateral
UN Convention to Combat Desertification (UNCCD)	1996	Multilateral
Kyoto Protocol (to the UNFCCC)	1997	Multilateral
Other SADC regional integration agreements:		
SADC Protocol on Trade	1996	Multilateral
SADC Protocol on Energy	1996	Multilateral
SADC Protocol on Transport, Communications and Meteorology	1996	Multilateral
SADC Protocol on Tourism	1998	Multilateral
Southern African Customs Union Agreement (SACU)	2002	Multilateral
Transfrontier conservation area (TFCA) agreements:		
Bilateral Agreement between the Government of the Republic of Botswana and the Government of the Republic of South Africa on the Recognition of the Kgalagadi Transfrontier Park	1999	Bilateral
Memorandum of Understanding between the Government of the Kingdom of Lesotho and the Government of the Republic of South Africa in Respect of the Maloti–Drakensberg Transfrontier Conservation and Development Area	2001	Bilateral
Treaty between the Government of the Republic of Namibia and the Government of the Republic of South Africa on the Establishment of the /Ai-/Ais–Richtersveld Transfrontier Park	2003	Bilateral

*Signed in 2000, the Revised Protocol came into force in 2003.


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An aerial view of 2010 World Cup Soccer City in Johannesburg's Soweto suburb. Slag piles to the west, a green golf course to the east and an industrial area to the south all surrounded by a dense urban area provides a picture of the diversity and intensity of water demand in Gauteng.

Water agreements relevant to the basin

Prior to the signing of the ORASECOM Agreement in 2000, all international agreements regulating various aspects of the management of the Orange–Senqu River basin had been bilateral. The ORASECOM Agreement is the first multilateral water agreement for the basin that involves all four basin states. Together with SADC's Revised Protocol on Shared Watercourses, the three types of agreements form an integrated legal regime for the management of the basin, as described below.

SADC's Revised Protocol is a regional framework agreement for the management of shared watercourses. It contains a comprehensive set of substantive and procedural rules for the management of shared watercourses in the SADC region. Drafted in line with the legal principles of the 1997 UN Watercourses Convention, the Revised Protocol is centred on the three key principles of international water law, i.e. the principles of equitable and reasonable utilisation, the obligation not to cause significant harm and the duty to cooperate.

The Revised Protocol also contains detailed provisions on aspects of environmental protection and ecosystem management, as well as detailed procedural rules, including those on dispute prevention and resolution. The purpose of the Revised Protocol is to establish a common legal framework that applies the same core set of international rules to the management of shared watercourses across the region. Within the framework set by the Revised Protocol, SADC Orange–Senqu basin states are encouraged to enter into basin-specific agreements tailored to the characteristics of a particular watercourse (Article 6(3)), while maintaining the key principles of the protocol.

Where a basin-specific agreement has been concluded, it becomes the primary agreement (so-called *lex specialis*, or specific law) for the management of the basin, and the framework agreement is only drawn upon if the primary agreement leaves legal gaps or is less elaborate than the framework agreement. In that case, interpretational guidance can be drawn from the framework agreement.

The Orange–Senqu basin states have concluded a basin-wide watercourse agreement, the ORASECOM Agreement. This agreement is the primary agreement for the basin with SADC's Revised Protocol only providing interpretational guidance and gap filling, for example, when elaborating on the required procedures for notification, which are less detailed in the ORASECOM Agreement.

The ORASECOM Agreement contains the core of the substantive law obligations of the Orange–Senqu basin states with respect to the management of the basin. The nature and normative content of the substantive law obligations contained in the agreement is, in essence, identical to those contained in SADC's Revised Protocol. Likewise, the nature of the procedural obligations contained in the two agreements is identical, but some (minor) differences can be found in the elaboration of procedural rules, such as the above-mentioned example of notification procedures.

Another type of agreement applicable to the basin is the bilateral agreement. All of these were entered into prior to the ORASECOM Agreement. This is important in the context of Article 1(3) of the ORASECOM Agreement, which specifies that rights and obligations from prior agreements (i.e. those concluded before the ORASECOM Agreement) shall remain unaffected.

The bilateral water agreements on the Orange–Senqu River can broadly be categorised into two types, those with the sole purpose of establishing a bilateral watercourse institution, and those concluded with respect to a specific bilateral infrastructure project (the latter commonly also establishing project specific institutions). The substantive scope of the bilateral agreements is much narrower than that of the ORASECOM Agreement. The only noteworthy overlap between the issues dealt with in the bilateral agreements and the ORASECOM Agreement is with regard to water allocation.

Some of the bilateral agreements contain provisions on the volumetric allocation of water resources to a specific country (e.g. the Lesotho Highlands Water Project Treaty). The ORASECOM Agreement does not specify volumetric allocations, but stipulates the 'equitable utilisation' rule as the basis for determining the overall utilisation of the basin's water resources.

The ORASECOM Agreement establishes the Commission (ORASECOM) as a technical advisor to the basin states. It also defines the relationship between ORASECOM and the bilateral commissions in stipulating that new bilateral commissions (i.e. established after the ORASECOM Agreement) 'will be subordinate' to ORASECOM, whereas existing commissions 'will liaise' with ORASECOM in terms of the ORASECOM Agreement. This differentiation between new and existing commissions indicates that the basin states intended to leave the role and functions of the existing commissions unaffected, maintaining a high degree of independence for them. In practice, much of the scope of work of the bilateral commissions is project specific and has no overlap with ORASECOM's functions.

However, in some aspects (e.g. water allocation under the bilateral agreements, and planning and implementation of new bilateral infrastructure) the scope of work of the bilateral commissions overlaps with the duties of ORASECOM. In such instances, the bilateral commissions are obliged to full and prompt disclosure of information to ORASECOM. Likewise, the bilateral commissions cannot take decisions that contravene the obligations that the basin states have committed to in the ORASECOM Agreement.

Gold Reef City in Gauteng, South Africa, is an amusement park and museum built on an old gold mine. The theme park is under threat of being flooded by rising acidic mine waters.

EQUITABLE AND REASONABLE UTILISATION

The equitable and reasonable utilisation rule is one of the core principles of international water law and is used to determine how the water resources of a watercourse are shared between the basin states. Accepted as customary international law, it is enshrined in virtually all recent transboundary water agreements globally. SADC's Revised Protocol and the ORASECOM Agreement are both based on this principle, making it the central rule for determining water utilisation by the Orange–Senqu River basin states.

A number of factors are considered in order to determine what constitutes equitable water use in the context of a particular basin. The ORASECOM Agreement does not list these factors, but Article 7(2) refers to SADC's Revised Protocol where these factors are listed in Article 3(8). In this context, two key aspects of the equitable utilisation principle need to be emphasised.

First, the principle and the factors for determining equitable use do not provide a model for the calculation of volumetric shares for each basin state. Instead, they provide a rules-based framework and guidance for negotiations between states based on a number of key determinants. Countries are free to use additional criteria beyond those listed in the agreement.

Second, while the factors specified to determine equitable utilisation cover a wide range of aspects, they have in common that they are all based on the notion of dependency of the basin states on the water resources, i.e. the dependency of the population on water for vital human needs, as well as social, economic and ecologic dependency. Thus, while natural factors such as runoff contribution are listed, they are, in case of scarcity, outweighed where states can substantiate dependency (as evidenced in numerous decisions of international tribunals).

The Orange–Senqu basin states have not yet determined what would constitute overall equitable utilisation in the context of the basin. However, some volumetric allocations are specified in bilateral agreements (e.g. the LHWP Treaty and the agreement of the Noordoewer–Vioolsdrift Joint Irrigation Authority).

Thus a partial status quo has been established as far as the allocation of these resources to specific countries is concerned. This would only be in contradiction with the equitable utilisation principle if the allocated volumes were obviously disproportionate and inequitable. Given the relatively limited volumetric allocation (compared to the total resource) contained in the agreements, it seems that the allocated volumes are well within the range of what the countries could substantiate as their equitable share, using the equitable utilisation principle. Whether the same holds true for each country's actual total water use in practice (outside that specifically allocated in the bilateral agreements), needs to be determined by the basin states using the above-mentioned factors.

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Flamingoes at the Orange River estuary, a Ramsar site in Namibia and South Africa

Other environmental and regional integration agreements

Several other international environmental agreements are applicable to the management of the Orange–Senqu River basin. The Ramsar Convention promotes the conservation of wetlands and establishes obligations for protection of so-called 'Ramsar sites'. There are several designated Ramsar sites in the basin, including the river mouth, which was declared a Ramsar site by both Namibia and South Africa under two separate exercises about five years apart, each with its own registration number.

The UN Convention on Biodiversity (UNCBD) stipulates riverine and aquatic habitat protection as a core element of biodiversity conservation. The basin states are parties to the UNCBD and have, as part of their obligations under the convention, developed national biodiversity strategies and plans, which need to be considered during the development of a basin-wide plan for the Orange–Senqu and integrated with the latter. Likewise, transfrontier conservation area (TFCA) management plans have been developed on the basis of the TFCA agreements and need to be integrated with the Orange–Senqu basin-wide plan.

The various SADC regional integration agreements impact on the management of the basin indirectly. In particular, the SADC Protocol on Trade (establishing a SADC-wide free-trade area) and the agreement establishing SACU shape the economic landscape in which the Orange–Senqu basin states operate and influence their economic policies. These in turn impact on their water needs and interests in utilisation of the Orange–Senqu water resources. The SADC Protocol on Energy and resulting energy strategies define the framework for increased energy security in the region. In particular, the power trade through the Southern African Power Pool has the possibility of providing countries with increased options for benefit-sharing that can be integrated with river basin management.

3.1.3 Strategic challenges and response options

While poor water quality is a problem in some parts of the Orange–Senqu River basin, the biggest long-term challenge facing the basin will be meeting increasing water demands. At present, the basin is already highly developed and there is limited scope for allocating additional resources to new or expanded uses. Environmental flow requirements are not yet fully implemented across the basin and, if this is done, it may further reduce the water available for allocation to productive uses. Likewise, predictions suggest that parts of the basin could become significantly drier in future as a result of climate change, which would further add to the challenge of ensuring adequate water supply to all uses.

At the same time, there has been a demand expressed for additional future uses, most notably for irrigation expansion in downstream Namibia. Providing sufficient quantities of water for maintaining existing uses and enabling legitimate future uses will require careful balancing. Legally, the equitable utilisation rule does not establish a priority for existing uses over future uses per se. However, as described above, when determining equitable utilisation, basin states have to substantiate the human, economic and environmental dependency on the water resources they claim. Water resources cannot be 'reserved' for some time in the future without quantifying the needs.

In practice it will usually be much easier to substantiate dependency for existing uses than for potential ones. On the other hand, determining equitable utilisation is not meant to establish an allocation regime that is 'cast in stone'. Dependency can change and so can a country's ability to substantiate their dependency on the resource. Thus, determining equitable utilisation requires a certain degree of flexibility in the basin-wide allocation regime so that changed conditions can be considered appropriately.

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Access to potable water is still a problem in many areas of the basin.

The key to achieving this is a basin-wide approach, as is currently underway in the Orange–Senqu with the development of the basin-wide IWRM plan. Such a plan would require a mechanism that provides for the periodic review of the allocation regime and the flexibility to amend allocations to specific countries over time. Given the growing water demands in the basin in the light of limited additional allocable resources, it seems likely that shifts from less to more productive uses will have to take place over time. It would be in the interests of the basin states to agree on and develop a common approach for using water for growth and development and optimise the use of water in economic terms.

The recent study on economic accounting of water use (SADC, 2010) suggests that efforts in this regard are starting to be made. Linking efforts to maximise the productivity of water with basin-wide economic benefit-sharing mechanisms beyond the mere sharing of water, would considerably increase the water management options for the basin in the long run. It is clear that ORASECOM, as the only basin-wide management organisation, has a key role to play in the development of such management options.

3.1.4 Summary

The Orange–Senqu River basin is managed within a wide-ranging framework of international agreements. These comprise bilateral and multilateral water management agreements, other multilateral environmental agreements and a number of economic cooperation agreements with indirect impacts on basin management. The ORASECOM Agreement (supported by the Revised SADC Protocol) provides a solid legal framework for basin management based on globally accepted rules for transboundary water management. A high commonality of interests between upper basin states increases potential for benefit-sharing and room for cooperation with established bilateral benefit-sharing mechanisms (e.g. Lesotho Highlands Water Project) and are provided for within the Agreement. The framework for this cooperation, however, is not always clear in practice.

The basin states are strongly committed to develop and manage the basin on the basis of a jointly agreed basin-wide plan and there is an ongoing process of developing such a plan. This process provides opportunities to effectively integrate other existing plans (e.g. biodiversity plans, TFCA management plans), but these are not yet adequately aligned and integrated with basin management. Furthermore, there is no standardised approach to using water to promote growth and development.

Equitable utilisation on a basin-wide scale has not yet been defined in terms of the basin. There is a risk of conflict over water use if downstream interests are not appropriately balanced with upstream interests and integrated into benefit-sharing arrangements.


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VIRTUAL WATER

Virtual water refers to the quantity of water used in the production of a product – for example, the water required for the production of wheat (whether rain-fed or irrigated). As the final product (for example, wheat) does not contain water anymore it is referred to as 'virtual water'. Trading virtual water is increasingly considered as a valuable, complementary strategy to the management of physical water resources.

The concept of trading virtual water means that water-scarce countries can potentially mitigate the local scarcity of water by importing large amounts of virtual water, i.e. goods that are water-intensive to produce, instead of producing the goods locally. Through the export of food stuffs on the other hand, water-rich countries could make use of their water abundance by becoming large-scale exporters of water intensive goods, primarily agricultural goods. For some water-rich developing countries, export-oriented agriculture could be a driver of economic growth and substantially contribute to poverty reduction.

While such virtual water trade is de facto already practised by some countries, including African countries, its implementation on a regional scale within Africa is only starting to be considered. In this context, the Nile Basin Initiative has recently commissioned a study exploring the possibility of a virtual water trade strategy for Nile basin states.

None of the Orange–Senqu River basin states would seem to be a potential virtual water exporter, at least for agricultural goods (Lesotho lacking sufficient land resources and the other three basin states being relatively water-scarce). Thus, in the context of the basin, a virtual water trade strategy would arguably have to be embedded in a wider regional strategy including water-rich, potential agricultural exporter countries.

A regional virtual water trade strategy would require significant improvements in trade regimes and supporting infrastructure, mainly transport. Effectively using the full potential of regional markets in Africa could prove to be a major growth factor only if certain trade impeding factors were to be removed.

Despite the establishment of free-trade areas (for example, the launch of a regional trade bloc comprising the members of SADC, the East African Community and the Common Market for Eastern and Southern Africa in June 2011), the elimination of tariff and non-tariff barriers has been neglected in practice. With transport costs being a major factor, the existing regional initiatives to build a functioning and cost-effective regional transport network need to be continued and intensified. This is essential to make trade-based solutions a viable policy option and to open up new benefit-sharing options in the context of water resources management.

3.2 COUNTRY PROFILE: BOTSWANA

Botswana has limited internal renewable water resources and is considered water scarce. It experiences highly variable rainfall patterns, and because of the prevailing, extremely arid conditions, it is estimated that up to 80% of precipitation is lost to evaporation. Water demand is expected to grow from the 120 Mm^3 recorded in 1990 to 355 Mm^3 by 2020 as a result of population growth, improvements in living conditions and economic development (Centre for Applied Research, 2010).


© Jem Perkins

Most of the basin in Botswana comprises Southern Kalahari Savannah.

3.2.1 Water and the economy

Botswana's economy is strongly dependent on its natural resources such as minerals, land for agriculture and pasture, and wildlife-based tourism. According to the report on water accounts (DEA, 2006), water use increased from 120 Mm^3 in 1990 to 170 Mm^3 by the early to mid-2000s (DEA, 2006; Centre for Applied Research, 2010). The availability of water is crucial and a shortage could become a constraint for future economic development.

Table 22: Main economic sectors, contribution to national income, and water use in 2008/09, Botswana

Sector	% water use	% GDP contribution
Agriculture	45	2
Mining	10	40
Services	9	38
Manufacturing	2	4

Source: BEDIA, 2010

3.2.2 Governance frameworks

Governance structure

Botswana is a democratic republic with a single parliamentary chamber – the national assembly – that sits in the capital, Gaborone. Botswana has a two-sphere government system comprising national (or central) government and local government. Central government is responsible for developing and overseeing implementation of national-level policy and legislation.

Local government has three types of local administration: ten district councils, six urban councils (three town councils, two city councils and one township authority) and 19 newly formed sub-districts (CLGF, 2011a). The 19 sub-districts were created in 2009 as a second tier of local government within the district councils – whose assigned responsibilities as elected bodies include the provision of social services such as water.

Also at district level is the tribal administration, which is responsible for administration of customary law, and functions through the kgotla, a forum for village-level discussion and participation.

Economic development policies

Vision 2016 is Botswana's strategy to use socio-economic and political development to become a competitive, winning and prosperous nation. It is a long-term development plan, a strategy that aims to achieve sustainable development by using renewable resources at a rate that balances their capacity for regeneration and limits the use of non-renewable resources. Vision 2016 has several ambitious targets, most of which are also part of the Millennium Development Goals. It is implemented through successive national development plans (NDPs), of

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Botswana relies heavily on groundwater sources to meet its water supply needs.

which NDP 10 is the current plan and covers the period 2010–2016. Based on a growth target of 5.9%, NDP 10 estimates that water demand will increase by about 2% per year as a result of increased demands from agriculture, industry and population growth (Centre for Applied Research, 2010).

Table 23: Overview of economic sector policies and relevance to water resources management (WRM), Botswana

Sector	Related policy	Relevance to WRM
Agriculture and food security	National Policy on Agricultural Development (1991)	Aims to improve food security through sustainable methods of production and increase employment and income in the sector through diversification
	National Master Plan for Arable Agriculture and Dairy Development (2002)	Aims to improve and ensure sustainable performance of the agriculture sector
Mining	Environmental Impact Assessment Policy for Mining Projects (2003)	Provides guidelines for environmental protection in mining projects
Manufacturing	Strategy for Waste Management (1998)	Minimises and reduces waste from industry and promotes treatment and disposal
Tourism	Tourism Policy (1990)	Objectives of the tourism policy are designed to ensure that tourist activities are carried out on an ecologically sustainable basis

NATIONAL WATER FOOTPRINT OF BOTSWANA

Botswana's internal renewable surface water resources are estimated at 800 Mm^3 per year (FAO, 2005). The country's surface water sources are restricted to ephemeral and perennial rivers, as well as water stored in reservoirs. All rivers in Botswana, apart from the Okavango and the Chobe, are ephemeral. The total groundwater resources are estimated at around 100,000 Mm^3 with an average annual recharge of about 1,600 Mm^3 (SMEC, 2006 cited in Arntzen et al., 2006). Total water consumption of Botswana was 171.2 Mm^3 in 2005 (DEA, 2006). The water footprint related to total national consumption per capita for Botswana is 288 m^3 per capita per year, below the SADC average, which is 776 m^3 per capita per year (Kort, 2010).

