Orange-Senqu River Basin

Orange-Senqu River Commission Secretariat
Governments of Botswana, Lesotho, Namibia and South Africa

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Development of Basin-Wide Water Resources Quality Guidelines and Monitoring System

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Contents

1. Introduction

The Orange-Senqu River basin is one of the larger river basins in southern Africa. The basin is regulated by some 30 large dams and includes several larger inter- and intra-basin water transfers. Extensive water utilisation for urban, industrial and agricultural purposes has significantly reduced natural flow, to the extent that the current flow reaching the river mouth is in the order of half of the natural flow.

Future river basin management in the Orange-Senqu River basin has to balance these competing water uses, and deal with increasing rates of human-induced change and the mounting concerns about the causes and consequences of this change. Differences in legal frameworks, historical backgrounds and technical capabilities of the four riparian States Botswana, Lesotho, Namibia and South Africa add to the complexity.

The four riparian States are strongly committed to a joint, basin-wide approach to addressing threats to the shared water resources. This led to the Agreement on the Establishment of the Orange-Senqu River Commission (ORASECOM) in 2000.

The UNDP-GEF Orange-Senqu Strategic Action Programme supporting ORASECOM compiled a Transboundary Diagnostic Analysis (TDA) of the basin (ORASECOM, 2013). The TDA charts the main environmental threats to the basin and ascertains their root causes. The deterioration of water quality was identified as one of five major transboundary issues of concern in need of further analysis.. The report serves as the scientific basis for a basin-wide Strategic Action Programme (SAP) and related National Action Plans (NAPs) in the four riparian States. The SAP is a negotiated basin-wide planning document that provides a basin-wide framework for the implementation of a prioritised set of national and joint transboundary actions and investments to address water-related environmental problems in the basin. The core of the SAP is a portfolio of projects that are envisaged to be implemented over the coming 5 to 10 years following the adoption of the SAP by the basin States.

This technical paper covers and reports on:

- A comparative assessment of current water resource quality (WRQ) guidelines/standards and methodologies applicable in Orange-Senqu basin States (Chapter 2);
- Key findings from the comparative assessment and an identification of gaps (Chapter 3);
- The identification of key components of harmonised, basin-wide WRQ guidelines and a basin-wide monitoring system with an outline of key activities required to establish such a system (Chapter 4, 5 and 6).

A collection of relevant previous studies in the region, and other background documents are listed in the Reference section.

2. Current institutional framework, WRQ guidelines, standards and monitoring

2.1 Definitions

Before addressing the aims with this investigation, it is advisable to define the meaning that will be attached to a number of terms.

Water quality guidelines provide information regarding the consequences that specific concentration ranges (or levels) of a specific water quality constituent can be expected to have for a specific water use (such as drinking water, irrigation or recreational use). It therefore includes water quality criteria for a specific constituent and use. It often also incorporates supporting information (such as the occurrence of that constituent in the aquatic environment, the norms used to assess its effects on water users, how these effects may be mitigated, possible treatment options, etc.).

Although usually founded upon a water quality guideline, a **water quality standard** is a regulatory criterion which sets legally enforceable limits for a water quality constituent. A water quality standard thus has legal status which facilitates its use to enforce adherence to the standard. A standard is typically used to set legally enforceable drinking water or effluent discharge criteria.

The combined term **water resource quality** (WRQ) guideline, as used in the TORs is not frequently encountered. Its meaning and use can be deduced from the fact that it is constituted of the terms WRQ and guidelines that are more frequently used. The term water resource quality considers the resource as a whole and thus gives an all-embracing description of the water resource's quality by a combination of all its physical, chemical, biological and ecological characteristics WRQ guidelines thus provide information regarding the seriousness of a water quality problem that is indicated by given concentration ranges (or levels) of a specific WRQ constituent.

Various terms are used to denote the properties of water and / or the substances dissolved or suspended in water and which collectively determines its suitability for use. Although there are some differences in meaning or connotation, in this document the term **water quality constituent** will be used interchangeably and assumed to mean the same as water quality characteristic, determinant, parameter or variable. Mostly the term used in a specific document has been retained in its discussion.

In its broader sense **WRQ monitoring system** (part of the phrasing describing the purpose of this investigation) refers to the monitoring of both surface and groundwater resources. Most of the concepts and considerations that are discussed in this document apply to both surface and groundwater, but there are also significant differences. These differences regarding the development of a monitoring system for each of surface and groundwater are considered to be so divergent that a separate effort is required for each. While some reference is thus made to groundwater, the emphasis in this document is on surface water resources.

2.2 Botswana

Institutional framework

Botswana's Water Act of 1968 controls the use of water in the country and provides an institutional framework for water allocation and control. The State owns public water and users have to apply for user and wastewater discharge rights to the Water Apportionment Board and Water Registrar. In order to fulfil its functions the Botswana Department of Water Affairs is organised into eight technical divisions; one of which is the Water Conservation and Quality division. Since the act is fairly old, it does not provide for water management approaches that have more recently become common. For example: very little provision is made for water quality management (e.g. standards) and control of water pollution. Prescribed penalties have, furthermore, not been adjusted for inflation and no longer serve as an effective deterrent. The Act mostly deals with individual rather than with basin wide rights and allocations. The Act makes no reference to the integrated water resource management approach and transboundary water management is not catered for. A new Draft Water Bill is currently under review. (Centre for Applied Research, 2010; Botswana DWA Website, 2013; Orange-Senqu River Awareness Kit, 2013).

