Orange-Senqu River Basin

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

UNDP-GEF
Orange-Senqu Strategic Action Programme
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Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth

Scoping Paper and Terms of Reference

Technical Report 10
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UNDP-GEF
Orange-Senqu Strategic Action Programme

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Scoping Paper and Terms of Reference

This report has been issued and amended as follows:

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1. Background

1.1 Orange-Senqu Strategic Action Programme

The Orange-Senqu River riparian States (Botswana, Lesotho, Namibia and South Africa) are committed to jointly addressing threats to the shared water resources of the Basin. This is reflected in bilateral and basin-wide agreements between the riparian States and led to the formation of the Orange-Senqu River Commission (ORASECOM) in 2000.

The 'Orange-Senqu Strategic Action Programme' Project supports ORASECOM in developing a basin-wide plan for the management and development of water resources, based on integrated water resources management (IWRM) principles. The Project currently finalises a Transboundary Diagnostic Analysis (TDA). This TDA will serve as the scientific basis for developing a set of interventions under the framework of a basin-wide Strategic Action Programme (SAP) and associated National Action Plans (NAPs) in the riparian States. In addition, Research and Demonstration Projects focus on:

- Environmental flows for the Fish River in Namibia and the Orange-Senqu River Mouth, shared by Namibia and South Africa;
- Community based rangeland management, with sites in Botswana and Lesotho; and
- Water resources management in the irrigation sector, with sites in Namibia and South Africa.

1.2 Context

The water resources of the Orange-Senqu River are heavily utilised. 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 at the same time having sufficient water of an acceptable quality to meet existing and proposed irrigation and other demands (including environmental) further downstream challenges planners, decision makers and stakeholders.

The Orange River System is highly regulated with 23 major dams within its Basin. It is also connected to other river systems for water import and export via six inter-basin water transfer schemes. As a result of the impoundments and inter-basin transfers, it is currently estimated that the mean annual runoff (MAR) reaching the Orange-Senqu River Mouth, has been reduced to about 43% of the natural MAR (some 10,800 million m3).

Operational management of the Orange-Senqu River (reservoir releases, transfers etc) is a continuous process and has to be done with great care making use of a complex water resource simulation model (Water Resource Planning Model, WRPM) to ensure that the different users around the basin have an assured supply of water. Downstream users, including the environment, are dependent on releases

from upstream dams, releases which takes several days to reach them. While assuring these downstream demands, management must equally assure that no more water than necessary is sent downstream, especially in times of water shortage. Good management depends, amongst other things, on an accurate knowledge of flows in the river and its tributaries. As the resource gets more limited the need for better accuracy and precision water management becomes even greater. As a result South Africa and Namibia to are busy establishing three new gauging stations in the Lower Orange to accurately measure low flows. The new gauging stations will make it easier to ensure that the required amounts of water for supporting the environment in the Lower Orange are left in the river.

In 2009, in preparation for the design and implementation of a basin-wide IWRM plan, ORASECOM, with the support of the GIZ, commissioned a study into environmental flow requirements in the Orange-Senqu River Basin (WRP et al., 2010 and 2011). This study was recently completed and has defined both the present ecological state and the environmental flows that would be required to maintain a range of ecological states at eight representative sites upstream of the confluence of the Fish and Orange Rivers. This represents an important step forward towards the ultimate goal of agreeing and monitoring environmental flows to be maintained in the future.

1.3 Rationale

Environmental flow requirements of the ephemeral but nevertheless significant Fish River and the Orange River from its confluence with the Fish down to the mouth were not covered in any detail by the GIZ study. This outstanding work is to be the subject of this Research Project. The importance of completing the environmental flow requirements picture is becoming increasingly urgent due to the fact that two large dams, one in the Lower Orange (Vioolsdrift Dam) and one in the Lower Fish (Neckertal Dam), are at an advanced state of planning. Clearly, these reservoirs will have a major impact on, as well as a role to play in the maintenance of environmental flows. Further to this, the Orange River Mouth Interim Management Committee (ORMIMC), a transboundary body comprising of the Environment Departments of Namibia and South Africa as well as other stakeholders, is now moving towards establishing a Management Plan for the Orange-Senqu River Mouth. ORMIMC sees this as an operational plan of three to five years duration, with prioritised discrete actions towards remediating the degradation of the Ramsar site and eventually getting it off the Montreux Record.

