Okavango River Basin Transboundary Diagnostic Analysis Technical Report

OKACOM

The Permanent Okavango River Basin Water Commission

Okavango River Basin Environmental Flow Assessment Guidelines for Data Collection, Analysis and Scenario Creation
Report No: 03/2009

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Environmental protection and sustainable management of the Okavango River Basin

EPSMO

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LIST OF REPORTS IN REPORT SERIES

Report 01/2009:	Project Initiation Report
Report 02/2009:	Process Report
Report 03/2009:	Guidelines for data collection, analysis and scenario creation
Report 04/2009:	Delineation Report
Report 05/2009:	Hydrology Report: Data and models
Report 06/2009:	Scenario Report: Hydrology
Report 07/2009:	Scenario Report: Ecological and social predictions
Report 08/2009:	Final Report

Other deliverables:

DSS Software

Process Management Team PowerPoint Presentations

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

PAGE

LIST OF TABLES

ACRONYMS AND GLOSSARY

DSS	Decision Support System
DWAF	Department of Water Affairs and Forestry (South Africa)
EF	Environmental Flows
EFA	Environmental Flow Assessment
GIS	Geographical Information Systems
HOORC	Harry Oppenheimer Okavango Research Centre
IUAs	Integrated Units of Analysis
MAR	Mean Annual Runoff
MRC	Mekong River Commission
TDA	Technical Diagnostic Analysis
UN-FAO	Food and Agriculture Organization of the United Nations

Introduction

The origin of the project is described in Report 01/2009: Project Initiation Report. Essentially, the project was an initiative of OKACOM, the Okavango River Basin Commission. Titled the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) project, it was approved by the United Nations Development Program (UNDP), to be executed by the United Nations Food and Agriculture Organization (FAO). The long-term objective of the EPSMO Project was to achieve global environmental benefits through concerted management of the naturally integrated land and water resources of the Okavango River Basin.

The project would follow a standard process used by all GEF funded International Waters projects: an objective assessment - the Transboundary Diagnostic Analysis (TDA) – followed by the development of a Strategic Action Programme (SAP) of joint management to address threats to the basin's linked land and water systems. The SAP would package initiatives that address issues raised by the TDA and would aim to overcome barriers to regional co-operation and thus help ensure that development of the basin would be sustainable and equitable. In the case of the Okavango Basin, the traditional approach, designed for rehabilitating degraded rivers, would have to be modified because of the near-pristine nature of the river ecosystem. It was suggested that this be done by incorporating an Environmental Flows Assessment as a major part of the TDA.

In 2008 EPSMO therefore collaborated with the BIOKAVANGO Project at the Harry Oppenheimer Okavango Research Centre (HOORC) of the University of Botswana, to jointly conduct a preliminary basin-wide Environmental Flows Assessment (EFA) for the Okavango River system.

National teams in Angola, Namibia and Botswana worked with a Process Management Team to complete the Environmental Flow Assessment (EFA) component of the TDA by July 2009.

At a Planning Meeting in July 2008, a workplan for the EFA was agreed on, which required Guidelines to be drawn up for several of the activities. This document provides the guidelines for:

- Basin delineation
- Selection of study zones and sites
- Selection of development scenarios for analysis
- Selection of indicators and flow components
- Date collection
- Construction of Response Curves for knowledge capture
- Writing of reports
- Determination of ecological condition.

Guidelines for basin delineation

Introduction

This Chapter provides guidelines for the designation of ecologically and socially-relevant river zones and sites in the Okavango Basin. The guidelines are presented with the assumption that each step will be recorded in a formal Delineation Report.

The primary objective of this task is to:

- divide the river into relatively homogeneous longitudinal zones in terms of biophysical characteristics (reach analysis) and land-use;
- select homogeneous sampling areas for socio-economic surveys;
- harmonise the biophysical river zones and social areas so that the social and ecological data focus on compatible zones;
- select representative sites for all the river and social work to follow; and
- develop simple (GIS) base maps for use as required.
- provide the information required for completion of the Delineation Report.

The delineation will be done in a workshop, which will be divided into a number of plenary sessions for the purpose of sharing information, and a number of group work sessions where sub-groups will work on river, delta and social analyses. In addition, a GIS team will provide maps and related information as required.

For Steps 1-4 below, sub-groups will be defined on the basis of discipline rather than country representation. For Step 5, sub-groups will be by country.

Outline of delineation procedures

STEP 1: Basin location and characteristics

Step 1.1 Describe the basin location and characteristics, including:

- Location
- Size
- Political and administrative boundaries
- Climate
- Geology
- Topography.

Step 1.2 Describe the land use and vegetation, including:

- Natural vegetation – types, distributions and total areas covered
- Cultivated areas – types, distributions and total areas covered.

Step 1.3 Describe the location of the main rivers, wetlands and floodplains, including:

- Mainstem river, and significant tributaries
- Source and length of each
- Significant features, e.g., Popa Falls
- The extent and nature of the delta.

Wherever possible, use maps and tables and ensure that coordinates are provided.

STEP 2: River zonation

For the main stem river and all significant tributaries:

Step 2.1 Delineate and describe homogenous surface water hydrological zones along the rivers on the basis of:

- Main hydrological basins
- Significant hydrological sub-basins
- Location of gauging weirs/measuring stations
- Seasonality of sub-basin hydrological regimes
- Mean Annual Runoff per sub-basin and contribution to total MAR
- Existing water-resource infrastructure
- Planned water-resource infrastructure.

Wherever possible, use maps and tables and ensure that coordinates are provided.

Step 2.2 Delineate and describe homogenous groundwater hydrological zones along the rivers on the basis of (if available):

- Aquifer flow systems (based on geology and climate) within a basin
- Groundwater-fed base flow
- Groundwater levels
- Springs
- Geological faulting
- Aquifer dependent ecosystems
- Groundwater use.

Wherever possible, use maps and tables and ensure that coordinates are provided.

Step 2.3 Delineate and describe homogenous geomorphological zones along the rivers on the basis of:

- Geology and dominant substrata
- Channel planform, valley form and the presence of floodplains

- Slope and sequence of hydraulic habitats.

Use the geomorphological zonation of South African river channels (Rowntree and Wadeson 1999) as a guide (Table 0.1). Wherever possible, use maps and tables and ensure that coordinates are provided. Depict longitudinal zonation for the river and significant tributaries using a line graph of altitude v. distance from source.

Step 2.4 Delineate and describe homogenous chemical and thermal zones along the rivers on the basis of (if available):

- Temperature
- Conductivity
- Dissolved salts
- Nutrients
- Pollution sources.

Wherever possible, use maps and tables and ensure that coordinates are provided.

Step 2.5 Delineate and describe homogenous biological zones along the river on the basis of (if available):

- Distribution of aquatic fauna and flora
- Distribution of semi-aquatic fauna and flora
- Distribution of animals dependent on the river/delta for any part of their life-cycle
- Overall ecological condition of the aquatic ecosystems (See suggested procedure in Chapter 0 and also link to field trips in Section 6.2). The procedure outlined in Chapter 9 will be completed to the extent possible in the Delineation Workshop, and then repeated with additional field data during the site visits.

Wherever possible, use maps and tables, and ensure that coordinates are provided.

Table 0.1 Geomorphological zonation of South African river channels (Rowntree and Wadeson 1999).

Longitudinal Zone	Characteristic Channel Features	
	Gradient	Description
Source zone	not specified	Low gradient, upland plateau or upland basin able to store water. Spongy or peat hydromorphic soils.
Mountain headwater stream (Mountain torrent)	>0.1	A very steep gradient stream dominated by vertical flows over bedrock with waterfalls and plunge pools. Normally first or second order. Zone types include bedrock fall and cascades.
Mountain stream	0.04 - 0.09	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Zone types include cascades, bedrock fall, and step-pool. Approximate equal distribution of 'vertical' and 'horizontal' flow components.
Mountain stream (transitional)	0.02 - 0.039	Moderately steep stream dominated by bedrock or boulder. Zone types include plane-bed, pool-rapid or pool-riffle. Confined or semi-confined valley floor with limited floodplain development.
Upper Foothills	0.005 – 0.019	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane-bed, pool-riffle, or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow floodplain of sand, gravel or cobble often present.
Lower Foothills	0.001 - 0.005	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Floodplains often present.
Lowland river	0.0001 – 0.001	Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct floodplain develops in unconfined reaches where there is an increased silt content in bed or banks.
Rejuvenated bedrock fall / cascades	>0.02	Moderate to steep gradient, confined channel (gorge) resulting from uplift in the middle to lower reaches of the long profile, limited lateral development of alluvial features, reach types include bedrock fall, cascades and pool-rapid.
Rejuvenated foothills	0.001 – 0.02	Steepened section within middle reaches of the river caused by uplift, often within or downstream of gorge; characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro-channel activated only during infrequent flood events. A limited flood- plain may be present between the active and macro-channel.
Upland flood plain	<0.005	An upland low gradient channel, often associated with uplifted plateau areas, as occur beneath the eastern escarpment.

Step 2.6 Combine the zonation resulting from Steps 2.1 to 2.5 into harmonized river zones:

The zones delineated according to separate considerations of hydrology, geohydrology, geomorphology, chemistry and biology should be compared and adjusted to arrive at ‘harmonized’ biophysical zones, which (to the extent possible) take account of the combination of these factors.

STEP 3: Socio-economic delineation

Step 3.1 Delineate and describe homogenous socio-economic areas within the basin on the basis of:

- Political boundaries
- Human population demographics
- Land use and commercial activities
- Livelihoods
- Use of water
- Household use of aquatic resources.

Step 3.2 Adjust the socio-economic areas so that they correspond with sub-basin hydrological boundaries:

In order to interpret hydrological changes in terms of socio-economic areas it is essential that the two sets of information are harmonised. Thus:

- Compare socio-economic areas with the hydrological zonation (Step 2.1).
- Adjust the socio-economic areas so that they correspond with sub-basin boundaries where possible.
- Where this cannot be done because sub-basin boundaries cross socio-economic areas or vice versa, divide or lump the socio-economic areas accordingly so that each individual sub-basin/social combination can be represented separately.

STEP 4: Identification of Integrated Units of Analysis

Integrated Units of Analysis (IUAs) are a combination of the harmonised socio-economic areas defined in Step 3.2 and the harmonized biological zones defined in Step 2.6. In some cases more than one socio-economic area may link with one biological zone (people living differently along one essentially similar stretch of river), whilst in other instances more than one biological zone may be nested within one socio-economic area (people living in much the same way along dissimilar stretches of river). In each case, the IUA is defined primarily by the socio-economic area: where two socio-economic areas share one biological zone, for instance, then the biological zone is split into ‘a’ and ‘b’ sections. On the other hand, if more than one biological zone occurs within a socio-economic area, then ultimately a choice will have to be made as to which zone is represented in the EFA (see Chapter 0).

Step 4.1 Harmonise the socio-economic areas with the biophysical zones, to identify and name the IUAs.

At completion, use maps and tables to indicate the IUAs for the basin. Present data ordered by 1) socio-economic zone and 2) by biophysical zone.

Note: The information in the IUA table should be entered into an Excel spreadsheet, as many of the procedures that follow require some form of re-ordering of the information.

STEP 5: Selection of study IUAs, zones and sites

Please refer to Chapter 0 for the guidelines on the selection of study IUAs, zones and sites. These guidelines refer to the selection for the TDA analysis only, but the process as a whole will identify all other IUAs and zones along the river system and can form the basis for wider studies outside the TDA.

Step 5.1 Discuss and agree on representative IUAs and zones as appropriate:

- Undertake the exercise in country groups
- Produce a final list of:

- Three IUAs/zones in Angola
- Two IUAs/zones in Namibia
- Three IUAs/zones in Botswana.

Step 5.2 Discuss and agree on a site to represent each chosen IUA/zone: Use maps and tables to identify and describe one study site per IUA/zone. Undertake the selection in country groups. The description of each site in the tables should include:

- Site name
- Site number and/or code
- Name of river
- X- and Y-co-ordinates of suggested sites
- Location
- Relevant Integrated Unit of Analysis
- Name of socio-economic area
- Biophysical zone
- Geomorphological zone
- Estimated ecological condition (Chapter 0).