On the other hand, Walmsley & Patel, 2012 reports that the Botswana Department of Water Affairs has been at the forefront of applying Environmental Impact Assessments (EIA) and has established procedures for preparing EIAs. The 1992 National Water Master Plan has also identified topics that should be included in environmental assessments of water development projects.

Water quality standards / guidelines

According to the Botswana Bureau of Standards website, 2013, they have (amongst others) developed water quality standards for drinking water quality (BOS 32:2009), irrigation water(BOS 463: 2011), the physical, microbiological and chemical requirements of waste water (BOS 93: 2012 2nd ed.) and drinking water for livestock and poultry (BOS 365: 2010). They have furthermore developed several standards for water sampling en the analysis of water quality constituents. The waste water quality standards (quoted by Walmsley & Patel, 2012) list the physical and microbiological requirements to which wastewater discharges have to comply as well as the maximum concentrations allowed for a range of inorganic macro- and micro- determinants (constituents). The drinking water standards (quoted by Walmsley & Patel, 2012) specify acceptable limits for microbiological safety determinants to which all drinking waters have to comply. The standards also specify physical, inorganic and organic chemical limits for water to be classified as Class I (acceptable) or Class II (maximum allowable) drinking water.

Water quality monitoring

The Department of Water Affairs has since 1969 been operating a network of approximately ten surface water gauging stations on rivers and impoundments. The data are captured in the HYDATA electronic database in Gaborone. The Department manages a new and sophisticated water analysis laboratory in Gaborone. Samples are drawn weekly from about 87 stations nationwide and analysed for inorganic chemical constituents (Scholes, 2001).

Every borehole that is drilled in Botswana must submit a drill record, after which a borehole certificate is issued. In the process, the location, depth to water, casing type, Total Dissolved Solids and pump test data are recorded in an electronic database maintained by the Department of Water Affairs. This database was begun in 1992. Well fields are monitored for groundwater level and major inorganic chemical constituents. The water yield of each well in a well field is recorded on a monthly basis (Scholes, 2001).

2.3 Lesotho

Institutional framework

In terms of the 2008 Environmental Act, the Department of Environment (DE) of the Ministry of Tourism, Environment and Culture (MTEC) is responsible for the development, implementation and enforcement of water quality guidelines and standards in Lesotho. These functions are carried out in consultation with, and some tasks can be delegated to, relevant Line Ministries, such as the Department of Water Affairs (DWA). DWA, which is part of the Ministry of Energy, Meteorology and Water Affairs (MEMWA), is responsible for the management of Lesotho's water resources. It keeps and provides records, information, results of monitoring activities (river flow, groundwater, water quality, etc.), research, and analyses to the office of the Commissioner of Water (CoW), who acts as the custodian of raw water resources. It appears that moves are afoot to develop the DE into a strong and competent custodian and the leading environmental authority in Lesotho. It is envisaged that all environmental information will find a home in a central data base at the DE. This would include relevant information and data from the Management Information System currently being established in the office of the CoW. (Fichtner Water and Transportation, 2013 and Walmsley & Patel, 2012).

Water quality standards / guidelines

Fichtner Water and Transportation (2013) recently completed the development of draft water quality guidelines and standards for Lesotho. These guidelines and standards were developed based on a review of numerous international and existing Lesotho guidelines and standards (both in operation and in draft format). Guidelines and standards from SADC countries received explicit consideration. The draft water quality guidelines and standards comprise the following uses:

- Standards for drinking water purposes;
- Standards for wastewater or industrial effluent discharge;

- Guidelines for natural aquatic ecosystems;
- Guidelines for irrigation purposes;
- Guidelines for recreation;
- Guidelines for aquaculture.

The documentation comprising the draft guidelines and standards are very comprehensive. In addition to providing standards and guideline values for the range of water quality determinants considered to be of importance to the specific water use under conditions in Lesotho, wide-ranging supporting information is also provided. Supporting information includes definitions and terminology, background to the purpose, scope and field op application of the guideline/standard, guidance regarding implementation and monitoring as well as background regarding the institutional framework and potential penalties. The actual guidelines consist of a narrative description of the effect that successive determinant ranges will have for the specific water use. Guidance is also provided on how the effects can be mitigated. The main differences between the documentation for guidelines and standards are related to the fact that a standard is a regulatory criterion which sets legally enforceable limits. For example; in the case of standards only one limiting value that should not be exceeded is specified per water constituent, analytical methods are prescribed and legal sanctioning for non-compliance is indicated.

At the time of writing this report, the draft water quality guidelines and standards still had to be discussed and approved within the relevant government departments and published in the Government Gazette before they will gain legal standing. The consulting team drafted an Implementation Plan which aims to (amongst others) facilitate the consultation and legal processes and implementation of the guidelines and standards.

Water quality monitoring

The monitoring of surface water resources is undertaken by the Hydrology Division in the Department of Water Affairs. There are a total of 95 active stations country-wide, although only 69 stations were operational at end of 2010/11. In addition, water levels at the Katse, Mohale and Muela Dams, as well as releases from these dams are monitored by Lesotho Highlands Development Authority. 20 key stations have been selected for reporting in the State of Water Resources Report. These stations are located at key points in the three catchments of the three main rivers, the Senqu, Mohokare and Makhaleng Rivers (The Government of the Kingdom of Lesotho, 2011).

Surface water quality is monitored by the Water Quality Division in the Department of Water Affairs. Measurements have been made for various purposes, sometimes as part of projects and as part of routine monitoring. There are as many as 152 water quality monitoring sites. However, measurements at most of these sites are rarely undertaken. Ten key sites have been selected for regular monitoring. Three sites are located on the Senqu River, four on the Mohokare River and three on the Makhaleng River. The parameters monitored are electrical EC, pH, TDS, SO4, PO4, NO3, SS, Fe, Al, Mn and F (The Government of the Kingdom of Lesotho, 2011).

