THE PERMANENT OKAVANGO RIVER BASIN WATER COMMISSION
FINAL DRAFT
OKACOM

The Permanent Okavango River Basin Water

Commission

Transboundary Diagnostic Analysis Report

OKACOM

Okavango River Basin
Transboundary Diagnostic Analysis

OKACOM

2010

ISBN 978- 99912-0-972-2

Front cover: Okavango at Popa 3 courtesy of Dr Eben Chonguiça.
Inside front cover: Using river resources at Cuito Cuanavale, Angola

Cite as: The Permanent Okavango River Basin Water Commission. 2010. *Okavango River Basin Transboundary Diagnostic Analysis*. Maun, Botswana: OKACOM
Photographs not otherwise credited courtesy of Professor Jackie King and Dr Cate Brown, OKACOM Environmental Flows Work, and IRBM
Designed by Twin Zebras, Maun, Botswana

CONTENTS

ACRONYMS AND ABBREVIATIONS

AIDS	acquired immunodeficiency syndrome
BIOKAVANGO	Building Local Capacity for Conservation and Sustainable Use of Biodiversity in the Okavango Delta
CITES	Convention for International Trade in Endangered Species
DSS	decision support system
EA	environmental assessment
EFA	Environmental Flow Assessment
EIA	environmental impact assessment
EPSMO	Environmental Protection and Sustainable Management of the Okavango River Basin
EU	European Union
FAO	Food and Agriculture Organisation (of the United Nations)
GDP	gross domestic product
GEF	Global Environment Facility
GIS	geographic information systems
GNI	gross national income
ha	hectare(s)
HEP	hydro-electric power
HIV	human immunodeficiency virus
HOORC	Harry Oppenheimer Okavango Research Centre
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IFA	integrated flow assessment
IFS	International Financial Statistics
IMF	International Monetary Fund
IMP	integrated management plan
IUA	integrated units of analysis
IWRM	integrated water resources management
km	kilometre(s)
l/c/d	litres per capita per day
MAR	mean annual runoff
masl	metres above sea level
MCM/a	million cubic metres per annum
mg	milligrams
mg/l	milligrams per litre
mm	millimetre(s)
Mm^3	million cubic metre(s)
mm/a	millimetres per year
MW	megawatts
NAP	national action plan
NBSAP	National Biodiversity Strategy and Action Plan
NCU(s)	national coordinating unit(s)
NGO	non-governmental organisation
NPV	net present values
OBSC	Okavango Basin Steering Committee
ODMP	Okavango Delta Management Plan
OKACOM	Permanent Okavango River Basin Water Commission
ORB	Okavango River Basin
OWMC	Okavango Wetlands Management Committee
PD	present day
PDO	Pacific Decadal Oscillation
RWP	Regional Water Policy
RWS	Regional Water Strategy
SADC	Southern Africa Development Community
SAP	Strategic Action Programme
SEA	strategic environmental impact
TDA	Transboundary Diagnostic Analysis
TDS	total dissolved solids
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention on Combating Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation

NAP Meeting with Governor, Menongue, Angola, March 2010

FOREWORD

by Mr Armindo Gomes Mario da Silva, Co-Chairperson, OKACOM, Angola

I am proud to present this document. It is the fruit of several years of hard work, intensive research and much patience. The various people involved in the elaboration of the present Transfrontier Diagnostic Analysis (TDA) have overcome difficulties in logistics, communications and resources to produce a unique study that not only provides us, the Permanent Okavango River Basin Water Commission (OKACOM) with an essential reference to be used in our future planning and decision making, but has also allowed us to grow as a Commission.

The TDA is an important step in the elaboration of the Strategic Action Programme, which will form the technical basis for the establishment of substantive agreements among the three Okavango Basin States. These agreements will allow OKACOM to succeed in the participative management of this all-important basin and to ensure that the countries which depend on it, will receive the best return on investment from the river's resources in a sustainable and equitable way.

This report is the product of research carried out by scientists from within our own region. It has been reviewed patiently, and with great honesty, by many different people to ensure the precision required in such a document. On behalf of the Commission, I would like to acknowledge everyone who contributed to this work – the list of whom is quite extensive.

Mr Armindo Gomes Mario da Silva, Co-Chairperson, OKACOM, Angola

Foremost, I would like to thank the three governments, the co-donors of this project, the Global Environment Facility (GEF) and the countries that contributed to the study. Sincere thanks are also due to the people of the basin for the patience and useful collaboration shown towards numerous researchers who visited the communities. We thank the United Nations Development Program (UNDP) and especially, Dr Gita Welch and Dr Dra Gabriela do Nascimento, for their support towards the implementation of the project. Our thanks, too, to the United Nations Food and Agricultural Fund (FAO), in their role as Executing Agency, with particular reference to Mr Jacob Burke, who followed this process throughout eight years.

The people of the Project Management Unit (PMU) in Luanda, namely Mr Chagas Macula, Mr Pedro André and to Ms Eva Kalunga deserve a special mention for their contribution, but we need to make special mention of Mr Manuel Quintino for his valuable contribution and professionalism. It was a privilege for us in Angola to be able work in close collaboration with this project. I would likewise wish to thank the members of the Okavango Basin Steering Committee (OBSC) for their valuable technical supervision, and acknowledge the hard work undertaken by the National Coordinators of the Project, namely Mr Manuel Quintino, Ms Tracy Molefi and Ms Laura Namene. Unfortunately, we cannot fail to mention, with some form of apprehension, the less elegant manner in which the Project Manager, Mr Chaminda Rajapakse, abandoned his duties before the conclusion of the final report.

The OKACOM Secretariat made valuable contributions, and for that, I express our heartfelt gratitude to Dr Eben Chonguiça and his staff. My thanks are also due to the Agostinho Neto University and to the University of Botswana (HOORC). Our gratitude also extends to the Namibia Nature Foundation and to ACADIR for their contributions, as well as to NamWater and the HOORC Biokavango Project for their assistance in the integrated flow assessments, which supported the TDA. An extensive thank you goes to Mr John Meynell who compiled the document and to Ms Sharon Montgomery for her final editing.

The 13 specialist authors of the final study reports and the more than 30 authors of the country reports, as well as all the country-based reviewers, need special mention for their hard work and perseverance.

While we acknowledge that it is necessary to undertake additional, substantial monitoring to ensure a good future for this basin, the Environmental Protection and Sustainable Management of the Okavango River Basin Project (EPSMO) has allowed OKACOM to fulfill its objective of obtaining valuable knowledge of the basin. With this background we will continue to increase our management capacity to manage the basin across borders as an Okavango River community.

'When we act, let us always think of the Okavango Basin as a whole'

CHAPTER 1: INTRODUCING THE OKAVANGO TRANSBOUNDARY DIAGNOSTIC ANALYSIS

The Okavango River Basin remains one of the basins least affected by human impacts on the African continent. In its present near-pristine status, the river provides significant ecosystem benefits and can continue to do so if managed appropriately. However, mounting socio-economic pressures on the basin in the riparian countries, Angola, Botswana and Namibia, could change its present character. Maintaining the river's benefits requires agreement over the sharing of both the benefits and associated liabilities through joint management of the basin's natural resources.

The 1994 OKACOM[1] Agreement, the Southern African Development Community Revised Protocol on Shared Watercourses of 2000 and the 1997 United Nations (UN) Convention on the Law of the Non-navigational Uses of International Watercourses provide a framework for such cooperation. Under the OKACOM Agreement, the riparian countries must work towards the implementation of an Integrated Management Plan (IMP) for the basin on the basis of an Environmental Assessment (EA).

This Transboundary Diagnostic Analysis (TDA) was formulated by the Permanent Okavango River Basin Water Commission (OKACOM) with funding from the Global Environment Facility (GEF) and the riparian governments to address critical transboundary elements of the proposed EA and IMP. The TDA forms the basis for OKACOM to develop a Strategic Action Programme (SAP) to manage the basin's linked water and land resources, and provides an essential monitoring and evaluation tool for the SAP. Through the application of physical and socio-economic models across the whole basin, the TDA establishes a rationale for joint management. In turn, the SAP will structure diverse inputs and identify specific resources necessary for implementation of the transboundary elements of the EA and the IMP.

1.1. THE OKAVANGO RIVER BASIN

The river rises in the headwaters of the Cuito and Cubango Rivers in the highland plateau of Angola. The topographic extent of the basin comprises approximately 700,000 km2, but it derives its principal flow from 120,000 km^3 of sub-humid and semi-arid rangeland in the Cuando Cubango Province of Angola before concentrating its flow along the margins of Namibia and Angola and finally spilling into the Okavango fan or Delta in Botswana. Geological controls on the boundaries of the fan determine the eventual flow of remaining water into a set of evaporation pans in the Kalahari Desert. The basin consists of the areas drained by the Cubango, Cutato, Cuchi, Cuelei, Cuebe, Cueio, Cuatir, Luassinga, Longa, Cuiriri and Cuito Rivers in Angola, the Okavango River in Namibia and Botswana, and the Okavango Delta. (Figure 1-1).

Figure 1-1: Location of the Okavango River Basin in southern Africa

The functional system boundary for water, land, forests and wildlife comprise much smaller sub-sets of the basin's geographic limit. This is because the area of the basin responsible for perennial flows is much smaller than the topographic limits of the basin. Equally, only a part of the basin's population and communities bounded by the topographic divide in Namibia and Botswana are directly engaged with the water resources of the basin. However, there are significant external linkages beyond the hydrological and topograpic system envelopes, notably:
• Demands for water abstraction in Namibia originating beyond the topographic limits of the basin.
• With the ongoing peace process in Angola, priority is given to resettlement polices and in the case of Kwando Kubango, it is expected that this will result in most of the original population returning to the area.

The wetland environment of the fan in Botswana provides a staging area for birds migrating to southern Africa during the boreal winter and is a storehouse of globally significant biodiversity. [end bullets]
Thus the significance of the basin's water resources extend beyond the physical boundary of the basin.

1 OKACOM – Permanent Okavango River Basin Water Commission

The Okavango waters are relatively clear with few dissolved chemicals, solutes or pollutants. The riparian landscapes along many of the waterways are largely unchanged with natural plant and aquatic life remaining healthy. The river supports people, their livestock and a myriad livelihoods ranging from artisanal fisheries to small-scale agriculture, as well as diverse wildlife. The Okavango Delta, a unique ecosystem, is a significant source of tourism income and cultural value to the people of Botswana.

The generally low level of economic development associated with the Okavango is a by-product of history and geopolitics. Nevertheless the current situation offers the riparian countries of the Okavango an opportunity to choose a development pathway for the basin without compromising the set of environmental goods and services, including global benefits, distributed across the whole basin.

Highlands source of Rio Cubango, Angola

1.2. OKACOM AND THE MANAGEMENT OF THE OKAVANGO RIVER BASIN

The OKACOM Agreement obliges the three member states to promote coordinated and environmentally sustainable regional water resources development, while addressing the legitimate social and economic needs of each of the riparian states.

Under this agreement, signed in 1994 by the three riparian states, the Permanent Okavango River Basin Water Commission (OKACOM) was established and was mandated to advise the party states on sustainable long-term yield, reasonable demand, conservation criteria, development of water resources, prevention of pollution and other matters pertaining to the management of the Okavango River Basin.

The role of OKACOM is to anticipate and reduce those unintended, unacceptable and often unnecessary impacts that occur due to uncoordinated resource development.

In early 2007, OKACOM reviewed its organisational structure to bring it in line with the Revised SADC Protocol on Shared Watercourses, formalised the Okavango Basin Steering Committee (OBSC) to provide technical advice and established a Secretariat to coordinate and inform decisions of the Commission. The three contracting parties signed a new agreement on the 'organisational structure for the Permanent Okavango River Basin Water Commission'. This agreement formally established the three organs of OKACOM: the Commission, the OBSC and the Secretariat.

It has been recognised for many years that proposed water development projects may give rise to concerns about management of the waters of the Okavango. Most of the issues and problems described in this report are not new, having been identified and discussed previously. The three countries of the basin have been wrestling with these issues both internally and collectively, and have already put in place some preventative mechanisms and policies, as can be seen from the description of governance mechanisms in Chapter 2.

1.3. EPSMO AND THE OKAVANGO TDA

The origin of the Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) Project lies with the formation of OKACOM in 1994. In line with the agreement, a preliminary TDA was completed in 1998. The proposal for the current project was developed through a GEF PDF-B grant and the EPSMO project was formally launched in 2004. The project has been executed by the Food and Agriculture Organization (FAO) and implemented by the United Nations Development Programme (UNDP).

The long-term objective of the EPSMO Project has been to achieve global environmental benefits through concerted management of the naturally integrated land and water resources of the Okavango River Basin. The specific objectives of the project are to:

- Enhance the depth, accuracy and accessibility of the existing knowledge base of basin characteristics and conditions and identify the principal threats to the transboundary water resources of the Okavango River Basin through a Transboundary Diagnostic Analysis (TDA)
- Develop and implement, through a structured process, a sustainable and cost-effective programme of policy, legal and institutional reforms and investments to mitigate the identified threats to the basin's linked land and water systems through the Strategic Action Programme (SAP)
- Assist the three riparian nations in their efforts to improve their capacity to collectively manage the basin.

Local Soba meeting place, Cuelei, Angola

1.4. TRANSBOUNDARY DIAGNOSTIC ANALYSIS AND STRATEGIC ACTION PROGRAMME[2]

A Transboundary Diagnostic Analysis (TDA) is a scientific and technical assessment of an area of international waters that identifies and quantifies environmental issues and problems and establishes their immediate, intermediate and fundamental causes. The analysis then assesses the scale and distribution of the potential impacts of these causes at national, regional and global levels, predominantly in socio-economic terms, and identifies potential remedial and/or preventative actions.

Although TDAs can be conducted by, and within, single countries, the need to identify transboundary effects and causes makes it desirable that the TDA process be conducted multilaterally with the participation of all the riparian states of an international water body. Ideally, the sequence of causes should be identified in a hierarchical manner from technical perspectives, through management and socio-economic perspectives, to the political (i.e. policy) level.

Damaged hydrological Station, Rio Cuito, Cuito Cuanavale, Angola

Accordingly, the term *'root causes'* should be reserved for the most fundamental in this hierarchy of causes. According to the GEF, this identification of the hierarchy of causes is known as a causal chain, or root cause analysis. It is intended to help specify potential actions to remedy current environmental problems or to address environmental threats. The most effective of these options for intervention then constitute the basis of a Strategic Action Programme (SAP) that can be formulated and applied by all riparian countries.

The Okavango TDA offers a framework to examine socio-economic benefits and environmental conditions across the basin. As such, the TDA underpins the SAP design and indicates monitoring and reporting criteria for SAP implementation. Most importantly, the consultative process of completing the TDA informs policies and initiatives to be launched in preparation for SAP implementation.

2 This section was abstracted from GEF IW literature available on the web. Bewers, J.M. (2001) Conducting a TDA – an initial review of existing Transboundary Diagnostic Analysis guidelines for the identification of components warranting specific evaluation from user perspectives.

The Okavango SAP includes baseline and additional actions to address priority transboundary issues and provides a monitoring and evaluation tool for implementation. It recommends development and testing of a set of institutional mechanisms and implementation methodologies, including pilot demonstrations that explicitly link regional, national and local initiatives in land and water management. Additionally, it involves preparation of a basin-wide framework in which transboundary priorities can be addressed and project interventions monitored.

A Chimapaca (reservoir made to hold water throughout the dry season, mainly for cattle watering in Cunene Province)

1.5. THIS TDA REPORT

The report is divided into six chapters, inclusive of this introduction.

Chapter 2 outlines the current hydrological, environmental, social and economic systems of the basin. It provides an analysis of the contributions made by the basin's natural resources to local livelihoods and national economics, as well as describing the status of regional and national governance for the basin, covering relevant legislation, policies and institutions.

Chapter 3 describes the TDA process and methodologies used. It covers the overall approach of the TDA and includes a description of the causal change analysis, the consultation process, and the management and people involved in the development of the TDA.

The main drivers of change (or root causes) and their role in determining future water resources developments and demand for water are highlighted in **Chapter 4**. The changes in water use are complemented by descriptions of trends in other fields such as land use and vegetation cover, sediment and erosion, water quality and the use of natural resources. It also examines potential transboundary challenges.

Liyapeka Rapids, Angola

Chapter 5 examines predicted impacts of the trends described in Chapter 4 and, using field-based evidence, identifies hotspots and key issues of concern. Causal change analyses are used to extrapolate the predicted effects on the basin as a whole.

Finally, **Chapter 6** focuses on the priority issues identified by the TDA. Recommendations for action are drawn out of these for all aspects of the basin. The chapter stresses the importance of addressing the macro-economic and governance issues that will lead towards the Strategic Action Programme.

While the three riparian countries have different names for the river: Cubango in Angola, Kavango in Namibia and Okavango in Botswana, to maintain consistency this report refers to the Okavango River/Basin throughout.

A data DVD containing all the EPSMO data in TDA basin-wide reports has been included with this document for easy referencing.

CHAPTER 2: THE OKAVANGO RIVER BASIN – ITS PEOPLE AND ENVIRONMENT

This chapter summarises studies of the biophysical and socio-economic status quo of the Okavango River Basin. Detailed results and analyses within the different disciplines can be found in the full reports contained in the DVD attached to this report. The chapter builds upon work established by John Mendelsohn and Selma el Obeid in their book *Okavango River: The flow of a lifeline* and accompanying database (RAISON).

For the purposes of this TDA, the studied area would comprise the perennial tributaries in the headwaters in Angola and the main river and catchment areas assumed to be associated with it. For some chapters and sections, however, this area was expanded to the administrative boundaries within which OKACOM is expected to operate for sustainable management of the water resources of these rivers.

2.1 GEOGRAPHIC SCOPE AND BOUNDARIES

The Okavango River flows from the highlands of Angola, through Namibia and into Botswana, where it forms the Okavango Delta. Figure 2.1 shows the location of the Okavango River Basin within southern Africa. The topographic limits of the basin have been delineated with the use of digital elevation models and are calculated to cover 707,000 km2. Within these topographic limits, much of the area in Namibia and Botswana is hydrologically dormant or contributes flow only periodically when rare rainfall events trigger runoff and groundwater recharge.

It is important to note that the Okavango River Basin includes areas with limited developed surface drainage, river channels that have not seen continuous flow in living memory, river systems with mainly headwater flows and rivers with limited and uncertain flow contribution to the main river. These areas were not considered in the TDA, which focuses on the flows in the perennial tributaries in the headwaters in Angola and in the main river.

Heronry, Okavango Delta, Botswana

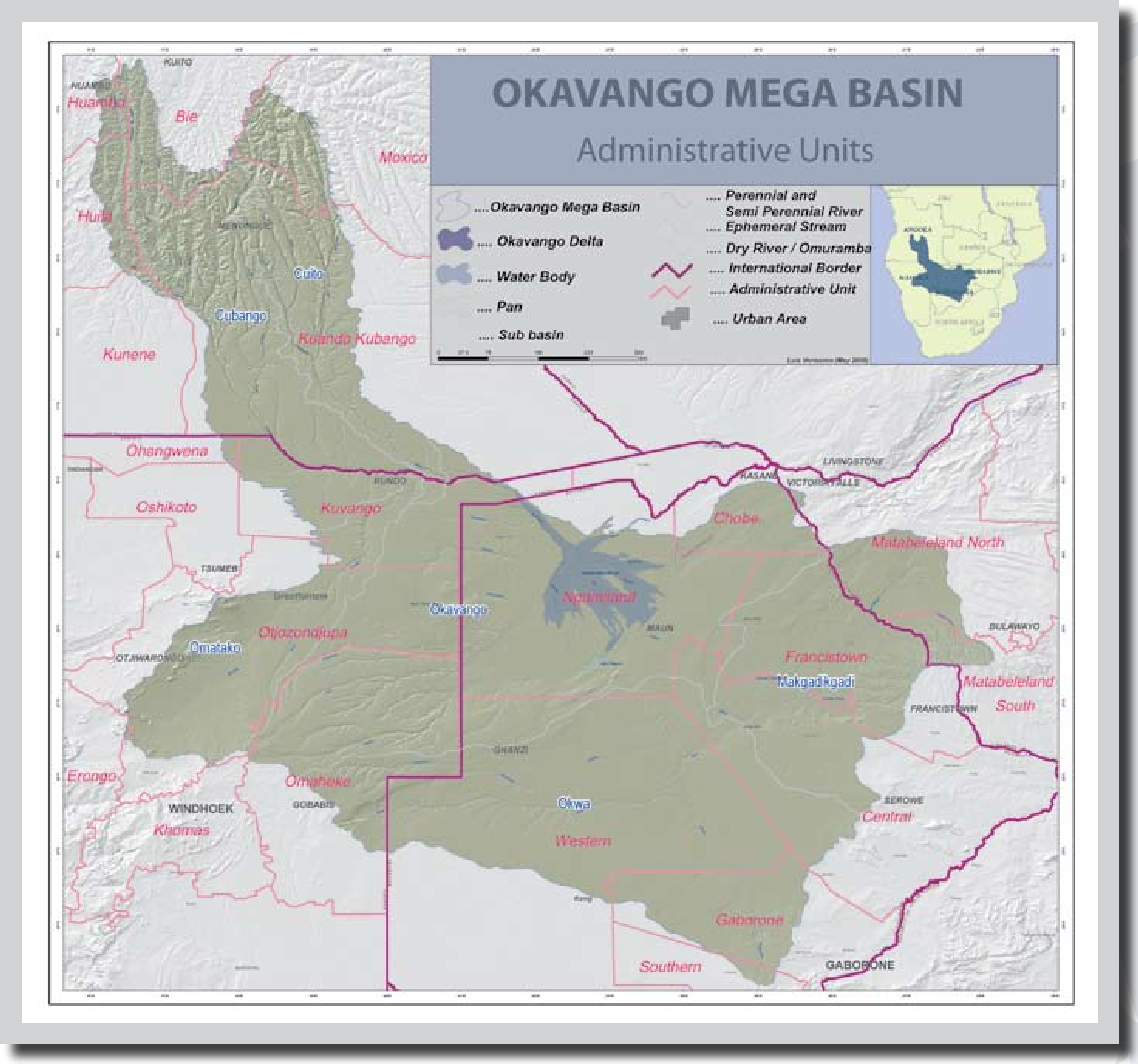


Figure 2-1: Okavango basin topographic limits, sub-basins and administrative boundaries

This topographic basin limit includes the area that is drained by the ephemeral Omatako River in Namibia. Outflows from the Okavango Delta are drained through the Boteti River which eventually joins the Makgadikgadi Pans The areas associated with each sub-basin are presented in Table 2.1. The Nata River drains the western part of Zimbabwe, discharging into the Makgadikgadi Pans from the east. The TDA study focuses on the perennial parts of the river situated in Angola, Namibia and Botswana, including the Delta and the Boteti River, but not the Makgadikgadi Pans or the ephemeral Nata River, which drains the western part of Zimbabwe, discharging into the Makgadikgadi Pans from the east.

The basin covers parts of five provinces of Angola, one region in Namibia and one district in Botswana (Table 2-2). Urban centres in the basin are found at Menongue and Cuito Cuanavale in Angola, Rundu in Namibia and Maun in Botswana. The administrative units lying within the Okavango River Basin are shown in Figure 2-3.

TABLE 2-1: TOTALS REFER TO OKAVANGO TOPOGRAPHIC BASIN

Subbasin	sq km (UTM 34S)
Cuito	58,839.1
Cubango	107,754.0
Omatako	59,542.5
Okavango	205,111.9
Makgadikgadi	92,379.6
Okwa	167,028.5
Total	**690,655.5**

Country	Administrative unit	sq km	% contribution to basin area
Angola	Bie	11,755.1	1.7%
	Huambo	3,502.7	0.5%
	Huila	8,297.7	1.2%
	Kuando Kubango	113,059.0	16.4%
	Kunene	851.1	0.1%
	Moxico	13,941..0	2.0%
Angola Total		**151,406.4**	**21.9%**
Botswana	Central Region	48,722.4	7.1%
	Chobe	14,368.7	2.1%
	Francistown Region	46,832.2	6.8%
	Gaborone Region	27,271.4	4.0%
	Ngamiland	93,461.9	13.5%
	Southern Region	1,314.5	0.2%
	Western Region	113,293.8	16.4%
Botswana Total		**345,704.0**	**50.1%**
Namibia	Erongo	146.8	0.0%
	Khomas	46.4	0.0%
	Kuvango	38,486.7	5.6%
	Ohahgwena	912.4	0.1%
	Omaheke	56,570.2	8.2%
	Oshikoto	103.5	0.0%
	Otjozondjupa	72,008.1	10.4%
Namibia Total		**168,274.0**	**24.4%**
Zimbabwe	Matabeleland North	19,255.8	2.8%
	Matabeleland South	6,044.0	0.9%
Zimbabwe Total		**25,269.8**	**3.7%**
Basin Total		***690,654***	***100.0%***

Note: EPSMO data based on UTM 34S

1 Administrative divisions in Angola are known as provinces, in Namibia as regions, and in Botswana as districts.
2 The part of the basin drained by the ephemeral Omatako River has been included in estimating the area of the basin within the Kavango Region.
3 The area of the basin in Botswana was taken as the area of the Okavango Delta Ramsar Site (DEA, 2005)

2.2 BIOPHYSICAL CHARACTERISTICS

2.2.1 Physical characteristics and water attributes

Geology

Four major geological periods dominate the features of the Okavango Basin (Table 2-2).

TABLE 2-2: DESCRIPTION OF MAJOR GEOLOGICAL PERIODS

Geological Period Million years ago	Dominant geology	Location
2,500-1,800	Granite, gneiss quartz	Highland catchment, Cubango
700-550	Dolomite, schist, sandstone (Damara Group)	Eastern Angola and central Namibia, north-eastwards to the south of the Delta; Scattered outcrops in southern Kavango and western Ngamiland; Popa Falls
300-180	Sediments compressed into coal, shale, sandstones (Karoo Group)	North-eastern parts of the Cubango, central Namibia and south of the Delta
65-2	Kalahari sands, other sediments	Underlying much of the length of the Okavango River

The oldest rocks of the basin were formed by volcanic and metamorphic processes, while the Damara Group rocks were laid down when the continent of Gondwana was created, forming the foundation of the land through which the Okavango now flows. During much of the past 65 million years, sediments were carried down into huge lakes and deltas and it is only in the last two million years that much of the basin has dried up.

Topography

The headwaters of the Okavango River are located between Huambo and Cuito at an altitude of 1,700-1,800 metres above sea level on the central highlands of Angola and drop to just over 900 metres above sea level in the Delta. The elevation map of the mega basin (Figure 2-4), illustrates the key topographical features. The gradients of the Cubango/Okavango and Cuito Rivers from the Angolan highlands to the Delta are shown in Figure 2-5.

Partial view of the Liyapeca Rapids, Cuando Cubango Province, Angola

The Okavango Delta is the most significant feature of the basin. It is a conical alluvial fan on Kalahari sands with a gradient of 1:3,300. The Delta is made up of active and inactive distributary channels, islands and floodplains.

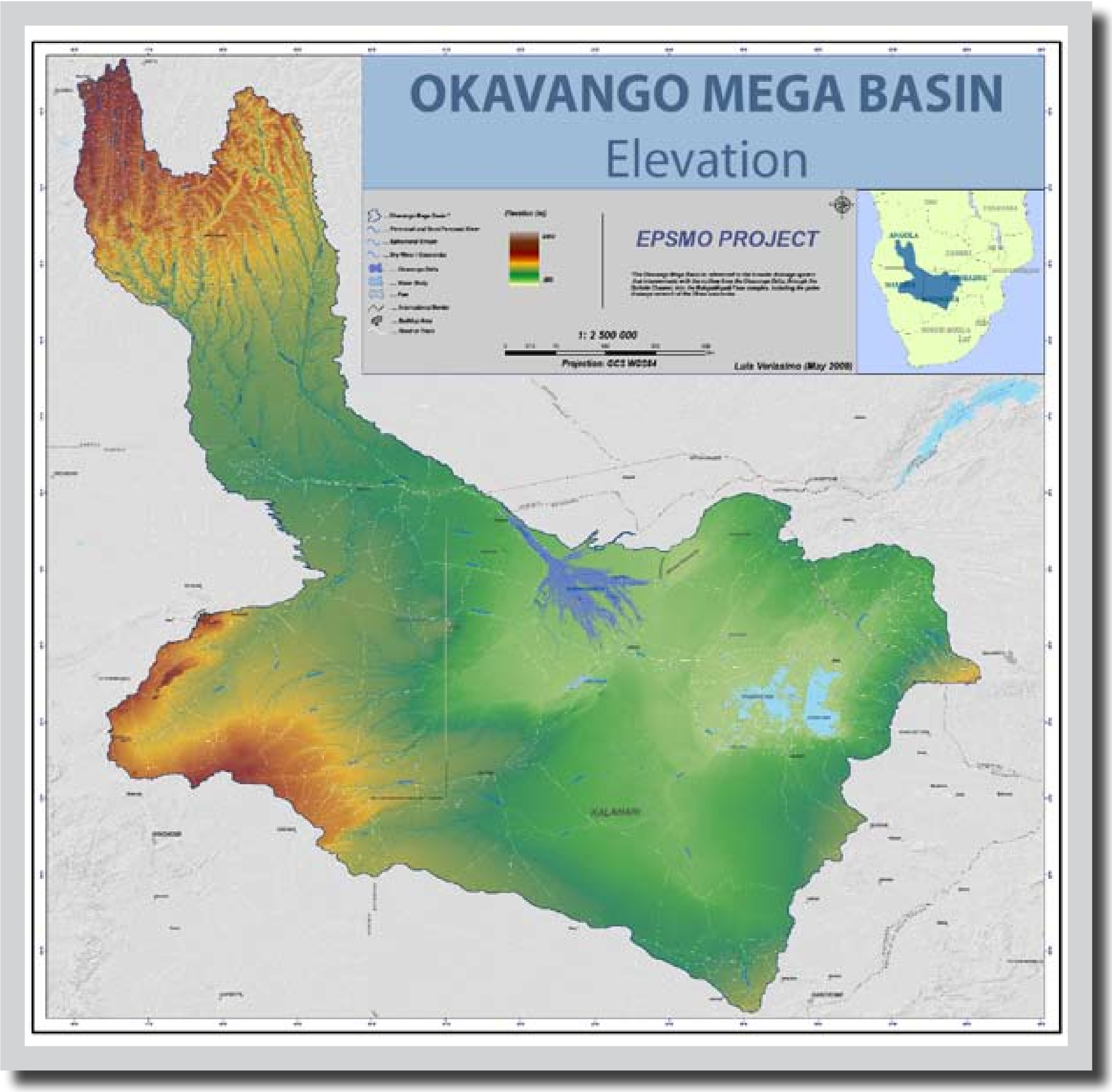


Figure 2-4: Okavango Basin – elevation and topography

Source: Mendelsohn and el Obeid 2004

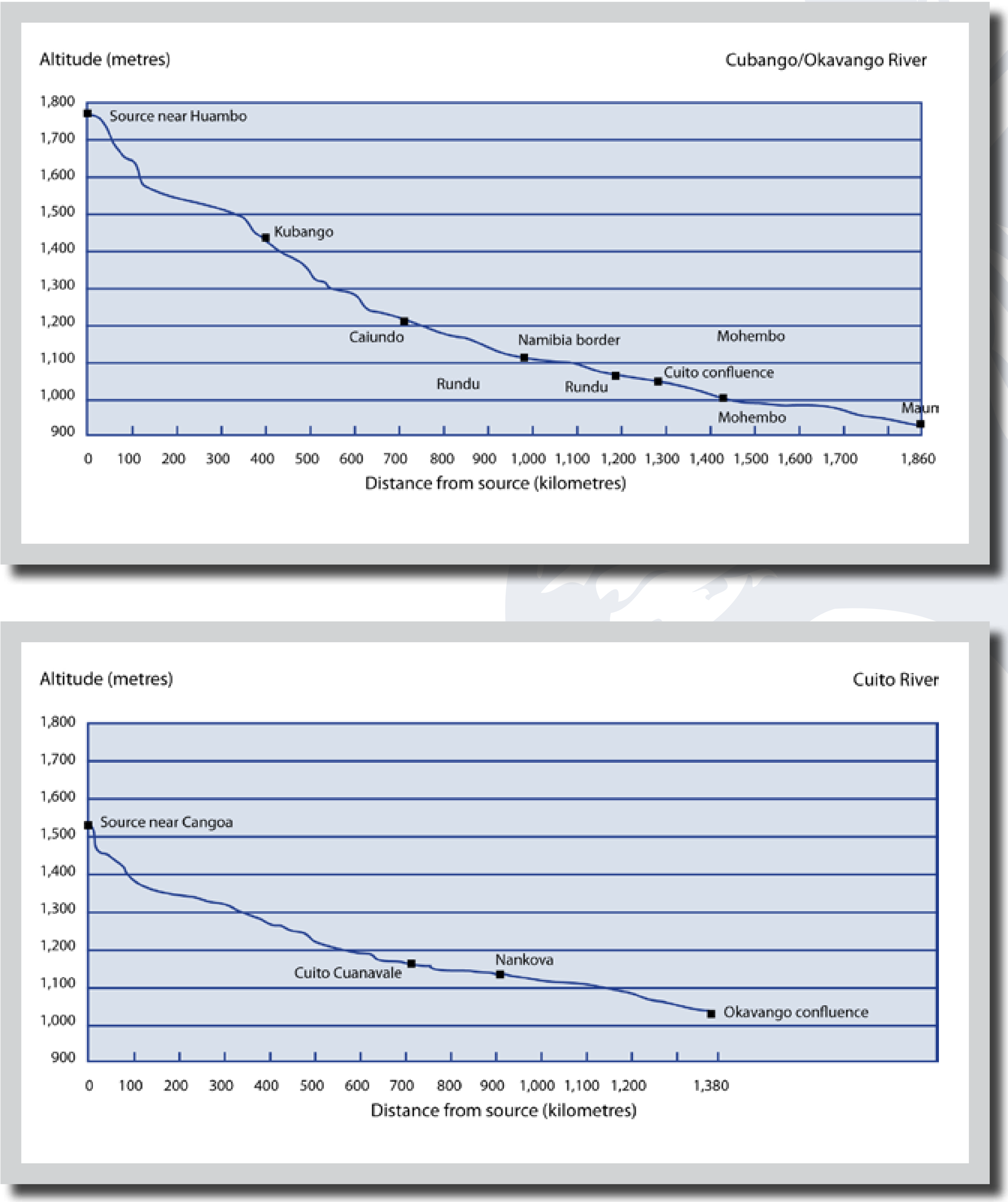


Figure 2-5: Gradients of the Cubango/Okavango and Cuito Rivers

Source: Mendelsohn and el Obeid 2004

Catchment zones and river morphology[4]

The Okavango River can be divided into several zones of morphological similarity. Within these broad zones of the catchment, differing hydrological and sediment characteristics interact to yield distinctive river dynamics and forms. These are used to group the ecosystem zones described in Section 2.2.2 and are:

- **Angolan headwaters** – The Cubango and Cuito Catchments
- **Middle reaches** – The lower Cuito and Cubango Rivers, as well as the Okavango upstream of the Panhandle
- **The Okavango Delta Panhandle** – The panhandle, which is formed by two parallel faults
- **The Delta** – The Okavango Delta comprising both permanent and seasonal swamp areas.

4 TDA contribution by Mark Rountree [mark.rountree@iburst.co.za]

Soils

The soils of the north-western part of the Cubango are low in nutrients and easily exhausted by crop production, but are often deep, permeable and with a stable soil structure so that they are more resistant to erosion. [5]

Most of the rest of the Angolan part of the basin through which the Cuito flows, is dominated by Kalahari sands, which extend to at least one metre, have less than 10% clay or silt content, and contain low nutrients. They are very porous, so that water drains rapidly, leaving little moisture for plants to access.

The soils that follow the river channels and floodplains consist of a mix of silt, clay and fine sands. They were deposited by high water flows and are usually characterised by a rich organic and nutrient content, especially in the Delta, where nutrients have progressively accumulated over many years. Immediately to the south of the Okavango in Namibia, repeated ploughing and crop production have resulted in soils of low nutrient content and may be subject to erosion as a result of vegetation clearing.

The Delta is the most fertile area in the basin. The soils are an accumulation of organic matter that is porous, well-aerated and found mainly in the outer areas of the Delta where there is less frequent flooding. Deep accumulations of clay and organic matter, that are perhaps the most fertile soils in the basin, are also present around the Delta.

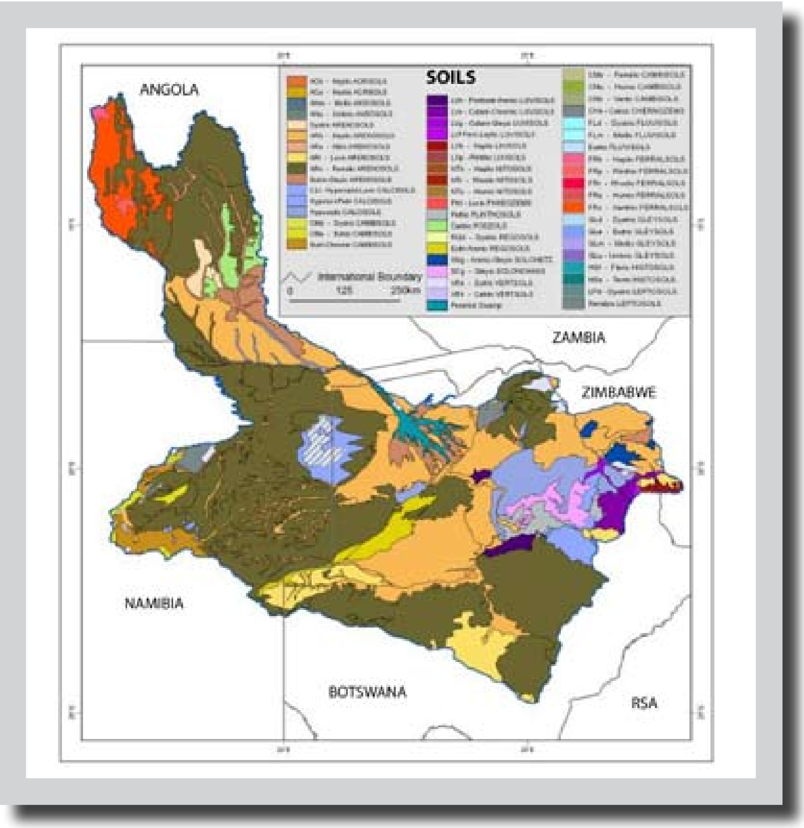


Figure 2-6: Soil map of the Okavango Basin

2.2.2 Climate and climate variability

The Okavango Basin lies within the 12° to 21° South latitude zone, which is characterised by rainfall in one distinct season, October to May. The northern parts of the basin receive the highest rainfall during the December to January period, while the southern parts, such as Maun, have peak rainfall during January and February. Mean annual rainfall varies from about 1,300 mm/a in the Huambo and Cuito areas in the headwaters of the basin, to 560 mm/a at Rundu, 550 mm/a at Mohembo, and 450 mm/a at Maun (Figure 2-7). The rainfall is highly variable and there is a tendency that high rainfall years group for a period and are then followed by below average rainfall years. Years with extremely low rainfall occur frequently, particularly in the southern parts of the basin.

Average daily maximum temperatures range between 30-35°C from August to March in the Namibian and Botswana parts of the basin. Average minimum daily temperatures are in the 7-10°C range during the June to July cool season.

5 Information abstracted from Mendelsohn, J. and el Obeid, S. (2004) and Christian, C. (2009).

Evaporation increases from north to south in line with increasing temperatures as can be seen in Figure 2-8. The average monthly evaporation rate is greater than monthly rainfall for all months in the middle to southern parts of the basin, thus most of the Okavango River Basin lies within a semi-arid zone.

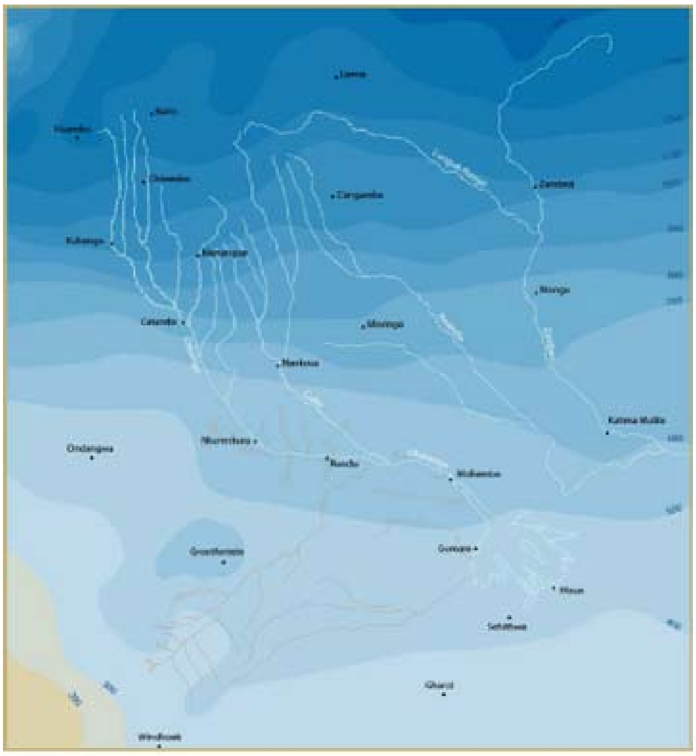
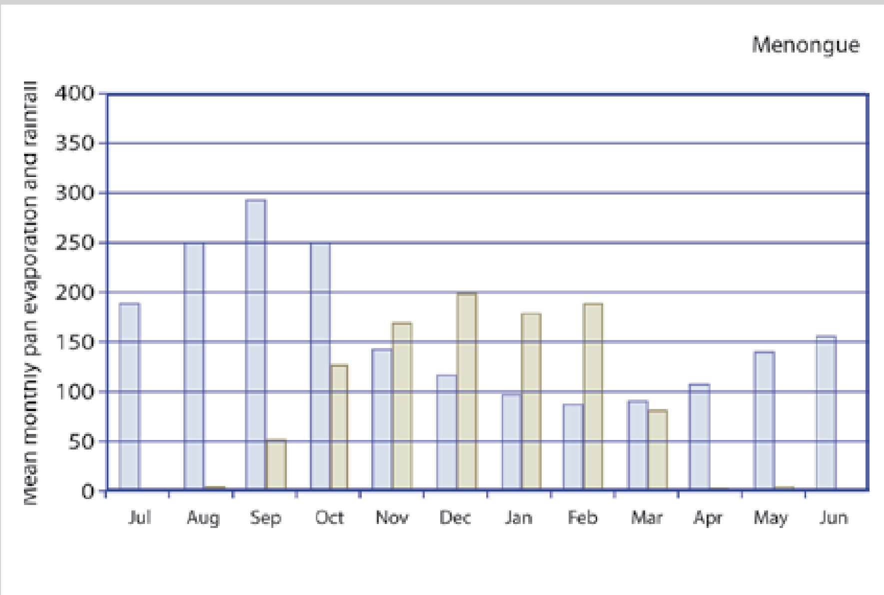
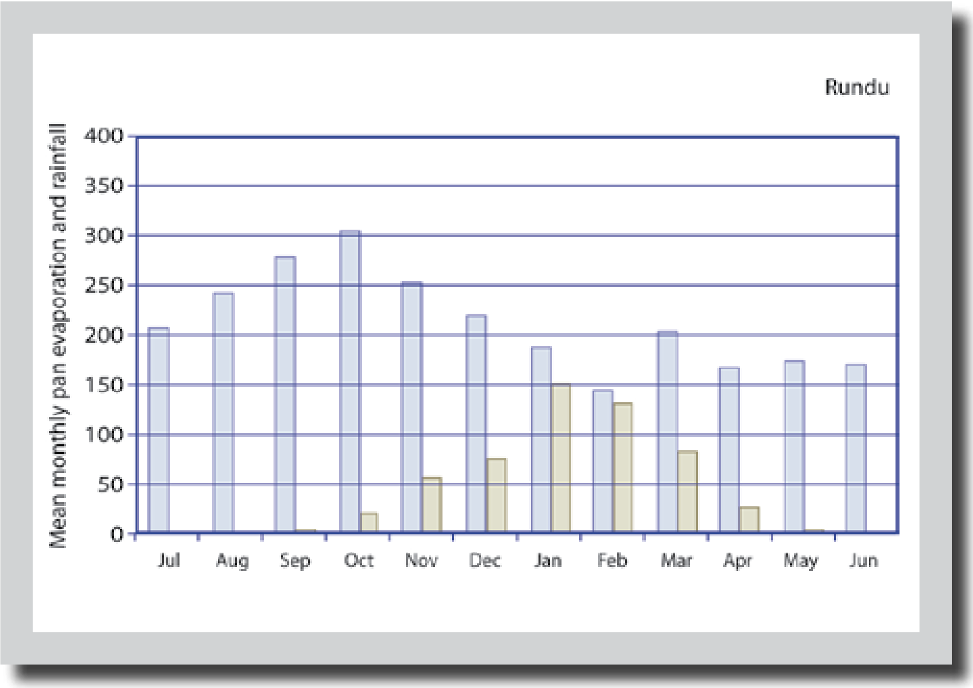


Figure 2-7: Annual rainfall patterns, showing the gradient from north to south of the basin.

Source: Mendelsohn and el Obeid 2004
(Perennial rivers shown in white and dry tributaries shown in brown)





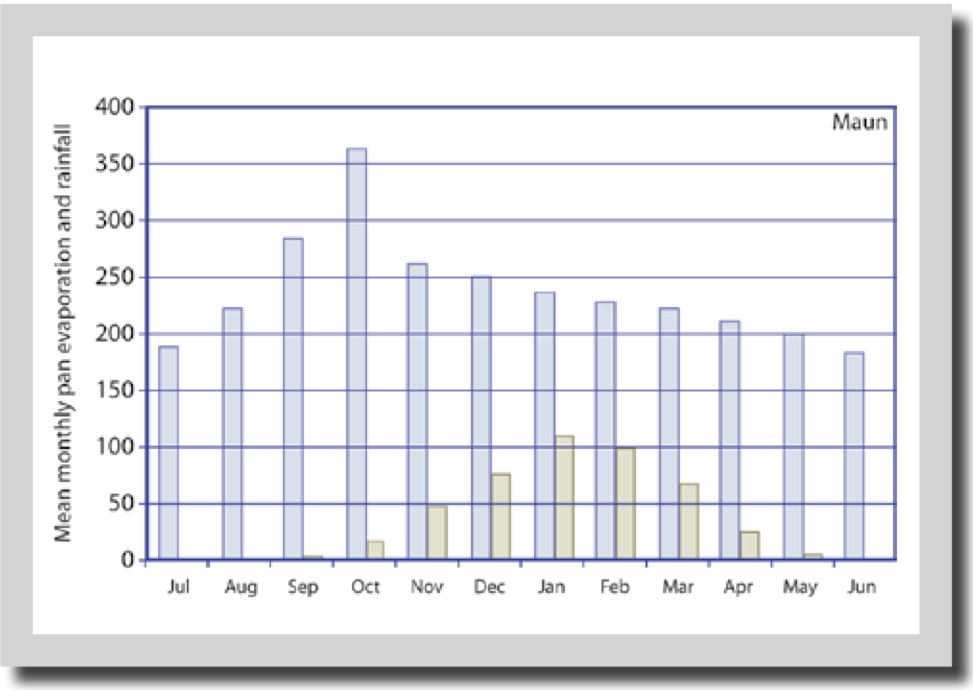


Figure 2-8: Balance of rainfall and evaporation throughout the year at Menongue, Rundu and Maun

There is long-term variability in the flow of the Okavango River and while it is not clear what causes this, it could simply result from normal inter-annual variability and randomness of rainfall. However, there is a very good relationship between the long-term rainfall in the Okavango and a long-term mode of variability in sea surface temperatures known as Pacific Decadal Oscillation (PDO). This could mean that the observed long-term variability in Okavango rainfall is caused in a way similar to how El Niño affects rainfall all around the world.

This hypothesis allows projections on the predictability of long-term variability of rainfall and runoff, because PDO is considered to result from natural processes. Recent research suggests that it is preserved under conditions of green-house gas-driven climate change. The alternative to this hypothesis is randomness. The reality is probably a combination of both – the effect of PDO modified by unpredictable randomness.

A separate study has been done on the impacts of climate change on precipitation and flows in the Okavango, and how to address and adapt to these changes. The report of this study is available as a companion volume to this TDA. Climate change is considered as a driver of change (Chapter 4).

2.2.3 Hydrology and sediment dynamics and water quality

Hydrology (flow patterns in the basin)

The flow measuring network across the portion of the basin that contributes to perennial flow is presented in Figure 2-? and basic data tabulated in Table 2-?. With 11 functional measuring stations, but only four in Angola, the network provides a limited basis for overall water resource assessment. However, it is inadequate for detailed water resource management in Angola and flood forecasting across the whole basin. These limitations notwithstanding, this hydrometric network provides the hydrological baseline for the detailed TDA analysis presented in the key hydrological reports (Beuster et al. 2009a, Beuster et al. 2009b. This serves to illustrate that there are no operational hydrological monitoring stations upstream of Rundu and none on any of the major tributaries where more than 90% of the runoff is generated.

From the description of the rainfall patterns, it is clear that virtually all the water flowing into the Delta comes from the upper catchment – the Cubango and Cuito rivers. Table 2-3 provides estimates of the contributions of the different sub-catchments to the overall flow in the river. Figure 2-9 shows the main catchments.[6]

TABLE 2-3: CONTRIBUTIONS OF THE OKAVANGO TRIBUTARIES TO THE MAIN FLOW IN THE RIVER

River / zone	Area km²	Mean Annual Rainfall mm	Mean Annual Runoff Mm³/year	Percentage contribution
Cubango	14,400	1,028	1,846.3	17%
Cutato	4,200	1,220	800.1	7%
Cuchi	8,900	1,117	821.2	8%
Cacuchi	4,800	1,207	759.5	7%
Cuelei	7,500	1,114	697.4	6%
Cuebe	11,200	969	678.8	6%
Cuatir	11,600	787	134.3	1%
Cueio	3,700	787	57.0	1%
Cuiriri	12,900	986	565.8	5%
Cuito	24,300	1,051	3,338.7	31%
Cuanavale	7,750	1,073	595.6	5%
Lower Okavango	45,000	608	620.0	6%
Total (upstream of Delta)	**156,250**	**837**	**10,914.7**	**100%**
Delta	35,300	469	0	0

6 The information for this section is drawn from Beuster, H. (2009 a and b)

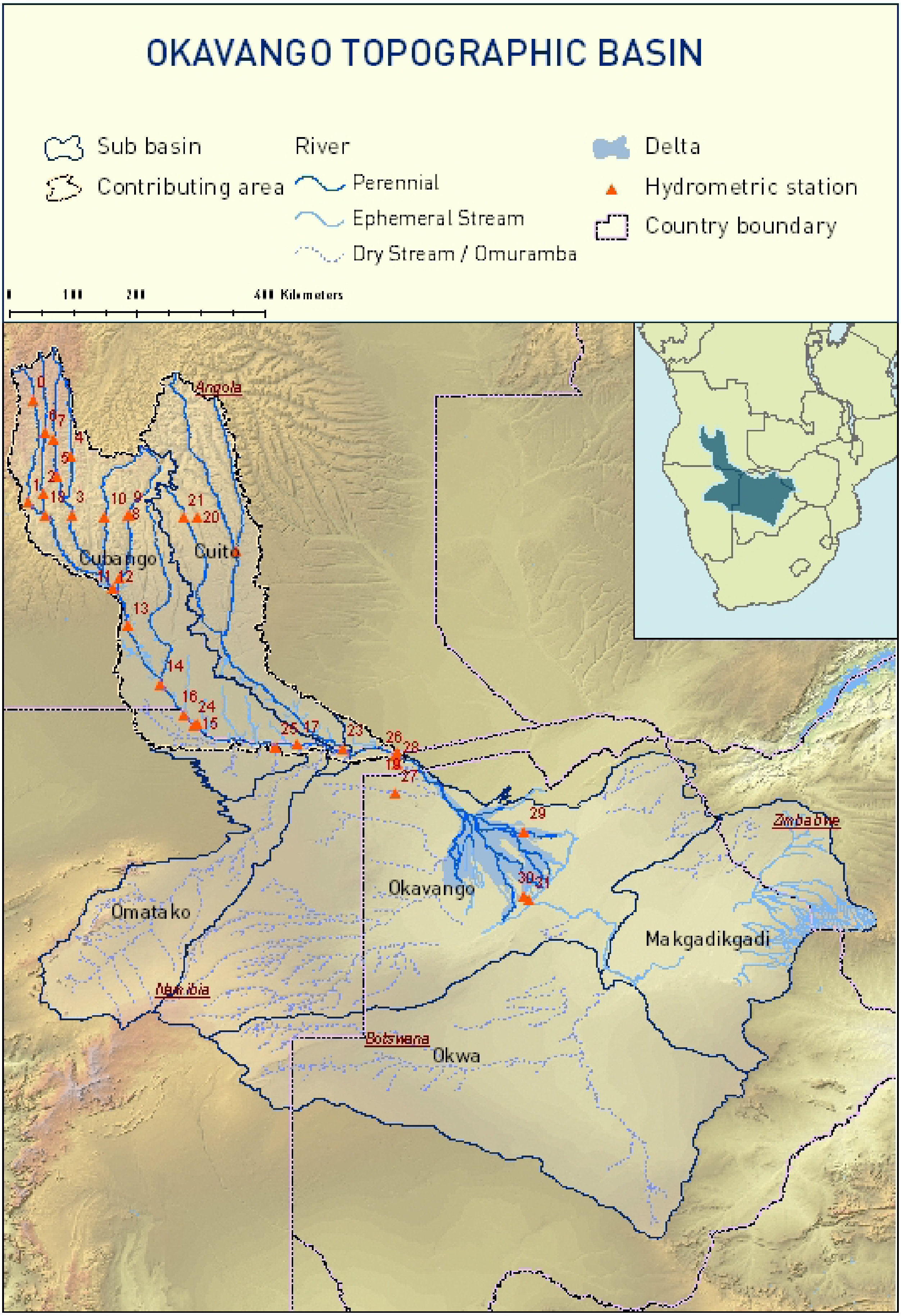

OKAVANGO TOPOGRAPHIC BASIN
Sub basin
Contributing area
River
Perennial
Ephemeral Stream
Dry Stream / Omuramba
Delta
Hydrometric station
Country boundary
Kilometers
Angola
Cubango
Cuito
Namibia
Botswana
Zimbabwe
Omatako
Okavango
Makgadikgadi
Okwa

TABLE 2-3: MAIN SUB-BASIN CONTRIBUTING AREAS AND AREAS LYING WITHIN EACH COUNTRY

ID	Country	Name of the Station	Ref no	River	Latitude	Longitude	Status	Beginning of Records	Rating Curve	lat–dd	lon_dd
0	Angola	Chinhama	637508	Cubango	13º03′00″	16°22′00″	Destroyed	Jan-66	YES	-13.05	16.36666667
1	Angola	Cuvango (Artur de Paiva)	637520	Cubango	14°29′00″	16°17′00″	Destroyed	Oct-65	YES	-14.48333333	16.28333333
2	Angola	Cutato	637528	Cutato	14°22′00″	16°30′00″	Destroyed	Nov-70	YES	-14.36666667	16.5
3	Angola	Cuchi(*)	637506	Cuchi	14°40′00″	16°54′00″	Functional	Oct-70	YES	-14.66666667	16.9
4	Angola	Camué	637504	Cacuchi	13º50′00″	16º53′00″	Destroyed	Sep-68	NO	-13.83333333	16.88333333
5	Angola	Unongue	637519	Cuchi	14º07′00″	16º42′00″	Destroyed	Dec-69	NO	-14.11666667	16.7
6	Angola	Jamba-Cutato	637528	Cutato	13º31′00″	16º32′00″	Destroyed	Nov-70	NO	-13.51666667	16.53333333
7	Angola	Jamba-Cuchi	637529	Cuchi	13º36′00″	16º39′00″	Destroyed	Nov-70	NO	-13.6	16.65
8	Angola	Menongue I(*)	637517	Cuébe	14°40′00″	17°42′00″	Functional	Oct-64	YES	-14.66666667	17.7
9	Angola	Menongue II(*)	637518	Luhaúca	14°40′00″	17°43′00″	Recently vandalized	Oct-62	YES	-14.66666667	17.71666667
10	Angola	Cuélei	637514	Cuélei	14°41′00″	17°22′00″	Destroyed	Jun-66	YES	-14.68333333	17.36666667
11	Angola	Capico(*)	637503	Cuébe	15°33′00″	17°34′00″	Functional	Feb-62	YES	-15.55	17.56666667
12	Angola	Caiündo(*)	637501	Cubango	15º42′00″	17°28′00″	Functional	Jan-57	YES	-15.7	17.46666667
13	Angola	Mucundi	637512	Cubango	16º13′00″	17º41′00″	Destroyed	May-57	YES	-16.21666667	17.68333333
14	Angola	Foz do Cuatir	637511	Cubango	17º02′00″	18º09′00″	Destroyed	Oct-62	NO	-17.03333333	18.15
15	Angola	Cuangar	637502	Cubango	17º35′00″	18º39′00″	Destroyed	Sep-69	NO	-17.58333333	18.65
16	Angola	Chissombo	637509	Cubango	17º28′00″	18º29′00″	Destroyed	Sep-69	NO	-17.46666667	18.48333333
17	Angola	Sambio (**)	637516	Cubango	17º53′00″	20º04′00″	Deactivated	Jan-62	YES	-17.88333333	20.06666667
18	Angola	Mumba	637513	Cubango	14º40′00″	16º31′00″	Destroyed	May-68	YES	-14.66666667	16.51666667
19	Angola	Mucusso	637525	Cubango	18º00′00″	21º27′00″	Destroyed	N/A	NO	-18	21.45
20	Angola	Quiriri-Ponte	637515	Quiriri	14º41′00″	18º40′00″	Destroyed	Jan-65	NO	-14.68333333	18.66666667
21	Angola	Longa-Ponte	637539	Longa	14º42′00″	18º28′00″	Destroyed	N/A	YES	-14.7	18.46666667
22	Angola	Cuito-Cuanavale	637507	Cuito	15º10′00″	19º12′00″	Destroyed	Feb-62	YES	-15.16666667	19.2
23	Angola	Dirico	637510	Cuito	17º56′00″	20º42′00″	Destroyed	Jan-57	YES	-17.93333333	20.7
24	Namibia	Nkurenkuru	2511M02	Kavango	17º36′04″	18º36′36″	To be opened	Oct-10 (planned)	NO	-17.60111111	18.61
25	Namibia	Rundu	2511M01	Kavango	17º54′35″	19º45′40″	Functional	Oct-45	YES	-17.90972222	19.76111111
26	Namibia	Mukwe	2512M04	Kavango	18º02′09″	21º25′40″	Functional	Oct-49	YES	-18.03583333	21.42777778
27	Namibia	Andara	2512M07	Kavango	18º33′45″	21º26′55″	Functional	Oct-08	NO	-18.5625	21.44861111
28	Botswana	Mohembo (Okavango)	7112	Okavango	18°09′50.5434″	21°28′16.8018″	Functional	Oct-74	YES	-18.16388889	21.47111111
29	Botswana	Xakanaxa (Khwai)	7525	Okavango	19°06′18.8634″	23°14′35.3394″	Functional	Oct-71	YES	-19.105	23.24305556
30	Botswana	Maun Bridge (Thamalakane)	7812	Okavango	20°00′6.5514″	23°15′11.955″	Functional	Oct-70	YES	-20.00166667	23.25305556
31	Botswana	Samedupi (Boteti)	8112	Okavango	20°03′50.652″	23°18′46.947″	Functional	Oct-70	YES	-20.06388889	23.31277778

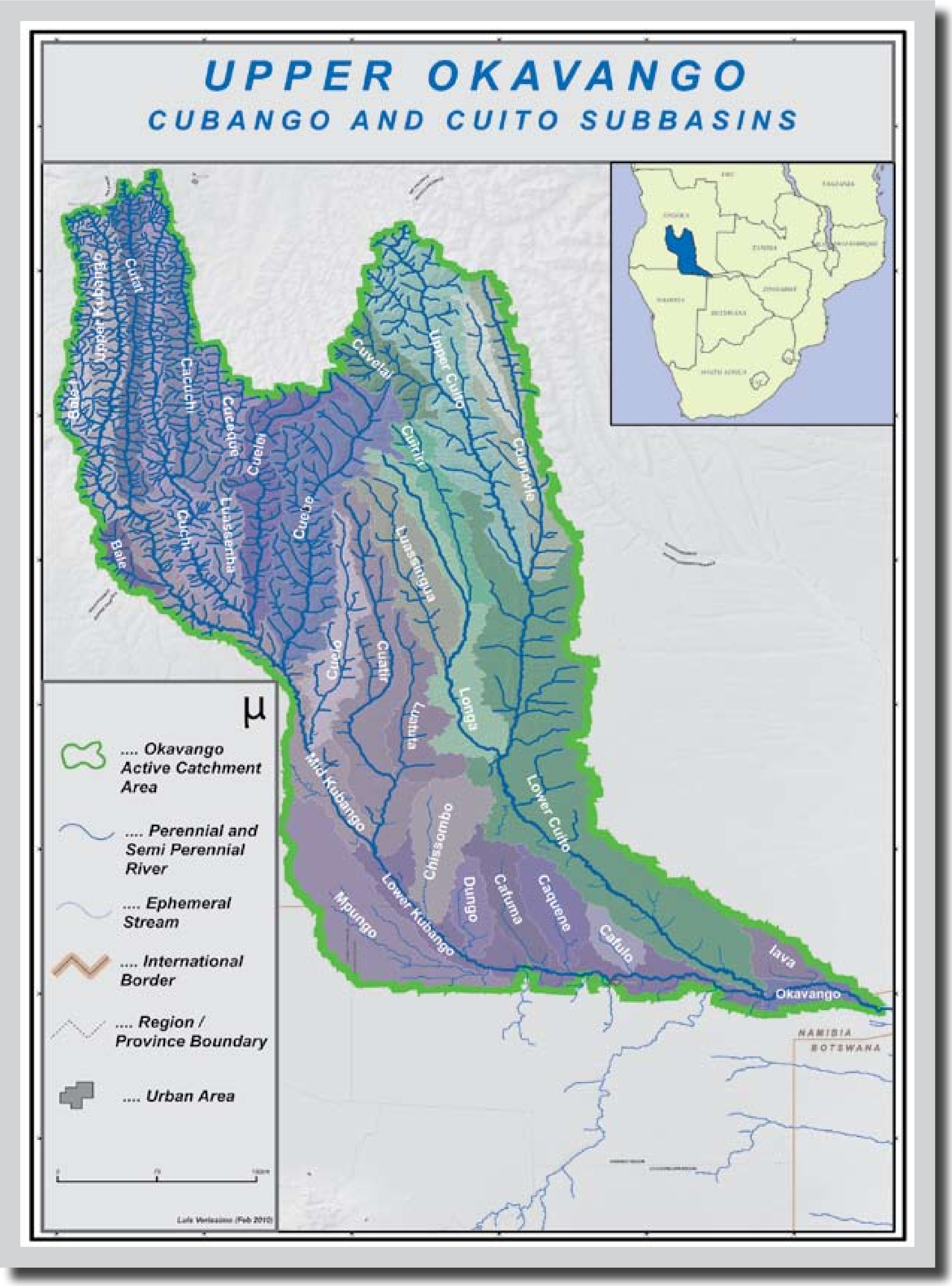
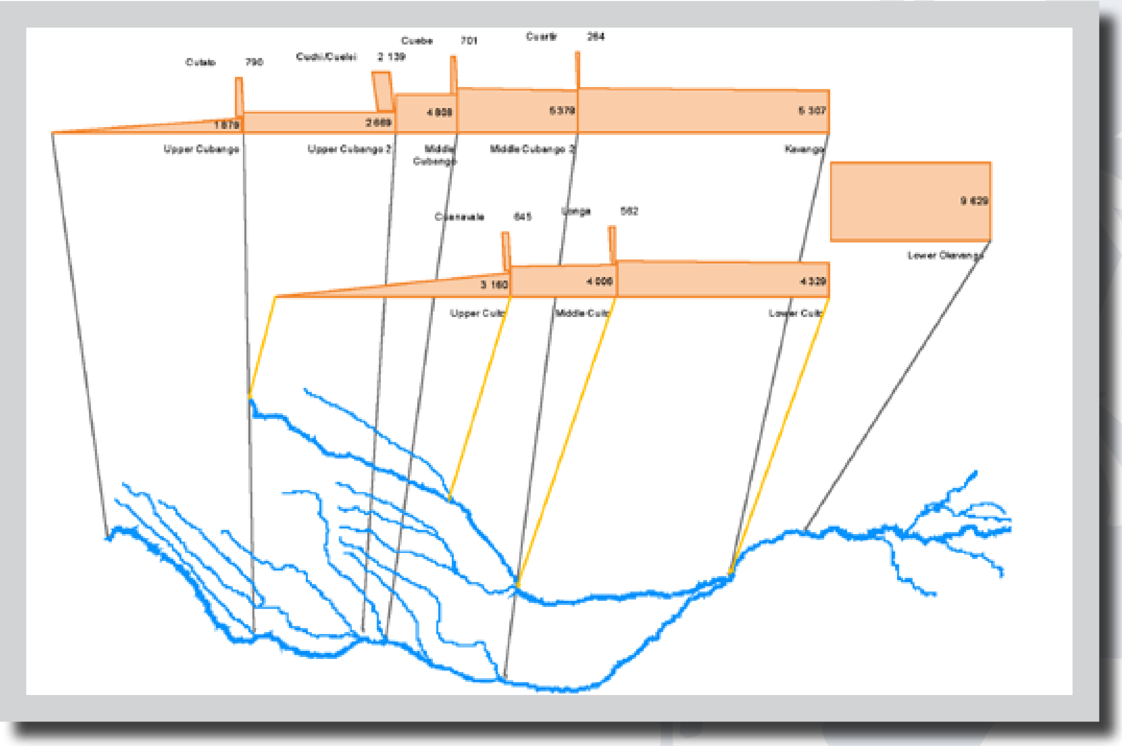
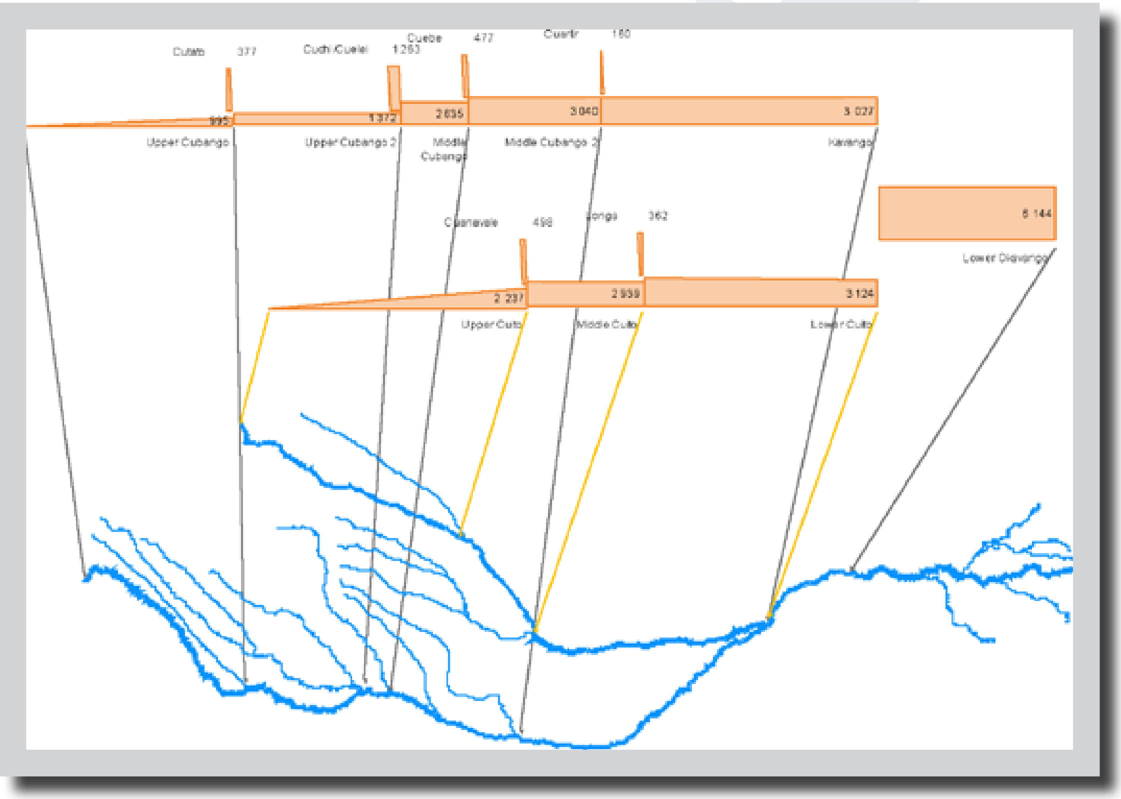


Figure 2-9: Sub-basins contributing to perennial flow in the Okavango basin

Figure 2-10 shows the present day mean annual runoff (MAR). Large losses from evaporation and about 60 Mm³/annum in abstractions (see below) reduce the runoff to about 9,600 Mm³/yr at the upper end of the Delta at Mohembo.



a): Mean Annual Runoff (Mm³/a)



b) Annual Runoff for driest year in 20 years (Mm³/a)

Figure 2-10: Present day flows in the Okavango River System

Mean annual precipitation in the upper catchment is of the same order of magnitude for the Cuito River and the upper Cubango River. Because of the nature of the rivers, the seasonal peak of the Cuito River is usually several weeks later than that of the Cubango, especially during low and medium flow years.

Once the river flows through a panhandle to reach the Okavango Delta, the flows are partitioned within the Delta between three main distributaries, the Thaoge, Boro and Maunachira Rivers. The substratum of channels is very permeable, resulting in substantial exchange of water between channels, floodplains and groundwater.

Popa Falls, Namibia

Droughts and floods

In very dry years (1:20 year drought conditions) the flows in the river are significantly restricted as shown by the flows in Fig 2-10(b), which closely resemble conditions experienced in the severe drought of 1998.

At Rundu, the range of observed low flows has been between 19.0 and 61.7 m^3/s, but flood peaks have ranged between 267.9 and 964.7 m^3/s. At Mukwe (downstream of the Cuito confluence) the range of low flows has been between 108.1 and 208.1 m^3/s with peak floods ranging between 384.8 and 1,177.4 m^3/s (DWA Namibia, 1994).

Flood peak contributions from the Cuito River cause a relatively small increase to flood peaks downstream of the confluence. This is due to the difference in flood response (lag) times of the two sub-basins, with the Cubango/Kavango floods rising much faster, and peaking at higher levels, than the Cuito.

Although historically, flooding in the basin does occur on a regular basis, the 2009 flood in the Cuvelai and Okavango regions had disastrous consequences as it had followed higher levels of flooding than the previous year. This was caused by a combination of above-normal rainfall received in the affected areas and high flood waters from southern Angola. The recent 2010 flood peak was slightly higher than the 2009 flood peak, with a much larger volume. The extensive impact of the 2009 floods was attributed to increased population settlement in the flood plains in the Okavango River.

Seasonal Variability – Seasonal river flow patterns in different parts of the basin vary widely. In the upper parts of the basin the seasonal variability corresponds closely to the occurrence of rainfall, but in the semi-arid Delta, the high-flow season occurs several months after the peak flows are recorded in Angola.

Seasonal flooding in the Okavango Delta is the result of a complex interaction of local, regional and basin-wide influences[7]. At the upstream end of the Delta, the flood peak occurs in April, and moves slowly across the Delta, taking 3-4 months to travel to Maun. Seasonal variation in the western parts of the Delta is strong compared to the eastern parts, where water levels show little seasonal variation.

Inter Annual Variability – In the Okavango River Basin, measured stream flows exhibit a long-term cyclical behaviour pattern of the order of 65 years, with a maximum in the 1960s, and a minimum in the late 1990s. This is based on an analysis of data obtained during the last 90 years. The cause for this is still unknown but it was found to be statistically significant. [8]

Figure 2-11 shows the average annual runoff measured at Mukwe, upstream of the Delta. The system is currently in a wetter period. River flow measurements made on the Thamalakane River at Maun, and the Boteti River at Samedupi and Rakops are illustrated in Figure 2-12.

