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Consolidation of Knowledge of Water Quality

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

2014

Report No. ORASECOM 017/2014

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Support to Phase 3 of the ORASECOM Basin-wide integrated Water Resources Management Plan

Consolidation of Knowledge of Water Quality

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

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CONSOLIDATION OF KNOWLEDGE OF WATER QUALITY

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

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1. Introduction

As part of the ORASECOM planning programme, Phase III, this current phase builds on the previous two phases towards the development of a basin-wide Integrated Water Resources Management (IWRM) Plan. The IWRM plan will include an implementation plan and identified activities that will be implemented by all parties through various processes. The development of the IWRM plan comprises 5 work packages. Work package 4 of the development process focuses on consolidating previous work and filling in gaps where necessary.

Work package 4 comprises the following sub-work packages, effectively the technical studies component of the Phase III work.

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

Consolidation of the available knowledge on water quality assessments forms one sub-component of this package Work Package 4e, which is the focus of this report. The water quality information generated from this consolidation will be used to support the conducting of an economic analysis of water use and to support the water resource modelling to be undertaken as part of the plan development. These Sub-Work Packages are critical to finalising the inputs required for the drafting of the IWRM Plan.

1.1 Water Quality

"Water quality" is a term used to express the suitability of water to sustain various uses or processes. Any particular use will have certain requirements for the physical, chemical or biological characteristics of water; for example limits on the concentrations of toxic substances for drinking water use, or restrictions on temperature and pH ranges for water supporting invertebrate communities. Consequently, water quality can be defined by a range of variables which limit water use by comparing the physical and chemical characteristics of a water sample with water quality guidelines or standards. Although many uses have some common requirements for certain variables, each use will have its own demands and influences on water quality (UNEP/WHO, 1996).

Quantity and quality demands of different users will not always be compatible, and the activities of one user may restrict the activities of another, either by demanding water of a quality outside the range required by the other user or by lowering quality during use of the water (e.g. discharges). Efforts to improve or maintain a certain water quality often compromise between the quality and quantity demands of different users.

The composition of surface and groundwater is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with seasonal differences in runoff volumes, weather conditions and water levels. Large natural variations in water quality may, therefore, be observed even where only a single water resource is involved. Human intervention also has significant effects on water quality. Some of these effects are the result of hydrological changes, such as the building of dams, draining of wetlands and diversion of flow. More obvious are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the water resource (whether intentional or accidental) and the spreading of chemicals on agricultural land in the drainage basin. A single influence (e.g. faecal pollution, eutrophication or diffuse pollution) may give rise to a number of water quality problems, just as a problem may have a number of contributing influences.

Water quality is neither a static condition of a system, nor can it be defined by the measurement of only one parameter. Rather, it is variable in both time and space and requires routine monitoring to detect spatial patterns and changes over time.

Water quality management is the process of administering and controlling the physical, chemical, toxicological, biological (including microbiological) and aesthetic properties of the water in water resources that determine sustained (1) healthy functioning of aquatic ecosystems; and (2) fitness for use (e.g. domestic, recreational, agricultural and industrial).

The water quality in the Orange-Senqu Basin is highly variable due to a combination of natural factors such as rainfall, evaporation, geology and soils, and anthropogenic factors which cause man-made changes to the chemistry of the rivers in the basin. In the case of the Orange-Senqu River, natural factors play a major role in determining water quality due to the size and extent of the catchment, stretching across several topographical, geological and climatic zones.

Against this natural variability in water chemistry, there are significant anthropogenic sources of pollution in the basin, particularly in the Vaal catchment. This catchment includes the main urban and industrial conurbations of South Africa, the main gold mining areas of the country, parts of the Highveld coal fields, some of the country's power stations and significant areas of dryland and irrigation agriculture. The Orange River catchment as a whole is less developed, although irrigation agriculture occurs extensively along the river downstream of Vanderkloof Dam (UNDP/GEF, 2008).

1.2 Objective of the Report

The main objective of this work sub-package (4e) was to:

- provide a consolidation of the state of knowledge on water quality in the Orange-Senqu Basin, and
- Provide recommendations on water quality related actions for the development of the IWRM plan.

1.3 Structure of the Report

The report structure comprises the following:

- Section 1: Introduction
- Section 2: Review of available information on water quality
- Section 3: Interpretation and conclusions of the results to provide a perspective on water quality status in the basin;
- Section 4: Identification of potential water quality implementation actions and activities required to be included in the IWRM plan.

2. Review of available information

2.1 Introduction

A number of studies and data sources are relevant to water quality in the Orange-Senqu Basin. A desk top survey identifying the available water quality information was undertaken as part of this study. Some of the studies do not solely address water quality but have sections which deal with water quality. The list of the key studies identified is given in Annex 1. The findings of these key studies are presented in the Sections below.

2.2 Orange Senqu-River Basin Preliminary Transboundary Diagnostic Analysis

The Transboundary Diagnostic Analysis (TDA) of the Orange-Senqu basin and Strategic Action plan was an initiative undertaken by the four member Orange-Senqu Basin states, with the support of the UNDP-GEF. The TDA was completed in 2008 and focused on comprehensively evaluating the degree of ongoing degradation of the Orange Senqu basin with aim of formulating an action plan to manage, institute corrective actions and reverse damaging trends where necessary. The approach was an integrated inter-country effort and consisted of the following:

- Identification and initial prioritisation of transboundary problems;
- Gathering and interpreting information on environmental impacts and socio-economic consequences of each problem;
- Causal chain analysis (including root causes) and
- Completion of an analysis of institutions, laws, policies and projected investments.

The TDA focused on transboundary problems with consideration of national concerns and priorities and identified information gaps, policy distortions and institutional deficiencies. The analysis is cross-sectoral and examines national economic development plans, civil society (including private sector) awareness and participation, the regulatory and institutional framework and sectoral economic policies and practices. The findings of the TDA were to feed into the development of a Strategic Action Programme.

2.2.1 Main activities

The main activities of the TDA methodology included:

- Identification of the priority transboundary issues. Five major transboundary issues in the Orange-Senqu Basin were identified as priority concern and required further detailed analysis;
- The development of Thematic Reports. Thematic Reports were drafted for these five priority transboundary problems of which deteriorating water quality (surface and groundwater) was one of them. The thematic reports constituted the main sources of information for the TDA.

- Development of causal chains for the priority transboundary problems. Once the priority transboundary issue was analysed a causal chain was developed for it. The aim of the causal chain was to link the sectors and causes of the transboundary problem with the impacts of the problem.
- A Stakeholder analysis component. The TDA was supported by a stakeholder analysis which included interviews/ surveys with 36 stakeholder groups from the basin countries. Water quality was also raised by the stakeholders as a major issue.
- Recommendations and conclusions were formulated based on the key findings of the analyses.

2.2.2 Outputs

The output of the TDA was the following:

Tableau 2-1 : Output of the Transboundary Diagnostic Analysis

Title	Type1	ORASECOM Report No.	Output summary details
Orange Senqu-River Basin. Preliminary Transboundary Diagnostic Analysis. Adopted by ORASECOM in April 2008	Main Report		Report details the key transboundary issues of the Orange-Senqu basins, provides an analysis of these issues, documents the findings in terms of the causal chain analysis and looks at knowledge gaps. The TDA proposes the conclusions and recommendations and potential short to medium term Strategic Action Programme Interventions.

2.2.2.1 Summary of Findings

The key findings of the water quality studies were as follows ((ORASECOM, 2008):

- There are concerns along all the rivers which flow through towns and villages throughout the catchment regarding localized microbiological pollution from untreated and partially treated sewage entering the rivers;
- The Vaal catchment is highly polluted which has implications for water resource availability and transboundary impacts. The water quality of the Upper and Lower Orange is said to be good however there are insufficient data for certain categories of contaminants to make any conclusive statements.
- The increase in Total Dissolved Solids (TDS) in the Vaal and Lower Orange catchments and the concomitant increase in constituents such as chloride and sulphate, has had major implications for domestic, industrial and agricultural water use;
- The transboundary impacts of persistent organic pollutants (POPs), heavy metals and radio-nuclides are unknown due to a lack of monitoring data and detailed studies, but some level of transboundary transfer of these pollutants is suspected;
- Eutrophication is a severe problem in the Vaal catchment and in isolated pockets in other parts of the Basin. Localised eutrophication and microbial pollution is known along the Caledon River, along the Orange River downstream of Lesotho and downstream of the Upington irrigation area to Namibia. However, there is insufficient information to determine the transboundary extent of this pollution;

- Water quality monitoring networks are poorly developed in Lesotho and Namibia. Analyses are confined to basic parameters such as pH, TDS and common anions and cations. Microbiological analysis is carried out in Lesotho;
- South Africa has a sophisticated and extensive monitoring system although there are a number of deficiencies in the data sets available, particularly along the Lower Orange River.

The key recommendations and conclusions of the water quality studies were as follows:

- Establish basin-wide Receiving Water Quality Objectives (RWQOs) and agree and develop sectoral short- and medium-term targets to meet the objectives. RWQOs were being set in isolation in priority catchments; whilst integration of the RWQOs for the Vaal River was addressed in the Integrated Water Quality Management Plan (IWQMP) that was developed by the South African DWA, there are no objectives agreed for the whole of the Orange-Senqu basin.
- Undertake a water quality assessment of the major aquifers in the basin. There are concerns regarding the quality of groundwater resources and their protection, however there is insufficient data to make any conclusive statements in this regard;
- Improve compliance monitoring and enforcement in all four countries. Lack of institutional capacity to effectively manage water quality in their respective countries is a major constraint;
- Improve the water quality monitoring network throughout the region. In Lesotho and Namibia, the water quality monitoring networks are poorly developed and there are no formal sampling networks or water quality databases. South Africa has a more sophisticated and extensive monitoring system, but there are still a number of deficiencies in the data sets, the extent of the network – especially along the Lower Orange and in some of the more polluted sub-catchments of the Vaal River.
- Undertake an assessment of Persistent Organic Pollutants (POPs), heavy metals and radio-nuclides in the Vaal and Lower Orange catchments for which there is a general lack of information in the catchment.

2.3 ORANGE SENQU-RIVER BASIN TRANSBOUNDARY DIAGNOSTIC ANALYSIS: FINAL DRAFT

The main purpose of the final draft transboundary diagnostic analysis (TDA) was to provide a scientific and technical basis for the identification and prioritisation of key issues concerning the degradation of aquatic ecosystems in the Orange–Senqu River Basin. It was intended as a decision-support tool for the Orange–Senqu Basin States and stakeholders to identify areas of future action to address key issues.

During the development of a preliminary TDA (ORASECOM, 2008) (described in section 2.2), extensive intersectoral discussions involving all four basin states identified the priority transboundary issues as:

- Stress on surface and groundwater resources;
- Altered water flow regime;
- Deteriorating water quality;
- Land degradation; and
- Spread of alien invasive plants and animals.

Building on the results and recommendations of the preliminary TDA, a number of studies were carried out, the information and findings which are included in the final draft TDA.

2.3.1 Main activities

The five main steps in the TDA process can be summarised as:

- Identification and initial prioritisation of transboundary problems;
- Production of the preliminary tda through gathering and interpreting information on environmental impacts and socio-economic consequences of each problem and developing preliminary causal chain analyses;
- Filling in knowledge gaps and initiating pilot projects to address issues following recommendations of the preliminary tda;
- Reworking the ccas in the light of new information and identifying points of intervention; and
- Review and validation.

2.3.2 Outputs

The output of the final draft TDA (ORASECOM, 2013) was the following:

Table 2-2 : Output of the Final Draft Transboundary Diagnostic Analysis

Title	Type1	ORASECOM Report No.	Output summary details
Orange Senqu-River Basin Transboundary Diagnostic Analysis: Final Draft Adopted by ORASECOM in April 2013	Main Report	Report 2013/004	To provide a scientific and technical basis for the identification and prioritisation of key issues concerning the degradation of aquatic ecosystems in the Orange–Senqu River Basin. It is intended as a decision-support tool for the Orange–Senqu Basin States and stakeholders to identify areas of future action to address key issues.

2.3.2.1 Summary of Findings

Water quality was not identified as an urgent issue in Botswana or Lesotho. However the current relatively good water quality needs to be maintained and concerns that do exist need to be addressed. Key water quality issues identified are listed below.

- The Caledon River in Lesotho has been identified as having high turbidity at high flow and high salinity (attributed to the textile industry) at low flow. Industrial wastewater from the textile industry is one of the major concerns in Lesotho, as well as solid waste and oil disposals and the potential effect of emerging diamond mines. This is especially in the light of relatively weak control measures and regulation;
- The impact of sand mining on river morphology is also recognised as affecting water quality;
- Waste disposal in urban centres, especially high-growth centres such as Qeme, and cultivated fields in the lowlands, near rivers that use outdated agricultural technologies such as dipping tanks, are also negatively affecting water quality in Lesotho;
- In Botswana, cattle kraals, poorly managed watering points and inadequate sanitation facilities in settlement areas pose a threat to vulnerable groundwater sources;
- Groundwater pollution is a concern in Namibia. There is a need to raise awareness among community members on potential pollution threats to groundwater sources and how to avoid contamination.
- Other problems in Namibia include return flows from irrigation schemes, sewage contamination of local water sources at many settlements and the lack of decommissioning plans for some mining operations.

South Africa however has the greatest problem due to being more industrialised and having high population pressure. Eight severe problems were identified in the basin:

- Acid mine drainage in the upper and, potentially, in the middle Vaal sub-basins;
- Microbial pollution, for example at the Vaal Barrage, and blue-green algal blooms;
- Inadequate sanitation services, non-functioning domestic wastewater treatment works, raw sewage inflows and other waste management threats to surface and subsurface resources related to human settlement;
- High concentration of POPs at Bloemhof Dam and Barberspan, and leaching of agrochemicals generally;
- Habitat loss and environmental degradation of the estuary;
- Alluvial mining of diamonds and sand extraction (often illegal, always uncontrolled) in the middle and lower Orange between Warrenton and Douglas and Windsorton and Prieska;
- Current poor groundwater quality, for example in isolated places around Pofadder and de Aar; and
- The potential threat to groundwater sources from hydrological fracking.

In summary, key elements related to declining water quality therefore included:

- Eutrophication;
- Increased salinity and sodicity of soils and water;
- Localised hotspots of heavy metals, POPs and PAHs;
- Acid mine drainage;
- Increasing concentrations of drug remnants;
- Inadequate systematic monitoring of surface and subsurface water quality;
- Inadequate enforcement of compliance to water quality standards and implementation of corrective action;
- High cost of appropriate pollution control;
- Lack of knowledge, capacity and awareness related to pollutants and appropriate measures to deal with them;
- Increased costs related to water treatment;
- Health risks; and
- Lack of a basin-wide pollution incident warning system.

2. REVIEW OF AVAILABLE INFORMATION

In line with the preliminary TDA recommendations, the key recommendations and conclusions of the water quality studies from the final draft TDA are as follows for the short and medium term actions and in the long term to follow through on these actions.

SHORT TERM:

- Upgrade irrigation scheme infrastructure;
- Upgrade sewerage infrastructure to cope with appropriate volumes of water;
- Improve plant operation and maintenance;
- Reduce leakages by maintenance of water infrastructure;
- Water conservation and demand management at municipal level;
- Provide capacity building, skills training and awareness raising on key pollution issues;
- Monitor pollutants in water and sediments, including heavy metals and agrochemicals;
- Monitor suspended sediment in water especially in the lower Orange and Fish;
- Establish basin-wide receiving water quality (RWQ) objectives and monitoring system;
- Enforce compliance, implement corrective action and 'polluter pays' principle;
- Develop best practice guidelines for mine closure;
- Enforce implementation of decommissioning plans for mine closure;
- Include cost of implementation of environmental management and closure plans into feasibility studies;
- Pilot treatment of acid mine drainage;
- Raise awareness among small-scale farmers and create incentives for large-scale farmers to reduce excess agrochemical applications;
- Move from dipping livestock to injecting;
- Research and explore options for pre-treatment of agricultural return flows;
- Develop skills of, and incentives for, farmers to implement best practices;
- Research emerging pollutants and pollution issues such as POPs and pharmaceuticals;
- Research and determine irrigation capacity of the basin;
- Research the impact of groundwater abstraction on water quality and recharge;
- Implement longer-term natural methods for remediation such as phyto-remediation of tailings and storage dams;
- Establish a basin-wide accident and pollution warning system;
- Research effects of acid rain; and
- Research payment for ecosystem services.