Groundwater is monitored by the Groundwater Division in the Department of Water Affairs. It monitors groundwater levels at 72 observation boreholes; many of them very infrequently. A number of key observation boreholes for each of the 7 main aquifers have been selected. In future, at least quarterly readings will be carried out for these key observation boreholes. The discharges of springs are also monitored. A total of 162 springs are monitored; many of them very infrequently. Three representative springs for each of the 10 districts have been selected as key monitoring springs. In future, at least quarterly readings will be carried out for these key observation springs. The distribution of monitoring boreholes and springs is considered to be adequate. However, the frequency of monitoring is currently low due to high operational costs but a programme is being put in place to increase the frequency of monitoring of selected key boreholes and springs (The Government of the Kingdom of Lesotho, 2011).

2.4 Namibia

Institutional framework

Namibia's Water Act (Act No. 54 of 1956) controls the use and conservation of water for domestic, agricultural, urban and industrial purposes. The Water Resources Management Act 2004, that was to replace Act No. 54 of 1956, was not implemented when it was realised that certain technicalities would hamper its practical implementation. The Water Resources Management Bill to replace it has been approved by the Cabinet in 2010. The bill recognises water resources to be scarce and unevenly distributed, and the need for them to be harmoniously shared between people and the environment. It promotes integrated and sustainable management of water, and recognises the need to delegate tasks to the regional or basin level in order to involve people at local level (particularly women) in watershed management and planning.

Water quality standards / guidelines

Namibia is currently still using the water quality standards/guidelines that were in force when the country gained independence in 1990. However, new standards/guidelines for potable and effluent disposal have already been drafted for implementation with the new Water Resources Bill once it is promulgated.

The new standards/guidelines for potable water quality are very comprehensive and detailed, covering a long list of constituents and water quality indicators. Guidance regarding sampling is provided and the frequency of microbiological monitoring and sampling methodology are prescribed. Two constituent levels or ranges are given. One represents an ideal guideline value and the other an acceptable standard which should not be exceeded. The new standards for effluent disposal give values for both a Special and a General Standard. Special Standards are for use in so-called Water Controlled Areas, i.e. areas that have a high vulnerability to pollution. While, it is possible for an effluent producer to obtain an “Effluent Disposal Exemption Permit" when they cannot comply with the special standard, everyone has to comply with the General Standard.

Water quality monitoring

The Division of Hydrology in the Department of Water Affairs operates a network of 120 river flow monitoring stations. Two of these are automatic, with two more planned and a further one not yet sited. The rest have chart recorders that are serviced three-monthly. Some of the flow records date from1940, but most records date from the 1970s. The number of monitoring sites is declining. The data are stored in digital database and are provided in a variety of formats, depending on user needs, at no cost. NamWater, a government owned company responsible for bulk water supply to industry, municipalities and the Directorate of Rural Water Supply, conduct water analysis on contract for the Department of Water Affairs. The department is responsible for maintaining the database. There does not seem to be a systematic sampling programme. Data principally originates from specific projects and from compliance monitoring. The data are currently stored in a paper filing system. An electronic database is planned (FAO, 2013). A programme to monitor Orange River water quality was started in 2010. Samples are collected twice per year and analysed for physical and chemical constituents. A survey of micro-invertebrates is also conducted to determine aquatic health (Personal communication, E. Mbandeka, Water Quality Division, DWA. August 2013)

The Division of Groundwater has an electronic database on boreholes dating from the early 1980s, and mostly populated with data from a survey conducted in the 1950s and 1960s on commercial farms. It is estimated that about 60% of Namibian boreholes are recorded in this database, which has the location, depth to water and geological details. The database is not very functional, and a new one is being created. Water level is monitored in about 900 boreholes. Ninety of these have automatic (chart) recorders, while the rest are manually recorded monthly or three-monthly. In future, EC data will be collected as well. NamWater maintains a database of the amount of water extracted from production well fields under its control. The data in the database is regarded as in the public domain (FAO, 2013). A programme to identify and quantify the impacts of irrigation on the groundwater quality started in 2013. Groundwater is sampled twice per year and analysed for physical and chemical constituents as well as for inorganic fertilizers (Personal communication, E. Mbandeka, Water Quality Division, DWA. August 2013).

2.5 South Africa

Institutional framework

The National Water Act, 1998 (Act No. 36 of 1998) mandates the Minister of Water Affairs to ensure that South Africa’s water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons. In this, the Minister is supported by the Department of Water Affairs (DWA), of which the Directorate Water Quality Management and the nine Regional Offices are jointly responsible for managing water quality so as to maintain its fitness for use (DWAF, 2013). In their management of water quality DWA aim to minimise or prevent the entry of pollutants into the water environment. Striving towards this goal they follow a hierarchy of decision making which firstly aim to prevent waste production and pollution, secondly, to minimise the production of water polluting waste and thirdly, to apply the precautionary principle when disposing of waste (i.e. effluents need to comply with either the General or Special Effluent Standard and the Special Standard for Phosphate). Should these standards be insufficient to ensure the fitness for use of the receiving water environment, stricter standards are considered in accordance with a so-called differentiated approach. Relaxation from compliance with the standards is only rarely considered. The differentiated approach takes account of catchment specific conditions and includes the determination of Resource Quality Objectives (RQOs), Resource Water Quality Objectives (RWQOs) and the setting of standards that must ensure compliance to both RQOs and RWQOs. Extensive use is made of the South African Water Quality Guidelines (DWAF, 1996) for the five user sectors in setting the RWQOs (DWAF, 2013).

