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SUPPORT TO PHASE 2 OF THE ORASECOM BASIN-WIDE INTEGRATED WATER RESOURCES MANAGEMENT PLAN

Overall Project Executive Summary

November 2011

ORASECOM

The *Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan* Study was commissioned by the Secretariat of the Orange-Senqu River Basin Commission (ORASECOM) with technical and financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) in delegated cooperation with the UK Department for International Development (DFID) and the Australian Agency for International Development (AusAID). The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) implemented the study.

giz

On behalf of
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Overall
Project Executive Summary

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Study Name	**Support to Phase 2 of the ORASECOM Basin-wide Integrated Water resources Management Plan**		
Report Title:	***Overall Project Executive Summary***		
Submitted by:	WRP Consulting Engineers in association with Golder Associates, DMM, PIK, RAMBOLL and WCE		
REPORTS, WPS AND OTHER DELIVERABLES SUBMITTED		**TYPE**	**No.**
Overall Study			
	Inception Report	Report	004/2010
	Overall Project Executive Summary	***Report***	***013/2011***
Work Package 1: WATER RESOURCES MODELLING OF THE ORANGE-SENQU BASIN			
	Strengths and Weaknesses of Existing Models	Report	005/2010
	Setting up and Testing of the Final Extended and Expanded Models; Changes in Catchment Yields and Review of Water Balance	Report	001/2011
	Modelling software and datasets	Software	None
	Capacity Building and Setting up the Models in each Country; Process of Continuous Review	Report	003/2011
Work Package 2: EXTENSION AND EXPANSION OF HYDROLOGY OF ORANGE-SENQU BASIN			
	Improvements to Gauging Network and Review of Existing Data Acquisition Systems	Report	005/2011
	Extension of Hydrological Records	Report	006/2011
	Hydrological Database	Database	None
Work Package 3: INTEGRATED WATER RESOURCES QUALITY MANAGEMENT PLAN			
	Development of Water Quality Monitoring programme and Data Management Framework	Report	007/2011
	Development of Specifications for the Water Quality Model	Report	006/2010
Work Package 4: CLIMATE CHANGE IN THE ORANGE-SENQU RIVER BASIN			
	Downscaling Methodology and Ongoing Climate Modelling Initiatives	Report	007/2010
	GCC Downscaling for the Orange-Senqu River Basin	Report	008/2011
	Projection of impacts and Guidelines on Climate Change Adaptation Strategies	Report	009/2011
Work Package 5: ASSESSMENT OF ENVIORNMENTAL FLOW REQUIREMENTS			
	Literature survey and Gap Analysis	Report	008/2010
	Delineation of Management Resource Units	Report	009/2010
	Desktop Eco Classification Assessment	Report	016/2010
	Goods and Services Report	Report	010/2010
	Environmental Flow Requirements	Report	010/2011
Work Package 6: WATER CONSERVATION AND WATER DEMAND IN THE IRRIGATION SECTOR			
	The Promotion of WC WDM in the Irrigation Sector	Report	011/2011
	Irrigation GIS Database, Interactive Database and Irrigation Scenario Tools	Report	012/2011
	Irrigation GIS Database and Interactive Classification Tool	Software	None
	Irrigation Scenario Generation Tool	Software	None

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1.1 General

The Orange-Senqu River basin as shown in **Figure 1.1** originates in the highlands of Lesotho some 3 300m above mean sea level, and it runs for over 2 300km to its mouth on the Atlantic Ocean. The river system is one of the largest river basins in southern Africa with a total catchment area of more than 850,000km^2 and includes the whole of Lesotho as well as portions of Botswana, Namibia and South Africa. The natural mean annual runoff (MAR) generated within the basin is estimated to be in the order of 11 900 million m^3 based on the 1920 to 2004 period of data record. The flow reaching the Orange-Senqu River mouth has been significantly reduced by extensive water utilisation for domestic, industrial and agricultural purposes as well as several major inter-basin water transfers, both into and out of the Orange-Senqu River basin. Based on the most recent assessments, the average annual water flow reaching the Orange-Senqu River mouth is estimated to be approximately 3 700 million m^3 which comprises the environmental requirements of the river mouth as well as the intermittent floods.

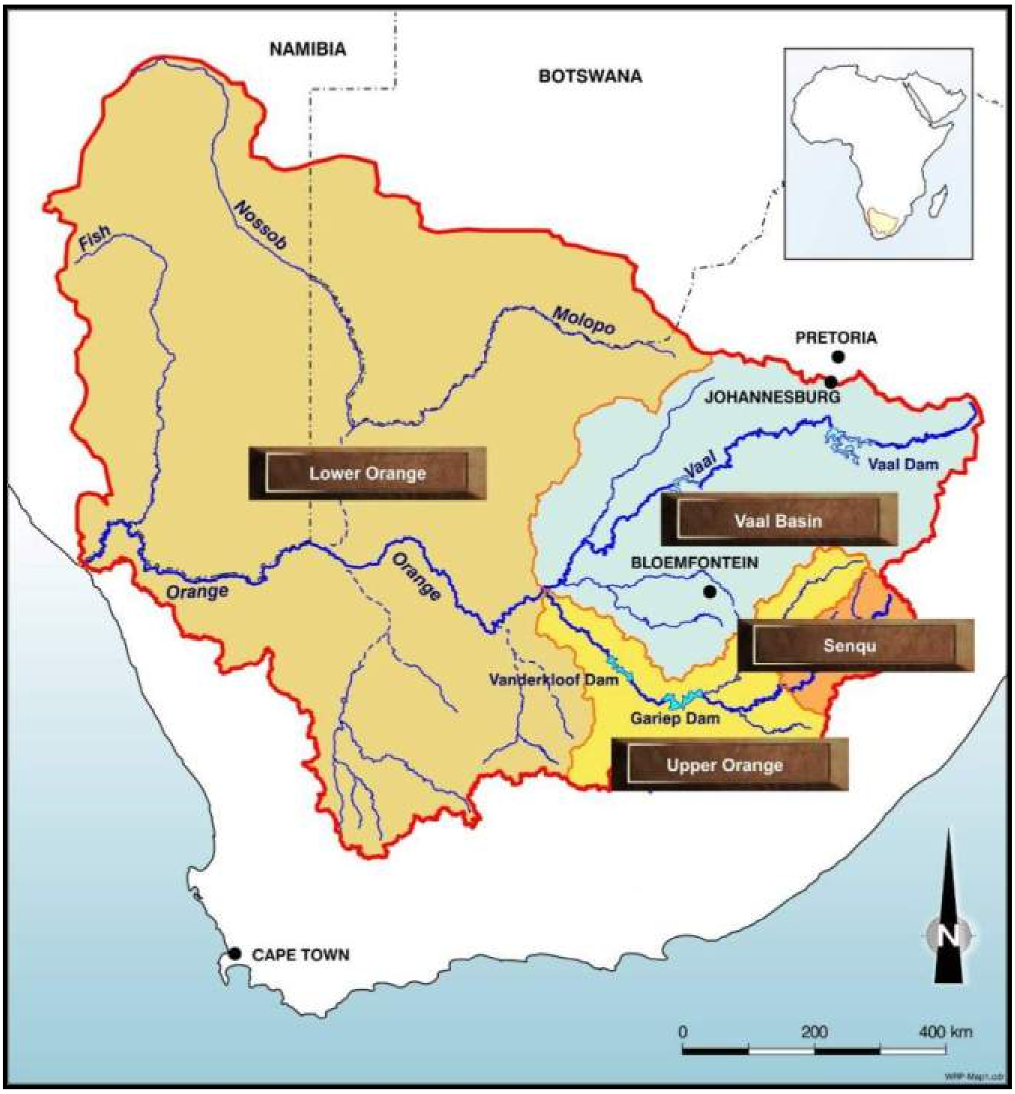

Figure 1.1: Orange-Senqu River Basin

The Orange-Senqu River system is regulated by more than thirty-one major dams with several hundred smaller dams being used to support local demand centres. It is therefore a highly complex and integrated water resource system with numerous large inter and intra-basin water transfers. It is one of the most complicated and integrated river basins in the world and is operated using highly sophisticated system models which have been developed over a period of more than 25 years.