Note:	The information in the site table should be entered into an Excel spreadsheet, as many of the procedures that follow require some form of re-ordering of the information.

Information required at the delineation workshop

The following information will be required in order to complete the above procedure at the Delineation Workshop:

Non-GIS information

Essentially, any and all information on the Okavango Basin is potentially useful for the basin delineation exercise.

1. 1:250 000 topographical maps of the basin
2. Any maps that delineate the basin using any of the above, or related, characteristics
3. Previous reports, particularly review articles, on aspects of the basin or sections thereof, on any of the following:
    a. Vegetation
    b. Wildlife
    c. Birds
    d. Fish
    e. Invertebrates
    f. Water quality

g. Social areas within the basin based on livelihoods, links to river, and similar
h. Economic areas within the basin based on livelihoods and similar

4. Field Guides for fauna or flora of the basin or sections thereof
5. Information on the hydrology of the Okavango Basin and the hydrological sub basins (from the National Team Specialist Hydrologists)
6. Relevant GIS layers
7. Google Images
8. Any data pertaining to the rivers.

Table 0.2 Suggested responsibilities for the collection of information for basin delineation

<table>
<tr><th>Discipline</th><th>Responsible team member(s)</th><th>Information/data/equipment</th></tr>
<tr><td rowspan="4">Hydrology</td><td rowspan="4">National Team Specialist Hydrologists</td><td>1:250 000 topographical maps of the basin</td></tr>
<tr><td>List and location of gauging weirs and measuring stations, with an indication of data availability</td></tr>
<tr><td>Water Resource Planning Reports</td></tr>
<tr><td>Summary rainfall data for the basin</td></tr>
<tr><td rowspan="2">Geohydrologist</td><td rowspan="2">National Team Specialist Geohydrologists</td><td>Any groundwater data for the basin, in particular that which can be used to determine depth of groundwater</td></tr>
<tr><td>Any GIS layers required but not listed under GIS below – please inform Dr Jackie King so that she can organise these from the GIS specialists</td></tr>
<tr><td rowspan="8">Geomorphology</td><td rowspan="6">National Team Specialist Geomorphologists</td><td>Geological maps of the basin</td></tr>
<tr><td>Historical Geological / Geomorphological Reports</td></tr>
<tr><td>Google images of the mainstem rivers</td></tr>
<tr><td>Any other satellite images of the basin</td></tr>
<tr><td>Any aerial photographs of the mainstem river</td></tr>
<tr><td>Map wheel</td></tr>
<tr><td rowspan="2">Process Team</td><td>Geomorphological zonation of South African river channels (Rowntree and Wadeson 1999)</td></tr>
<tr><td>Any GIS layers required but not listed under GIS below – please inform Dr Jackie King so that she can organise these from the GIS specialists</td></tr>
<tr><td rowspan="3">Water Quality</td><td rowspan="3">National Team Water Quality Specialists</td><td>Water quality data for points along the basin, summarised as appropriate (e.g., seasonally)</td></tr>
<tr><td>Any information of point source pollution</td></tr>
<tr><td>Any water quality reports on the basin</td></tr>
</table>

Discipline	Responsible team member(s)	Information/data/equipment
Biology	National Team Specialists - Biology	Field Guides for fauna or flora of the basin or sections thereof
		Any biological survey data pertaining to the rivers
		Previous reports on flora and/or fauna of the basin or sections thereof, including EIA specialist reports for any water resource developments
		Any information of distribution of flora or fauna that depend on the river systems in anyway, including aquatic and terrestrial
		Any GIS layers required but not listed under GIS below – please inform Dr Jackie King so that she can organise these from the GIS specialists
Sociology	Process Team – Resource economist	Any information on household use of aquatic resources, i.e., what resources are used, by whom and when
		Previous reports on socio-economic interactions with the river systems, including EIA specialist reports for any water resource developments
		Any information on general livelihood strategies in the basin
		Any GIS layers required but not listed under GIS below – please inform Dr Jackie King so that she can organise these from the GIS specialists
GIS	HOORC	Standard GIS layers for the basin, e.g. • Digital Terrain Model • Towns and roads • Land cover • Rivers, wetlands and swamps • Ambient temperature

GIS layers

See Table 0.2 and inform Dr Jackie King of any additional requirements.

Guidelines for the selection of integrated units of analysis, river zones and study sites

Selection of Integrated Units of Analysis and river zones

Several IUAs will be identified in Chapter 0 along the length of the river. Ideally, each would contain a discrete biological river zone, and be represented by at least one site where data are collected, understanding of biophysical and socio-economic relationships developed, and predictions made on change resulting from water-resource developments. For the TDA, a more limited exercise is planned.

Three sites have been allocated to Angola, two to Namibia and three to Botswana. If the number of IUAs recognised per country does not exceed these allocations, then one or possibly more sites can be allocated per IUA. If, however, there are more IUAs than the 3-2-3 allocation then some will not be represented in the TDA Flows Assessment.

Where IUAs need to be dropped, decisions will have to be made, per country, on which are the priority ones to be retained. This exercise can be structured through rating a number of characteristics for each IUA, providing a weighting for each characteristic in terms of its importance, and then computing the final ranking of each IUA (Table 0.1). Useful characteristics to consider per IUA – you may wish to add more - are as follows:

- Number of people living in and dependent on the IUA
- Rare species, habitats or river features
- IUA that is targetted for possible water-resource development
- Area of great scenic beauty/tourist attraction
- IUA in need of rehabilitation through improvement of flow regime
- IUA that is particularly sensitive to manipulations of the flow regime

The final scores per IUA should indicate the priority ones for the TDA. An electronic version of Table 0.1 will be provided at the Delineation Workshop. Once the priority IUAs have been identified, a similar exercise should be repeated for those containing more than one biological zones, in order to identify the priority zone to represent each IUA.

Table 0.1 IUA Rating Table

Delineated IUAs from Chapter 1	IUA name or number	Number of people	Rare species, habitats	Targetted for development	Scenic, tourism	Rehab flow regime	Flow sensitive	Other
Angola								
1								
2								
3								
4								
Namibia								
1								
2								
3								
4								
Botswana								
1								
2								
3								
4								

Site selection

Sites for data collection and scenario analysis need to be representative of wider areas. They should provide the greatest range possible of the environmental and social conditions characteristic of the part of the river/basin that they are representing. In this project, sites will be chosen within each of the prioritised IUAs/river zones.

Important considerations when choosing sites are as follows (only some will apply at each site):

- Proximity to a hydrological station so that reasonably accurate hydrological data can be simulated for the site under each scenario.
- Reasonably accessible: having to walk several kilometres carrying equipment from vehicles to a site would be onerous and time-consuming. Also, as the sites could double up as monitoring sites for compliance in the future, they need to be quickly accessible to monitoring teams.
- Area where potential water conflicts are high.
- Area where there is good understanding of the sediment dynamics.
- Area where there is good understanding of the soil chemistry.
- Area of high conservation importance. In the case of the Delta, which has this status overall, areas of particular concern for specific rare species could be chosen.
- Area that is suspected to be particularly vulnerable to changes in flow or sediment regimes, such as:
    - shallow rocky rapids
    - steep cobble beds
    - channels with intermittently flooded floodplains

    - channels vulnerable to silting up or eroding deep into their bed
- Area with good data already available in any or, preferably, all relevant ecological and social disciplines.
- Area in good ecological condition, so that the relationships between flow, ecosystem components and social use are not masked by a degraded environment.
- Area where there is a reasonable chance of doing hydraulic or hydrodynamic modelling of water depths, velocities, widths and inundations areas.
- Area of high social use or dependence on the goods and services provided by the river system, such as:
    - fish
    - nutritional herbs
    - wild vegetables
    - firewood
    - construction materials
    - livestock grazing and shade
    - reeds for roofs and mats
    - plants for crafts markets
    - drinking water
    - navigation
- Area of high tourism value.
- Areas with a strong link between the river system and people and animal health (e.g. any areas prone to malaria, bilharzias etc).

Discuss the list of criteria and amend as appropriate. Use it as the basis for discussions on where the sites should be.

Guidelines for scenario identification

The concept of scenarios

Scenarios are a means of exploring possible pathways into the future. They do not indicate that such a future will occur but, rather, aid discussion and negotiation leading to agreement on what would constitute acceptable ways forward. In the case of a river system, the scenarios can describe the ecological, social and economic outcomes for a range of potential management options, such as further development of the river's water resources, revision of operating rules for existing water-resource infrastructure or rehabilitation of a degraded system.

Integrated Water Resource Management (IWRM) is a relatively new concept that promotes sustainable use of water, encouraging people to move away from traditional project-driven ways of operating and toward a larger-scale basin or regional approach that takes into account the overall distribution and scarcity of water resources and the needs of other potential water users (King and Brown, in press). The concept may be expressed through the desired output of equal consideration in decision making of the three pillars of sustainability: social justice, ecological integrity and economic wealth. Water-resource scenarios should be designed so that these three streams of information are all represented with equal detail and weighting, in a way that stakeholders can understand and use in discussions and negotiation.

Stakeholders

Stakeholders of rivers may be defined as any group with an interest in the way the river is developed and managed. In the past, governments, as the major stakeholders of rivers, have often made decisions regarding the rivers with minimal input from other stakeholders, deeming themselves able to act in the best interests of society as a whole. Increasingly, following the IWRM concept, input from other stakeholders is becoming a part of river management, widening the base of consultation and considerations involved in decision-making.

In the context of EFAs, the purpose of scenarios is to describe the outcome of a range of management options for stakeholder consideration. These scenarios should cover the widest range possible of planned or possible options, whether they be for development or rehabilitation (Table 0.1). The scenarios should reflect the issues of concern to stakeholders, and so identification of the range of scenarios, through consultation with stakeholders, is a crucial step in EFAs. Major stakeholders could include:

- National and basin water-resource departments
- National and basin environment departments
- National and basin agricultural departments
- Planning departments
- Catchment Management Agencies, Basin Water Offices and similar
- Public and Livestock Health departments
- Hydro-power operators

- Community organisations
- National Parks and Conservation Agencies
- And more.

Table 0.1 **Hypothetical example of the matrix of information that could be developed for each part of a river basin.** The indicators would be more numerous than shown and would differ from river to river. The crosses represent the level of beneficial use under each scenario as gleaned from directed supporting research and are used here merely to illustrate possible trends in the status of each indicator. PD = Present Day. HEP = Hydropower (King and Brown in press).

Indicators	Scenarios of increasing levels of basin development					
	PD	A	B	C	D	E
Development benefits						
HEP generation	x	x	x	xx	xxx	xxx
Crop production	x	x	xx	xxx	xxxx	xxxx
Water security	x	xx	xxx	xxx	xxxx	xxxx
National economy	x	x	xxx	xxxx	xxxx	xxxx
Aquaculture	x	xx	xxx	xxx	xxx	xxx
Development costs						
Wild fisheries	xxxx	xxx	xxx	xx	xx	x
Water quality	xxx	xxx	xx	xx	x	x
Floodplain functions	xxxx	xxxx	xxx	xx	x	x
Cultural, religious values	xxxx	xxx	xxx	xxx	xx	xx
Natural-resource buffer against need for compensation for subsistence users	xxxx	xxx	xx	xx	x	x

Identification of scenarios

To the extent that it is possible, the major stakeholders should be consulted, perhaps by means of a Stakeholder Workshop, on the major water-related issues and trends within the basin. Water-related issues and concerns that might be identified and described could include:

- Water supply
- Water shortages
- Water quality
- Climate change
- Catchment degradation
- River degradation
- Water-borne pollutants
- Water over-allocation and conflicts between stakeholders
- Uncoordinated basin planning
- Rivers drying up
- Lack of conservation awareness
- Lack of enforcement of relevant legislation.

Possible water-resource trends within the basin could then be identified with the stakeholders. These possible trends could include:

- Further development of hydro-electric power facilities
- Further expansion of irrigated farming areas
- Further modification of river flow regimes
- Increases in population numbers, leading to pressure on urban supplies and increasingly severe shortages
- Increasing reliance on groundwater and rainwater harvesting
- Further deterioration in the water quality of donating rivers
- Loss of biodiversity in the river ecosystems
- Buy-back of water for the environment
- Climate change
- Afforestation or deforestation.