Water quality standards / guidelines

The South African Water Quality Guidelines (DWAF, 1996) comprise the following fresh water uses:

- Volume 1: Domestic Water Use;
- Volume 2: Recreational Water Use;
- Volume 3: Industrial Water Use;
- Volume 4: Agricultural Water Use: Irrigation;
- Volume 5: Agricultural Water Use: Livestock Watering;
- Volume 6: Agricultural Water Use: Aquaculture;
- Volume 7: Aquatic Ecosystems;
- Volume 8: Field Guide.

These guidelines are used by the DWA as its primary source of information and decision-support to judge the fitness of water for use and for other water quality management purposes. Although the guidelines contain similar information to what is available in the international literature, the information is more detailed, and not only provides information on the ideal water quality, but also provides background information to help users to make informed judgements about the fitness of water for use. The introductory chapters define some important water quality concepts, explain how the specific water use was characterised for the purpose of developing the guidelines, describe how the guidelines were developed and provide some guidance on how they should be used. The actual guidelines consist of a narrative describing the effect that successive concentrations (or levels) of different water quality constituents, will have for the specific water use. For each water quality constituent there is a No Effect Range. This is the range of concentrations (or levels) at which the presence of that constituent would have no known or anticipated adverse effect on the fitness of water for a particular use or on the protection of aquatic ecosystems. These ranges were determined by assuming long-term continuous use and incorporate a margin of safety. In the guidelines, the No Effect Range is referred to as the Target Water Quality Range. It should be noted that it specifies good or ideal water quality instead of water quality that is merely acceptable.

A Field Guide summarising the Target Water Quality Range (ideal water quality) for the different water quality constituents for the seven different uses, was also compiled for easy reference.

In addition to the Guideline for Domestic Water Use, the South African National Standards specification of water quality required for human water consumption (SANS, 2006), has become a widely used guideline for drinking water quality. Furthermore a General and Special Effluent Standard as well as a Special Standard for Phosphate effluents in specified catchments sensitive to eutrophication, that were issued under the Water Amendment Act, 1984 (Act No.96 of 1984), are still in force.

Future risk based, site-specific water quality guidelines

Emanating from an assessment of what it is expecting from water quality guidelines, DWA developed a general philosophy and drafted general specifications for revised water quality guidelines for South Africa (Murray et al, 2008). The new guidelines will differ from the existing guidelines in a number of fundamental ways. Firstly, they will be risk-based – a fundamental change in philosophy from the 1996 guidelines. Secondly, they will allow for much greater site-specificity – a widely-recognised limitation of the generic 1996 guidelines. Thirdly, they will be made available primarily in a software-based decision support system. An initiative within DWA is underway to secure approval and funding for the next phase in revising these guidelines. In their 2013 request for research projects, the South African Water Research Commission has made it known that they are willing to fund the development of risk-based water quality guidelines for agricultural water uses.

Water quality monitoring

Under the National Water Act, DWA is required to establish national monitoring networks to collect relevant information on the quality of water resources. In order to satisfy this requirement and to assist with water resource quality assessment, DWA manage and operate a number of national water quality monitoring programmes. The oldest of these is the so-called National Chemical Monitoring Programme. This programme has been in operation since the early 1970s and samples are regularly collected at approximately 1 600 monitoring stations at a frequency that varies from weekly to monthly sampling. The samples collected for this programme are analysed at the laboratories of the Directorate Resource Quality Services within the Water Resource Information Management Chief Directorate. The data from this and the following other national water quality monitoring programmes (which are of more recent origin and user-centric in design) are stored on DWA's database and information management system, called the Water Management System (WMS):

- National Microbial Monitoring Programme;
- River Health Programme;
- National Chemical Monitoring Programme (basic chemical constituents and salinity);
- National Eutrophication Monitoring Programme;
- National Radioactivity Monitoring Programme;

- National Toxicity Monitoring Programme;
- National Aquatic Ecosystem Health Monitoring Programme;
- Hydrological Monitoring Programme (establish water resource yield (quantity)).

All of these monitoring programmes were custom designed employing a "user-centric design" approach, namely, that the design starts with establishing who the primary information users are, and what their information needs are. These information needs dictate the design of the monitoring programme; starting with the information generation and dissemination function, followed by the data management and storage function and finally the data acquisition function. Processed and unprocessed data from these monitoring programmes are available on request and also by using web based information systems (DWAF, 2004(a), DWAF, 2004(b), DWA, 2013). DWA is currently in the process to develop and roll out over the next five years a National Integrated Water Information System (NIWIS) which will integrate the many disparate water information systems which are currently managed by different functional areas within the department (Nungu et al, 2012).

DWA's National Groundwater Quality Monitoring Project (NGwQMP) was started in 1994 by the then Directorate: Geohydrology to ascertain the influence of rainfall on groundwater quality and to determine the time series and spatial trends in groundwater quality on a national scale. Currently 369 monitoring points are being sampled twice a year and the analyses of macro-elements are captured on the WMS. From time to time monitoring investigations are conducted to also determine trace elements, environmental isotopes and radioactivity. Geostatistical assessments of the groundwater quality data have been completed for the periods 1999/2000 and 2007/2008. Data from the NGwQMP is currently available on DWA's WMS system and eventually environmental isotope data will also be uploaded (WMS. DWA, 2013(b)).