7 McCarthy, T. S. et al. (2000)
8 Mazvimavi, D. and Wolski, P. (2006).

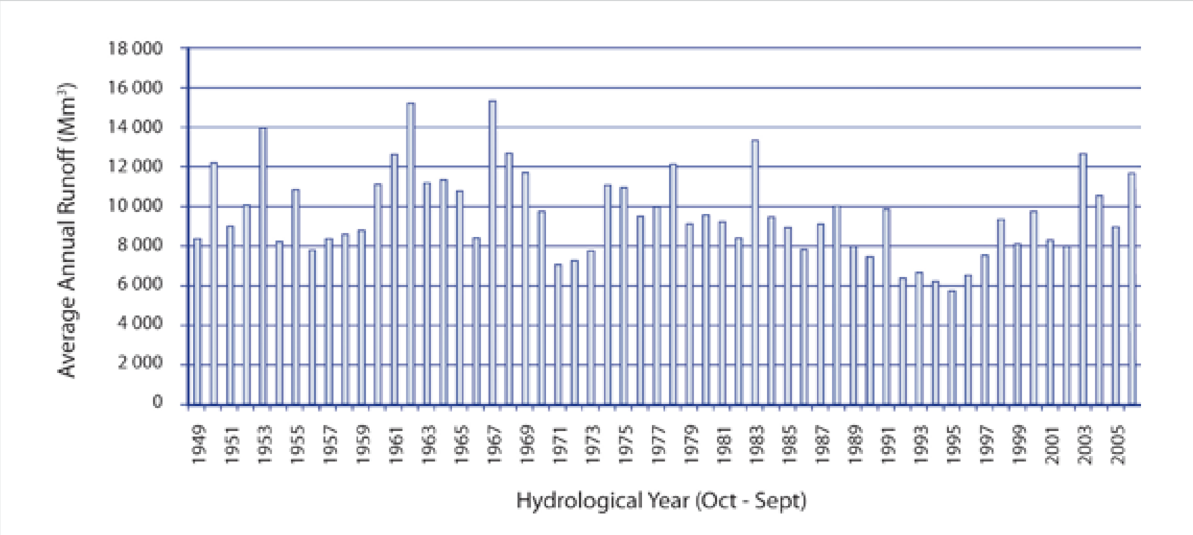


Figure 2-11: Annual runoff at Mukwe for the period 1949-2005

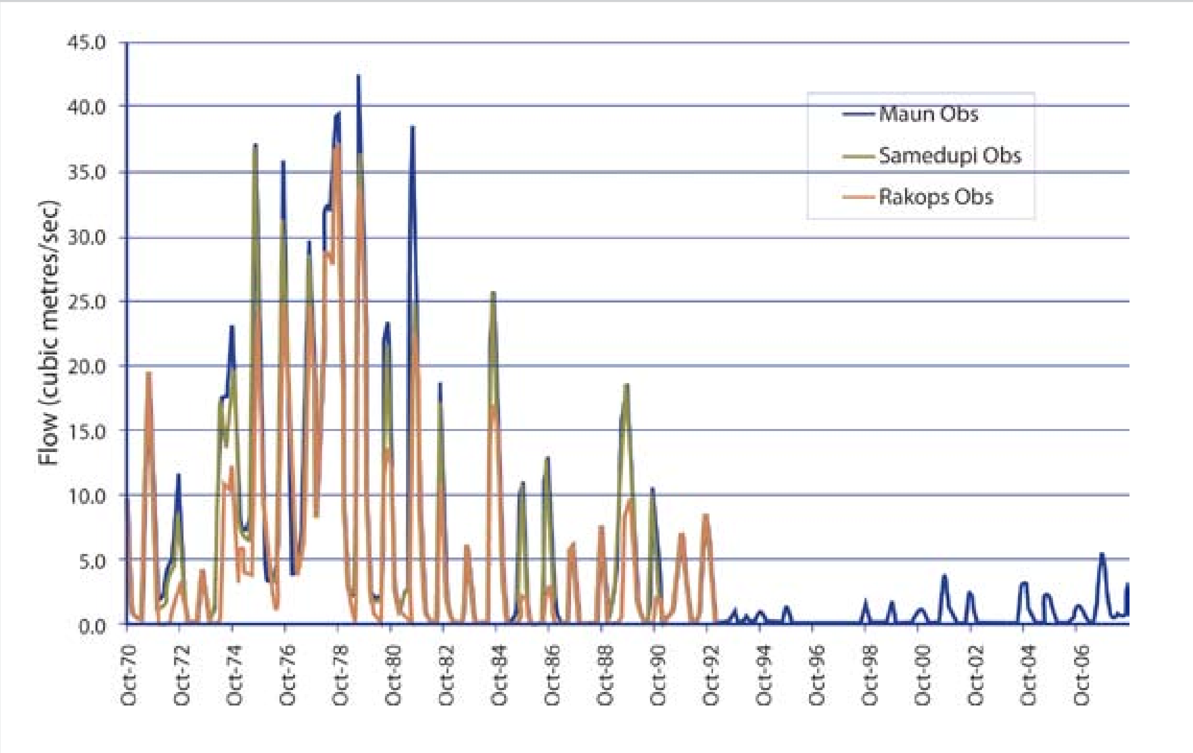


Figure 2-12: Observed monthly flows at Maun, Samedupi and Rakops

Groundwater

The role of shallow groundwater circulation in the basin is instrumental is maintaining the character of the Okavango's annual pulse. This is evident from baseflow characteristics and field observations. However, basic groundwater information for the Cuito and lower Cubango sub-basins remains sparse. Making a coherent account of the basin's hydrogeological processes and their relation to surface flows and quality will require more applied research (Jones, 2010). It is in these 'hinge' zones of the basin where the relative contribution of direct (diffuse) and indirect recharge processes, aquifer storage and release, all play a central role in regulating surface flow quantity and quality.

Notwithstanding these limitation, the aquifers in the basin can be considered in three sections[9]:

9 Beuster, H. (2009 b)

Bridge over the Cubango River, Angola

- ***The Angolan headwaters.*** The western headwaters of the basin are underlain by Pre-Cambrian granites and some Karoo Group sandstone and mudstone. The hard rock has low hydraulic conductivity and is overlain with a relatively thin mantle of Kalahari sand. The eastern headwaters are located on a much thicker layer of Kalahari sands. Together, these factors contribute to the low baseflows and strong seasonal variation in discharge in the Cubango with higher baseflows and a much lower seasonal variation in the Cuito.
- ***The lower basin.*** There are two aquifer types: the primary Kalahari sand and sandstone aquifers and secondary aquifers with fractured and weathered strata. Primary aquifers may be reached by some boreholes at a depth of about 350 m. The yield of boreholes near the Cuito River is less than 1 m^3/h, while in the Kavango Region of Namibia, most boreholes yield up to 8 m^3/h. In areas where the Kalahari aquifers have a shallow groundwater gradient, the Okavango River recharges the aquifers, but in most sections the river gains groundwater from the permeable Kalahari sands.
- In the ***Okavango Delta,*** there are three major aquifer formations – the basement rocks, Karoo and Kalahari group sediments. Where Karoo and basement rocks are present at shallow depth, they form locally important aquifers, but the majority of the aquifers lie in the Kalahari group sediments.

In the lower basin in the vicinity of the Angola/Namibia border, shallow aquifers are recharged directly either by rainfall and ephemeral runoff while deeper aquifers are recharged from the Kalahari basin margins or the underlying fractured aquifers. The eastern boundary of the Cuvelai - Etosha Basin seems to be discharging into the Kavango Basin. Recharge in the Okavango Delta has been estimated to be about 7-10 mm/a.

Sediment transport

The Okavango River's patterns of sediment transport are highly characteristic. There are very few clays or silt carried by the river and the concentration of dissolved solids is low. Three categories of sediment are transported down the river to the Delta:

- **Fine sand –** the bulk of which is transported as bed-load by saltation during times of high flows, rather than in suspension.
- **Suspended load –** consists of fine silt, clay and organic matter, which is fine enough to be held in suspension at the typical flow velocities encountered in the river channel. The suspended silt and clays are important because they carry nutrients that maintain the fertility of floodplains.
- **Solutes –** the concentration of dissolved solids in the water is very low with about 40 mg/l. Nevertheless, it has been estimated that 380,000 tonnes of solutes reach the Delta each year, and only about 24,000 tonnes leave the Delta outflows. The solutes are made up of silica, calcium and magnesium carbonate, sodium and potassium bicarbonate.

Despite the low sediment transport observed in the Okavango, the fragility of soils and underlying weathered lithologies make the base highly susceptible to land degradation and erosion processes when land use changes occur. The susceptibility of riparian strips to erosion from grazing is one contributing process, but large-scale land preparation for cultivation is also expected to have an impact.

Water quality

The water of the Okavango River Basin is well known for its clarity that results largely from the geology and soils through which the river flows, and from the relatively isolated sources of pollution from urban and agricultural areas.

The groundwater quality in the Kavango district of Namibia is variable with 'stripes' of saline water with high fluoride in the Kalahari aquifer and other areas. Groundwater in the Kalahari aquifer along the banks of the river is often of poor quality due to high iron and manganese content – occasionally higher than limits for safe drinking . During flood events, the river recharges the aquifer and improves the groundwater quality. Total dissolved solids (TDS) concentrations in groundwater along the Kavango River are of the order of 1,000 mg/l.

The shallow aquifers surrounding the Okavango Delta are generally saline, but interspersed with important freshwater lenses along the ephemeral streams that are recharged by the wetlands of the Okavango Delta. Groundwater quality in the Delta itself is characterised by salt accumulation zones in the islands with TDS values of up to 20,000 mg/l, surrounded and underlain by a fresh aquifer with TDS of around 180 mg/l, and a deeper saline aquifer with TDS of around 2,600 mg/l.

Angola: Table 2-4 shows some recent water quality measurements from the tributaries of the Okavango. While these measurements are mostly well within the European Union criteria for water quality, the sites in the upper reaches of the tributaries show high, relatively alkaline pH levels. Nutrients (nitrogen and phosphorus) are generally low, but tend to be higher in the dry season when they are concentrated by evaporation.[10]

The Cuebe River at Capico registers an increasing conductivity with the rainy season, probably due to pollution from Menongue. In general, human induced sources of pollution within the Angolan basin are considered to be low. However there are localised areas where water quality has deteriorated, and they have the potential to deteriorate further due to factors such as:

- Deposition of faecal matter and bathing, washing of clothes and washing of vehicles, giving rise to soaps (higher phosphates), oils and greases entering the water, especially around centres of population e.g. Menongue
- Dumping of solid wastes in the canal and along river banks at Menongue
- Civil works and stream deviation e.g. on the Cutato River and a bridge over the Cuelei River giving rise to higher sediment loads
- Small irrigation schemes e.g. 600 ha around Menongue and near Chitembo on the Cuchi River, which use chemical fertilisers
- Changes in subsistence farming practices, which currently use little agricultural chemicals or inorganic fertilisers.

The high quality of the water is important in Angola, because a large proportion of the people living in this part of the basin rely on river water for drinking. In Angola, various international water quality standards are used. For the purposes of the TDA, reference has been made to the Water Quality standards for aquatic habitats and Angola uses the World Health Organisation water quality standards for drinking water.

TABLE 2.4: RECENT WATER QUALITY MEASUREMENTS FROM THE UPPER CATCHMENT IN ANGOLA

Locality	Rivers	Latitude	Longitude	Cond.	Turb.	DO	Temp	TDS	pH
Chinhama	Cubango	13° 03' 04"	16° 22' 18.8"	20.84	4.87	10.47	14.7	12.22	***9.30***
Cuvango	Cubango	14° 27' 57.8"	16° 17' 36.2"	34.35	0.76	7.4	15.4	21.05	***9.00***
Cutato	Cutato	14° 32' 1.6"	16° 29' 53"	30.69	0.88	5.26	16	18.83	***8.80***
Cuchi	Cuchi	14° 38' 59.2"	16° 54' 24.5"	37.06	1.23	6.97	16.7	24.06	***8.80***
Cuelei	Cuelei	14° 42' 8.1"	17° 22' 41.5"	18.8	0.60	6.23	15.3	18.57	***8.80***
Cuito Cuanavale	Cuito	15° 10'11"	19° 11' 06"	11.48	2.50	7.45	17.4	7.71	6.64
Menongue	Cuebe	14° 39' 45"	17° 41' 27.4"	13.62	1.40	7.98	17.3	8.94	***9.10***
Chitembo	Cuchi	13° 36' 14.3"	16° 39'4.6"	24.13	2.60	6.63	14.5	19.03	***8.90***
Chicala Choloanga	Cubango	12° 36' 55.7"	16° 03' 2.8"	12.89	5.90	7.26	17.7	7.09	***9.40***
Capico	Cuebe	15° 33' 05"	17° 34' 00"	41.45	3.64	4.05	26.5	43.49	6.72
Mucundi	Cubango	16° 13' 05"	17° 41' 00"	34.5	1.39	6.09	27.4	54.38	6.77

Source: Pereira 2009

(**Note** figures in ***bold italic*** show readings outside the European Union Water quality standards)

10 Pereira, M. J. (2009 a)

TABLE 2-5: RECENT WATER QUALITY MEASUREMENTS (WET SEASON) IN NAMIBIA AND BOTSWANA

Locality	River	Country		Cond.	Turb.	DO	Temp.	pH
Kapako	Okavango	Namibia	Mainstream	35.2	3.69	4.91	27.1	7.1
Popa	Okavango	Namibia	Mainstream	41.4	3.17	6.63	27.4	7.69
Shakawe	Okavango	Botswana	Panhandle	61	3.3	4.2	26	7.06
Xakanaxa	Khwai	Botswana	Permanent swamp	26	1.3	6.9	18	6.54

Source: Ortmann, 2009 and Masamba, 2009

Table 2-5 shows similar measurements for water quality in Namibia and Botswana, which reinforce earlier water quality surveys. These confirm that water quality in the Okavango is generally very good. What stands out here is a gradual increase in conductivity and turbidity going down the river, which however, falls off in the permanent swamp. The high dissolved oxygen in the permanent swamp reading may be due to the lower temperature recorded. Generally, dissolved oxygen is stable throughout the length of the mainstream, with a predictable increase after Popa Falls. Chlorophyll – an indicator of the productivity – is generally very low in the riverine sections but increases in the permanent swamp location.[11]

In *Namibia,* with the concentration of human populations along the river, there is potential for decreasing water quality, especially during periods of low flow. The South African Water Quality Standards and guidelines of 1956 were used during this study. Recent measurements associated with this TDA indicate that turbidity may be increasing, since the average values in 1991 ranged from 0.5-3.5 NTU, and were highest below the dry floodplain area at the junction of the Omatako Omuramba and the Okavango River. [12]

Where there are higher values of phosphates recorded locally, these have been found to be associated with human and cattle waste and detergents used for laundry. The phosphate concentrations downstream of large agricultural developments were not significantly different when compared to upstream sites.[13]

In Namibia, the main anthropogenic causes of lower water quality include:

- Intensive irrigated agriculture using fertilisers, which increase nutrient content of the waters, and agricultural chemicals
- Solid wastes, washing and bathing concentrated in urban centres
- Potential overflows from septic tanks and sewage treatment facilities.

The effects of these causes may be made worse during storm events, which tend to wash a great deal of solid waste into the river.

The sources of pollution tend to be more concentrated than in Angola, with clearer foci.

The water quality guidelines in use in Namibia classify water into four groups, dependent upon the aesthetic, physical and inorganic determinants. These groups are[14]:

- Group A: water with excellent quality
- Group B: water with good quality
- Group C: water with low health risk
- Group D: water with higher health risk, or unsuitable for human consumption.

The readings shown in Table 2-5 indicate that the river might be classified as between Group A or Group B at the sites sampled.

In *Botswana,* there are some differences between the Okavango Delta Panhandle and the Delta, and seasonal differences are more marked. Generally pH decreases with flow at all sites, but electrical conductivity increases with flow as rainwater flushes salts higher up in the basin. The turbidity also shows differences between the sites, increasing in the Okavango Delta Panhandle (similar to the mainstream above it) as the flow increases, while the turbidity is lower in the Delta due to filtering effects as it passes through the panhandle. In Xakanaxa and in the Boteti, the turbidity falls with decreasing flow.[15]

The dissolved oxygen in the river tends to decrease with increasing flow in the panhandle, attributed to the oxygen demand

11 Ortmann, C. (2009) and Masamba, W. *Output 4 - Water Supply and Sanitation* (2009)
12 Ortmann, C. (2009) quoting Bethune, S. (1992)
13 Ortmann, C. (2009) quoting Trewby, F. (2003), Andersson, J. (2006) and Bethune, S. (1987)
14 Namibia, Department of Water Affairs. (1988)
15 Masamba, W. (2009 a)

of increased organic matter washed into the river during higher flows. Conversely, in the Delta the dissolved oxygen tends to increase with increasing flow.

In Botswana, the sources of pollution are more concentrated near settlements along the panhandle and around the Delta such as Shakawe and Gumare, and along the Thamalakane River near Maun. These include:

- Small quantities of polluted water overflowing from sewage ponds and septic tanks into streams
- Washing of clothes and bathing
- Runoff from subsistence agriculture
- Localised pollution from solid wastes and waste waters from tourism camps and lodges, especially in the Delta. Botswana has water quality standards set by the Botswana Bureau of Standards for the protection and control of the quality of water supplies for various uses.

2.2.4 Biological components

Land cover[16]

The land cover classes within the basin are fairly well defined among the three countries. The wooded highlands of Angola give way to open and transitional woodlands as the river flows southwards, to tree/shrub savannah as the river flows into and through Namibia, and then into the mosaic of flooded grasslands and swamps of the Delta in Botswana (Figure 2.13).

A number of features emerged in this study.

- In the headwaters of the Cubango, there is an intense area of modified natural cover and a mosaic of settlements and agricultural lands in the north-western part of the basin due to high population densities.
- By contrast the catchment of the Cuito is relatively unmodified, with settlements and only small cropland areas around Cuito Cuanavale.
- There is pressure on the vegetation in Namibia south of the river, increasing around the urban centre of Rundu, which clearly reflects the relatively higher productivity of the land adjacent to the river.
- In Botswana, the cropland mosaic areas are evident around Shakawe, and along the western edge of the Delta, following the road through Gumare to Maun.
- The more open grasslands to the west and south of the Delta are clear.

The approximate total areas of these land cover classes for the whole basin are shown in Table 2-6.

TABLE 2-6: APPROXIMATE AREAS OF DIFFERENT LAND-USE CLASSES IN THE BASIN

Landcover	Area/km^2	%
Barren	6,004	0.9
Open grass savannah	210,119	31.0
Open shrub savannah	180,070	26.5
Tree/shrub savannah	85,056	12.5
Thicket	88,111	13.0
Transitional woodland	46,598	6.9
Open woodland	18,208	2.7
Dense woodland	22,640	3.3
Developed	4,493	0.7
Cropland mosaic	8,147	1.2
Seasonally flooded grassland	6,337	0.9
Seasonal marsh	313	0.05
Permanent marsh	1,297	0.2
Permanent swamp	1,033	0.2
Total	**678,426**	**100**

16 EPSMO data (http://epsmo.iwlearn.org/publications/envana/basin-wide-final-reports/)

The principal vegetation types of the Okavango River Basin are shown in Figure 2-13.

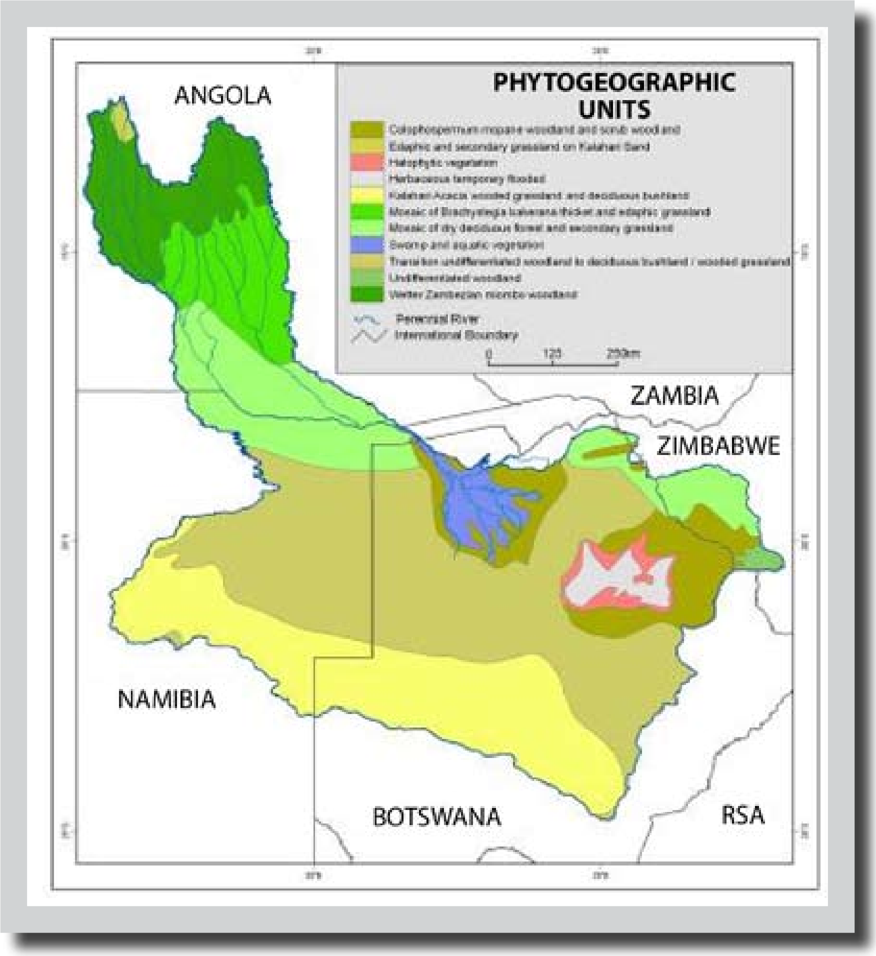


Figure 2-13: Vegetation types of the Okavango River Basin

Basin ecosystems

The principal basin ecosystems are arranged according to the four catchment zones, described in Section 2.2.1.[17]

The focus is upon the riverine ecosystems, but these are put in the context of the surrounding landscape and terrestrial ecosystems. The key features of each in terms of flora and fauna and current threats and trends are outlined. Additional information from the field surveys is included in a matrix outlining the features of each Integrated Flow Assessment IFA field site (Annex 1).

The four catchment zones of the Okavango Basin

- **Angolan headwaters** – The Cubango and Cuito Catchments
- **Middle reaches** – The lower Cuito and Cubango Rivers, as well as the Okavango upstream of the panhandle,
- **The panhandle** – The panhandle, which is formed by two parallel faults.
- **The Delta** – The Okavango Delta comprising both permanent and seasonal swamp areas.

Angolan headwaters

The Angolan headwaters are divided into the Cubango River and Cuito River catchments and extend to the confluence of the Cubango River with the Cuatir River, and to the confluence of the Cuito River with the Cuiriri River. Each catchment has its own ecosystem type and related fauna (Table 2-7).

17 This section has drawn upon the IFA Delineation Report No 4 and IFA specialist reports (2009) together with Mendelsohn, J and el Obeid, S (2004).

TABLE 2-7: SUMMARY OF ANGOLAN HEADWATERS ECOSYSTEMS

	Ecosystem type	Typical fauna	Human landscape
Cubango	Headwaters Water-logged grassland	Eland, lechwe, reedbuck (sitatunga) 68 spp. wetland birds	High population density Heavily modified by agricultural pressure
	Miombo woodland	Sparse populations of roan, eland, wildebeest 85 spp. wetland birds	
	Miombo/dry woodland transition area	Transition area for large mammals 85 spp. wetland birds	
	Dry woodland/savanna mosaic	Elephant, buffalo, zebra, road, sable 82 spp. wetland birds	Human settlement. Disturbance to vegetation limited to road/river corridor
Cuito	Headwaters Brachystegia woodland	Eland, lechwe, reedbuck (sitatunga) 68 spp. wetland birds	Low population pressure
	Miombo woodland and flood plains	Sparse populations of roan, eland, wildebeest 85 spp. wetland birds	
	Miombo/dry woodland transition	Transition area for large mammals 85 spp. wetland birds	Cropland production around Cuito Carnavale Little other human pressure

Middle Reaches

This section extends from Catambue on the Cubango Catchment, past the border between Angola and Namibia at Katwitwi, and through Namibia over Popa Falls to Bagani in the Caprivi. It includes the lower reaches of the Cuito River from Nankova to the confluence with the Okavango River near Dirico. The different ecosystems are summarised in Table 2-8.

TABLE 2-8: SUMMARY OF THE MIDDLE REACHES ECOSYSTEMS

	Ecosystem type	Typical fauna	Human landscape
Mainstream river	Reed beds, sedges, dry woodland	Low wildlife numbers High bird biodiversity in parts	High livestock numbers, agricultural cultivation in parts
Cuito/Cubango Confluence	Permanent swamp with oxbows, channels and sandbanks Woodland savanna	Elephants, hippo, otters, crocodiles (sitatunga)	
Rocky river section (Popa)	Good riparian woodlands at Popa	Macro-invertebrates Endemic fish Rare bird species Otters	High pressure – rapid clearance of reeds and trees outside Popa Falls Wildlife Reserve
Popa Falls to Mohembo	Riparian woodland, reed beds, papyrus	Great diversity, numbers and size of fish Rare bird species High number of wildlife including sitatunga, waterbuck, hippo, elephant and reedbuck	Less pressure as a result of the Bwabawata National Park Insignificant pressure on fish from angling

The panhandle

Downstream of Bagani, the river begins to widen to form the panhandle. It flows into Botswana at Mohembo, and extends past Shakawe for some 100 km to the beginning of the alluvial fan between Ikoga and Seronga.

TABLE 2-9: SUMMARY OF THE PANHANDLE ECOSYSTEM

	Ecosystem type	Typical fauna	Human landscape
Panhandle, permanent swamp (part of Ramsar Site)	Riparian woodlands, channels fringed with reed beds and papyrus, floodplain	One of richest fishing areas in the river system Sitatunga, hippo, crocodiles and reedbuck	Signficant pressure from human activites – agriculture, collection of natural resources, livestock

Okavango Delta

The Okavango Delta is the best known feature of the river basin, important for its dynamics. It is one of the largest Ramsar Sites in the world and its variety of habitats and the resulting biodiversity make it one of the most unique areas for biodiversity conservation. The Delta has been divided into five zones[18] (see Figure 2-14) depending on the duration and frequency of inundation, and the response to inflow from upstream and local rainfall. It can be characterised into areas that are permanently flooded, seasonally flooded, occasionally flooded and drylands. Table 2-10 provides a summary of the Delta ecosystems.

Zones of the Delta

1. The panhandle stretching from Mohembo to the northern limits of the alluvial fan (described above)
2. Eastern zone, fed by flows from the Nqoga River into the Maunachira, splitting into the Mboroga and the Khwai Rivers
3. Central zone, mainly fed by flows from the Jao-Boro River, including the Boro and Xudum distributaries
4. Western zone, with the Thaoge River
5. Outflow zone, with the Thamalakane-Boteti River to Chanoga

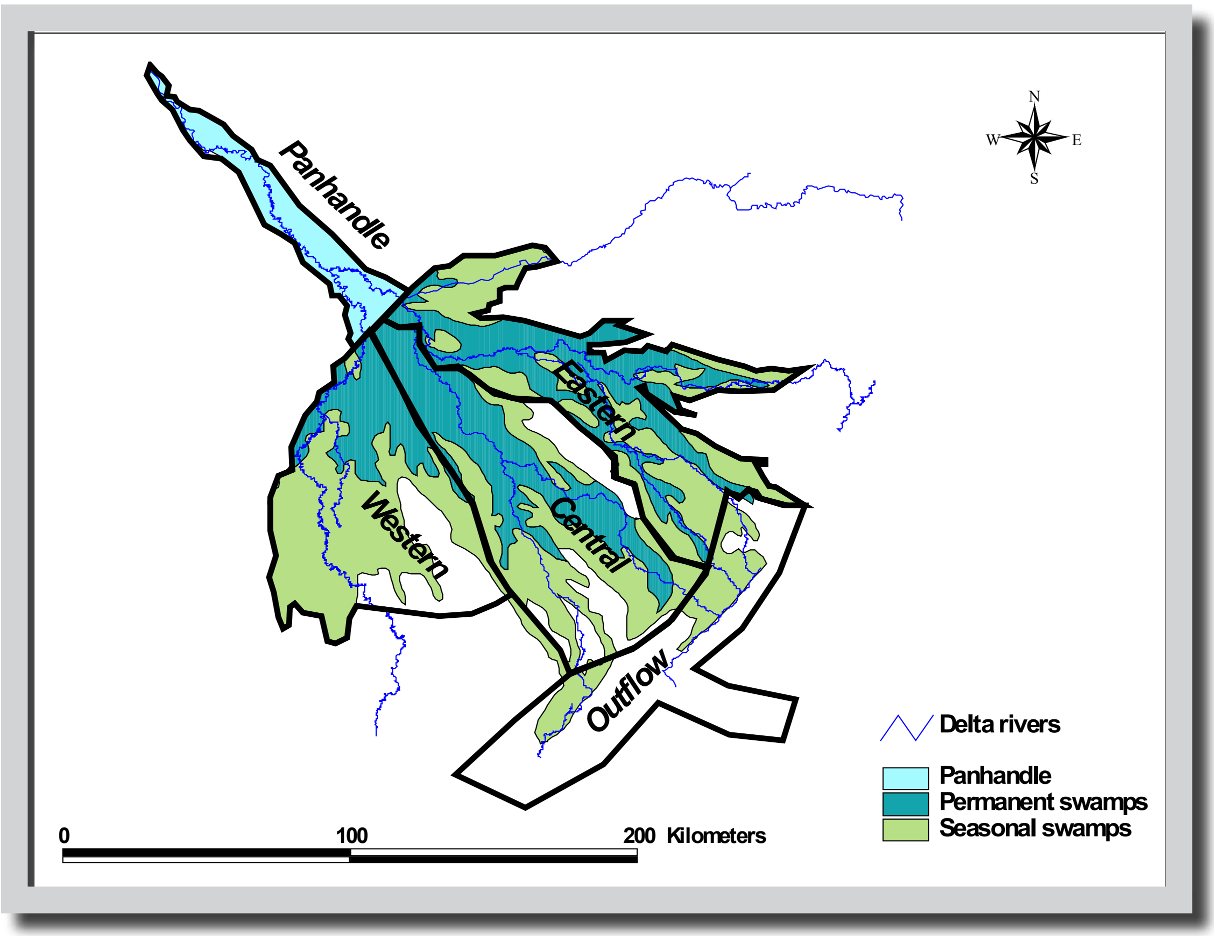


Figure 2-14: Zonation of the Okavango Delta

TABLE 2-10: SUMMARY OF THE DELTA ECOSYSTEMS

	Ecosystem type	Typical fauna	Human landscape
Western Delta	Permanent swamp with extensive floodplains 131 plant species dominated by reeds and papyrus	Distinct aquatic invertebrate and fish species Abundance of bird and mammal species.	Heavy human and livestock pressure Encroachment into Ramsar Site by livestock farming and cropping
Central Delta	Seasonal and permanent swamp 108 plant species	Distinct aquatic invertebrate and fish species Higher wildlife diversity including sitatunga, waterbuck, hippo, elephant and impala	Moremi Game Reserve (including Chief's Island) is protected Tourism lodges and photographic concessions throughout the zone
Eastern Delta	Seasonal swamps Responds to local rainfall and later to flood input Reed and papyrus, surrounded by mopane woodland	High diversity of mammals and bird	
Delta outflows (Included in the Ramsar Site)	Occasional flooding, distributary channels *Nymphae sp., Nymphoides, Marselia* and floodplain grasses	No tiger fish in the zone Mammals are characterised by floodplain grazers such as tsessebe	Increased population pressure from *molapo* farming. Maun is the centre of tourism in the Delta Southern buffalo fence protects the main part of the Delta from livestock incursion
Lake Ngami (Part of the Ramsar Site)	Ephemeral floodplain lake Floodplain grasses, Acacia woodland and *Ludwigia* spp.	High diversity of wetland birds when flooded Low fish species diversity	Pressure from human settlements and livestock farming Molapo farming also practised

Biodiversity and biological production

The Okavango River Basin is internationally important for its biodiversity and biological production. The three riparian countries are signatories of the Convention on Biodiversity and as such have produced National Biodiversity Strategy and Action Plans (NBSAPs) as guiding tools for the implementation of the Convention at nationl level. In the Delta alone there are 1,300 species of plants, 71 fish species, 33 species of amphibians, 64 species of reptiles, 444 species of birds, and 122 mammal species.[19 20] The specialist reports that provide in-depth information are included in the DVD accompanying this report. Table 2-11 describes a variety of species that are considered important indicators and their status according to the IUCN Red Data List[21].

The Red Data List

The IUCN Red Data List uses precise criteria to evaluate the extinction risk of species and subspecies. The broad categories of vulnerability are described as critical, endangered or vulnerable. The aim is to update the list every five to ten years

Throughout the basin there are a number of *vulnerable* and *near threatened* species. There are at least 330 species of the macro-invertebrates in these categories.

19 Ramberg, L et al. (2006)

20 This section developed with reference to the IFA specialist reports – Van Dunem, C. (2009) Morais, M. (2009) Gomes, A. (2009); Nakanwe, S. (2009), Curtis, B. (2009), Van der Waal, B. (2009). Paxton, M. and Roberts, K. (2009) and Bethune, S. (2009); Mosepele, B. and Dallas, H. (2009), Mosepele, K. (2009), Hancock, P. (2009), Bonyongo, M. (2009)

21 All Red List information comes from www.iucnredlist.org, accessed September 2009.

TABLE 2-11: IMPORTANT INDICATOR SPECIES FOR RIVER BASIN STATUS

Indicator species	Status
Dragonflies good indicators of the status of wetlands	100 species red listed 1 species near threatened 3 species data deficient
West African dwarf crocodile **Crocodiles** in general are excellent indicators of the status of main river channels and their banks/sandbanks	Vulnerable
Okavango mud turtle Indicator for river banks and fine sediments	Data deficient

Eighty species of fish (of which 10 are Red Listed) have been identified in the basin as a whole.

Three species of wetland birds are considered *vulnerable,* while three are considered *near threatened.*

Of the mammals associated with wetlands, the common hippopotamus and the African elephant are listed as *vulnerable* and *near threatened* internationally, but not in the Okavango Basin. Elephant numbers are increasing in both Botswana and Namibia, and there are renewed reports of conflict between human populations and elephants occurring in Angola as well. In large numbers, elephants can have devastating impacts on vegetation, e.g. damage to riparian vegetation in the Mahango.[22] However, it is the populations of large mammals that the Okavango is famous for, although their numbers in the Angolan section of the basin are considered to be very low.

The wide diversity of species in the Okavango River Basin is largely due to the variety of habitats providing different ecological niches as a result of the hydrological gradient throughout the basin. As river flows change there are constant changes in patterns of nutrient deposits, plant succession and dependent animals.

The biodiversity and biological production of the Okavango River Basin is under pressure and is changing. Some of the Red Listed species are seen to be decreasing.

Some of the threats that can be attributed to human pressure are discussed below.

- Fires – while naturally occurring fires are important, increased human activity leads to more frequent fires
- Overgrazing – more cattle and small-stock are maintained by an increasing human population
- Natural resource exploitation, hunting, fishing – pressures are rising on all the natural resources utilised by increasing human populations who are reliant on them
- Changes in habitat – demand for land for agriculture, especially land near the river , which leads to encroachment of different habitats in the river, reducing its diversity and productivity
- Changes in flow of the river due to abstraction for water supply, irrigation and hydropower.

Ecosystem functions and services

A list of four ecosystem services has been identified for wetlands by the Millennium Assessment and is used by the Convention on Biological Diversity. These are

1. Provisioning

The river provides water, sources of food, construction material, fuel and many other goods for people.

2. Regulating

The river affects the local climate of Namibia and Botswana, and the Delta and floodplains are important carbon sinks. It regulates the groundwater recharge along its length and, with the floodplains, plays an important role in flood mitigation. As the water in the river at present is very clear, it can diffuse and remove excess nutrients and pollutants, especially in the Delta, although not in large amounts. Vegetation along the river prevents bank-erosion.

3. Cultural and recreational

Ecosystem services

Most people are users of inland waters in some form, but human links with them are strongest in developing countries. As international aquatic ecosystems globally are degrading and disappearing through overuse and water-resources development, realisation has grown of what is being lost, and of the full range of services provided by the inland waters on which all of humanity depends.

22 Bethune, S. (2009)

The river contains sacred and cultural sites for the people of all three countries and while these are of great importance for the riparian communities, no formal studies have been undertaken on the location and significance of these sites along the river.

Recreational and tourism services are becoming increasingly significant and the value of tourism to Botswana and to a lesser extent Namibia is already of great consequence.

4. Supporting

The river and its floodplains (especially the Delta) play a unique role in nutrient management, soil formation and the accumulation of organic material, providing nursery and breeding areas for fish and aquatic birds. Wetlands are also among the most effective ecosystems for primary production and carbon sequestration by plants. The Delta provides a crucial habitat for pollinators.

2.3 THE PEOPLE OF THE OKAVANGO RIVER BASIN

2.3.1 Demographic characteristics and trends

The human population in the basin is predominantly rural and communities are most often located either adjacent to the river or along roads. In each country, the basin populations are very remote relative to the countries' capital cities and main centres of economic activity.

TABLE 2.12 : COMPARATIVE DEMOGRAPHIC CHARACTERISTICS OF ANGOLA, NAMIBIA, AND BOTSWANA

National values	Angola	Namibia	Botswana
Population	16,752,000	2,089,000	1,842,000
Population density (people/square km)	13	3	3
Birth rate (number of births per 1,000 people)	47	25	24
Death rate (number of deaths per 1,000 people)	21	15	14
Rate of natural increase (% per annum)	2.7%	1.0%	0.9%
Infant mortality rate (deaths per 1,000 live births)	132	47	44
Total fertility rate (number of children per woman)	6.8	3.6	2.9
Proportion of population aged less than 15	46%	41%	38
Urbanisation rate (% of population)	57%	35%	57%
Rate of change of urban population (2005-2010)	4.4%	2.9%	2.5%
Gross National Income (per capita, US$)	$4,400	$5,120	$12,420

Note: 2008 unless otherwise stated

Sources: The national level data were extracted from several websites, including UNHDR Human Development Reports (http://hdr.undp.org), World Bank Key Development Data & Statistics (http://web.worldbank.org), and Population Reference Bureau (PRB) (http://www.prb.org).

National trends

Table 2-12 shows some indicative figures describing the general demographic features of Angola, Namibia and Botswana at country level, which are useful for comparison with conditions in the basin. The higher population figure and overall density of people in Angola reflects the better rainfall and generally higher agricultural productivity found in most of the country.

Angola: It is only very recently that Angola's population growth rate has shown signs of slowing. This can largely be explained by the war, which curtailed social and economic development and also resulted in high rates of urbanisation, primarily caused by displacement. While urbanisation is normally accompanied by better education or higher incomes leading to lower birth rates, most of the urban populations live without services. However, with the advent of peace and with the country's resource-rich economy, Angola's population could well be on a path towards reduced child mortality and reduced fertility. There is a lower incidence of HIV/AIDS in Angola than in Botswana and Namibia and if this situation can be maintained, it could represent the start of a permanent demographic transition.

Namibia and Botswana: Both Namibia and Botswana have been undergoing a demographic transition during the past 30 years. Fertility rates and population growth rates have slowed due to factors such as urbanisation, female education and generally improved household income associated with social and economic development[23]. The HIV/AIDS pandemic that has developed in both these countries during the past 20 years has further reduced population growth by increasing mortality rates, a trend that is expected to persist for some time.[24]

Tchinyama, Huambo Province, Angola

Situation in the Okavango River Basin

Table 2-13 indicates more specific details for the Okavango river basin within the three countries and Figure 2-15 indicates the population distribution throughout the basin. The total population of the basin is estimated at nearly 882,000, in 195,000 households. About 549,000 people live in the rural areas, with an overall urbanisation rate of about 38%. Here it is important to distinguish between macro-economic data compiled at national level for each country and the more detailed socio-economic data that has been compiled by the EPSMO project within the study areas in the basin - the unit of analysis in the integrated flow assessment. Unless otherwise stated, all the micro-economic analysis carried out by Barnes et al relate to regional/provincial and district levels within the areas studied in the basin - the areas contributing to perennial flow.

TABLE 2-13: OKAVANGO RIVER BASIN, SPECIFIC VALUES

	Angola	Namibia	Botswana
Basin population (estimated)	505,000	219,090	157,690
Basin population as proportion of national total	3.0%	10.5%	8.6%
Basin households (number)	126,250	35,120	33,550
Basin household size (people)	4.0	6.2	4.7
Urbanisation rate in basin (% of population)	48%	20%	30%
Basin rural population (people)	262 600	175,270	110,630

Sources: The national level data were extracted from several websites, including UNHDR Human Development Reports (http://hdr.undp.org), World Bank Key Development Data & Statistics (http://web.worldbank.org), and Population Reference Bureau (PRB) (http://www.prb.org).

Fish traps, Tchinhama, Huambo Province, Angola

23 Mendelsohn et al. (2002); Dorrington et al. (2006)
24 Dorrington et al. (2006)

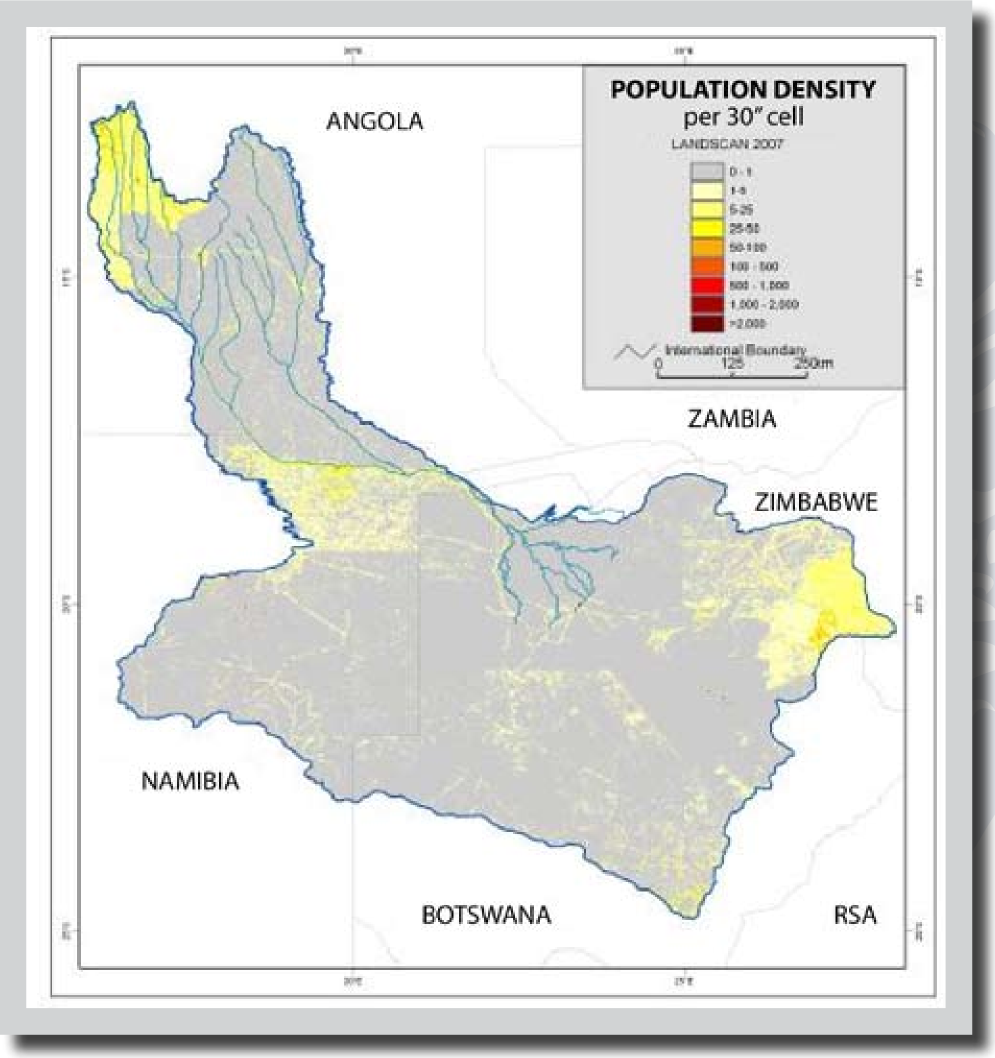


Figure 2-15: The population distribution throughout the Okavango River Basin

Angola: The high urbanisation rate, mainly in the larger centres of Cuito Cuanavale, Cuvango, Chitembo, Mumbué, Cuchi and the largest, Menongue (122,300 inhabitants), appears to have been abating somewhat since the end of the war, with people moving back to settle on rural land. This trend has not been rapid however, because most people lack the means to start farming, and there is still a threat from uncleared land mines in many areas.

The rural population of the Angolan part of the basin is the most relevant to the analysis of river-related resource use and is estimated to be 262,600, represented by some 65,650 households. Rural populations are likely to grow faster than urban ones, and while it might be expected that the growth rate in the basin would have been higher than that for the nation as a whole, there was some emigration from the basin during the war. The population in the basin is growing at around 2.7% per annum.

The density of the population in the Angolan basin is generally less than one person per km^2, significantly lower than that for the rest of the country, although population densities differ widely, with concentrations of people in the headwaters of Cubango, Cutato, Cuchi and Cacuchi Rivers, and around Menongue. There is also a clear distribution of settlements that follow the Cubango and the Cuito Rivers and the roads southwards.

Namibia: In the Namibian part of the basin there are about 219,090 people, amounting to some 10.5% of the national population[25]. Most of these people (94%) live within 5 km of the river and about 20% of them are urban, living in Rundu. The urbanisation rate in the Namibian part of the basin is lower than that for the whole country, although the population density is much higher than the national average. This reflects the fact that most of the population is concentrated along the narrow active basin – the river.

25 Based on data from Mendelsohn et al. (2002) and Mendelsohn, J. and el Obeid, S. (2003)

The population growth rate in the Namibian basin has been very high – up to 7% per annum between 1981 and 1991[26]. This is partly due to natural increase, but there was significant immigration from Angola during the war for security and economic reasons. The position has since stabilised and the current and future population growth is expected to remain slightly higher than that for the nation as a whole, i.e. at a rate of 1.5%.

Botswana: Most of the people living in urban areas in the basin are concentrated in Maun, Gumare and Shakawe. The rural population is estimated at 110,630 in 23,540 households. The population density in the Botswana basin is 1.1 persons per km^2, about one third of the national density. [27]

The population growth rate is slightly higher than the national rate, probably because the population is more rural and this rate is expected to remain in the region of 1.5%.[28]

Figure 2-16 shows the urban and rural distribution of the basin population.

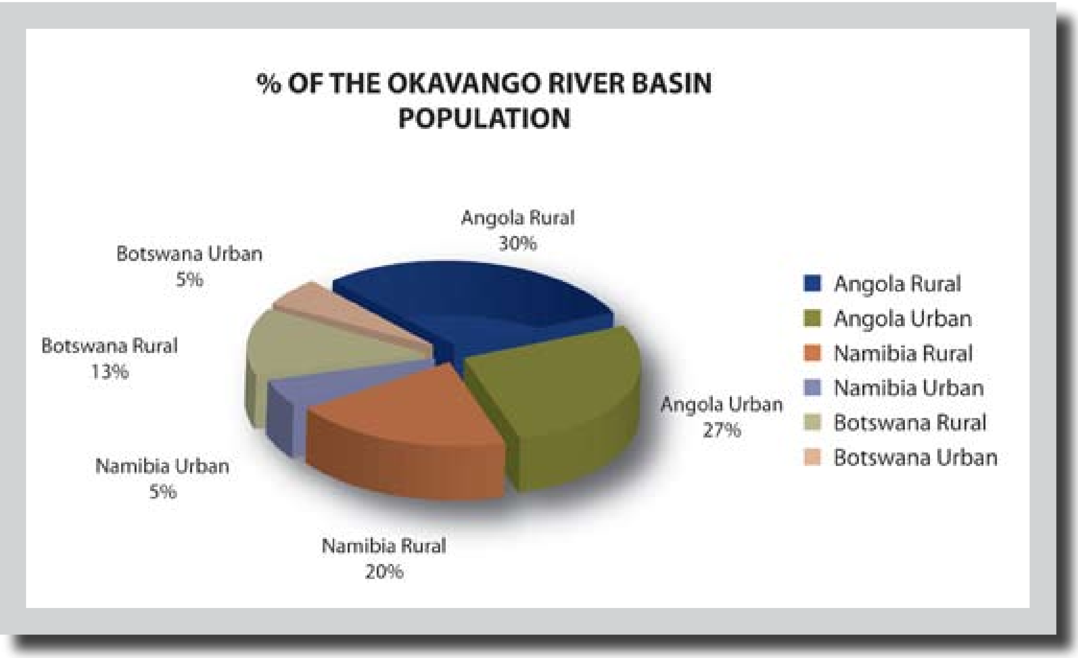


Figure 2-16: Distribution of the Okavango Basin population in urban and rural areas

Ethnic diversity of the basin
A wide ethnic diversity of the peoples of the Okavango Basin is present in all three countries, although the same ethnic group may be fragmented by the river or national borders.

Angola: There are five major ethno-linguistic groups within the population of the Angolan basin.

- The Umbundo occupy the upper reaches of the Cubango in fairly dense settlements (about 16% of the basin's population) and mainly use the olonaka farming methods.
- The Ganguela (nearly 50%) are mainly traditional farmers in the east, and are cattle breeders in the west.
- The Lunda-Tchokwe (nearly 33%) are farmers who occupy most of the centre of the basin.
- The Ambó live on the Namibian border to the west, with a strong reliance on cattle breeding.
- There are a few Xindonga living on the Namibian border to the east, between the river courses of the Cubango and Cuando, who are cattle farmers.

There are also small enclaves of the original, non-Bantu Koisan populations in the province of Cuando-Cubango.[29]

26 Mendelsohn, J. and el Obeid, S. (2003)
27 ODMP, (2008)
28 Detailed analysis by Dorrington et al. (2006)
29 Saraiva et al. (2009)

Namibia: Five ethnic groups occupy the Namibian part of the basin from west to east along the river – the Kwangali, Mbunza, Shambyu, Gciriku, and Mbukushu. [30] The first two groups, almost half the people, speak Rukangwali. The Shambyu and Gciriku speak Rumanyo, and the Mbukushu speak Thimbukushu. About a third of Rundu residents and 15% of rural inhabitants speak an ethnic Angolan language such as Umbundu, Cokwe and Ngangela, reflecting their origins.

Botswana: The ethnic groups in Ngamiland are dominated by[31]:

- The Bahambukushu in the panhandle area
- The Bayeyi in the western, central, and south-eastern Delta
- The Batawana in the southern and eastern parts of the Delta.

Other groups include:

- The Dxeriku, living in the panhandle,
- The Bugakwe and Xanekwe – Koisan who have traditionally practised fishing, hunting, and the collection of wild plant foods. The Bugakwe utilise both forest and riverine resources while the Xanekwe mostly focused on riverine resources.

The Bahambukushu, Dxeriku, and Bugakwe are also present along the Okavango River in Angola.

People bathing, Rio Cuito, Cuito Cuanavale, Angola

2.3.2 Social, educational and health characteristics

Table 2-14 shows a selection of indicative national-level social, educational and health characteristics for Angola, Namibia and Botswana.[32]

TABLE 2-14: COMPARATIVE HUMAN WELL-BEING, HEALTH, AND HUMAN DEVELOPMENT INDICATORS FOR ANGOLA, NAMIBIA AND BOTSWANA

Characteristic national values	Angola	Namibia	Botswana
Population with access to improved water sources (2006)	51%	93%	96%
Population using improved drinking water (urban)	62%	99%	100%
Population using improved drinking water (rural)	39%	90%	90%
Literacy rate, ages 15-24 (female, 2000-2004)	63%	94%	93%
Literacy rate, ages 15-24 (male, 2000-2004)	83%	91%	86%
High school enrolment (female, 2000-2004, % of age group)	17%	66%	75%
High school enrolment (male, 2000-2004, % of age group)	21%	59%	70%
Underweight children, age <5	28%	20%	11%
Human poverty index (HPI-1) (2005)	89%	26.5%	31.4%
HIV/AIDS among adults, ages 15-49 (2001)	1.6%	14.6%	26.5%
HIV/AIDS among adults, ages 15-49 (2007)	2.1%	15.3%	23.9%
Undernourished population (2002-2004)	35%	24%	32%
Life expectancy at birth (years)	44	47	49
Human development index (1990)	-	0.65	0.68
Human development index (2000)	0.45	0.64	0.62
Human development index (2005)	0.48	0.63	0.66

Note: 2008 unless otherwise stated

30 Yaron et al. (1992)
31 Turpie et al. (2006)
32 The data were extracted and synthesised from several websites, including UNHDR Human Development Reports (http://hdr.undp.org), World Bank Key Development Data & Statistics (http://web.worldbank.org), and Population Reference Bureau (PRB) (http://www.prb.org).

National trends

At the national level, the indicators of social development in Namibia and Botswana are better than those in Angola. As can be seen from the above table, access to improved water sources is very low in Angola especially for rural Angolans. However, current plans suggest that access will improve significantly within the basin in the next few years.[33]

The comparative educational statistics also indicate that literacy and educational enrolment are lowest in Angola. The same applies to nutrition measurements. The HPI-1 human poverty index is between 25% and 30% for Namibia and Botswana, but is much higher for Angola at 89%.

The incidence of HIV/AIDS differs significantly between Angola and the other two countries. Among adults it is 2.1% in Angola, but up to 15.3% Namibia and 23.9% in Botswana. The pandemic spread very fast in the latter two countries between the mid 1980s and the late 1990s[34]. However, the prevalence rate has slowed and seems to have stabilised since 2000. The rate in Botswana has even declined slightly.

HIV/AIDS significantly increases mortality among people of reproductive age and young children. This has had a significant impact on the life expectancy at birth in Namibia and Botswana, which has been reduced from around 60 years in the early 1990s to 47 and 49 respectively, close to that of Angola which is 44 years. The result is a significant reduction in population growth. In the past few years, the introduction of anti-retroviral treatment (ART) programmes has reduced death rates, particularly in Botswana, but this effect is only partial.

The human development index (HDI) provides a useful overall measure of how a country is meeting its Millennium Development Goals. It is calculated as an average of three indices: life expectancy, educational attainment and income. The HDIs presented in Table 2-14 show that Namibia and Botswana both have higher values, and are classified as having medium human development. Angola is classified as having low human development.

The HDIs for Angola increased between 2000 and 2005, but in Namibia and Botswana the indices have declined since 1990. In Namibia, these declines are entirely due to the mortality effect of the HIV/AIDS pandemic, despite marked improvements in the education and income indices. [35]

Social indicators in the Okavango Basin

The main differences between national social development indicators and those of the Okavango Basin stem from the remoteness of the basin from national centres. In general, the people of the basin are poorer, less healthy, and less well educated than other groups in their respective countries.

Angola: In the Angolan part of the basin, data collected by the TDA team during a recent household survey indicated that fewer than 4% of households surveyed have access to improved water supplies, far fewer than the 51% for the nation as a whole. They also found that over 54% of rural households relied on rivers for their water source, compared to 14% of urban households. In Menongue most urban households indicated that they used water holes or wells, rather than the river. Houses in the basin are more likely to be made of wood, mud and grass, and the people are more dependent on wood and charcoal for fuel, and less likely to have access to electricity, than in the country as a whole. The literacy rate is very low – more than 31% of those surveyed did not know how to read and write. More than 40% also considered that access to health services was very poor, and besides the problem of AIDS, malaria was of greatest concern. [36]

Chicomba Huila Province, Angola

33 Administração Municipal do Cuchi 2008; Administração Municipal de Menongue 2008; GEP/Gabinete de Estudos e Planeamentos 2007; FAO/ADB Cooperative Programme 2007.
34 Dorrington et al. (2006)
35 Levine, R. (2007)
36 Saraiva, R. (2009)

Namibia: The Kavango Region has the highest incidence of poverty amongst all 13 regions in Namibia with 57% of households classified as poor[37] and 36% as severely poor.[38,39] This can be compared with the incidence for the whole country where 27.6% of households are poor or severely poor, and 13.8% are severely poor. 62% of rural households (which make up 80% of the population) are considered poor in comparison to only 33% of urban households. The high incidence of poverty highlights the importance of using natural resources in the coping strategies of households, and their vulnerability to changes in these natural resources.

High poverty levels have also contributed to a significant incidence of tuberculosis (TB), malaria, acute respiratory infections, diarrhoea, and urinary and intestinal bilharzia, and malnutrition in the Namibian part of the basin. Some of these are secondary to HIV/AIDS and have increased as a result of the pandemic. Others such as malaria, which affects half the population each year, are linked to the summer rains and associated standing water. Urinary and intestinal bilharzia are water-borne diseases and both are prevalent in the river and riparian communities. Their incidence appears to have increased dramatically between 1990 and 2000. [40]

Botswana: In Ngamiland, the socio-economic conditions are also slightly less favourable than in the country as a whole, for example the lower literacy rate. The incidence and patterns of HIV/AIDS in the basin are similar to those of the country as a whole[41].

Drying fish, Boteti River, Botswana

2.3.3 Economic characteristics and livelihoods[42]

There has been a relatively low level of human development in the Okavango Basin. The total income and per capita income values for the three countries are shown in Table 2-15. Based on their incomes, Botswana and Namibia can be ranked as being at the lower end of the medium income category, while Angola is ranked near the upper end of the low income category.

Rough estimates of the amount of natural habitat remaining within the Okavango Basin in each country show that a very high value of 90% – 95% of the natural habitat is still intact. The generally intact ecosystem integrity is not surprising as the basin has low population densities and is remote within all three countries.

Grain storage basket, Cafima, Cunene Province, Angola

Rural livelihoods

In all parts of the basin outside the bigger towns, land is public, held by the state or the local traditional authorities. Households throughout the basin practise small-scale traditional land and natural resource uses. It is common for households and communities to be settled close to river banks or floodplains with access to water and the richer natural resources there. Significant parts of the lower basin in Botswana are protected and used for conservation and tourism. Rural households in the basin derive much of their income from direct use of the basin's natural resources.

Households throughout the basin grow crops. In Angola crop production is the most important source of household income and food, earning some 80% of household income. Here the sub-humid and humid climate makes it possible to grow crops in uplands. In the lower semi-arid parts of the basin the growth of crops is carried out in both uplands and on floodplains, where additional wetness and fertility enhance yields by some 40%. Crop production is

37 Poor household = monthly expenditure of N$262 or less per adult equivalent.
38 Severely poor household = monthly expenditure of N$186 or less per adult equivalent.
39 CBS (2008)
40 Mendelsohn, J. and el Obeid, S. (2003)
41 ODMP, (2008)
42 This section is based upon Barnes et al. (2009)

small-scale in gardens, with tillage largely by hand or draught livestock. Very limited tractor power is available in the Namibian and Botswana parts of the basin. In Namibia and Botswana, crop production is of lesser importance for households because yields are low and there are significant losses caused by elephants.

Livestock are very important for households in the lower basin, providing a range of household utilities, such as meat, milk, draught power, and serving as a store of value. Their value is lower further up the basin, mainly because many households in Angola lack stock. Here, livestock husbandry is mostly small-scale and household-based for subsistence. Some 22% of small-scale livestock retaining value is attributable to the availability of floodplain grasslands where wetness enhances value. In Botswana and Namibia, medium-scale livestock production takes place around boreholes at cattle posts in the higher ground away from the river or Delta.

Subsistence agriculture, Tchinhama, Huambo Province, Angola

Fish are caught throughout the basin in river channels and on floodplains where seasonal floods can bring a marked peak in catches. Commercial fishing by groups of semi-motorised small-scale fishermen is only practised in the panhandle area of Botswana. Elsewhere, fishing is at household level using traditional gear such as locally made traps, gill nets, hook and line and dugout canoes.

Households throughout the basin harvest firewood, poles and non-timber forest products for food, honey, medicines, and raw materials. In the Namibian part of the basin such products are often not river/wetland related, but are collected from the very important humid to semi-arid woodlands of the basin. Specific qualities of thatching grass are harvested on floodplains. Reeds and sedges are harvested from the wetter parts of floodplains and riverbanks, and used for building and craft making.[43]

Tourism in the Namibian and Botswana parts of the basin is overwhelmingly non-consumptive and nature-based. Medium to large-scale lodges and camps with between 10 and 30 beds, serving middle and up-market tourists are most common. There are also significant numbers of self-drive camping and guided mobile visitors. Nearly all the value of this tourism is attributable to the presence of the river/wetlands, although the activities offered can be either land- or water-based. Local households may provide direct small-scale services to tourists, such as guided canoe trips, which supplement the commercial lodge operations.

Estimating the economic value of the river

Estimates of the economic incomes generated from the Okavango River Basin are nearly all based on direct use values, rather than on the indirect use values or ecosystem services. The indirect use values have only been studied in the Botswana part of the basin and not in great detail.[44] They are dominated by carbon sequestration, wildlife refuge function, flood attenuation, provision of clean water and educational-scientific value. Non-use values have been studied even less, and only through tourists. The global willingness to pay for existence-value in the Delta is likely to be very significant as the area is widely known and respected as a conservation site. It is probable that these non-use values are extremely underestimated.

Liyapeka Rapids, Angola

Table 2-15 shows the estimated livelihood and economic values for the uses of natural resources and tourism activities in the basin that can be affected by flow change. This table separates the values into the household net income that contributes to the livelihoods of the people living in the basin. A second column estimates the direct contribution of the river and wetland resources to the national economy in each of the three countries. This is an estimate of the contribution to the gross national income. The third column calculates the total contribution to the gross national income including national income multipliers. This is a sum of both direct and indirect contributions to the economy.

43 Barnes et al. (2005)
44 Turpie et al. (2006)

TABLE 2-15: ESTIMATED CONTRIBUTIONS OF OKAVANGO RIVER/WETLAND-BASED NATURAL RESOURCES TO LIVELIHOODS AND THE NATIONAL ECONOMIES IN ANGOLA, NAMIBIA, BOTSWANA AND THE BASIN AS A WHOLE

Value (US$, 2008)	Livelihoods*	Direct GNI**	Total GNI***
Angola			
Fish – household	2,124,000	2,567,000	6,160,900
Reeds – household	575,500	586,400	1,407,300
Grass – household	1,357,400	1,433,400	3,440,100
Gardens – household	29,700	17,700	42,400
Grazing – household	71,800	49,500	118,700
Tourism – household	125,800	125,800	301,900
Household subtotal	**4,284,200**	**4,779,800**	**11,471,300**
Other income (tourism)	125,800	125,800	301,900
Indirect use value	0	0	1,766,000
Non-use value****	0	0	24,500
Angola total	**4,410,000**	**4,905,600**	**13,563,700**
Namibia			
Fish – household	1,455,200	1,758,700	4,221,000
Reeds – household	561,100	571,700	1,372,100
Grass – household	1,741,700	1,839,200	4,414,100
Gardens – household	314,400	187,200	449,200
Grazing – household	402,600	277,200	665,200
Tourism – household	3,700,400	3,700,400	7,400,700
Household subtotal	**8,175,400**	**8,334,400**	**18,522,300**
Other income (tourism)	3,700,400	9,549,200	19,098,400
Indirect use value	0	0	5,365,100
Non-use value****	0	0	218,700
Namibia total	**11,875,800**	**17,883,600**	**43,204,500**
Botswana			
Fish – household	252,600	305,300	732,800
Reeds – household	336,300	342,600	822,300
Grass – household	535,300	565,300	1,356,600
Gardens – household	113,500	67,600	162,200
Grazing – household	157,400	108,400	260,100
Tourism – household	21,316,300	21,316,300	42,632,700
Household subtotal	**22,711,400**	**22,705,500**	**45,966,700**
Other income (tourism)	21,316,300	55,009,100	110,018,200
Indirect use value	0	0	19,428,600
Non-use value****	0	0	1,904,000
Botswana total	**44,027,700**	**77,714,600**	**177,317,500**
Okavango River Basin			
Fish – household	3,831,800	4,631,100	11,114,700
Reeds – household	1,472,900	1,500,700	3,601,700
Grass – household	3,634,300	3,837,900	9,210,900
Gardens – household	457,600	272,400	653,700
Grazing – household	631,800	435,000	1,044,100
Tourism – household	25,142,500	25,142,500	50,335,300
Household subtotal	**35,170,900**	**35,819,600**	**75,960,400**
Other income (tourism)	25,142,600	64,684,200	129,418,300
Indirect use value	0	0	26,559,700
Non-use value****	0	0	2,147,300
Basin total	**60,313,500**	**100,503,800**	**234,085,700**

*Household net income, contributing to livelihoods
**Direct contribution to national economy in the form of gross national income
***Total (direct and indirect) contribution to the broad economy in the form of gross national income, including the effect of the national income multiplier
****Non-use values presented here are partial and seriously underestimate the real values, particularly in the lower basin

Contribution of Okavango resources to livelihoods

Table 2-16 shows the estimated proportions of household income provided by river and wetland natural resources that can be affected by flow change, i.e. those that formed the IFA indicators. An important factor influencing this is the area of floodplain present, which increases from the upper basin in Angola to the Delta in Botswana.

TABLE 2-16: PROPORTIONS OF HOUSEHOLD INCOME IN ANGOLA, NAMIBIA AND BOTSWANA DERIVED FROM RIVER/WETLAND RESOURCES [45]

Source	Country		
	Angola	Namibia	Botswana
River/wetland	19%	32%	45%
Upland	81%	68%	55%
Total	**100%**	**100%**	**100%**

In *Angola,* households only derive about 19% of their income from river/wetland resources. There are smaller areas of floodplain, and river/wetland resource use is limited mostly to fish from the river channels, and reeds and grass from the river banks. Crops are important for Angolan livelihoods, but these are nearly all grown in rain-fed areas above the river. Similarly, Angolan livestock grazing, and much thatch-grass harvesting, takes place in the uplands, along with all harvesting of forest products. Almost no income is derived from tourism in the Angolan basin. Figure 2-17 shows the proportions contributed by different river/wetland-based natural resource uses to the household livelihoods in Angola. The importance of harvesting river channel resources such as fish, reeds and grass is evident in the overall value of US$ 4.4 million per year.

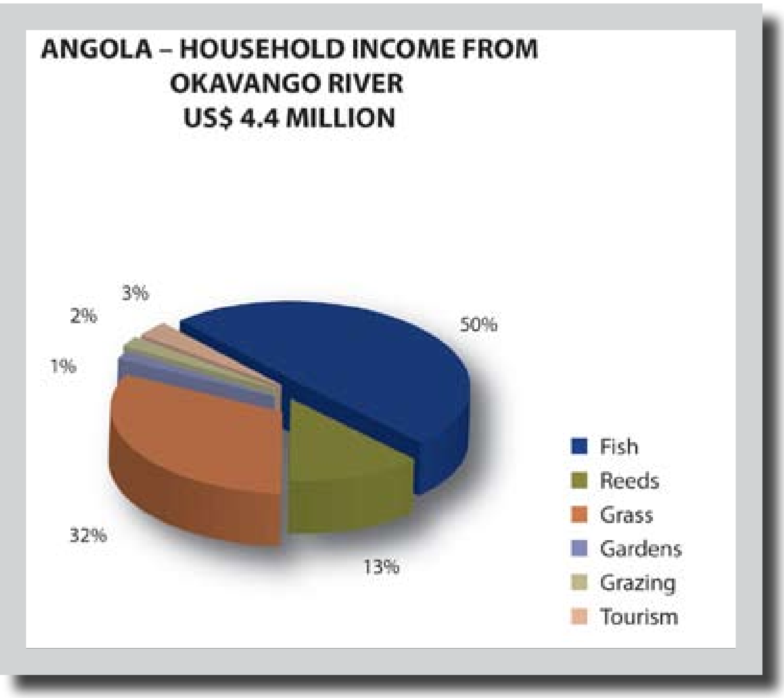


Figure 2-17: Estimated livelihood value of Okavango river/wetland-based natural resource use in Angola in 2008

In *Namibia,* there are larger areas of floodplains and a fair amount of tourism development which allows households in the basin to derive about 32%, of their income from river/wetland resources. The floodplains provide some income from wetland crop production, where better water relations and humic soils enhance crop production in small-scale gardens. Namibian households graze livestock on the floodplain for part of the year. Livestock productivity is increased by better water availability and the specific grassland communities that grow there. In both cases the higher values of crops and livestock are directly based on the river and its wetlands.

The river and wetlands allow tourism activities which would not be there otherwise. These take the form of some 30 private commercial, medium to large-scale lodge investments. Figure 2-18 shows the proportions contributed by different river/wetland-based natural resource uses to the household livelihoods in Namibia. It is interesting that the total livelihood values of fish, reeds and grass are very similar to those in Angola.

45 Derived from Saraiva, R. (2009), Mendelsohn, J. and el Obeid, S. (2003; 2004), Turpie at al. (2006), and Mmopelwa, G. (2009a, 2009b)

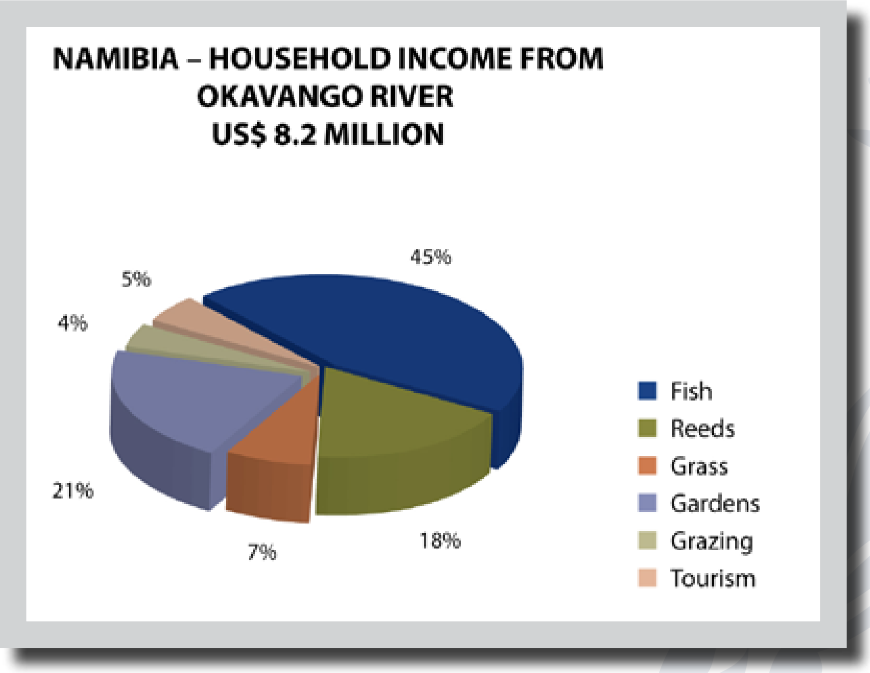


Figure 2-18: Estimated livelihood value of Okavango river/wetland-based natural resource use in Namibia in 2008

In *Botswana,* the panhandle and Delta cover a vast floodplain area. The north, west, and south-east parts are occupied by rural communities, while the central and north-east parts are reserved for tourism concessions based on the wildlife and nature. This large floodplain area means that households around the Delta derive nearly half (45%) of their income from river/wetland resources. Fish, reeds, wetland grass, floodplain crops (molapo farming), and floodplain grazing all tend to be more significant than they are in the upper parts of the basin.

The tourism industry is large, involving approximately 85 medium to large-scale private commercial investments in the basin. Basin households in Botswana derive income from these through wages and salaries, but also though small-scale tourism services, craft sales, and in the form of community-level royalty payments from tourism operators. Figure 2-19 shows the proportions contributed by different river/wetland based natural resource uses to the household livelihoods in Botswana. The impact of the tourism contributions to livelihoods is very evident here, making up nearly 94% of the total livelihoods derived from the river, which come to US$ 22.7 million. The contributions of fish, reeds and grass, the direct products from the river, are just over US$ 1 million in Botswana, significantly less than in Angola and Namibia.