The identified issues and trends form the basis for selection of the scenarios. The number of scenarios chosen will depend partly on time and cost limitations, but another important factor is acknowledging any data limitations. Where data are few, and understanding of the social and ecological structures linked to the river are poor, then fewer rather than more scenarios should be chosen. These should be as dissimilar as possible, so that broad basin-level trends can be described. In general, four to six scenarios is a good starting point, with more added later as discussions produce more aspects to be explored and as understanding grows.

Other considerations that should be taken into account include:

- the available hydrological modeling capacity, which will dictate the variables that can be changed per scenario
- the possible spatial resolution (i.e. number of sites), which will be partially driven by the hydrological delineation of the basin (see Step 2.1)
- the base year and time of interpretation for the scenarios – often taken as 20-30 years into the future from the base year.

A long list of possible scenarios could be tabulated, as per the examples in Table 0.2, for discussion and final selection.

Table 0.2 **Examples of scenarios used in EFAs elsewhere.** BHN = Basic Human Needs. D/I = Domestic and Industrial. Residual = any water left after priority demands met.

Name	#	**Priority**				
		1	**2**	**3**	**4**	**Residual**
Maximise Agriculture	1	BHN	D/I	Agric	HEP	River
Maximise HEP	2	BHN	D/I	HEP	Agric	River
Status Quo with Climate Change	3	BHN	D/I	Agric	HEP	River
Maximise river condition	4	BHN	River 1	D/I	Agric	HEP
Moderate river condition plus Agriculture	5	BHN	River 2	D/I	Agric	HEP
Moderate river condition plus HEP	6	BHN	River 2	D/I	HEP	Agric

The final decision on scenarios will likely be made by governments/basin managers in consultation with the EFA team.

Guidelines for the identification of indicators, links between indicators and flow categories

Introduction

This Section provides an overview of the procedures for the identification of:

- flow-related indicators;
- links between indicators, and;
- flow categories,

for use in the Okavango Basin TDA EF study.

The primary objectives of this task are to identify the aspects of the river ecosystem for which flow-related change will be predicted, and the indicators that are required in order to make those predictions.

The final list of indicators, linked indicators and flow categories will be agreed on at the Delineation Workshop, which will allow the specialists a chance to debate and discuss their ideas with other members of the teams.

The identification of flow-related biophysical indicators

Flow-related indicators are comprised of riverine items that respond to a change in river flow by changing in their:

- abundance;
- concentration; or
- extent (area).

<u>The lists should not include processes.</u> While it is accepted that changes in flow result in changes in processes, it is important that the implications of these process changes are described rather than the processes themselves. For example, a reduction in wet-season low-flows may result in a reduction in the **process** of downstream movement of invertebrates (downstream drift), which in turn may lead to a reduction in the **process** of recolonisation of downstream reaches. The implication of this would be a reduction, in the downstream reaches, in the abundance of macroinvertebrate species that rely on drift as a means of recolonisation. Thus, the indicator of interest is not downstream drift *per se* but a species that is a representative of all or many of the species that rely on drift as a means of recolonisation, and predictions will reflect its expected changes in abundance under various scenarios.

Selecting discipline indicators

Predictions of change are done in a standard discipline sequence, always as a response to flow change:

- hydraulic changes
- geomorphological changes
- chemical and thermal changes
- vegetation changes

- invertebrate changes
- fish changes
- other wildlife changes.

Change at each step in the sequence will be expressed as change in a number of indicators. The number of indicators per discipline will be limited to enable more efficient database design and operation. Each discipline will be represented by a maximum of ten (10) indicators.

NOTE: For each of the selected indicators, the likely consequences will be described for changes in up to ten (10) flow categories for each site. Thus, if the maximum number of indicators (10) is elected, 100 response curves (Chapter 0) will have to be provided per site!

There are some important considerations when selecting indicators (Table 0.1).

Table 0.1 Important considerations in the selection of indicators

No.	Indicator requirement	Comment
1	The indicator should be linked to flow/water levels, albeit indirectly.	Indicators that are not linked to flow/water level will not be able to produce predictions of flow-related change.
2	The indicator should be an item for which change can be described in terms of a change in abundance, area or concentration.	See explanation in text.
3	It should be possible to describe the links between the indicator and flow.	Curves of the expected response to flow-related change (see Chapter 0) will need to be constructed for each and every indicator.
4	If several items are expected to respond in the same way to flow (for all flow categories), then they can be combined into a single indicator.	For instance, fish species with the same or similar relationships to flow can be combined in Flow Guilds. Similarly, some water quality determinands, such as conductivity and Total Dissolved Solids may respond in a similar way to flow and can be grouped.
	Indicators may vary from site to site. However, if the outcome for any indicator is dependent on what happens to it at another site, then that indicator should be included in the indicator lists for all relevant sites.	This is likely to be especially relevant for sediment, water quality and fish.
5	Linked indicators for other biophysical disciplines should be included, as required	See Selecting linked indicators - Biophysical. Disciplines may require information from other disciplines earlier in the sequence. The donating discipline should ensure it has provided an indicator as required.
6	Linked indicators should include any resources identified as important from a social perspective.	See Section 0.

Selecting linked indicators - Biophysical

It may not be possible to predict the consequences for some indicators without input on how an indicator earlier in the sequence has performed. For instance, biological specialists will require information on the expected changes of selected physical or chemical indicators before they can predict biological change. As an example, the consequences of a reduction in dry-season low-flows for a riffle-dwelling fish species (Sp A), may be dependent on the EFFECT of the flow change on the following (Figure 0.1):

- depth and wetted area (from the hydraulic specialist);
- water velocity (from the hydraulic specialist);
- temperature (from the WQ specialist);

- salinity concentrations (from the WQ specialist);
- habitat quality (e.g., riffle embeddedness; from the geomorphologist), and;
- inundation of marginal vegetation (from the botanist);
- extent of instream vegetation (from the botanist).

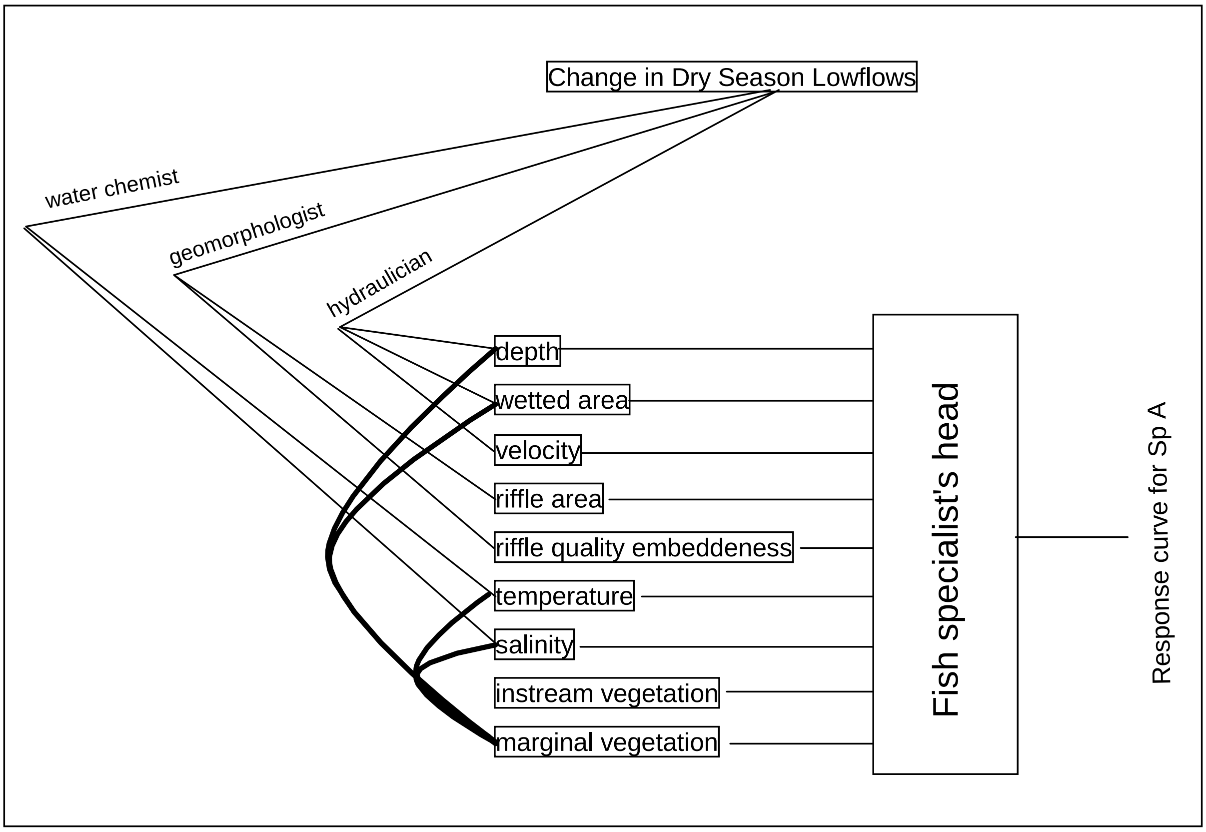

Figure 0.1 Schematic giving hypothetical example of information needs for a fish specialist to provide a response curve of a change in dry-season low-flows for fish species A.

If the indicator lists compiled by the physical specialists do not include the necessary linked indicators then the information required by the fish specialist will not be available. It is therefore vitally important to identify the information required from other specialists BEFORE they complete their indicator lists.

In order to do this, each discipline group completes its indicator list per site and then uses these to determine the information required from other specialists so that the linked indicators required can be included in their lists.

Note from Figure 0.1, that some specialists may also need information from other specialists before they can provide an answer to someone further along the sequence. Thus, they too must identify the information they will require from other specialists BEFORE the other specialists complete their generic lists. It may be that the example in Figure 0.1 is incomplete and the fish specialist may also need to consider food availability and thus, perhaps, seek some input on invertebrates..

Importantly, all specialists are limited to ten indicators, so only the most important links can be chosen. Each discipline group will need to ensure the following:

1. The information can be used. For instance, if there are no data or information linking the distribution of fish species A to salinity, then asking for salinity information is not useful.
2. The input 'wish list' represents only the critical links. Each additional required indicator increases the work and complexity almost exponentially for all linked disciplines.
3. The route of data flow is established. This will be done by the whole team in the Delineation Workshop.

The identification of flow-related social indicators

The socio-economics component of the EF study will be tasked with estimating the changes in resource economics, livelihoods and societal well-being for each of the chosen scenarios as a result of changes in ecosystem condition. External to the EF study, the economics of the chosen scenarios will also be addressed.

With respect to the social impacts of flow changes, social indicators will need to be chosen that reflect the links between people and the river, sych as:

- Household incomes, from good harvested from the river
- Food security, from goods harvested from the river
- Social wellbeing, with regard to religious and cultural links to the river, including rare or iconic species, baptism sites, international or national conservation areas and more
- Health, including both people and livestock health related to the river
- Safety and water supply, including groundwater and surface water, flood attenuation and other services provided by the river.

The socio-economic study will not predict how flow will change any of these things, but rather will take information from relevant biophysical indicators. It is thus important to ensure that the required information can be provided by the selected biophysical indicators.

The identification of flow categories

One of the main assumptions underlying the EF process to be used in the TDA is that it is possible to identify ecologically relevant elements of the flow regime and isolate them from the historical hydrological record. Thus, one of the first steps in the process, for any river, is to consult with local river ecologists to identify these ecologically most important flow categories. Up to ten relevant flow categories can be selected for each river zone/site. These flow categories will differ depending on the type of river system under consideration. Table 0.2 provides some examples of flow categories used in past studies for different types of rivers. Thus, in the case of the Okavango River, the categories selected for the upper parts of the basin are likely to differ from those selected for the delta. For instance, the upper reaches of the rivers may have flow categories similar to those used in the past for temperate perennial rivers, without a major floodplain, whereas those for the delta may be similar to those used in the past for tropical rivers with a major floodplain (Table 0.2; Figure 0.2). The categories that can be selected are not limited to those listed in Table 0.2, but they are limited to categories that can be defined and summarized from the available hydrological data. To this end, the list of flow categories suggested by the ecologists will be finalised in consultation with the specialist hydrologists.