1.2 Management and Environmental Issues

1.2.1 General

Management issues, including environmental protection, conservation and sustainable development have to deal with problems relating to, both, water quantity and quality. Potential conflicts between users, pollution sources from industry, mining, agriculture, watershed management practices must all be managed in order to protect ecologically fragile areas. The riparian countries have for some time recognised that a basin-wide integrated approach has to be applied in order to find sustainable solutions to these problems and that this approach must be anchored through strong political will. The development of this strong political will is one of the key initiatives of Southern African Development Community (SADC), in particular the Revised Protocol on Shared Watercourses and the establishment of the Orange-Senqu River Commission (ORASECOM). These initiatives are intended to facilitate the implementation of the complicated principles of equitable and beneficial uses of a shared watercourse system. It is accepted by all countries that the management of water resources should be carried out on a basin-wide scale with the full participation of all affected parties within the river basin.

Water supply in terms both of quantity and quality for basic human needs is being outstripped by the demands within and outside of the basin. Meeting the water supply needs of rapidly growing towns and cities while supplying sufficient water of an acceptable quality to meet existing and proposed future demands is therefore a key challenge for planners and stakeholders in the Orange-Senqu River basin.

1.2.2 ORASECOM

Southern Africa has fifteen trans-boundary watercourse systems including the Orange–Senqu system. SADC has adopted the principle of basin–wide management of the water resources for sustainable and integrated water resources development. In this regard, the Region recognises the United Nations Convention on the Law of Non-navigational Uses of International Watercourses, and has adopted the “Revised Protocol on Shared Watercourses in the SADC Region”. Under this Revised Protocol, a further positive step has been the establishment of river basin commissions in order to enhance the objectives of integrated water resources development and management in the Region, while also strengthening the bilateral and multilateral arrangements that have been in existence for some time. The Orange–Senqu River Commission (ORASECOM) was established on 3 November, 2000 in Windhoek, Namibia and is a legal entity in its own right.

The highest body of ORASECOM is the Council consisting of three permanent members, including one leader, for each delegation from the four riparian states. Support from advisors and ad hoc working groups can be established by the Council when required. The main task of the Council is to "serve as technical advisor to the Parties on matters relating to the development, utilisation and conservation of the water resources in the River System". The Council can also perform other functions pertaining to the development and utilisation of water resources as directed by the Parties.

1.3 Context of the Study and this Overall Project Executive Summary

1.3.1 GIZ (BMZ/UKAID/AusAID) Support to SADC and ORASECOM

The overall goal of the German International Cooperation (GIZ)-supported 'Transboundary Water Management in SADC' programme is to strengthen the human, institutional, and organisational capacities for sustainable management of shared water resources in accordance with SADC's Regional Strategic Action Plan (RSAP). The programme, which GIZ implements on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), and in delegated cooperation with the United Kingdom (UK) Agency for International Development(UKAID) and the Australian Agency for International Development (AusAID), consists of the following components:

- Capacity development of the SADC Water Division
- Capacity development of the river basin organisations (RBOs) and
- Capacity development of local water governance and transboundary infrastructure.

The activities of this Consultancy, "Support to Phase II of the ORASECOM Basin-wide Integrated Water Resources Management Plan", being undertaken by WRP (Pty) Ltd and Associates, contributes to Component 2 above. The work of Phase 2 comprises six work packages as briefly outlined in **Section 1.3.2.**

1.3.2 Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan

1.3.2.1 Objectives of the Overall Consultancy

The main objectives of this consultancy were to enlarge and improve the existing models for the Orange-Senqu River Basin, so that they incorporated all of the essential components in the four Basin States and are accepted by each Basin State. These models must be capable of providing the current and likely future information needs of ORASECOM. This will involve being able to assess the implications of additional water resource development options to achieve water security in each Basin State – including possible changes to operating rules for water supply and storage infrastructure. This will ensure that ORASECOM is able to demonstrate that its operations are aligned with the principles embodied in the SADC Water Protocol.

1.3.2.2 The Six Work Packages

In order to achieve the above-mentioned objectives, the project included six work packages as outlined in **Table 1-1**. The first of these work packages can be considered as central to Phase 2 of the IWRM Plan and will also be required to develop the final plan in Phase 3 of the project. In Work Package 1, the water resources yield/simulation model (WRYM) was updated and expanded to cover the entire river basin for the first time.

Table 1-1 Summary of Work Package Objectives and Main Activities

Work Package	Main Objectives	Main Activities
WP 1: Development of Integrated Orange-Senqu River Basin Model	To enlarge and improve existing models so that they incorporate all essential components in all four States and are accepted by each State	• Extension and expansion of existing models • Capacity building for experts and decision-makers • Review of water balance and yields • Design/initiation of continuous review process
WP 2: Updating and Extension of Orange-Senqu River Basin Hydrology	Updating of hydrological data, hands-on capacity building in each basin state for generation of reliable hydrological data including the evaluation of national databases	• Assessment of Required Improvements to the Existing Gauging Networks • Capacity Development • Extension of Naturalized Flow Data • Review of Existing Data Acquisition Systems, proposals on basin-wide data acquisition and display system
WP 3: Preparation and development of integrated water resources quality management plan	Build on Phase 1 initial assessment to propose water quality management plan, based on monitoring of agreed water quality variables at selected key points	• Establishment of protocols, institutional requirements for a water quality monitoring programme, data management and reporting • Development of specifications for a water quality model that interfaces with the systems models • Capacity building to operate the water quality monitoring system and implement the water quality management plan
WP 4: Assessment of global climate change	Several objectives leading to assessment of adaptation needs	• Identification of all possible sources of reliable climate data and Global Climate Model downscaling for the Orange-Senqu River Basin • Scenario assessment of impacts on soil erosion, evapotranspiration, soil erosion, and livelihoods • Identification of water management adaptation requirements with respect to expected impacts on water resources • Assessment of major vulnerabilities and identification of measures for enhancing adaptive capacities
WP 5: Assessment of Environmental Flow Requirements	Several objectives leading to management and monitoring system responsive to environmental flow allocations	• A scoping level assessment of ecological and socio-cultural condition and importance • Delineation into Management Resource Units and selection of EFR sites • One biophysical survey to collate the relevant data at each EFR site and two measurements at low and high flows for calibration • Assessment of the Present Ecological State and other scenarios • Assessment of flow requirements, Goods and Services, and monitoring aspects
WP 6: Water Demand management in irrigation sector	To arrive at recommendations on best management practices in irrigation sector and enhanced productive use of water	• Establish a standard methodology for collecting data on irrigation water applied to crops, water use by crops and crop yields • Document best management practices for irrigation in the basin and finalise representative, best-practice demonstration sites through stakeholder consultation • Consider and assess various instruments that support water conservation/water demand management

The other work packages are both self-standing and intended to provide inputs to an improved and more complete water resources simulation model for the whole basin. The model will be enhanced by:

- a more complete hydrology (WP2),
- better and more complete water quality information (WP3),
- allowance for climate change impacts and adaptation (WP4),
- inclusion of environmental flow requirements at key points (WP5) and
- modelling of scenarios with improved water demand management in the key irrigation sector (WP6).