2. Environmental Flows in the Orange-Senqu Basin

2.1 Environmental Flow Methodologies

The process of setting Environmental Flow Requirements (EFRs) for perennial rivers is well established in the region. A sequential approach is followed. The assessment is normally initiated through a scoping study of ecological and socio-cultural importance. For the Orange-Senqu River Basin this was already carried out as part of the recently-completed GIZ study and provides information on where the important areas for more detailed assessment are situated. Key areas are normally identified by delineating the rivers into units which are relatively uniform in terms of their biophysical attributes and operation. A specific study site (referred to as an EFR site) should be situated within the most important of these units.

The EFRs usually consist of two aspects:

- Determining the health of the rivers – described as the Present Ecological State (PES) and deriving alternative states, usually an improved state and a state in worse condition than the PES.
- Setting flow requirements for these alternative states.

It is generally accepted that a holistic EFR methodology is preferred, as this provides the highest confidence results and is based on an ecosystem approach. A range of EFR scenarios should be proposed and presented, together with their ecological and socio-economic implications, to the appropriate stakeholders. This approach enables informed decisions to be made because it provides information on the trade-offs between environmental protection and economic development. EFR scenarios should be considered for each site and should comprise consideration of the EFR to maintain the PES, the EFR to improve the PES and the EFR for a deteriorated PES.

The EFR scenarios are then used to set the baseline for evaluating any other proposed flow scenarios which might require testing to determine ecological and socio-economic consequences during future study phases.

In deriving EFRs an integrated approach is required meaning that the assessment of Goods and Services takes place during all steps. The Goods and Services assessment cannot take place in isolation, as the quantification, and qualification of the scale of changes and their importance, with different flow regimes, depends on specialist input generated during the EFR study.

Non-perennial rivers are primarily distinguished from perennial ones by their hydrological regime, which is spatially and temporally much more variable, and by the loss of connectivity of surface water within the system as flow periodically fails and surface water is confined to isolated pools that may

themselves dry up eventually. The variability and unpredictability in the flow regime – the fundamental driving force of the river – result in high levels of disturbance for the riverine biotas. Species tend to have lifecycle strategies that can cope with periodic and unpredictable flood and desiccation, with some aestivating and others depending on pools as refugia. Species that cannot cope with such conditions tend to be rare or absent, whilst even those that can may, or may not, appear in any one pool in any one year. Riparian vegetation may be the most obvious and persistent biological component of the ecosystem of such rivers, tapping into underground flows and perhaps showing some greater community development around persistent pools. Classic examples of the persistence of such vegetation are the 'linear oases' – the green ribbons of trees – along dry channels in the deserts and semi-deserts of Namibia and north-western South Africa. These are essential resources for local people and wildlife.

Drawing on the research findings on the Seekoei River in South Africa, a prototype methodology has begun to emerge for environmental flow assessments for non-perennial rivers (WRC 2005 and recent unpublished work).

The Research Project covers three methodological areas, the non-perennial Fish River in Namibia, the Orange River downstream of its confluence with the Fish River and the Orange-Senqu River Mouth. A considerable amount of work has been carried out on the perennial Orange-Senqu River system. However, very little work on environmental flow requirements in non-perennial rivers systems in general and on the the Fish River in particular, as well as on environmental flow requirements for estuaries and the Orange-Senqu River Mouth in particular.

As a result the work on the Lower Orange River will largely be limited to the application of existing accepted methodologies while the work on the Fish River and the Orange-Senqu River Mouth will also include the development and workshopping of an appropriate methodology.

2.2 Study Area

The Fish River

The Fish River rises to the south-west of Windhoek and runs nearly 900km to its confluence with the Orange River. It si the largest of Namibia's ephemeral river basins. Despite very low rainfall over all of the basin, some areas have unusually high unit runoff values and the mean annual runoff of the Fish River is significant at around 450 Mm^3/annum. This corresponds to nearly 5% of the Orange-Senqu's MAR. The largest dam; on the Fish River is the Hardap Dam near the town of Mariental, which it supplies with water together with the Hardap irrigation scheme. Further downstream it makes its confluence with the Naute River, on which is found another large dam, supplying water to the town of Keetmanshoop. The Fish River passes through the Fish River Canyon before making its confluence with the Konkiep River and finally the Orange itself to the west of Noordoewer. The

Neckertal Dam, for which plans are at an advance stage is situated just upstream of the Fish River Canyon.