In order to assist with the identification of flow categories, for each of the biophysical indicators at each of the river sites:

- list the part(s) of the flow regime that the indicators are likely to be most responsive to;
- describe how each indicator is likely to react to an increase or decrease in that flow category.

Input from the social team should include which parts of the flow regime may have special significance for people.

These lists will then be used in consultation with the hydrologists to derive the flow categories that will eventually be used for each of the river sites.

Table 0.2 Examples of flow categories used in past studies for different types of rivers

Type of river	Flow categories	Type of change	Reference
Temperate perennial rivers, without a major floodplain	Wet season lowflows	*ranges* of low flows within each chosen season	e.g., Metsi (2000); PBWO/IUCN (2008)
	Dry season lowflows		
	four size classes of intra-annual floods	*average number per annum* of each class of flood (high-flow) event.	
	1:2 year floods	Present or absent	
	1:5 year floods		
	1:10 year floods		
	1:20 year floods		
Tropical rivers with a major floodplain (Figure 0.2)	Minimum dry season discharge	Millions of cubic metres	e.g., MRC (2005); Bielfuss and Brown (2006)
	Onset of dry season	Day of year	
	Average flood season discharge	Millions of cubic metres	
	Onset of flood season	Day of year	
	Average discharge in Transition 1	Millions of cubic metres	
	Onset of Transition 1	Day of year	
	Average discharge in Transition 2	Millions of cubic metres	
	Onset of Transition 2	Day of year	

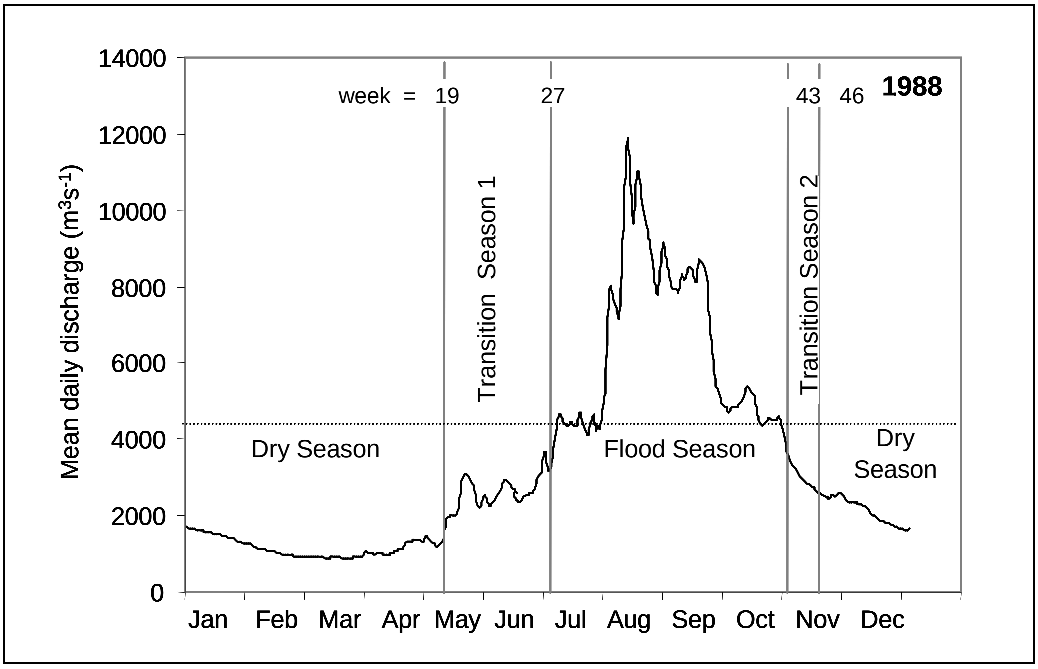

Figure 0.2 **The annual hydrograph for the Lower Mekong River at Luang Prabang in 1988, showing the four ecologically relevant flow seasons recognized for the Lower Mekong River.** Data source: Mekong River Commission; analysis Peter Adamson.

Guidelines for data collection for environmental flow studies

Possible sources of data

The science of Environmental Flow Assessments is young and experience has shown that most river specialists, whilst being highly experienced in their fields, may not be able to immediately contribute appropriate data. This is because all data for EFAs need to be linked, either directly or indirectly to flow or water levels; if they are not then the results of flow changes cannot be predicted and so the scenarios cannot be constructed and analysed. It may take years or even decades for these kind of data to accumulate for a river basin, and meanwhile lower-confidence predictions of flow-related change can be based on a mixture of relevant data, international understanding of river functioning and river use, national understanding of the specific river and its users, and local wisdom.

Within the Okavango Basin TDA study, information will be captured through four main activities: 1) a Delineation/Planning Workshop in September 2008, 2) a Field Trip in October 2008, 3) independent work, including international literature reviews, by each National Team between September 2008 and January 2009, leading to the compilation of specialist reports, and 4) the Knowledge Capture workshop in February 2009.

Activity 1 information is dealt with in Chapter 0 and activity 4 information in Chapter 0. This chapter addresses data collection during the field visit (activity 2); at the time of that visit on-site discussions will determine what can be accomplished by the National Teams in subsequent field visits (activity 3 information). Each National Team will meet with the Process Management Team at the selected sites in their country.

The October 2008 field trip

Purpose of the field trip

As explained above, the TDA EFA will rely heavily on expert opinion and general understanding of the river and its users for predictions of change. An effective approach to developing this understanding is to bring the various discipline specialists together at the river, where each explains the river/users from his or her perspective. In this way, the team as a whole sees and understands perspectives not realised before. A useful sequence of speakers (if available) at any one site is:

1. a basin water manager, who provides background on the location of the site visited and the main landscape and water-resource influences on it
2. an ecologist, who outlines the ecoregion, vegetation and faunal characteristics of the site
3. an hydrologist, who explains the hydrological regime
4. an hydraulic modeler, who explains the behaviour of water as it flows through the site, including, for instance, bank overtopping, flood levels, wetting of secondary channels, inundations of floodplains and similar
5. a fluvial geomorphologist, who identifies the river zone and its main characteristics, as well as the range of morphological units (physical habitat) present at the site
6. an aquatic chemist, who outlines the water chemistry of the river and any special natural or anthropogenic features, including water quality linked to different kinds of flow or different seasons.
7. a vegetation specialist, who outlines the main features of the aquatic, marginal and riparian vegetation and the degree of naturalness in terms of alien invasive species

and condition of the vegetation communities; any obvious links between flow/water levels and vegetation communities should also be pointed out.

8. a fish biologist, who outlines the nature, abundance and importance of the local fish species, their conservation status and any known migratory species, or life-cycle links to flow.
9. an aquatic invertebrate biologist, who outlines the invertebrate communities present, potential or actual pest species (human or livestock health) and any known life-cycle links to flow.
10. an ecologist to outline any other relevant aspects of the site/zone, including reptiles, amphibians, mammals, water birds, conservation status or similar.
11. a sociologist, who outlines the human use of the river in that zone, its cultural and religious importance in their lives, and any riverine plant or animal species of economic or personal importance.

These kind of introductory talks may require some preparatory work by the designated persons in order to provide useful and up-to-date information.

After the general introduction, the national team will split into smaller groups for some preliminary familiarization activities as follows:

- <u>Physical habitat</u>
    - i. Draw sketch maps of the channel layout, width, geomorphological features, flow types, and any other distinguishing features (Table 0.1).
    - ii. *Equipment needed*: clipboards, graph paper, tracing paper, coloured pens and pencils, erasers, 100 m or 50 m tapes.
- <u>Chemical habitat</u>
    - i. Record any obvious manifestations of water quality (e.g. filamentous algae, turbid water, green water, scums.
    - ii. Measure water quality with any available instruments: e.g. conductivity, dissolved oxygen, turbidity, pH.
    - iii. *Equipment needed:* field water-quality meters.
- <u>Biological communities</u>
    - i. <u>Vegetation</u>: take samples of all important riparian, marginal and aquatic for later taxonomic identification; draw sketch maps of the location of different vegetal communities, particularly with respect to flow/flood levels, and bank/instream physical habitat
    - ii. <u>Fish</u>: assess the site in terms of available fish habitat and note potential flow-sensitive areas that could be important for fish migration or spawning; show coloured photos of likely fish species to locals for identification of those likely to be present as well as those of social importance; catch and identify fish if time and conditions allow.
    - iii. <u>Invertebrates</u>: sample all major aquatic habitat and attempt at least family level identification; apply SASS scores and complete preliminary assessment of river health
    - iv. <u>Other</u>: record any signs, or local knowledge, of any other animal species with links to the river (water birds, reptiles, amphibians, mammals).
    - v. *Equipment needed:* plant press, nets, sorting trays, identification guides, preservatives, jars and labels for any collected animal specimens, pens and data books, other discipline-specific equipment as required.
- <u>Ecological condition</u>
    - i. The exercise done in Step 5.2 in the Delineation Workshop will be repeated on site with field data included.
    - ii. *Equipment needed:* Delineation Report, basin and local maps.

- Social use of the river
    i. Dr Barnes to provide guidelines.

Table 0.1 Physical characteristics for inclusion in site sketch maps

Substratum	**Flow type**	**Cover**
Silt	Still	Marginal vegetation
Sand	Barely perceptible flow	In-channel vegetation
Gravel	Slow smooth flow	Organic litter
Cobble	Rippled medium flow	Algae
Boulder	Fast, turbulent flow	Roots
Bedrock	Cascade	

Further data collection

A programme of further data collection will be agreed with the appropriate National Team on site, taking into account time, funding and other limitations.

Guidelines for the construction of response curves

Response curves are a means of capturing information and understanding, from in-depth scientific data through international and national knowledge and local wisdom. They are created by EF specialists with a working knowledge of the river ecosystem and its users; are graphic and explicit with supporting explanations; and are amenable to adjustment as knowledge increases.

In the Knowledge Capture Workshop, response curves will be constructed for two aspects of the TDA:

1. conceptual relationships between each biophysical indicator and each of the flow categories (Sections 0and 0);
2. conceptual relationships between each socio-economic indicator and their linked biophysical indicator(s) (Section 0).

The concept of biophysical Response Curves

Two kinds of response curves are constructed to describe the relationship between each biophysical indicator and each flow category (e.g., median of wet season discharge, see Section 0). These are:

- biophysical indicator abundance vs. change in flow category;
- ecosystem integrity vs. change in flow category.

The axes of a response curve are (Figure 0.1):
x-axis = Range of possible change in flow category, e.g., median wet season discharge.
y-axis = Response of indicator in terms of abundance or integrity.

Biophysical indicator abundance vs. change in flow category

The starting point of a response curve is Present Day (PD) flow conditions, which equate to zero value for the indicator. Thus, in Figure 0.1, the circle represents PD median wet season discharge (e.g. 35 $m^3 s^{-1}$), and the change in the indicator under PD conditions (y-axis), which would be zero (0). A response curve should ALWAYS be zero at Present Day conditions.

The Natural (NAT) flow condition, e.g., NAT median wet season discharge (e.g., 60 $m^3 s^{-1}$), is usually also provided (Figure 0.1) as this is a useful reference when assessing change.

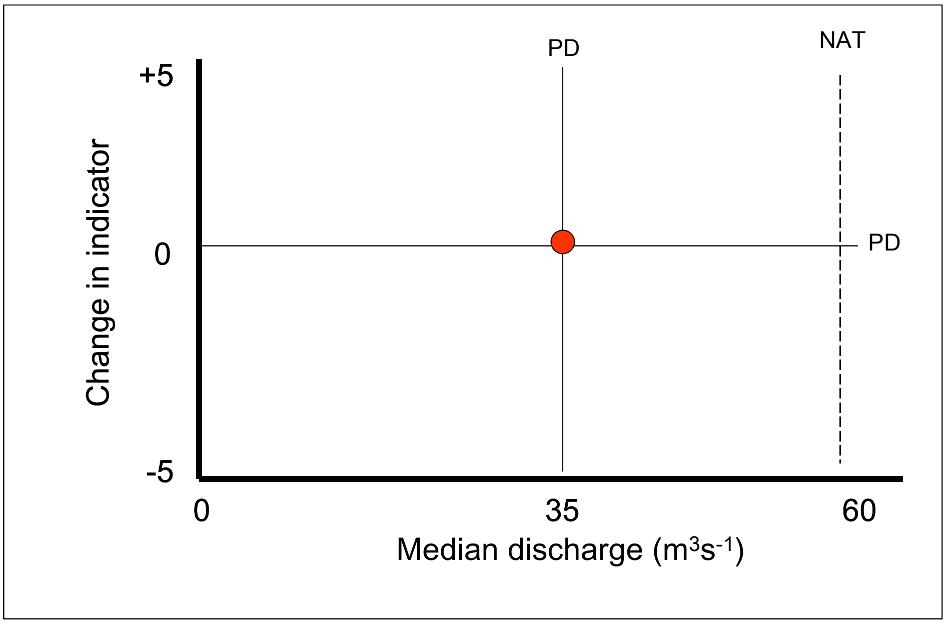

Figure 0.1 Start of an hypothetical response curve for the relationship between an indicator abundance and median discharge in the wet season.