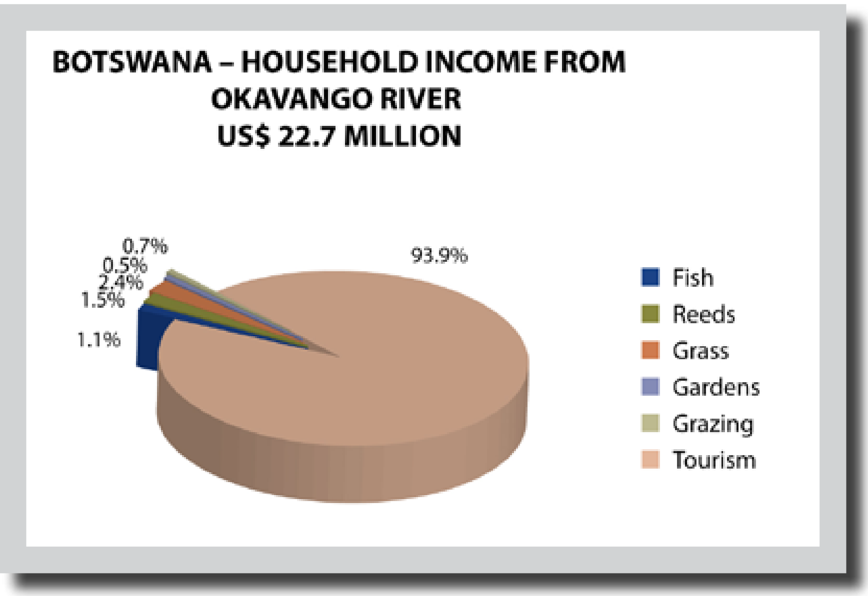


Figure 2-19: Estimated livelihood value of Okavango River/wetland-based natural resource use in Botswana in 2008

Okavango Basin livelihoods

Figure 2-20 shows an aggregation of these national figures for the basin as a whole. This shows the weight of the tourism contributions to the livelihoods of the people in the basin at 71% of the total US$ 35.1 million, while fish, reeds and grass make up 25% of the livelihoods.

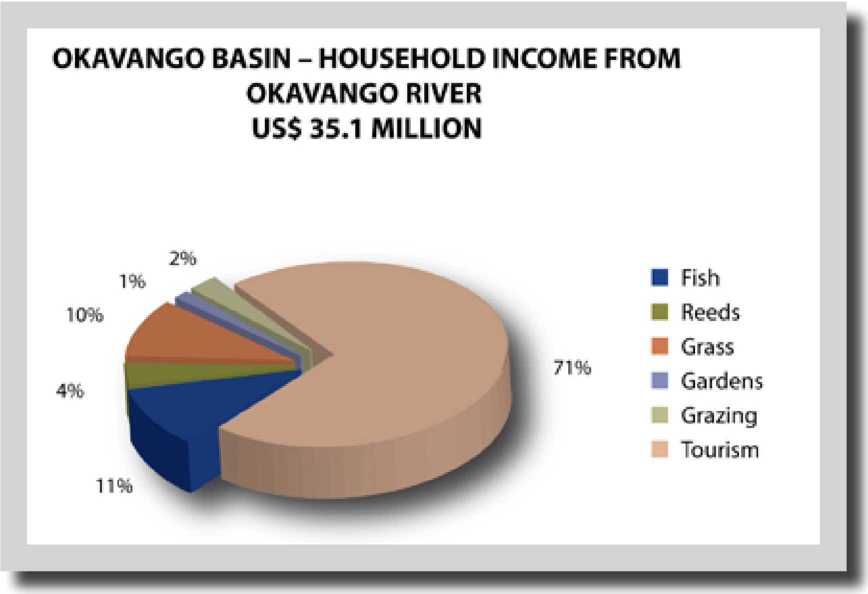


Figure 2-20: Estimated livelihood value of river/wetland-based natural resource use in Okavango Basin in 2008

When these livelihood values are attributed to the rural population, the differences between the three countries becomes even more apparent as shown in Table 2-17. The livelihoods based on the use of the wetland natural resources (excluding tourism incomes) shows that Namibia's rural population earns about US$ 25/person/year, compared to Angola's rural population that earns about US$ 16/person/year. In Botswana, the reliance on the river's resources is as low as about US$ 13/person/year. When tourism incomes are taken into account, Botswana's rural population earns a total of US$ 205/person/year, compared to Namibia's US$ 47/person/year, and Angola's US$ 16/person/year.

TABLE 2-17: RIVER RELATED LIVELIHOOD INCOME PER PERSON FOR RURAL POPULATIONS IN THE BASIN

	Extractive livelihood values	Livelihood value including tourism	Rural Population	Extractive livelihood value per person	Value per person including tourism
	US$/yr	US$/yr		US$/yr	US$/yr
Angola	4,158,400	4,284,200	262,600	15.84	16.31
Namibia	4,475,000	8,175,400	175,270	25.53	46.64
Botswana	1,395,100	22,711,400	110,630	12.61	205.29
BASIN	10,028,400	35,170,900	548,500	18.28	64.12

Contributions of Okavango resources to the national economies

Figure 2-21 shows the totals for these livelihood and economic values for each country and for the basin as a whole, based upon the figures shown in the table above.

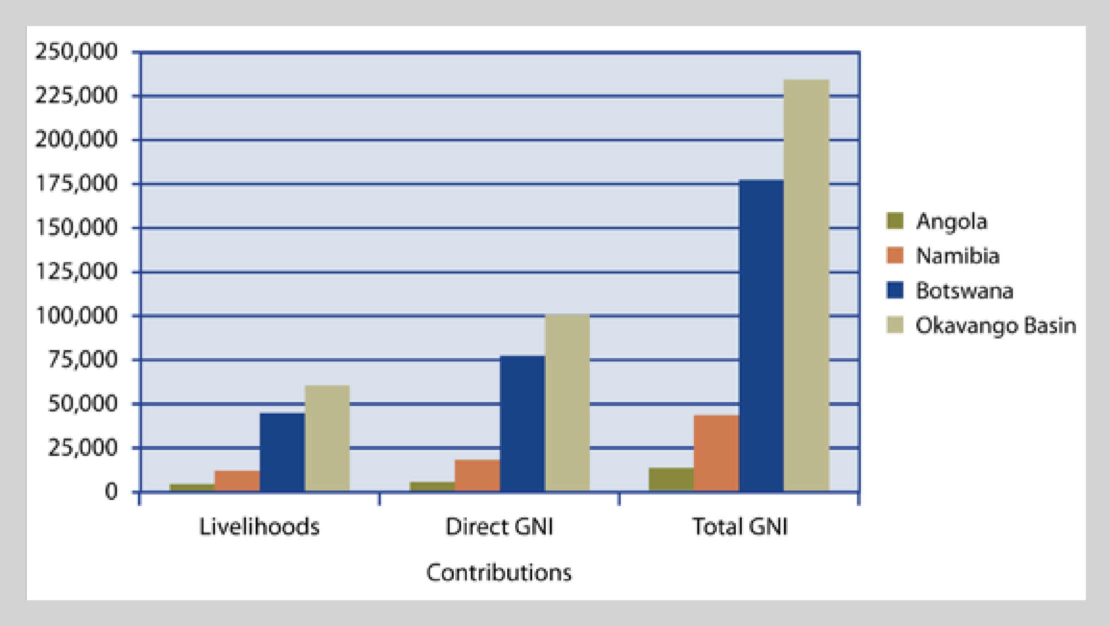


Figure 2-21: Estimated contributions of Okavango River/wetland-based natural resources

Livelihoods = contribution to household livelihoods; Direct GNI = contribution to direct gross national income; Total GNI = contribution to direct and indirect gross national income (US$, 2008)

There is a striking pattern regarding the river/wetland-based natural resource use among the countries. Botswana currently generates significantly more than Namibia, and Namibia generates significantly more than Angola. There are several reasons for this, the most important being the very high value of tourism in the lower basin. Also, the people in the upper parts of the basin derive less of their income from river/wetland resources. Households in Angola are poorer than those in the lower basin and they currently experience shortages of equipment, fishing gear, livestock and inputs with which to earn incomes – a legacy of war.

It is also clear that the contribution of the Okavango river/wetlands to national economies is very significant. It has been estimated that for every dollar contributed to the livelihoods of basin residents, some US$ 1.60 is contributed directly to the national income. If the impact of the income multiplier, indirect use values, and non-use values are taken into account, the total impact on the broader economies rise to about US$ 4.00. [46]

In Botswana, other floodplain natural resource uses such as gardens and grazing become a little less important, and wage income from tourism becomes very significant. Rural households derive lower amounts of their income from the harvest of river/wetland resources compared to their counterparts in Angola and Namibia as shown in Table 2-17.

2.4 MACRO-ECONOMIC STATUS

2.4.1 Macro-economic overview and trends

Angola has the largest economy of the three basin countries, mainly due to its much larger population – eight times as large as Namibia or Botswana, as shown in Table 2-18. The Angolan economy is also growing at a much faster rate (currently almost 20%), than the other two economies, which are growing at about 5% per year. In large part this reflects the rapid economic gains Angola is making after two decades of internal strife. The increase in the price of oil has also been fortuitous, as Angola is now the leading oil exporting country in Africa. Meanwhile Namibia and Botswana, while growing more slowly, have had decades of steady but significant growth. Botswana's gross domestic product (GDP) per capita at $5,739 is by far the largest of the three countries.

Botswana also has the largest level of government expenditure at 35% of GDP, reflecting the government's efforts to provide basic services to its rural populations. This and the higher level of GDP may explain the lower level of household consumption at 24% in Botswana. With similar GDP per capita levels, household consumption in Namibia is much higher than in Angola, with figures at 53% and 32%. This most likely reflects the much lower living standards of the bulk of the population in Angola.

46 Lange et al. (2004); Turpie et al. (2006)

Although Angola's GDP has grown rapidly, it is not as well distributed as that of Namibia, which has had a longer period to develop its economy after independence. As expected, gross capital formation is higher in Angola, reflecting its early stage in development and the capital intensive nature of the oil industry.

TABLE 2-18: SUMMARY OF MACROECONOMIC INDICATORS

Indicator	Angola	Namibia	Botswana	Source
Population 2007 (millions)	16.75	2.09	1.84	UNPD
Unemployment rate 2006/7	20%	33.8%	17.5%	Various
Gini Coefficient 2007/8	n/a	74.3	60.5	UNDP HDR
Gross Domestic Product 2007				
GDP (National currency, millions)	4,006,900	52,208	66,287	UNSD
GDP (US$ millions)	52,237	7,410	10,798	UNSD
GDP per capita (US$)	3,068	3,573	5,739	UNSD
GDP growth (average, 5 yrs)	14.96	4.68	5.92	UNSD
GDP growth (average 10 yrs)	9.87	4.27	5.91	UNSD
Composition of GDP (as % of GDP)				
Household Consumption	32%	53%	24%	UNSD
Gross Capital Formation	12%	26%	18%	UNSD
Government Expenditure	22%	24%	35%	UNSD
Exports	71%	49%	58%	UNSD
Prices				
CPI – 2007	12.25%	6.73%	7.08%	IMF IFS
GDP Deflator (average, 2002-07))	20%	14%	20%	UNSD
Exchange Rates				
NC/$ - 2007 average (NC/$)	76.71	7.05	6.14	IMF IFS
2008 end of period (NC/$)	75.17	9.31	7.52	IMF IFS
Balance of Payments 2007 (US$ millions)				
Goods Imports	(13,662)	(3,102)	(3,447)	IMF IFS
Goods Export	44,396	2,922	5,158	IMF IFS
Trade Balance	30,734	(180)	1,711	IMF IFS
Goods & Service Balance	18,402	(95)	1,675	IMF IFS
Current Account Balance	9,402	693	2,434	IMF IFS
International Liquidity (US$ millions)				
Reserves 2007 (less Gold)	18,359	1,293	9,118	IMF IFS

Sources: UNPD = United Nations Population Division, UNDP HDR = United Nations Development Program, Human Development Report, UNSD= Statistical Division of the United Nations, IMF IFS = International Monetary Fund, International Financial Statistics

Cuebe Cubango confluence

The distribution of income in all three countries is uneven with Gini indices[47] that are among the highest in the world. Income inequality is more exaggerated in Namibia (Gini index of 74) than in Botswana (Gini index of 60). While no inequality measure was available for Angola, it is likely to exceed that of both other countries. Exploitation of the country's oil reserves, the rapid rise in the price of oil and the resulting windfall profits are likely to be exacerbating the gap between the urban elites, the urban poor and rural populations.

Unemployment and underemployment in Angola are major issues for the country as it demobilises forces and works to create economic opportunities. No unemployment numbers are reported by UN agencies for Angola. Unemployment in Botswana is relatively low for the region at 17.5%. In Namibia the rate is almost double this at 33.8%.

All three countries have strong export-led economies, reflected in positive or near-positive trade balances, as well as current account balances.

47 The Gini index measures inequality of income

In terms of liquidity, at the end of 2007, Angola had US$19 billion in liquid reserves (not counting gold). Botswana had half this amount, but Namibia had just US$1.2 million.

The World Bank classifies Namibia and Botswana as upper-middle-income countries. Neither Namibia nor Botswana are currently eligible for grants from the International Development Association (IDA) of the World Bank, but could qualify for loans from the International Bank for Reconstruction and Development (IBRD). Namibia has developed an Interim Strategy Note with the Bank and may engage in borrowing in the future. Botswana recently completed a Country Partnership Strategy with the Bank, which looks to re-engage in lending with Botswana in the near future.

Angola is classified as a lower-middle-income country by the Bank and is IDA-eligible. The Bank and other donors have been supporting Angola's transition since the war ended. With the recent rapid growth in the country, the EU, the African Development Bank and the World Bank are all updating their country strategies to focus on governance, particularly development of an effective private sector. They will continue the attempt to provide social services and assist in providing economic opportunities for the poor. The World Bank reports that Angola received US$ 442 million in international assistance in 2006 and that the country had programmed investments of up to US$ 7 billion in new infrastructure between 2008 and 2010.

2.4.2 Sectoral Baseline

Angola

The dominant feature of Angola's economy is the extractive sector, particularly oil and gas, which accounts for over half of GDP (see Table 2-19). The combined resources sector – agriculture, hunting, forestry and fisheries – are the third most prominent, making up 7.8% of GDP or US$ 3.8 billion in 2006. Despite their relatively small participation in GDP, the resource sector employs a large share of the workers in the country, by some estimates up to 85%. In addition, a large percentage of this activity is of a subsistence nature. Just 10% of agricultural land is being used on a commercial basis. Despite this high level of activity in the agricultural sector, the country recently became a net importer of foodstuffs.

TABLE 2-19: ANGOLA, GDP BREAKDOWN BY SECTOR, 2006[48]

Economic Activity	Share of GDP (%)	GDP Value (in US$ million)	GDP change (%)	Employment rate (%)
Oil and gas	57.1	28,350	n/a	n/a
Services	14.0	6,951	13.3	10.0
Agriculture, hunting, forestry and fishery	7.8	3,873	18.3	60-85
Manufacturing	4.9	2,433	17.1	n/a
Construction and public works	4.4	2,185	17.0	0.3
Mining and utilities	2.4	1,192	3.9	n/a

Namibia

Namibia has the most diversified economy of the three countries. Trade, transport, manufacturing and mining all contribute around 10% of GDP (see Table 2-20). Agriculture and forestry contribute 6.6% or US$ 491 million. Farming itself is fairly limited due to climate and soils, but large areas in communal conservancies or private lands are devoted to livestock and game ranching/wildlife. Tourism is also a significant factor in the economy, earning 2% or US$ 139 million. A portion of this tourism comes from the Okavango region, though probably the bulk of it is associated with Etosha, the coast and the dunes. Water and electricity contribute an additional US$ 99 million, or on average US$ 50 per capita.

48 Source: UNSD, World Bank and African Development Bank, in Boccalon (2008)

TABLE 2-20: NAMIBIA, GDP BREAKDOWN BY SECTOR, 2007 [49]

Economic Activity	Share of GDP (%)	GDP Value (in US$ million)	GDP change (%)	Employment rate (%)
General Government	20.65	1,530	(0.5)	56 (services overall)
Trade	12.18	903	6.0	
Transport	11.70	867	7.5	
Manufacturing	11.20	830	13.0	12 (industry overall)
Mining and quarrying	10.46	775	0.2	
a. Diamond mining	8.26	612	(0.8)	
b. Other mining	2.19	162	4.1	
Agriculture and forestry	6.62	491	3.2	31
a. Commercial	4.32	320	6.5	
b. Subsistence	2.30	170	(2.4)	
Construction	5.44	403	32.7	
Banks, insurance and business services	4.36	323	2.4	
Fishing	2.80	207	(16.2)	
Hotels and restaurants	1.88	139	3.8	
Water and electricity	1.33	99	(18.2)	
Social and personal services	0.94	70	2.6	

Botswana

Botswana, like Angola, is heavily reliant on extractive industries for its economic well-being (see Table 2-21). Diamond mining brings in just over 30% of GDP. Manufacturing is limited to just 3.1% of GDP. Given the climate, agriculture is limited, making only a 1.7% contribution to GDP, the lowest of the three countries. As a consequence, services – government, banking, trade, transport, tourism, utilities and social services – make up a large portion of the remainder of the economy. Tourism plays a modest role in the country's economy and returns from tourism in the Okavango Delta amount to almost US$ 400 million. Water and electricity are also responsible for US$ 300 million in value added. The higher level of development in the country compared to its neighbours is revealed by the higher level of spending on these basic services at US$ 100/per capita.

TABLE 2-21: BOTSWANA, GDP BREAKDOWN BY SECTOR, 2007 [50]

Economic Activity	Share of GDP (%)	GDP Value (in US$ millions)	GDP change (%)	Employment rate (%)
Mining	34.7	4,478	5.2	2.63
General government	12.9	1,663	1.7	19.18
Banks, insurance and business services	8.5	1,102	6.6	1.56
Trade	6.2	800	15.5	14.36
Construction	3.6	469	8.7	5.12
Transport	3.1	405	20.3	2.98
Hotels and restaurants	3.1	399	19.7	2.72
Manufacturing	3.1	398	12.0	6.67
Social and personal services	3.0	389	1.6	4.56
Water and electricity	2.3	303	5.9	0.77
Agriculture	1.7	217	2.9	28.35

2.5 CURRENT LAND-USE PATTERNS

Agriculture is the main form of land use in the basin; predominantly extensive livestock farming. Rural households also collect natural resources for food (predominantly fish), construction and fuel. In addition, there are areas used as hunting, tourism and concession areas, as well as protected areas and national parks. This section describes the character and extent of these land uses.

49 Source: Central Bureau of Statistics (Namibia), in Boccalon (2008)
50 Source: Central Statistics Office (Botswana), in Boccalon (2008)

2.5.1 Agriculture

Dryland and recession agriculture

The predominant land use throughout the basin is subsistence agriculture with a few hectares being cropped and small numbers of cattle and goats being kept. Principal cropping areas are shown in Figure 2-22, while the present extent of cropping is shown in Figure 2-23.

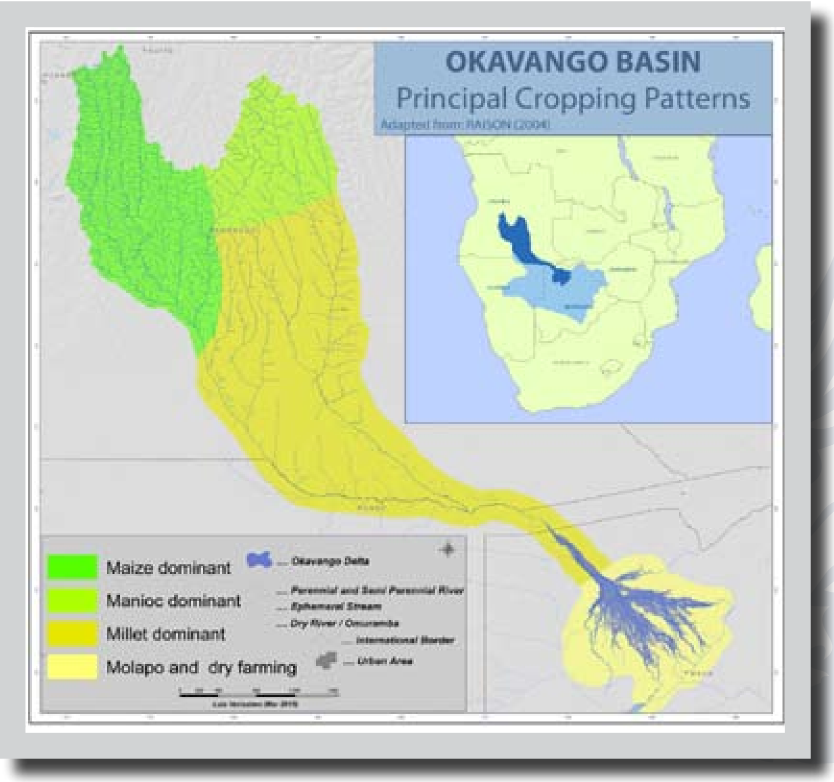


Figure 2-22: Principal cropping patterns

Source: Mendelsohn and el Obeid, 2004

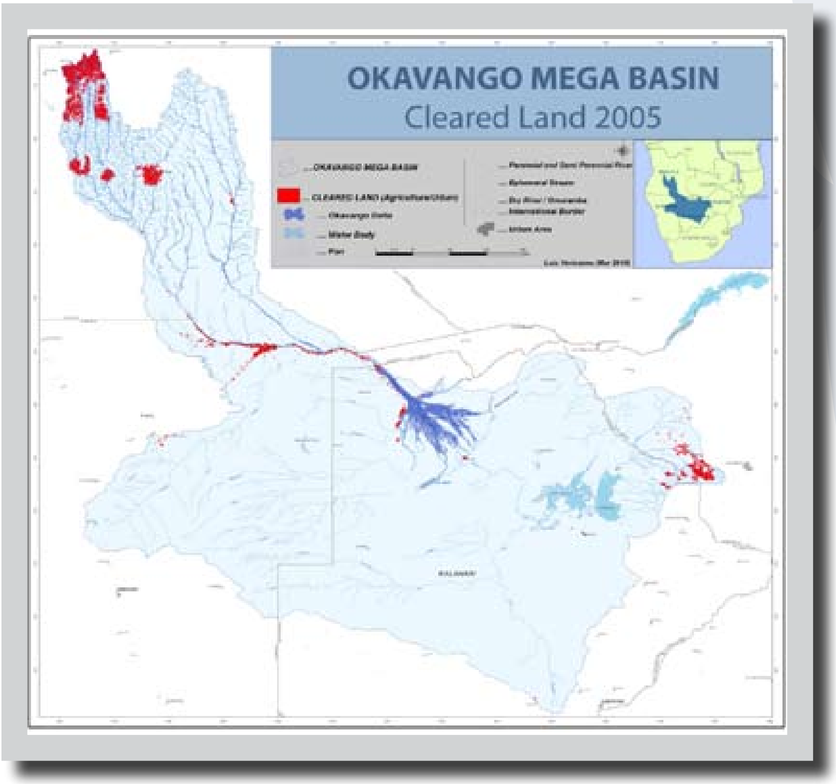


Figure 2-23 : Intensity of cultivation – cleared land

Source: Mendelsohn and el Obeid, 2004

There has been an extensive increase in the areas under cultivation. For example, in 1943 in the basin in Namibia, only 26,000 ha of woodland had been cleared, increasing to 72,000 ha in 1972 and to 194,500 ha in 1996 – an increase of about 3.9% per year.[51]

Cultivation and cropping depends on the season, with intense activity just before the rains. Most farmers do not use agricultural chemicals or fertilisers, with little use of compost or organic manures. [52] Crop productivity is generally very low, except in the northern parts of the basin where it is significantly higher.

There are traditional forms of recessional agriculture used – the *'molapo'* system in Botswana and the *'olonaka'* system in Angola – but there is no similar system in Namibia. This type of farming takes place close to rivers and streams and tends to be much more productive than dry land agriculture, since the fertility and moisture of the soils is maintained by seasonal flooding of the land (Table 2-22).

TABLE 2-22: AGRICULTURE YIELDS FROM DRY LAND AND RECESSIONAL FARMING

	Maize dry land yield – kg/ha	Molapo/olonaka kg/ha	Millet dry land yield – kg/ha
Angola	500 – 700		250
Kavango	100 – 160	N/A	100 – 150
Ngamiland	100 – 160	2,100	100 – 150

Irrigated agriculture

Irrigated agriculture has potential for much higher productivity than rain-fed agriculture in the dry lands. [53] There have been different approaches in the three riparian countries (Figure 2-24):

- In *Angola* there are currently three schemes totalling about 1,200 hectares of land which may be irrigated. All three schemes abstract water from the Cuébe River.
- To date, *Namibia* has invested the most in irrigated agriculture, with 12 agricultural schemes covering a total 2,197 ha. Most of the crops grown are either maize or wheat, or a mixture of both, with fruit trees and vegetables.
- Around the Delta in *Botswana,* out of 188.15 ha allocated for irrigation, only 31.35 ha (17%) is currently being utilised.

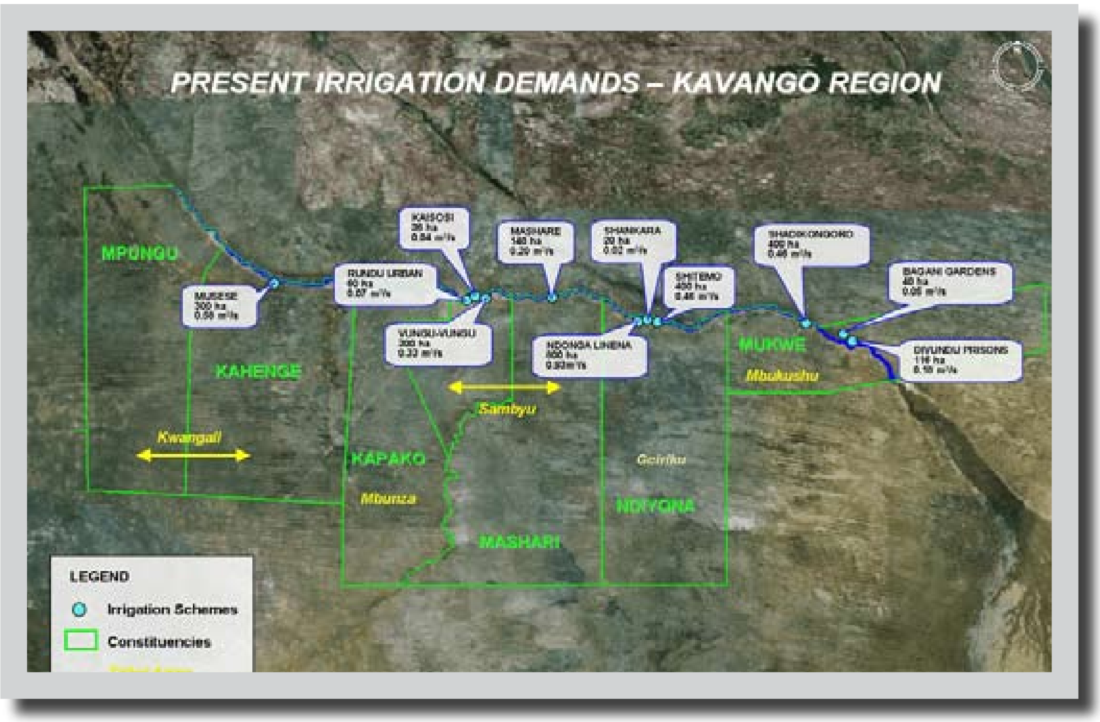


Figure 2-24: Existing irrigation schemes in Kavango, Namibia

Source: Liebenberg, 2009

51 Mendelsohn, J. (2009)
52 Mendelsohn, J. (2009)
53 Information from Duarte, J. (2009), Liebenberg, P. (2009), Masamba, W. (2009b) and Beuster, H.(2009b)

Livestock

Throughout the Okavango Basin, livestock are a critically important feature of livelihoods and land use, with many households owning several cattle and goats, and with larger herds being kept at cattle posts and ranches throughout Botswana and Namibia. Cattle are used as a source of income, meat, draught power and milk. In Angola, very few farmers have cattle, perhaps less than 5% of households, in comparison to Kavango and Ngamiland where about 50% of all households own some livestock.

The estimates of current numbers of livestock in the whole basin are shown in Table 2-23. However, most of the cattle are kept at cattle posts more than 20 km from the river or Delta, and are dependent on borehole water. Estimates of the livestock numbers kept within 20 km of the river, i.e. with an influence on grazing, water use and quality of water in the river, have been put at 150,000 cattle and 145,000 goats.[54]

TABLE 2-23: LIVESTOCK NUMBERS IN OKAVANGO RIVER BASIN[55]

	Cattle	Goats	Sheep	Donkeys	Pigs
Angola, Cuando Cubango Province	192,200	66,327	12,598		22,827
Kavango, Namibia	125,972	44,135	1,472	1,555	1,778
Ngamiland, Botswana	625,000	243,000	21,000	70,000	n/a
TOTAL Okavango Basin	**943,172**	**353,462**	**35,070**	**71,555**	**24,595**

Note: These figures relate to the basin as a whole

While livestock numbers have generally increased over the years as a result of better disease control and an increasing number of relatively wealthy people acquiring herds, the numbers have fluctuated markedly, especially in very dry periods. In order to control Cattle Lung Disease and especially Foot and Mouth Disease, a network of veterinary cordon fences has been erected around the Okavango Delta and in Namibia. Because of their influence on land use and transboundary movement, these fences are shown in Figure 2-25.

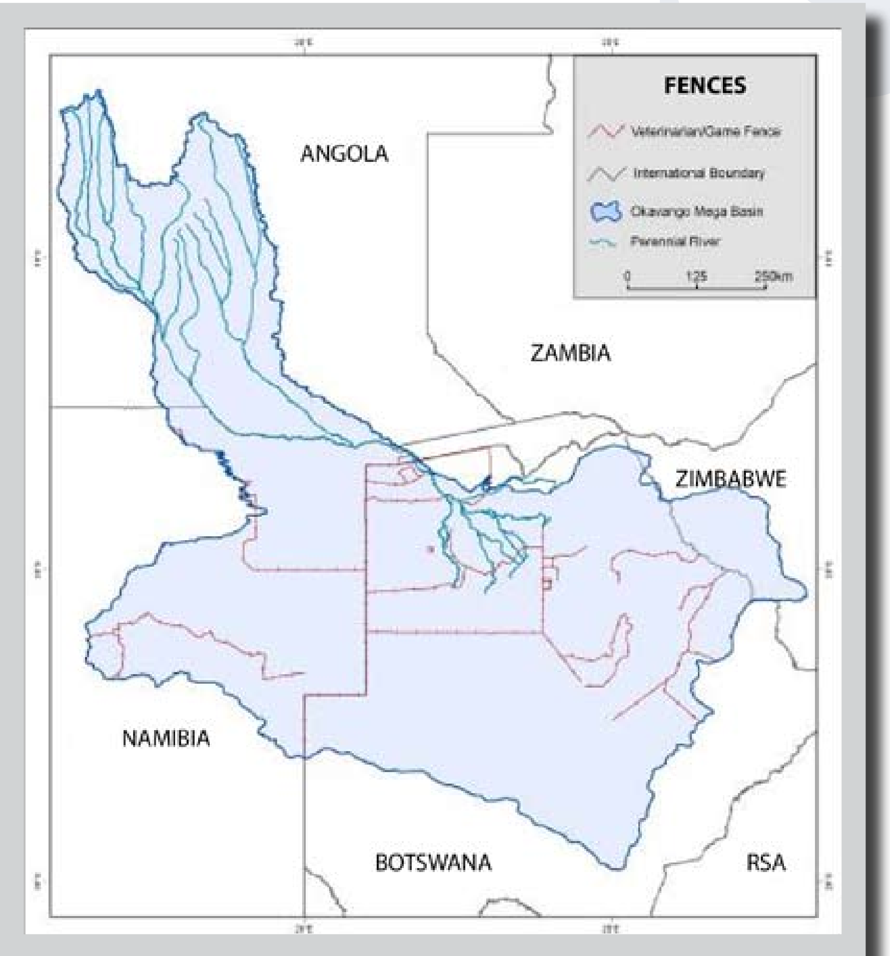


Figure 2-25: Alignments of existing veterinary cordon fences in the Okavango River Basin

54 Mendelsohn, J. and el Obeid, S. (2004)
55 Beuster, H. (2009a)

Veterinary checkpoint, Botswana

Harvesting of natural resources

All the communities in the Okavango River Basin use the natural resources of the river, especially the fish and the surrounding land, as an important contribution to their livelihoods. The importance of fisheries to livelihoods varies in different sections of the river.

The most productive section in *Botswana* is in the north of Ngamiland, around the panhandle, where 65% of the population depend on fishing. In 2004/2005, almost 130 tonnes of fish were caught in the Delta, of which 68% were bream and 25% were catfish. This is about 80% of Botswana's freshwater fish production. [56]

In *Namibia,* fishing also makes an important contribution to the livelihoods of riparian communities, although they recognise that the fish catches have been changing, with fewer cichlids being caught in some areas as a result of selective gillnetting. The fish catches around the Mahango Game Reserve have been better protected. [57]

In *Angola,* local fishermen recognise the importance of fish migrations, and the fact that during flood season, fish catches decline significantly. When consulted during the TDA study, the majority of people felt that the fishing situation was quite stable, but were aware that habitat destruction and overexploitation contribute towards reduced catches, and that there is a need for conservation measures. [58]

Other natural resources harvested from the river and its floodplains include firewood, reeds and grasses, fruits, wild foods and medicinal plants. Devil's claw (*Harpagophytum procumbens*), a medicinal herb, is in high demand in Europe, with up to 600 tonnes exported from Namibia annually. It thus requires careful management to prevent it from becoming locally extinct.

Some of the other medicinal plants in the basin have potential commercial value for oils for the international cosmetics market. However, the depletion of the riverine forest and dry woodland areas in Namibia has considerably reduced the availability of such bush products.

Fire

While fire is an ecologically important agent, determining the character of the vegetation and favouring species that are adapted to regular outbreaks of fire, it tends to produce sparse dry woodland with large areas of thickets dominated by fire resistant shrub species. The mosaic of dry deciduous forest and secondary savannah grassland covering the area south of Cuando Cubango Province in Angola and in the Kavango region in Namibia, can be considered the fire epicentre zone in the basin. Repeated fire cycles affect the composition, density and diversity of the vegetation.

In south-eastern Angola, on average more than 60% of the area is burned every dry season[59]. In the Kavango region, the frequency of fire is shown in Figure 2-24. There is particularly intense burning on either side of the river after the confluence between Okavango and Cuito Rivers.

In northern Ngamiland, fires are less frequent due to different land management practices, and tend to occur more frequently as a result of 'spill' events from Namibia. Fires very often occur as a result of human activity such as clearing land for cultivation, and hunting, but also as a result of movement along roads, tracks and fence lines. The use of fire for hunting is a particular issue in the panhandle area.


Boating in the Okavango Delta, Botswana

56 FAO Fishery Country Profile 2007
57 Van Der Waal, B. (2009)
58 Saraiva, R. (2009)
59 (Luis Verissimo, pers com, based on experience of IBRM project)

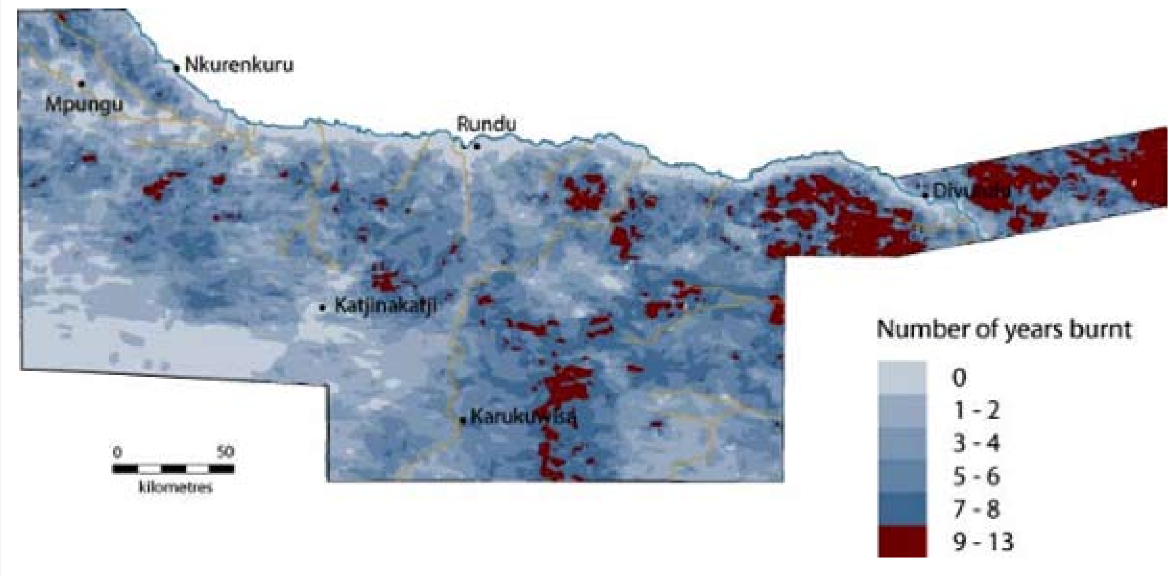


Figure 2-24: Frequency of fire outbreaks in the Kavango region of the Okavango River Basin (1989-2001)

Source: Mendelsohn and el Obeid 2004

2.5.2 Tourism and hunting concessions

Over the past 20 years, tourism development in Botswana has been extensive throughout the Okavango Delta, to such an extent that it is now a major feature of land use in Ngamiland. Non-consumptive uses include photographic safaris, camps and lodges providing game drives, boat safaris and horse trails. Consumptive uses include trophy hunting, sport hunting and game farming.

The number of visitors coming to Botswana has risen from a total of 620,000 in 1994 to nearly 1.9 million in 2005, a growth rate of about 3% per year, with about 40,000 visiting the core Moremi Game Reserve in 2006. [60] To cater for the increasing numbers of tourists in the Delta there are now over 80 hotels, lodges and camps within the Ramsar Site, providing 1,635 beds.

The major goal of the Botswana Government, as expressed by various policy documents and plans, is to expand tourism revenue in the Okavango Delta. This means tourist numbers, tourist activities and tourism infrastructure such as lodges and hotels are bound to increase. The increase of tourism development in the Okavango Delta is thus bound to have socio-cultural, economic and environmental impacts in the wetland. Increasing numbers of visitors in the Delta could put added pressure on the ecosystem and natural resources of the river.[61]

The distribution of tourism development in the three countries is shown in Figure 2-27. As can be seen, there is considerable untapped potential for tourism in the highlands of Angola. Tourism developments in this area would slow down haphazard mushrooming of settlements that could have detrimental effects on the ecology of the river and the Delta.

Rural village in Matala, Huila Province, Angola

60 Mbaiwa, J. (2009)
61 Mbaiwa, J. (2009)

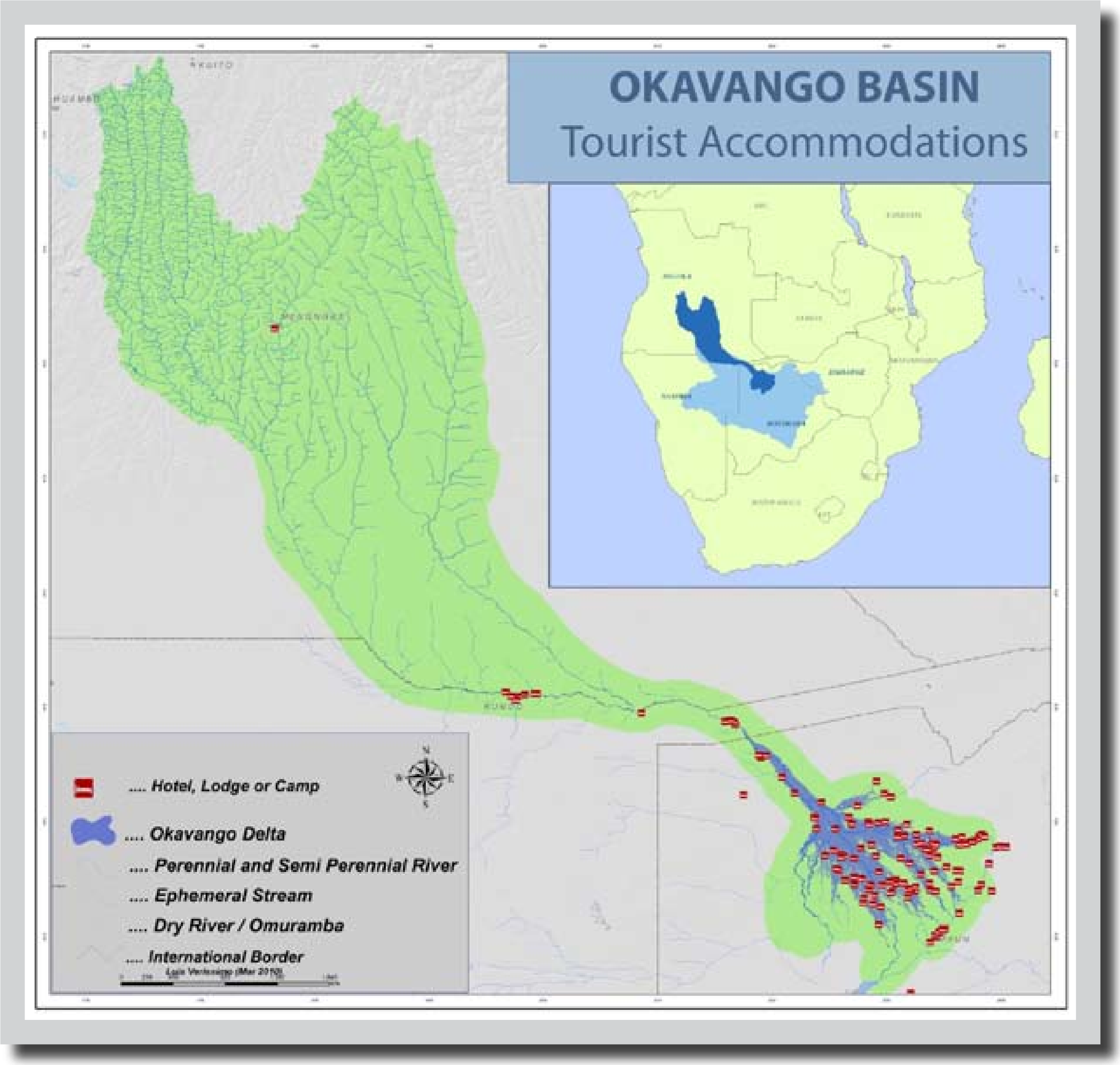


Figure 2-27: Distribution of tourist accommodation throughout the Okavango River Basin

Source: Mendelsohn and el Obeid 2004

2.5.3 Protected areas

Both Botswana and Namibia have developed systems of protected areas, and the Okavango Delta has been divided into a complex of differently managed areas, with the Moremi Game Reserve providing the core of the Delta's protection. It is surrounded by various hunting and photographic concessions and community managed areas. The extent of protected areas and areas managed for conservation throughout the basin and in the Delta is shown in Figures 2-28a and b.

Both Namibia and Botswana are signatories to the Ramsar Convention, and Botswana's one Ramsar Site encompasses the whole of the Okavango Delta. The government has, through an extensive process, developed an Okavango Delta Management Plan for the Ramsar Site. Namibia has no Ramsar Site in the ORB, and Angola is not yet a signatory to the Ramsar Convention.

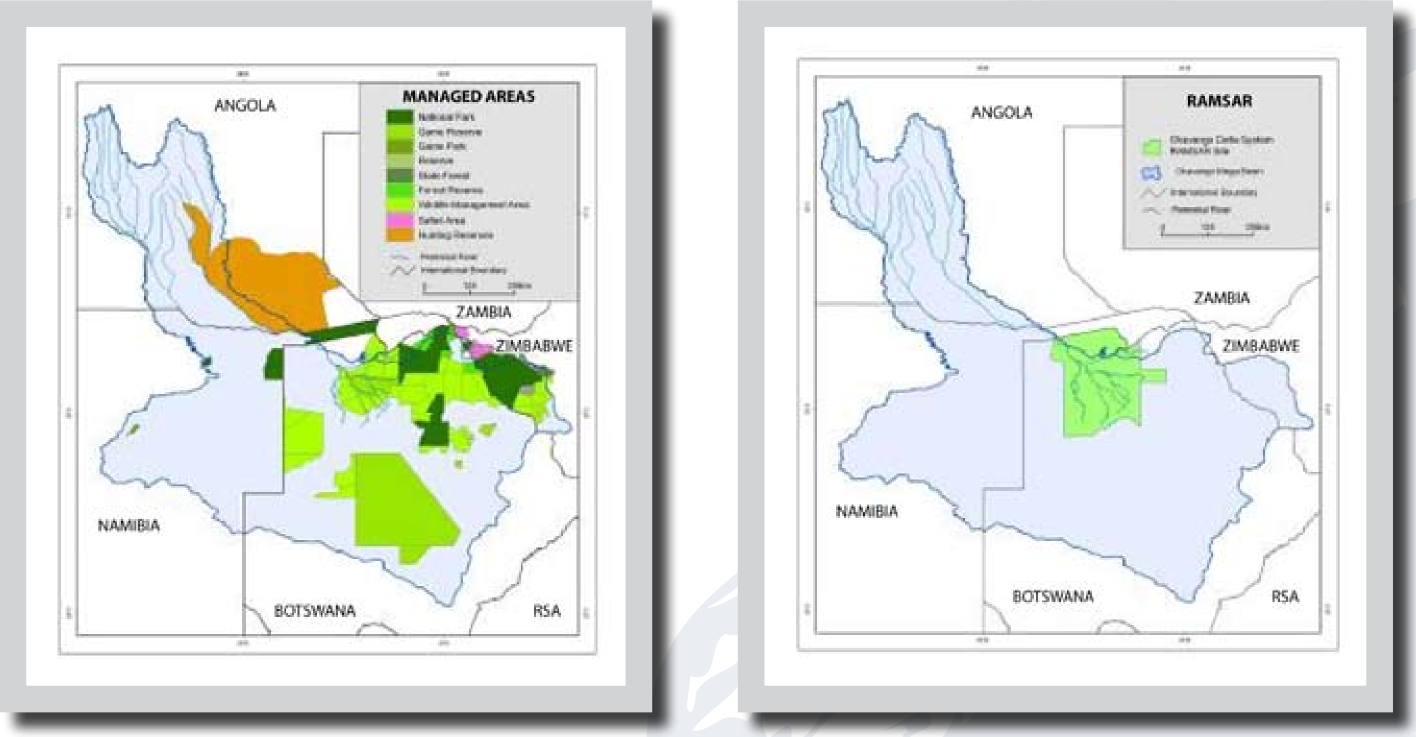


Figure 2-28: a) Protected and managed areas in the Okavango River Basin

b) Okavango Delta Ramsar Site

2.6 CURRENT WATER USE PATTERNS

2.6.1 Water use

Overall, the direct exploitation of the Okavango River is limited. Table 2-24 presents an estimate of water use by economic sector in each country (EPSMO Project 61).[62]

TABLE 2-24: PRESENT DAY WATER USE BY COUNTRY

Water users	Angola	Namibia	Botswana
	Water use – Mm³/year		
Urban domestic	8.20	7	3.55
Rural domestic	5.10	2	0.29
Livestock watering	2.50	3	15.92
Irrigated agriculture	15.60	36	0.52
Fish farming	0.00012	2	0
Tourism industry	0	1	0.2
Total	**31.40**	**51**	**20.48**

Note: Water use by wildlife is considered as part of ecosystem demand, see Chapter 4, Section 4.2

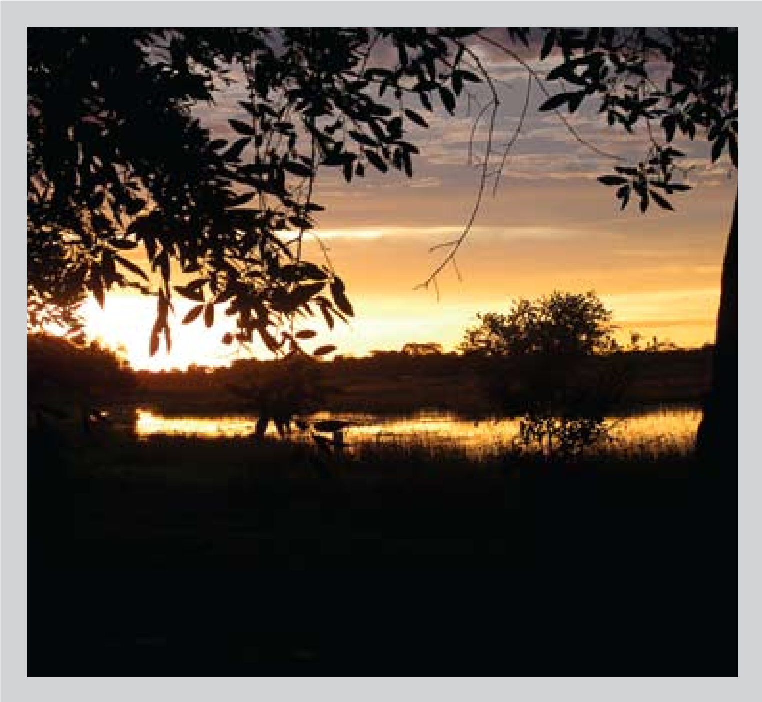
2.6.2 Water supply

Angola: In the urban centres of Menongue and Cuito Cuanavale 225,523 people are supplied with a total of 8.2 Mm^3/yr out of a total requirement for water of rural and urban populations of about 13.3 Mm^3/yr. More than 50% of the inhabitants depend on the river for direct supply of water.[63]

Namibia: there are three categories of water supply –

- Commercial bulk water supplied by NamWater to local authorities, regional councils, settlements and villages
- Rural water supplied by the Directorate of Rural Water Supply (DRWS) to rural communities
- Direct water drawn from rivers and streams by communities, tourist lodges, irrigation and fish farms.

62 Beuster, H. (2009b).
63 Saraiva, R. (2009)



Sunset at Rundu, Namibia

NamWater has nine water abstraction points along the river and 12 groundwater schemes. Most of the water for the DRWS supply comes from boreholes. About 70% of the population in Kavango live within 5 km of the river and are therefore dependent on water from the river.[64]

Botswana: there are urban water supply schemes in Maun, Gumare and Shakawe, and integrated rural village water supply schemes at Sepopa/Ikoga and at Kauxwi/Xakao/ Mohembo east. Ninety-five percent of the people living in the Botswana section of the basin have some access to potable water supplies from boreholes and are not directly reliant on river water. Most of the camps and lodges in the Delta have their own boreholes. [65]

2.6.3 Sanitation

Angola: there are virtually no sanitation services which means that people use either the environment or earth toilets. There are no waste water treatment facilities in the urban areas and solid wastes are often dumped in the river.

Namibia: approximately 82% of the rural population have no access to sanitation services and the majority use the bush, although some have access to pit latrines and septic tanks. Fifteen percent of the inhabitants of Rundu are connected to a central sewer system.[66]

Botswana: there is a sewage treatment plant in Maun that was designed in 1993 and experiences regular breakdowns and could be reaching its capacity by now.[67] Other waste water treatment systems in Botswana include a 100 m^3 per day plant at Boro Farm, a constructed wetland facility at Thuso Rehabilitation Centre, and a new sewer network and treatment plant at Gumare. Within the Delta each camp or lodge requires its own waste water disposal system. There is concern that there may be localised water pollution and eutrophication of the wetlands around such tourism facilities.[68]

2.6.4 Hydropower

Only one hydropower scheme exists in the Angolan section of the basin. This station, situated at Cuvango, was damaged during the civil war and is being rehabilitated. There is also a small operational hydropower station with an average capacity of 25 kW at Andara in Namibia. Future plans for hydropower schemes are discussed in Section 4.2.2.

2.6.5 Aquaculture

There is currently one aquaculture scheme in Angola at Menongue, which abstracts 10 m^3 per month from the Cuebe River. After use, the water in the ponds is diverted for crop irrigation.[69]

In Namibia, the Ministry of Fisheries and Marine Resources operates three community-based fish farms at Nkurenkuru, Kangongo and Kaisosi, which account for about 4% of the water abstraction in Namibia. [70]

Aquaculture in Botswana is at a very early stage with a number of small ponds located at research and educational institutions. There has also been some research and development of crocodile farming in the Okavango Delta. [71]

64 Nashipili, N. (2009)
65 Masamba, W. (2009a)
66 Nashipili, N. (2009)
67 ODMP (2008).
68 Masamba, W. (2009a)
69 Beuster, H. (2009a)
70 Nashipili, N. (2009)
71 FAO Fishery Country Profile 2007

2.7 GOVERNANCE

This section covers the governance and organisation of the three riparian countries and describes legislation, policies and institutions that have an impact on environmental management relevant to the Okavango River Basin. The final study report on governance review,[72] which can be found on the DVD accompanying this document, contains summary tables of applicable international policies, strategies and action plans for select natural resource management, and the institutional responsibilities for this management in the three countries.

Basket maker at Capico, Kuando Kubango Province, Angola

2.7.1 Organisation of states

All three Okavango Basin states are independent republics with written constitutions as the supreme law of the land. These post-independence constitutions – Angola 2010 (replacing the constitution of 1992), Botswana 1966 and Namibia 1990 – establish the respective states as parliamentary democracies with an elected president as both Head of State and Head of Government. For an overview of government structures in the three Okavango Basin states see Figure 2-29.

Angola

Angola has four layers of government – national, provincial, municipal and communal, which also include traditional authorities. These are not independent spheres of government; instead, the latter three are hierarchically related and integrated into central government. It is incumbent on the provinces to execute the policy of central government at provincial level through the coordination of central government agencies in the territory. The respective provincial governor, appointed by the president, is the representative of central government in the province, and provincial directorates mirror the ministerial structure at national level.

Likewise, municipal administrations are de-concentrated bodies of the central government, reporting to provincial government with municipal administration replicating the ministerial structure. In the same way, village administrations are de-concentrated bodies of central administrative power and are answerable to the respective municipal administration[73]. The provincial governor appoints village administrators to head the village administrations and to act as spokespeople for the day-to-day problems of communities.

The Angolan Parliament approved a new constitution on 20 January 2010, which follows the 2001 Strategic Plan for Deconcentration and Decentralisation and envisages a reformed structure of government over time, ultimately culminating in the creation of autonomous local municipalities[74].

Children at Liyapeca Rapids, Angola

Namibia

Namibia's 1990 Constitution establishes three independent spheres of government – national, regional and local. Each regional and local government has an elected council and an executive administration. Local authorities can take different forms such as municipalities, or town settlement areas and village councils. The powers and functions of regional and local government are assigned to them by an Act of Parliament. Regional and local government have some revenue raising power and also share in the revenue raised by central government. As in Botswana, traditional authorities play an important role in local decision making, particularly with respect to land allocation.

72 Malzbender, D. (2009)
73 UNDP, (2006)
74 Ibid

Botswana

Botswana has no separately administered provinces or states, having national and local government levels only. The latter is single-tiered, comprising both urban (two city councils, five town councils, one township authority) and rural councils (10 district councils)[75]. Local government in Botswana works with participative structures such as the kgotla (village assembly) and village development committees as institutions for two-way communication between the government and the community[76]. Traditional authorities play an important role in local-level decision-making, particularly concerning issues of land allocation (see Section 2.7.3).

Councils have their own jurisdiction but their activities and plans are coordinated through various mechanisms and forums organised by central government, for example national and local-level decentralised development planning, National District Development Plans and the National Development Plan[77]. A recent White Paper in 2004 proposed reforms that would further strengthen the role of local government in Botswana. The proposed reforms include greater autonomy of local government in local-level development planning and management[78].

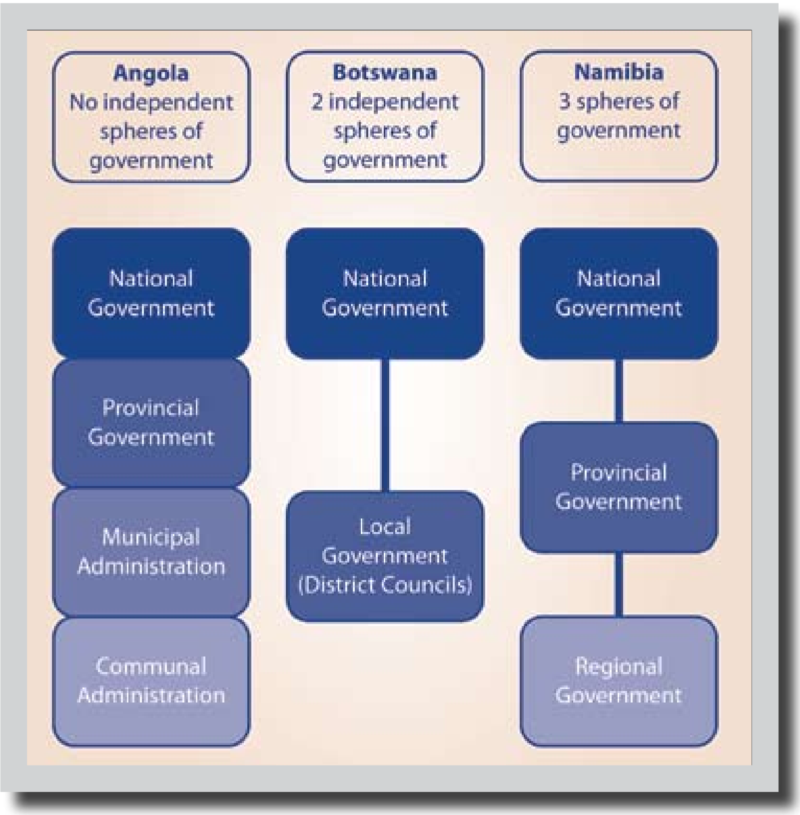


Figure 2-29: Overview of government structures in the three Okavango Basin states

2.7.2 National Development Policies and Key Sector Policies

Angola

Angola's post-conflict priority on economic growth and development for poverty reduction and improvement of livelihood is reflected in two key national development policies. The Angola 2025 Long-term Strategy (Estrategia de Longo Prazo), reviews the significant development challenges in the country, some of which include: low human development, a weak economy and institutional instability. It suggests various strategies, including the possible growth of designated sectors and key activities.

The long-term strategy is complemented by the Strategy to Combat Poverty (ECP) 2005, which was developed in terms of the key goals of reconstruction and national development as stated above. Its overall objective is to improve the living conditions of Angolan citizens. Specific objectives under this strategy include minimising the hunger risk, enabling rural economies, and to reconstruct, rehabilitate and expand basic infrastructure in order to foster socio-economic development.

75 CLGF (2006)
76 Ibid.
77 Ibid.
78 Ibid.

An ambitious rural water supply program known as 'Água para Todos' or 'Water for All', it is implemented in 17 provinces of Angola, with the exception of Luanda Province.

The most relevant sector policies in the context of the management of the Okavango Basin are energy related. Although the country does not yet have a comprehensive Energy Policy, the Development Strategy for Angola's Power Sector (2002) and the Strategy for the Development of the Electricity Sector of Angola (2002) prioritise the rehabilitation of hydropower infrastructure as it is considered to be an important component of the national energy mix. Angola does not have sector policies for International Trade as yet, although there is a medium-term development plan for Agriculture.

Namibia

Namibia's development visions are contained in Vision 2030, which deals extensively with all aspects of the environment, including water, land use and biodiversity. Strict pollution control is a guiding principle underlying all of the above through its policy of integrated water resources management. Vision 2030 is complemented by the National Development Plan 3, a more detailed planning document with an overall theme of accelerated economic growth through extensive rural development. Productive utilisation of natural resources and environmental conservation are key goals. Namibia's White Paper on National Water Policy provides the policy framework for equitable, efficient and sustainable water resources management and water services. It sets out a set of basic principles in accordance with which all water-related decisions need to be carried out. These include:

- The equitable access to sufficient safe water for a healthy and productive life for all Namibians
- Harmonisation of human and environmental requirements, recognising the role of water in supporting the eco-system
- Management and planning of water resources in an integrated manner across economic, environmental and social dimensions
- Promotion of equitable and beneficial use of international water courses, based on generally accepted principles and practices of international law.

Soba, Cuelei, Kuando Kubango Province, Angola

The Namibian energy policy is enshrined in the Energy White Paper (1998), which emphasises the need for achieving security of supply, social upliftment, effective governance, sustainable growth, competitiveness and efficiency. The White Paper emphasises the need for an energy mix that is increasingly based on renewable energy, as well as for making Namibia a centre of excellence for solar energy.

Rundu, Kavango Region, Namibia

Namibia's National Agricultural Policy (1995) focuses largely on generating increased income levels through agriculture, while at the same time acknowledging the limitations of the country's soil and advocating sustainable use of natural resources. In a similar vein, the National Drought Policy and Strategy (1997) shifts the onus for drought management from the government to farmers by establishing appropriate techniques to cope with drought.

While the National Agricultural Policy recognises that agriculture cannot be expanded at the expense of the natural environment, the country has developed the Green Scheme initiative, which encourages the development of irrigation-based agriculture in order to increase Namibia's GDP. The result is intended to be a four-fold increase in irrigated agricultural land in the country. The Kavango Region has been identified as one of the areas for the development of irrigated agriculture under the Green Scheme.

Namibia's Industrial Policy (1992) advocates a change in direction for Namibian industry towards a more value-added manufacturing sector which would lead to increased exports.

Botswana
Vision 2016 is the country's overarching development vision, which aims to achieve the sustainable economic growth and development of the country by 2016, identifying environmental degradation as a key challenge in the achievement of such.

The National Development Plan 9 is a more detailed national development plan, which calls for the appropriate use of natural resources and the consideration of environmental costs when planning for the development of the country. It is complemented by a wide range of sector policies and strategies. The National Energy Policy (2006), complemented by the Botswana Energy Master Plan, aims at providing a least-cost mix of energy supply, which reflects total life cycle costs and externalities of its generation. The Energy Policy emphasises the need to reduce deforestation and the promotion of solar energy, aiming to make Botswana a centre of excellence for solar technology.

The National Policy on Agricultural Development (NPAD) (1991) has as its objectives, improving food security, diversifying the sector, increasing employment and conserving scarce agricultural resources for future generations. This policy is very similar to the 1977 Arable Land and Development Programme. These agricultural policies are complemented by the Botswana National Master Plan for Arable Agriculture and Dairy Development (NAMPAD), which seeks to greatly increase the commercialisation of agriculture through easier access to agricultural land and a steady stream of agricultural inputs.

Trade and industry development in Botswana is steered by the Industrial Development Policy (1998), which guides the government's approach and outlines the associated guiding principles. The policy is directed at increasing productivity through the employment of highly skilled labour and modern technology. The country does not have a designated international trade policy.

2.7.3 Natural resource management laws, policies and institutions

Water resources management
In 1994, the three Okavango Basin countries established the Permanent Okavango River Basin Water Commission through the OKACOM-Agreement, subsequently complemented by the 2007 Agreement on the Organisational Structure of OKACOM. While the OKACOM-Agreement makes reference to key principles of international water law (e.g. equitable utilisation in Article 4(3)) it does not itself establish these as international legal obligations of the three Parties. At the time, the Parties would have drawn from customary international law, which clearly establishes the principles of

1. equitable utilisation
2. the duty to take all reasonable measures to prevent transboundary harm
3. the duty to cooperate

as substantive legal obligations of states for the management of internationally shared water resources.

With the entry into force of the (Revised) SADC Protocol on Shared Watercourses in 2003, these three key legal rules for shared waters are today applicable treaty law for the Okavango Basin states, as all three have ratified the Revised Protocol. In addition to these three key principles, the Revised Protocol [79] contains a number of substantive and procedural obligations (mostly related to ecosystem protection), making it the water-specific international legal instrument applicable to the basin. The Revised Protocol is complemented by other relevant international agreements, such as the UN Convention for Biological Diversity (UNCBD) and the Ramsar Convention.

At policy level the Revised Protocol is complemented by the SADC Regional Water Policy (RWP) and the SADC Regional Water Strategy (RWS). Subscribing to the principle of integrated water resources management (IWRM), the two instruments lay down regionally agreed policy guidelines concerning water resources management, covering a wide range of topics from infrastructure development, information exchange and capacity building to gender aspects and stakeholder involvement. Chapter 5 of the RWP deals with water and environmental sustainability and recognises the environment as a resource base and legitimate user of water in its own right.

Informal market in Menongue, Angola

79 This mirrors the text of the 1997 UN Convention on the Law of the Non-navigable Uses of International Watercourses, not yet in force.

At the national level, all three basin countries have adopted designated water resources management legislation, which recognises the obligations resulting from international water agreements.

Angola

The Angola Water Act (2002) establishes the state as the custodian of the country's water resources in charge of administering the water use rights system. It establishes a water allocation framework (licensing system) and water quality control regime and, in line with IWRM principles, provides for the establishment, over time, of basin committees (Comités de Bacia) as stakeholder forums. A river basin authority for the Okavango is in the process of being set up and will have administrative responsibilities on the committee. A Master Plan for the Angolan portion of the ORB will start in the second quarter of 2010. In February 2010 the Ministry of Energy and Water was created, housing the Water Secretariat that has two main departments: water and sanitation, and water resources management.

Angola has established an inter-ministerial committee for international waters, assisted by a Technical Support Group and is in the process of setting up a national institute for water resources management.

Missombo irrigation scheme

Namibia

Namibia is currently going through a transitional phase in which the 1956 Water Act (still applicable) is being replaced by the Water Resources Management Act (2004) that is soon to commence. In the interim Namibia has started implementing significant elements of the new Act, amongst others the progressive establishment of basin management committees, in which context the Okavango Basin Management Committee was established in 2008. Namibia is also in the process of developing a national IWRM plan.

The Namibia Water Corporation Act of 1997 aims to provide bulk water supply to customers:

- in sufficient quantities
- of a quality suitable for the customers' purposes
- by cost effective, environmentally sound and sustainable means in the best interests of the Republic of Namibia.

It also provides for the secondary business of rendering water-related services, supplying facilities and granting rights to customers upon their request. The Water Supply and Sanitation Sector Policy of 2008 aims to improve the provision of water supply in order to:

- Contribute to improved public health
- Reduce the burden of collecting water
- Support basic water needs
- Promote water conservation.

Botswana

Botswana is in the process of reforming its domestic water legislation, parallel to the development of a national IWRM plan and substantial reform of the institutional structure for water resources management. This restructuring process is a result of recommendations by the Botswana Water Sector Master Plan Review.

A draft Water Bill has been produced and will, once promulgated as an Act, replace the currently applicable 1968 Water Act. The proposed new Act brings the country's legislation in line with IWRM principles and, like the new Namibian Act, provides for the devolution of water management responsibilities to the lowest possible level (through the establishment of water management area bodies and village water development committees). The forthcoming Act also establishes a new Water Resources Council with key decision-making functions in water resources management and allocation. Notably, the Water Resources Council shows strong elements of inter-ministerial cooperation, as a wide range of relevant line-ministries is required to be represented on the council.

In terms of policy/strategy, Botswana has, through a consultative process, developed a comprehensive Okavango Delta

Management Plan (ODMP). The ODMP is an inter-sectoral management plan governing the management of the Delta's natural resources in an integrated way. The development of the draft Wetlands Policy led to the establishment of the Okavango Wetlands Management Committee (OWMC).

Land Management

The most important international agreements applicable to the basin with respect to land-use management are the UNFCCC and the UNCCD, which provide an international law framework for adaptation measures and land management. At the regional level, the SADC Protocol on Forestry promotes sustainable forestry and related land use management.

Angola

Angola has two primary policies with regards to land-use management: The Programa Nacional de Gestão Ambiental (PNGA) (2009), which is seen as an important instrument for achieving sustainable development, and the Estratégia Nacional do Ambiente (ENA); which is closely related to the PNGA, and aims at identifying and addressing the main environmental problems in Angola, in order to achieve sustainable development.

Land-use management legislation in Angola is largely contained in the Land Law (Lei de Terras) (1992), which is framed within the concept of integrated planning. Further regulation is contained in the Framework Law on Environment (1998) and the Land Act (2004), both of which follow the sustainable development principles contained in the Land Law. Angola currently has three ministries involved in land-use management: the Ministry of Planning, Ministry of Urban planning and Construction and Ministry of Environment (see overview of institutional responsibilities in the final TDA Governance Report[80]).

Namibia

In Namibia, the National Land Policy (1998) and the Draft National Land Tenure Policy (2005) both acknowledge the environmental limitations on land use and seek to ensure sustainability through improved resource use and land management. Neither has led to the enactment of legislation to date, although such principles are broadly covered under the Environmental Management Act and the Communal Land Reform Act (2005). Namibia has developed a National Strategy to Combat Desertification under the United Nations Convention to Combat Desertification (UNCCD). Of particular relevance to the Okavango Basin is a regional land-use plan for the Kavango Region, which is currently under development and nearing completion.

Namibia has seven ministries which each oversee land-use management to varying degrees. Multi-departmental entities are also central to land management in Namibia, and include the Land Boards and Management Committees. Traditional authorities play a strong role in land allocation decision-making.

Botswana

Botswana has a multitude of policies and laws that impact directly on land-use management. These include the country's National Strategy and Action Plan to Combat Desertification under the UNCCD. The Okavango Delta Land-use Management Plan (ODMP) aims to align sustainable land use with other natural resource use. The mandate for the conservation of biodiversity lies with the Ministry of Environment, Wildlife and Tourism, although activities of many different ministries could impact positively or negatively on biodiversity. In Botswana, eight ministries are involved in land-use management as well as several multi-departmental entities, including the Land Boards and Tribunals. Traditional authorities play a key role in the allocation of land.

Biodiversity Management

The applicable international law framework for biodiversity management and protection in the basin is provided by the UNCBD, CITES, and the Bonn Convention on Migratory Animals, complemented at regional level by the SADC Protocol on Wildlife, which promotes conservation and the sustainable use of biodiversity at regional level.

Selling Okavango dried fish, informal market in Menongue, Angola

80 Malzbender, D. (2009)

Angola

Angola's two overarching environmental policies, the *Programa Nacional de Gestão Ambiental* (PNGA) (2009) and the *Estratégia Nacional do Ambiente* (ENA) (2000) deal with matters affecting biodiversity and conservation. The National Biodiversity Strategy and Action Plan (under the UNCBD) presents more specific and concrete biodiversity objectives. The main legislation for biodiversity protection is the Environmental Framework Act (1998), which contains provisions for pollution prevention and natural ecological protection.

At present six ministries in Angola are involved in biodiversity management, of which the Ministry of Environment is the leading line ministry.

Mcundi, Cubango River, Angola

Namibia

Namibia has several policies impacting on biodiversity protection in the country, which are predominantly agricultural in nature. The Agricultural Policy (1995), discussed above, and the National Drought Policy (1997), which makes provision for drought management procedures in order to reduce long-term vulnerability to drought, are both underscored by sustainable land and resource use. More specifically, biodiversity protection is an integral part of the Wildlife Policy for Communal Areas (1995) and the Draft Tourism Policy (2007), both of which emphasise sustainable biodiversity use through community-based natural resource management (CBNRM). Like Angola and Botswana, Namibia has also developed a National Biodiversity Strategy and Action Plan under UNCBD covering the period 2001-2010.

The Environmental Management Act (2007) contains environmental management principles important to biodiversity preservation, while the Forest Act (2001), Nature Conservation Amendment Act (1996) and the Draft Parks and Wildlife Management Bill all provide for specific biodiversity protection in designated areas. Biodiversity import and export is regulated under the Biosafety Act (2006).

Five ministries play a role in biodiversity preservation in the country with the Ministry of Environment and Tourism being the lead line function ministry.

Botswana

Botswana's primary policy on biodiversity is the National Policy on Natural Resources Conservation and Development (1990), which entrenches sustainable development and environmental protection within the national planning process. This policy is supported by the Botswana National Biodiversity Strategy and Action Plan (NBSAP) under the UNCBD, which provides for a series of activities and projects related to biodiversity conservation. Botswana recognises biodiversity conservation as a major economic development opportunity (through *inter alia* eco-tourism). This aspect is further strengthened through relevant legislation such as the Wildlife Conservation and National Parks Act (1992) which, along with various other tourism related acts, provides for preservation of wildlife resources inside parks and reserves, and for the controlled use of wildlife resources elsewhere, in order to strengthen the country's eco-tourism sector. The mandate of the conservation of biodiversity lies with the Ministry of Environment, Wildlife and Tourism (MEWT).

At present, four ministries are responsible for the protection of the country's biodiversity.