1.3.2.3 This Overall Project Executive Summary

This overall project executive summary provides an overview of the work carried out under Phase 2 of GIZ Support to the ORASECOM Basin-wide IWRM Plan and summarises the outputs produced under each of the six work packages.

A number of overall conclusions and recommendations are presented in Section 4 and are essentially of a strategic nature aimed at defining some of the key issues to be included in the Basin-wide IWRM Plan to be developed in Phase 3.

2 PROJECT OVERVIEW

2.1 Introduction

The Contract between WRP (Pty) Ltd and Associates to undertake the GIZ support to Phase 2 of the ORASECOM Basin-wide IWRM plan was signed on 11 August 2009.

The consortium undertaking the work comprised:

- WRP : Hydrology, Resource Modelling and Project management
- Golder : Water Quality, Irrigation Efficiency
- RAMBOLL : Specialist inputs on Environmental Flows
- Potsdam Institute for Climate Impact Research : Global Climate Change
- WCE : Specialist inputs on hydrology, modelling and irrigation efficiency

Water for Africa, was sub-contracted to WRP to carry out the majority of Work Package 5 on Environmental Flow Requirements.

It was originally anticipated that this phase 2 project would be completed by the end of January 2011 and the findings reported to the Project Steering Committee (PSC) in early February 2011. Due to a number of delays which affected progress during the second half of 2010, however, the project as a whole fell behind schedule. Work Packages 1, 2 and 4 were significantly affected while all substantive work on Work Packages 3 and 5 was completed and presented either before or at the PSC meeting in December 2010. These delays resulted in the final end of contract dates being revised from 31 March 2011 to 30 April 2011.

2.2 Reporting

This Overall Project Executive Summary has been preceded by five quarterly reports and an inception report:

- Inception Report covering period 11 August to 31 October 2009; published 5 November 2009
- 1st Progress Report covering the quarter 1 November 2009 to 31 January 2010; published 31 January 2010
- 2nd Progress Report covering quarter 1 February 2010 to 30 April 2010; published 19 May 2010. This report was mistakenly labelled as the “3rd Progress Report.
- 3rd Progress Report covering quarter 1 May 2010 to 31 July 2010.
- 4th Progress Report covering period 1 August to 30 November 2010 (4 months)
- 5th Progress Report covering the period 1 December 2010 to 28 February 2011

Although there were a number of documents still being finalised at the time of publication of the 5th Progress report, all substantive work had been completed and it was therefore possible to provide a number of overall conclusions and recommendations at the end of that progress report. These were already presented at the PSC meeting on 9 and 10 March 2011 and were subsequently refined slightly as presented in the final chapter of this project executive summary.

2.3 Website

A project website was set up during the second quarter and was used to provide details on different aspects of the project and to disseminate updated versions of all reports and working papers.

The various outputs for each work package as discussed in **Sections 3.1 to 3.6** can now be accessed via the ORASECOM's website via www.orasecom.org.

2.4 Individual Work Packages

Each of the work packages are discussed in more detail in Section 3 including details of the key objectives of each package and the main activities. The main focus is, however, on the progress achieved through the study as well as the main deliverables and the associated conclusions and/or recommendations.

3 REPORT BACK ON INDIVIDUAL WORK PACKAGES

3.1 Work Package 1: Water Resources Modelling

3.1.1 Objectives

The main objectives for this Work Package were:

- to enlarge and improve the existing models to cover the total Orange-Senqu River Basin and
- to capacitate representatives of each of the basin states to set up and use the models.

3.1.2 Main Activities

The main activities undertaken to achieve the objectives were:

a) Assessment of strengths and weaknesses of existing models
b) Extension and expansion of the existing models
c) Assessment of system yields
d) Review the water balance for the Orange-Senqu River Basin
e) Developing a system schematic for the full system
f) Assist representatives from each of the four Basin States to set up and use the models

The outputs related to these activities are presented in **Section 3.1.3**.

3.1.3 Outputs

The final outputs of the work package are summarised **Table 3-1**. They comprise three reports, some of which combine draft working papers drafted earlier in the process. In addition to these documents there are other electronic deliverables which were central to the work of this package. These include working versions of the model and the accompanying datasets. These have been be uploaded on laptops, one for each one of the countries. As stressed in both reports namely ORASECOM 001/2011 and 003/2011, the modelling software is constantly being upgraded so it will be important to update it on a regular basis. The same applies to the datasets.

Table 3-1: Summary of Outputs of Work Package 1; Water Resource Modelling

Title	Type	ORASECOM Report No.	Notes on Contents
Strengths and Weaknesses of Existing Models	Report	005/2010	Provides an analysis of both the WRYM and WRPM models and the WRIMS system. (Activity a))
Setting up and Testing of the Final Extended and Expanded Models; Changes in Catchment Yields and Review of Water Balance	Report	001/2011	Provides details of the extended and expanded models, their setting up and testing. The report also summarises the changes in catchment yields and water balance. (Activities b), c) and d))
Schematics of the system	Maps	None	These can be viewed and/or downloaded from the ORASECOM's WIS website (Activity e))
Capacity Building and setting up the Models in each Country; Process of Continuous Review	Report	003/2011	Summarises and provides feedback from the expert and decision-maker level capacity-building workshops. There were four such workshops in total (Activity f)). Also makes recommendations on Review Process.
Modelling software and datasets	Software	None	WRYM and WRPM Modelling software and datasets loaded on to laptops or CPUs for each country and ORASECOM (Activity f)).
Water Resource Modelling Manuals	Manual	None	The electronic manuals were supplied to those attending the capacity building course and can be viewed and/or downloaded from the ORASECOM's WIS website. Activity f)).

The surplus yield result obtained using the updated Water Resource Yield Model (WRYM) configuration is presented in **Table 3-2**. This surplus yield is based on the existing operating rules of the system as provided by the four basin States, and can be increased if any changes in the operating rules or infrastructure augmentation take place. The WRYM has now been configured to analyse and answer any scenarios that ORASECOM may want to consider. In relative terms the result indicates that there is little spare capacity in the system as it exists. The conditions and assumptions under which this surplus yield was obtained are summarized in the bullets following the table.

Table 3-2: Total Orange-Senqu Basin surplus Yield and Balance

Contribution	Volume (mill m^3/a)	Details
+	3609	Natural Hydrology Vaal
+	8220	Natural Hydrology Orange
+	478	Thukela transfer inflow
-	2205	Net Demands Vaal
-	4022	Demands Orange
-	1724	Evaporation & Dam storage adjustment
-	4182	Spills to sea
=	175	TOTAL ORANGE-SENQU RIVER SURPLUS YIELD

Conditions and assumptions regarding operation of the Vaal system:

- Historical data record covers period from 1920 to 2004;
- Demand of Grootdraai Dam abstracted from Grootdraai Dam, Grootdraai Dam does not support Vaal Dam;
- Present day water transfer from Thukela system into Sterkfontein Dam is included, Sterkfontein Dam supports Vaal Dam;
- Demands equal to the present day water requirements of Sedibeng, Midvaal and Small Towns supplied from their points of abstraction in the system;
- Current water demand on Bloemhof Dam abstracted from dam;
- Vaal Dam supports Bloemhof Dam;
- Lesotho Highlands water transfers into the Vaal system;
- Rand Water demand abstracted from Vaal Dam.
- In short, the Vaal system is in deficit and requires additional interbasin transfers in order to meet its present day requirements and as a result very little water, with the exception of the occasional spills, reaches the main stem of the Orange River.