The Lower Orange River

The Lower Orange River downstream of its confluence with the Fish River and upstream of the estuary passes through the rugged, dry and desolate Richtersveld National Park before reaching the Atlantic Ocean. There are no further significant tributaries joining the river downstream of the Fish River.

The Orange-Senqu River Mouth

The Orange-Senqu River Mouth comprises a channel system between sand banks, a tidal basin, the estuary mouth and the salt marsh on the south bank. Its wetlands situated between the north and south flood margins of the river have an area of some 2,000 ha. The wetlands were designated Ramsar status, i.e. a wetland of international importance in 1991. However, due to the severely degraded state of the salt marsh on the south bank the Ramsar site was placed on the Montreux Record in 1995 (a list of Ramsar sites around the world that are in degraded state).

Catchment Management Organisations

In Namibia the Orange-Fish Basin Management Committee (OFBMC) has been established to manage resources in the Fish River Catchment. The Committee includes government departments as well as civil society stakeholders.

The Orange River Mouth Interim Management Committee (ORMIMC), a transboundary body comprising of the Environment Departments of Namibia and South Africa as well as other stakeholders, is now moving towards establishing a Management Plan for the Ramsar site at the Orange-Senqu River Mouth.

Furthermore, the /Ai-/Ais–Richtersveld Trans-frontier Park Joint Management Board (ARTP JMB) manages the Lower Orange Trans-frontier Conservation Area. This includes the Lower Orange River Valley.

Catchment Management Agencies (CMAs), statutory bodies established in South Africa under the Water Act are obliged to develop and implement a Catchment Management Strategy. For the Lower Orange the CMA has not yet been established.

2.3 Current Knowledge

Fish River

Although environmental flow requirements in ephemeral rivers have not been studied in depth, some work has been done. The National Water Policy (2002) includes a number of "Basic Principles" including the "Principle of Ecosystem Values and Sustainability" which states that the "management of water resources needs to harmonise human and environmental requirements, recognising the role of water in supporting the ecosystem". The Environmental Water Reserve is specifically included in the "Legislative and Regulatory Principles" that state that: "The legislation will provide for determining an environmental water reserve for freshwater sources before they can be used to supply any other demand than domestic and subsistence livestock watering."

However, with few exceptions, for the existing dams on major ephemeral river courses in Namibia, no allowance was made at the design stage, for environmental releases. These include and number of dams in the Orange-Senqu basin such as the Hardap and Naute Dams on the Fish and Lowen Rivers respectively and the Otivero Dam system on the Nossob. Other major impoundments for which no allowance was made include the Von Bach and Swakoppoort Dams on the Swakop River. However, for all of these dams, environmental releases are possible through the use of either gated spillways (Hardap, Naute and Von Bach) or scour valves.

One noticeable exception was the Oanaob Dam commissioned in 1990 on the Oanob River, an upper tributary of the Fish River. During the design phase, it was recognized that the construction of a dam would influence the riverine ecology downstream of the dam site. A project was thus initiated to study the potential impacts, the first such study of its kind in Namibia at the time. The findings resulted in certain changes being made to the design to allow the release of water from the dam to assist the ecological balance of the riverine system. At the time of commissioning it was stated that the effect of the releases would be monitored on a regular basis by the Department of Water Affairs, forming part of an on-going baseline monitoring project. It would appear that the releases were largely calculated to maintain the camelthorn, *Acacia erioloba*, woodland in the floodplain immediately below this dam.

Orange-Senqu River

The present ecological state and environmental flow requirements at the "intermediate" level have been investigated as part of the recent Phase 2 of GIZ support to the ORASECOM Basin-wide IWRM Plan. The final outputs of the work were in the form of a number of reports:

Literature survey and Gap Analysis (ORASECOM Report 008/2010)

- Delineation of Management Resource Units (009/2010). This report defines the Management Resources Units which are homogenous units in terms of impacts and biophysical characteristics.

- Desktop EcoClassification Assessment (016/2010). The results of a Reconnaissance EcoClassification process to determine integrated Environmental Importance.
- Goods and Services Report (010/2010) provides an assessment of the impacts of the various scenarios on goods and services
- Environmental Flow Requirements Report (010/2011) defining the environmental flow requirements for different ecological states at selected EFR sites.