The largest water user in Botswana is the agricultural sector, but it also has limited productivity per unit of water. Under the physical conditions found in Botswana, livestock production is a more appropriate use of water than irrigation. The economic contribution of water to the economy by agriculture declined from BWP6.75/m^3 in 1993, to BWP6.52/m^3 in 1998, mainly due to a decline in livestock and relative increase in cultivation. Although the productivity of water in agriculture increased to BWP9.00/m^3 in 2005/06, it is still limited when compared to other water uses.

The irrigation potential in the Orange–Senqu basin for Botswana is negligible because of a lack of renewable water resources. Previous studies (e.g. Arntzen et al., 2006), have also shown that the value added per unit of water is highest in the service, manufacturing and mining sectors (DEA, 2006).

In 2003, an average of 2,807 paid jobs was created for each million cubic metres of water used (DEA, 2006). In agriculture, most jobs are provided through self-employment of farmers and informal employment. If these jobs were included, water efficiency in terms of employment would exceed 1,500 jobs/Mm^3 (DEA, 2006).

The development of surface water in Botswana is constrained by a number of factors such as its low and erratic runoff, lack of available dam sites and high rates of evaporation (CSO, 2009).

In 2003, 40% of Botswana's electricity supply was generated in the country, and 60% was imported, mainly from SAPP (Anon. 2008a). Botswana does not produce hydropower.

International agreements

Botswana is a party to the Revised SADC Protocol on Shared Watercourses, the regional SADC framework agreement for the management of shared rivers, and the ORASECOM Agreement. While there are a number of bilateral international agreements on the Orange–Senqu River, none of them involve Botswana as a party. Other relevant international environmental agreements that Botswana is a party to are listed below.

Table 24: Main international agreements ratified by Botswana

Convention/protocol	Date*
UN Framework Convention on Climate Change (UNFCCC)	1994
UN Convention on Biological Diversity (UNCBD)	1995
UN Convention to Combat Desertification (UNCCD)	1996
Convention on Wetlands of Importance Especially as Waterfowl Habitat (Ramsar Convention)	1997
London Amendment to the Montreal Protocol	1997
Bilateral Agreement on Kgalagadi Transfrontier Park (Botswana and South Africa)	1999
ORASECOM Agreement	2000
Revised SADC Protocol on Shared Watercourses	2003
Cartagena Protocol on Biosafety to the UNCBD	2002
Stockholm Convention on Persistent Organic Pollutants	2002
Kyoto Protocol to the UNFCCC	2003

*Ratification or accession date

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There is a dependence on the seasonal clay pans that are found interspersed in the Kalahari Savannah, for stock watering.

Domestic legal and institutional framework for natural resources management

The Botswana Government has embarked on an ambitious water sector reform project (2008–2013), under which a new National Water Policy and a draft Water Bill were developed. The National Water Policy (2012) was established under this reform project to provide guidance to all economic sectors that are custodians and/or users of water resources in Botswana. The reform brings significant changes to the roles of various organisations in the water sector. These include the re-allocation of responsibilities for water supply and distribution between the three key players, Water Utilities Corporation (WUC), Department of Water Affairs (DWA) and Local Authorities. As a result, new institutions have been established as part of the reform process, namely the Water Resources Board (WRB), water management area bodies and village water development committees.

The new draft Water Bill will, once enacted, replace not only the 1968 Water Act, but also the Borehole Act and the Water Works Act. The proposed new Act brings the country's legislation in line with IWRM principles. It establishes the new WRB with key decision-making functions in water resources management, allocation and development of policies related to water resources. The WRB is a cross-sectoral body representative of all relevant ministries, as well as other stakeholders. Its primary role will be decision-making on water allocation based on cross-sectoral consultation and inputs from all sectors whose interests must be taken into account. The technical functions of the WRB will be carried out by a division of DWA, which will act as the executive arm of the WRB.

Under the new water sector framework the DWA will no longer have any water service delivery functions and will only be responsible for assessing, national planning, developing and managing water resources for short-, medium- and long-term purposes. The WUC takes on the responsibility of a water supply authority (including wastewater operations) for all cities, townships and villages.

Table 25: Institutions in the Botswana water sector

Institution	Roles and responsibilities
Water Utilities Corporation (WUC)	The WUC will be responsible for the delivery of water and wastewater services countrywide. WUC must be financially viable and use cross-subsidisation to keep water affordable.
The Regulatory Commission	The Commission regulates more than one sector, e.g. water and electricity, or water, electricity and telecoms. The Regulatory Commission should become financially sustainable.
Department of Water Affairs (DWA)	DWA's post-reform mandate is described as: 'To serve the nation through protecting and developing the country's water resources, such that the growth of the economy is not vulnerable to inherent climate variability or constrained due to inadequate availability of sustainable water sources of required quality.'
Water Resources Board (WRB)	The WRB is an advisory body to the Minister of Minerals, Energy and Water Resources on water matters. It allocates water resources among users, monitors water resources and develops water resources management policy.
Water management area (WMA) bodies	In conjunction with the WRB, the WMA bodies investigate and advise interested persons on the availability, protection, use, development, conservation, management and control of water resources in their water management areas; and contribute to the development of the national water resources strategy.
Village water development committees	The committees advise residents on the protection, use, development, conservation, management and control of water resources in the village area; ensure that water is used in compliance with any regulations applicable to the water resources concerned; promote community participation in the protection, use, development, conservation, management and control of the water resources in their area; and contribute to the development of the national water resources strategy.

3.2.3 Summary

Botswana is party to regional water protocols as well as a number of transboundary river basin organisations, including ORASECOM. This is in spite of the fact that current domestic water legislation is outdated and makes no provision for transboundary water management and does not incorporate the concept of IWRM. Furthermore, there is no reference to water quality in the Water Act.

Botswana is addressing these shortcomings through their ongoing project to reform the water sector, which is expected to implement far-reaching institutional reforms, and prepare new water legislation and tariffs. The new Water Bill establishes strong elements of inter-ministerial cooperation in water management and provides for the devolution of water management responsibilities to the lowest possible level. Water resources protection is also well articulated in the national development plans, such as NDP 10.

Other areas that require addressing include translating sustainable development in policies into law and producing a coherent policy on climate change.

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Goats are particularly well adapted to thriving under conditions in southern Botswana, not always to the advantage of the environment.

BOTSWANA'S CURRENT NATURAL RESOURCES LEGISLATION


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The 1968 Water Act controls the use of water in Botswana and provides an institutional framework for water allocation and control. The Act specifies conditions to water rights for industrial, mining, power generation, and forestry use. It deals mostly with individual water rights rather than with basin-wide rights and allocations. There is no reference to an IWRM approach and transboundary water management is not provided for. There is very little legislation on water quality (such as, standards) and water pollution control. The penalties have never been adjusted and no longer form an effective deterrent against water abuse.

The Draft Water Bill (2005) proposes that the country's legislation be brought in line with IWRM principles. This requires the devolution of water management responsibilities to the lowest possible level through the establishment of water management area bodies and village water-development committees (Centre for Applied Research, 2010). The new bill also establishes a Water Resources Board (WRB) with key functions in water resources management and allocating decision-making. Notably, the WRB shows strong elements of inter-ministerial cooperation that requires representation of a wide range of relevant line ministries

Table 26: Overview of main natural resources management legislation, Botswana

Water resources	Land	Environment and biodiversity	CC mitigation and adaptation
Water Act, 1968	Tribal Land Act, 1970	Environmental Impact Assessment Act, 2005	Atmospheric Pollution Prevention Act, 1971
Draft Water Bill, 2005	State Land Act, 1966	Mines and Minerals Act, 1999	Herbage Preservation (Prevention of Fires) Act, 1978
Boreholes Act, 1956	Town and Country Planning Act, 1980	Wildlife Conservation and National Parks Act, 1992	Agrochemicals Act, 1999
Waterworks Act, 1962	Forestry Act, 1968 and 2005	Tourism Act, 1992	Agricultural (Conservation) Resources Act, 1974
Water Utilities Corporation Act, 1970	Waste Management Act, 1998		

Water policy in Botswana is guided by the National Water Master Plan (NWMP), which was developed in 1991. Reform recommendations were made in a 2006 review leading to NWMP2, which recognises water as an economic, social and environmental resource that provides the intersectoral linkages. In adopting this plan, the Botswana Government is therefore adopting an integrated approach to water resource development. NWMP2 recommends an urgent review of the draft National Water Conservation Policy 2004 (Centre for Applied Research, 2010) and delivering sustainable and equitable access to water resources will be essential if NDP10 is to succeed. This will require investment in sustainable water resources management, including management of water demand and the reduction of inefficient and wasteful water use (and systems) to ensure access for the poorest in society.

Aloe ferox blossoms brightly in contrast with the overgrazed slopes in the dry season in Lesotho.

3.3 COUNTRY PROFILE: LESOTHO

Lesotho is a landlocked, mountainous country, geographically surrounded by South Africa. Situated within the headwaters of the Orange–Senqu River, the country generates about 40% of the basin's mean annual runoff despite covering only 3% of its land area. The mountains of Lesotho support numerous unique wetlands (so-called 'sponges'), which form the sources of the three major rivers in the country (DWA, 2007). These rivers, the Senqu, the Mohokare (known as the Caledon in South Africa) and the Makhaleng, are all tributaries of the Orange–Senqu system. The runoff from the Lesotho lowlands drains westwards to the Mohokare River, while the highlands drain to the south via the Senqu (DWA, 2007).

The country has a population of 1.8 million, with an annual growth rate of one per cent (BOS, 2010). Population density is 59 people per km^2, and 82% of the population is rural. The lowlands zone is the most populated and intensively cultivated, followed by the foothills, the mountains and the Senqu River valley.

3.3.1 Water and the economy

Because of Lesotho's topography, economic activities are largely confined to the lowlands, the foothills and the Senqu River valley (Ministry of Natural Resources, 2000). The economy is dependent on a limited number of sectors and almost 80% of the rural population depends mostly on subsistence agriculture for their livelihood (Ministry of Natural Resources, 2007).

Other key sectors are mining and garment manufacture. The bulk of Lesotho's GDP comprises revenue from the Southern Africa Customs Union (SACU) which accounts for over 50%, and royalty payments from water transfers to South Africa through the Lesotho Highlands Water Project (LHWP), which account for 14% (UNDP, 2008). Further development of the LHWP has led to increased water transfers to South Africa becoming a key economic development initiative for the country.

Water use in Lesotho consists of local use and foreign transfers to South Africa through the LHWP. At the local level, the highest percentage of water is used by the garment manufacturing industry, followed by the domestic, mining and agriculture sectors (Table 27).

Table 27: Economic sectors, water use and contribution to GDP, Lesotho

Sector	% water use	% GDP contribution
Manufacturing	49	17.1
Mining	5	9.1
Services	3	52.2
Agriculture	1	7.1

Source: BOS, 2010; UNDP, 2008

3.3.2 Governance frameworks

Governance structure

Lesotho is a constitutional monarchy, with the king as the head of state and a prime minister as the head of government. The country has two spheres of government: central and local.

At the local level, Lesotho is divided into ten administrative districts, each with its own district capital. The districts are further subdivided into 80 constituencies and 129 local community councils. Local government comprises traditional authorities (chiefs) and democratically elected councillors, thus merging traditional governance systems with a democratic system.

The Ministry of Local Government has set priorities (2009–2013) according to which it aims to ensure that chieftainship and local authorities operate in harmony. This is supported through capacity-building to enable chiefs to participate effectively in the local government decentralisation process (CLGF, 2011). Local government institutions are charged with control of natural resources, environmental protection and the maintenance of water supply.

Economic development policies

Lesotho's Vision 2020 and Poverty Reduction Strategy aim to address the challenges that face the country's development. Both place food security, employment creation and rural development as priorities on Lesotho's development agenda. They identify water availability as a key driver of social and economic development in the country.

Table 28: Overview of economic sector policies and relevance for water resources management, Lesotho

Sector	Related policy	Relevance to water resources management
Agriculture and food security	Agricultural Sector Strategy (2003)	Emphasises the need for irrigation in ensuring food security
	Irrigation Policy (2002)	Promotes efficient use of water resources and enables farmers to diversify and intensify their crop production base
Energy	Energy Policy (2003)	Identifies hydropower as an important component of the national energy mix
Industry	Industrialisation Master Plan (2007)	Industrial sector is dominated by the garment manufacturing sub-sector, with its high impact on water use and water quality

Garment manufacturing is an important industry in Lesotho and a provider of employment.

NATIONAL WATER FOOTPRINT OF LESOTHO

Lesotho's natural renewable water resources are estimated at 5,230 Mm^3 per year. The water footprint related to total national consumption per capita for Lesotho is 292 m^3 per capita per year, which is below the SADC average of 776 m^3 per capita per year (Kort, 2010). The industrial water footprint for Lesotho for the 1996–2006 period was 0.055 m^3/USD (Kort, 2010).

In recent years, garment manufacturing has played a critical role in generating employment and export earnings. Lesotho has become the largest exporter of textiles and clothing in sub-Saharan Africa. The existing water-using industries (such as mining and agriculture) and further proposed expansions of the textile industry have the potential to place extra pressure on Lesotho's available water resources, as well as on water and wastewater infrastructure. Industry currently uses a significant portion of the readily available freshwater. In the Maseru area alone, it is estimated that up to 20% of the water supplied is used by industry.

Lesotho is believed to have high hydropower potential. At present 76 MW are being exploited through the Muela Dam and Hydropower Scheme. The Muela Dam was constructed as part of Phase I of the LHWP. It has a storage capacity of 6 Mm^3 and acts as the tail pond of the Muela Hydropower Station. Since its completion, Lesotho has been largely self-sufficient in its domestic electricity requirements except during peak periods. However, in the future, drought induced by climate change might affect the generation of hydropower. Phase II of the LHWP, which will feature the 1,200 MW Kobong Pump-storage Hydroelectric Scheme, and the construction of the Polihali Dam for increased water transfers to South Africa, was scheduled to commence in 2012.

Lesotho is not self-sufficient in food production and relies on maize imports from South Africa. Crop production is mostly rain fed, therefore periodic droughts and excessive rainfall events result in fluctuations in vegetable and maize production. The frequency of prolonged drought, combined with the persistent problem of land degradation, has led to poor agricultural production, making subsistence farming an insufficient and unreliable main source of livelihood. The trend for internal migration (as people move from rural to urban areas in search of better livelihoods) also puts pressure on available water resources in Lesotho's urban areas to supply both domestic and industrial water demands. The Metolong Dam, which is scheduled to be completed by 2013 at a cost of USD413 million, is a planned measure to address this challenge for Maseru and the surrounding smaller towns.

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Lets'eng-la-Letsie, Lesotho, Ramsar site of the source of the Quthing River

International agreements

Like its Orange–Senqu River co-basin states, Lesotho has committed to a number of water and other multilateral environmental agreements, an overview of which is provided in Table 29.

Table 29: Main international agreements ratified by Lesotho

International agreement	Date*
Treaty on Lesotho Highlands Water Development (Lesotho and South Africa) with Protocols I–VI	1986
UN Convention to Combat Desertification (UNCCD)	1995
UN Convention on Biological Diversity (UNCBD)	1995
UN Framework Convention on Climate Change (UNFCCC)	1996
ORASECOM Agreement	2000
Cartagena Protocol on Biosafety to the UNCBD	2001
Stockholm Convention on Persistent Organic Pollutants	2001
MoU between the Government of the Kingdom of Lesotho and the Government of the Republic of South Africa in respect of the Maloti–Drakensberg Transfrontier Conservation and Development Area	2001
Revised SADC Protocol on Shared Watercourses	2003
Convention on Wetlands of Importance Especially as Waterfowl Habitat (Ramsar Convention)	2004

*Date of ratification or accession

Domestic legal and institutional framework for natural resources management

Over the past decade, Lesotho has embarked upon a series of progressive reforms within its water sector. The reforms were aimed at enabling the country to better capitalise on development opportunities afforded by its geographically strategic location and relative abundance of water resources. The management of water resources in Lesotho is governed by the Water Act (2008), which provides for the management, protection, conservation development and sustainable utilisation of water resources in the country.

The Water and Sanitation Policy (2007) incorporates the country's IWRM strategy. Although Lesotho has developed instruments for IWRM, there are still factors that hamper its smooth implementation at different levels.

Table 30: Institutions in the Lesotho water sector

Institution	Role and responsibility
Water Commission	Policy planning and strategy guidance for the sector
Department of Water Affairs	Water resources assessment, protection and conservation
Department of Rural Water Supply	Rural community water supply
Lesotho Lowlands Water Supply Unit	Bulk water development – local urban water supply
Lesotho Highlands Development Authority	Bulk water development – export (water transfers to South Africa)
	Dam safety and maintenance
	In-stream flow requirements policy
	Community development
Metolong Authority	Development of Metolong Dam and associated infrastructure

3.3.3 Summary

Lesotho has an IWRM-based water legislation that explicitly recognises obligations from international agreements; however, the lack of an IWRM plan prevents coordinated implementation of the IWRM strategy. Currently, there are no catchment (or sub-catchment) management institutions. Furthermore, uncoordinated and overlapping natural resources laws and policies constrain progress in the implementation of IWRM at operational level (Mokorosi and Matete, 2009). The Environment Act, although enacted in 2001, has not yet been enforced.

Benefit-sharing arrangements between Lesotho and South Africa under the LHWP have a functioning bilateral cooperation mechanism. These benefit-sharing arrangements with South Africa are likely to expand through further development of the LHWP. Lesotho also has a high potential for hydropower development.

Horses and donkeys provide practical and important forms of transport in the highlands of Lesotho.

LESOTHO'S NATURAL RESOURCES LEGISLATION

The Water Act (2008) was introduced to manage water resources in Lesotho in an integrated and sustainable way. It explicitly recognises Lesotho's international obligations to water management and makes provisions to conserve and protect its water resources from all forms of pollution. The Act also provides for the allocation of permits, such as abstraction and construction permits, and the regulation of conditions for obtaining different types of permits. It makes provision for the ownership of all water resources to be vested in the Basotho nation and held in trust by the King of Lesotho.

The IWRM strategy was developed in 2007 and is a roadmap to achieve the policy goals of the water sector as outlined in the Water and Sanitation Policy of 2007. To address the key areas of importance for water resource sustainability in Lesotho – namely improved catchment management and combating erosion – the policy promotes integrated management at catchment (or basin) level. However, given the size of Lesotho and the technical capacity of the existing institutions, there are no plans for establishing basin management organisations in the near future (Ministry of Natural Resources, 2007). The IWRM strategy also constitutes two supporting strategic policies, a water demand management strategy and a drought management strategy.

The present lack of catchment management and high levels of erosion reduce the potential for groundwater storage. The resulting lowered groundwater level affects water availability from boreholes and in the many springs that are currently the sources for the majority of the rural water systems (Ministry of Natural Resources, 2007).