Conditions and assumptions used to determine Orange-Senqu River surplus system yield:

- Historical data record covers period from 1920 to 2004;
- In accordance with existing operating rules, spills from the Vaal system are available to support Douglas irrigators, however, downstream Orange River demands are not supported from the Vaal system (mainly due to water quantity constraints and water quality considerations);
- All Lower Orange River tributaries (including the Namibian Fish River) are simulated such that they do not support lower Orange River main stem water demands as per current operating practice;
- All Orange River water demands and losses are supplied from Gariep and Vanderkloof Dams fully before the surplus yield is calculated;
- Katse and Mohale Dams do not support Gariep and Vanderkloof Dams and only spillage and the environmental releases from these dams reach Gariep Dam;
- Orange-Senqu River surplus yield (175 million m^3 per annum) represents surplus total or basin wide/system wide yield after all Orange and Vaal River Sub-Basins' demands have been met.

3.1.4 Conclusions and Recommendations

3.1.4.1 Conclusions

The existing "Yield" (WRYM) model was updated to include additional components in various parts of the Orange-Senqu River basin. The updated models also make use of the updated and extended hydrology. Only the Fish River in Namibia has not been completed as a result of delays in obtaining the water flow records. The modelling work was complicated to some extent by the fact that the Department of Water Affairs of South Africa (DWA-SA) is currently upgrading the models and the Project Team had to work with the available versions. The current model developments by DWA-SA is likely to continue for most of 2011, and may be followed by more upgrading phases. Any upgrades to the models will be made available to the 4 basin states as and when available. This also complicated the capacity building process in some respects and it is clear that follow up training or capacity building courses will be required as new software versions become available.

3.1.4.2 Recommendations

A number of activity related conclusions and recommendations are provided in the various reports listed in **Table 3-1.** In addition to these, a number of important general recommendations can be made.

- Regular capacity building sessions at both the expert and decision-maker level should continue in Phase 3 support of GIZ (BMZ/UKAID/AusAID) to ORASECOM and beyond. This will allow each basin state to keep abreast of new software developments, promote transparency and ensure that decision-makers from each basin state can contribute to basin-wide water resources management decisions on an equal footing.
- The ORASECOM Secretariat should serve as custodian of the updated model setups, ensuring that updates carried out at the country level are properly consolidated.
- The ORASECOM Secretariat should play a leading role in facilitating the annual technical review process.

3.2 Work Package 2: Hydrology

3.2.1 Objectives

The central objective of this Work Package was to produce updated and extended hydrological sequences for the basin as a whole. This will help to address certain deficiencies with the existing hydrological data sets which are not consistent throughout the Orange-Senqu river basin. To ensure that the hydrological data sets are easily accessible for any future work, they have been incorporated into an appropriate database system with proper referencing.

3.2.2 Main Activities

The main activities were:

a) Provision of appropriate Capacity Building in a number of key areas agreed with each basin state
b) Recommendations on appropriate protocols and procedures for data collection and data sharing throughout the basin
c) Proposals on a data acquisition and display system to be adopted by all four basin states
d) Assessment of Required Improvements to the Existing Gauging Networks
e) Extension of Naturalised Flow Data

3.2.3 Outputs

The final outputs of the work package are summarised in **Table 3-3**.

Table 3-3: Summary of Outputs of Work Package 2; Hydrological Studies

Title	Type	ORASECOM Report No.	Notes on Contents
Improvements to Gauging Network and Review of Existing Data Acquisition Systems	Report	005/2011	Provides an assessment of the national networks within the basin, SADC Hydrological Cycle Observing System (SADC HYCOS) from data collection activities through to data dissemination. Proposals for improvements and a shared display system are included. (Activities b), c) and d))
Extension of Hydrological Records	Report	006/2011	Central report to the work package provides overview of methodology and results obtained. (Activity e)). The appendices include several maps
Extension of Hydrological Records	Data sets	Associated with 006/2011	All the data sets used and derived have been organised and stored on an external hard disk for each country (Activity e)).

3.2.4 Conclusions and Recommendations

3.2.4.1 Conclusions

Capacity Building

Capacity in basic hydrometry is lacking, particularly in Lesotho and Botswana, both in terms of existing personnel being sufficiently capacitated and shortage of staff. In Botswana there is a serious need to develop capacity within the Hydrology Division. In Namibia and South Africa there is a shortage of staff, although essential systems appear to be operating in each country.

There is a need to improve the quality of hydrological data throughout the basin. This could be achieved through a combination of infrastructure/equipment related measures and improved capacity and personnel levels.

Rainfall Measurement

Although certain areas of the Orange-Senqu River basin still have adequate coverage of rainfall gauges, there has been a significant reduction in operating rainfall stations in most of the sub-catchments of the basin. The current density of rainfall stations that are still open and used in the analysis ranges from between 0.3 and 3.2 gauges per 2500 km^2.

Streamflow gauges

Although there appears to be an adequate coverage of the flow gauging stations within the Orange-Senqu basin, it is of utmost importance that at least the stations used for the hydrological extension work be maintained to ensure ongoing monitoring. This will ensure that the effects of the ever-increasing water and land-use impacts can be assessed and that the impact of projected trends in the climate can be monitored. Once again the high runoff catchments, such as the Senqu (SE), Caledon (CA), Upper Vaal (V_U) and the Upper orange (O_U), should receive adequate attention when it comes to monitoring.

Modelling

A relatively fine spatial resolution hydrological model has been developed and it is essential to update the model at regular intervals with land-use changes as they occur to ensure that the hydrological database remains representative. In the Senqu River basin, it may be necessary to revisit the original “agreed hydrology” since it is now possible to create a better rainfall-runoff calibration due to the additional 15 or 20 years of recorded streamflow data now available in Lesotho.

3.2.4.2 Recommendations

- Provision of technical support to both Botswana and Lesotho, perhaps through a technical assistant to assist in upgrading their hydrological monitoring operations so that the network is managed more effectively.
- Expansion of the DWA-SA data acquisition and display system (which already includes selected Lesotho stations) to incorporate key Namibian stations, and the addition of a link to the Orange-Senqu River basin gauging network via the ORASECOM portal.
- The rainfall data (historic and present day) for the higher runoff yielding catchments, Senqu (SE), Caledon (CA), Upper Vaal (V_U) and the Upper orange (O_U), should be re-evaluated to ensure that the best available point sources are identified. These stations should remain operational to ensure that future analyses can be undertaken.
- With the projected effects of climate change it is very important to safeguard and even expand the basin’s rainfall monitoring network. This will help to establish if the projected effects are actually occurring and, if so, what impact they will have on the meteorological conditions and water resource capabilities.
- The original Senqu Catchment Hydrology needs to be revisited. In the recalibration process undertaken during this study it was identified that the initial part of the natural runoff record was simulated with a lesser standard deviation and with a slightly lower MAR than the observed portion of the record. An investigation is required to assess the possible impact on the yield if a more representative natural runoff record is simulated based on a new calibration against the longer observed record.

3.3 Work Package 3: Water Quality

3.3.1 Objectives

The central objective of this work package was to provide the tools, methods and training for the implementation of a water resource quality management plan. A framework for the management of water resource quality in the Orange–Senqu River Basin had been proposed by a European Union Development Fund project which was also providing support to ORASECOM. The framework developed through the European Union supported project proposes institutional arrangements, the location of monitoring points, water quality variables to be measured, resource water quality objectives, trigger values and a basis for a regional analytical quality control system for testing of water quality samples. The framework document giving the vision for such a water resource quality management system, was finalised in collaboration with the GIZ supported project team working on Work Package 3.