Old bridge on the way to Cuelei, Angola

2.7.4 Permanent Okavango River Basin Water Commission (OKACOM)

Established in 1994 by the 'Agreement between the Governments of the Republic of Angola, the Republic of Botswana and the Republic of Namibia on the Establishment of a Permanent Okavango River Basin Water Commission', OKACOM serves as a technical advisory body to the Parties on matters relating to the conservation, development and utilisation of water resources of common interest. Whereas the OKACOM Agreement does not create substantive rights and obligations of the Parties with respect to the management of the basin, it determines the issues for which OKACOM is mandated to advise the Parties.

In April 2007 the three Parties concluded the 'Agreement between the Governments of the Republic of Angola, the Republic of Botswana and the Republic of Namibia on the Organisational Structure of OKACOM' (the OKACOM-Structure Agreement) which establishes the organs of OKACOM as

- the Commission
- the Okavango Basin Steering Committee (OBSC) and
- the Secretariat,

with the Commission being the principal organ responsible for defining and guiding the development policy and the general supervision of the activities of OKACOM. The OBSC is the technical advisory body to the Commission, whereas the secretariat is responsible for providing administrative, financial and general secretarial services to OKACOM.

The OKACOM Structures Agreement defines the functions of the three organs in significant detail, together with regulating other procedural matters relevant for the functioning of OKACOM, such as financing, working language and communication. Article 7(n) permits the Commission to establish ad hoc working groups or specific temporary or permanent committees. Three Task Forces have subsequently been established, namely a Biodiversity Task Force, a Hydrology Task Force and an Institutional Task Force.

Issues upon which OKACOM is mandated to advise the Parties

- Measures and arrangements to determine the long-term safe yield of the water available from all potential water resources in the Okavango River Basin
- The reasonable demand for water from the consumers in the Okavango River Basin
- The criteria to be adopted in the conservation, equitable allocation and sustainable utilisation of water resources in the Okavango River Basin
- The investigations, separately or jointly by the Contracting Parties, related to the development of any water resources in the Okavango River Basin, including the construction, operation and maintenance of any water works in connection therewith
- The prevention of the pollution of water resources and the control over aquatic weeds in the Okavango River Basin
- Measures that can be implemented by any one or all the Contracting Parties to alleviate short-term difficulties resulting from water shortages in the Okavango River Basin during periods of drought, taking into consideration the availability of stored water and the water requirement within the territories of the respective Parties at that time
- Such other matters as may be determined by the Commission.

In addition, the basin countries are considering maintaining National Coordination Units (NCUs), initially established as temporary, project-specific bodies for the EPSMO project, as permanent structures in order to strengthen OKACOM's linkages with the basin states at local, operational level. However, a final decision on the matter as well as the exact position of the NCUs in the operational structure of OKACOM is yet to be taken.

The Commission consists of the three national delegations, each comprising three Commissioners appointed by the respective country. The Commissioners are representatives of relevant government departments who attend to OKACOM matters as part of their departmental functions but do not work on OKACOM matters on a full-time basis.

The establishment of the OKACOM secretariat and subsequent appointment of an executive secretary with support staff has put OKACOM on a firmer administrative footing. Guided by the OKACOM Secretariat's three year plan, it provides the necessary support for OKACOM to operate effectively and meet the increasing responsibilities OKACOM is entrusted with.

In line with its mandate of being an information sharing platform for the three basin states, OKACOM has recently concluded the development of a Data Sharing Protocol, and the development of a Stakeholder Participation Strategy for OKACOM is ongoing.

2.8 SUMMARISING THE STATE OF THE OKAVANGO RIVER BASIN – A STORY OF CO-DEPENDENCE

This summarising section of Chapter 2 brings together key transboundary features of the present state of the Okavango River Basin, starting the causal chain analysis (Figure 2-30).

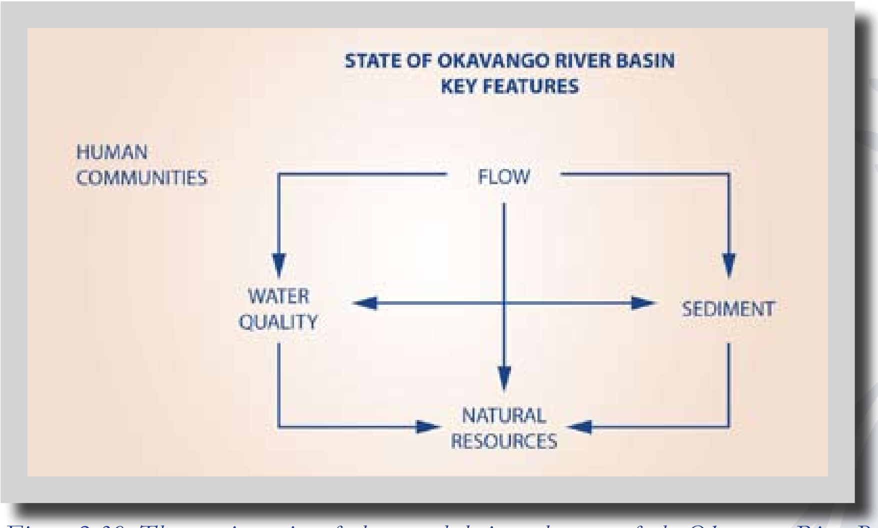


Figure 2-30: The starting point of the causal chain – the state of the Okavango River Basin

At present, the Okavango River is in very good condition environmentally, with clear water with low nutrient and pollution status, although local pollution and sedimentation does occur around urban centres and, civil works. Effluent discharges from tourist lodges in the Delta are generally controlled or light enough not to raise the pollution levels detectable by the ODMP bio-monitoring programme. As virtually the entire flow of the river originates upstream of Namibia and Botswana, these two countries are dependent on the flow from Angola.

The population in the basin is largely rural, with the highest densities in the Angolan highlands. The people living in the basin tend to be poorer, less well educated and with lower levels of development than in other parts of the respective countries. Angola has a 2.7% population growth rate while Namibia and Botswana experience a high prevalence of HIV/AIDS, which may limit future population growth in these countries.

The people in the basin are practically all directly dependent on the natural resources of the basin, with Angolan communities largely dependent on cropping agriculture, while Namibian and Botswana communities mainly use the resources generated by the river and flood plains. Tourism is a major source of household income in Botswana and to a lesser extent in Namibia. The contribution of the river system to the national economies is significant, with Angola deriving most benefits from the natural resources, Namibia from an almost equal mix of natural resources and tourism and Botswana almost entirely from tourism.

The natural systems of the river basin contain rich biodiversity and high biological productivity in the flood plains and Delta. The river's ecosystem services are essential for the provision of food, fuel and water as well as to regulate the recharge of ground water and regulate floods, amongst others. The river is also a significant part of the cultures of all the people in the basin.

Dry land agriculture is the predominant land use in the basin, with large numbers of livestock found in Namibia and Botswana. Protected areas and hunting concessions exist in all three countries and the Okavango Delta is a Ramsar Site, attracting numerous tourists and recreational visitors. Namibia is the largest abstractor of water from the river, mainly for irrigation agriculture, while Angola abstracts water for a small irrigation site and urban water supply. In Botswana most of the water used comes from groundwater supplies. There are currently no operational hydropower schemes on the river.

On a macro-economic level Angola is heavily dependent on its oil and gas sectors with agriculture and fisheries contributing some 12% to GDP. Namibia has the most diversified economy, with trade, transport, manufacturing and mining each contributing 10% of GDP with large areas of livestock and game farming. Botswana is very dependent on mining (40% of GDP) with a very small contribution from farming. Tourism, which is mostly associated with the Okavango, plays a modest role contributing about US$ 200 million (2.1% of GDP).

There are a number of policies and sectoral development plans in all three countries that are particularly applicable in the Okavango River Basin. The most significant institution for management of water resources in the basin is OKACOM, with full representation from all three countries. All the riparian countries have developed their own National Biodiversity Strategies and Action Plans.

It is clear from the present status of the Okavango River Basin that the system is still largely unaffected by human activities. This is the status on which the Transboundary Diagnostic Analysis (TDA) was based, using it to start the causal chain illustrated in Figure 2-30 above. Chapter 3 discusses the causal chain analysis in more depth as well as management procedures and methods used during the course of the TDA.

CHAPTER 3: THE OKAVANGO TDA

This chapter describes the preliminary TDA, the management of the subsequent TDA process and the methodologies used in its development. These methodologies include hydrological modelling, the Integrated Flow Assessment (IFA), economic analysis, and governance and policy review.

3.1 THE PRELIMINARY TDA OF THE OKAVANGO RIVER BASIN

The preliminary TDA was presented at a review workshop in June 1999. The OKACOM meeting in the same month concluded that as a result of a dearth of information on the Angolan section of the basin, both the process and products would require revision before the TDA could be used as a basis for consultation with stakeholders. The Commission also identified a need for concentrated effort in Angola.

In terms of the process, the lack of communication among the different national teams often led to varying quality and coverage of the reports. The TDA report itself was divided into two sections; Section A described the status of the basin and Section B concentrated on analysis of the issues.

The review committee felt that it was too descriptive and narrative, without attention to understanding the linkages and ecosystem processes. The overall focus of the report appeared to be on the lack of information and data, which, it was felt, led to recommendations to remedy this situation for the Strategic Action Plan, rather than prioritising issues and defining their transboundary nature. The review committee also felt that there was not enough emphasis on issues related to changes in land use and that there was a lack of consideration of lessons learnt from other river basins.

Table 3-1 shows some of the criticisms of the preliminary TDA and how these have been addressed in the current TDA.

TABLE 3-1: ADDRESSING THE SHORTCOMINGS OF THE PRELIMINARY TDA

Criticism of the preliminary TDA	Measures taken to address these in present TDA
Budgetary and time constraints in compiling a draft TDA acknowledged	• EPSMO is adequately funded
Process – lack of communication between national teams	• Thematic coordinators of the TDA covering all three countries • Framework and experimental results provided by the integrated flow assessment • Strategic and focused meetings bringing national teams together
Too descriptive and narrative, without enough analysis of linkages and processes	• The TDA process of the causal chain analysis is used to underpin the analysis • The integrated flow assessment component emphasises the linkages between changes in flow through biophysical to socio-economic changes. • The document is limited in description of the status, with a stronger focus on the analysis of issues
Strong focus on information gaps as the issue, rather than more fundamental issues threatening the basin	• Consultation exercises have been undertaken in each country to identify threats and issues • Lack of information is just one of many issues to be considered
No real prioritisation of issues and identification of transboundary issues	• Consultation processes have also allowed a prioritisation and classification of the issues, which will lead to a more clearly defined SAP • A clear distinction between transboundary issues that are different from purely national ones
Not enough emphasis on changes in land use	• The TDA uses an analytical approach based on trends for different levels of water use, which themselves depend on the changing patterns of land use in the basin

Despite the criticisms of the preliminary TDA report, Section A does provide a good, albeit patchy description of the different aspects of the Okavango River Basin as perceived in the mid 1990s. It therefore provides a reference document with which to compare trends and changes that have occurred over the past 10 years.

3.2 THE OKAVANGO TDA PROCESS

3.2.1 Overview

The Okavango TDA process started from an analysis of the baseline – the present state of the Okavango River Basin (ORB). It used observed trends in population growth and sectoral developments and identified three water use scenarios[1], which represented possible future pathways of increasing water-use in the basin. The probable implications of these three water use scenarios (low, medium and high water use development) were then analysed using two interrelated processes:

1. An in-depth analysis at eight representative sites along the river (the Integrated Flow Assessment (IFA))
2. A basin-wide macro-analysis.

The IFA took as its starting point hydrological simulations of how the pattern of flows would change along the river system under each of the three scenarios. It is true that land use change will change flow. The trans-boundary impact of that change would be transmitted through flow regime changes downstream. Therefore, by assessing impacts of flow changes, these impacts would be captured. The next step would be to determine how land use change would impact flow by the use of more precise hydraulic modelling as opposed to the hydrological modelling used to assess overall flows and water balances in this TDA.


Soba, Cuelei, Kuando Kubango Province, Angola

A multidisciplinary team from each riparian country collaborated in a parallel research programme that ended with the capture of present knowledge on:

- The relationships between river flow and important attributes i.e. 'biophysical indicators' of the river ecosystem
- The relationships between the biophysical indicators and important attributes of peoples' lives i.e. 'socio-economic indicators'.

The predictions of flow change were linked with the database of relationships to produce predictions of ecological and social change for each development scenario.

In parallel with the IFA, a series of basin-wide research activities was undertaken to understand the present status, trends and emerging issues throughout the basin beyond the eight representative sites as described in Chapter 2. One of the trends identified as important in the TDA process is climate change. This has been dealt with separately in a supporting report.

The IFA provided the scientific basis for the TDA by linking water resources development with changes in flow, ecology and socio-economics at the specific sites. The basin-wide studies allowed these observations to be extrapolated and highlighted basin-wide trends and issues emerging from the changes in the river.

The TDA includes a wide socio-economic and macro-economic analysis of developments in the basin to clarify trade-offs between water resources developments and the use of the river and its natural resources. There is also a review of water governance that includes assessments of the legal, policy and institutional frameworks and the capacity to address emerging issues.

The Okavango causal chain analysis, characteristic of TDAs, was predictive of challenges that may arise as a result of future developments in the basin and was used to identify possible trans-boundary impacts of water resources development. This started with an analysis of the drivers of change (or root causes) affecting four key characteristics of the river – flow, water quality, sediments and biological resources.

The TDA process allowed the identification of the priority issues and hotspots, especially those with transboundary implications, which would be taken forward in the development of the Strategic Action Programme (SAP).

The steps of the Okavango TDA are shown in Figure 3-1. Further details on the methods used during the process are described in Chapter 4.

---

1 The three water use scenarios are described in detail in Chapter 5.

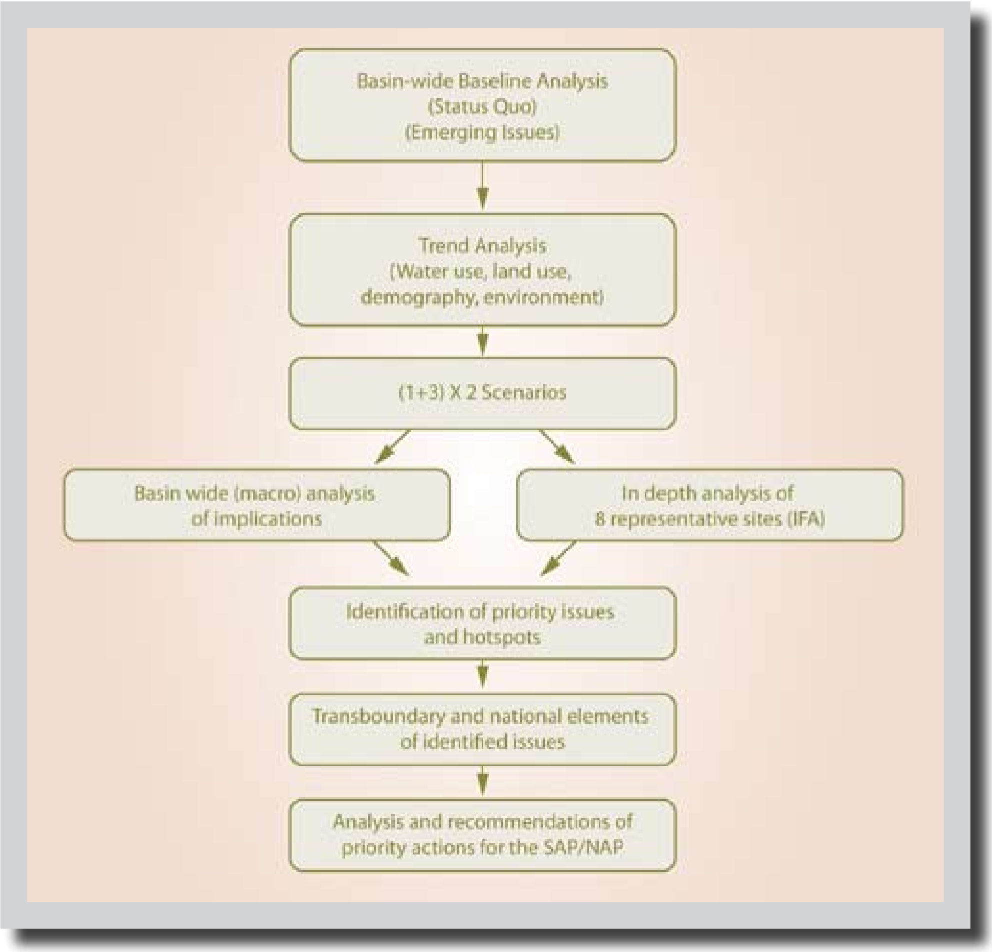


Figure 3-1: Outline of the Okavango River Basin TDA process

Note: '(1+3) x 2 Scenarios' refers to present day plus three water use scenarios, with 2 two climate change variations. IFA refers to the integrated flow assessment.

3.2.2 TDA Management and stakeholder consultations

The Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO) is a joint project of the three Okavango riparian countries and is managed by OKACOM. As the executing agency, the Food and Agriculture Organisation of the United Nations manages the day-to-day affairs of the project and is responsible for the disbursement of the project budget. A team of FAO officials forms the Project Management Unit (PMU) based in Luanda, Angola.

The following management structure (with respective responsibilities) was developed for the EPSMO project:

3 National coordinating units (NCUs)
Manage project activities on a national level in the three countries
3 Inter-sectoral committees
Ensure sectoral integration in each country
3 National project coordinators
Act as focal points in the three countries; ensure efficient and effective collaboration between the Project Management Unit, National coordinating units and their respective governments
Tripartite review committee (3 OKACOM co-chairpersons, UNDP country director and FAO senior water policy officer
Approve annual budget and work plans for the project
Project Steering Committee
Asses project progress in accordance with approved work plan and budget bi-annually
3 Okavango Basin Steering Committee (OBSC) chairpersons
Represent the Okavango Basin Steering Committee in the Project Steering Committee meetings
OBSC Technical Task Team
Provides technical oversight to the project

A concerted effort was made to integrate project structures with existing regional, national and provincial structures during the development of the management structure.

- The considerable scope of the work in *Angola* required a small and dynamic National Coordinating Unit (NCU). The inter-sectoral committee consisted of representatives from key sectors based in Luanda and the province of Cuando Cubango.
- In *Namibia,* in line with recent government legislation, the project assisted the Department of Water Affairs to merge the national inter-sectoral committee and the Okavango Basin Management Association to form the Okavango Basin Management Committee. This new group acted as the Inter-sectoral Committee and the executives within the committee formed the National Coordinating Unit.
- In *Botswana,* the Okavango Wetlands Management Committee, set up and coordinated in the Ngamiland District by the Department of Environmental Affairs, acted as the Inter-sectoral Committee. The executive committee of the group acted as the National Coordinating Unit responsible for overall direction and key decisions regarding TDA work in Botswana.

The Okavango Basin Steering Committee (OBSC), the organ within OKACOM responsible for technical level coordination, acted as the Technical Task Team for the project and was the highest technical authority for the TDA. Not only did the OBSC identify the priority focus areas for the TDA but key representatives of the OBSC were involved throughout the TDA development process.

3.2.3 Three country teams

The EPSMO project worked closely with the BIOKAVANGO team on the integrated flows assessment work, sharing data, expertise and financial resources to bring about a rounded, inclusive assessment of flows into the Delta.

While it was decided to assemble three country teams coordinated by thematic coordinators for the purposes of this TDA, their work was integrated by a separate team consisting of the thematic coordinators, project personnel, the country team leaders and other key specialists.

This allowed each national team to deal directly with information and the situation in their own countries – especially important in the case of Angola, as the previous TDA had been hampered by language differences and paucity of information.

Floodplain grazers, Namibia

- In *Angola,* most of the bio-physical studies were undertaken by a team from the Agostinho Neto University's Science Faculty. Other key thematic studies such as social, economic, demographic and irrigated agriculture were conducted by private consultants.
- In *Namibia* the research towards the TDA was coordinated by a leading environmental non-governmental organisation (NGO), the Namibia Nature Foundation. The project and the NGO developed a Letter of Agreement to conduct comprehensive research in the Kavango Region. Staff of the Department of Water Affairs and Forestry, Namibia Water Corporation (NamWater) as well as private consultants participated in developing the TDA.
- *Botswana* recently concluded a detailed study of the Delta Ramsar Site to develop a comprehensive management plan. This plan, known as the Okavango Delta Management Plan, contained most of the information required from Botswana to develop the Okavango TDA. Therefore, the project developed a Letter of Agreement with the University of Botswana Harry Oppenheimer Okavango Research Centre to synthesise the information for the TDA.

3.2.4 The TDA Integration Team

The role of the TDA Integration Team was to provide the country specialists with a framework for the initial country reports so that they were systematic and compatible. These were used to compile the basin-wide assessment that is the final TDA report.

The TDA Integration team consisted of the following specialists:

- TDA Coordinator, whose task it was to coordinate with the different specialists in the integration team (i.e. coordinate the integration team towards the TDA) and compile the overall TDA report
- Hydrologist, who led the development of the different scenarios used in the IFA and applied the hydrological models, linking with hydrologists and river morphologists in each country
- Natural sciences specialist , who linked with the different specialists undertaking the biological aspects of the IFA studies
- IFA coordinator, who designed and led the national IFA studies, coordinating the outputs from each of the national specialists
- GIS and mapping specialist, who developed the GIS database for the project. He drew upon the GIS databases and products from the national GIS specialists and drew up a consistent set of maps
- Socio-economic specialist, to link up with and guide the work of the three national socio-economic counterparts to develop a basin-wide socio-economic analysis
- Macro-economic specialist, who worked closely with the socio-economic specialist to develop the macro-economic analysis for the TDA
- Governance and policy analyst, who worked with national government.

Overgrazed banks, Shamvura, Namibia

A joint understanding of transboundary issues was encouraged through a series of integration meetings of the IFA specialists and the overall TDA integration team to:

- Develop the structure and outline of the TDA report
- Interact with the national teams and process management team at the IFA Knowledge Capture Workshop
- Develop the causal chain analysis and refine the contents of the TDA report
- Enable counterparts to review the appropriate laws, policies and institutions.

The Project Management Unit provided guidance and general coordination for the TDA Integration Team.

3.2.5 Consultation

The development of the Okavango TDA required considerable consultation with a wide array of sectors including government, academic and research, private individuals, and communities. The project facilitated the inclusion of most stakeholders through inter-sectoral committees and National Coordinating Units. In the course of developing the TDA, four consultative meetings were held in each of the three countries to identify issues and information in preparation for the process, and to present the intermediate and final results.

In order to ensure the widest possible community participation in the project, the consultation process was executed in Angola and Namibia through selected NGO partners with guidance and support from the project leaders. In Botswana the community participation exercises conducted in the course of developing the Okavango Delta Management Plan were synthesised for the TDA. The overall objective of the community participation exercise was to facilitate the inclusion of community requirements, concerns, needs and variables.

A detailed report on these consultations can be found on the DVD accompanying this document.

3.3 METHODOLOGY

3.3.1 Hydrological modelling

In order to assess the reliability and quantity of a water resource, an understanding of flow conditions unaffected by human-induced land cover and water use changes is required. This is called the naturalised stream flow. For water resources planning purposes, estimates of future water demands and water infrastructure (dams and abstraction works) can be 'superimposed' on the naturalised flow sequence to determine the reliability with which the future demands can be met. The future, modified flow sequence can then be used to assess the ecological impacts of future water abstractions and regulation of the river.

As there is often a lack of relevant data in the areas where water resources planners require information about flow conditions, calibrated hydrological models are used to produce long synthetic records of stream flow (naturalised and under future conditions of water use) at points of interest in a river system. The most important inputs to the models are measured rainfall records and estimates of water abstractions, and the models are calibrated against available measured stream flows.

Data on the hydrology of the Okavango River Basin are relatively weak, but were first modelled in 2003 with the monthly time-step Pitman model. The model was developed at a spatial resolution that would allow for assessments of development impacts at various locations in the basin and on inflows to the Delta.[2] Since then, a modified Pitman model for the Cuito River has been developed[3] and subsequently extended to the whole basin upstream of the Delta. The modified model accounts for groundwater recharge and discharge, and drainage density. However, as with all lumped hydrology models, the Pitman model cannot be used to simulate flood peaks. For this, much more sophisticated, data intensive hydraulic models need to be used.

The model for the entire basin upstream of the Delta was updated in 2006[4] and comprised 24 distinct sub-basins. Calibration of the model was complicated by the limited availability of measured stream flow and rainfall records, especially in Angola. However, with satellite rainfall data, stream flow sequences could be generated for the period spanning hydrological years 1958-2002. A prototype water resources planning model of the Okavango River Basin was developed as part of the Sharing Waters Project.[5]

For the Okavango IFA Study, the hydrological working group opted to make use of the WEAP modelling system to model water resources development scenarios, as it incorporates a simple but powerful scenario creation tool, is capable of simulating run-of-river and storage-based hydropower schemes and is especially well suited for the training of hydrologists in systems analysis and scenario planning techniques.

Bridge over the Cubango River in Angola

The naturalised or undeveloped runoff sequences of the 24 sub-catchments upstream of the Delta were exported from the modified Pitman model and used as an inflow time series in the WEAP model. Present day water use serves as the reference, while future water resources developments were configured in the WEAP model for use in the scenario simulations.

The three hydrological models of the Delta, described in the text box, are conceptually very different, and are used for different applications. For the Okavango IFA study, the DHI model, (based on the MIKE SHE MIKE 11 models) was used to determine channel flow velocities and depths at the IFA sites, while the HOORC model was used to determine inundation extents and frequencies in the Delta, and wetted length and state changes along the Boteti River.

2 Anderson et. al. (2003)
3 Hughes, D. (2004)
4 Hughes et al. 2006)
5 Sharing Waters Project (2004)

Hydrological modelling of the Delta

Hydrological modelling of the Okavango Delta has a long history, starting with a conceptual model developed by Dincer in the mid-1970s (UNDP, 1977), (Dincer, 1985). A series of progressively more sophisticated models has been developed, most of which recognise the importance of groundwater-surface water interactions in the Delta. The three most recent models are discussed below.

ETH MODFLOW

A spatially distributed model of the Delta was developed by Bauer (2004) at the Swiss Federal Institute of Technology in Zurich (ETH Zurich). The model is based on MODFLOW software (Harbaugh et al. 2000). Surface water with overland and channel flows and the aquifer are represented by two layers in the model. The grid resolution is 1 km x 1 km. The model has recently been adapted to explicitly simulate flows in the major channels (Milzow et al. 2008).

DHI MIKE SHE-MIKE 11 Integrated Hydrologic Model (IHM)

In March 2004 the development of an Integrated Hydrologic Model (IHM) for the Okavango Delta was initiated under the Okavango Delta Management (ODMP) project (Government of Botswana), and it was completed in March 2005. The model was transferred to the Department of Water Affairs for future use and analysis of scenarios to support ODMP. The model was developed using the DHI Water and Environment, MIKE SHE-MIKE 11, 2005 (Recently upgraded to MIKE SHE 2008) modelling system and integrates the following four components:

- Soil-vegetation-atmosphere transfer module, describing the loss of water from open water, swamp and terrestrial vegetation to the atmosphere
- MIKE 11 surface water module describing water levels and flows through the main river channels of the Delta
- The distributed overland flow module (MIKE SHE) to simulate the two-dimensional flow pattern through the swamps and flood plains
- MIKE SHE ground water module.

HOORC Semi-Conceptual Model of the Delta and Boteti

A semi-conceptual model was developed by the Harry Oppenheimer Okavango Research Centre (HOORC) (Wolski et al. 2006) to model inundation frequencies and extents in the Delta. It is composed of four sub-models.

- A reservoir sub-model simulates flow of water through the Delta as flow through an array of nine quasi-non-linear reservoirs. It incorporates a representation of surface water-groundwater interactions, where floodplains and dryland/island groundwater are simulated separately. The model operates on a monthly time step.
- A GIS-based model is used to simulate inundation distribution. In this sub-model the lumped inundated area is obtained on a monthly basis from the hydrological sub-model and distributed according to an analysis of historical inundation obtained from NOAA AVHRR images at a 1 km grid resolution.
- A dynamic ecotope sub-model was developed in order to classify hydrological conditions obtained from the hydrological/GIS models for the Okavango Delta in terms of hydro-ecological functionality. The model is based on assumption that vegetation assemblages observed at any given site change in response to varying hydrological conditions. Vegetation is captured using four functional classes: aquatics, sedges, grasses and savannah (or permanent swamp vegetation, primary floodplains, secondary floodplains and dry floodplains). Three additional classes were introduced for the EPSMO-BIOKAVANGO Environmental Flows Assessment Study, namely channels, lagoons and floodplain pools.
- The Delta model has recently been extended to incorporate the Thamalakane/Boteti System downstream of the Delta (EPSMO, 2009). This sub-model determines the wetted length of the Boteti River and accounts for the strong hysteresis in volume-flow relationship observed at hydrometric stations along the Boteti. The model works under assumption that the surface water-groundwater flows are one-directional, i.e. there is only infiltration from surface water to channel groundwater reservoir, and that there is only flow from channel groundwater to riverine groundwater.

Full details of the methods used and the results of the hydrological modelling are presented in the IFA reports Nr.5 – *Hydrological Data and Models* and Nr. 6 – *Scenario Hydrology Report*[6] available on the DVD accompanying this document.

6 Beuster, H. (2009a)

3.3.2 Integrated Flow Assessment

The IFA provided the TDA with the scientific basis for predictions about the changes in the river ecosystem and the associated socio-economic uses of the natural resources that would result from changes in the flow regime. Eight representative sites within the basin were analysed in depth. The IFA aimed:

- To synthesise present knowledge
  - on the river ecosystem
  - on how people use the river
- To predict
  - how the river could change with water-resource development
  - how these river changes could affect people and the riparian countries.

A full multi-disciplinary team was appointed in each country, with specialists in each relevant discipline. In addition, information was drawn from the other TDA specialist reports on irrigation, water supply and sanitation, tourism, and hydropower in order to describe the planned developments and projected growth in these sectors within each country that would influence the demand for water, and hence the flow regimes of the river.

The IFA followed a recognised sequence of steps that is accepted internationally.

Basin delineation: The basin was divided into homogenous units (Integrated Units of Analysis – IUAs) so that data and knowledge for any one site could be extrapolated over a wider area. A representative site was chosen in each of the eight most important IUAs as the focal point for data collection and interpretation. The IFA field sites are shown in Table 3.2 and Figure 3-2.

TABLE 3.2: LISTING OF IFA SITES AND LOCATIONS

IFA site No.	Country	River Channel	Location
1A	Angola	Cuebe	Capico
2A	Angola	Cubango	Mucundi
3A	Angola	Cuito	Cuito Cuanavale
4N	Namibia	Okavango	Kapako
5N	Namibia	Okavango	Popa Falls
6B	Botswana	Okavango	Panhandle
7B	Botswana	Okavango Delta	Xakanaka
8B	Botswana	Boteti	Chanoga

Source: Mendelsohn and el Obeid 2004

Note: Three sites in Angola (marked A), two in Namibia (N) and three in Botswana (B).

Figure 3-2: Location of the eight representative sites for the integrated flow assessment

Scenario development: Water use scenarios, based on likely demand for water in all sectors, were developed to enable an understanding of the effects of changing flow regimes. These scenarios were developed through discussions between the countries, project members and OKACOM and led to the identification of three scenarios of increasing water use – *Low, Medium* and *High* water-use development, which would be compared to Present Day conditions (Section 5.1).

Hydrological modelling: Collated flow regimes were simulated at the representative sites for each of the four water-use development scenarios as described in Section 3.3.1 above.

Selection of discipline indicators: Each discipline group selected the key indicators that represented the major relevant changes or issues that would result from change in the flow regime. These indicators formed the focus for site visits, data collection, literature reviews and analysis.

Data collection and survey: The country teams, working in the discipline groups, collected and synthesised all known data on the indicators and carried out new research and surveys focused on the indicators selected during a series of visits to the representative sites. Specialist reports described the findings and the relationships between flow and river ecosystem, and between river and social wellbeing.

The IFA process led to the development of a Decision Support System (DSS).

A Decision Support System captures the biophysical and socio-economic specialists' knowledge and uses the relationships between the indicators and flow to form the knowledge base of the system. Simulated flow regimes for each development scenario for the whole basin were also entered into the DSS, which used this knowledge base to predict the ecological and social outcomes for each scenario. These predictions of change were assessed and approved by the full IFA team. The box below describes the DSS in greater detail.

Decision Support System

The DSS houses response curves to flow change for all the biophysical and social indicators used in the project. The response curves were programmed in the DSS by the country specialists to calibrate the system. The inputs to the DSS are hydrological data representative of a scenario, summarised as a time series of ecologically-relevant statistics, such as duration of the dry season, minimum dry season discharge and flood season peak discharge.

The outputs of the DSS are:

- **Biophysical:**
    - time-series of abundance, area or concentration for all indicators
    - estimated mean percentage changes from present day in the abundance, area or concentration for all indicators
    - estimated change in discipline-specific integrity, relative to present day
    - estimated change in overall ecological integrity, relative to present day.
- **Social:**
    - change in household income from local agriculture
    - change in household income from natural resources
    - change in household income from tourism
    - change in intangible, indirect use and non-use values.

The DSS is not restricted to the three scenarios used in this IFA, but has been prepared so that it can predict changes that may occur for any other scenario of water use in the basin. Different flow regime modifications can be inserted and the predictions about the hydrology and changes in basin features will form the output.

While some new data were collected during the IFA, the main focus was on expert opinion from specialists through visits to the eight sites and on existing data and knowledge of the Okavango and similar river systems. As this first estimate remains relatively poor in data, it is recognised that ongoing detailed research would be essential in the future, to more accurately reflect the changes likely to occur with development.

Although the IFA outputs largely describe negative impacts of water-resource development on the river ecosystem and its subsistence users, it is understood that development can also have positive effects. The macro-economic assessment of the three development scenarios described below and reported on in Chapter 4 provides a balanced prediction of the outcome of water-resource development. The IFA and the macro-economic assessments together outline the predicted consequences of development in terms of the three pillars of sustainable development: ecological integrity, economic wealth and social well-being, illustrated in Figure 3.3.

Full details of the process and findings are available in the complete set of IFA reports available on the DVD accompanying this document. A summary of the scenario findings is provided in Chapter 4.

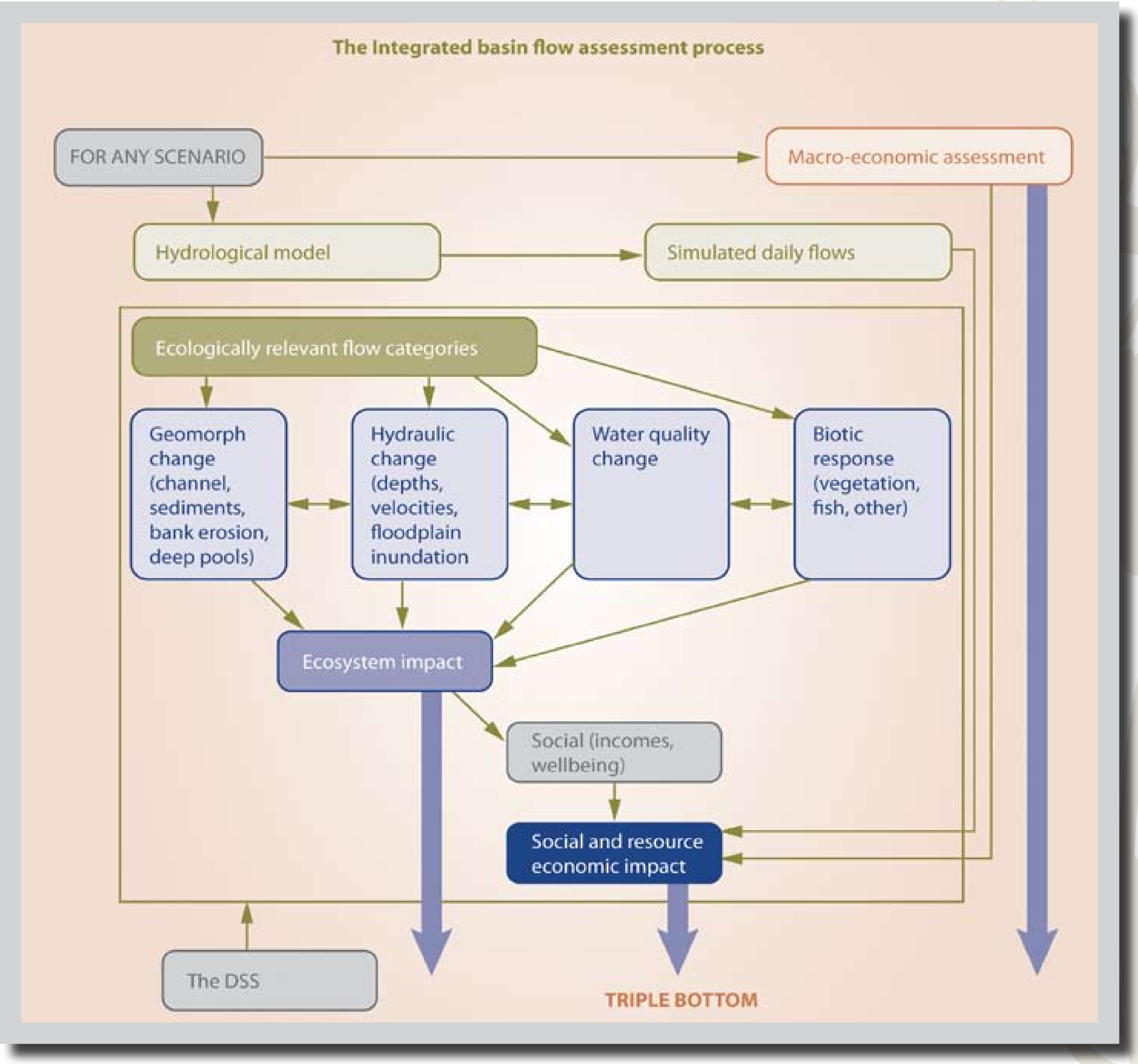


Figure 3-3: The IFA process showing the outputs and the linked macro-economic assessment

3.3.3 Economic Analysis

A socio-economic and economic analysis was conducted to determine the following:

1. The general social and economic baseline for the people living in the basin. This included a description of the key demographic, economic characteristics and main challenges faced by people and observable trends.
2. What goods and services people use from the river, and then estimate the changes in their values (and resulting changes in welfare) as water resources developments increase from the Present Day situation.
3. The impact of water resources development to the macro-economy of the basin states to enable a comparison between the current situation and alternative paths of development.

Water and natural resource use economics
Information was gathered from the literature on the goods and services used by the people of the river and the economic values attributable to the river system in the basin and the southern African region. Brief surveys involving focus group and key informant interviews were carried out at the eight field study sites as part of the IFA. A more detailed household and community level survey was undertaken in the Angolan part of the basin. A small survey of tour operators in Botswana was also conducted, aimed at measuring the likely economic effects of flow change on tourism.

The valuation of the natural resources used in the basin that could be affected by changes in flow was undertaken at each of the field sites and then scaled-up for the basin as a whole, including values of the water required for different water use development scenarios.

The economic analyses measured both the private well-being of the basin inhabitants, as well as the national well-being of the basin countries.

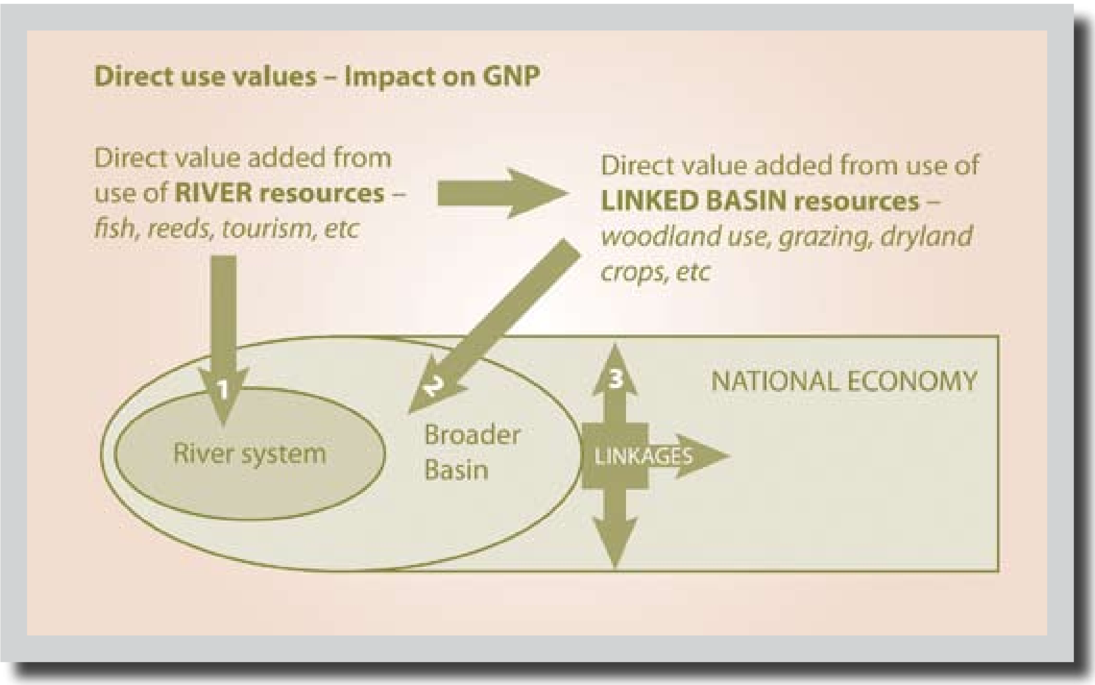
Private well-being

Private well-being was measured as the net change in household livelihoods or the net gain in household welfare due to the resources of the river basin and its functions. This is the net profits earned by households in their income-earning activities. Private well-being as affected by intangible factors such as water quality was subjectively assessed, but not included in livelihood measures.

National well-being

National well-being was measured as the direct net change in national income, using gross national product as the indicator. Measurement of the direct contribution to the national income was extended to highlight the total direct and indirect contribution of resource use to the national economies (Figure 3-4).

The contributions of indirect use values and ecosystem services to the national well-being were also measured in terms of national income. Non-use value affecting national well-being (existence, bequest and option value) was assessed in terms of willingness to pay for preservation at local, national and international levels.



Note: 1) Direct river system values considered for the IFA. 2) Additional broader basin direct values considered for the TDA. 3) Indirect linked values in the national economy.

Figure 3-4: Depiction of economic values

Macro-economic analysis
Building on the socio-economic analysis of direct river system values during the IFA, a quantitative macro-economic analysis was conducted on potential economic consequences of future alternatives for the management of water in the basin as a whole. The results of this analysis are discussed in more detail in Chapter 5.

The changes in economic activity as a consequence of changes in the flow regime were calculated as the annual value of ecosystem goods and services provided by the river system. In the subsequent scenario analyses, these annual values were converted into streams of costs and benefits over a 40-year time horizon at 4% and 8% discount rates. On a country-by-country basis these losses (and gains) were offset against the potential net benefits of the water resources developments that alter the flow regime. The assumptions used for this macro-economic analysis are described in a box in Chapter 5, Section 5.5.

For each project, good and service, a reference case net present-value was calculated based on present day use of water in the basin, which was extrapolated for the Low, Medium and High water resource scenarios. The change between each of the three scenarios and the Present Day scenario showed the net gains or losses to the economy for (a) the water resources developments and (b) ecosystem goods and services. This analysis was applied for each of the three countries and for the basin as a whole.

Kambube River, tributary of the Cuebe River in Menongue, Angola

As each successive scenario incorporates the development projects of the former scenario they should not really be compared, but rather serve to illustrate trends. The results from the three scenarios show how increasing levels of water use will affect the national economies of each country. The trade-offs between the distribution of these values between countries and sectors highlight the issues of transboundary water allocation and management in the basin.

The existence value of the Okavango River Basin, particularly of the Okavango Delta, is considered important by the international community at large. This value is estimated, based on existing studies of existence values for wetlands as part of the scenario analysis.

A more detailed description of the methods and results of river/wetland natural resource use analysis and macro-economic analysis are provided in the TDA Socio-economic Assessment, and the Economic Valuation of Basin Resources background reports respectively.[7]

3.3.4 Governance and Policy Review

The overall objectives of the governance review were to:

- Provide an overview of the current legal, policy and strategy, and institutional landscape for the Okavango Basin
- Analyse policy drivers impacting the development of the basin
- Identify current and (possible) future governance constraints and opportunities in the light of different future development pathways
- Make recommendations for the long-term adaptation of the governance framework to sustainable basin management.

The governance and policy review provided a brief overview of the constitutional order in the three Okavango Basin states and examined the three countries' overarching national development policies and planning instruments, with a view to identifying key policy drivers that influence, or could in the future influence, the management of the Okavango Basin.

Based on their identification as key fields for the sustainable long-term management of the basin, the legal, policy and strategy, and institutional frameworks for the fields of water resources management, land (use) management, biodiversity management and climate change adaptation/mitigation were compared using a series of descriptive matrices. There was particular focus on the current mandate, role and functions of the OKACOM.

7 Barnes, J. et al. (2009), Aylward, B. (2009)


Maize field, Angola

The governance analysis took into account the wide spectrum of relevant international, national and local legal and policy instruments as well as responsible management organisations at all levels. It aimed to illustrate the multi-layered, interrelated governance framework within which the management of the basin takes place.

Using both primary (e.g. international agreements, national legislation) and secondary sources (e.g. sector studies, national review reports), the legislative framework in each of the countries was subsequently analysed and compared to internationally accepted best practice. Gaps and shortcomings in the legislative framework were highlighted where they existed. Similarly, an in-depth analysis of national development policies and sector policies was undertaken with a view to identifying possible discrepancies between policies both within and among countries. The current strengths and weaknesses of the institutional framework were analysed, both internally within countries as well as among countries at basin/regional level, with particular emphasis on the effective cooperation between national governments and OKACOM.

Based on the analysis of the current governance framework, the process identified possible future constraints and opportunities that could arise as potential development pathways for the basin were followed.

3.3.5 Trend analysis

The present relatively undeveloped state of the basin provides a known reference point from which extrapolations can be made to assess future development states. The trend analysis clearly indicates that the principal pressures on the Okavango River Basin come from increasing demands for water and other natural resources, and changing land use.

By following existing trends in population growth and distribution in the basin, it is possible to describe how future pressures on water, land and other resources may increase from present levels. At the same time, the three riparian countries are proposing developments within the next 10–15 years that will have an impact on these resources. The most important sectors in this respect are water supply, especially for the growing urban populations, irrigated agriculture, livestock, mining and industry, and tourism.

The IFA teams could identify sectoral growth predictions and planned development through the process of consultations with relevant agencies in the three countries and quantify these in terms of their water-use requirements. Growth projections were applied to current levels of water use by the various sectors to quantify future demands.

The Present Day state represents one of the four main scenarios that were assessed as part of the IFA. The three future water-use scenarios (based on a combination of actual proposed and hypothetical developments) represent hypothetical situations of low, medium or high levels of water resources development in the Okavango Basin. As a separate exercise, the effects of possible climate change variations were superimposed on the water use scenarios. The key drivers of the water resources development scenarios are described in Chapter 4.

Other trends in the biophysical condition of the river, its surrounding land and its natural resources are described qualitatively, based on the observations of the specialist teams and supported by a literature review. Observed pressures on the river that contribute to these trends have also been noted.

3.3.6 Causal Chain Analysis

The causal chain analysis lies at the heart of the TDA and follows the *Pressure – State – Response model* of environmental change. The starting point for the causal chain analysis was an understanding of the key features that describe the present status of the Okavango River Basin. These are all interconnected, so that changes in one, e.g. changes in the flow regime, will have implications for changes in the other features.

The analysis was undertaken by the TDA integration team as a group, developing an understanding of the linkages shown in Figure 3.5. The combination of professional experience and judgement of the team, based on observed impacts and scientific analysis, underpins the causal chain predictions. The analysis is conducted through classification of the causes of change according to a hierarchy running from the Drivers of Change (or Root Causes) – things such as population growth, sectoral policies and plans – through to Changes in Uses of Land, Water and Natural Resources. It is these changes in use which will change the *State* of the ORB.

The changes in the *State* of the ORB will have observed impacts, for example on health and livelihoods of people and on the other different sectors using water, such as tourism and cultural activities. These impacts have social and economic consequences, namely increasing poverty and vulnerability or costs of provision of services.

The *Pressure – State – Response* model can also be used to identify the responses or entry points for addressing the unwanted changes in state, impacts and consequences, or for taking advantage of positive opportunities. This can be done at policy level – addressing one of the Drivers of Change, by changing the way in which land and water are used or by dealing with impacts such as treatment of waste water where there are water quality issues. Such an analysis then leads naturally into recommendations for the Strategic Action Programme.

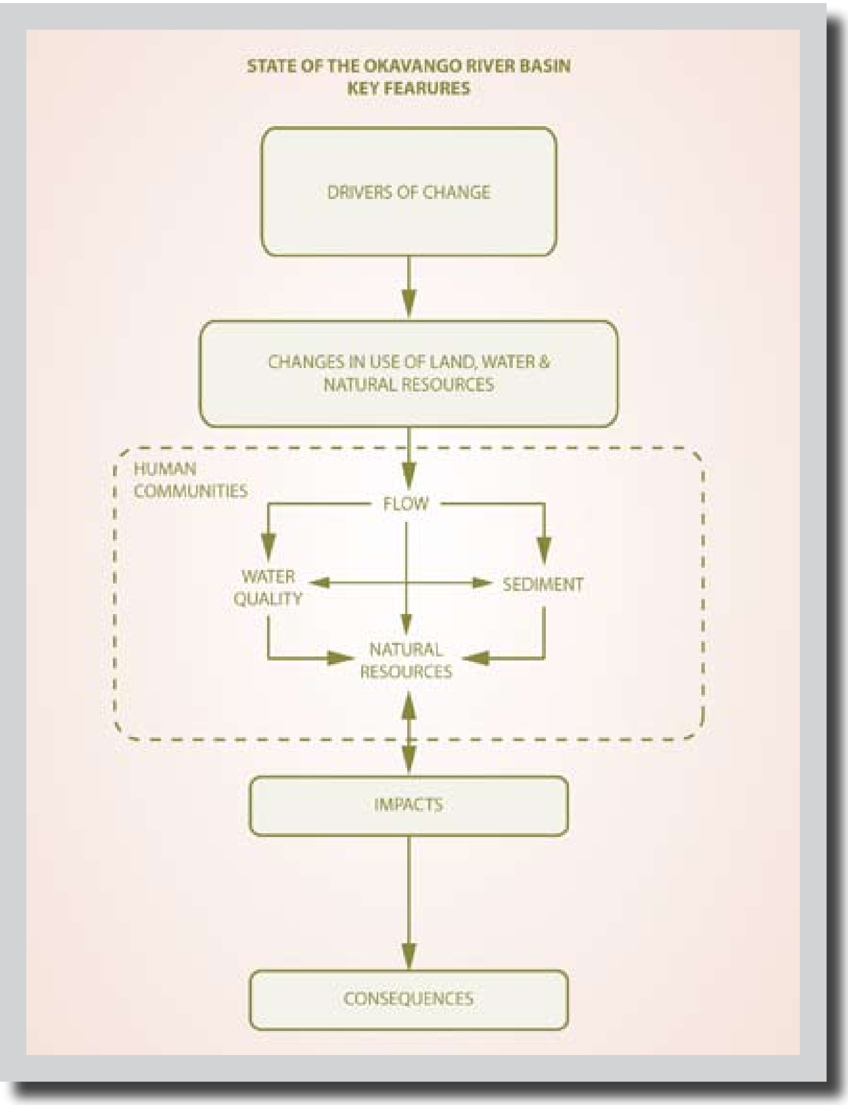


Figure 3-5: Outline of the Causal Chain Analysis

CHAPTER 4: DRIVERS OF BASIN CHANGE AND THEIR IMPLICATION FOR WATER USERS

Chapter 4 builds on the knowledge base of the present status of the basin described in Chapter 2. It examines trends in land and water use and the livelihoods of people, highlighting the main drivers, or root causes of changes that can affect future water resources developments and demand for water. These potential changes are all interconnected, so that changes in one trend can result in changes to others. As stated in Chapter 2, the data presented here relate to the areas of the basin studied for the IFA – the areas contributing to perennial flow to the Okavango Delta.

The predictions are guided by the Causal Chain Analysis described in outline in Chapter 3 (Section 3.3.5, Figure 3.5), and are shown in added detail in Figure 4-1, which includes the trends described in this chapter. The analysis was conducted by identifying the major root causes for change in the basin such as population growth, poverty and international and regional markets, which could lead to changes in both land use and the use of water and natural resources. It also takes into consideration the concomitant effects of climate change, which are discussed in more detail in a supporting document.

Thus, following the *Pressure – State – Response* model, the Causal Chain Analysis can be used to identify potential responses to unwanted or positive changes and leads naturally to recommendations for the Strategic Action Programme.

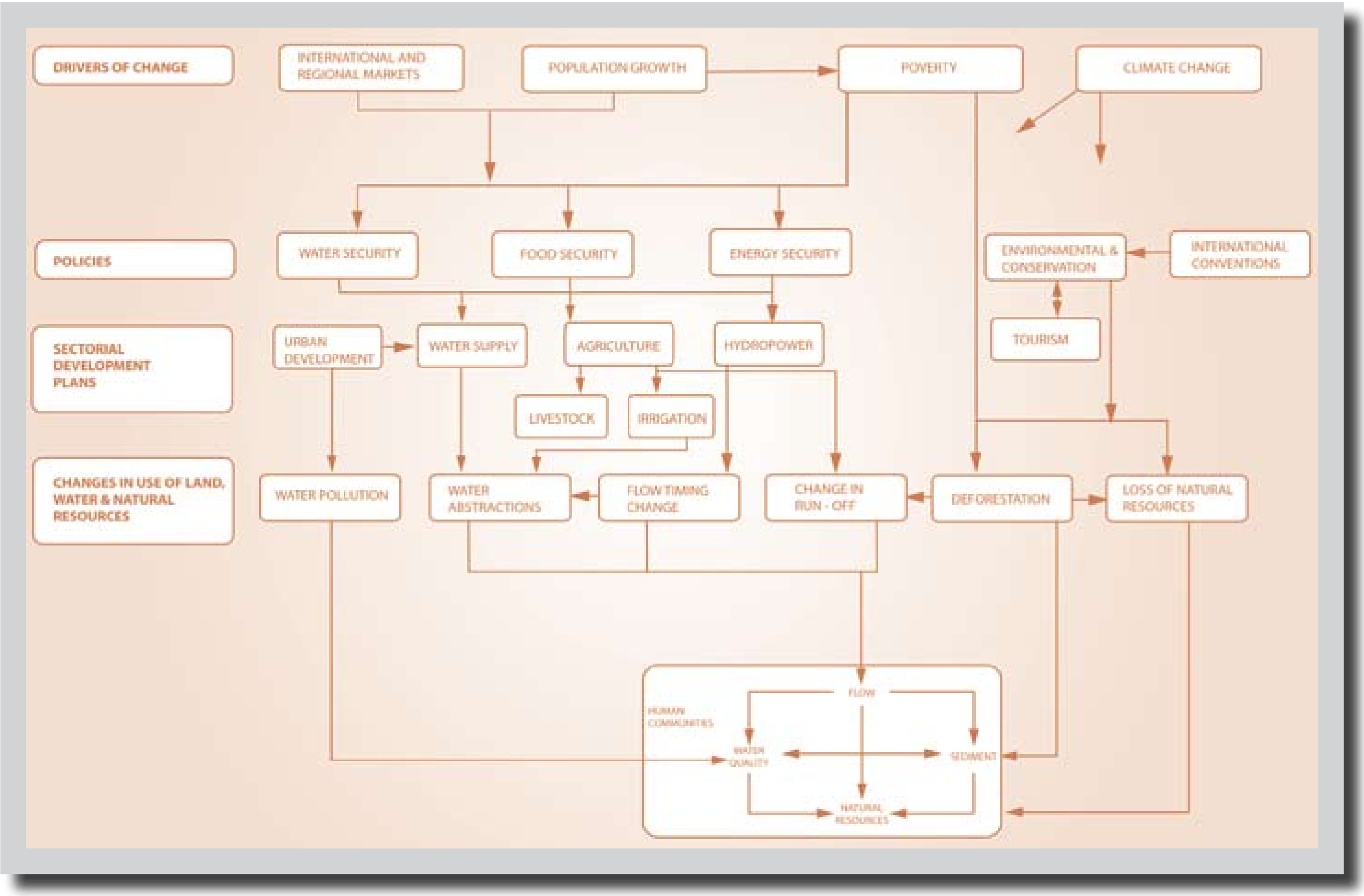


Figure 4-1: Causal Chain – Drivers of change in land and water use

4.1 ROOT CAUSES

Environmental, social and economic conditions are changing globally, nationally and within the Okavango Basin, driven by both external and internal factors. This section examines the root causes of change in the basin, which could lead to more immediate changes.

4.1.1 Population growth

The population of the Okavango River Basin in all three countries is increasing steadily and this, with the concurrent increase in demand for goods and services is likely to be the key driver of change in the basin. Even if the populations did not increase as predicted, the demand for goods and services would increase as a result of growing demands for a higher standard of living among all inhabitants of the basin.

The present population in the basin is 921,890. By 2025, the population for the basin as a whole is projected to be over 1.28 million people, with 62% living in Angola, 22% in Namibia and 16% in Botswana (Figure 4-2). In Angola, the population projections until 2025 for the Cubango and Cuito sub-basins are shown in Table 4-1; the projections for Namibia for rural and the urban population in Rundu are shown in Table 4-2 and projections for Ngamiland in Botswana can be found in Table 4-3.

TABLE 4-1: POPULATION PROJECTIONS TO 2025 FOR OKAVANGO RIVER BASIN IN ANGOLA[1]

Municipality	Sub-basin	2008	2010	2015	2020	2025
Catchiungo	Cubango	85,010	89,663	102,438	117,035	133,711
Cuvango	Cubango	49,626	52,342	59,800	68,321	78,056
Menongue	Cubango	189,435	199,803	228,272	260,799	297,960
Cuchi	Cubango	29,915	31,552	36,048	41,185	47,053
Cuangar	Cubango	16,226	17,114	19,553	22,339	25,522
Calai	Cubango	16,638	17,549	20,049	22,906	26,170
Total Cubango sub-basin		**386,850**	**408,022**	**466,161**	**532,584**	**608,471**
Chitembo	Cuito	60,622	63,940	73,051	83,459	95,352
Cangamba	Cuito	9,969	10,515	12,013	13,725	15,680
Cuito Cuanavale	Cuito	35,523	37,467	42,806	48,905	55,874
Dirico	Cuito/Cubango	12,216	12,885	14,720	16,818	19,213
Total Cuito sub-basin		**118,330**	**124,806**	**142,590**	**162,907**	**186,120**
Total Angola		**505,180**	**532,828**	**608,750**	**695,491**	**794,591**

TABLE 4-2: POPULATION PROJECTIONS TO 2025 FOR THE OKAVANGO RIVER BASIN IN NAMIBIA[2]

Namibia	2009	2010	2015	2020	2025
Rundu urban	43,820	46,039	52,088	58,933	66,677
Kavango rural	175,270	180,568	194,523	209,556	225,751
Total	**219,090**	**226,606**	**246.611**	**268,489**	**292,429**

TABLE 4-3: POPULATION PROJECTIONS TO 2025 FOR THE OKAVANGO BASIN IN BOTSWANA[3]

Botswana	2008	2010	2015	2020	2025
Maun urban	47,060	48,482	52,229	56,266	60,614
Ngamiland rural	110,630	113,974	122,782	132,271	142,494
Total	**157,690**	**162,456**	**175,011**	**188,537**	**203,108**

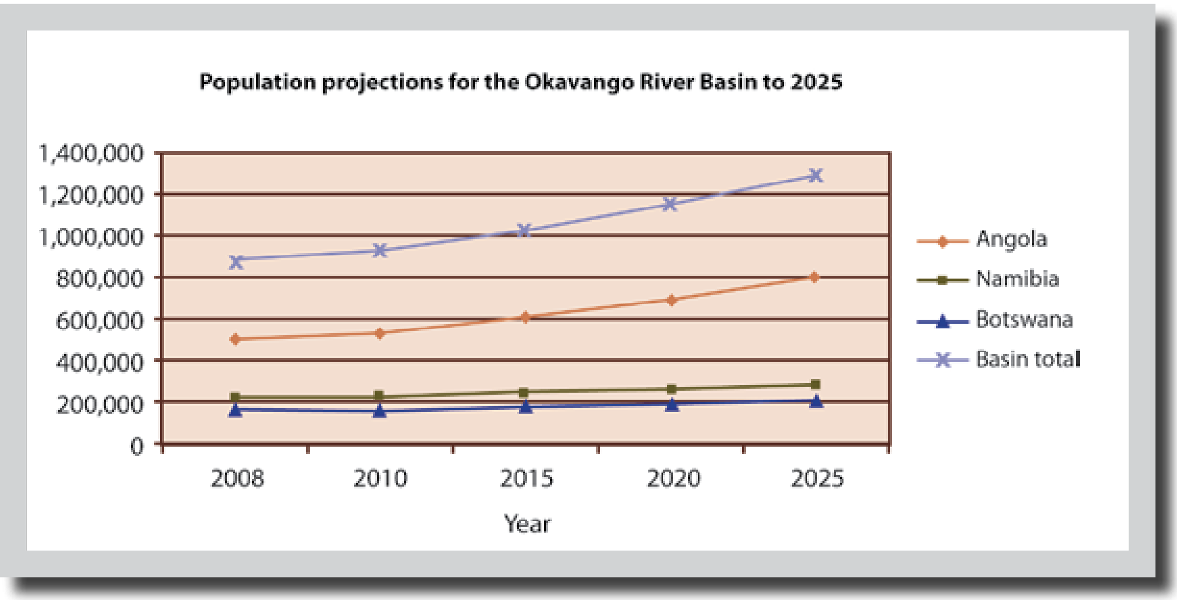


Figure 4-2: Population projections for the Okavango River Basin

Note: based on Tables 4-1 to 4-3

1 Projections based upon 2008 figures quoted in Table 2-12 compounded at 2.5% per annum
2 Projections based upon 2008 figures quoted in Table 2-12 compounded at urban 2.5%, rural 1.5% per annum
3 Projections based upon 2008 figures quoted in Table 2-12 compounded at 1.5% per annum

4.1.2 Urbanisation

Throughout the basin, there is a trend towards increasing urbanisation associated with population growth and a lack of alternative livelihood options. Although the population in the basin is predominantly rural, Angola has an urban population of about 40%, while in Namibia the figure is approximately 20% and in Botswana around 30%. The centres of Menongue and Cuito Cuanavale in Angola, Rundu in Namibia and Maun and, to a lesser extent, Gumare and Shakawe in Botswana, are all growing in size. In particular, Rundu is growing at a rate of 2.5% per annum compared to 1.5% in the rural areas of Kavango.

Increased urbanisation leads to increased demand for services and will lead to an increased need for service supply, including water supply and sanitation, and this could lead to water pollution caused by inefficient waste disposal. Intensified land use around the towns will lead to depleted vegetation cover and natural resources, and storage facilities to provide for the projected higher demand for services could deplete the flow of the river through changes in siltation patterns.

4.1.3 Poverty

Poverty is a feature of the human populations in all three basin countries as described in Chapter 2, with the incidence of poverty in the Okavango Basin being much higher than in other parts of each of the countries. This is partially due to the remoteness of the basin, but given the highly unequal distribution of wealth in the three countries, it is clear that poverty alleviation in the basin should be a major investment target for governments. The ambitious water use development plans inherent in the future development scenarios suggest that this is the case, particularly in Angola and Namibia.

It is essential for the river to remain in a good condition, as poor rural communities tend to depend on natural resources more directly than communities in urban centres or those involved in commercial economic activities. Natural resources such as fish and plants are often important 'safety nets' for poor communities in adverse times. If these natural resources were to decline for whatever reason, the poor commonly have few options other than to continue using them, placing ever more pressure on the resources.

All three countries have national poverty reduction strategies aimed at improving the welfare and living conditions of their populations through increased economic growth. These are discussed in more detail in Section 2.7 (Chapter 2).

4.1.4 International and regional market forces

Development Stagnation

The current global recession also forces consideration of the possibility of economic stagnation with very limited possibilities for development. Under a stagnation scenario, populations in the basin continue to grow, but investment resources to pursue low water use developments that raise social and economic development levels are limited. The end result is that no improvements in domestic water supply, hydropower or irrigation are made. In addition, if the global recession continues, tourism numbers and incomes will fall, with lower opportunities for employment. A scenario of economic stagnation is considered under Section 5.7.5.

International and regional markets will continue to impact local market conditions and development trends in the basin and could have both positive and negative effects on economic, social and environmental sustainability. The extent and nature of any impact will depend on whether the basin is a producer and exporter of market goods, rather than an importer. The degree to which these external market forces influence conditions on the ground depends on whether the countries are 'open' to the global economy. Botswana and Namibia are generally regarded as open economies, Angola less so.

Resource and environmental markets such as agriculture, livestock and tourism will most likely be of primary economic importance. Energy markets will also affect the basin, but in a less interactive way given that the basin is not a major energy producer. Apart from the Eastern National Water Carrier project proposed in Namibia, market forces related to water are largely internal to the basin.

Recent trends towards higher food and commodity prices will have an adverse impact on an importing region such as the basin. The tendency is therefore to promote food production, particularly irrigated agriculture, as a food security solution. However, given the poor soils and the potential economic consequences of large-scale withdrawal of water for irrigation in the basin (as highlighted later in Chapter 5), the production of significant amounts of food in the basin may be an expensive proposition. If food can be imported to local markets and sold for less than the cost of local production, large-scale agricultural expansion would be a questionable strategy.

If trade policies are not 'open', there is an additional drive to produce such goods locally. The inclusion of Angola in the Southern African Customs Union would integrate the three economies more closely. In addition, opportunities to expand existing markets

basin-wide, such as export of livestock products to overseas markets, particularly the EU, continue to be high on the agenda, especially in Botswana. The development of a rain-fed livestock sector in Angola may be critical to both local food security and the potential to develop export markets.
Intra-country trade barriers that restrict the movement of goods and services within the basin tend to impede the evolution of an efficient basin economy. With increasing regional integration across the basin, basic goods and services might be able to compete with imported commodities.

4.1.5 National policies and plans

Decisions concerning the development pathways for the basin and the nature of investments are usually made within the key national policies. The most relevant policies are the overarching national development policies and key sector policies, e.g. agriculture and food security, energy, water resources development and conservation and sustainable natural resource management.

Current policy

An analysis of the current policy framework outlined in Chapter 2 shows that there are some inconsistencies between sector policies within and among the countries. However, the combined policy framework does allow sufficient flexibility in implementation to achieve the economic development objectives, while ensuring the environmentally and socially sustainable use of the basin's water and other natural resources.

Economic and social development policies – poverty alleviation

The three countries share the overarching policy objective of alleviating poverty and improving the welfare and living conditions of their populations through increased economic growth. They foresee increasing future water demands to support such growth. In Angola the drive for economic growth is made more difficult by the need for post-conflict reconstruction and the gradual return and resettlement of previously displaced people to the Angolan part of the basin.

While emphasising the need for economic growth and associated increasing water demands, all three countries recognise the importance of the environmentally sustainable use of natural resources and have made it an integral part of their national policy frameworks. Botswana in particular has identified the economic opportunities from ecosystem preservation and sustainable natural resource use (e.g. through tourism) as one of the main focus areas for the country's future economic development.

Among the most important social development objectives in the three countries is the extension of domestic water supply services with the ultimate goal of full coverage. This has particularly high priority in Angola where coverage rates are on average the lowest of the three countries in the basin. An increase in service coverage will require the construction of abstraction infrastructure and an increase in water abstraction volumes.

Agriculture and food security policies

The national objectives to increase agricultural production both for food security and for job and wealth creation by developing agricultural export industries are likely to form the key drivers affecting decisions on development options for the basin. The policies of all three countries emphasise the need to strengthen the agricultural sector to ensure food security, and both Angola and Namibia have identified areas in the Okavango Basin where increased agricultural production (with investments in irrigated agriculture) can take place. This would obviously lead to increased water abstraction from the river.

Energy policies

SAPP grid

Botswana and Namibia are integrated in the Southern African Power Pool (SAPP), which aims to develop the regional grid and increase regional generation capacity. Angola is currently in the process of signing agreements to integrate with the SAPP grid.

Improved energy security is likely to be a key policy driver in the development of the basin. A significant increase in energy availability and reliability of supply is essential for the economic development objectives of the three countries, which is reflected in their energy-related policies and plans.

Botswana and Namibia, in their respective energy policies, recognise the relationship between energy generation from fossil fuel sources and climate change, placing strong emphasis on the increased use of renewable energies. Angola is still in the process of developing a national energy policy, but identifies hydropower as an important component of the national energy mix and maintains the option of developing its hydropower potential. The feasibility of some of the proposed hydropower developments on the upper Okavango River is currently being considered. All but one of the planned schemes in the Angolan portion of the Okavango River Basin, will be run-of-river type.

4.1.6 Climate change and flow variability

While the Okavango River Basin experiences long-term natural climate variability, an analysis of projected climate change effects[4] predicts a rise in temperature and rainfall in the basin. Higher temperatures (2.3^{0}C-3^{0}C) will affect the south of the basin more strongly than the north, increasing evaporation. There is a projected increase in rainfall of 0-20% across the basin, with the greatest effect in the north because of the north-south rainfall gradient.

The projected increase in rainfall will more than compensate for higher evaporation rates. This could result in an increase in runoff (total and monthly) with proportionately stronger peak flows.

Three scenarios are envisaged for the Okavango Delta –'dry', 'moderate' and 'wetter' than present day. In the Okavango Delta, in the 'dry' scenario, the increase in evaporation and transpiration may exceed the increase in local rainfall and inflow from the catchment, resulting in drier conditions. This would result in a decrease in frequency and duration of flooding throughout the Delta and in a reduction of low flows in the rivers draining the system.

However, if the rainfall increases substantially (in the 'wetter' scenario) there will be an increase in duration and frequency of inundation throughout the Delta, and the increase of high and low flows in the rivers draining the system. Under the 'moderate' and 'wetter' scenarios, expansion of the permanently inundated areas and areas subject to long inundation could be observed. There would also be a relative reduction in areas subject to short inundation.

4.2 IMMEDIATE CAUSES

4.2.1 Changes in land use

Despite the relatively low population densities in the Okavango River Basin in comparison to other major river basins, the pressure of human activities on land use and vegetation cover has been marked.

This is clear from the three temporal examples of Landsat images from the 1970s, 1990 and 2003 for the upper Cubango River Basin in the Angolan highlands, around the Rundu/Calai area in Namibia and around the Divundu/Shakawe area on the border between Namibia and Botswana. The locations are shown in Figure 4-3, and the images are shown in Figures 4-4 to 4-6.