Table 31: Overview of main legislation for management of natural resources, Lesotho

Water resources	Land	Biodiversity	CC mitigation and adaptation
Water Act (2008)	Land Regulations (2011)	Environment Act (2008)	Environment Act (2008)
Environment Act (2008)	Land Act (2010)	Mines and Minerals Act (2005)	National Adaptation Programme of Action (2007)
Water and Sewerage Authority Order 29, of 1991	Land Administration Authority Act (2010)	Forest Act (1998)	
Lesotho Highlands Development Order, 23 of 1986	Local Government Act (1997)	National Parks Act (1975)	
Public Health Order, 12 of 1970	Land Survey Act (1980)		
	Town and Country Planning Act (1980)		
	Deeds Registry Act (1967)		

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Although there is little surface water in many areas of the basin in Namibia, springs are not uncommon and provide an important source of water.

3.4 COUNTRY PROFILE: NAMIBIA

Namibia is one of the driest countries in sub-Saharan Africa. Its primary sectors, such as agriculture, fisheries and mining, account for about 30% of the total GDP (Lange, 2003; Reid et al., 2007). The country has a relatively high economic dependency on these natural resource-based sectors, as well as landscape-based tourism, many of which are climate-sensitive. Namibia has no perennial surface water resources that originate within its boundaries, and for its water needs it depends heavily on groundwater and transboundary surface water resources that it shares with its neighbours. The Orange–Senqu River is key for southern Namibia, where commercial agriculture and mining activities depend on the river as a reliable water resource.

3.4.1 Water and the economy

The main water users in Namibia include agriculture, mining, manufacturing and the service sectors (DWAF, 2005). Agriculture (commercial and communal) is the biggest water user (75%). Each of the economic sectors is highly dependent on water, and consequently, water management policy is a critical component of Namibia's development strategy.

Table 32: Contribution of sectors to economy as compared to water use (2001/02), Namibia

Sector	% water use	% GDP contribution	% employment
Agriculture (commercial and communal)	75	7	24
Government	5	25	15
Services	3	35	45
Manufacturing	3	13	5
Mining	2	9	1

Source: MAWF, 2005

3.4.2 Governance frameworks

Governance structure

Namibia's post-independence Constitution of 1990 established three independent spheres of government – national, regional and local. The powers and functions of regional and local governments are assigned to them by an act of parliament, and each regional and local government body has an elected council and an executive administration. Regional and local government bodies have some revenue-raising power and also share in the revenue raised by central government. The regional council is responsible for regional socio-economic planning. Local authorities take different forms, such as municipalities, town or village councils, and are responsible for provision of local services such as water supply, sanitation, public places, roads, electricity, cemeteries, public transportation and housing to the people within their jurisdiction.

Traditional authorities, particularly in rural areas, continue to have a strong influence and have important functions in the governance of natural resources, most notably related to the allocation and use of communal land (CLGFc, 2011).

Economic development policies

Namibia's development vision is contained in Vision 2030, which recognises the lack of readily available fresh water in the interior of the country as the 'most important limiting factor for development' (NPC, 2004). Vision 2030 is complemented by the current Fourth National Development Plan (NDP 4), which recognises the importance of water and has specific targets on access to potable water and sanitation, as well as targets for the water sector to effectively support economic development (NPC, 2012). Vision 2030 is supported by a number of sector-specific economic development policies (Table 33).

Table 33: Overview of economic sector policies and relevance for water resources management, Namibia

Sector	Related policy	Relevance to water resources management
Agriculture and food security	Green Scheme Plan (2008)	Aims to encourage the development of agricultural production through irrigation, and enhance the contribution of agriculture to GDP
Mining	Minerals Policy (2002)	Recognises the effect that mining has on water and the need for appropriate legislation to regulate water use in mining
Industry	White Paper on Industrial Development (1992) Namibia's Industrial Policy (2011)	Aims to increase addition of value of manufacturing by stimulating productivity and increasing exports
Tourism	Tourism Policy (2001–2010)	Specifies that no tourist development should be at the cost of biodiversity, and requires that some of the income derived be reinvested into natural resource conservation

NATIONAL WATER FOOTPRINT OF NAMIBIA

Available water from different sources in Namibia, currently amounts to 423 Mm³ per year with long-term availability of water estimated at 660 Mm³ per year (DWA, 2005). The Namibian part of the Orange–Fish River basin is dominated by commercial farming and mining activities, as well as tourism, including the /Ai-/Ais–Richtersveld Transfrontier Park. There is some potential for conflict between the different water and other resource needs (particularly concerning land) between the tourism sector and the agricultural and mining sectors. However, all interest groups have to cooperate through existing intersectoral structures in order to use the natural resources of the basin in a socio-economically and environmentally sustainable way.

While improvements in water productivity have occurred in the mining (14.4%), manufacturing (2%), services (4%) and government (11%) sectors, a decline in water productivity has been observed in fishing (inland aquaculture) and fish processing. Most importantly, water productivity in the agriculture sector, which at 75% is the biggest water user, has recently declined, which is largely attributed to an increase in (inefficient) irrigation schemes. The value added per cubic metre of water in agriculture, and more specifically irrigation (NAD7.2/m³), is very low compared to the manufacturing (NAD272/m³) and service (NAD574/m³) sectors (DWA, 2005). (NAD10 was equivalent to USD1 in 2013.)

As Namibia's perennial surface water resources originate outside its boundaries, it is highly dependent on cooperation with its neighbours for securing its water supply. It is estimated that shared rivers currently provide around a third of the water consumed in Namibia. These shared surface water resources are also important for Namibia's electricity supply. The large Calueque Dam on the Kunene River in Angola has a 240 MW installed capacity and supplied up to 60% of Namibia's electricity in 1995 (1,134 GWh), although in dry years this has fallen to 45% (672 GWh in 1994).

Studies have been conducted to identify and estimate cost and production for all potential hydropower projects in the lower Kunene, Kavango and lower Orange rivers. The lower Orange and Kavango rivers show potential for a number of smaller-scale hydroelectric plants, which could total a capacity of at least 120 MW, contributing about 0.3 TWh per year (Anon. 2008b).

The halfmens, *Pachypodium namaquanum*, is endemic to the Succulent Karoo which straddles the western-most stretches of the lower Orange River.

International agreements

Namibia is party to the main international agreements related to the management of water and other natural resources. Namibia is party to the SADC Revised Protocol on Shared Watercourses, the regional framework agreement for the management of shared rivers. The country has also ratified the 1997 UN Convention on the Non-navigable Uses of International Watercourses (although this convention is not in force as it has not yet received the required minimum number of 35 ratifications globally). Furthermore, Namibia is party to a number of bilateral and multilateral agreements on the Orange–Senqu River. It is also party to a number of major multilateral environmental agreements (Ruppel and Ruppel-Schlichting, 2011), as shown in Table 34.

Table 34: Main international agreements ratified by Namibia

International agreement	Date*
Samewerkingsooreenkoms Tussen die Regering van die Republiek van Suid-Afrika en die Oorgangsregering van Nasionale Eenheid van Suidwes-Afrika/Namibie Betreffende die Beheer, Ontwikkeling en Benutting van die Water van die Oranjerivier	1987
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	1990
Agreement on the Establishment of a Permanent Water Commission between Namibia and South Africa	1992
Agreement on the Vioolsdrift and Noordoewer Joint Irrigation Scheme between Namibia and South Africa	1992
United Nations Framework Convention on Climate Change (UNFCCC)	1992
United Nations Convention on Biological Diversity (UNCBD)	1992
Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention)	1995
United Nations Convention to Combat Desertification (UNCCD)	1995
UN Convention on the Non-navigable Uses of International Watercourses	2000
ORASECOM Agreement	2000
Cartagena Protocol on Biosafety to the Convention on Biological Diversity	2000
Revised SADC Protocol on Shared Watercourses	2003
Treaty on the Establishment of /Ai-/Ais–Richtersveld Transfrontier Park	2003
Kyoto Protocol on Climate Change	2003
Stockholm Convention on Persistent Organic Pollutants	2005

*Date of ratification or accession

Domestic legal and institutional frameworks for water and natural resources management

The Namibian legislative framework and institutional landscape for water resources management has recently undergone a transition towards an IWRM-based approach. This brings legislation in line with internationally accepted principles for water resources management. Table 35 provides an overview of institutional responsibilities for water management in terms of the new dispensation.

Table 35: Institutions in the Namibian water sector

Institution	Roles and responsibilities
Department of Water Affairs and Forestry (DWAF)	Responsible for the administration of water affairs and management of water resources through the Under Secretary for Water Affairs and Forestry
Namibia Water Corporation Limited (NamWater)	National supplier of water in bulk
Basin management committees (BMCs)	Advise the minister on the protection, sustainable use, development, conservation, management and control of water resources and resource quality within a clearly demarcated area of common concern. The Orange–Fish Basin Management Committee was established in 2009
Water-point committees	Manage and control water service provision by the water point or water supply scheme
Regional councils	Control all aspects of planning and development related to socio-economy, natural resources, land utilisation and infrastructure in the region with specific reference made to water
Local authorities	Establish, acquire, construct, operate and maintain any waterworks, either within or even outside their areas in order to provide their water users with a reliable water supply of a quality suitable to the needs of the users


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Cattle shelter from the sun under the alien *Prosopis* tree, which provides one of the few sources of shade in Nama Karoo.

The water management governance framework is complemented by a relatively strong framework for other natural resource management, such as land, biodiversity and protected areas and, most recently, the development of a comprehensive climate change policy. However, there remains a possibility of sector policy conflicts, particularly agricultural policies, which, if unresolved, could pose a risk for sustainable water resources management (MAWF, 2009).

3.4.3 Summary

Namibia's policy and legal frameworks provide for transboundary water management and subscribe to IWRM principles. These are supported by strong natural resources management policies and strategies in place or under development (e.g. land, biodiversity, protected areas, climate change). Based on new climate change policy, opportunities now exist to integrate aspects of climate change into national sector policies and basin management. There are however potential policy conflicts, for example between agricultural expansion policies and water resources availability. Namibia's first industrial policy was tabled in 2012.

In line with policy in Namibia, a committee exists for the integrated management of the Orange–Fish sub-basin in Namibia. Increased cooperation and economic integration (e.g. TFCAs) provide additional development options for the basin in Namibia. Currently, however, there is inadequate intersectoral cooperation and coordination for IWRM to be effective. Although this could potentially be improved through strengthening basin management committees, inadequate human resources and financial capacity are hampering basin management. Insufficient integration and coordination of planning and implementation between national-, regional- and local-level bodies also affect water resources management.

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Communal waterpoint, Namibia

NAMIBIA'S NATURAL RESOURCES LEGISLATION

The Namibia National Water Policy (2000) recognised the threats to the country's water resources and proposed a set of measures and approaches on the assessment of water resources, management of shared watercourses, the economic pricing of water, water demand management, a new legislative framework with ownership of water vested in the state, and institutional strengthening (MAWF, 2009).

Subsequently, a new water Act has been developed and promulgated, the Water Resources Management Act of 2013. Namibia went through a transitional phase during its development, which included the promulgation of the Water Resources Management Act (2004) that was never applied. Both the Acts of 2004 and 2013 subscribe to the principles of IWRM and reform the institutional framework for water management in the country. Importantly, the Act of 2013 places strong emphasis on the involvement of stakeholders in water resources management by, for example, providing for the establishment of basin management committees (BMCs). While it has not formally been brought into force, many of the changes provided for are already being implemented, including the establishment of BMCs (MAWF, 2009).

The BMCs represent a step towards decentralisation of responsibilities to key stakeholders on different levels within demarcated basin areas. Each BMC includes regional and local representatives and liaises closely with regional and local authorities (e.g. the Orange–Fish Basin Management Committee has representatives from Hardap and Karas Regional Councils). Eleven river basins were identified by the Department of Water Affairs for the establishment of BMCs and six have been established. In the Namibian part of the Orange–Senqu River basin, the Orange–Fish Basin Management Committee was first established in 2009 through an interim committee (DRFN, 2010).

Table 36: Overview of main legislation related to management of natural resources, Namibia

Water resources	Land	Biodiversity	CC mitigation and adaptation
Environmental Management Act (2007)	Communal Land Reform Act (2002)	Environmental Management Act (2007)	Pollution Control and Waste Management Bill (in preparation)
Water Act (1956)	Environmental Management Act (2007)	Forestry Amendment Bill (2001)	Soil Conservation Act (1969)
Water Resources Management Act (2013)	Forestry Amendment Bill (2001)	Nature Conservation Amendment Act (1996)	Environmental Management Act (2007)
Namibia Water Corporation Act (1997)	Nature Conservation Amendment Act (1996)	Soil Conservation Act (1969)	Electricity Act (2000 and 2007)
Minerals (Prospecting and Mining) Act (1992)	Soil Conservation Act (1969)		Forestry Amendment Bill (2001)
Pollution Control and Waste Management Bill (in preparation)	Draft Parks and Wildlife Management Bill (in preparation)		Communal Land Reform Act (2002)
			Nature Conservation Amendment Act (1996)
			Atmospheric Pollution Prevention Ordinance (1976)
			Soil Conservation Act (1969)

3.5 COUNTRY PROFILE: SOUTH AFRICA

The Orange–Senqu River basin is of great geographic and economic significance for South Africa. Rising in the mountains in Lesotho, it flows westwards into South Africa and is later met by the Vaal River, its major tributary. Downstream, the river forms the border between Namibia and South Africa before discharging into the Atlantic Ocean. With South Africa already experiencing some degree of water scarcity and with water demand increasing, the sustainable management of the Orange–Senqu River is essential for the country's long-term water security.


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Orange Farm near Johannesburg is one of the youngest informal settlements in South Africa and experiences challenges delivering water supply services.

3.5.1 Water and the economy

South Africa has by far the largest and most diverse economy of the four Orange–Senqu basin states. It is several times the size of the combined economies of its three co-basin states. Economic activity in the Orange–Vaal river system is dominated by the urban-industrial centre of Gauteng, the economic hub of southern Africa. Gauteng accounts for 38% of South Africa's GDP and hosts nearly nine million people, or 20% of South Africa's population (ORASECOM, 2007c).

While agriculture and mining are important economic sectors, manufacturing and services play a much larger role in the economy than in the other basin states. Economic growth averaged 3% per year between 1994 and 2004. Since 2004, it exceeded 4% per year, reaching 5% in 2005. Beyond 2010, the national target is a growth rate of 6% per year, although this will possibly be reduced by the current slowing of the global economy. As the economy grows, however, the competition for water among the various use sectors is likely to increase.

Table 37: Economic sectors, water use and GDP contribution, South Africa

Sector	% water use	% GDP contribution
Agriculture	60	3
Manufacturing	3	16
Mining	3	9
Energy	2	15
Tourism	~0	7

Source: DWA, 2012

3.5.2 Governance frameworks

Governance structure

South Africa is a constitutional, parliamentary democracy with three spheres of government, national, provincial and local. These are distinctive, interdependent and interrelated (South African Constitution, Section 40). There are nine provincial governments and local government is comprised of 283 municipalities categorised into three types: six metropolitan municipalities, 46 district municipalities and 231 local municipalities.

The separation of functions between national and provincial government is regulated in Schedules 4 and 5 of the Constitution. Schedule 4 lists functional areas of concurrent national and provincial legislative competence, and Schedule 5 lists functional areas of exclusive provincial legislative competence.

The concurrent functions (Schedule 4) related to water management include pollution control, regional planning and development. Moreover, the Constitution provides that national and provincial government must, through legislative or other measures, support and promote the development of capacity and regulate the exercise of executive authority by local government. Local government may make (non-conflicting) by-laws on any matter over which it has executive authority (Section 156(2)), namely the functions in Parts B of Schedules 4 or 5 and any others that may be assigned. This includes water and sanitation services.

Economic development policies

The Water for Growth and Development Framework (DWA 2009) presents a comprehensive response to the water scarcity challenges facing the country while simultaneously responding proactively to the needs of the country's economy. The framework addresses the relationship between water availability and the many forms of economic activity that depend on an available water supply of a specific quality. It highlights the government's intention to ensure that water is mainstreamed in national planning and decision-making processes and embarks on a process of institutional re-alignment for water resource management functions. The framework further promotes diversifying the water mix, such that desalination and effluent re-use are considered, while also promoting water conservation and water demand management.

Table 38: Overview of economic sector policies and relevance for water resources management, South Africa

Sector	Related policy	Relevance to water resources management
Agriculture and food security	Water for Development and Growth Framework (2009)	Aims at ensuring that water is able to support both economic growth and social development goals in South Africa
	Integrated Food Security Strategy (2002)	Target is to reduce the number of food-insecure households by half by 2015
Mining	Mineral and Petroleum Resources Development Regulations (2004)	Deals with environmental regulations for mineral development, petroleum exploration and production
Manufacturing	South African Water Quality Guidelines – industrial water use	Used as a basis for developing materials to inform water users about the physical, chemical, biological and aesthetic properties of water
Energy	Integrated Energy Plan for the Republic of South Africa (2003)	Considers the importance of diversifying energy resources to other energy forms and renewable energies (hydropower, solar, wind, biomass) to improve supply security, improve environmental performance and facilitate regional development

The Vaal Dam is the main source of water to the economic hub of Gauteng. It receives up to 777 million m^3 per year from the Katse Dam in Lesotho in order to meet demands in Gauteng.

International agreements

Like its Orange–Senqu co-basin states, South Africa is party to a number of water and other international environmental agreements. These include several bilateral agreements that specifically focus on the management of the Orange–Senqu River basin, and the development and management of water infrastructure projects.

Table 39: Main international agreements ratified by South Africa

International agreement	Date*
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	1973
Treaty on Lesotho Highlands Water Development (Lesotho and South Africa) and associated Protocols I–IV	1986
Samewerkingsooreenkoms Tussen die Regering van die Republiek van Suid-Afrika en die Oorgangsregering van Nasionale Eenheid van Suidwes-Afrika/Namibie Betreffende die Beheer, Ontwikkeling en Benutting van die Water van die Oranjerivier	1987
Agreement on the Establishment of a Permanent Water Commission (Namibia and South Africa)	1992
Agreement on the Vioolsdrift and Noordoewerr Irrigation Authority (Namibia and South Africa)	1992
UN Convention on Biological Diversity (UNCBD)	1995
UN Convention to Combat Desertification (UNCCD)	1995
Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar Convention)	1995
UN Framework Convention on Climate Change (UNFCCC)	1997
Bilateral Agreement on Kgalagadi Transfrontier Park (Botswana and South Africa)	1999
UN Convention on the Non-navigable Uses of International Watercourses	2000
ORASECOM Agreement	2000
Cartagena Protocol on Biosafety to the Convention on Biological Diversity	2000
MoU between the Government of the Kingdom of Lesotho and the Government of the Republic of South Africa in respect of the Maloti–Drakensberg Transfrontier Conservation and Development Area	2001
Stockholm Convention on Persistent Organic Pollutants	2002
SADC Revised Protocol on Shared Watercourses	2003
Treaty on the Establishment of /Ai-/Ais–Richtersveld Transfrontier Park	2003

*Date of ratification or accession

Domestic legal and institutional framework for natural resources management

Since the end of the apartheid area in 1994, South Africa has undergone a substantial policy and legal reform process, which has also seen drastic changes to the legal and institutional landscape for water management (Braid and Görgens, 2010). South Africa has adopted new water legislation that promotes equity, sustainability and efficiency through water management decentralisation, new local and regional institutions, water users' registration and licensing, and the emergence of markets in water rights (Braid and Görgens, 2010). The institutional framework for the South African water sector is shown in Table 40.