The framework, however, does not provide details on how and when the water resource quality management plan will be implemented and these have been addressed in more detail in Work Package 3.

3.3.2 Main Activities

The main activities addressed under Work Package 3 were:

a) Establishment of the protocols, institutional requirements for a water quality monitoring programme, data management and a reporting system to provide water quality management information to the water resource managers of the basin states.
b) Development of the specifications for a water quality model that addresses the water quality variables of concern and can interface with the existing systems models.
c) Provision of training to develop capacity within the basin states to operate the water quality monitoring system and implement the water quality management plan.
d) Documentation of findings in a report describing the proposed water quality management plan.
e) 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.

3.3.3 Outputs

The final outputs of the work package are summarised in **Table 3-4**.

Table 3-4: Summary of Outputs of Work Package 3; Water Quality Management Plan

Title	Type[1]	ORASECOM Report No.	Notes on Contents
Development of Water Quality Monitoring programme and Data Management Framework	Report	007/2011	Report details the water quality management plan (Activities a) and d)) and also reports back on activities c) and e)). 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	Development of algorithms for the inclusion of river and reservoir phosphate and chlorophyll-a in the WQT and WRPM planning models (Activity b). Possible development routes have also been considered.
Participation in the Joint Basin Survey 1 sampling program	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 demonstrated (Activities c) and e)).

3.3.4 Summary, Conclusions and Recommendations

With respect to the development of a water quality monitoring programme and data management framework, the following issues were addressed:

- Water quality sampling points were established for the trans-boundary sampling program. Workshops were held in selecting the points and the points were sampled jointly as part of the 1st Joint Basin Survey. This exercise served as a training exercise.
- Sampling procedures, data storage and chains of custody were developed.
- With regard to the ongoing implementation of the monitoring system, reporting and management of the data, it was proposed that the ORASECOM Secretariat manage the process after the completion of the project.

With respect to the development of specifications for the water quality model the following conclusions were drawn:

- Satisfactory salinity modelling functions are already integrated into the “WRPM” and “WQT” models and improvements are being incorporate as required.
- Algorithms for a river and reservoir phosphate and chlorophyll-a model that is suitable for inclusion in the “WQT” and “WRPM” models have been developed.
- The high level requirements for water quality operating models and possible development routes have been considered.

The following recommendations were made;

- The procedures and location of the sampling points must be refined as experience is gained with the sampling process.
- The number of water quality variables analysed for and the trigger values must be reviewed.
- The use of online water quality monitoring linked to flow monitoring should be developed.
- A web-based water quality data entry, management and reporting system should be developed to manage the data more effectively than the current system.
- Institutional responsibilities to manage the system should be finalised.
- The phosphate and chlorophyll-a modelling algorithms that have been developed should be incorporated in the WQT and WRPM models.
- Water quality operating model requirements should be examined in detail and tested on key system elements.
- Ongoing improvements to the “WQT” and “WRPM” salinity modelling routines should proceed.

3.4 Work Package 4: Climate Change

3.4.1 Objectives

The Overall objective of Work package 4 was to carry out a detailed assessment of the occurrence, extent and possible effects of climate change in the Orange-Senqu River basin. This work involved the following:

- Detection of statistically significant change in the climate including an assessment of to which extent the detected climate change is consistent with the predicted climate change
- Identification of physically plausible explanations of any detected climate change
- Assessment of major adaptation needs in terms of water resource management, communities and economic activities, with a view to countering observed and/or expected impacts of climate variability and change on the hydro-climatology and water resources

3.4.2 Activities

The main activities undertaken as part of this work package were:

a) Description of completed and ongoing climate modelling initiatives; assessment of their strengths and weaknesses
b) Investigation into and recommendations on the most appropriate statistical methodology to detect climate change
c) Identification of all possible sources of reliable climate data
d) Statistical and Dynamic downscaling to reveal nature, extent and spatial coherence of climate change in the basin
e) Identification of water management adaptation requirements based on the identification of vulnerabilities of communities, economic activities and livelihoods to potential impacts of climate change

3.4.3 Outputs

The final outputs of the work package are summarised in **Table 3-5**.

Table 3-5: Summary of Outputs of Work Package 4; Climate Change

Title	Type[1]	ORASECOM Report No.	Notes on Contents
Downscaling Methodology and Ongoing Climate Modelling Initiatives	Report	007/2010	This report provided an overview of the methodology (Activity a)) following presentations at the Inception Meeting
GCC Downscaling for the Orange-Senqu River Basin	Report	008/2011	Provides an overview of the methodology and details of the results of the Global Climate Change downscaling work (Activities b), c) and d)).
Projection of impacts under Plausible Scenarios and Guidelines on Climate Change Adaptation Strategies	Report	009/2011	Taking into consideration the vulnerability of both communities and economic activities, potential impacts are assessed and adaptation measures proposed (Activity e)).

3.4.4 Conclusions and Recommendations

3.4.4.1 Conclusions

Based on available climate data (up to 2007), there is no clear signal of climate change (both for temperature and precipitation) in the Orange-Senqu River basin. Conclusive evidence is hard to obtain due to the high variability of the local climate where natural variability tends to mask the more subtle influences of Climate Change. The downscaling according to the International Panel for Climate Change (IPCC) Special Report Emission Scenarios SRES “A1B” scenario yielded the following results:

2m Temperature

The two images in **Figure 3-1** show the projected increase of the average 2m temperature (i.e. temperature taken at 2m above ground surface). The image on the left depicts the results from the dynamic climate model “CCLM” and shows the difference between the average temperature predicted for the 2031 to 2060 period compared to the actual temperature for the 1971 to 2000 period. The image on the right hand side depicts the results from the statistical climate model STAR. From 100 generated scenarios, the median wet scenario is shown (check full report for details). In this case, the projected average temperature for the 2051 to 2060 period is compared to the actual average temperature for the period 1958 to 2007. Both results suggest that there is likely to be an increase in temperature of approximately 2.5 °C in the central Kalahari areas. The increase in temperature is likely to be less severe towards the coastal areas.