The detailed results and conclusions for each of the Environmental Flow Requirements Sites are presented in reports 010/2010 and 010/2011 respectively. Based on the confidence evaluation of the results, recommendations were made where additional information is required to improve the confidence. These include:

- Initiation of an Ecological Water Resources Monitoring (EWRM) programme as this is essential to measure whether objectives are being achieved.
- 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.
- Presentation to stakeholders so that agreement can be reached on the future ecological state of the river.
- Implementation of an extensive and joint monitoring system.

Orange-Senqu River Mouth

As part of the 'Pre-feasibility study into measures to improve the management of the Lower Orange River and to provide for future developments along the border between Namibia and South Africa; Lower Orange River Management Study' (LORMS, Burmeister&Partner *et al.* 2005), a short scoping study conducted under the Project (UNDP-GEF 2010) and a Preliminary Situation Assessment (CSIR *et al.*, 2011) a number of anthropogenic influences were identified as contributing to the degraded state of the River Mouth. The most obvious of these is of course changes in river flow, the construction of an access road, changes in sediment supply, construction of an oxidation pond in the flood plain, mining activities and artificial mouth breaching.

The current status of knowledge with respect to the status of the Orange-Senqu River Mouth has been summarised in terms of the status of estuarine biota:

- ***Microalgae***. No data are available, but phytoplankton is probably unimportant because of high flows and regular flushing would preclude the development of resident populations. Benthic microalgal biomass could be high in quiet backwater areas. Microalgae are probably important primary colonizers after floods.
- ***Macrophytes***. The literature states that estuarine plant communities were distributed primarily along the southern bank of the estuary, corresponding to the 2 to 2.5 kilometre limit of saltwater penetration. *Scirpus littoralis* occurred close to the mouth in small clumps but was replaced by the dominant species *Phragmites australis* (common reed) along the shallow edge habitats further upstream. Both species thrive in brackish conditions when

- ***Invertebrates.*** Estuarine benthic invertebrates information consist of two sets of data collected in the river mouth area (intertidal zone) below the Ernest Oppenheimer Bridge. Data collected in 1959 indicated that the intertidal benthic fauna at the time was extremely poor, both in species number and biomass. The fluctuating abiotic conditions of the intertidal zone create a harsh environment for intertidal communities and only the hardiest survive. However, there are likely to be pockets among the mosaic of channels where conditions are more stable and communities may become better established over time. No information is available on the subtidal benthic community. Very little information (brief comments) exists for the zooplankton in the main channel. It is described as consisting of freshwater species that are present in very low numbers. This community is unlikely to establish itself permanently because of strong flushing at the surface. The invertebrates present in the sheltered wetland on the southern bank near the mouth of the Lower Orange are likely to assume estuarine characteristics, although there are no hard data to support this. An estuarine type community probably exists (benthos and zooplankton) in the more sheltered backwaters, but no data are available to substantiate this.
- ***Fish***. Twenty-nine species of fish representing 14 families are been recorded from the Orange-Senqu River Mouth. Overall, 31 % of the fish species recorded from the Mouth are either partially or completely estuarine dependent, 21 % are marine and 48 % freshwater in origin. Two species of kob, silver kob Argyrosomus inodorus and Angolan kob A. coronus are known from the Orange-Senqu River Mouth, the latter only been caught by anglers in the mouth region. On the whole, the current fish assemblage and the presence of estuarine residents suggests that the Mouth functions as a viable nursery area and refuge for juvenile and adult estuarine fish though not as well as under natural conditions.
- ***Birds***. The number of waterbirds recorded at the estuary has varied considerably since 1980 when the first comprehensive survey was conducted and 21 512 waterbirds were recorded . this number has not been matched since and numbers dropped significantly in more recent years. The estuary continues to support more than 1% of the southern African and global populations of all the waterbird species listed by Williams (1990).

Major Gaps

The Orange-Senqu River System down to the Orange-Fish confluence has been analysed at the "intermediate" level of detail. The remainder has not been examined at any where the same level. Thus the major gaps that need to be filled (by this Research Project) are as follows:

- Determination of present ecological state and environmental flow requirements in the Fish River.
- Determination of present ecological state and environmental flow requirements in the Orange River between its confluence with the Fish River and the Orange-Senqu River Mouth.
- Determination of present ecological state and environmental flow requirements of the Orange-Senqu River Mouth (and associated marine environment).