Table 40: Institutions in the South African water sector

Institution	Roles and responsibilities
The Department of Water Affairs (DWA)	The DWA ensures that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner.
Catchment management agencies (CMAs)	CMAs manage water resources at catchment and water management area (WMA) level.
Water-user associations (WUAs)	Associations of local user groups within a specific WMA.
Water boards	Agencies providing bulk water at local and regional levels.
Water service authorities (WSAs) and providers (WSPs)	WSAs ensure delivery of water services at local level (local government), while WSPs provide water services to WSAs who do not have the capacity to do so themselves.
Trans-Caledon Tunnel Authority (TCTA)	Implements development of large water resources infrastructure of regional and international magnitude.
As yet to be established National Water Resources Infrastructure Agency (NWRIA)	Will see a phased integration of the DWA's National Water Resources Infrastructure Branch (WRIB) and the TCTA to handle the financing, construction and management of mega water resource infrastructure and will raise investment funds on the capital market, supplemented by the DWA's budget; extra costs are envisaged for 'social investment' requirements.

Source: DPME, 2012

3.5.3 Summary

South Africa's legislation provides for cooperative governance and integrated resource management and there are strong natural resources management policies and strategies in place regarding land, biodiversity, protected areas and climate change. The Water for Growth and Development Framework responds to water scarcity challenges, while proactively focusing on the needs of the country's economy. However, lack of capacity and financial resources hamper the process towards fully fledged IWRM. Currently none of the CMAs in the WMAs located in the Orange–Senqu River basin is operational.

Ensuring water for domestic and economic requirements, while maintaining healthy aquatic ecosystems for long-term sustainability is one of the main objectives of IWRM.

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SOUTH AFRICA'S NATURAL RESOURCES LEGISLATION

The National Water Act of 1998 (NWA) establishes the principle that as the public trustee of the nation's water resources, the national government, acting through the Minister of Water and Environmental Affairs, ensures that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons and in accordance with its constitutional mandate.

The South African water management legislation is firmly rooted in the principles of IWRM. The legislation provides for the integration of water resources management with the management of other natural resources through the implementation of a system of water management areas (WMAs) managed by catchment management agencies (CMAs). The National Environmental Management Act of 1998 further provides for integrated resource management. All legislation that affects environmental protection and management must adhere to the principles contained in the Act.

The National Water Resource Strategy II (NWRS II; DWA, 2012) further defines the ways in which water resources will be managed. The NWRS II consolidates the number of WMAs from the previously envisaged 19 to 9. The NWA makes provision for the progressive establishment of CMAs within each WMA.

The purpose of the CMAs is to delegate water resources management to the regional or catchment level and to involve local communities in decision-making processes. So far, the establishment of CMAs is significantly behind schedule and only a few CMAs are fully operational. The delay in their establishment is attributed to the lack of capacity in the areas being dealt with, as well as financial constraints (PMG, 2011). Through the consolidation of WMAs, the Orange–Senqu basin in South Africa spans two WMAs, instead of the initial five. The new WMAs under NWRS II are the Orange River WMA and the Vaal River WMA. CMAs are not yet operational in these WMAs.

Table 41: Overview of main natural resources management legislation, South Africa

Water resources	Land	Biodiversity	CC mitigation and adaptation
National Water Act (1998) Water Services Act (1997) Mountain Catchment Areas Act (1970)	Development Facilitation Act (1995) Conservation of Agricultural Resources Act (1983) Physical Planning Acts (1965, 1991) Fertilisers, Farm Feeds, Agricultural Remedies Act (1947)	National Environmental Management: Protected Areas Act (2003) National Environmental Management: Biodiversity Act (2004) National Environmental Management Act (1998) Environmental Impact Assessment Regulations The National Forests Act (1998)	National Environmental Management Act: Air Quality Act (2004) Climate Change Response Strategy (2004) National Veld and Forest Fire Act (1998)

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Many suburbs in the basin are expanding rapidly and often informally, as shown here on the outskirts of Kliptown, one of the oldest residential areas of Soweto, Gauteng. It is built on land that formed Klipspruit farm, named after the Klip Spruit (rocky stream) that runs nearby in the upper Vaal sub-basin.

4. ASSESSMENT OF ISSUES

4.1 INTRODUCTION

This chapter presents a description and an analysis of the priority water-related problems in the Orange–Senqu River basin. These problems – mostly transboundary in nature – have resulted in the deterioration of the basin's aquatic ecosystems. The functioning of wetlands, riverine habitats, the estuary and groundwater are impaired, virtually throughout the basin. This, in turn, has socio-economic costs related to the loss of goods, services and opportunities that these ecosystems would otherwise provide.

The skewed distribution of rainfall, the geographical demand for water in the upper half of the system, significant agricultural demands in the drier parts of the basin, and the storage and transfer infrastructure and operation of this infrastructure to meet the demands, are the driving forces behind the transboundary issues. With increased abstraction, there is less water in the river system and reservoirs, weirs and water transfer systems have altered flow regimes. Water quality has deteriorated because of increased volumes and types of pollutants and less water to dilute them. Other important drivers affecting aquatic ecosystems include poor land management and the invasion of alien plants. This chapter examines the causes and impacts of these problems and recommends points of intervention to address them.

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Windmills that pump groundwater to the surface, often from great depths, are iconic to the landscape in the western areas of the basin in particular.

4.1.1 Approach and methodology

Priority transboundary and common problems were identified through a consultative process during the preliminary TDA (ORASECOM, 2008). Building on this, ecological and socio-economic impacts and immediate, underlying and root causes were examined. A preliminary causal chain analysis (CCA) was produced for each of the five prioritised issues, as well as a sixth issue that was subsequently identified. These were:

1. Increasing demand on water resources
2. Changes to hydrological regime
3. Declining water quality
4. Land degradation
5. Invasion of riparian and aquatic habitats by alien species
6. Changes in sediment dynamics and quality.

When examining the transboundary problems, biodiversity and climate change were considered cross-cutting issues; the latter is discussed in Section 2.5 of this report.

National consultations were held in each of the four basin states to further verify and prioritise water-related (environmental, transboundary, common and national) problems in the Orange–Senqu River basin from each country's perspective, and review the draft CCAs. Potential interventions for implementation in the short-, medium- and long-term were also identified, as well as localities in each of the countries that epitomised the problem, and identified potential stakeholders and complementary projects.

The information from the basin states (UNDP–GEF 2012, 2013a, b, c) has been combined to produce a basin-wide analysis presented in this chapter. Prioritisation of the transboundary problems are summarised in Table 42.

Opposite: In arid areas of the basin harvesting rain from rooftops and storing it for later use helps households meet their water needs.

Irrigation farming along the lower Orange

Table 42: Prioritisation of transboundary issues: Results from four national workshops

Transboundary issue	Botswana	Lesotho	Namibia	South Africa	Overall
Increasing water demand	1	4	1	2	1
Changes to hydrological regime	5	3	3	3	3
Declining water quality	3	2	2	1	1
Land degradation	2	1	6	4	2
Invasion by alien species	4	5	4	5	4
Changes in sediment dynamics and quality	5	5	5	6	5

Note: 1 = highest priority; 6 = lowest priority

Due to the outcome of discussions at the national workshops, 'changes in sediment dynamics and quality' and 'invasion by alien species' were removed as standalone problems and the issues around them incorporated into the remaining four transboundary problems, as and where appropriate.

4.1.2 The causal chain analysis

One of the most useful aspects of the TDA is the CCA, which is developed for each problem. It graphically relates the transboundary problem to ecological and socio-economic impacts, provides an analysis of what has caused it, and offers potential interventions to address it (Figure 35). To help identify and understand the causes, they have been examined by economic sector and divided into immediate, and underlying and root causes.

Immediate causes are usually a direct, technical and predominantly tangible cause of the problem, and generally have a distinct area of impact.

Underlying and root causes identify resource uses and practices, and related social and economic causes to the problem. They are related to fundamental aspects of macro-economy, demography, consumption patterns, social and environmental values, and access to information and participatory processes. For example, an immediate cause of eutrophication is human waste in runoff, but one of the underlying causes of this is the lack of sewerage infrastructure in informal settlements.

These CCAs form the basis for development of the National Action Plan (NAP) and the basin-wide Strategic Action Programme (SAP) interventions. Therefore, potential points of intervention to address the problems have also been included in the CCAs.

TRANSBOUNDARY PROBLEM					
Impacts		Sector	Causes		Points of intervention
Ecological	Socio-economic		Immediate	Underlying and root	
The effects of the problem on the biophysical environment, e.g. eutrophication or change of species	The effects of the problem and ecological changes on the social and economic wellbeing of the population, e.g. increased costs of water treatment or health risks	The sectors associated with the causes, e.g. mining, agriculture, urban	The immediate causes of the problem, e.g. effluent in streams	The underlying and fundamental reasons for the problem, e.g. lack of sewerage infrastructure in informal settlements	Potential actions that can be taken to address the problem in the short, medium and long terms

Figure 35: Schematic presentation of the impacts, causes and potential interventions of the problem

Points of intervention that address underlying or, better still, root causes, are more likely to have a lasting effect and help address more than one problem. On the other hand, the effects of interventions that attend to the immediate, obvious symptoms are usually simpler to implement and results are quickly realised. A combination of interventions addressing immediate and underlying causes could therefore provide the most comprehensive and sustainable solution.


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Welbedacht Dam on the Caledon River near Wepener augments water supply to Bloemfontein, South Africa.

4.2 INCREASING DEMAND ON WATER RESOURCES

4.2.1 Problem statement

The volume of water presently reaching the mouth of the Orange–Senqu is estimated to be 4,200 Mm^3 per year on average – less than half the annual natural flow, which is estimated at 11,300 Mm^3. Water is abstracted for irrigation, industry and mining, domestic use and livestock farming. Demands are steadily growing with little surplus water to allow for increased abstraction. Groundwater is of major importance in the drier western areas of the basin for domestic use, stock watering, wildlife and tourism and even some irrigation, but little is known about this hidden resource. Groundwater potential in the basin needs to be better understood to determine how its use could be improved, especially locally.

There is less available water for further development and limited options for additional dam and transfer development to increase water supply. Interventions such as water conservation, demand management, re-use of water, desalination, rainwater harvesting, etc. need to be explored and increasingly implemented through an integrated approach. It is vital that water is used in the most beneficial and efficient manner. To achieve this, reliable data and accurate analyses are required.

4.2.2 Overview of the causal chain analysis

The impacts and causes of increasing demand for water and potential interventions to address this problem are summarised in the causal chain in Figure 36. As a result of high and increasing demands for water, especially in the upper area of the basin and for irrigation in the drier areas of the basin, there is less water flowing through the system and less water to dilute pollutants. Ecologically, these factors have led to the degradation of wetland and riverine habitats, including ephemeral riverbeds and the estuary. Increased groundwater abstraction has also led to the degradation of pans. Water security and assurance are declining, limiting the socio-economic opportunities, especially downstream, and increasing the cost of water supply.

The main sectors linked to the immediate causes of the problem of increasing demand for water have been identified as agriculture – particularly irrigation agriculture, but also livestock – mining and industry, and urban and domestic. There are cross-cutting issues related to assuring water supply, especially to the aforementioned sectors, that also contribute to the problem.

Each of these sectors is associated with the abstraction of water for substantial and often inefficient use. This is thought to be especially true for irrigation, where the economic returns per cubic metre of water used are low. Losses of water because of poor maintenance and aging infrastructure, is a problem in all the sectors. This is particularly pressing in the urban and domestic sector where demand is increasing exponentially. Service providers are pressurised to expand supply systems for a greater proportion of society, because of high urban migration and improved living standards. There is a limited appreciation of the value of water among many users, and insufficient demand management interventions and incentives to use less water.

PROBLEM: INCREASING DEMAND FOR WATER

Impacts: Ecological	Impacts: Socio-economic
• Less water in the river basin • Natural flow dynamics altered, including floods and low flows • Reduced recharge, lowered water table; less available groundwater • Concentration of contaminants, including in groundwater in arid areas, and eutrophication • Changes in turbidity, sediment loads and water temperature • Changes in river morphology • Degradation of wetland and riverine habitats, including dry riverbeds , pans and the estuary • Changes in abundance and composition of alien vegetation, especially around infrastructure • Loss of natural ecosystem services, including suitable soils for irrigation • Disruption to migration of estuarine-dependent marine species	• Limited options for meeting increasing demands • Increased cost of water infrastructure development for diminishing returns • Reduced capacity of reservoirs and ability to meet demands • Declining water security and assurance of supply, especially of potable water, for all users • Water becomes more expensive • Loss of socio-economic opportunities, including tourism, establishment of new mines • Decreased potential for hydroelectric power generation • Human migration to where water is provided • Potential effect on marine fisheries • Water reallocation between sectors • Disputed cost-sharing model • Commercial losses of unaccounted for water

Sector	Causes: Immediate	Causes: Underlying
Agriculture	• Inefficient use • Poor infrastructure causing losses • Unlicensed water abstraction (illegal off-takes; unregistered boreholes) • Increased abstraction	• Pricing structure and insufficient demand management • No incentive for water-saving development • Limited awareness-raising or education on improved technologies, such as irrigation technologies and rainwater harvesting • Inappropriate agricultural development priorities • Disparity in land-use planning and water availability • Inappropriate management practices for arid conditions, including drought management strategies and programmes • Disharmony of legislation and regulations, and enforcement of these; disharmony in plans and programmes • Aging and poorly maintained infrastructure • Fragmentation of management • Expansion of irrigation areas • Increased demand for agricultural products • Ineffective management at catchment level; limited number of WUAs, CMAs and BMCs in place and operational
Mining & industry	• Inefficient use (wastage) • Transfer of water out of the system • Dilution of acid mine drainage to meet water quality standards • Dewatering draws down water table locally	• Aging and poorly maintained infrastructure • Poor management of resource infrastructure and use (impoundments, abstraction and water management regime) • Mining activity and inappropriate closure of and/or abandoned mines, especially due to high cost of EMP implementation at closure • Rehabilitation of mines with irrigated vegetation • Limited implementation of innovative technologies • Inappropriate and/or illegal mining practices, especially of sand, calcrete and gravel • Economic growth and socio-economic development priorities • Poor water demand management • Disharmony in policy and legislation
Urban & domestic	• Water wastage and leakage • Losses due to poor maintenance and aging infrastructure • Expanded supply systems covering a larger proportion of society	• Population growth, urban migration and pockets of high densities • Transformation to more equitable society • Increased demand due to improved living standards • Limited technical skills and poor management at local level • Lack of information and knowledge on the systems used among managers • Lack of awareness of users on scarcity of water and alternative options, such as rainwater harvesting • Poor understanding of why water should be paid for • Insufficient demand management • Lack of universal metering • Ineffective revenue collection • Ineffective implementation of free basic water needs policy (South Africa)
Cross-cutting	• Transfer of water out of the system • High unaccounted-for water (technical) losses in supply and reticulation systems • Reduced storage capacity of reservoirs • Increased (natural) evaporation from dams • No basin-wide flow regimes in place • Increased alien vegetation • Reduced recharge to groundwater	• Construction of new dams • Trapping of sediments by dams • Aging and poorly maintained infrastructure • Limited technical skills and poor management at local level • Disharmony and fragmentation (municipal, provincial, national, regional) in management of the resource • Poor understanding of total required volumes and functioning of systems • Limited understanding of groundwater recharge • Insufficient water demand management • Unilateral development of water resources Historic status quo of water use • Equitable allocation disputed • Uncoordinated management • Implementing environmental flow requirements

Term	Points of intervention
Short term	• Apply internationally recognised law in water allocation • Examine options for equitable cross-border water supply • Prioritise water use for the most sustainable and economically viable land uses • Develop policies and practices to promote and improve water use efficiency, e.g. in irrigation and on farm • Reduce losses in water transport from source to use by improving maintenance and infrastructure • Strengthen skills base and capacity and develop a long-term recruitment strategy • Improve management structures and maintenance systems • Continue moving to air-cooled power plants • Improve long-term water monitoring networks: rainfall, flow, groundwater levels, water quality and metering • Improve monitoring system: data capture, analysis, real-time modelling, distribution of findings • Update models to reflect evolving information on climate change and changing priorities • Improve understanding of groundwater recharge and resource potential • Manage groundwater usage • Introduce policies and practices to manage demand, e.g. introduce metering and volume-based pricing in all sectors • Increase sectors' awareness of water as a finite resource and as an economic good • Examine alternative interventions and sources: water-saving technologies, water re-use and desalination, rainwater harvesting, small-scale dams, etc. • Determine basin-wide environmental flow requirements • Examine potential for new infrastructure development, including intra- and inter-basin transfers
Medium term	• Follow through short-term interventions • Improve analysis of information and real-time information; disseminate • Explore conjunctive use of surface water and groundwater • Introduce alternative interventions and sources: water-saving technologies, water re-use and desalination, rainwater harvesting, etc. • Promote ways to reduce quantity of water required for processes and improve quality of return flows • New infrastructure development • Revisit and adjust basin-wide environmental flow regime
Long term	• Follow through short- and medium-term interventions • Update models to reflect evolving information on climate change and changing priorities • Increase water utilisation for greater productivity and efficient use; move to higher value uses of water • New infrastructure development • Strategic water supply, demand and management planning by water authorities

Figure 36: Causal chain analysis related to increasing demand for water

A large proportion of cultivation in the eastern areas of the basin is rain-fed and not irrigated.

Although there are limited options to increase abstraction and use of surface water in the basin to meet increasing demands, a number of interventions to improve the efficiency and management of the supply and use of it are suggested, including managing demand and examining the potential of alternative sources. To better understand the resources, improved monitoring and modelling of rainfall, flow and groundwater are essential. To ensure the health of the system over the longer term, basin-wide environmental flow regimes must be established and consideration given to the allocation of water in an equitable manner for the most sustainable and economically viable activities.

4.2.3 Overview of basin-wide and national aspects

Increasing demand for water is perceived as a high priority problem for all basin states and the effects of it are felt throughout the basin, but especially in the drier areas. The pressures on the ecological and socio-economic environments caused by the high demands on water are significant within the basin context.

Environmental requirements are largely ignored at present and aquatic ecosystems have deteriorated. Increasing use of water in one part of the basin – especially in the high-demand upper basin areas – affects the balance available for downstream users, including the volumes available to the ecosystems.