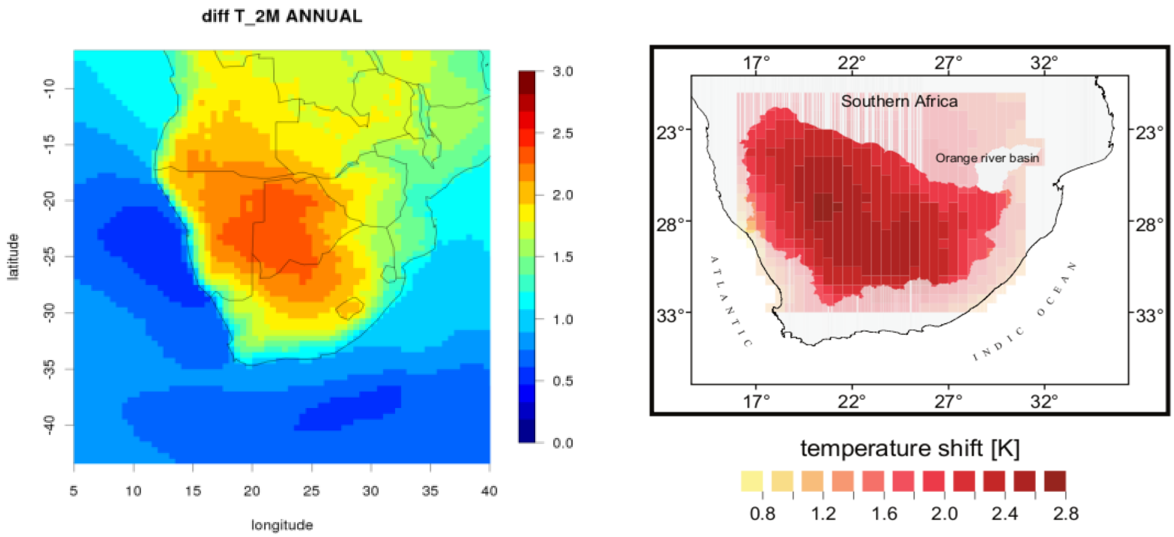

Figure 3.1: Projected Increase of the Average 2m Temperature

Precipitation

Figure 3.2 shows three equally likely climate scenarios as produced by the statistical climate model "STAR". The images depict the projected change in precipitation for the period 2051 to 2060 compared to the measured average precipitation for the period 1958 to 2007 . The results from the "CCLM" are not shown since they were not found to be reliable and further work in this regard will be required before such results can be used. Of the 100 scenarios generated by "STAR" a dry (5-percentile) is shown on the left, a median wet scenario (50-percentile) is depicted in the middle while a wet scenario (95-percetile) is featured on the right. All thee realisations predict a decrease in precipitation for most of the basin while a slight increase in precipitation is possible in the eastern (Lesotho) portion of the basin. Since most of the runoff is generated in the eastern portion of the basin, the implications of the projected changes in precipitation may cause increased runoff in such areas. The overall impact of such climate change will have to be assessed through a more comprehensive assessment involving rainfall-runoff modelling.

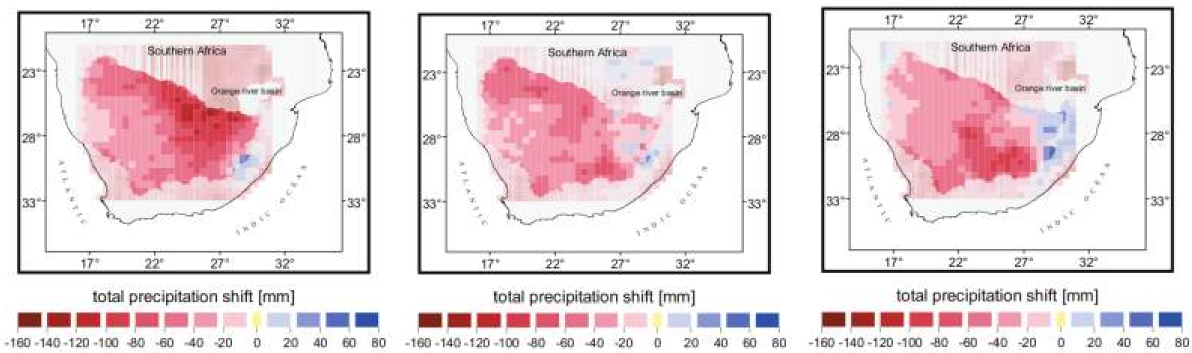

Figure 3.2: Climate Realisations as produced by Statistical Climate Model

3.4.4.2 Recommendations

Downscaling

The downscaling can be improved with respect to several aspects. The “CCLM” could be fine-tuned for the region to include various technical improvements such as an improved convection scheme. Another possible strategy in the simulation of the local climate could be to carry out the long term simulation using “STAR. These runs then could be complemented by short term simulations with an improved “CCLM” which will generate extreme event scenarios. An improved “CCLM” could also be used to focus on specific areas by undertaking high resolution runs. Clearly the high runoff areas such as the Lesotho Highlands would be obvious targets. Furthermore, the latest climate predictions suggested by the IPCC from the Global Climate Model (GCM) are due for release during 2011 which should help to provide greater confidence with the downscaling results.

Adaptation

In many respects the required adaptation measures will look similar to those measures which are already in place or proposed under the various water demand management initiatives.

- In the irrigation sector, crop water requirements will increase with the result that improved water conservation/demand management will become a higher priority
- The marginal farming areas will most likely become less viable with the result that alternative livelihoods may have to be sought if agronomic solutions cannot be found
- Improved management of the water resource: The total water resources may not decrease and could even increase if rainfall in the eastern source areas increases. It seems likely that the runoff from rivers taking their source further to the west will decrease, however, most of the Orange-Senqu River basin water does originate from the eastern portions of the basin.

An adaptive measure of a different kind is to improve the accuracy and reliability of climate change predictions by improving the input data. It is recommended that the climate station network in the source areas of the basin be improved both in terms of spatial coverage and the quality and detail of data.

3.5 Work Package 5: Environmental Flow Requirements

3.5.1 Objectives

The main objective for this Work Package is to assess Environmental Flow Requirements (EFRs) at selected key areas of the Orange-Senqu River Basin at an "Intermediate Level".

3.5.2 Activities

The main activities were:

a) A scoping level assessment of ecological and socio-cultural condition and importance across the basin.
b) Delineation into Management Resource Units (MRUs) and selection of Environmental Flow Requirements sites.
c) One biophysical survey to collate the relevant data at each Environmental Flow Requirements site.
d) Measurements at a low and a high flow to calibrate the hydraulic model.
e) Assessment of the Present Ecological State and other ecological state scenarios.
f) Assessment of flow requirements following a holistic approach, preferably those developed specifically for local and regional conditions for each ecological state.
g) Assessment of the ecosystem services, also referred to as Goods and Services.
h) Monitoring aspects.

3.5.3 Outputs

The final outputs of the work package are summarised in **Table 3-6**.

Table 3-6: Summary of Outputs of Work Package 5; Environmental Flow Requirements

Title	Type[1]	ORASECOM Report No.	Notes on Contents
Literature survey and Gap Analysis	Report	008/2010	This report provides an overview of the review of previous environmental flow (allocation) studies and includes a gap analysis
Delineation of Management Resource Units	Report	009/2010	This report defines the Management Resources Units which are homogenous units in terms of impacts and biophysical characteristics. The aim would be to select a critical Environmental Flow Requirements site within this unit which would then be applicable for the unit (Activity b)).
Desktop Eco-Classification Assessment	Report	016/2010	A Reconnaissance Eco-Classification process is used to determine the integrated Environmental Importance in terms of three components, Ecological Importance and Sensitivity, Socio-Cultural Importance (SCI), and the Present Ecological State (PES) for the whole study area (Activity a)). This is combined with the Water Resource Use Importance to identify areas of critical importance for further study
Goods and Services Report	Report	010/2010	Natural habitats and ecosystems provide a huge range of environmental Goods and Services that contribute enormously to human well-being. This report provides an assessment of the impacts of the various scenarios on goods and services (Activity g)).
Environmental Flow Requirements	Report	010/2011	Volume 1: Main Environmental Flow requirements report that defines the environmental flow requirements for different ecological states at selected EFR sites (Activities c), d), e),and f)). Volume 2: Support to Volume 1 in terms of monitoring. Ecological Specification and Thresholds of Potential Concern are identified for each site (Activity h)). Once monitoring is undertaken, this information is used to measure whether the ecological state and objectives are being maintained or achieved. Volume 3: Appendices which provides specialist contributions which supports Volume 1 and 2.
Groundwater report	Working Paper		Many of the rivers in the study area (specifically Botswana, Namibia and in the Kalahari in South Africa) are ephemeral. It has always been assumed that these ecosystems are dependent on groundwater and that groundwater abstraction, could impact on these ecosystems. This working paper includes an extensive literature survey and discusses the potential for such impacts on some key ephemeral rivers. Research needs are also prioritised and identified.