MEDIUM TERM:

- Follow through short-term interventions;
- Implement environmental flow requirements;
- Increase human resources and capacity in all departments responsible for water pollution control;
- Establish an effective and coordinated monitoring network and reporting;
- Treat acid mine drainage;
- Install sewerage infrastructure or other appropriate technologies such as constructed wetlands (phyto-remediation); and
- Analyse and model long-term sediment yield and loads and develop an understanding of fluvial morphology processes

2.4 NATIONAL ACTION PLANS

The National Action Plans (NAP) are strategic implementation plans to address priority environmental concerns in specific parts of the Orange–Senqu River basin. The NAPs are based on an assessment of the priority environmental concerns as identified by the Orange–Senqu Transboundary Diagnostic Analysis (TDA) which is a scientific and technical assessment of the priority environmental concerns and shared management issues in the basin. For the priority issues, the analysis identifies the scale and distribution of the environmental and socio-economic impacts at national and basin levels, and, through an analysis of the root causes, identifies potential remedial and/or preventative actions.

The NAPs are endorsed at political level and closely linked to the Orange–Senqu Strategic Action Programme (SAP), a programme addressing priority environmental concerns at the basin-wide level and which is taken from the TDA report. The NAPs were developed through intensive stakeholder consultation processes involving inter-sectoral dialogue to achieve integration in water resources management and, most importantly, national endorsement of the NAP which is structured around the four environmental priority areas of concern identified in the TDA – increasing water demand, changes to water quality, changes to the hydrological regime and land degradation.

In this respect, the overall objective of the NAP is to identify actions and activities with a view to resolving the problems and threats to the integrity of the river basin, at national level, in order to promote sustainable management and development of the Orange–Senqu River basin. This overall objective will be achieved through a set of four thematic areas, in line with the priority areas identified by the TDA process, which include:

- *Thematic area 1:* Increasing water demand;
- *Thematic area 2:* Declining water resources quality;
- *Thematic area 3:* Land degradation; and
- *Thematic area 4:* Sustainable natural resources use practices for livelihoods improvements.

2.4.1 Outputs

The outputs of the National Action Plans are the following documents:

Table 2-1: Outputs of the National Action Plans

Title	Type1	ORASECOM Report No.	Output summary details
National Action Plan for the Orange-Senqu Basin in Botswana	Technical Report	**Technical Report 039/2014**	National Action Plans (NAP) are strategic implementation plans to address priority environmental concerns in specific parts of the Orange–Senqu River Basin. The NAPs are closely related to the basin-wide Orange–Senqu Integrated Water Resources Management (IWRM) plan, together forming the environmental component of the IWRM plan. The NAPs and SAP, like the IWRM plan, are developed for a 10-year planning time span with targets set for that period.
National Action Plan for the Orange-Senqu Basin in Lesotho	Technical Report	**Technical Report 040/2014**	
National Action Plan for the Orange-Senqu Basin in Namibia	Technical Report	**Technical Report 041/2014**	
National Action Plan for the Orange-Senqu Basin in South Africa	Technical Report	**Technical Report 042/2014**	

2.4.2 NAP for the Orange-Senqu River Basin in Botswana

Botswana is currently undergoing the National Development Plan 10 (NDP 10) review process, the findings of which were fed into the NAP. The NDP 10 Review has indicated that in the years remaining for the development plan (2016), the country has to overcome the challenges posed by environmental degradation by undertaking legislative intervention via promulgation or review of policies, laws, regulations, standards and guidelines in sectors which include agriculture, water, energy, transport, mining, environment and health. In addition to the NDP 10, the NAP takes cognisance of the National Water Policy for Botswana which has been developed and is before Parliament for endorsement and subsequent implementation. Furthermore, the national integrated water resources management and water efficiency plan developed in May 2013 was considered in the development of the NAP.

2.4.2.1 Declining water resources quality in Botswana (Thematic area 2)

Only 7.9 per cent (79,000 km²) of the Orange–Senqu River Basin is in Botswana, mainly falling within the Kalahari Desert: an area that receives the least amount of rainfall in the country. The average annual precipitation in that part of Botswana is 295 mm/a, much less than the mean annual rainfall for Botswana of approximately 400 mm/a (FAO, 1997). The Molopo and the Nossob rivers (which form the border between southern Botswana and South Africa) are the major surface drainage features in the area and the main tributaries of the Orange–Senqu basin in Botswana. In this respect Botswana relies on both groundwater and surface water with groundwater supplying two thirds of the water consumption. In addition water resources are unevenly distributed throughout the country.

The basin area groundwater is often saline with a limited number of boreholes providing adequate quality water for livestock watering and other uses. The largest cause of groundwater quality problems in the basin are due to human activities such as spillage of oils and lubricants at borehole points, disposal of wastewater through soak-away systems, and elevated nitrate levels from unlined pit latrines and cattle kraals around watering points.

Coupled with limited development options for additional supply, this necessitates an integrated water resource management and comprehensive water demand management approach, including water re-use and protection of groundwater from pollution. Jwaneng mine is in the basin and could be a good pilot for using saline/wastewater which has been found a distance of more than 200 km away.

2.4.2.2 Proposed interventions

The following interventions are proposed in relation to improving water resources quality (ORASECOM, 2014):

- Effluent discharge reduced by:
  - Use of waterless technologies and low volume flush systems;
  - Re-use of grey water and black water (treated effluent);
  - Introduction of water conservation and preservation techniques; and
  - Determination of the link between effluent discharge and groundwater quality.
- Involvement of private sector in the entire water and waste management chain by:
  - Reviewing ongoing WUC plans for privatisation of waste (sewage) disposal;
  - Fully enforcing by also including private sector Waste Management Act;
  - Ensuring local authorities develop and implement waste management guidelines for solid waste management; and
  - Introducing private recycling initiatives.
- Aquifer vulnerabilities assessed and mapped and well-field zoning/protection enforced by:
  - Audit/inventory point sources of pollution and identify risk to existing and potential new well-field water supplies;
  - Implementation of recommendations of physical well-field protection zones; and
  - Requirement for mandatory cooperation between land boards and DWA with regard to future land-use plans.
- Technologies for more efficient and minimal use of potable water for industrial/mining processes implemented:
  - Memorandum of Understanding between large water users (mines, heavy industries, etc.) and universities/research institutions, Department of Research and Technology to look at current developments, best practice, process technology, paste thickening; and
  - Research on appropriate use of non-potable water for uses such as mining, construction and agriculture.

2.4.3 NAP for the Orange-Senqu River Basin in Lesotho

The main national macro-economic policies, namely the National Vision 2020 and National Strategic and Development Plan for 2012/13–2016/17 (NSDP), explicitly declare the management and conservation of the environment to be key drivers for social and economic development of the country. The developmental goals are also included in the IWRM strategy to harmonise social and economic developmental goals with integrated management of water resources.

Under the Vision 2020, sustainable development with the adoption of firm environmental management practices is a key strategy. The NSDP recognises the vital role played by sound environmental policies, adaptation to climate change and physical planning for sustainable long-term economic growth of the country. In view of this, the NSDP developed strategic objectives and actions aimed at reducing land degradation, protecting water resources, conserving biodiversity and promoting sustainable use. These aspects together with the Environment Act (2008), Local Government Act (1997) and the Nature Conservation Bill (2008) were used as input for the development and implementation of the Lesotho NAP.

2.4.3.1 Declining water resources quality in Lesotho (Thematic area 2)

In Lesotho surface water resources are affected by both point and non-point source pollution stemming from the sources listed below.

- Urban storm water drainage systems;
- Overflowing septic tanks and broken sewage reticulation systems;
- Garment factories;
- Other types of industries such as canneries, pharmaceuticals, breweries and mills;
- Insecticides used for spraying/dipping of livestock; and
- High sediment yields as a result of erosion.

In addition, poor land management practices and infrastructure development have serious negative impacts on water resources quality. These practices degrade the capacity of wetlands to regulate and purify flows. The main contributors to underground water pollution in Lesotho include:

- Pesticides and herbicides (through leaching);
- Latrine water filtering through the ground;
- Leaching from waste dump sites; and
- Leaching from urban drainage systems.

The decline in water resources quality is more severe in the Lowland areas, especially in urban and peri-urban areas where industrial effluents and domestic wastewater play a dominant role. A number of underlying causes for decline in water resources quality were identified by stakeholders including:

- Animal dipping using dipping tanks;
- Accidental oil leaks from sand mining in rivers (not well researched);
- Impacts from diamond mines (not well researched);
- Industrial wastewater (generated by such industries as canneries, pharmaceutical companies, breweries, flour mills and clothing manufacturers); and
- Improper management of solid waste.

2.4.3.2 Proposed interventions

The following interventions are proposed in relation to improving water resources quality (ORASECOM, 2014 (a)):

- Point-source pollution mitigated
  - Identify and map point-sources of pollution;
  - Introduce and encourage technologies for re-use and recycling of waste materials and effluent;
  - Upgrade waste disposal facilities and WWTWs; and
  - Develop inventory of chemicals and establish licensing system of chemical use.
- National water quality guidelines and standards implemented and enforced
  - Enact and implement national water quality standards and guidelines;
  - Monitor and enforce compliance with water quality standards; and
  - Include agrochemicals in the monitoring framework of river water and sediments.
- Preventive measures towards declining water resources quality enhanced
  - Encourage livestock farmers to use environmentally friendly paraciticides rather than tank dipping;
  - Develop strategies for proper management of solid waste and hazardous materials;
  - Assess the impact of sanitation (pit latrines) on groundwater resources; and
  - Resuscitate and capacitate national committees responsible for water quality management.
- River health programme (classification, mapping management) developed and implemented
  - Improve and expand national river health classification systems and produce river health maps;
  - Document and disseminate information on river health status;
  - Rehabilitate river banks; and
  - Build capacity for monitoring river flows.
- Mitigation of environmental impact of sand mining in rivers
  - Assess the impact of sand mining on water quality and land degradation;
  - Draft sand mining strategies and enforce sand mining by-laws/ regulations; and
  - Assess impact of sandstone quarrying on water quality.

2.4.4 NAP for the Orange-Senqu River Basin in Namibia

The Namibian part of the basin includes the Orange–Fish River Basin and the Nossob–Auob basins. The Orange–Fish Basin covers an extensive area of southern Namibia, draining nearly 120,000 km^2 (Swart, 2008) representing 15 per cent of Namibia's surface area. The Orange–Fish Basin is defined mainly by the surface catchments of the Orange and Fish rivers in Namibia.

Namibia's Vision 2030 provides the long-term development framework for the country, aimed at improving the quality of life for its people and achieving the status of an industrialised nation by the year 2030. The national development plans are the main vehicles to translate the vision into action and make progress towards its realisation by 2030. In this regard, the Fourth National Development Plan (NDP4) 2012–2017 was launched in 2012 and all the national planning documents should support Namibia's Vision 2030 and NDPs.

Water sector priorities are guided by a number of policies developed by the Ministry of Agriculture, Water and Forestry (MAWF) the guiding documents being: the national Integrated Water Resources Management Plan adopted by Cabinet in 2012, the National Water Policy (2000) and the Water Supply and Sanitation Policy (2008). MAWF is also working on the Water Resources Management Bill; meanwhile, until the implementation of the new Act, the Water Act of 1956 and its regulations remain in force. The NAP for Namibia was developed to address specific concerns within the Namibian part of the Orange–Senqu River Basin, in line with these national guiding documents.

2.4.4.1 Declining water resources quality in Namibia (Thematic area 2)

The key water quality issues in the Namibian part of the basin are high nitrate/ nitrite and fluoride concentrations, groundwater salinity and potential pollution from improper sanitation facilities and irrigation.

The rural areas rely on groundwater for domestic and livestock watering. Most of the groundwater resources in the basin are of good quality and are suitable for domestic and livestock use as well as irrigation. However, in some areas that rely on groundwater, high nitrate/nitrite concentrations exceed the limit for human consumption (>45mg/l). The concern is that the scale of groundwater contamination by nitrate/nitrite is not known.

In addition, groundwater quality is influenced by the geology of the basin. Groundwater salinity is a major problem in the area referred to as the 'salt block'. With predominantly shallow groundwater tables in the basin, recharge of groundwater happens very fast after rainfall events. As a result, pollutants can easily be transported into the aquifer system and therefore special precautions are necessary to prevent this.

Improper sanitation facilities (including lack of sanitation facilities and improperly managed domestic wastewater treatment systems in almost all local authorities and some lodges) is believed to contribute to pollution of both surface and groundwater sources, and consequently poses a threat to human health. Most of the domestic wastewater treatment facilities in Namibia are overloaded and deliver substandard effluent unsuitable for discharge into the environment. The majority of the towns and settlements in the basin rely on oxidation and maturation ponds which were originally designed not to discharge effluent into the environment. Seepage from unlined ponds creates an immediate threat to groundwater resources, an example being the pond systems in Rehoboth. As a result of both organic and hydraulic overloading at these works, substandard effluent is discharged into the environment (rivers and dams), for example from abattoirs and the tannery at the Brukarros Meat Processor plant.

2.4.4.2 *Proposed interventions*

The proposed interventions identified in the Namibian NAP (ORASECOM, 2014 (b)) are:

- Understanding of water resources quality improved by:
  - Water quality monitoring;
  - Integration of monitoring networks/systems; and
  - Awareness-raising on pollution.
- Mechanisms for pollution control developed, enforced and implemented:
  - Finalise and enforce pollution control regulations; and
  - Enhance coordination in the sector
- Awareness on the impact of agrochemicals/POPs on water resources quality created by:
  - Study on agrochemicals: and
  - Create awareness on impact, use and management of agrochemicals
- Innovative methods for water quality improvements identified and implemented in pilot sites:
  - Investigate options for wastewater re-use in local authorities;
  - Implement wastewater re-use technologies;
  - Investigate and implement small-scale desalination where appropriate; and
  - Research on appropriate use of non-potable water for uses such as mining, construction and agriculture.

2.4.5 NAP for the Orange-Senqu River Basin in South Africa

The Orange–Senqu River Basin is of great geographical and economic significance for South Africa. Rising in the Drakensberg Mountains in Lesotho, it flows westward into South Africa and is later met by the Vaal River, its major tributary. On its downstream areas, the river forms the border between Namibia and South Africa before discharging into the Atlantic Ocean. Because South Africa is already experiencing some degree of water scarcity and increase in demand for water, the sustainable management of the Orange–Senqu River Basin will be important for the country's long-term water security. The Orange-Senqu River Basin is the largest in South Africa and drains almost two-thirds of the interior plateau of the country.

The highest level planning document in South Africa is the National Development Plan (NPC, 2011). This plan draws together all aspects of South Africa's development path. The plan recognises the threats to environmental sustainability and of climate change in particular, and chooses a low carbon and green economy future. It proposes a high level plan to manage, monitor and protect water resources for growth and sustainability. It also deals in broad terms with demand management, re-use, pollution, conservation and institutional arrangements. The actions identified in the NAP are aligned with the following strategies:

- National Water Resource Strategy (NWRS);
- National Water Conservation and Water Demand Management Strategy (a component of the NWRS II);
- National Biodiversity Strategy and Action Plan; and
- National Protected Area Expansion Strategy (NPAES).

2.4.5.1 Declining water resources quality in South Africa

The key water resources quality concerns in the Orange–Senqu River system have been identified as:

- Nutrient enrichment primarily linked to increased phosphorus and nitrogen concentrations;
- Increased salinity from irrigation return flows, effluent discharges and acid mine drainage;
- Microbial contamination from urban settlements and poorly operated domestic wastewater treatment works; and;
- Elevated sediment concentrations resulting from runoff from degraded land. There are growing concerns relating to the impact of pollution on food safety.