There is a perception that the water needs of all basin states and consequent allocation are not incorporated in long-term planning; such concerns and perceptions could lead to future conflict. Nationally, the sectoral allocation of water is also questioned. At current rates of demand (excluding environmental requirements) and modus operandi, there is little room for increasing supply.

To meet increasing demands, additional water infrastructure and alternative interventions to increase the efficiency and effectiveness of water use need to be researched and implemented where appropriate.

Limited understanding of resource potential in the basin, especially of groundwater, but also surface waters, is a key concern. Rainfall, flow and groundwater resource monitoring, analysis and evaluation need to be improved. There is also a need to improve the water balance model of the basin. The boundaries of sub-systems and inputs and outputs of transfer systems need to be better defined, especially in the quantification of inter-basin transfers.

Key transboundary elements to this problem include:
- transfer of water out of the system
- water wastage and leakage
- inefficient use of water, especially in the irrigation sector
- dilution of acid mine drainage
- lack of provision for basin-wide environmental flows
- limited data for planning and modelling
- limited management of demand
- limited research and implementation of alternative sources and improved technologies
- limited awareness on the value of water.

Botswana has not contributed water to the mainstream in recent history and currently has little influence on water resources in a transboundary sense. The Orange River is not a very practicable source for south-western Botswana, however, transfers from the LHWP to Botswana are being considered for future phases of the project. The basin area in Botswana is presently fully reliant on groundwater sources to meet its water requirements, including Jwaneng, a town centred around a diamond mine in Southern District. As the Orange–Senqu basin is currently delimited, Jwaneng falls within it. However, the mine, town


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Most rainfall soaks into the loose Kalahari sands in south-western Botswana, forming little runoff.

and well field that supply them are situated along the Naledi River, an ephemeral river that flows northwards into the greater Okavango basin.

At present there are no other mines within the Botswana basin area. However, there are four kimberlitic fields of quality grade diamonds that could potentially be developed into mines in the future, most likely the one at Tsabong which is earmarked for commissioning within the next decade. There are other significant kimberlitic fields at Kokong and Middelpits. Such developments might well require water transfer from other areas of the basin. Diamond mining contributes about 60% of Boswana's revenue.

Four main well fields – Middelpits, Tsabong, Makopong and Sedibeng – supply the larger settlement areas, the responsibility of which falls on the District Council (Sedibeng), the Geological Survey (Middelpits and Makopong) and the Department of Water Affairs (Tsabong). Vandalism and the misuse, wastage and loss of water, especially in larger settlements (Tsabong, Werda, Bokspits, Middelpits, Goodhope), are concerns, as well as management and pollution issues. There is also concern that groundwater is over-abstracted at cattle posts, which lowers the water table and increases water salinity, as well as encouraging overgrazing. *Prosopis* invasion along dry watercourses is thought to reduce groundwater recharge.

The geohydrology of the basin is not well understood in Botswana and other arid areas of the basin (Namibia and central and western South Africa), where there is reliance on groundwater sources. More effort is required to collect and analyse information on groundwater to better understand the potential of this resource. In addition, alternative supply mechanisms such as rainwater harvesting, desalination and wastewater re-use options, especially to support rural communities, need to be examined.

In *Lesotho*, the national demand for water is relatively small in relation to the resources available. However, the LHWP, which transfers water from reservoirs in Lesotho to the Vaal sub-basin, has a significant impact on the river downstream. Inappropriate management of the catchment and resultant erosion in Lesotho contributes to sedimentation and loss of reservoir storage capacity in Lesotho and downstream in South Africa. Degraded wetlands in the Lesotho highlands have reduced the natural water storage capacity of this ecosystem.

High proportions of non-revenue water through physical loss and/or unbilled consumption, also contribute to water 'losses' in Lesotho, as in all the basin states. There is a need to strengthen governance and management within institutions.

Increasing demand for water from the Orange–Senqu system was identified as the priority concern for *Namibia*. The quantification of inter-basin transfers, questions around water balance and limited understanding of resource potential, especially related to groundwater, were of key concern. Inappropriate agricultural development priorities, such as promotion of production for food self-sufficiency and employment creation in Namibia, were recognised as fundamental issues contributing to increasing demand for water in the basin.

Increasing demand for water for expansion of irrigation areas in *South Africa,* as well as irrigation methods and the limited economic benefits derived from this sector, were also identified as key concerns. Irrigation expansion is a particular concern in Kakamas and Keimoes, upstream of Augrabies, and around Kimberley and Jacobsdal. The growing demand for water by municipalities was largely attributed to mismanagement.

4.2.4 Potential points of intervention

Points of intervention identified to address increasing demand are aimed at increasing the efficiency of water supply and use, enhancing the perceived value of water and improving knowledge about the potential of the basin's resources. In addition, equity of access to the basin's resources is also addressed:

- Readdress water allocation between basin states.
- Improve efficiency of water use: prioritise water use for sustainable and economically viable land uses; improve irrigation and on-farm water efficiency; improve maintenance and infrastructure to reduce transmission losses.
- Improve skills base and capacity; develop recruitment structures; improve management and maintenance structures and systems.
- Improve water monitoring networks (quantity and quality) of rainfall, flow, groundwater levels and water metering; capture data; analyse, model and distribute findings.
- Improve understanding of groundwater recharge and resource potential; manage groundwater use.
- Manage demand by increasing awareness that water is a finite resource and an economic good; introduce volume-based water pricing.
- Examine and introduce alternative interventions and sources: water-saving technologies; water re-use and desalination; rainwater harvesting; small-scale dams; and conjunctive surface and groundwater use.
- Determine and implement basin-wide environmental flow requirements.

Community volunteers have built stone walls to stop further erosion and rehabilitate rangelands at Mount Moorosi, Lesotho.

4.3 CHANGES TO HYDROLOGICAL REGIME

4.3.1 Problem statement

As a consequence of upstream development, the hydrological regime of the river has changed dramatically. Apart from the mean annual runoff being reduced to half the estimated natural flow, the pattern of flow is different to that of the natural river. There is less variability in flow from one year to the next and, within the year, there is a less-distinct seasonal pattern. The frequency of smaller floods has also been reduced, with most being absorbed by upstream abstraction and storage.

There is less water in the system to dilute increasing volumes and types of contaminants; reduced and altered patterns of flow and flushing; and changes in sediment load and balance and river morphology along its length. These changes in the hydrological regime of the river impact downstream ecosystems, including the estuary, a Ramsar site, resulting in a loss of ecosystem services. More water needs to be found for environmental needs.

4.3.2 Overview of the causal chain analysis

The impacts and causes of changes in the hydrological regime of the Orange–Senqu River system are summarised in the CCA (Figure 37). The changes in hydrological regime can be attributed to storage, and release or transfer of water to meet significant demands at areas and times when water would otherwise not be available. In assuring that these demands are met, disruption of the natural flow of the river compromises the integrity of downstream aquatic ecosystems and the services they provide. Water quality deteriorates and pests and invasive species increase.

By providing opportunities in some areas by assuring water supply, other options and potential opportunities are lost, especially those reliant on healthy wetland habitats and related natural resources. In addition, direct costs of water treatment, environmental management and disease control increase.

PROBLEM: CHANGES TO HYDROLOGICAL REGIME

Impacts: Ecological	Impacts: Socio-economic	Sector	Causes: Immediate	Causes: Underlying and root	Term	Points of intervention
• Altered and reduced flushing of estuary and flow through the mouth • Reduced frequency of flood events • Less natural dilution of increased types and amounts of contaminants • Changes in degradation and aggradation of riverbed downstream of reservoirs • Changes in the morphology of the river and mass balance of sediment • Poor water quality • Disruption of food chains • Blue-green algal blooms caused by eutrophication • Increase in *Cladophora filamentous* algal occurrence • Biodiversity changes and/or losses • Increase in alien organisms – terrestrial and aquatic fauna and flora • Increase in pests (blackfly) • Loss of ecological functioning of water resources (wetlands, rivers, estuary) • Disruption of fish spawning sites or habitat	• Although increased winter flow in lower Orange, overall reduced options for downstream users • Increased costs related to reduced ecosystem goods and services • Increased costs for environmental management (blackfly control, algal blooms, reed control) • Loss of livestock and income due to blackfly • Increased cost of water treatment • Increased health risks • Increase in employment opportunities through agricultural sector, especially during harvest • Loss of economic opportunity, especially recreational and tourism (blackfly, loss of habitats, altered flows)	Agriculture	• Change from cash crops to permanent crops • Proliferation of farm dams	• Demand for irrigation water during dry season • Demand for food self-sufficiency	Short term	• Mitigate anthropogenic impacts at river mouth • Get agreement on a basin-wide, equitable (quantity, cost and environment) allocation model • Implement the South African National Water Resources Strategy • Comprehensively determine basin-wide environmental flow requirements (dry and wet season) for rivers and mouth • Manage floods to ensure dam safety and minimisation of downstream flood damage, loss of life and environmental requirements (simulate natural floods) • Optimise operating rules for dams (including power-generation operations) to benefit downstream ecosystems and water users • Implement current water legislation in the formation of IWRM participatory bodies • Introduce interventions to change attitudes and improve water-use efficiency • Improve incentives for reduced water use • Examine feasibility of possible new infrastructure development
		Energy	• Releases of water for hydropower generation mostly in winter	• High demand for energy, especially in winter • Socio-economic		
		Mining	• Open-cast mining impacts on runoff and vegetation • Underground mining impact on water table and recharge • Illegal diversion of the river • Illegal construction of low-level crossings • Development of golf courses, roads, etc. in the floodplain of the estuary • Inappropriate breaching of sand bank of estuary	• Uncoordinated authorisation of mining and inadequate enforcement of regulations, e.g. EMP implementation • Inadequate regulation and/or enforcement of small-scale mining • Increased demand for mining products • Fast development of mines and industry • Socio-economic		
		Urban & domestic	• Localised increased runoff over paved areas • Increased urban return flows	• Increased urbanisation, growing population • Water wastage • Poor urban planning • Inadequate awareness creation, information-sharing and capacity-building		
		Cross-cutting	• Stronger winter flows • Reduced frequency of flood events • Damming for abstraction and for release as required • Inter-basin transfer schemes • Evaporation from dams • Degradation of wetlands • Increased alien invasive species	• Damming operating rules do not meet downstream environmental and in-stream flow requirements • High demand for water use • Urbanisation • Improvement in living standards and increased water use • Socio-economic development priorities • Poor coordination between developmental industries and water sector • Inadequate planning, monitoring and identification of priorities • Inadequate knowledge of ecosystems • Inadequate information-sharing and training • Population growth	Medium term	• Follow through short-term interventions • Monitor and adapt environmental flow management as necessary; continue operating flows according to these • Establish a basin-wide flood warning network
					Long term	• Follow through short- and medium-term interventions

Figure 37: Causal chain analysis related to changes to hydrological regime

The main sectors linked to the immediate causes of the problem – changes to hydrological regime – have been identified as:

- agriculture (particularly irrigation demands for water during the dry season);
- energy, which requires greatest releases of water in winter;
- mining (for diversion and disruption of waterways and wetlands);
- the urban and domestic sector (for increased runoff and return flows).

A number of cross-cutting issues related to assurance of water supply and the development of the river system, were also identified.

Each of the above-mentioned sectors is associated with the disruption of the natural flow of the river by requiring water at a time of year when, naturally, it would be less available; by contributing extra runoff through return flows when naturally there would be less runoff; and by disrupting waterways and wetlands through physical excavations and constructions. These immediate causes are largely driven by socio-economic development priorities and skewed demand for and natural availability of water.

The negative effects of the altered hydrological regime could, however, be greatly reduced by implementing basin-wide environmental flow requirements for the river system and estuary. This would require optimising the operating rules for dams to simulate natural floods and to benefit downstream ecosystems and users. It would also require, to some degree, a change in attitudes towards the value of water, its use, storage and release. Such interventions are supported by existing strategies and legislation, but are not yet fully implemented.

Irrigation demands water during the dry season, contributing to the changed hydrological regime.

Katse Dam on the Malibamatso River in Lesotho releases almost 800 Mm³ of water per year to the Vaal sub-basin.

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This pond of fresh water was constructed to attract birds away from the polluted and acid waters of the slimes dam at Skorpion Zinc mine, Rosh Pinah, Namibia.

4.3.3 Overview of basin-wide and national aspects

Changes to the hydrological regime of the river are intrinsically linked to demand and the development of the river to assure supply at times when and places where there would otherwise be a shortfall. While this is essential to maintain and provide opportunities in certain economic sectors such as agriculture, it affects the overall health of the river, and reduces opportunities dependent on a healthy and well-functioning environment. The problem is perceived to be of particular concern in the lower Orange River and estuary, where the effects are most seriously felt.

Key transboundary elements of this problem include:

- storage and transfer of water for abstraction as required, without provision for environmental flow requirements
- reduced flows and flushing – volume and frequency
- higher winter flows
- changes in degradation and aggradation and resultant river morphology and sediment balance
- changes in balance of riparian and aquatic ecosystems, especially the estuary
- loss of ecosystem goods and services
- reduced water quality
- lack of basin-wide flood and drought warning networks.

It is, however, not only in the main perennial river system that the flow of water is disrupted. In the drier, western ephemeral rivers, it is recognised that existing and proposed dams affect hydrological regime, as do dense sections of alien invasive vegetation and other obstructions within the river channel and riparian zone. Invasive *Prosopis* trees and shrubs in the Nossob River in Namibia impede downstream flow, especially in the Leonardville area.

Apart from the factors related to large-scale storage and release of water in *Lesotho*, there are other factors thought to contribute to changes in flow regime here, at least locally. Important services provided by the highland sponges related to flood attrition and slow release of water in the highlands are being lost through land degradation. Alluvial mining (diamonds and sand) is also considered to be changing the morphology of the river and consequently its hydrological regime. Developing interventions to address land degradation and protection and conservation of important ecosystems are needed, as well as the development of an integrated flood management plan and an early-warning dissemination network.

Dams provide more water for the basin as a whole, but for downstream users on the lower Orange, including the environment, the effect is negative, especially in the absence of comprehensive dam operating rules. The effects of changes to the hydrological regime are most severely felt at the Orange River estuary, shared by *Namibia* and *South Africa*. Other areas for protection were identified through the National Freshwater Ecosystem Priority Areas Project. In Namibia, Oanob Dam is the only dam with a regime of environmental flow releases to maintain the downstream *Acacia* woodland; Hardap, Naute and other dams in the basin have no policy for environmental releases.

4.3.4 Potential points of intervention

The establishment of basin-wide environmental releases is central to mitigating this problem. As it will put an added demand onto water requirements of the basin, it is important that these are implemented with concurrent interventions to improve water efficiency and change attitudes to the value of water and environmental requirements. Greater coordination between development industries, especially, and the water sector is also required.

To create a better understanding of what the environment requires, there is a need to increase the number of hydrological monitoring stations, especially downstream of Upington, and environmental monitoring throughout the basin.

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Abandoned and decommissioned mines are one of the main sources of pollution in the Vaal sub-basin.

4.4 DECLINING WATER QUALITY

4.4.1 Problem statement

The key water quality issues in the Orange–Senqu River system have been identified as nutrient enrichment, primarily linked to increased phosphorus and nitrogen concentrations; increased salinity from acid mine drainage and irrigation return flows; microbial contamination from urban settlements and poorly operated wastewater treatment works; and changes in sediment load. In addition, radionuclides, heavy metals and persistent organic pollutants, while they do not pose a basin-wide risk currently, do show high concentrations in certain localised areas, and precaution should prevail.

At a time when the types and sources of pollution are increasing, reduced volumes of water in the system prevent their effective dilution, compounding the water quality problem.

4.4.2 Overview of the causal chain analysis

The impacts and causes of declining water quality in the Orange–Senqu River basin are summarised in the CCA (Figure 38). Although a common problem throughout the basin, pollution and declining water quality are most severe in the Vaal sub-basin. Both underground as well as surface water resources are subject to declining quality.

The immediate causes of the problem are attributed to three sectors: the urban and domestic sector, mining and industry, and agriculture, with some cross-cutting causes related to groundwater abstraction. The problem can be largely ascribed to: cost, ignorance and lack of incentives to adopt best practices; aging and poorly maintained infrastructure; limited monitoring and ineffective enforcement of compliance; and inadequate closure of mines.

A number of potential interventions have been identified in the short term to start addressing the problem with some urgency. Upgrading infrastructure, improving monitoring and enforcing compliance will go a long way to addressing the issues. However, research is also required to establish the extent of some of the pollution concerns and to determine best practices for addressing them.

4.4.3 Overview of basin-wide and national aspects

The problem of declining water quality is more severe in certain areas of the basin, especially the Vaal sub-basin, but inadequate pollution control and declining water, soil and sediment quality are recognised as growing problems in all four basin states. Even at the most basic level, wastewater control and contamination of freshwater resources as a result of inadequate facilities, infrastructure and maintenance, are issues that need to be addressed in all four countries. Agricultural return flows containing agrochemicals and seepage from agricultural areas, tailing facilities and landfills are other potent sources of pollution.