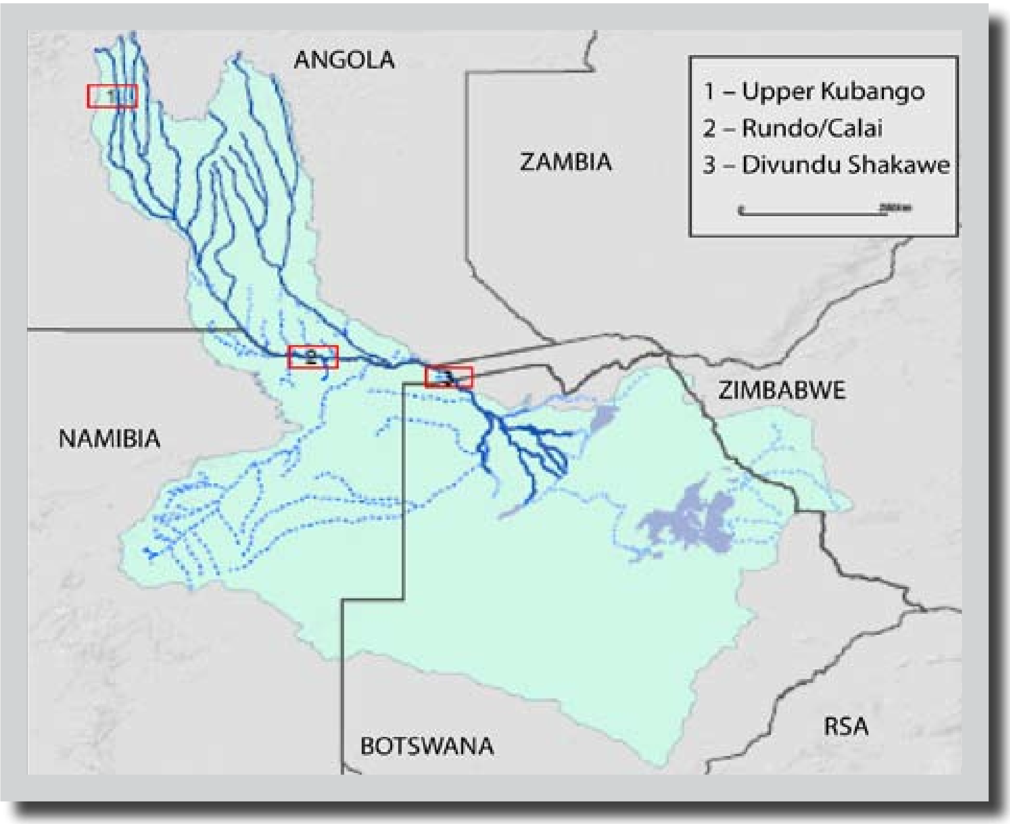


Figure 4-3: Locations of temporal Landsat images illustrating land cover change

Figure 4-4 shows the progressive increase in the mosaic of croplands in different parts of the upper Cubango. In 1975, the settlements and cropland were relatively small and isolated, as shown by the white patches amongst the overall red colouration which indicates high vegetation cover. By 1990, the (white/light green) croplands have expanded markedly, covering much of the land area in the central part of the picture, and the earlier dense vegetation cover has more or less disappeared as the woodlands have been cleared. By 2003, the crop field areas have been extended, although the woodland ridge between the Cutato and Cuchi Rivers remains relatively undisturbed.

4 Wolski, P. (2009)

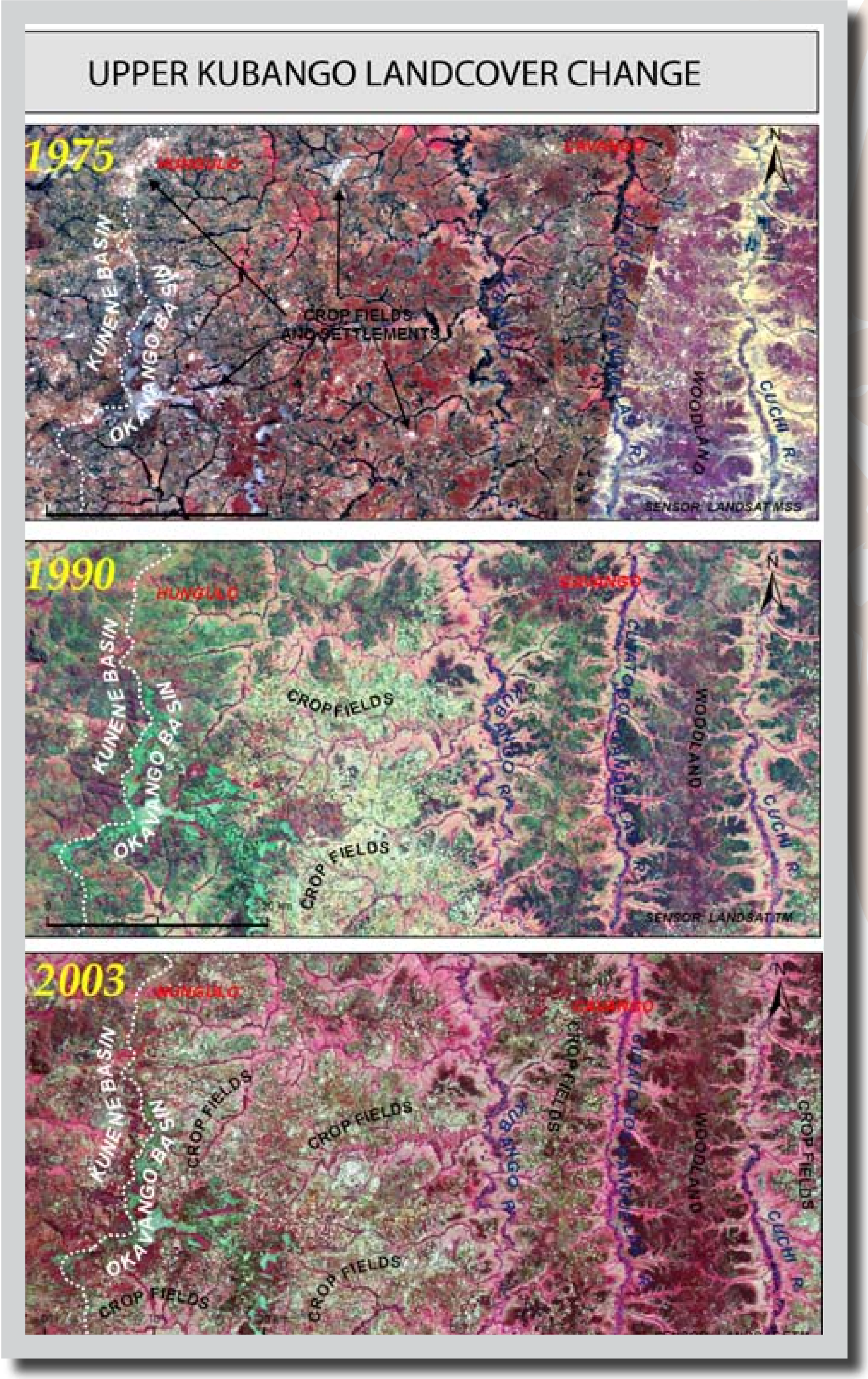


Figure 4-4: Landcover changes in the Upper Cubango sub-basin, 1975, 1990 and 2003

In the Rundu/Calai area (Figure 4-5) in 1973, woodland covered both the Namibian bank to the south of the Okavango River and the Angolan bank to the north. The floodplain areas are clearly visible along the river valley. By 1990, these woodland areas along both banks had more or less been cleared and crop fields had been established along both banks, more extensively to the south on the Namibian side and sometimes extending 5-10 km from the river. There is no indication of riparian vegetation on the Namibian side.

By 2003, the crop field areas had expanded further, and 'fingers' of cropping extend southwards along the seasonal rivers or fossil drainage lines, where the soils tend to be more fertile, and ground water is more available. The Angolan north bank shows a marked contrast, with much higher vegetation cover (red colour) and the only significant crop fields showing around Calai. This emphasises the rate of clearance of areas of woodland in Kavango, estimated at 3.9% per year between 1943 and 1996[5].

5 Mendelsohn, J. (2009)

The urban population of Rundu expanded from a few thousand in the early 1970s, to about 30,000 in the 1990s and to just under 50,000 in 2003. In the early 2000s there was intense spontaneous resettlement of populations along the Cubango River, with many people being displaced into Namibia from Angola as a result of the conflict. This situation has now reversed, with many families returning to Angola, and it is expected that the pressure on vegetation along the north bank of the Okavango in Angola will increase.

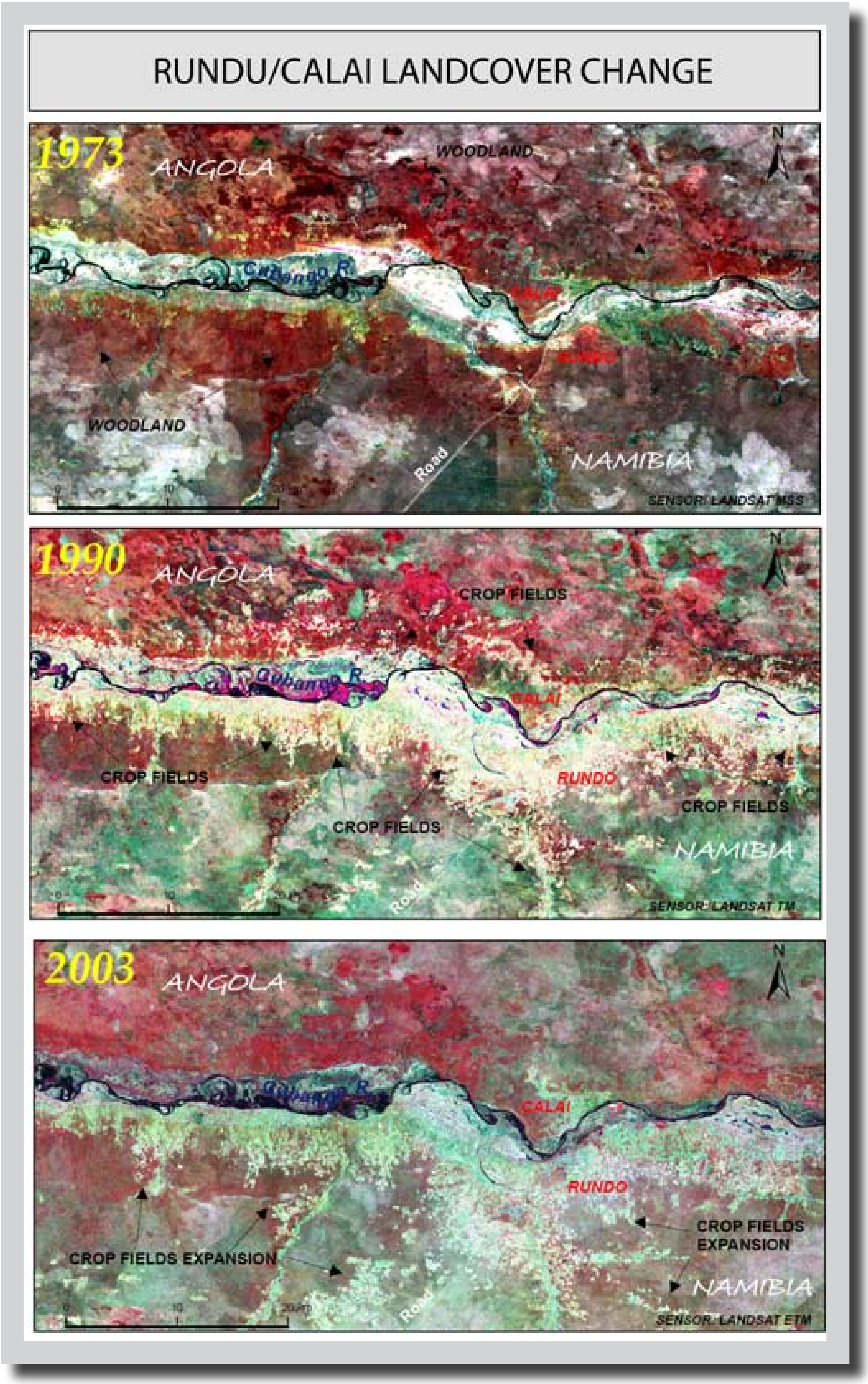


Figure 4-5: Landcover changes around Rundu/Calai, Namibia, 1973, 1990 and 2003

In the Divundu – Shakawe Landsat images (Figure 4-6), the pattern of degrading land cover is repeated, with progressive increases in crop field areas between 1979 and 2003 on the right bank of the river south of Divundu, with less on the left bank where there has been some protection in the Caprivi Game Park. The Mahango Game Reserve, which extends westwards from the river along the Namibia/Botswana border has also reduced the expansion of crop fields further south of Divundu. In Botswana, crop fields have expanded on both sides of the panhandle, but not by more than 5 km, which perhaps reflects the lower population pressure compared to the Rundu area.

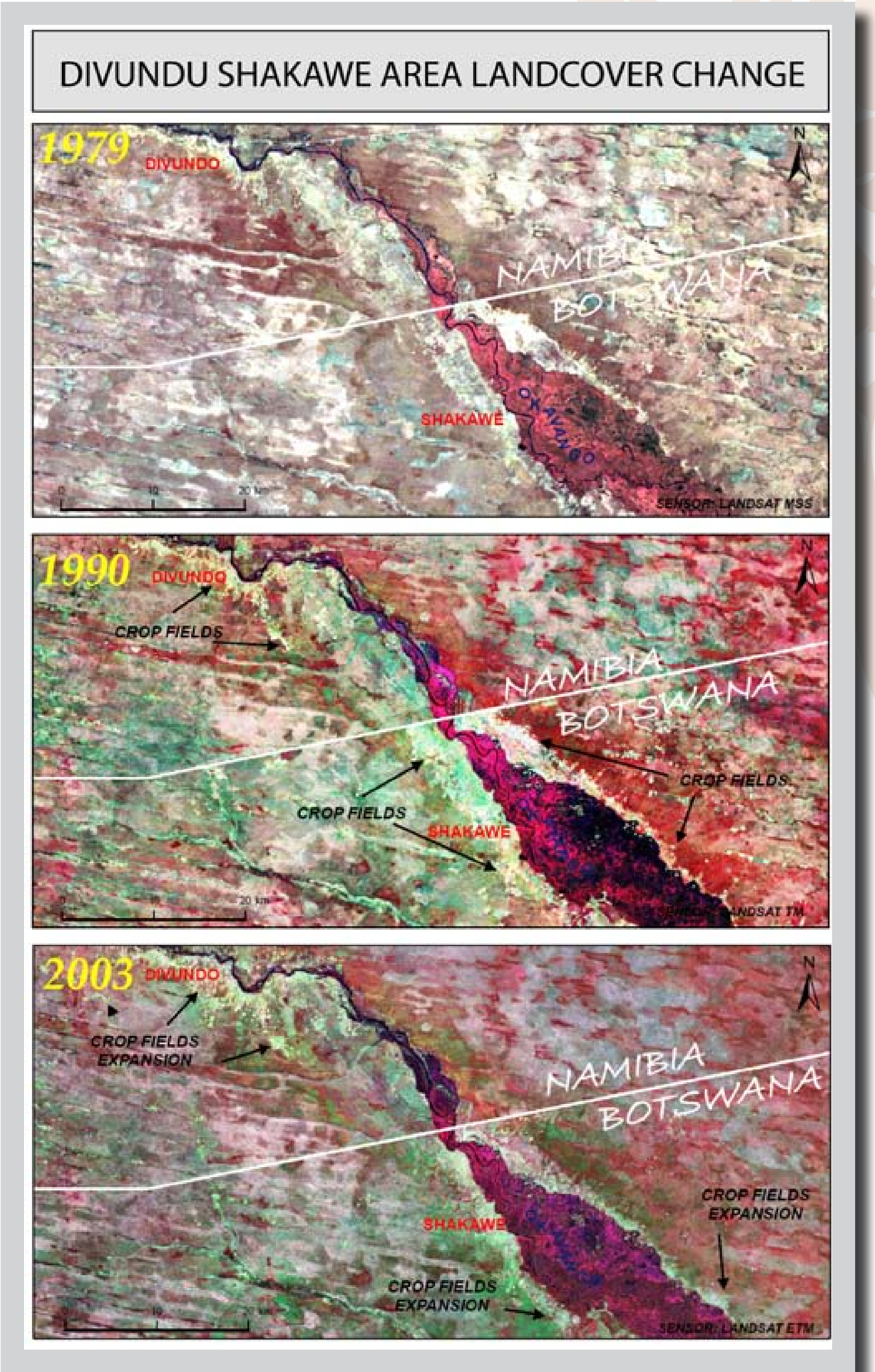


Figure 4-6: Landcover changes between Divundu and Shakawe, 1979, 1990 and 2003

The presence of significant numbers of livestock can degrade riparian vegetation. Table 2-23 (Chapter 2) indicates the density of livestock throughout the basin, and it is clear that the river provides a focus for medium and high density livestock numbers, especially in Namibia and along the western side of the Okavango Delta.

In Angola and Namibia livestock numbers are expected to increase substantially by 2025 – in Angola by up to 175%, and in Namibia, where numbers are already high, the increase may be up to 125%. In Botswana, the present high numbers of cattle (625,000) are expected to decrease somewhat to about 560,000 by 2025.

In Botswana, overgrazing coupled with climatic variations such as periods of drought, can lead to bush encroachment resulting in changes of species composition of grasses – from more palatable perennial species to less palatable annuals. Wind erosion in the rangelands could also be increased by overgrazing[6]. While this is more of an issue for the rangelands away from the Okavango River, the increasing numbers of livestock kept within the 10 km corridor of the river will have a significant localised impact upon the riverine and floodplain vegetation.

The use of fire for clearing land could become even more prevalent and have a greater effect on the composition, density and diversity of the vegetation.

Hydrological impacts of deforestation

A recent study of the impact of deforestation in the Okavango River Basin found that it can have a significant effect on water availability and the flooding regime of the river. It was assumed that increased population pressure along the river banks would lead to deforestation of a 2km wide band along the main river courses. Analysis of the hydrological impacts of the deforestation scenario on the Delta, indicated that average inflow to the Delta would increase by around 7%, with an associated increase in average ground water levels (+0.03 m) in the Delta. These increases were partially offset by increased evapo-transpiration from the greater flooded area. Outflows from the Delta were minimally affected

Other hydrological impacts that can be attributed to deforestation include an increased occurrence of minor flood events (storm flows rather than peak flows), soil erosion, downstream sedimentation and associated water quality problems. Prolonged, severe soil degradation could also affect infiltration and groundwater recharge, thereby increasing surface runoff and lowering base flows in the rivers.

4.2.2 Changes in water use

The demand for water in the Okavango comes from three main activities – water supply for domestic consumption, watering of livestock and irrigated agriculture. Each one of these will be studied along, with projections based upon the population numbers and actual developments for water use and abstraction that have been considered. This does not mean that these developments will actually be implemented, but rather that the projections are rooted in reality. While annual flows may be most relevant to the Okavango River Delta, considerations of minimum flow may be more relevant for lower reaches of the basin. Assessments of monthly water use have been made for the peak demand months, which are also the months with minimum flow – October/November.

Tables 4-4(a) and (b) summarise the overall demand for water from the different water users detailed below. This table shows that it is possible that, in the medium to longer term, the demand for water may rise steeply from the present 103 Mm^3/yr to over 3,871 Mm^3/yr by 2025, especially for irrigation. This also includes a progressive implementation of the water transfer scheme in Namibia.

TABLE 4-4 A: PROJECTIONS OF WATER USE TO 2015 IN THE OKAVANGO RIVER BASIN

	2010			2015		
	Angola	Namibia	Botswana	Angola	Namibia	Botswana
Water users	Water-use Mm^3/a			Water-use Mm^3/a		
Urban industrial and domestic	8.6	3	4.1	9.8	3.4	4.4
Rural domestic	4.3	2.3		4.9	2.5	
Livestock watering	4.6	3.6	15.9	5.3	3.9	13.2
Irrigated agriculture	24.0	33.7	0.5	489.0	46.2	5.0
Water Transfers						
Total	**41.5**	**42.6**	**20.5**	**509.0**	**56.0**	**22.6**
Total for basin	**104.6**			**587.6**		

Note: Irrigation and urban demands correspond to those used for the IFA Present, Low (2015), Medium (2020) and High (2025) scenarios. Projection based on study area for this TDA

6 Fraser, G. and Mabusela, L. (2003)

TABLE 4-4 B: PROJECTIONS OF WATER USE TO 2025 IN THE OKAVANGO RIVER BASIN

	2020			2025		
	Angola	**Namibia**	**Botswana**	**Angola**	**Namibia**	**Botswana**
Water users	**Water-use Mm^3/a**			**Water-use Mm^3/a**		
Urban industrial and domestic	11.0	3.9	4.7	12.5	4.3	5.1
Rural domestic	5.6	2.7		6.4	2.9	
Livestock watering	6.3	4.2	13.7	7.2	4.5	13.6
Irrigated agriculture	1653.0	125.7	10.0	3471.1	223.4	20.0
Water Transfers		17.0			100.0	
Total	**1675.9**	**153.5**	**28.4**	**3497.2**	**335.1**	**38.7**
Total for basin	**1857.8**			**3871.0**		

Note: Irrigation and urban demands correspond to those used for the IFA Present, Low (2015), Medium (2020) and High (2025) scenarios. Projection based on study area for this TDA

Water supply for domestic consumption and water diversion schemes
The World Health Organisation (WHO) minimum target requirements are 20-40 litres/capita/day, which provide for drinking water and sanitation, but exclude water for cooking and cleaning. The TDA hydrologists have used the following unit requirements:

- *Angola:* 50 l/c/d (rural) and 100 l/c/d (urban)
- *Namibia:* Future water demand projections are based on extrapolation of historical sales volumes from bulk water supply schemes. Per capita consumption for Namibia stands at 340 l in Rundu, 8-9 l in rural areas.
- *Botswana:* rural and urban: 75 l/c/d (based on National Water Master Plan).

The projected water demand for the basin will rise from 22.28 Mm^3/annum in 2010 to 31.24 Mm^3/annum in 2025.

Based on the population projections given above, the urban water demand in Angola can be focused on the two existing towns of Menongue and Cuito Cuanavale, which are projected to have the following populations and water demands over the next 15 years, using 100 l/c/d. Rural populations use different sources of water that can be surface water, boreholes or wells. An estimated 40 l/c/d is assumed for all rural users regardless of the source (Tables 4-5 and 4-6).

TABLE 4-5: ANGOLA – URBAN WATER DEMAND PROJECTIONS

Town	Menongue		Cuito Cuanavale		Total
Year	**Population**	**Urban water demand Mm^3/a**	**Population**	**Urban water demand Mm^3/a**	**Urban water demand Mm^3/a**
2010	199,025	7.26	37,321	1.36	8.63
2015	225,179	8.22	42,226	1.54	9.76
2020	254,769	9.30	47,774	1.74	11.04
2025	288,248	10.52	54,052	1.97	12.49

TABLE 4-6: ANGOLA – RURAL WATER DEMAND PROJECTIONS

	Cubango, rural		Cuito, rural		Total Angola, rural	
Year	**Population**	**Mm^3/a**	**Population**	**Mm^3/a**	**Population**	**Mm^3/a**
2010	208,219	3.04	87,339	1.28	295,558	4.32
2015	237,888	3.47	99,784	1.46	337,672	4.93
2020	271,785	3.97	114,002	1.66	385,787	5.63
2025	310,512	4.53	130,246	1.90	440,758	6.44

In *Namibia*, the forecasts made by NamWater (the national bulk water supply company) for the supply of water to the Rundu Urban area takes into account the population projections above, and also accounts for expected growth in industrial and commercial water demand. These are shown in Table 4-7, together with the rural projections[7], which include the water required for schools and clinics. Most of the rural water supply in Namibia comes from groundwater rather than surface water.

7 Obtained from Regional Rural Water Supply Development Plan 2003 for the Kavango Region, Ministry of Agriculture, Water and Rural Development.

TABLE 4-7: NAMIBIA – RURAL DOMESTIC AND URBAN DOMESTIC, COMMERCIAL AND INDUSTRIAL WATER SUPPLY PROJECTIONS

	Rundu, urban		Kavango, rural		Total Namibia
Year	Population	Urban water demand Mm^3/a	Population	Urban water demand Mm^3/a	Domestic water Mm^3/a
2010	45,144	2.99	180,568	2.31	5.30
2015	48,633	3.38	194,523	2.49	5.87
2020	52,392	3.85	209,556	2.69	6.54
2025	56,441	4.32	225,751	2.89	7.21

In *Botswana,* the National Water Master Review 2006 indicated that the projected demand for water in Ngamiland District, including the settlements all around the Delta, might reach 5.1 Mm^3/annum by 2025 (Table 4-8) including water for human requirements, livestock, small-scale irrigation, and construction. About 75% of the water being abstracted in Botswana comes from groundwater around the Delta. There is significant recharge of the freshwater lenses in the groundwater around the Delta from ephemeral streams (Chapter 2, Section 2-2), so the overall surface flows through the Delta are important for maintaining the groundwater supply.

TABLE 4-8: BOTSWANA – PROJECTED WATER DEMAND FOR DOMESTIC SUPPLY

Ngamiland		Water demand Mm3/a
Year	Population	
2010	162,456	4.07
2015	175,011	4.38
2020	188,537	4.74
2025	203,108	5.10

The 2025 projected abstraction of ground water allows for increasing populations in these areas, showing an additional water demand of 21.5 Mm^3/annum or 0.2% of the average annual inflow into the Delta. (Table 4-9)

TABLE 4-9: SURFACE WATER ABSTRACTIONS FROM RIVERS IN NGAMILAND, IN 2005 AND 2025

Surface water abstractions				
River	Abstractions			
	2005		2025	
	m^3/day	Mm^3/a	m^3/day	Mm^3/a
Okavango	6,285	2.29	9,107	3.32
Thaoge	1,475	0.54	2,140	0.78
Boro	1,483	0.54	2,710	0.99
Maunachira	275	0.10	399	0.15
Khwai	148	0.05	215	0.08
Thamalakane	26,571	9.70	38,553	14.07
Nhabe	5,100	1.86	7,400	2.70
Boteti	5,203	1.90	7,549	2.76
Total	**46,540**	**16.99**	**68,073**	**24.85**

Source: Beuster 2009b

Groundwater is also abstracted from boreholes around the Delta, mainly to supply Maun and settlements along the western margin. The increase in groundwater abstractions by 2025 is predicted to be around 14 Mm^3/annum, or 0.17% of the inflow.

Water transfer schemes

In addition to water supply for the people living in the Okavango River Basin, ,in Namibia there is a proposal for the transfer of water from the Okavango through the Eastern National Water Carrier (ENWC). This scheme is an integrated water infrastructure scheme that was first envisaged in the early 1970s. It would have augmented water supply for domestic and economic use to the central area of Namibia and for the rural population in the waterless areas of the eastern parts of the now Otjozondjupa Region. The scheme would have integrated various dams and aquifers in the Omatako River drainage and further south, and ultimately have included a pipeline link from the Okavango River. At the time, the design capacity of the scheme was 6 m3/s, equivalent to about 180 Mm3/a, but the operation would be such that on average not more than 100 Mm3/a would have been pumped from the river. The ENWC was implemented up to the Grootfontein-Omatako Canal in the 1980s, but its extension to the Okavango River was then put on hold, as the actual water needs remained far below the original forecasts.

During a severe drought in the 1990s, an investigation into crisis measures indicated a need for this pipeline link to be established with a capacity of 17 Mm3/a for the anticipated shortage. An EIA was satisfactorily completed, but while the detailed design study was commencing, more favourable rainfall conditions returned and there was no need for further action. Since then, groundwater investigations have indicated the availability of more groundwater in the Omatako River drainage, and the pipeline link to the Okavango River has been shelved. However, any return of a severe drought may necessitate such an emergency scheme in the short-term. Increased water needs of the population in the interior of Namibia, including in the Okavango River Basin, may require the initial plan to be pursued in the long-term. If need arises to transfer water from the Okavango River through the ENWC, it would be done within the framework of the Revised SADC Protocol on Shared Watercourses[8].

No water transfer schemes are planned in Angola or Botswana.

Water supply for livestock and wildlife

Livestock use water at rates of between 45 litres/day (Botswana) and 60 litres/day (Angola) per livestock unit. Small stock such as sheep and goats require 12 litres/day. The projections of livestock numbers in each of the three countries and their annual water demand is shown in Table 4-10. In Namibia, water for livestock is estimated at 45 litres/day for large stock units and 7.5 litres/day for small stock units.

TABLE 4-10: PROJECTIONS OF LIVESTOCK NUMBERS AND ANNUAL WATER DEMAND IN ORB

		2010	2015	2020	2025
Angola					
Cattle		187,666	217,557	254,468	292,379
Goats		68,980	83,925	104,778	124,230
Sheep		13,102	15,941	19,769	23,597
Pigs		23,740	28,884	35,820	42,756
Livestock units		208,830	243,307	286,541	330,496
Water demand	**Mm^3/a**	**4.57**	**5.33**	**6.28**	**7.24**
Namibia					
Cattle		125,972	135,446	145,622	157,202
Goats		44,135	47,454	51,020	55,077
Sheep		1,472	1,583	1,702	1,837
Donkeys		1,555	1,672	1,798	1,941
Livestock units		135,404	145,588	156,526	168,973
Water demand	**Mm^3/a**	**3.59**	**3.86**	**4.16**	**4.48**
Botswana					
Cattle		625,000	526,000	543,000	561,000
Goats		243,000	208,000	221,000	209,000
Sheep		21,000	17,000	17,000	15,000
Donkeys		70,000	54,000	53,000	44,000
Livestock units		691,800	581,800	601,200	614,600
Water demand	**Mm^3/a**	**15.92**	**13.22**	**13.70**	**13.62**
Total water demand Okavango		**24.08**	**22.41**	**24.13**	**25.34**

Source: IFA Reports 5 & 6, 2009

Wildlife

Wildlife also exerts a water demand and there are standard unit water requirements for different species[9] as indicated in Table 4-11. However, the hydrological models used by the TDA are based on the assumption that water-use by wildlife (and natural vegetation) is an integral part of the hydrological cycle and is accounted for prior to arriving at a reference, or 'naturalised' condition. Thus, the naturalised runoff has already been reduced and should therefore not be added to the water balance as a 'demand'. The exception to this rule is if wildlife concentrations are expected to increase beyond long-term historical levels, but, with the exception of elephants, this is considered unlikely.

8 G. van Langenhove, pers. comm. (2010)

9 Report of Wildlife specialist for Botswana National Water Master Plan (2005)

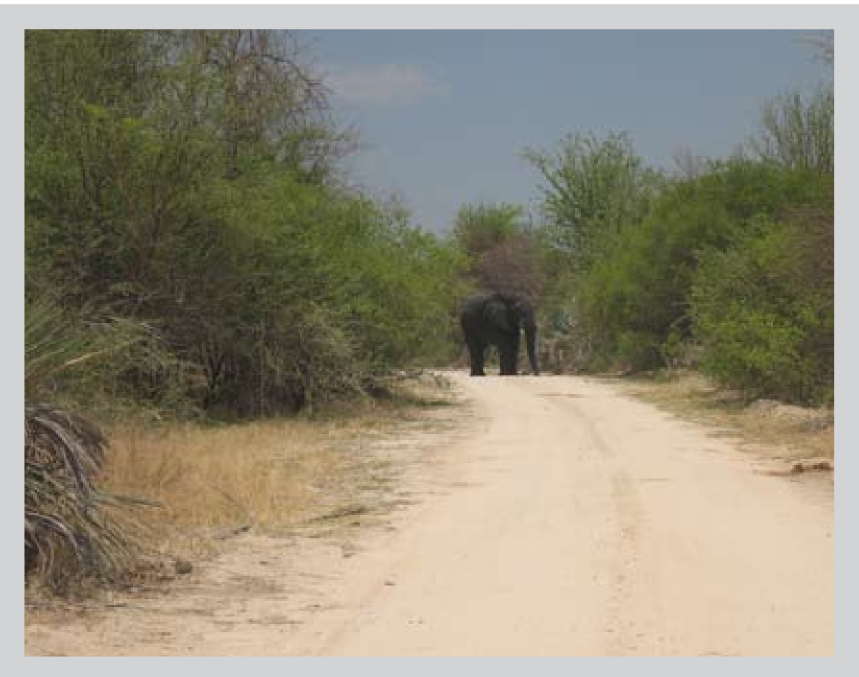
TABLE 4-11: ESTIMATED WILDLIFE WATER CONSUMPTION (ADULT ANIMALS)

Species	Water Dependence	Water Consumption (litres/day)
Blue Wildebeest	WD	9
Buffalo	WD	31
Burchell's Zebra	WD	12
Common Duiker	WI	1
Eland	WI	23
*Elephant	WD	225
Gemsbok	WI	9
Giraffe	WI	40
Impala	WD	2.5
Kudu	WD	9
Red Hartebeest	WD	5.5
Reedbuck	WD	3
Roan	WD	10
Sable	WD	9
Springbok	WI	1.5
Steenbok	WI	0
Tsessebe	WD	5
Warthog	WI	3.5
Waterbuck	WD	9

Note: Water-dependent (WD; obligate drinkers) and water-independent (WI) species and estimated consumption per adult animal per day (du P Bothma et al. 2002; du Toit 2002).

*The elephant populations are expected to increase in the basin in Namibia and Botswana, with consequent pressure on vegetation and increased demand for water from the river, especially in the dry season. Elephants drink at least 225 litres/day, so for every 1,000 elephants in the Okavango, there is an annual demand of 82,000 m^3/annum.

Management measures that have been considered (apart from culling) include dispersal of the populations by constructing artificial watering points supplied from boreholes and the opening up of historic elephant migration routes into southern Zambia and Angola, through the proposed Kavango/Zambezi Trans-frontier Conservation Area.



An elephant in Mahango, Namibia

Irrigated Agriculture

There are a number of proposals for irrigated agriculture that would draw water from the Okavango River Basin. These are principally in Angola and Namibia, with limited schemes in Botswana.

In *Angola,* the proposals for large-scale irrigated agriculture are shown in Table 4-14. The locations for the larger schemes are indicated in Figure 4-7. In the medium term about 270,000 ha are proposed for irrigation, most of which are located in the Cubango catchment, especially on the Cuchi and Cuebe rivers. The water requirement for these would be 3,510 Mm^3/annum[10]. In the longer term, there are an additional three large schemes proposed, bringing the total irrigated land to 490,000 ha requiring nearly 6,400 Mm^3/yr. The projections for construction of new small and medium-scale irrigation schemes and rehabilitation of existing schemes are shown in Table 4-12.

10 Based on 13,800 m3/ha/yr.

TABLE 4-12: LAND PROJECTED TO BE IRRIGATED BY SMALL AND MEDIUM SCALE SCHEMES IN ANGOLA BY 2025

Type of works	2010 (ha)	2015 (ha)	2025 (ha)	Total (ha)
Construction of small-scale Irrigation schemes	16,200	48,600	16,200	**81,000**
Construction of medium-scale irrigation schemes	2,000	30,097	68,226	**100,323**
Rehabilitation and upgrad-ing	1,200	3,800		**5,000**
TOTAL				**186,323**

Source: Ministry of Agriculture, Angola, Duarte, J 2009

The availability of water in Angola is usually not the limiting factor for the development of irrigated agriculture, but rather the suitability of soils for irrigation and the lack of water infrastructure (Table 4-13). Irrigated crops will depend on agro-ecological features, agricultural practices and market opportunities, so horticulture and fruit production will be the principal irrigated crops, while cereal crops will continue to be cultivated as rainfed crops.

However, in some places in Angola, lack of water can limit the development of irrigated agriculture, for example, the proposed Missombo Irrigation Scheme (1000 hectares), the so-called Menongue Agricultural Scheme (10,000 hectares) and EBRITEX (17,000 hectares) along the Cuebe River. This amount of land will need roughly 28 m^3/sec. During the dry season the flow of Cuebe River drops to 10-13 m^3/sec.

TABLE 4-13: SUITABILITY OF SOILS FOR IRRIGATED AGRICULTURE IN ANGOLA

Country	Region/area	Soils	Agricultural suitability	Crops
Angola	Region I: 33,600 km^2 (Upper Cubango)	Slightly ferralic, presence of lateritic and paraferralitic soils	Rain-fed agriculture	Maize, sweet potatoes, fruit trees
	Region II: 79,900 km^2 (Upper Cubango)	Kalahari sand cover, mainly psamofferalic and ferralic arenosols and arenosols	Low value	Massango (*Panicum italico*) cassava
	Region III: 36,200 km^2 (Lower Cubango)	Alluvial soil,	Limited agricultural use	Grazing, rice
		Calcarious formations	Unlimited use	Tropical fruit trees, cereal, cotton
		Soils related to the Kalahari sand platform	Limited used	Extensive cattle breeding
Namibia, Kavango	Inland sand plateau	Infertile aeolian soils of Kalahari group with low organic matter	Well drained with high infiltration rate and low water retention capacity. Requires compost and high initial fertiliser application	With irrigation – maize, wheat, fruit and vegetables. Extensive cattle breeding
	River terrace	Sandy soils enriched with clay and silt deposits	Limited use for irrigation because of annual inundation during rains	Grazing, rice
Botswana	Inland sand plateau, north and west Ngamiland	Infertile aeolian soils of Kalahari group with low organic matter	Limited agricultural use without irrigation	Extensive cattle breeding
	Panhandle and Delta	Sandy soils enriched with clay and silt deposits	Molopo recession agriculture	Grazing, maize, fruit and vegetables

Sources: Gomes and Liebenberg 2009; Masamba 2009

TABLE 4-14: PROPOSED IRRIGATION SCHEMES IN ANGOLA[11]

Municipality	Name of irrigation scheme	Source of irrigation water	Flow to be abstracted from river, m³/s	Annual water requirement Mm³/yr	Area, ha	Implementation term	Remarks
Menongue	Perímetro Agrícola de Menongue	Cuebe River	10	129.60	10,000	Medium term 2013	Water to be abstracted in the section of the Rapids of Liyapeka
Cuvango	Cuvango	Cubango/ Okavango River	11	142.56	10,000	Medium term 2013	
Cuchi	Cuchi	Cuchi/ Cacuchi Rivers	16.5	213.84	15,000	Medium term 2013	Cuchi is a tributary of the Cubango/ Okavango River. Production of maize and pulses
Cuchi	Vissati	Cuchi River	18	233.28	15,000	Medium term 2013	Corn and pulses
Cuchi		Cuchi River	120	1,555.20	100,000	Medium term	Private venture in Chiguanja communal area. Sugar cane
Cuchi		Cuchi River	12	155.52	10,000	Medium term	Production of sugar cane by small local farmers
Cuchi	Vissati	Cuchi River	12	155.52	10,000	Medium term 2013	Oil crops
Cuito Cuanavale	Cuito Cuanavale	Longa River	120	1,555.20	100,000	Medium term. Possibly 10%	Longa is a tributary of Cuito River. Rice production in Lupira, Longa communal areas
Total medium term				**4,140.72**	**270,000**		
Calai/Dirico	Calai/Dirico	Cuito/ Okavango Rivers	66	855.36	60,000	Long term	Mainly production of irrigated soya
Calai and Dirico		Cubango and Cuito Rivers	84	1,088.64	70,000	Long term. Possibly part of this will be developed. Recommend from Cuito, rather than Cubango	This is called 'Programa dos Generais'. Production of soya
Cuangar and Calai		Cubango/ Okavango River	108	1,399.68	90,000	Long term. Possibly part of this will be developed. Recommend from Cuito, rather than Cubango	This is a private venture. Production of soya and sugar cane
Total medium and long term				**7,484.40**	**490,000**		
Key		Cubango sub-basin				Medium term	
		Cuito sub-basin				Long term	

In *Namibia,* irrigated agricultural development is already well advanced, at some sites, with a number of additional proposed schemes. For the time being, Namibia has restricted its planned expansion to an area not exceeding 16,000 hectares, which was derived from assumptions on minimum flows, irrigation use peak factors, priority for environmental requirements and fair allocations between the three countries. Under these assumptions, the water use for irrigation in Namibia would not exceed 240 Mm³/a, based on a crop water demand of 15,000 m³/ha/a. Details of present and envisaged possible schemes are presented in Tables 4-15 a and b.

However, figures for Namibia only reflect the areas that are suitable for irrigation with no flow regulation. These estimates are based on a crop water-demand of 15,000 m³/ha/a. (Table 4-15 a. and b.)

11 Some schemes will supplement rain-fed agriculture, so actual requirements for water would be less – 3,510 Mm³/yr for Medium term and 6,400 Mm³/yr in longer term.

TABLE 4-15 A. WATER DEMAND UPSTREAM OF THE CUITO RIVER (NAMIBIA)

No	Tribal area	Place (if known)	Existing area under irrigation (ha)	Future planned irrigation area (ha)
1	Kwangali	a. Musese & Maguni	300	200
		b. Simanya	0	200
		c. Sihete	0	200
		d. Other	0	200
		Total	**1,100**	
2	Mbunza	a. Sikondo	0	800
		b. Other	0	300
		Total	**1,100**	
3	Sambyu	a. Rundu	60	0
		b. Kaisosi	36	0
		c. Vungu-Vungu	285	0
		d. Mashare Irrigation Training Centre	60	0
		e. Mashare CFU	80	30
		f. Mashare	0	574
		Total	**1,125**	
4	Gciriku	a. Ndonga Linena	400	400
		b. Shankara	20	0
		c. Shitemo	400	0
		Total	**1,220**	
			1,641	2,904
Total development upstream from Cuito			**4,545**	

TABLE 4-15 B. WATER DEMAND DOWNSTREAM OF THE CUITO RIVER (NAMIBIA)

No	Tribal area	Place (if known)	Existing area under irrigation (ha)	Future planned irrigation area (ha)
4	Ggiriku	a. Other	0	3,500
		Total	**3,500**	
2	Mbukushu	a. Shadikongoro	400	0
		b. Bagani gardens	40	0
		c. Divundu prisons	116	40
		d. Katondo	0	4,000
		e. New projects	0	3,018
		Total	**7,614**	
			556	10,558
Total development downstream from Cuito			**11,114**	

Source: Liebenberg 2009

In *Botswana,* only 31.35 ha (17%) of 188.15 ha allocated for irrigation, is being utilised, mostly for vegetables.[12] Most schemes are between 1 and 2 ha in size. There is only one commercial farm allocation of 85 ha for water abstraction using a centre pivot system in Okavango District, and although only 1.25 ha is being irrigated at present, the allocation could be fully implemented in the future. There are a number of small-scale irrigated plots, the use of which is expected to increase in the future (Table 4-16). Estimates of the water demand from these irrigation projects have been included in estimates of abstractions from the river and ground water around the Delta. (Section 4-2.2)

12 Masamba (2009b)

TABLE 4-16: PRESENT ALLOCATIONS FOR IRRIGATION PROJECTS IN BOTSWANA

District	No. of projects	Area allocated (ha)	Current area irrigated (ha)	Source of water	Crops
Ngamiland East (Maun)	35	48.8	15.2	21 schemes use river water, 14 use boreholes	Vegetables and citrus
Nagmiland West (Gumare)	15	20	8.5	9 schemes use river water, 6 use open wells	Vegetables
Okavango	20	119.35	7.65	18 schemes use river water, 1 borehole and 1 standpipe	Vegetables and citrus
Total	**70**	**188.15**	**31.35**		

Source: Masamba 2009b

Hydropower

Both Angola and Namibia have considered the construction of hydropower schemes on the Okavango (Table 4-17). The locations of the potential hydropower dam sites are shown in Figure 4-7. The hydrological studies indicate that the combined output of the hydropower schemes included in the high development scenario is about 460 Gigawatt-Hour.

In *Angola,* prior to independence, sites for 17 hydropower projects were identified in the basin, . Although detailed feasibility studies have not been conducted recently, only the projects indicated in Table 4-16 are considered viable by the government. Only one hydropower scheme exists in the Angolan section of the basin. This station, situated at Cuvango, was damaged during the civil war and is being rehabilitated.

Feasibility and design studies for three other dams are being prepared, at Liyapeka on the Cuebe River, Malobas on the Cuchi River and Maculungungu on the Cubango River with target operational dates in 2013. Except for the Malobas scheme, these are designed as run-of-river schemes, with relatively low weirs and small reservoirs. The project at Malobas is designed to have a 47 m high dam wall with an active storage of 1,634 Mm^3, a reservoir size of 120 km^2 and an installed capacity of 84 MW. A larger storage dam at Mucundi is projected to have a reservoir size of 161 km^2 and 2,540 Mm^3 of active storage and installed capacity of 74 MW. Many of the run-of-river schemes in Angola involve a diversion channel to the power house which may be up to several kilometres downstream to take advantage of the difference in elevations.

Kavango River near Rundu, Namibia

In *Namibia,* Popa Falls, where the river drops a few metres, is the only feasible location for hydroelectricity generation. The feasibility of three alternative run-of-river sites associated with this location were considered in 2003 in an attempt to preserve the falls themselves because of their high tourism value. However, the proponent of the Popa Falls Hydropower Scheme, NamPower, shelved the proposal, because they identified a possibly fatal flaw regarding sediment transport. This would have required excessively high resources for full monitoring and analysis, which were not justified in relation to the magnitude and benefits of the possible scheme.[13]

13 Christian, C. (2009)

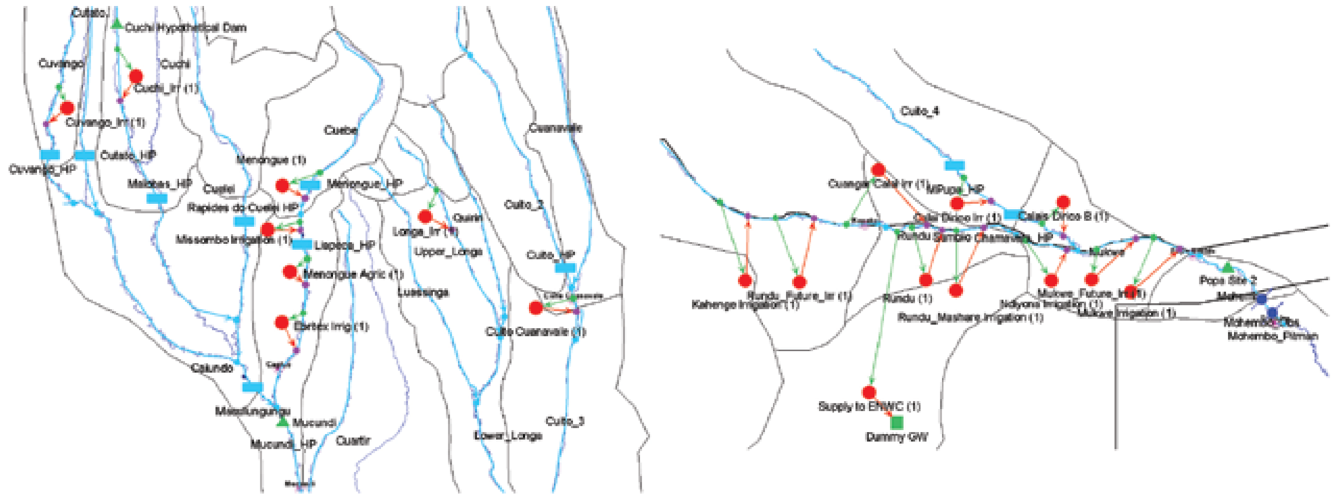
TABLE 4-17: PROPOSALS FOR HYDROPOWER SCHEMES IN THE OKAVANGO RIVER BASIN[14]

Name	River	Location/ elevation	Type and size	Comments	Date operational	Installed capacity	Reservoir area	Head	Mean annual power output	Annual release value	Rated discharge	Active storage capacity
						MW	km^2	m	GWh/yr	Mm^3/yr	m^3	Mm^3
Angola												
Cuvango	Cubango	Headwaters 1553 masl	Storage – 26m high, 700 m wide, 3 m drawdown	Existing but not functioning	2009	7	51	16	29.8	870	54.7	393
Chazenga	Cubango	1501 masl	21m high, 500 m wide 3 m drawdown			15	65	17	67.4	1783	110.3	440
Mangonga	Cubango	1463 masl	8 m high, 200 m wide, 3 m drawdown			26		30	124.2	1430		
Liyapeka	Cuebe	d/s of Menongue	Run-of-river, low weir	Hydraulic parameters collected. Technical design ongoing	2013							
Kaquima/ Malobas	Cuchi	1420 masl	Run-of-river 47 m high, 120 m wide, 3 m drawdown	Planned	2011	84	120	58	215.5	1903	206.9	1634
Maculungungu	Cubango	u/s of Caiundo, 1173 masl	Run-of-river, 15 m high, 400 m wide, 3 m drawdown	Hydraulic parameters collected. Design will start soon	2011	54		20	241.5		24	
Mucundi	Cubango	d/s of Mucundi 1153 masl	Storage, 35 m high, 750 m wide, 3 m drawdown			74	161	25	330.8	6765	422	2541
Cutato	Cutato	1483 masl	Run-of-river, 10m high, 250m wide, 3 m drawdown	Planned		32.5		80	159.7	933	6	
Rapidos do Cuelei	Cuelei		Run-of-river	Planned				22			8	
Cuito Cuanavale	Cuito	13 km u/s of confluence	Diversion, run-of-river	Planned, but not considered by the WEAP model				7			90	
M'Pupa	Cuito		Run-of-river	Planned				5			100	
Chamavera	Cuito	d/s of M'pupa	Run-of-river	Planned				6			100	
Namibia												
Popa Falls	Okavango	Popa Falls	Run-of-river, 9.75 m high weir			20	5.3	9.75			2820	22.5

Sources: Climate, Hydrology and Water Resources, Angolan sector 1999 TDA, Andersson et al 2006, Christian 2009, Beuster 2009b

Blue highlighting indicates the schemes that were included in the WEAP hydrological model.

14 Some of these schemes may not be considered viable. For instance Menongue, Calemba and Popa Falls.



(a) Upper Okavango in Angola

(b) Lower Okavango in Angola and Namibia

Key: green dots = water abstraction points, red dots = proposed irrigation sites, red arrows = return irrigation waters, blue rectangles = run-of-river hydropower dam sites, green triangle = storage hydropower dam.

Figure 4-7: Locations of potential hydropower and irrigation sites in the Okavango River Basin

4.3 TRANSBOUNDARY CHALLENGES

Taking into consideration the trends based on population growth with the resultant increase in water consumption, land use changes and future development plans for the three riparian countries explained above, this section examines how these could challenge transboundary management of the basin.

The most significant root cause (driver) of change in the Okavango River Basin is population growth. There will be an increasing trend towards urbanisation, especially in Angola and Namibia, with increased demand for services including water and sanitation, and risks of water pollution and pressure on natural resources in the basin as a whole.

4.3.1 Flow regimes

To meet the hypothetical projected increase in demand for goods and services in the basin, abstraction of water could rise from a current 100 Mm³/yr to over 6,600 Mm³/yr by 2025 in the High-use Scenario, which would have serious consequences on the flow volumes in the river. As the major contribution to the overall flow of the river originates in Angola (94%), any changes in the flow will have implications for both Namibia and Botswana, with the Okavango Delta being most vulnerable. With higher levels of water use, water quality may be expected to decline, especially in the lower sections if there is no additional run-off to dilute contaminants.

4.3.2 Sediment dynamics

The character of the Okavango River and the diversity of the river ecosystems, especially in the Delta, depend on sediment transport. Increased erosion in the Angolan highlands as a result of land clearance and cultivation could yield more sediment in the river, leading to loss of water quality, and may threaten aquatic habitats. Bank erosion could increase, especially in Namibia and in the panhandle, made worse by the removal of riparian vegetation, trees and reeds. Any impoundment that traps sediment could have significant negative impacts, both for the life of the dams and for downstream river bank and bed erosion, and changing flow and sediment dynamics within the floodplains and the Delta.

4.3.3 Changing Water Quality

As described in Chapter 2, the present water quality of the Okavango River is considered to be very good, although there may be localised lowering of water quality as a result of geological conditions and human activities.

Increased effluents and waste from growing urban areas would give rise to organic pollution and high bacterial contamination. Drainage from irrigation schemes carrying nutrients and agricultural chemicals could affect the overall productivity of the system, possibly changing the river from a nutrient poor to a nutrient rich system, with the consequent risks of eutrophication in different parts of the system.

Changes in dissolved oxygen and temperature as a result of storage dams could affect water quality, although most of the planned dams are run-of-river with smaller impacts on water quality. Salinity balance in the Delta is important for its dynamic; salinity may change as a result of changes in the flow regime, e.g. if less water is available during low flows. The river's ecosystem services of water purification and nutrient storage may be affected by changes in flow.

4.3.4 Changes in the abundance and distribution of biota

As the population increases, the use of natural resources for food, fuel, construction and fibre will increase by nearly 50% in Angola and by 25% in Namibia and Botswana, leading to further degradation and loss of resources, especially of fish. Changes in water availability in the river system will have impacts on the distribution, diversity and productivity of the natural systems, including wildlife.

Wildlife populations are most concentrated in Botswana, while there are some pockets of abundance in Namibia. In Angola, most of the large herbivores were displaced during the conflict, although there are indications that populations may be recovering. Increased numbers of elephants in Botswana and Namibia will pose a threat to vegetation and water resources and lead to increased conflict with humans. A transboundary frontier conservation initiative among the riparian countries could allow an increased range for the elephants.

There is the risk of alien invasive species migrating between riparian countries, in particular the aquatic weed, *Salvinia molesta* and the fish species *Oreochromis niloticus,* an escapee from fish farms that has not yet been found in the Okavango.

4.3.5 Social Issues

Heightened pressure on and overall decline of the natural resources in the basin resulting from the predicted population growth will significantly increase the vulnerability of the poor rural populations that are dependent on them for their livelihoods. The rural poor are also more vulnerable to changes in environmental conditions caused by human activities or climate-induced disasters, such as prolonged drought.

4.3.6 Conclusion

At present the Okavango Basin, including its river ecosystem, is in exceptionally good condition, which for a large international river is very unusual at the global level. Current trends in the basin are much the same as those facing most developing regions: growing population numbers and the need for food security, social upliftment, reliable supplies of good quality water and increasing energy generation to support social and industrial growth. Trends of what could happen next are by now well documented globally: considerable benefits are enjoyed from water-resource developments such as hydropower generation and irrigated agriculture but, increasingly, the costs are becoming apparent in the form of massive environmental degradation and the loss of river resources.

The Okavango countries are dependent in several different ways on a river ecosystem that is not degraded: for food, for drinking and washing, for flood attenuation, for water storage and reliable dry-season supplies, and for tourism. While the reliance of the Angolan population on water consumption directly from the river is expected to diminish, it is likely to remain an important issue.

These attributes of the river, with a considerable inherent monetary worth (see Chapter 2), are vulnerable and will decline with water-resource development. The statistics in this chapter illustrate the potential size of the water demand and thus of the vulnerability of the river and its dependent social structures. The next chapter details the ecological and social impacts that could emerge if the countries decide to follow individual and uncoordinated development pathways. These impacts do not have to happen but they could. The basin stands at a crucial point in its history, and the Okavango countries have a near-unique opportunity to forge a new approach to basin development that is truly sustainable in the long term and that could serve as a global model.

CHAPTER 5. THE IMPACTS OF POTENTIAL WATER RESOURCES DEVELOPMENTS

Increasing water demands can take many forms. Irrigated agriculture is often the main demand, and its impacts include reductions of river flow as water is abstracted for crops; drainage of fertilisers, pesticides and sediments back into the river from agricultural land, and in-channel storage dams to store wet-season flows for dry-season irrigation. The storage dams themselves impact the river by acting as barriers to the natural movement of water, sediments, plants and animals along the system and by harnessing floods that maintain river beds, banks and floodplains. Hydropower dams do not greatly reduce the overall amount of water in the river because they usually have much less storage capacity, but they change the pattern of downstream flows, often with sharp intra-daily fluctuations in releases that become highly abnormal flows in the river.

Other major man-made catchment manipulations that can impact the river are deforestation, which tends to increase the amount of water flowing overland to the river and reduce the amount penetrating the soil to recharge groundwater (and thus river flow). Urban areas also 'harden' the catchment and discharge effluents into the river. All of these interventions can affect the flow, sediment, chemical and thermal regimes of the river. The river is a dynamic living system and will respond by changing. This chapter describes the nature of the changes that can be expected with water resources development, both in the river, in livelihoods of riparian people and in local and national economies. Some of the changes may be seen as benefits, and some as costs.

The predictions are presented as a set of scenarios, each of which represents a possible level of future water use.

Scenarios

The water-use scenarios assessed are simply ways of exploring possible management options. None of the scenarios described in this study will necessarily happen but they could. They are designed to alert the Okavango Basin countries to possible future benefits and problems and help them identify, through negotiation, a preferred future pathway. The scenarios were chosen through an iterative process of discussion between project staff, OKACOM and other government representatives. The most important of these meetings took place in Maun in November 2008 when two major decisions were made:

1. The scenarios would be development-based rather than sector-based. In other words they would explore a progressive growth in water use through various kinds of development, rather than exploring the implications of, for instance, maximising basin-wide hydropower generation or basin-wide irrigated crops.
2. The scenarios would represent three levels of potential water use in the basin: Low, Medium and High. The Low water-use Scenario would equate approximately to the three countries' present short-term (i.e. 5-7 year) national plans. The Medium water-use Scenario would reflect possible medium term (approx. 10-15 year) plans, and the High water-use Scenario possible long-term (>20 year) plans.

Major water uses included in the scenarios were hydropower generation; agriculture, including irrigated crops and livestock; mining and industrial; growing numbers of people in urban areas and as tourists, and inter-basin transfers of water.

The details of where to place individual potential developments within the basin hydrological model were decided by the hydrological team after consultations within their respective countries. This does not imply that the development will happen or, if it happens, that it will be in the location indicated in the model. Modification of the site of a development, or of its design or operating rules, could affect the consequent flow regime and thus the predicted ecological and social impacts.

The creation of a Decision Support System (DSS) for this project enables many permutations of development projects (scenarios) to be explored in terms of their ecological and social impacts, not just the three created in the project. The DSS will reside with OKACOM.

5.1. THE WATER-USE SCENARIOS

Details of the levels of water use included in the scenarios are as follows.

5.1.1 The Present Day (PD) Scenario

This includes all existing water resource developments, notably:

- About 2,200 ha of irrigation in Namibia
- The urban water demands of Menongue and Cuito Cuanavale (Angola), Rundu (Namibia), and Maun (Botswana).

5.1.2 The Low water-use Scenario

This describes the continuation of historical growth in water demand in the three countries, and essentially equates to the countries' short-term (5-7 year) plans. Growth rates in Angola reflect the recent acceleration associated with resettlement in de-mined areas. Increased water consumption is mainly due to growth in urban and rural domestic, livestock and irrigation water demands. The largest water demands are represented by:

- About 3,100 ha of irrigation in Namibia
- About 18,000 ha of irrigation along the Cuebe River in Angola
- One storage-based and three run-of-river hydropower stations in Angola.

5.1.3 The Medium water-use Scenario

This has a possible 10-15 year planning horizon and includes all the developments in the Low Scenario plus:

- Increased water demand for domestic and livestock consumption due to population growth
- About 8,400 ha of irrigation in Namibia
- Development of a first phase of the Eastern National Water Carrier (17 $Mm^3 a^{-1}$) for water supply from the Kavango to Grootfontein and Windhoek,
- About 198,000 ha of irrigation at various locations in Angola
- One storage-based and four run-of-river hydropower stations in Angola.

5.1.4 The High water-use Scenario

This includes all previous developments in the Low and Medium Scenarios, and has a planning horizon of 20 years or more. Its purpose was to add in all considered water resources developments, even though some were unrealistic, in order to assess if at this stage the river ecosystem would start to show severe degradation and its users thus would feel severe impacts. Developments added in were:

- Increased water demand for domestic and livestock consumption due to population growth
- About 15,000 ha of irrigation in Namibia
- About 338,000 ha of irrigation at various locations in Angola
- Completion of all planned hydropower stations in Angola, i.e. one storage based and nine run-of-river hydropower stations
- Completion of a second phase of the Eastern National Water Carrier in Namibia (total capacity 100 $Mm^3 a^{-1}$)
- Development of a scaled down version of the schemes for the increased water provision for communities and urban and industrial water supply from the Delta to Maun
- At these levels of demand, it was necessary to introduce a hypothetical dam in the upper basin (Cuchi River) with a capacity of about 500 Mm^3 to provide for shortfalls in irrigation water supply and inter-basin transfers.

The changes in river flow caused by these scenarios, and their potential ecological and social impacts, are described for eight points along the river system that were chosen in a basin delineation exercise (Figure 5-1). Each of these points represents a longer length of river and its surrounding social area. Some parts of the basin could not be represented due to the time and financial limitations of the project.

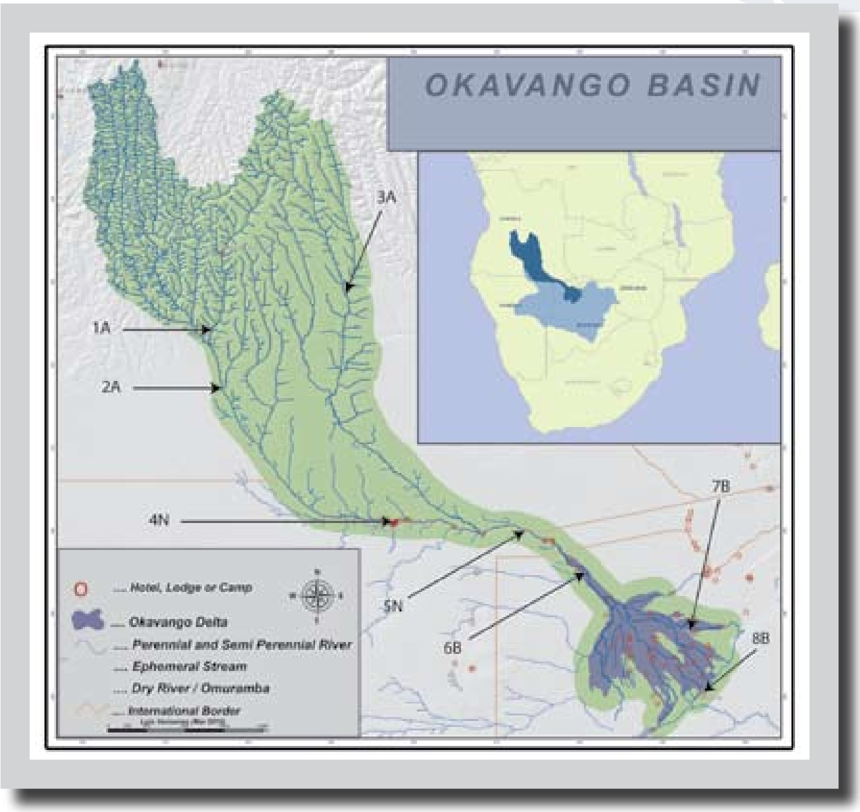


Figure 5-1: Location of the eight representative sites: three in Angola, two in Namibia and three in Botswana.

The water resources developments affecting each of these sites under each scenario are summarised in Table 5-1.

TABLE 5-1: DETAILS OF THE LOW, MEDIUM AND HIGH WATER-USE SCENARIOS THAT WOULD AFFECT EACH REPRESENTATIVE SITE.

<table>
<tr><th rowspan="2">Site</th><th rowspan="2">Present</th><th rowspan="2">Low</th><th>Medium</th><th>High</th></tr>
<tr><th>Low schemes plus:</th><th>High schemes plus:</th></tr>
<tr><td rowspan="6">Site 1
Capico</td><td rowspan="6">Menonge</td><td>Menongue 257 000 people</td><td>Menongue 30 000 people</td><td>Menongue 70 000 people</td></tr>
<tr><td colspan="3">Irrigation: Missombo 1000 ha, weir division</td></tr>
<tr><td colspan="3">Irrigation: Menongue, Agriculture 10 000 ha, pump sump on river bank</td></tr>
<tr><td colspan="3">Irrigation: Ebitrex 17 000 ha, pump sump on river bank</td></tr>
<tr><td colspan="3">HEP: Menongue, run-of-river, low weir, turbines d/s, H=8 m, Qmax = 12 m³/s</td></tr>
<tr><td colspan="3">HEP: Liyapeka, run-of-river, low weir, turbines d/s, H=16 m, Qmax = 24 m³/s</td></tr>
<tr><td></td><td colspan="4">ALL CAPICO DEVELOPMENTS PLUS</td></tr>
<tr><td rowspan="7">Site 2
Mucundi</td><td rowspan="7"></td><td colspan="3">HEP: Cuvango, Existing / not functioning. Rehabilitation in 2009 , Qmax = 3.5 m³/s</td></tr>
<tr><td colspan="3">HEP: Cuchi – (Kaquima (Malobas)), run-of-river, H=14 m, Qmax = 3 m³/s</td></tr>
<tr><td colspan="3">HEP: Maculungungu (on Cubango u/s Caiundo), run-of-river, H=22 m, Qmax = 24 m³/s</td></tr>
<tr><td colspan="3">HEP: Mucundi, 40 m high reservoir , H=1 250 m, Qmax = 70 m³/s</td></tr>
<tr><td colspan="2" rowspan="2"></td><td>HEP: Cutato, run-of-river, H=30 m, Qmax = 6 m³/s</td></tr>
<tr><td>HEP: Radipos do Cuelei, run-of-river, H=22 m, Qmax = 8 m³/s</td></tr>
<tr><td>Irrigation: Cuchi, 15 000 ha, pump intake</td><td>Irrigation: Cuchi, 150 000 ha, pump intake</td><td>Cuhci Hypothetical Dam – 500 Mm³ storage to supplement Irrigation</td></tr>
<tr><td rowspan="2">Site 2
Cuito
Cuanavale</td><td>Cuito Cuanavale: 110 435 people</td><td>Cuito Cuanavale: 115 000 people</td><td>Cuito Cuanavale: 128 600 people</td><td>Cuito Cuanavale: 160 000 people</td></tr>
<tr><td colspan="2"></td><td colspan="2">HEP: Cuito Cuanavale, (13 km u/s confluence). Diversion, Run-of-river, H = 70 m, Qmax = 90 m³ /s</td></tr>
</table>

Signs of rapid economic empowerment, informal market Menongue, Angola

Site	Present	Low	Medium	High
			Low schemes plus:	**High schemes plus:**
ALL CAPICO AND MUCUNDI DEVELOPMENTS PLUS				
Site 4 Kapako	Irrigation: **Kahenge** 300 ha, pump intake on river bank	Irrigation: **Kahenge** 700 ha, pump intake on river bank	Irrigation: **Kahenge** 900 ha, pump intake on river bank	
			Irrigation: **Rundu Future** 1,100 ha, pump intake on river bank	
				Irrigation: **Cuangar Calai** 45,000 ha, pump intake on river bank
All Capico, Mucundi, Kapako and Cuito Cuanavale developments plus				
Site 5&6 Popa Pan-handle			Irrigation: **Longa** 10,000 ha, pump intake on river bank	
				Irrigation: **Calai Dirico** 35,000 ha, pump intake on river bank
				Irrigation: **Calai Dirico B** 60,000 ha, pump intake on river bank
	Irrigation: **Mukwe** 560 ha, pump intake on river bank			
	Irrigation: **Rundu-Mashare** 521 ha, pump intake on river bank	Irrigation: **Rundu-Mashare** 551 ha, pump intake on river bank		
	Irrigation: **Ndiyona** 870 ha, pump intake on river bank	Irrigation: **Ndiyona** 1,270 ha, pump intake on river bank		
	Rundu urban tower on right bank, 2.8 Mm^3/a	**Rundu** urban tower on right bank, 3.0 Mm^3/a	**Rundu** urban tower on right bank, 3.4 Mm^3/a	**Rundu** urban tower on right bank, 4.3 Mm^3/a
			Irrigation: **Mukwe Future** 4,000 ha, pump intake on river bank	Irrigation: **Mukwe Future** 10,600 ha, pump intake on river bank
			Eastern National Water Carrier for water supply from Okavango River to Namibia. Tower on right bank, 17 Mm^3/a	**Eastern National Water Carrier** for water supply from Okavango River to Namibia. Tower on right bank, 100 Mm^3/a
				HEP: **Popa** Falls. Run-of-river weir at Site 2. H = 7.5 m Qmax = 280 m^3/sec, 22.5 Mm^3 capacity
				HEP: Cuito – **M'Pupa**. Run-of-river. H 5 m.
				HEP: Cuito – **Chamavera** (d/s M'Pupa). Run-of-river. H = 6 m, Qmax -= 100 m^3/sec.
Site 7 Khwai	**All Capico, Mucundi, Kapako and Cuito Cuanavale and Popa/Panhandle developments plus**			
Site 8 Boteti	**All Capico, Mucundi, Kapako and Cuito Cuanavale and Popa/Panhandle developments plus**			
				Dam at **Samedupi** (37 MCM/a)

These potential water developments were inserted into the basin hydrological model, which then predicted how flows along the Okavango River drainage basin could change (Section 5.2). The flow changes were then translated into predicted changes in the river ecosystem and its dependent wildlife (Section 5.3), and how these environmental changes could affect people's lives and livelihoods (Section 5.4). The macro-economic implications of the developments were addressed next (Section 5.5), and the chapter ends with an analysis of governance, identifying gaps and institutional constraints that could limit management of the basin's water resources (Section 5.6), and a summary (Section 5.7).

5.2. THE IMPACT OF THE WATER RESOURCES DEVELOPMENTS ON THE FLOW REGIME

The Present Day (PD) flow regime of the whole system is close to natural, which is extremely unusual for a large transboundary river. A prominent and very important characteristic of this PD flow regime is the great difference between the two headwater tributaries, the Cubango and the Cuito, and the massive storage capacity for floods in the floodplains along the system. The Cubango exhibits a flashy hydrograph with sharp increases in flow after rain events, receding quickly to low base flow levels. The Cuito exhibits a smoother rise and fall, more characteristic of large monsoonal systems, because of the combined effects of wet-season storage of floodwaters in the floodplains and their drainage back into the river in the dry season. The Okavango River system as a whole is a floodplain-driven system, with floodplains throughout but most prominently on the Cuito in Angola, on the Okavango along the Angola/Namibia border, and in the Okavango Delta in Botswana. These floodplains sustain the river in the dry season and also store floodwaters that would otherwise increase flooding downstream.

The following summary of predicted flow changes first addresses Sites 1,2,4,5 and 6 (the river sites), and then Sites 7 and 8 (the Delta and outflow sites) where consideration of changes in inundation are more appropriate. Site 3 is excluded because as it happened, none of the chosen developments were upstream of the site that was chosen earlier in the project.

The flow changes are described using key variables that are of great importance for maintenance of the health of the system:

- In the basin upstream of the Delta
    - Mean Annual Runoff (MAR)
    - The flood season parameters: onset, peak, volume and duration
    - Dry season parameters – onset and duration, especially extended duration, and minimum flow.
- In the Delta
    - Frequency and extents of inundation
- In the Thamalakane/Boteti system downstream of the Delta:
    - presence or absence of water (wet river bed or disconnected pools or dry river bed).

5.2.1 Sites 1,2,4,5 and 6: the river sites

Table 5-2 summarises how, according to the scenarios, each of the variables along the river would change. The overall trend would be for run-of-river abstractions to reduce flows throughout the year, with the effect being particularly noticeable in the dry season. Dry-season flows would tend to be lower, start earlier and last longer than PD, with the effect greatest at Sites 1, 5 and 6. Flood volumes would become progressively smaller, the flood season progressively shorter and its onset a little later. Again, Sites 1, 5 and 6 would show the greatest impact. Flood peaks would not be reduced significantly and there would not be a marked transfer of water from the flood season to the dry season, as with many developed basins, because there would not be enough dams with sufficient storage to effect this.

TABLE 5-2: MEDIAN VALUES OF THE ECOLOGICALLY-RELEVANT SUMMARY STATISTICS FOR EACH SCENARIO FOR RELEVANT RIVER SITES.