The salinity levels in the Upper Vaal River area have been at acceptable, albeit increasing levels. Downstream of its confluence with the Riet River which drains the Johannesburg area, the salinity in the Vaal River has been problematic for several decades. While the salinity of the Orange–Senqu River main stem remains within the 'ideal' range along most of its length, salt concentrations gradually increase downstream.

The sources of pollution in the basin are:

- Nutrient enrichment from:
  - Effluent discharges from domestic wastewater treatment works; and
  - Wash-off from urban areas and in agricultural areas where fertilisers are applied to fields.
- Salinity from:
  - Irrigation return flows;
  - Effluent discharges from domestic wastewater treatment works;
  - Acid mine drainage
- Microbial contamination from:
  - Failing domestic wastewater treatment works and sewerage reticulation systems; and
  - Densely populated but poorly serviced settlements.
- Radionuclides (mainly uranium, thorium and radium) have been noted at certain sites (transient levels)
- Persistent Organic Pollutants: preliminary findings indicate that POPs are not a threat except that there may be some ecological risk associated with bioaccumulation of POPs that reside in the bottom sediments and that near the urban areas, the concentration of some POPs is higher and consequently research should be sustained.
- Heavy metals: a total of 42 different heavy metals across 61 sites were analysed for the special survey commissioned for the TDA. The research was however inconclusive with higher concentrations of some heavy metals observed from background causes such as the dolomitic geology of the area around the Molopo Eye than from mining areas.
- Turbidity due to diamond and sand mining.

2.4.5.2 Proposed interventions

The following are proposed interventions for the South Africa NAP (ORASECOM, 2014 (c)):

- Basin-wide receiving water resources quality objectives are set and a monitoring system is operational
    - Finalise specific interim receiving water quality objectives according to the approved system; and
    - Implement a monitoring system
- The impact of the agricultural sector on water resources quality is mitigated
    - Research water quality issues in the agricultural sector
- A basin-wide water quality research and monitoring programme is implemented on POPs, radionuclides, heavy metals and other exotic substances
    - Catchment situational assessment;
    - Prioritise the substances of importance and their thresholds where possible;
    - Assess the possible impact (using precautionary principle) of prioritised exotic substances on ecosystems, humans and agricultural productivity; and
    - Develop management guidelines incorporating a monitoring system
- All wastewater treatment plants achieve Green Drop status as a step towards compliance with discharge water quality standards Identify core needs of municipalities
    - Design capacity-building programmes;
    - Appoint mentors and troubleshooters;
    - Establish easily accessible scientific advisory service;
    - Assist with upgrading of reporting systems;
    - Sponsor technical training; and
    - Sponsor increased incentives in Green Drop programmes.

2.5 STUDY ON POPS, PAHS AND ELEMENTAL LEVELS IN SEDIMENT, FISH AND WILD BIRD EGGS IN THE ORANGE-SENQU BASIN

As described in 2.2.2.1, a key recommendation of the water quality studies undertaken as part of the TDA of the Orange-Senqu River Basin was to undertake an assessment of Persistent Organic Pollutants (POPs), heavy metals and radio-nuclides in the Vaal and Lower Orange catchments, for which there was a general lack of information.

The four countries which share the basin of the Orange-Senqu River are Parties to the Stockholm Convention (SC) on Persistent Organic Pollutants (POPs) which currently targets 21 chemicals and classes of chemicals: polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzo furans (PCDFs), aldrin, dieldrin, 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethane (DDT) and its major metabolites 1,1-dichloro-2,2-bis (p-chlorophenyl)ethane (DDD) and 1,1-dichloro-2,2 (p-chlorophenyl) ethylene (DDE), endrin, chlordane, hexachlorobenzene (HCB), mirex, toxaphene, heptachlor, chlordecone, hexabromobiphenyl, hexabromodiphenyl ether (hexaBDE), tetrabromodiphenyl ether (tetraBDE), pentabromodiphenyl ether (pentaBDE) heptabromodiphenyl ether (heptaBDE), HCH (including α-HCH, β-HCH and γ-HCH), pentachlorobenzene, perfluorooctane sulfonic acid (PFOA) and perfluorooctane sulfanyl fluoride (Stockholm Convention, 2010).

Previously, POPs researched in South Africa were of the organochlorine compounds (OCs) with special emphasis on DDT and its metabolites; the reason being that it is still used in the country for control of mosquitos. Even though the malaria areas in South Africa do not lie in the Orange-Senqu River catchment, (Bouwman, 2008) noted that bird eggs from the Vaal River have levels of DDT and its metabolites. Industrial pollutants investigated include PCBs, mostly in marine organisms (in the previous millennium) and more recently in environmental matrices such as sediment, soil and air. PCBs, PBDEs and some OCs were also on the list of compounds detected in bird eggs from the Vaal River. In the study, industrial and urban areas were targeted as suspected hot-spots and sources of industrial POPs, the main reason for focussing on the stretch of the Vaal River going through the Vaal Triangle.

2.5.1 Main activities

In this respect as a contribution to the TDA of the Orange-Senqu Basin a study was undertaken in September 2010 and initially included an assessment of POPs and heavy metals, in water bodies, riverine sediments. Polycyclic aromatic hydrocarbons (PAHs) were added during the study as an additional research topic. The entire catchment was targeted for sediment collection and 61 sites were sampled: 33 in the Vaal River catchment and 28 in the Orange-Senqu River at sites that do not drain into the Vaal River. The sites largely conformed to the sites used by other components of the TDA. Fish and wild bird eggs were sampled to investigate the levels of contamination in the biota of the Orange-Senqu Basin. A health risk assessment examined whether possible human health effects might be anticipated based on chemical contaminants detected in sediment, wild bird egg and fish samples.

2.5.2 Outputs

The output from the study was a report summarising the chemicals of concern and a health risk assessment in the Orange-Senqu Basin and making recommendations for monitoring and identification of potentially affected communities.

2.5.2.1 Summary of findings

The main findings of the study (ORASECOM, 2010 (a)) were as follows:

ORGANIC COMPOUNDS

Sediment had higher levels of POPs in the east, decreasing considerably downstream towards the west, while the opposite was true for the biota:

- In general, dioxin-like toxic equivalence (TEQ) levels were low in all media. TEQ levels were higher in sediment from the east decreasing towards the mouth;
- PCBs in sediment, as for the dioxin TEQs, were higher towards the eastern than the western parts of the catchment. In biota, however, it seems as if fish and birds had higher levels towards the west;
- In sediments, OCs were higher in Gauteng, and less downstream, however the OC biota differed from the sediment distribution pattern with the highest OC levels in fish from Parys but the highest levels in birds from Bloemhof Dam. In this respect it would appear as if Bloemhof Dam may be acting as a retainer for certain compounds
- Although none of the sediments had detectable levels of PFOS, they were quantified in fish and bird eggs, where concentrations seemed to increase downstream;
- The three sediment sites with the highest PAH levels were downstream of both urban and industrial areas in South Africa and Lesotho. The sources for the PAHs were pyrogenic in nature often due to the combustion of coal or smelters.

ELEMENTS

- When compared against the sediment quality guidelines for The Netherlands (arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, zinc, uranium and selenium). All sites had heavy metal levels less than half the guidelines and were thus considered to have a low probability of being toxic to biota. However, the levels of heavy metals detected at Molopo Eye site were regarded as having a high probability of being toxic to the biota;
- The levels of copper, chromium, zinc, arsenic, selenium, cadmium and lead in fish fillets compared to international guidelines were deemed safe for consumption; and
- Strontium had the highest level in bird eggs, followed by iron.

HEALTH RISK ASSESSMENT

The screening risk assessment identified the chemicals that could be responsible for adverse health effects if fish were to be eaten, over a 30 year period. The contaminants over the risk threshold were identified as arsenic, benzo(a)pyrene, PCBs, chromium and selenium. The type of adverse effect that might result was also identified as predominantly carcinogenic associated with arsenic, benzo(a)pyrene and PCBs exposure, with other toxic effects being anticipated from heavy metal exposure to chromium, arsenic and selenium.

2.6 Support to the Phase 2 of the Basin-Wide Integrated Water Resources Management Plan

The Phase 2 work undertaken between 2009 and 2011 consisted of two main components, *viz.* (1) the enlargement and improvement of existing models and (2) an understanding of the components of hydrology, water quality information, climate change and adaptation, environmental flow requirements and improved water demand management in the irrigation sector to support these model enhancements.

The above was achieved through the work carried out under Phase 2 of the German International Cooperation (GIZ) Support to the ORASECOM Basin-wide IWRM Plan which comprised 6 work packages. The purpose of this phase was to ensure an improved more complete water resources simulation model for the whole Orange-Senqu Basin. The sub-components were intended to provide inputs to the simulation model, but were however also self-standing information packages.

Work package 3 of ORASECOM Phase 2 focussed on the preparation and development of water quality management plan that included the monitoring of agreed water quality variables at selected key sites.

2.6.1 Main activities

The work package included:

- The establishment of protocols and institutional requirements for a water quality monitoring programme, data management and reporting;
- The development of specifications for a water quality model that interfaces with the systems models.
- Provision of training to develop capacity within the basin states to operate the water quality monitoring system and implement the water quality management plan.
- Documentation of findings in a report describing the proposed water quality management plan.
- Participation in the 1st Water Resources Quality Joint Basin Survey (JBS1) that was undertaken between September and December 2010, to manage the inter-laboratory benchmarking process.

2.6.2 Outputs

The final outputs of the work package are summarised in *Table 2-2*.

Table 2-2 : Summary of Outputs of Work Package 3: Water Quality Management Plan

Title	Output	ORASECOM Report No.	Output summary details
Development of Water Quality Monitoring programme and Data Management Framework	Report	007/2011	Report details the water quality management plan and a proposed water quality monitoring programme. An Inter-laboratory bench-marking procedure was developed based on the initial set of samples collected during the Joint Basin Survey 1.
Development of Specifications for the Water Quality Model	Report	006/2010	The report included the development of algorithms for the inclusion of river and reservoir phosphate and chlorophyll-*a* in the WQT and WRPM planning models. Possible development routes have also been considered.
Participation in the Joint Basin Survey 1 sampling programme	Training	-	The sampling protocols and chains of custody were developed for the Joint Basin Survey 1 sampling exercise. Sample collection and in-stream water quality measurement techniques were also developed.

2.6.2.1 *Output: Water Quality Monitoring Programme*

The objective of the surface water sampling programme was to develop trust in the water quality data, identify issues and investigate training to address the issues. The member states sample the river at various monitoring points in the basin. The water quality samples are tested in laboratories within each of the member states. The integrity of the water quality analysis is often questioned by the member states. The need for the development of a collaborative monitoring programme and reporting system was expressed by the member states so that trust can be developed in the data and the perceived water quality issues can be clarified. The Development of Water Quality Monitoring programme and Data Framework report presents the trans-boundary water quality monitoring programme developed for the Orange Basin as part of the water quality work package number 3.

- Management Framework
- Trans-boundary monitoring points were selected;
- A monthly monitoring programme is proposed for implementation.
- The Basin States that will sample the various points were confirmed.
- A sampling protocol and procedures, a data management structure and trigger values are proposed.

More detail on the above is included in Annex 2.

2.7 A Fitness for Use Assessment of the waters of the Orange-Senqu Basin

The Fitness for Use Assessment undertaken in the Orange-Senqu River Basin in 2009 formed part of the European Union support to ORASECOM as part of the African Transboundary River Basin Programme. It provides an assessment of the suitability of use of groundwater and surface water based on key water quality parameters. The assessment serves as a broad overview of the possible impacts on the water resources in the basin on the use of that water. The focus of the assessment was on the possible impacts of known water quality concerns on the major users and not specifically on the suitability of use. The four member states of ORASECOM guided the approach and methodology and provided supporting information, data and reports. The overall aim of the undertaking was to improve water resources in the four member states (Botswana, Lesotho, Namibia and South Africa) by promoting a common understanding of water quality issues from a transboundary perspective.

2.7.1 Main activities

The assessment included an evaluation of the impact of water quality on major uses of water in the Orange-Senqu Basin. The methodology was as follows:

- The major categories of water use were identified through liaison with the ORASECOM Member States and a review of previous reports;
- Collation of relevant water quality data from all four member states was then undertaken (assessment period was five years between 2003 and 2008). The Orange-Senqu basin was divided into 19 sub-basins and all relevant data was collected. Data for a particular sub-basin were amalgamated into a single set for the analyses ;
- The quality requirements for each of the identified major users were then agreed upon. The major users were agriculture (livestock and irrigation); domestic; industrial and recreational. The quality requirements for these users were identified from all member state water quality standards where available.
- A comparison between these standards and the current water quality condition of the water source was performed to assess the suitability for use. This judgement took the form of four generic description assessment terms ('good', 'tolerable', 'poor',' unsuitable') which was indicated as green, blue, amber and red respectively Red, Blue, Amber, Green).
- The results of the assessment per major water user category were then represented as a series of 'Fitness for Use' maps indicating the suitability of use across the basin.
- The implications of assessment and the overall findings for transboundary basin management are discussed.

2.7.2 Outputs

The outputs from this initiative are 'Fitness for Use' maps for each of the major water users in the basin. This method provided a consistent, robust and statistically defensible approach to assessing water use suitability at a high level. It also identified areas where inadequate data (*i.e*. insufficient data values or range of variables tested) does not allow for an assessment to be made.

The final outputs of the project were as follows (*Table 2-3*):

Table 2-3 : Outputs of the Fitness for Use Assessment

Title	Output	ORASECOM Report No.	Output summary details
A Fitness for Use Assessment of the waters of the Orange-Senqu Basin	Report	001/2010	Report details a high level assessment of the suitability of use of surface water and groundwater in the Orange-Senqu Basin for major water user categories based on possible impacts of known water quality concerns.
Fitness for Use' maps for each of the major water users in the basin	Maps		Series of maps representing suitability of use at a sub-basin level for each major water user category (assessments indicated on map as good', 'tolerable', 'poor', 'unsuitable)

2.7.2.1 *Summary of Findings*

The key findings of the water quality assessment were as follows (ORASECOM, 2010a):

- Sub-basins with water quality most suitable to the key water uses in the Orange-Senqu River Basin were the Upper Vaal, Mokahare / Caledon and Upper, Middle and Lower Orange. In particular, the Upper Orange River sub-basin was suitable for all the key water uses identified.
- Botswana saline groundwater, Namibia Stampreit and Lesotho lowland surface water were the least suitable sub-basins for the key water uses in the Orange-Senqu River Basin, due to high TDS levels and high iron / nitrate concentrations, respectively.
- Botswana non-saline groundwater, Lesotho highland ground and surface water, Lesotho lowland groundwater, Namibia supply reservoirs and the middle and lower Vaal were suitable for some of the key water uses in the Orange-Senqu River Basin.
- Domestic and industrial type III categories assess similar water use quality requirements. A comparison between the 133 assessments completed for these two uses showed similar results with three-quarters of the paired assessment descriptions being exactly the same and none being significantly different.
- Fitness for use assessments for sub-basins in neighbouring member states were very similar. The Mokahare / Caledon (Lesotho and South Africa datasets used) and Lower Orange (Namibia and South Africa datasets used) showed similar assessments for suitability against all key water uses except for domestic (Lower Orange) and industrial and agricultural irrigation (Mokahare / Caledon).
- Some water quality criteria could not be assessed against water use standards due to limited data. In particular, a lack of iron data in South Africa and faecal coliform and phosphate data in Botswana and Namibia were apparent.

The summary of the fitness for use assessment and a representative example of a 'Fitness for Use' map is included in Annex 2.

2.8 A Framework for monitoring water resource quality in the Orange-Senqu River Basin

The Framework for Monitoring Water Resource Quality in the Orange-Senqu River Basin developed in 2009 formed part of the European Union support to ORASECOM as part of the African Transboundary River Basin Programme. The project aim was to develop a framework together with ORASECOM within which Council can make recommendations for managing water quality and water environmental issues. The intention being to establish and maintain a regionally effective water quality management programme in terms of an organisational approach as agreed upon by the Member States. Options are considered in terms of how this can be achieved by ORASECOM. Taking into account the current financial and human resource constraints in the region, an initial monitoring network is proposed only for transboundary water management, which makes use of current national monitoring locations.

