ORANGE - SENQU RIVER COMMISION
BOTSWANA LESOTHO
ORASECOM
NAMIBIA SOUTH AFRICA
Established 2000

THE STATE OF THE ORANGE-SENQU RIVER SYSTEM

SETTING THE BASELINE WATER RESOURCES QUALITY IN 2010

2010

ORASECOM

THE ORANGE-SENQU RIVER COMMISSION

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BOTSWANA LESOTHO

ORASECOM

NAMIBIA SOUTH AFRICA

Established 2000

A report on

ORASECOM's

First Joint Basin Survey

JBS-1

October and November 2010

SURVEY UNDERTAKEN WITH SUPPORT FROM:

THE ORANGE-SENQU RIVER SYSTEM

OBTAINABLE FROM

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Compiled by G Quibell and JN Rossouw for the Orange-Senqu River Basin Commission, Pretoria, South Africa

As part of the:

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Case of the Orange-Senqu River in Botswana,
Lesotho, Namibia and South Africa
Global Financial Commitment No. 9 ACPRPR 53

Southern African Development Community
Water Sector Support Unit - Gaborone
European Development Fund

PREFACE

*"One river,
four nations"*

Water, especially in southern Africa, is one of our most precious resources. Water is not only becoming increasingly limited as populations grow, but rainfall is highly variable and unevenly spread across the region. Frequent droughts, often broken by severe flooding, have affected lives, slowed economic growth and pose significant challenges for our water managers. Climate change promises to intensify these challenges.

These water management challenges are even more complex when water crosses borders. In these cases water managers in different countries need to work together to share and protect water resources and realise benefits for all. We need increasingly close cooperation if we are to continue to sustain vibrant and growing economies, address poverty, realise the Millennium Development Goals and protect shared aquatic ecosystems.

The Southern African Development Community (SADC) has lead the way by providing a framework for countries sharing river systems to come together to address these challenges. The Orange-Senqu River Commission (ORASECOM) was established under this framework, and was one of the first Shared Watercourse Institutions to be established under SADC's Revised Protocol on Shared Watercourses.

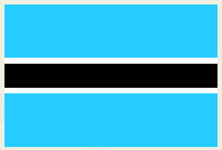
The ORASECOM Agreement was signed by Botswana, Lesotho, Namibia and South Africa on 2 November 2000. These four countries share the waters of the Orange-Senqu System,and this Agreement tasked us with advising these countries on the development, use and conservation of the water resources of the shared river system.

To do this ORASECOM has focussed its attention on building a common understanding of the River System, studying the factors impacting on it and on developing the tools that will help us develop a Basin Wide Plan to address issues of concern for all four countries.

The first Joint Basin Survey (JBS-1), undertaken during the last quarter of 2010, continued this spirit of cooperation and was the first survey of the state of the whole Orange-Senqu River System. This survey further contributed to our common understanding of the river system, and represented an important milestone in ORASECOM's development.

This book represents our on-going commitment to openness and transparency between the Parties, but also towards all the people of the basin. It presents the results of the JBS-1 in an easily understandable form, highlighting the "state" of the water resources and aquatic ecosystems of the shared watercourse.

Mr V. Bagopi
Head of Delegation
Botswana



Mr K. Tau
Head of Delegation
Lesotho

Ms A. Shiweda
Head of Delegation
Namibia

Ms D. Twayi
Head of Delegation
South Africa

FOREWORD

"We all live downstream"

2010

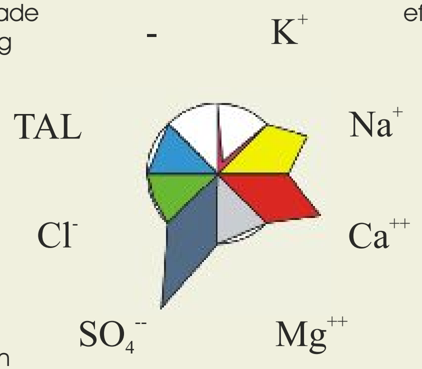
One of the most important lessons coming out of the global debate on sustainable development has been the recognition that we are all linked together through ecosystem processes.

This concept is close to the heart of the Orange-Senqu River Commission. The ORASECOM Agreement, as well as the Revised SADC Protocol on Shared Watercourses, require all four countries sharing the basin to jointly protect and conserve the environment of the shared watercourse.

The cornerstone of this task must be a scientifically sound and common understanding of the state of the river system, as well as the factors that affect the quality of its waters and ecosystems. ORASECOM has already made considerable progress towards establishing common methods for monitoring and managing the shared waters and to share and build trust in the data from each country.

These procedures were tested in our first Joint Basin Survey. This survey determined of the state of the system as it was in 2010, and set the baseline conditions against which we can measure progress towards our common goals. This marked the first joint survey of the whole river system, and probably the first such comprehensive survey of such a large river system anywhere in Africa. We hope to be able to repeat this every 5 years, monitoring the implementation of the Basin Wide Plan.

Fish populations provide a wealth of information on the state of river systems.



The chemical composition of the water tells us what is affecting water qualtity.

Small insects found in the river show a healthy system.

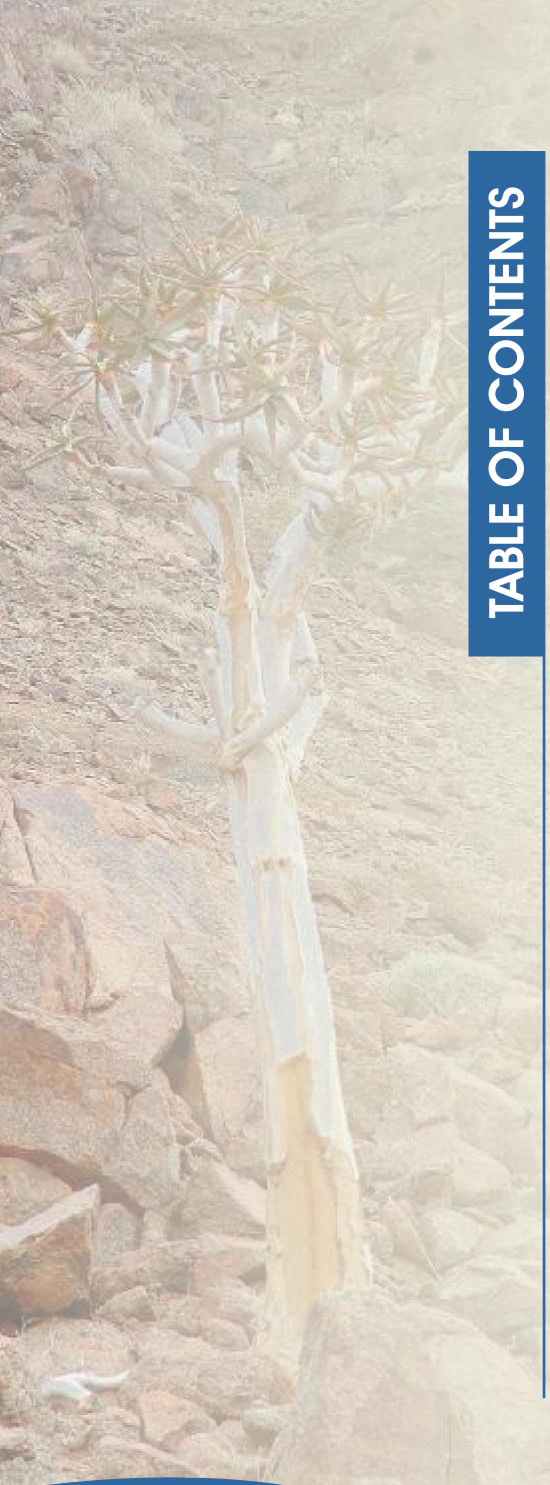
Importantly, this survey was "joint" not only in that it is being actively supported by all four countries, but also by all the major donor support programmes. The European Union, Germany, the United Kingdom and the UNDP- Global Environment Facility are all gratefully acknowledged for their contributions to this event. Similarly, the Lesotho Highlands Development Authority is thanked for the data provided through their monitoring programmes. We have also drawn on data available from South Africa's Water Information System, particularly to compare our results with long term trends in the system.

Perhaps most importantly, the success of this survey was also largely attributed to contributions of the specialist staff from all four countries who participated in the planning and execution of the survey, and who contributed to the sampling effort and robust scientific discussions.

However, an event like the JBS-1 relies on the efforts of a great many people, and I would like to extend my appreciation to all who have contributed. This summary of the "State of the Water Resources of the Orange-Senqu River System" is largely thanks to their efforts.

Lenka Thamae
Executive Secretary
ORASECOM: Secretariat

THE JOINT BASIN SURVEY PLANNING TEAM



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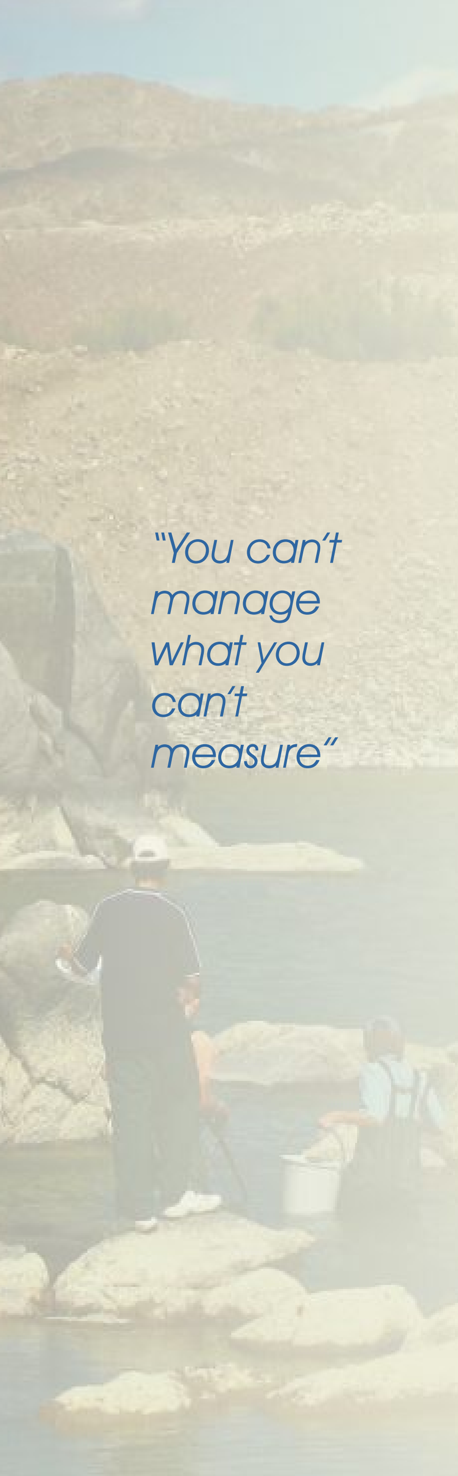


"You can't manage what you can't measure"

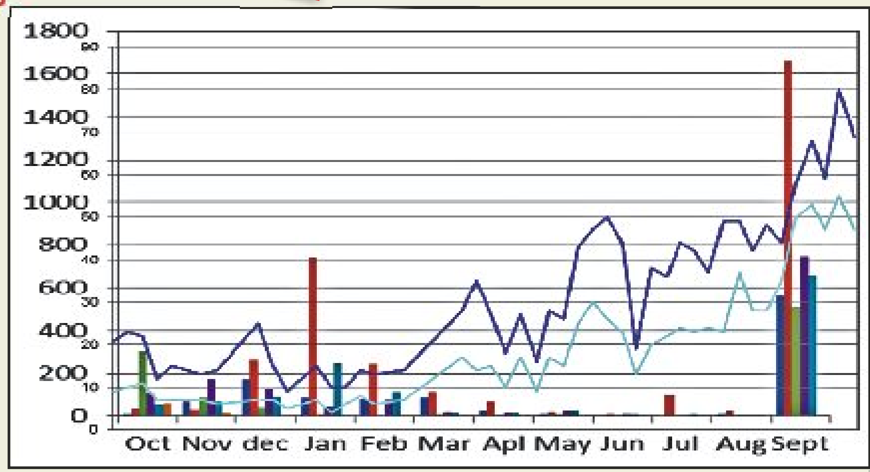
INTRODUCTION

Effective management of water resources requires an understanding of the state or 'health' of river ecosystems and the factors that impact on these ecosystems. ORASECOM has already made significant progress towards this goal, identifying water quantity and quality concerns across the basin. Specialist studies have also identified some of the underlying causes of degrading water quality and ecosystems.

Work on building this understanding of the system is continuing. However, monitoring and reporting is complicated because the rivers cross borders. While there is a great deal of data and information available on the Orange-Senqu River System; to date this information has been scattered both in time and geographically between the four countries. Different methods of collecting and processing the data also make direct comparisons problematic.

It has therefore been difficult to establish the baseline water resources quality for the whole system. We need common methodologies for measuring and processing the data, so that information from each of the countries can be directly compared.