3. Comparative assessment and gap identification of the current institutional framework, WRQ guidelines, standards and monitoring

From the description of the current institutional framework, WRQ guidelines, standards and water resource monitoring in the Orange-Senqu basin States, it transpires that:

- Lesotho and South Africa currently have the most advanced legislation for the management of water quality. However, both Botswana and Namibia are in the process of updating their respective water acts. All four basin States thus already have, or in the near future are expected to acquire modern legislation with which to manage their water resources. Lesotho and South Africa recently revised their legislation regulating water resource management, while a new Draft Water Bill is currently under review in Botswana, while Namibia is awaiting the promulgation of their new Water Resources Management Bill. **It is thus expected that the existing gap between the basin States regarding an appropriate regulatory framework will soon be an issue of the past.**
- The legal and institutional framework of all four basin States require of them to manage and protect the quality of their water resources, and by implication also that of the Orange-Senqu basin.
- Each of the basin States has standards to regulate the quality of their drinking water.
- Each basin State also has effluent standards to define an upper threshold concentration to which effluents need to comply for disposal. A small change in concentration level to exceed the threshold will thus trigger action.
- South Africa is the only basin State that goes further than the enforcement of effluent standards to protect the quality of its water resources. This is done by setting water quality thresholds in the form of Resource Quality Objectives to which the water resource must be managed. Resource Quality Objectives are set with as aim to obtain a sustainable balance between protection, on the one hand, and water use and development, on the other. **It is likely that this gap in their water quality management toolkit, does not currently affect the effectiveness of the water quality management of other basin States, but the situation is expected to change when the anticipated increase in use and demand on water resources is realised in future.**
- Lesotho and South Africa have advanced furthest with the development of water quality guidelines for the different water uses. The Lesotho guidelines were cast in the same mould as those for South Africa. However, South Africa has developed guidelines for more water user groups than did Lesotho. **In view of the fact that Namibia currently makes only**

limited use, and Botswana makes no use of Orange-Senqu River water, this gap may for the moment be of little consequence (see next bullet).

- Botswana and Namibia have not yet developed any water quality guidelines in the sense that water quality guidelines have been defined for purposes of this document. What they refer to as guidelines are in essence standards, as have been defined for purposes of this document. **This gap in the availability of water quality guidelines between basin States may make it more difficult to reach agreement concerning the development of basin wide guidelines, or may result in other basin States taking a back seat relative to South Africa.**
- All of the current water quality standards/guidelines are spatially "generic" (i.e. they assume some kind of "average" or typical scenario and do not differ for different parts of the countries concerned). See next bullet.
- South Africa is considering upgrading their water quality guidelines to be risk based and to provide for the development of site specific guidelines. **This may create a potential future gap between basin States.**
- All of the current water quality guidelines are user and constituent specific. Any agreement in guideline concentration ranges between different users for a given constituent, are coincidental.
- None of the basin States has as yet developed water resource quality guidelines as defined in this document.
- All of the basin States have operational surface and groundwater monitoring programmes, albeit at differing complexities.
- South Africa has a sophisticated and extensive surface water quality network that, compared to the other basin States, has by far the densest network of monitoring sites, sampling for the most water quality constituents, most frequently. All aspects of Lesotho's network has improved significantly over the last couple of years, but still lags behind that of South Africa. The situation in Namibia has also improved. By far the major portion of water flowing in the Orange-Senqu basin originates in Lesotho and South Africa (and is currently primarily utilised by South Africa). **Since these two states are also furthest advanced regarding their surface water quality monitoring networks, they can be expected to make the major contribution to the development of a basin-wide water resources monitoring system.**
- Analytical capacity appear to be a problem in all basin States, but less so in South Africa. **Quality assurance and control (QA/QC) also need to be enhanced, while the introduction of an inter-laboratory comparative testing scheme can be expected to increase the confidence of basin States in the quality of each other's analytical results.**

- South Africa is the only basin State that adopted a user-centric approach towards the design of monitoring programmes; i.e. to provide water resource managers, planners and other stakeholders with the specific management information about water resource quality they require, rather than to report to them on the constituents that is being measured as part of the monitoring programme. **This represents an important gap with the other basin States since when volumes of data appears to find little application in water resource management and do not satisfy the needs of important stakeholders, the rationale for continuing with costly monitoring programmes may be questioned. The establishment of a basin-wide WRQ monitoring network presents an opportunity to incorporate the user-centric approach into its design.**
- All basin States appear to have functioning databases, or are in the process of developing suitable databases for storage of water quality monitoring data. South Africa has developed an advanced capacity to process stored data and to generate and disseminate useful information. Monitoring data collected by the South African DWA are freely available on request and through the internet. Monitoring stations can be identified and accessed using Google Earth.
- Lesotho and South Africa have done most regarding the generation and dissemination of information based on their WRQ monitoring networks. The Government of the Kingdom of Lesotho, 2012, recently published its first annual state of water resources report for the period March 2010 to April 2011, while South Africa has published several reports on the state of its water quality and also make the information available on the internet.

4. Key components of harmonised basin-wide WRQ guidelines

A key decision has to be made about whether the needs of ORASECOM will be better served by using a monitoring system based on the reporting of WRQ problems (e.g. salinity, eutrophication, microbial contamination) or by using a monitoring system based on the reporting of specific WRQ constituents (e.g. electrical conductivity, phosphorous, E. coli). Since the basin-wide WRQ monitoring system and associated WRQ guidelines, need to be in harmony with each other, this decision will have defining implications for both of them. Although making this decision up front would simplify the key components that need to be considered in the development of WRQ guidelines and a monitoring system, this decision is left to ORASECOM. In discussing the key components of developing WRQ guidelines and a monitoring system, some of the implications associated with both a problem orientated and a constituent orientated approach, are pointed out.