2.8.1 Main activities

The project included:

- An assessment of the previous studies, which included an analysis of the existing water quality work undertaken by ORASECOM, and in particular the water and environmental components of the TDA and the work done under Phase I of the GTZ support.
- The development a framework for ORASECOM to provide recommendations to address water resource quality concerns. This activity was to support ORASECOM to develop approaches to water resources quality management that; maintain appropriate sovereignty of the Member States, are consistent with the resource constraints in the Member States, and that recognise the commitment to cooperate and share skills and best practices. It has been aimed at producing a vision and supporting framework for how the organisation wishes to address water resource quality management.
- The development of management objectives firstly by determining what the most appropriate form of management objective ORASECOM needs. Secondly, to introduce management objectives for key water resource quality concerns in the basin.

2.8.2 Outputs

The output of the activity is as follows (Table 2-4:

Table 2-4 : Output of study

Title	Output	ORASECOM Report No.	Output summary details
A Framework for Monitoring Water Resource Quality in the Orange-Senqu Basin	Report	002/2010	Report details the framework proposed for regional water quality management in the Orange-Senqu basin. Options for organisational arrangements; a proposed monitoring network; monitoring variables; introduction of quality assurance and quality control procedures; a groundwater monitoring network; use of trigger values as a management tool and options for data management are defined.

2.8.2.1 Summary Framework

The summary of the proposed framework is as follows (ORASECOM, 2010b):

- Establishment of a regionally effective water quality management and quality assurance system, in terms of an organisational approach the Member States may choose to (a) provide support under the auspices of the current Technical Task Team, (b) designate an Implementing Agent, (c) employ consultants through ORASECOM, or (d) instigate the formation of a Task Team with specific responsibilities for monitoring, laboratory analysis, information and data management.
- The proposed monitoring network for regional water quality can make use of the existing monitoring locations. The selection of 11 surface monitoring locations based on transboundary criteria is recommended. Further monitoring stations, relating to point source discharges, abstraction points and water transfers may be added to the monitoring network by the Member States in the future as required. The initial surface water quality monitoring stations are proposed as follows:

  Upper Orange Senqu:
  - Caledon River at confluence with little Caledon
  - Little Caledon River at the Poplars
  - Caledon River at Ficksburg
  - Caledon River at Maseru
  - Kornetspruit at Maghaleen
  - Orange River at Oranjedraai

  Lower Orange:
  - Vaal River at Douglas
  - Orange River at Pella Mission
  - Orange River at Vioolsdrift
  - Orange River at Sendelingsdrift
  - Orange River at Alexander Bay
- A use of priority monitoring variables and trigger values (TV) are proposed for the following water uses in the Upper Orange-Senqu and the Lower Orange catchment areas - agriculture (aquaculture, irrigation and livestock watering); domestic, ecosystem protection, industrial and recreation. The TVs will need to be agreed on a bilateral basis for each sampling station based on the current status, historical trend and level of protection required by the Member States.
- The basis for a transboundary groundwater monitoring programme (as part of the regional monitoring programme) is suggested for the four main transboundary aquifers. A proposal is made for qualitative and quantitative monitoring. A decision is required from the Member States in relation to the choice of monitoring boreholes.
- The basis for an effective regional analytical quality control is proposed. This includes the introduction of (i) analytical accuracy targets for monitoring the quality of water, and (ii) a performance-testing scheme, which needs to be established and implemented as the primary inter-laboratory quality control program in the Orange-Senqu River Basin, with the participation of the laboratories involved in the transboundary water quality monitoring.

- The procedure of data collection must start on a national level of each country. National Information Managers (NIMs) are proposed to take responsibly for collection of the data from the national laboratories involved in regional monitoring where the data from sampling and analysis are generated. In the next step the NIMs may take responsible for data checking, preparation in an agreed data exchange file format (DEFF) ready for sending to the Central Point. After the consultation process the data will need to be merged and stored in one relational database for further use. It is proposed that regional data be ultimately stored under the auspices of the South Africa DWA in their Water Management System Water Quality Database in order to extend the present DWA WMS to include data from Botswana (groundwater only), Lesotho and Namibia.
- An assessment of the collated data should be presented in a summary annual report on an annual basis, highlighting the status of the Orange-Senqu River Basin in respect to water quality.

2.9 Joint Basin Survey-1: State of the Orange-Senqu River System

The Joint Basin Survey-1 (JBS-1) was undertaken by ORASECOM to provide a snapshot of the quality of the water resources of the Orange-Senqu River Basin in 2010. The above was achieved through the work carried out as part of the African Transboundary River Basin Support Programme. The survey formed the first joint monitoring of the basin supported by all four Member States working together and provided assessments of a wide range of water quality, aquatic ecosystem health and ecosystem habitat parameters. The main focus of the effort was to understand the current state of the system at the time in terms of all these aspects as well as the main factors causing degradation of the system. The survey also allowed for the testing of monitoring programmes developed (*viz.* aquatic ecosystem health and transboundary water quality monitoring).

2.9.1 Main activities

The survey included:

- Sampling of approximately 60 sampling sites throughout the Orange-Senqu River system during October and November 2010. This was however supplemented from other recent surveys and sampling exercises as well as data from the Lesotho Highlands Development Authority. Data was also obtained from some water treatment plants and from South Africa's Information Management System.
- Monitoring of ecosystem health (macro-invertebrates, fish, diatoms, riparian vegetation and habitat). These components were integrated to provide a broad assessment of the Aquatic Ecosystem Health at points throughout the Orange-Senqu River System.
- Monitoring of water quality (salts, nutrients, microbiological quality). Samples were taken at 40 sites throughout the basin to understand the chemical status of the system and provide information on algal concentrations and the microbiological quality of the water;
- Monitoring of persistent organic pollutants and heavy metals to investigate levels he levels of these pollutants in the rivers throughout the basin;

- An inter-laboratory bench marking exercise to enable each of the Member State laboratories analyse samples to common standards. Intention was to identify laboratories that can provide reliable data and to ensure that laboratories are producing quality data to a common standard. Ten transboundary sites were selected for the exercise.

2.9.2 Outputs

The outputs of the exercise were as follows (Table 2-5):

Table 2-5: Summary of Outputs of Basin wide survey

Title	Output	ORASECOM Report No.	Output summary details
Joint Baseline Survey-1: Baseline Water Resources Quality State of the Orange-Senqu River System in 2010	Report	ORASECOM 2011	The JBS-1 was the first joint monitoring of the Orange-Senqu River Basin. This publication provides a brief overview of the results of the survey. It gives a snapshot of the
Salts Poster and Aquatic Ecosystem Health Poster	Posters	2011	Posters
Specialist scientific Reports on Water Quality, Persistent Organic Pollutants, Aquatic Ecosystem Health	Reports		Scientific reports detailing the sampling, analysis and results of the survey in terms of each component surveyed.
Participation of Member States in the Joint Basin Survey 1 sampling programme	Joint monitoring	-	Sample collection and in-stream water quality measurement were undertaken jointly in accordance with techniques and protocols developed and training provided.
Inter-laboratory bench marking exercise	Participation of Member State Laboratories in sample analysis	-	Homogenised samples collected from the surveys were analysed by each of the Member State laboratories. Inconsistencies were identified. Recommendations to address the related issues were made to improve the transboundary sampling programme.
Public Participation	Five public participation events	-	Stakeholders, school children, students and officials were given the opportunity to interact with specialists from each country and the specialists on the sampling teams to find out more about the Orange Senqu River basin.

2.9.2.1 Summary of Findings

The key findings of the assessment of the basin wide survey are as follows:

- *Water Quality* - The Vaal River is impacted on by high nutrient concentrations and salts. Water quality in the Orange-Senqu River System does not appear to be significantly impacted however localised impacts are noted. Increase in salinity is noted lower reaches of the Orange River. Nutrient concentrations throughout most of the Basin are sufficiently high to cause algal blooms. Microbiological quality risks seem to be localised, and associated with the large urban areas.
- Aquatic Ecosystem Health – The results indicate that ecosystem health is impacted along the length of the Orange River. However ecosystems in most parts of the Basin seem to have retained most of the ecological functioning.

- Organic Pollutants and Metals: These are for most part found in low concentrations however some localised spikes in concentration are noted which need to be investigated further.

2.10 VAAL RIVER BASIN STUDIES

The water resources of the Vaal River System is an important asset to South Africa and its people, supporting major economic activities and a population of about 12 million people. There is an extensive urbanisation, mining (iron ore, diamonds, manganese, gold and coal) and industrial activities taking place in the catchment area. Farming activities range from extensive livestock production and dry land cultivation to intensive irrigation enterprises. The supply area of the Vaal River System stretches far beyond the catchment boundaries. Over decades the water resources of the Vaal River System were augmented to match the growing water requirements and major inter-basin transfer schemes were developed to convey water into the system from the high rainfall regions of the upper Thukela and Usutu rivers as well as from the headwaters of the Orange River in the highlands of the Kingdom of Lesotho.

The water resource components of the Integrated Vaal River System are highly inter-dependant due to the cascading orientation of the three Vaal River Water Management Areas as well as the links that exist as a result of the transfer schemes. The Vaal River is a strategically important water resource and is managed to achieve a balance in meeting specific requirements in each WMA as well as fulfilling the transfer obligations between the WMAs. The Vaal system is a well-studied system. The Department of Water Affairs in South Africa has over recent years conducted a number of studies in the Vaal River Basin. The Vaal River System was prioritised from a systems analysis point of view which resulted in a number of integrated strategies being developed.

The Vaal River basin is a major tributary catchment to the Lower Orange River. Inflows from the Vaal are of great importance for the Lower Orange River since the salt loads rising in the Vaal River are very large. The impact on the Orange River is mitigated by the fact that much of the pollution is detained in the Vaalharts irrigation scheme and the storage in Bloemhof Dam allows the Vaal River to be operated in such a manner as to minimise the spillage of polluted water from Douglas Weir. However, uncontrolled spillage does occur during times of flood. This is exacerbated by the transfer of increasing quantities of diluting fresh water from the Senqu and the future possibility that return flows from the Upper Vaal River may exceed downstream requirements, thereby increasing the frequency of uncontrolled spillage from Bloemhof Dam. Such occurrences during minor flood events, or even low flow conditions, would adversely affect the dilution factor in the Orange River below the Orange-Vaal confluence. Moreover, the introduction of a new dam on the lower Orange River could also have the effect of trapping polluted flood waters, allowing salts to concentrate during subsequent dry periods.

2.10.1 Main studies

The key studies undertaken in the basin include:

- *Vaal River System: Large Bulk Water Supply Reconciliation Strategy (Department of Water Affairs, 2009a):*

  The Reconciliation Strategy for the Vaal River System was completed in 2009 by the Department of Water Affairs (DWA) and a Strategy Steering Committee (SSC) was formed in July of the same year to oversee the implementation thereof. The objectives of the strategy is to reconcile the current and future water requirements with the available water by implementing appropriate interventions to increase the available water, conserve water through conservation and demand management measures as well as improve the water quality in the river systems.

  Over decades the water resources of the Vaal River System were augmented to match the growing water requirements and major inter-basin transfer schemes were developed to convey water into the system from the high rainfall regions of the upper Thukela and Usutu rivers as well as from the headwaters of the Orange River in the highlands of Lesotho.

  The Vaal River System supplies water to about 60% of economy and 45% of population – the mines and industry on the Mpumalanga Highveld, the bulk of Eskom's coal fired power stations, Gauteng, the North West and Free State goldfields, Kimberley, small towns as well as large irrigation schemes. There are complex issues impacting on the Vaal River System, because it is a dynamic area with a huge growth in water requirements. All users in the area contribute to the effluent and the complex water quality issues.

  The following form the key pillars of the Reconciliation Strategy:

  - Eradicate unlawful irrigation water use;
  - Implement Water Conservation and Water Demand Management measures and aim to save 15% in the urban sector;
  - Prepare for the next augmentation scheme;
  - Implement water quality management measures; and
  - Treat and use effluent with mine water as a priority.

- Integrated Water Quality Management Strategy (Department of Water Affairs and Forestry, 2009b) :

  The aim of the IWQM Strategy is:

  - Maintaining or improving the water quality of the water resources within the VRS for the benefit of all recognised water users and beneficial water uses in order to assist in securing ecologically sustainable development, while also promoting justifiable social and economic development;
  - Managing the water resources of the Vaal River System in order to comply with the determined integrated Resource Water Quality Objectives (RWQOs);
  - Controlling the salinity, eutrophication and microbiological contamination levels in the VRS, and major tributaries, as the key water quality issues identified;
  - Improving source management controls and measures as a means to limit and control point and diffuse sources that significantly impact on the water resources of the System; and
  - Improving management of the water resources of the Vaal River System by more effective monitoring, assessment, reporting and management participation.

- *Comprehensive Reserve Determination Study of the Upper, Middle and Lower Vaal Water Management Areas (2010) (Department of Water Affairs, 2010):*

  The DWA initiated a Comprehensive Reserve Determination Study for the water resources of the Integrated Vaal River System in 2007. The purpose of the study was to determine the ecological and basic human needs water quantity and quality Reserve for the Vaal River at a comprehensive level of detail. Specialist surveys for the macroinvertebrate, fish, riparian vegetation, water quality and hydraulics were undertaken during 2007 and 2008.

  Selected Ecological Water Requirement (EWR) sites were selected within the Vaal River System. The Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS) and Recommended Ecological Category (REC) for each EWR site in the Vaal WMAs were then determined. EcoSpecifications and Thresholds of Potential Concern (TPC's) for the maintenance of the ecological Reserve for each EWR site for components consisting of the drivers (geomorphology, physico-chemical variables and hydrology) and the response (riparian vegetation, fish and macroinvertebrates) were determined.

- *Classification of Water Resources (2013) (Department of Water Affairs, 2013) :*

  The purpose of this study was to implement the Water Resource Classification System (WRCS) WRCS in the three Vaal WMAs in order to determine a suitable management class for each significant water resource. The WRCS is guided by a set of procedures grouped together into seven steps that when applied to a specific catchment, will ultimately assist in the process of maintaining a balance between protecting our water resources and using them to meet economic and social goals.

  Water resources must be classified into one of the following three management classes (MC):

  - Class I water resource is one which is minimally used and the overall ecological condition of that water resource is minimally altered from its pre-development condition;
  - Class II water resource is one which is moderately used and the overall ecological condition of that water resource is moderately altered from its predevelopment condition; or
  - Class III water resource is one which is heavily used and the overall ecological condition of that water resource is significantly altered from its predevelopment condition.

  The water resources of the Vaal Basin were classified as Class II or III, with the Vaal River being in a Class II from its headwaters to Grootdraai Dam and Class III from downstream Grootdraai Dam to its confluence with the Orange River.

- *Determination Resource Quality Objectives (current):*

  The Department of Water Affairs is currently undertaking Resource Quality Objectives (RQO) Determination within the three Vaal Water Management Areas (WMAs). This study follows on from the recently completed Water Resource Classification Study in the area, and forms the next step in the water resource protection process. The setting of RQOs for the water resources is aimed at balancing sustainable and optimal water use with the protection of the water resources. The aim of this study is to implement the RQO methodology developed by the DWA in 2011 Vaal River Basin and thereby determine the RQOs for significant catchment areas identified within the WMA. The above study was initiated by the DWA during the last quarter of 2012 and will conclude in August 2014 at which time RQOs will be set for the Vaal River and tributary catchments

  RQOs are defined as clear goals relating to the quality of the relevant water resources. RQOs are descriptive or quantitative, spatial or temporal, and are aimed at ensuring that local water resource priorities are appropriately balanced with broader spatial and temporal perspectives (WMA and national level) and that water resources are adequately protected to ensure their long term sustainability. RQOs incorporate stakeholder needs and dictate the level of impact that may be collectively produced by upstream users.