The ORASECOM Agreement, therefore, requires the development of standard methods of collecting and presenting data on the state of the shared watercourse. We have already agreed on common methods of assessing Aquatic Ecosystem Health, and have developed a Transboundary Water Quality Monitoring Programme to supplement the monitoring undertaken by each of the Parties.



The Joint Basin Survey was launched not only to provide a snapshot of the quality of the water resources of the basin but also allowed us to test these Monitoring Programmes - providing the baseline against which future improvements could be measured.

JBS-1 was the first joint monitoring of the Orange-Senqu basin supported by all the Parties. This publication provides a brief overview of the results of survey - in lay person's terms. It is aimed at the people of the basin, who ultimately have the biggest stake in the quality of the water resources.

More detailed scientific reports on the various elements of the survey are available from the ORASECOM Secretariat and the ORASECOM website (**www.orasecom.org**).


Windhoek
Mariental
NAMIBIA
Keetmarshoop
Molopo
Kuruman
Johannesburg
Parys
Klerksdorp
Schweizer-Reneke
Taung
Harts
Bethlehem
Upington
Augrabies
Orange
Kimberley
Douglas
Vaal
Bloemfontein
Thaba Nchu
Caledon
Pofadder
REPUBLIC OF SOUTH AFRICA
Riet
Prieska
LESOTHO
Grootvloer Pan
Aliwal-North

AN OVERVIEW OF THE ORANGE-SENQU BASIN

The Orange-Senqu River System

The Orange-Senqu River originates in the Lesotho Highlands at an altitude of more than 2750m, from where it flows 2500 kilometres westwards to its mouth at Alexander Bay/ Oranjemund on the Atlantic West Coast of Africa. The river basin is the third largest in southern Africa, after the Zambezi and the Congo, covering an area of 1,000,000 km^2, most of which lies inside the Republic of South Africa. The basin is home to just over 14 million people; however many people living outside the basin are also dependent on its waters.

Key facts for the Orange-Senqu River System

	Botswana	Lesotho	Namibia	South Africa
% of the polulation of the basin	0.3	15.4	2.6	81.7
% of the land area of the basin	7.9	3.4	24.5	64.5
Average rainfall mm/a	295	755	185	365
% of the natural runoff	0.3	41.5-46	5.2	49-53
% of the total water use	Negigible	<0.37	1.4	98

Usutu Basins shared with Swaziland and Mozambique. The Orange-Senqu System therefore has a much larger regional impact, affecting a significant portion of southern Africa.

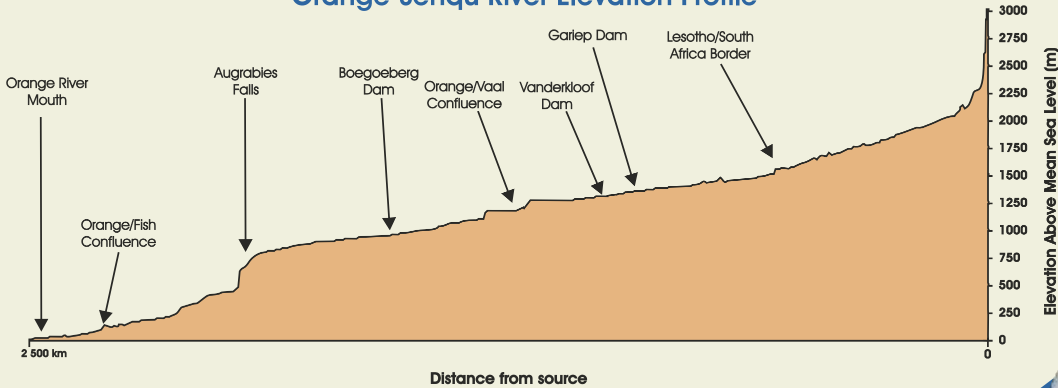
The part of the Basin in Botswana lies in the Kalahari Desert with very little surface runoff, but underground water contributes to the water demands in this portion of the basin. The Kalahari Groundwater basin is shared between Namibia, Botswana and South Africa. Groundwater resources are also shared between Lesotho and South Africa.

Lesotho, the most upstream country, falls entirely within the basin and contributes over 41% of the total flow in the rivers from only 3.4% of the total basin area, but Lesotho is one of the smallest users of water from the basin. The Senqu River in Lesotho, changes its name to the Orange River when it flows into South Africa. The Vaal River flowing through South Africa's industrial heartland and the Fish River in Namibia are two major tributaries to the Orange River.

The water requirements in the lower reaches of the river are driven primarily by irrigation demands from both Namibia and South Africa, as well as the need to maintain environmental flows to the estuary. The middle and lower reaches of the river are subject to periodic and often devastating floods. The Orange River estuary is ranked as one of the most important wetland systems in southern Africa. Altered freshwater inflows have resulted in environmental degradation of this important Ramsar[1] site.

South Africa is by far the biggest user of water from the System, and this drives the economy of South Africa. Some of the Orange-Senqu water supplied to South Africa's Gauteng Province as well as to some towns in North West Province is discharged as waste water in to the Limpopo Basin, shared with Botswana, Zimbabwe and Mozambique. Water is also transferred into the basin from the Inkomati and

Orange-Senqu River Elevation Profile



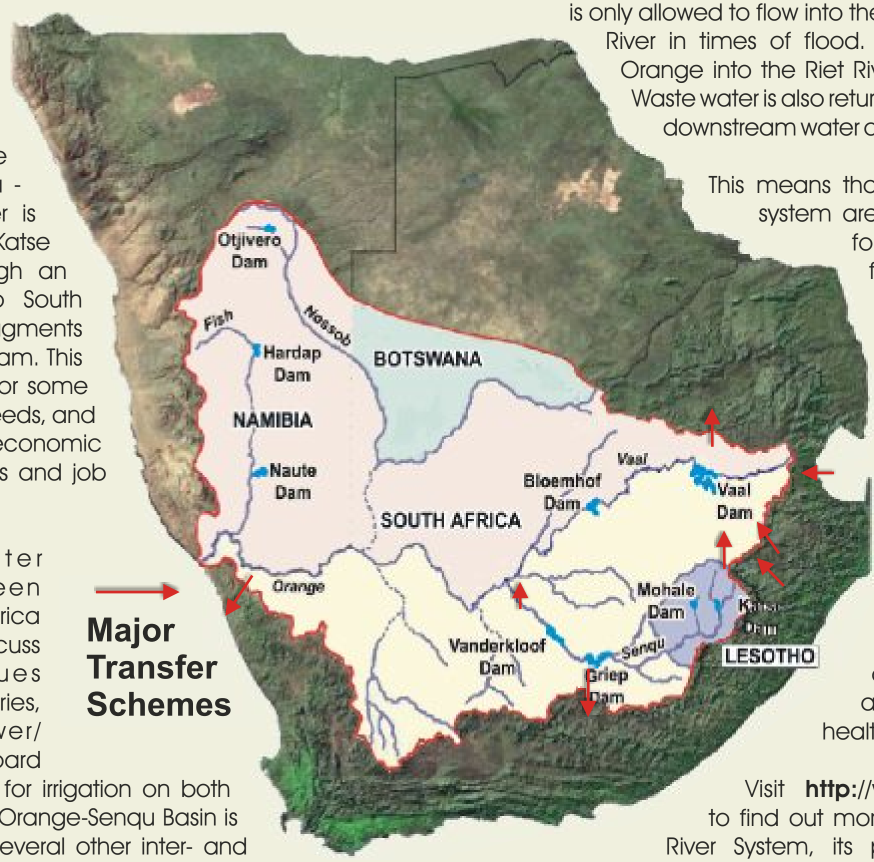
[1]Ramsar = Convention on Wetlands of International Importance.

Managing water supply in the System

ORASECOM was not the first transboundary water management arrangement in the Orange-Senqu Basin. As early as the mid 1970's the need to find water for the rapidly growing Gauteng Region of South Africa and for irrigation from the lower Orange Riverprompted agreements between South Africa and its neighbours. These agreements still dominate water management in the basin.

The Lesotho Highlands Water Project was established primarily to meet growing water demands in the Johannesburg - Pretoria - Rustenburg area. Water is transferred from the Katse Dam in Lesotho through an underground tunnel to South Africa, from where it augments the supply to the Vaal Dam. This scheme also provides for some of Lesotho's electricity needs, and contributes to Lesotho's economic growth through Royalties and job creation.

A Permanent Water Commission between Namibia and South Africa meets regularly to discuss water related issues between these countries, and the Noordoewer/ Vioolsdrift Irrigation board manages water supply for irrigation on both sides of the border. The Orange-Senqu Basin is also characterised by several other inter- and intra- basin transfers. Transferring water around the basin to maintain reliable water supply for coal fired power stations and irrigation users. Water is also transferred out of the basin at Gariep Dam for South Africa's Eastern Cape Province, and out of the lower Orange to provide water to towns in the Northern Cape Province.



Major Transfer Schemes

Because it is so expensive to transfer water around the basin, the Orange-Senqu River System is operated to minimise these operational costs and to maximise water availability. For this reason, the Vaal River is operated as a closed system, and water is only allowed to flow into the Orange River from the Vaal River in times of flood. Similarly, transfers from the Orange into the Riet River are kept at a minimum. Waste water is also returned to the rivers to help meet downstream water demands.

This means that all the main rivers of the system are affected by development for virtually their entire length. To further complicate things there are many large dams in the system. These features make the Orange-Senqu River system one of the most complex and regulated in the world.

As we will see later in this book, this regulation of the whole system, as well as the intensive reuse of water by discharging effluent back to the system has affected the water quality and aquatic ecosystem health of the entire system.

Visit **http://www.orangesenqurak.com** to find out more about the Orange-Senqu River System, its people, history and water resources management.

LARGE DAMS IN THE ORANGE-SENQU SYSTEM

PLANNING THE JOINT BASIN SURVEY-1

ORASECOM started planning the first Joint Basin Survey in June 2009, after a visit to the International Commission for the Protection of the Danube River (ICPDR). The ICPDR has already conducted two "Joint Danube Surveys", and discussions with them provided the seed of an idea to undertake a similar survey of the Orange-Senqu system.

The survey manual

A number of separate studies and surveys were already being planned as part of ORASECOM's ongoing programme of work. As there was added value in combining these efforts, and because other elements - like public outreach - could be added, we decided to plan a single Joint Basin Survey for the whole Orange-Senqu River System.

Identifying sampling sites and sampling routes

Detailed planning for the first Joint Basin Survey began in early 2010, with the establishment of a planning team made up of specialists from each of the member countries and the Secretariat, supported by the various donor support programmes. Building on ORASECOM's close ties with the ICPDR, the planning team also included the water quality and monitoring specialist from the ICPDR Secretariat. This team planned the sampling logistics; deciding on where to sample, what would be sampled, and how the samples would be handled and analysed.

Ultimately, this team decided on over 60 sampling sites scattered throughout the whole Orange-Senqu River System - from the uppermost reaches of the Vaal, Wilge and Senqu Rivers to the most downstream site at Rosh Pinah only 100km from the river mouth.

Most of the sampling was undertaken in October and November 2010, but this was supplemented from other recent surveys and sampling exercises as well as by data from the Lesotho Highlands Development Authority (LHDA). Data was also collected from some water treatment plants and from South Africa's Water Information System.