Whereas Chapters 2 and 3 deal with a comparative assessment of the current situation regarding the availability and application of water quality guidelines and monitoring in the Orange-Senqu Basin States, the following chapters will attempt to identify:

- The key components of harmonised basin-wide WRQ guidelines (Chapter 4);
- The key components of a basin-wide WRQ monitoring system (Chapter 5); and
- An outline of key activities that are required to establish such a regime (Chapter 6).

While the issues in Chapters 4 to 5 are conceptually split into a number of sections, these sections need to be considered as an integrated whole, where a change in one may affect another. A successful end-product will be the result of an iterative process aimed at an optimised outcome. In Chapters 4 and 5 alternative approaches and their implications are discussed, while Chapter 6 identify the specific decisions and choices that have to be made in order to progress towards the design of a basin-wide WRQ monitoring system and complementing (harmonised) basin-wide WRQ guidelines.

4.1 Decide whether to use a user or problem orientated approach to the development of WRQ guidelines

The quality of water can be evaluated from at least two cross-cutting perspectives, namely from the perspective of a potential user of the water (e.g. an irrigator, an industrialist or a person who wish to drink it) or from the perspective of the quality problem manifested by the water (e.g. the water is saline, eutrophic or microbially contaminated). A guideline is developed to address one of these approaches. Choosing between these alternatives is thus a key decision, affecting not only the use that can be made of the guidelines but also its format and much of its look and feel. However, it is important to note that the guidelines developed using either of these approaches will be based on the same scientific information. The choice between the two alternatives approaches to guideline development is largely determined by design of the WRQ monitoring system it must serve.

Lesotho and South Africa developed water quality guidelines from a user perspective. This makes sense since the guidelines are used to provide the water resource manager with information about how different water users will be affected by a given concentration of a specific water constituent. Should it be decided to base the ORASECOM guidelines on the user orientated approach, the water quality guidelines developed by Lesotho and South Africa should serve as a valuable resource. ORASECOM, 2009(a) demonstrated the feasibility of using user orientated guidelines to assess WRQ at the basin level for the Orange-Senqu basin. However, this assessment had to limit the assessment to only a few water quality constituents and still produced rather complex reporting tables that are not very user friendly.

South Africa followed the problem orientated approach when they established monitoring networks to generate the information required for reporting on the quality of water resources from a national perspective (see water quality monitoring under 2.4). Should it be decided to follow the problem orientated approach for WRQ guideline development, much can be learned from the South African experience and about how reporting can be done. However, selecting the problem orientated approach will require that the currently existing guidelines be rewritten into another format.

4.2 Identify the users or issues of concern for which guidelines need to be developed

The decision made under 4.1 will have the unavoidable implication that WRQ guidelines need to be developed either for the potential water user groups/sectors in the Orange-Senqu basin or for the most prominent water quality problems that are experienced or expected in the basin.

Should the user orientated approach be used, the user groups identified by Lesotho and South Africa during their development of water quality guidelines should serve as a valuable resource. Should Lesotho and South Africa agree, water quality guidelines for the Orange-Senqu basin could be prepared largely by cutting and pasting relevant portions from the current Lesotho and South African guidelines.

Should the problem orientated (issues of concern) approach be selected, the information contained in the Lesotho and South African guidelines should still serve as a valuable resource, but in this case the information will need to be re-arranged. For example; the severity of the eutrophication problem may be reported as waters experiencing increasing levels of Chlorophyll a. The guidelines will need to indicate how the different users (e.g. an irrigator, an industrialist or an institution treating water for drinking) are affected by successive Chlorophyll a concentration ranges.

4.3 Establish which questions the monitoring programme should answer and the guidance regarding their interpretation that will be provided by the guidelines

In line with a user-centric approach to the design of monitoring programmes, it is important to learn from potential users of the monitoring network which questions they would like to be answered by the monitoring programme. It would be expected of the guidelines to provide guidance regarding the interpretation of monitoring results. Possible questions that the monitoring system would be expected to answers are:

- What is the status or level of the water quality problem (be it e.g. eutrophication, microbial organisms, salinity) in the river basin and at specific points; and how serious are the implications. (The guidelines should e.g. provide concentration ranges and the likely effect thereof for different user groups.)
- Is the seriousness of the water quality problem increasing or decreasing over time.
- How frequently is a trigger value, such as the No Effect Range of the guidelines, or a resource water quality objective, exceeded..
- How successful was management initiatives to affect the status of the water quality issue? (because of lags in the system this can sometimes take very long).

4.4 Supplementary issues that should form part of the WRQ guidelines

In addition to the above-mentioned considerations that will determine the approach to guideline development and the water quality concerns that should be addressed, it is proposed that a number of supplementary issues also be addressed to provide the potential user with valuable supporting information.

- By way of introduction the guideline document should provide background to the basin-wide monitoring system and how the WRQ guidelines are adding value to it and its products.
- Also in the introductory chapters, the guideline document should discuss important water quality concepts that should be understood in order to use the guideline document optimally.
- Background should be provided concerning the development of the guidelines and guidance given on its use.
- The guidelines should be based on local and international literature and as far as possible be in harmony with the water quality guidelines in use in the different Orange-Senqu basin States.
- The rationale for the inclusion of each of the water quality constituents/indicators should be given.

- For each water quality constituent/indicator a No Effect Range should be identified where no user sector will be affected. Meaningful successively higher concentration ranges should be identified and the effect on user sectors associated with these ranges should be explained. Preferably the threshold, above which the water becomes unacceptable to all users, should also be identified.