3.5.4 Conclusions and Recommendations

3.5.4.1 Conclusions

Environmental Flow Requirements

The detailed conclusions for each of the Environmental Flow requirements sites are presented in Report 010/2011 and 010/2010. A summary of the Environmental Flow Requirements results are provided in

Table 3-7. The natural Mean Annual Runoff (nMAR) and present day Mean Annual Runoff (pMAR) are provided as Mm^3 in the first column.

Table 3-7: Summary of Results as a Percentage of the Natural MAR at EFR 1 to 7

EFR site	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
		(%nMAR)	Mm^3	(%nMAR)	Mm^3	(%nMAR)	Mm^3	(% nMAR)	Mm^3
Virgin MARs									
EFR O2 nMAR 10574 pMAR 4630	PES/REC	11.6	1226.55	4.4	465.24	5.4	570.98	15.2	1607.20
	AEC↓: D	5.8	613.27	3.1	327.78	5	528.69	11.3	1194.83
EFR O3 nMAR 10513 pMAR 4628	PES: C	8.4	883.10	2.6	273.34	4.7	494.12	11.9	1251.06
	REC: B	17.6	1850.31	3.4	157.37	4.7	494.12	19.2	2018.52
	AEC↓: D	4.1	431.04	2.2	231.29	4.4	462.58	9	946.18
EFR O4 nMAR 10335 pMAR 3907	PES: C	6.3	651.11	0.9	35.16	4.2	434.07	8.9	919.82
	REC: B/C	10.1	1043.85	1.3	134.36	4.2	434.07	12.2	1260.88
	AEC↓: D	3.1	320.39	0.8	31.25	3.8	392.73	6.9	713.12
EFR C5 nMAR 56.9 pMAR <56.9	PES/REC: C/D	13.8	7.85	5.8	3.30	11.4	6.49	26	14.80
EFR C6 nMAR 1348 pMAR 1135	PES/REC: D	8.8	118.62	0.3	3.40	10.5	141.54	20.1	270.94
	AEC↑: C	15.5	208.93	2.2	29.66	13.1	176.58	26.1	351.82
EFR K7 nMAR 683 pMAR 641	PES/REC: C	11.4	77.81	0	0.00	8.4	57.33	18.1	123.53
	AEC↑: B	16.5	112.61	1.2	7.70	8.4	57.33	21.8	148.79
	AEC↓: D	5.1	34.81	0	0.00	7.1	48.46	12.9	88.04

No environmental flow requirements were set at the first Environmental Flow Requirements site "EFR 1" (downstream of Vanderkloof Dam) as it was felt that there would be no scope in terms of adjusting flows. The ecological state was assessed and recommendations made that included non-flow related measures.

"EFR 8" situated in the Molopo wetlands downstream of the Molopo eye was also approached in a different manner. Setting flow requirements within such a modified system will serve no purpose. In order to improve the wetland the main objectives set for “EFR 8” were to revert back to a functioning wetland which can be achieved by:

- Improved *Phragmites* cover.
- Reinstatement of shallow areas with constant depth.
- Cease spraying of toxic pesticides for control of the Red-billed Quelea (*Quelea quelea)* and reeds.

Good and Services

The range of Goods and Services available at the lower end of the Orange-Senqu River River ensures that these reaches are rendered more sensitive to management interventions. The converse is generally true for the upper sites. In addition, there are a body of users of Goods and Services in the lower part of the Orange-Senqu River for whom livelihood and linkage to these Goods and Services is of paramount importance. Conversely for the Caledon catchment, particularly the upper site, in spite of a dependency on Goods and Services, the highly impacted state of the river means that management interventions will not result in substantial changes to the delivery of Goods and Services. In addition, in these areas the most important management interventions will not be flow-related and probably relate to a wider programme of catchment management. The Kraai River is in many respects in a good state, and the usage relatively low. As such, management interventions will not yield dramatic results.

Table 3-8 summarises the overall evaluation results. These were derived from modelling the results for each EFR site with the importance of each category of Goods and Services weighted. Those deemed to be most important at the site were given a weighting of 100. Those of marginal importance were given lesser weightings.

Table 3-8: Summary of Results with Weighting

	AEC Up	AEC Down
Hopetown	NA	NA
Boegoeberg	NA	-45.5
Augrabies	125.5	-58.5
Vioolsdrift	146	-87
Upper Caledon	NA	-17
Lower Caledon	32.25	NA
Kraai	42	-64.25
Molopo	13.25	-40.5

3.5.4.2 Recommendations

Based on the confidence evaluation of the results, recommendations were made where additional information is required to improve the confidence. This is summarised in **Table 3-9.** A recommendation which is standard for all the Environmental Flow Requirements sites is to initiate an Ecological Water Resources Monitoring (EWRM) programme as this is essential to measure whether objectives are being achieved.

Table 3-9: Summary of Recommendations required to improve Confidences

EFR sites	Low flow confidence	High flow confidence	Recommendations
O2	2.5	3.3	Initiate EWRM programme. Obtain hydraulic low flow calibrations.
O3	2	3.5	Initiate EWRM programme. Obtain hydraulic low flow calibrations.
O4	2.5	2.8	Initiate EWRM programme. Obtain hydraulic low flow calibrations.
C5	3.5	3	Initiate EWRM programme. Obtain hydraulic high flow calibrations.
C6	2	3	Initiate EWRM programme. Obtain hydraulic low flow calibrations.
K7	3	3	Initiate EWRM programme. Obtain hydraulic low and high flow calibrations.
M8			Hydraulic confidence in the areas of the wetland that does not receive backup from the crossing was moderate (3). It is however not recommended that more hydraulic calibrations are done as it would be more cost-effective to implement the recommendation (Sc 2 - lowering the Bosbokpark crossing by 2.2 m) and monitoring the biological responses. Monitoring should include the impact on the lower wetland to determine whether the required improvements in these sections are achieved.

This would lead to a key strategic level actions that are required as part of a basin-wide plan that should include the following:

- Testing of various operational scenarios that could include new developments or changes in the existing operation of the system. Testing of these scenarios must be done in terms of changes in ecological state and Goods and Services.
- These results should then be presented to the stakeholders so that agreement can be reached on the future ecological state of the river.
- An extensive and joint monitoring system should then be implemented. It is strongly recommended that an Ecological Water Resources Monitoring (EWRM) programme is initiated as soon as possible. The information gathered during this study is suitable for the baseline, but if too much time relapses between the baseline and monitoring, new surveys and Eco-Classification process will have to be undertaken. It must be noted that monitoring of essential Goods and Services should be included as part of the EWRM.

3.6 Work Package 6: Irrigation Water Demand Management

3.6.1 Objectives

The overall objective of the work package was to attain an overall understanding of how better management practices could reduce water demand in the irrigation sector in the Orange-Senqu River Basin, and to make recommendations on improved water demand management in this sector in the future. In order to reach this goal a number of sub-objectives were identified in the terms of reference:

- Building up of a GIS Database irrigation inventory through the collection and collation of reliable and detailed information about the use of irrigation water by crops and crop yields
- Assessment of various instruments for enhancing productive use of water, e.g. water markets and their operation in a local as well as trans-boundary context
- Detailing the best management practices for irrigation in the basin
- Selection and evaluation of demonstration projects of best practices at suitable sites

3.6.2 Activities

a) Identify potential pitfalls related to the practical implementation of results of previous studies and experiences in the basin
b) Document best management practices for irrigation in the basin
c) Consider and assess various instruments that support water conservation and demand management, also in a transboundary context
d) Hold stakeholder workshops
e) Finalise and evaluate representative, best-practice demonstration sites; and make recommendations on how the generalisation of best management practices could improve water conservation and water demand management in the sector
f) Establish a standard methodology for collecting data on irrigation water applied to crops, water use by crops and crop yields
g) Building up of a GIS Database irrigation inventory through the collection and collation of reliable and detailed information about the use of irrigation water by crops and crop yields
h) Development of an interactive irrigation classification tool for investigating the irrigation GIS database
i) Development of an interactive (web-based) irrigation scenario generation tool

The last two activities were not a part of the initial terms of reference, but as work progressed, it became evident that their inclusion would be highly useful.