2.10.2 Outputs

The outputs of the above studies are as follows (Table 2-6):

Table 2-6: Summary of Outputs the Vaal River Basin Studies

Title	Output	Report No.	Output summary details
Vaal River System: Large Bulk Water Supply Reconciliation Strategy	Reports	P RSA C000/00/4406/08	The report details the strategy to manage the growing water requirements in the Vaal River System. Implementation of the strategy is underway through a Strategy Steering Committee.
Development of an Integrated Water Quality Management Plan for the Vaal River System	Reports	P RSA C000/00/2305/7	A management strategy to address water quality that is currently being implemented complimentary to the reconciliation strategy. Water quality objectives for total dissolved salts, phosphate and nitrate are proposed for Vaal River. Actions address acid mine drainage is also being addressed through the strategy.
Comprehensive Reserve determination study for selected water resources in the Upper, Middle Vaal and Lower Vaal Water Management Areas	Reports	RDM/ WMA08C000/ 01/CON/; RDM/ WMA09C000/ 01/CON/ ; RDM/ WMA10C000/ 01/CON/	Ecological water requirements have been set at 18 EWR sites in the Vaal River System. Ecological categories have been recommended.
Resource Directed Measures: Classification of Significant Water Resources (River, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas (WMA) 8,9,10,	Reports	RDM/WMA8,9,10/00/ CON/CLA/	Significant water resources in the Vaal River WMAs have been classified as MC I, II or III.

2.11 ACID MINE DRAINAGE

The gold and coal mineral deposits within South Africa are most prone to acid generation during mining activity and pose a severe strain on the environment in the form of acid mine drainage (AMD) and associated water quality impacts. The process of mining increases the exposure of pyrite-bearing rock to oxygenated water, which results in acid generation. This occurs in different ways in gold and coal mining. Poor water quality is indicative of mining activities as one of the key contributors to the current status is observed in the mining areas of the Vaal catchment, with high levels of TDS and sulphate with a high degree of non-compliance to water quality objectives.

In terms of the Report of the Inter-Ministerial Committee on Acid Mine Drainage (IMC, 2010), an analysis of the currently known mine drainage sources in South Africa has identified priority mining areas as a being a potential threat. Among the high priority WMAs requiring immediate management of mining impacts are the Upper Vaal and Middle Vaal areas (the Vaal River).

AMD on the Rand mining areas has become a major environmental challenge, necessitating various short term interventions and a lasting long-term solution.

Critical problems are known to exist in the Western and Central Basins where, respectively, limited and no pumping is taking place. Decant has occurred in the Western Basin, while the Central Basin is currently flooding and will decant within two to three years. Measures are being implemented to deal with these AMD problems. The Eastern Basin is also considered an AMD priority area, due to the lack of adequate measures to manage and control the problems related to AMD. The critical urgency in this basin is to implement intervention measures before problems become more serious.

In April 2011 the Minister of Water Affairs in South Africa directed the TCTA to undertake emergency works as a part of short term interventions to deal with the problem of Acid Mine Drainage on the Witwatersrand. The main objectives of these works are:

- Treating the current uncontrolled AMD decant on the Western Basin (this intervention is known as "the immediate intervention").
- Drawing down the Acid Mine Drainage in the Western Basin by pumping to what it is known as the Environmental Critical Level (ECL), (this is the highest water level in the mine void which can be allowed without the mine water negatively impacting on the shallow ground water aquifers and the surface water resources).
- Preventing the rising water levels in the mine voids from exceeding the ECL's in the Central and Eastern Basins.
- Treating the current uncontrolled AMD decant occurring on the Western Basin involves upgrading the Rand Uranium treatment plant. This plant consists of four parallel treatment process units, of which only one unit is operational and is currently being used to treat mine water at a peak rate of 12 million litres per day.

The South African Department of Water Affairs appointment consultant teams in January 2012 to investigate and recommend a feasible long-term solution to the AMD problem emerging in the study area, in order to ensure long term water supply security and continuous fitness for use of Vaal River water.

The removal of salts is driven by the reduced assurance of supply in the VRS that will be caused by excess releases from Vaal Dam for dilution purposes. Should the underground mine water induced salt-loading not be eliminated timeously, water supply security can be compromised. Because there is a substantial risk of delays if conventional project implementation processes are followed after the completion of the Feasibility Study, alternate fast-tracked implementation methods are being considered.

2.12 ORANGE RIVER SYSTEM STUDIES

The Orange River and its catchment have a long history of exploitation and modification, especially in terms of flow regulation. Several new developments have been identified, both in Namibia and South Africa, which will result in greater water demands from the Lower Orange River in the future. Increases in water demands in all water use sectors over the last number of years have resulted in a river system, which is currently in balance but which will experience water deficits in the near future.

In order to provide for anticipated water deficits the South African Department of Water Affairs in 2012 embarked on the study, 'Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River'.

The objective of the study is to develop a reconciliation strategy for the bulk water resources of the Orange River System, to ensure that sufficient water can be made available to supply the current and future water needs of all the users up to the year 2040. The aim is to ensure that the strategy be flexible to accommodate future changes in the actual water requirements and transfers, with the result that the Strategy will evolve over time as part of an on-going planning process.

The outcomes of the Strategy will be specific interventions with particular actions needed to balance the water needs with the availability through the implementation of regulations, demand management measures as well as infrastructure development options.

With the Orange and Vaal River Systems covering five water management areas (WMAs) within South Africa, the Department of Water Affairs also identified that integration across the Orange River System is essential from a systems analysis perspective. The DWA has made substantial investments in the Water Resource Planning Model (WRPM) as a modelling tool and has effectively applied the model to undertake system analysis of the Vaal River. The WRPM has been developed and applied to the Vaal River System and is currently being maintained by the DWA for that system. The WRPM for the Vaal River was expanded to include the Orange River thus providing a model of the entire Orange River Basin.

The water quality component of the model was recently expanded for the Orange River. In 2013 the Department completed the study 'Water Quality TDS (WQT) Modelling and Water Resource Planning Model (WRPM) setup requirements for the Orange River' (referred to as the Orange River WQT study). The modelling capability of the WRPM has now been extended and improved in order to enable integrated systems planning and management that incorporates the Orange River catchment area specifically in respect of TDS.

In 2009 the Department of Water Affairs also undertook an overarching water quality study which focussed on an Assessment of Water Quality data requirements for Water Quality Planning Purposes' of the Orange River. The aim of this study was to undertake a water quality assessment of the Orange River (Upper and Lower Orange Water Management areas) to determine the current status, establish in-stream water quality management objectives and to provide recommendations for future planning and strategy development activities.

2.12.1 Main studies

The key studies undertaken in the basin include:

- *Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River (current (* (Department of Water Affairs, *In preparation*)*)*: The study comprises the identification of options for achieving and maintaining a water balance in the future, screening those that are feasible and combining the most appropriate options into preliminary and final water reconciliation strategies. The technical process started with a literature survey and review of current information. The next three steps of the technical process, i.e. baseline evaluation, investigation of reconciliation options and assessment of environmental impacts have led to the development of a preliminary reconciliation strategy. The gaps in the preliminary reconciliation strategy are being investigated and the reconciliation options will be accordingly refined. The development of the Final Reconciliation Strategy will be the last step in the technical process of the study.
- Water Quality Total Dissolved Salts (WQT) Modelling and Water Resource Planning Model (WRPM) setup requirements for the Orange River (Department of Water Affairs, 2013). The key activities of the of the study included:
  - Set up and calibration the WQT model for the Orange River;
  - Preparation of the salinity model setup files for the existing Orange River Basin WRPM based on the calibrated WQT model;
  - Set up of the WQT component of the WRPM for the Orange River and testing of the configured WRPM.
- *Assessment of Water Quality data requirements for Water Quality Planning Purposes' of the Orange River:* The main objective of the study was to obtain a clearer picture of the current water quality status and data requirements of the Orange River and in doing so identify the potential water quality problem areas and issues/aspects that have an impact on the overarching planning and management of the system. The study included:
  - Determination of the current status;
  - Development of a monitoring programme;
  - Providing future monitoring requirements and preliminary RWQOs, and
  - Providing recommendations for future planning and strategy development activities.

2.12.2 Outputs

The outputs of the above studies are as follows (Table 2-7):

Table 2-7: Summary of Outputs the Orange River System Studies

Title	Output	Report No.	Output summary details
Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River	Report	Still to be published	The preliminary and final reconciliation strategies form the two main outputs of the study. They are supported and based on a number of baseline investigations and assessments.
Water Quality Total Dissolved Salts (WQT) Modelling and Water Resource Planning Model (WRPM) setup requirements for the Orange River	Calibration Report[1], WRPM Testing Report[2]; WQT Model, WRPM model	P RSA 000/00/17112[1] P RSA 000/00/17212[2]	Calibrated WQT Model for the Orange River Configured and Tested WRPM for the Orange River System
Orange River: Assessment of water quality data requirements for planning purposes: Upper and Lower Orange Water Management Areas (WMAs 13 and 14).	Water Quality Status Quo Report*, Monitoring Report**, RWQO Report	P RSA D000/00/8009/1*, P RSA D000/00/8009/3**, P RSA D000/00/8009/2	Reports detailing: The water quality status quo of the Upper and Lower Orange WMAs based on historical data and a snapshot survey; Proposed RWQOs for the Orange River; Proposed monitoring sites and a programme for water quality

2.13 SUMMARY OF DATA/INFORMATION SOURCES

The studies and information collected and reviewed provide wide array of data sources, key findings, summary information and outputs regarding water quality aspects in the Orange Senqu Basin. Some of these are integral to management of the water quality of the Orange Senqu basin that require integration into the basin-wide IWRM Plan. These aspects could be consolidated and divided into a water quality activity, output or data source. The activity, output or data source information is summarised in Table 2-8 below:

Table 2-8 : Summary of water quality aspect and source information

	ACTIVITY/OUTPUT/DATA SOURCE	SOURCE INFORMATION
1	Monitoring networks/programmes: Monitoring of salinity, nutrients, microbiological quality, persistent organic pollutants, heavy metals	Phase 2 IWRM Plan Framework for monitoring Vaal River Studies Orange River Studies JBS-1`
2	Selection of surface Water Quality Variables and Monitoring Points	Fitness for use Assessment Phase 2 IWRM Plan Framework for monitoring Orange River Studies
3	Sampling and data acquisition Protocols; institutional requirements	Phase 2 IWRM Plan Framework for monitoring
4	Data storage and management	Framework for monitoring Phase 2 IWRM Plan
5	Quality Control and Assurance system	Framework for monitoring JBS
6	Laboratory analyses	Framework for monitoring JBS-1
7	Reporting, Information generation and dissemination	Framework for monitoring JBS-1
8	Salinity Management (Modelling of salts)	Orange River Studies Vaal River Studies Water Resources Planning Model/WQT Model
9	Nutrient management	Orange River Studies Vaal River Studies TDA
10	Development of Water Quality Objectives/Trigger Values	Fitness for use Assessment Orange River Studies Framework for monitoring
11	Water Quality Status Quo	TDA Fitness for use Assessment JBS- 1 Vaal River Studies Orange River Studies
12	Consolidation/Integration of Water Quality data sources	Databases from Member States Fitness for use JBS-1 Orange River Studies Vaal River Studies
13	Water quality assessment of major aquifers	TDA Fitness for use Assessment Framework for monitoring
14	Training and capacity building	JBS-1 Phase 2-IWRM

3. Water Quality of the Orange-Senqu River basin

The quality of surface water at any point in a catchment reflects the combined effect of many physical, chemical, and biological processes that affect water as it moves along its course and through the land. Water quality is neither a static condition of a system, nor can it be defined by the measurement of only one parameter. Rather, it is variable in both time and space and requires routine monitoring to detect spatial patterns and changes over time.

The water quality in the Orange-Senqu River Basin is highly variable due to a combination of natural factors such as rainfall, evaporation, geology and soils, and anthropogenic factors which cause man-made changes to the chemistry of the rivers in the basin. In the case of the Orange-Senqu River, natural factors play a major role in determining water quality due to the size and extent of the catchment, stretching across several topographical, geological and climatic zones. Against this natural variability in water chemistry, there are significant anthropogenic sources of pollution in the basin, particularly in the Vaal catchment. This catchment includes the main urban and industrial conurbations of South Africa, the main gold mining areas of the country, parts of the Highveld coal fields, some of the country's power stations and significant areas of dryland and irrigation agriculture. The Orange River catchment as a whole is less developed, although irrigation agriculture occurs extensively along the river downstream of the Vanderkloof Dam

The Orange-Senqu River Basin is one of the largest river basins in Southern Africa spanning four Southern African countries (Botswana, Lesotho, Namibia and South Africa). The relatively scarce surface and groundwater resources in the Orange-Senqu River Basin are critical for the sustainable social and economic development of each country. Existing patterns of land and water use have reached the point where great care is needed to ensure that the scarce and vulnerable water resources are not over-exploited. The TDA focused on transboundary problems with consideration of national concerns and priorities. The TDA identified five major transboundary issues in the Orange-Senqu River Basin which were identified as priority concern of which deteriorating water quality (surface and groundwater) was one of them.

3.1 Consolidation Methodology

The state of water quality in the Orange-Senqu Basin is summarised below by the consolidation of the results, outputs and findings of the previous work undertaken. The status quo is presented as a summary of findings and a qualitative description of the key issues and concerns. Where possible, that is where recent actual data was available, the status of the indicator water quality parameter/results are reported (95th percentile values; mean for orthophosphate and chlorophyll-*a*). Due to the variances in water assessment studies/surveys, objectives of the assessments, data manipulation, water quality monitoring sites, water quality variables analysed, period of analysis it was not possible to consolidate the individual results into a single set dataset for spatial presentation.

The findings reported below were obtained from historical data on physico-chemical parameters as well as hydrological data that were assessed for the Senqu, Orange and Caledon Rivers and some major tributaries where available. Information obtained from once-off monitoring results, the TDA, the fitness for use assessment, the JBS-1, the Orange and Vaal River system studies were also consolidated into the results reported below.

For the purpose of the status perspective, water quality of the Orange-Senqu is described by selected physical, chemical, and biological characteristics. These were primarily related to water quality user requirements, impacting activities and key water quality issues that have been identified (e.g. salinization; eutrophication). These include:

- pH
- Electrical conductivity and/or Total dissolved salts (TDS)
- Ammonia
- Alkalinity
- Chloride
- Fluoride
- Chlorophyll-*a*
- Nitrogen and phosphorus related compounds (e.g. nitrate, ortho-phosphate)
- Major ions (sodium, potassium, calcium, magnesium, sulphate)
- Metals
- *E. coli*
- Total suspended solids
- Sodium absorption ratio
- Turbidity
- Organic Pollutants (e.g. DDT, Dioxins)

Multiple uses of the Orange River water occur within the Orange-Senqu Basin. Each user sector has different water quality requirements. The analysis provided below is reported on in terms of the level of protection required for the most stringent water user (fitness for use). In addition, in South Africa, the DWA have proposed resource water quality objectives (RWQOs) for the Orange River for a range of water quality parameters. The analysis provided below in some instances refers to these water quality objectives that have been set and reports on compliance.

A high level desktop assessment of the water quality status of the Orange-Senqu Basin and a perspective on key issues and concerns is provided below.