3. Scope of the Proposed Research Project

3.1 Objectives and Expected Outcomes

Objectives

This Research Project on environmental flows shall:

- Focus on the Fish River and the Orange-Senqu downstream of its confluence with the Fish, including a particular focus on the Orange-Senqu River Mouth.
- Engage stakeholders.
- Develop and implement a baseline monitoring programme covering flow-related biophysical parameters. The monitoring programme shall cover a wide range of flow conditions in at least one full hydrological cycle.
- Document monitoring results in an environmental flows database.
- Research and assess non-flow related impacts.
- Describe the Present Ecological State.
- Define (at the "intermediate" level of detail, where applicable) environmental flows that would be required to maintain a range of ecological state at selective site(s) in the Fish and the Lower Orange as well as at the Orange-Senqu River Mouth.
- Recommend attainable and satisfactory environmental flows for application.
- Design a long-term monitoring programme to assess the efficacy of environmental flows and other management interventions.
- Cooperate with and provide specific inputs to related projects, namely the Vioolsdrift and Neckertal Dam projects, as well as the Orange-Senqu River Mouth Management Plan.

For the Fish River these will be defined for representative sites upstream and downstream of the proposed Neckertal Dam on the Fish River. For the Orange River, representative sites should be selected on the Orange River upstream of the estuary as well as within the estuary itself.

Expected Outcomes - Fish River

The following outcomes are expected for the Fish River:

- An assessment of environmental goods and services provided by the river. This assessment should be an integral part of all steps of the EFR process.
- The development and acceptance, with the assistance of through an expert-level workshopping process of an appropriate methodology for the determination of present ecological state and environmental flow requirements.
- Present ecological state for selected representative sites on the Fish River. This must include at least one site upstream of the proposed Neckertal Dam and one downstream of it.

- Environmental Flow Requirement for selected representative sites on the Fish River. This must include at least one site upstream of the proposed Neckertal Dam and one dosnstream of it Specification of release procedures (if any) for the Hardap, Naute and proposed Neckertal dam sites.

Expected Outcomes - Lower Orange River

The following outcomes are expected for the Lower Orange River:

- An assessment of environmental goods and services provided by the river. This assessment should be an integral part of all steps of the EFR process.
- Present ecological state for selected representative site(s) on the Orange River between its confluence with the Fish River and the estuary.
- Environmental flow requirements for selected representative site(s) on the Orange River between its confluence with the Fish River and the estuary. Values should be derived corresponding to a range of ecological states.
- The overall outputs should correspond to and compliment those of the recently completed GIZ study on the Orange-Senqu River further upstream.

Orange-Senqu River Mouth

In the LORMS study a number of environmental management objectives were proposed. These should represent a point of departure for development of the methodology to be finalised and agreed during the Inception Phase. These objectives included both sustainable management objectives and objectives related to the rehabilitation of the salt marsh area.

The estuary should meet the following sustainable natural resource utilization objectives:

- Ecological systems and processes must be maintained, particularly those on which human survival and development depend.
- Since the Orange-Senqu River Mouth was designated as a Wetland of International Importance in terms of the Ramsar Convention, future river flows should be sufficient to ensure that the ecological integrity of the mouth is maintained now and in the future.
- Genetic diversity is essential for the functioning of ecological processes and must be conserved.
- The sustainable and equitable utilization of the natural resources that support communities and industries must be promoted.
- The quality of life of rural communities must be improved by developing opportunities for a sustainable tourism industry in publicly administered protected areas.
- A clean and healthy living environment for the people of the catchment should be created and maintained.
- Development must be sustainable and environmentally compatible.
- The integrity of the natural environment must be protected to ensure its sustained ability to produce renewable commodities and to serve as a basis for tourism.

- The flows in the river should ensure that the requirements for a sustainable biodiversity are met.

4. Proposed Project Activities

4.1 Project Duration and Phasing

The Research Project will run for some two years. It is anticipated that the Inception Phase will start in September 2011 and that all work will be completed by October 2013.

The project will be phased with clear outputs for each of the phases. The following phases are anticipated:

- Inception (2 – 3 months);
- Survey; and
- Determination of Environmental flow Requirements.