3.6.3 Outputs

The final outputs of the work package are summarised in **Table 3-10**.

Table 3-10: Summary of Outputs of Work Package 6; Environmental Flow Requirements

Title	Type[1]	ORASECOM Report No.	Notes on Contents
The Promotion of Water Conservation and Water Demand Management in the Irrigation Sector	Report	011/2011	Reports back on activities a) to e) above. Included a high level of stakeholder consultation in identifying best management practices and key direction to be followed to promote WC/WDM
Irrigation GIS Database, Interactive Database and Irrigation Scenario Tools	Report	012/2011	This report describes the work carried out to populate the irrigation GIS database (Activities f) and g)). This was largely carried out through classification of satellite images and existing databases.
Interactive Irrigation Area Classification Tool and Irrigation GIS database	Software	None	A web-based interactive irrigation area classification tool was developed allowing the user to analyse and classify imagery according to a range of criteria (Activity h)). All the satellite images, GIS layers and data have been put onto an indexed Hard disk, one for each country and the ORASECOM Secretariat.
Interactive Irrigation Scenario Tool	Software	None	A (web-based) irrigation scenario tool has been developed to assist with the calculation of present day irrigation water demands, and future irrigation scenarios which could include crop and irrigation method changes to improve efficiency of water use and adaptation to climate changes in the region (Activity i)).

3.6.4 Conclusions and Recommendations

3.6.4.1 Conclusions

Report 011/2011 drew numerous conclusions on the importance and benefit of best management practices in the basin. One issue which came up repeatedly was the importance of measuring water usage at the farm and distributer level. This step is fundamental to successful implementation of a whole range of practices which can lead to improved water conservation and water demand. Directly linked to the issue of measurement is how water is paid for. Once paid for volumetrically, a whole range of incentives can be put in place to encourage farmers to use their allocations of water more efficiently.

Another important conclusion was that although best management practices can be individually identified and described, they can only work properly if a holistic approach to scheme and farm management is followed allowing the full benefits of each best management practice to be realised.

Finally, and perhaps most importantly, within the South African context, there was generally agreement that the South African Water Act and its provisions for water user associations and water management plan provided an excellent framework for water conservation and water demand management to take place.

The establishment of the irrigation database has shown that significant changes in irrigation practices are taking place and that additional areas are being put under irrigation.

3.6.4.2 Recommendations

Implementation of the South African Water Act and its provisions for water user associations and catchment management agencies should be accelerated and supported. There are valuable lessons from this framework which could also be valuable to the other basin states.

The need for improved irrigation water measurement at both the distributor and irrigator level should be encouraged and become mandatory as far as possible. It is recommended that an investigation into the extent and cost of this need should be carried out and funding options identified.

ORASECOM should investigate the possibility of assisting Water User Associations in establishing an appropriate GIS-type data base of irrigation lands, cropping patterns, irrigation, requirements etc (including the training of personnel) to improve water management and water use. The information gathered would be used at the Water User Association level and could also be used to improve estimates of irrigation taking place basin-wide.

The Best Practice demonstration sites (for both irrigation water suppliers and irrigators) should be used as a means of spreading the news about irrigation best practice efficiency.

It is recommended that the database of irrigated areas should be updated on an annual basis and that the remote sensing classification tools developed in this project, supplemented by Water user Association GIS ground truth information.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion of the Work

As indicated in this overall executive summary, a number of reports have been produced and posted on the ORASECOM's Water Information System (WIS) website.

4.2 Overall Conclusions and Recommendations

There are a number of broad conclusions and strategic recommendations that come out of the study as a whole and which could be considered as providing some key elements of a strategic framework for, among others, Phase 3 of GIZ (BMZ/UKAID/AusAID) support to ORASECOM, the design and implementation of the Basin-wide IWRM Plan.

Improved knowledge of the resource base: A main input for the yield and planning models is hydrological data.

- Long historic data records are important in establishing reliable estimates of yields. Reliable real-time data are required for operational planning. ***A major drive at improving the quality of data from key river gauging stations is required.***
- Hydrological modelling (rainfall-runoff modelling) requires historic and real-time rainfall data from an adequate number of rain gauges with good areal coverage. ***Efforts to improve the rain gauge network should be pursued and the current trend of closing rainfall stations should be reversed.***

Improved Water Resource Modelling and increased Basin-wide Transparency:

- Efforts have been made to expand and enhance the existing water resources models and to capacitate decision-makers and experts in all basin states. ***Continuous upgrading of the models as well as regular capacity building*** should be an essential part of the IWRM plan.

Reduced Water demand: Overall wasteful water demands should be reduced, or at least growth rates must be kept to very low levels.

- The irrigation sector has to be made more efficient. Examination of best management practices has shown that this is possible. Priorities ***include accelerating the creation of water user associations*** and empowering them. ***Measurement and billing volumetrically is essential*** for other Water demand management measures to follow. **Potential savings in water demand use are highest in this sector** and are achievable.
- Water demand management in the urban environment already receives attention but more effort is required. ***Leakage management and other water demand management interventions should be pursued vigorously throughout the basin.***

Environmental Flows:

- Now that environmental flow requirements for different ecological states have been established, there is a need for the basin ***states to agree on what ecological states should be maintained in the future*** and the ***means to monitor this.***
  - o ***Testing of various operational scenarios*** that could include new developments or changes in the existing operation of the system. Testing of these scenarios must be undertaken in terms of changes in ecological state and Goods and Services.
  - o These results should then be ***presented to the stakeholders*** so that ***agreement can be reached on the future ecological state*** of the river.
- ***An extensive and joint monitoring system should then be implemented***. It is strongly recommended that an Ecological Water Resources Monitoring (EWRM) programme is initiated as soon as possible. The information gathered during this study is suitable for the baseline, but if too much time relapses between the baseline and monitoring, new surveys and Eco-Classification process will have to be undertaken. It must be noted that ***monitoring of essential Goods and Services*** should be included as part of the EWRM.

Climate Change: There is a need to prepare for the impacts of climate change and also to continually improve estimates of the anticipated climate change:

- ***Fine-tuning of the CCLM*** for the region and incorporation of further technical improvements such as improved convection scheme.
- An improved CCLM could be used **to focus on particular areas** by undertaking high resolution runs. Clearly the source areas such as the Lesotho Highlands would be obvious targets.
- This year's (2011) new IPCC emission scenarios and GCM results should be used to yield improved downscaling results.
- Improved accuracy of GCC downscaling will depend not only on advances in the modelling process but relies on large and good quality climate observation datasets. In view of the importance of having accurate predictions of climate change in the source areas***, there is a need to improve the meteorological network in these areas***.
- ***Design of a flexible adaptation strategy*** for the different parts and livelihoods around the basin.

Water Quality: There is a need to formalise the joint basin-wide initiative of water quality monitoring at critical points and to make this part of the overall resource modelling process throughout the basin. Phase 3 of GIZ support to ORASECOM should ***see implementation of the water quality monitoring programme***. During this process capacity-building should continue.

ORASECOM