3.2 Analysis of the Results

The main water quality status findings for the Orange-Senqu Basin can be summarised as follows:

- The water quality in the Senqu River is reported as being very good (natural state). The TDS in Lesotho Highlands are generally less than 100mg/l and phosphorus concentrations are typically below 0.03mg/l.
- The phosphorus concentrations in the Senqu River just before it flows into South Africa were reported at 1.7mg/l (due to high sediment loads). A high degree of soil erosion does occur resulting in high turbidity in the lower reaches of the Senqu River.
- The water quality and quantity in the uppermost reaches of the Orange River, above Gariep Dam, is still in a fairly natural state and show minor changes over the past 13 years.
- The water in these uppermost reaches of the Orange River is moderately soft, relatively low in salt concentrations, but generally high in suspended solids and turbidity. For example, at Aliwal North the TDS is reported as low at 221 mg/ℓ, with ideal concentrations of ammonia, sulphate and nitrate. The relatively high phosphate concentrations (0.020 – 0.067 mg/ℓ) in the upper Orange River are considered to be largely natural.
- The concentration of total suspended solids (TSS) and turbidity in the upper Orange River are high because of soil erosion, but fluctuate seasonally. However, the TSS in the Orange River in and downstream of the major dams has decreased extensively during the past 35 years, which has decreased the turbidity, therefore increases the underwater light regime and the potential for algal blooms.
- The water quality in the Senqu and Upper Orange Rivers is suitable for domestic use, recreational use and irrigation with low TDS and low sodium adsorption ratio.
- The mean chlorophyll-a concentrations (algal biomass) in the Gariep and Van der Kloof Dams were low (<12 µg/ℓ) and fall in the range of oligotrophic systems, but the Chl-*a* concentrations, were much higher at Upington and Pella (mean 30 µg/ℓ) corresponding to mesotrophic water bodies. More monitoring data is required to obtain a better understanding of the trophic status of these sites. Chl-*a* data is limited and more data is required to provide a conclusive understanding.
- The water quality in the Orange River at Marksdrift is reported as good with most water quality parameters analysed in the ideal or acceptable range. The mean phosphate concentration of 0.030 mg/ℓ is considered to be largely natural. Similar phosphate concentrations were also observed at Upington, Pella and Vioolsdrift.
- The water quality in the Lower Orange River was occasionally above the water quality objective for irrigation water use especially because of high salts and high pH values. Some of the water withdrawn for irrigation is returned to the river environment for reuse, but its quality is seriously degraded with considerably higher salts and nutrient concentrations and evidently contributes significantly to the salts load in the Orange River.
- The water quality at Boegoeberg Dam was also good apart from for the unacceptable high phosphate concentration (0.033 mg/ℓ). High phosphate concentrations usually stimulate algal growth.

- The nutrient (nitrate and ortho-phosphate) concentrations in the Orange River are in general non-compliant to the water quality objectives that have been set. Total phosphate concentrations in the Upper Orange River range from less than 0.02mg/l to 0.05mg/l, while concentrations in the lower Orange range from 0.02mg/l to 0.07mg/l. However total phosphorus and total nitrogen ratios tend to be higher in this part of the system, suggesting that nutrients could come from the agricultural fertilisers.
- Very high nitrogen concentrations are noted in the groundwater in Namibia, which are considered to be typical of underground water in agricultural areas.
- The salt concentrations show an increasing trend downstream with high concentration at Pella (460 mg/ℓ). Long-term studies indicated that the overall dissolved salt concentrations in the Orange River are increasing significantly (in time and space), especially in the Lower Orange River (below Marksdrift). However the higher evaporation in this stretch of the river will also contribute to increased salt concentrations (Figure 3-1).
- The pH values in the whole Orange River were high (median, 8.1); generally increase downstream and occasionally exceeds the upper limit for irrigation of 8.4.
- The concentration of some metals, aluminium, cadmium, copper and lead were occasionally unacceptable high and potentially harmful for human health and for the aquatic environment. Spikes in metal concentrations in the Vaal, Caledon/Mohakare, Riet, Modder and Lower Orange River are also observed and are unclear and should be investigated further. Mining and industrial activities in the areas could be a potential source of some of the metals observed.
- Persistent organic pollutants for most part of the Orange-Senqu Basin were found to be in low concentrations however some localised spikes in concentration were noted.
- The general water quality in Kornetspruit and Kraai River is good. Orthophosphate levels are however high which indicate wastewater discharge impacts.
- The Seekoei River's salt and nutrient concentrations are high but are considered to represent natural conditions. The stream flow in the river has decreased dramatically and indicates over-extraction of the water.
- The Stormbergspruit also indicates high salts and nutrient levels. The pollution levels are unacceptably high in the Stormbergspruit at Burgersdorp. The high nutrients (nitrate and phosphate) and faecal coliforms contamination indicate that poorly treated sewage is entering the system.
- The water quality in the Caledon/Mohakare River is highly variable but in general is in a fair condition however, nutrient levels are elevated and increase downstream of Maseru. Clear signs of eutrophication because of the high phosphate concentrations are noticeable.

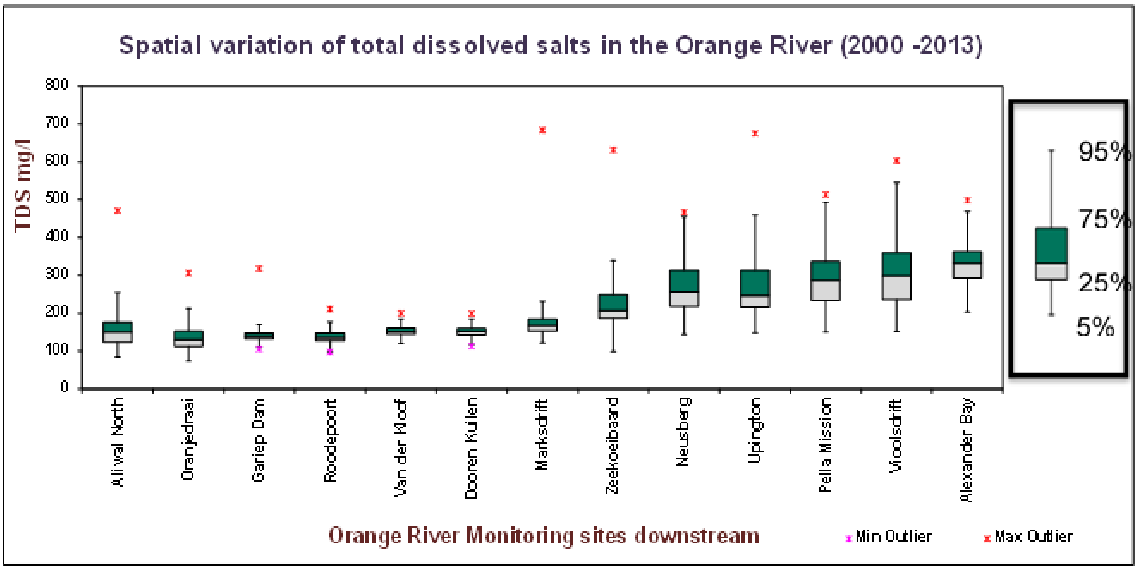

Figure 3-1: Spatial variation of Total dissolved salts (mg/ℓ) in the Orange River during 1999 – 2013 ((Department of Water Affairs, In preparation)

- The water quality in the Modder River is reported as being poor, especially because of high dissolved salts and unacceptable nutrients (nitrate and phosphate) concentrations and very high pH values. However, the trends show decreasing values.
- The general water quality of the Riet River at Jacobsdal was good, except for the high pH but it shows a decreasing trend. However, the water quality in the lower end of the Riet River at Zoutpansdrift is unacceptable primarily because of very high salt concentrations (TDS, exceed 1000 mg/ℓ). Water quality in the Lower Riet River is of concern, and also impacts on water quality in the Lower Vaal River and at the Douglas Weir.
- The water quality in the Douglas Barrage on Vaal River was generally poor because of high TDS (approximately 900 mg/ℓ), pH and high phosphate concentration

The main water quality issues and concerns for the Orange-Senqu River Basin are summarised in Table 3-1 below:

Table 3-1 : Water Quality issues and concerns identified for the Orange-Senqu River Basin

ISSUES/CONCERNS	DETAILS
Soil erosion and wetland degradation	High degree of soil erosion experienced in Lesotho (~2 % of top-soil/annum). Wetlands are seriously degraded and under threat.
Increasing siltation	High sediment load in Caledon as a result of the soil erosion in the upper regions, mainly in Lesotho. Siltation of dams is occurring, e.g. Welbedacht Dam, Lower Orange, diamond mining activities. Because of the silt retention capacity of the two major dams in the Orange, silt and sediment loads in the lower Orange have been considerably reduced.
Increased loads of salts (salinity)	Increase in time and space. Ascribed to irrigation return flow and reduced flows. Special concern, between Boegoeberg Dam and Kakamas – regularly exceeds 500 mg/ℓ TDS. Salinity problems in Lower Riet River are observed. Impact on sustainability of agriculture is a concern. Salinisation of irrigated soil could lead to greater salt loads on the river, ultimately to the point where quality may be impaired and the uses of the water restricted. The salt load from the Vaal River needs to be taken into account – specifically in relation to mining pollution and effluent disposal
Eutrophication	Serious cyanobacterial blooms in the Lower Orange River since 2000 and more recently in the Upper Orange; aesthetic problems; toxic species in the Middle and Lower Orange River.
Microbiological pollution	Due the large number of sewage effluent discharges microbiological pollution and increase in health risks is growing in the Orange River. Much of the outbreaks are localised, however, the situation is becoming symptomatic of the general decline in microbiological quality. Pollution levels in the Caledon River are a matter of concern.
Impact of irrigation	Huge volumes of irrigation return flows enter the Orange River. These return flows have a major impact on the water quality. The extent of the impact is not well understood.
Water Transfers	Developments in Lesotho and increased transfers of water out of the Senqu system (Lesotho Highlands Phase 2) can have a major impact on the water quality and water availability in the Upper Orange River.
Flow regulation	Flow regimes have been homogenized and flow variability is almost absent. There is altered the natural dynamics of the ecology and biota patterns of the river.
Reduced flow	Enhanced salinity and eutrophication; formation of sandbars in the river mouth.
Turbidity	The Orange River is a turbid river. The growth of benthic algae and phytoplankton, which include important nuisance organisms, is limited by light availability, which is restricted by the turbidity. New dams, or an increase in the salinity of the water (with which flocculation and sedimentation of suspended solids is associated), or both factors acting together, could reduce the turbidity allowing blooms of algae and phytoplankton.
Groundwater pollution	Groundwater pollution around many of the smaller towns and urbanised areas are becoming a growing concern. This is related to poor and inadequate sanitation systems. In the Lower Orange catchment are groundwater is emerging as key issue and further investigation is needed.
Reed encroachment	Reed encroachment of the channel in the middle reaches of the Orange River has been considerable, subsequent to the regulation of flow by the Gariep and Vanderkloof Dams.

3.3 Key findings / conclusions

Deterioration of the quality of the water resources (both surface and groundwater) in the Basin is therefore mainly attributable to one or more of the following land-use impacts, depending on the location within the Basin (ORASECOM, 2008):

- Discharges from waste water treatment works in the numerous small towns and urbanised areas within the Basin, many of which are not in compliance with the waste water discharge standards and licence conditions;
- Mining pollution from point sources e.g. direct discharge from mine dewatering and effluent disposal; and non-point or diffuse pollution from runoff and seepage from mining waste dumps;
- Runoff and seepage from developed and informal urban areas;
- Runoff from agricultural lands and irrigation return flows;
- Industrial pollution originating from direct discharges to the water course and stormwater runoff and seepage from polluted industrial sites;
- Overgrazing and poor land management practices, especially on steep slopes and in marginal agricultural areas.

The key threats to water quality in the Orange River as identified by previous work are salinisation, algal blooms (eutrophication), metals and organic pollutants and microbiological pollution. The findings and some recommendations are summarised below:

- *Salinisation*: The salinisation of the Orange-Senqu River Basin was shown to be an important water quality problem. Anthropogenic increases in salinity and electrical conductivity in surface waters are largely due to agriculture, urbanisation and industrial activities. Agricultural irrigation in the upper Orange River accounts for approximately 81 % of the water demand and approximately 94 % for the lower Orange. This demand will increase with implementation of planned developments in the Lesotho lowlands and the extension of irrigation in Namibia and South Africa. A once-off sampling exercise during by the Department of Water Affairs South Africa indicated that the dissolved salts and nutrient concentrations in the irrigation return flows are orders higher than in the Orange River and apparently contribute significantly to the salt loads in the Orange River. However, the precise volumes of return flows from irrigation along the river are uncertain and should be investigated further.
- Modelling of salts: The main variables that impact on the salinity loads in the Orange River system should be assessed on a continuous basis to establish the need to update the TDS model and to commission studies accordingly. The high TDS concentrations in the Orange River may influence the turbidity of the water. Although flow regulation is not necessarily the main cause of salinity problems, flow and river salinity are intimately linked, so it makes sense to co-ordinate their management through an integrated program supported by appropriate salinity modelling.
- Eutrophication: Algal blooms have become a visible water quality problem in the Orange River. Algal blooms, including cyanobacteria, were recorded in the Gariep Dam and Upington. Eutrophication is a severe problem in the Vaal catchment and in isolated pockets in other parts of the Basin. Localised eutrophication and microbial pollution is known along the Caledon River, along the Orange River downstream of Lesotho and downstream of the Upington irrigation area to Namibia. However, there is insufficient information to determine the transboundary extent of this pollution;

- Trace metals and Organic Pollutants: The transboundary impacts of persistent organic pollutants (POPs), heavy metals and radio-nuclides are unknown due to a lack of monitoring data. These should be investigated further to determine the possible sources. The role of the numerous mineral mines along the river should be particularly investigated as possible sources of metals.

Water quality monitoring networks are poorly developed in Lesotho and Namibia. Analyses are confined to basic parameters such as pH, TDS and common anions and cations. Microbiological analysis is carried out in Lesotho. South Africa has a sophisticated and extensive monitoring system although there are a number of deficiencies in the data sets available, particularly along the Lower Orange River. A regional water quality monitoring programme is required that initially includes a monitoring network for transboundary water management that is able to determine surface water quality status and trends.

4. Actions required / Potential interventions

4.1 Introduction

The assessment of the water resources of the Orange Senqu River Basin in terms of water quality status, fitness for use and water quality objectives should link to water quality management related goals, a management action or intervention that is required. Elements of management may include control of pollution and impacts, use of water and land use. Specific management activities are determined by natural water quality, the uses of water in natural and socio-economic systems and future developments.

The water quality assessment information requires decisions to be made on:

- Identification of the actual and emerging problems of water pollution/ water quality deterioration.
- Formulating plans and setting priorities for water quality management.
- Developing and implementing water quality management programmes.
- Evaluating the effectiveness of management actions.

The water quality condition/state can be linked to the type and urgency of water quality management action necessitated. This can range from no action to immediate intervention (Figure 4-1).

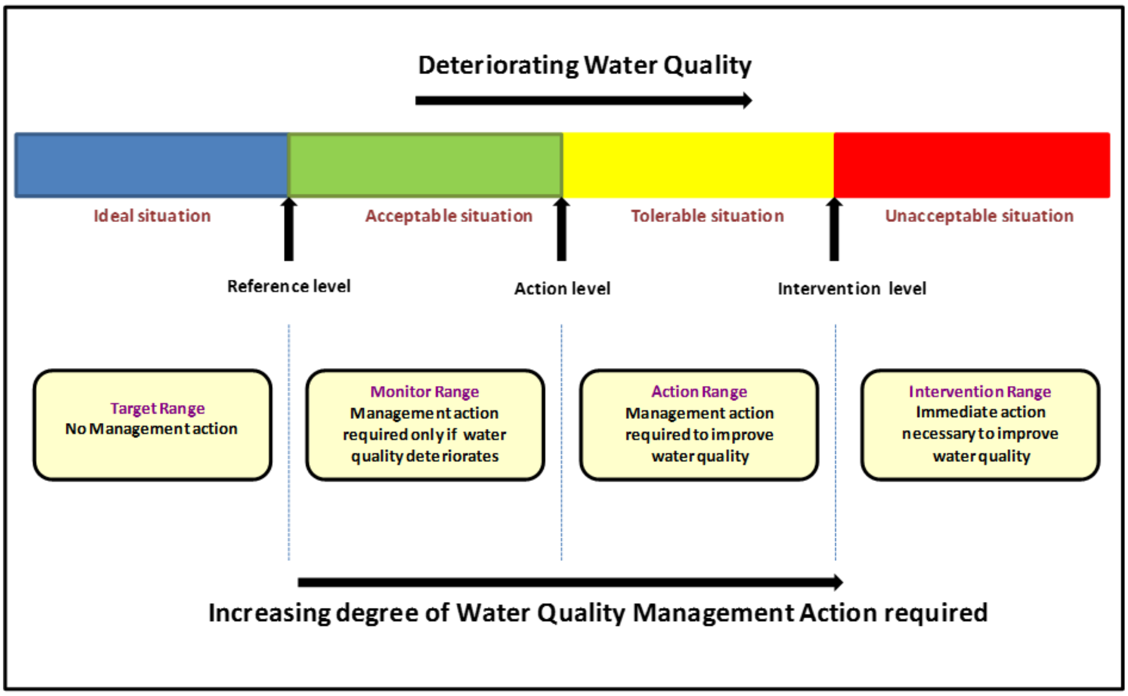

Figure 4-1 : Relationship between assessment rating and degree of water quality management action required

The previous work undertaken and the water quality status review indicate that key actions and interventions are required to manage the water quality of the Orange Senqu River Basin, to limit further deterioration and ensure the water is fit for use. Some of these actions/interventions are required at the ORASECOM level, however others require implementation by the Member States individually or at a bilateral level.