4.2 Inception

The Inception Phase will be relatively long at three months. This is recognition of the fact that during this phase a preliminary methodology for the determination of environmental flow requirements in the Fish River must be further developed from that presented in the consultant's proposal. Similarly for the Estuary it is anticipated that the Consultant will have to further develop and refine their methodology. In developing the methodology the Consultant should consider the following points of departure:

- The methodology used for perennial systems (as used in the GIZ Phase 2 support and proposed below for the Lower Orange. Which parts of it are relevant and how could it be adapted to an ephemeral system.
- The inherent variability of an ephemeral river such as the Fish and the presence and length of both inter-annual and intra-annual zero flows periods .
- The prototype methodology that has begun to emerge for environmental flow assessments for non-perennial rivers (WRC 2005 and recent unpublished work) which largely draws on the research findings on the Seekoei River in South Africa.

Three weeks before the end of the Inception Phase the Consultant will be required to workshop their preliminary methodologies for the Fish River and estuary. This will allow the development of accepted methodologies to be described in the Inception Report.

For the Orange River between the Fish River confluence and the Orange-Senqu River Mouth the Inception phase should focus on the identification of the representative sites to be used. The methodology should also be presented in detail and while the same methodology as that used for the recently completed GIZ study is to be utilised, the Inception report should indicate how it can be improved, especially in view of the longer project duration.

For the Orange-Senqu River Mouth, the first two months of the Inception Phase should be utilised for the development and fine-tuning of the methodology to be applied. This methodology should be based on the knowledge of what data can realistically be collected during the project period. It will, therefore, be necessary to a certain amount of investigatory fieldwork during the inception phase.

During the Inception Phase the design of the stakeholder process and a preliminary stakeholder consultation should take place. This should build on the work already carried out as part of the GIZ Phase 2 support..

The Inception Report shall be submitted three months after project commencement and presented to a workshop. It shall outline:

- The Consultant's mobilization;
- The detailed work plan;
- A revised methodology and timetable for the services; and
- Progress monitoring and quality assurance.

4.3 Survey

The Survey Phase is the period in which all the required data is to be collected following the approval of the methodology. It is anticipated that the work will be carried out by at least two teams of specialists although some overlapping would be possible. The Survey Phase is to cover two hydrological seasons.

Fish River

In view of the fact that the methodology will only be finalised during the Inception Phase the following list of activities should be taken as indicative only and for consideration in planning the required inputs and expertise required.

- Selection of representative sites / reaches; identify the important reaches of river in terms of ecological and social importance
- Evaluation and definition of current ecological status – should this be done only for selected sites and in detail at them and/or in a broader fashion looking at whole reaches of the river (reach affected by Hardap Dam, affected by Naute Dam, affected by potential Neckertal Dam.)
- Identification and assessment of Goods and Services that are currently being provided by the river and its associated ecosystems.
- Examination of hydrology. Careful examination of historical records to understand all aspects of the natural variability. Comparison of pre and post Naute and Hardap hydrologies. The selected sites should also be monitored through the two year period.
- Examination of ecosystems status as a function oif their distance downstream of existing dam sites.

- Evaluation of possible future ecological states and the requirements to maintain them. This should consider both improved and worsened states compared to the present ecological state.
- Identification and assessment of Goods and Services associated with possible future states as identified under the previous point

Lower Orange River

In carrying out the following, the methodology should be based on:

- Following on from the scoping level work carried out under the GIZ project and work carried out in the Inception Phase finalise the locations of the important reaches of river in terms of ecological and social importance.
- Evaluate through detailed surveys, the current ecological state of the management resource unit, including identification of what would be required to improve it, and what could cause deterioration.
- Identify and value the goods and services under present conditions and assess the potential for goods and services to change (linked to the improved and degraded scenarios).
- Evaluate the environmental flow requirements to maintain the stipulated range of different ecological states.

Orange-Senqu River Mouth

In the LORMS study it was suggested that the baseline study be conducted on a "comprehensive level to improve future ecological flow requirement studies for the Orange-Senqu River Mouth. The level of detail required should be discussed and motivated in the finalised methodology."