5. Key components of a basin-wide WRQ monitoring system

WRQ is an all-embracing description of the water resource's quality through a combination of all its physical, chemical, biological and ecological characteristics. It is important to recognise that no single monitoring system can lead to a comprehensive expression of WRQ. It is thus necessary to implement and maintain different monitoring systems to provide information on different aspects of WRQ.

The phrase WRQ monitoring is often misunderstood to refer only to the collection and storage of data related to the quality of water resources. These activities generate large volumes of data that often do not find the expected application in practice; most likely because in practice the data base proofs to be "data rich but information poor". The recognition of this shortcoming led to a fundamental re-evaluation of the rationale with WRQ monitoring, and the design of monitoring systems (programmes) in several countries (including South Africa). The outcome of this re-evaluation was the implementation of a user-centric approach to the design of monitoring systems. As a result the purpose of monitoring was redefined as **delivering the management information about water resource quality they require, to water resource managers, planners and other stakeholders**. Whereas Data Acquisition and Data Management and Storage was previously viewed as the two main components in the design of WRQ monitoring systems, Information Generation and Dissemination was now added as a third (DWAF, 2004(a)). This third component actually became the determining factor guiding the design of the rest of a WRQ monitoring system.

Against this background DWAF, 2004(a) identified the following phases as part of a design framework to develop a WRQ monitoring system. It is proposed that this would also apply to the design of a basin wide WRQ monitoring system for the Orange-Senqu basin, except that most of the issues under Phase 2 will not be applicable because the Orange-Senqu monitoring system is expected to make use of data collected by basin States from their existing monitoring networks. However, the sampling sites that will be selected and the WRQ constituents that will be used will largely be determined by the outcome of Phase 1 (which WRQ are the end users interested in and in which format do they require the information).

Phase 1: Information generation and dissemination

Step 1: Identify the primary users of the information

Step 2: Identify the information products required by the primary information users

Step 3: Design the information generation protocols

Phase 2: Design the monitoring network

Issue 1: Select and finalise the water resource quality constituents to be included in the monitoring programme based on the following considerations:

- Exactly which information is needed;
- Significance of physical processes in affecting constituents;
- Relationships between constituents may reduce need to analyse for all of them;
- Logistics / feasibility of data acquisition;
- Institutional and statutory considerations;
- Financial implications;
- Continuity of records.

Issue 2: Selecting the data acquisition (sampling) sites

- Macro scale location of data acquisition stations
- The micro-scale location of the data acquisition (sampling) points

Issue 3: Frequency of data acquisition (sampling frequency)

Phase 3: Design the operational requirements for the monitoring system

Component 1: Information generation and dissemination;

Component 2: Data management and storage;

Component 3: Data acquisition, quality control and assurance.

In the design of a WRQ monitoring system for the Orange-Senqu basin it could pragmatically be assumed that the Orange-Senqu monitoring system will make use of data collected by basin States from their existing operational monitoring networks. The Orange-Senqu monitoring system should thus largely be designed around the current monitoring sites and data that are currently collected. Much attention should thus be devoted to the abovementioned Phase 1, since its outcome will largely determine the choices that will be required during Phase 2. Phase 3 will again require considerable input and decision making.

Orasecom, 2009 outlines a framework for WRQ monitoring of the Orange-Senqu River basin that maintains appropriate sovereignty of the Member States, is consistent with the resource constraints in the Member States, and that recognises their commitment to cooperate and share skills and best practices. The framework makes use of current national monitoring locations and will initially exclude the Vaal River basin. Six monitoring sites have been identified in the upper Orange-Senqu catchment and five in the lower Orange River catchment on the Namibian-South African border. An initial set of priority monitoring constituents has been identified for each of the proposed monitoring sites. Initial Trigger Values have been proposed for each of the proposed constituents at each of the monitoring sites. Proposals are further made for improved quality control and assurance. Alternative options from which ORASECOM are expected to select its preference, have been identified regarding management arrangements, the monitoring network, constituents to monitor, a quality control and assurance system, trigger values and data management.

Although only a relatively small number of WRQ constituents are proposed for initial inclusion, the proposed framework represents a good start and is considered to be practical and executable. This proposal represents the more traditional approach to WRQ monitoring network design, namely to monitor the concentrations of primarily chemical constituents and interpret the effect they will have on different users as a result of observed concentrations.

The author would like to propose an alternative approach for consideration by ORASECOM, namely to use the information generated by the South African National WRQ Monitoring Programmes (DWA, 2013(c)), for the development of its basin wide WRQ monitoring system. These Programmes were specifically designed to assess the status and trends of a number of pertinent WRQ problems (See water quality monitoring under 2.4). The attractiveness of this option is further enhanced by the fact that there is considerable overlap between the WRQ problems being addressed by the South African National WRQ Monitoring Programmes and the water quality problems that were identified by ORASECOM, 2008 (see Table below). Furthermore, the report that was commissioned to design an ecosystem health monitoring programme for the Orange-Senqu basin (ORASECOM, 2009 (c)) also recommended that the ORASECOM programme be constituted by using data from the South African and Lesotho equivalent programmes (along similar lines as proposed by the author).