Note: It is absolutely essential that change in any one flow category be considered in ISOLATION, i.e., only that category will change and the rest of the flow regime will stay at Present Day levels. This is important because sometimes two or more categories of flow can fulfill a similar function. For instance, both small and big floods may move sediment, but big floods may move more. Thus a loss of big floods will not mean that no sediment is moved, only that much less is moved. Similarly, a loss of small floods may not greatly affect sediment movement.

Completed response curves will have many shapes, depending on the indicators and the sensitivity of their response to the flow category. Several examples are provided in Figure 0.2 to illustrate this.

A: Response for an indicator that has a direct and negative response to a decline in mean wet season discharge (e.g., total suspended solid concentrations).

B: Response of an indicator that is not particularly sensitive to reduction in mean wet season discharge relative to PD, but would benefit from an increase, i.e., restoration, of mean wet season discharge back towards NAT (e.g., rare sensitive riffle-dwelling invertebrate species).

C: Response of an indicator that is not necessarily highly dependent on wet season discharges but requires some flow in the wet season (e.g., pool dwelling fish species).

D: Response of an indicator that would benefit from a decrease in wet season discharge (e.g., pest species, such as mosquito).

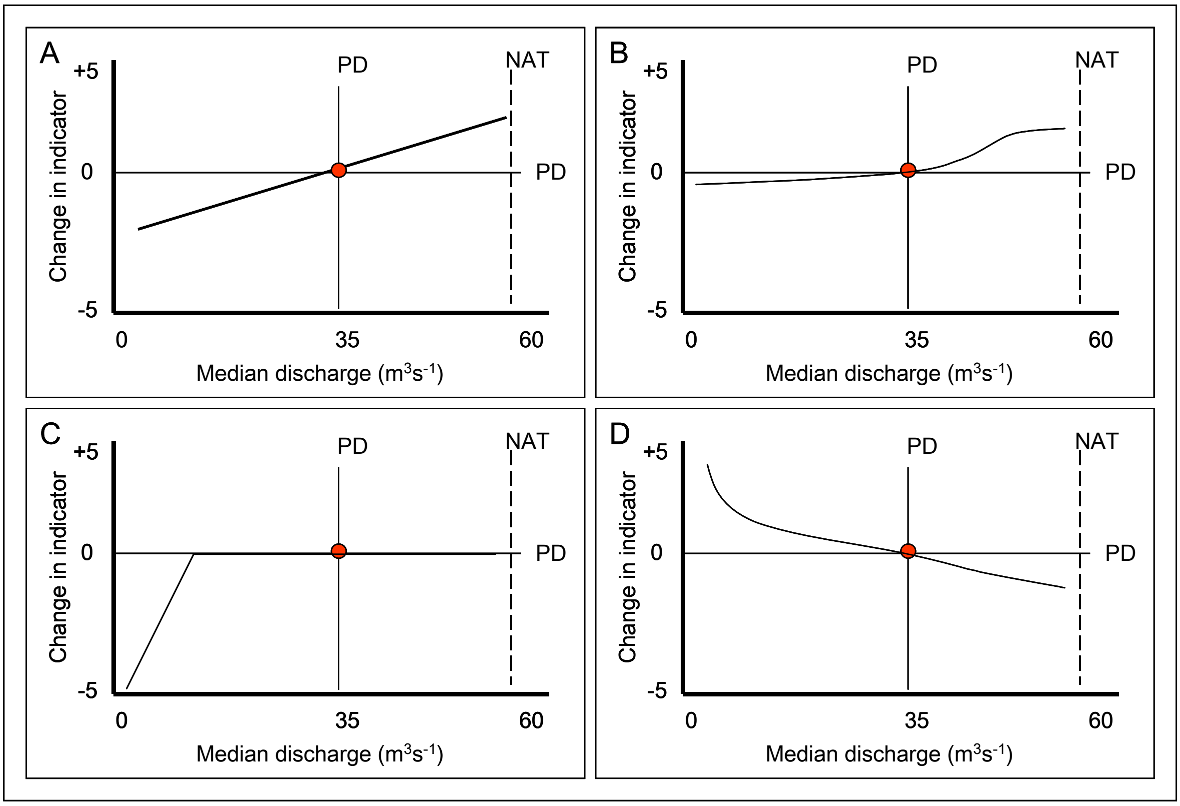

Figure 0.2 Examples of different shaped response curves – change in abundance

Ecosystem integrity vs. change in flow category

The ecosystem integrity versus change in flow category response curves are an indication of whether or not the changes in abundance described above represent a move towards or away from natural. For instance, an increase in a threatened fish species may represent a move towards natural but an increase in sediment on the river channel may be a move away from natural. Thus, the ecosystem integrity response curves for each flow category use the same data as generated but with the sign representing a move towards or away from natural. Using the examples for Figure 0.2, and adjusting them for integrity Figure 0.3 would yield the following:

A: A reduction in total suspended solid concentrations may be a move towards natural, i.e., the integrity curve is the same shape as the abundance curve.

B: An increase in a rare sensitive riffle-dwelling invertebrate species may be a move towards natural, i.e., the integrity curve is the same shape as the abundance curve.

C: A decrease in an indigenous pool dwelling fish species may be a move towards natural, i.e., the integrity curve is the same shape as the abundance curve.

D: An increase is a pest species, such as mosquito, may be a move away from natural, i.e., the integrity curve is a mirror image of the abundance curve.

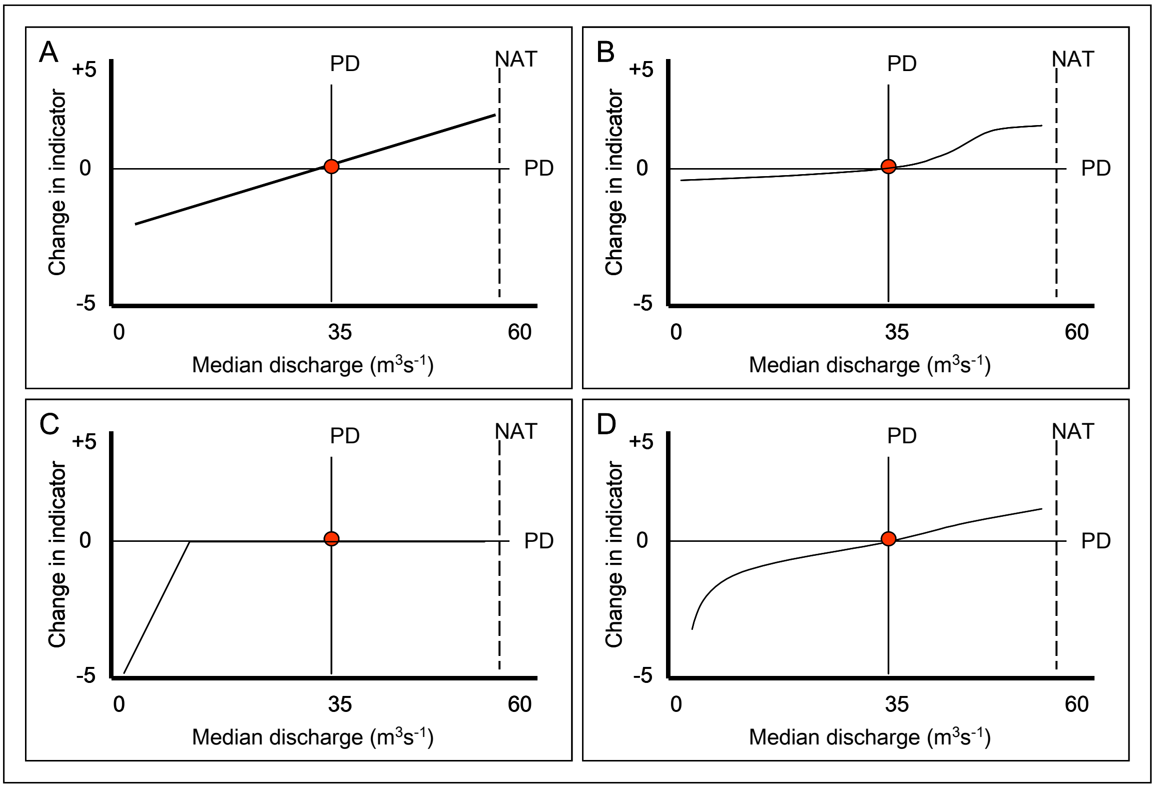

Figure 0.3 Examples of different shaped response curves – change in integrity

Outline of the procedures for the construction of response curves for the biophysical indicators

Response curves for the biophysical indicators can only be prepared once the flow categories have been chosen (see Section 0), and the range of possible change in each of the flow categories has been provided by the hydrologists. This range will be identified from the selected list of scenarios. Once the flow categories and range of possible hydrological change are known, each specialist group will use its own data, and its own methods to derive the response curves for the indicators on their list.

At the Knowledge Capture Workshop, the data defining the response curves will be entered directly into the TDA Flow Decision Support System (DSS). The workshop will be divided into a number of plenary sessions for the purpose of sharing information, and a number of group work sessions where discipline groups will work on their indicator response curves for each site. The steps outlined below are site-specific, i.e., the full sequence of steps needs to be done for every river site.

STEP 1: Familiarise yourself with the data entry forms

The Data Entry file for each discipline will be presented to the relevant groups at the Knowledge Capture Workshop.

Step 1.1 Open the Data Entry file relevant to your discipline

When opening a Data Entry file at the workshop, macros should be **disabled** and links should **not be updated**[1].

Each Data Entry file contains a number of worksheets. The worksheets are arranged into two groups on the basis of their functions. These are:

Indicator list (and hydrology):	The list of chosen indicators per discipline, for which response curves will be created This worksheet also includes hydrological data that automatically comes from the TDA Flow DSS. This flow change information is linked to each of the other worksheets in the data entry file, providing the information needed for the specialist to develop flow-response curves. Hydrological data should never be adjusted on Indicator List.
Data Entry and Review:	Data entry worksheets for each flow category, i.e., 10 worksheets, which contain the data describing the conceptual relationships between each indicator and flow. These are the sheets that will be populated at the Knowledge Capture Workshop.

Step 1.2 Update the Indicator lists on the Indicator (and hydrology) worksheet

- Access the Indicator worksheet by clicking on the Tab: Indicator Lists.
- Enter the names of the selected indicators into the cells with light blue background (Cells C5 to C14). Once entered, the indicator names should not be changed unless the whole database is undergoing a revision, as they link to the Data Storage worksheets.

NOTE: All indicators used in the TDA Flow DSS should be listed in the same order and numbering as on the Indicator List. If a particular indicator is not relevant at one site, its place should be left blank in order to retain the same numbering.

Step 1.3 View and cross-check the data entry worksheets

- Access the data entry worksheet for each flow category by clicking on the Tab for the category.

There is a great deal of information contained in the data entry worksheets for each flow category as illustrated for Wet-Season Low-flows (WSLF) in Figure 0.4. The information is arranged as follows (Figure 0.4).

- Site and discipline names (automatic link)
- Indicator names from Indicator List
- Summary hydrology for WSLF from Indicator List
- Data entry area

[1] This is because you will not be provided with the full TDA Flow DSS, and so the linked files are not available.

- Graphic displays of the resultant relationship between indicator abundance and change in WSLF
- Graphic displays of the resultant relationship between indicator integrity (health) and change in WSLF
- Space for explanations, if required/relevant
- Space for references, if relevant
- A data analysis section where the information provided is extrapolated to additional flow change levels (not shown on Figure 0.4, but can be accessed by scrolling down).