Based on the overview assessment the following key actions are recommended for inclusion in the IWRM Basin plan:

- Establish basin-wide RWQOs and agree and develop sectoral short- and medium-term targets to meet the objectives.
- Develop and implement a regional water quality monitoring network throughout the Basin to report on water quality status.
- Increasing salinity resulting from the effects of irrigated agriculture specifically in the Lower Orange and the impact of the Vaal River should be investigated further.
- Undertake an assessment of Persistent Organic Pollutants and heavy metals in the Vaal and Lower Orange catchments.
- A nutrient balance or nutrient modelling is necessary to determine the fate of nutrients in the Orange-Senqu system. A more detailed study on the effect of eutrophication on the Orange River should be undertaken, especially to understand the development of algal blooms in the Improve compliance monitoring and enforcement

4.2 Action 1 – Set Resource water quality objectives

4.2.1 Overview

For each of the key water quality parameters selected for a monitoring in the Orange-Senqu River Basin, it is important to also set water quality objectives to measure whether the desired environmental values/water quality requirements are at risk. In order to ensure that the water quality of the Orange River Basin is suitable for use and supports a health ecosystem, RWQO will need to be set for the chemical, physical and biological parameters selected for the assessment programme.

RWQOs are required at different levels in the Basin to manage water quality. RWQO will be needed at the local level to manage water quality within the tributary catchments. From an overall Basin perspective, RWQO will be required at key points along the Vaal and Orange Rivers. The RWQO are essential to the management of water quality in the Basin. The RWQO are the management objective for which the water quality management plans have to be developed to achieve. The setting of RWQO at the local and catchment level is the responsibility of the individual Basin states. However the setting of RWQO at transboundary locations and to provide an overall perspective of the Basin water quality should be undertaken under ORASECOM as it involves the co-operation of the Basin States.

The setting of water quality objectives requires the understanding of the current water quality status, pollution sources and the water user water quality requirements (including the ecology). There are existing sets of trigger values, RWQO and there will be RWQOs set for the Vaal River as part of the current RQO processes. These will form the basis for the Basin wide RWQOs.

Ideally the setting of RWQO would be undertaken as part of the development of a water quality management plan in which water quality modelling is undertaken to develop the strategy to manage pollution sources to achieve the RWQO set. The modelling and source management process may result in some of the RWQO being revised to make meeting them achievable.

4.2.2 Proposed Actions

The following actions will be required to set the RWQOs:-

- Consolidation of the water quality data collected from the different water quality databases and assessments to provide a consolidated view of the water quality statistics required to set RWQO.
- Confirmation of key points at which RWQOs are required. The current set of 12 transboundary points will serve as the base set of key points. The base set will be revised based on the water quality issues, reporting requirements and international boundaries. This will be done in a workshop environment.
- The water quality requirements of the water users along the main stem of the Orange River and Vaal River will be identified. This includes the water quality requirements to sustain the ecology in the required ecological category. There will need to be interaction with the aquatic ecology actions.
- The key water quality variables will be selected for which RWQOs need to be set. Based on the current understanding of the water quality status, water quality variables for which RWQO need to be set will be selected. Based on the key water quality issues in the Basin, these will be indicators of salinity, nutrients, trophic status, toxics (heavy metals) and microbiology.
- Group of key stakeholders including representatives of the Basin states as well as water quality and ecological specialists will be convened in a workshop to set the RWQO at the key points.
- The RWQOs will be documented.

4.2.3 Time frames and costs

This action should be implemented as one of the first actions to be undertaken as they form the basis for the development of the water quality management strategy. It is proposed that this action starts in July 2014 assuming that July is the start date for the next phases of the ORASECOM studies.

An indicative cost for the setting of the RWQOs is €100 000.

4.3 ACTION 2 - WATER QUALITY MONITORING AND DATA MANAGEMENT

4.3.1 Overview

A Regional Water Quality Assessment Programme is proposed that initially includes a monitoring network, data management and reporting only for transboundary water management that is able to determine surface water quality status and trends within funding constraints and that maximizes the use of available water quality monitoring information. These include (1) defining the scale of data analysis and reporting (2) collaboration and integration of data/databases from Member States, as well as regional and local organizations. This process will be developed concurrently with the setting of the RWQOs.

A transboundary monitoring programme, data management system, inter laboratory benchmarking programme and reporting system already set up will form the basis of this action. The initial system set up required further resources and support to be successful. The proposal is therefore to expand the existing system and provide support to ORASECOM to assist with the implementation and running of the monitoring system.

4.3.2 Proposed Actions

The following actions will be required to set up the water quality monitoring network:-

- The monitoring network needs to be identified in terms of the points that require to be monitored. The monitoring points will be based on the currently selected 12 transboundary points. The location of the points will be confirmed and additional points added where necessary. The need to include sources of pollution in the monitoring programme will be discussed. Currently the performance of the wastewater treatment works is a water quality issue in the Basin. Although the responsibility to manage the works lies with the individual basin states, it might be necessary to include the monitoring results of the effluent discharges from the major works in the Basin wide monitoring program as this is of concern to the Basin states.
- The water quality variables to be monitored and monitoring frequency needs to be confirmed and variables added if necessary. Consideration should be given to the inclusion of Persistent Organic Pollutants and heavy metals in the monitoring program.
- The available data at the points selected will be collated from the various databases. The existing database will be updated with the data collected to provide the water quality history at the monitoring points.
- The inter-laboratory benchmarking and quality assurance and quality control (QA/QC) protocols need to be revisited.
- A workshop is required to review the monitoring programme, inter-laboratory benchmarking protocols, reporting requirements and to assign responsibilities to the Basin States.
- Consideration should be given to setting up a website to input results and display the reporting results.
- Support to ORASECOM and the Basin States for a 6 month period is required to train and assist with the monitoring program implementation.

4.3.3 Time frames and costs

The development and implementation of this program should run in parallel to the setting of RWQOs. The duration of this action will be one year and will cost €150 000. The costs are assuming that the Basin States carry the costs of the Inter-laboratory benchmarking and QA/QC.

4.4 Action 3 - Salinisation due to irrigation return flows

4.4.1 Overview

Significant volumes of irrigation return flows enter the Orange River, particularly the Lower Orange. In assessing the water quality data in the Lower Orange River, an increasing trend in TDS concentrations was observed. In calibrating the WQT water quality model, there was limited water quality data against which to calibrate the models irrigation modules. These return flows have a major impact on the water quality of the river. The extent of the impact is not well understood. Increasing salinity resulting from the effects of irrigated agriculture specifically in the Lower Orange should be investigated further.

4.4.2 Proposed Actions

The proposed actions to address the irrigation return flows and salinization are:-

- With the co-operation of the Irrigators, select two schemes to monitor. Preferably one in South Africa and the other in Namibia. The schemes selected should be representative of the agricultural practises in the area.
- A monitoring programme should be set up for the irrigation schemes measuring the inflow volumes and qualities, channel supply efficiencies, application rates and the return flow drainage channels should be monitored.
- The water quality variables monitored must not only include salts but also nutrients. The contribution to the nutrient loading can also be assessed during the proposed study.
- The groundwater quality should also be assessed as the modelling exercise indicated that a significant portion of the salt load is entering the groundwater system and not returning in the return flow.

4.4.3 Time frames and costs

The time frame for this study will be 1 year to cover a complete year of irrigation and crop cycles. The cost of this action is estimated to be € 200 000.

4.5 ACTION 4: EUTROPHICATION MANAGEMENT

4.5.1 Overview

Eutrophication of the Vaal and Orange Rivers is currently the most significant water quality management challenge. The nutrient mass balance for the Basin is not well understood. The sources of nutrients in the Basin have not been quantified. The management tools in terms of Basin wide nutrient models and eutrophication models are not available to assess nutrient management options. The framework for a basin wide nutrient model suitable to run with the WRPM was developed in Phase 2 of the ORASECOM Study. The model needs to programmed and tested to see if it can be calibrated.

A detailed study is required to use the available water quality and flow data to develop a nutrient balance for the basin. This will enable the major nutrient sources to be identified which will indicate the sources that need management.

4.5.2 Proposed Actions

The proposed actions to develop the management of eutrophication are:-

- The development of the nutrient balance using the available instream flow and water quality data. The balance must include all the point sources and estimates of the wash-off loads from urban and agricultural areas. The monitoring of the return flows of the irrigation schemes as part of the salinization study will support the nutrient balance study.
- The phosphorus model framework developed in Phase 2 needs to be reviewed and changed where necessary based on the nutrient balance. The phosphorus model should be programmed and calibrated against the available water quality data. At this stage consideration should be given to the modelling of phosphorus as this is the limiting nutrient in the majority of the basin rivers.
- The calibrated phosphorus model should be run with the WRPM to develop a nutrient management strategy. The strategy should indicate the discharge standards required for the wastewater treatment works and industrial discharges. The management of the phosphorus load from agricultural runoff and return flows should also be addressed. The results of the modelling will assist in setting the RWQO for nutrients.

4.5.3 Time frames and costs

The nutrient balance and modelling should be undertaken concurrently with the RWQO setting and the monitoring program development. The action will take 18 months to complete and will cost €250 000.

4.6 Action 5: Assessment of Persistent Organic Pollutants and Heavy Metals

Very little understanding of persistent organic pollutants (POPs) and heavy metals is available. There is extensive irrigation practised in the Basin where herbicides and pesticides are used. These could be present in the return flows and conveyed in the surface runoff to the river systems. The current water quality database does not support the identification of organic pollutants in the rivers. The Joint Basin Survey 1 provided some insight into the magnitude of the water quality issues related to POPs and heavy metals. These water quality variables should be monitored further to determine the extent of the problem and the trends in the water quality. This aspect will be addressed in the development of the monitoring programme.

4.7 Action 6: Monitoring of Implementation of Interventions Identified in each National Action Plan via the Strategic Action Programme

The Orange–Senqu Strategic Action Programme (SAP) is a negotiated document that provides a basin-wide framework for the implementation of a prioritised set of national and joint transboundary actions and investments to address jointly agreed priority environmental concerns in the Orange–Senqu River Basin. The SAP is endorsed at political (ministerial) level and with the related National Action Plans (NAPs) of the four basin states, provides a basis for the implementation of SAP priority actions at national and basin level, and the integration of transboundary and basin concerns into national legislative, policy and budget decision-making processes. Close collaboration between the ORASECOM Secretariat and responsible national organisations will be necessary to ensure coordination and monitoring between the implementation of SAP and NAP activities in the four basin states.

4.8 Summary of Actions

Action	Activity	Start date	Duration	Cost (€)	Responsibility
1	Setting RWQOs	July 2014	8 months	100 000	Orasecom to lead with the support of the Basin States
2	Water Quality monitoring and data management	July 2014	12 months	150 000	Orasecom to lead with the support of the Basin States
3	Salinisation due to irrigation return flows	October 2014	12 months	200 000	Orasecom
4	Develop nutrient management plan	July 2014	18 months	250 000	Orasecom and Basin states in particular South African DWA
5	Assessment of Persistent Organic Pollutants	As part of Monitoring Programme (Action 2)			
6	Monitoring of implementation of NAP interventions	Orasecom to lead with the support of the responsible national organisations in the Basin States			

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6. Appendix

6.1 Previous Studies

AVAILABLE INFORMATION		DETAILS
1	Orange Senqu-River Basin. Preliminary Transboundary Diagnostic Analysis. Adopted by ORASECOM in April 2008	UNDP/GEF/ORASECOM Project
		Support from the GEF/UNDP
		Main Report
		April 2008
		TheTransboundary Diagnostic Analysis provides an analysis using best available verified scientific information and an objective and participatory process that examined the state of the environment of the Orange-Senqu basin and identified the root causes for its degradation.
		It identified priority transboundary, problems, assessed environmental impacts and socio-economic consequences, developed causal chain analysis and provided a basis for the formulation of the Orange-Senqu Strategic Action Plan. Thematic reports were proposed as part of the study, which included a Water Quality Report (ORASECOM 007/2007 : November 2007)
2	Support to the Phase 2 of the Basin-Wide Integrated Water Resources Management Plan: Work Package 3: Integrated Water Resources Quality Management Plan (2009-2011)	ORASECOM Project
		Support from the BMZ, DFID, AusAID, GIZ
		6 Work Packages – Primary output the WRYM for the entire basin, supported by self-standing packages that serve as inputs to water resource simulation modelling for the basin. Water quality related aspects formed part of package 3.
		Work Package 3 Reports : • Development of a Water Quality Monitoring Programme and Data Management. Document No. 007/2011. April 2011 • Development of Specifications for the Water Quality Model. Document N0. 006/2010. December 2010
		Establishment of protocols, institutional requirements for a water quality monitoring programme, data management and reporting.
		Specifications for a water quality model that interfaces with the system models.
3	A Fitness for Use Assessment of the waters of the Orange-Senqu Basin	EU Support programme to ORASECOM
		Funded by the South African Development Community/European Development Fund. African Transboundary River Basin Support Programme Case of the Orange-Senqu River in Botswana, Lesotho, Namibia and South Africa
		Report No. ORASECOM 001/2010
		November 2009
		Provides an assessment of the suitability of use for both ground and surface water in the Orange-Senqu River Basin. The assessment evaluates the impact of water quality on major uses of water in the basin.
		Series of maps of water quality condition at a sub-basin level indicating different water quality concerns that may pose a risk to major water uses.