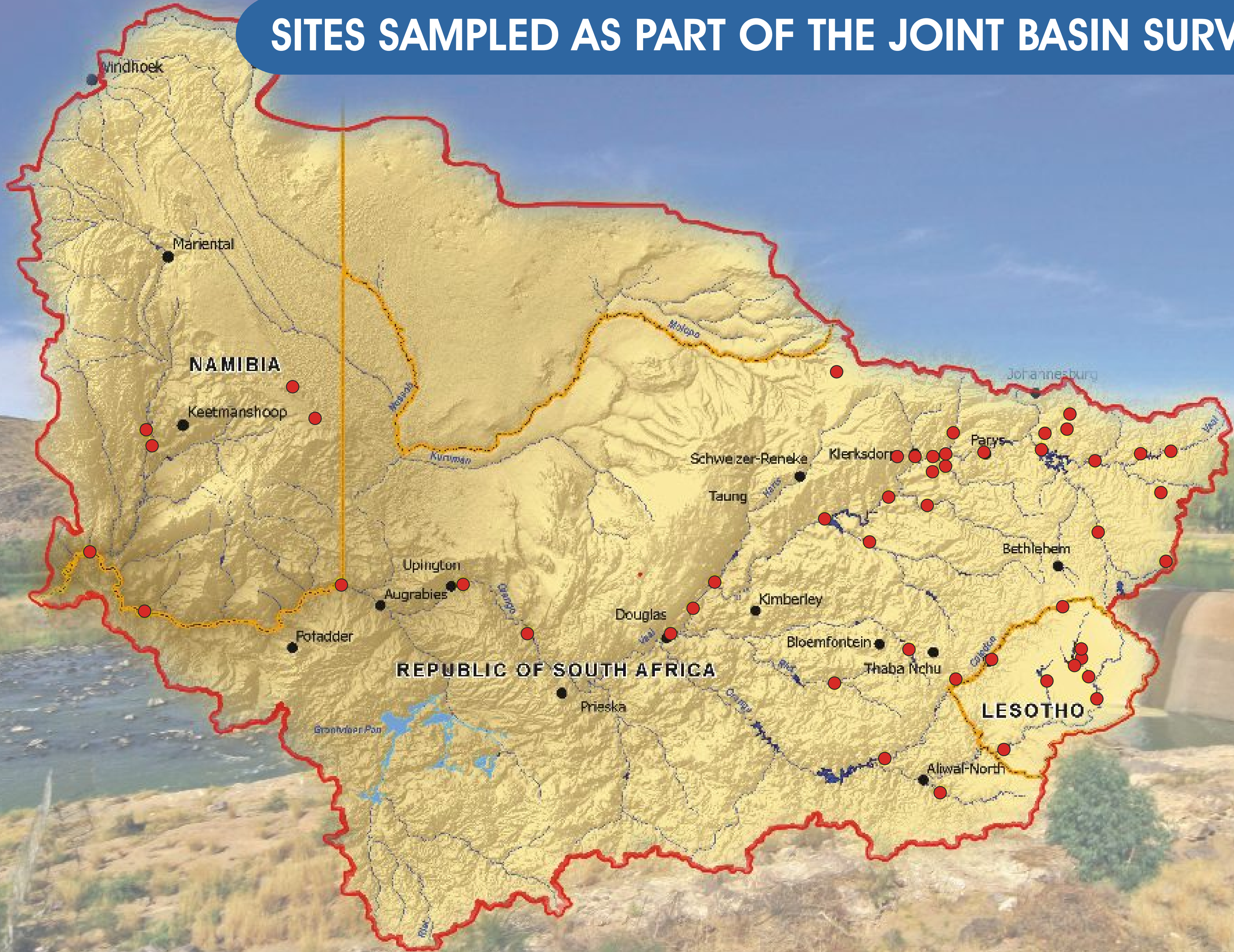
The survey was constructed around four elements:

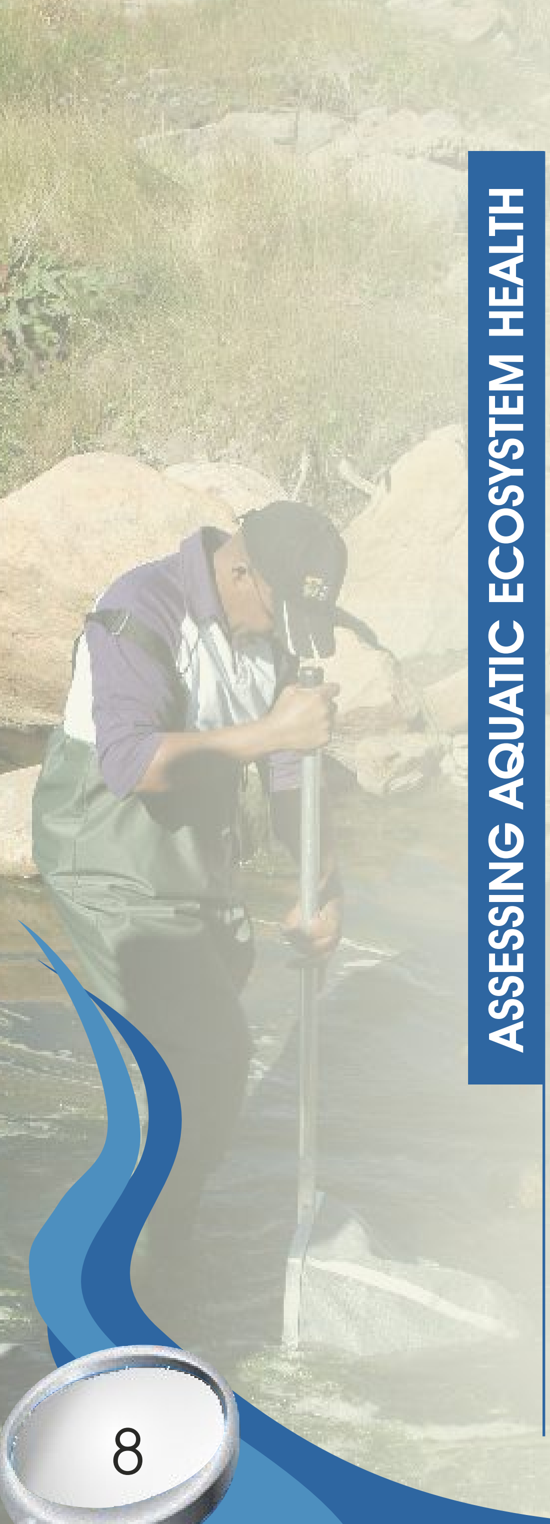
- Aquatic ecosystem health surveys - to assess the state of aquatic ecosystems based on macro-invertebrates, fish, diatoms and habitat.
- Water and sediment chemistry - to determine the concentrations of key pollutants in the water and sediments.
- Biological water quality - to determine plant nutrient concentrations and bacteriological pollution.
- A public participation and outreach programme - to involve the public and schools in the survey.

The rest of this book provides a summary of the results of each of these components.

A separate investigation of the participating laboratories was also done using standard concentration samples from the South African Bureau of Standards, which helped ensure that the results were reliable and accurate.

SITES SAMPLED AS PART OF THE JOINT BASIN SURVEY -1





ASSESSING AQUATIC ECOSYSTEM HEALTH

Why do we measure aquatic ecosystem health?

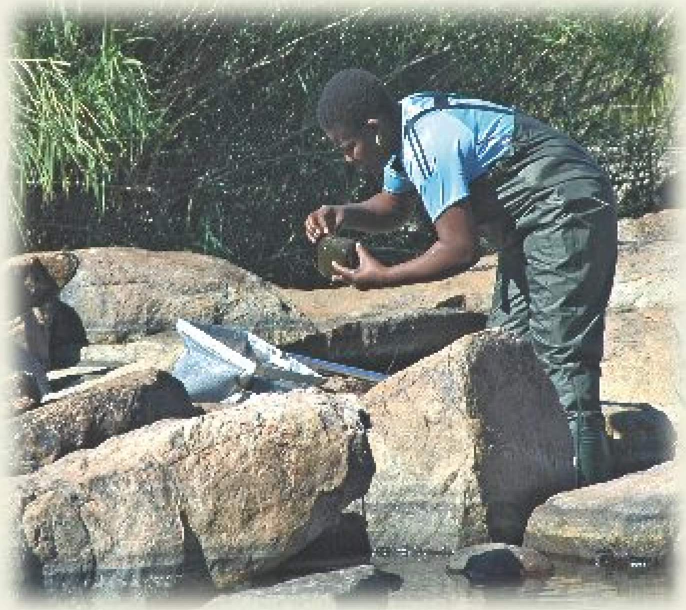
River ecosystems provide a range of 'goods and services', like self-cleaning processes, recreational fishing and cultural values. The sustainable use of rivers depends on maintaining these 'goods and services'. Possibly the least appreciated, but in the long term perhaps the most important of these ecosystem services, is "resilience to a changing world".

Ecosystems have the capacity to absorb change and recover from damage. When an ecological system loses this resilience it becomes vulnerable. For example, if climate change raises the average temperature, several species may die out, but in a healthy system, there will be new ones which take over their role in the ecosystem. 'Unhealthy' ecosystems lose this resilience making us more vulnerable to change. Assessing the 'health' of aquatic ecosystems is therefore vital to managing the water resource. This is done by assessments of the numbers and types of aquatic organisms found at any site.

However, aquatic organisms also respond to the habitat available. If, for example, certain species require rapids to survive, they will not be present where there are no rapids. Any assessment of aquatic ecosystem health must therefore also include assessments of the habitat, and whether any the lack of suitable habitats is natural or due to habitat destruction.

Comparing the numbers and types of species you would expect to find at any point, with what you actually find, and taking the available habitats into account, provides a good idea of the health of the system at that point. Using this approach we can determine the ecological state on a scale of 'Unmodified' all the way through to 'Seriously modified'.

Perhaps more valuably, aquatic organisms live permanently in the river system, and respond to even short term changes that can be missed by sampling that occurs irregularly. So monitoring of aquatic ecosystem health can provide a more complete picture of impacts on the river, than sampling chemical water quality alone.

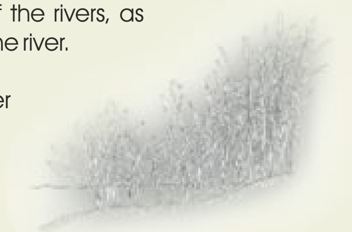


What components of aquatic ecosystem health were assessed?

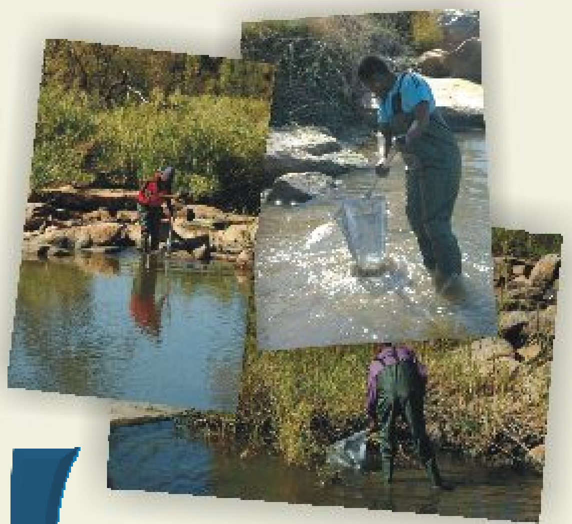
The first Joint Basin Survey included monitoring of:

- Macro-invertebrates: These are small animals - mostly insects found in large numbers in flowing water.
- Fish: Assessing the numbers and types of fish found to those that you would expect to find under natural conditions.
- Diatoms: Are algae found on rocks. Diatoms are sensitive to pollution and are good indicators of pollution.
- Riparian vegetation and habitat: This includes plants in and on the banks of the rivers, as well as changes in habitats in the river.

All these factors were used together to provide an overall assessment of Aquatic Ecosystem Health at monitoring points throughout the Orange-Senqu River System.



DETERMINING AQUATIC ECOSYSTEM HEALTH USING MACRO-INVERTEBRATES



Ecological Category	Description
A	Unmodified, natural.
B	Largely natural with few modifications.
C	Moderately modified, but most ecosystem functions remain.
D	Largely modified, a significant loss of species and ecosystem functions.
E	Seriously modified, extensive loss of ecosystem functions, habitats and species.

SENSITIVITY SCORES

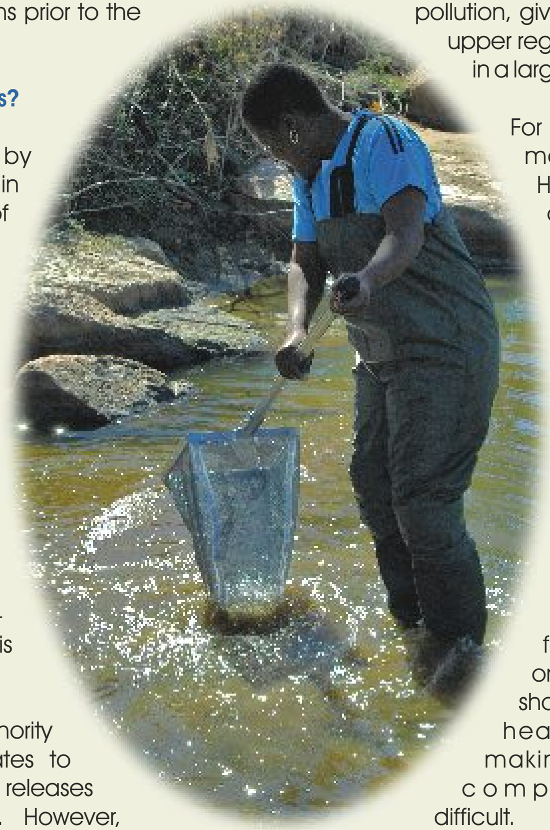
MACRO-INVERTEBRATE ASSESSMENTS

Why are macro-invertebrates important?

Macro-invertebrates are small insects, crustaceans, snails and worms - usually found in large numbers in flowing water. They have different sensitivities to pollution, and by checking what types or groups we find, we can get an idea of how the river has been impacted by human activities.

Macro-invertebrates are short lived, and their populations recover from short term pollution events. They are also found attached to rocks and do not move far upstream or downstream. They therefore provide a good indication of impacts on the river at that point, and for the few months prior to the sampling.

How do we monitor macro-invertebrates?



Macro-invertebrates are sampled by sweeping a net through different habitats in the river. By counting the number of different macro-invetebrates we find, and scoring these against 'sensitivity scores', we can get an indication of impacts at that site. Two scoring systems are used by ORASECOM, the South African Scoring System (SASS5) and the Namibian Scoring System (NASS2).