Acid mine drainage into the Vaal system from abandoned and decommissioned mines with inadequate closure is a problem that has been building up for decades and has reached critical proportions. The symptoms are now being addressed, but require enormous amounts of fresh water until more sustainable solutions are identified and implemented. Localised hotspots of heavy metals, POPs and

PROBLEM: DECLINING WATER QUALITY

Impacts

Ecological

- Eutrophication
- Blue-green algal blooms (increase in *Cladophora* algal strings)
- Deoxygenation of water
- Increased salinity and sodicity of soils, groundwater and rivers
- Contamination of groundwater with pollutants and waste products
- Chemical contamination of sediments
- Localised hotspots of heavy metals, POPs and radionuclides
- Bioaccumulation of toxins
- Risk to ecosystem health
- Degradation of aquatic and riparian ecosystems
- Increase in aquatic and riparian invasive alien plants
- Decreased channel and flow capacity
- Loss of habitat, increase in bank erosion and sedimentation and increase in turbidity of water, negatively affecting fish

Socio-economic

- Loss of potable water source
- Water has odour and taste
- High cost of water treatment
- Increased irrigation costs
- Decrease in agricultural productivity
- Contaminated agricultural products
- Increase in cost of treating soils and infrastructure (e.g. roofs and fences)
- Increased risk to livestock health
- Increased risk to human health
- Decrease in water use options, including recreational and tourism
- Loss of income
- Potential loss of livelihood subsistence use of fish
- Potential effect on cultural ceremonies

Causes

Sector: Urban & domestic

Immediate

- Human waste in runoff
- Overflow and seepage from sewage sludge disposal
- Non-compliant discharges from wastewater treatment works
- Direct discharge of effluents into rivers, especially tourist facilities
- Seepage from waste dumps
- Leaching of metals and salts from landfills

Underlying and root

- Lack of sewerage infrastructure in informal settlements
- Rapid population increase without upgrading wastewater treatment works and landfills: operating over capacity
- Insufficient maintenance of infrastructure
- Lack of affordable housing; informal settlements outside planning framework
- Poor landfill design, maintenance and management
- Non-existent or ineffective solid waste management
- Runoff and drainage systems not well maintained; storm water runoff into wastewater treatment plants
- Lack of funding or inappropriate budgeting for remediation and maintenance
- Ineffective revenue collection by utilities
- Shortage of skills and capacity and commitment at local government level
- Large settlements on small rivers, thus small dilution factor
- Inappropriate gardening techniques
- Increased concentrations of drug remnants in water

Sector: Mining & industry

Immediate

- Discharge of acid mine drainage into surface streams, especially the Vaal system
- Direct discharge of effluents into rivers
- Pumping polluted waters from mines
- Diffuse runoff from industrial and mining sites
- Decant and seepage from tailing facilities, waste dumps and closed mines
- Spills and accidents from slimes dams
- Mobilisation of heavy metals and radionuclides from mine dumps and excavations
- Atmospheric deposition of pollutants, e.g. PAHs
- Inappropriate in-stream sand mining
- Clearing of vegetation, floodplains and other wetlands by alluvial miners

Underlying and root

- Ineffective pre-treatment plants
- High cost of correct waste management practices and appropriate technology
- Inadequate facilities for disposal of hazardous waste
- Poorly placed slimes dams
- Abandoned and decommissioned mines with inadequate closure
- Lack of commitment to environmental management plans
- High cost to government to rehabilitate abandoned mines
- Low levels of compliance
- Ineffective enforcement and control of discharge quality
- Relaxed requirements for newcomers into the market
- Limited monitoring of water quality due to inadequate human and financial resources
- Uncoordinated management and mandates between sectors
- Alluvial mining (e.g. sand and diamonds), including illegal and subsistence mining

Sector: Agriculture

Immediate

- Nitrogen and phosphorus in return flows and seepage
- Saline return flows and seepage
- High salinity of irrigation water
- Leaching of trace metals from agrochemicals in irrigation return flows and from dryland crop fields
- Direct or indirect deposition of pesticides into watercourses
- Runoff and seepage from feedlots and kraals
- Contamination from dip tanks
- Clearing of vegetation, floodplains and other wetlands
- Erosion

Underlying and root

- Over and incorrect application of agrochemicals and irrigation
- Artificial leaching of root zone to reduce salinity and excess nutrients
- Inefficient and poor management of irrigation systems and dryland farms
- Aging and leaking infrastructure and seepage into soils
- Nodes of informal settlements along irrigation canals
- Schemes a priority for national development purposes
- Lack of incentives to improve farming methods and/or infrastructure
- Non-compliance to regulations relating to waste disposal
- Ineffective enforcement and control
- High cost of monitoring and water analyses of certain chemicals
- Inadequate coordination of monitoring and sharing results
- Natural geological conditions
- Use of marginal soils for agriculture
- Poor management of feedlots

Sector: Cross-cutting

Immediate

- Mobilisation of heavy metals, etc. from natural deposits through groundwater pumping, changed pH in surface waters, etc.
- Saline intrusion

Underlying and root

- Poor planning or inadequate environmental impact assessment
- Low levels of technical knowledge and inadequate extension services
- Non-compliant implementation of environmental management plans and ineffective enforcement
- Over-abstraction of groundwater
- Limited monitoring
- High cost of monitoring and water analyses
- High cost of waste disposal
- Fracking?

Points of intervention

Short term

- Upgrade irrigation scheme infrastructure
- Upgrade sewerage infrastructure to cope with appropriate volumes of water
- Improve plant operation and maintenance
- Reduce leakages by maintenance of water infrastructure
- Water conservation and demand management at municipal level
- Provide capacity building, skills training and awareness raising on key pollution issues
- Monitor pollutants in water and sediments, including heavy metals and agrochemicals
- Monitor suspended sediment in water, especially in the lower Orange and Fish
- Establish basin-wide receiving water quality (RWQ) objectives and monitoring system
- Enforce compliance, implement corrective action and 'polluter pays' principle
- Develop best practice guidelines for mine closure
- Enforce implementation of decommissioning plans for mine closure
- Include cost of implementation of environmental management and closure plans into feasibility studies
- Pilot treatment of acid mine drainage
- Raise awareness among small-scale farmers and create incentives for large-scale farmers to reduce excess agrochemical applications
- Move from dipping livestock to injecting
- Research and explore options for pre-treatment of agricultural return flows
- Develop skills of, and incentives for, farmers to implement best practices
- Research emerging pollutants and pollution issues, e.g. POPs, drugs, etc.
- Research and determine irrigation capacity of the basin
- Research the impact of groundwater abstraction on water quality and recharge
- Implement longer-term natural methods for remediation, e.g. phyto-remediation of tailings and storage dams
- Establish a basin-wide accident and pollution warning system
- Research effects of acid rain
- Research payment for ecosystem services

Medium term

- Follow through short-term interventions
- Implement environmental flow requirements
- Increase human resources and capacity in all departments responsible for water pollution control
- Establish an effective and coordinated monitoring network and reporting
- Treat acid mine drainage
- Install sewerage infrastructure or other appropriate technologies, e.g. constructed wetlands (phyto-remediation)
- Analyse and model long-term sediment yield and loads and develop an understanding of fluvial morphology processes

Long term

- Follow through short- and medium-term interventions

Figure 38: Causal chain analysis related to declining water quality

PAHs have been identified through preliminary basin-wide assessments, but more research is required to understand the scope and extent of declining water quality. Currently, potable water is being lost, the costs of treating water are increasing and public health is at risk.

Tackling pollution – immediate and underlying – requires a number of costly interventions related to clean-up, adequate monitoring, research and implementation of best practices. This is especially true as more complex, emerging pollutants, such as POPs, PAHs and drug remnants are becoming increasingly common and are currently inadequately addressed.

Many of the issues related to the problem are common to all the basin states. Some appear to be localised at this point, but may still pose a threat to the basin's water resources as a whole. Key elements related to declining water quality include:

- eutrophication
- increased salinity and sodicity of soils and water
- localised hotspots of heavy metals, POPs and PAHs
- acid mine drainage
- increasing concentrations of drug remnants
- inadequate systematic monitoring of surface and subsurface water quality
- inadequate enforcement of compliance to water quality standards and implementation of corrective action
- high cost of appropriate pollution control
- lack of knowledge, capacity and awareness related to pollutants and appropriate measures to deal with them
- increased costs related to water treatment
- health risks
- lack of a basin-wide pollution incident warning system.

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A dry and polluted pan outside Hendrina in the Vaal River sub-basin.

Water quality was not identified as an urgent issue in *Botswana* or *Lesotho*, but the challenge is to maintain current relatively high water quality by addressing the issues that do exist. For example, the Caledon River in Lesotho has been pinpointed as having high turbidity at high flow and high salinity (attributed to the textile industry) at low flow. Industrial wastewater from the textile industry is one of the major concerns in Lesotho, as well as solid waste and oil disposals and the potential effect of emerging diamond mines, especially in the light of relatively weak control measures and regulation. The impact of sand mining on river morphology is also recognised as affecting water quality.

Other issues negatively affecting water quality in Lesotho include waste disposal in urban centres, especially high-growth centres such as Qeme, and cultivated fields in the lowlands, near rivers that use outdated agricultural technologies such as dipping tanks. Similarly, in Botswana, cattle kraals, poorly managed watering points and inadequate sanitation facilities in settlement areas pose a threat to vulnerable groundwater sources.

As in Botswana, groundwater in *Namibia* is not potable in places because of naturally occurring salts and elements. Small-scale desalination is an option that should be considered for some rural settlements. Groundwater pollution is also a concern in Namibia. There is a need to raise awareness among community members on potential pollution threats to groundwater sources and how to avoid contamination. Other problems in Namibia were identified as posing severe or locally severe threats to water quality. These include return flows from irrigation schemes, sewage contamination of local water sources at many settlements and the lack of decommissioning plans for some mining operations.

The scale of the problem is by far the greatest in *South Africa*, which is more industrialised and has high population pressure. Eight severe problems were identified in the basin:

- the impact of acid mine drainage in the upper and, potentially, in the middle Vaal sub-basins and finding a sustainable solution to address it;
- microbial pollution, for example at the Vaal Barrage, and blue-green algal blooms;
- inadequate sanitation services, non-functioning sewage and wastewater treatment works, raw sewage inflows and other waste management threats to surface and subsurface resources related to human settlement;
- high concentration of POPs at Bloemhof Dam and Barberspan, and leaching of agrochemicals generally;
- habitat loss and environmental degradation of the estuary;
- alluvial mining of diamonds and sand extraction (often illegal, always uncontrolled) in the middle and lower Orange between Warrenton and Douglas, and Windsorton and Prieska;
- current groundwater quality, for example in isolated places around Pofadder and de Aar;
- the potential threat to groundwater sources from hydrological fracking.

4.4.4 Potential points of intervention

While some of the issues around water quality are large-scale and require concerted effort and resources to address, some water quality issues, especially those related to small rural settlements, could be addressed with existing technologies, capacity-building and awareness-raising. There is an urgent need to improve knowledge on the scale and extent of the problem, acceptable water quality standards, and how to deal with emerging, pollution issues.

Many areas throughout the basin require immediate measures to curb the inflow and seepage of wastes by upgrading wastewater treatment works and landfills, and sourcing and addressing seepage problems. Monitoring must be improved, best practices established and compliance enforced. To implement such interventions, capacity and skills need to be developed. There is also a need to implement a 'polluter pays' principle and/or volume-based pricing to help overcome the costs of monitoring and remediation.

4.5 LAND DEGRADATION

4.5.1 Problem statement

Inappropriate land management in parts of the Orange–Senqu basin has led to loss of wetland storage and aquifer recharge, increased sediment loads, deteriorating water quality, increased distribution and abundance of alien invasive plants, loss of biodiversity, and lowered land productivity. At a time when increasing numbers of people are faced with dividing up the land into smaller pieces, they are also faced with it being less productive. In some parts of the basin, livestock production is in decline and opportunities for community-based natural resource management and alternative livelihood options are inadequately considered. Land use should be optimised sustainably.

4.5.2 Overview of the causal chain analysis

The impacts and causes of land degradation and potential interventions to address this problem are summarised in the CCA in Figure 39. Land degradation was identified as a particularly pressing problem in both Botswana and Lesotho, but is not limited to these two basin states. Poor land management practices,

<table>
<tr><th colspan="8">PROBLEM: LAND DEGRADATION</th></tr>
<tr><th colspan="2">Impacts</th><th rowspan="2">Sector</th><th colspan="2">Causes</th><th colspan="2" rowspan="2">Points of intervention</th></tr>
<tr><th>Ecological</th><th>Socio-economic</th><th>Immediate</th><th>Underlying and root</th></tr>
<tr>
<td rowspan="6">• Deforestation of riparian zone
• Loss of vegetation
• Rangeland degradation
• Bush encroachment
• Desertification
• Change in frequency and extent of fire regimes
• Changes to physical environment
• Loss of wetland and aquifer storage potential
• Increased evapo-transpiration
• Decreased groundwater recharge
• Destabilisation of the soil
• Formation of sand dunes
• Soil erosion
• Declining soil fertility
• Reduced water quality in rivers and reservoirs
• Increased sedimentation
• Indigenous species outcompeted by alien invasive species
• Decreased indigenous habitat
• Biodiversity loss
• Decline of key populations, including wildlife
• Loss of ecosystem integrity, especially wetlands, including pans, and the riparian zone of perennial and ephemeral rivers</td>
<td rowspan="6">• Decreased potential land productivity
• Reduced potential for agricultural production and food security and/or self-sufficiency
• Loss of land and infrastructure due to erosion and sedimentation
• Increased surface runoff and local flood risk
• Siltation of dams
• Increased siltation of irrigation canals
• Aesthetic degradation of land and wetlands
• Decreased availability of groundwater
• Loss of ecosystem services
• Increased human–wildlife conflict
• Loss of indigenous technical knowledge
• Increased unemployment
• Increased poverty
• Increased inequity of income
• Fragmentation of rangelands
• Increased urban migration
• Encroachment of dunes
• Costs related to eradication of alien invasive plants and land rehabilitation</td>
<td>Subsistence agriculture</td>
<td>• Overstocking of livestock
• Overgrazing
• Poor rangeland management
• Cultivation in riparian, wetland and steep areas
• Unsustainable harvesting of natural resources, including medicinal plants
• Veld fires
• Invasion of areas by alien plants</td>
<td>• Poor farming practices
• Poorly developed markets for livestock and crops
• Inadequate understanding of ecosystems
• Lack of integrated land-use planning and management systems
• Poor co-ordination between conservation and livelihood development agencies
• Changed traditional land tenure system; weak control over communal lands
• Contradiction between statutory legislation and traditional rules
• Skewed land ownership
• Dual grazing rights
• Regulations, where they exist, not enforced and policies not implemented
• Government interventions and/or policies conflict with sustainable land-use practices, especially in arid and fragile areas
• Limited institutional and individual capacity
• Over-reliance on short-term, externally funded projects
• Increased human pressure
• Limited alternative livelihoods
• Poverty
• Fragile ecosystems and natural soil structure</td>
<td rowspan="3">Short term</td>
<td rowspan="3">• Develop locally based effective monitoring systems on rangeland condition and occurrence of alien invasive species
• Harmonise sector policies and programmes, e.g. review subsidies, fences, etc.
• Harmonise traditional and statutory laws; revive traditional laws where appropriate
• Initiate participatory sustainable land-use planning
• Execute SEA for southern Kalahari to revisit the way the area is being developed (including role of protected areas, key biodiversity areas, investment options and opportunities, eco-tourism opportunities)
• Demarcate mining areas
• Demarcate areas of jurisdiction of traditional authorities in relevant areas, e.g. Lesotho
• Build capacity of farmers and small miners in best practices
• Initiate detailed study on the potential impacts of climate change and development of mitigation measures
• Establish community-based natural resource management initiatives, based on best practice
• Establish best-practice guidelines for eradication of alien invasive species and rehabilitation
• Map invasive alien species across basin with consistent methodology
• Integrate eradication efforts across the basin to control common alien invasive species
• Explore alternative livelihood options, e.g. tourism, game ranching, veld product industries, community-based partnerships in eco-tourism
• Revive indigenous technical knowledge to help address, e.g. over-harvesting of veld products, management of natural resources
• Introduce appropriate conservation agricultural techniques, e.g., introducing rotational grazing systems, improving cattle health and meat yield, holistic farm management systems
• Evaluate degradation by informal mining and establish remedial measures
• Create awareness of potential new mines and mining areas for long-term land and water supply planning
• Enforce regulations for sustainable range and land management practices
• Create awareness and education on land management, including the youth
• Raise public awareness, especially among farmers and gardeners, on alien invasive species
• Initiate land rehabilitation projects of degraded lands and areas cleared of alien invasive species</td>
</tr>
<tr>
<td>Commercial agriculture</td>
<td>• Inappropriate agricultural practices
• Manipulation of land and water resources for cultivation of crops
• Overstocking and overgrazing
• Over-utilised pastures
• Invasion of areas by alien plants</td>
<td>• Agriculture on marginal lands
• Poor investment in agricultural infrastructure
• Poorly developed markets for livestock and crops
• Introduction of alien invasive species as fodder plants, wind breaks and crops
• Absentee landlords
• Poor land-use planning and management
• Regulations, where they exist, not enforced and policies not implemented
• Demand for products
• Political priorities
• Dual grazing rights</td>
</tr>
<tr>
<td rowspan="2">Mining</td>
<td rowspan="2">• Removal of ground to extract minerals
• Alluvial mining of river banks
• Poor rehabilitation practices, especially by informal mining practices</td>
<td rowspan="2">• Inherited defunct mining operations
• Inadequate compliance monitoring and enforcement
• Unregulated small-scale mining, especially of sand, gravel and calcrete
• Limited institutional capacity
• Little incentive for effective rehabilitation
• Lack of knowledge of rehabilitation practices
• Extractive industries are economically important</td>
</tr>
<tr>
<td rowspan="2">Medium term</td>
<td rowspan="2">• Follow through short-term interventions
• Foster community-based natural resource management initiative
• Continue study on the potential impacts of climate change and development of mitigation measures
• Develop alternative livelihood options based on studies
• Review punitive measures for breaking regulations and laws
• Review and update policies and legislation
• Invest in more infrastructure in the area</td>
</tr>
<tr>
<td rowspan="2">Cross-cutting</td>
<td rowspan="2">• Disturbance or degradation of areas
• Borrow-pits not rehabilitated
• Escape and introduction of alien invasive plants into surrounding areas</td>
<td rowspan="2">• Poor planning and rehabilitation practices
• Inadequate compliance monitoring and enforcement
• Ignorance
• Preferred use of alien invasive plants for firewood, timber, gardens and shade
• Limited availability of indigenous species
• Limited monitoring of alien invasive plants and fragmented eradication programmes
• Pioneering nature of invasive species and ease of dispersal especially along watercourses</td>
</tr>
<tr>
<td>Long term</td>
<td>• Follow through short- and medium-term interventions
• Increase protection of marginal lands (extensive agriculture, alternative land uses)
• Stringently enforce policies and laws</td>
</tr>
</table>

Figure 39: Causal chain analysis related to land degradation


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Erosion is a common feature of the riverine landscape in eastern areas of the basin.

associated mostly with agriculture and mining, have altered conditions of the land, affecting its interactions with water and having far-reaching consequences on the health and integrity of riparian and aquatic ecosystems. Not only is the land less productive with subsequent loss of livelihood opportunities, there are increased risks of changes in water quality and sediment loads during local flooding, groundwater recharge and invasion by alien plants.

The main sectors linked to the immediate causes of land degradation are agriculture (at commercial and subsistence levels) and mining. Cross-cutting causes relate to the disturbance and degradation of areas and spread of alien invasive species.

The problem is driven by a number of underlying factors:
- lack of integrated planning
- poor wider understanding of ecosystems
- misguided policies and interventions
- limited alternative livelihood options
- population pressures
- land tenure
- contradictory statutory and traditional rules
- poor rehabilitation practices in construction and mining industries.

Addressing the problem of land degradation requires greater integration of development sectors with water and environmental sectors to produce and promote sustainable policies, programmes and alternative livelihood options. Concurrent interventions are recommended to rehabilitate degraded lands, build skills and capacity by introducing community-based natural resource management programmes, and promote appropriate farming methods and best practices. There is also a need to integrate efforts across the basin to eradicate alien invasive plants.

4.5.3 Overview of basin-wide and national aspects

Land degradation is perceived as a high priority problem in Botswana and Lesotho. This pertains in particular to land that is under pressure from unsustainable farming practices, which are decreasing productivity and contributing to the degradation of wetland habitats. Symptoms (or effects) and causes of the problem are interlinked and include invasion of riparian and wetland habitats by alien plants, an extensive problem throughout the basin in disturbed and degraded areas, as well as bush encroachment, soil erosion and remobilisation of sand dunes. The problem is not only related to agriculture, but any activities that disturb and require clearing of land. These include construction, mining, crop cultivation (especially in fragile ecosystems) and where environmental management or rehabilitation plans are not implemented.