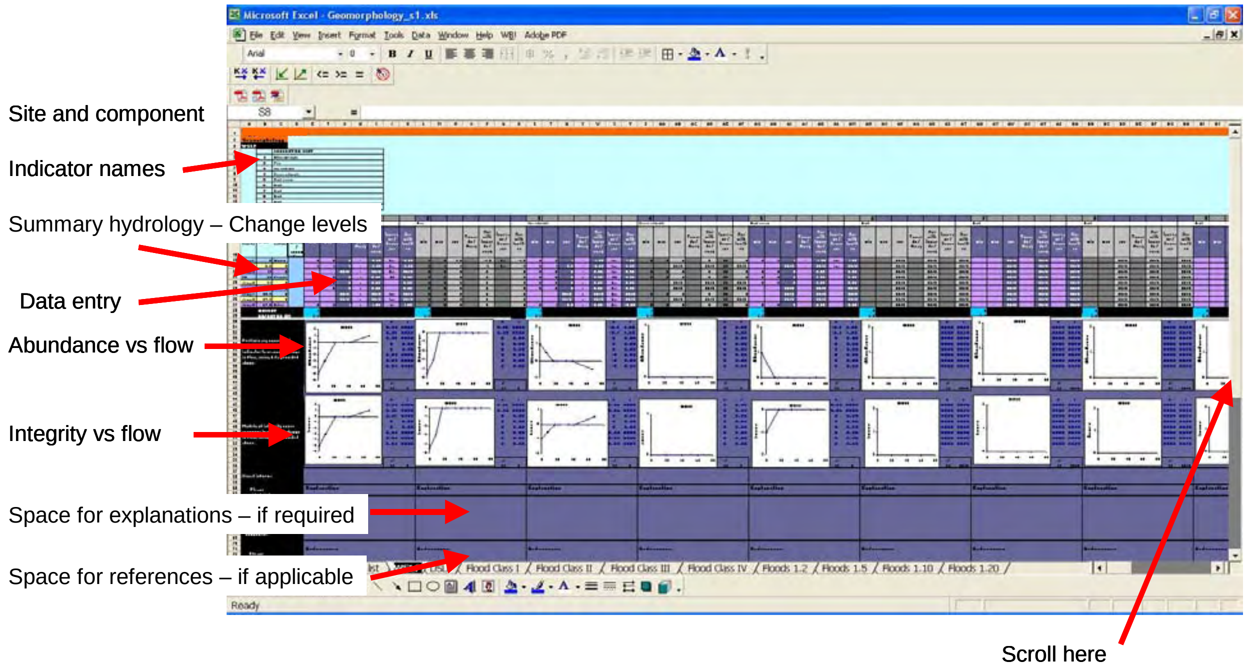

Figure 0.4 The WSLF Data Entry Worksheet

- Check that the indicators are correctly displayed and thus that the links to the indicators are working correctly.
- Check that the hydrological data are correctly displayed and thus that the links are working correctly.
- Check that the site name and the discipline (e.g. Geomorphology) appear correctly as a heading on each worksheet in the database.
- Check that the graphic displays update automatically when you enter data into the data-entry area.

STEP 2: Populate the data entry worksheets with response curves

Step 2.1 Obtain the response curves for linked indicators

To construct a response curve for an indicator it is necessary first to obtain the response curves for its linked indicators, if any. Any linked indicators will have been identified in the data-flow mapping exercise in the Delineation Workshop. These responses from all linked indicators will need to be integrated to arrive at the indicator-specific response curve.

For this reason, it makes sense to start with indicators that have no or few linked indicators, as this will give the other specialists a chance to populate the linked indicator response curves. The workshop agenda will be arranged to facilitate this, to the extent possible.

Step 2.2 Determine whether the indicator is expected to increase or decrease

Remember:	Change in any one flow category must be considered in ISOLATION, i.e., only that category will change and the rest of the flow regime will stay at Present Day levels.

- Consider whether the indicator will increase or decrease in abundance for the highest flow change in isolation, i.e., with the rest of the flow regime staying at Present Day. Enter either "Inc" or "Dec" in the "Increase/Decrease" column in order to indicate either an increase or decrease in abundance of the particular indicator (see Table 0.1).
- The row for Present Day does not require an "Inc" or "Dec" statement.
- Fill in the rows between the highest change and Present Day with the relevant "Inc" or "Dec" statement.
- Fill in the rows between the lowest change and Present Day with the relevant "Inc" or "Dec" statement.

Step 2.3 Determine whether the increase or decrease is a move towards or away from natural

- Enter either a + sign or a – sign in the "Towards/Away" column in order to indicate a move towards natural (+) or away from natural (-) (see Table 0.1). The row for Present Day does not require a + or – sign.

Step 2.3 Determine the likely severity of the predicted increase or decrease

The severity of the response to the flow change level of the indicator being dealt with is entered into the Min and Max columns. Severity is rated on a scale of 0-5 (see the severity ratings in Table 0.1).

It is not necessary to fill in every flow change. Predictions **must** be made for at least five flow changes, however, unless there are fewer than five changes for the flow category, in which case every flow change must be filled with a response. These points provide definition of the shape of the response curve. The predictions **must** include the highest and lowest flow change, and Present Day. The Severity Rating for the Present Day **must** equal 0.

A standard format is used for describing the consequences of flow change (after King *et al*. 2003), as described in Table 0.1.

Uncertainty is expressed through the range of Severity Ratings given for an item. As shown in Table 0.1, each rating already encompasses a range of change. For example, a rating of 1 implies a 0-20% loss or a 1-25% gain in the indicator.

If uncertainty is greater than that already contained in the Severity-Rating range, this may be expressed as a range of Severity Ratings in the “Min” and “Max” columns, e.g., 2-4 (2 is typed in “Min” and “4 in “Max”. This increases the spread of predicted percentage change, e.g., if rating 2 = 5-24%, and rating 4 = 51-75%, then ratings 2-4 would translate to an expected change of anywhere between 5 and 75%.

Table 0.1 Rules for data entry

Severity Ratings

For each prediction, there should be a description of the ***severity*** of the predicted change (if any) using a Severity Rating between 1 and 5 for every Indicator.

Severity Rating	Severity of change	Equivalent loss (abundance/concentration)	Equivalent gain (abundance/concentration)
0	None	no change	No change
1	Negligible	80-100% retained	1-25% gain
2	Low	60-79% retained	26-67% gain
3	Moderate	40-59% retained	68-250% gain
4	Severe	20-39% retained	251-500% gain
5	Very severe	0-19% retained; includes local extinction	501% gain to ∞: up to pest proportions

Integrity Ratings

For each prediction, there should be an indication of whether the change represents a move towards or away from the natural condition of the river. A move towards natural is illustrated by a positive (+) sign and a move away from natural by a negative (-) sign.
The addition of the sign changes the Severity Rating to an Integrity Rating.

Increase or decrease

For each prediction, there should be a description of the direction of predicted change (if any). The direction of change represents an increase or decrease in the ***abundance, concentration or extent*** of an Indicator.

NOTE: The formulae contained in the columns headed “Ave”, “Ave with towards/ away” and “Ave with Inc/Dec” help to create the graphs presented below this section. These columns **should not be overwritten or deleted**.

STEP 3: Check the response curves

Once data are entered, the relationships resulting from these predictions can be reviewed in graphical format. Two types of graphs are provided (Figure 0.5):

- One shows the relationship between changes in Wet-Season Low-flows and percentage changes in **abundance** (presented in rows 30-42).

- The second shows the relationship between changes in Wet-Season Low-flows and indicator **integrity** (health) (presented in rows 44-56)
- If the relationships require adjustment, this is done in the data entry section (see Step 2, above).

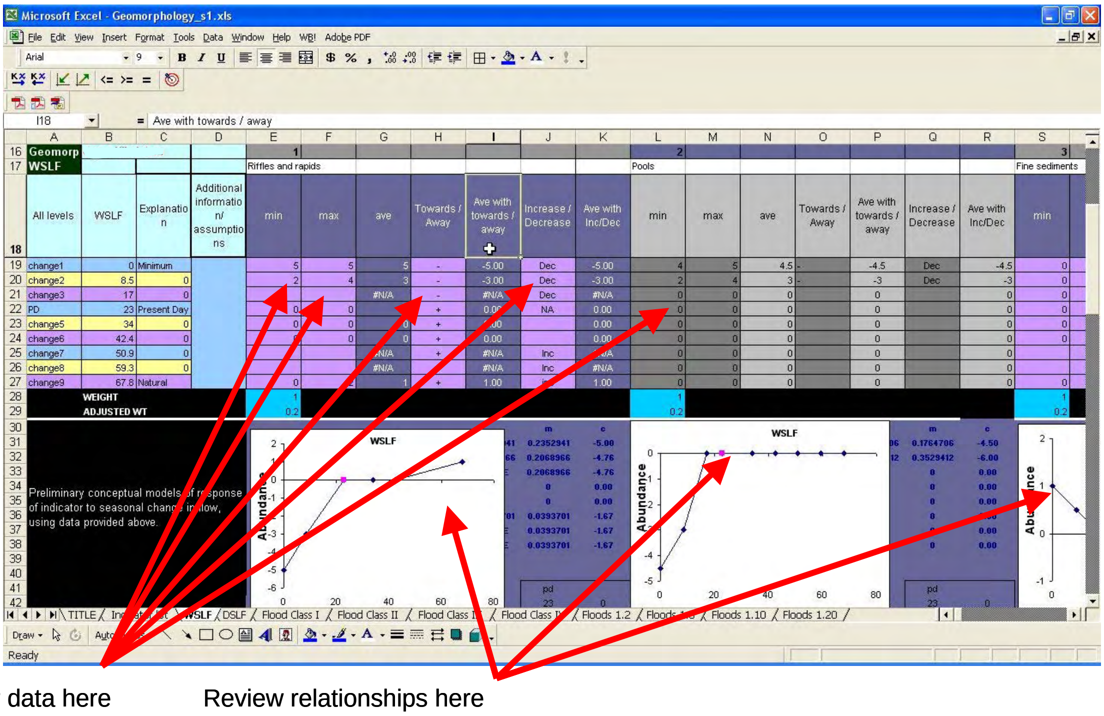

Figure 0.5 The WSLF Worksheet – close up of the data entry area

Below the Data Reviewing section is a section for entering explanations for the relationship provided, and a section for providing references where possible.

Rows 80 to 123 contain the equations necessary to extrapolate the given information to more flow change levels.

Columns BZ to EG contain the equations necessary to determine the minimum and maximum responses (rather than the averages). Do not overwrite or delete any of these cells, rows or columns.

STEP 3: Repeat for all indicators and all flow categories

Once the response curve has been created for one indicator and one flow category, the above steps should be repeated for all indicators and all categories.

Response curves for socio-economic indicators

Social response curves are constructed in much the same way as biophysical ones. Further details will be provided at the Knowledge Capture Workshop.

Guidelines for specialist reports for the TDA EF process

To ensure conformity and that all required aspects are covered, templates will be provided for all reports. The layout and headings will be developed by the Process Management Team and the National Team Leaders.

Once finalized, an electronic version laid out with a style sheet will be supplied to each specialist or team writing a report.

Suggested procedure for the determination of ecological condition

The method used here is taken from the Habitat Integrity Assessment as described in DWAF (1999) with one major difference. Ideally, the habitat integrity assessment is based on a recent low-altitude videograph of the river taken from a helicopter from the source to the most downstream section being investigated (DWAF 1999). Helicopter surveys are expensive and often inappropriate for the level of study being undertaken, and so in this study, aerial photographs and Google images will be used instead of a videograph.

Habitat Integrity method[2]

The ecological integrity of a river is defined as its ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components on a temporal and spatial scale that are comparable to the natural characteristics of ecosystems of the region. Habitat integrity in this sense then refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region.

The method is based on the qualitative assessment of a number of pre-weighted criteria that indicate the integrity of the instream and riparian habitats available for use by riverine biota. The assessment is based on the professional judgement and experience of the study team.