These scores are influenced by changes in flow, habitats, and by water quality. So the ecological state is determined by comparing what was found, to similar sites in a natural condition. Where there are no un-impacted sites specialist knowledge is used to assess the ecological condition.

The Lesotho Highlands Development Authority (LHDA) also samples macro-invertebrates to assess the effects of environmental flow releases from the Katse and Mohale Dams. However, because these samples are for a different purpose, the data cannot be directly compared to that for the rest of the system.

What did we find?

Macro-invertebrates were sampled at 45 sites throughout the Orange-Senqu River System.

We did not find any unimpacted or pristine sites in the system, and even sites in the high mountain regions show some impacts. In Lesotho macro-invertebrates are affected by the changed flow patterns from the Katse and Mohale Dams. (The site on the Senqu River just before it flows into South Africa shows less species diversity, but those that are present tend to be sensitive to pollution, giving an artificially high reading.) Sites in the upper regions of the Grootdraai and Wilge Rivers are in a largely natural state.

For the most part, the rest of basin is in a moderately modified ecological state. However, some sites in or near large urban centres in South Africa show a largely modified state. At some sites in the lower Vaal River System seriously modified conditions are due to localised habitat related impacts. Sites in the lower Orange and Caledon Rivers show a moderately modified state. However, the site near Upington shows a largely natural condition, in part because of the good habitat at this site.

The results from the Fish River in Namibia (using NASS2) suggest a moderately modified system, but macro-invertebrate communities in that river are influenced by fact that the river only flows for a short time after heavy rains, making direct comparisons difficult.

AQUATIC ECOSYSTEM HEALTH - MACROINVERTEBRATES

COLOUR	DESCRIPTION
(blue)	Unmodified, natural.
(green)	Largely natural, with few modifications.
(orange)	Moderately modified, but most ecosystem functions remain.
(red)	Largely modified, a significant loss of species and ecosystem functions.
(purple)	Seriously modified, extensive loss of ecosystem functions, habitats and species.

AQUATIC ECOSYSTEM HEALTH: FISH

Why are fish important?

Fish are longer lived than macro-invertebrates, and provide an indication of impacts over a longer period. Fish populations are also often directly linked to the human use of rivers through recreational fishing, or by providing a source of protein for poor communities. People also see the presence of fish as a sign of a healthy system, and fish kills are often the first visible sign of problems in the river system. In many places the reporting of fish kills has helped identify and manage pollution events.

How do we monitor fish health?

Fish are sampled through an electro shocking system. An electrical current is passed through the water using hand-held probes. This stuns the fish, and they can be collected. The probes are swept through the different habitats in the river, and the number and types of fish found are recorded. In some places we used nets to catch fish.

The numbers and types of fish identified through this method can be compared to what we expect to find at any site and habitat type. Because the time spent in electroshocking is also carefully recorded, the 'catch per unit effort' can also be determined.

Once the numbers, types and health of the fish have been recorded, they can be returned to the water unharmed.

What did we find?

The assessment of ecosystem health using fish shows very similar results to those found using macro-invertebrates.

The Maloti minnow (Pseudobarbus quathlambae), a rare and endangered species found in the Lesotho Highlands

Fish populations are in a moderately modified state for most of the river system. Sites in the upper reaches of the Grootdraai and Wilge Rivers are in a largely natural state, but fish populations at sites near large urban centres show a largely modified state - with significant loss of species and ecosystem functioning.

In the lower reaches of the system fish populations show moderately modified ecological functioning. Importantly, the fish survey identified rare and endangered species at several places in the river system.

In most places, the types of fish we expected to find actually did occur in the river. But the numbers of fish found was often lower than expected. In many places the fish also carried heavy parasite loads suggesting that the fish populations are stressed in many places in the basin.

AQUATIC ECOSYSTEM HEALTH - FISH

COLOUR	DESCRIPTION
	Unmodified, natural.
	Largely natural, with few modifications.
	Moderately modified, but most ecosystem functions remain.
	Largely modified, a significant loss of species and ecosystem functions.
	Seriously modified, extensive loss of ecosystem functions, habitats and species.

OVERALL AQUATIC ECOSYSTEM HEALTH

How is the overall assessment done?

The overall assessment Aquatic Ecosystem Health is based on the macro-invertebrate, fish, diatoms and habitat assessments. This not only assesses the overall ecosystem health of the river at that point, but also the possible causes of any impacts noted. This 'corrects' impacts that might be associated with a natural lack of certain habitat types in different parts of the river - providing a better idea of the human impacts on the river ecology.

What did we find?

Assessments of the overall ecological health show similar results to that noted from the macro-invertebrate and fish surveys. However, certain conclusions can be drawn from a closer look at the assessments in different parts of the Basin.

In Lesotho

The results from the LHDA's regular monitoring of macro-invertebrates show that river ecosystems seem to be recovering from the construction of the Lesotho Highlands Dams, although some impacts are still noted from the modification of natural river flows and land degradation.

The Vaal, Grootdraai and Wilge Rivers

Sites in the upper reaches of these rivers show a largely natural condition, with some flow modifications noted from the inter-basin transfers. However, further downstream the impacts of agriculture, industrial development and small towns are felt, and the river systems are mostly in a moderately modified state.

In the Middle Vaal River (Vaal Dam to Bloemhof Dam)

The tributaries to the Vaal River in this stretch mostly show a largely modified state, and in places in or near large urban areas a seriously modified state was noted. These impacts are mostly due to the effects of domestic and mining waste water which alter natural flows and impact on water quality. There is significant loss of species and ecological functioning in these systems. However, in the main stem of the Vaal River, moderately modified ecological functioning is noted, possibly due to improved habitat availability and the dilution of pollutants in the larger river.

In the lower Vaal River (Bloemhof Dam to the Orange River)

The lower Vaal River is in a moderately to largely modified state. The effects of irrigation and the use of agrochemicals are noted in the Harts River. Sites in the Riet / Modder River system show a moderately modified state. Just downstream of the Bloemhof Dam, local habitat conditions result in a largely modified system.

In the Caledon/Mohokare River

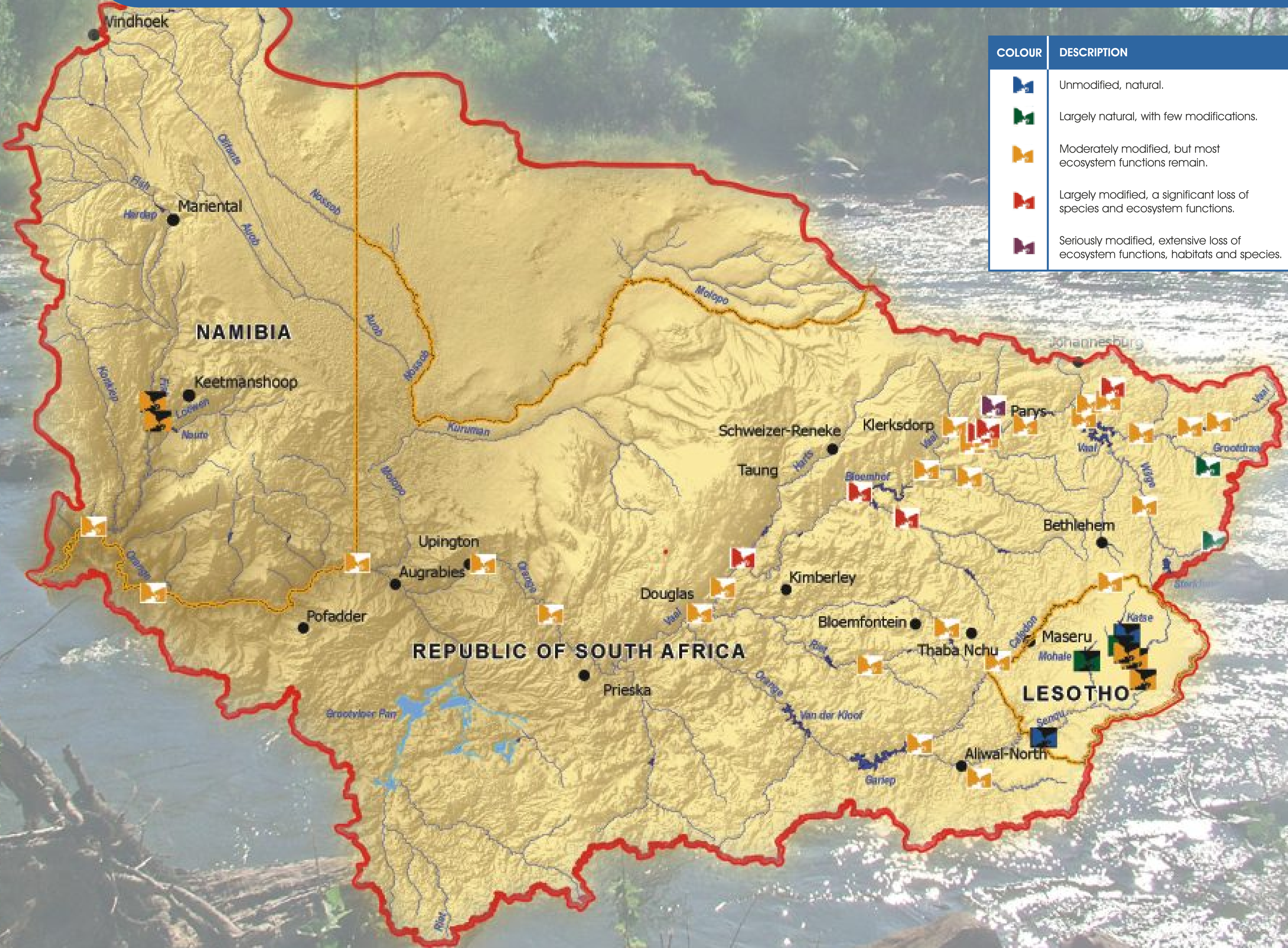
The two sites sampled in this system, both show a moderately modified state. However, the upstream site is affected by flow modifications and agricultural impacts, while urban runoff and flow effects are noted at the downstream site.

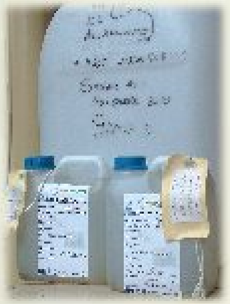
In the Orange River

Moderately modified ecological functioning was noted at all the sites along the length of the Orange River in South Africa, mostly due to flow modifications and agricultural impacts. The site just upstream of Upington, while showing largely natural macro-invertebrate and fish populations, shows a moderately modified state once habitat is accounted for. In Namibia and Lesotho the assessments were complicated by the different methodologies applied, but the data from the Fish River suggests moderately modified ecological functioning.

AQUATIC ECOSYSTEM HEALTH - OVERALL ECOLOGICAL HEALTH

COLOUR	DESCRIPTION
	Unmodified, natural.
	Largely natural, with few modifications.
	Moderately modified, but most ecosystem functions remain.
	Largely modified, a significant loss of species and ecosystem functions.
	Seriously modified, extensive loss of ecosystem functions, habitats and species.



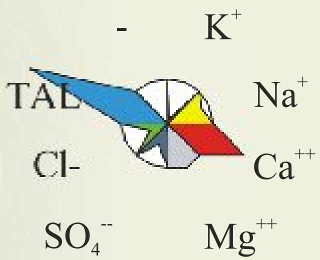


Why do we measure water quality?

The chemical composition of water provides an idea of the possible sources of pollution, and the impacts this may have on water users. The JBS-1 therefore included water quality analyses for the main salts dissolved in the water. We also took multiple samples at 8 sites of transboundary importance. These samples, together with 3 samples with known concentrations prepared by the South African Bureau of Standards, were sent to laboratories in each country. This allowed us to compare the results to build trust in the shared data, as well as to provide support to the laboratories.

"Fingerprinting" water quality

It is possible to 'fingerprint" water from the relative composition of the salts dissolved in the water. This provides information on the main pollution sources impacting on the river.

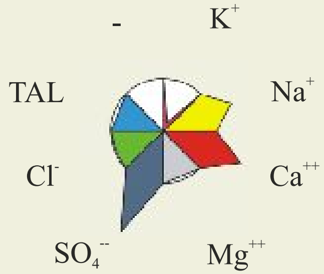


The background water quality fingerprint of the upper Senqu River.

The natural background "fingerprint" typical of the upper reaches of the basin in Lesotho and in the upper Vaal and Wilge Rivers - is dominated by Calcium Carbonate (Ca, and Total Alkalinity). Total salt concentrations in the Lesotho Highlands are generally less than 100mg/L.

The inflows to the Vaal Dam are affected by the transfer of water from Lesotho, and total salt concentrations in the Wilge River inflow were 76 mg/L. This compares to 360 ml/L in the Vaal River. The Vaal River shows increased levels of Magnesium.