A) MEAN ANNUAL RUNOFF (MCM)

Site	PD	Low	Medium	High	Comment
1	22	14	14	13	All Scenarios similar and about 64% lower than PD
2	166	155	140	128	Gradual decline to 93%, 85%, 77% of PD
4	164	152	140	129	Progressive decline to 93%, 85%, 79% of PD
5/6	270	261	245	186	Progressive decline: 97%, 91%, 69% of PD

B) DRY SEASON ONSET

Site	PD	Low	Medium	High	Comment
1	Aug	May	May	May	All Scenarios similar and 11 weeks earlier than PD
2	July	July	July	July	All Scenarios similar. Onset 2-3 weeks earlier than PD
4	July	July	July	July	Approximately same throughout
5/6	Aug	July	July	June	Progressively earlier than PD by 1, 3, and 7 weeks

C) DRY SEASON DURATION (DAYS)

Site	PD	Low	Medium	High	Comment
1	86	212	212	213	All Scenarios similar and approx 18 weeks longer than PD
2	96	124	143	152	Progressively longer than PD by 4, 7 and 8 weeks
4	135	150	168	176	Progressively longer than PD by 2, 5 and 6 weeks
5/6	115	130	145	193	Progressively longer than PD by 2, 4 and11 weeks

D) DRY SEASON MINIMUM FLOW (M3S-1)

Site	PD	Low	Medium	High	Comment
1	12	0.4	0.3	0.3	All Scenarios similar. Drastic drop from PD
2	32	16	12	24	Minimum Q drops to 50% (L), 38% (M) of PD and then under H increases to 75% because of dam releases in dry season
4	35	20	15	19	Decline through L and M to 43% of PD then increase for H to 54%
5/6	114	101	93	21	Progressive decline from PD to very large drop for H: 89%, 82%, 18%

E) FLOOD SEASON ONSET

IFA Site	PD	Low	Medium	High	Comment
1	Dec	Jan	Jan	Jan	All Scenarios similar: delay by about 7 weeks compared to PD
2	Jan	Jan	Jan	Jan	Progressive delay from PD by 2-3 weeks
4	Jan	Jan	Jan	Feb	Slight delay by about 2 weeks from PD in H
5/6	Jan	Jan	Jan	Feb	Slight delay by 1 weeks (M) and 2 weeks (H)

F) FLOOD SEASON PEAK (M3S-1)

IFA Site	PD	Low	Medium	High	Comment
1	38	35	35	35	All Scenarios similar with slightly smaller peak than PD
2	429	430	429	401	Peak not affected until (H), when drops to 93% of PD
4	452	446	453	433	Medium about same as PD; L slightly lower at 99% and H at 96% of PD
5/6	620	618	611	573	Progressive very slight decline: 99%, 98, 92% of PD

G) FLOOD SEASON VOLUME (MCM)

IFA Site	PD	Low	Medium	High	Comment
1	456	231	231	230	All Scenarios similar and half of PD
2	3713	3558	3178	2531	Progressive decline to 96%, 86%, 68% of PD
4	3694	3535	3209	2580	Progressive decline to 96%, 87%, 70% of PD
5/6	5269	4980	4450	3294	Progressive decline to 96%, 84%, 63% of PD

H) FLOOD SEASON DURATION (DAYS)

IFA Site	PD	Low	Medium	High	Comment
1	197	97	97	97	All Scenarios similar and approximately 14 weeks shorter than PD
2	148	135	123	111	Progressive shortening of flood season: 2, 3, 5 weeks less than PD
4	154	147	130	117	Progressive shortening of flood season: 1, 4, 6 weeks less than PD
5/6	150	143	129	103	Progressive shortening of flood season: 1, 3, 7 weeks less than PD

PD = Present Day; L = Low Scenario; M = Medium Scenario; H = High Scenario

The statistics can be re-arranged to show the combined effects for any one section of the river, such as for Kapako/panhandle. This section of the river flows between Angola and Namibia and into the top end of the Delta. This part of the system would be significantly impacted by water resources development because it is downstream of almost all of the potential infrastructure (Table 5-1). Its MAR could potentially reduce to 69% of PD; the dry season could start up to seven weeks earlier and last 11 weeks longer with a minimum flow that could be only 18% of PD; its flood season could start a week or two later, and be up to seven weeks shorter with a reduced flood volume of 63% of PD (Table 5-3; Figure 5-2; Figure 5-3).

TABLE 5-3: MEDIAN VALUES FOR THE ECOLOGICALLY-RELEVANT SUMMARY STATISTICS FOR EACH SCENARIO FOR POPA FALLS (SITE 5) AND PANHANDLE (SITE 6).

Flow category	PD	Water-development scenarios			Comment
		Low	Medium	High	
Mean Annual Runoff (Mm^3)	270	261	245	186	Progressive decline: 97%, 91%, 69% of PD
Dry season onset	Aug	July	July	June	Progressively earlier: 1, 3, and 7 weeks earlier than PD
Dry season duration (days)	115	130	145	193	Progressively longer dry season: 2, 4,11 weeks more than PD
Dry season minimum flow (m^3s^{-1})	114	101	93	21	Progressive decline to very large drop for H: 89%, 82%, 18% of PD
Flood season onset	Jan	Jan	Jan	Feb	Slightly delayed by 1 week (M) and 2 weeks (H)
Flood season peak (m^3s^{-1})	620	618	611	573	Progressive very slight decline: 99%, 98, 92% of PD
Flood season volume (Mm^3)	5269	4980	4450	3294	Progressive decline: 96%, 84%, 63% of PD
Flood season duration (days)	150	143	129	103	Progressive shortening of flood season by 1, 3, 7 weeks

PD = Present Day; L = Low Scenario; M = Medium Scenario; H = High Scenario

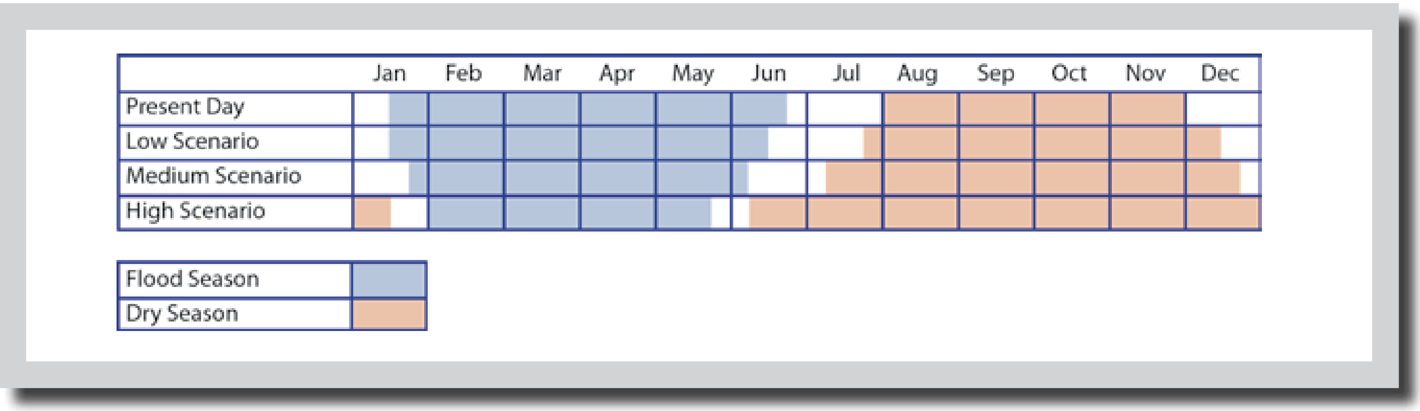


Figure 5-2: Changes in onset and duration of dry and flood seasons at Popa Falls and the panhandle under different scenarios. White areas are times of transitional flow between flood and dry seasons.

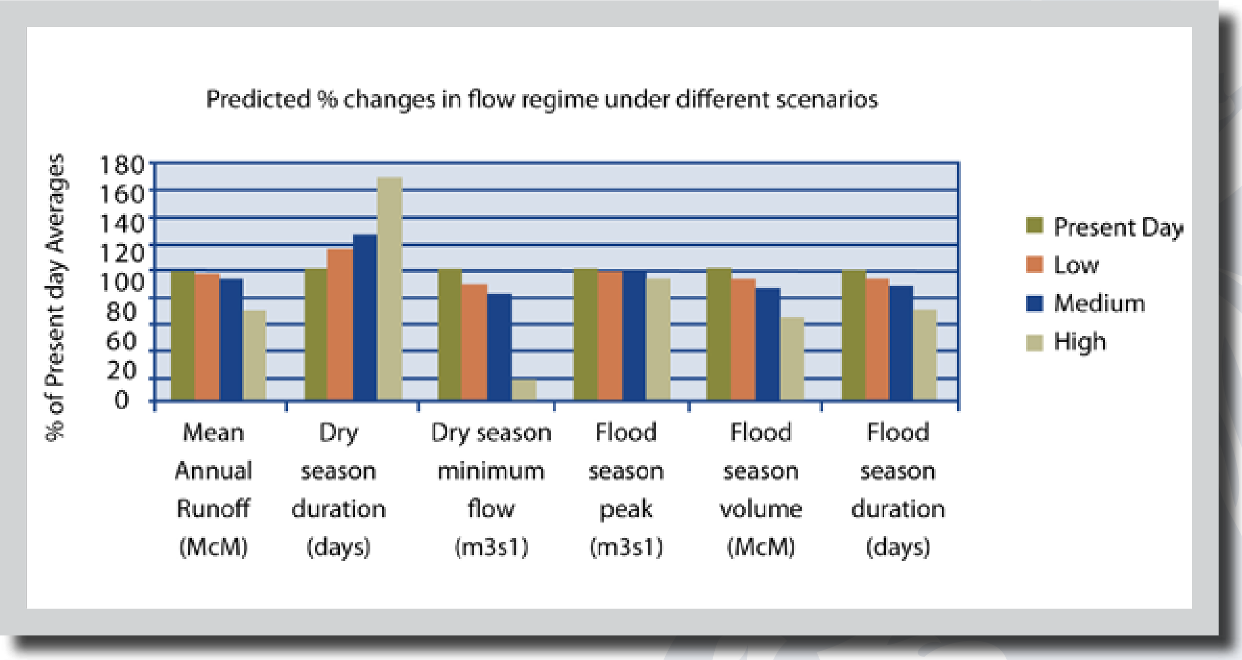


Figure 5-3: Predicted percentage changes in the flow regime at Popa Falls and the panhandle, compared to Present Day under different scenarios

5.2.2 Sites 7 and 8: the Delta and outflow sites

Xakanaxa[1] in the Delta would receive essentially the same amount of water as the panhandle, in the same pattern of flows as described above. This would manifest as changes in inundation patterns in the Delta, with a decrease in all major types of permanent swamp (open channels, lagoons and backswamps) and an increase in seasonal swamps (seasonal pools, sedgeland and grassland) as well as in dry-floodplain savannah.

Hydrological flow sequences are not particularly useful in the analysis of the Okavango Delta and its outflows into the Thamalakane/Boteti system. The extent and frequency of flooding drive the distribution of vegetation types and habitats. For this reason, a semi-conceptual hydraulic model (Wolski *et al.* 2006) was used to generate inundation patterns and vegetation type changes in the Delta, and state changes (wet river bed/disconnected pools/dry river bed) in the Thamalakane and Boteti Rivers.

For all vegetation types, the High Scenario would show a much greater change than the other scenarios, with the various types of permanent swamp decreasing to about 22% of PD average levels and seasonal swamp types increasing to 104 –178% of PD. Savannah ecosystems would show the largest change, increasing by more than four-fold in the High Scenario. These shifts would represent a progressive drying-out of the Delta (Table 5-4; Table 5-5).

Comparison of the Present Day and potential High Development flows in the Delta

- A reduction of mean annual Delta inflows from about 289 m^3s^{-1} (9,100 $Mm^3 a^{-1}$), to about 203 m^3s^{-1} (6,400 $Mm^3 a^{-1}$)
- An 8% (40 m^3s^{-1}) reduction in the median flood season peak flow, and an 81% reduction (93 m^3s^{-1}) in the median dry season minimum flow. The large decrease in dry season flows, and the relatively small decrease in flood flows is due to the predominance of run-of-river abstraction schemes as opposed to storage-(dam) based water supply schemes

The out-flowing Boteti River at Chanoga[2] that normally exhibits dry and wet cycles, each a number of years long, would be similarly affected. There would be a progressive decline in the number of years when it contains water and in the High Scenario it would be completely dry for most of the time, holding water only in the wettest years (Figure 5-4; Figure 5-5).

1 Site 7
2 Site 8

TABLE 5-4: VEGETATION TYPES IN THE DELTA

Abbreviation	Description
CH-ps	Channels in permanent swamp
L-ps	Lagoons in permanent swamp
BS-ps	Backswamp in permanent swamp
SP-sf	Seasonal pools in seasonally flooded zone
Sed-sf	Seasonal sedgeland in seasonally flooded zone
Gr-sf	Seasonal grassland in seasonally flooded zone
S-sf	Savannah-dried floodplain in seasonally flooded areas

TABLE 5-5: MEAN PERCENTAGE OF COVER FOR VEGETATION TYPES IN THE AREA OF THE DELTA REPRESENTED BY SITE 7, FOR SIMULATED PD CONDITIONS, AND FOR THE LOW, MEDIUM AND HIGH SCENARIOS.

Inflow scenarios	CH-ps	L-ps	BS-ps	SP-sf	Sed-sf	Gr-sf	S-sf
	Mean percentage cover						
Present-day	0.49	0.98	47.58	0.89	27.27	16.32	6.47
Low	0.46	0.92	44.62	0.94	27.84	18.08	7.13
Medium	0.43	0.867	41.67	0.98	26.28	21.51	8.29
High	0.11	0.23	11.02	1.18	28.59	29.12	29.74

State changes in the Thamalakane/Boteti system for present-day conditions and the Low, Medium and High water-use scenarios are shown in Figures 5-4 to 5-7.

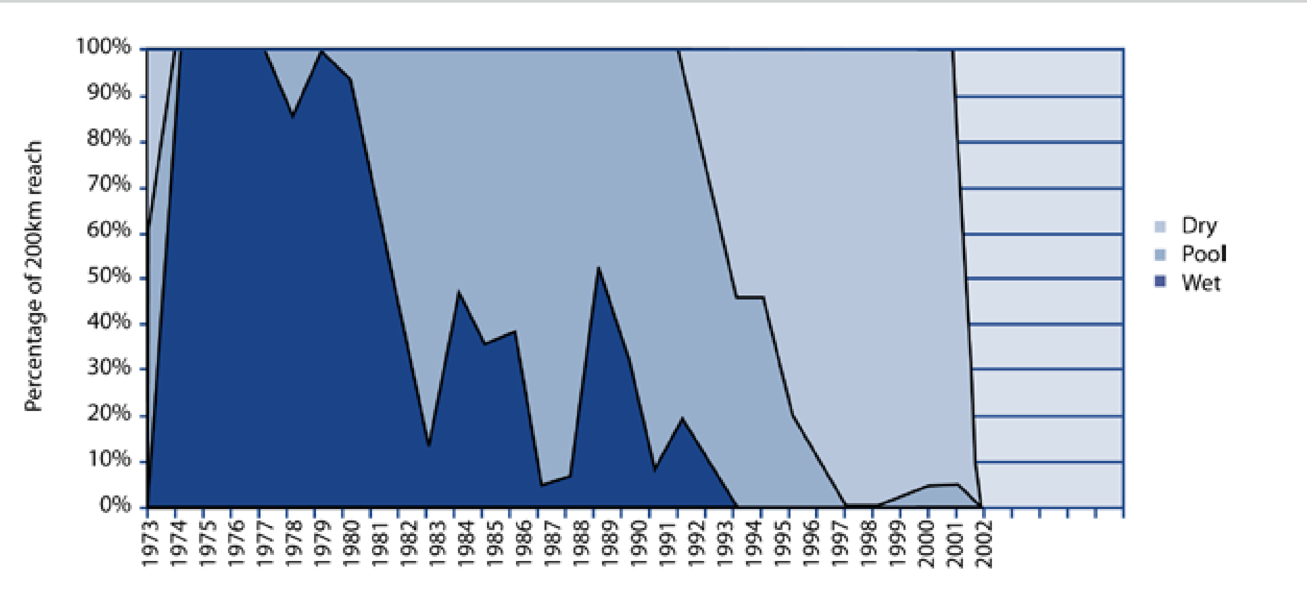


Figure 5-4 : Percentage of the 200-km study reach of the Boteti River that will be inundated (wet); isolated pools (pool) and dry under the present-day simulated conditions given climatic conditions that prevailed from 1973-2002.

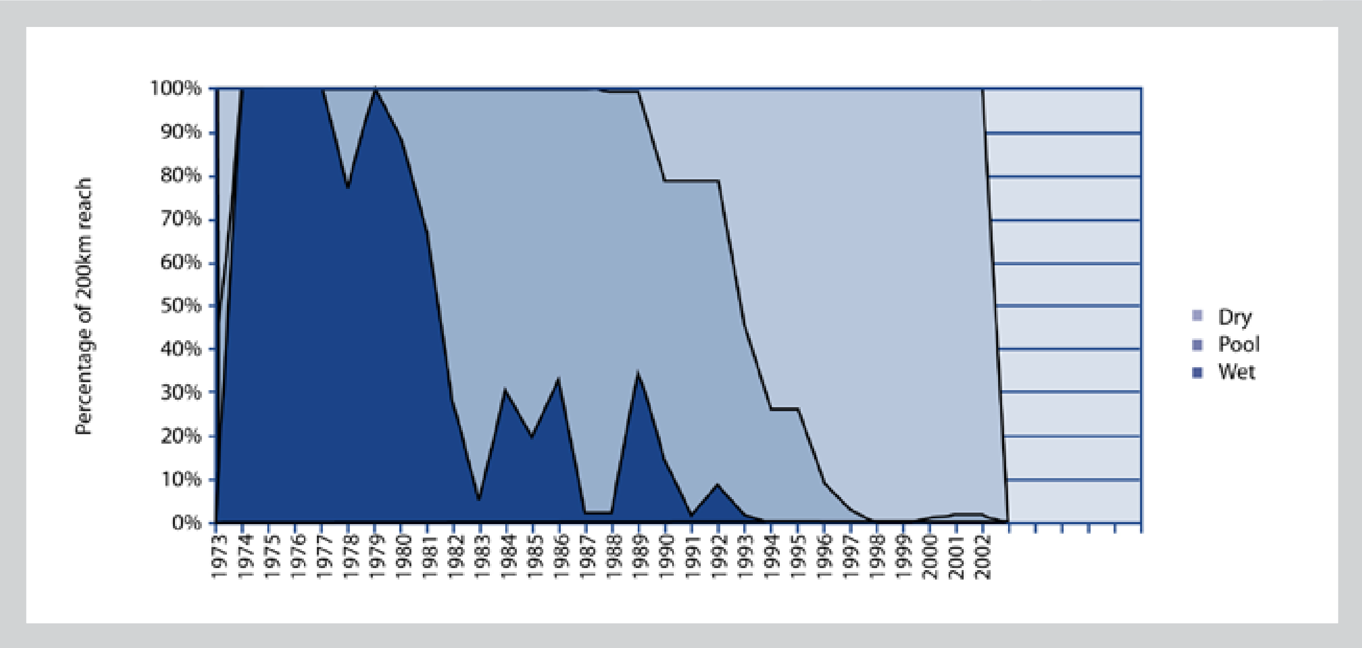


Figure 5-5: Percentage of the Boteti River study reach that will be inundated (wet); isolated pools (pool) and dry under the Low Scenario

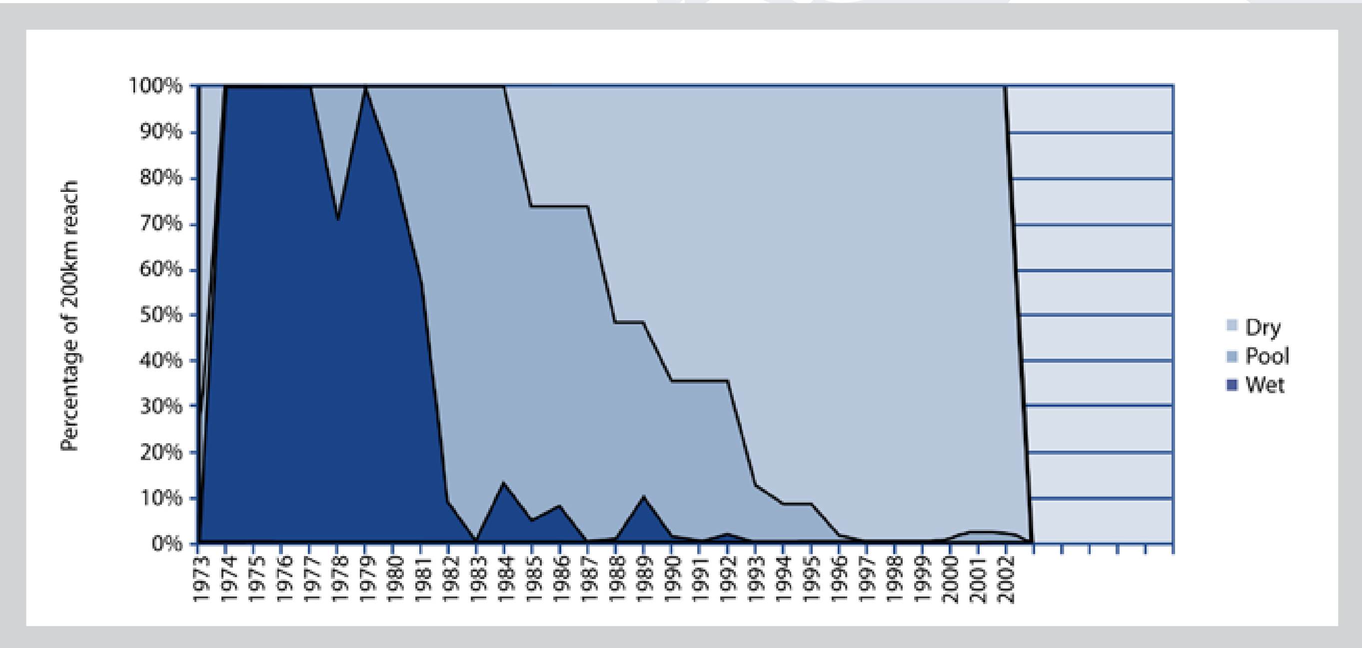


Figure 5-6: Percentage of the Boteti River study reach that will be inundated (wet); isolated pools (pool) and dry under the Medium Scenario

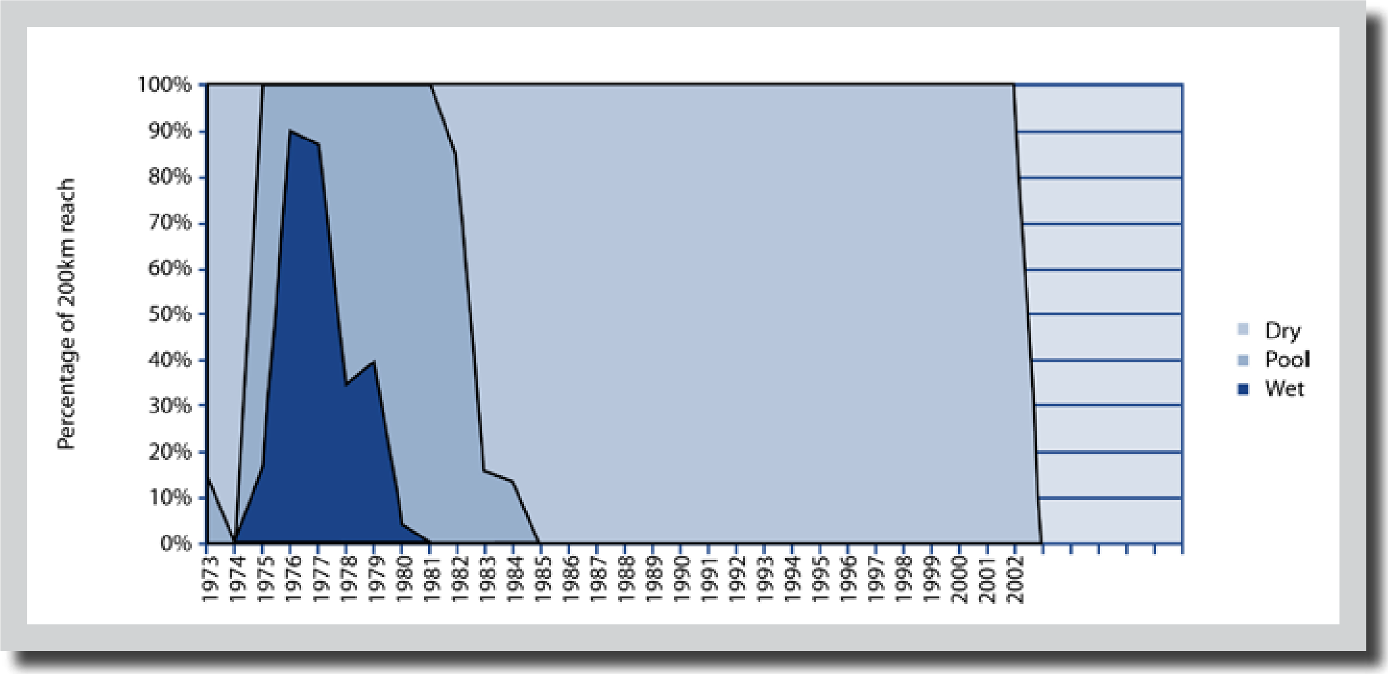


Figure 5-7: Percentage of the Boteti River study reach that will be inundated (wet); isolated pools (pool) and dry under the High Scenario

5.2.3 Conclusion on potential flow changes

The Okavango River system has floodplains that store floodwaters and sustain the river in the dry season. If they were diminished, there would be increased flooding downstream and a significant drying out of the Delta and its outflow due to the weakening of dry-season flows. The Cuito River is key to the functioning of the whole lower river system, because of its strong year-round flow, its wet-season storage of floodwaters on vast floodplains and the gradual release of water back into the river in the dry season. The riverine ecosystems and associated social structures of people along the lower Okavango River, the Okavango Delta and the outflowing Thamalakane and Boteti Rivers are sustained mostly by the annual flow regime of the Cuito. If these areas are of concern at the basin level, then water resources development along the Cuito, or intervention in the functioning of its floodplains, should be modest and undertaken with extreme caution.

The severe impacts on the flow regime predicted for Site 1 (Table 5-2) could be mitigated by opting for a less intrusive series of developments on the Cuebe River. Any development that does take place on this tributary is likely to have impacts that are largely limited to the Angolan part of the basin. The impacts on flow predicted for Sites 5-8 are less easily mitigated as they would result from many developments along the whole system. Increasing the number and nature of the developments, as one moves from the Low to the High Scenario, would inevitably extend the impacts from localised to transboundary. Mitigation could realistically only be addressed by planning and managing at the basin level.

5.3. IMPACTS ON THE RIVER ECOSYSTEM

The above potential flow changes became the input for the Decision Support System (DSS) developed for the project. The DSS then predicted how flow changes would translate into river ecosystem changes and how these river changes would in turn translate into impacts on subsistence users of the system.

5.3.1 The context

International experience has shown that five main attributes of the natural flow regime are important for healthy functioning of river ecosystems:

1 The magnitude of flows
2 Their frequency
3 Their timing
4 Their duration
5 The overall variability of flows on every scale from daily to decadal.

The flow changes described in the last section would impact on all of these aspects of the flow regime and so the river ecosystem would inevitably change. These changes were described using 70 biophysical indicators.[3]

The importance of flow variability

A river ecosystem is much more than a wetted channel. Swamps, deltas, floodplains, marshes, river banks, complex secondary-channel networks and the associated groundwaters play their roles in adding to the river's biodiversity and its ability to support the abundance of plants and animals so valued by humans.

All parts of the river system are sculptured by the 'master' or 'driving' variable, the flow regime, which dictates its overall nature if:

- It is perennial or non-perennial in flow;
- It has winter or summer floods;
- It has pronounced dry and wet seasons;
- It exhibits flashy, short-lived flood flows or has a long, monsoonal flood season; and much more.

The flow regime in turn largely dictates the nature of the sediments, and the chemistry and temperature of the water, at any point along the system. There is a constant interchange of materials, energy and nutrients between the water in the river, its banks and its bed: sediments are continuously transported, sorted by size, re-sorted, eroded and deposited by the daily, yearly and decadal variations in flow, giving rise to permanent and semi-permanent river-channel features such as pools, rapids, ox-bow lakes, sandbars and floodplains.

This dynamic, ever-changing environment creates the physical template upon which the river's plants and animals live their lives. Species respond to day-to-day changes in flow conditions, with each river's mix of plant and animal species having evolved over millennia to live in synchrony with its unique short and long-term cyclical flow patterns. Plant species have evolved to flower and fruit at specific times of the annual flow cycle; fish time their spawning to coincide with the optimal flow and temperature conditions for their young to survive; insects emerge from the water to mate and release their eggs at specific times of the year when air temperatures, food and other conditions are optimal; and great herds of large mammals move onto floodplains as floods recede, each species dependent on a different band of vegetation with a different inundation history.

Some species thrive in drier years and others in wetter years, and so the balance of species is maintained with none dominating but rather the mix of species changing from year to year. This is the process that controls pest animals and plants, which are natural parts of ecosystems but normally in a healthy system are held in low numbers due to competition from other species. Reductions in the natural variability of flows, and changes in the timing of different flows disrupt these life cycles and reduce diversity, abundance and resilience of the ecosystem.

Information from King J and C Brown. (In press). Inland water ecosystems. in *Water Resources, Planning and Management: Challenges and Solution*. Cambridge University Press.

The indicators covered the major parts of the ecosystem:

- Channel form
- Water quality
- Vegetation
- Aquatic invertebrates
- Fish
- River-dependent terrestrial wildlife
- Water birds.

Their present status and predicted changes at each site under each scenario are described in the four volumes of Report 07 of the Environmental Flows series of reports and summarised in Table 5-6.

Combining all parts of the ecosystem mentioned in this table, the overall picture of predicted change was depicted in two ways: overall ecosystem health and status of river zones.

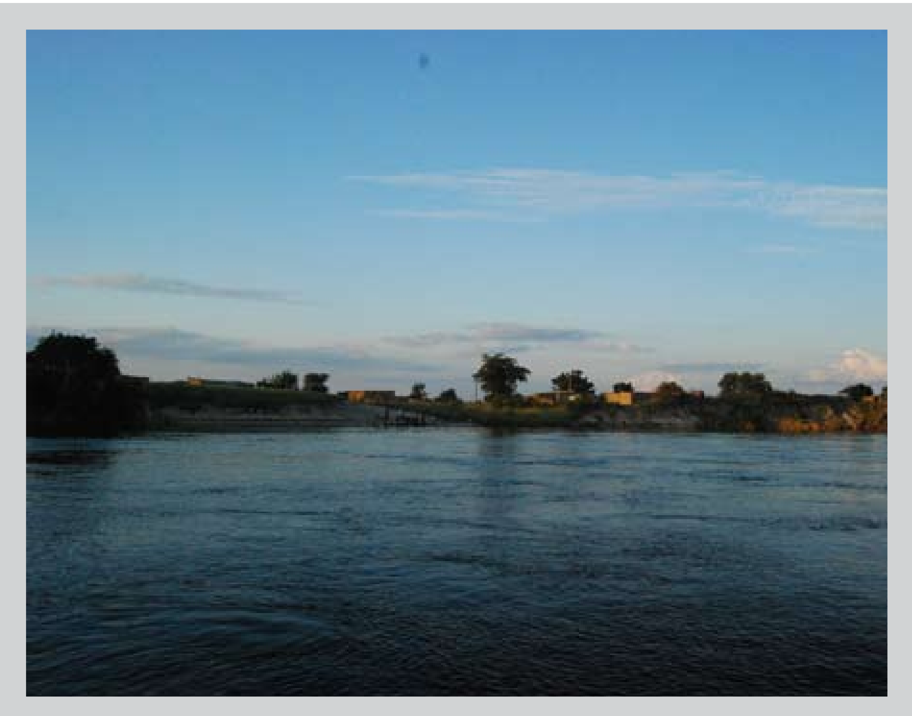
3 Table 3.1 in Report 07 in the EFI Report Series

5.3.2 Overall ecosystem health

This is a measure of the extent to which the river system is functioning in a close-to-natural way. Several countries use a scoring system from A to F to signify the health of the system, where A is a natural, unmodified system and F is a critically modified system that has essentially lost all its natural attributes and has little value for people. A general aim among countries using such a system could be to not let any rivers fall below a D category and to keep those of conservation value at a B or high C. The Okavango River system was estimated in 2008 to be at a level B throughout, which translates as: 'Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged'.

Cuito Cuanavale, Angola

The DSS predicted how the overall health of the system could change under the three scenarios. In the ecosystem health plot (Figure 5-6) the eight sites are shown along the horizontal axis and the value for health (integrity) is shown along the vertical axis. The fuzzy horizontal lines indicate the approximate health values where the ecosystem moves from one class to the next. The fuzzy blue line, for instance, shows that ecosystem health drops from a B to a C at an integrity value of about -0.5. Present-day health is rated at 0, and the thin black line indicates that all sites are presently sitting above the B to C transition, i.e. in a B condition.



Rundu, Namibia

TABLE 5-6: SUMMARY OF PREDICTIONS OF ECOSYSTEM CHANGE UNDER THE THREE DEVELOPMENT SCENARIOS

Ecosystem component	Predicted change
Channel	There would be a trend towards stabilisation and narrowing of the main channels, possibly accompanied by a deepening of the channel and thus some drying out of the floodplains. Lack of data on sediment dynamics of the system means that predicted changes could have been seriously underestimated.
Water quality	The water quality of the Okavango system is good, and in the Low and Medium Scenarios all indicators should remain largely within their natural range of variability. Most indicators would noticeably move away from PD values with the High Scenario, particularly from Kapako downstream. Only flow-related developmental changes were addressed, and water-use developments could cause additional water-quality changes as described in Section 4.2.
Vegetation	Aquatic and semi-aquatic vegetation would be negatively affected at Capico, Mucundi, Popa Falls, the panhandle and in the Boteti at Chanoga4, where abstraction would seriously reduce low flows, particularly in the dry season. Riparian trees and shrubs would be less affected, but once impacted would take a long time to recover, if recovery was in fact possible. In some parts of the system, floodplain grasses would increase in area because of general drying out of the system.
Aquatic invertebrates	With the exception of Capico, the Low and Medium Scenarios are expected to have a low to negligible impact. The High Scenario could cause significant declines in some indicators, mostly at Popa Falls, the panhandle, Xakanaxa and in the Boteti at Chanoga, whilst inhabitants of woodland pools would increase several fold in the Delta as *mopane* woodlands expand.
Fish	At Capico in the Cuebe, fish losses are expected to be high for all three scenarios because of run-of-river abstraction during the low-flow season. Elsewhere the fish assemblages are expected to cope fairly well with the Low Scenario, and slightly less well with the Medium Scenario. Under the High Scenario, fish in the lower part of the catchment, e.g., Kapako, Popa Falls, the panhandle, Xakanaxa and in the Boteti at Chanoga5 would be severely and negatively impacted, and local extinctions would be highly likely, particularly from Popa Falls downstream to the Boteti.
Wildlife	The present abundance of wildlife would decline progressively through the scenarios, with the High Scenario having a severe impact. Some species at some sites could permanently decline to as low as 5% of PD values. The notable exception to this is the Delta, where one group of wildlife – the large herbivores – would benefit from the scenarios as permanent swamps give way to seasonal floodplains, but even they may show an eventual decline as wetlands give way to savannah.
Water Birds	Moderate declines in abundance of some bird groups could occur at Capico, Mucundi, Kapako, The panhandle and at Chanoga6, especially under the High Scenario, with some local extinctions. At Xakanaxa, conversely, there would be mild to moderate increases in several indicators as open water and permanent swamp give way to seasonal grass and sedge lands. Birds are highly mobile and soon arrive when conditions become favourable or leave when they are unfavourable. This implies that there are other areas for them to arrive from or depart to. Development in the Okavango Basin, however, will probably be mirrored by that in other nearby basins such as that of the Zambezi River, and it cannot be assumed that there will always be suitable habitat elsewhere. The Okavango River is a vital part of the southern African mosaic of wetlands that supports both resident and migrant birds, and would need to maintain that status to ensure their long-term viability.

PD = Present Day. L = Low scenario, M = Medium Scenario, H = High Scenario

4 Sites 1, 2, 5, 6 and 8
5 Sites 4, 5, 6, 7 and 8
6 Sites 1, 2, 4, 6 and 8

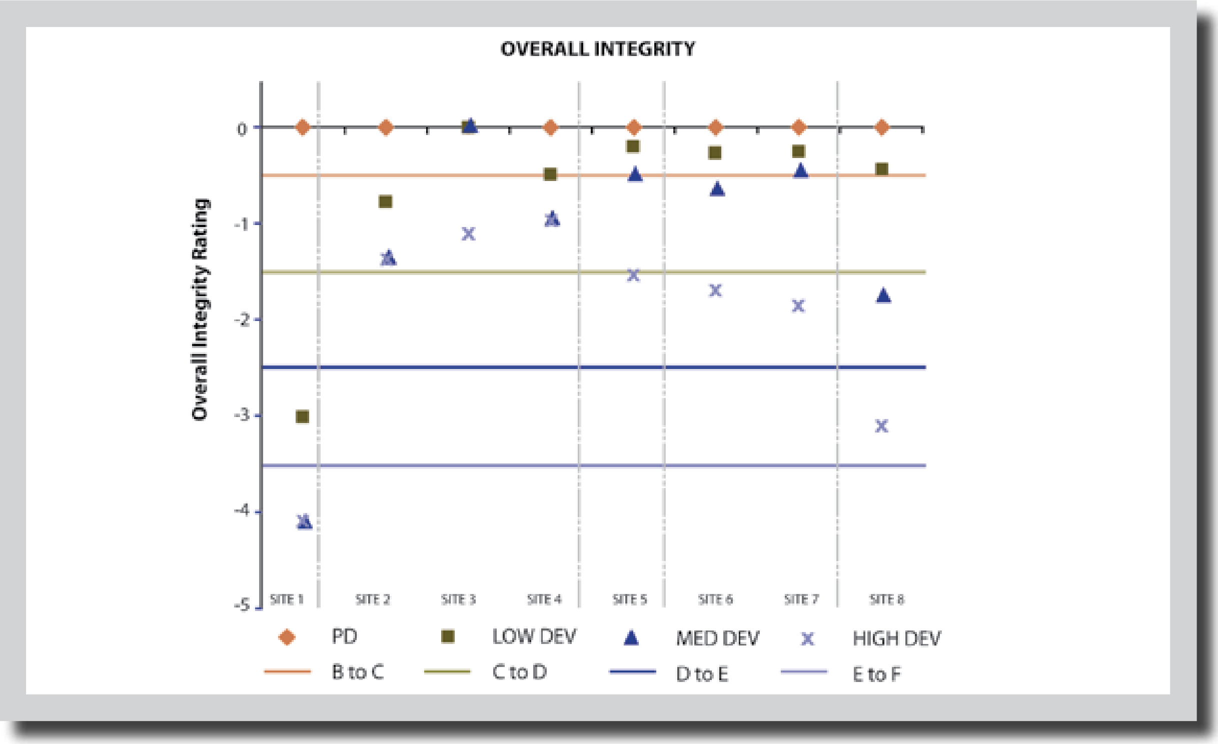


Figure 5-8: Overall ecosystem health for the three scenarios at each of the study sites, showing the health (integrity) value of each site under each development scenario and the approximate transitions of shifts to lower health classes

It was predicted (Figure 5-8) that with the water resources developments encompassed in the three scenarios, ecosystem health would decline, that is, no sites would improve to an A. This is why only negative integrity values are shown on the plot. The overall picture is that:

1. There would be no change at Site 3, because it was upstream of the proposed developments.
2. Site 1 (Capico) would be heavily impacted by all scenarios, dropping to an E condition, mainly because of the loss of dry-season flows.
3. The remaining sites (2,4,5,6,7,8) would show a mild loss of health under the Low Scenario, mostly remaining in a (slightly lower) B or upper C condition.
4. The same sites would show a moderate loss of health under the Medium Scenario, declining to a C condition and, for Site 8, to an upper D.
5. The same sites would show a severe decline in health under the High Scenario, dropping to a D condition, and, for Site 8, to an E.
6. Ecosystem health would generally decline with distance downstream, under all scenarios.

5.3.3 Status of river zones

The impacts predicted for the representative sites can be translated to expected impacts over the whole river network. In the basin graphic of ecosystem health (Figure 5-9) rivers depicted in black had no representative sites and so were not included in the assessment. Those coloured blue were predicted to retain their present-day B status, while the remainder declined to a C (green), D (orange) or E (red). The sections most under threat are shown with red flags, because they would be unable to sustain present beneficial uses of the system.

If the developments listed in Table 5-1 were to be constructed with their assumed design and operating rules then three main predicted trends are clear.

1. A progressive decline in condition of the river ecosystem would occur from the Low to High Scenarios, with the High Scenario rendering large parts of the system unable to sustain present beneficial uses and causing significant drying out of the Delta.
2. A severe impact in an upper-basin tributary would be localised around Capico (Low Scenario) until it, together with further downstream developments, triggered a widespread decline in the middle reaches to condition C (Medium Scenario).
3. Transboundary impacts would be felt first and most severely in the Delta and its outflow.

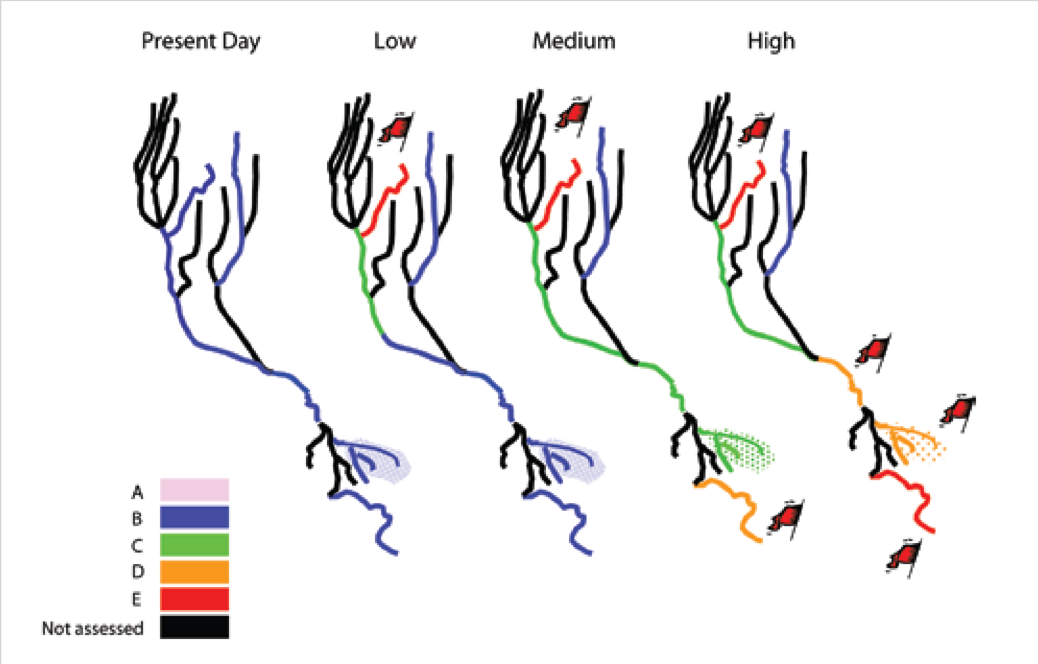


Figure 5-9: Summary of expected changes in ecosystem health for the Low, Medium and High scenarios.

All the predicted impacts are likely to have been underestimated because they do not include the localised impacts of construction such as water pollution. It is clear that the level of development represented by the High Scenario would have a significant impact on this river system and severely reduce the services it presently provides.

5.4. SOCIO-ECONOMIC IMPLICATIONS[7]

5.4.1 Short-term livelihood implications of developing water resources

Many of the changes in the river ecosystem described above translate into impacts on the livelihoods and welfare of the basin's people and on national economies. As a first statement of these impacts, the ecosystem changes were applied to enterprise models that measure private net incomes (livelihoods) and economic national income (economic contribution).

At the basin level, the livelihoods value would drop from the PD estimate of US$ 60 million per year, to less than US$ 10 million per year for both the Medium and High water-use scenarios (Figure 5-10).

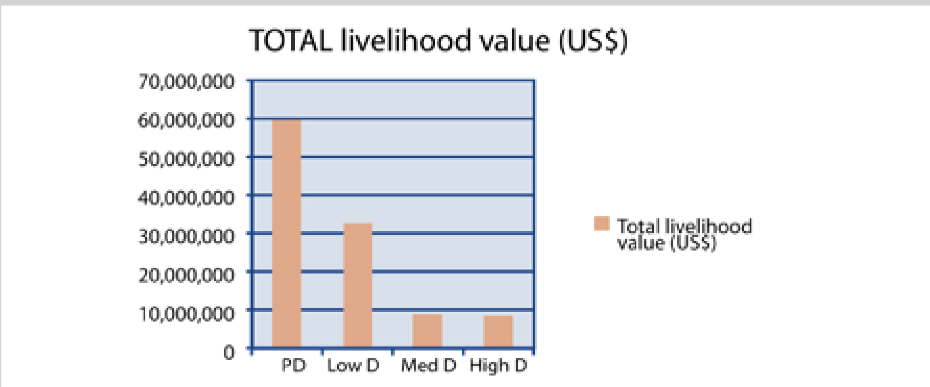


Figure 5-10: The short-term implications of water-use scenarios for livelihoods in the Okavango River Basin. Present Day (PD), Low development (Low D), Medium development (Med D) and High development (High D) (US$, 2008)

7 Full details of this section can be found in Barnes et al. (2009)

These predicted changes can be scaled up to economic national incomes as shown in Figure 5-9, combined for the basin as a whole. Direct economic contribution to the national income provides a better measure than household net income of the real impact on socio-economic welfare. [8] This variable shows a decline from US$ 100 million per year to less than US$ 10 million per year for the Medium and High development scenarios.

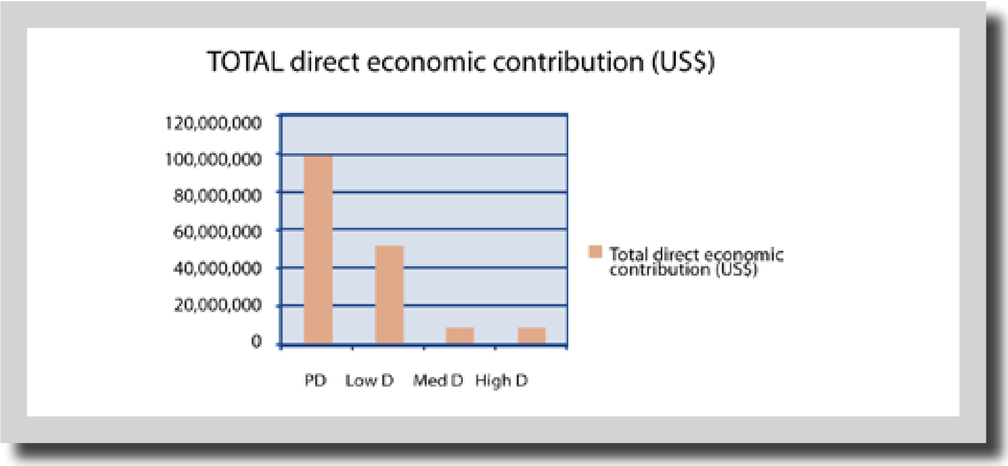


Figure 5-11: The short-term implications of water-use scenarios for direct economic income in the Okavango River Basin. Present day (PD), Low development (Low D), Medium development (Med D) and High development (High D) (US$, 2008)

The significant declines in both these indicators through the water-use scenarios are primarily linked to declines in tourism. Both the economic model and the tour operators in Botswana predicted that tourism in the Delta would follow a short-term response, with turnover dropping by about 15% as the flooding regime of the Delta changed (Figure 5-12). Flooding levels that are both higher and lower than natural would result in a marked reduction in tourist numbers. Relatively small, sustained reductions in tourism demand would severely reduce livelihood values and economic contributions to national incomes.

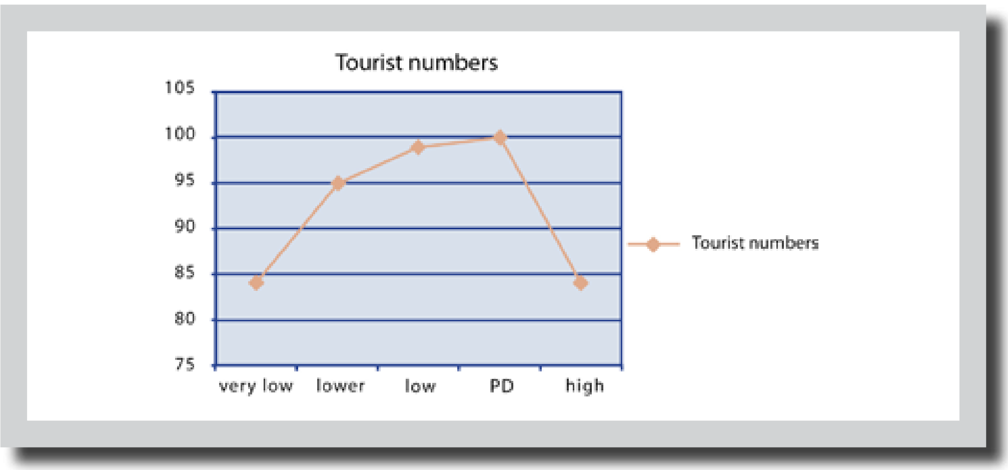


Figure 5-12: Response of tourist numbers as a percentage of present day (PD) to four changes to average Delta flooding levels, as predicted by tourism operators in Botswana. PD = 100%

8 Direct contribution is a comprehensive measure that includes the basin household net income, as well as the income to other basin investors, and stakeholders.

5.4.2 Longer-term economic implications of developing water resources

People and societies adapt to change, although with high levels of poverty and vulnerability adaptation can be both risky and costly if indeed it is possible. When the predicted changes in natural resources were modelled over a longer, 40 year period with possible adaptations included, then the overall impacts of the scenarios that emerge are probably more realistic. These impacts are detailed below, by country.

Angola

It is predicted that increasing water use would reduce the direct income derived from the river's natural resource use by about 40% (Table 5-7). The effect is the same for all natural resources used by rural households as this makes up nearly all of the income generated.

The effect would not differ much between the three levels of water use (Figure 5-13). The value of fish would be affected most, with about 60% of income lost in each scenario. The other main river wetland resources used – reeds and floodplain grass – would lose about 30% of their value.

Assumptions for longer term economic analysis

For each level of water use, using the immediate impacts as a base, 40-year discounted streams of expected future direct income were generated. These included expected future growth in population numbers and tourism and expected long-term adaptations where relevant. Population growth was assumed to be 1.5% per annum in Botswana and Namibia, and 2.7% in Angola. Tourism growth was anticipated to be 5% per annum on average in all scenarios. Where tourism was found to collapse as a result of drying out the lower Okavango, its output was assumed to settle at different levels for each scenario (25%, 10%, and 5% of present-day values). These levels were thought to be more or less consistent with what one might expect in comparable savannah areas, e.g., Hwange National Park. Carrying capacity limits to growth for certain activities were also assumed (+75% of starting output in the case of tourism, and +100% of starting output in the case of fishing). The adaptation assumptions were subjective, while assumptions on growth in tourism demand and populations were more analytical.

TABLE 5-7: EFFECT OF LOW, MEDIUM AND HIGH LEVELS OF WATER USE ON THE 40-YEAR NET PRESENT VALUES (NPVs) ATTRIBUTABLE TO RIVER/FLOODPLAIN NATURAL RESOURCE USE IN THE ANGOLAN OKAVANGO RIVER BASIN

ANGOLA	Present day	Low Development	Med Development	High Development
Net present value @ 4%	**(US$, 2008)**			
Tourism sector	5,866,500	5,866,500	5,866,500	5,866,500
Rural household sector	141,051,200	78,159,800	74,992,500	76,790,800
TOTAL resource use	**146,917,700**	**84,026,300**	**80,859,000**	**82,657,300**
• Fish use	75,322,900	30,267,600	27,270,600	27,128,300
• Floodplain reeds use	17,229,100	12,073,000	12,057,800	12,105,700
• Floodplain grass use	40,893,300	28,213,300	28,058,200	29,950,800
• Floodplain gardens	457,800	457,800	457,800	457,800
• Floodplain grazing	1,281,700	1,281,700	1,281,700	1,281,700
• Tourism wages	5,866,500	5,866,500	5,866,500	5,866,500
Losses from present day				
Tourism sector		0	0	0
Rural household sector		62,891,300	66,058,600	64,260,400
TOTAL resource use		**62,891,300**	**66,058,600**	**64,260,400**
• Fish use		45,055,300	48,052,300	48,194,600
• Floodplain reeds use		5,156,000	5,171,300	5,123,300
• Floodplain grass use		12,680,000	12,835,100	10,942,500
• Floodplain gardens		0	0	0
• Floodplain grazing		0	0	0
• Tourism wages		0	0	0

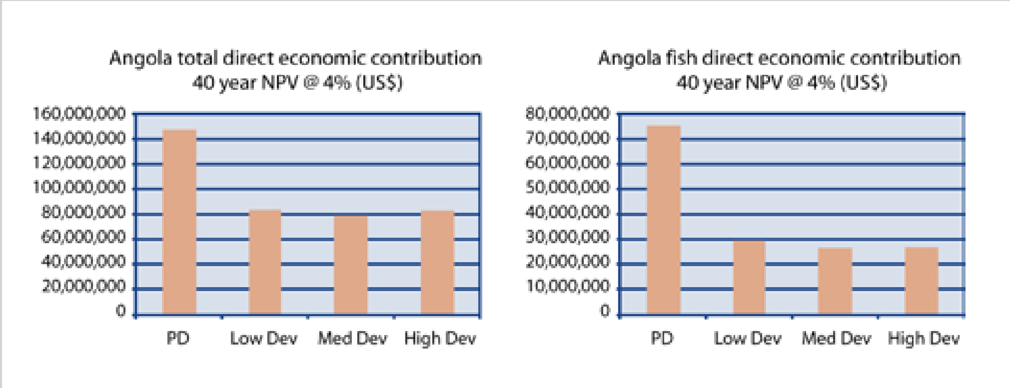


Figure 5-13: Effect on direct economic contribution of all river/wetland natural resource uses in the Cubango River Basin with increasing water use

(Present day (PD), Low development (Low Dev), Medium development (Med Dev) and High development (High Dev) water-use scenarios)

Namibia

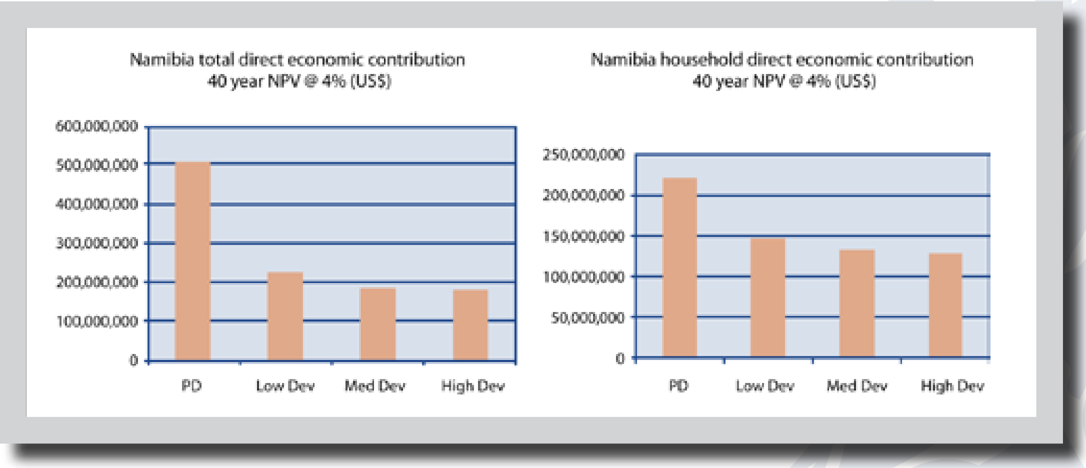
It is predicted that increasing water use would reduce the direct income derived from the river's natural resource use by about 60% – more than in Angola (Table 5-8). As the present-day values for Namibia are much higher than those for Angola, the losses would be even more significant.

TABLE 5-8: EFFECT OF LOW, MEDIUM AND HIGH LEVELS OF WATER USE ON THE 40-YEAR NET PRESENT VALUES (NPVs) ATTRIBUTABLE TO RIVER/FLOODPLAIN NATURAL RESOURCE USE IN THE NAMIBIAN OKAVANGO RIVER BASIN

NAMIBIA	Present Day	Low Development	Med Development	High Development
Net present value @ 4%	**(US$, 2008)**			
Tourism sector	286,183,100	79,677,200	50,273,800	49,576,500
Rural household sector	224,152,200	148,255,900	133,053,600	129,614,200
TOTAL resource use	**510,335,300**	**227,933,200**	**183,327,400**	**179,190,700**
• Fish use	42,983,600	38,501,600	36,319,100	34,586,900
• Floodplain reeds use	13,972,500	15,727,700	15,370,100	15,408,900
• Floodplain grass use	44,950,300	50,590,400	49,446,400	48,832,500
• Floodplain gardens	4,574,000	5,013,300	4,997,200	4,905,800
• Floodplain grazing	6,774,200	7,547,400	7,439,400	6,668,900
• Tourism wages	110,897,600	30,875,400	19,481,400	19,211,200
Losses from Present Day				
Tourism sector		206,505,900	235,909,300	236,606,600
Rural household sector		75,896,300	91,098,600	94,538,000
TOTAL resource use		**282,402,100**	**327,007,900**	**331,144,600**
• Fish use		4,482,000	6,664,500	8,396,600
• Floodplain reeds use		(1,755,200)	(1,397,600)	(1,436,400)
• Floodplain grass use		(5,640,200)	(4,496,100)	(3,882,200)
• Floodplain gardens		(439,300)	(423,100)	(331,800)
• Floodplain grazing		(773,200)	(665,200)	105,300
• Tourism wages		80,022,200	91,416,200	91,686,400

The Low Scenario would have a slightly lower impact than the others at around 40% and the Medium and High Scenarios would have much the same impact (Figure 5-14). The highest impact would be on tourism income, a reduction of about 75%. Household income from reeds, floodplain grass, crops and grazing would be likely to rise by about 10% as permanent swamp areas transform into seasonal swamps with increasing off-channel use of the water. The amounts involved with such wetland resources are relatively small, however, and the overwhelming impact would be the reduction in tourism income.

A) DIRECT ECONOMIC CONTRIBUTION B) HOUSEHOLD



C) TOURISM D) GRASS

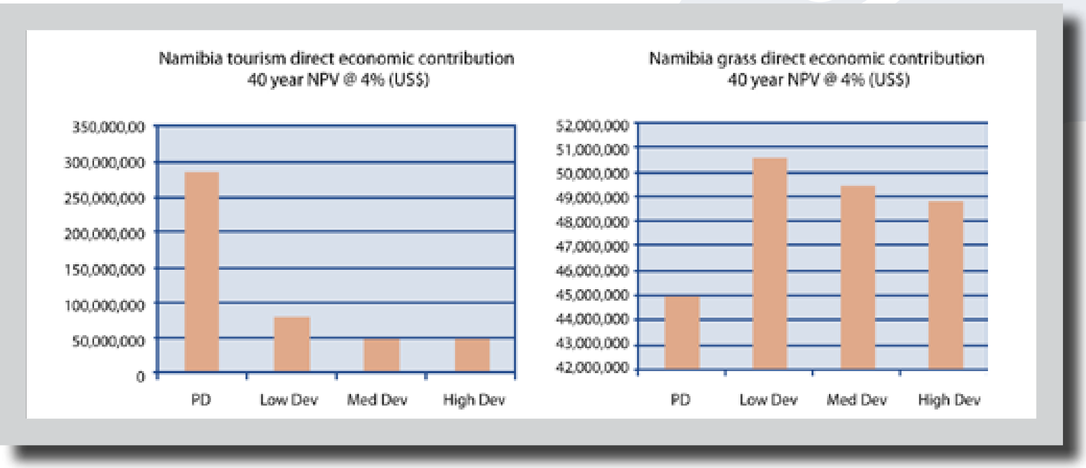


Figure 5-14: Effect on direct economic contribution of all river/wetland natural resource uses in the Namibian Okavango river basin with increasing water use

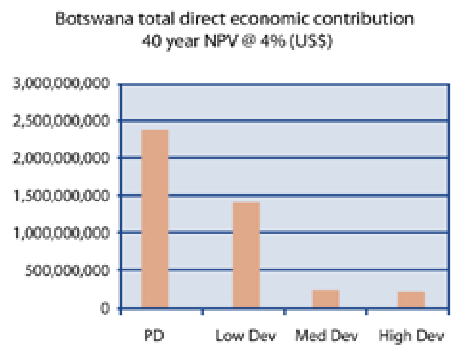
Botswana

It is predicted that increasing water use would reduce the direct income derived from tourism by about 40% in the Low Scenario rising to a 90% loss for the Medium and High Scenarios (Table 5-9). The effect would be similar for all income generated, whether by households, tourism sector activities or both (Figure 5-15). The losses would be much more significant for Botswana than for the other countries as the present-day income from the river system is higher there than in Namibia and very much higher than in Angola.

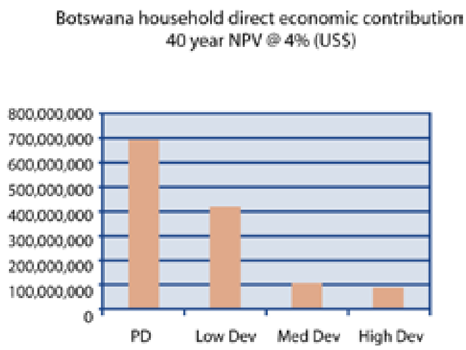
TABLE 5-9: EFFECT OF LOW, MEDIUM AND HIGH LEVELS OF WATER USE ON THE 40-YEAR NET PRESENT VALUES (NPVs) ATTRIBUTABLE TO RIVER/FLOODPLAIN NATURAL RESOURCE USE IN THE BOTSWANA OKAVANGO RIVER BASIN

BOTSWANA	Present Day	Low Development	Med Development	High Development
Net present value @ 4%	**(US$, 2008)**			
Tourism sector	1,697,546,600	1,003,678,900	142,964,400	150,898,600
Rural household sector	692,364,700	420,525,700	108,017,900	89,311,000
TOTAL resource use	**2,389,911,300**	**1,424,204,700**	**250,982,300**	**240,209,600**
• Fish use	7,598,700	6,679,500	5,475,900	2,822,200
• Floodplain reeds use	8,520,900	8,584,600	8,794,100	8,733,500
• Floodplain grass use	14,058,000	14,153,100	14,448,700	14,149,500
• Floodplain gardens	1,681,000	1,891,200	1,823,200	2,035,600
• Floodplain grazing	2,696,700	285,900	143,800	3,096,100
• Tourism wages	657,809,300	388,931,500	77,332,400	58,474,100
Losses from Present Day				
Tourism sector		693,867,700	1,554,582,200	1,546,648,100
Rural household sector		271,838,900	584,346,700	603,053,700
TOTAL resource use		**965,706,600**	**2,138,929,000**	**2,149,701,700**
• Fish use		919,200	2,122,800	4,776,500
• Floodplain reeds use		(63,700)	(273,100)	(212,600)
• Floodplain grass use		(95,000)	(390,600)	(91,500)
• Floodplain gardens		(210,100)	(142,200)	(354,600)
• Floodplain grazing		2,410,800	2,552,900	(399,400)
• Tourism wages		268,877,800	580,476,900	599,335,200

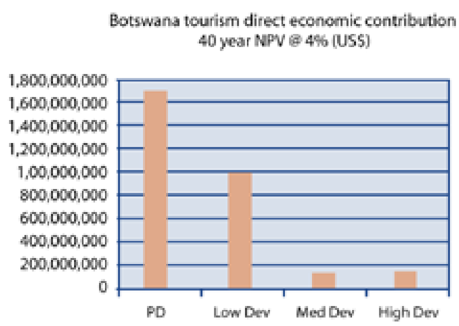
A) TOTAL DIRECT ECONOMIC CONTRIBUTION



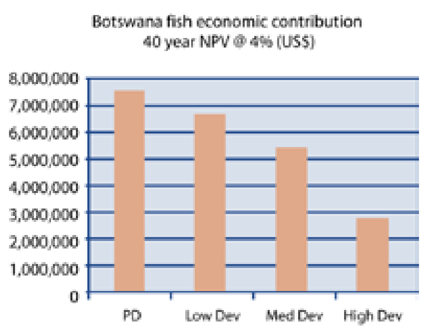
B) HOUSEHOLDS



C) TOURISM



D) FISH



E) GRASS F) GRAZING

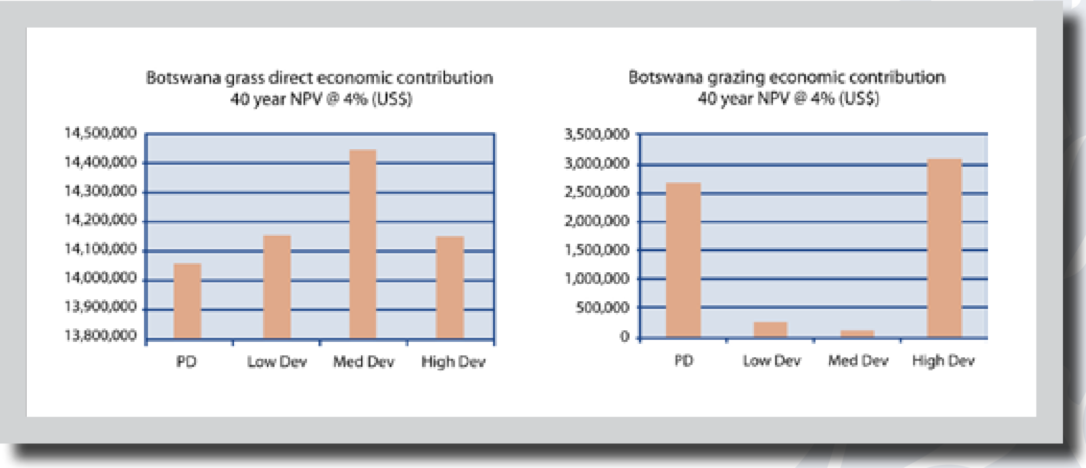


Figure 5-15: Effect on direct economic contribution of all river/wetland natural resource use in the Botswana Okavango River Basin with increasing water use

(Present day (PD), Low development (Low Dev), Medium development (Med Dev) and High development (High Dev) water-use scenarios)

The whole Okavango Basin

For the Okavango Basin as a whole income losses in Botswana dominate the picture (Table 5-10). The negative impacts of the Low Scenario would be moderate, but those of the Medium and High Scenarios would be very significant (Figure 5-16).

TABLE 5-10: EFFECT OF LOW, MEDIUM AND HIGH LEVELS OF WATER USE ON THE 40-YEAR NET PRESENT VALUES (NPVS) ATTRIBUTABLE TO RIVER/FLOODPLAIN NATURAL RESOURCE USE IN THE WHOLE OKAVANGO RIVER BASIN

OKAVANGO BASIN	Present Day	Low Development	Med Development	High Development
Net present value @ 4%	**(US$, 2008)**			
Tourism sector	1,989,596,200	1,089,222,700	199,104,700	206,341,600
Rural household sector	1,057,568,000	646,941,500	316,064,000	295,715,900
TOTAL resource use	**3,047,164,200**	**1,736,164,100**	**515,168,700**	**502,057,500**
• Fish use	125,905,100	75,448,600	69,065,500	64,537,400
• Floodplain reeds use	39,722,500	36,385,300	36,221,900	36,248,100
• Floodplain grass use	99,901,600	92,956,800	91,953,300	92,932,800
• Floodplain gardens	6,712,800	7,362,300	7,278,200	7,399,200
• Floodplain grazing	10,752,600	9,115,000	8,864,900	11,046,700
• Tourism wages	774,573,400	425,673,400	102,680,300	83,551,800
Losses from Present Day				
Tourism sector		900,373,500	1,740,491,500	1,783,254,600
Rural household sector		410,626,600	741,504,000	761,852,100
TOTAL resource use		**1,311,000,100**	**2,531,995,500**	**2,545,106,700**
• Fish use		50,456,500	56,839,600	61,367,700
• Floodplain reeds use		3,337,100	3,500,600	3,474,400
• Floodplain grass use		6,944,800	7,948,300	6,968,800
• Floodplain gardens		(649,400)	(565,300)	(686,400)
• Floodplain grazing		1,637,600	1,887,700	(294,100)
• Tourism wages		348,900,000	671,893,100	691,021,600

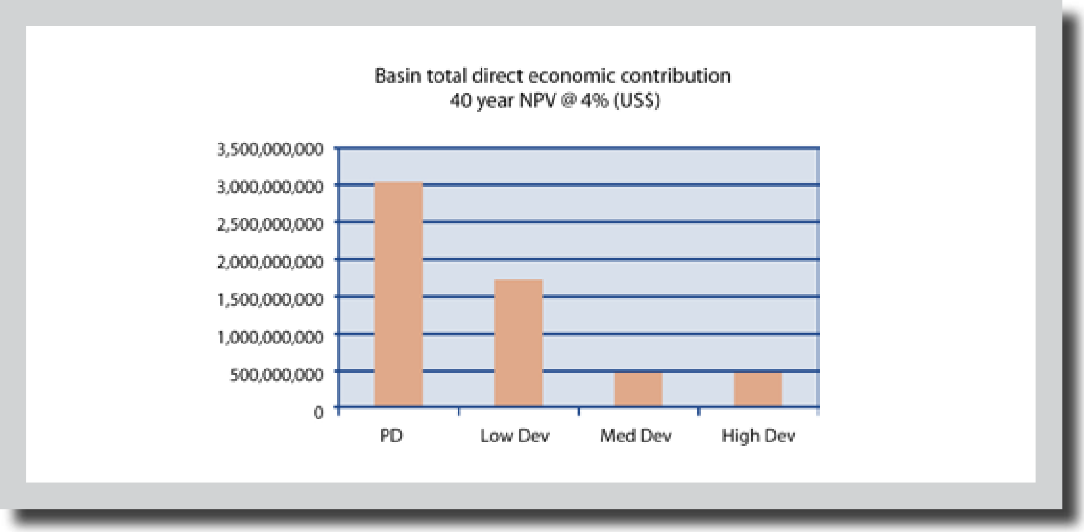


Figure 5-16: Effect on direct economic contribution of all river natural resource use in the Okavango River Basin as a whole

Present day (PD), low development (Low Dev), Medium development (Med Dev) and High development (High Dev) water use

The results suggest that the levels of water developments represented by the three scenarios would significantly reduce the income that people in the basin and in the broader economies derive from the river. For the Medium and High Scenarios, the aggregate losses would be lowest in Angola, at about US$ 65 million and five times greater in Namibia at about US$ 330 million. Such losses would be 30 times greater in Botswana than in Angola, at around US$ 2.1 billion.

These losses would be felt differently at household level in the three countries. Within the socially defined areas linked to the river, Angolans derive 19% of their total household income from it, Namibians 32% and Motswana 45%. With the predicted changes in the river, the percentage of their annual income that they might lose ranges from 8% to 39%, with a basin average of about 20% loss under the Medium and High Scenarios (Table 5-11).

TABLE 5-11: PROPORTION OF INCOME PREDICTED LOST BY THE AVERAGE RURAL HOUSEHOLD WITH THE THREE WATER-USE SCENARIOS, BY COUNTRY AND OVER THE WHOLE BASIN

	% income lost per household			
Scenario:	**Present Day**	**Low Development**	**Medium Development**	**High Development**
• Angolan basin	0%	8%	9%	9%
• Namibian basin	0%	11%	13%	13%
• Botswana basin	0%	18%	38%	39%
Whole basin	**0%**	**11%**	**20%**	**20%**

These aggregate losses will impact on basin populations that are already poor and vulnerable relative to the broader populations of their countries. As the losses are likely to be greater for the tourism industry than for the rural household sector (Table 5-11), the impact on the main income earners in this industry – the investors, owners of capital, government and employees, including wage earners from rural populations – might be even greater than for the rural population as a whole.

The emerging picture is that the people in the Angolan basin currently derive relatively little income from the river system, while those in the countries downstream, and most notably Botswana, derive considerably more from it. By far the major part of this income is based on the natural status of the river/wetland ecosystem, with tourism making up the bulk of this. Botswana has invested in this natural system through land allocation and protection, and relies on it for the bulk of its basin economy.

The difference between private and national wellbeing

Private values effectively measure how the *investor*, in the basin context, usually a household, loses or benefits from natural resource use. This benefit/loss is his/her *net gain* from the activity in terms of either own consumption or money. Thus a fisher household might acquire a canoe, some nets and hooks and line to undertake fishing in the river/floodplain system. The fisher then applies this gear to fishing, making costs annually in time, bait, and repairs to gear, and making income in caught fish, either consumed by the household or sold in the local market. The difference between the annual value of fish caught and the annual fishing and capital depreciation costs is the *annual profit or loss* (the private livelihood value of fishing).

Similarly, in a larger tourism lodge investment, the investor develops a lodge and buys all the equipment and vehicles needed. This capital is applied to providing accommodation and other services for tourists, and earns income in tariffs, and incurs costs in terms of fuel and food for guests, staff wages, and capital depreciation of loan repayments. The difference is the annual net profit of the enterprise, a private value. In addition, from a basin point of view, any salaries and wages earned in the lodge enterprise by employees from the basin represent private livelihood values accruing to the basin households.

National values effectively measure how the *national economy* gains or loses from the natural resource-use activity. This means the change in *all income*, and not just the profit/loss of the private investor. Thus in a tourism lodge enterprise, income may be earned by the investor as net profit, by the employees as salaries and wages, by the owners of any loan capital invested as interest, by the landholders as rentals, and by the government through various taxes and levies. All of these income categories constitute the value added by the enterprise. National income is the aggregate of all the value added in all the production units of the economy. In this project, national wellbeing was measured as the direct net change in *national income*. The specific national income measure used was *gross national product*.