Design and implement an appropriate data collection programme covering at least the following areas:

- Hydrodynamics. This could include
  - Continuous or quasi-continuous measurement of discharge at the head of the estuary (using Acoustic Doppler Current Profiler (ADCP).
  - Continuous water level recordings near mouth of estuary.
  - Daily observations on the state of the mouth.
  - Colour georeferenced aerial photography of the estuary (low tide in summer).
  - Sediment dynamics; this could include:Cross-section profiles along beach, bar, mouth and lower basin region at appropriate intervals for evaluation of sediment dynamics.
  - Collection of samples for particle size distribution analysis.
  - Collection of sediment core samples for historic characterisation.
  - Measurement of sediment load near head of estuary.

- Water quality. This could include:
  - At least monthly water quality measurements of appropriate variables.
  - Longitudinal salinity and temperature profiles during low flow season when mouth open and closed.

- Microalgae. This could include:
  - Chlorophyll measurements at a number of selected sites and at suitable times at surface and sub-surface.
  - Intertidal and sub-tidal benthic chlorophyll-a measurements at a number of selecxted site
  - Collection of epipelic diatoms for identification.
  - Note that simultaneous measurements of flow, light, salinity, nutrients etc should be carried out.

- Macrophytes. This would include:
  - Aerial photography of the estuary at 1:5,000 or better to reflect the present state.
  - Inventory plant communities, number of macrophyte species, rare and endangered species etc.
  - Establishment of permanent transects to measure change in vegetation in response to salinity change etc.
  - Measurements of salinity, water level, sediment moisture content and turbidity, depth to groundwater.

- Invertebrates. Collection and evaluation of information on invertebrates is a critical taks and involves intra-seasonal and inter-seasonal surveys in several locations. Careful thought should be given to this in the survey design. Work should include
  - Collection of sediment samples for analysis of organic content and identification of species, from lowest taxon possible and calculation of densities (high and low flow seasons).
  - Collection of replicated hyperbenthic samples. Surveys of shorelines for crabs, prawns etc.
  - Collection of replicated zooplankton samples.

- Fish. Work should include:
  - Quarterly surveys of the estuary for at least one full year and subsequent summer and winter surveys.
  - Sampling from the Mouth up to Brandkaros 35km upstream at appropriate intervals.

- Birds. Work should include:
  - Full bi-annual counts.
  - Additional counts during times of mouth closure.

The survey phase would include a goods and services study which would collect information on the following socioeconomic aspects relating to the Orange-Senqu River Mouth's ecosystem Goods and Services:

- Recreational fishing of the estuary and beach fishes;
- Mining activities;
- Tourism;
- Conservation;
- Farming activities;
- Flood protection;
- Recreational activities (e.g. boating, golf courses); and
- Mitigation measures proposed for the rehabilitation of the Orange-Senqu River Mouth.

The goods and services study is to look at the types and value of the various goods and services provided by the estuary including both direct and indirect use values.

4.4 Determination of Environmental Flow Requirements

In this final phase of the study the environmental flow requirements corresponding to the present ecological state and future desired state are to be determined for the three areas. Once this has been done there will be a workshops involving stakeholders from all riparian States to examine and make recommendations on the desired future ecological state in each of the studied areas.

Ecological Flow Requirements of the Fish River

During this final phase of the study the Environmental Flow Requirement for selected representative sites on the Fish River are to be determined. This must include at least one site upstream of the proposed Neckertal Dam and one downstream of it. Specification of release procedures (if any) for the Hardap, Naute and proposed Neckertal dam sites should be included in the recommendations.

Ecological Flow Requirements of the Orange River between confluence with Fish River and the Orange-Senqu River Mouth

Environmental Flow Requirement Environmental for selected representative site(s) on the Orange River between its confluence with the Fish River and the estuary are to be determined. Values should be derived corresponding to a range of ecological states. The overall ouputs should correspond to and compliment those of the recently completed GIZ study on the Orange-Senqu River further upstream.

Ecological Flow Requirements of the Orange-Senqu River Estuary

Including the following steps:

- Statement of Reference Conditions;
- Present Ecological State;
- Estuarine importance;
- Determine the EFR (quantity and quality).

Ecological Flow Requirements of the Marine Environment

The following should be undertaken:

- Assessment of the role of freshwater inflows and associated fluxes in the coastal and shelf marine ecosystems of the Orange River Mouth and the potential effects of changes in the freshwater-related fluxes into these ecosystems.
- Setting up and running a mathematical model to numerically model the foot print of the Orange River (both flow and sediment) on the nearshore marine environment should be considered.