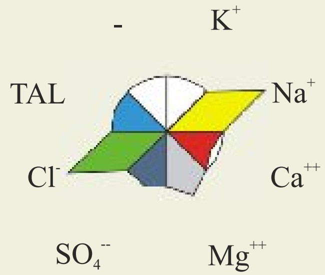
In the middle Vaal River the total alkalinity (TAL) is assimilated by acid mine drainage, and is replaced by Sulphate (SO_4). Higher



The water quality fingerprint of the middle Vaal River.

SO_4 concentrations are a good indicator of mining pollution. However, total salt concentrations in the Vaal River are regulated by releases of better quality water from the Vaal Dam. However, salt concentrations in the tributaries to the Vaal River flowing in from the north have higher salt concentrations and are dominated by Sulphates.

In the Lower Riet River system, return flows from irrigation systems increase the Sodium (Na) and Chloride (Cl) concentrations, and total salt concentrations exceed 1000 mg/L. A dilution option has also recently been introduced here, reducing total salt concentrations.

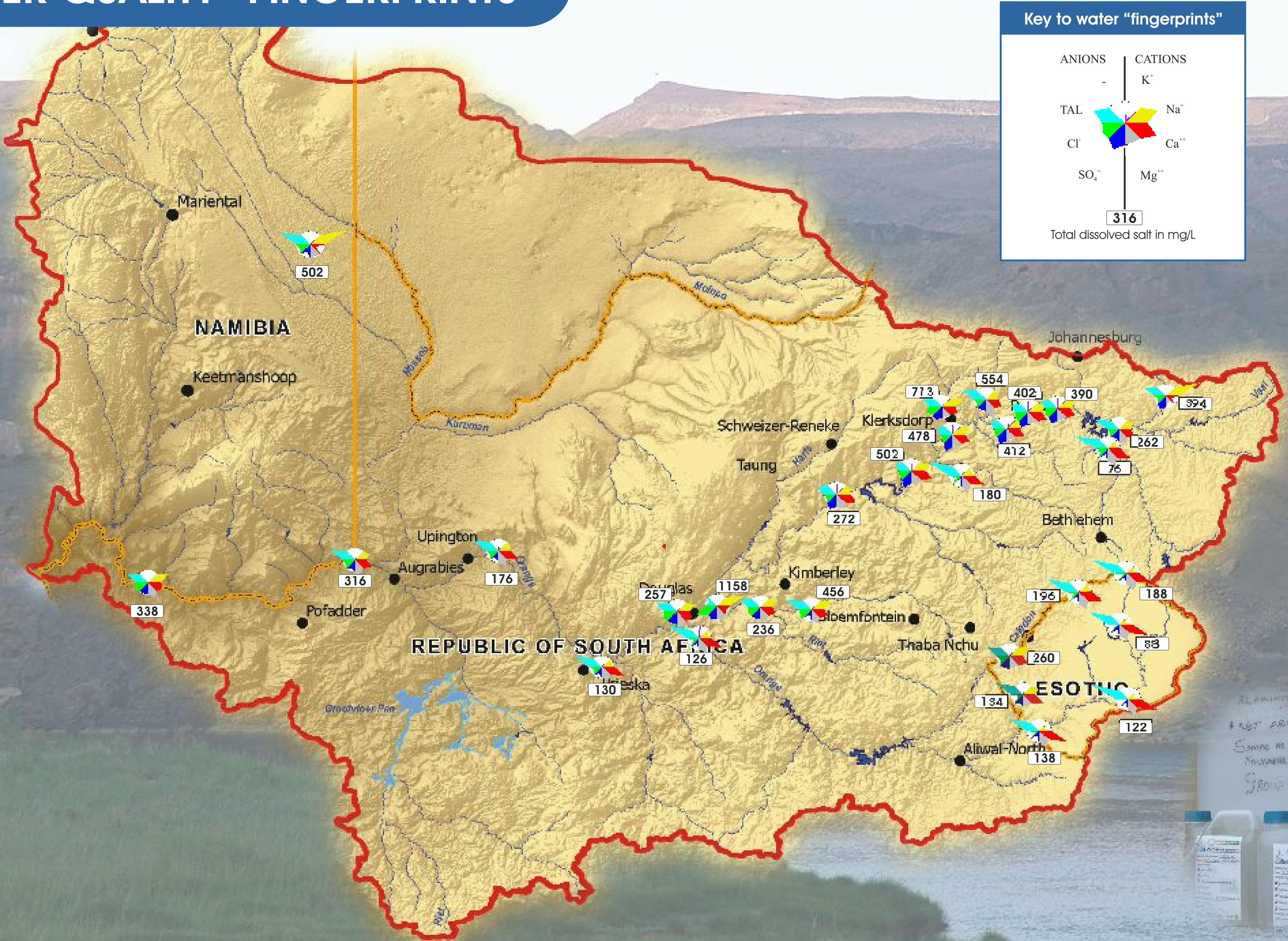


The water quality fingerprint of the Lower Riet River.

The Orange River System maintains its Calcium Carbonate character for most of its length, but salt concentrations increase rapidly downstream of Upington. This is associated with increased contributions from Sodium and Chloride, an indication of return flows from irrigation areas. However, the higher evaporation in this stretch of river will also contribute to increased salt concentrations.

[2]Sites where rivers flow across borders.

WATER QUALITY “FINGERPRINTS”



TRENDS IN SALT CONCENTRATIONS

Why do we monitor trends in salt concentrations?

We can get an indication of whether water quality is deteriorating by analysing long term changes in concentrations. Fortunately South Africa has been monitoring some points in the Orange-Senqu River system for over 40 years, and this provides a good indication of how things have changed over time.

While salt concentrations vary widely with changes in rainfall and river flow (higher rainfall generally means lower salt concentrations), long term trends are still evident from annual average concentrations[3]. We have analysed the trends in total dissolved salt (TDS) concentrations, measured as electrical conductivity (total salts is approximately 6.8 x EC), at several key points in the system.

Trends in salt concentrations in the inflow to the Vaal Dam

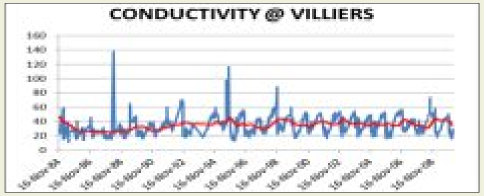
There are no significant trends in TDS concentrations in the Vaal River inflow to the Vaal Dam at Villiers. However, there is evidence that concentrations are higher in winter. Annual average TDS concentrations in the 1980's were generally around 150-200 mg/L, while from the late 1990's concentrations ranged from 200-280 mg/L.

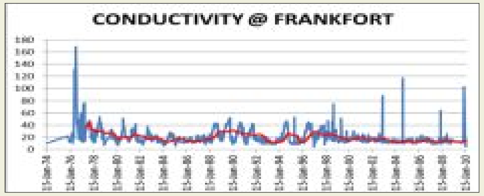
Average annual total salt concentrations in the Wilge River inflow to the Vaal Dam at Frankfort are generally lower at about 140 mg/L. TDS concentrations at this point show slight decreases since the mid 1990's, probably as a result of the import of water from the Lesotho Highlands.

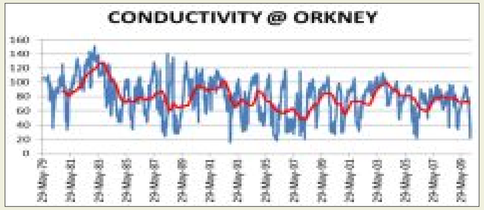
Trends in salt concentrations at Orkney in the middle Vaal River.

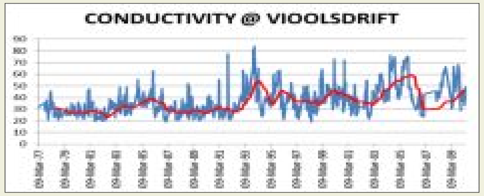
Salt concentrations in the middle Vaal River have fluctuated from over 950mg/L in the early 1980's to less than 600mg/L since the mid 1990's. There is a gradual decrease in salt concentrations over this period, due to the introduction of a dilution option. Under this option, salt concentrations in the outflow to the Vaal Barrage are kept at 600 mg/L, by releasing water from the Vaal Dam. Treatment and reuse of the acid mine water may also have some impacts on salt concentrations in the future.

Trends in salt concentrations in the lower Orange River





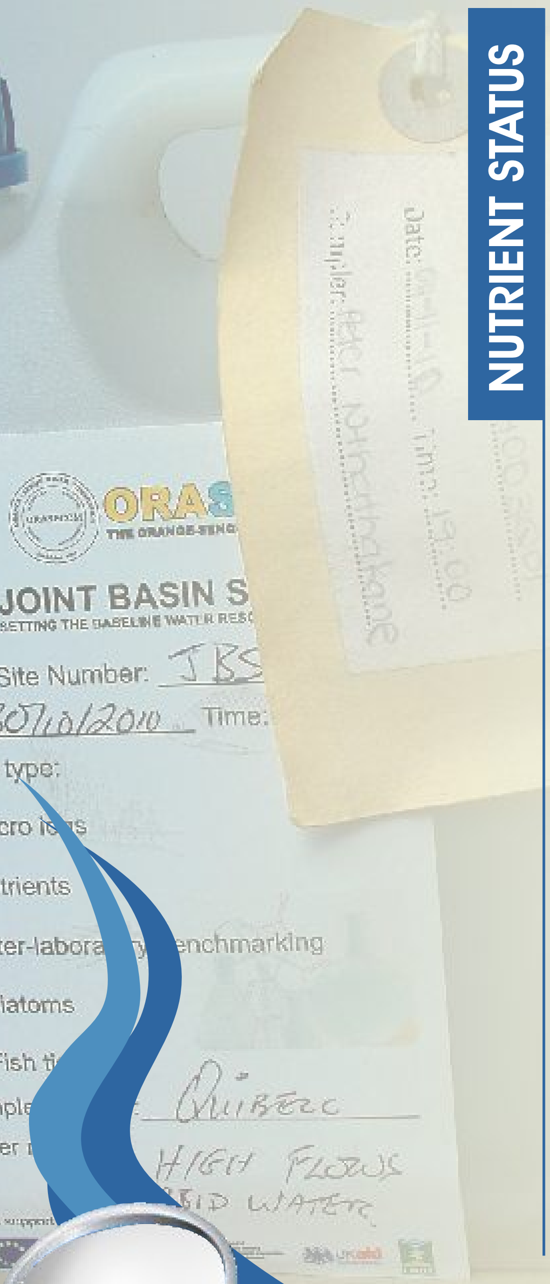




Salt concentrations in the lower Orange River show an increasing trend. In the late 1970's annual average salt concentrations were around 200 mg/L. These increased to 280-380 in the mid 1990's. This increase is statistically signifi-cant and may be associated with increased irrigation along this part of the river.

Decreases in 2005 and 2006 were associated with higher flows and hence greater dilution. The provision of environmental flows for the estuary may regulate salt concentrations in this stretch of river in future.

[3] In these graphs the blue line represents actual measured values, while the red line is an average of the data for 6 months on either side of the measured concentration.



NUTRIENT STATUS

Why do we measure nutrients?

Plant nutrients like nitrogen and phosphorus stimulate the growth of floating algae. Algal 'blooms' affect the use of the rivers for recreational purposes and impair ecosystem functioning. Blooms of certain kinds of algae can cause "swimmers itch" and have been known to be toxic, resulting in livestock deaths.

High concentrations of algae in water also cause problems for water treatment plants, increasing treatment costs and producing substances that may be harmful to human health. High concentrations of nutrients also stimulate the growth of aquatic weeds like water hyacinth and water fern causing a variety of problems in river systems.

Where do nutrients come from?

Nutrients are found in high concentrations in rivers in urban areas, in stormwater runoff, from overflowing sewers and from poorly serviced and maintained sanitation systems. As farmers use fertilisers on their crops, increased nutrient levels are also typical of agricultural and irrigation areas particularly in the underground water. Phosphorus is also found in detergents and soaps and many countries are banning phosphorus containing detergents.

The ratio of total nitrogen to total phosphorus in the water also provides useful information. Treated sewage effluent generally has lower nitrogen to phosphorus ratios. However, the nitrogen in agricultural fertilisers is readily dissolved in water, while the phosphorus is held back in the soil. Higher nitrogen to phosphorus ratios consequently suggest agricultural origins for elevated nutrient concentrations.

What did we find?