The criteria considered indicative of the habitat integrity of the river were selected on the basis that anthropogenic modification of their characteristics could generally be regarded as the primary causes of degradation of the integrity of the river. Certain modifications will have a detrimental impact on the habitat integrity of a river, the extent of that impact being dependent on their severity.

The assessment of the severity of impact of modifications is based on six descriptive categories with ratings ranging from 0 (no impact), 1 to 5 (small impact), 6 to 10 (moderate impact), 11 to 15 (large impact), 16 to 20 (serious impact) and 21 to 25 (critical impact).

The Habitat Integrity Assessment is based on assessment of the impacts on two components of the river, the riparian zone and the instream habitat. Assessments are made separately for both components, but data for the riparian zone are interpreted primarily in terms of the potential impact on the instream component. The relative weightings of criteria are detailed in Table 0.1.

[2] Taken from Harding *et al.* (2001), originally summarised from DWAF (1999)

Table 0.1 Criteria and weights used for the assessment (from Kleynhans, 1996).

INSTREAM CRITERIA	WEIGHT	RIPARIAN ZONE CRITERIA	WEIGHT
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	12
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water quality	14	Water abstraction	13
Inundation	10	Inundation	11
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Solid waste disposal	6		
TOTAL	100	TOTAL	100

The estimated impact of each criterion is calculated as:
Rating for the criterion /maximum value (25) x weight (percent).

The estimated impacts of all criteria calculated in this way are summed, expressed as a percentage and subtracted from 100 to arrive at a provisional assessment of Intermediate Habitat Integrity for the instream and riparian components, respectively.

The total scores for the instream and riparian zone components are then used to place the habitat integrity of both in a specific intermediate habitat integrity category. These categories are indicated in Table 0.2.

Table 0.2 Habitat Integrity categories (from Kleynhans, 1996)

CATEGORY	DESCRIPTION	SCORE (% OF TOTAL)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0

Guide to assigning scores when there are few data available[3]

One of the major drawbacks of the Habitat Integrity assessments is that the scores assigned to the criteria are somewhat subjective. This means that an assessment done by one person may produce different results from one done by someone else. In an effort to overcome this problem, we have developed a guide that breaks each of the criteria down into more quantifiable sub-criteria. The guide is essentially a scoring system within a scoring system. Nonetheless, we have found that the scores assigned by different people using the guide are a lot closer to one another than without it. Furthermore, we found that inexperienced river scientists obtained scores that were close or identical to those obtained by scientists with a great deal of experience in the study rivers. The guide is divided according to the criteria presented in Table 0.1, *viz*.

- Water abstraction
- Inundation
- Flow modification, divided into:
  - Flood manipulation
  - Lowflow manipulations
- Bed modification
- Channel modification
- Water quality
- Exotic macrophytes
- Exotic fauna
- Solid waste disposal

Please note:	These are only guidelines. Should the specialists wish to use a different method to arrive at the scores, they should do so.

Water abstraction

Brief explanation of the impacts of water abstraction:
The three driving variables determining the character of a river are climate, geology and topography. These factors dictate the flow regime, the general geomorphological character of the river, the shape and size of the river channel, the size of the bed particles, and the basic water chemistry and temperature. These in turn determine the fauna and flora that inhabit the river. Abstraction of water alters the flow regime, thereby potentially affecting all aspects of a river.

Without detailed hydrological records it is extremely difficult to deduce a score for water abstraction, thus the scoring system presented here attempts to use various clues from the activities in the catchment or on the river to arrive at a likely abstraction pressure.

The scoring system for water abstraction work as follows:

[3] Taken from Harding *et al.* (2001)

Step 1. If hydrological records are available, and thus the % MAR abstracted from the system is known, then use only % MAR abstracted to determine the water abstraction score (see column 1 in Table 0.3).

Step 2. If hydrological records are not available, use columns 2-6 to estimate abstraction pressure.

Step 3. If nothing is know about one of the variables listed in columns 2-6 in Table 0.3, then leave that column out and move to the next one.

Step 4. The abstraction score will equal the HIGHEST score obtained using the criteria in columns 2-6 in Table 0.3. For example, in a catchment with approximately 50% of the catchment area given over to vineyards, approximately 3 pumps in the river per kilometre, and a major dam upstream of the study reach, the abstraction score would be 21.

Table 0.3 Scoring system for water abstraction

SCALE: Reach level (i.e. between major tributaries).

	% abstracted	Score		Yes/No	Score		Upstream system	Score		No. per sq km	Score		No. per km	Score		U/stream system	Score		Upstream system	Score
Percentage MAR abstracted:	0	0	Stream (both perennial and seasonal) only flows after unusually high rainfall, i.e., no lowflows only floods	NO	0	Major Dams (unmitigated)	NO	0	No. of farm dams	0	0	No. of pumps	0	0	Abstraction weirs (unmitigated)	0	0	% of catchment under forestry, alien veg, vineyards, cashcrops and/or orchards	0	0
	n/a	1		n/a	1		n/a	1		n/a	1		n/a	1		n/a	1		n/a	1
	n/a	2		n/a	2		n/a	2		n/a	2		n/a	2		n/a	2		n/a	2
	10	3		n/a	3		n/a	3		n/a	3		n/a	3		n/a	3		n/a	3
	20	4		n/a	4		n/a	4		n/a	4		n/a	4		n/a	4		n/a	4
	30	5		n/a	5		n/a	5		</=0.25	5		</=1	5		n/a	5		10	5
	35	6		n/a	6		n/a	6		n/a	6		n/a	6		n/a	6		n/a	6
	40	7		n/a	7		n/a	7		n/a	7		n/a	7		n/a	7		n/a	7
	45	8		n/a	8		n/a	8		</=1	8		</=1.5	8		1	8		n/a	8
	50	9		n/a	9		n/a	9		n/a	9		n/a	9		n/a	9		n/a	9
	55	10		n/a	10		n/a	10		n/a	10		n/a	10		n/a	10		25	10
	60	11		n/a	11		n/a	11		n/a	11		n/a	11		n/a	11		n/a	11
	65	12		n/a	12		YES	12		n/a	12		n/a	12		2	12		n/a	12
	70	13		n/a	13		n/a	13		</=1.5	13		</=2	13		n/a	13		40	13
	75	14		n/a	14		n/a	14		>1.5	14		>2	14		n/a	14		45	14
	n/a	15		n/a	15		n/a	15		n/a	15		n/a	15		n/a	15		50	15
	80	16		n/a	16		n/a	16		n/a	16		n/a	16		n/a	16		n/a	16
	n/a	17		n/a	17		n/a	17		n/a	17		n/a	17		n/a	17		n/a	17
	85	18		n/a	18		n/a	18		</=2	18		</=3	18		n/a	18		60	18
	n/a	19		n/a	19		n/a	19		>2	19		>3	19		n/a	19		n/a	19
	90-94	20		n/a	20		n/a	20		n/a	20		n/a	20		n/a	20		75	20
	n/a	21		n/a	21		n/a	21		</=3	21		</=4	21		n/a	21		n/a	21
	n/a	22		n/a	22		n/a	22		n/a	22		>4	22		n/a	22		n/a	22
	n/a	23		n/a	23		n/a	23		n/a	23		n/a	23		n/a	23		80	23
	n/a	24		n/a	24		n/a	24		n/a	24		n/a	24		n/a	24		n/a	24
	>/=95	25		YES	25		n/a	25		>3	25		n/a	25		n/a	25		n/a	25

MITIGATION:

% contribution to flow by undisturbed tributaries	>/= 10%	multiply score by 0.75
	>/= 20%	multiply score by 0.5
	>/=50%	multiply score by 0.25

Step 5. Un-disturbed tributaries can considerably mitigate the impacts of water abstraction (Table 0.3). Thus, if the study reach is situated downstream of an undisturbed tributary, then the abstraction score should be mitigated as indicated in the table overleaf. For example, if the study reach in 2b was situated downstream of an undisturbed tributary that supplied 10% of its MAR, the abstraction score would be adjusted by multiplying by 0.75. Thus, the final abstraction score would be 16.

Inundation

The scoring system for inundation works as follows:

Step 1. Estimate the percentage of the upstream channel that is inundated by dams, weirs, road crossings, etc., use corresponding score in Table 0.4.

Step 2. This can be estimated most effectively using 1:250 000 topographical maps, aerial photographs and/or Google images.

Table 0.4 Scoring system for extent of inundation of the river channel

	Percentage inundation	Score
Extent of inundation of the river channel.	0	0
	4	1
	8	2
	12	3
	16	4
	20	5
	24	6
	28	7
	32	8
	36	9
	40	10
	44	11
	48	12
	50%	13
	56	14
	60	15
	64	16
	68	17
	72	18
	76	19
	80	20
	84	21
	88	22
	92	23
	96	24
	100%	25

Flood manipulation

The scoring system for flood manipulation works as follows:

Step 3. The timing, magnitude and frequency of flood are most affected by in-channel large dams in the upstream catchment. Thus, these are the two factors used to estimate a score for manipulation of flood flows.

Step 4. The flood manipulation score will equal the HIGHEST score obtained using the criteria in columns 1-2 in Table 0.5. For example, a study reach with approximately 1 farm dam per km^2 in the upstream catchment and a single large dam less than 15 km upstream of the reach, the flood manipulation score would be 18.

Step 5. Un-disturbed tributaries can considerably mitigate the impacts of upstream dams. Thus, if the study reach is situated downstream of an undisturbed tributary, then the abstraction score should be mitigated as indicated in Table 0.5. For example, if the study reach in 2 was situated downstream of an undisturbed tributary that supplied 20% of its MAR, the abstraction score would be adjusted by multiplying by 0. 5. Thus, the final abstraction score would be 9.

Table 0.5 Scoring system for flood manipulation

	Whole upstream system	Score		No. per sq km	Score
	0	0		0	0
	n/a	1-11		n/a	1-11
	YES > than 5 km	12		n/a	12
	n/a	13		n/a	13
	n/a	14		n/a	14
	n/a	15		n/a	15
	n/a	16		n/a	16
Major Dams (unmitigated)	n/a	17	No. of farm dams	n/a	17
	YES within 5 km of reach	18		n/a	18
	n/a	19		n/a	19
	n/a	20		n/a	20
	n/a	21		n/a	21
	n/a	22		n/a	22
	n/a	23		n/a	23
	n/a	24		n/a	24
	n/a	25		n/a	25

MITIGATION:

% contribution by undisturbed tributaries	>/= 10%	x score by 0.75
	>/= 20%	x score by 0.5
	>/=50%	x score by 0.25

Lowflow manipulation

Impacts on lowflows are extremely difficult to judge without detailed hydrological information. Thus, the scoring system presented here concentrates on changing perennial rivers into seasonal rivers. It is, however, acknowledged that there may be other, more-subtle, impacts on lowflows that will not be assessed using this scoring system.

The scoring system for flood manipulation works as follows:

Step 6. Determine, through consultation with people familiar with the area (e.g., country specialists), whether on not the river was once perennial and whether or not it now dries up during the summer months.

Step 7. If so, determine the frequency and duration of no-flow periods.
Step 8. Obtain a score for lowflow manipulation by dividing the water abstraction score by the appropriate compounding factor given in Table 0.6.

Table 0.6 Scoring system for lowflow manipulation

Propensity to dryout in months where flow would have naturally occurred	
If flow occurs in all months where it naturally occurred.	= abstraction score
Flow stops every year in months where it naturally occurred:	Divide abstraction by 0.5 to a maximum of 25
Flow stops occasionally (less frequently than 3 years) in months where it naturally occurred:	Divide abstraction by 0.75 to a maximum of 25
In perennial systems if flow stops for > 1 month:	Subtract 0.2 from above (before dividing)

Bed modification

The scoring system for bed modification (with reference to Rowntree and Wadeson, 1999) considers a combination of three factors most commonly responsible for bed modification in rivers, *viz*. sedimentation as a result of a loss of flushing flows, concrete canalisation and/or bull dozing of the river channel (usually resulting in a uniform trapezoidal channel shape). Once again, there may be other factors that can result in bed modification, and incorporation and assessment of these is at the discretion of the assessor.

The scoring system for bed modification works as follows:
Step 9. The bed modification score will equal the HIGHEST score obtained using the criteria in columns 1-3 in Table 0.7. For example, a river channel that has been canalised with concrete will ALWAYS score 25, regardless of whether or not there are silt depositions in the channel.