	AVAILABLE INFORMATION	DETAILS
4	A Framework for Monitoring Water Resource Quality in the Orange-Senqu River Basin	EU Support programme to ORASECOM
		Funded by the South African Development Community/European Development Fund . African Transboundary River Basin Support Programme Case of the Orange-Senqu River in Botswana, Lesotho, Namibia and South Africa
		Report No. ORASECOM 002/2010
		November 2009
		Report outlines a framework for water resource quality monitoring for ORASECOM (and its Member States). The development of a regional framework is to support the establishment and maintenance of a regionally effective water quality management programme. A basis for an effective regional analytical quality control is outlined.
		An initial monitoring network for transboundary water management is proposed, an initial set of priority monitoring variables has been identified at each site and an initial trigger values for these variables are proposed. The basis four a groundwater monitoring programme is suggested for four main transboundary sites.
5	Orange-Senqu Commission (ORASECOM) (2011). Joint Basin Survey-1: Baseline Water Resources Quality State of the Orange-Senqu River System in 2010.	ORASECOM Project
		African Transboundary River Basin Support Programme Case of the Orange-Senqu River in Botswana, Lesotho, Namibia and South Africa South African Development Community, Water Sector Support Unit – Gaborone. European Development Fund
		Joint Basin Survey -1 Report
		2011
		The joint basin survey provides a snapshot of the quality of the water resources of the basin. It provides an assessment of water quality, aquatic ecosystem health and ecosystem habitat integrity based on the first joint basin monitoring undertaken by the parties.
		The joint basin survey provides a set of baseline conditions in the Orange-Senqu River System in 2010.
6	Integrated Water Quality Management Plan (IWQMP) for the Vaal River System (2009)	South Africa : Department of Water Affairs Study
		Directorate National Water Resource Planning
		Final Report : Report No. P RSA C000/00/2305/7
		September 2009
		The IWQMP study details the water quality management strategy proposed for implementation in the Vaal River System in the immediate, medium (2015) and long term (2025 and beyond). The focus is on the Vaal River main stem. A description of water quality status is provided and resource water quality objectives are proposed for strategic monitoring points. Management strategies for salinity and nutrients are proposed.
		A series of reports were developed as part of the IWQMP study. These were as follows : • Water Quality Status Assessment • Salinity Balance • Integration of Resource Water Quality Objectives • Water Quality Economic Impact Modelling • Evaluation of Water Quality Management Scenarios • Monitoring Programme • Water Quality Management Strategy

AVAILABLE INFORMATION		DETAILS
7	Vaal River System: Large Bulk Water Supply Reconciliation Strategy: Second Stage Reconciliation Strategy (March 2009)	South Africa : Department of Water Affairs Study
		Directorate National Water Resource Planning
		Final Report : Report No. P RSA C000/00/4406/08
		March 2009
		The strategy proposed options for the reconciling water requirements with current water resource situation as well as likely future scenarios for the Vaal River System. Reconciliation interventions are formulated for meeting the growing water requirements.
8	Vaal River Reserve, Classification and Resource Quality Objectives Studies	South Africa : Department of Water Affairs
		Directorate Resource Directed Measures
	Comprehensive Reserve Determination study for selected water resources in the: Upper Vaal Water Management Area; Middle Vaal Water Management Area and Lower Vaal Water Management Area	2009 -2010
		The Reserve studies provide ecological specifications for ecological condition required at each of ecological water requirements sites selected in the Vaal River system. Eighteen comprehensive sites were selected and four rapid sites.
	Classification of Significant Water Resources (Rivers, Wetlands, Groundwater and Lakes) in the Upper, Middle and Lower Vaal Water Management Areas 8,9,10	September 2012
		Report No. : RDM/WMA 8,9,10/00/CON/CLA/0212
		The Water Resource Classification System was implemented in the Vaal River System. Management classes are specified for selected water resources in the Upper, Middle and Lower Vaal WMA. Water resources are classified as Class I, II or III.
	Determination of Resource Quality Objectives in the Upper, Middle and Lower Vaal Water Management Areas	Current
		The Resource Quality Objectives determination methodology developed by the Department of Water Affairs is being applied in the Vaal River catchment area. Resource Quality Objectives for selected water resources are being developed.
9	Report of the Inter-Ministerial Committee on Acid Mine Drainage (2010). Mine Water Management in the Witwatersrand Goldfields with special emphasis on Acid Mine Drainage.	South Africa Inter-Ministerial Committee under the Co-ordination of the Council of Geoscience
		December 2010
		A team of experts provides an assessment and reappraisal to Inter-Ministerial Committee of the acid mine drainage situation focusing on the Witwatersrand Gold Fields. An analysis of the currently known mine drainage sources in South Africa were identified with the Vaal catchment being one of priority areas.
10	Water Quality TDS (WQT) Modelling and Water Resource Planning Model (WRPM) Salinity Setup Requirements for the Orange River: WQT Model Calibration Report.	South Africa : Department of Water Affairs Study
		Directorate Water Resource Planning Systems
		December 2013
		Report No. : P RSA 000/00/17112
		The Water Quality TDS (WQT) model for the Orange River was calibrated. A combined model (WRPM) incorporating volume and salts for the Orange River system (which includes the Vaal River System) was developed.

AVAILABLE INFORMATION		DETAILS
11	Orange River: Assessment of Water Quality data requirements for Water Quality Planning Purposes (2009)	South Africa : Department of Water Affairs Study
		Directorate Water Resource Planning Systems
		August 2009
		Report No. : P RSA D000/00/8009/1,2,3
		A Status quo assessment and snapshot survey of the Upper and lower Orange catchment areas was undertaken. Recommendations on a proposed monitoring network were provided. Preliminary water quality objectives for selected variables in the Orange River are proposed.
12	Orange River Reconciliation Strategy Development Study	South Africa : Department of Water Affairs Study
		Directorate National Water Resource Planning
		Current Study
		The study is focus is to develop a reconciliation strategy for the bulk water resources of the Orange River System to ensure that sufficient water can be made available to supply the current and future water needs of the Orange River catchment users up to the year 2040. The strategy will consider all the tributary rivers and transfers affecting the water balance of the system. This core area forms part of the Orange-Senqu River Basin.

6.2 PREVIOUS STUDIES – DETAILS, DATA, INFORMATION GENERATED

Support to the Phase 2 of the Basin-Wide Integrated Water Resources Management Plan: Work Package 3: Integrated Water Resources Quality Management Plan. Work Package 3 Report : Development of a Water Quality Monitoring Programme and Data Management. Document No. 007/2011. April 2011

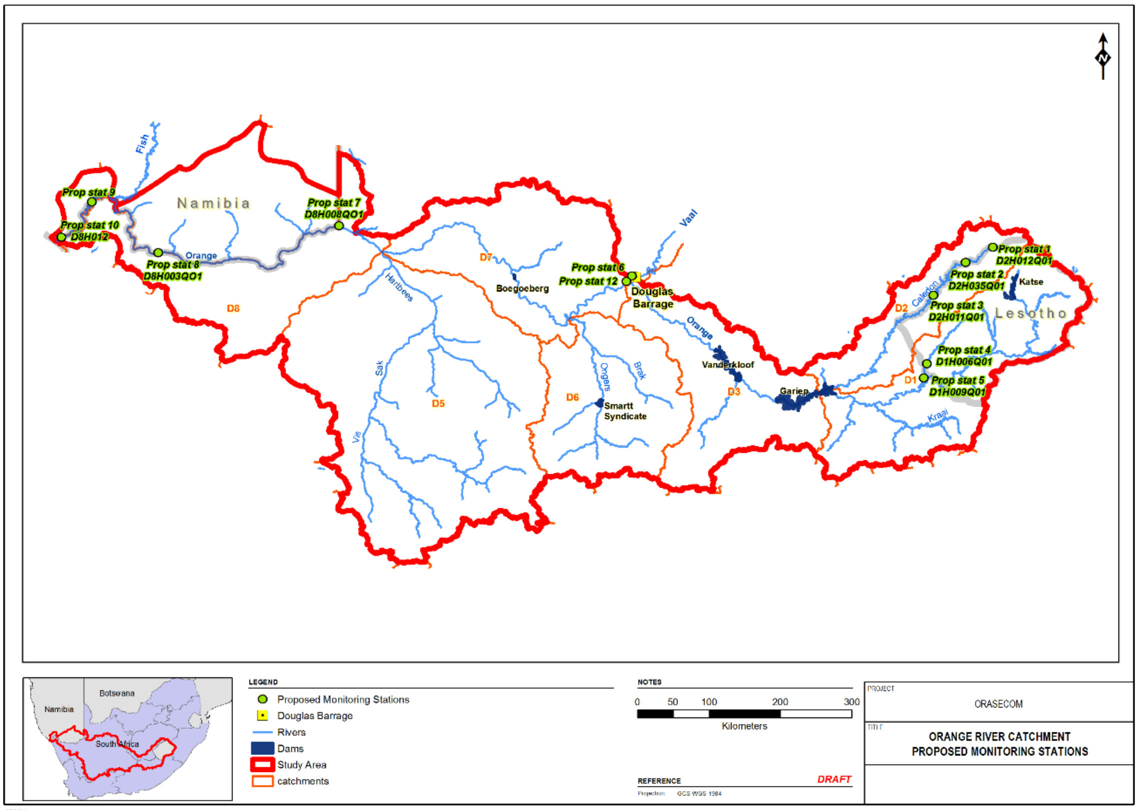
TRANS-BOUNDARY SITES:

Location of Trans-Boundary sampling points

Sampling Site	Co-ordinates		Details of Location	Member states responsible for sampling*
	South	East		
1	-28.6948	28.23486	D2H012Q01 Little Caledon River at the Poplars	Lesotho/South Africa
2	-28.8833	27.89	D2H035Q01 Caledon at Ficksburg at Ficksburg bridge	Lesotho/South Africa
3	-29.2978	27.48528	D2H011Q01 Caledon River at Maseru	Lesotho/South Africa
4	-30.16	27.40145	D1H006Q01 Kornetspruit at Maghaleen	Lesotho/South Africa
5	-30.3377	27.36277	D1H009Q01 Orange River at Oranjedraai	Lesotho/South Africa
6	-29.0528	23.68738	C9R003Q01 Vaal River at Douglas Barrage	South Africa
7	-28.4249	20.00087	D8H008QO1 Orange River at Pella Mission	South Africa/Namibia
8	-28.7621	17.72631	D8H003QO1 Orange River at Vioolsdrift (GEMS SITE)	South Africa/Namibia
9	-28.1229	16.89032	OSEAH 28 5 Orange River at Sendelingsdrift	South Africa/Namibia
10	-28.5669	16.50728	D8H012 Alexander Bay	South Africa/Namibia
11	-	-	Vaal Gamagara Pipeline providing water to Botswana	South Africa/Botswana
12	-29.123686	23.619969	Orange River Downstream of Vaal confluence	South Africa

*Botswana may join any of the teams at sites of preference. While Lesotho, South Africa and Namibia have allocated sites of responsibility for the inter-lab sampling exercise, they may also join in sampling at other sites. Samplers from all four member states will be trained.

Location of sampling sites



Analytical laboratories

The laboratories that will conduct the water quality sample analysis include:

- Lesotho - Department of Water Affairs, Water and Sewage Authority and National University of Lesotho
- Republic of South Africa - Department of Water Affairs
- Namibia – Namwater
- Botswana – Department of Water Affairs and Geological Surveys

The samplers will take bottles to the sampling sites. There will be two samples collected at each site for each laboratory. One bottle will contain a preservative and will be for the nutrient fraction and the second for the major cations and anions.

6. APPENDIX

Water quality variables to be analysed for at sampling sites

Sampling site	Water quality variables	
	Physical	Chemical/microbiological
Caledon and Senqu Rivers: Sites 1 to 5	pH, Electrical Conductivity/Total Dissolved Salts Suspended solids	Na, Cl, NH_4, NO_3-NO_2, PO_4, E-Coli
Orange River Sites 6 to 12	pH, Electrical Conductivity/Total Dissolved Salts	Na, Ca, Total alkalinity, Mg, Cl, K, SO_4, F, NH_4, NO_3-NO_2, PO_4, E-Coli At site 11 residual chlorine to be added

Sampling frequency

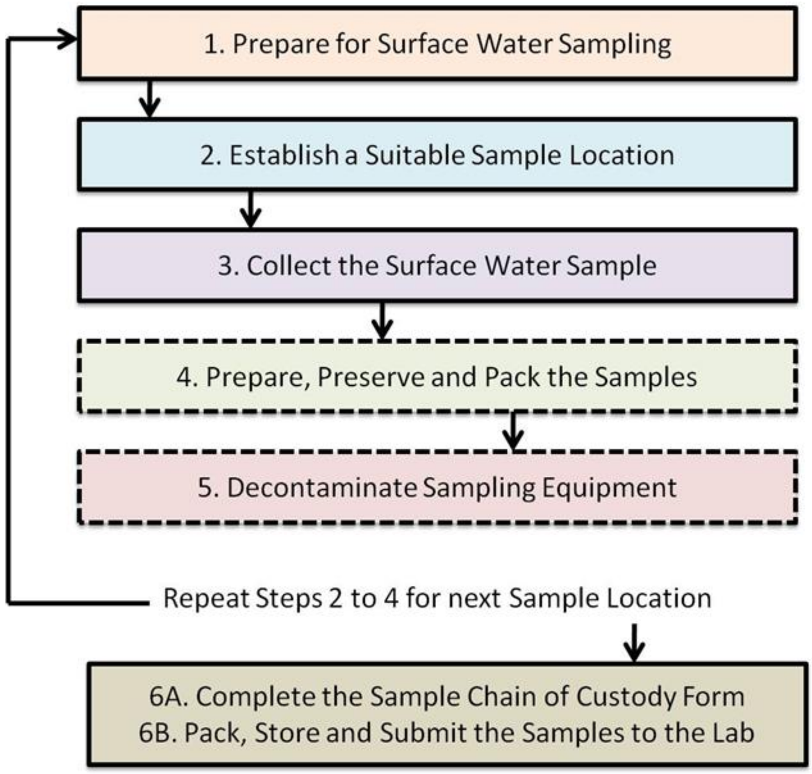
The goal was to collect the optimal number of samples that would provide reliable results. For rivers (flowing water) more frequent samples are needed. In general bi-weekly samples from a river are adequate. This will be sufficient to pick up on any water quality changes. The minimum and recommended number of samples and sampling frequency for the Orange, Caledon and Senqu Rivers is listed below. Initially the sample frequency for the trans-boundary monitoring program will be monthly. This can be revised with time depending on the results and the objectives of the monitoring programme.

The minimum and recommended number of samples and sampling frequency for Orange River catchment

SAMPLING POINT	MINIMUM PER POINT		RECOMMENDED PER POINT	
	Number of samples per year	Sampling Frequency	Number of samples per year	Sampling Frequency
Points 1 to 11 (Orange, Caledon and Senqu Rivers)	4	3 monthly	26	2 weekly

If any serious water quality deterioration or contamination is detected, sampling frequency should be increased to weekly if possible.

SAMPLING PROTOCOLS



6. APPENDIX

A Fitness for Use Assessment of the waters of the Orange-Senqu Basin. Report No. ORASECOM 001/2010. November 2009.

Member State data	Sub-basin	Waterbody Type[1]	Reach	Assessment code
Botswana	Whole region falling inside the O-S basin	Saline G/W	n/a	B1
Botswana	Whole region falling inside the O-S basin	Non-saline G/W	n/a	B2
Lesotho	Highlands	S/W	n/a	L1
Lesotho	Highlands	G/W	n/a	L2
Lesotho	Lowlands	S/W	n/a	L3
Lesotho	Lowlands	G/W	n/a	L4
Lesotho	Mokahare	S/W	n/a	L5
Namibia	Lower Orange	S/W	The length of common border with South Africa	N1
Namibia	Supply reservoirs (Naute & Hardap Dams)	S/W	n/a	N2
Namibia	Stampreit	G/W	n/a	N3
South Africa	Wilge	S/W	n/a	S1
South Africa	Upper Vaal	S/W	n/a	S2
South Africa	Middle Vaal	S/W	Upper-reach – up to Vaal Dam	S3
South Africa	Middle Vaal	S/W	Lower-reach Vaal Dam to Bloemhof Dam	S4
South Africa	Lower Vaal	S/W	Below Bloemhof Dam	S5
South Africa	Upper Orange River	S/W	From the Lesotho Border to Vaal confluence	S6
South Africa	Middle Orange River	S/W	From the Vaal confluence to the common border with Namibia	S7
South Africa	Lower Orange River	S/W	Length of the common border with Namibia	S9
South Africa	Caledon	S/W	n/a	S10

[1] G/W = Groundwater; S/W = Surface water

Sub-basin division for the Fitness for Use Assessment

Summary of fitness for use assessment for key water uses in the Orange-Senqu Basin

Member State	Sub basin	Agricultural Irrigation	Agricultural livestock	Domestic	Industrial	Recreational
Botswana	Whole region falling inside the O-S basin	NS	NS	NS	NS	G
Botswana	Whole region falling inside the O-S basin	NS	G	P	NS	G
Lesotho	Highlands	NS	G	P	P	G
Lesotho	Highlands	NS	G	P	P	NS
Lesotho	Lowlands	NS	P	NS	P	NS
Lesotho	Lowlands	P	G	G	P	NS
Lesotho	Mokahare	NS	G	G	P	G
Namibia	Lower Orange	P	G	P	P	G
Namibia	Supply reservoirs (Naute & Hardap Dams)	NS	G	P	P	G
Namibia	Stampreit	NS	NS	NS	NS	G
South Africa	Wilge	G	NS	P	P	NS
South Africa	Upper Vaal	P	G	G	G	G
South Africa	Middle Vaal	G	G	P	P	G
South Africa	Middle Vaal	G	NS	P	G	NS
South Africa	Lower Vaal	P	NS	P	G	NS
South Africa	Upper Orange River	G	G	P	P	G
South Africa	Middle Orange River	G	G	G	G	G
South Africa	Lower Orange River	P	G	G	P	G
South Africa	Caledon	P	G	G	P	G

TABLE KEY (red) = Not suitable; (orange) = Poor; (green) = Good (the tolerable description has not been used in this table for clarity purposes, this is an intermediate suitability descriptor and as such the predominance of other descriptors was used to describe overall suitability).

Example: Agricultural Irrigation (Crops) Fitness for use ma