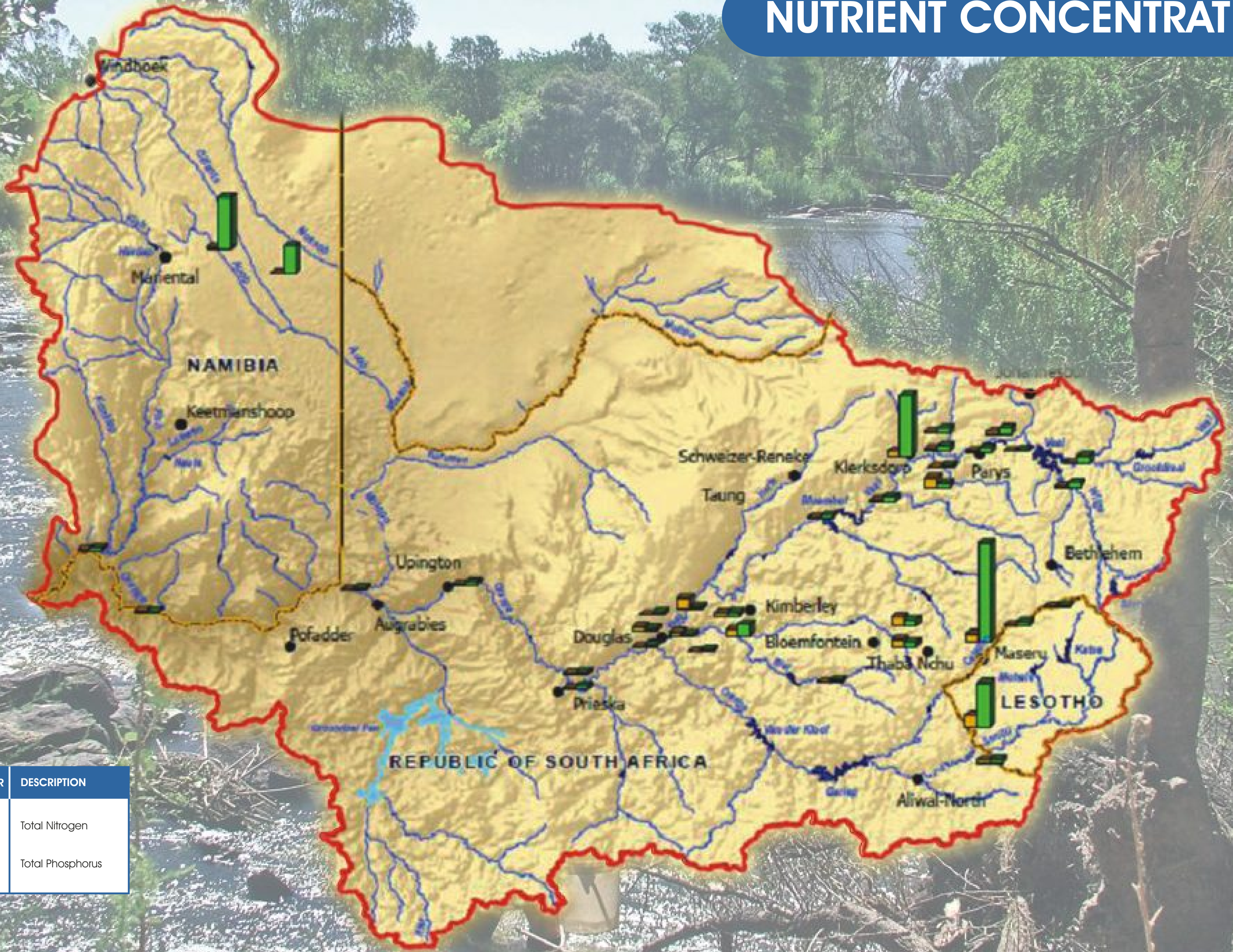
Nutrient concentrations throughout most of the Basin are sufficiently high to cause algal blooms. However, concentrations in the middle and lower reaches of the Vaal and Riet Rivers are noticeably higher than those typical of the rest of the basin. Total phosphorus concentrations along this stretch of river range from 1.0 - 5.0 mg/L. Major algal blooms have been noted along this entire stretch, resulting in substantial problems with the treatment of water.

Nutrient concentrations further upstream in the Vaal and Wilge Rivers are much lower at 0.1 mg/L total phosphate. Suggesting that urban pollution from the southern Gauteng area is a major source of increased nutrient concentrations.

Total phosphorus concentrations in rivers in the Lesotho Highlands are typically below 0.03mg/L, while those in the Senqu River just before it flows into South Africa were 1.7 mg/L due to the high sediment loads at the time of sampling. Nutrient concentrations in the Caledon / Mohakare River increase downstream of Maseru. This may however also be partly associated with a rainfall event just before sampling.

Total phosphate concentrations further downstream in the Orange River range from less than 0.2 mg/L to 0.5 mg/L, while concentrations in the lower Orange River range from 0.2-0.7 mg/L. However, total phosphorus to total nitrogen ratios tend to be higher in this part of the system, suggesting that the nutrients come from agricultural fertilisers. Very high nitrogen concentrations in the groundwater in Namibia are typical of underground water in agricultural areas.

NUTRIENT CONCENTRATIONS



COLOUR	DESCRIPTION
Green	Total Nitrogen
Yellow	Total Phosphorus

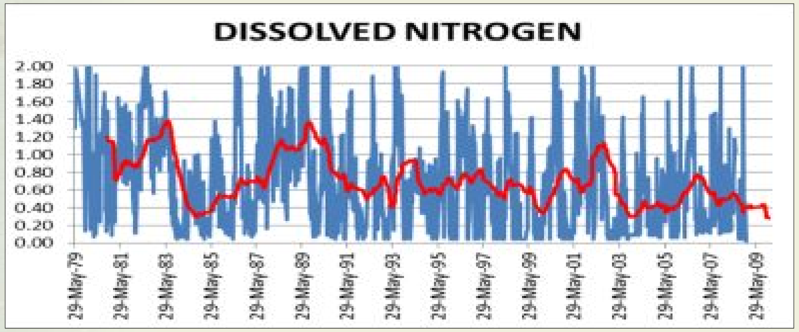
NUTRIENT TRENDS IN THE VAAL RIVER

Why have we analysed nutrient trends in the Vaal River?

The data from the Joint Basin Survey showed high nutrient (particularly total phosphate) concentrations along the middle Vaal River. However, because nutrient concentrations can vary widely it was decided to compare what we found with JBS-1 with the longer term situation in this part of the river - using data from South Africa's Water Management System.

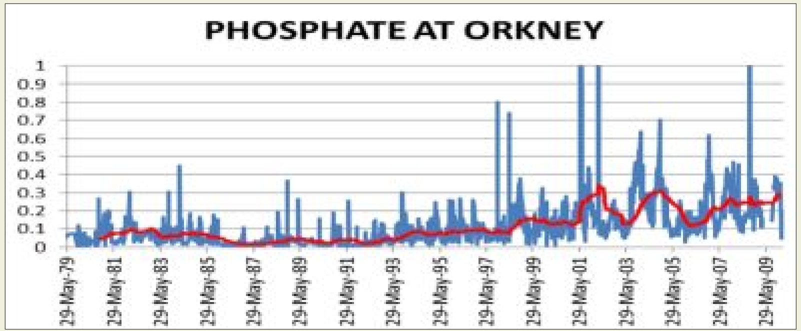
Trends in nutrient concentrations in the middle Vaal River

We chose the sampling point at Orkney as this point is about halfway along the middle Vaal River, and it has a good long term record of data. However, other points along this stretch show similar trends.



These trends are not as evident with dissolved nitrogen and annual average dissolved nitrogen concentrations at this point have remained relatively constant. An analysis of the total nitrogen to total phosphorus ratios for the 1990's (the only period for which data exists) shows a decreasing ratio - suggesting the increasing effect of treated sewage effluent on nutrient water quality.

During the 1980's and early 1990's annual average dissolved phosphate concentrations were generally below 0.1 mg/L. However, in the mid-1990's concentrations started increasing steadily and since the late 1990's annual average dissolved phosphate concentrations have been above 0.1 mg/L, frequently exceeding 0.2 mg/L - a 100% increase. The sample taken for the Joint Basin Survey showed dissolved phosphate concentrations of 0.3 mg/L at this point.



Why do we measure bacterial concentrations?

Bacteria are present in large numbers in human and animal waste, and their presence in water usually indicates contamination from human or animal faecal matter. Drinking or swimming in water with high concentrations of faecal bacteria poses serious health risks.

Faecal contamination of water is normally measured through the numbers of Faecal Coliforms or E. coli bacteria in the water, and comparing these to water quality standards.

While Faecal Coliform and *E. coli* bacteria have been known to cause diseases, their presence in water is also a good indicator of the risk of other water borne diseases like cholera.

Where do faecal bacteria come from?

High concentrations of faecal bacteria may come from a variety of causes, like failing waste water treatment works discharging untreated or partially treated sewage into rivers. Intensive animal feedlots, storm water runoff from densely populated areas, or settlements that do not have adequate sanitation facilities are also sources of faecal bacteria.

Water samples for bacteriological analysis must be analysed within 24 hours of sampling, and must be kept cold before analysis. This posed some challenges for the JBS-1 teams, and so faecal coliform data were collected from laboratories throughout the basin. This included the data from the South African National Microbiological Monitoring Programme, the LHDA, Midvaal and Sedibeng Water, and Water Treatment works.

What did we find?

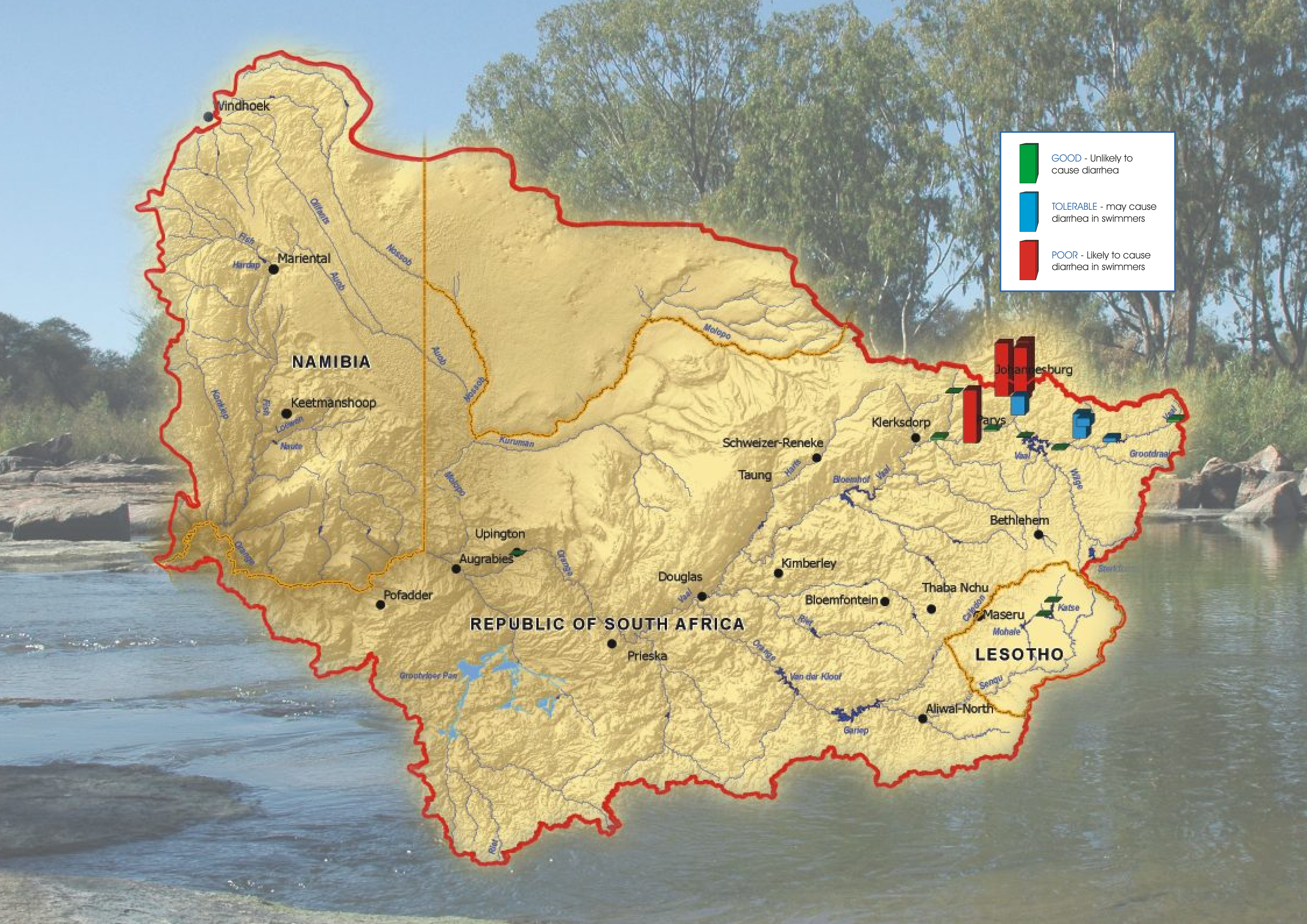
Faecal coliform data was assessed by comparing the concentrations found with the guidelines for swimming. This allowed us to assess the water as:

- Poor - Likely to cause diarrhea with full contact swimming.
- Tolerable - May cause diarrhea with full contact swimming.
- Good - Unlikely to cause diarrhea with full contact swimming.