Embeddedness refers to the condition where spaces between coarser material (cobbles and boulders) are infilled with fine particles (normally sand or silt).

Step 10.

Table 0.7 Scoring system for bed modification

		Score			Score		% river bed affected in the reach	Score
Habitat degradation, as a result of sedimentation as a result of bank or catchment erosion and or reduction in transporting power - *not applicable to lower river and/or foothill gravel bed*	0	0	Canalisation	NO	0	Dredging/bulldozing/ road crossings	0	0
	n/a	1			1		4	1
	n/a	2			2		8	2
	n/a	3			3		12	3
	n/a	4			4		16	4
	Silt/gravel in interstitial spaces but spaces between particles are largely open.	5			5		20	5
	n/a	6			6		24	6
	n/a	7			7		28	7
	n/a	8			8		32	8
	Silt/gravel in interstitial spaces, and space between the cobble and boulders are in-filled with fine material fine material – sand and silt).	9			9		36	9
	n/a	10			10		40	10
	n/a	11			11		44	11
	n/a	12			12		48	12
	Silt drapes at channel margins, evidence of deposition in runs and pools. Space between the cobble and boulders are in-filled with fine material fine material	13			13		52	13
	n/a	14			14		56	14
	n/a	15			15		60	15
	n/a	16			16		64	16
	n/a	17			17		68	17
	Large drapes at channel margins, evidence of deposition in runs and pools. Cobble and boulders more than 1/2 covered by fine material – sand and silt.	18			18		72	18
	n/a	19			19		76	19
	n/a	20			20		80	20
	n/a	21			21		84	21
	n/a	22			22		88	22
	n/a	23			23		92	23
	n/a	24			24		96	24
	Cobbles and or boulders completely covered.	25		YES	25		100%	25

Channel modification

The scoring system for channel modification considers the impacts resulting from infilling or channelisation (digging down) on channel shape and structure. It also takes account of the potential impact of bridges or other features that constrict river flow, thereby affecting channel shape and direction. Once again, there may be other factors that can result in channel modification, but these are less frequent than the ones listed above and incorporation and assessment of any additional factors is at the discretion of the assessor.

The scoring system for channel modification works as follows:

Step 11. The channel modification score will equal the HIGHEST score obtained using the criteria in columns 1-2 in Table 0.8.

Table 0.8 Scoring system for channel modification

	% in reach	Score		% in reach	Score
Infilling and channelisation	None	0	Bridges	None	0
	n/a	1		n/a	1
	n/a	2		n/a	2
	n/a	3		n/a	3
	n/a	4		n/a	4
	Infilling evident in less that 10% of the reach	5		No lowflow/or arches bridges. < 1 single span bridge per 1 km.	5
	n/a	6		n/a	6
	n/a	7		n/a	7
	n/a	8		n/a	8
	n/a	9		n/a	9
	n/a	10		n/a	10
	n/a	11		n/a	11
	n/a	12		n/a	12
	Infilling evident in less than 50% of the reach (e.g. one bank only or both banks for 25% of reach length)	13		< 0.5 lowflow/or arches bridge and/or < 1 single span bridge per 1 km.	13
	n/a	14		n/a	14
	n/a	15		n/a	15
	Channelisation > 60% of reach, infilling evidence elsewhere	16		n/a	16
	n/a	17		n/a	17
	n/a	18		< 1 lowflow/or arches bridge and/or < 2 single span bridge per 1 km.	18
	n/a	19		n/a	19
	n/a	20		n/a	20
	Channelisation > 75% of reach, infilling evidence elsewhere	21		n/a	21
	n/a	22		n/a	22
	n/a	23		n/a	23
	n/a	24		n/a	24
	Canalisation	25			25

Water quality

No guide available.

Presence of exotic macrophytes

Estimate the percentage of the reach that is covered by exotic aquatic macrophytes – regardless of species.

Table 0.9 Scoring system for exotic macrophytes

	% cover	Score
Percentage cover in reach - regardless of species	0	0
	4	1
	8	2
	12	3
	16	4
	20	5
	24	6
	28	7
	32	8
	36	9
	40	10
	44	11
	48	12
	52	13
	56	14
	60	15
	64	16
	68	17
	72	18
	76	19
	80	20
	84	21
	88	22
	92	23
	96	24
	100	25

Presence of exotic fauna

The scoring system presented here relates specifically to fish, however, if information is available on other harmful alien species then it should be incorporated at the discretion of the assessor.

The scoring system for exotic fish is based on the relative impact of different fish species (Table 0.10). It is necessary to have some idea of the composition of fish assemblages in a study reach.

Table 0.10 Scoring system for exotic fish

	Percentage	Score
Composition of fish community	None	0
	n/a	1
	n/a	2
	n/a	3
	n/a	4
	Exotics present but indigenous fish dominate.	5
	n/a	6
	n/a	7
	Exotic and indigenous species present in roughly the same proportions.	8
	n/a	9
	n/a	10
	n/a	11
	n/a	12
	n/a	13
	n/a	14
	n/a	15
	n/a	16
	n/a	17
	n/a	18
	Fish fauna dominated by exotic fish species	19
	n/a	20
	n/a	21
	n/a	22
	n/a	23
	n/a	24
	Only exotics - regardless of species	25

Presence of solid waste

The scoring system presented here relates specifically to litter and building rubble. Table 0.11 is self-explanatory.

Table 0.11 Scoring system for solid waste

	No. in 100m stretch	Score
Litter and rubble in the macro-channel	None	0
	n/a	1
	n/a	2
	n/a	3
	n/a	4
	10 pieces of litter and or building rubble (e.g. bricks, gutter) within a c. 100m stretch of river.	5
	n/a	6
	n/a	7
	n/a	8
	10-50 pieces but no evidence of dumping	9
	n/a	10
	n/a	11
	n/a	12
	n/a	13
	Evidence of once off dumping in >/= 1 place in the reach. >50 pieces but no evidence of dumping	14
	n/a	15
	n/a	16
	Evidence of once off dumping in >/= 2 places in the reach.	17
	n/a	18
	n/a	19
	n/a	20
	Evidence of ongoing dumping into the river channel in >/= 1 place in the reach.	21
	n/a	22
	n/a	23
	n/a	24
	Evidence of ongoing dumping into the river channel in >/= 2 places in the reach.	25

Removal of indigenous vegetation

The scoring system for removal of indigenous vegetation works as follows:

Step 12. Estimate the percentage of the reach that is devoid of natural riparian vegetation – regardless of species (Table 0.12).

Step 13. This includes riparian vegetation that has been out competed by alien trees.

Step 14. As a standard rule use 30 m from the top of bank to define the riparian zone.

Table 0.12 Scoring system for removal of indigenous vegetation

	% cover	Score
Percentage cover in reach	0	0
	4	1
	8	2
	12	3
	16	4
	20	5
	24	6
	28	7
	32	8
	36	9
	40	10
	44	11
	48	12
	52	13
	56	14
	60	15
	64	16
	68	17
	72	18
	76	19
	80	20
	84	21
	88	22
	92	23
	96	24
	100	25

Encroachment into the riparian zone by exotic vegetation

The scoring system for encroachment by exotic vegetation works as follows (Table 0.13):

Step 15. Estimate the percentage of the riparian zone of the reach that is invaded by exotic species. As a standard rule, use 30 m from the top of bank to define the riparian zone.

Step 16. Estimate the density of the cover in the invaded areas, *viz*. light or dense. As a general rule, invasion should be considered light/medium if there are indigenous plants clearly visible among the alien plants, and heavy if there are few if any indigenous plants growing between the alien plants.

Table 0.13 Scoring system for encroachment into the riparian zone by exotic vegetation

	% cover	Score
Percentage cover in reach	0	0
	n/a	1
	n/a	2
	10- light	3
	n/a	4
	n/a	5
	10 - dense	6
	n/a	7
	n/a	8
	30 - light	9
	n/a	10
	n/a	11
	30 - dense	12
	n/a	13
	n/a	14
	50 - light	15
	n/a	16
	50 - dense	17
	n/a	18
	60-70	19
	n/a	20
	100 - light	21
	n/a	22
	n/a	23
	n/a	24
	100 - dense	25

Evidence of bank erosion

Erosion is assessed according to two sets of criteria:

- Evidence of erosion caused by river flow;
- Evidence of erosion caused by other means such as cattle or stormwater runoff.

The scoring system for erosion uses bank slumping, undercutting or scouring as an indication of the seriousness of erosion caused by river flows (Table 0.14). Erosion by other means is evident from rilling (small gulleys formed as a result of erosion) or livestock trampling. The degree of erosion is assessed according to the percentage of the bank length affected in a representative 100 m reach of river.

If banks are stablised by vegetation, and no bank erosion is evident then erosion score = 0 even if there is some bed erosion.

Table 0.14 Scoring system for evidence of bank erosion

	No. in 100m stretch	**Score**
Presence of erosion.	None	0
	n/a	1
	n/a	2
	n/a	3
	n/a	4
	Evidence of >/= 10%	5
	n/a	6
	n/a	7
	n/a	8
	Evidence of >/= 20%	9
	n/a	10
	n/a	11
	n/a	12
	n/a	13
	Evidence of >/= 40%	14
	n/a	15
	n/a	16
	n/a	17
	Evidence of >/= 50%	18
	n/a	19
	n/a	20
	n/a	21
	n/a	22
	n/a	23
	n/a	24
	Evidence of >/= 75%	25

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The Okavango River Basin Transboundary Diagnostic Analysis Technical Reports

In 1994, the three riparian countries of the Okavango River Basin – Angola, Botswana and Namibia – agreed to plan for collaborative management of the natural resources of the Okavango, forming the Permanent Okavango River Basin Water Commission (OKACOM). In 2003, with funding from the Global Environment Facility, OKACOM launched the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project to coordinate development and to anticipate and address threats to the river and the associated communities and environment. Implemented by the United Nations Development Program and executed by the United Nations Food and Agriculture Organization, the project produced the Transboundary Diagnostic Analysis to establish a base of available scientific evidence to guide future decision making. The study, created from inputs from multi-disciplinary teams in each country, with specialists in hydrology, hydraulics, channel form, water quality, vegetation, aquatic invertebrates, fish, birds, river-dependent terrestrial wildlife, resource economics and socio-cultural issues, was coordinated and managed by a group of specialists from the southern African region in 2008 and 2009.

The following specialist technical reports were produced as part of this process and form substantive background content for the Okavango River Basin Transboundary Diagnostic Analysis.

Final Study Reports	***Reports integrating findings from all country and background reports, and covering the entire basin.***		
		Aylward, B.	*Economic Valuation of Basin Resources: Final Report to EPSMO Project of the UN Food & Agriculture Organization as an Input to the Okavango River Basin Transboundary Diagnostic Analysis*
		Barnes, J. et al.	*Okavango River Basin Transboundary Diagnostic Analysis: Socio-Economic Assessment Final Report*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Project Initiation Report (Report No: 01/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment EFA Process Report (Report No: 02/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Guidelines for Data Collection, Analysis and Scenario Creation (Report No: 03/2009)*
		Bethune, S. Mazvimavi, D. and Quintino, M.	*Okavango River Basin Environmental Flow Assessment Delineation Report (Report No: 04/2009)*
		Beuster, H.	*Okavango River Basin Environmental Flow Assessment Hydrology Report: Data And Models(Report No: 05/2009)*
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		Jones, M.J.	*The Groundwater Hydrology of The Okavango Basin (FAO Internal Report, April 2010)*
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		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions (Volume 2 of 4: Indicator results) (Report No. 07/2009)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions: Climate Change Scenarios (Volume 3 of 4) (Report No. 07/2009)*
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		Malzbender, D.	*Environmental Protection And Sustainable Management Of The Okavango River Basin (EPSMO): Governance Review*
		Vanderpost, C. and Dhliwayo, M.	*Database and GIS design for an expanded Okavango Basin Information System (OBIS)*

		Veríssimo, Luis	*GIS Database for the Environment Protection and Sustainable Management of the Okavango River Basin Project*
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Environmental protection and sustainable management of the Okavango River Basin

EPSMO

Boteti River shoreline, Botswana

Republic of Botswana

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