5.5. MACRO-ECONOMIC IMPLICATIONS

5.5.1 Developing a trade-off analysis

Developing the basin's water resources will involve economic trade-offs.[9] Economic benefits can be increased by manipulations of the river's flow regime for municipal and individual water supplies, and for hydropower generation and irrigation. These manipulations will impact on the natural functioning of the river ecosystem, with a resulting change in the ecosystem services it presently provides. Something will be gained but something will also be lost. How much the countries are willing to lose for the benefits they aspire to is a value judgement to be made by them.

This macro-economic trade-off analysis can inform their discussions and negotiations. In it, the existing natural resource and tourism benefits from the basin are grouped as ecosystem services, and the water supply and sanitation, irrigation and hydropower values are grouped as water resources developments. This is not a complete valuation of all ecosystem services (Table 5-12), but relates principally to the values of provisioning services and some cultural services. It thus underestimates the total value of such services and the potential losses that could occur with water resources development.

TABLE 5-12: FULL LIST OF AQUATIC ECOSYSTEM SERVICES RECOGNISED IN THE MILLENIUM ECOSYSTEM ASSESSMENT

Provisioning services	Regulating services	Cultural services
• Edible plants and animals • Fresh water • Raw materials: rocks and sand for construction; firewood • Genetic resources and medicines • Ornamental products for handicrafts and decoration	• Groundwater recharge • Dilution of pollutants • Soil stabilisation • Water purification • Flood attenuation • Climate and disease regulation • Refugia/nursery functions	• National symbols and borders • Religious and spiritual enrichment • Aesthetic appeal • Inspiration for books, art, photography and music • Advertising • Recreation
Supporting services Nutrient cycling, soil formation, pollination, carbon sequestration, primary production		

9 Full details of this section are in Aylward, B. (2009)

Pertinent assumptions made and data used in the trade-off analysis are:

- There will be a progressive growth of improved water supply and sanitation as opposed to the use of raw water from the river and boreholes.
- Both *conservative* and *optimistic* projections for economic profitability are provided, using data as follows:
  - a) irrigation – net operating income of US\$ 0.05 to US\$0.015 m^3 for irrigation water and investment cost of US\$ 15,000 to 10,000 ha^{-1}
  - b) hydropower – revenue at US\$ 0.08 to US\$0.10 KwH^{-1}, investment cost at US\$ 3,000 to US\$ 2,500 MW^{-1}, and O&M costs at 5% to 3% of investment costs
  - c) water supply and sanitation – benefits and costs for improvements based on WHO studies
- The streams of costs and benefits are discounted at 8% to arrive at present values for each sector by country, with 4% used for a low discount rate sensitivity analysis.

5.5.2 Predicting the macro-economic consequences for each country

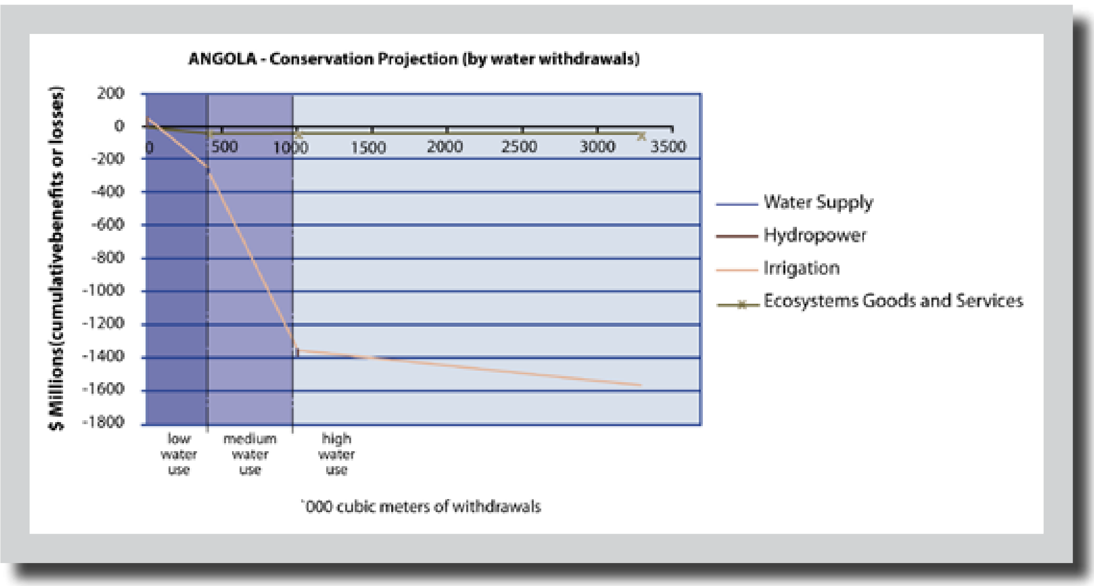
Angola

It is predicted that under the conservative projection, large and increasing economic losses from US$ 250 to US$ 1,600 million would be generated by the scenarios (Figure 5-15). Hydropower would generate increasing but modest net benefits of US$ 60 to US$ 100 million, and water supply and sanitation would impose net costs on the economy of from US$ 5 to US$ 85 million as the level of improved access was increased. Irrigation would be a major drain on the economy, posting US$ 300 million in losses for the Low Scenario and growing to US$ 1.6 billion under the High Scenario. The conservative projection demonstrates the risk of investing in the costly irrigation infrastructure that would be needed in such an area remote from major markets and with poor soils.

Under the optimistic projection, water supply and sanitation would generate increasing net economic benefits from the Low to High Scenarios (in the US$ 10 to US$ 85 million range). The net benefits of hydropower would double in value and irrigation would generate positive returns ranging from US$ 300 million to US$ 950 million, with the exception of the Medium Scenario where the large Cuchi scheme (at 150,000 ha) would reach only half its proposed command area. Such failures to complete very large irrigation schemes, leaving stranded infrastructure costs, are common. In this case under the Medium Scenario, net benefits of just US$ 38 million would be generated after an investment of US$ 1.2 billion.

The impacts of water withdrawal on Angolan subsistence users of the river would be a loss of about US$ 30 to US$ 50 million, reflecting the relatively small change in ecosystem functioning expected in the upper basin compared to that lower down.

A) CONSERVATIVE PROJECTION



B) OPTIMISTIC PROJECTION

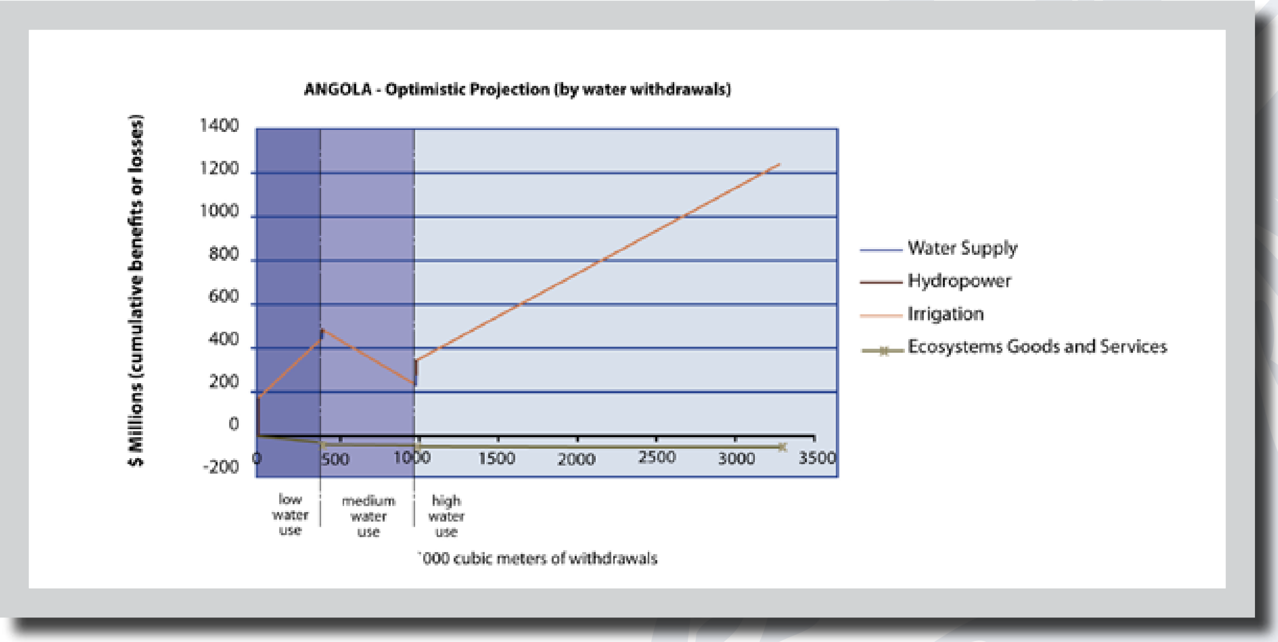


Figure 5-17: Macro-economic trade-offs for the three water-use scenarios according to the quantity of water diverted for Angola[10]

Investment costs would differ widely between scenarios and with the two projections used, with those for the Low Scenario being US$ 400-600 million and for the High Scenario being US$ 1.7-2.6 billion.

The net benefits also differ widely between scenarios. Under the conservative projection the net effect of water withdrawal to the Angolan economy would be:

- Low Scenario: US$ 290 million loss
- Medium Scenario: US$ 1.4 billion loss
- High Scenario: US$ 1.6 billion loss.

Under the optimistic projections the picture improves substantially:

- Low Scenario: US$ 450 million gain
- Medium Scenario: US$ 200 million gain
- High Scenario: US$ 1.2 billion gain.

The difference between the conservative and optimistic projections is largely driven by the prospect of economic returns from large areas of agriculture. Employing the lower discount rate would increase these net benefits due to the large up-front investment costs and the sizeable returns over 40 years.

As the Angolan loss in ecosystem services would vary only slightly (around US$ 10 million) between the three scenarios, the net benefits of water development could conceivably be the key factor in choosing a development pathway. The wide range of potential benefits from the water developments highlights the importance of studying these projects more closely, as the economic risk of proposed irrigation is significant.

Namibia

It is predicted that under the conservative projection there would be positive net benefits under the Medium and High Scenarios for water supply and sanitation, with just minor losses and gains for the limited hydropower and irrigation efforts – overall the water developments would provide little economic return under the Low Scenario, growing to US$ 60 million under the High one.

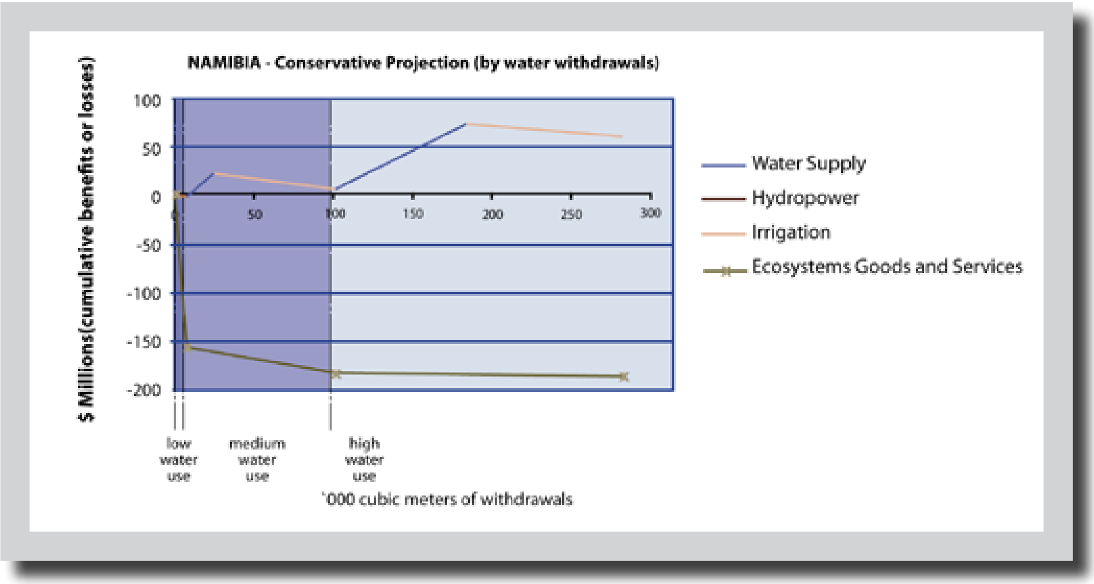
Under the optimistic projection, Namibia would benefit even more from improvements in water supply and sanitation – up to US$ 230 million under the High Scenario, with hydropower and irrigation net benefits ranging from US$ 6 to US$ 90 million, depending on the scenario.

10 Given that the analysis envisions further development that subsequently cause losses of ecosystem services, the figures included for each country show the benefits of further development as the line extending **above** the x-axis, while the losses of ecosystem values are portrayed as costs **below** the x-axis.

The impacts of water withdrawal on the Namibian economy would be considerable, particularly in terms of the loss of tourism revenues. Losses of from US$ 150 million to US$ 190 million would accrue as levels of water withdrawal proceed from the Low to High Scenarios.

Investment costs for the water resources development projects would range widely from one alternative to the next, with maximum investment costs for the Low Scenario of just US$ 5 million and for the High Scenario of up to US$ 300 million. A large part of this would be associated with the Eastern National Water Carrier project.

A) CONSERVATIVE PROJECTION



B) OPTIMISTIC PROJECTION

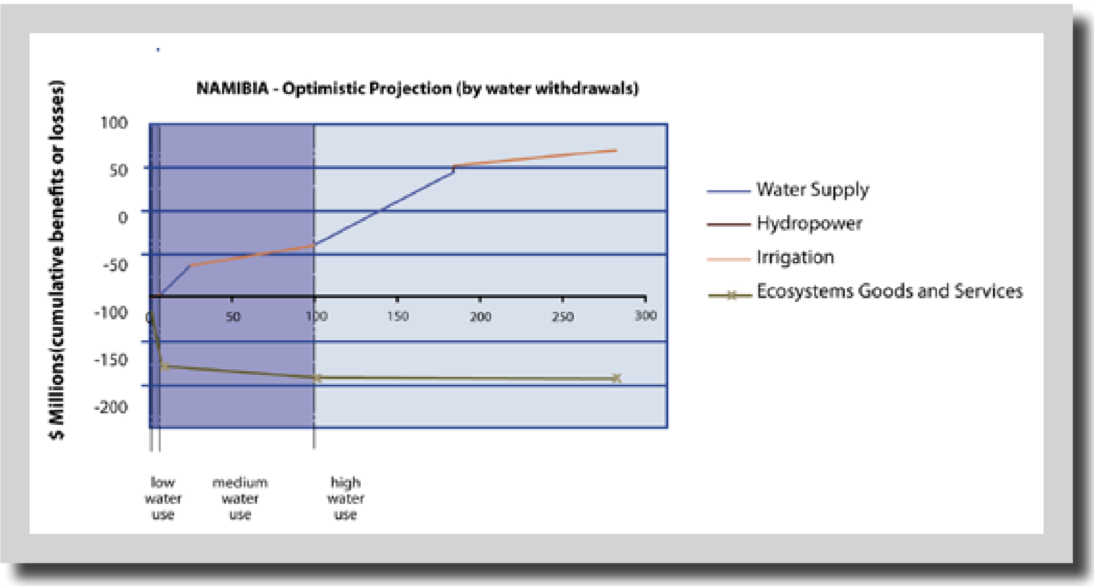


Figure 5-18: Macro-economic trade-offs for different water-use scenarios according to quantity of water diverted for Namibia

Totalling up gains and losses, under the conservative projection all the alternatives would generate large economic losses for the Namibian economy, of the order of US$ 125-175 million. On the positive side, there would be benefits from improving water supply and sanitation. Under the low discount sensitivity analysis the water-supply benefits and ecosystem losses would increase significantly through the scenarios, exaggerating the net losses under the Low and Medium Scenarios and exaggerating the positive water supply and sanitation returns under the High Scenario – leading this alternative to a break-even point at the 4% discount rate.

Under the optimistic projection, net benefits would remain negative under the Low (-US$ 150 million) and Medium (-US$ 60 million) Scenarios, but positive returns for the country's economy would be seen in the High Scenario (from US$ 150 million with the 8% discount rate to US$ 530 million, with the lower rate).

Practically all the positive sectoral benefits in Namibia would come from improvements in water supply and sanitation, which would have very little effect on the losses occurring in ecosystem services. All things being equal, the optimal choice for Namibia would be to avoid the ecosystem losses and economic risks associated with major water withdrawals for irrigation, but move forward with improvements in water supply and sanitation.

Botswana

Under both conservative and optimistic projections Botswana would see positive net benefits from water supply and sanitation. Implementation of the Low Scenario would generate net benefits of the order of a few million dollars, while providing improved water supply and sanitation for all under the High Scenario would generate up to US$ 55 million in net benefits under the optimistic projection.

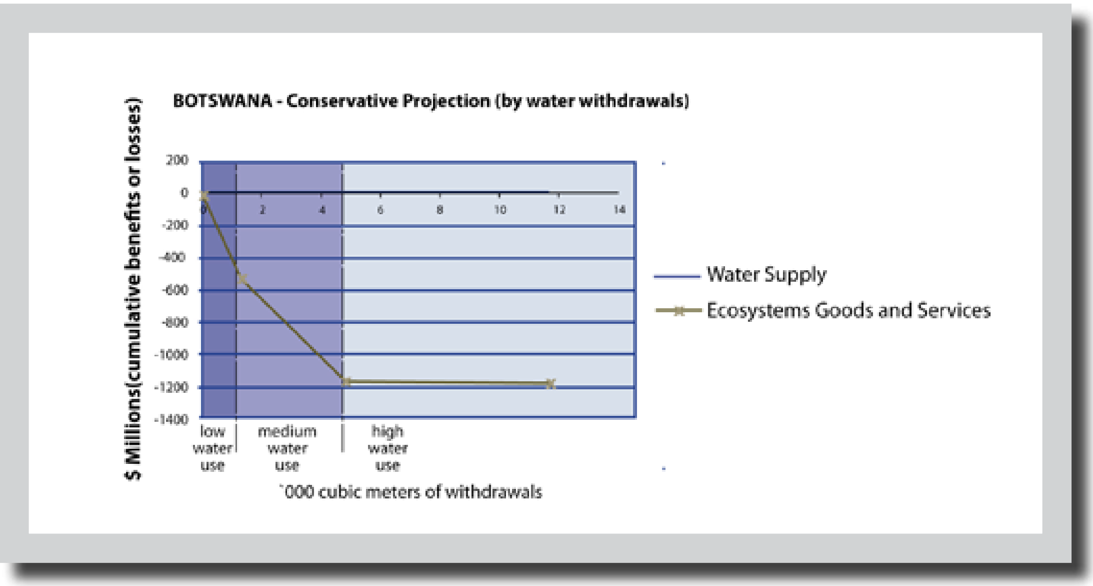
Ecosystem losses due to changes in harvesting and use of natural resources would be of the order of US$ 4 to US$ 8 million, while losses from a strong decline in tourism revenues would result in losses of US$ 500 million under the Low Scenario. Under the Medium and High Scenarios the losses would be over US$ 1,150 million.

Under the low discount sensitivity analysis, the water supply and sanitation net benefits and the ecosystem losses would practically double in size, exaggerating the net losses under all scenarios.

Investment costs in the case of Botswana would be limited to that of water supply and sanitation and vary from a million dollars through US$ 25 million depending on the level of improvements and the population served.

For Botswana, the impacts of all three scenarios would be significant – from a loss of US$ 500 million for the Low Scenario to a loss of the order of US$ 1,150 billion for the Medium and High Scenarios. Botswana would clearly be better off without the upstream development of irrigation, which the analysis in Section 5.4 shows would have devastating impacts on tourism in the Delta and on the Delta economy.

A) CONSERVATIVE PROJECTION



B) OPTIMISTIC PROJECTION

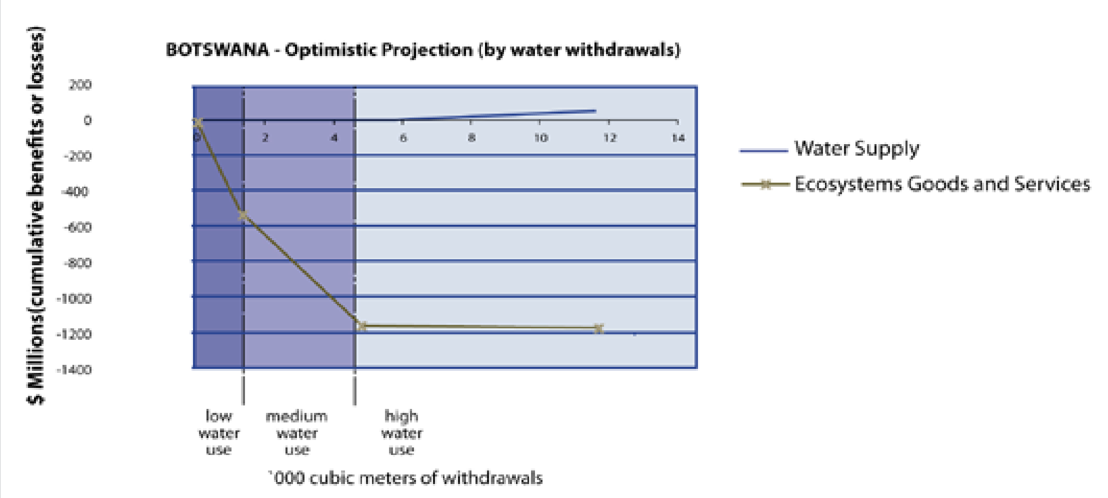


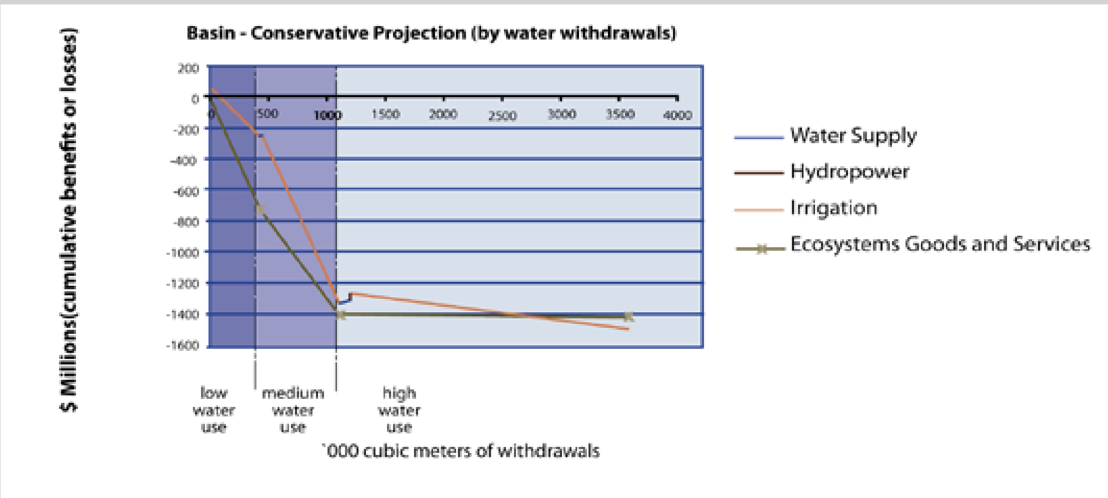
Figure 5-19: Macro-economic trade-offs for different water withdrawals according to quantity of water diverted for Botswana

5.5.3 A basin perspective

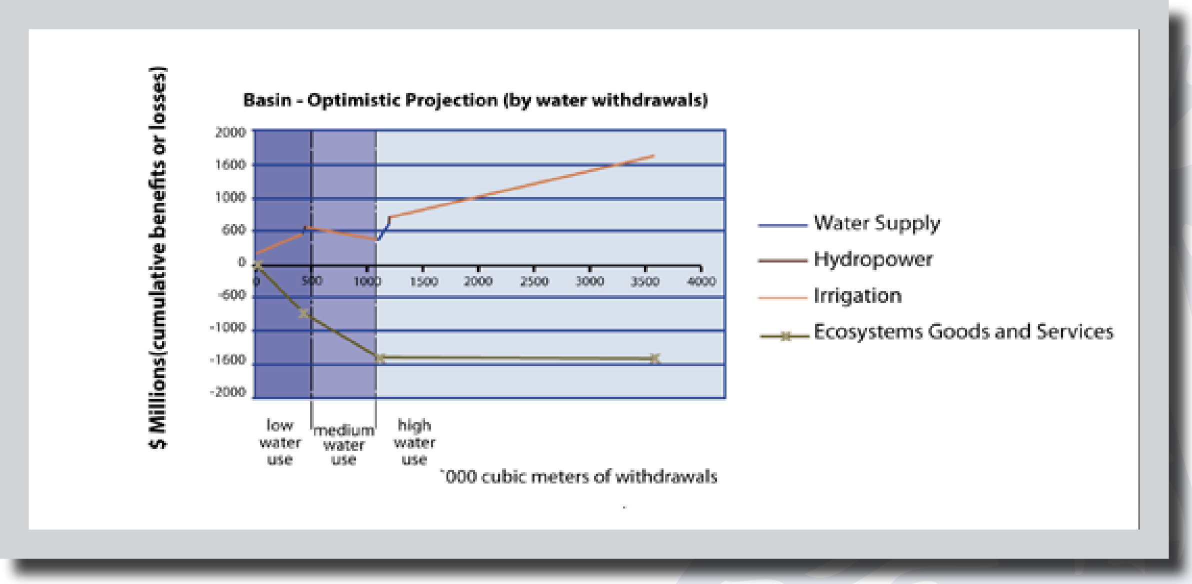
From a basin perspective, the potential large ecosystem losses faced by the downstream riparian countries would be from US$ 700 million for the Low Scenario through US$ 1.4 billion for the Medium and High Scenarios.

Under conservative assumptions regarding the profitability of irrigated agriculture, these losses could double in size with the large expansion of irrigated area expected under the Medium and High scenarios. Under optimistic assumptions the net returns remain negative under the Low (-US$ 260 million) and Medium (-US$ 1 billion) Scenarios. Only with the full implementation of the large Cuchi irrigation scheme do net returns generate positive returns (of US$ 215 million) under the optimistic projection. However 60% of the positive returns under this alternative come from water supply and sanitation, and hydropower. Measured in terms of net benefits to irrigation and the resulting ecosystem losses from the large increase in water consumed, the net impact of irrigation may be a loss of US$ 0.5 billion to the basin. This analysis does not take into account any willingness to pay for the continued existence of the Okavango Delta as a Ramsar Site, which would accentuate the losses of ecosystem services.

A) CONSERVATIVE PROJECTION (BY WATER WITHDRAWAL)



B) OPTIMISTIC PROJECTION (BY WATER WITHDRAWAL)



C) OPTIMISTIC PROJECTION (BY INVESTMENT COSTS)

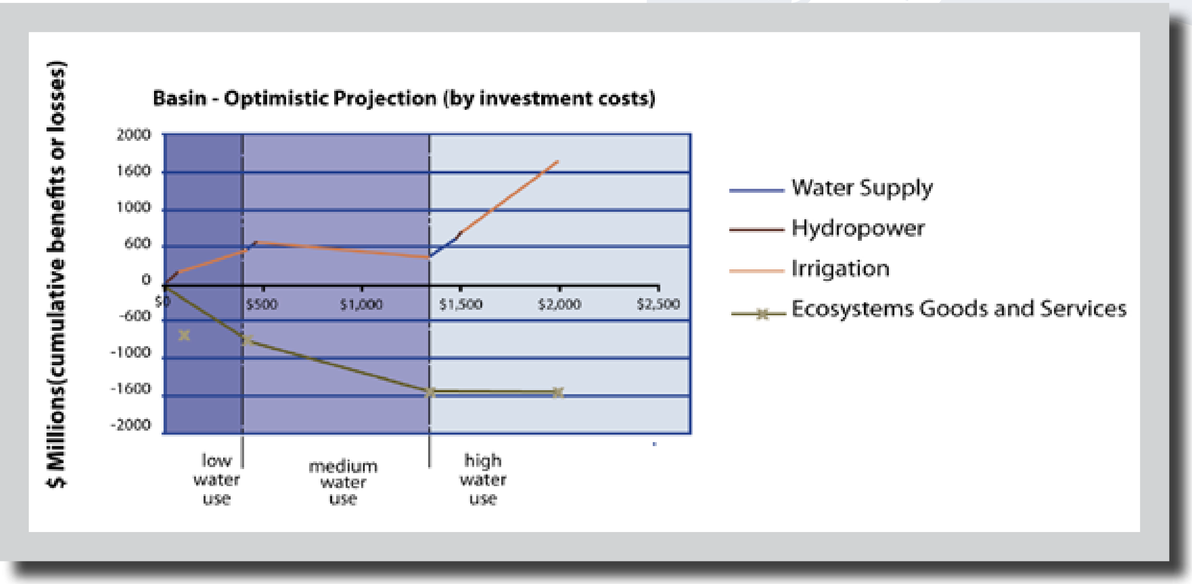


Figure 5-20: Macro-economic trade-offs for different water withdrawal alternatives from a basin perspective

In sum, prospective water withdrawals would generate an order of magnitude of economic losses and risk that would overwhelm the potential benefits of the full suite of proposed water resources developments across all three countries. From a basin-wide perspective, caution and further study is called for before proceeding with the different water resource-development projects, given that there is no guarantee that these developments will produce 'optimistic' results (collectively or individually) and given that such developments are predicted to result in substantial economic loss of ecosystem services.

5.5.4 Comparing development pathways

The impacts of these results allow a comparison of different development pathways:

- The status quo – a stagnation scenario (Low Scenario)
- High water-use pathway, (High Scenario)
- A sustainable development pathway

Table 5-13 presents a comparison of changes in some development indicators under these different development pathways through to the year 2028.

The alternatives considered above assume a continued progress of economic development. Under an economic stagnation scenario, such as may be envisaged with continued global recession, populations in the basin would continue to grow, but investment resources to pursue the Low Scenario and thereby raise social and economic development levels would be limited. The end result would be that no improvements in domestic water supply, hydropower or irrigation are made. This would leave increasing numbers of people in the basin without access to improved water supply and the basin would have to import or find alternative sources of food and electric power to underpin basin development.

This situation compares poorly with the economic indicators derived from the High Scenario. In this, substantial gains would be made in these specific indicators, particularly in Angola and Namibia. For example, new hydropower projects in these two countries could supply up to 2.4 million Angolans and 62,000 Namibians with electric power at current national average consumption levels. If projections for 2028 were made at current national average consumption levels for South Africa, which are considerably higher than current levels in the basin, these hydropower projects would produce enough power for 100,000 people or 7% of the basin's expected population in 2028.

TABLE 5-13: COMPARISON OF PER CAPITA INDICATORS FOR DIFFERENT BASIN DEVELOPMENT PATHWAYS

Country	Angola	Namibia	Botswana	Totals
Basin population – 2005	505,180	219,090	157,690	881,960
Basin population – 2025	860,706	295,081	212,385	1,368,172
Growth rate	2.7%	1.7%	1.5%	
Status quo – stagnation alternative (Low Scenario)				
Water supply				
People accessing improved water supply	–	64,668	112,274	176,942
Hydropower				
People served	–	–	–	–
Irrigation				
Lands irrigated (ha)	1,300	1,951	–	3,251
Water withdrawals (Mm^3)	17	29	–	47
People fed (low meat)	27,282	45,635	–	72,917
People fed (high meat)	13,431	22,466	–	35,898
High Scenario				
Domestic water supply				
Water withdrawn	20	15	5	40
People accessing improved water supply	683,774	242,479	193,769	1,120,023
Hydropower				
Annual production (GWh)	367	97	–	464
People served (at current consumption)	2,404,145	62,589	–	2,466,734
People served (at current RSA levels)	76,362	20,104	–	96,466
Irrigation				
Lands irrigated (ha)	338,900	14,081	–	352,981
Water withdrawals (Mm^3)	3,296	210	–	3,506
People fed (low meat)	5,149,959	328,021	–	5,477,980
People fed (high meat)	2,535,364	161,487	–	2,696,852
Sustainable Development alternative				
Domestic water supply				
Water withdrawn	13	7	3	22
People accessing improved water supply	683,774	242,479	193,769	1,120,023
Hydropower				
Annual production (GWh)	257	–	–	
People served (at current consumption)	1,680,873	–	–	1,680,873
People served (at current RSA levels)	53,389	–	–	53,389
Irrigation				
Lands irrigated (ha)	43,700	2,381	–	46,081
Water withdrawals (Mm3)	431	36	–	467
People fed (low meat)	674,186	55,713	–	729,899
People fed (high meat)	331,907	27,428	–	359,335

Note: "People serviced with electric power" is based on national averages, with Namibia and Botswana at 10 times the Angolan level and RSA (South Africa) at 3 times the Namibian and Botswana levels.

The large extent of irrigation development contemplated under the High Scenario would likewise greatly improve food production in Angola and Namibia. For low meat diets (roughly approximating consumption levels for sub-Saharan Africa) these irrigation schemes would make Angolan and Namibian portions of the basin self-sustaining in caloric terms. Even if the proportion of meat consumed shifted by 2028 to reflect higher meat diets, these projects might greatly increase food self-sufficiency. Again, these projections are limited by significant assumptions about the uptake and profitability of these schemes. If they do not perform well, these benefits would be greatly reduced.

The Low and High Scenarios may also be compared to a sustainable development alternative. Under this alternative the linkages between water withdrawal and the triple bottom line of ecological, social and economic sustainability would be recognised, and a more discerning, moderate level of water withdrawal pursued. In this case, the Medium Scenario in terms of domestic water supply and hydropower could be combined with the Low Scenario in terms of irrigation. The results suggest that significant gains in social and economic development could occur in the basin without the need to put the Okavango Delta and the Namibian and Botswana basin economies at risk. Under such a sustainability option some 82% of the population would receive access to improved water supply compared to 13% under the Low Scenario (Table 5-14). The difference between the two scenarios would simply be that a much larger proportion would be on the less expensive community standpipe systems – which in turn would lead to lower water withdrawals (40% less).

With the sustainable development alternative, less hydropower and irrigated food would be produced in Namibia and Angola. However, the trade-off would be the maintenance of the sizeable wildlife tourism economies in Namibia and Botswana.

Hydropower production would be constrained but still provide Angolans with twice the national average consumption (down from almost three times under the high water withdrawal alternative). If per capita consumption levels are assumed for the basin in 2028 that match today's consumption levels for South Africa, the percentage of basin consumption supplied under these two alternatives would be 7% (High Scenario) and 4% (Sustainable Development) respectively. In other words, even under the High Scenario the amount of power provided from the river would be fairly limited in absolute terms.

It is with respect to food production that the two alternatives show the most difference. Using the low meat consumption figures, moving to the Sustainable Development alternative would lower the percentage of basin food requirements provided by irrigation from 400% to 53%. While this is a large drop it still indicates that with only limited irrigation expansion (and limited water withdrawal) irrigation could provide almost half the basin requirements. This is a significant improvement over the Low Scenario where irrigation would meet only 5% of the need. Obviously, rain-fed agriculture and imports to the basin would provide the bulk of current food supply and would maintain an important role under a Sustainable Development alternative.

TABLE 5-14: PERCENTAGE OF THE POPULATION SERVED UNDER DIFFERENT BASIN DEVELOPMENT PATHWAYS

Population served (as percent of total population)				
Country	**Angola**	**Namibia**	**Botswana**	**Totals**
Status quo – stagnation				
Improved domestic water supply	0%	22%	53%	13%
Hydropower – electric power	0%	0%	0%	0%
Irrigation – food production (low meat)	3%	15%	0%	5%
Irrigation – food production (high meat)	2%	8%	0%	3%
High Scenario				
Improved domestic water supply	79%	82%	91%	82%
Hydropower – electric power (current levels)	279%	21%	0%	180%
Hydropower – electric power (RSA levels)	9%	7%	0%	7%
Irrigation – food production (low meat)	598%	111%	0%	400%
Irrigation – food production (high meat)	295%	55%	0%	197%
Sustainable Development alternative				
Improved domestic water supply	79%	82%	91%	82%
Hydropower – electric power (current levels)	195%	0%	0%	123%
Hydropower – electric power (RSA levels)	6%	0%	0%	4%
Irrigation – food production (low meat)	78%	19%	0%	53%
Irrigation – food production (high meat)	39%	9%	0%	26%

5.5.5 Extreme events – floods and droughts

Any consideration of these scenarios needs to appreciate the varying impact of extreme events – floods and droughts. While the hydrological modelling used for the TDA cannot be used to simulate these flow events, they clearly have transboundary impacts, including the transmission of waterborne diseases. The management of flood events also needs strong cooperation between riparian countries.

The Okavango River Basin is characterised by annual flood events. Depending on flood peak magnitude and volume, the floods could have severe impacts on the livelihoods of people living in flood prone areas. The 2009 flood has so far been the largest in terms of the geographical area affected, and had disastrous consequences. The flood caused an estimated N$1.7 billion (1% of Gross Domestic Product) worth of damages and losses to the public and private sectors. The extensive nature of the impact in Namibia was attributed to increased population settlement in the flood plains in the Kavango Regions. Flooding in some urban areas was mainly due to inadequate storm water drainage. The other major contributing risk factor was the construction of infrastructure in the flood plain without disaster risk reduction considerations. There is a need to find a lasting solution to the continuous effect of flooding on people who live in flood-prone areas.

Recent flooding events have been interspersed by severe droughts in 1998 and 2007. These have severely reduced the resilience of a significant number of poor households that are reliant on water sources other than the currently perennial Okavango River. As has been shown in the water use scenarios, growth in water abstractions from the rivers could reduce low flows significantly, or even dry up previously perennial tributaries such as the Cuebe River. This would exacerbate the overall impact of droughts in the basin.

5.6. GOVERNANCE IMPLICATIONS

5.6.1 Legal and policy constraints

The analysis of the policy and legal landscape in the three basin countries shows a relatively strong framework of natural-resource management policies and legislation, although there is some variation between countries. The policy and legal framework is currently less developed in Angola due to the country's relatively recent emergence from armed conflict. However, Angola is fast addressing policy and legislative gaps, with a Water Act and other environmental legislation already passed some time ago and a number of environmental policies and strategies being completed or under development (see overview of existing policies contained in the Governance Review accompanying this document).

Okavango River in the panhandle, Botswana

The strength of the current policy landscape is the recognition of the economic and social development opportunities of sustainable natural-resource management. Particularly in Botswana and Namibia, emphasis is placed on sustainable resource use as an economic driver, primarily through tourism and Community Based Natural Resource Management (CBNRM) activities and as such is reflected in policy and legislation. In Angola there is growing recognition of the need for sustainable management and it is expected that this aspect will be increasingly mainstreamed into sector policies under development. Yet there remains a number of existing or potential conflicts between sector policies that require resolution in order to determine the development pathway for the basin.

Mussombo irrigation scheme, Angola

Of great importance for integrated basin management is that all countries have replaced old water legislation with IWRM-based water legislation that emphasises the need for integrated management and provides the legal mechanism for implementing integrated management in practice. Of particular relevance is the provision in law for the establishment of local-level basin management committees, the composition of which legally requires inter-sectoral representation.

On the other hand, there are some policy and legislative gaps at national level that currently hamper the optimal economic use of natural resources in a sustainable way – for example the inadequacies in the land tenure systems, e.g. insecurity of titles, making it difficult to obtain bank loans for tourism or CBNRM developments on communal land. Other examples include the exemption by law of communal land from meeting certain environmental protection requirements or the lack of strategic environmental assessment legislation/standards at national and basin level[11].

Whereas the type, scope and area of legislative gaps vary between the three countries, there are several common challenges that the countries face. Arguably the most important in this respect shortcomings in land-allocation and tenure system, which are of concern in all of the countries. Likewise, inadequate environmental impact assessment (EIA) and strategic environmental assessment (SEA) regimes are common to the three countries.

The common gaps in the policy, legislative and planning framework are mirrored at transboundary level. The most relevant issue is the absence of a harmonised land-use planning framework between the three countries that allows integrated basin-wide planning. Similarly, harmonised basin-wide water quality standards and basin-wide climate change adaptation strategies are missing at present.

Having noted the existence of gaps in the policy and legal framework at national and basin level, these problems are comparatively easy to identify and address (at policy and legislation level) in practice. More complex to solve, largely because of their structural nature, are constraints resulting from a lack of institutional coordination and lack of effective implementation and enforcement of existing policies and legislation.

The most significant constraints for the effective sustainable management of the basin lie in the institutional framework. These constraints are largely of a structural nature, namely the fragmentation of management responsibilities across different line function ministries, the lack of inter-sectoral planning, limited coordination between different spheres of government, weak institutional structures at the local level, a lack of skills, management capacity and resources for integrated planning and effective monitoring, implementation and enforcement.

5.6.2 Fragmentation and lack of inter-sectoral planning

The overview of the responsibilities of different line function ministries in the respective natural resource management fields shows that numerous ministries and departments regularly need to be involved in most planning and decision-making processes and subsequent implementation[12]. While the required coordination between national ministries does happen to some extent, it is still underdeveloped with sectoral planning being the norm rather than integrated planning and decision-making. In some cases this is aggravated by conflicting sector policies that hinder integrated planning since line-function ministries have to pursue contradictory policy objectives.

11 Malzbender, D. (2009)
12 Malzbender, D. (2009)

Planning and decision-making across sectors and line function ministries or departments are arguably easier to achieve at local level where common local interests provide stronger incentives for cooperation and integrated planning. In Botswana, the Okavango Delta Management Plan (ODMP), a fully integrated management plan for the Okavango Delta developed with strong involvement of a vast diversity of stakeholders at all levels, might serve as a good example in this regard. However, even where integrated planning occurs and leads to the development of a fully integrated management plan, the challenge remains that implementation responsibilities reside in a diversity of agencies, again raising the issues of lack of coordination and cooperation at implementation level. This often leads to inefficient use of government resources if not failure to implement altogether.

It is in this context that the provision in the three countries' water laws for the establishment of a basin-management committee is of great importance. Using the Okavango Basin Management Committee in Namibia as an example, the committee is comprised of representatives from a wide range of national ministries, local government and other relevant stakeholders, ensuring that a diversity of management responsibilities and sector interests can be considered in basin planning. The effectiveness of these basin management committees for integrated basin management requires strong institutions with adequate skills and capacity level, as well as effective coordination and cooperation between the local committees in the three countries, directly and/or through OKACOM.

5.6.3 Weak institutions at local level

The need for strong institutions at local level is at present the biggest governance challenge in the Okavango basin. All three countries have made provision in law or policy to strengthen and give greater autonomy to local government in local level development decision-making. Practical implementation is, however, lagging behind and local government continues to be under-resourced and with limited decision-making power, resulting in central government remaining the dominant development decision-making power. Likewise, local basin-management committees established under the respective national water acts are either not yet established or have low levels of skills and financial capacity. They would require significant strengthening in order to fulfil their role in an effective manner.

5.6.4 The role of OKACOM

Established as a cooperation, coordination and information-sharing platform for the three basin states with respect to water resources management, it is clear that OKACOM has a central role to play in the management of the basin, particularly since there are no established basin-wide cooperation mechanisms in other natural-resource management fields, such as land-use or biodiversity. However, integrated water resources management cannot be undertaken effectively without considering land-use management, agricultural practice and waste disposal on the basin's water cycle. OKACOM itself has already recognised the integrated nature of water resources management institutionally by establishing the Biodiversity Task Force.

TABLE 5-15: OVERVIEW OF THE MAIN GOVERNANCE CHALLENGES COMMON TO THE THREE COUNTRIES AND OF GOVERNANCE PROBLEMS WITH TRANSBOUNDARY IMPACTS

COMMON PROBLEMS	TRANSBOUNDARY PROBLEMS
• Intra-governmental cooperation • Lack of enforcement because of insufficient institutional capacity and resources • Insufficiencies in the land tenure system • Conflicting and repetitive institutional responsibilities • Insufficient EIA and SEA regimes • Insufficient long-term policy formulation (Angola and Namibia) • Minimal integration of poverty reduction into conservation schemes through community-based natural resource management • Low awareness of traditional authorities on environmental and land-use issues • Insufficient long-term policy formulation, particularly with respect to climate change adaptation • Low financial resources at local level	• No harmonised water quality standards • Insufficient basin-wide cooperation at different levels (particularly local level) • Lack of enforcement because of insufficient institutional capacity and resources • Inadequate EIA and SEA regulation and standards • Insufficiencies in the land tenure system • Insufficient integration and coordination of planning and implementation at national, regional and local level • Ineffective implementation and enforcement • Limited response to deforestation • Lack of a comprehensive natural resource management plan • No integrated basin tourism plan • Unharmonised land-use and development plans • No integrated biodiversity management systems • Inadequate basin-wide climate change adaptation and mitigation strategies

The member states decide on the exact scope of activities of OKACOM in the overall management of the basin, choosing, for example, between a narrower focus on water resources management only and a broader economic development focus.

Any choice cannot ignore the integrated nature of basin management and the need for inter-sectoral cooperation and coordination. At national level, inter-sectoral coordination is increasingly recognised and to some extent reflected in policy and legislation such as the proposed Water Resources Council of the Botswana draft Water Bill and the Grupo de Apoio Técnico Inter-Ministerial (GATECI) in Angola (the Inter-Ministerial Technical Support Group), which deals with matters related to international agreements on river basins.

However, this need is not yet reflected in the composition of the national delegations of all the countries to the Commission and/or to OBSC. Given the importance of agriculture and energy demands on the basin's natural resources, increasing the diversity of sectors represented in the different organs of OKACOM would allow greater consideration of and coordination between different sectors. This would provide a much firmer institutional base from which t implement coordinated land-use planning and pollution control.

The linkages between OKACOM and the member states could also be strengthened at local level, meaning closer ties between the respective local basin-management committees and OKACOM. This would not replace or undermine the decision-making power of the Commission made up of the national delegations, but could take the form of direct information exchange between OKACOM and the national basin-management committees. This would allow OKACOM to become more informed about local level planning, implementation and enforcement. Such direct information exchange mechanisms would improve the cooperation between the local committees in the three countries and bring implementation and enforcement challenges that require basin-wide cooperation to the attention of OKACOM.

Closer direct linkages are also desirable between OKACOM and the broad range of stakeholders in the basin and it is assumed that the stakeholder-participation strategy currently under development will adequately address this matter. The institutional linkages between local basin management committees and OKACOM could also be incorporated as an integral part of the stakeholder participation strategy.

Without pre-empting any decisions taken by member states on the exact role of OKACOM in the management of the basin it is foreseeable that its role and scope of activities will grow significantly, particularly once the Strategic Action Programme for the basin has been agreed on, and when a more detailed basin management plan is developed and implemented. This requires the further strengthening of its capacity, particularly at an operational management level. The OKACOM Structures Agreement gives OKACOM the necessary flexibility to structure its organs in a way that will accommodate its growing managerial role, with the establishment of Task Forces being one such option.

At operational level it is foreseeable that the Secretariat would have to play a stronger role, possibly over time taking on a key role in day-to-day monitoring and overseeing joint activities and also the implementation of joint projects and programmes between the three countries. A number of proposals for the further institutional evolution of OKACOM, and the Secretariat in particular, are already under consideration. It is critical for the effective, integrated management of the basin that OKACOM plays a central role and its institutional capacity is progressively strengthened in line with its evolving role and increased scope of activities.

Capico, Angola

5.7. SUMMARY

There is a pressing need for development within the Okavango Basin, particularly within Angola. This country has 57% of the basin's human population and contributes by far the greatest amount of water to the Okavango system but its people derive relatively few benefits from it. Botswana, with 18% of the basin's human population, derives the greatest benefit from the river, with both it and Namibia having well-developed Okavango-based tourist industries. The three countries all aim to address poverty and vulnerability as a priority issue, and water resources developments for the improvement of water accessibility, delivery and quality will support this. These same water resources developments, however, have the potential to drastically impact the ecosystem services provided by the river.

As has happened globally with water resources developments, and is still happening in developing regions, a trade-off is made between what is gained in the form of, for instance, irrigated crops, hydropower and urban piped supplies of water, and what is lost, in the form of services provided naturally by the river. Mostly, in the past, this trade-off has been largely by default – the benefits have been wished for and the costs, in terms of a degrading river ecosystem, have not been spelt out at the planning stage and so have emerged later as unwanted impacts.

Cuebe Cubango confluence

With modern approaches to Integrated Water Resources Management, driven by the wish for truly sustainable development, it is now possible to make predictions of what could happen to the ecosystem and its users as development proceeds, in other words, what the costs could be. Such an approach was used in this project to provide predictions for the Okavango Basin, which can inform discussions among the countries on their preferred way forward.

Part of the approach was to capture understanding of the human societies and natural resources of the Okavango Basin in four summary causal-chain tables that were prepared by the TDA Report writing team. These focus on the sequence of events that would follow water resources development, and specifically on the predicted changes in the flow regime, sediment delivery, water quality, and biodiversity of the river system (Tables 5-16 to 5-19). In each table, the 'issue', that is the predicted change (centre column), is traced back through primary causes to its root causes (left-hand columns) and also projected forward to its predicted impacts (right-hand columns). Each table is completed by a set of recommended actions or solutions (extreme right-hand column). These tables are used below to summarise the potential transboundary impacts investigated in this project.

5.7.1 Changes in the flow regime

It is predicted that continuing trends in population growth, urbanisation and agricultural and industrial expansion will lead to water resources development that could drastically change the flow regime of the Okavango system (Table 5-16). Dry-season flows would start earlier, become lower and last longer than at present, and flood volumes smaller, the flood season progressively shorter and its onset a little later. The impacts would be felt most in the Lower Okavango and thence down into the Delta and its outflow. For example, under the scenarios considered in this project, the MAR of the reach flowing through Kapako/panhandle would potentially reduce to 69% of present, the dry season would start up to seven weeks earlier and last 11 weeks longer with a minimum flow that could be only 18% of present, and its flood season could start a week or two later, and be up to seven weeks shorter with a reduced flood volume of 63% of present.

River laundry at Caiundo, Angola

Such significant changes in flows would trigger channel adjustments and a swing toward increasingly severe floods and droughts, dry out of parts of the Delta and lead to a substantial loss of the ecosystem services presently provided by the river system. The recommended actions are addressed in Chapter 6 and then more fully in the Strategic Action Programme (SAP), but essentially they focus on collaborative basin-wide planning guided by an agreed limit to river degradation.

5.7.2 Changes in sediment dynamics

It is predicted that the flow changes, together with land-use changes, could lead to considerable changes in the amount and nature of sediments in the river system (Table 5-17). Increased agriculture, urban expansion, over-grazing, deforestation and fires will all mobilise basin soils, which will move downhill and toward the river. If riparian vegetation has also been cleared there will be no last line of protection preventing them entering the river, where they could smother habitats, cause channel changes, reduce water quality and damage the gills and hunting ability of aquatic life.

Introducing in-channel dams to the system will also affect the sediment dynamics of the river. Sediments arriving in the reservoirs will be stored there, thereby shortening the reservoirs' life spans and reducing sediment delivery to the downstream river. Without detailed knowledge of proposed land changes and the design and operating rules of such dams it is difficult to predict whether more or less sediment will occur in any one river reach: those reaches downstream of dams may receive fewer floods with which to move sediments than at present but may also have reduced supplies of sediments, which could balance out. Additionally, changes in sediments arriving from the catchment will add their own layer of complexity. Confusing as the conflicting influences may be, sediment dynamics of the river are an important, though oft-neglected, aspect of water resources planning that needs to be grappled with, as channels, infrastructure such as roads and bridges, land and floodplains could all be vulnerable as flow and sediment regimes change.

The recommendations include maintenance and rehabilitation of riparian vegetation, construction of off-channel water storage, and design of in-channel dams that allow the passage of sediments.

5.7.3 Changes in water quality

Increased population numbers will lead to increases in urban areas, crop-growing areas and water resources developments, all of which have the potential to cause deterioration in water quality as listed in Table 5-18. This would lead to a decline in the natural state of the river ecosystem and in the resources available for harvesting from it, and in an increase in the costs of purifying water for human consumption. There would be a suite of economic implications. Recommendations for addressing potential water-quality problems include an integrated basin-wide system of sharing data, methods and standards, monitoring and enforcement of standards. The impact of land use and agricultural practice on the water cycle cannot be over-emphasised. Intensive development on free-draining riparian soils in the lower basin will transmit nutrients and pesticides rapidly to the watercourses. The low levels of organic material in the Kalahari Sand soils mean that nutrients such as N will not be retained in the soil horizons when applied, but will rapidly drain to aquifers and adjacent watercourses.

5.7.4 Changes in biodiversity

The impacts of development on ecosystems are by now well understood and recorded and the predictions made in this project align well with that general understanding (Table 5-19). The Okavango is unique at global level for its close-to-natural condition and its magnificent wetlands and biodiversity. Detailed predictions of how this could change with development are provided in the Scenario Report (Report 07, volumes 1-4, of the Environmental Flows series). In Sections 5.2 and 5.3, these impacts have been summarised, revealing that under the developments listed in the High Scenario, ecosystem condition could decline drastically down to what has been internationally recognised as the limit to which degradation should be allowed even for a 'working' river feeding and draining intensive urban, industrial or agricultural areas. The Okavango system has a far higher present status than 'working', with the Delta being an internationally-recognised Ramsar wetland. This status could be jeopardised by development that aims only to harness and harvest the water. With that would be lost not only the present level of ecosystem benefits enjoyed by people locally, nationally and internationally, but also the opportunity to forge a truly sustainable pathway into the future.

Water bird at Rundu, Namibia

TABLE 5-16: THE CAUSES AND PREDICTED IMPACTS OF CHANGES IN THE FLOW REGIME

Root Causes	Primary Causes	Issue	Predicted impacts	Recommended actions/ solutions
• Urbanisation • Population growth • Increasing industrialisation • Limited information (and uptake) on appropriate / relevant development options and their costs and benefits • Poverty • Lack of agreed basin-wide policies, allocations and management approaches • Need for food security • National imperatives to deliver development • Need for water security	• Dams and other water infrastructure, including abstractions • Inefficient and inappropriate water use • Land cover change – overgrazing, fires, deforestation and land transformation for farming • Changing land use and resettlement • Increased abstraction for urban use (urban expansion) • Climate change	**Change in flow regime (water quantity, timing and variability)**	• Loss in biodiversity and river ecosystem productivity, resilience and services • Loss of floodplains (grazing), riparian belt (collapse of river banks, decline in veld and medicinal plant resources), reeds, fisheries, wildlife, rare and red data species, reduction in water quality, reduced water recharge, loss of sediment transport • Loss of stability in the ecosystem with increasingly severe floods and droughts • Loss in household livelihoods and commercial productivity because of extended low water flow); declining water quality and in some places loss of access to river water; declining fish (food and sales), reeds (construction, mats), grass (thatching), grazing, veld foods and medicines, floodplain crops, tourism employment, river navigation; reduced quality of life (e.g. recreation, cultural practices such as baptism in river), increased water-borne disease (e.g. gastroenteritis, bilharzia) • Loss in economic productivity – fish, reeds, agriculture (livestock and irrigation), tourism, urban water supply • Loss of local, national and global existence values (willingness to pay for the continued existence and integrity of the Okavango)	• Agree on 'low water use – high economic development' policy • Agree on basin-wide water use, allocation and development plan, encompassing an agreed limit of degradation to the river ecosystem and an agreed flow regime • Harmonise land use planning • Improve water demand management practices • Agree to share and integrate basin policies and plans for all relevant sectors and institutions operating in the basin • Design effective monitoring and data sharing system • Design effective enforcement – institutional capacity, incentives and regulations • Develop off-channel flood storage • Complete full environmental and strategic assessments prior to any development; ensure all developments to not jeopardise the agreed flow regime • Create integrated, basin-wide disaster information management systems, emergency response plans, disaster preparedness plans and a mitigation preparedness plan.

TABLE 5-17: THE CAUSES AND PREDICTED IMPACTS OF CHANGES IN SEDIMENT DYNAMICS

Root Causes	Primary Causes	Issue	Predicted primary impacts	Predicted secondary impacts	Recommended actions/ solutions
• Population growth • Increased industrialisation • Poverty • Lack of agreed standards and regulations and limited implementation capacity • Unmanaged resettlement (and aftermath of civil war) in Angola • Need for food security • National imperatives to deliver 'development'	• Land cover change – overgrazing, fires, deforestation and land transformation for farming • Cultivation in floodplains • Dams for irrigation and hydropower • Irrigation • Destruction of riparian belt • Climate change • Peri-urban (small cluster settlements) population increases	**Change in Sediment Dynamics**	***Increase in sediments from catchment and decrease in sediment bed-load transport***	• Hydraulic change, including channel formation and reduced flood spillage • Loss of floodplain and delta dynamics • Increased salination • Impacts on river, floodplain, panhandle and Delta ecosystem functioning • River bank erosion • Impacts on infrastructure	• Study bed-load sediment dynamics • Harmonise land use plan • Investigate off-channel storage • Design infrastructure to permit sediment movement to continue along the river • Design effective monitoring and data sharing systems • Establish riparian belt buffer zones and where necessary, rehabilitation
			Increase in water column sediments (turbidity)	• Decline in rooted aquatic vegetation, increase in floating algae, declining potability and gastrointestinal problems in people and animals, blocks gills of fish, reduces hunting efficiency of species hunting by vision • Increased deposition of very fine sediments downstream – on floodplains, panhandle and delta • Smothering of habitats and sedentary communities (mainly rocky areas) • Increased water treatment costs • Impacts on infrastructure such as blocking irrigation systems	• Maintain or rehabilitate riparian vegetation as a buffer between human activities and the river

TABLE 5-18: THE CAUSES AND PREDICTED IMPACTS OF CHANGES IN WATER QUALITY

Root Causes	Primary Causes	Issue	Predicted impacts	Recommended actions/solutions
• Urbanisation • Population growth • Increased industrialisation • Increased tourism • Poverty • Lack of agreed standards and regulations, and limited implementation capacity	• Untreated waste water discharge and accidental spillage (i.e. through flooding) from urban centres, tourism and other infrastructure • Solid waste in river and on river edges, including litter • Return flows from irrigation • Pesticides – from agriculture, for human (malaria spraying) and animal (tsetse fly spraying) disease prevention • Nutrient inflows from human and livestock defecation in river and on edges • Land cover change – overgrazing, fires, deforestation and land transformation for farming • Degradation of wetlands • Aquaculture • Destruction of riparian belts, including by elephants	**Change in Water Quality** (chemical, biological and physical aspects)	• Increased cost of treating water for human consumption • Impacts on public health, including diarrhoea, dysentery, bilharzia • Impacts on biodiversity and ecosystem functioning • Impacts on groundwater quality • Impacts on economic productivity (e.g. fish, tourism) • Impacts on water use for irrigation, recreation, cultural uses	• Agreed harmonised water-quality standards • Effective monitoring • Data-sharing system • Investment in appropriate water and sanitation schemes, including water management infrastructure and waster water / sewage treatment • Harmonised land use planning • Riparian buffer zones along river banks between river/floodplain and irrigation areas • Wildlife corridors • Integrated pest management • Water demand management • Effective enforcement – institutional capacity, incentives and regulations

TABLE 5-19: THE CAUSES AND PREDICTED IMPACTS OF CHANGES IN BIODIVERSITY

Root Causes	Primary Causes	Issue	Predicted impacts	Recommended actions/ solutions
• No or inappropriate land and natural resource tenures • Population growth • Increasing industrialisation • Limited information (and uptake) on appropriate / relevant development options and their cost-benefit • Poverty • Lack of agreed basin-wide policies, allocations and management approaches • Need for food security • National imperatives to deliver 'development' • Limited capacity	• Changes in flow regime • Changes in water quality • Changes in sediment transfers • Land cover change – overgrazing, fires, deforestation and land transformation for farming • Over- harvesting • Floodplain degradation • Destruction of riparian belt • Climate change • Expanding human settlements and infrastructure • International pressures, markets and conventions, e.g. CITES, Kyoto – biofuels • Poisons, pesticides and toxins	**Changes in the diversity and abundance of the riverine fauna and flora, and in ecosystem functioning and services**	• Reduction in tourism value • Reduction in fish harvesting • Reduction in household livelihoods, income and food security • Reduction in access to medicinal plants, timber, firewood and other household and cultural resources • Increase in human–animal conflict • Reduction in global gene pool • Reduction of resilience of ecosystem • Reduction of other wetland resources (e.g. grazing, reeds) • Loss or rare, Red Data Listed and high value species • Loss of Ramsar status resulting in loss of international recognition and marketability • Loss of un-described and little known species before they and their values to society and ecosystems are known • Lost opportunity to gain comparative and competitive advantage through adopting low-impact biodiversity-based development trajectory • Decline in ecosystem functioning and services	• Promote protected, conservation and natural-resource management areas (including community-based conservancies, forests and river sanctuaries) within an integrated co-managed basin context • Create wildlife corridors across the basin • Harmonise biodiversity and wildlife legislation and management • Design an integrated land-use plan • Design an effective monitoring and data sharing system • Devolve responsibility for and benefits of natural resources to local level (policy and practices over wildlife, forests, grazing, fish) • Create effective enforcement, via institutional capacity, incentives and regulations • Integrate basin management with biodiversity management – create smart partnerships within and between countries

CHAPTER 6: KEY FINDINGS AND RECOMMENDATIONS

6.1 KEY FINDINGS

Chapter 6 provides a focus on the key messages from the TDA. It draws upon the description of the baseline and trends in the status of the basin of Chapter 2, the experimental results of the integrated flow assessment process and other predictions of impacts of Chapter 4, and the diagnostic analysis of Chapter 5. The key findings of the TDA identify priority issues, and recommendations for action are drawn out of these for systematic and basin-wide issues, and for each of the water and land use sectors. In addition, the chapter stresses the importance of addressing macro-economic and governance targets important in the development of the Strategic Action Programme (SAP).This final chapter of the TDA thus sets the scene for the development of the SAP.

Assessment of the present state of the basin shows a **system that is minimally altered from its natural state.** There are currently no water diversions or impoundments that significantly alter the hydrology of the river. Localised land-use degradation in parts of the upper and middle catchment, and small urban settlements such as Menongue, Cuito Cuanavale, Rundu and Shakawe are starting to show some impacts on water quality, but these are still easily manageable. The ecological components of the river are close to a natural state with a healthy abundance and diversity of animals and vegetation.

Riverside grass resources

Socio-economic assessment shows that the **people living in the Okavango Basin are poorer and have less access to basic services** than the general public in each of the three countries. Furthermore, the assessment shows that the river provides a significant and important source of water, food, building materials, recreation and income for the people living along the river and for the regional and national economies. Here the value of the river as a source of direct and piped clean water to communities throughout the basin is of important concern; more than half the households in the Angolan section of the basin use water drawn directly from the river for their daily needs. In Botswana and Namibia, the assessment shows significant economic gain and employment from tourism related to the river.

Assessment of the basin economies shows that in Angola, the Okavango, remote from centres of commerce, contributes marginally to the national economy. In Namibia, which has the most diversified economy of the three, the contribution of the Okavango is marginally higher through tourism, water supply and agriculture. Tourism, which is mostly associated with the Okavango Delta, contributes about US$ 200 million (2.1% of GDP) in Botswana.

But **this situation is likely to change** in the future as pressures of development draw upon the resources of the Okavango River Basin. All three basin states clearly prioritise social and economic growth. Considering the lower socio-economic conditions among the people living in the basin compared to the general populations, economic development within the areas encompassing the Okavango River Basin is indicated as an urgent need in most national development agendas.

The Okavango is an essential resource for economic development, but how exactly the river and its associated resources will be used for development is an uncertainty that the TDA has been commissioned to guide. For this analysis, observed water use trends were projected into the future to anticipate threats and potential consequences that might arise from a development pathway based on increasing water resources development.

Based on observed trends and national development plans, four water resources scenarios i.e. Present Day; Low Water Use; Mid-Term (Medium Water Use) and Long Term (High Water Use) were developed, identifying specific irrigation, hydroelectricity and water abstraction projects. Three hydrological models were then developed to describe the actual hydrological response to these water uses. Through extensive field surveys and research, and a structured and detailed scientific and participatory exercise, the assessment built up a database of ecological responses to these hydrological changes. The ecological responses were then also translated into socio-economic impacts based on community direct and indirect use and livelihood dependence on river resources identified through detailed community surveys in the basin.

An in-depth assessment of eight representative sites provided the scientific basis for this analysis by linking water resources development with flow, ecology and socio-economics at the specific sites. Then, further basin-wide studies allowed these observations to be extrapolated to the rest of the basin and highlighted basin-wide trends and issues possibly emerging from the changes in the river. The 'links' connecting developments in one country to impacts in another are the four characteristics of flow: timing, quantity, quality and sediment.

The Okavango causal chain analysis was predictive of concerns that may arise as a result of future development in the basin.

Emerging human and natural trends found by the research teams include:

- Population increasing steadily in Angola 2.7%, Namibia (urban 2.5%, rural 1.5%) and Botswana 1.5%
- Food self-sufficiency policies expected to increase irrigation from 3,000 ha to 200,000 ha by 2025
- Tourism growth exceeding 3% per annum
- Up to 12 run-of-river hydroelectric projects under consideration in response to regional demand
- Increasing urbanisation: at least 2.5% vs 1.5% in rural areas
- Climate change: increasing variability.

Four water development scenarios demonstrate hypothetical water resources developments up to 2025. While these scenarios were based on actual proposed developments, they aim at creating understanding of potential impacts rather than predicting specific outcomes.

Present
3,200 ha irrigation, urban water demand in three centres.

Low
Increased urban consumption due to Angolan resettlement. 46,000 ha irrigation. One storage and three run-of-river hydro-power stations.

Ducks at Rundu, Namibia

Medium
206,000 ha irrigation. One storage and four run-of-river hydro stations. One inter-basin transfer of 17 Mm^3 per annum.

High
350,000 ha irrigation. One storage and nine run-of-river hydro stations and a large dam in the upper basin. Extended interbasin transfer of 100 Mm^3 per annum. Additional urban water development scheme.

The results describe specific consequences of individual planned water resources developments as well as general pressures on the basin. The findings present a detailed and illustrative picture of the causes and impacts of changing water use along the river. This includes hydrological impacts of water use for irrigation, hydropower and domestic use in terms of key flow parameters such as changes in flood patterns and the onset of seasons.

Principal pressures on the Okavango River Basin come from increasing demand for water, other natural resources and changing land use. Populations in the Okavango Basin are steadily increasing, and so is the demand for goods and services. By following the trends in population and development, it is possible to describe how pressures on water, land and other resources may increase. At the same time, developments in different sectors using these land and water resources are being proposed, some of which will take place in the next 10 to 15 years.

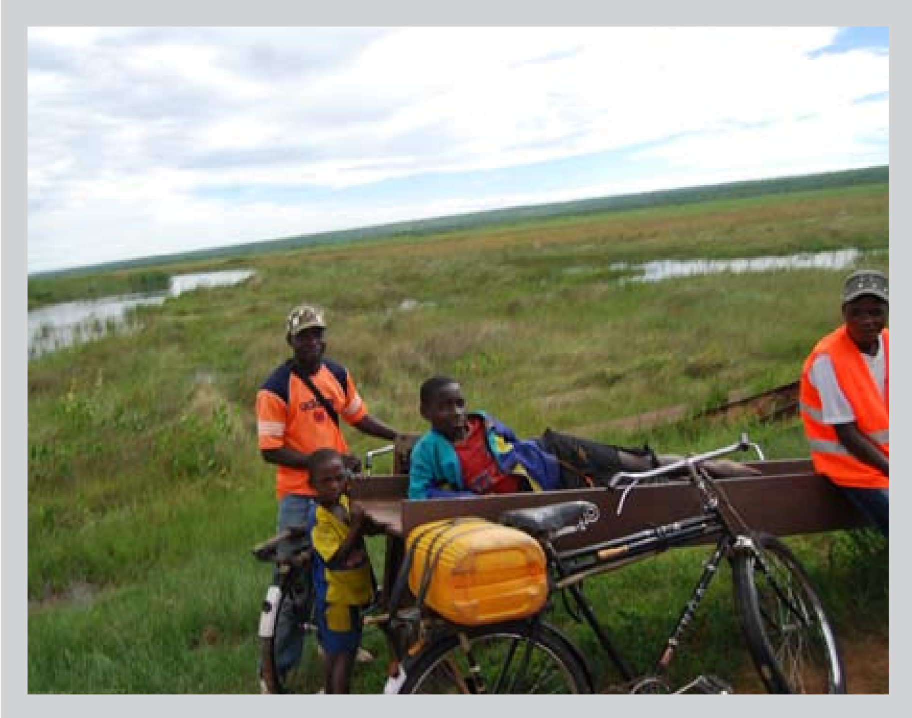
When planning their activities, the countries need to consider the following:

- **Flow variability is important** for the continued functioning of the ecosystem. The benefits people and nations derive from the river are dependent on this. All proposed developments should consider the impact on the hydrology of the river.
- The Cuito River maintains the dry season flows downstream to the Delta, thus if water resources development is limited, these flows could buffer other developments by moderating flow fluctuations, diluting pollutants and by continuing to supply the crucial bed-load sediment.
- Direct abstractions from watercourses for agriculture and drainage returns can threaten downstream environmental services but the economic returns of irrigation in the basin are low in relation to economic returns from alternative uses, including tourism and community based management of land and water resources. Bulk water supplies from groundwater sources away from watercourses would minimise water quantity impacts but not water quality impacts.

Okavango catch

- **Hydroelectric power tradeoffs are largely positive,** especially considering run-of-river schemes located on tributaries. But they would need to have effective mechanisms for allowing the continuous flow of sediments; ensure that discharge of poor quality waters from reservoirs is avoided and that migrating fish still find their way.
- **Providing water to people living in the river basin is unlikely to have severe impacts,** as long as growing urban areas incorporate alternative municipal water and sanitation systems that avoid direct disposal to watercourses and mobilise protected groundwater sources where available. Only major water supply schemes need to be presented for joint discussion among the countries.
- Considering the high costs of treating contaminated water, **conserving the good water quality of the Okavango offers the most cost effective option.**
- While transfer of water out of the basin is likely to use lower quantities of water than irrigated agriculture would**, the hydrological implications of any large transfer schemes should be discussed** among the three countries.
- Conservation of river banks and buffer zones can allow riparian vegetation to recover in urbanised areas, and protected areas can support wildlife migration and tourism. **The links between land use and water management are important** considering the river basin's poor soils.
- The overall social and economic **benefits of water resource-intensive development pathways are estimated to be lower than the benefits of other development pathways.** The current near pristine state of the river basin is a clear comparative advantage if the returns from in-situ environmental goods and services can be maximised.
- As the water resources development in terms of diversions and impoundments increases, downstream ecosystem functioning, river bank structure, availability of water downstream and beneficial effects of flooding could be reduced.

Assessments also noted some significant areas of importance throughout the basin requiring specific attention. A network of hitherto undescribed **floodplain wetlands in the Cuito River sub-catchment is believed to be very important** not only for the ecology but also for the hydrological functioning of the river. Wetland systems provide a host of important ecological services (Chapter 5, Section 3.1) and *hydrologically,* these wetlands retain water from the wet season which is released slowly throughout the dry season, thus regulating the flows downstream throughout the year.



Rio Cuito, Cuito Cuanavale, Angola

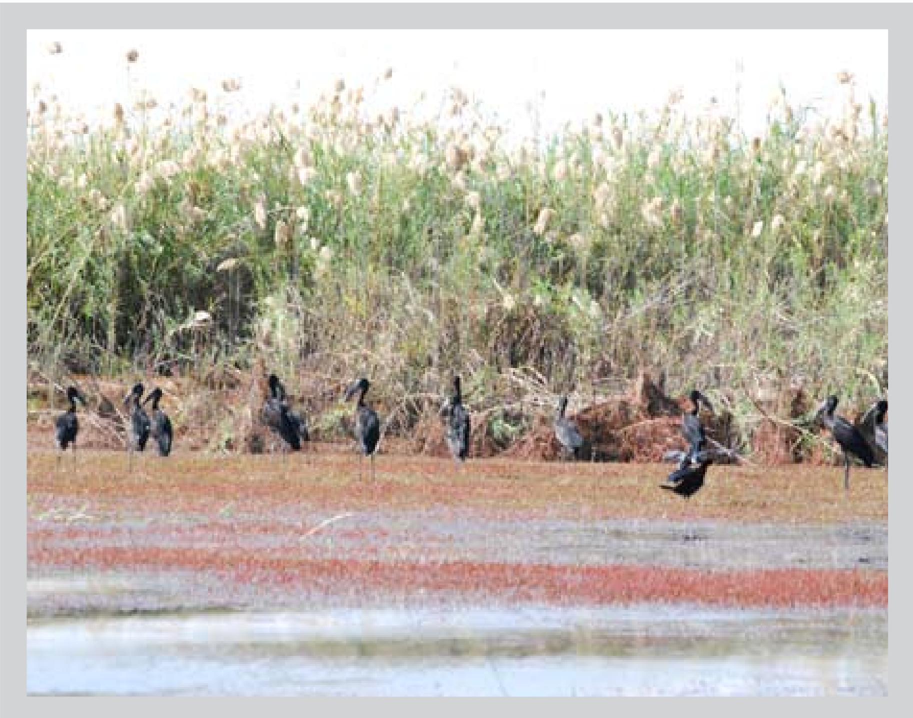
Furthermore, the **hydrological significance of the Cuito sub-catchment was highlighted** indicating the complementary functions of the Cubango and Cuito sub-basins. Whereas the Cubango displays a 'flashy' hydrograph throughout the seasons of the year, the Cuito, in part due to the wetland mentioned above and also the sandy soils, displays a much smoother rise and fall. Therefore, while the dry season water flow downstream is partially guaranteed by the Cuito, the flood events essential for ecosystem functioning occur more as a result of the Cubango flows.