Most of the samples taken in Johannesburg and the surrounding urban areas fall in the 'poor' range - indicating high risks associated with swimming. Further downstream concentrations decrease to tolerable levels. However, high concentrations of faecal bacteria are found in the Vaal River at Parys. Further downstream in the Vaal River bacterial quality falls in the 'Good' range.

Samples taken downstream of the Secunda industrial complex are mostly in the 'Tolerable' range, while concentrations in the rivers flowing into the Katse and Mohale Dams in the Lesotho Highlands are in the 'Good' range. Concentrations at the Upington Water Treatment Works are in the 'Good' range.

Microbiological risks therefore seem to be localised, and associated with the large urban areas in South Africa.



GOOD - Unlikely to cause diarrhea
TOLERABLE - may cause diarrhea in swimmers
POOR - Likely to cause diarrhea in swimmers
NAMIBIA
REPUBLIC OF SOUTH AFRICA
LESOTHO
Windhoek
Mariental
Keetmanshoop
Upington
Augrabies
Pofadder
Douglas
Prieska
Kimberley
Bloemfontein
Thaba Nchu
Maseru
Aliwal-North
Bethlehem
Klerksdorp
Schweizer-Reneke
Taung
Johannesburg
Parys

METALS

What are heavy metals and why do we sample them?

Metals are often found in rivers in urban or industrial areas. Metals pollution is associated with rain water wash off from urban, mining and industrial areas, and may also be present in certain agricultural chemicals. The large scale burning of coal also releases metals into the environment. While some metals are needed in all living organisms, others can be toxic even in low concentrations and may accumulate in the body.

Metals also often accumulate in the bottom sediments of rivers and dams. The JBS-1 therefore also included an assessment of the concentrations of metals in the bottom sediments of rivers at 61 sites throughout the basin.

How do we monitor heavy metals?

We analysed metals in the sediment of 61 sites throughout the Orange-Senqu basin. We also analysed metal concentrations in fish fillets from the Sharptooth Catfish (as these may be consumed by people) at 4 sites in the basin. All these samples were analysed at the North-West University in Potchefstroom.

What did we find?

We calculated the Metal Pollution Index (MPI) for the sediment at each of the sites, using the concentrations of 42 different kinds of metals. The MPI provides an overview of pollution from all the metals, but does not indicate the actual risk to humans or aquatic ecosystems at any point.

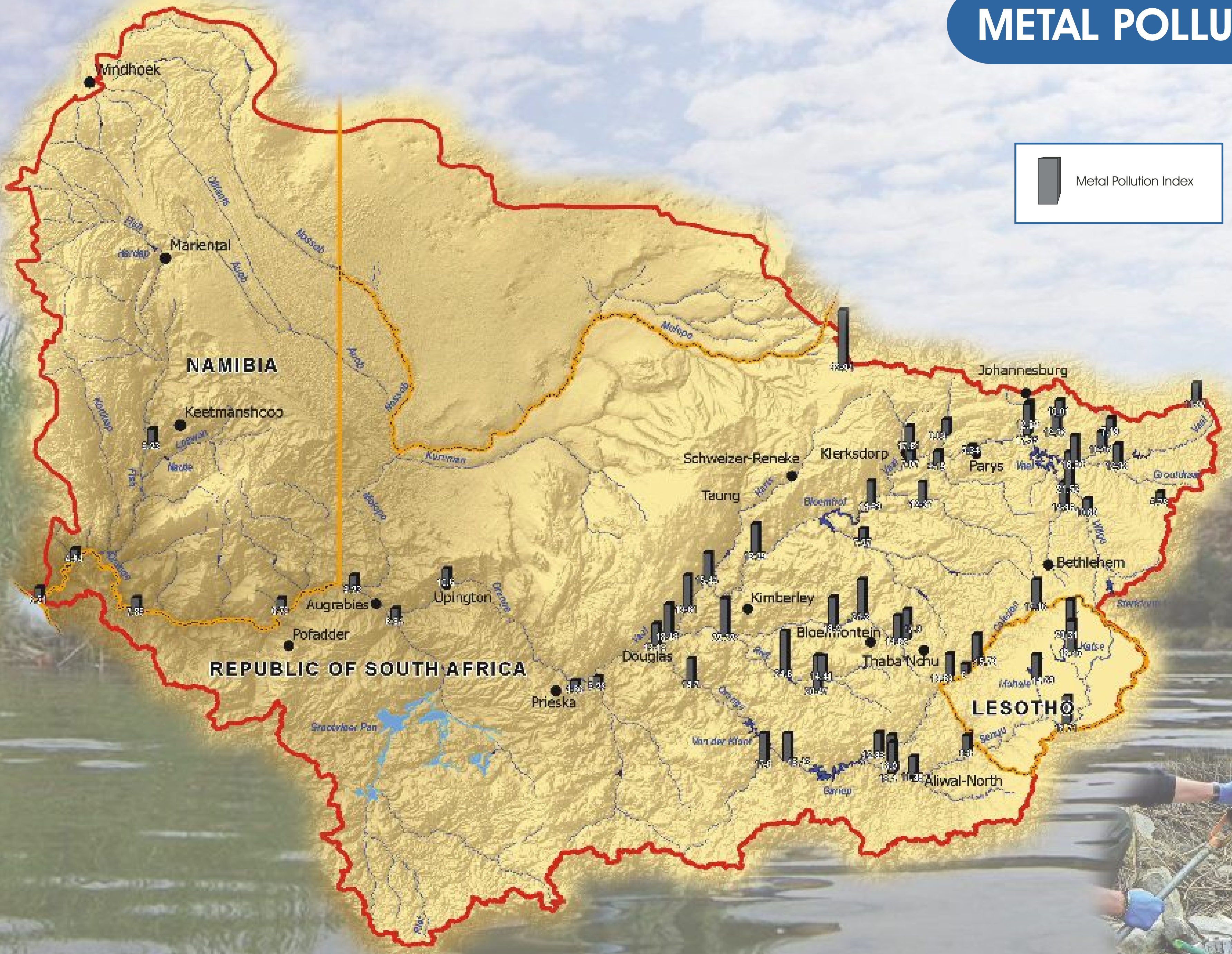
The origin of the Molopo River showed the highest MPI score of 33.94. There does not seem to be any immediately obvious source of metals pollution in this area and high concentrations may be of natural origin or from contamination of the underground water. High MPI scores (22.22) were also found in the Riet River in the western Free State, possibly as a result of agricultural activities in this area of the basin.

Generally MPI scores of over 10 are found in the urban, industrial, irrigation and mining areas. As such, the Caledon / Mohakare, Vaal, Riet and Modder Rivers show some evidence of metals pollution. However, these metals do not seem to be transported through the system and MPI scores in the lower Orange River are below 10. The higher MPI scores in the upper reaches of the Senqu River may be a result of diamond mining in the area.

We also calculated a 'Sediment Quality Guideline Index' for each of the sites using international standards for toxicity from metals. This analysis showed that only the Molopo River site had a high probability of being toxic. None of other sites showed a high potential for toxicity.

The levels of metals found in the in the fish tissue also seems to be low. However, this may be due to the fact that the metals could not accumulate in the fish muscle tissue. This will require further investigation.

METAL POLLUTION



Organic Pollutants

Why are organic pollutants important?

Certain chemical compounds, such as the pesticide DDT persist for long periods in soil, sediments plants and animals. These substances affect human health and impact on the functioning of aquatic ecosystems even in low concentrations. Bird eggs are known to concentrate some of these substances, and are often used as good indicators of this kind of pollution.

These organic pollutants enter the environment via variety of sources. Pesticides applied to crops may be washed into water via rain or irrigation. Other chemicals may enter the water from solid waste dumps in urban areas or chemical spillages. Improper disposal of dangerous chemicals in households can also be a major source of these substances.

How do we monitor organic pollutants?

Teams of highly trained scientists took samples from aquatic birds, fish tissue and from sediments. These samples were carefully prepared and sent to a laboratory in Germany, where they were analysed with sophisticated apparatus for a range of organic pollutants; such as DDT, Dioxins, and a range of other organic pollutants.

What did we find?

The sediments throughout the basin generally had very low levels of organic pollutants. However, certain sites showed spikes in some of the organic pollutants. In particular dioxins (which are caused by low heat burning of plastics) are higher (over 0.3) near urban centres. However, further investigation will be necessary to identify the actual sources of these substances.

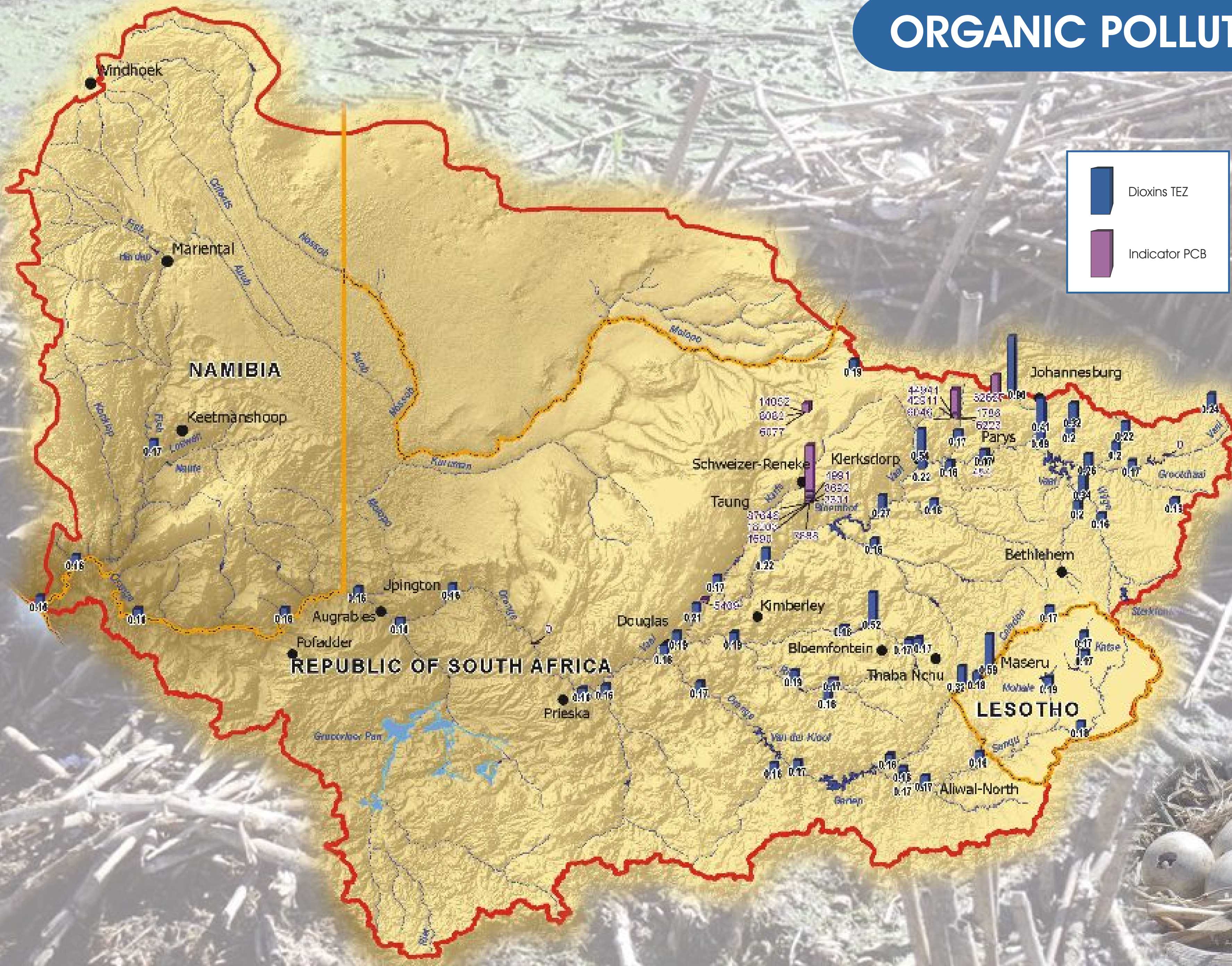
As with the metals, Dioxin concentrations in the lower Orange River are lower, and there does not seem to be significant transport of these substances through the river system. Spikes in PCBs are also noted in parts of the North West Province of South Africa, however, there is no immediately obvious cause for this.

Fish tissue also had relatively low levels of organic pollutants, except for higher than expected levels of some contaminants near Rooipoort in the Northern Cape Province. Again, the potential source of this pollution needs to be determined.

Bird eggs taken from breeding colonies in Bloemhof Dam, and near Potchefstroom also showed some spikes in organic pollutant concentrations. The sources of these pollutants are again unclear. There is however evidence of bio accummulation in fish and bird eggs.

Concentrations of organic pollutants are, for most of the basin, quite low. The JBS-1 has nevertheless shown that spikes of important organic compounds suggest sources of pollution in areas that would otherwise be considered clean.