The following steps are suggested:

- Describe the issues of concern around potential changes in freshwater inflows (and associated fluxes of nutrients and sediment) in the coastal and marine ecosystem;
- Describe the potential freshwater-dependant functional linkages between coastal marine ecosystems and adjacent catchment; and
- Assessment of the potential risks associated with such changes, based on a driver-response approach (assessment of the ecological response to primarily abiotic drivers that are likely to be influenced by changed in freshwater inflows (and associated sediment and nutrient fluxes) into the coastal marine ecosystem.

The goal should be to use the outcome of the assessment to recommend allowable changes in freshwater inflow into the marine environment within the constraints of maintaining or improving the present health status of the marine ecosystem and optimisation of the existing "ecosystem services" provided by the coastal ecosystem.

Recommendations and Final Report

Drafting of a single overall report with the environmental flow requirements to maintain the stipulated range of different ecological states in the Fish and Orange Rivers including the Estuary.

5. Implementation Arrangements

5.1 Project Team and Organisation

The Consultant is free to suggest an appropriate team of expertise to carry out the assignment but it is anticipated that expertise in the following fields will be required:

- Water Quality
- Hydrology (including ephemeral rivers)
- Resource economics
- Stakeholder participation
- Geohydrology
- Hydrodynamics
- Estuarine vegetation
- Sediment dynamics
- Microalgae
- Macrophytes
- Invertebrates (including zooplankton, benthic invertebrates and macrocrustaceans)
- Fish (ichthyofauna)
- Birds (avifauna)
- Estuarine resource economics
- GIS and remote sensing
- Database design and management.

It is suggested that two appropriately structured teams are put in place, one to handle the Fish River and Orange River between the confluence with the Fish and the Mouth, and the other to handle the Estuary itself.

A Project Manager shall oversee both teams and report to the Client.

The Client will:

- Assist with permissions that may be required to enter sensitive areas in Oranjemund and Alexander Bay.
- Facilitate contacts with government officials and representatives in the riparian States.

5.2 Tentative Budget

A budget in the range of USD 750,000 has been earmarked for this Research Project. The following tentative allocation has been made. All funds are under the Consultant:

No	*Description*	*Quantity*	*Costs (USD)*	*Comments*
1	**Project team**			
	Project manager	8 person months	100,000	Project manager (> 15 years experience), senior professional/scientist. Part-time assignment, some 30% over 25 months.
	Scientists, project team members	20 person months	200,000	Pool of experts, medium to senior level professionals/scientists (5 to 10 years experience). To be called upon as per requirements.
	Field and support staff	40 person months	200,000	Junior level scientists for field surveys and recurrent monitoring, data management, etc.
2	**Expenses**			
	Miscellaneous expenses	Lump sum per month	25,000	To be specified.
	Transport	Per km	25,000	i.e. 4WD, 4,000km per month.
	Subsistence	Daily rate	50,000	For field work, 40 field days per month.
3	**Equipment and consumables**			
	Scientific equipment and related consumables, laboratory costs.	Estimate	150,000	To be specified.
	Total Research Project		**750,000**	

5.3 Reporting

Management Reports

The following management reports are required:

- Monthly progress notes. A short standard format progress note will be required on a monthly basis. It will provide an update on project progress and highlight problem areas and bottlenecks
- Quarterly reports. The quarterly report will provided detailed feedback on progress on an activity by activity basis. Problem areas and bottlenecks will be highlighted and solutions for solving them will be proposed.

- Inception report. The consultant will submit an acceptable inception report, six weeks after commencement. The report shall outline the Consultant's mobilization, the work plan, revised methodology and timetable for the services as well as a quality assurance plan. The consultant will present the envisaged outline of major reports and recommendations for better completion of the assignment. The Inception report will also include details of the planned structure for the GIS database.

Technical/Scientific Products

The following are required:

- Database. All data and maps should be suitably organised and stored on a project GIS. The GIS system should be compatible with ARC-GIS 9. A complete copy of the GIS database including metadata is to be handed over to the Client at the end of the project. Short descriptive report.
- Specialist reports, covering thematic and spatial areas, as appropriate.
- Final report. A draft final report is to be submitted six weeks before the end of project date. It will be presented to and discussed at a meeting of stakeholders two weeks later. The final report will take into account the discussions, conclusions and recommendations of the stakeholder workshop and comments provided by the Client.

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