Comparison of South African National WRQ Monitoring Programmes and Water Quality Problems identified by ORASECOM	
South African national programmes*	**ORASECOM water quality problems****
National Microbial Monitoring Programme	Microbial organisms and water borne pathogens
River Health Programme	No equivalent
National Chemical Monitoring Programme (basic chemical constituents and salinity)	Salinity
National Eutrophication Monitoring Programme	Eutrophication
National Radioactivity Monitoring Programme	Radio-nuclides
National Toxicity Monitoring Programme	Heavy metals
National Aquatic Ecosystem Health Monitoring Programme	No equivalent
Hydrological Monitoring Programme (establish water resource yield (quantity))	No equivalent
No equivalent	Persistent organic pollutants (POPs)
No equivalent	Temperature

* DWA, 2013(c)

** ORASECOM, 2008

6. Key activities required to establish a basin-wide monitoring system

Chapters 4 and 5 identified the key components of basin-wide WRQ guidelines and of a basin-wide WRQ monitoring system. The components and related information that are presented in Chapters 4 and 5 provide for alternative approaches and choices from which one or more should be selected on the road leading to the establishment of the guidelines and monitoring system. These choices should be made in a way that ensure that the structure and output from the monitoring system on the one hand and the structure of the guidelines, on the other hand, are fully compatible and in harmony with each other. It should thus be easy for a user to use the guidelines to interpret the seriousness of a problem/constituent from the output reported by the monitoring system. The key activities and decisions that need to be made in order to ensure the successful establishment of a basin-wide monitoring system and guidelines are listed below:

i. Consult with the primary users of the information emanating from the monitoring programme (representatives from each basin State) to identify the information products they require. This will be determined by the management decisions or actions that they are required to take, where these decisions are influenced by WRQ related information. They may e.g. require a common basis which is accepted and trusted by all basin countries:

   a. That reports the level and provides an assessment of the implications thereof, for a range of WRQ problems (e.g. salinity, eutrophication, microbial contamination) or specific WRQ constituents (e.g. electrical conductivity, phosphorous, E. coli) at strategic locations in the Orange-Senqu River System. This information may aid a water resource manager with a decision to introduce special source directed control measures that are indicated to reduce microbial contamination to acceptable limits.

   b. That enable the detection of spatial and temporal trends and that would report on these trends for a range of WRQ problems or specific WRQ constituents. This information may aid a water resource manager with a decision to timeously introduce special source directed control measures to ensure that a critical eutrophication level is not exceeded.

   c. That enables the detection of the effectiveness of a management initiative that was aimed at affecting the status of a water quality problem.

ii. Design the information products that were identified by the primary users, produce a mock up of the information product to make sure it meets with their requirements and confirm that it would be possible to generate the product by using the data that will be collected as part of the planned WRQ monitoring system.

iii. Consult with the primary users and other decision makers in order to decide whether their needs can be better served by using a monitoring system based on the reporting of WRQ problems (e.g. salinity, eutrophication, microbial contamination as in the National Programmes of the South African Directorate Resource Quality Services) or by using a monitoring system based on the reporting of specific WRQ constituents (e.g. electrical conductivity, phosphorous, E. coli). This decision is a fairly early Key Activity since a number of other aspects depend on the choice that is made. In order to reduce repetition, in the rest of the document it will be assumed that the decision will be to base the monitoring system on WRQ problems. However, should the decision be to base the monitoring system on WRQ constituents, the reader is requested to substitute the one to mean the equivalent of the other within context.

iv. Consider and finalise the selection of WRQ problems that will be included in the monitoring system. This decision will be largely determined by the WRQ problems that are of operational concern to the primary users of the information, as well as by their strategic considerations. In the case where WRQ problems were selected in iii, the individual WRQ constituents used as indicators of the problem have already been identified as part of the design of the relevant national programme. However, if specific constituents were selected in iii, the list of specific constituents are not preselected and a process will have to be developed to reach consensus about the final list of specific constituents to include in the monitoring system.

v. Provided the monitoring system will be based on WRQ problems, it may not be necessary to select suitable monitoring sites for the South African portion of the Orange-Senqu basin, as suitable sites have already been selected as part of South Africa's National Programmes initiative. However, the appropriateness of this selection will have to be confirmed with other basin States and it may be found necessary to include additional monitoring sites. Similar suitable sites for which the required constituent analyses are available, will have to be identified in Lesotho and possibly Naminbia for each of the selected WRQ problems.

vi. Provided the monitoring system will be based on WRQ problems, it may not be necessary to select suitable sampling frequencies for each of the WRQ problems that will form part of the monitoring system. The optimum sampling frequency for each WRQ problem have already been identified and incorporated into the sampling programme as part of South Africa's National Programmes initiative. However, the acceptability of the sampling frequency will have to be confirmed with other basin States. It will have to be ascertained whether suitable sites at which the required constituents are analysed at the required frequency, are available in Lesotho and possibly Naminbia, for each of the selected WRQ problems. If not, it will have to be determined whether additional sampling sites can be introduced.

vii. Since the monitoring system will make use primarily of data generated by the basin States for their own monitoring purposes, it is necessary to formalise arrangements for making the data available to ORASECOM.

viii. In order to ensure that basin States accept and trust the data in the data base it is necessary that the basin States agree on quality assurance/ quality control protocols regarding the sampling procedures, sample transport, preservation, analyses and data storage. It is also advisable that an inter-laboratory comparative testing scheme be introduced.

ix. A decision by the basin States are required regarding who will take responsibility for developing, hosting and maintaining the database of the WRQ monitoring system. This institution should also manage, prepare and distribute the WRQ status and trend reports and manage access to the database by basin States and interested individuals.

x. Since the WRQ monitoring system will be based on WRQ problems, it is logical that the development of WRQ guidelines should follow the same approach and develop guidelines that describe the effect that the different water users in the Orange-Senqu basin will experience when they use water affected by the most prominent water quality problems.

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