ORGANIC POLLUTANTS



PUBLIC PARTICIPATION IN THE SURVEY

Why involve the public?

The livelihoods of people living in the basin, particularly in an arid basin like the Orange-Senqu, are often directly linked to the way the system is managed. In many cases people also depend directly on healthy river ecosystems. Ultimately, river systems are managed for these people, and it is essential to involve the people of the river in water resources management.

We therefore decided to involve the people of the Orange-Senqu Basin in the first Joint Basin Survey through five public participation events. Stakeholders and local officials were given the opportunity to interact with specialists from each of the countries as well as the specialists in the sample teams, to find out more about the river system and about ORASECOM.

Perhaps most importantly, the JBS-1 also provided the opportunity to interact with school children and students at the public events. Local schools and technical training institutes were invited to send their students to the events. In South Africa schools were selected from the EcoSchools database, while in Namibia and Botswana all the local schools where the event was held were invited to participate. In Lesotho the local polytechnic students participated.

Students were shown how to use the miniSASS sampling system to assess the health of the river. This is a simplified version of the method used in the JBS-1 to measure invertebrate health, but which can be used by the general public. Remarkably, the miniSASS system applied by the students showed very similar results to the full SASS5 and NASS2 analyses carried out by the specialists.

Sampling equipment was left with the schools, so they could repeat the exercise with new classes and learners. In Botswana, where there are no flowing rivers, it was not possible to use the miniSASS system, and the schools participation revolved around groundwater sampling.

Introduction

The Orange-Senqu River System is one of the most complex systems in the world. The unique characteristic of having a large urban and industrial complex on its watershed, and the arid nature of the Basin, means that water has to be imported into, as well as shifted around the basin to meet growing demands.

The cost of establishing and operating these schemes has had a significant impact on the way the system is operated to maximise water availability. This, together with the need to reuse waste water has, and will continue to have, the overwhelming impact on the water quality and aquatic ecosystem health of the Orange-Senqu River System.

Water quality in the Vaal and Wilge River Systems

Growing water demands and the associated increase in waste water effluent returned to the rivers, together with acid mine drainage from a long history of intensive mining activities, have had the predominant effect on water quality in the Vaal River.
Both total salt and nutrient concentrations increase significantly in the middle reaches of the Vaal River. The dominance of sulphate salts in this stretch of river is a good indicator of the impacts of acid mine drainage. However, the implementation of a 600mg/L dilution option for this part of the river has prevented long term increases in salinity.

South Africa is now considering the treatment and reuse of acid mine drainage, which may have beneficial impacts salt concentrations in rivers flowing into the Vaal River from Gauteng. This may obviate the need for further dilution releases from the Vaal Dam, a further saving on water. However, the potential effects of this on nutrient concentrations and algal blooms in the middle Vaal River would have to be taken into account when further investigating this option.

Virtually the whole of the Vaal and Wilge River systems have sufficient nutrients to sustain algal blooms, and algal blooms are common in the Grootdraai, Vaal and Bloemhof Dams as well as along the middle Vaal River. This stretch of river is also characterised by particularly high nutrient concentrations. Both nitrogen and phosphorus concentrations along this part of the River are high enough to promote significant algal blooms, with the associated problems for aquatic ecosystems and water treatment.

Phosphorus concentrations appear to be increasing along this stretch of river, most likely due to the increased effluent flows from sewage treatment works as well as problems with treating the water to the appropriate standards. The significant inroads South Africa is making, and will continue to make, in providing sanitation services to the poor will have to be paralleled with increased attention on managing nutrient loads to this part of the system.

Further downstream, large irrigation areas also increase demands for water and affect water quality. High concentrations of both nutrients and salts in the lower Riet and Vaal Rivers are most likely a result of return flows from irrigation areas, but also the operation of the system. The Vaal and Riet Rivers are operated as closed systems and spills into the Orange River and Douglas Barrage are kept at a minimum. This means that pollutants tend to concentrate in the lower reaches of these rivers.

Water quality in the Orange-Senqu River System

Water quality along most of the length of the Orange-Senqu River System does not seem to be significantly degraded through pollution. Localised impacts have been noted along the Caledon/Mohakare River shared between Lesotho and South Africa due to industrial and urban pollution from Maseru.

The Orange River maintains its natural chemical composition ('fingerprint') for most of its length. However, increased salt concentrations and the dominance of Sodium and Chloride salts downstream of Upington are indicative of an increasing impact from the

intensive irrigation along the lower reaches of the river.

Longer term increases in salt concentrations in the lower Orange River are also most likely due to increased irrigation. The possible impacts of the planned dam at Vioolsdrift/Noordoewer and the provision of environmental flows on these trends will have to be further investigated.

Aquatic ecosystem health

While aquatic ecosystem health is impacted along virtually the whole length of the Orange-Senqu River System, aquatic ecosystems in most parts of the Basin seem to have largely retained most of their ecological functions.

For the most part ecological functioning of the whole system is 'moderately modified', with some loss of species and habitats. However, some sites near the large urban and industrial areas are 'largely modified' with a significant loss of ecosystem functions and species. Nevertheless, losses and changes in the species composition are noted virtually throughout the basin.

The losses of habitat and biota may be related to changes in the flow patterns and volumes, as well as destruction of the habitats both in, and on the banks of the river, as well as pollution impacts. These impacts will be monitored on a regular basis to determine if any further degradation is occurring.

Organic pollutants and metals

Both organic pollutants and metals concentrations are for the most part only found in low concentrations throughout the basin. However, there is some evidence that both metals and dioxin concentrations are higher near the urban centres. There are, nevertheless, some spikes in concentrations at some points in the system. These spikes do not appear to be associated with any particular development and may be related to localised sources.

There is evidence that these substances accumulate in fish and bird eggs and further work is needed.

Putting the results in context

It is clear that the development and operation of large dams and transfer schemes in the Orange-Senqu River System to provide water for irrigation and urban demands has had significant effects on both water quality and aquatic ecosystem health.

Significant and growing water quality problems in the middle Vaal River, as well as possible changes in the operation of this part of the system may have longer term implications for basin as a whole. Our basin wide plan will play particular attention to these aspects, as well as to ensuring the future water demands from all four countries can be met.

It is important, nonetheless, to recognise the contribution this part of the Orange-Senqu River System makes to the regional economy. Gauteng contributes over 30% of the regional Gross Domestic Product (GDP) of all four countries together, and makes up 10% of the GDP of Africa as a whole. These benefits are shared to some extent through other regional trading agreements. Royalties paid to Lesotho for the water transferred to this region make up 6% of that country's GDP, while electricity generated by the transfer of water from the highlands to South Africa makes a significant contribution to Lesotho's power needs. Elsewhere in the basin the water needs coal fired power stations, as well as the potential for hydropower means that the regional energy and water needs are closely linked.

Our ongoing monitoring of the system and future Joint Basin Surveys, as well as the basin wide plan will not only help us maximise benefits for all the countries, but will also help manage the impacts of economic growth on water quality and aquatic ecosystems. The basin wide plan will be key to ensuring all four countries can meet their current and future water demands, while protecting the shared aquatic ecosystems. Providing scientifically sound advice to the governments of these countries in this respect will remain the key focus of ORASECOM's activities.


ORASECOM
ORANGE-SENQU RIVER COMMISSION
JOINT BASIN SURVEY-1
SETTING THE BASELINE WATER RESOURCES QUALITY 2010
With support from:
South Africa
UNDP
gtz

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Contributors and support

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  - Hoeksteen Primary School (Rosh Pinah)
  - Rosh Pinah Academy (Rosh Pinah)
  - Lerotholi Polytechnic (Maseru)
  - Schools in Tsabong, Bostwana

Photo and figure credits

- The Orange-Senqu River Awareness Kit
- Ms Fonda Lewis, the Public Events
- Dr Horst Vogel
- Mr Manie Maré
- Mr Gavin Quibell
- The Aquatic Ecosystem Health monitoring teams
- Mr Peter Pyke
- Dr Ronnie McKenzie
- Mr Christoph Mor, and the POPs team

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Orange-Senqu River Awareness Kit:

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ORANGE - SENQU RIVER COMMISION

BOTSWANA LESOTHO

ORASECOM

NAMIBIA SOUTH AFRICA

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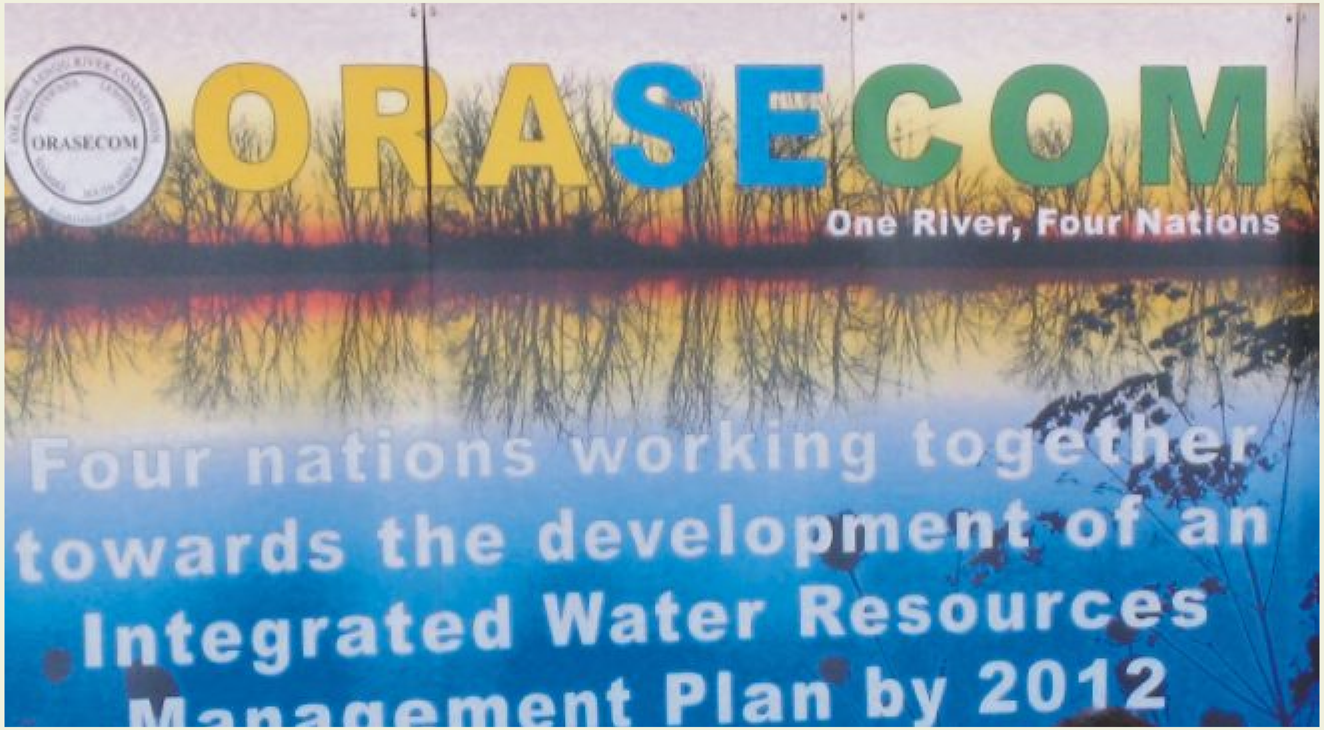

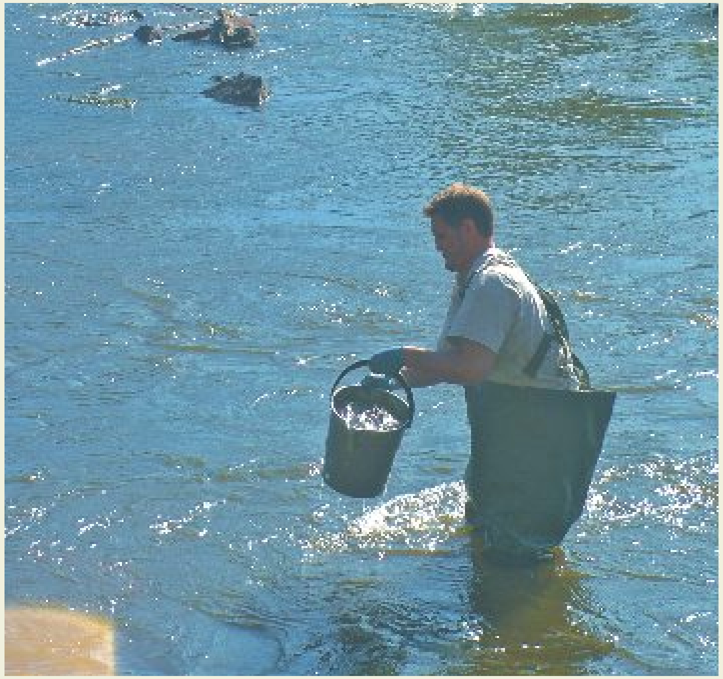

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