Key transboundary elements to this problem include:
- loss of land and infrastructure because of erosion
- decreased wetland storage potential
- reduced groundwater recharge
- reduced water quality in rivers and reservoirs
- increased abundance of alien invasive plants
- decreased potential for land productivity
- poor co-ordination and lack of integration between development, and the water and environmental sectors.

A conflict of interest between interventions aimed at poverty eradication and ecosystem health is a common issue in all four basin states, as well as issues around tenure systems and dual grazing rights. Well-meaning policies and programmes to improve livelihoods of subsistence farmers are very often centred around farming, without thought to environmental sustainability, especially on marginal lands. There is a need for the development of alternative livelihoods and improved land management practices.

Land degradation is of major concern in the Orange–Senqu basin area of *Botswana*. Current land-use practices here, especially in the area around the Kgalagadi Transfrontier Park, are not sustainable. The lands outside the park have become fragmented with fences impeding wildlife migration and are subject to frequent fires.

The large die-off of wildlife during the drought of the early 1980s and introduction of various policies and subsidies resulted in communities moving from a livelihood based on wildlife and hunter-gathering to livestock ownership. Communities have settled, often at pans, creating competition between livestock and natural wildlife populations and causing land degradation at these pans. Degradation is also a problem around cattle posts, which are associated with lowered groundwater levels and groundwater pollution.

Ephemeral pans can gather substantial quantities of rainwater in the summer months, but their shallow nature allows the water to evaporate rapidly as the season turns.

Agricultural policies and initiatives introduced to support this livelihood change are not necessarily suitable for this relatively low-rainfall and fragile area. Alternative livelihoods, such as those based on wildlife through tourism, game ranches, and integration of livestock and game, and sustainable industries around veld products, need to be examined and where appropriate, introduced.

There are large tracts of under- and unutilised lands in the southern Kalahari giving no returns, especially along the fence of the Kgalagadi Transfrontier Park. There are very few lodges in the area. Wildlife conflicts do occur along the park's borders and currently there are no benefits to communities in the area. Consideration should be given to adopting the Namibian conservancy programme to help improve livelihoods and conserve wildlife.

Sand and gravel mining along river courses, in particular the Nossob and Molopo, is an additional problem, as are areas excavated for construction purposes, for example around Werda.

In *Lesotho*, land degradation is largely attributed to unsustainable land management practices related to livestock rearing and over-harvesting of wetland resources. The importance placed on the number of cattle a person owns in Lesotho is identified as a root cause for degradation. However, poor land management and governance practices are thought to be more of a problem than overstocking. Overstocking is particularly severe in the lowlands, although erosion is more visible in the highlands, especially where animals are grazed in the wetlands.

Numbers of livestock are lower than they were ten years ago, but conditions around grazing permits are not observed. Since the late 1970s, jurisdiction over areas has changed. The alpine areas overseen by Principal Chiefs have become smaller, as a result of incoming local councillors. Boundaries of jurisdiction are unclear and respect for traditional laws and chiefs has been lost. In addition, traditional management practices, such as burning rangelands to promote new growth, are no longer appropriate management tools and relevant traditional knowledge around the management of natural resources is being lost. Community members, especially the youth and herders, need to be targeted to raise awareness on best land management practices, and laws and regulations.

Other issues include afforestation with inappropriate species, such as eucalyptus, and invasion of riparian, aquatic and rangeland habitats by alien species. Eradication of alien invasive vegetation needs more emphasis in all four basin states, especially along river courses and in disturbed areas.

This livestock exclusion plot gives an indication of the level of grazing on the Lesotho rangelands.

4.5.4 Potential points of intervention

Potential interventions are aimed at improving land management practices, identifying alternative livelihoods and rehabilitation of degraded areas through an integrated and participatory approach. It requires changes in policy, as well as practice.

4.6 DETERIORATION OF AQUATIC ECOSYSTEMS

4.6.1 Problem statement

Ecosystem functioning is impaired for virtually the entire Orange–Senqu River system. In most parts, the impacts are primarily related to the four main transboundary problems discussed above. These impact the aquatic ecosystems that are vital for maintaining the integrity and health of the system in the long term and the goods and services it provides, thus representing the crux of the problems.

Five broad aquatic ecosystems are threatened: highland sponges; pans and vleis; riparian belt; the estuary; and groundwater aquifers. Making provision for environmental flows; improving monitoring and land and water management practices; increasing awareness; enforcing regulation; and integrating these with current operational systems is likely to improve the condition of the river basin as a whole.

4.6.2 Overview of the causal chain analysis

The broad impacts and causes of degradation of the five ecosystems are summarised in the CCA in Figure 40. The CCA identifies five aquatic ecosystems and discusses causes and interventions around these, rather than sectors as in the other CCAs. Each aquatic ecosystem is vital in providing goods and services, directly and indirectly, and in maintaining the integrity of this valuable basin. Some of these impacts might be localised, such as those affecting specific pans or confined aquifers, whereas others will influence the whole system.

Highland sponges

At the river system's source there is an extensive network of high altitude wetland bogs and sponges, crucial in the hydrological cycle of the entire river. Their retention and slow release of water helps stabilise stream flow, attenuate floods, reduce sedimentation loads and absorb nutrients. The sponges and bogs are becoming degraded through overgrazing and overharvesting of resources, as well as the proliferation of ice rats. The steep terrain and harsh climatic conditions, particularly at high altitude, exacerbate the situation, creating a fragile ecosystem. Species diversity is declining and soil is exposed to wind and water erosion.

Pans and vleis

The sand and calcrete habitats of the Kalahari are dotted throughout by a number of small, closed basins or pans. These play an important role in the Kalahari, especially for wildlife. Their relatively high silt to clay content offers minerals and otherwise unobtainable soluble salts, as well as standing water following rain. Many pans have become ringed by sizeable human settlements making them less accessible to wildlife. Increased reliance on livestock for livelihoods has caused the area around the pans and livestock watering boreholes to become denuded and degraded and dunes have remobilised.

<table>
<tr><th colspan="7">PROBLEM: DEGRADATION OF AQUATIC ECOSYSTEMS</th></tr>
<tr><th colspan="2">Impacts</th><th rowspan="2">Habitat</th><th colspan="2">Causes</th><th rowspan="2">Points of intervention</th></tr>
<tr><th>Ecological</th><th>Socio-economic</th><th>Immediate</th><th>Underlying and root</th></tr>
<tr>
<td rowspan="5">• Disruption of hydrological functioning
• Less water in the system
• Reduced flushing
• Declining water quality
• Increased eutrophication and salinity
• Modified aquatic ecosystems and habitats
• Loss of biodiversity
• Loss of storage capacity
• Loss of flood attenuation capacity
• Loss of carbon storage capacity
• Increased erosion
• Collapse of river banks
• Increase in alien invasive vegetation
• Lowering of water table
• Prevalence of pest species</td>
<td rowspan="5">• Loss of ecosystem services
• Loss of aquatic and wetland resources
• Loss of water yield capacity and water assurity
• Loss of socio-economic opportunities
• Decreased fishery potential
• Aesthetic degradation
• Loss of global recognition and importance of certain habitats
• Loss of recreational value and tourism potential
• Increased cost of water supply
• Expensive interventions to address pests</td>
<td>Highland sponges</td>
<td>• Land degradation
• Erosion
• Overstocking and overgrazing
• Trampling by livestock
• Over-harvesting of wetland plant resources
• Encroachment of highly competitive pioneer species
• Increased population of ice rats
• Veld fires
• Construction of poorly planned roads and infrastructure</td>
<td>• Unsustainable rangeland management practices (see degradation CCA)
• Lack of alternative livelihoods
• Poor co-ordination between conservation and livelihood development agencies
• Fewer predators to control ice rat population
• Natural soil structure
• Increased human pressure
• Degraded tenure system
• Unbalanced trade-off between development imperatives and environmental costs
• Recommendations of EIAs not followed</td>
<td>• See points of intervention in CCA on land degradation
• See points of intervention in CCA on declining water quality regarding infrastructure development, environmental monitoring and enforcement issues
• Physical removal and effective monitoring of encroaching species
• Rehabilitation and restoration of wetlands
• Raise awareness on importance of wetlands
• Full inventory, mapping and categorising of wetlands regarding economic importance
• Clarification of roles and responsibilities in declaring protected areas</td>
</tr>
<tr>
<td>Pans and vleis</td>
<td>• Land degradation around wetlands
• Localised overstocking and overgrazing
• Increased water abstraction
• Seepage and runoff of manure
• Discharge of sewage and industrial pollutants into wetlands</td>
<td>• Increased settlement and developments around pans and vleis
• Livestock watering in immediate vicinity
• Poor farming practices
• Greater number of boreholes
• Limited monitoring
• Inappropriate poverty reduction policies
• Poor pollution control practices (see CCA on declining water quality)</td>
<td>• See points of intervention in CCA on land degradation
• See points of intervention in CCA on declining water quality</td>
</tr>
<tr>
<td>Riparian belt</td>
<td>• Barriers built across watercourses
• Reduced volumes and changed flow and sediment dynamics
• Changes in river morphology
• Alteration of river banks
• Acid mine drainage
• Sewage runoff
• Destruction of riparian vegetation
• Encroachment of highly competitive pioneer and alien species</td>
<td>• Need to store water
• High demand for water
• Development pressures and priorities
• Population growth and uneven population distribution
• Urban settlements and agriculture along rivers
• Disruption of flow by weirs and water storage facilities
• Mechanical control of riverbeds
• Inadequately addressed mining and industrial pollution
• Inadequate sewerage treatment
• Aging and poorly maintained infrastructure
• Poor agricultural practices
• Limited capacity
• Inadequate regulations, enforcement and monitoring</td>
<td>• See points of intervention in CCA on increasing demands on water
• See points of intervention in CCA on changes to hydrological regime
• See points of intervention in CCA on declining water quality
• See points of intervention in CCA on land degradation
• Implement basin-wide environmental flow requirements</td>
</tr>
<tr>
<td>Estuary</td>
<td>• Altered flow dynamics and reduced flood volumes
• Lower frequency of floods
• Infrequent flushing
• Concentration of salts and pollutants
• Mouth seldom closes
• Altered water and sediment properties
• Mining infrastructure
• Saline slimes dam seepage
• Wind-blown waste particles from mines
• Road embankments and other infrastructure developments</td>
<td>• See causes in CCA on changes in hydrological regime
• Lack of basin-wide environmental flow requirements
• Poor planning, impact mitigation and rehabilitation of mining operations in the immediate</td>
<td>• See points of intervention in CCA on changes to hydrological regime
• Implement basin-wide environmental flow requirements</td>
</tr>
<tr>
<td>Aquifers</td>
<td>• Increased salinity
• Seepage and contamination from cattle kraals and sewage
• Seepage and contamination from slimes dams and industrial pollution sources
• Lowering of water levels
• Reduction in recharge</td>
<td>• Over-abstraction of water
• Land degradation
• Increased alien invasive plant species
• Inadequate monitoring, regulation and protection of resources</td>
<td>• See points of intervention in CCA on increasing demands on water
• See points of intervention in CCA on land degradation
• See points of intervention in CCA on declining water quality
• Implement basin-wide environmental flow requirements</td>
</tr>
</table>

Figure 40: Causal chain analysis related to degradation of aquatic ecosystems


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Azolla filiculoides (red water fern) is one of the most problematic aquatic alien invasives in the system's waterways.

In the wetter grassland areas of the basin, a number of seasonal freshwater lakes, vleis and pans provide a number of goods and services within the system and form important areas for wetland birds and other species. Barberspan, Blesbokspruit and Seekoeivlei, for example, are declared Ramsar sites, i.e. wetlands of international importance. These and other such wetlands are threatened by pollution and degradation from mining, farming and industrial activities.

Riparian belt

Dams, weirs and canals, rural and urban settlements, agriculture and mining constructions dominate the riparian zone along the river and its main tributaries. Large demands on the water resources also mean that less water flows through the system and hydrological flows and sediment balance have been altered. Consequently, the morphology of the riverbed, banks and land alongside have been altered extensively and very little pristine riparian habitat remains. The riparian belt has become prone to invasion by alien species, which together with deforestation disrupts the hydrological cycle of the river.

Estuary

The Orange River mouth and estuary is a declared Ramsar site and is recognised to be of high importance. The area is shared by Namibia and South Africa and is an extensive area of freshwater lagoons, marshes, sand banks and reed beds


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Ephemeral pans and the vegetation surrounding them, which supported migratory lifestyles in the past, are under increasing pressure as permanent settlements become established and people become more dependent on livestock for their livelihoods.

important for resident and migrant waterbirds. There are large diamond mining operations and associated small towns on either side of it.

Apart from direct effects of activities in the area (encroaching tailings dams, pollution and road embankments), drastically reduced flows and an altered hydrological regime have further impacts on the estuary and the opening and closing of the mouth to the sea. In 1995 the estuary was added to the Montreux Record as a result of the collapse of the salt marsh, which once supported a large diversity of wildlife. Interventions to re-establish the salt marsh have been taken in recent years, but the site remains on the Montreux Record.

In practice, it will not be possible to reverse the flow modifications and anthropogenic developments to the extent that would improve the ecological category to the desired Category A or B. At best it is considered that Category C could be attained, but the first step would be to achieve and maintain a Category D state for the river mouth. Mitigation is very dependent on the flow patterns, particularly seasonality, and the removal of non-flow related impacts.

An extensive monitoring programme is required to improve the understanding of the ecology and flow regimes of the mouth and river. This will enable comprehensive ecological flow determinations on the Orange River and mouth, with a reasonable degree of confidence in the results.

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Monitoring programmes are required to improve the understanding of the ecology and how it is affected by flow regimes. This is necessary for setting comprehensive ecological flow requirements for the river and particularly for the mouth.

Aquifers

Although arguably not an ecosystem, these largely hidden resources deserve special mention. They cannot be regarded separately from the river system and aquatic ecosystems because they are linked, and degradation of one contributes to the degradation of the other. In addition, many rural areas of the basin and the drier western areas of the basin are almost wholly dependent on groundwater sources to meet their supply needs.

Although groundwater resources are limited in comparison to surface waters, the extent, quality and contribution, if any, that they could make to the water balance is not well understood. There are insufficient data regarding this hidden resource.

There is concern that in some areas abstraction is not sustainable and that it is impacting water levels. Lowering of groundwater levels hampers the ability of plants to take up water and leads to the desiccation of springs and, consequently, destruction of habitats. Salinisation due to increasing TDS, nitrates and fluorides is another concern. In extreme cases, over-abstraction can also reduce fluid pressure in confined and artesian aquifers and cause aquifer deformations through the compaction of geological material. Heavy metals can also leach out into the groundwater and find their way into surface water courses.

Groundwater sources are also highly susceptible to pollution from land-use activities through seepage and runoff, even in sparsely populated rural settings. Reversing pollution problems of groundwater is much more difficult than dealing with similar issues in surface sources.

In the region as a whole the transboundary implications of groundwater use are not particularly significant. A major factor, however, is that reduced flows in the lower Orange River will inevitably lead to a significant reduction in aquifer resources close to the river.

Improving understanding of groundwater sources through monitoring and implementing regulations around the abstraction and protection of groundwater resources would go a long way to addressing these concerns.

5. FINAL ANALYSIS AND RECOMMENDATIONS

This TDA consolidates information on the Orange–Senqu River basin, with a focus on its water resources and the problems affecting these. It analyses the factors that influence the health of its riparian, wetland and groundwater systems, and identifies and prioritises key transboundary issues. Potential interventions to address these issues have also been identified.

The transboundary problems and areas of intervention are synthesised below, providing a basis for the development of the long-term *Strategic Action Programme for the Orange–Senqu River Basin* (SAP) .

5.1 OVERALL SYNTHESIS OF TRANSBOUNDARY PROBLEMS

Four main transboundary environmental problems impacting on aquatic ecosystems in the Orange–Senqu River basin are described and analysed in Chapter Four. These can be summarised as:
- increasing demand on water resources
- changes to hydrological regime
- declining water quality
- land degradation.

The transboundary elements and underlying causes of these four problems and the sectors involved are summarised below. They cannot be regarded in isolation from each other, as the impact of one problem is very often the cause of another.

5.1.1 Transboundary elements

All four problems have elements that are transboundary in nature and spill over into the other basin states, affecting their riparian and wetland habitats and the amount and quality of water available for economic activities and social wellbeing. Each problem also has elements that are not necessarily transboundary, but are common to more than one basin state, while others might be purely national. Depending on the scope and extent of the common and national elements, they have the potential to become transboundary in nature if they remain unchecked.

Transboundary problems can have immediate or direct effects, such as pollutants on water quality. Other effects are less direct or not as immediate, such as the change in flow on habitats and the balance of ecosystems.

Common *direct* transboundary effects include:
- less water in the system
- reduced flows, reduced flushing
- altered pattern of flows
- increased contaminants, reduced water quality.

Common *indirect* transboundary effects include:
- increased abundance of alien invasive vegetation
- loss of species
- loss of wetland storage capacity
- degradation of aquatic ecosystems
- decreased land productivity
- reduced goods and services provided by ecosystems
- reduced economical potential.

Opposite: The Mohale Dam on the Senqunyane River is the second largest dam of the Lesotho Highlands Water Project, currently. It was built to augment South Africa's water supply and generate electricity for Lesotho. It is connected to the Katse Dam on the Malibamatso River via a 31-km transfer tunnel.

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Highly variable rainfall from one rain season to the next and from one area of the basin to another, necessitates the storage and transfer of water to assure supply when and where it is required.

5.1.2 Underlying causes

The immediate causes of the main transboundary problems are largely attributable to inappropriate resource uses and practices. Common underlying causes are attributable to related social and economic drivers. These include gaps in knowledge and awareness; limited financial and human capacity; inadequate coordination, integration and enforcement of compliance; and development priorities. Population pressure, climate change and a diversity of natural and economic drivers can also be considered root causes.

5.1.3 Sectors

While there are some cross-cutting causes of the main transboundary problems, many can be attributed to specific economic sectors:

- agriculture: irrigation and livestock, commercial and subsistence
- mining
- industry
- energy
- urban and domestic.

5.2 GOVERNANCE CHALLENGES

All four basin states – Botswana, Lesotho, Namibia and South Africa – are members of ORASECOM, which provides them with a forum for consultation and coordination for the sustainable management of the Orange–Senqu River basin's water resources. The basin states are committed to develop and manage the basin through an integrated approach for long-term economic and environmental sustainability.

Each of the basin states is party to a number of relevant international and regional protocols to do with water resource and environmental management. In addition, they have all adopted or are in the process of adopting an IWRM approach through the reform of their respective water sectors.

The basin states also share common challenges that hamper the implementation of IWRM to a greater or lesser degree:

- shortcomings in policy and legislation – outdated legislation, gaps with respect to different aspects of water resource management, translation of policies into laws, potential conflicts between policies from different sectors;
- insufficient intersectoral cooperation and coordination;
- insufficient integration and coordination between national-, regional- and local-level bodies;
- limited institutional capacity and inadequate financial resources;
- weak knowledge management.