Another well known and amply described feature of the river basin is the Okavango Delta. **The Delta is recognised as a wetland of international importance by the Ramsar Convention** and is currently almost synonymous with the Okavango. The functioning of the Delta is heavily dependent on the quantity, quality and timing of the water entering the system at the panhandle. Sediment transport along the river and the timing of the flow are crucial for the ecology of the Delta and the corresponding tourism and related industries, with the sediment playing a crucial role in the dynamic that forms and blocks channels and regulates the salinity of the water in the Delta.

6.2 RECOMMENDATIONS

The TDA reveals four main agendas for natural resource management across the basin. These four agendas are the areas in which the countries need to engage if the economic and environmental value of the Okavango River Basin is to be sustained. As such, the agendas help define the outline of the SAP:

1. A policy and institutional agenda that can facilitate positive benefit sharing and progressive institutional development
2. A planning and investment agenda that can generate positive natural resource management capacity
3. A monitoring agenda to track SAP implementation and the accrual of environmental and economic benefits
4. An applied research agenda to underpin SAP implementation through development of bio-physical, social and economic indicators of environmental change.



Open billed storks, Rundu, Namibia

6.2.1. A policy agenda that can facilitate positive environmental externalities through benefit sharing and progressive institutional development

The TDA clearly shows that the benefits from cooperation will likely outweigh the benefits of uncoordinated development – not only cooperation between the countries, but also within sectors in the country. The TDA also shows that as water use increases across the basin. the environmental impacts become increasingly transboundary in nature.

Full socio-economic development potential of the basin can be harnessed through a coordinated effort by all three countries to set alternative pathways to water cycle management in the basin. The assessment shows that while uncoordinated development may benefit one country, it will be at a significant cost to another. Conversely, strategically selected and placed investments planned and managed at a basin level are likely to be more beneficial than when made at a country level. This allows the basin to exploit comparative advantages of the basin and of the individual countries.

Local administrator, Cuito Cuanavale, Angola

The platform for this cooperation is OKACOM. In order to realise these alternative development pathways, the mandate of the Permanent Okavango River Basin Water Commission could be consolidated to move beyond an advisory and monitoring role towards a management role. The Commission should be the primary force that selects, attracts, executes, manages and shares the benefits of a consolidated and integrated investment portfolio for the basin.

To achieve this, **OKACOM needs a clear mandate from the contracting states** – Angola, Botswana and Namibia. Although the 1994 OKACOM agreement and the 2007 Agreement on the Organisational Structure of OKACOM define the mandate, the assessment proposes significant scope for expansion of the Commission's work. This includes widening the sectors represented in the Commission to include agriculture, energy, environment and other relevant sectors and also the establishment of a ministerial council.

Internal relationships within OKACOM also require further consolidation with clear and robust procedures for decision – making and execution. This includes horizontal linkages at the policy level (the Commission) and the technical level (the OBSC and taskforces) to streamline the way decisions are made and followed through. In addition, vertical consolidation to empower and to clearly define the role and the mandate of the three organs of the Commission (policy, technical and administrative) is essential for OKACOM to coordinate and manage investments in the basin.

At a national levels, management decisions related to natural resource use may be taken in relative isolation and lead to developments being planned without coordination. The TDA points out conflicting and sometimes contrasting national policies and development objectives. **A pragmatic strategy is required to coordinate development efforts** with potential impact on the linked water and land resources of the Okavango and implemented at the relevant levels of government.

Governance recommendations

For **OKACOM:**
- Strengthen the **operational capacity** of OKACOM in line with increasing management responsibilities
- **Increase number of sectors represented** in OKACOM organs for improved inter-sectoral coordination and planning at basin level
- Create **effective institutional linkages** among OKACOM, local basin management committees and relevant stakeholders
- Strengthen, and where necessary establish, **local basin management committees** for improved inter-sectoral planning and implementation.

For sectoral agencies:
- Where possible, harmonise sector policies within and among countries to avoid policy conflicts and create additional development options (i.e. integration of food security into international trade strategy)
- Develop comprehensive climate change adaptation strategies and mainstream climate change aspects into sector policies (see technical report on climate change adaptation on accompanying CD).

6.2.2 A planning and investment agenda that can generate positive environmental externalities and natural resource management capacity

The TDA assessment clearly establishes the economic costs and benefits of water resources developments and indicates the economic as well as financial trade-offs of development among sectors in the countries. It demonstrates that the distribution of current economic benefits of the river is skewed downstream. People and the national economy in Botswana and Namibia currently benefit more from the river from both indirect and direct use of river resources, whereas Angola gains the least. Economic analysis shows that, as water resources developments increase, the benefits of development will accrue upstream, whereas the indirect costs of development will be paid downstream.

The current state of the river creates a comparative advantage for the region in the tourism and wildlife sector, an advantage that could be reduced by increases in upstream consumptive use of water. A tourism-intensive development pathway for the basin, with complementary investment in small run-of-river hydropower facilities and the extension of improved water supply and sanitation to basin cities and communities, may be the best alternative to exploiting the comparative advantage of the basin as a whole.

In the short term, the relative comparative advantage lies in the tourism sector in Botswana and Namibia in that these countries have the capacity and know-how to generate substantially more benefit by investing in tourism than by investing in other sectors. **In the long run this comparative advantage could shift,** depending on regional demand for outputs from other sectors, such as energy.

Focusing on allocating water among the countries for new consumptive water uses will distract the countries from being able to exploit the basin's comparative advantages. In such a scenario, one country may forgo water for a less productive use in another country; in so doing, the benefit of the water to the overall basin will not be maximised.

Instead, a comprehensive settlement may be necessary. This settlement would both acknowledge equitable access by countries to the water resource and provide for using water in a productive manner and sharing of the resulting benefits. This would allow the resources of the basin to be put to the most beneficial use and for those benefits to be shared among the countries through a formula devised in consultation through OKACOM. Therefore a country that forgoes the use of water for a less beneficial use could be compensated by another country that has the comparative advantage to benefit more from the water, leaving both countries better off. As the countries develop and situations change, different advantages are likely to emerge and these agreements will need to be renegotiated.

Road crossing, Boteti River, Botswana

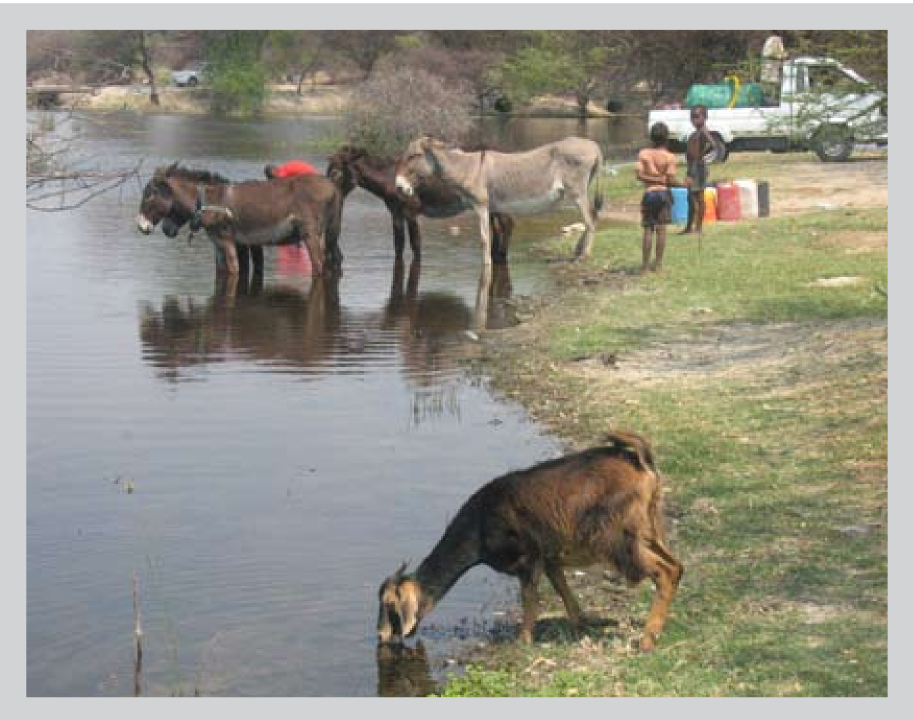
Rather than allocate and share the water resource a better (and easier) alternative would be to allocate and share the benefit of water resource use. However, this may be difficult as information on the costs and benefits of different uses of water is inexact and new uses are always prospective, subject to revision and experience. In addition, future external events may influence which activities are beneficial and to what degree. In comparison, flows and quantity of the water resources are well known and while not fully predictable, are more a matter of risk (and statistics) than uncertainty (the unknown).

Water lily, Botswana

Therefore an option for the future governance of the Okavango might be to incorporate an allocation of the water into such a plan and strategy. Water might be allocated into three tranches.

- The first may be an allocation for present and future human use within the basin.
- A second tranche might come as an allocation for sustaining other existing beneficial uses of water. In the Okavango case this would involve only a few out-of-stream uses for irrigation and other subsistence uses, but it would probably involve negotiating a substantial allocation to ecosystem use in the Delta. This allocation should be a variable flow regime that reflects the difference in wet and dry seasons and years, and maintains the ecosystem at a basin-wide agreed level of condition.
- The remaining (third) tranche of water might then be reserved for future allocations to underpin new uses under a **cooperative basin investment plan.**

Note that there is no presumption here of ownership or proprietorship on the part of any country. It may be that the three countries wish to hold the water in common. The negotiation would then be about how these tranches would be used and deployed, and how any revenues derived from their use would be shared. For example, the ecosystem reservation might be used to engage the international community in the basin plan, as a way to raise investment funds.



Water utilisation, Boteti River, Botswana

Future allocations from the third tranche might then be subject to a charge or fee of some kind in respect of the water use. The fee might be constituted as a payment for ecosystem services and the proceeds invested in an endowment to fund the basin investment strategy. The fee could be set to reflect the opportunity cost of water, in other words approximating the value of water in its economic uses in the Delta. Such pricing may serve to discourage uneconomic uses of water. Making such allocations tradeable could also be considered as a way to ensure that water users continue to face the true opportunity costs of water over the longer term. Benefit sharing under such a scheme would derive from the deployment of the funds (as well as funds from other sources) into the basin according to the investment strategy, particularly in the upstream countries.

Basin planning and investment recommendations

- Sustainable opportunities for investment should be investigated at a basin level to accelerate social and economic development.
- A process for selecting, managing and sharing the benefits from an optimal portfolio of investment should be led by OKACOM
- This process should be supported by an ongoing and adaptive monitoring process that tracks the changing parameters of basin resources

6.2.3 A monitoring and evaluation agenda to monitor SAP implementation and the accrual of environmental and economic benefits

To plan and monitor the impact of investments effectively, OKACOM needs up-to-date and relevant information about land, water and socio-economic parameters.

Critical baseline information is missing precisely where it is needed most to track the effects of land and water management on environmental goods and services. This makes it difficult to analyse trends and changes, and assess impacts. This includes information about hydrology, biophysical and socio-economic conditions.

A basin-wide hydrological monitoring programme is only emerging now and a water quality monitoring programme does not exist. Sound water resources planning needs to be based on adequate information about the variations in space and time of the available water resources. The current hydrological monitoring network does not adequately cover the Okavango River Basin.

The network needs to be expanded by setting up or rehabilitating stations for measuring (i) rainfall, (ii) evaporation, (iii) river flows, and (iv) sedimentation. There is a need for near real-time rainfall and flow data to provide flood warning information. To make the data collected available to water managers and water users, a data archival and information dissemination system should be developed for the basin. The basin-wide hydrological information system should be linked to other information systems maintained by the respective basin states.

Groundwater makes a significant contribution to rural and urban water supply particularly for domestic use, agricultural production, and for maintaining vital ecosystems. There are however, several gaps in the available information about the potential for groundwater development within the Okavango Basin. These include:

- Limited assessment of groundwater resources
- Unknown transboundary implications of groundwater utilisation
- Inadequately evaluated contributions of groundwater to various sectors within the basin.
- A lack of institutional framework for the involvement of groundwater users at local, regional and basin levels in managing this resource
- Current management approaches that do not take into account existing linkages between surface water and groundwater.

Signing MoU with local NGO to facilitate community participation in the TDA, Capico, Angola

A basin-wide evaluation and monitoring of groundwater resources (that includes determining the locations of aquifers and establishing their potential and the linkages with surface water), is necessary for optimising use of water resources. Groundwater use should be carried out within the integrated water resource management framework that considers linkages between surface water and groundwater, and the vital role of groundwater in maintaining ecosystems at local and basin levels. Routine monitoring of groundwater aimed at ensuring that the use of groundwater is within the limits of the potential of the resource, and identification of potential sources of groundwater contamination is required.

Moremi Game Reserve, Botswana

The limited water quality data collected for this assessment reveals that in general, human activities have not significantly modified water quality. Since large parts of the basin are in a near natural condition, and since most of the activities of the largely rural population have low impacts, the water remains relatively clean. The large settlements in all three countries – Menongue (Angola), Rundu (Namibia) and Shakawe (Botswana) – do however have noticeable, localised effects on water quality. Future growth of settlements and expansion of irrigation have the potential to further affect water quality along the river.

Currently there is very limited routine and systematic monitoring of water quality. The control of activities likely to cause undesirable water quality changes in future will be difficult without such a monitoring system. Therefore a basin-wide assessment of existing and potential sources of water pollution should be executed with an assessment of transboundary implications of such pollution. **A bio monitoring system should be established to enable the identification of water quality changes that may affect aquatic biological elements.**

The TDA conducted some preliminary assessment of land-use parameters such as crop areas, deforestation, protected areas and livestock abundance but such assessments should be conducted at regular intervals within an established programme.

Likewise, data on population density, access to services, and the wellbeing of the people living in the basin need to be monitored, collated and analysed to monitor the impact of subsequent interventions.

An ecosystem health monitoring programme should be developed, perhaps using some of the indicators developed for the IFA studies, in addition to a system of visually recording the integrity status of different reaches of the river. The system used by the IFA studies in this report could be adapted further.

Biodiversity monitoring. The lack of a full inventory of biodiversity in the system makes it difficult to be definitive about the presence or absence of different species; to determine trends in populations and distributions or to conclude whether a species is endangered. Biodiversity monitoring should also include invasive alien species.

Boteti River, Botswana

Monitoring recommendations

- Baseline information for the key biophysical and socio-economic characteristics of the Okavango Basin should be collected and shared among the three countries. The information should include hydrology, sediment transport, water quality, biodiversity indicators and socio-economic indicators
- Monitoring programmes with common methods and standards should be established across the basin. Regular monitoring should include hydrology, sediment transport, water quality, ecosystem health and biodiversity.

6.2.4 A RESEARCH AGENDA: THE ROLE OF APPLIED RESEARCH AND MONITORING ECOSYSTEM PROCESSES

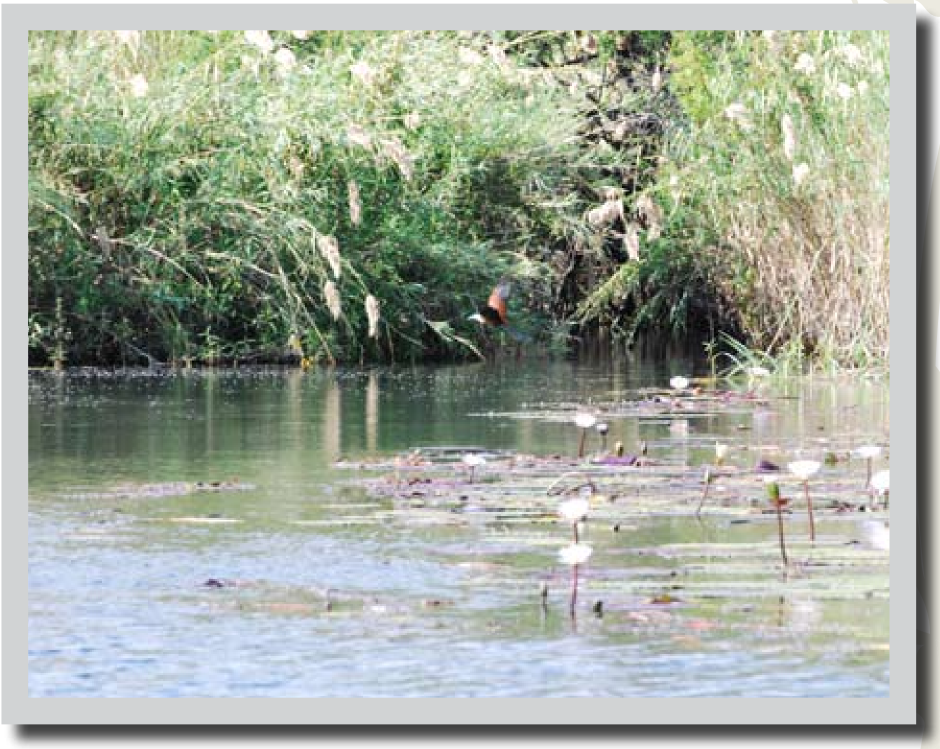
The TDA identified knowledge gaps regarding natural resources and their management within the Okavango River Basin. This knowledge is essential to allow the comprehensive monitoring of ecological processes, which are key to maintaining biodiversity. Attainment of economic, social and environmental sustainability requires knowledge about the potential and limitations of natural resources, and the most appropriate management approaches. Closing the knowledge gaps requires research. This research however, should be focused on problems and aimed at formulating solutions that are relevant within the Okavango Basin.

All three countries have a pressing need to identify those issues for which there is insufficient information so that they can promote or facilitate relevant research to fill these gaps. Important research, for example, would be expected to focus on development of scientifically defensible indicators of system state, economic drivers and impacts.

The conditions under which development interventions will be implemented will change over time, thus creating new knowledge gaps. Management interventions must be adaptable to changing conditions and thus need to be informed by relevant research. This research agenda has to address country development priorities within the basin, but it also needs to be orchestrated at basin level. OKACOM take on the role of promoting and facilitating research as part of building capacity within the basin to identify and formulate solutions to problems.

In this sense OKACOM will have a key role in formulating an applied research programme that complements a portfolio of development and environmental protection initiatives across the basin.

The Okavango River Basin in its current state is an opportunity for an enhanced level of regional cooperation and a demonstration of the capacity of Angola, Botswana and Namibia to understand and manage a rare and valuable combination of natural resources for their mutual benefit. An effective Strategic Action Programme will set the scene for just such a demonstration of regional knowledge and ability. Above all, the TDA has demonstrated that there are alternative pathways for reaching socio-economic objectives within the basin that do not involve high water use and degradation of the aquatic environments. Higher levels of income growth amongst a growing basin population does not necessarily mean high levels of water use.



Aquatic habitat, Okavango Delta, Botswana

REFERENCES

Administração Municipal de Menongue. 2008. Plano de intervenção municipal, 2008. Administração Municipal de Menongue, Menongue, Angola. 44pp.

Administração Municipal do Cuchi. 2008. Plano de intervenção municipal, 2008. Administração Municipal do Cuchi, Cuchi, Angola. 51pp.

Andersson, J. 2006. Land cover change in the Okavango River Basin: historical changes during the Angolan civil war: contributing causes and effects on water quality. Masters thesis. Linköping University, Linköping.

Andersson, L, T Gumbricht, D Hughes, D Kniveton, S Ringrose, H Savenije, M Todd, J Wilk and P Wolski. 2003. Water flow dynamics in the Okavango River Basin and Delta: a prerequisite for the ecosystems of the Delta. Phys Chem Earth 28:1165.

Angola Gabinete de Estudos e Planeamentos. 2007. Plano de investimento público Kuando Cubango, 2009-2013. Governo da Província de Kuando Cubango, Governo de Angola. 51pp.

Aylward, B. 2009. 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: Final Draft. OKACOM. Maun.

Barnes, J, R Saraiva, G Mmopelwa, J Mbaiwa, L Magole and D Wamunyima. 2009. Okavango River Basin Transboundary Diagnostic Analysis: Socio-economic Assessment Final Report. OKACOM. Maun.

Barnes, JI, J Cannon and J MacGregor. 2008. Livestock production economics on communal land in Botswana: Effects of tenure, scale and subsidies. Development Southern Africa 25(3): 327-345.

Barnes, JI, O Nhuleipo, PI Muteyauli and J MacGregor. 2005. Preliminary economic asset and flow accounts for forest resources in Namibia. DEA Research Discussion Paper No 70, Directorate of Environmental Affairs, Ministry of Environment and Tourism, Windhoek, Namibia. 20 pp.

Bauer, P, W Kinzelbach, T Babusi, K Talukdar and EP Baltsavias. 2002. Modeling concepts and remote sensing methods for sustainable water management of the Okavango Delta, Botswana. ETH Zurich, Institute of Geodesy and Photogrammetry doi:10.3929/ethz-a-004333841.

Bethune, S. 2009a. Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO): Transboundary Diagnostic Analysis: Basin Ecosystems Report. OKACOM, Maun.

Bethune, S. Mazvimavi, D. and Quintino, M. 2009.Okavango River Basin Environmental Flow Assessment Delineation Report (Report No: 04/2009) . OKACOM. Maun.

Bethune, S. 1987. Limnological baseline survey of the Okavango River in South West Africa/Namibia 1984-1986. Department of Water Affairs. Windhoek.

Beuster, H. 2009a. Okavango River Basin Environmental Flow Assessment Hydrology Report: Data and Models (Report No: 05/2009). OKACOM. Maun.

Beuster, H. 2009b.Okavango River Basin Environmental Flow Assessment Scenario Report : Hydrology (Report No: 06/2009). OKACOM, Maun.

Boccalon, A. 2008. Emerging Water Needs in the Okavango River Basin: an Analysis of Shared Water Uses. Report to the Land and Water Division, FAO, Rome.

Bonyongo, M.C. 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Wildlife. OKACOM, Maun.

Chappell, N and M Bonell. 2006. Uncertainties in the hydrology of tropical reforestation: beyond "From the mountain to the tap". in ETRFN News, No 45-46 Winter 2005/06.

Collin Christian & Associates CC. 2009.Okavango River Basin: Transboundary Diagnostic Analysis Project: Environmental Flow Assessment Module: Geomorphology. OKACOM, Maun.

Curtis, BA. 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report Country: Namibia Discipline: Vegetation. OKACOM, Maun.

Department of Water Affairs, Namibia. 1994. Investigation into the Surface Water Resources of the Okavango Region with Special Reference to the Okavango River. Report 2500/3/1/H. Windhoek.

Dorrington, RE, TA Moultrie, and T Daniel. 2006. The demographic impact of HIV/AIDS in Botswana: Modeling the impact of HIV/AIDS in Botswana. UNDP and National Aids Coordinating Agency (NACA), Gaborone, Botswana. 152pp.

du P Bothma, J (ed.). 2002. Game Ranch Management. 4th ed. Van Schaik,Pretoria.

du Toit, JT. 2002. Wildlife harvesting guidelines for community-based wildlife management: a southern African perspective. Biodiversity and Conservation. 11(8):1403-1416

FAO/ADB Cooperative Programme. 2007. Upper Okavango Agricultural Water Management for Food Security Programme, Angola and Namibia: Final programme preparation report (confidential). Report No. 07/010 ADB-RAF, Investment Centre Division, FAO, Rome, Italy. 265pp.

Fraser, G and L Mabusela.2003. Sustainability of traditional agriculture in the Southern African savannas of Botswana. South African Geographic Journal 85(ii): 11-17

Gomes, A. 2009. Análise Técnica, Biofísica e Socio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final:Vegetação da Parte Angolana da Bacia Hidrográfica Do Rio Cubango. OKACOM, Maun.
Gomes, JD. 2009. Análise Técnica dos Aspectos Relacionados com o Potencial de Irrigação no lado angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final. OKACOM, Maun.
Hancock, P. 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module : Specialist Report: Country: Botswana: Discipline: Birds. OKACOM, Maun.
Hudson, DJ and M Wright. 1997. Income inequality in Botswana – trends since independence. In: Salkin, JS, D Mpabanga, D Cowan, J Selwe and M Wright (eds.). Aspects of the Botswana economy: selected papers. Lentswe La Lesedi, Gaborone, Botswana. 447-471.
Hughes, DA. 2004. Incorporating groundwater recharge and discharge functions into an existing monthly rainfall-runoff model. Hydrol Sci J 49:297–311
Hughes, DA, L Andersson, J Wilk, HHG Savenije. 2006. Regional calibration of the Pitman model for the Okavango River. J Hydrol 331:30–42
Jones, MJ. 2010. The Groundwater Hydrology of the Okavango Basin (FAO Internal Report). FAO, Rome.
King, J and C Brown. In press. Inland water ecosystems. In Water Resources, Planning and Management: Challenges and Solution. Cambridge University Press.
King, J.M. and Brown,C.A. 2009a. Okavango River Basin Environmental Flow Assessment Project Initiation Report (Report No: 01/2009). OKACOM. Maun.
King, J.M. and Brown,C.A.2009b. Okavango River Basin Environmental Flow Assessment EFA Process Report (Report No: 02/2009). OKACOM. Maun.
King, J.M. and Brown,C.A. 2009c. Okavango River Basin Environmental Flow Assessment Guidelines for Data Collection, Analysis and Scenario Creation (Report No: 03/2009). OKACOM. Maun.
King, J.M. and Brown, C.A.2009d. Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions (Volume 1 of 4)(Report No. 07/2009). OKACOM. Maun.
King, J.M. and Brown, C.A. 2009e. Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions (Volume 2 of 4: Indicator results) (Report No. 07/2009). OKACOM. Maun.
King, J.M. and Brown, C.A. 2009f. Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions: Climate Change Scenarios (Volume 3 of 4) (Report No. 07/2009). OKACOM. Maun.
King, J, CA Brown, AR Joubert and J Barnes. 2009. Okavango River Basin Environmental Flow Assessment Scenario Report: Biophysical Predictions (Volume 4 of 4: Climate Change Indicator Results). (Report No: 07/2009). OKACOM. Maun.
King, J, CA Brown and J Barnes. 2009. Okavango River Basin Environmental Flow Assessment Project Final Report (Report No: 08/2009). OKACOM. Maun.
Lange, G, K Schade, J Ashipala and N Haimbodi. 2004. A social accounting matrix for Namibia 2002: a tool for analyzing economic growth, income distribution and poverty. NEPRU Working Paper 97 Namibia Economic Policy Research Unit, Windhoek, Namibia. 47pp.
Levine, S. 2007. Trends in human development and human poverty in Namibia: Background paper to the Namibian Human Development Report. United Nations Development Programme (UNDP), Windhoek, Namibia. 30pp.
Liebenberg, PJ. 2009. Technical report on irrigation development in the Namibia section of the Okavango River Basin. Unpublished Paper. Ministry of Agriculture, Water and Forestry, Windhoek, Namibia. 24pp.
Malzbender, D. 2009. Transboundary Diagnostic Analysis: Governance Review . OKACOM, Maun. 69pp.
Masamba, WR. 2009a. Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Output 4: Water Supply and Sanitation. OKACOM, Maun
Masamba,WR. 2009b. Transboundary Diagnostic Analysis of the Botswana Portion of the OkavangoRiver Basin: Irrigation Development. OKACOM. Maun.
Mazvimavi, D, and P Wolski P. 2006. Long-term variations of annual flows of the Okavango and Zambezi rivers. Phys Chem Earth 31:944–951.
Mbaiwa, JE. 2009. Transboundary Diagnostic Analysis of the Okavango River Basin: the Status of Tourism Development in the Okavango Delta: Botswana. OKACOM, Maun.
McCarthy, TS. 2003. Sediment movement in the Okavango River at Divundu. Prepared for Eco.plan.
McCarthy, TS, GRJ Cooper, PD Tyson, WN Ellery. 2000. Seasonal flooding in the Okavango Delta, Botswana – recent history and future prospects. South African Journal of Science: 96:11, 25-33
McCarthy, TS and WN Ellery. 1998. The Okavango Delta. Transactions of the Royal Society of South Africa, v.53, 157-182
Mendelsohn, J. 2009. Transboundary Diagnostic Analysis: Land use in Kavango: past, present and future. OKACOM, Maun. 30pp.
Mendelsohn, J and S el Obeid. 2003. Sand and water: A profile of the Kavango region. Struik Publishers, Cape Town, South Africa. 136pp.
Mendelsohn, J and S el Obeid. 2004. Okavango River: The flow of a lifeline. Struik Publishers, Cape Town, South Africa. 176pp.

Mendelsohn, J, S el Obeid, N de Klerk and P Vigne. 2006. Farming systems in Namibia. Namibia National Farmers Union (NNFU), Windhoek, Namibia. 80pp.

Mendelsohn, J, A Jarvis, C Roberts and T Robertson. 2002. Atlas of Namibia: a portrait of the land and its people. David Philip Publishers, Cape Town, South Africa. 200pp.

Milzow, C, l Kgotlhang, P Bauer-Gottwein, P Meier and W Kinzelbach. 2008. The hydrology of the Okavango Delta: Processes, data and modelling, Hydrogeology Journal, Vol. 17 (6), 2009, page 1297ff.

Mmopelwa, G. 2009a. Output 5: Socio-economic profile. Unpublished Report, EPSMO Project, Harry Oppenheimer Okavango Research Centre (HOORC), University of Botswana, Maun, Botswana. 37pp.

Mmopelwa, G. 2009b. Output 6: Profile and value of priority ecosystem services for the Botswana portion of the Okavango River Basin. Unpublished Report. EPSMO Project, Harry Oppenheimer Okavango Research Centre (HOORC), University of Botswana, Maun, Botswana. 14pp.

Morais, M. 2009. Análise Diagnóstica Transfronteiriça da Bacia do Análise Rio Cubango (Okavango): Módulo da Avaliação do Caudal Ambiental: Relatório do Especialista País: Angola Disciplina: Ictiofauna. OKACOM, Maun.

Mosepele, B and H Dallas. 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Aquatic Macro Invertebrates. OKACOM, Maun.

Mosepele, K. 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Fish.

Nakanwe, SN. 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Aquatic Macro Invertebrates. OKACOM, Maun.

Namibia Central Bureau of Statistics. 2008. A review of poverty and inequality in Namibia. Central Bureau of Statistics, National Planning Commission, Windhoek, Namibia. 99pp.

Nashipili, N. 2009. Okavango River Basin Technical Diagnostic Analysis: Specialist Report: Country: Namibia: Discipline: Water Supply and Sanitation. OKACOM, Maun.

ODMP. 2008. Okavango Delta Management Plan. Department of Environmental Affairs, Gaborone Botswana. 191pp.

Ortmann, C. 2009. Okavango River Basin Transboundary Diagnostic Analysis: Environmental Flow Module specialist report – Namibia water quality specialist report. OKACOM, Maun. 70pp.

Paxton, M. 2009. Okavango River Basin Transboundary Diagnostic Analysis: Environmental Flow Module: Specialist Report:Country:Namibia: Discipline: Birds (Avifauna. OKACOM, Maun.)

Pereira, Maria João. 2009a. Qualidade da Água, no Lado Angolano da Bacia Hidrográfica do Rio Cubango. OKACOM, Maun.

Pereira, MJ. 2009b. Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Qualidade da Água. OKACOM. Maun.

Ramberg, L et al. 2006. Species Diversity of the Okavango Delta, Botswana. Aquatic Sciences Vol. 68, No 3: 310-337.

Roberts, K. 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Wildlife. OKACOM, Maun.

Saraiva, R. (Ed.). 2009. Diagnóstico transfronteiriço Bacia do Okavango: Análise socioeconómica Angola. Relatório não Publicado, Projecto de Protecccção Ambiental e Gestão Sustentável da Bacia Hidrográfica do Okavango (PAGSO), Luanda, Angola. 54pp.

Santos, Carmen Ivelize Van-Dúnem S.N. 2009. Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango:Módulo Avaliação do Caudal Ambiental: Relatório de Especialidade: Angola: Aves. OKACOM. Maun.

Trewby, F. 2003. The effect of land use/land cover change on the water quality of the Okavango River, Namibia. Masters Thesis. University of Arkanses, Fayetteville. 102pp.

Turpie, J, J Barnes, J Arntzen, B Nherera, G-M Lange and B Buzwani. 2006. Economic value of the Okavango Delta, Botswana, and implications for management. Department of Environmental Affairs, Gaborone, Botswana. 136pp.

van der Waal, B. 2009. Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Fish Life. OKACOM, Maun.

Vanderpost, C and M Dhliwayo. 2009. Database and GIS design for an expanded Okavango Basin Information System (OBIS). OKACOM. Maun.

Verissimo, L. 2009. GIS Database for the EPSMO Project. OKACOM. Maun.

Wilk J, D Kniveton, L Andersson, R Layberry, MC Todd, D Hughes, S Ringrose and C Vanderpost. 2006. Estimating rainfall and water balance over the Okavango River Basin for hydrological applications. J Hydrol 331:18–29

Wolski, P, HHG Savenije, M Murray-Hudson and T Gumbricht. 2006. Modeling of the flooding in the Okavango Delta, Botswana, using a hybrid reservoir-GIS model. Journal of Hydrology, 331, 58-72.

Wolski, P. 2010. Transboundary Diagnostic Analysis: Assessment of the hydrological effects of climate change in the Okavango River Basin. OKACOM, Maun. 58pp.

Yaron, G, G Janssen, U Maamberua and D Hubbard. 1992. Rural development in the Okavango region of Namibia: an assessment of needs, opportunities and constraints. Gamsberg Macmillan, Windhoek, Namibia, 245pp.

ANNEX 1: DESCRIPTIONS OF THE EIGHT FIELD SITES INVESTIGATED DURING THE IFA STUDIES AND PREDICTED FLOW-RELATED CHANGES

Site	**Field Site 1 – Angola, Capico on Cuebe River**	
	Existing conditions	**Changes with water use developments**
Pressures and trends	The right bank, which is populated, has a higher pressure on the vegetation than the left bank which is more heavily vegetated.	All of the developments envisaged for Capico were inserted into the Low Scenario, and so the following consequences apply to all three scenarios. The developments are: run-of-river abstractions that feed 28,000 ha of irrigation, increased urban supply for up to 100,000 more people and a small run-of-river HEP diversion at Liyapeka.
Hydrology		These result in the MAR in the Cuebe dropping to about half, because of water being diverted into croplands. Diversions take place year round, but the biggest volumes are diverted during the dry season. The impact is greater in the dry season, which starts 3 months earlier, is more than 4 months longer and has flows close to zero. The wet season is 3 months shorter and the volume of flood water is about half of present.
River morphology	Sinuous river channel flowing through fine-grained Kalahari sands and bands of calcareous rock, with a number of straight reaches, contained within high-sided valleys. Alternating eroding banks and flat, low lying depressions with exposed rocky substrates.	Because of the very low dry-season flows, much of the river bed becomes exposed, the water is very shallow and the quiet backwaters that offer refuge for aquatic life mostly disappear.
Water quality	Water quality is considered good, but with reduction in dissolved oxygen during the rainy season, probably due to decomposition of submerged vegetation. Low nutrients, but increasing conductivity and sediments during wet season.	The shallow slow water becomes less pure, and temperature and pH levels rise. Concentrations of dissolved salts and nutrients increase, encouraging much higher growths of algae; these can be a problem because they can clog irrigation structures.
Vegetation	Short miombo shrubs extend to near the water's edge, which is fringed with *Phragmites* reeds and other species of *Rhus* and *Ficus pigmea* that stabilise the banks. The flow is quite rapid here and macrophytes such as *Nymphaea* rarely occur, except in shallow rocky areas.	The riparian reeds and trees die off on the outer margin, being replaced by dry-land species, and new individuals start to intrude into the drying channel in order to reach water. Some may be swept away in the flood season but others establish themselves there during drier years, causing sediment deposition, narrowing of the channel and thus unnaturally higher flooding during wetter years.
Macro-invertebrates	Macro-invertebrates of faster flowing rivers are fairly well represented, as are those found amongst emergent vegetation, especially dragonflies, and those found in fine sediments such as *Unionid* molluscs.	There is less living space for the small aquatic animals in the smaller, shallower water areas and less favourable conditions for most species, and so the river food chain is considerably reduced.
Fish	Of the fish species, 16 species inhabiting the channel and riparian vegetation were recorded, such as *Hydrocynus vittatus*, *Clarias gariepinus* and *Synodontis* spp.	This, with the decrease in flows, impacts fish because they do not have adequate food sources or depth of water, and so all groups of fish could decline to very low levels – as low as 5% of present.
Birds	The trees and shrubs provide refuge for many bird species, especially cormorants, owls and fruit eaters (Turaco).	There are almost no river-dependent birds, because they are very mobile animals and move away quickly when conditions are unsuitable.
Wildlife	Crocodiles and otters are thought to occur here	The river can no longer support appreciable numbers of semi-aquatic animals such as hippos, otters and frogs, or riparian grazers such as duikers, because of lack of habitat, refuge and food. If they are there at present their numbers drastically decline; if they are not there the river is not able to support their re-introduction

Site	Field Site 2 – Angola, Mucundi on Cubango River	
	Existing conditions	**Changes with water use developments**
Pressures and trends	Human pressures at Mucundi are relatively low, although there are small settlements and cultivation along the river banks. Livestock numbers are moderate, and tend to be concentrated along the river. The road between Katwitwi and Menongue runs alongside the river.	All the developments for Capico still apply, and in addition further major developments in hydropower generation and croplands are included. Run-of-river HEP schemes with diversion structures are added with each scenario, but there is also one storage based scheme with a substantial dam wall. Irrigated cropland gradually increases to a maximum of 175,000 ha, all areas using run-of-river abstraction, except for a large dam on the Cuchi River that is introduced in the High Scenario.
Hydrology		The impacts on flow are not as severe as at Capico because of the contribution of undeveloped tributaries. MAR declines gradually to about 80% of present, and the dry season starts about a month earlier and lasts up to 2 months longer. Because of the continual abstractions, dry-season flows fall to less than half of present flows in the Low and Medium Scenarios, but they increase again in the High Scenario due to dam releases. Wet-season flows start later and with lesser floods, because of filling of the dams on the Cubango and Cuchi, and are up to a month shorter.
River morphology	The Cubango River at Mucundi is contained in a narrow V-shaped valley, bordered by high steep banks, related to the underlying geology which comprises layers of well-consolidated sandstone alternating with more resistant calcareous steps. In some areas the banks alternate with flat low lying depressions covered with dark muds. There are areas of intense bank erosion and areas which collect sediment from upstream.	
Water quality	The water quality is good.	Water quality declines progressively as development increases, with sharp spikes of increased concentrations in conductivity, temperature and nutrients, as well as increased algal levels, in the driest years. This suggests that although this reach is not impacted by development as severely as the Capico reach, it is vulnerable in drier years.
Vegetation	The river is generally contained within the channel and would only overtop at times of very high flow into a plain on the left bank vegetated with herbaceous grasses, shrubs and trees such as *Acacia sp. Piliostigma toningii* and *Bauhinia petersiana*. On the right bank *Phragmites mauritianus*, *Syzigium guineensis* and *S. caudatum*, and *Rhus* spp. are found.	Reeds and other aquatic plants decline by up to 80% under the Medium Scenario, for the reasons given for Capico.
Macro-invertebrates	The aquatic macroinvertebrate fauna is well represented with ephemeroptera, trichoptera and odonata indicating a good state of the river.	The small aquatic life declines by 50%, for the reasons given for Capico. They do not recover under the High Scenario because although dry-season flows increase somewhat with dam releases, the overall duration of dry-season conditions is much longer than normal and so the wet-season conditions could arrive too late to trigger migrations, spawning, flowering, seeding and other ecosystem processes.
Fish	There are 15 species of fish dominated by cyprinids, and characids, with few cichlid species. *Clarias gariepinus* is recorded here.	Fish progressively show a 20-60% reduction from present day through the scenarios for the same reasons given for Capico, and also because of the declining water quality and food base. The good (wet) years do not produce such high abundances as at present, there are more bad (dry) years, and so there is dampening of the natural year-to-year variability in numbers reflecting a weakening of the functioning of the whole ecosystem.
Birds	The water dependent birds include cormorants and egrets, and the fruit eating grey turacos feed in the trees along the banks.	Birds decline in numbers because of the loss of their roosts in trees, refuges and food species (fish and invertebrates), and some species become locally extinct.

Wildlife	Crocodiles were reported here, and local people identified the presence of the Okavango mud turtle. Monitor lizards were not seen. Large mammals are generally considered to be scarce, particularly because the low nutrient status of the soils does not offer good quality grazing. Otters such as *Aonys capensis* are found in the Cubango, as is the water mongoose, *Atilax paludinosa*.	Any semi-aquatic animals present, such as hippos, otters and frogs, also decline in numbers, perhaps to local extinction. The Low and Medium Scenarios do not have much effect on riparian grazers, but under the High Scenario the loss of some parts of the flood regime reduces the abundance of suitable grasses and so grazers decline by 70-80%.

Site	**Field Site 3 – Angola, Cuito Cuanavale on the Cuito River**.	
	Existing conditions	**Changes with water use developments**
Pressures and trends	The town of Cuito Cuanavale is the principal source of pressure upon the river, with deposition of solid wastes, bathing and washing activities. There is a mosaic of cultivation around the town on both banks of the river, especially at confluences between the Cuito and Cuanavale Rivers, but these bands of cultivation do not extend for more than 2-3 kms from the banks. There is little cultivation in the floodplain itself, although cattle will graze there in the dry season.	Most developments included for the Cuito River are downstream of the Cuito-Cuanavale site and so do not affect it. The scenarios include 50,000 more people in urban areas and a small run-of-river HEP diversion on the Cuito River upstream of Cuito Cuanavale.
Hydrology		These do not have a noticeable impact on the flow regime although the HEP infrastructure might have a presently unknown impact on sediment movement along the river. If only flow changes are considered, the developments included for this site would have a minimal impact on the river ecosystem at this site.
River morphology	The Cuito River forms a meandering channel in a vast floodplain, up to 3 km wide, with isolated oxbow lakes and meanders connected to the main channel. The underlying Kalahari sands sometimes slope gently towards the valley and in other places form steep slopes. The right valley margin is intersected by steep gulleys which may contribute significantly to the sediment loads. The depth of the river varies between 3-4 m in the deepest parts and 1-2 m at the margins, and there is evidence of sand waves with areas of alternating pools and riffles, and also of lateral erosion on the concave banks of meanders.	
Water quality	The water quality is good, although small scale human activity, such as bathing and washing of clothes may give rise to localised foam in the water.	
Vegetation	The vast floodplain is covered in grasses, and reeds are abundant along the margins of the floodplain. Shrubs, e.g. *Rhus* spp. are rarely over 1 m high. In some places there are large pools with macrophytes such as *Nymphaea lotus, N. nouchali caurulea, Aeschymone fluitans* and *Nymphoides indica*. On sandy exposed substrates, submerged macrophytes appear, such as *Ottelia ulvifolia, O. muricata* and *Ultricularia sp.*	
Macro-invertebrates	A wide variety of macro-invertebrate groups are represented especially those associated with low-lying floodplain vegetation.	
Fish	There are 25 fish species reported at this site, with good representation of Mormyridae, Cyprinidae, Characidae and Cichlidae. The latter includes the vulnerable *Oreochromis andersonii*. Some are mainstream dwellers such as the tiger fish, *Hydrocynus vittatus* and others such as *Clarias* spp, *Tilapia* spp. are caught commercially.	

Birds	The floodplain bird species are well represented including *Egretta garzetta* and the African Openbill, *Anastomaus lamelligerus.*	
Wildlife	Otters were observed in the Cuito river, including *Aonys capensis* and *Lutra maculicollis.*	

Site	**Field Site 4 – Namibia, Kapako on the Okavango River**.	
	Existing conditions	**Changes with water use developments**
Location	The Kapako field site is about 30 km upstream of Rundu and near the villages of Kapako, Mupini to the east and Mukundu to the south.	
Pressures and trends	About 2,500 people live near Kapako, with the greatest density alongside the river, and all use the river and its resources to some extent, for fishing, grazing of livestock, collection of reeds and grasses etc. Local people have recognized that water quality and fish resources are decreasing. The vegetation alongside the river is overgrazed, to such an extent that some cattle are grazed across the river on the Angolan side. Fire frequency is increasing as is the land being cleared for cultivation. The road westwards from Rundu has been upgraded and allows for greater exploitation along the river to Katwitwi. So far there has not been an excessive exploitation of the water resources in the main channel	All developments included for Capico and Mucundi are upstream of this site and so are included, and in addition a further 48,000 ha of run-of-river irrigation in the Kapako area is added gradually through the scenarios.
Hydrology		There are no significant tributaries between Mucundi and Kapako and so flow changes upstream are transmitted downstream without amelioration of other inflows. The annual volume of water flowing down the river progressively declines to 80% of present day. The dry-season flow falls by about half and the dry season extends up to 1.5 months longer. The wet season is shorter by about the same length of time with up to a 30% drop in volume but little change in flood onset time and size of flood peak.
River morphology	The site included the mainstream channel of the Okavango and the annually flooded plains forming concentric scrollbars, with several braided side channels and deeper pools. There is a higher fluvial terrace with alluvial deposits that is seldom flooded, and a steep, well vegetated bank at the edge of the floodplain close to the main road, that rises several metres above the floodplain. The floodplain may be up to 4 km wide. The main channel and some backwaters may be up to 3 m deep.	There are 30% fewer quiet backwaters under the Low and Medium Scenarios because of low dry-season flows, but the situation reverses somewhat under the High Scenario (15-20% loss) because of irrigation releases from upstream dams. The vast floodplains in this area (and along the Cuito) are a dominant feature of the river system and their natural functioning is a critical factor in maintaining its character. These floodplains are most affected under the High Scenario when they never flood to their full extent. In 5% of the years they do not flood at all – a completely new situation as they always flood under present conditions. Reduced flooding leads to reduced productivity, including lower fish, bird and wildlife numbers.
Water quality	Water quality at Kapako is generally very good, with very low concentrations of nutrients, turbidity and suspended solids.	Conductivity, temperature, oxygen and nitrogen are naturally higher in dry periods than in average and wet periods. With increasing development, the dry periods show progressively larger and more marked increases above normal, indicating potential water-quality problems. Algae similarly increase by up to 200% of present in dry years.

Vegetation	The vegetation of the floodplains shows a gradation dependent upon the duration of the flooding from the lowest beds of hippo grass *Vossia cuspidata* and other grasses *Setaria sphacelata* and *Panicum coloratum*. Pygmy fig *Tacaazzea apiculata* occur on the edges of the floodplain islands and on the least flooded islands shrubby river *Rhus*, *Searsia quartinian,* grow with the Chobe candle-pod acacia and *Acacia tortilis.* The upper wet bank is vegetated by river *Rhus* and buffalo thorn, and riparian trees such as large leaved *Albizia* and strangler figs.	Reeds and other aquatic plants decline by 30-40% under all the scenarios, and trees and shrubs by a massive 70% under the Medium Scenario, mainly because of low dry-season flows. The impact on them is less severe under the Low and High Scenarios. Because of reduced flooding of the floodplains and a longer dry season, various categories of floodplain vegetation, including grazing grasses, decline by up to 70%.
Macro-invertebrates	The macro-invertebrates associated with the aquatic vegetation in the main channel include ephemeropterans such as Caenids and Baetids, while in the floodplains the marginal vegetation is dominated by odonata such as Libellulidae and Coenagrionidae.	
Fish	A total of 26 fish species were collected here, dominated by the small fish migrating into the floodplains such as *Marcusenius macrolepidatus*, *Barbus paludinosus, Petrocephalus catostoma, Brycinus lateralis* and *Synodontis* spp. which made up over 75% of the numbers caught. Larger main channel dwellers such as tiger fish and *Oreochromis andersonii* were recorded, as were back swamp dwellers *Tilapia* spp. and *Clarias* spp.	Fish numbers reflect the drying out of the floodplain, with groups that rely on floodplains and backwaters progressively falling to 10%-30% of present as development proceeds. Wet years, with high floods and good high breeding success no longer occur, especially under the High Scenario, reducing the overall abundance and resilience of the fish communities. Large floodplain fish, such as red-breast tilapia, become locally extinct in drought years.
Birds	The site offers a diverse habitat suitable for most of the indicator species of birds, particularly floodplain dwellers and feeders. The floodplain is exposed to livestock grazing and fires which can create favourable conditions for nesting and feeding. However over-extensive collection of reeds and grasses can destroy the habitat for birds. Fish-eating birds may be affected by fishing activities which tend to deplete even the residual pans of fish stocks.	Floodplain-dependent birds such as openbill storks and wattled cranes are locally extinct within 10 years under the High Scenario, and other less vulnerable bird species, such as herons, egrets, parrots, weavers, bishops and gallinules decline by up to 90% in dry years. These birds leave the local area for more-favourable locations in the region, if they are available.
Wildlife	The wildlife in the floodplains tends to be restricted to those animals that can cope with the different levels of inundation, since on the one hand the flooding restricts the available space for terrestrial wildlife, and on the other, human pressures, such as hunting, have reduced the larger grazing mammals except for hippos and duiker. The alternative wet season habitats normally used by wetland wildlife are now largely used for stock grazing or farmland.	Semi-aquatic animals, such as hippos, otters and frogs, are most affected by the long, low dry seasons of the Medium Scenario. Because there are few pools, they are forced to leave the area, and local numbers are low (20% of present). Grazers decrease by up to 20% in average years, and by up to 60% in dry years when the floodplain is no longer flooded and grasses are fewer and less nutritious.

Site	Field Site 5 – Namibia – Popa Falls on the Okavango River.	
	Existing conditions	**Changes with water use developments**
Pressures and trends	About 3,000 people live in the area surrounding Popa Falls, but at the rapids site itself the population density is low because it lies within an 8km^2 park and the islands are uninhabited. Immediately downstream, the riverside population increases again and the area includes a number of tourist lodges. Only a few local people that have their own mukoros, hooks, and line and gill nets have access to fishing, which is therefore a secondary income source. On the left bank of the river at Popa Falls there is a circular (300 m radius) irrigation plot, abstracting water just upstream of the falls.	All developments upstream in Capico, Mucundi, Cuito Cuanavale and Kapako are included, plus a gradual increase of run-of-river irrigation along the lower Okavango and a large increase along the lower Cuito River in the Medium and High Scenarios to more than 178,000 ha above present (mostly in Angola), up to 130 m^3 s^{-1} more diversion in Namibia for urban supply, and three additional run-of-river HEP structures, one with a dam wall height of 7.5 m.
Hydrology		These translate as a decline to 69% of MAR and a dry season that starts up to 2 months earlier and is 3 months longer than present. Under the High Scenario, dry-season flows drop to 18% of present. The flood season onset and peak are only slightly affected but it is up to 2 months shorter and declines to about two-thirds of its present volume.
River morphology	At the Popa Falls site, the river is rocky without floodplains but has many sand and rock based islands set in the braided channels. The falls are formed by an exposed bed-rock bar that crosses the river, with a fall of between 2-3 m. The quartzite rocks were formed from sediments deposited in rift valleys, some 900 million years ago.	There is little impact from the Low and Medium Scenarios, and the following information is relevant to the High Scenario unless otherwise stated. There is a 200%-250% increase in exposed rocky and sandbar habitat in the dry season. This is a massive impact on the ecosystem, because living space, critical habitats and refuge areas are lost.
Water quality	The water quality is good and after the confluence of the Cuito with the Okavango, there is evidence of a dilution of nutrients compared to upstream sites. The dissolved oxygen below the falls is higher due to the aeration received as the water flows over the falls.	Water quality is likewise affected, with values for some variables such as conductivity and nitrogen increasing significantly.
Vegetation	Each main channel is lined by submerged vegetation with a succession passing through a papyrus zone, with bog ferns and pygmy figs followed by a reed zone leading into the river bank with dense riparian woodland. The upper wet bank is dominated by river *Rhus* and *Syzygium* spp. Species stabilising the river banks include *Garcinia livingstonei*, *Albizia versicolor* and *Diospyros mespiliformis.* The islands have a similar vegetation structure but with narrow zones. There is very little grass cover.	Under the High Scenario, reeds, hippo grass, papyrus and the trees and shrubs lining the channel decline to 5%-10% of present, and the large riparian trees are gradually replaced by dry-land species.
Macro-invertebrates	The site offers a number of different habitats for macro-invertebrates but favours those adapted for fast flowing water such as Simulium, Hydropsychidae, Economidae, Perlidae and Heptageniidae.	Insects and other small animals drop by 50%-70% because of loss of habitat such as submerged and marginal vegetation in the dry season, and of unnatural flooding patterns.
Fish	29 species of fish were recorded here, dominated in numbers by the rock dwellers *Labeo cylindricus* and *Opsiaridium zambezense,* a very different mix compared to floodplain fish species.	All fish groups also drop by 50%-70% because of loss of habitat such as submerged and marginal vegetation in the dry season, and due to unnatural flooding patterns.
Birds	The bird species found around Popa Falls are typical of well forested areas, and birds such as the rock pratincole breed on emergent rocks, sandbars and islands.	Most bird groups are not significantly affected, except those that breed on sandbanks, which increase in abundance because of increased habitat.

Site	Field Site 5 – Namibia – Popa Falls on the Okavango River.	
	Existing conditions	**Changes with water use developments**
Wildlife	There is an absence of floodplain species. Evidence of the wildlife species present include hippos, otters, cane rat, swamp musk shrew, terrapins and frogs such as the puddle frog (*Phrynobatrachus natalensis*)	Hippos, otters, frogs, snakes, and grazers drop to 10%-30% of present. Survival rates are reduced because of lack of breeding success, increased predation and reduced food sources.

Site	Field Site 6 – Botswana, Panhandle at Shakawe	
	Existing conditions	**Changes with water use developments**
Pressures and trends	There is fairly high human pressure in the Panhandle area, with extensive fishing activities, and reed collection. Fires are a significant part of the ecology but fire outbreaks caused by humans have been increasing. There are relatively high livestock numbers on both sides of the Panhandle. There is some small irrigated agriculture and one commercial irrigation allocation that has not been fully implemented yet.	All developments upstream apply.
Hydrology	At Mohembo, there is a hydrometric station, recording minimum dry season flows of 120 m^3/sec, rising to 815 m^3/sec in peak flood season.	The hydrological impacts are the same as for Popa Rapids above, but the impacts are different.
River morphology	The start of the Panhandle at Mohembo is still fairly narrow ranging from 0.5 km across at the Mohembo ferry, widening quickly to about 10 km across by the time it reaches Shakawe. The main channel meandering within the floodplain may be 100–150 m across. A general feature of the Panhandle is the absence of lagoons and islands, as a result of fluvial processes in the river. There are widespread deposits of clay on underlying sand with organic detritus which varies in character between different plant communities.	All parts of the ecosystem show little change in the Low and Medium Scenarios. The following comments refer to the High Scenario. The channel cross-sectional area declines by 40% over 40 years as flood volumes decline, the flood season shortens, and vegetation encroaches.
Water quality	The water is deeper than in the main parts of the Delta, and has lower dissolved oxygen and electrical conductivity.	Water quality declines, with levels of variables such as conductivity, temperature, nitrogen and phosphorus increasing by up to 50% because of the high reduction in low flows in the dry season.
Vegetation	The banks of the river are characterised by savannas and deciduous trees relying on the continuous flow of the river throughout the year. The river fringes are lined with papyrus and hippo grass (*Vossia cuspidate*).	Algal growth is up to 300% more than present in the quiet waters of the dry season, and reeds, hippo grass and papyrus decline by 50%-90% because of reduced inundation.
Macro-invertebrates	The site is important for a number of macro-invertebrate species, which depend on inundated floodplains for their lifecycles; the enormous variety of species is shown by the fact that 98 morphospecies were recorded in a study in 2003. The unique backwaters host abundant crustacea (Atyid freshwater shrimp).	The small aquatic animals decline to 30%-50% of present, mainly because of low dry season flows and the loss of 'good' wet years that would normally boost numbers.
Fish	The six guilds of fish species used in the IFA are well represented including tiger fish and pink bream, (*Serranochromis robustus)* that live in the main channel, the small species that undertake lateral migrations into the floodplains such as the silver catfish (*Schilbe intermedius*) and the larger species such as *Tilapia rendalli* and *Oreochromis andersonii* and *O. machrochir.*	Most fish species decline to 30%-50% of present, mainly because of low dry season flows and the loss of 'good' wet years that would normally boost numbers.

Birds	In the September low flows, there is an annual "barbel" migration run hunted by piscivorous birds such as egrets and herons such as the slaty egret. This area is a unique area for birds, where the open waters are used by fish eating birds such as African fish eagles, pied kingfishers, African darters and reed cormorants. Pels fishing-owl is also relatively common in the Panhandle. The outer curves of the steeply cut banks are used as nesting sites for several of the kingfisher species, and southern carmine and white-fronted bee-eaters. The low-lying sandbanks are used by African skimmers and water thick-knees for breeding sites. This is the most important area for African skimmers in Botswana. The papyrus and hippo-grass areas are used by the greater swamp warbler. The backswamps and floodplains are used by egrets, herons, jacanas, ducks and geese, and African openbills.	Various bird groups, including piscivores such as pelicans, herons, egrets and storks and water-lily specialists such as jacanas, decline by up to 30% from present. Bee-eaters and skimmers increase by up to 40% in places because of increased exposed and sandy habitat respectively.
Wildlife	The dominant wildlife species in the Panhandle are the semi-aquatic species such as hippos and crocodiles, sitatunga and waterbuck. The permanent swamps provide habitat for frogs, water snakes, terrapins, otters and water monitors, but the terrestrial grazing species are not common here.	Similarly, the semi-aquatic animals decline in numbers.

Site	**Field Site 7 – Botswana – Xakanaxa in the Delta**.	
	Existing conditions	**Changes with water use developments**
Pressures and trends	The main human pressure in this managed area comes from disturbance by the tourism and safari operators.	All developments upstream apply.
Hydrology	The Xakanaxa lagoon is situated on the Maunachira River and is characterised by very long dry grassland with dry season flows of 3 m^3/sec rising to 8 m^3/sec in the flood season.	Declining upstream inflows into the Delta and changes in the patterns of flow.
River morphology		Decrease in all major types of permanent swamp to as low as 22% of present under the High Scenario, and an increase in seasonal swamps into these areas. Dry flood-plain savannah also expands to more than four times its present area, representing a significant drying-out of the Delta.
Water quality		Water quality declines with the gradual reduction in water area and depth, with conductivity, turbidity, temperature, nutrients and algae (chlorophyll) all showing sustained and significant increases. The most extreme increases are in the driest years and under the High Scenario. Oxygen levels show a mirror-image trend, declining in these years.
Vegetation	The habitats included the main channel with fast flowing water, side channels with slower flows (<0.3 m/sec) with marginal vegetation, instream vegetation, backwaters, lagoons and seasonal pools. It can be divided into areas with three flood regimes – permanently flooded, partially inundated and completely dry. These areas have different stretches of woodland vegetation and occasionally flooded grasslands.	
Macro-invertebrates	The different habitats provide for a wide variety of macro-invertebrates; a 2003 survey recorded 125 morphospecies, including a Leptophlebid mayfly and a 2007 survey identified an unusual record of *Setodes* spp. The seasonally flooded pools are unique and host several crustacean species including Anostraca and Cladocera, and rare fairy shrimp, although macro-invertebrate fauna is dominated by Hemiptera & Coleoptera.	Most invertebrate groups also decline in abundance under these conditions, affecting the food-base available for other riverine animals.

Site	Field Site 7 – Botswana – Xakanaxa in the Delta.	
	Existing conditions	**Changes with water use developments**
Fish	Similar to the Panhandle, six guilds of fish are raecorded and it is noted that the Delta's seasonal flood pulse is a major driver of ecological/ biological change in the fish populations. One of the best examples is the annual catfish run between August and October where catfish (*Clarias gariepinus* and *C. ngamensis)* form hunting packs which migrate slowly downstream and feed voraciously on *Marcusenius macrolepidotus* that are back-migrating into the main channel from the slowly drying out floodplains. Also, as the floods rise, terrestrial food sources are washed into the channels, as is evidenced by the high proportion of termites in the diet of *Schilbe intermedius* at that time of year.	All fish groups fall to as low as 10% of present abundances in the driest years and the High Scenario, because natural flooding patterns are disrupted, affecting availability of floodplain habitat and thus migratory movement. Breeding success and survival weakens, exaggerated by the reduction in nutrient-rich sediments and organic material reaching the floodplains.
Birds	The key habitats for birds are the open waters of the lagoons, the river Maunachira/Khwai and the permanently wet areas of papyrus. This is generally an inferior site for birds with lower species diversity and numbers compared to the Panhandle, with few piscivorous species, e.g. African fish eagle, Pels fishing-owl and kingfishers, and diving birds such as African darters and reed cormorants. Key features of the area are the islands with water figs used as breeding sites for African darters, reed cormorants, Marabou storks and yellow-billed storks. African spoonbills and slaty egret have been recorded as breeding here, choosing the security of the islands for breeding and going elsewhere in the Delta to feed.	Bird groups are to a large extent relatively unaffected as they tend to be seasonal visitors exploiting the shallow seasonal swamps.
Wildlife	Almost all of the wildlife found in the Delta are found here, with the floodplains and associated islands providing suitable habitats for semi-aquatic and aquatic species and suitable grazing for the floodplain grazers when the floods recede e.g. terrestrial grazers such as zebra, buffalo, and wildebeest.	Most wildlife fall to half or less of present abundances, although mid-floodplain grazers (e.g. elephant, buffalo) and outer-floodplain grazers (e.g. zebra, wildebeest) increase in the short term as permanent swamps shrink in area. They too eventually show reduced abundance however, as wetlands give way to dry-land savannah.

Site	Field Site 8 – Botswana, Boteti at Chanoga.	
	Existing conditions	**Changes with water use developments**
Pressures and trends	The area is close to the town of Maun and not protected in any way, so disturbance is high. Various forms of farming are practised along the river, including livestock farming and subsistence irrigation of vegetables. The river is also used for fishing and supply of drinking water.	All developments upstream apply.
Hydrology	The Boteti River at Chanoga represents the outfall of the Okavango Delta, receiving water from the Boro main channel through the Thamalakane River, which splits into the Nhabe River going to Lake Ngami and the Boteti draining into Makgadikgadi Pan. In the past, the river did not flow at all, but there has been flow in recent years.	The Boteti River, representing the Delta outflow normally exhibits dry and wet cycles lasting many years. Through the scenarios the number of years it contains water progressively declines until in the High Scenario it is completely dry for most of the time, holding water only if there are prolonged wet periods.
River morphology	The river is located in an almost flat area of Kalahari Sands. The Boteti River has a channel width of 20–60 m within a valley which is 120–500 m across. The main flows in the Boteti occur during the dry season – June to September – after the peak inflows from Angola have passed through the Delta. Due to the low gradient, the flows have very low velocities, and it can take up to 14 days for the flood flows to travel over 9 km along a previously dry channel.	

Site	Field Site 8 – Botswana, Boteti at Chanoga.	
	Existing conditions	**Changes with water use developments**
Water quality	The waters are rich in nutrients that have been leached out of the upstream areas or accumulated from the grazers that are present when the area is dry.	Because of this increasing rarity of water, levels of all water quality indicators except oxygen are very high when water is present (dissolved oxygen level is very low), reflecting the nature of stagnant, shallow, evaporating pools.
Vegetation	Because of the variability in flows, the aquatic vegetation is limited to emergent marginal plants and areas covered with water lilies. The river flows through an area of disturbed acacia woodland with very little or very dry grass during the dry season.	All vegetation classes except woodland trees drastically decline in abundance because of the scarcity of water.
Macro-invertebrates	Aquatic macro-invertebrates are abundant when the water is flowing, especially the channel dwellers living in marginal vegetation, such as Phragmites, and these provide food for fish species.	Aquatic invertebrates decline in abundance because of the scarcity of water
Fish	These are restricted to resident channel dwellers such as *Serranochromis* spp, and fish that live in the marginal vegetation, such as *Brycinus lateralis* and *Barbus poechii.*	Fish disappear from the system except perhaps for modest immigrations during rare wet periods.
Birds	This site, although unprotected is a surprisingly rich area for birds. Large numbers of ducks, geese and other water birds use the river when there is water, such as white-faced and white-backed ducks, red-billed teal and comb duck. The water lily areas are used by African pygmy goose, and jacanas, whilst the muddy margins are used by African sacred and glossy ibis and blacksmith lapwings. During the flooding cycles, there is large fish production, which becomes trapped as the river dries, and large numbers of great white pelicans, Marabou storks and fish eagles are attracted to the Chanoga Lediba. Also when the waters recede large number of African openbills exploit the shallow margins where *Pina occidentalis* and *Lanistes* snails are exposed. Wattled cranes also feed on the corms and bulbs of sedges along the margins of Chanoga Lediba.	Under the High Scenario, water birds disappear except those that are specialist eaters of fruit from riparian trees (e.g. turacos, bulbuls, starlings), because of lack of food and habitat.
Wildlife	There is little wildlife in this area, apart from semi-aquatic species such as hippos and crocodiles, and aquatic species such as frogs, river snakes and water monitors.	All wildlife (e.g. hippos, frogs, lower floodplain grazers) declines, possibly to local extinction

ANNEX 2: LIST OF TDA AUTHORS AND SUPPORTING REPORTS

Reports integrating findings from all country and background reports, and covering the entire basin.			
Final Study Reports		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)*
		Beuster, H.	*Okavango River Basin Environmental Flow Assessment Scenario Report : Hydrology (Report No: 06/2009)*
		Jones, M.J.	*The Groundwater Hydrology of The Okavango Basin (FAO Internal Report, April 2010)*
		King, J.M. and Brown, C.A.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Ecological and Social Predictions (Volume 1 of 4)(Report No. 07/2009)*
		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)*
		King, J., Brown, C.A., Joubert, A.R. and Barnes, J.	*Okavango River Basin Environmental Flow Assessment Scenario Report: Biophysical Predictions (Volume 4 of 4: Climate Change Indicator Results) (Report No: 07/2009)*
		King, J., Brown, C.A. and Barnes, J.	*Okavango River Basin Environmental Flow Assessment Project Final Report (Report No: 08/2009)*
		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*
		Wolski, P.	*Assessment of hydrological effects of climate change in the Okavango Basin*

Country Reports *Biophysical Series*			
	Angola	Andrade e Sousa, Helder André de	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Sedimentologia & Geomorfologia*
		Gomes, Amândio	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Vegetação*
		Gomes, Amândio	*Análise Técnica, Biofísica e Socio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final:Vegetação da Parte Angolana da Bacia Hidrográfica Do Rio Cubango*
		Livramento, Filomena	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina:Macroinvertebrados*
		Morais, Miguel	*Análise Diagnóstica Transfronteiriça da Bacia do Análise Rio Cubango (Okavango): Módulo da Avaliação do Caudal Ambiental: Relatório do Especialista País: Angola Disciplina: Ictiofauna*
		Morais, Miguel	*Análise Técnica, Biófisica e Sócio-Económica do Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final: Peixes e Pesca Fluvial da Bacia do Okavango em Angola*
		Pereira, Maria João	*Qualidade da Água, no Lado Angolano da Bacia Hidrográfica do Rio Cubango*
		Santos, Carmen Ivelize Van-Dúnem S. N.	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório de Especialidade: Angola: Vida Selvagem*
		Santos, Carmen Ivelize Van-Dúnem S.N.	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango:Módulo Avaliação do Caudal Ambiental: Relatório de Especialidade: Angola: Aves*
	Botswana	Bonyongo, M.C.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Wildlife*
		Hancock, P.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module : Specialist Report: Country: Botswana: Discipline: Birds*
		Mosepele, K.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Fish*
		Mosepele, B. and Dallas, Helen	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Botswana: Discipline: Aquatic Macro Invertebrates*
	Namibia	Collin Christian & Associates CC	*Okavango River Basin: Transboundary Diagnostic Analysis Project: Environmental Flow Assessment Module: Geomorphology*
		Curtis, B.A.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report Country: Namibia Discipline: Vegetation*
		Bethune, S.	*Environmental Protection and Sustainable Management of the Okavango River Basin (EPSMO): Transboundary Diagnostic Analysis: Basin Ecosystems Report*
		Nakanwe, S.N.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Aquatic Macro Invertebrates*
		Paxton, M.	*Okavango River Basin Transboundary Diagnostic Analysis: Environmental Flow Module: Specialist Report:Country:Namibia: Discipline: Birds (Avifauna)*
		Roberts, K.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia: Discipline: Wildlife*
		Waal, B.V.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module: Specialist Report: Country: Namibia:Discipline: Fish Life*

Country Reports *Socioeconomic Series*			
	Angola	Gomes, Joaquim Duarte	*Análise Técnica dos Aspectos Relacionados com o Potencial de Irrigação no Lado Angolano da Bacia Hidrográfica do Rio Cubango: Relatório Final*
		Mendelsohn, .J.	*Land use in Kavango: Past, Present and Future*
		Pereira, Maria João	*Análise Diagnóstica Transfronteiriça da Bacia do Rio Okavango: Módulo do Caudal Ambiental: Relatório do Especialista: País: Angola: Disciplina: Qualidade da Água*
		Saraiva, Rute et al.	*Diagnóstico Transfronteiriço Bacia do Okavango: Análise Socioeconómica Angola*
	Botswana	Chimbari, M. and Magole, Lapologang	*Okavango River Basin Trans-Boundary Diagnostic Assessment (TDA): Botswana Component: Partial Report: Key Public Health Issues in the Okavango Basin, Botswana*
		Magole, Lapologang	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Land Use Planning*
		Magole, Lapologang	*Transboundary Diagnostic Analysis (TDA) of the Botswana p Portion of the Okavango River Basin: Stakeholder Involvement in the ODMP and its Relevance to the TDA Process*
		Masamba, W.R.	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Output 4: Water Supply and Sanitation*
		Masamba,W.R.	*Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin: Irrigation Development*
		Mbaiwa.J.E.	*Transboundary Diagnostic Analysis of the Okavango River Basin: the Status of Tourism Development in the Okavango Delta: Botswana*
		Mbaiwa.J.E. and Mmopelwa, G.	*Assessing the Impact of Climate Change on Tourism Activities and their Economic Benefits in the Okavango Delta*
		Mmopelwa, G.	*Okavango River Basin Trans-boundary Diagnostic Assessment: Botswana Component: Output 5: Socio-Economic Profile*
		Ngwenya, B.N.	*Final Report: A Socio-Economic Profile of River Resources and HIV and AIDS in the Okavango Basin: Botswana*
		Vanderpost, C.	*Assessment of Existing Social Services and Projected Growth in the Context of the Transboundary Diagnostic Analysis of the Botswana Portion of the Okavango River Basin*
	Namibia	Collin Christian & Associates CC	*Technical Report on Hydro-electric Power Development in the Namibian Section of the Okavango River Basin*
		Liebenberg, P.J.	*Technical Report on Irrigation Development in the Namibia Section of the Okavango River Basin*
		Ortmann, Cynthia L.	*Okavango River Basin Technical Diagnostic Analysis: Environmental Flow Module : Specialist Report Country: Namibia: discipline: Water Quality*
		Nashipili, Ndinomwaameni	*Okavango River Basin Technical Diagnostic Analysis: Specialist Report: Country: Namibia: Discipline: Water Supply and Sanitation*
		Paxton, C.	*Transboundary Diagnostic Analysis: Specialist Report: Discipline: Water Quality Requirements For Human Health in the Okavango River Basin: Country: Namibia*

Republic of Botswana

GLOBAL ENVIRONMENT FACILITY

OKACOM

Tel +267 680 0023 Fax +267 680 0024 Email okasec@okacom.org www.okacom.org
PO Box 35, Airport Industrial, Maun, Botswana