5.3 THE WAY AHEAD: FRAMEWORK FOR A STRATEGIC ACTION PROGRAMME

The TDA provides the basis to develop strategic plans to address problems identified in the basin, as well as each of the basin states. The basin-wide Strategic Action Programme (SAP) and National Action Plans (NAPs) should identify and expand on agreed management responses to the environmental problems identified in this document.

The SAP is a negotiated basin-wide planning document, whereas the NAPs should respond to the specific circumstances and priorities of each basin state. The NAPs should provide a vehicle to integrate basin-wide plans with national priorities, policies, legal frameworks, development plans and budgets. They should preferably be in harmony with each other and feed into the SAP. The SAP should identify supporting activities, including but not limited to capacity building, strengthening basin-wide cooperation, coordination and knowledge.

The prioritisation of the transboundary problems was originally undertaken by a working group of experts and stakeholders during the preparation of the preliminary TDA and reconfirmed through a second process of stakeholder consultation. The geographical scope of the problems was taken into account during this process, as well as the severity of the impacts. The causes of the problem were not generally taken beyond the underlying causes, because it is rarely practicable to address root causes.

In identifying points of intervention to address in the SAP and NAPs, the scale of benefits that would result from solving the problem and the feasibility of finding solutions to the problem need to be taken into account. Other points to consider are:

- Attend to the immediate, obvious symptoms.
- Actions taken nearer to the root causes, i.e. the underlying causes are more likely to have a lasting impact than those that address immediate causes.
- Address, correct or eliminate the underlying cause.
- Where feasible, trace problems back to common underlying causes.

A number of potential points of intervention were identified during the consultation process, which are summarised below. It is recommended that these areas of intervention form the basis for the development of the SAP and NAPs. In addition, using lessons learnt and best practices from demonstration projects, such as those that piloted methods to improve irrigation efficiency, rangeland rehabilitation and livelihood diversification, should be adopted and rolled out to other areas in the basin where applicable.

5.3.1 Proposed areas of intervention

The objectives of the interventions should be to address the prioritised transboundary environmental issues and help support governance challenges. These objectives could be summarised as follows:

- improved basin-wide understanding of available resources;
- creation of additional yields of water in the system;
- improved quality of water resources;
- adverse effects of a changed hydrological regime mitigated;
- environmental degradation reversed and sustainability of land use improved;
- basin-wide IWRM facilitated.

Specific interventions and activities recommended to meet these strategic objectives are outlined below. Some actions are specific to certain problems or areas of the basin; others have the advantage of being cross-cutting by addressing more than one issue or targeting different places in the basin.

Objective 1: Improved basin-wide understanding of available resources

In order to manage and develop the resources in the basin, it is important to have a clear understanding of what is available, how this changes over time and what factors are important in maintaining a healthy system.

1. Improve the monitoring network systems and operation at both the basin-wide level and locally. Focus on strategic monitoring stations relevant for climate change and to serve other important objectives such as identifying biodiversity and pollution hotspots. Variables monitored at appropriate regular intervals should include rainfall, hydrology, groundwater levels, water quality, supply, biota and rangeland condition amongst others.

Water supply is just one of many variables that should be monitored and analysed on a regular basis in order to effectively manage the basin's water resources.

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The use of soil moisture censors for scheduling irrigation was tested in the Noordoewer–Vioolsdrift irrigation demonstration project. The application of such 'smart irrigation' methods will be adopted increasingly in the future in an attempt to make irrigation more efficient.

2. Enhance ORASECOM's Water Information System with new functionalities so that it provides a point for effectively collecting, collating and sharing data and information.
3. Provision should be made to ensure that data is regularly analysed, published and used to update models, and enhance understanding of available water resources and their sustainable use.

Objective 2: Creation of additional yields of water in the system

Increasing demand on water resources is a pressing problem in the basin. The perception is that there is little surplus water in the system. However, using water more efficiently and effectively, especially in the irrigation sector, and exploring alternative sources, will make more water available. This will help make provision for environmental flow requirements and to address water quality issues, both of which will improve the health of aquatic ecosystems.

1. Improve water use efficiency through efficient maintenance and refurbishment of existing water supply systems.
2. Manage demand by creating awareness and developing incentives in all sectors throughout the basin to conserve and protect water.
3. Improve efficiency in the irrigation sector to create additional yields for other uses. Lessons learnt and best practices from the Noordoewer–Vioolsdrift irrigation demonstration project should be scaled up to other irrigation areas. Appropriate incentives for irrigators to improve their water-use efficiency should be developed and implemented across the basin.
4. Develop Phase II of the Lesotho Highlands Water Project.
5. Explore the options to integrate and optimise the conjunctive use of surface water and groundwater resources.

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Understanding the quality of your water is as important as understanding yield in the management of your resources.

Objective 3: Improved quality of water resources

Declining water quality is perceived as one of the biggest threats to the basin's water resources. Acid mine drainage, inadequate sewage treatment and irrigation return flows are three areas that require interventions. Although many water quality issues are localised, they are common to all four basin states. Improved understanding of the sources, types and extent of water quality issues is required, and basin-wide water quality guidelines need to be provided.

Improving water quality will make more water available and enhance the overall health of the system.

1. Identify water quality hotspots in the basin and, with this in mind, strategically increase the basin-wide water quality monitoring network (see Objective 1 above).
2. Develop basin-wide water quality guidelines.
3. Develop tools and incentives to improve the quality of irrigation return flows.
4. Innovative solutions for both the large- and small-scale treatment of sewage and other wastewater should be identified and piloted at various sites in the basin.
5. Develop and implement a sustainable solution to address acid mine drainage to protect the resources of the system.

Objective 4: Adverse effects of a changed hydrological regime mitigated

Decreased water in the system and the reduced size and frequency and timing of floods in the river system have had a deleterious effect on the functioning of the basin's riparian and estuarine ecosystems. The estuary (a Ramsar site) has also been affected by various developments and activities in the immediate vicinity. A number of environmental flow requirements studies have been carried out in different areas of the basin, each with valid yet not necessarily integrated recommendations. To address this:

1. Collate and synchronise the recommendations of existing environmental flow requirements studies to develop and implement basin-wide flow scenarios.
2. Implement a management plan for the Orange River mouth in a coordinated and integrated way to:
   - remove anthropogenic structures in the floodplain and at the mouth;
   - align fishing legislation and compliance in South Africa and Namibia; and
   - verify and address the origin of elevated nutrients in estuary.

Objective 5: Environmental degradation reversed and sustainability of land use improved

Land degradation affects people's livelihoods, as well as the dynamics and quality of water in the basin. The effects of degradation on rangelands at the headwaters of the Orange–Senqu are of particular concern, as is degradation around pans in southern Botswana and invasion of the riparian zone by invasive alien plants. Addressing these areas of degradation will make the land more productive as well as improve water quality, hydrological functioning and water yields. Interventions should:

1. Build on lessons learnt in the Lesotho rangelands demonstration project regarding catchment rehabilitation and protection and roll out on a larger scale.
2. Develop appropriate rehabilitation methods and technologies for areas that are significantly degraded.
3. Introduce more sustainable livelihood options.
4. Develop and establish local-level monitoring systems for rangeland condition.
5. Use best practices developed in South Africa to implement basin-wide management of alien invasive plants with a special focus on the ephemeral river courses of Namibia and Botswana.

Objective 6: Basin-wide integrated water resources management facilitated

Supporting activities should be carried out to facilitate the development, adoption and implementation of basin-wide monitoring, standards and practices; build capacity of water resource practitioners; facilitate the implementation of transboundary environmental assessments; and strengthen regional legal and financing mechanisms.

It is recommended that the actions in these six areas of intervention should be further defined, prioritised and detailed during the development of the NAPs and SAP. More detailed information should be sought from specialists, experts and practitioners in each of the basin states to ensure the NAPs and SAP are honed to support and complement national priorities, plans and activities. These planning documents should build on local knowledge, expertise and experience. Furthermore, they should facilitate the sharing and coordinated adoption of best practices across the basin.

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The removal of anthropogenic structures, such as the causeway, at the Orange River mouth, is one of the recommendations for rehabilitating the estuary.

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Land degradation and erosion are the underlying causes of more than one transboundary problem. Addressing them will help alleviate these problems and make the land more productive.

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Sharing information and building the capacity of water resource practitioners will help support and facilitate an integrated approach to the management of the basin's water resources.

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GLOSSARY

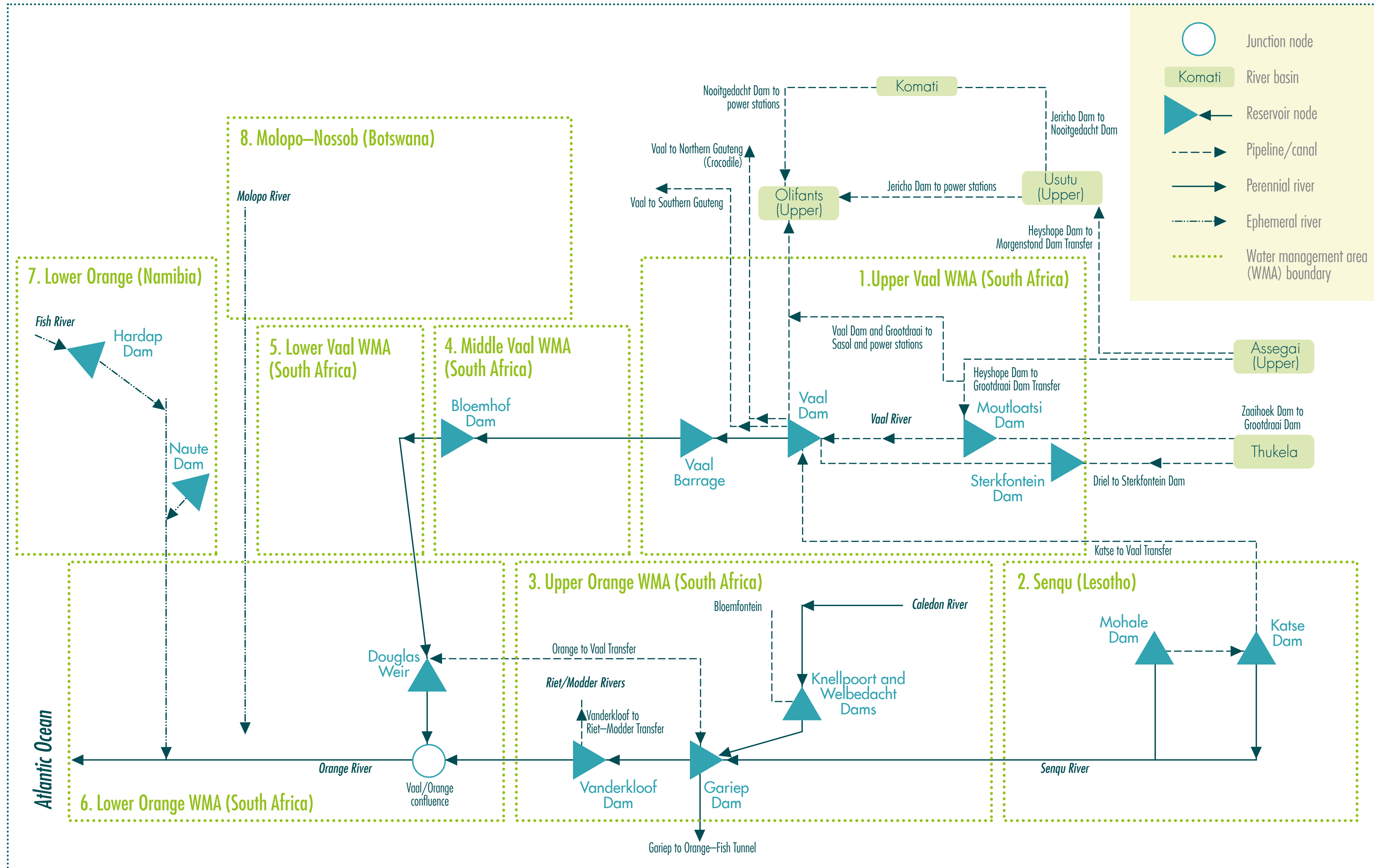
alien invasive plant	A plant that has been introduced from another geographical location and establishes itself, grows and propagates; they usually have adverse economic, environmental, and/or ecological effects on the habitats they invade and the indigenous vegetation found there
aquifer	A geological formation that holds groundwater
assurance of supply	The amount of water that can be supplied with statistical certainty
basin	Area of common drainage; often including groundwater sources as well as surface waters
biodiversity hotspot	An area with a high number of species
biome	A region that has similar characteristics of climate and other physical conditions which supports a typical array of fauna and flora that show adaptations to these conditions
catchment	The area from which rainfall flows into a river
causal chain analysis	A series of statements linking the effects (impacts) of a problem with its causes
climate change	A significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years
common (or shared) issue	An environmental problem that exists in two or more basin states, but is not transboundary in nature
dam	A barrier or structure across a river to confine and control the flow of water
demand management	Reducing the amount of water that is required through pricing, regulation, incentives and increased awareness on the value of water
ecological impact	The effects of a problem on the integrity of an ecosystem
ecosystem	A natural unit of physical and living parts that interact to produce a stable system
emission scenarios	The Intergovernmental Panel on Climate Change (IPCC) published a Special Report on Emissions Scenarios (SRES) in 2000. The greenhouse gas emissions scenarios described in the report have been used to make projections of possible future climate change. The emission scenarios, or SRES scenarios as they are often called, were used in the IPCC Third Assessment Report in 2001 and in the IPCC Fourth Assessment Report in 2007. The A1B scenario is characterised by rapid economic growth and a convergent world, with respect to income and a way of life with extensive social and cultural interactions worldwide. It assumes the spread of efficient technologies with a balanced emphasis on energy sources (fossil and non-fossil fuels)
endemic	A plant or animal that is only found in a particular region
environmental flow	This describes the quantity, timing and quality of water flow required to sustain freshwater and estuarine ecosystems and the human livelihoods and wellbeing that depend on these (Hirji and Davis, 2009)
environmental impact	The effect of a problem on the integrity of an ecosystem
estuary	A transition zone between river and sea environments that is subject to and dependent on both marine influences, such as tides, waves, and the influx of saline water, and riverine influences such as flows of fresh water and sediment

fluvial morphology	The features of a watercourse, such as its profile – longitudinal and cross-section – alignment, bed form, bed slope and sediment budget, as well as the geomorphic processes that shape its channel
geoaccumulation index	An index calculated in order to determine and define metal contamination in sediments, by comparing current concentrations with pre-industrial levels
hydrophilous	Growing in water
intersectoral	Involving a number of economic and/or social sectors
laser levelling	Levelling or smoothing a field within a certain degree of desired slope using a guided laser beam
Montreux Record	The Montreux Record is a register of wetland sites on the List of Wetlands of International Importance where changes in ecological character have occurred, are occurring, or are likely to occur as a result of technological developments, pollution or other human interference. It is maintained as part of the Ramsar List
National Action Plan	Planning document containing agreed management responses to address problems identified in the TDA at a national level
national issue	A priority environmental problem of one basin country that is not caused, nor affects any other basin country
pH	A logarithmic scale for expressing acidity/alkalinity of water
Ramsar site	Wetlands of international importance, designated under the Ramsar Convention, which is an international agreement signed in Ramsar, Iran, in 1971 that provides for the conservation and good use of wetlands
reservoir	A body of water collected and stored in an artificial lake behind a dam
socio-economic impact	Changes in the welfare of people and society, attributable to the problem or its environmental impact
Strategic Action Programme	Planning document that contains agreed basin-wide management responses to address transboundary problems identified in the Transboundary Diagnostic Analysis
sub-basin	A geographical drainage basin that feeds into a larger basin
transboundary	Transcends the boundaries of any one country, thereby affecting another
Transboundary Diagnostic Analysis	An analytical document that forms the scientific-technical baseline for strategic basin-wide planning
transboundary issue	An environmental problem originating in one basin country (or more) and affecting another (or more); the impact of such a problem might damage the natural environment or human welfare
water productivity	A measure of the economic, livelihood or biophysical outputs derived from the use of a unit of water such as brick making, crop production, livestock watering, mining, etc.
well field	Area containing one or more boreholes or wells that produce usable amounts of water
wiki	A website for collaborative use by a community of contributors, allowing each to add and edit content

INFRASTRUCTURE OF THE ORANGE–SENQU RIVER BASIN

The Orange–Senqu provides the water required to drive the most economically active area in southern Africa, supports large-scale irrigation and meets the domestic needs of 19 million people. Water supply required to meet these needs has been assured through the construction of numerous dams and a series of transfer schemes. An overview and summary of the main infrastructure in the basin is shown in the schematic diagram (left).

A comprehensive catalogue and reference to the infrastructure on the Orange–Senqu and how these are used to manage the surface waters of the basin to meet human demands can be found at http://wis.orasecom.org/content/study/UNDP-GEF/general/Documents/Techincal%20Reports/TR21_InfrastructureCatalogue_LowRes_Ed2_10Oct2013.pdf



Clockwise from top left: Hardap Dam (UNOPS/L Marinovich); Naute Dam (UNOPS/C Mor); Vaalharts irrigation canal (UNOPS/L Marinovich); Gauteng purification works (UNOPS/G Marinovich); Ash River outfall (SA Tourism); Boegoeberg Dam (Wollie Burger); Gauteng wastewater works (UNOPS/G Marinovich); Katse Dam (Daleen Loest/Shutterstock); Mohale Dam (S Crerar); Knellpoort Dam (UNOPS/L Marinovich); Vaal Dam (Zootar/Dreamstime); Vanderkloof Dam (S Crerar); Gariep Dam (Hendrik van den Berg/Panoramio); Sterkfontein Dam (tomKli/Shutterstock); and a streamflow gauge on the Orange River (UNOPS/C Mor).

The Orange–Senqu River Commission (ORASECOM) was established in 2000 by the governments of Botswana, Lesotho, Namibia and South Africa, which share the water resources of the Orange–Senqu River Basin. The Commission provides a forum for consultation, sharing information and cooperation between the countries. For more information on ORASECOM, visit http://www.orasecom.org/

The Orange–Senqu Strategic Action Programme is a four-year project working in close collaboration with ORASECOM. It assists the basin states in identifying threats to the water resources of the Orange–Senqu and in developing a basin-wide plan to address these. The objective of implementing such initiatives contributes towards ORASECOM's programmes and the long-term goal of sustainable development of the Orange–Senqu River basin. The project is implementing a Transboundary Diagnostic Analysis and Strategic Action Programme process to meet this objective, while concurrently implementing a number of projects and activities to help strengthen ORASECOM, fill knowledge gaps, and raise awareness and encourage participation of the public.

The project is funded by the Global Environment Facility (GEF) through the United Nations Development Programme (UNDP) and is executed by the United Nations Office for Project Services (UNOPS).

For more information on the project, visit http://undp.orasecom.org/